312

Intermediate (TOSS) Course

Senior Secondary Course

PHYSICS

CORE MODULES - 3
&
LABORATORY MANUAL - 4

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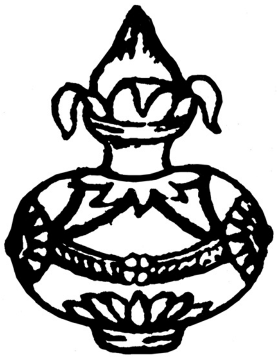

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FOREWORD

Dear Learner,

We are very happy that you have joined NIOS and decided to become an Open and Distant Learner.

NIOS has brought out its revised Senior Secondary Course material. This course has been designed in a **modular format** in the sense that the content is divided into different modules. These modules are made up of a number of lessons. The modules are self contained and you can pick up any of the modules first that interests you. However, we would like you to proceed as the modules have been arranged because there are references and cross references to other lessons.

One of the main features of this course is the division of the modules into **core** and **optional** modules. The core modules are compulsory for all learners, but you can choose any **one** of the two optional modules. For example, in Geography, you can pick up either Local Area Planning **or** Tourism Geography; in Business Studies, you can study either Wage Employment in Business **or** Self Employment in Business, Each subject offers two optional modules. The idea is to allow you to study what interests you more even in one particular subject. This is something unique to the NIOS courses of study. You will not find such **choice** elsewhere.

This course is revised on the lines of the guidelines contained in the National Curriculum Framework 2005. We have tried to make the material as **activity based** as possible. We believe that you learn more when you do something with your own hands rather than just passive reading. We have made efforts to keep the **language of the study material simple** to facilitate you to understand the content easily.

The examples that we have chosen and used in the course material are from daily life to enable you to relate easily what is new to what you already know. Through the Self Learning Materials, we are trying to help you to construct your own knowledge so that you learn by understanding and not just by memorizing everything.

Another important feature of this learning material is integration of Adolescence Education issues with the learning content. Realising that development of life skills like self awareness, critical thinking, negotiation and communication skills is important, we have used different opportunities to build desirable skills in the lessons.

The study materials developed by NIOS are **self-learning materials.** You are supposed to read and work on your own. Unlike a textbook, you do not need a teacher to tell you what to do.

With our good wishes, start studying, do what you are told to do, attempt all activities, answer the intext questions, check your answers from the answers given, learn each topic well and be a **successful self learner.**

Chairman, NIOS

A Word With You

Dear Learner,

Welcome!

Keen observation, careful experimentation and single minded devotion have helped successive generations of researchers to accumulate vast treasure of knowledge. As you go to higher classes, you will appreciate that the method of sciences is characterised by objectivity, openness to change, innovation, self-correction and dynamism. It is therefore important in these formative years for you to learn science by doing: develop problem solving and experimenting skills to unfold unknown situations. To encourage this, we have included a number of exercises and activities. These can be performed by using readily available materials to get a feel of the physical principles in operation. This will also provide you an opportunity to reflect on how a scientist works.

Physics has always been an exciting subject. But fundamental discoveries in rapid succession in the early half of the 20th century brought in profound changes in our concepts of space, time, matter and energy. Another phenomenon characteristic of the previous century is the reduction in the time gap between a new discovery and its applications from a decade or so to a few years due to close linking of science and technology. Therefore, future development in knowledge society will heavily depend on the availability of well trained scientific human capital endowed with entrepreneurship capabilities. This should provide you enough motivation to study science, do well and participate in the process of sustainable growth and national development.

The organisation of the course is generic. It is divided into eight core modules spread over 29 lessons. Out of two optional modules, which intend to develop professional competencies, you will be required to opt for any one. You will get an opportunity to work in a physics laboratory and make precise measurements using sensitive instruments. This will also give you an opportunity to understand basic physical principles.

As a self-learner, you would be required to demonstrate the ability, capacity and eagerness of Ekalavya. Your confidence in yourself and genuine interest in learning science should help you develop being an independent learner with drive and initiative. Experience shows that interactive learning is more rewarding. So to ensure your active participation in teaching-learning as also to facilitate self-regulation and pacing, we have given questions in the body of each lesson. You must answer these.

In curriculum design an effort has been made to put thematically coherent topics together for braviety and completeness. Although we have strived hard to lucidly explain various concepts, it is possible that you may still find some concepts/topics difficult to comprehend. You are therefore advised to make a note of your difficulties and discuss them in the counselling sessions as well as amongst peers.

You will find some useful information on the life and works of leading physicists/scientists who have contributed to our vast pool of knowledge. It is sincerely hoped that their lives will inspire you as role models to contribute your best!

Our best wishes are with you.

Curriculum Design and
Course Development Team

A Note From the Director

Dear Learner,

Welcome!

The Academic Department at the National Institute of Open Schooling tries to bring you new programmes is accordance with your needs and requirements. After making a comprehensive study, we found that our curriculum is more functional, related to life situations and simple. The task now was to make it more effective and useful for you. We invited leading educationists of the country and under their guidance, we have been able to revise and update the curriculum in the subject of Physics.

At the same time, we have also removed old, outdated information and added new, relevant things and tried to make the learning material attractive and appealing for you.

I hope you will find the new material interesting and exciting with lots of activities to do. Any suggestions for further improvement are welcome.

Let me wish you all a happy and successful future.

(K. R. Chandrasekaran)

April 2007

FORE WARD

Education plays an important role in the modern society. Many innovations can be achieved through Education. Hence the Department of Education is giving equal importance to non-formal education through Open Distance Learning (ODL) mode on the lines of formal education. This is the first State Open School established in the country in the year 1991 offering courses up to Upper primary Level till 2008. From the academic year 2008-2009 SSC Course was introduced and Intermediate Course from the year 2010-2011. The qualified learners from the Open School are eligible for both higher studies and employment. So far 7,67,190 learners were enrolled in the Open Schools and 4,50,024 learners have successfully completed their courses.

With the aim of improving the administration at the grass-root level the Telangana Government re-organized the existing Districts and formed 31 new Districts. The formation of new Districts provide wide range of employment and Business opportunities besides self employment. Given the freedom and flexibilities available, the Open School system provides a second chance of learning for those who could not fulfill their dreams of formal education.

Government of Telangana is keen in providing quality education by supplying study materials along with the text books to enable the learners to take the exam with ease. Highly experienced professionals and subject experts are involved in preparing curriculum and study material based on subject wise blue prints. The study material for the academic year 2018-19 is being printed and supplied to all the learners throughout the state.

I wish the learners of Open School make best use of the study material to brighten their future opportunities and rise up to the occasion in building Bangaru Telangana.

With best wishes ....

S. Venkateshwara Sharma
DIRECTOR,
Telangana Open School Society,
Hyderabad

HOW TO USE THE STUDY MATERIAL

Your learning material has been developed by a team of physics experts in open and distance learning. A consistent format has been developed for self-study. The following points will give you an idea on how to make best use of the print material.

Title *is an advance organisor and conveys an idea about the contents of the lesson. Reflect on it.*

Introduction *highlights the contents of the lesson and correlates it with your prior knowledge as well as the natural phenomena in operation in our immediate environment. Read it thoroughly.*

Objectives *relate the contents to your desired achievements after you have learnt the lesson. Remember these.*

Content *of the lesson has been divided into sections and sub-sections depending on thematic unity of concepts. Read the text carefully and make notes on the side margin of the page. After completing each section, answer intext questions and solve numerical problems yourself. This will give you an opportunity to check your understanding. You should continue reading a section till such time that you gain mastery over it.*

At some places you will find some text in ***italics and bold.*** *This indicates that it is important. You must learn them.*

Solved Examples *will help you to understand the concepts and fix your ideas. In fact, problem solving is an integral part of training in physics. Do them yourself and note the main concept being taught through a particular example.*

Activities *are simple experiments which you can perform at your home or work place using readily available (low cost) materials. These will help you to understand physics by doing. Do them yourself and correlate your findings with your observations.*

Intext questions *are based on the concepts discussed in every section. Answer these questions yourself in the space given below the question and then check your answers with the model answers given at the end of the lesson. This will help you to judge your progress. If you are not satisfied with the quality and authenticity of your answers, turn the pages back and study the section again.*

What you have learnt *is essentially summary of the learning points for quick recapitulation. You may like to add more points in this list.*

Terminal exercises *in the form of short, long and numerical questions will help you to develop a perspective of the subject, if you answer these meticulously. Discuss your responses with your peers or counsellors.*

Answers to intext questions : *These will help you to know how correctly you have answered the intext questions.*

Audio: *For understanding difficult or abstract concepts, audio programmes are available on certain content areas. You may listen to these on FM Gyanvani or may buy the CDs from Priced Publication Unit, NIOS*

Video: *Video programmes on certain elements related to your subject have been made to clarify certain concepts. You may watch these at your study center or may purchase these CDs from Priced Publication Unit, NIOS.*

www *These are few selected websites that you can access for extended learning.*

Studying at a distance requires self-motivation, self-discipline and self-regulation. Therefore you must develop regular study habit. Drawing a daily schedule will help you in this endeavour. You should earmark a well-ventilated and well-lighted space in your home for your study. However, it should not be noisy or distract your concentration from your work.

Overview of the Learning Material

1

Module - I
Motion, Force and Energy
1. Units, Dimensions and Vectors
2. Motion in a straight line
3. Laws of Motion
4. Motion in a Plane
5. Gravitation
6. Work Energy and Power
7. Motion of Rigid Body

Module - II
Mechanics of Solids and Fluids
8. Elastic Properties of Solids
9. Properties of Fluids

Module - III
Thermal Physics
10. Kinetic Theory of Gases
11. Thermodynamics
12. Heat Transfer and Solar Energy

Module - IV
Oscillations and Waves
13. Simple Harmonic Motion
14. Wave Phenomena

2

Module - V
Electricity and Magnetism
15. Electric Charge and Electric Field
16. Electric potential and Capacitors
17. Electric Current
18. Magnetism and Magnetic Effect of Electric Current
19. Electromagnetic induction and Alternating Current

Module - VI
Optics and Optical Instruments
20. Reflection and Refraction of Light
21. Dispersion and Scattering of Light
22. Wave Phenomena of Light
23. Optical Instruments

Module - VII
Atoms and Nuclei
24. Structure of Atom
25. Dual Nature of Radiation and Matter
26. Nuclei and Radioactivity
27. Nuclear Fission and Fusion

Module - VIII
Semiconductor
28. Semiconductors and Semiconductor Devices
29. Applications of Semiconductor Devices

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Module - IXA
Electronics and Communications
30. Electronics in Daily Life
31. Communication Systems
32. Communication Technique and Devices
33. Communication Media

Module - IXB
Photography and Audio-Videography
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31. Film Exposing and Processing
32. Audio-Video Recording
33. Compact Disc for Audio-Video Recording

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MODULE - IXA

ELECTRONICS AND COMMUNICATIONS

30A

ELECTRONICS IN DAILY LIFE

It is often said that the only permanent thing in the world we live in is change. And the change which improves the well being of people is always favoured; many a time such a change may become all pervasive and powerful. The invention of fire and wheel proved turning points in the development of human civilisation. The same is true of communication. The simplest ways to communicate are talking and listening (audio) and seeing (visual).

Physicists have strived hard and continuously for years to develop tools and understand processes involved in different forms and formats of communication. In this endevour, path breaking changes in electronic science have contributed significantly. Now we can cannect face to face to our loved ones living across oceans and continants using Computer mediated telephoney. We do not have to go miles flying for watching cricket, football, hockey and other events. To see them live via satellite is a routine activity unimagined a decade or two ago. We are searching life beyond the earth and the solar system. Nanotechnology is offering possiblities for pushing these frontiers further.

As a result efforts have to provide support to these developments, electronic circuitary was miniaturised.

Now radio transisor, television, cassettee players, compact disc Player, DVD player, mobile phone, UPS, microwave oven inverter can be seen in every house hold. Circuit breakers used in electric supply ensured safety. In fact, electronics has moved too fast in less than fifty years. Miniaturisation revolution helped electronic devices and gadgets to be more reliable, less expensive, less power consuming, portable and more convenient.

In this lesson, you will learn about some electronic gadgets in everyday use.

Objectives

After studying this lesson, you will be able to:

- explain basic concepts involved in the design of power supply, inverter, UPS, circuit breaker, timer, alarm clock etc.

- explain the working of above mentioned systems

30.1 Power Supply – Inverters and UPS

You now know that in India, electricity supplied in our homes and industries is in the form of alternating voltage. The supply has a voltage of 220 V (rms) at a frequency of 50 Hz. (In USA, it is 120 V and 240 volts at 60 Hz.) This energy is generated using hydel, gas, wind, coal, solar or nuclear fuel. In our country there is an immense shortage of electric supply and even today we do not have enough electricity to light every home or irrigate every field. The problem is particularly acute in metro-cities and people are forced to look for alternatives in the form of generator sets, inverters, uninterrupted power supply (UPS), etc. In fact, these gadgets have now become a part and parcel home appliances.

The inverter and the UPS both serve as sources of power supply and convert dc from 12v, 17v or 24v battery to 220v 50 Hz ac that can be used for different applications: light homes, run radio, TV, computers, fans etc. like normal power supply. These alternate sources of power supply are purely a back up arrangement, i.e. these supplies come into action only in the absence of the regular supply from the commercial grid. Although these sources are very popular now because of short supply of the power, they can provide supply only for short duration and that too for appliances which do not need high power. For heavy loads, (that require large power supplies to operate), these are not suitable. Let us now learn their working principles.

30.1.1 An Inverter

An inverter is a very common appliance kept in a corner of your home, school or office. As the name suggests it inverts dc into 220 50 Hz ac. It supplies electrical power to our appliances for hours, depending on the capacity of the battery and consumption. These are available in the market with many brand names from 150 VA to several kVA. (You may have seen celebraties advertising for a few brands). They find applications in hospitals, airports and emergency services. A block diagram of an inverter is given in Fig. 30.1.

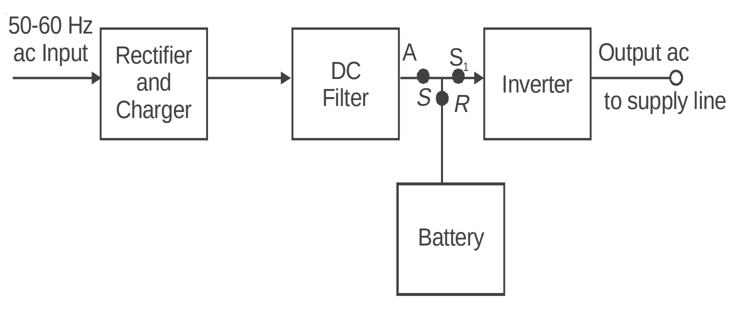


Fig. 30.1 : ***Block diagram of an inverter***

The battery of the inverter is charged (with overcharge protection) by mains. The output of the battery is fed to the inverter circuit through switch ***<u>SS′</u>***. The output of the inverter is connected to the electric supply line. In the event of mains power failure, the inverter circuit may be automatically switched on (with a time lag of the order of a millisecond) by automatic changeover circuit A and 220V, 50Hz supply begins to flow again in (s) to the home appliance. However, it is advisable not to keep it in automatic mode to guard against overload and likely demage.

In general, the output of an inverter is a square pulse of 50 Hz, which is different from normal sinusoidal output of the mains. (Fig. 30.2.)

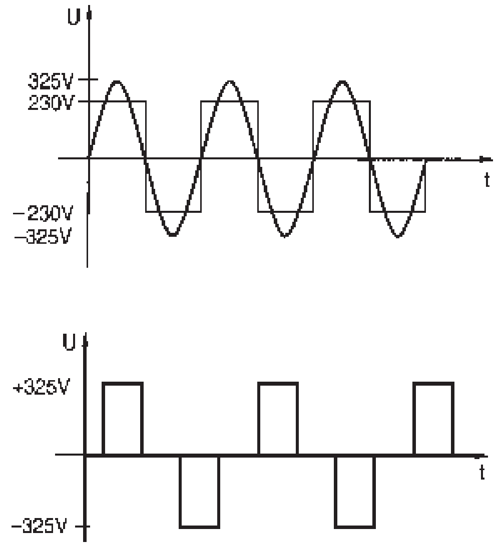


Fig. 30.2: Square wave voltage with duty cycle 25% for 230 V_{rms}

A good quality inverter is expected to give near sine wave output, which requires complicated electronic circuitry and is very crucial for gadgets like TV and fan. As such inverters do not suck the life of your battery. But regular check on water level helps better upkeep. The latest inverters with MOSFET (Metal-Oxide-Semiconductor Field Effect Transistor) technology are very efficient.

30.1.2 Uninterrupted Power Supply

UPS is required for computers and computer controlled systems like local area networks for fault free power supply (Fig. 30.3). It has a battery back up system which can provide supply from a few minutes to a few hours, depending on the load. You must have seen a UPS

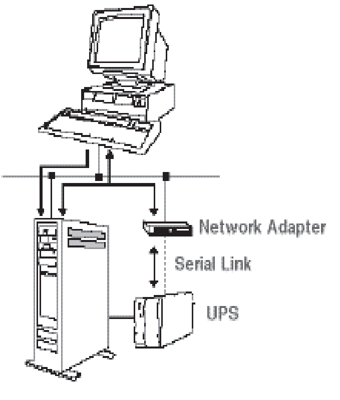


Fig. 30.3 : *A UPS connected to a CPU.*

supplied with your computer so that when there is a power failure, the machine continues working without affecting its performance or disturbing memory. The data can be stored and the system can be shut down properly during the back up time of UPS.

Online UPS are very useful. The power to the system is given through battery only. There is no loss when there is a power failure. The switchover time of UPS is much smaller (~microsecond) than that of an inverter (~millisecond). The UPS gives the desired sine wave output.

Intext Questions 30.1

1. What is the purpose of an inverter?

....

2. What is the purpose of a UPS?

....

3. How is UPS different from Inverter?

....

30.2 Circuit Breaker – MCB (miniature circuit breaker)

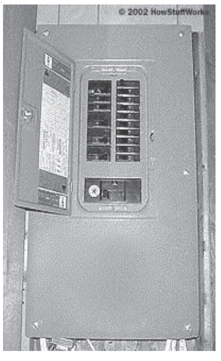


Fig. 30.4: MCB Box

When electrification was in initial stages, very conventional switches were used. And many a time sparking was observed when large current was drawn or there was short circuiting due to wiring problem or equipment failure. This would cause fuse wire to burn, cutting off main supply and engulfing the entire building in Darkness.

Many a time, it would lead to fire, resulting in huge loss of life and properly. This became more frequent as high rise buildings began a norm, particularly in big cities. To minimise such risks it was considered prudent to localise fault. That is, within a home, each room was to be treated as independent entity with seperate circuit. This was actieved by using miniature circuit breaker (MCB). Normally, the MCB drops down cutting off supply to only one circuit (room). This enables us to fix the fault immediately. The circuit breaker has proved very safe and is now an absolutely essential mechanism in almost every house/ office/industry.

You will now learn how circuit breakers and fuses monitor electrical current and how they cut off the power when current levels get too high. You will realise that circuit breaker is an incredibly simple solution to a potentially deadly problem.

To understand circuit breakers, it is important to recall how household electricity works.

The power distribution grid delivers 220V, 50 Hz electricity to our house. Inside our house, the electric current moves in a large circuit, which consists of many smaller circuits. One end of the circuit, the *hot wire*, leads to the power plant. The other end, called the *neutral wire*, leads to *ground*. Because the hot wire connects to a high energy source, and the neutral wire connects to an electrically neutral source, there is a voltage drop across the circuit - charge moves whenever the circuit is closed. The current is said to be *alternating current*, because it rapidly changes direction.

The power distribution grid is designed to deliver electricity at around a consistent voltage but resistance and therefore the current varies in a house. In Module 5 you have learnt that different electrical appliances behave as if they are resistors (also described as **load**) connected in parallel. Their resistance makes the appliances work.

While wiring, the hot wire and the neutral wire are so arranged that they never touch directly. The current in the circuit always passes through an appliance and its electrical resistance limits the value of current. When too much current flows in a circuit at a particular time, the building's wiring may be heated up to unsafe levels, and can cause a fire.

Occasionally due to some fault, something may connect the hot wire directly to the neutral wire or something else leading to ground. For example, a fan motor might overheat and melt; fusing the hot and neutral wires together or someone might drive a nail into the wall, accidentally puncturing one of the power lines. When the hot wire is connected directly to ground, there is minimal resistance in the circuit, and voltage pushes a huge amount of current in the wires. If this continues, the wires may get overheated igniting a fire.

The circuit breaker cuts off the circuit whenever the current jumps above a safe level.

> The simplest protection device provided in building wiring is in the form of a fuse. A fuse is just a thin wire, enclosed in a casing that plugs into the circuit. When a circuit is closed, all charge flows through the fuse wire - the fuse experiences the same current as any other point along the circuit. The fuse is designed to disintegrate when it heats up above a certain level or if the current climbs too high, the wire burns up. Destroying the fuse opens the circuit before the excess current can damage the building wiring/appliance. The problem with fuses is that they work only once.

Every time a fuse blows up, you have to replace it with a new one. A circuit breaker does the same thing as a fuse without any need of replacement: it opens a circuit as soon as current climbs to unsafe levels and you can use it over and over again.

The basic circuit breaker consists of a simple switch, connected to either a bimetallic strip or an electromagnet. Fig. 30.5 shows a typical electromagnet design.

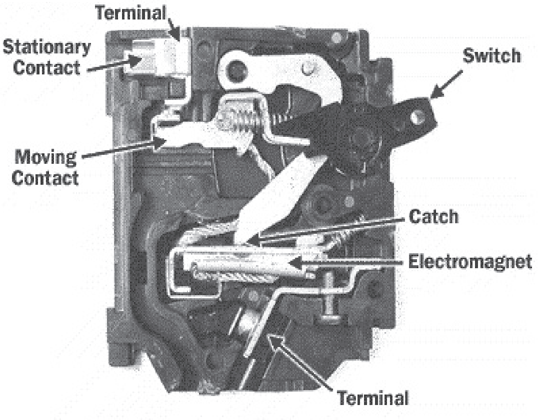


Fig. 30.5: An electromagnet type MCB

The hot wire in the circuit connects to the two ends of the switch. When the switch is flipped to the 'on' position, electricity can flow from the bottom terminal, through the electromagnet, up to the moving contact, across to the stationary contact and out to the upper terminal.

The electricity magnetizes the electromagnet. Increasing current boosts the electromagnet's magnetic force, and decreasing current lowers magnetism. When current jumps to unsafe levels, the electromagnet is strong enough to pull down a metal lever connected to the switch linkage. The entire linkage shifts, tilting the moving contact away from the stationary contact to break the circuit and cutting off electricity.

A bimetallic strip design works on the same principle, except that instead of energizing an electromagnet, the high current bends a thin strip to move the linkage. Some circuit breakers use an explosive charge to throw the switch. When current rises above a certain level, it ignites explosive material, which drives a piston to open the switch.

More advanced circuit breakers use electronic components (semiconductor devices) to monitor current levels rather than simple electrical devices. These elements are a lot more precise, and they shut down the circuit very quickly, but they are more expensive too. For this reason, most houses still use conventional electric circuit breakers.

One of the newer circuit breaker devices is the ground fault circuit intrupter or GFCI. These sophisticated breakers are designed to protect people from electrical shock, rather than prevent damage to a building's wiring. The GFCI constantly monitors current in a circuit's neutral wire and hot wire. When everything is working correctly, the current in both wires should be exactly the same. As soon as the hot wire connects directly to ground, the current level surges in the hot wire, but not in the neutral wire. The GFCI breaks the circuit as soon as this happens, preventing electrocution. Since it doesn't have to wait for current to climb to unsafe levels, the GFCI reacts much more quickly than a conventional breaker.

All the wiring in a house runs through a central circuit breaker panel (or fuse box panel). A typical central panel includes about a dozen circuit breaker switches leading to various circuits in the house. One circuit might include all of the outlets in the living room, and another might include all of the downstairs lighting.

Intext Questions 30.2

1. Describe the function of circuit breaker.

   ....

30.3 Digital Timer

The integrated circuit (IC) technology (discussed in module 8, unit 2) is now widely used. The basic advantages are: small size, light weight and economy. One of the most common and day-to-day use of this technology is in digital clocks. Fig. 30.6 shows a digital clock. Now a days wrist watches, table clocks are mostly digital. The flight information at airports, train schedules at railway stations, and breaking news at Newspaper buildings are displayed digitally. Even in a microwave oven, the time of cooking, frying or roasting is displayed digitally. Now a days people speak of digital technology for mobile learning supported by computers and mobile phones. A digital clock is made of digital counters which in turn are made up of flip flops (a device which latches binary digits). It not only gives time, but can also be used as a timer. A timer sets the duration or time at which some operation is to be performed (e.g. alarm clock, switching on/off radio, TV etc.). IC-555 integrated cricuit is most commonly used in timers.

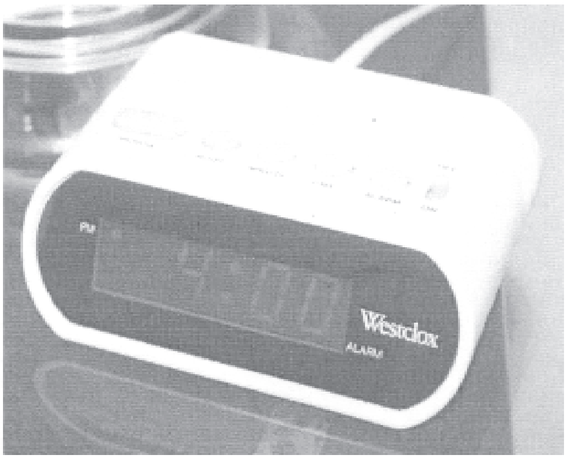


Fig. 30.6: A Digital Clock

Intext Question 30.3

1. What is the basic component of a digital clock?

   ....

2. What is the application of a timer?

   ....

30.4 Processor – Calculator

A calculator is a device that performs arithmetic and logic operations manually or automatically using mechanical, electromechanical, or electronic operations. The core component of an electronic calculator is Arithmetic Logic Unit (ALU), which performs all the processing operations. It has electronic circuitry having logic gates, counters, flip flops, registers etc. A modern scientific calculator shown in Fig. 30.7 can be used as a simple computing machines.

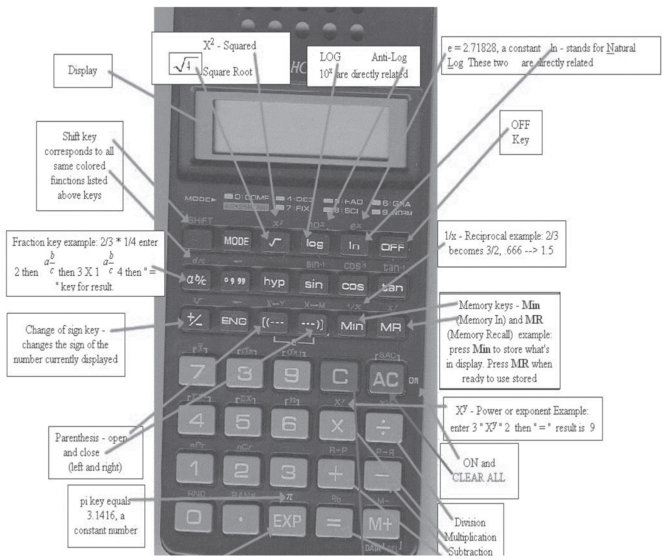


Fig. 30.7: Front Panel of a scientific calculator

Liquid Crystal Display

You probably use items containing an LCD (liquid crystal display) everyday. They are all around us — in laptop computers, digital clocks and watches, microwave ovens, CD players, glucometers, blood pressure monitors, digital televisions and many other electronic devices. LCDs find so many applications, because, they offer some real advantages over other display technologies. They are thinner and lighter and draw much less power than cathode ray tubes (CRTs), for example.

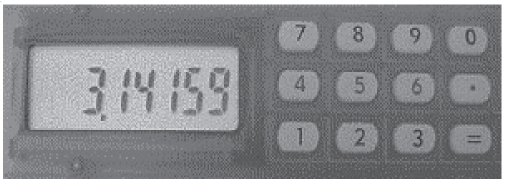


Fig. 30.8: A simple LCD display from a calculator

You may like to know: Do liquid crystals act like solids or liquids? The answer to this question is: Liquid crystals are closer to a liquid state than a solid. It takes a fair amount of heat to change a suitable substance from a solid into a liquid crystal, and it only takes a little more heat to turn that same liquid crystal into a real liquid. Liquid crystals are very sensitive to **temperature** and are used to make thermometers and displays. This explains why a laptop computer display may act funny in cold weather or during a hot day at the beach.

The combination of four facts makes LCDs possible:

- Light can be polarized.
- Liquid crystals can transmit and change polarized light.
- The structure of liquid crystals can be changed by electric current.
- There are transparent substances that can conduct electricity.

To create an LCD, you take **two pieces of polarizing glass**. A special polymer that creates microscopic grooves in the surface is rubbed on the side of the glass that does not have the polarizing film on it. The proper orientation of direction of polarization makes the display possible. The display is possible because of the contrast of two different components of polarization.

Simple LCD requires an **external light source,** or say, a back light as the liquid crystal materials emit no light of their own.

30.5 Transducers and control Systems-Burglar Alarm/Fire Alarm

A **transducer** is a device that transforms energy from one form to another form. Most of the transducers either convert electrical energy into mechanical nergy (displacement) and/or convert a non-electrical physical quantity (such as temperature, light, force, sound etc.) to an electrical signal.

In an electronic instrumentation system, the functions of a transducer (being the input device) are two fold:

- detect or sense the presence, magnitude and change in the physical quantity being measured; and
- provide a proportional electrical output signal as shown is Fig. 30.9. Let us now

learn how transducers are used in control systems.

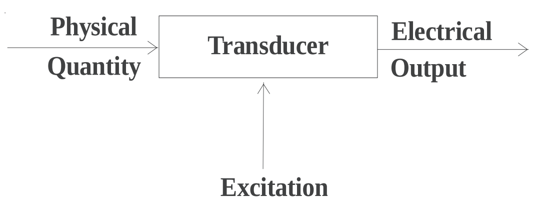


Fig. 30.9: Function of a typical trainsducer

30.5.1 Control Systems

The basic strategy on which a control system operates is the same as that at work in living organisms to maintain temperature, fluid flow rate, and similar other biological functions. This control process is natural.

The technology of artificial control was first developed using a human as an integral part of the control action. For an automatic control we use electronics and computer. There are two types of control systems:

(a) *Open loop type:* Here output has no effect on control system. Some sensor measures the output and switches on/off the system. Example: Hotwater gyser switching on/off heating. It is cheap and simple but less accurate.

(b) *Closed loop or Feedback:* First compares the output with the reference (or input set by you) and accurately controls the desired parameter by changing the input accordingly. Microprocessor controlled electronic furnace is a familiar example. It is complicated and expensive.

The basic characteristics of the processes related to control are:

- Inputs to the controller give precises indication of both the controlled variable and its desired value expressed in the same units.
- The controller output signal represents the action to be taken when the measured value of the controlled variable deviates from the preset value.

30.5.2 Burglar Alarm

Burglar alarms are now standard equipment in business Malls and shops dealing in costly items. Due to safety reasons, these are becoming increasingly common in private homes as well. If you shop for a home security system, you will know a wide variety of available options. These systems range from do-it-yourself kits to sophisticated whole-house security networks which are normally installed by professionals. As such, most alarm systems are built around the same basic design concept. The burglar alarm parts (Fig. 30.10) are:

- buzzer, a device that makes noise;
- battery; and
- buzzer switch

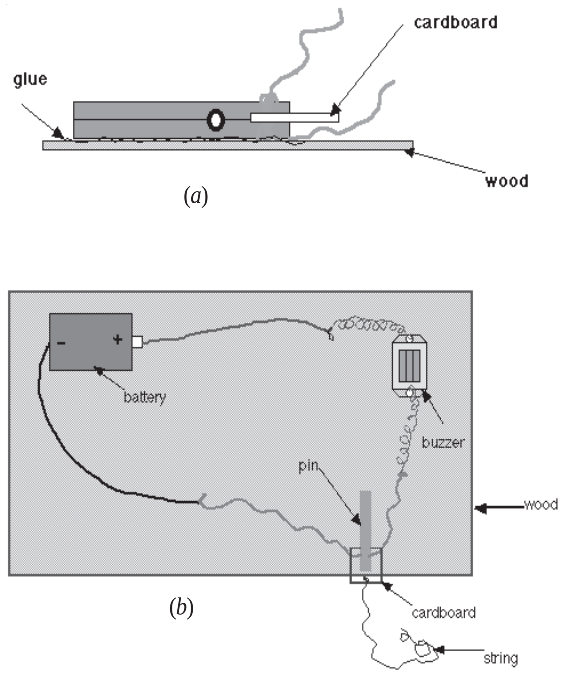


Fig. 30.10: Burglar Alarm

When some intruder tries to enter, the battery gets automatically connected (say because of activation of some circuit due to movement of door and getting sensed by some transducer) and the buzzer begins to ring or light starts glowing.

30.5.3 Fire Alarm

It is similar to a burglar alarm with the difference that the sensing device in a fire alarm is an infrared detector or smoke detector. Now a days, fire alarms have been made mandatory for high rise buildings and smoke detectors are an integral part of sensitive buildings.

The automatic actuation of fire safety functions can include interfacing with the buildings' air-handling system for the purpose of smoke management. Fans will shut down automatically, stairwell doors can be unlocked, smoke/fire doors released, and elevators automatically recalled to a predetermined floor. Today fire alarm systems do far more than detect smoke and pinpoint the location of a fire.

Intext Questions 30.4

1. List the essential parts of a burglar alarm.

   ....

2. What is the essential difference between a fire alarm and a burglar alarm?

   ....

What Have You Learnt

- Inverter and UPS are used as back-up systems. In case of power failure, these devices convert power from form a dc battery to 220V ac at 50Hz within millisecond (inverter) and microsecond (UPS).
- The output of an inverter is a square pulse of 50 Hz whereas the output of UPS is sinusoidal.
- Circuit breaker is a safety device, which automatically breaks the circuit if it gets overheated or current goes very high due to some accident or overloading.
- Digital clock not only gives time, but can also be used as a timer to set the time and duration of some operation (alarm clock, automatic switch on/off radio, TV or any other system. It works on the principle of digital counters and flip flops.
- Processor-calculator is used to carry out mathematical operations and the essential component is Arithmetic Logic Unit (ALU). It has electronic circuitry having logic gates, counters, flip flops, registers etc.
- A transducer is a device that converts energy in one form to energy in other form. The basic strategy by which a control system operates is logical and natural. There are two types of control systems: (a)Open loop type: Here output has no effect on control system. (b)Closed loop or Feedback type: First compares the output with the reference and accurately controls the desired output parameter by changing the input accordingly.
- A burglar alarm consists of three parts: buzzer, battery and a buzzer switch connected to entry or door. In switch-on mode, it is automatically activated when an intruder tries to enter, the building.

  A Fire alarm has infra-red or smoke sensing device.

Terminal Exercise

1. What is an inverter? Explain its functioning.
2. Why UPS is needed for a computer? Explain its functioning.
3. What is the utility of circuit breaker? Explain its working.
4. List the essential components of a digital clock?
5. Write short notes on (i) Burglar alarm (ii) Fire alarm, and (iii) scientific calculator.

Answers to Intext Questions

30.1

1. An inverter supplies power when main line fails. It essentially converts d.c power (battery) to square wave a.c power.
2. UPS is used to provide *continuous* power to a computer and its peripherals when mains fails.
3. (i) An inverter provides square waveform where as a UPS provides sinusoidal waveform.

   (ii) The switch over time of an inverter is of the order of a millisecond whereas it is a microsecond for a UPS.

30.2

1. The function of a circuit breaker is to cut off the circuit whenever the current jumps above a safe level.

30.3

1. A digital clock is made of digital counters which, in turn, are made up of flip flops.
2. A timer sets the duration at which some operation can be performed (e.g. alarm clock)

30.4

A burglar alarm has three main parts:

(a) a buzzer, the device that makes noise

(b) The battery

(c) The buzzer switch

30.4

2. The basic difference between a burglar alarm and fire alarm is in the sensing device. Fire alarm acts as fire sensor or smoke detector.

31A

COMMUNICATION SYSTEMS

Communication is a basic characteristic of all living beings. Communication entails transmitting and receiving information from one individual/place to another. In the world of animals, communication is made by mechanical, audio and chemical signals. You may have observed how sparrows begin to chirp loudly on seeing an intruder, who can put their life in danger. However, human beings are blessed with very strong means of communication – speech. We can express what we see, think and feel about whatever is happening around us. That is to say, we use sound (an audible range, 20Hz - 20kHz) and light (in visible range, 4000 Å – 7000 Å), apart from mechanical (clapping, tapping) and opto-mechanical signals (nodding, gesturing), for communication. You must realise that language plays a very significant role in making sense out of spoken or written words.It comes naturally to us. Prior to the written alphabet, the mode of communication was oral. The second era of communication began with the invention of printing press. Invention of the telegraph in the early nineteenth century marked the beginning of the third stage. Revolutionary technological developments enabled as rapid, efficient and faithful transfer of information. Using tools and techniques such as telegraph, fax, telephone, radio, mobiles, satellites and computers, it is possible to communicate over long distances. The oceans and mountain ranges no longer pose any problem and the constraints of time and distance seem to be non-existent. On-line learning, (education), publishing (research), banking (business) which were topics in science fiction not too long ago, are now routine activities. In fact, combination of computers with electronic communication techniques has opened a very powerful and fertile field of information and communication technologies (ICT_s).

Have you ever thought about the technology that has made all this development possible? You will discover answers to this question in the following three lessons. In this lesson you will learn the general model of communication and how electromagnetic waves render themselves so gainfully for communication.

Objectives

After studying this lesson, you will be able to:

- list the components used in a long distance communication system,
- explain the terms analogue and digital signals; and
- describe how electromagnetic waves act as carriers of information.

31.1 A Model Communication System

Communication systems endeavour to transmit information from

- one to one, i.e. point-to-point communication;
- one to many, i.e., broadcast communication; and
- many to many, i.e. telephone conference call or a chat room.

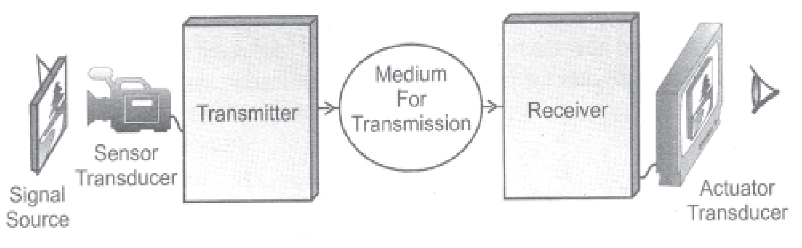


Fig. 31.1 : A schematic arrangement for the communication system.

In a typical modern day communication system, the information is in the form of electrical signals (voltage or current), spread over a range of frequencies called the signal **bandwidth**. (Some **noise** gets added to the signal and tries to obscure the desired information.) For scientific analysis of any system, we model the system into its basic components. You will now learnt about these.

31.1.1 Components of a Communication System

Refer to Fig. 31.1. It shows building blocks of a typical communication system. As may be noted, the essential elements of a communication system are:

- a source of signal, a sensor transducer and a **transmitter,** which launches the signal carrying information,
- an intervening **medium/channel** to guide and carry the signal over long distances, and
- a signal **receiver** and an actuator transducer to intercept the signal and retrieve the information.

Commonly used signals in communication are either audio or visual. These are characterized by amplitude, frequency, phase and polarisation. For example for sound signals, we confine to audible range (20kHz – 20kHz), whereas for normal telephony, the range is limited to 4kHz only.

You may have seen policemen or security personal carrying Walkie-Talkie sets to minitor the movement of dignitaries or public rallies. The range of such sets is limited to 1kHz.

A communication which depends on the range of frequencies is called band width limited communication. An obvious disadvantage of band-limited communication is in the form of poor voice quality.

For optical signals, the frequency range of interest is 10^{13}–10^{14} Hz.

An input signal (bearing information) is transmitted to a distant point by a transmitter. A **receiver** intercepts such signals and transforms them in such a way that the information hidden therein can be converted into usable form. In the case of A **radio** transmission the input signal is usually in the form of voice or music and the transmitter transforms it (by a process called **modulation,** which you will learn in the next lesson) into electrical signal (by superposing over electromagnetic waves in the frequency range 30 kHz – 300 MHz These radio signals are broadcast by means of aerials or antennas either in all directions or in some specified direction.

An **antenna** or **aerial** is essentially a system of conductors, which effectively radiates and absorb electromagnetic waves. The antenna can be in the form of a long, stiff wire (as AM/FM radio antennas on most cars) or a huge dish (for far away satellites). In a radio transmitter the antenna launches the radio waves into space. In a receiver, the idea is to pick up maximum transmitted power and supply it to the tuner. The **optimum size** of a radio antenna is related to the frequency of signal that the antenna is trying to transmit or receive. The size of these conductors has to be comparable to the wavelength λ of the signal (at least $\lambda/4$ in dimension), so that they can detect the time-variation of the signal properly.

In the case of radio receivers, the signals picked up by the receiving antenna may be extremely weak, often only a small fraction of a microwatt. Such signals are amplified before being analysed. The important characteristics of a receiver are: sensitivity to input signal, amplitude range of the input signal which can be received and converted to output, linearity, between the input and output signals, and *frequency response* or *fidelity*, which refers to the degree of faithfulness to which input signals can be reproduced.

i. **Sensitivity** signifies the minimum input voltage required to produce a standard output signal voltage. The greater the amplification of the receiver, the greater is its sensitivity. A limit to sensitivity is set by the noises picked up by the antenna, and thus the signal to noise ratio, abbreviated as the **S/N ratio**, plays an important role in determining the sensitivity of a receiver. For gainful utilisation of a signal, the system should not introduce any internal noise. And if any external noise enters the systems, it must be filtered out using some signal processing technique.

ii. **Selectivity** is the capability of a receiver to differentiate between a desired signal of a particular frequency and all other unwanted signals of nearby frequencies. Selectivity depends on the sharpness of the resonance curves (Core Module 5, Unit 5) of the tuner circuits used in the receiver.

iii. **Fidelity** represents the variation of the output of a receiver with the modulation frequency and denotes the ability of the receiver to reproduce the waveform of the modulating signal.

A signal is communicated from the transmitter to the receiver through a medium. The carrier is in the form of a wave and for sound as well as e.m. waves; Normally air serves as the intervening linear medium, ie. superposition principle holds, under normal intensity conditions. Electromagnetic waves can travel through free space (vacuum) as well and it acts as a linear medium for these.

You may be wondering as to why are we emphasizing on linearity. It is for two reasons: To transmit music (sound) over long distances, we have to superpose the audiosignal over radio frequency waves. So linearity of medium suports the principle of superposition. Secondly, if a medium shows non-linearity, it can cause distortion and noise. These can adversely affect the quality of signal received. Since faithful reproduction of transmitted signal is both necessary and desirable, a circuit designer makes every effort to ensure best possible reproduction at the receiving end.

Intext Questions 31.1

1. What is the frequency range of radio waves?

   ....

2. How do you determine the optimum size of a radio antenna?

   ....

31.2 Types of signals – Analogue and digital

You now know that communication of information involves use of signals, which are classified on the basis of their origin and nature. Accordingly we have

– continuous time (analog) end discrete time (digital) signals;

– coded and uncoded signals;

– periodic and aperiodic signals;

– energy and power signals; and

– deterministic and random signal.

Of these, we will consider only analog and digital systems. The sound produced by human being in conversation/interaction or photograph are converted into continuously varying electrical analog signal [Fig. 31.29(a)]. But in modern electronic communiction systems, these are converted into discrete form, which has finite values at different instances of time and zero otherwise [Fig. 31.2 (b), (c)] form Fig. 31.2, you will note that the waveforms used to represent correspond to a particular frequency and are periodic; while one of these is sinusoidal, the another is pulsed. In fact these may be viewed as a sub-class of sine and square waveforms.

Information can be packaged in both analog (or continuous) and digital (or discrete) forms. Speech, for example, is an analog signal which varies continuously with time. In contrast, computer files consist of a symbolic "discrete-time" digital signal.

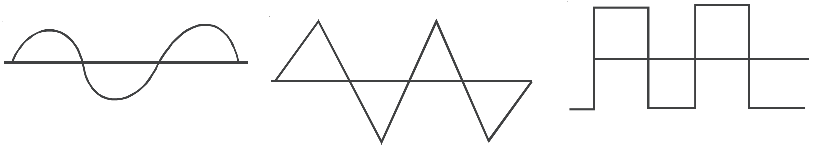


Fig. 31. 2 : *Examples of (a) continuous (sinusoidal) and (b) discrete signals.*

In the digital format, signals are in the form of a string of **bits** (abbreviated from **bi**nary digi**ts**), each bit being either 'ON' or 'OFF' (1 or 0). The **binary** system refers to a number system which uses only two digits, 1 and 0 (as compared to the **decimal** system which uses ten digits from 0 to 9). We can convert all information-bearing signals into discrete-time, amplitude-quantised digital signals. In a compact disc (CD), the audio is stored in the form of digital signals, just as a digital video disc (DVD) stores the video digitally.

Communication systems can be either fundamentally analog, such as the amplitude modulation (AM) radio, or digital, such as computer networks. Analog systems are in general, less expensive than digital systems for the same application, but digital systems are more efficient give better performance (less error and noise), and greater flexibility. Interestingly, digital as well as analog transmission accomplished using analog signals, like voltages in Ethernet (an example of wireline communication) and electromagnetic radiation in cellular phone (wireless communication).

The most crucial parameter in communication systems is the signal bandwidth, which refers to the frequency range in which the signal varies. However, it has different meaning in analog and digital signals. While analog bandwidth measures the range of spectrum each signal occupies, digital bandwidth gives the quantity of information contained in a digital signal. For this reason, analog bandwidth is expressed in terms of frequency, i.e. H_E, the digital bandwidth is expressed in terms of bits per second (bps). The frequency range of some audio signals and their bandwidths are given in Table 31.1. Note that human speech has bandwidth of nearly four kilo hertz. The bandwidth is about 10kHz in amplitude modulated (AM) radio transmission and 15kHz in frequency molulated (FM) transmission. However, the quality of signal received from FM broadcast is significantly better than that from AM. The compact discs have bandwidth of 20kHz. The bandwidth of a video signal is about 4.2MHz and television broadcast channel has bandwidth of 6MHz. The bandwidth

of a typical modem, a device used for communication of digital signals over analog telephone lines, are 32kbps, 64 kbps or 128 kbps.

Table 31.1 Typical audiobandwidths

Source	Frequency range(H_E)	Bandwidth (kHz)
Guitar	82–880	... 0.8
Violin	196–2794	... 2.6
Vowels (a,e,i,o,u)	250–5000	... 4
consonants		
Telephone signal	200–3200	... 3

31.3 Electromagnetic Waves in Communication

In communication, we use different ways to transport the electrical signal from the transmitter to the receiver. From Modules on electricity and magnetics, you may recall that current passes through a metal conductor in the form of current signal or voltage drop, through air in the form of electromagnetic radiation or converted into light signal and sent through an optical fibre. Irrespective of the mode transmission of signal is governed by the classical theory of electromagnetic wave propagation, given by Maxwell.

As the name suggests, e.m. waves consist of electric and magnetic fields, which are inseparable. An electric field varrying in time produces a space-time varrying magnetic field, which, inturn, produces electric field. This mutually supporting role results in propagation of electromagnetic waves according to e.m. laws. The pictorial representation of a plane e.m. wave is shown in Fig. 31.3.

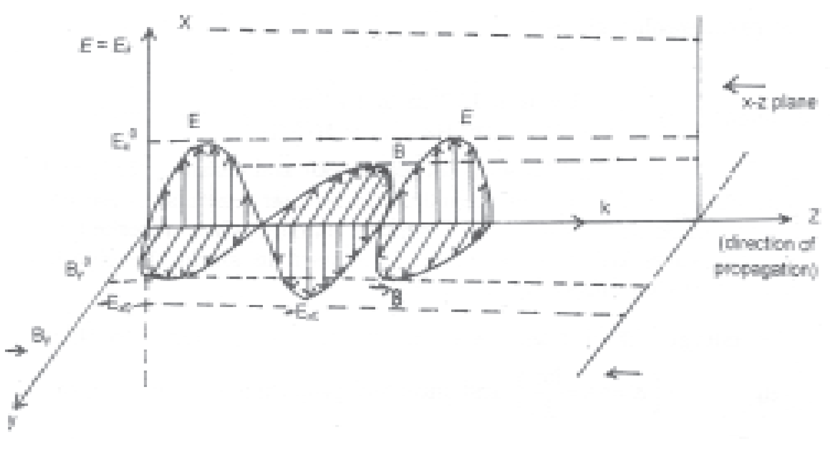


Fig. 31. 3: *Propagation of electromagnetic waves*

Mathematically we can express these as $E = E_0 \sin(kz - \omega t)$ and $H = H_o \sin(kz - \omega t)$. The direct experimental evidence for the existence of e.m. waves came in 1888 through a series of brilliant experiments by Hertz. He found that he could detect the effect of e.m. induction at considerable distances from his appparatus. By measuring the wavelength and frequency of e.m. waves, he calculated their speed, which was equal to the speed of light. He also showed that e.m. waves exhibited phenomena similar to those of light The range of wavelengths, as we now know is very wide from radio waves (λ is 1m to 10m) to visible light (400nm) as shown in Fig. 31.4. This generated a lot of interest and activity. In 1895 Indian physicist Jagadis Chandra Bose produced waves of wavelength in the range 25mm to 5m and demonstrated the possibility of radio transmission. This work was put to practical use by Guglielmo Marconi who, succeeded in transmiting e.m. waves across the Atlantic Ocean. This marked the beginning of the era of communication using e.m. waves. Marconi along with Carl Ferdinand Braun, received the 1909 Nobel Prize in

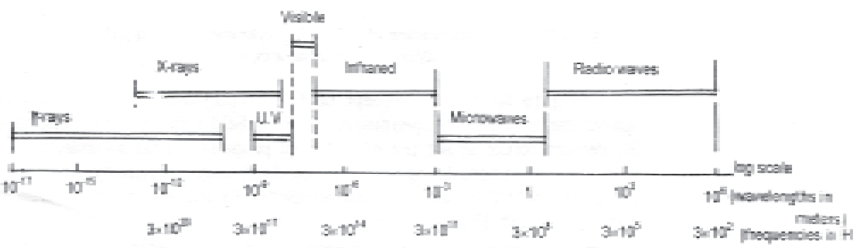


Fig. 31. 4: *The electromagnetic spectrum: The wave values of length correspond to vacuum (or air) The boundaries between successive regions of the spectrum are not sharply defined.*

In a communication system, a transmitter radiates electromagnetic waves with the help of an antenna. These waves propagate in the space and captured by the receiver. At the receiver, another antenna extracts energy (in formation) from the electromagnetic waves. Now we use radio waves for different purposes television (TV) broadcasts, AM (amplitude modulated) and FM (frequency modulated) radio broadcasts, police and fire radios, satellite TV transmissions, cell phone conversations, and so on. Each such signal uses a different frequency, and that is how they are all separated.

You will learn the details of the mechanism of these transmissions and working of some common communication devices in the following two lessons. In Table 31.2, we have listed internationally accepted electromagnetic spectrum relevant for radio and TV broadcast, popular band names, and their application.

(Frequencies ν in Hz are related to wavelengths λ in m in vacuum through the relationship $c = \nu\lambda$, where $c = 3 \times 10^8$ m/s is the speed of electromagnetic waves in vacuum.)

Table 31.1: Radio frequency bands

Band	Frequency Range	Wavelength Range	Application
Extremely Low Frequency (ELF)	< 3 kHz	> 100 km	Mains electricity
Very Low Frequency (VLF)	3 - 30 kHz	100 – 10 km	SONAR
Low Frequency (LF)	30 - 300 kHz	10 – 1 km	Marine navigater
Medium Frequency (MF)	300 kHz - 3 MHz	1 km – 100 m	Medium wave radio
High Frequency (HF) Very High Frequency (VHF)	3 - 30 MHz 30 – 300 MHz	100 – 1 m 10 – 1 m	short wave radio FM radio
Ultra High Frequency (UHF)	300 MHz – 3 GHz	1 m – 10 cm	commercial, TV, Radio, Radar
Super High Frequency (SHF)	3 – 30 GHz	10 – 1 cm	Satellite communiction, cellular mobile, commercial TV

AM radio is broadcast on bands, popularly known as the Long wave*:* 144 - 351 kHz (in the LF), the Medium wave: 530 - 1,700 kHz (in the MF), and the Short wave*:* 3 – 30 MHz (HF). **Medium wave** has been most commonly used for commercial AM radio broadcasting. **Long wave** is used everywhere except in North and South Americas, where this band is reserved for aeronautical navigation. For long- and medium-wave bands, the wavelength is long enough that the wave diffracts around the curve of the earth by ground wave propagation, giving AM radio a long range, particularly at night. **Short wave** is used by radio services intended to be heard at great distances away from the transmitting station; the far range of short wave broadcasts comes at the expense of lower audio fidelity. The mode of propagation for short wave is ionospheric.

Frequencies between the broadcast bands are used for other forms of radio communication, such as walkie talkies, cordless telephones, radio control, amateur radio, etc.

You must have read about Internet enabled mobile phones and Internet Protocol Television. Have you ever thought as to which technology is enabling such empowerment? Is it fibre optic communication? Does laser play any role? You will learn answers to all such questions in the next unit.

Table 31. 3 : Frequency ranges for commercial FM-radio and TV broadcast

Frequency Band	Nature of Broadcast
41 – 68 MHz	VHF TV
88 – 104 MHz	FM Radio
104 – 174 MHz	S Band (Sond-erkanal meaning Special Channel) for cable TV networks
174 – 230 MHz	VHF TV
230 – 470 MHz	H (Hyper) Band for cable TV networks
470 – 960 MHz	UHF TV

Intext Questions 31.2

1. What is an electromagnetic wave?

   ....

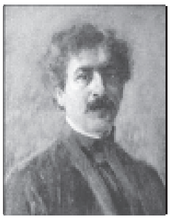
2. Calculate the wavelength of a radio wave of frequency of 30 MHz propagating in space.

   ....

3. What is the frequency range of visible light?

....

Jagadis Chandra Bose
(1858 – 1937)



Jagadis Chandra Bose, after completing his school education in India, went to England in 1880 to study medicine at the University of London. Within a year, he took up a scholarship in Cambridge to study Natural Science at Christ's College – one of his lecturers at Cambridge, Professor Rayleigh had a profound influence on him. In 1884 Bose was awarded B.A degree by Cambridge university and B.Sc degree by London University. Bose then returned to India and took teaching assignment as officiating professor of physics at the Presidency College in Calcutta (now Kolkata). Many of his students at the Presidency College were destined to become famous in their own right. Satyendra Nath Bose who became well known for his pioneering work on Bose-Einstein statistics and M.N. Saha who gave revolutionary theory of thermal ionisation, which enabled physists to classify the stars into a few groups.

In 1894, J.C. Bose converted a small enclosure adjoining a bathroom in the Presidency College into a laboratory. He carried out experiments involving refraction, diffraction and polarization. To receive the radiation, he used a variety of junctions connected to a highly sensitive galvanometer. He developed the use of *galena* crystals for making receivers, both for short wavelength radio waves and for white and ultraviolet light. In 1895, Bose gave his first public demonstration of radio transmission, using these electromagnetic waves to ring a bell remotely and to explode some gunpowder. He invited by Lord Rayleigh, to give a lecture in 1897. Bose reported on his microwave (2.5 cm to 5 mm) experiments to the Royal Institution and other societies in England. But Nobel prize alluded him probably for want of vivid practical appliction of this work by him. By the end of the 19th century, the interests of Bose turned to response phenomena in plants. He retired from the Presidency College in 1915, and was appointed Professor Emeritus. Two years later the Bose Institute was founded in Kolkata. Bose was elected a Fellow of the Royal Society in 1920.

What You Have Learnt

- In a typical modern-day communication system, the information is in the form of electrical signals (voltage or current).
- The essential elements of a communication system are (i) a transmitter (ii) a medium or mechanism to carry the signal over long distances, and (iii) a receiver to intercept the signal and retrieve the information.
- An antenna or aerial is essentially a system of conductors, which is an effective radiator and absorber of electromagnetic waves in the desired radio frequency region.

- Analog signals are physical signals that vary continuously with time while digital signals have the form of discrete pulses.
- Digital communication systems are more efficienct, give better performance, and greater flexibility than their analog counterparts.
- AM radio is broadcast on three bands, the Long wave at 144 – 351 kHz (in the LF), the Medium wave at 530 – 1,700 kHz (in the MF), and the Short wave at 3 – 30 MHz (HF). FM radio is broadcast on carriers at 88 – 104 MHz (in the VHF). Commercial TV transmission is in the VHF-UHF range.

Terminal Exercise

1. What are the essential elements of a communication system?
2. What is an antenna?
3. What are the important characteristics of a receiver in a communication system?
4. Distinguish between the terms analogue and digital signals. Define a ‘bit’.
5. The VHF band covers the radio frequency range of 30 – 300 MHz. Using the known relationship of speed to frequency and wavelength of an electromagnetic wave, determine the VHF wavelength range in vacuum. Take the speed of light in vacuum to be 3×10^8 ms^{-1}

Answers to Intext Questions

31.1

1. 30 kHz – 300 MHz
2. The optimum size of a radio antenna is related the frequency the signal that it is designed to transmit or receive & must capture maximum radiated part.

31.2

2. $\lambda = \frac{C}{\nu} = \frac{3\times10^8\,ms^{-1}}{30\times10^6\,s^{-1}} = 10m$

3. $10^{14} - 10^{15}$ Hz

Answer to Problems in Terminal Exercise

5. 10m – 1m

32A

COMMUNICATION TECHNIQUES AND DEVICES

In the previous lesson you have learnt about the building blocks of a communication system. You will recall that communication systems can be categorised as

- audio systems, which include AM and FM radio and walky-talkies
- video systems like TV;
- telecommunication systems like land line and cellular mobile phones; and
- computer communication systems like email, chat and computer-conferencing.

For signal transmission in these systems, we use different media, such as transmission lines, wave guides, free space and optical fibres. In this lesson you will learn about wireless audio and video communicaiton systems.

You may recall that the first step in wireless communication was taken by Dr. JC Bose and G. Marconi. Since then, technology has moved a long way. However, the most easily available source of information the entertainment and education continues to be radio. In initial years, radio communication was via amplitude modulated (AM) transmission. Subsequently, it gave way to frequency modulated (FM) transmission. Now a days, it is possible to transmit radio signals using satellite. But for simplicity, we shall confine ourselves to using analog and digital signals, AM and FM modulation and demodulation processes. Since the digital system of communication is more efficient and noise-free, we intend to convert an analog signal to its digital counterpart. This is done using sampling technique. You will discover answer to questions such as: How does a carrier wave carry a signal (voice or music) over long distances? How is the signal detected at the receiver? You will also learn about some typical communication devices, such as AM radio, TV, Fax and computer modem.

Objectives

After studying this lesson, you will be able to

- explain how an analog signal, is converted into a digital signal;
- describe the processes of modulation and demodulation and explain how these are used to transmit information over long distances; and
- explain the basic working principles of communication devices, such as radio, TV, fax machine and the modem.

32.1 Sampling

In the preceding lesson, you learnt that a digital signal is comparatively error free, noise free, more efficient and effective. You may therefore logically ask: How do we convert an analog signal to an equivalent digital signal with no loss of information. To answer this question, you may recall that an analog signal has an infinite number of very precise values in a certain time interval. Since we can not possibly count and store its values at infinitesimally close instants of time with infinite precision, we devise a practical way of picking a good digital approximation. The first step in this process is **sampling**. To sample a signal, we note its values at regular intervals of time. (The rate at which the samples are taken is called sampling rate.) You may logically ask : what is the optimum sampling rate? That is, at what intervals of time should we record the values? Obviously, sampling a signal at small steps of time will increase the size of the data load to be stored and transmitted, but will result in better quality, i.e., a better approximation of the analog signal. This is described by **sampling theorem,** which states that an analog signal is completely described by its samples, taken at equal time intervals T_s, if and only if the sampling frequency $f_s = 1/T_s$ is greater than or equal to twice the maximum frequency component (i.e., the bandwidth) of the analog signal. The equality defines what is called the **Nyquist rate**. Thus by sampling an analog signal, the signal is converted (without any loss of information) into an amplitude continuous time-discrete signal, which in turn can be converted by a quantiser into a signal discrete in both amplitude and time. This means that the infinite precision values of amplitudes are converted to values which can be stored digitally.

Recall that a bit is a binary digit, either 0 or 1. In general, the purpose of quantisation is to represent a sample by an *N*-bit value. In the process of *uniform* quantisation, the range of possible values is divided into 2*N* equally sized segments and with each segment, an *N*-bit value is associated. The width of such a segment is known as the *step size*. This representation results in clipping if the sampled value exceeds the range covered by the segments. In *non-uniform* quantisation, this step size is not constant. A common case of non-uniform quantisation is logarithmic quantisation. Here, it is not the original input value that is quantised, but in fact the log value of the sample. This is particularly useful For audio signals since humans tend to be more sensitive to changes at lower amplitudes.

32.2 Modulation – Analogue AM and FM, digital (PCM)

The process of processing a signal to make it suitable for transmission is called *modulation.* Most of the information-bearing signals in day-to-day communication are audio signals of frequency less than 20 kHz. For small distances, we can form direct link. But it is not practical to transmit such signals to long distances. This is because of the following two reasons:

- The signal should have an antenna or aerial of size comparable to the wavelength of the signal so that the time variation of the signal is properly sensed by the antenna. It means that for low-frequency or long-wavelength signals, the antenna size has to be very large.
- The power carried by low frequency signals is small and can not go far. It is because of cantinuous docline or attemation due to absorption/radiation loss. It means that for long distance transmission high frequencies should be used. But these can not carry useful information. We are therefore confronted with a situation analogous to the following:

On a front port, Indian army spots advancing enemy forces. To minimise loss of life and save the post from falling to enemy, they need reinforcement from the base camp. But by the time an army jawan goes, conveys the message and the reinforcement reaches, the port would have fallen. Therefore, it wants a carrier, say a horse, which can run fast. But the horse can not deliver the message. The way out is: Put the jawan on the horseback; let the horse run and jawan convey the message.

For signal transmission, audio signal acts as jawan and high (radio) frequency acts as the horse (carrier). So we can say that by super imposing a low frequency signal on a high frequency carrier wave, we process a signal and make it suitable for transmission. We convert the original signal into an electrical signal, called the *base band signal* using a signal generator. Next we super impose the base band signal over carrier waves in the modulator. The change produced in the carrier wave is known as modulation of the carrier wave and the message signal used for modulation is known as *modulating signal*. The carrier wave

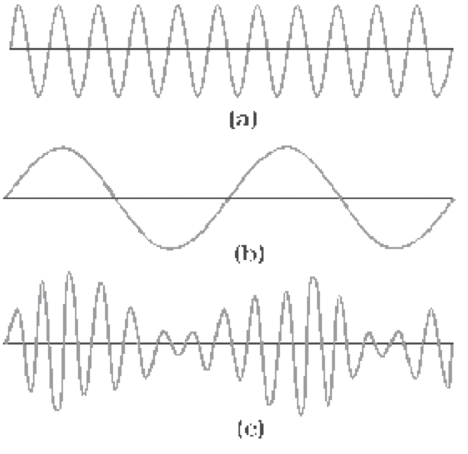


Fig. 32.1: Modulation of a carrier wave by a modulating signal: (a) a sinusoidal carrier wave of high frequency, (b) a modulating signal (message or information signal) of low frequency, (c) amplitude modulated carrier wave.

can be continuous or pulsed. Since a sinusoidal wave, is characterised by amplitude, frequency and phase it is possible to modulate (i.e. modify) either of these physical parameter. This is known as analog modulation. There are different types of analog modulation: **Amplitude Modulation** (**AM**); **Frequency Modulation** (**FM**); and **Phase Modulation (PM),** respectively For pulsed carrier waves, **Pulse Code Modulation** (**PCM**) is the preferred scheme.

In Amplitude modulation, the amplitude of a high-frequency carrier wave (Fig. 32.1a) is modified in accordance with the strength of a low-frequency audio or video modulating signal (Fig.32.1.b). When the amplitude of the modulating wave increases, the amplitude of the modulated carrier also increases and vice-versa — the envelope of the modulated wave takes the form depending on the amplitude and frequency of modulating signal (Fig. 32.1.c) .

To understand this, we write expressions for instantaneous amplitudes of audio signal and carrier wave:

$$\upsilon_a(t) = \upsilon_{ao} \sin\omega_a t \qquad (32.1a)$$

and

$$\upsilon_c(t) = \upsilon_{co} \sin\omega_c t \qquad (32.1b)$$

where w_a and w_c are the angular frequencies and V_{ao} and V_{co} denote of audio and carrier waves, respectively. denote the amplitudes. In amplitude modulation the modulationg (audio) signal is superimposed on the carrier wave, so that the amplitude of the resultant modulated wave can be expressed as

$$A(t) = \upsilon_{co} + \upsilon_a(t) = \upsilon_{co} + \upsilon_{ao} \sin\omega_a t$$

$$= \upsilon_{co}\left[1 + \frac{\upsilon_{ao}}{\upsilon_{co}} \sin\omega_a t\right] \qquad (32.2)$$

Hence the modulated wave can be expressed as

$$\upsilon_c^{mod}(t) = A\sin\omega_c t = \upsilon_{co}\left[1 + \frac{\upsilon_{ao}}{\upsilon_{co}}\sin\omega_a t\right]\sin w_c t \qquad (32.3)$$

From Eqn. (32.3) we note that the instantaneous amplitude of the modulated wave is determined by the amplitude and frequency of the analog audio signal. The ratio $\upsilon_{ao}/\upsilon_{co}$ gives us a measure of the extent to which carrier amplitude is varied by the analog modulating signal and is known as amplitude modulation index. We will denote it by m_a. In terms of modulation index, we can rewrite Eqn. (32.3) as

$$\upsilon_c^{mod} = \upsilon_{co}(1 + m_a \sin\omega_a t)\sin\omega_c t$$

$$= \upsilon_{co}\sin\omega_c t + \upsilon_{co} ma \sin\omega_a t \sin\omega_c t$$

$$= \upsilon_{co}\sin\omega_c t + \frac{\upsilon_{co} m_a}{2}\cos(\omega_c - \omega_a)t - \frac{\upsilon_{co} m_a}{2}\cos(\omega_c + \omega_a)t \qquad (32.4)$$

From Eqn. (32.4) we note that

- the modulated wave shown in Fig. 32.1(c) has three components. The first term represents carrier wave the second term whose frequency is lower than that of the carrier wave, constitutes the lower side band, and the third term with frequency higher than the carrier wave is the upper side band; and

- the frequency of the modulating signal is not directly contained in the amplitude modulated wave.

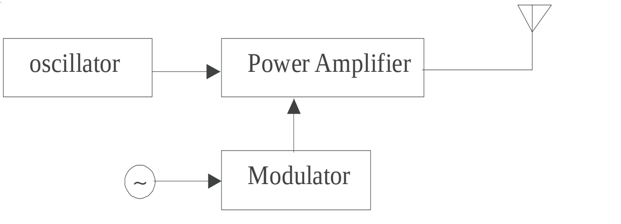
If the modulating signal in an AM system is given by $\upsilon_a = 4\sin 6283t$ and frequency of the lower side band is 3.5×10^5Hz, the angular frequency of the carrier wave is given by

$$\omega_C = \omega_a + 2\pi \times (3.5) \times 10^5$$
$$= 6283 + 22 \times 10^5$$
$$= (2200 + 6.283) \times 10^3 \text{rad}$$
$$= 2.206 \times 10^6 \text{rad}$$

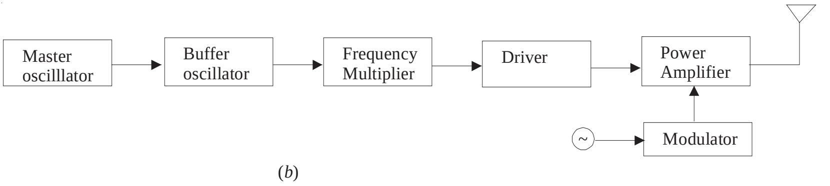
It is important to appreciate that the most efficient information transfer takes place when maximum power transmitted by the comunication system is contained in the side bands.

The block diagram of a basic analog AM transmitter is shown in Fig. 32.2 (a). The oscillator provides a fixed frequency and the power amplifier modulates the signal. (In unit 29 you have learnt about class A, class B and class C amplifies. We use these singly or in combination). In a typical AM broadcast transmitter [Fig. 32.2(b)] Hartly-Colpitts or systal controlled oscillators are used.

Moreover a better amplifier is introduced between the master socillator and the remaining circuit. Also, to enhance the frequency and amplitude of the signal frequency multiplier and driver amplifiers are added before modulating the signal in a power amplifier.



(*a*)



(*b*)

Fig. 32.2 Block diagram of a) a basic and b) practical AM transmitter

For any broadcast, the maximum power that can be radiated is controlled by the GOI. It is in the range 500W to 50kW for radio transmitters. Every broadcaster is allocated a definite frequency, which has to be observed strictly to avoid interfrence with other signals. To ensure this, undesirable frequencies are filtered out by using coupling circuits. We will not go into these details further.

The most popular form of radio communiction in India over the past 50 years had been medium wave (520 – 1700kHz) and short wave (4.39 – 5.18MHz; 5.72 – 6.33MHz) analog AM broadcast. It continues to have the widest spread, though analog FM broadcast is now being preferred because of better quantity. Moveover, radio waves are now comparatively free and private broadcasters are also entering the field in a big way. FM radio stations are also being created by educational institutions for education as well as empowerment of rural youth and homemakers. In TV transmission, audio is frequency modulated whereas the video (picture) is amplitude modulated.

In **frequency modulation**, the amplitude of the carrier wave remains constant, but its frequency is continuously varied in accordance with the instantaneous amplitude of the audio or video signal. When the amplitude of the modulating signal voltage is large, the carrier frequency goes up, and when the amplitude of the modulating signal is low, the carrier frequency goes down, i.e., the frequency of the FM wave will vary from a minimum to a maximum, corresponding to the minimum and maximum values of the modulating signal (Fig. 32.3).

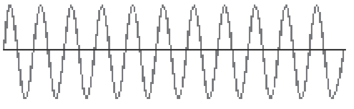


Fig. 32.3: Frequency modulated career wave

An FM Transmitter essentially contains an oscillator, whose frequency of the carrier is varied depending on the input audio signal. (It is usually accomplished by varying capacitance in an LC oscillator or by changing the charging current applied to a capacitor, for example, by the use of a reverse biased diode, since the capacitance of such a diode varies with applied voltage.) After enhancing the power of the modulated signal, it is fed to the transmission antenna. Low-frequency radio broadcast stations use amplitude modulation, since it is a simple, robust method.

Phase modulation involves changing the phase angle of the carrier signal is accordance with the modulating frequency. Analog pulse modulation is either amplitude modulated or time modulated. Similarly, digital pulse modulation is of two types: pulse code modulation and pulse delta modulation.

In **pulse code modulation**, the modulating signal is first sampled, and the magnitude (with respect to a fixed reference) of each sample is quantised. (It is a digital representation of an analog signal where the magnitude of the signal is sampled regularly at uniform intervals of duration T_s. The binary code is transmitted usually by modulating an analog current in a transmission medium such as a landline whereas pulse code modulation is used in digital telephone systems and for digital audio recording on compact discs.

32.3 Demodulation

The modulated signal carrying the information, once radiated by the antenna, travels in space. Since there are so many transmitting stations, thousands of signals reach our antenna.

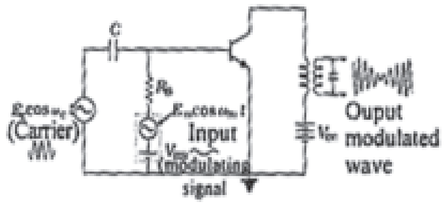


Fig.32.4: Circuit diagram of a demodulator

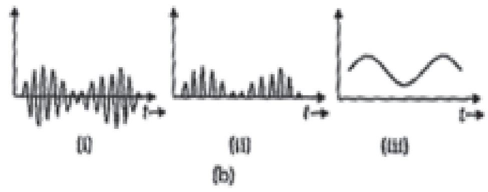


Fig. 32.5: The modulated wave form (i) input (iii) output

We have to choose the desired signal and decouple the carrier wave and the modulating signal. This process is known as *demodulation*. That is, in demodulation process, we eliminate the radio frequency carrier and separate (filter) the modulation signal. For performing amplitude demodulation, the simple circuit shown in Fig. 32.4 can be used. The modulated wave received by the antenna is fed into a resonant circuit. The diode conducts only when the modulated signal is in positive half cycle. Due to this, the output emf changes rapidly to peak value via forward resistance of the diode. The low pass filter (made of C_Z

Fig. 32.5: i) input modulated wave, and iii) output demodulated wave

and R) removes the carrier frequency. Capacitor C_Z discharges slowly. Another capacitor (C_3) is used to remove the dc component in the detected signal.

Note that due to modulation and demodulation of the audio signal, distortions arise in its amplitude, frequency and phase. These give rise to higher harmonics, time delays and other such disturbances.

Intext Questions 32.1

1. Choose the correct option in each case:

   (a) Modulation is used to

   (i) reduce the bandwidth used

   (ii) separate the transmissions of different users

   (iii) ensure that information may be transmitted to long distances

   (iv) allow the use of practical antennas.

   (b) AM is used for broadcasting because

   (i) it is more noise immune than other modulation systems

   (ii) it requires less transmitting power compared to other systems

(iii) it avoids receiver complexity

(iv) no other modulation system can provide the necessary bandwidth for faithful transmission.

32.4 Common Communication Devices

Having discussed the basic physics of signal transmission and detection, we now describe a few typical electronic devices. We begin by considering a rather familiar device such as a radio.

32.4.1 Radio

You have already learnt the details of radio transmission – a high-frequency carrier wave is first modulated by the information signal (voice or music), the modulated carrier is then transmitted in space by an antenna. The instrument used to detect such a modulated carrier is commonly called a radio or a transistor. A radio **receiver** intercepts the radio waves with an antenna or aerial, selects the desired signal by tuned LC circuits, amplifies the weak radio-frequency (rf) signal by tuned rf amplifiers, decodes the audio signal from the radio wave through the process of demodulation and amplifies the audio signal. The amplified audio signal is then fed to a loudspeaker which reproduces the input audio signal.

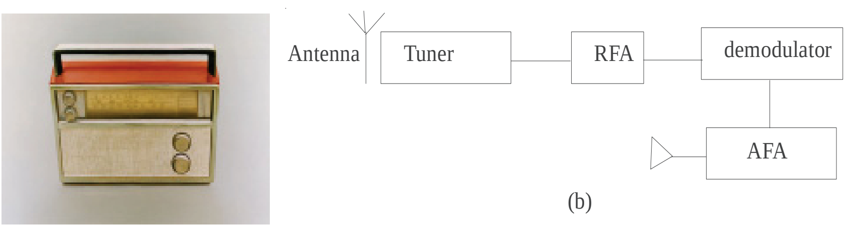


Fig. 32.6 : (a) a radio, and b) block diagram of a radio receiver circuit

Before the discovery of transistors and subsequent revolutionary developments in electronic circuitory, radio sets were bulky and the quality of reception was also not so good. But now we have pocket transistor radios. Even mobile phone carry added facilities of radio, camera with video capacity, etc. Another very common device which facilitates video communication is television. It has become an integral part of our lives. It is being used for entertainment, sharing news information, inparting education, as monitor for a computer, display device for a closed circuit TV system based surveillances and replaying pre-recorded video programmes, movies, playing cable/satellite/dish videogames. You learn about it now. But for simplicity, we will confine ourselves to TV as transmit receive system only.

32.4.2 Television

Have you ever spared thoughts to discover: How does a television decode the signals it receives to produce the picture? There are two amazing features of the human brain that make TV possible. The first is: If we divide a still image into a collection of small coloured dots, our brain reassembles the dots into a meaningful image. In fact, television and computer screens (as well as newspaper and magazine photos) rely on this capability of fusion in the human brain and their displays are divided into thousands of individual elements, called **pixels (picture elements)**. The resolution of a modern computer screen (**S**uper **V**ideo **G**raphics **A**dapter) is 800 x 600 pixels or more.

The second feature is: If we divide a moving scene into a sequence of still pictures and show the still images in rapid succession, the brain will reassemble the still images into a single moving scene. Our brain fuses the dots of each image together to form still images and then fusing the separate still images into a moving scene.

Conventional television sets used a **modification of the cathode ray tube** (**CRT**) to display the images. In a cathode ray tube, the **"cathode"** is a heated filament which emits a ray of electrons which move in vacuum created inside a glass **"tube"**. The stream of electrons is focused by a focusing anode into a tight beam and then accelerated by an accelerating anode. This creates a sharp beam of high-speed electrons which ultimately hits the flat screen at the other end of the tube.

The inside of the screen is coated with phosphor, which glows when struck by the beam. In a black-and-white screen, phosphor glows white when struck. In a colour screen, there are three phosphors arranged as dots or stripes that emit red, green and blue light. There are also three electron beams to illuminate the three different colours together. When a colour TV needs to create a red dot, it fires the red beam at the red phosphor. To create a white dot, red, green and blue beams are fired simultaneously — the three colours mix together to create white. To create a black dot, all three beams are turned off as they scan past the dot. All other colours on a TV screen are combinations of red, green and blue. On the inside of the tube, very close to the phosphor coating, there is a thin metal screen called a *shadow mask*. This mask is perforated with very small holes that are aligned with the phosphor dots (or stripes) on the screen. (Fig. 32.7)

CRT based TV sets were quite bulby and fragile. With revolutionary developments in materials and devices, the TV screens are being replaced by liquid crystal displays (LCD) and plasma display screens. The advancements have miniaturised the TV sets. Though these are incresingly becoming popular, these continue to be costly.

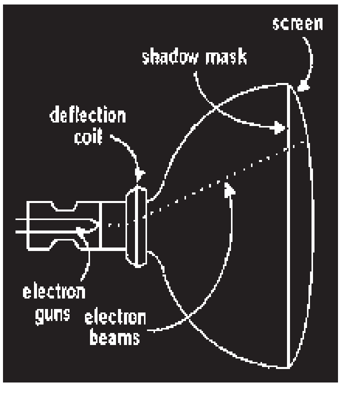


Fig. 32.7: Schematic diagram of CRT in a television set

The TV station sends a composite **video** signal, amplitude-modulated into the appropriate frequency, and a **sound** signal which is frequency-modulated as a separate signal.

There are currently three main non-compatible television standards worldwide:

• **NTSC** (**N**ational **T**elevision **S**tandards **C**ommittee), used in North and Central America and Japan. It is the oldest existing standard. It was developed in USA and first used in 1954. It consists of 525 horizontal lines of display. The timing cycle of 60 vertical lines (or 30 frames per second) is based on the 60 Hz electrical system used in these countries. Only one type of video bandwidth/audio carrier specifications exists.

• **PAL** (**P**hase **A**lternating **L**ine), a German-invented system is used in UK and most of Europe, India, Africa, Australia, and South America. It was patented in 1963 and the first commercial application of the PAL system was made in August 1967. It has 625 horizontal lines of display, 100 more than the NTSC, 50 vertical lines (or 25 frames per second), and an improved colour system. Different types use different video bandwidth and audio carrier specifications.

• **SECAM** (**Se**quential **C**ouleur **a**vec **M**émoire) is used in France, Eastern Europe, and Russia. It was developed in France and first used in 1967. It is also a 625-line horizontal and 50-line vertical display.

Usually an ordinary television set from the USA working in NTSC will not be able to receive Indian PAL transmissions, unless a special converter is provided. Now some manufacturers have started providing both options. Therefore, while buying a set, you should check such details.

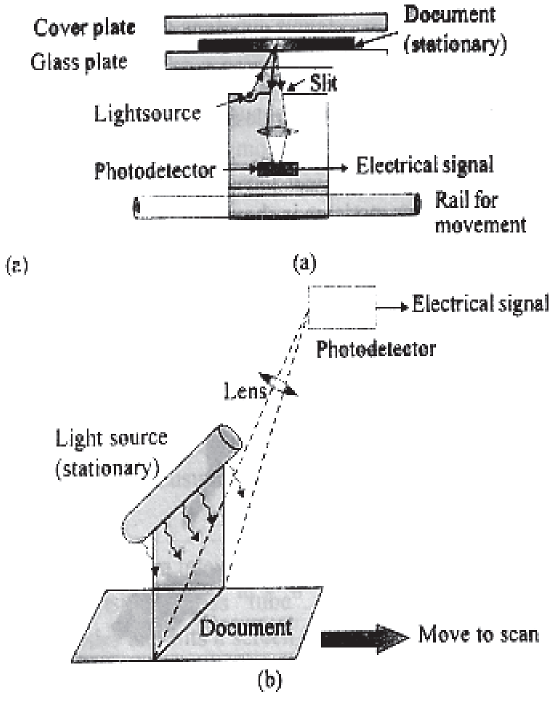


Fig. 32.7 : a) Fixed document scanner, b) Movable document scanner

32.4.3 Fax

A facsimile or fax is seen in every modern office. When connected to a telephone line, a fax allows us to communicate our message to someone else far away. It is almost instant, faster than any other communication in delivery of documents. It can transmit any document such as printed material, hand written copy, picture or diagram and reproduce it faithfully.

Fax machines have existed for more than 150 years. However, its design has continuously evolved in accordance with developments in electronic circuitry. Present day fax machines are very fast. Basically a fax machine consists of a scanner and a printer. The scanner scans the document electrically line by line and transmit it by telphone. The message is decoded at the other end and reproduced through a printer. That is, the scanner and the printed are not co-located; these are linked by a telecome medium. To scan a document, light from a powerful source is focussed and reflection of each small element on a line is evaluated progressively from left to right and it is repeated line by line till the end. To give you an idea of the numbers, every horizontal line on A-4 size sheet is scanned 1728 times. And present day fax machines can simultaneously scan all 1728 elements comprising the entire line in a single stroke by an array fo 1728 sensors.

Thermal printing is most common, using thermal sensitive paper. Normally, printing on thermal paper does not last long and for long term official record, it is advisable to keep a photocopy.

32.4.4 Modem

Modems came into existence in 1960s as a way to connect terminals to computers over the phone lines. The word **modem** is coined out of the words **mo**dulator **dem**odulator. A series modem modulates the digital data from a computer into an analog signal compatible with an analog communication channel (telephone line). On the other hand, receiving modem demodulates the analog signal into a digital data for the receiving computer. It means that the same modem works as a modulator when sending messages and as a demodulator when receiving messages. Wireless modems convert digital data into radio signals and back.

A typical arrangement that uses modems is shown is Fig. 32.8.

Fig. 32.8: computers with a modem

Modems work at different speeds. The rate at which a modem can receive or transmit data is devoted by kilobytes per second (Kbps). The 56 Kbps modems are taken as standard. Now a days, we use our modems to connect to an *Internet Service Provider* (ISP) and the ISP connects us to the Internet.

Thus modems are used as a transmitter to interface a digital source to a communication channel, and also as a receiver to interface a communication channel to a digital receiver.

Intext Questions 33.2

1. State whether the following statements are TRUE or FALSE:

(a) In the cathode-ray tube in a television set, the "ray" is a stream of electrons that are emitted from a cathode.

(b) Television specifications have been standardised in the world and thus television sets in all countries are compatible.

(c) In a fax machine, the document to be transmitted is scanned by a photo sensor to generate a signal code before it is transmitted through a telephone line.

(d) A modem can convert a digital bit stream into an analogue signal but not vice-versa.

What You Have Learnt

- An analogue signal is completely described by its samples, taken at equal time intervals T_s, if and only if the sampling frequency $f_s = 1/T_s$ is at least twice the maximum frequency component of the analogue signal.
- Low frequencies can not be transmitted to long distances using aerials or antennas of practical dimensions. Low-frequency messages are loaded on a high frequency carrier signal by a process called modulation. In amplitude modulation (AM), the amplitude of a high-frequency carrier wave are modified in accordance with the strength of a low-frequency information signal. In frequency modulation (FM), the amplitude of the carrier wave remains constant, but its frequency is continuously varied in accordance with the instantaneous amplitude of the information signal, i.e., the frequency of the modulated carrier wave varies from a minimum to a maximum corresponding to the minimum and maximum values of the modulating signal.
- In the digital pulse code modulation (PCM) technique, the modulating signal is first sampled, the magnitude (with respect to a fixed reference) of each sample is quantised, and then the binary code is usually transmitted modulating an analogue current in a landline.
- In the cathode-ray tube in a television set, the "cathode" emits a ray of electrons in a vacuum created inside a glass "tube". The stream of electrons is focused and accelerated by anodes and hits a screen at the other end of the tube. The inside of the screen is coated with phosphor, which glows when struck by the beam.

- In a fax machine, the document to be transmitted is scanned by a photo sensor to generate a signal code before it is transmitted through a telephone line.
- A modem (modulator/demodulator) can convert a digital bit stream into an analog signal (in the modulator) and vice-versa (in the demodulator). It is used as a transmitter to interface a digital source to an analogue communication channel, and also as a receiver to interface a communication channel to a digital receiver

Terminal Exercise

1. What is sampling?
2. What do you understand by modulation? Explain.
3. Explain the process of demodulation.
4. How does a TV work? State the basic differences between a black-and-white TV and a colour TV.
5. Explain the working principle of a fax machine.

Answers to Intext Questions

32.1

1. (a) (iv), (b) (iii).

32.2

1. (a) True, (b) False, (c) True, (d) False.

33A

COMMUNICATION MEDIA

In the previous lessons, you have learnt about communication systems, techniques and devices. In this lesson, you will learn about communication media. Electrical communication channels are either *wireline* (using guided media) or *wireless* (using unguided media).

Wireline channels physically connect the transmitter to the receiver with a "wire," which could be a twisted pair of transmission lines, a coaxial cable or an optical fibre. Consequently, wireline channels are more private and comparatively less prone to interference than wireless channels. Simple wireline channels connect a single transmitter to a single receiver, i.e., it is a point-to-point connection. This is most commonly observed in the telephone network, where a guided medium in the form of cable carry the signal from the telephone exchange to our telephone set. Some wireline channels operate in the broadcast mode, i.e., one or more transmitters are connected to several receivers, as in the cable television network.

Wireless channels are much more public, with a transmitter antenna radiating a signal that can be received by any antenna tuned close by. In radio transmission, the wireless or unguided propagation of radio waves from the transmitter to the receiver depends on the frequency of the electromagnetic waves. As you will learn in this lesson, the waves are transmitted as ground (or surface) waves, sky waves, or space waves by direct line-of-sight using tall towers, or by beaming to artificial satellites and broadcasting from there. Wireless transmission is flexible endowed with the advantage that a receiver can take in transmission from any source. As a result, desired signals can be selected by the tuner of the receiver electronics, and avoid unwanted signals. The only disadvantage is that the interference and noise are more prevalent in this case.

For transmitting em signals, we use microwave frequencies. From Lesson 30A, you may recall that it varies from 1GHz to 300GHz. This frequency range is further divided into various bands. Indian satellite INSAT – 4C operates in the C band (4 – 8 GHz), whereas

Edusat operates in Ku bond (12–18 GHz).

Objectives

After studying this lesson, you will be able to:

- explain how transmission lines are used as media for propagation of electromagnetic waves in the microwave region;
- describe the use of optical fibres as high capacity media for propagation of electromagnetic waves in the optical region,
- explain wireless ground (or surface) wave communication, sky wave (or ionospheric) communication, and space wave (or tropospheric) communication for radio frequencies,
- explain the role of communication satellites and
- explain the salient features of a cellular phone, computer networking and the Internet.

33.1 Media for Guided Transmission

33.1.1 Transmission lines

For guided signal transmission, a transmission line – a material medium forms a path. As such, the construction of a transmission line determines the frequency range of the signal that can be passed through it. Fig. 32.1 shows some typical transmission lines. The simplest form of transmission line is a pair of parallel conductors separated by air or any dielectric medium. These are used in telephony. However, such lines tend to radiate, if the separation between the conductors is nearly half of the frequency corresponding to the operating frequency. This may lead to noise susceptibility, particularly at high frequencies, and limit their utility. To overcome this problem, we use a *twisted pair of* wires. These are used in computer networking.

At high signal frequencies $(\leq 3\text{GHz})$ we minimise radiation losses by using *coaxial cables*, where one conductor is hollow and the second conductor is placed inside it at its centre throughout the length of the cable. These conductors are separated by dielectric spacer layers of polythylene and the electric field is confined in the annular space in between the conductors. These cables are used for carrying cable TV signals. It is important to note that ideally the dielectrics should have infinite resistance. But in practice, their resistance is finite and that too decreases with frequency. As a result, even coaxial cables are useful in a limited range (upto a maximum of 40GHz when special dielectric materials are used). Beyond 40GHz, we use *waveguides*. However, for frequencies greater than 300GHz, their dimensions become too small (is 4mm or so) and it presents practical problems.

Above this frequency, we use optical fibres for guided wave transmission.

Figure 33.1: (a) A twisted pair (b) A coaxial cable

33.1.2 Optical Fibre

The 1960 invention of the **laser** (acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation) completely revolutionized communication technology. The laser, which is a highly coherent source of light waves, can be used as an enormously high capacity carrier wave for information carrying signals (voice, data or video) transmitted through an **optical waveguide**, such as an **optical fibre**. The basic principle involved in all long distance communication systems is **multiplexing**, i.e., simultaneous transmission of different messages over the same pathways. To illustrate it, let us consider transmission of an individual human voice. The frequency band required for transmitting human voice extends from v_1 = 200Hz to v_2 = 4000 Hz, i.e., the information contained in this frequency band can be transmitted in any band whose width is $v_1 - v_2$ = 3800 Hz, regardless of the region of the spectrum in which it is located. Higher frequency regions have far more room for communication channels, and hence, have a much greater potential capacity than the lower frequencies. The frequency corresponding to the visible optical region at 600 nm is 5×10^{14} Hz, while that at a wavelength of 6 cm is 5×10^9 Hz. Thus, the communication capacity of visible light in an optical fibre is about 100,000 times greater than that of a typical microwave in a metallic conductor.

The most extensively used optical waveguide is the step-index optical fibre that has a cylindrical central glass or plastic core (of refractive index n_1) and a cladding of the same material but slightly (about 1%) lower refractive index (n_2). There is usually an outer coating of a plastic material to protect the fibre from the physical environment (Fig. 33.2)

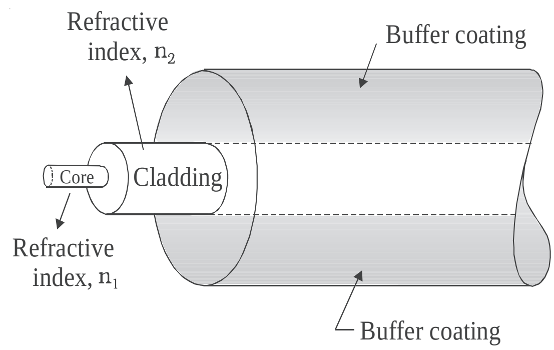


Fig. 33.2: A typical optical fibre with a doped silica core and a pure silica cladding.

When light from the core (n_1) is incident on the interface of the cladding ($n_2 < n_1$), the *critical angle* of incidence for *total internal reflection* is given by $\theta_c = \sin^{-1}(n_2/n_1)$. Thus in an optical fibre, the light ray is made to enter the core such that it hits the core-cladding interface at an angle $\theta_1 > \theta_c$. The ray then gets guided through the core by repeated total internal reflections at the upper and lower core-cladding interfaces. You may recall from wave optics that when a plane wave undergoes total internal reflection, a wave propagates in the cladding (rarer medium) along the interface, with its amplitude decreasing exponentially away from the interface. The entire energy of the wave in the core is reflected back, but there is a power flow along the interface in the cladding. Such a wave is called an *evanescent wave*, and is extensively used in integrated optics for the coupling the energy of a laser beam into a thin film waveguide (Fig. 33.3)

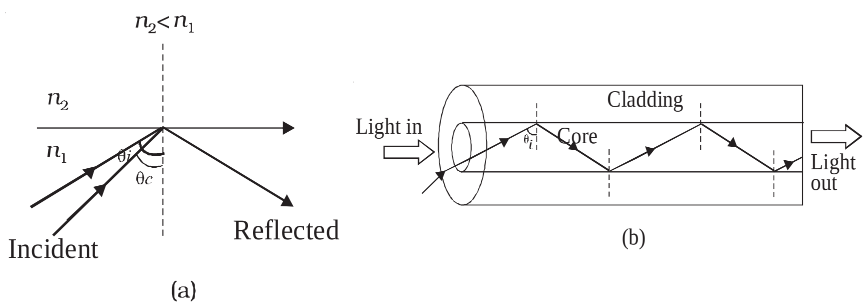


Fig. 33.3: (a)Total internal reflection (b) Ray confinement in actual optical fibre

Intext Questions 33.1

1. What is a coaxial cable? Write down its frequency range of operation.

   ....

2. State the basic principle used for guiding light in an optical fibre.

   ....

33.2 Unguided media

The wireless communication between a transmitting and a receiving station utilising the space around the earth, i.e. atmosphere is called *space communication.* The earth's atmosphere plays a very interesting role the propagation of e.m. waves from one place to another due to change in air temperature, air density, electrical conductivity and absorption characteristics with height. For example, most of the radiations in infrared region are absorbed by the atmosphere. The ultaviolet radiations are absorbed by the ozone layer.

Five layers are considered to play main role in communicaiton:

- *C layer* at about 60km above the surface of earth reflects e.m. waves in the frequency range 3kHz – 300kHz. It is therefore used for direct long range communication.
- *D layer* at a height of about 80km reflects e.m. waves in the low frequency range (3kHz – 300kHz) but absorbs waves in the medium frequency range (300 kHz – 3MHz) and high frequency range (3 – 30MHz).
- *E layer* at a height of about 110km helps in propagation of waves in the medium frequency range but reflects waves in the high frequency range in the day time.
- F_1 *layer* at a height of about 180 km lets most of the high frequency waves to pass through.
- F_2 *layer* (at a height of 300 km in daytime and 350 km at night) reflects e.m. waves upto 30MHz and allows waves of higher frequencies to pass through.

You may recall from your easlier classes that, based on the variation of temperature, air density and electrical conductivity with altitude, the atmosphere is thought to be made up of several layers. The atmospheric layer close to the earth called the *troposphere* extends up to about 12 km above the sea level. The temperature in troposphere vary between 290K (at the equator) to 220K (at tropopause). The air density is maximum but electrical conductivity is the least compared to other layers. The next layer up to about 50 km is called the *stratosphere*. An ozone layer is in the lower stratosphere extends from about 15 km to about 30 km. The layer above the stratosphere and up to about 90 km is called the *mesosphere*. The minimum temperature in mesosphere in about 180K. Beyond mesosphere upto 350km, there is a zone of ionised molecules and electrons called the *ionosphere*. In ionosphere, temperature increases with height to about 1000k. The ionosphere affects the propagation of radio waves. It is divided into D, E, F and F_2 regions based on the number density of electrons, which increases with height from about $10^9 m^{-3}$ in Dregion to $10^{11} m^{-3}$ in region and $10^{12} m^{-3}$ in F_2 layer[1]. These variations in temperature, density and conductivity arise due to different absorption of solar radiations at different heights and changes in composition etc.

The essential feature of space communication is that a signal emitted from an antenna of the transmitter has to reach the antenna of the receives. Depending on the frequency fo radio wave, it can occur as *ground wave, space wave, sky wave* and via satellite communication. Let us now learn about these.

33.2.1 Ground Wave Propagation

In ground *wave* propagation, the electromagnetic waves travel along the surface of the earth. These can bend around the corners of the objects but are affectd by terrain. A vertical antenna is used to transmit electromagnetic waves. If electric field *E* is vertical, and the magnetic field *B* is horizontal, the direction of propagation k is horizontal but perpendicular to both E and *B* vectors. The material properties of the ground, such as its conductivity refractive index and dielectric constant, are seen to control propagation of such waves. That is why ground waves propagation is much better over sea than desert. In practice, ground waves are rapidly attenuated due to scattering by the curved surface of the the earth. A larger wavelength results in smaller attenuation. That is, ground waves are more useful as lower frequencies & constitute the only way to communicate into the ocean with submarines. Moreover, this mode of propagation is suitable for short range communication. For these reasons, ground wave propagation is used for radio wave (300kHz – 3MHz) transmission.

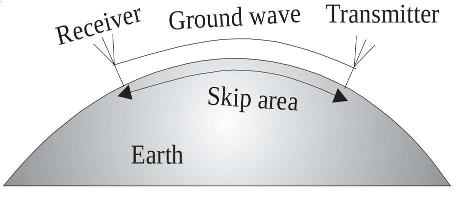


Fig. 33.4: Ground wave propagation

33.2.2 Sky Wave or Ionospheric Propagation

In **sky wave** or **ionospheric** propagation, the electromagnetic waves of frequencies between 3MHz – 30MHz launched by a transmitting antenna travel upwards, get reflected by the ionophere and return to distant locations. In this mode, the reflecting ability of the ionosphere controls the propagation characteristics of the sky wave. The ionosphere acts as an invisible electromagnetic "mirror" surrounding the earth – at optical frequencies it is transparent, but at radio frequencies it reflects the electromagnetic radiation back to earth.

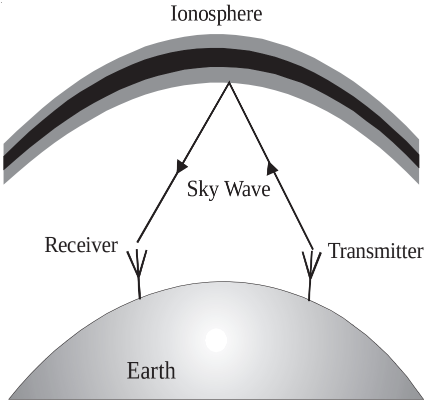


Fig. 33.5: Skywave propagation

Notes

The maximum distance along the surface of the earth that can be reached by a single ionospheric reflection ranges between 2010 and 3000 km depending on the altitude of the reflecting layer. The communication delay encountered with a single reflection ranges between 6.8 and 10 ms, a small time interval. This mode of propagation is used for long-distance (short wave) communication in the frequency range approximately between 5 and 10 MHz. Above 10 MHz, the waves pass through the ionosphere and do not reflect back to the earth. It is, however, subject to erratic daily and seasonal changes due to variations in the number density and height of the ionized layers in the ionosphere. The composition of the ionosphere at night is different than during the day because of the presence or absence of the sun. That is why international broadcast is done at night because the reflection characteristics of the ionosphere are better at that time.

33.2.3 Space Wave Propagation

You may have seen very high antennas at radio station. These are used for broadcasting. In space wave propagation, some of the VHF radio waves (30 MHz – 300MHz) radiated by an antenna can reach the receiver travelling either directly through space or after reflection by the curvature of the earth. (Note that earth reflected waves are different from ground waves.)

In practice, direct wave mode is more dominant. However, it is limited to the so-called *line-of-sight* transmission distances and curvature of earth as well as height of antenna restrict the extent of coverage.

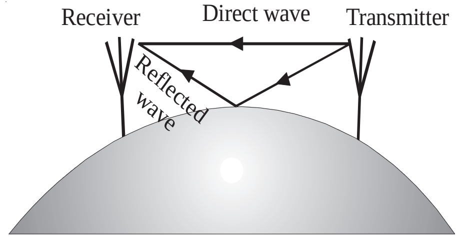


Fig. 33.6: Space-wave propagation

So far you have learnt that ground waves suffer conduction losses, space waves have limitations due to line of sight and sky waves penetrate the ionisalion beyond a certain frequency. Some of these difficulties were circumvented with the launch of communication satellities in the 1950s. Satellite communication has brought about revolutionary changes in the form and format of transmission and communication. We can now talk is real time at a distance. Let us now learn about it.

33.2.4 Satellite Communication

The basic principle of satellite communication is shown in Fig. 33.6. The modulated carrier waves are beamed by a transmitter directly towards the satellite. The satellite receiver amplifies the received signal and retransmits it to earth at a different frequency to avoid interference.

These stages are called uplinking and down-linking.

As we have seen already in connection with communication with light waves, the capacity of a communication channel can be increased by increasing the frequency of communication. How high up can we go in frequency? You now know that the ionosphere does not reflect waves of frequencies above 10 MHz, and for such high frequencies we prefer space wave propagation with direct transmission from tall towers. But this line-of-sight transmission also has a limited range or reach. Hence for long-range wireless communication with frequencies above 30 MHz, such as for TV transmission in the range of 50-1000 MHz, communication through a satellite is used.

The gravitational force between the earth and the satellite serves as the centripetal force needed to make the satellite circle the earth in a f*reefall* motion at a height of about 36,000 km. An orbit in which the time of one revolution about the equator exactly matches the earth's rotation time of one day is called a *geostationary* orbit, i.e., the satellite appears to be stationary relative to the earth. Ground stations transmit to orbiting satellites that amplify the signal and retransmit it back to the earth. If the satellites were not in geostationary orbits, their motion across the sky would have required us to adjust receiver antenna continually. Two other orbits are also currently being used for communication satellites: (i) *polar circular orbit* at a height of about 1000 km almost passing over the poles (i.e., with an inclination of 90^0), and (ii) *highly elliptical inclined orbit* (with an inclination of 63^0) for communications in regions of high altitudes.

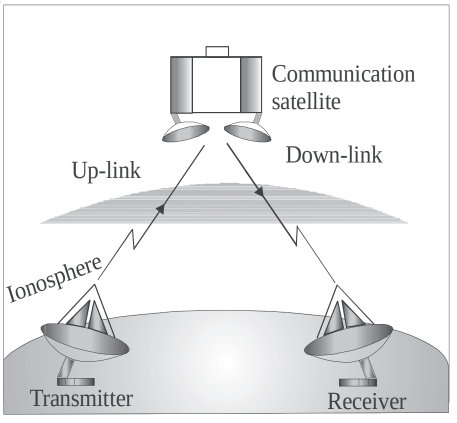


Fig. 33.7: Satellite communication.

Intext Questions 33.2

1. Why do you hear some radio stations better at night than in the day?

....

2. Choose the correct option in each case:

   a. Frequencies in the UHF range normally propagate by means of

   i) Ground Waves

   ii) Sky Waves

   iii) Surface Waves

   iv) Space Waves.

   b. Satellites are used for communication

   i) With low (< 30 MHz) frequencies and for a small range

   ii) With low (< 30 MHz) frequencies and for a long range

   iii) With high (> 30 MHz) frequencies and for a small range

   iv) With high (> 30 MHz) frequencies and for a long range.

   ....

33.3 Communication applications

In recent years, the world of communication has advanced rapidly from printed texts to the telegraph, the telephone, the radio, the television, mobiles, Internet and computer conferencing (Audio and video). Countries all over the world are striving to achieve high standards of national and international communications. Radio and TV broadcasting through communication satellites is routinely achieved to reach out to the majority of the population even in remote corners of the globe. The domestic system of automatic telephone exchanges is usually connected by modern networks of fibre-optic cable, coaxial cable, microwave radio relay, and a satellite system.

Cellular or mobile telephone services are now widely available and include roaming service, even to many foreign countries. The cellular system works as a radio network of base stations and antennas. (The area of a city covered by one base station is called a cell, whose size ranges from 1 km to 50 km in radius.) A cell phone contains both a low-power transmitter and a receiver. It can use both of them simultaneously, understand different frequencies, and can automatically switch between frequencies. The base stations also transmit at low power. Each base station uses carefully chosen frequencies to reduce interference with neighbouring cells.

In a situation where multiple personal computers are used, as perhaps in your local study centre, it helps to get all the computers connected in a network so that they can “talk” to each other, and we can

- share a single printer between computers;
- share a single Internet connection among all the computers;
- access shared files and documents on any computer;
- play games that allow multiple users at different computers; and
- send the output of a device like a DVD player to other computer(s).

To install such a network of personal computers, there are three steps:

- Choose the technology for the network. The main technologies to choose between are standard Ethernet, phone-line-based, power-line-based and wireless.
- Buy and install the hardware.
- Configure the system and get everything talking together correctly.

The Internet is a vast network of computers throughout the world. It combines many different forms of communications. As the technology advances it could replace all other forms of communication by combining them into one. Magazines and newspapers are already being put online along with libraries, art, and research. Unlike most forms of communication, it facilitates access to vast store of information through the World Wide Web (WWW). The World Wide Web is the multimedia part of the Internet and combines text with sound, photos, drawings, charts, graphs, animation, and even video. New innovations such as Java, a web-based programming language, allow simple tasks to be performed inside the document. The more widespread the Internet becomes, the more important and powerful type of communication it will become. In India, several hundred thousand schools are being provided access to computers and Internet to impure the quality of education. The MHRD is developing a one stop portal –Sakshat– which can be accessed by you. The National Institute of open schooling is also contributing for it.

EDUSAT

The Indian Space Research Organisation (ISRO), Department of Space, Government of India, launched an exclusive education satellite EDUSAT in Sept. 2004. The satellite has its footprints all over the country and operates in KU band. It is designed to provide services for seven years. This satellite has capability for radio and TV broadcast, Internet-based education, data broadcasting, talk-back option, audio-video interaction, voice chat on Internet and video conferencing. It has opened up numerous possibilities: a teacher of a leading educational institution in a city may video-conference with students of a remote school, or school drop-outs in villages may receive Internet-based education support and get back into mainstream education system. EDUSAT has the capability of telecasting 72 channels. A large number of networks have been created by state governments and national institutions including NIOS. Such networks are being successfully used to impart education even in regional languages.

What You Have Learnt

- Electrical communications channels are wireline (using guided media) or wireless (using unguided media).
- Multiplexing refers to the process of simultaneous transmission of different messages (each with some frequency bandwidth) over the same path way. The higher the frequency of the carrier, the higher is its message-carrying capacity.
- Comparing the different wireline channels, the communication capacity of visible light (of frequency of about 10^{14} Hz) in an optical fibre is thus much larger than that of typical microwave (of frequency of about 10^9 Hz) in a metallic conductor.
- An optical fibre guides a light beam (from a laser) from its one end to the other by the process of total internal reflection at the interface of the inner core (of refractive index n_1) and the cladding (of refractive index $n_2 > n_1$).
- In the wireless radio transmission, a system of conductors called antenna or aerial launches the carrier radio waves in space and also detects them at the receiver location. The propagation of radio waves in the atmosphere depends on the frequency of the waves. Low and medium frequency radio waves up to about 1 MHz are used in ground (or surface) wave communication. Medium frequency (MF) waves of 300 kHz – 3 MHz are largely absorbed by the ionosphere. The high-frequency (HF) waves of 3 – 30 MHz are, however, reflected back by the ionosphere. VHF and UHF waves are transmitted either by direct line-of-sight using tall towers (space wave or tropospheric propagation), or by beaming to artificial satellites and broadcasting from there.
- The cellular or mobile telephone system works as a radio network in which a city is divided into 'cells' of 1 km to 50 km in radius, and each cell is covered by one base station. A cellular phone contains a low-power transmitter and a low-power receiver.

Terminal Exercise

1. Long distance radio broadcasts use shortwave bands. Explain.
2. Satellites are used for long distance TV transmission. Justify.
3. The core of an optical fibre is made of glass with a refractive index of 1.51 and the cladding has a refractive index of 1.49. Calculate the critical angle for total internal reflection.
4. List some advantages of creating a local network of personal computers.

Answers to Intext Questions

33.2

2. (a) iv), (b) iv).

TERMINAL QUESTION

3. $\sin^{-1}(n_2/n_1) = 80.66^0$

Senior Secondary Course
Physics
Student's Assignment – 9A

Maximum Marks: 50 **Time : $1\frac{1}{2}$ Hours**

Instructions

- Answer All the questions on a seperate sheet of paper
- Give the following information on your answer sheet:
  - Name
  - Enrolment Number
  - Subject
  - Assignment Number
  - Address
- Get your assignment checked by the subject teacher at your study centre so that you get positive feedback about your performance.

Do not send your assignment to NIOS

1. What is the function of inverter? (1)
2. Is transformer a transducer? Why? (1)
3. What is the function of a solar cell? Generally which type of material is used to make it? (1)
4. What is the band width of AM radio station? (1)
5. What are the essential components of a communication system? (1)
6. Name the principle of working of an optical fibre. (1)
7. What is the role of a satellite in a communication system? (1)
8. Minimum how many geostationary satellites are required for global communication system? How should they be arranged? (1)
9. Give the full form of the following terms

   (i) Modem (ii) Fax (2)
10. Explain the role of circuit breaker in industry and household supply? (2)
11. Give the number of IC used in timers. What is its funciton? (2)
12. What is the need of voltage regulation? Name the device used for the purpose. (2)
13. Explain the need of modulation in long distance communication. Why is an FM signal less susceptible to noise than an AM signal. (4)
14. Give examples of various types of guided media communication and unguided media transmission. (4)
15. Explain the role of computers in communication. (4)

16. Draw block diagrams of a radio trtansmitter and a radio receiver. (4)

17. Explain the meaning of the following terms:

    (i) Pixel (ii) Multiplexing (iii) LASER (iv) Ionosphere (4)

18. With the help of suitable diagrams explain the process of modulation. . (4)

19. Drawing circuit diagram explain the process of demodulation. (5)

20. Explain a fibre optic communication system with the help of a suitable diagram. (5)

MODULE - IXB

PHOTOGRAPHY AND AUDIO-VIDEOGRAPHY

30 B

PHOTOGRAPHY AND CAMERA

It is said that change is the law of nature. We witness so many changes in our lives. The simplest observable changes include our physical growth with time, change in seasons, blossoming of flowers, cycle of days and nights and so on. As thinking individuals, we discover that some events/moments in life leave everlasting impressions and we wish to freeze and preserve them for years to come. For example, your photographs of childhood, with family and school friends, visit to a hill station, etc. if preserved, enable us to go down the memory-lane and re-live those happy moments. This has become possible with *photography*. Today, photography is used in almost every aspect of human activity – education and research, astronomy, industry, health care, architecture, journalism and remote sensing.

Photography can be said to be one of the most important inventions in the history of mankind; it truly helped transform people's perception of the world. Sir John Herschel, a 19th century astronomer and one of the first photographers, introduced the term *photography* in 1839. Photography is a combination of two Greek words: *photos*, which means light and *graphing*, which means writing (or drawing). So we can say that photography is a process of writing with light, i.e. making pictures through the combined action of light and chemical processing. Note that the process of making a photograph begins and ends with light.

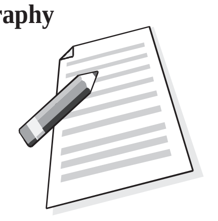
A logical question arises here: How to photograph?

In this lesson you will learn about the basic principles, construction and working of different tools and techniques used to obtain the photographs (of people, animals, nature, places and objects) around us. You will also learn about different types of cameras, including the digital cameras, how to select a camera for a particular purpose, what is the role of cost etc. You will also learn different processes involved in making a photograph.

Objectives

After studying this lesson, you will be able to:

- explain the term photography and list the processes involved in making a photograph;



- state the importance of photography in our day-to-day life;
- identity different parts of a camera;
- explain the term exposure and state the relation between *f*-numbers and shutter speed;
- highlight main features of different types of cameras and their lenses;
- explain the working of a video camera; and
- explain the salient features of a digital camera.

30.1 Photography

In lesson 23 on optical instruments, you learnt that we see an object when light reflected by it reaches the retina of our eyes. It is subsequently interpreted by human brain. The image stays on retina for (1/16)th of a second. (Perception of light is a very interesting phenomenon and you may like to read about it in detail). Similarly, in non-digital photography, the light reflected by the an object to be photographed, is projected on to a light-sensitive film by a lens. (The action of a lens is based on refraction). The film responds, when exposed, in proportion to the intensity of light. A latent image, i.e. invisible image, is formed by chemical interaction of light with the molecules of the sensitized emulsion. This latent image transforms into a visible image when a reel/film is developed.

Depending on the type of film, the image is either positive or negative; negative in ordinary black & white film and in complementary colour, if negative colour film is used and positive, if reversal colour film is used. In a negative image, the value of light and dark are reversed; in a colour negative, the subjects' colour is represented by complementary colours (cyan, magenta, yellow) for primary (Red, green, blue). The developed film is made impervious to further exposure by fixing in a chemical solution. To make it permanent, it should be freed from all processing chemicals by washing or other stabilizing processes, before it is dried. The tonal values of the image - negative becomes a positive – are reversed in printing. Printing by contact printers or enlargment of black & white or negative colour film is essentially a repetition of the process of exposing and developing a film. The image contained in the negative is projected on to a light sensitive emulsion paper. Interaction between light and the emulsion produces a latent image, which, after being developed, fixed, and washed, becomes the final print.

Some of the functional uses of photography are in:

– education in the form of visual aids;

– forensic science, for inverstigations and generating records and evidences.

– medicine as a diagnostic tool to record specimen and assess progress of patients, with the aid of X-rays, and endoscopies for internal examination;

– industry as a medium for recording, viewing and documenting process details and increasing output;

– archaeology, aerial photography and remote sensing, which helped us to map, discover and survey otherwise unsuspected sites;

– architecture and building industry, where photographic records provide information for reconstruction work;

– astronomy to record images of distant stars, for spectroscopic analysis of their composition, etc; and

– scientific research in electron microscopy, light microscopes, high speed photography, crystal analysis, etc.

Photographs speak a universal language and are being used to an ever increasing extent for presenting a picturesque account of an event, preserving human affections, provide security of identity for passports and visas.

30.2 Camera

You must have seen a photographer carrying a camera and a bag carrying accessories for taking photographs on occasions such as marriage or birthday party, school function, arrival of a dignitary, etc. A camera is a device which makes light from an object of interest to fall on the photographic plate. The lens of a camera focuses the rays of light reflected from an object to form a permanent image on the film. Thus in its simplest form, a camera is essentially a lightproof box with a lens at one end and film at the other. It has in-built provisions to control the amount of light from the object that would eventually reach the film.

One day Leonardo da Vinci, the great Italian painter, architect and inventor was sitting in a tightly shuttered room to keep out the hot summer sun. On the wall opposite to the shuttered window, he was amazed to see the picture of the sun-drenched street outside. The picture was upside down, and it was painted on the wall by the rays of light coming through a tiny hole in the shutter of the window (see Fig 30.1). This heralded the birth of the camera, which took its name from camera obscurer, meaning "darkened room".

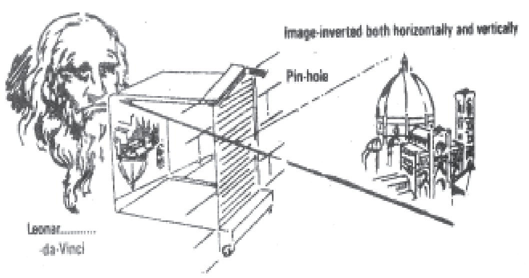


Fig. 30.1 : Principle of pin-hole camera

A crude type of camera was first developed around 1500 AD. The growth of Science & Technology has helped develop very sophisticated cameras. The quality of lenses, the film and the chemicals used for developing & printing changed drastically and for the better. The arrival of Digital Technology has advanced it further.However, the first true photograph was made in the year 1826. Early photographers needed much equipment and a knowledge of chemistry. But now a person can take a picture simply by aiming the camera at the subject and pressing a button. An instant camera (polaroid) can produce a photo in about 15s. Digital cameras, which were introduced in the early 1990's, can produce an image almost instantly. These filmless cameras have a light sensitive mechanism, called Charge Coupled Device (CCD) or Complementry Metal Oxide Semiconductor (CMOS) Sensor. The lens focuses light on the CCD instead of film, which changes it into electronic signals. The image can be viewed immediately on cameras equipped with liquid crystal display (LCD) screen without any chemical processing. The digital cameras are now built into mobile phones also. And the prints are obtained using a PC.

30.2 Parts of Camera

Refer to Fig. 30.2. It shows schematic diagram of a simple camera containing a lens, a shutter, a diaphragm, a film holder and a view finder. Some cameras are provided with a focusing mechanism and a flash contact also.

The basic technology that makes all this possible is fairly simple. A still film camera has three basic elements: an optical element (the lens), a chemical element (the film) and the mechanical element (the camera body itself). Nearly all cameras have the same design. However, cameras vary widely in such features as adjustability. The main parts of camera are :

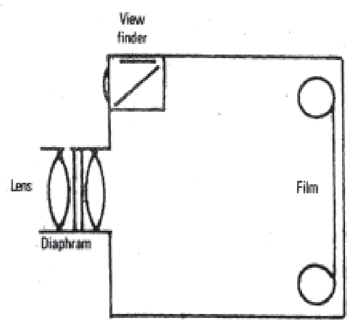


Fig. 30.2 : Schematic diagram of a lens camera

(a) *Light-tight box* is generally of plastic or metallic and painted black from inside. Light from outside cannot enter this box unless the shutter is open. This box is opened mostly from the back for loading or unloading the film.

(b) *Camera lens* is the eye of camera and consists of several elements. It helps to form a sharp image of the object on the photographic film.

(c) *Diaphragm* controls the amount of light that reaches the photographic film. Usually, the diaphragm is mounted between the camera lens and film.

(d) *Shutter* controls the length of time for which light is allowed to enter the camera to expose the film. Different shutter speeds are available in a good camera. Shutters are operated for a predetermined time by pressing the shutter release button.

(e) *View-finder* is used for locating the scene to be photographed. The view-finders used in different types of cameras are of direct vision type, ground glass and mirror type, prism type, waist level reflexing type etc. Some of the view-finders are also coupled with a range finder. In modern cameras, view-finders also act as a range finder to focus the object/scene on the film without parallax.

(f) *Film transport mechanism and frame counter* transports the photographic film held inside the camera body without opening it. Every time a frame is exposed by pressing the shutter, the film is advanced by one frame. The number of frames exposed by the camera on the loaded film is shown by the frame counter.

(g) *Focusing mechanism* helps to get a good and clear photograph. Most cameras have a focussing ring, which has a distance scale in feet (and some time in meters as well) engraved on it. At one end, there is a sign of ∞ (infinity) and at the other, (3½), 3 to may be even 2 feet (depending on the minimum focussing distance). Rotation of this ring takes the lens backward or forward, focussing it at different distances. Light, which comes from a (distant) object, is focussed at a short distance behind the lens. For this, the lens is brought nearer to the film plane. On the other hand, to focus light from a nearer point, the lens must be moved away from the film plane (see Fig. 30.3). For close-ups, you have to use a long lens extension which is specially designed for this purpose and is popularly referred to as a *tele-photolens*.

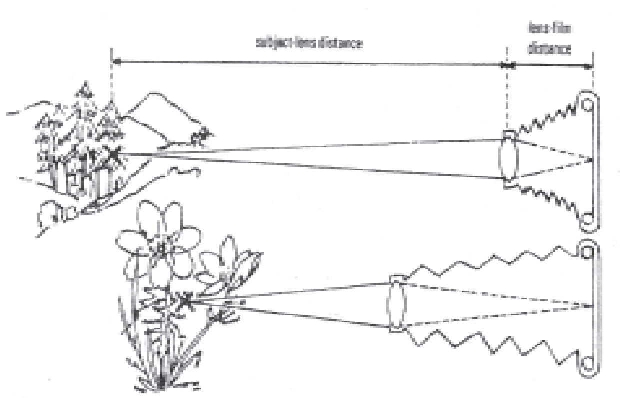


Fig. 30. 3 : Typical object to lens distance and lens to film distance

(h) *Flash contact and hot shoe* are in-built in most modern cameras. (In earlier versions, the flash gun was connected to the camera with a flash contact or a hot shoe contact. Through these contacts, flash lights were synchronized with the shutter release button as and when required to illuminate the object).

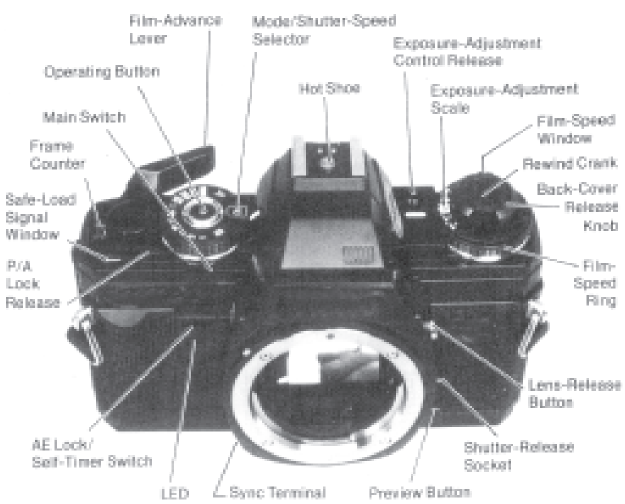


Fig 30. 4 : Parts of a non-digital modern photographic camera.

Fig. 30.4 shows a photograph of a non-digital modern camera and all its important parts have been labelled. You will now learn about their functions in detail.

a. Camera lens

The lens is the optical component of a camera.It focuses light from an object to form a real image. In its simplest form, we use a convex lens. However, in practice, photographic lenses are a combination of many lenses to give you a perfect image, free from all types of distortions. The focal length and aperture (diameter) of a lens determine its light collecting power. The performance of a lens depends on – *Degree of sharpness*, i.e. how far the lens designer was able to correct the five main faults (aberrations) inherent in any lens- spherical and chromatic aberrations, curvature of field, astigmatism, and coma. As a photographer, you must know that sharpness is incompatible with high lens speed and great covering power; the higher the speed, or larger the angle of view encompassed by a lens, the more difficult it will be to satisfactorily reduce its inherent faults to an acceptable level.

– *Resolving power* of a lens is measured in terms of no. of lines per milimeter. In other words, the higher the no. of lines, the higher will be the resolution or sharpness of the lens.

– *Colour correction*, which essentially provides for non-uniform bending (refraction) of different wavelengths (colours) by glass. This is because a simple lens (such as a magnifier, or positive spectacle lens) produces an image in which different colours located at the same distance from the lens are focussed at different distances behind the lens. If such lenses were used in photography, they would produce pictures that are not sharp in a black & white photograph and fringed with bands of colour in colour photography. That is why all photographic lenses are colour-corrected to some extent, the degree varying with the design of the lens.

– *Flare and fog:* It is observed that a part of the incident light transmitted by a lens is reflected by the lens of the camera and eventually reaches the film in the form of a flare and fogs the negative. Flare manifests itself as light-spots on the negative. These can be of any size and shape but are most frequently circular crescent shaped, oval, or repeating the shape of the diaphragm's aperture. Flare is the reflected and distorted image of a light-source within (and sometimes outside) the field of view of the lens. Fog, which is an effect of over-all flare, degrades a negative by lowering its contrast: areas which should have been perfectly transparent (by receiving no light) have a more or less pronounced density due to exposure to light scattered within the lens.

  In a camera with high speed lens, the glass to air surface increases and chances of getting flare & fog increase. To minimise it, the lens is coated with an antiflare or anti-reflection coating.

– *Evenness of light distribution:* Almost all the lenses deliver proportionally less light on the edges of the negative than at the center. In lenses of moderate covering power, this illumination fall off is usually insignificant and can be ignored. But greater the covering power of a lens, greater, is the difference in the amount of light-received by the center of the film and its edges. The discrepancy is maximum in extreme wide angle lenses.

– *Distortions:* This lens fault is inherent in many wide angle and zoom lenses and results in degenerating straightlines into curves. As a result, two types of distoritions arise: Pin-cushion distortion and barrel distortion. In pin-custion distortion, a square appears as if its sides were curving inward, whereas in barred distortion, the sides appear to bulge ontwards.

The 'speed' of a shutter is the duration of the interval between the opening and closing of the shutter which is controlled either by spring tension, a set of gears, or an electronic circuit.

b. The Diaphragm and the Shutter

The most important function of "D" is to decide the amount of light that should come in. These are generally of two types: leaf type and focal plane type.

It is spring loaded so that when the exposure button is pressed, the shutter opens and the light comes in through the "D."

The shutter decides the duration for which the light should be permitted to come in for proper exposure. This depends on the shutter speed, which is fixed before the exposure takes place. It is normally a fraction of a second. Shutter in simple cameras consists of a single blade, and sometimes have only one speed of about (1/30)th of a second. You may have also seen a camera with speeds varying in steps of 0.04s. Most shutters have built in contacts for synchronization with flashlight.

The synchronized shutter speeds are marked as X. This mode is designed for use with electronic flash, where the timing of the contacts coincides exactly with the full opening of the camera shutter. It is the fastest shutter speed that can be used with flash. Using a faster shutter speed than the sync speed with flash results in partial blackout of the image. The synchronized speeds are of three types: M (medium) sync, F(fast) sync, or FP (focal plane) sync, designed for use with corresponding bulb types.

Sync speed is important for two reasons: Fast sync helps stop motion. For example, we shoot at (1/500) or even faster to stop an action. Faster sync speeds help get enough flash power to balance sunlight during outdoor photography.

Each successive speed is half of the previous one. That is, changing by one speed either halves or doubles the light which falls on the film. Some fraction of a second are indicated by their denominators only, thus (1/250), Intermediate settings, cannot be used below (1/80) on the F2.

Aperture determines how wide the lens' iris opens. The wider it opens, more light gets in.

It is like the iris of human eye, which opens when light gets dimmer. Wider the aperture for the same subject, smaller is the required shutter speed to get correct exposure. The shutter speed is directly related to aperture size.

The aperture of a given lens is referred as the *f*-number. Bigger apertures have smaller numbers like *f*/4, while smaller apertures have larger numbers like *f*/16. A smaller aperture like *f*/16 will tend to get everything in focus.

In modern cameras, highly mechanized shutter units are used, which open and shut in fractions of seconds without causing vibrations. The actual shutter consists of three or more thin metal blades which open like curtains from the centre of the lens outwards towards the edges and expose the whole film surface simultaneously. This type of shutter is shown in Fig 30.5. In spite of the fact that this type of shutter is sometimes located immediately behind the lens, it is usually known as the between-lens shutter. These are driven and controlled by a small and unusually constructed wheel and lever assembly with tensioning springs and control breaks. Shutter is usually coupled to the film transport, so that when you wind the film, you automatically tension the shutter. Because of mechanical limitation, lens-shutters are not normally built with speeds faster than (1/500)s. For most pictures, this extremely fast speed is adequate. Only in a few cases we need a faster shutter speed (e.g. for car racing etc.). For such purposes, focal plane shutter is the only solution which gives speed upto (1/2000)s.

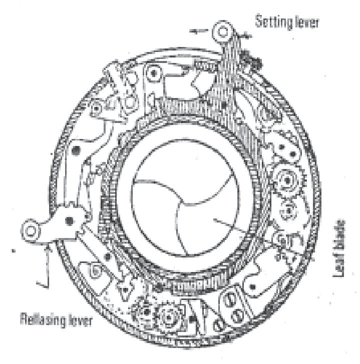


Fig 30. 5 : Diagram of focal plane shutter

The focal plane shutter is usually found in expensive miniature cameras with interchangeable lenses. It consists of two cloth or metal blinds immediately in front of the film and exposure is governed by the distance scparating these blinds. Shutter tensioning is always coupled with the film transport mechanism. In this type of shutter, the first blind rolls very fast on to spindle, exposing the film to light. After a certain (very short) time, which depends on the shutter speed the second blind unrolls from its spindle and covers the film again. So, with fast shutter speeds, where there is only a narrow slit between the blinds, the film is exposed progressively and not at the same time. Under certain circumstances, this can cause distortion; the subject can appear sligthtly elongated, compressed or even twisted, But with modern focal plane shutters, we can forget about it altogether.

30.3 Camera's Special Lenses

Some of the modern cameras have interchangeable lenses. This helps us to tackle different situations with ease, particularly in outdoor shooting. For example, we want to take a picture of a lion in a zoo. Obviously, we can not go very close to the lion. Increasing the focal length of the lens will help to bring it closer but the angle of view decreases. (Angle of view is the angle formed by the extremities of any distant subject at the eye or the camera lens.) The angle of view offered by a camera depends on the focal length of the camera lens and the size of the film used. Table 30.1 gives the angle of view corresponding to lenses of different focal lengths when used with 35 mm camera. For normal human eye, angle of view is 50°.

Table 30.1 : Relation between focal length and angle of view of camera lens

Focal length of lens (mm)	Angle of View (degrees)
21	90
28	76
35	62
50	46
85	29
105	23
200	12
400	6
1000	2.5

The choice of a lens is made in terms of its focal length, angle of view and aperture, depending on the purpose. Camera lenses are classified accordingly. We now discuss these in brief.

(a) *Normal lens* provides an angle of view similar to that of the normal eye. From Table 30.1, you can see that 50 mm lens in a 35 mm camera acts as a normal lens because its angle of view lies between 45° and 50°. Actually, a normal lens is one whose focal length is approximately equal to the diagonal of the negative of the film. Most of the cameras are provided with normal lens of proper focal length.

(b) *Wide-angle lens* has more than 60° or so angle of view. With this lens, you will get a lot more into your picture than normal lens Fig 30.6 but everything will be much smaller. Everything in the foreground appears much larger and distant objects appear really small. These short focal length lenses seem to stretch distances, particularly with near subjects. Indoor pictures, which would be impossible with the normal lens, can be easily taken with a wide angle lens, as it makes the room appear larger. A group photograph or the photograph of large building complex can be taken from a very close distance using a wide angle lens. Lenses of focal length less than 35 mm, for 35 mm camera, are generally treated as wide angle lenses. (Wide angle lenses with angle of view more than 100° and so are known as *fish-eye-lenses*.) Since wide angle lenses have great depth of field, we use slower shutter speeds for these.

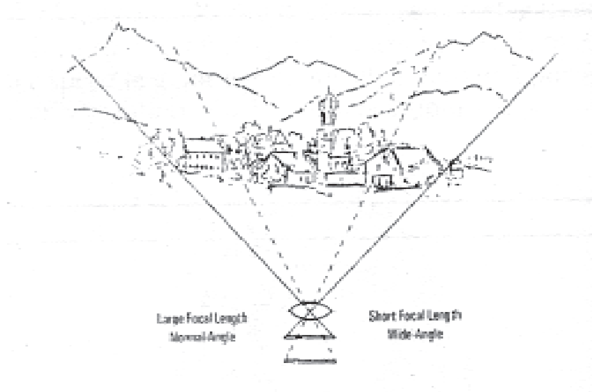


Fig. 30.6: The wide-angle takes in more than the normal lens

(c) *Telephoto lens* is also a narrow lens because it offers a small angle of view (30° or less) and forms larger image of the object on the photographic film. Telephoto lenses usually resemble standard telescopes. A telephoto lens is used to photograph an object while separating it from its background or take close ups. These are popularly used in sports coverage, especially if the action of a player (bowler, batsman, dribbler, penalty shooter) is required to be selected exclusively. This lens is specially suitable for taking distant landscapes, architecture, works of art animals and portraits.

(d) *Zoom lens* is a variable focal-length lens. It can function both as a wide angle lens or as telephoto lens.Its focal length can be continuously varied between the marked extremes. A zoom lens also keeps fixed aperture constant and maintains reasonably sharp focus, irrespective of focal length. These days, a zoom lens is quite popular because this lens can perform the functions of several interchangeable lenses of different focal lengths.

A zoom lens is actually a combination of several lenses. It consists of two groups of lenses, which are coupled to shift or move in a proper fashion. Mostly zoom lenses are used with Simple Reflex camera (SLRs) and a vast range of lenses is available in the market for 35mm SLR cameras. These lenses are heavy, expensive and not as sharp as fix focal length lenses.

Intext Questions 30.1

1. Write three uses of photography.
2. Which parts of a camera control the amount of light entering the camera box?
3. What is the focal length of a normal lens of 35 mm camera?
4. State whether the following statements are True or False:

   a) Shutter speed is the only way to control exposure.

   b) Wide-angle lens has narrow depth of field.

   c) Telephoto lens exaggeate the perspective.

   d) Through view finder, we can see whether a film has been exposed or not.

30.4 Types of Cameras and Their Uses

The evolution of cameras has been truely remarkable. Starting with a simple pin-hole camera to box camera, to single and twin lens reflex camera, to miniature and polaroid camera. The latest innovation is digital camera, which is now used by individuals as well as professional photographers. We will discuss only the latest forms for brevity and utility.

30.4.1 Miniature Camera

Modern day cameras are usually of roll film type taking perforated 35 mm film rolls giving 24 or 36 exposures. These are small, portable and range from simple models of low cost to complex high precisen cameras with a great variety of attachments. The lens aperture is generally high. The focal length of standard normal lenses is about 50 mm. Many 35 mm miniature cameras have focal plane shutters, giving a range of speed upto (1/500)s with interchangeable lens.Most cameras have built – in range finder, coupled with its focussing mechanism and all have an optical view-finder. Most have automatic shutter winding or setting combined with film advance mechanism. Some miniature cameras, frequently referred to as subminiature cameras are of very small size and use 16, 9.5 or 8 mm roll film. Some fall in the category of novelties but others are precise instruments. However, the small size of the negative limits the size of the enlarged print upto 5 to 7 inches in the best cases.

30.4.2 Polaroid Camera

These cameras are used for producing photographs almost instantly. The secret of the Polaroid camera lies in the film used. It is quite possible to use polaroid film with ordinary plate cameras, though in practice it is common to use the cameras designed for use with the film as shown in Fig. 30.7. The basis of the process is exactly the same as in conventional photography but developer, fixer and print material are all combined in one film pack, thus doing away with the need for a darkroom or any other kind of processing.

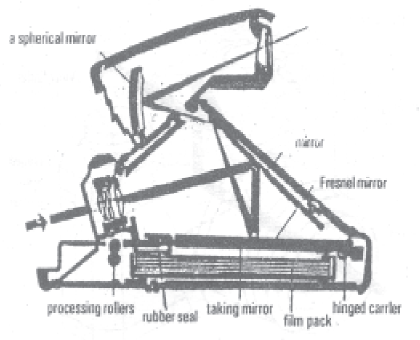


Fig 30. 7 : Line diagram of a poloroid camera

High speed (sensitivity to light) of polaroid black and white film makes it possible for several novel features. Practically all objects near and far, are in its focus. Polaroid photography is not likely to replace conventional photography because of its film packs and limited usefulness of prints compared with a negative. It is only useful where instant results are desired, as for passport office, driving license, courts of law, etc. These are used in dental photography, forensic investigations and the production of identity cards etc.

30.4.3 Movie and Video Camera

You now know that persistence of vision is $(1/16)^{th}$ of a second. It means that human eye is unable to distinguish images presented to it at a rate greater than 16 images per second. That is, images faster than persistence of vision are seen as continuously evolving scenes. (That is why we are unable to detect voltage changes in an ac supply). In a video/movie camera a lens focuses light on the strip (film or magnetic tape), a lens diaphragm controls the aperture and a shutter exposes the film at the required instant. It differs from still camera in that the movement of film and shutter has to most precisely coordinated to produce a series of evenly spaced correctly exposed frames. Schematic diagram showing the location of different parts of a video camera is shown in Fig. 30.8.

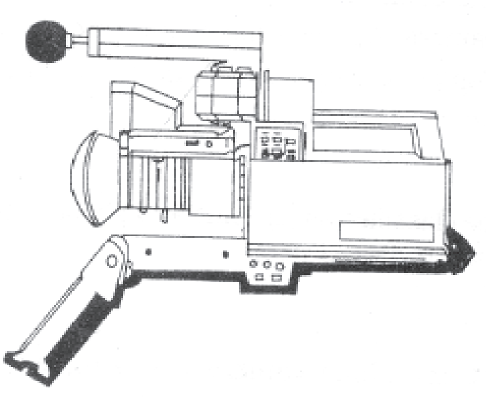


Fig 30.8 : Schematic diagram of a video camera showing different parts

The format of movie camera is determined from the width of the film it takes. Of the three most common formats, Super 8, an amateur format, which uses 8 mm wide film, has been almost completely overtaken by a video camera. 35 mm is standard format for feature films and the 16 mm format was used by amature as well as professional meets. This is often used by documentary and experimental films makers. A modern 35 mm movie camera is a versatile instrument with interchangeable lenses, filter holders, viewfinders and film spools allowing it to be configured for a variety of uses from macro-photography to feature films.

30.4.4 Digital Camera

In a digital camera, light reflected by a subject is focussed by the camera lens onto a recording surface called Charge Coupled Device (CCD). It is an array of semiconductors and records the image electronically. A digital signal processor (DSP) then processes the image and sends it to the memory disk. Unlike conventional cameras, all digital cameras have a built-in computer. A digital camera (image) is just a long string of 1s and 0s that represents all the tiny coloured dots-or pixels-that collectively make up the image. The computer breaks this electronic information into digital data.The special features of this camera are :

(i) *Filmless camera* : The key difference between a digital camera and a film based camera is that the digital camera has no film; it has a sensor that converts light into electrical signals. The image sensor employed by most digital cameras is a charge coupled device. Some low-end cameras use CMOS technology.

The CCD is a collection of tiny high sensitive diodes, which convert photons (light) into electrons (electric charge). These diodes are called photosites. In a nutshell, each photoisite is sensitive to light - the brighter the light that hits a single photo site, greater the electrical charge that will accumulate at that site.

A CCD is an array of light sensitive picture elements or pixels, each measuring five to 25 micrometer 1 (m) across. The camera lens focuses the scene on to this pixel array. Just as the resolution of the conventional photographic film is related to the size of grain, a CCD chip is measured by the number of pixels (picture elements). The cost and quality of the picture is measured in Mega pixel. Now a days digital cameras available in the market are from 2 Mega pixel to 14 Mega pixel. The cost will be around Rs. 10,000 to Rs. 3 lakh depending on the features of the camera.

(ii) *Resolution* : The amount of detail that a camera can capture is called its resolution, and is measured in pixels. The more pixels your camera has, greater details it can capture. The more details you have, more you can enlarge a picture before it becomes “grainy” and starts to lose out of focus. Some typical resolutions that you find in digital cameras today include:

– **256 × 256 pixels,** which we get in low-end cameras. The resolution is so bad that the picture quality is almost always unacceptable;

– **640 × 480** pixels provided satisfactory resolution;

– **1216 × 912 pixel** enable us to get large print size; and

– **1600 × 1200 pixel** provide high resolution and good quality.

(iii) ***Capturing Colour*** : To get a colour image, most sensors use filters to break up light in its three primary colours. Once all three colours have been recorded, they can be added together to create full spectrum of colours. There are several ways of recording these colours in a digital camera. The highest quality cameras use three seperate sensors, each with a differnt filter over it. Light is directed to different sensors by placing a beam splitter in the camera. Each sensor gets an identical look at the image but because of the filters, each sensor only responds to one of the primary colours. The advantage of this method is that the camera records each of the three colours at each pixel location. Unfortunately, cameras that use this method tends to be bulky and expensive.

(iv) ***Image transfer to PC***: You can transfer the image to your PC. The camera usually has a cable to connect it to your PC through USB port. Many manufacturers also provide a video cable. So you can see the image on your TV. Professional photographers now a days develop photographs in this mode.

Intext Questions 30.2

1. Which camera can produce photographs almost instantly?

   ....

2. In subminiature cameras, to what size is enlarge print limited in the best possible cases?

   ....

30.5 Choosing a Camera

A wide range of cameras of various types, sizes and price tags are available in the market. No completely perfect camera exists; all cameras have their unique characteristics and limitations. Choice of a camera is usually a matter of personal preference and how much we are willing to invest. Good photographs can be, and have been, taken with every type of camera, from the inexpensive box camera to the subminiature cameras. As a general principle, if you want technically good results, make sure to buy a camera with a good lens.The major considerations while choosing a camera are :

(i) ***Cost of a camera is*** an important, if not the first, consideration while choosing a camera. At the lower end of the price scale are simple cameras of very limited scope and relatively low performance; suitable only for snapshots taken in good sunlight and for the print of the same size as the negative (or only slightly enlarged). Costing only a little more, the same type of camera with a better quality lens gives sharper images that can be enlarged satisfactority, and with a range of two or three lens apertures and two three shutter speeds, allows photography of a greater range for outdoor subjects.

For serious photography of a wide range of subjects and activities, it is necessary to use a camera fitted with professional quality lenses, with shutter speeds ranging from (1/25) th to (1/200th) of a second, and variable lens apertures. It would however be costly. The thumb rule is : More you pay, more facilities you get to explore and better will be the resolution of picture quality.

(ii) ***Size of the camera*** is another important consideration. Miniature cameras using 35 mm film usually produce 24 × 36 mm negatives, which is the smallest useful size for photography work. The reflex cameras use roll film and usually produce negatives 6 × 6 cm size. Most professional, technical and standard cameras use sheet film or plate in sizes 4″× 5″ , 5″ × 7.2″. Larger the size of the negative, easier it is to enlarge life size to produce good sharp result(for say group photographs). Smaller the negative, greater is the precision required in manufacturing the camera, and more you will have to pay for the equivalent quality in the final print.

Your choice should depend largely on the kind of photography you intend to do. If you want to produe mainly colour transparencies of your own interest, a 35 mm camera will be the right choice.

(iii) ***Types of camera***: For general purpose, 35 mm camera is quite useful. However, professional photographers prefer to use digital cameras, to take picture and store then in a computer. You will not to be required to wait for the conmpletion of the roll. You can take print either by loading photographs on the computer or directly by attaching the camera to the printer. Now-a-days, you can get any number of copies simultaneously within say 30 second, without any loss in quality.

(iv) ***Other features*****:** Within the 35 mm cameras, there is lot of variation in quality/price brand like Nikon, Pentex, Minolta, Olympus, Yashica, Kodak. Cost of the cameras varies from say Rs. 3000 to Rs. 50,000. You can choose a camera from these branded ones. Finer the adjustments, costlier the camera. The following adjustments are of concern.

For photography in dim and low lux light, you need a large lens aperture.

Between-lens shutter gives full flash synchronization at all shutter speeds, but interchangeable lenses must then have their own individual shutters which makes them more costly. Focal plane shutters make it is easy to change lenses, but flash synhronization is limited to slow shutter speeds, up to a maximum of (1/125)th or (1/60)th second.

A view finder at eye level is best for working among people and crowds.

As a general principle, give preference to simple specification but fitted with good lens from a reputed and well known manufacturer. One should prefer complete mechanical cameras rather than an electronic camera for the simple reason that functions of the latter are affected adversely in low temperature, high humidity and high altitude.

Intext Questions 30.3

1. State whether the following statements are True are False:

   a. A high resolving power lens is very sharp.

   b. Rays coming through the edges of the lens are bad for photograph's definition.

   c. If we shorten the focal length of the lens, keeping picture size the same, the angle of view will decrease.

2. What is the better and cheaper idea to take a photograph in poor lighting conditions?

3. Which property of the camera lens can not be spot checked by amateur photographer.

What You Have Learnt

- Photography is used in every day life. It is used in science, engineering, medicine law, education.
- The shutter in a camera controls the time for which light is allowed to pass through the camera lens and to strike the film.
- Shutter speeds are chosen so that we can balance these very well with the aperture-setting for some constant exposure value.
- The present day cameras are miniature, polaroid, movie & video, and digital.
- A telephoto lens and a wide angle lens are used only for a special purpose.
- Polariod camera produces photographs almost instantly. However, polariod photography is not likely to replace conventional photography.
- Digital camera needs no film, the image is stored on a semiconductor array, called charge coupled devices.
- Look for wide aperture, wide angle of view and good resolving power lens, while choosing a camera.

Terminal Exercise

1. Describe a digital camera. How is it different from a miniature camera.

2. Describe the special features of Zoom lens?

Answers to Intext Questions

30.1

1. In Engineering, Medicine and Education.
2. Aperture & Shutter
3. 50 mm
4. (a) False; (b) False; (c) False; (d) False

30.2

1. Polariod camera;
2. 5 by 7 inch.

30.3

1. (a) True; (b) True; (c) False.
2. Use faster film.
3. Maximum aperture, angle of view and resolving power.
4. Correctness of the lens.
5. $\frac{f}{4}$ and $\frac{f}{8}$.

31B

FILM EXPOSING AND PROCESSING

In the previous lesson, you have learnt about the importance and impact of photography in different walks of life. You also learnt about different types of cameras used by ameture as well as professional photographers. Now, you must be eagar to know as to how to use a camera to photograph your friend, family or house, places around you or a garden in full bloom to keep a record down the memory lane The process essentially begins with the loading of camera with a film of an appropriate size. However, before loading a camera, it is a good habit to read the manual provided with the camera and follow all the instructions step by step with care. In module-6, you learnt about the formation of images with the help of a convex lens. You may recall that we can see a real image on a screen, which could be a white cloth or white wall, i.e. it should not be transparent. In photography, we produce this real image on a film with the help of camera lens. And the brightness of image depends on the illumination of object (subject). In the preceeding lesson, you learnt that when visible light from a source like sun or flash bulb, falls on a light sensitive surface (film), it interacts with the surface and a latent (invisible) image is formed on it. The latent image can be retained on the film by exposing and processing it using a technique called developing and fixing.

In this lesson, you will learn the details of the characteristics of a photographic film, and latest techniques of exposing, processing and printing.

Objectives

After studying this lesson, you will be able to:

- state the characteristics of a photographic film;
- describe the process of exposing a film;
- explain the importance of filters in processing a film;
- describe how an exposed film is processed and
- explain the procedure of making prints (positives) on photographic papers.

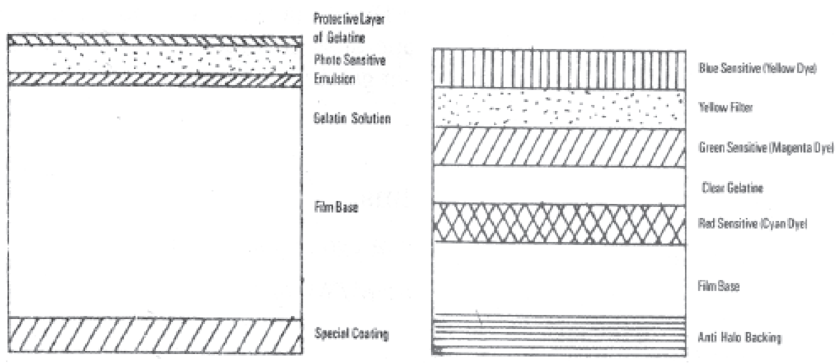
31.1 The Photographic Film

In the previous lesson you have learnt that a camera lens produces a sharp image on the film, which is a photosensitive surface, coated on the base of a glass or plastic / cellulose sheet. Let us now learn about the structure of photographic film.

31.1.1 Structure

A photographic film has four constituents: (i) Base, (ii) Emulsion, (iii) Special coating and (iv) Anti Halation coating (Fig. 31.1). We now discuss these.

(i) **Base** of a photographic film, on which the photosensitive material is coated, consists of either glass plates or plastic cellulose sheets.



(*a*) (*b*)

Fig. 31.1 : Cross section of a) black & white film, and b) colour film

(ii) Emulsion: For black and white negatives, a mixture of silver bromide or silver iodide with gelatin and silver nitrate is used as emulsion. This is because photosensitivity of silver halides is maximum for silver iodide. Silver bromide comes next. Silver chloride is least sensitive. Gelatin is a transparent and colourless material with gum like properties. A solution of gelatin is coated as substratum on one side of base material of the film (due to its sticking property) with the base as well as the photosensitive emulsion.

In case of a colour film, the emulsion has three layers as shown in Fig. 31.1(b). The first layer on the base is sensitive to blue colour, the second layer (middle layer) is sensitive to green and the third layer upper most layer is sensitive to red colour. Between the first and the second layers, there is a thin layer of yellow filter. These three primary colours are used to create other colours.

(iii) Special coating: Due to flexible nature and thin base of the film, it may bend on one side when gelatin dries up. In order to prevent the film from curling, its backside is coated with a thin layer of gelatin, so that both the sides of the base continue to have the same thickness of gelatin.

(iv) Anti-Halation coating is added to the base of all film negatives to prevent Hallation or internal reflection of light. If this happens, the sharpness of the image diminishes. This coating also prevents light from going through the film.

The (B/W) or colour films may be negative films or positive (slide) film/reversal film.

31.1.2 Characteristics

There are a wide range of negative materials available to photographers. One negative material may differ form another in respect of (i) speed, (ii) colour sensitivity, (iii) gradation, (iv) graininess, (v) resolving power, (vi) development characteristics, (vii) physical characteristics of emulsion, and (viii) nature of support.

The extent to which an emulsion is sensitive to light is usually referred to as its speed. The speed of a film has been standardised by the American standards association. It is referred in terms of A.S.A, which is the speed rating assigned to a film of a specific sensitivity. For instance, a 200 A.S. A film is more sensitive than a 100 A.S. A film. Films of 500 A.S. A and a 1000 A.S.A are used for special purposes.

The German rating system is referred to as DIN (Deutsche Industry Norman).

Every film is designed to respond to a specific quality of light, which is broadly classified as daylight and artificial light. Films meant to be exposed outdoors or in daylight are designed to respond to natural light, while films designed for indoor usage are made to respond to artificial lights.

Intext Questions 31.1

1. State whether the following statements are TRUE or FALSE.
   (a) A fast film gives fine details in the photograph.
   (b) The bigger size of the grains of silver halides in emulsion make the film more sensitive.
   (c) Higher the A.S.A. speed rating, more sensitive is the film
2. What make a photographic film fast or slow?

   ....

3. Write the units in which speeds of the commonly used photo films are expressed.

   ....

31.2 Film Exposing

Exposing a film refers to the process of actually taking a picture. The primary requirement for taking a picture is availability of light.Once this is ensured, we have to control the quantum of light reaching the film. To do so, we devise a control mechanism. In the lesson on optical instruments, you learnt about aperture which governs the amount of light reaching the lens for forming an image.

The aperture of a lens is referred to as its *f*-number. The *f*-number of a lens varries according to its focal length and is calculated using the relation

$$f\text{-number} = \frac{\text{focal length}}{\text{working diameter}}$$

It means that *f*-number will be more for a lens of larger focal length and or smaller working diameter or effective aperture. That is, the numerical value of *f*-number will be higher if the hole through which light is allowed to enter to form an image on the film is small.

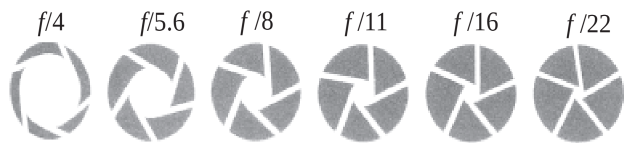


Fig. 31.2 : Pictorial representation of *f*-number sizes

In a camera, focal length of a lens is constant, except when a zoom lens is used. (In a zoom lens, a combination of elements can function as a wide angle lens, normal lens or a telephoto lens.) Fig. 31.2 shows the apertures at different *f*-numbers.

The size of the aperture used to take a photograph depends on the intensity of light. If intensity of light is strong, less quantum of light would be required. It means that *f*-number will have a higher numerical value, say *f*/22, *f*/16 or *f*/11. But if light is weak, we will have to open the aperture more to permit more light to enter and use aperture corresponding to *f*/5.6, *f*/4 or *f*/2.8. The total quantity of light required is calculated as

Light required for exposure = Intensity × time.

The exposure time is specified by the duration for which light is allowed to enter the camera lens. It is controlled by the shutter speed. The exposure time is marked on the body of a camera. The exposure time can be set as a fraction of a second $(\frac{1}{20}, \frac{1}{100}, \ldots)$ or even as integral interval like 1, 2, 4 s.

An additional "B" setting on the shutter speed allows us to keep the shutter open as long as we desire. This is normally used in night photography.

The setting of these two controls depends on many factors. The important factors are :

- *The depth of field required.* Depending on the range, the aperture has to be adjusted.
- *Movement of camera.* Under the most favorable circumstances, people find it difficult to keep a hand held camera steady at shutter speeds lower than (1/100th) second. Movement of the camera during exposure is one of the commonest causes of diffused negatives. Therefore, camera must be kept steady during exposure.
- *Adjustment of shutter speed.* It the subject is moving, you will be required to adjust shutter speed; faster the subject moves higher the shutter speed required to obtain a sharp image.
- *Variation in intensity of light* falling on the subject, which can occur at different times of the day and of the year, according to weather conditions, and with different types of artificial light sources.
- *Variation in the kind of subject.* The size of the aperture of the lens is adjusted accordingly.
- *The speed of the negative used.*

31.2.1 How to Expose a Film Correctly

One of the basic requirements to get a technically perfect negative or colour transparency is correct exposure. A correct exposure is said to have occured when the exact amount of light necessary to produce negatives with the correct density and colour transparencies is admitted to the film. It is controlled by the aperture and the shutter speed. As the filters absorb light, less of it reaches the film. Therefore, a compensation in the exposure must be made. This increase in exposure time depends on the filter used.

Aperture alterations can be calculated from filter factor. For example, a 2x filter factor requires twice the exposure time or one stop larger aperture. Some manufacturers also recommend the compensation required while using a specific filter. The effects of typical of filters on a colour slide are listed below :

Filter	Colour	Effect
Ultraviolet	UV absorbing	Haze cutting, Reduces blue casts
Sky light	Very pale, pink	Similar to UV filter, slightly warmer
Natural density	Grey	Reduces light without altering the colour
Polarizing	Light Blue	For use with low, red sunlight
	Mid blue	For using day-light film with clear flash bulbs
	Deep blue	For using day-light film with studio floods
Amber	Light amber	For day light film with dull bluish lighting outdoors
	Deep amber	For using type A (tungsten 1 film in daylight)

31.2.2 Depth of Field ($D_2 – D_1$) and Depth of Focus

When a lens is focused at a distance, only one subject plane can be brought to critically sharp focus in the image. The distance between the nearest (D_1) and the farthest points (D_2) in the subject at which the required standard of sharpeness is attained is known as the depth of field. It depends on the

– focal length of the lens;

– *f*-number used;

– distance focused on; and

– maximum permissible size of the circle of confusion.

All other factors being equal, shorter the focal length of a lens, greater will be the depth of field. That is, depth of field is inversely proportional to focal length. This is one of the reasons why a 35 mm camera can be used with lenses of extreme aperture, say *f*/1.4, the focal length of normal lens for this format is only 50 mm.

The smaller the aperture under any given condition, the greater the depth of field and the main reason for stopping lens down is to increase *f*-number will be higher the depth of field to cover subject that are deep from front to back.

An important and helpful rule is that for a given image size, all lenses give the same depth of field at the same *f*-number. Thus, if a person is photographed with a 100 mm and 50 mm lenses, at *f*/11, at distances giving the same size of image, there will be no difference in the magnitude of the depth of field. The two pictures will however show different perspectives because of the different viewpoints.

The depth of focus is a measure of the distance behind the lens wherein subjects remain sharply in focus. It depends only on *f*-number and not on the focal length of the lens. There is however a relation between the time you allow the light to strike the film in your camera via the lens and shutter and the quality you get in your final prints or transparencies. The best method is to use an exposure meter. Then you will not be required to judge the strength or suitability of light with unaided eye; a selenium cell helps record the light strength and thereby activate a pointer with which you can fix correct exposure. Most expensive cameras have a built-in exposure meter.

31.2.3 Factors Affecting Exposure

The main factors which affect duration of exposure are time of year, time of day, the geographic latitude, the weather, the type of subject and the speed of the films being used. You will discover that films have different ratings written on the cartridge. This gives you an indication of speed of films.

31.2.4 Exposure Meter

Decision on duration of exposure requires creativity. Yet for convenience, quality and economy some photographers prefered to use an exposure meter to know the intensity of light in a given situation. This helps them to determine proper combination of shutter speed and aperture setting. The major types of exposure meters are *incident* and *reflected light meters.*

Incident light meters measure the intensity of light falling on the subject. To take an incident light reading, the meter is placed along side the subject and pointed at the camera. Reflected light meters measure the intensity of light reflected by the subject. They are read with the meter at the camera**,** pointed towards the subject. These meters cover a much broader angular range from 30 degrees to 50 degrees, for reflected light meter, and 180 degrees for an incident light meter.

Another type of meter, called **spot meter**, measures reflected light in an area as little as one degree.

The simplest meter contains a photoelectric cell, generates electric current when exposed to light and a sensitive electical current measuring instrument. The meter is provided with an adjustable dial indicating film speed. When the dial is aligned with the pointer, the meter shows various combinations of shulter speed and aperture size that will produce equivalent exposure. In this way, you can easily set the desired aperture and the shutter speed in the camera.

If a sensitive current measuring meter in an exposure meter is connected to a selenium cell, the deflection of the meter needle indicates the intensity of light incident on the cell.The scale of the meter indicates the exposure value (EV) for a given speed of the film.

31.2.5 Use of Electronic Flash Gun

An electronic flash is often necessary to give good colour to pictures. Most cameras have a built-in flash tied to a light sensor. This activates flash when necessary. Better cameras generally have a pre flash option that helps eliminate under exposure.

A flash gun is used for throwing light on the subject to be photographed in night or dim-light. Exposing time is nearly (1/1000) second. So it can even take photograph of a moving object. When a charged condenser discharges through flash tube, it flashes. In case of focal plane shutter, shutter time is set to be (1/25) or (1/30) second. Now a days a very light and compact flashgun is available, which uses four pencil cells only. Many of the electronic flash guns throw a fixed amount of light on the subject after setting film speed and distance range of the subject. Remember that *in 35 mm camera, the shutter speed dial marked X is to be set while using an Electronic Flash.*

In brief, the following steps should be followed to expose a photographic film.

– opening camera and loading the film correctly;

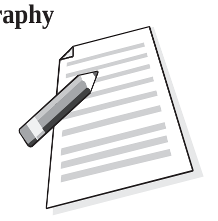
– viewing the picture through viewfinder and focusing the subject;

– setting the distance of the subject from the lens of camera (focussing);

– setting the lens aperture/ *f*- number, which depends on the light available;

– setting the shutter speed and locking it;

– clicking the shutter; and



– unloading the exposed film.

You may now like to answer the following Intext Questions.

Intext Questions 31.2

1. State Whether the following statements are True or False:

   (a) Depth of focus decreases as *f*-number increases.

   (b) If filter factor is 2X, then *f*/8 will be changed to *f*/16

   (c) When the aperture number is increased, the shutter speed must be decreased to get same exposure.

   ....

2. The setting of a camera lens is changed from *f*/4, to *f*/8. Has the aperture increased or decreased and by what factor?

   ....

3. A camera lens, set at exposure time $t = 200$ is changed to $t = 100$. By what factor does the light entering the camera increase or decrease?

   ....

4. An object requires exposure time $t = 125$ and $f = 16$. For the same exposure, what will be the exposure time, when the camera lens is reset at $f = 11$?

   ....

31.3 Processing of the Exposed Film

The processing of an exposed film involves three steps: (i) Developing, (ii) Fixing, and (iii) Washing and Drying. However, the chemicals and physical conditions are different for B/W and colour films. Let us learn about these now.

31.3.1 B/W Film

a. Developing a film

When silver halide is exposed to light, it is reduced to silver (invisible) and a latent image is formed on the film. In the first stage, exposed film is placed in a chemical solution, called developer, in a darkroom. The developer reduces the light affected grains on the exposed film to metallic silver. Silver in this form is black and it is possible to see the image on the film. Thus, whatever we see on the developed film is just the opposite scene, opposite in black and white, colour and contrast. That is why on developing a film, we get negatives, one for each frame of the film.

When the film has been developed, it is taken out of the developer and put in a stop bath. The use of stop bath prevents the fixer from being contaminated by the developer. A dilute solution of acetic acid is commonly used for a stop bath. 20 mL of acetic acid is added to one liter of water to make stop bath. For films, stop bath with 3% alum is also used.

Different types of the developers are used for films and papers of different companies. Three types of developers are used for developing a black and white film :

- Simple developer,
- Fine grain developer, and
- Monoblast developer. Developers for coloured films are different.

In the second stage, the film is carried through fixing. When we expose the film, light from the original scene generally does not affect all the light sensitive grains on the film. These grains stay on the film even after the film has been developed. These light sensitive grains may ruin the negative by turning dark, if exposed to light. To prevent this, the developed film is immersed in another solution, called the **fixer**. (This process is called fixing. Fixing removes unaffected light sensitive grains. As a result the negative no longer has light sensitive gelatin, making the negative less likely to be scratched.) Sodium thiosulphate solution, commonly known as hypo, is used as fixer. Potassium metal bisulphite may also be added to hypo to stop the developer action. In order to make fixer, first dissolve 200 gram hypo in one liter of water and then dissolve 20 gram potassium metal bisulphate.

b. Washing and Drying

In the third stage, the film is finally washed in running water for about half an hour to remove any remaining chemicals. You can wash the film in still water, provided water is changed completely every few minutes. Even after washing, the film emulsion is highly sensitive to touch. Therefore film should be hung with the help of a clip in a warm, dry, dust- free room for at least an hour or so.

c. Methods of Film Processing

For film development, the following two methods are commonly used:

- Tray Development
- Tank Development

In B/W film, one sensitive layer is developed. Tank Development is preferred for processing, as 35 mm films are commonly used now-a-days.

31.3.2 Colour Film

Colour films have at least three emulsion layers. Primary colours affect one emulsion layer only, while complementary colours affect other two layers. The processing depends on the type of film: whether it is a negative type or reversal (slide).

In a negative colour film, the dyes produced are complimentary to the primary colours of light. Therefore, blue light records as yellow, green light records as magenta, and red light records as cyan. All colours within a scene are recorded through various combinations of yellow, magenta, and cyan dyes. There are four chemical steps and two wash cycles: colour developer, bleach, wash, fix, wash, and stablizer.

The first step in colour negative processing is colour development. It works in nearly the same way as a black and white developer. Its primary function is to develop the exposed silver halide crystals to metallic silver and forming dye around the metallic silver using the oxidized colour developing agent. Of all the processing steps, maintaining adequate temperature of the colour developer is most critical. Usually, the temperature of the colour developer should be kept around 37.8ºC, while all other wet steps in the process can be executed in the range 24ºC – 40ºC. However, maintaining all solutions at constant temperature, is always advisable and frequently recommended for ease, convenience and quality.

In colour films, it is mandatory to remove entire silver so that only colour dyes are responsible for formation of the image. This can be done using a bleaching agent which chemically converts the silver metal back to a soluble silver halide.

The function of fixer is the same in colour processing as in black and white processing. Most fixers use thiosulphate as the fixing agent in an acidic solution. If fixing process is incomplete, it causes loss in contrast, added density, and an unwanted colour cast.

The final step in colour negative film processing is the stabilizer. The primary purpose of this process is to prevent spotting of the film.

Intext Question 31.3

1. State whether the following statements are True or False;

   (a) The function of the film developer is to affect grains of silver halide on the exposed film into metallic silver.

   (b) Stop bath is a weak solution of sodium thiosulphate.

   (c) Exposed film is developed before fixing.

   ....

2. What is the action of the film developer on the exposed film?

   ....

3. Name the correct sequence of steps involved in film processing.

   ....

4. What is sodium thio- sulphate solution commonly know as ? What role does it play in film processing?

   ....

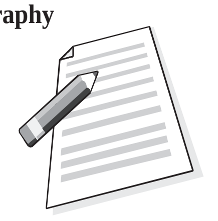
31.4 Printing

If you look through a B/W negative, everything that was white (light) in the original scene appears black (dark) and vice versa. Similarly, if you look at coloured negative, colours of the original scene appear as complimentary colours. In order to make true picture, which resembles the original scene, another process, called printing, is carried out on a photographic paper from negatives. For B/W prints, chloride and bromide papers are used. These papers are coated with a emulsion containing silver chloride and siver bromide respectively, which are also sensitive to light.

When photographic paper is exposed to light coming through a negative, a latent image is produced on the paper. On paper developing, which is very similar to film developing, the latent image becomes visible.

What You Have Learnt

- Photographic film is a strip of celluloid, whose one side is coated with a light sensitive emulsion.Silver halides in the emulsion make it sensitive to light.
- Photographic films are available with varying speeds. Film speed is expressed in A.S.A, number.
- Combination of aperture and hence, the *f*-number and the shutter speed decides the amount of light falling on the film.
- For a lens, decrease in aperture increases the depth of field.
- Exposing a photographic film means allowing calculated amount of light to strike it through the camera lens.
- Film processing is done to make latent image on the exposed film visible. In this process,, negative images are produced.
- The steps involved in film processing are developing, fixing, washing and drying.
- The developer reduces the light affected grains of silver halides on the exposed film to metallic silver.
- Printing paper used for making a print is sensitive to light.
- Silver chloride paper is used for making B/W contact prints and silver bromide paper is used for enlarged prints.
- For making a print, the photographic paper is exposed by light coming through the negative before it is developed.
- Colour negative film appears very similar to a black and white film, whereas a colour reversal film produces transparent positive, called slides.
- Colour films and photography paper are coated with three layers of light sensitive emulsion, each layer being sensitive to one of the primary colours.



Terminal Exercise

1. What do you understand by the terms: film size and film speed ?
2. Write down the relation between exposure time and *f*- number.
3. Explain film processing. List the steps involved in the processing of an exposed film ?
4. Name the functions of a developer and a fixer on the exposed film.
5. List the steps involved in the making of black & White contact prints.

Answers to Intext Questions

31.1

1. (a) False (b) True (c) True
2. Size of grain of silver halides in the emulsion; Larger the grain, faster the film.
3. A.S.A & D.I.N.

31.2

1. (a) False (b) True (c) True
2. Increases, gets doubled, 3. Increases four times 4. t = 250

31.3

1. (a)True, (b)False, (c)True.
2. To reduce light affected grains of silver halide into metallic silver.
3. developing, stop bath, fixing, washing and drying
4. Sodium thiosulphate solution is commonly known as hypo. It removes the left out (unexposed) highly sensitive grains from the film.

32B

AUDIO AND VIDEO RECORDING

Millions of people enjoy listening to music on long play records (LPs) as well as tape recorders in their homes, automobiles (auto rickshows, buses and cars) or on the portable (pocket) tape recorder (walkman). In addition, tape recorders are used to record audio and video dictation, readings from scientific instruments and data from satellites. Usually, A/V signals are recorded on magnetic medium (tape). In Lesson 4 of your physics module 5, you have learnt about the magnetic properties of substances. These properties are used in A/V recording. In this lesson, you will learn about different types of devices and the materials used to record audio and video, with special emphasise on magnetic tape recording.

You now know that the movie as well as video camera work on the principle of persistence of vision, i.e. still images in continuity lead to creation of an illusion of movement. These devices capture movements as a sequence of still photographs or frames along a strip of photographic film or a magnetic tape. The use of this technology in sports is now so familiar to us. To judge the winner in 100m sprint photofinish or close call for run out in a cricket match, use of technology is now almost a routine affair. Do you know that Sachin Tendulkar was the first cricketer in the world to be given run out in England using this technology and the olympic bronze medal loss to PT Usha by a fraction of a second could not have been decided by unaided eye? You must have seen a movie on a VCR or in a cinema hall. Have you ever thought as to how the pictures and sound on these movies are recorded and played back at our command? In this section, you will also learn about A/V recording on a magnetic tape. We have also discussed the precautions to be taken to protect tapes & LPs from dust, humidity and temperature changes, which may deteriorate their performance on repeated use as also their life.

Objectives

After studying this lesson, you will be able to :

- *explain the basic principles of audio and video recording;*
- *recognize the devices used in and methods employed for audio and video recording;*

- *differentiate between the basic principles of audio and video recording;*
- *state the relation between various formats of video;*
- *distinguish between the LP and magnetic tape for audio and video recording;*
- *state precautions to protect magnetic tapes against humidity and temperature;*
- *state the problems encountered in recording video signals on magnetic tapes and the way out and;*
- *apply the basic principles of A/V recording in practice.*

32.1 Types of Recording Systems

Audio and video recording systems are of two types : *analog* and *digital*. Sounds and images on disc or tape have traditionally been recorded by a system in which the depth of a groove in long playing records (LPs) or the strength of magnetism in a tape has varied in a way closely following the variations in the intensity of a musical sound or brightness of a picture. Such recording is known as analog recording. It has the characteristic that reproductions improve as the close variations in the recording follow those of the original sound.

An acoustic (audio/sound) or visual (picture/video) signal, on reaching the detector (a microphone for sound, a camera or a CCD for pictures), is converted into a time varying electrical signal. The information in the signal can be preserved either by reproducing its variation in time as a magnetic variation along the track of the tape or disc (analog recording) or by converting it into a coded sequence of fixed levels (1s or 0s) digital recording. Magnetic tape or a disc can be used to store audio and/or video signal. Note that a moving picture involves much greater information per second than does the sound/audio signal. As a result, it introduces many practical difficulties. However, the principle of storing or recording information is exactly the same. While audio requires frequencies only upto 20 kiloHz or so, video involves signals of five MegaHz or more.

Intext Questions 32.1

1. Name basic types of recording systems.

   ....

2. Give one example each of analog signal and digital signal.

   ....

3. Do basic principles of audio and video recording differ?

   ....

4. Sepecify the frequency range in which audio and video recording is done.

   ....

32.2 Basic Principle of Recording

To understand the basic principle of audio recording, it is important to recall the characteristics of sound. You may recall from your earlier classes that sound needs a medium through which it can travel; it cannot travel through vaccum. Moreover, media heavier than air may transmit sound more quickly.

In audio recording, sound is encountered in three different states:

- sound as it exists physically (having a physical dimension);
- sound as it exists in human perception; and
- sound as idea, an aural representation of an abstract or tangible concept, an emotion/feeling.

Each of these states directly influence the recording process.

Five physical dimensions of sound are central to audio recording. These characterise sound waveform as *frequency*, *amplitude*, and *time*. The fusion of frequency and amplitude creates *timbre*. The interaction of the sound source (timbre) and the environment in which it exists creates alterations to the waveform according to variables of *space*.

The first machine which recorded and replayed sound was invented by Thomas Elva Edison in 1877. In this instrument, sound waves picked up by a diaphragm were used to press tiny indentations on a sheet of tin foil. He used a very simple mechanism to store an analog wave mechanically. In Edison's original phonograph, a diaphragm directly controlled the needle, and the needle scratched (recorded) an analog signal on a tin foil cylinder. To play the sound back, the needle was made to move over the groove scratched during recording causing the needle to vibrate. This, in turn, set the diaphragm to vibrate and playback the same sound.

The system was improved by Emil Berliner in 1887 to produce a gramophone, a mechanical device using a needle and a diaphragm. The gramophone's major improvement was the use of flat records (Vinyl LP) with spiral grooves. The modern phonograph works in the same way but the signals read by the needle are amplified electrically.

Sound recording and reproduction are two separate processes. Sound recording uses microphones to pick up sound waves in air. The pressure changes associated with the waves are converted into electrical waves (signals), which can be coded and stored for future access. Sound reproduction or playback uses additional devices to retrieve information and convert it into electrical signals. The signals are then fed to a loudspeaker, which converts them back into sound.

32.2.1 Conversion of Audio Signal into Electrical Signal

To record sound, a microphone is used to change the acoustic energy into electrical signals. A microphone has a thin, flat, metallic plate, called diaphragm. A small movable induction coil attached to the diaphragm is suspended in a magnetic field. When sound waves reach the microphone, the changes in air pressure around the diaphragm make this arrangement to vibrate. These vibrations create electrical signals having similar variations. These signals are then transferred to a cassette tape, phonograph, LP, compact disc, etc.

To reproduce sound, a playing device–a cassette player, a record player or a CD player – is required to access the stored information. The playing device reads the data through a magnetic head or a needle stylus or a laser (optical pick up system) and converts the stored information (music, speech etc.) into electrical pulses (of varying voltage). The electrical signal is then sent to loudspeaker, which reconverts these electrical signals into mechanical/pressure waves.

32.2.2 Conversion of Video Signal into Electrical Signal

You now know that to convert an audio signal into electrical signal, we use a microphone. You may like to know: How do we convert video signal? For this, into electrical signals, we use a video camera or picture tube.

You may recall that a photograph is reproduced on a page by a mass of tiny individual dots. Similarly, in video technology, a scene is recorded and played back in the form of thousands of pixels (picture elements), each of which details the brightness of single small area. One device for recording a scene in this way is *vidicon tube* (Fig.32.1)

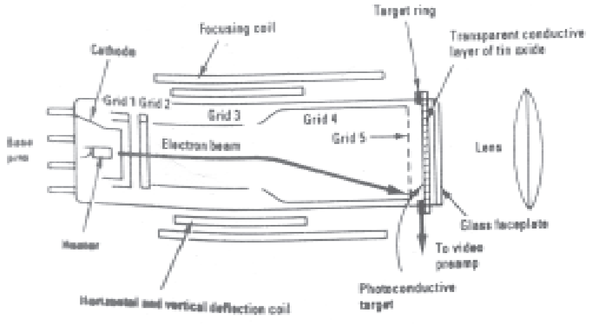


Fig 32.1: A cross-sectional view of a conventional monochrome vidicon tube.

A vidicon tube is about 200 mm (8 in) long and 25 mm (1 in) in diameter. Light entering through the lens is focused onto the photoconductive target which is scanned by the electron beam, and converts the light image into a varying electrical signal. An optical image is formed on a target disc coated with a photo-conducting material whose electrical resistance decreases as light falls on it. For each pixel, a separate measure of light intensity produces a tiny electrical signal. These are then amplified and scanned by electron beam emitted by a heated cathode at the vidicon's back end and focused by magnetic coil in a carefully synchronized process; the beam scans the pixel row, one line after another, completing its coverage of entire scence in about four hundredth (1/400) of a second. To record a picture in color, color strength as well as brightness must be detected. Video cameras may comprise three vedicons, one for each primary colour, as it is done in colour television cameras. Alternatively, they may incorporate a 3-colour matrix forged within a single tube.

At he heart of any camera is the picture tube, which turns the incoming light into electrical signals. Although a large variety of camera tubes are now available, most domestic cameras employ a vidicon tube of about 200 mm length.

Light from the image enters through the lens, and is focussed onto the light sensitive element of the tube. This is protected from the outside by a glass faceplate. The light sensitive part of the tube, the target disc, can be envisaged as an array of photosensitive registers whose end is connected to the video pre-amplifier. The electron beam can then be considered to be the other contact of a complex switching system.

The target disc is made from two electrically separate parts–a conducting transparent film (usually tin oxide) on the inside of the glass faceplate and a layer of photo-conducting material on scanning side. The resistance of the photo-conducting material (usually antimony trisulphide) decreases as light falls on it. In this way, differences in light intensity are transformed into differences in resistance.

These differences in resistances are then turned into useful electrical signals by scanning the target with an electron beam in exactly the same way as we do in a conventional cathode ray tube. The beam scans a target disc line, from top to bottom, and flies back to the top when the bottom is reached. The brightly illuminated part of the target has a comparatively low resistance, and thus a large current flows from a dark, high resistance area. Although this current is very small (around 1-4 microampere), it is amplified and processed into a video signal.

An interesting property of the vidicon tube is its ability to use an automatic sensitivity to enable its output to be altered and cope with the changes in lighting levels. This is particularly useful for domestic equipment, which is often used under less than perfect lighting conditions (low lux). *Auto target control*, as it is called, is achieved by feeding a small sample of the output from the tube back to the target disc. The circuitry is so arranged that the tube output drops and the sampling circuits send an increasing signal to the target. As the target voltage increases, it becomes more sensitive and increases tube output.

Tube for colour cameras. A monochromatic camera detects changes in brightness, as does a black & white photographic film.

In a colour camera, a tube (or tubes) has to reproduce not only differences in brightness (luminance) but also differences in colour (chroma) of the scene. The broadcast camera manufacturers build cameras using four vidicon tubes, one for luminance (that is, for the general scene) and chrominance and one for each primary colour. The separation of the colours is achieved by simple red, green and blue filters, or by prism with different coloured surfaces (Fig. 32.2). Such cameras give a very good colour and sharp pictures, but are very expensive and relatively bulky.

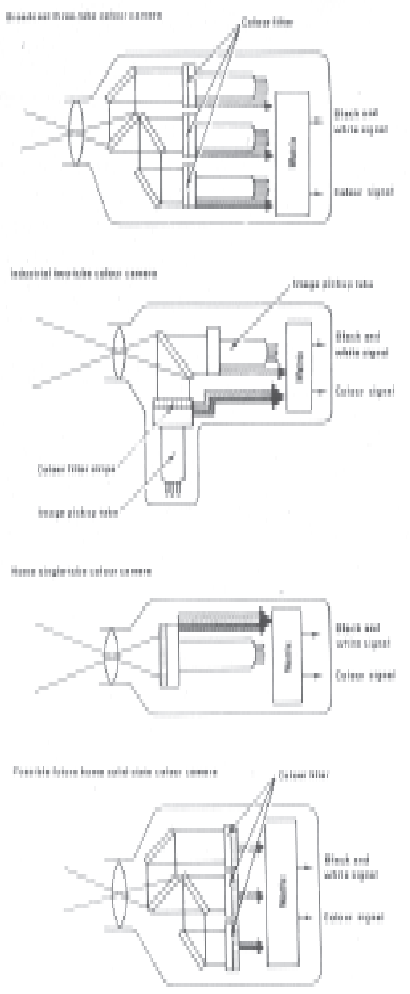


Fig 32.2 : A colour camera

The vidicon can be compared with a microphone, as they are both transducers, which convert light and sound respectively into electrical voltages.

32.2.3 The Charge Coupled Device (CCD)

Now-a-days, vidicon tubes have been replaced with CCD, which is smaller in size, lighter in weight, more sensitive to light, robust and less power consuming. A charge coupled device is an analog device enabling analog signals (electric charges) to be transported through successive stages (capacitors) in a controlled manner. The CCD image sensors can be implemented in different architectures. The most common are full-frame, frame-transfer and interline. Consumer snap-shot cameras use interline devices. On the other hand, for applications that require the best light collection and where issues of money, power and time are less important, the full frame device is the right choice.

CCD comprising grids of pixels are used as light-sensing devices in digital cameras, video cameras and scanners. They are far more efficient than a photographic film, which captures only about 2% of the incident light. An image projected by a lens on the array of pixels (capacitor array), causes each capacitor to accumulate an electric charge, which is directly proportional to the intensity of light falling on it. A control circuit causes each capacitor to transfer its contents to its next neighbour and the last capacitor in the array dumps its charge into an amplifier that converts the charge into a voltage. By repeating this process, the entire contents of the array are converted into a varying voltage, which is then digitized and stored in memory. The stored images can be transferred on to a printer, another storage device or a video display.

Better colour separation is achieved by using three CCD devices and a dichroic prism, which splits the image into red, green and blue components. Most professional cameras are 3-CCD cameras and are quite expensive.

Intext Questions 32.2

1. List the steps involved in audio/video recording and reproduction.

   ....

2. Why does a colour camera have four vidicon tubes?

   ....

33.3 Storage of Audio-Video Signals

Sound is recorded and reproduced for a wide variety of purposes. Music provides entertainment; the spoken voice is recorded for business purposes (dictation), lectures and language training, other sounds may be recorded for various other reasons. Sound recording and reproduction form the foundation of many industries, including entertainment, communications and multimedia businesses. Radio networks rely on sound recording and reproduction for storing news and other programmes.

Television and motion pictures combine images with music, speech and sound effects in a well coordinated manner, to provide the viewer with an enriched experience. Computer program, multimedia software and video games also use sound to make programs more engaging. We will have only a brief account of mechanical and optical systems. However, we will discuss magnetic systems in greater details.

Over the years, several techniques have evolved for recording and reproduction of sound, but only three have managed to survive. These are mechanical (phonograph), magnetic (tape recorder), and optical (sound track on motion picture film).

We now discuss mechanical and magnetic techniques.

32.3.1 Mechanical System

Refer to Fig. 32.3. It shows a phonograph, which reproduces sound by directly or indirectly transmitting to the air the mechanical vibrations of a stylus in contact with a sinusoidal groove on a moving record having prerecorded sound. As a child, you may have enjoyed the music on a phonograph in a fare, party, some family funciton or street vendor.

Phonographs play records that have been produced by analog disc recordings. In this process, an analog (likeness) of the original sound waves is stored as jagged waves in spiral grove on the surface of a plastic disc. As the disc rotates on the phonograph, a needle, called stylus, rides along the grooves. The waves in the groove cause the stylus to vibrate. These vibrations are then transformed into electrical signals and converted back into sound by speakers.

Most phonograph records are plastic discs with a diameter of 7 or 12 inch (18 cm or 30cm). A 7-inch record is played at a speed of 45 revolutions per minute (rpm) and has only a few minutes of sound per side. A 12 inch long-playing (LP) record holds 30 minutes of sound per side. However, these are not much in use now-a-days.

Fig 32.3: A phonograph

32.3.2 Magnetic System : A Tape Recorder

A tape recorder uses magnetic tape for recording sound as well as pictures, and other kinds of information. It can also playback tape recordings. These are widely used by the recording industry and in the radio/television broadcasting. Millions of people enjoy listening to music on tape recorders in their home, automobiles or while walking using a portable tape recorder (walkman). In addition, tape recorders are used to record computer data, dictation, readings from scientific instruments, etc.

Tape recordings can be easily edited by cutting out the unwanted sections and then joining the ends of the tape. However, tapes are less durable than Compact Discs (CDs).

a) *Audio Tape*

An audio recording tape is a thin plastic ribbon coated on one side with particles of iron oxide or chromium dioxide, which can be easily magnetized. It has a shiny side and a dull side. The dull side is used for recording. The dullness is due to a coating of oxide of iron or chromium.

In present day devices, information is recorded on a wide range of magnetic media, which include the linear tape and hard disc. In audio recording, the tape is composed of several layers of materials, each serving a specific purpose. The base material that makes up most of the thickness of the tape is composed of plastic or poly vinyl chloride (PVC). This is a durable polymer and can withstand great deal of stress. Bonded to the PVC base is the most important layer of magnetic oxide. The molecules of this oxide join together to create some of the smallest known permanent magnets, called domains. On an unmagnetised tape, these domains are oriented randomly, and lead to cancellation of the north and south poles of each domain at the reproducing head. As a result, there is no signal at the recorder's output in this state.

When a signal is recorded, the magnetization from the record head orients the individual domains (at varying degrees in positive and negative angular directions) in such a way that their average magnetism is much larger. This alternating magnetic field can be amplified and further processed for reproduction when played back at the same speed at which it was recorded. A tape recorder receives sound in the form of electrical signals and converts these into a changing magnetic field. During recording, the field places the particles on the tape into magnetic patterns. When the tape is played back, the magnetic patterns regenerate the same electrical signal to produce the original sound.

Tape recording can be accomplished by two different processes: *analog recording* and *digital recording*. In analog recording, the patterns of the electric signals are similar to magnetic signals. Analog tape recording stores a signal in a form that looks like the waveform of the original sound. In digital recording, the electrical signals are converted into a digital (numerical) code. This code of 1s and 0s represents the sound. Digital recording produces better sound quality with less background noise and distortion than analog recording. Digital technology is also used in compact discs (discussed in the next lesson).

Digital audio tapes get damaged more easily than analog audio tapes and need more careful handling. Analog tape needs a thicker coating of magnetic materials than digital tape. The quality of magnetic coating, rather than its thickness, affects digital tape sound quality.

Working : Most audio tape recorders, whether analog or digital, have two reels - a full supply reel of magnetic tape and an empty take up reel. One end of the tape from the supply reel is attached to the take up reel. Between the two reels, a soft rubber pinch roller presses the tape tightly against a metal rod, called a capstan. When the tape recorder is on, a motor turns the capstan. At the same time, the take up reel pulls gently on the tape to wind it up.

Before the tape reaches a capstan, it passes over the head of the tape recorder. The head is a small electromagnet (Fig 32.4) that erases, records, and plays back. The speed at which the tape moves past the head depends on the type of the tape recorder. The speeds are measured in inches per second (ips) or in centimeter per second (cms^{-1}). The higher speed produces recordings of better quality, but recording at slower speeds adds to the playing time of the tape.

Fig 32.4 : Standard reel to reel recording system

When an analog tape recording is done, the tape first comes into contact with the eraser head. The eraser head, which is automatically activated during recording, produces a strong magnetic field that removes previous recording, if any, from the tape. The blank tape then moves past the recording head.

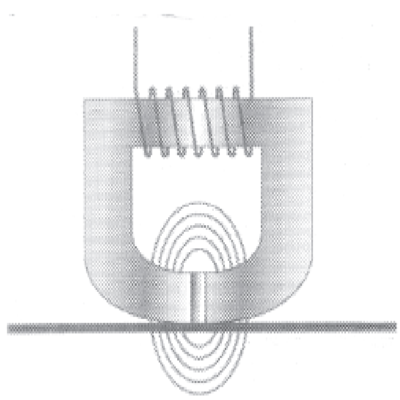


Fig 32. 5: A high frequency eraser

The sound to be recorded on the tape is translated into a varying electric current by a microphone and amplifier increases the amplitude of a given signal without affecting other characteristics, e.g. frequency and phase. As the current flows through the head, it sets up a changing magnetic field around a small gap in the electromagnet (Fig 32.6).

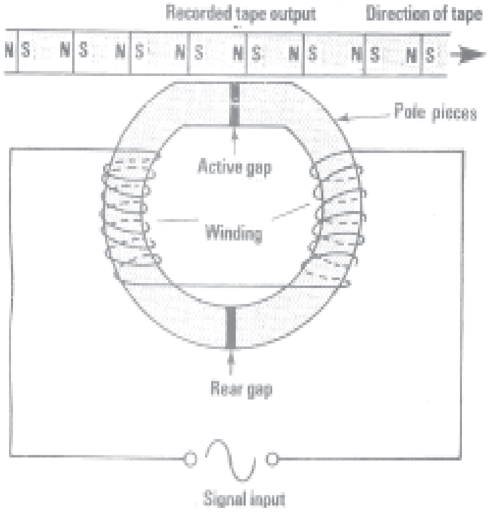


Fig 32.6: A recording head

When the magnetic tape passes over the gap, the magnetic field places the magnetic particles on the tape into a pattern that represents the sound waves entering a microphone.

Unlike analog recorders, most digital recorders do not have a erase head. Instead of erasing the tape first, they overwrite to record new sound. Recording and playback heads may be either stationary or rotating. Stationary heads are like the heads on an analog tape recorder. In a rotating system, two heads are mounted opposite one another on a rotating cylinder called a drum. During recording and playback, the tape moves past the spinning drum.

A digital audio tape recorder converts the original electrical signal into digital format in several steps. The signal is first filtered to prevent interference from unwanted high frequencies. Each second of sound is then broken up into thousands of segments, called samples. Each sample is given a numerical code, which is recorded on the tape in the form of magnetic patterns.

Before a tape recording is played, it must be rewound on the supply reel. The tape is then sent through the recorder again. This time, the playback head is switched on, and neither the erase head nor the recording head is activated. As the tape passes the playback head, the magnetic patterns on the tape generate a weak electric current in the electromagnet. An amplifier strengthens the current before it reaches the speaker, which reproduces the recorded sound.

During playback, the pattern of current generated by the analog tape corresponds to the pattern of recorded sound waves. Playing a digital tape produces electric pulses that represent a numerical code. The recorder translates the code into a varying current, which an amplifier strengthens and sends to the speaker.

Analog recording has a few drawbacks. There is a limit to the size of the magnetic field that can be produced and hence the loudness of sound that can be stored in the tape. This distortion effect, called saturation, happens when all the magnetic particles in a stretch of tape have the same alignment. In addition, the quitest passage that can be recorded have to be louder than the noise background. This is a hiss produced by the random orientations of the magnetic particle in the unrecorded tape. Even with the noise reducing circuitry, these constraints imply that in the dynamic range of an analog recording, the difference between the loudest and the quitest parts is limited.

Other problems include small variations in tape speed, which produce unwanted vibration effects. For this reason, digital recording is better than analog one.

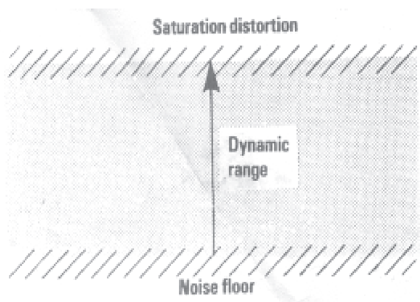


Fig. 32.7 : Dynamic range in recording is limited by background noise and at the tape saturation

b) *Video Tape Recorder*

Video tape recorder is a device that records visual images and sound on magnetic tape. Video tape recorders, also known as VTR's or simply video recorders, also playback and record video (picture) and audio (sound) information on television sets. Video recorders were first used by television broadcasting industry during the 1950's. Since then, video tape recorders have become essential equipment in that industry. Commercials, regular TV serials, and many other telecasts are recorded on videotapes. In addition, most television newscasts, feature reports are also recorded on tape.

Consumers can record TV programs and play back prerecorded cassettes of movies on VCR's (Video Cassette Recorders). The various types of video recorders differ in size of the tape they use and the quality of pictures they produce.

Portable video tape recorders are commonly used to make home movies. These devices, called *camcorders*, combine a camera and a recorder in a single unit that is powered by batteries. The camera and a microphone send video and audio signals to the recorder.

Videotape consists of a long plastic strip coated with particles of iron oxide. Video tape recorder records TV signals by translating them into the electric currents and then into magnetic field in the same way as does an audio tape recorder. These fields create patterns of magnetization in the coating. The process is reversed during playback, when the magnetic patterns are translated into television signals for viewing on TV sets. Videotape recorders store visual images and sound in the form of analog signals or digital signals.

Recording: The recorder converts TV signals into electric current, which travels through wire coils of small electromagnets, called heads. The head is a ring of metal that has a narrow cut called a gap. Opposite the gap, a coil of wire is wrapped around the ring. This coil conducts current corresponding to the TV signals. The current produces a strong magnetic field in the ring and in the gap. When videotape passes over the gap, the field induces/creates the pattering of magnetization. The patterns are removed by an erase head, which demagnetizes the tape.

The patterns recorded on many types of analog video tape consists of three types of tracks (lines of magnetized particles): Video tracks, Audio tracks, and Control track, as shown in Fig. 32.8

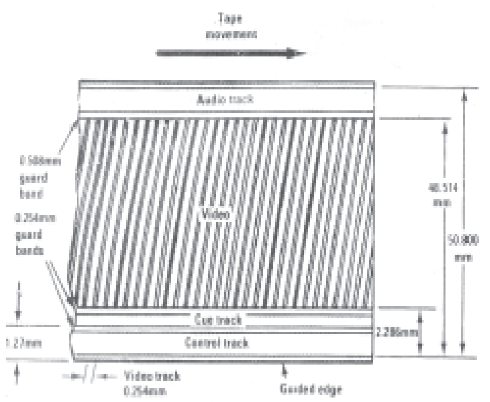


Fig. 32.8 : Recording parameters of the quadruple video recording format

Video tracks contain signals that represent visual images. Video tracks are recorded helically (diagonally) between edges of the tape. These tracks take up most of the tape. Video tracks are created by video heads that are mounted on a rotational metal cylinder, called drum. The video heads scan (pass over) the tape at high speed while recording or playing back video signals. Note that rapid scanning is necessitated for electrical frequency of TV signals. If video heads were stationary or slow moving, a large amount of tape would be required to record a small amount of video program.

Analog audio tracks contain sound signals and signals of control tracks save recorded images from tilting or merging into one another when they appear on the TV screen. Analog audio tracks and the control tracks are recorded by separate stationary heads. The tracks are recorded horizontally. Audio tracks run along one edge of the tape, and control tracks along the other. However, all recorders do not use control tracks.

When tape passes over the head during play back, the tape's magnetic pattern creates a varying magnetic field in the head. When the magnetic field reaches the wire coil, it is converted into electrical voltage variations. The varying voltage, which contains the audio and the video signals, is sent to a television set, which transforms it into sound and picture.

Intext Questions 32.3

1. What is the popular name of a portable tape recorder?

   ....

2. State one advantage and one disadvantage of digital audio tape over analog audio tape.

   ....

3. How can the same cassette be used to record new programmes?

   ....

4. In what respects is video tape different from audio tape?

   ....

32.4 Quality of Sound

We now know that sound is recorded either in analog form or digital form. The term format is also used to describe the number of channels or streams of sound used to record and playback. Two of the most common formats are: monaural (mono) and stereophonic (stereo). Earlier recordings were made in mono using single channel to record and playback sound. Broadcast on AM radio are also in mono. Stereo recording was introduced in the 1960s. It uses two channels for sound. In stereo recording, each channel has a different form of sound. The signals are sent to separate loudspeakers during playback. When played, the sound from these channels combines in air and gives the illusion of direction. A different percentage of each sound might appear at each loudspeaker, giving each sound source its own location between the two loudspeakers. The spatial quality of stereophonics are absent form monaural recording. Quadraphonic recording, which were popular in 1970s, used four channels. Each channel was different, and each of the four loudspeakers were placed in a separate corner of a room. This approach expanded on stereo and gives the listener a sense of sound coming from all directions. Quadraphonic recording is basic to sound systems used as home theaters now-a-days. Here we use more than four speakers to improve the quality of sound.

32.5 Types of Tape Recorders

A cassette tape recorder has the advantage that the tape is fully protected from dust and damage, and is easily loaded into the equipment with no threading whatsoever. It is convenient to send a cassette through the post and to store. Moreover, the recorder deck need not be so large as in a reel-to-reel machine.

But the cassette has a serious disadvantage in that the tape is very thin and does not allow a lot of handling. As such, a tape recorder is available in different formats.

(a) Reel-to-Reel: Reel-to-Reel machine uses a wider tape (6.25 mm or 1/4 in) and offers a variety of available tape speed upto 38.1 cm s^{-1}. This combination permits top quality recording and playback, resulting from an extended frequency range and better signal/noise ratio.

The capacity to take large reel (up to 27 cm in diameter) enable an uninterrupted playing time of 6 h 24min to be achieved using 1100 m triple play tape. The main advantage of a reel machine is that the tape is easily handled for editing, and this combined with the varied speeds makes the reel-to-reel format essential for the serious tape recording enthusiast who wants to make his own programmes. Its main disadvantage is its weight. Apart from one or two exceptions, these machines are large and heavy, because of the mechanical complexity and robustness required. Also the new machines are very expensive.

(b) Stereo or mono?

Most tape recorders now are in stereo formats having two separate recording and playback channels which allow the apparent sources of sound to be spread out into two channels, left hand and right hand. This is achieved by recording on two tracks of the tape simultaneously.

It must be remembered that stereo recording halves the playing time available with the machine in the mono mode. If one wishes to edit stereo recording by cutting the tape, then a full track machine is more suitable as there is no danger of cutting the recordings on the other two tracks. So the creative recordist needs a full track stereo reel recorder that can be used in either mono or stereo mode.

Mono cassette recorders play back stereo cassette tapes in a mono mode. But the same is not true for reel to reel machines. The stereo machine will replay mono tapes, but the reverse is not possible.

(c) Cartridge or cassette?

Both systems have advantages. The higher speed of the cartridge tape results, in better frequency response and less wow and flutter. However, cassette players have been so well developed for hi-fi (high-fidelity) use that much of the improvement has filtered down to the in-car player, while cartridge player development has remained fairly static. Thus there is little difference in performance between the two. For example, the wow & flutter of a typical car cassette player is 0.35 percent while that of a cartridge player is 0.30 percent.

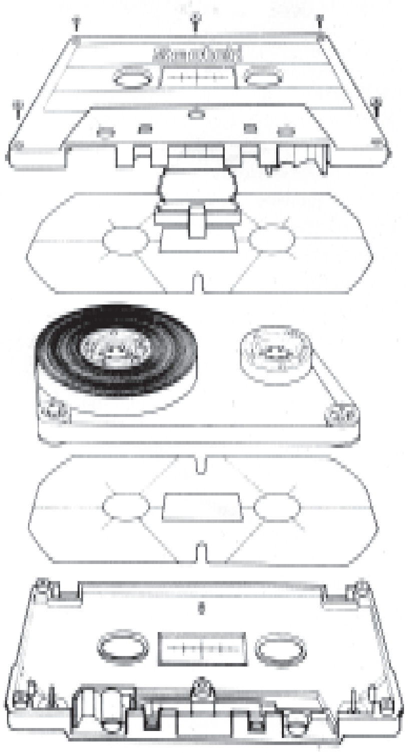


Fig. 32.9 : Cartridge or Cassette

Track width of the cassette is greater, giving theoretical improvement in noise & dropout (momentary breaks in sound due to irregularities in the tape or its coatings).

Cassette tape measures only (0.15 inch (3.81 millimeters)) in width Analogue tape carriers four tracks, two on each side. Analogue cassette tape operators at $1\frac{7}{8}$ ips (4.8 centimeters per second) professional reel to reel tape, which is 6.2 mm (0.25 in) wide.

(d) Standard tape speed

It is apparent that the slower the motion, the greater is the amount of information or longer the program that can be stored on a tape of a given length. However, faster the tape motion, better is the high frequency response. The two common type of tape speeds are 3.75 inch and 7.5 inch of tape per second. For the highest quality audio work, a speed of 15 ips (inch per second) is used. For dictation and storing more information on a small tape, the tape recorder with is a speed of $1\frac{7}{8}$ ips is available. For accurate reproduction, a tape must be played back at exactly the same speed at which it was recorded.

(e) Compact Cassette

The compact cassette consists of two open spools contained within two plastic moldings which sometimes be separated by extracting several screws, to reveal the tape spools and other components.

The tape is about 3.81 mm wide, and on this four tracks can be laid in two stereo pairs, each track being about 0.6 mm wide. A 0.7 mm guard band of unrecorded tape separates the two stereo pairs as approximately half the width of reel audio tape and is generally thinner, ranging from about 9mm to 18 μm (that is, 9 - 18 thousandths of 1 mm) depending on playing time. When one pair of tracks has been recorded or replayed, the cassette can be turned over so that the other pair can be recorded or replayed. There are two sides marked *A* and *B*. S 660 cassettes run for a total of 60 minutes (30 minutes per side) and a C90 get a total of 90 minutes (45 minutes per side). C120 cassette has two hours total running time, tape is rather thin being about 9 μm and nearly six times thinner than standard play reel-to-reel domestic tape. At about 12 μm thickness, the C90 cassette represent a good compromise.

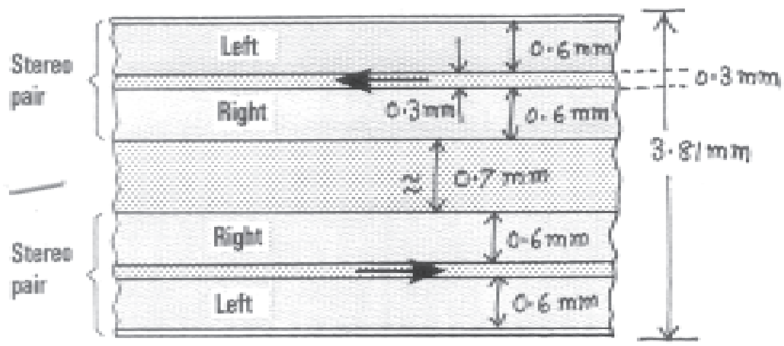


Fig. 32.10 : Magnified view of compact cassette tape

It can be seen that this particular design of cassette employs five screws to secure the two molded half-sections. The tape is wound on to small hubs which, although sandwiched between two radically creased, graphite coated steps sheets (or shims), are free to rotate without undue binding and with just about the right degree of torque. The hubs have keyed holes which engage on the keyways of the drive shaves of the machine flanged; low friction rollers guide the tape to and from the hubs, while correct tracking of the tape across the head is achieved by six guide posts.

The coated side of tape passes several cutouts at the front of the cassette, and the main center cut out accommodates the record/replay head. (Some machines use a common head for both functions while more expensive ones use two separate heads.) In the record mode, the erase head makes contact with the tape through a smaller cutout at the left. Large cutouts on either side accommodate the transport pressure roller, which work against the driving capstan so that the tape is “rolled” along between the capstan and pressure roller.

The head pole pieces make contact with the tape coating, and a close contact is ensured by a felt pad on a bronze circuit. The tape is permanently secured on the hubs by captive latches, and on this particular range of cassette a length of strong polyester leader absorbs the deceleration of foot spooling without stretching or breaking.

Intext Questions 32.4

1. State is the difference between monoaural and stereophonic sounds.

   ....

2. Which device uses a wider tape: reel to reel cassette recorder or a compact cassette recorder? Give the actual tape size in each case.

   ....

3. What happens when the tape is not played back at the same speed at which it was recorder?

   ....

32.6 Tape Characteristics & Parameters

Tape characteristics, structure and composition, tape format and tape speeds are some of the important parameters for audio and video recording magnetic tapes. In conventional magnetic tapes for recording sound or pictures, the signal density depends on the smallest change or transition that the medium can resolve per unit length. Sound engineers refer to the effect of these transitions on the magnetic particle as the recorded wavelength. The shorter the wavelength that the tape can record, the more data it can hold. The resolution of both analog and digital signal is related directly to the shortest wavelength which the magnetic medium can capture.

Recorded wavelengths depend on two factors: the size of the magnetic particles on the tape, and the speed at which the tape passes the recording head. Just as light cannot resolve details smaller than its wavelengths, particles cannot record a wavelength smaller than their dimensions. The speed of the tape past the head affects recorded wavelength as follows:- a musical note of frequency 15 kHz (kilohertz) has a recorded wavelength of 3 micron (3 μm) on a conventional cassette tape running at 4.75 cm s^{-1}. On reducing the tape speed to one-half, the recorded wavelength falls to 1.5 micron, which is impractical for current domestic hi-fi systems. However, doubling the tape speed doubles the recorded wavelength to 6 micron.

The tape developed for 8 mm video can record a wavelength of 0.75 μm (micron) even when the tape passes the rotating recording heads at the slowest speed of 1 cms^{-1}. For example, the individual particles that coat the tape, colour the desired signal with random noise. In analog sound recording, these particles cause background hiss. The noise gets worse if the particles are of uneven size. Present day tapes have a circular or needle shaped particles of very consistent size.

The particles on magnetic tape change magnetic polarity when they record signals, but if the particles are very small, as they need to be if they are to register small transitions in the recording signal, they tend to demagnetize one another. The solution to this problem is to use a material that needs too strong magnetic field.

The high quality tapes used in audio and video recorders have a coating of either chromium di-oxide or pseudochrome - ferric oxide with a little cobalt. These coatings have coercivity up to 700 oersteds. However, **coercivity** of about 1500 oersted needed for 8 mm video and DAT is obtained from a new type of tape based on pure metal. A metal tape is obtained by coating a plastic film with particles of pure metal powder or by evaporating the metal in vacuum so that its vapours deposit on a chilled plastic film.

Coercivity is a measure of the strength of magnetic field required to change a magnetic material from saturation to zero state of magnetization.

Video tape

To record audio and video signals simultaneously on a videotape, the recorder comprises two sections: The video section and the audio section. As the audio tape passes the head on record, small magnets are induced along the audio track. Their strength corresponds to the intensity of the signal and their length to the speed of the tape and the frequency of the signal. The tape speed of the VHS format, for example, is 2.339 cm s^{-1}. For each complete cycle of audio signal, two magnets are recorded; one for the positive and the other for the negative half-cycle.

The wavelength of a recorded pair of magnets may be obtained by dividing the speed (υ) of the tape by the frequency (f) of the signal. If the lowest frequency of interest is 30 Hz and the highest is 12 kHz, we get wavelengths of 779.6 μm and 1.95 μm, respectively corresponding to the VHS tape speed.

The poles of the head are formed to provide a very fine gap across which the magnetic flux concentrates and the tape passes. For the head on replay to respond fully to the recorded signal, the gap must not straddle more than one of a pair of full cycle magnets. When the wavelength is equal to the gap dimension, the replay output falls to zero. This is because the two opposite halves of a recorded full wavelength appear in the gap simultaneously. The corresponding frequency is called the *extinction frequency*. At half of the extinction frequency, the signal is attenuated by about 3 dB, and these may be considered to be the “full” response.

At the VHS tape speed, the gap cannot be wider than about 1.975 mm, for a full replay response required up to 12 kHz. In practice, the gap needs to be smaller because there is incomplete contact between the tape and the head. In most domestic video machines, high frequency deterioration starts at 8 kHz or so.

The principles of video recording are closely related to those of audio recording. But their upper frequency ranges differ in magnitude. While audio requires upper frequencies upto 20 kHz, video involves signals upto 5 MHz or more! This has particular implication for head gap size. The wavelength corresponding to 5 MHz at the VHS tape speed is 0.0023 μm. Even if it were possible to engineer such a fine gap, the tape would never retain such short magnets. For this reason, a video head with the smallest practical gap is used and the speed between the tape and the video head is increased. In video parlance, this is called the 'writing speed'. For a gap of 1 μm and an upper video frequency of 5 MHz, the writing speed is about 10 ms^{-1} and the corresponding extinction frequency is approximately 10 MHz. In domestic machines, the writing speed is less than this. In non-professional applications, we can generally tolerate a value corresponding to about 3 MHz bandwidth with a diminishing upper frequency resolution. Even so, a very fine gap is essential for the video head, which serves for both recording and replaying.

Video	Writing speed ($m\ s^{-1}$)
Betamax	6.6
SVR	8.21
VCR	8.1
VCR-LP	8.1
VHS	4.85
V2000	5.08

To obtain the high writing speed, while retaining an acceptable tape speed through machine, the tape head speed relied on rotating video heads. The Ampex system used four video heads mounted on a head drum spinning at 240 or 250 revolutions a second and geared to the 60 Hz (American) or 50 Hz (European and Indian) picture field rate. This gave birth to the quadruplex transverse scanning system, which is used worldwide now.

Quadruplex Video: As the 50 mm tape is transported at 35 cms^{-1} across the head drum (or 19 cms^{-1} with different head and reduction in ultimate resolution), each head writes approximately 16 lines of picture across the width of the tape before switching to the next head. However, it is very costly.

Helical scan video: Due to high cost, a quadruplex machine is less popular in the normal domestic market. A less complex arrangement achieves the high writing speed with two video heads mounted at about 180° to each other on a rotational section, which forms a part of a head drum. The tape passes around the drum as a helical wrap and then transported at a fairly low speed. For the 50 Hz field rates, the head makes 25 revolutions a second, so that one complete revolution takes 40 ms. As the head is in contact with the tape for half revolution, a video scan lasting 20 ms is made in turn by each head diagonally. A complete TV picture (called a frame) is composed of two interlaced fields. So, each field of the TV system is synchronized to the 50 Hz rate (matching the mains supply frequency), each occupies 20 ms. It means that each diagonal video track carries the complete information in 312.5 line field.

Three formats at domestic level are Betamax (Sony), V2000 primary (Phillips & Grunding) and VHS (JVC). A compact VHS video system using smaller tape cassettes (92 × 39 × 23 mm) has been launched by JVC. The cassette giving 20 minute playing time can be used in the conventional VHS machines with the addition of an adapter in the shape of normal VHS Cassette.

8 mm Video: The above mentioned formats use 1/2 inch tape. But a common standard for new miniature Video System uses a tape width of about 8 mm. This is not a replacement for the prevailing 12.65 mm tape, which is still regarded ideal with for domestic video recording. Instead, it presents an alternative non-conflicting format for portable applications, where video camera and recorder form an integrated unit.

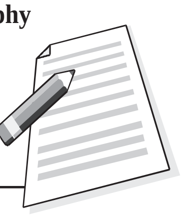
Video tape Recorder (VTR) is a device which when connected to a television set, can be used to record both sound and picture on magnetic tape. The tape is normally enclosed in a cartridge (a video cassette). Video tape recorders can also be used to 'play back' these tapes, whether they have been prepared from a television broadcast transmission or using a video camera.

Cassettes loaded with Cobalt - enhanced high energy ferric oxide (fe) tape are available for the Betamax, VCR and VHS formats. The tape is spooled within the cassette so that it can easily be not touched with fingers; grease on the tape coating hinders good head contact and encourages dropout effects. The spools of SVR and VCR cassettes are placed one above the other, resulting in a screw tape path. But this is of little importance because the tape is extracted automatically by the machine and threaded around the head drum. The Betamax & VCR cassettes (also VCC 200 cassettes) have side-by-side reels as in audio compact cassette.

The 8 mm video system relies on metal tape. Metal tape has broken the micrometer barrier. The signal density on 8 mm Video tape is more than on any other recording medium. In other words, if the tape were as wide as English Channel (32 km), the recorded wavelength would have the length of a tiny boat (3 m).

On 8 mm videotape, the signals needed for one minute of colour TV and digital stereo sound occupy just 48 cm^2 on a VHS tape occupies 180 cm^2. The first video recorder used by broadcast industry some 40 years ago needed 12,000 square centimeters of tape for a minute of black and white picture with mono sound.

Digital audio tape is a direct development from the technology of 8 mm video. Both rely equally on short-recorded wavelengths.



Video image versus photographic image

1. A video image is a magnetic recording and the base can be reused after erazing the recorded image.
2. A photographic image needs to be processed viz., developed, fixed and then printed for viewing whereas, a video image can be instantly played back and previewed.
3. A video image is temporary while a photographic optical image is permanent and withstands the test of time.
4. A video image has a short life if not stored properly; the image can perish.

32.7 Preservation of Tapes, Storage Techniques, Precautions during Handling and Transportation:

Records kept in clinical conditions can be played 50-100 times without audible degradation. They should be stored away from direct heat or sunlight and kept vertically in the rack under slight side pressure. If they are stacked in horizontal piles, they will warp, and it may be impossible to reclaim them. The first essential for a disc is to prevent it from dirt. So you should keep records sleeved/covered. Most visible dust is on the surface and does little harm; the dust in the groove is difficult to see and even more difficult to remove. If the surface is rubbed with a brush, pad or cloth, the vinyl may be minutely scuffed, which can produce a high frequency hiss, or static charge may be added, which will attract more dust. Vigorous rubbing can remove high frequency information. A brush may push foreign matter further into the groove.

To a lesser extent dust is also an enemy of tapes (audio/video). It can act as an abrasive, not only stripping the oxide from the plastic hacking but also causing rapid head wear. Tapes, reels and cassettes should be returned to their protective boxes or cases immediately after use.

The edge of the tape, particularly long and doubly play, are very easily erased, causing poor reproduction of the outer tracks. Thus the reel-to-reel tapes should not be spooled at excessive speeds, which can also cause oxide shedding and hence dropouts. Cassette decks usually have a moderate winding speed, but the narrow tape guides must be kept scrupulously clean.

All tapes should ideally be stored vertically at a temperature not exceeding 10°C. Avoid magnetic fields from television sets, motors and loud speakers. Don’t subject them to vibrations or sudden jolt at this may cause signal loss; particularly at high frequencies.

(a) Video Cassettes: Care and Maintenance

The most widely used domestic tapes are VHS which are available in the range of sizes from E 30 (lasting 30 minutes) to E 240 (four hours); next are Betamax ranging from L125 (35 minutes) to L830 (215 minutes); V2000 format tapes are double sided with playing time of VCC 120 (2 × 240 minutes). It is advisable to use quality tapes from manufacturers of repute.

- Store Cassettes at a moderate temperature in a dust free enclosure.
- When not in use, cassettes should be kept in the sleeve provided with the tape edge farthest from the opening.
- Rack Cassettes in a vertical position to minimize the risk of warping.
- Warping can also result from heat. Do not put cassette on a warm surface; it can harm the video heads.
- Avoid touching the tape with fingers. Grease on the oxide surface can harm the video heads.
- Use the pause control sparingly as it increases the wear on the tape.
- When fast winding cassettes, operate the control firmly to avoid loops of tape becoming slack and creased.
- To reduce handling, label every cassette or sleeve.

Intext Questions 32.5

1. State the factors on which the wavelength recorded on a magnetic tape depends.

   ....

2. Name two materials normally used for coating on high quality magnetic tapes.

   ....

3. Write four points for the care and maintenance of video cassettes.

   ....

What You Have Learnt

- Phonograph was the most elementary device for recording and reproduction of sound.
- In the phonograph, sound produced in front of a horn vibrated a diagram, which in turn set a needle into vibrations to trace grooves in a tin foil (or a vinyl disc). When played back the needle moving in the goooves vibrated the diaphragm to reproduce the original sound.
- The audio/video recording – reproduction systems are very similar in their working principles and can be classified in three categories : Mechanical systems, magnetic systems and optical system.

- In magnetic systems, the audio/video signals are converted into electrical variations of the same type, using appropriate transducer : a microphone for audio (sound) and a vidicon tube/CCD for video. The electrical variations are amplified and stored as magnetic variations of a material coated on a disc or a tape.
- During reproduction of audio/video, the whole process is replayed in reverse order : magnetic variations $\rightarrow$ electrical variations $\rightarrow$ orginial audio/video.

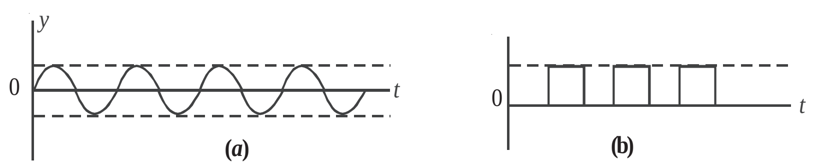
Terminal Exercise

1. How are sound waves converted into electrical signals and vice-versa?
2. Distinguish between (a) Analog and digital recording, and (b) Audio and video recording.
3. Describe the working of (i) a phonograph, and (ii) a tape recorder.

Answers to Intext Questions

32.1

1. (i) analog system, and (ii) digital system
2. "A normal acoustic or visual signal where the magnitude of the signal varies continuously with time is called analog signal as shown in fig. (a)



   The analog signal can be converted into a coded sequence of fixed levels (1s and 0s) called as digital signals. These are shown in Fig. (b) above.

3. There is no basic difference in the principles of audio and video recording. Only the two are done in different frequently range.
4. Audio recording is done at 20Hz to 20 kHz whereas video recording is done at frequencies greater that 5 MHz.

32.2

1. A transducer is a device which converts any one form of energy into another form of energy. (a) microphone (b) vidicon tubes/CCDs.
2. (a) Audio or video signals are converted into corresponding electrical signals with

the help of appropriate transducers.

(b) Electrical signals being weak are magnified.

(c) Magnified signals are recorded on a disc or a tape in the form of (i) grooves (ii) magnetic changes or (iii) mechanical grooves.

(d) The records are replayed to produce the original signals.

3. A colour camera has four vidicon tubes – one for luminance and one for each primary colour.

32.3

1. Walkman.

2. **Advantage** : Digital recording produces better sound quality with lesser background noise and distortion than analogue recording.

   Disadvantage : Digital audio tape can be damaged more easity than analogue audio tape.

3. The programme recorded on a magnetic tape can be easily erased by passing it through the erasing head. Then the cassette becomes ready for recording a new programme on it.

4. Video tapes are wider than audio tapes and run at a higher speed.

32.4

1. Stereophonic sound has a spatial quality which is missing in mono aural sound.

2. Reel to reel recorder uses a wider tape. Its width is 6.25 mm whereas a compact cassette tape is 3.81 mm in width.

3. The sound produced is distorted.

32.5

1. The wavelength recorded on a magnetic tape depends on two factors: (i) size of magnetic particles on the tape, (ii) the speed at which the tape passes the recording head.

2. (i) chromium-di-oxide and (ii) pseudo chrome.

33B

COMPACT DISC FOR AUDIO AND VIDEO RECORDING AND REPRODUCTION

In Lesson 32, you have learnt that audio and video recordings are done as a continuous variation of electrical energy obtained from devices such as microphone and video camera. These variations recorded on the magnetic media are analog. The entertainment world is now going digital. Sophisticated digital technology holds promise for virtually complete fidelity in sound reproduction and superb picture quality in television sets. A number of products based on digital technology such as Compact Disc(CD), Digital Audio Tape (DAT), digital television, Digital Versatile Disc (DVDs) etc. have been developed and are available in the market. As a professional entrepreneur, you would be required to keep pace with new developments. So you must acquire competency and skills in handling and management of digital devices.

In this lesson, you will learn about construction and working of compact disc and DVDs used for audio and video recording. These devices encode music digitally on light reflecting plastic. Though DVDs look like an ordinary CD, these play pictures as well as music with superb quality.

Objectives

After studying this lesson, you will be able to:

- *state the properties of compact disc for superb quality of audio and video pictures*;
- *highlight the advantages of compact disc player and video disc player; and*
- *describe the construction and working of a compact disc and a digital versatile disc*.

33.1 Compact Disc

In the previous lesson you have learnt how a magnetic tape and LPs are used to record audio information. You also learnt about the limitations of these devices. To eliminate the adverse influence of their drawbacks, we use a device known as *compact disc*. You will now learn how information is encoded on a disc.

Compact disc is a rigid plastic platter of 12 cm diameter. Audio information is encoded and stored in the form of digital format. A specially designed player is required to playback the pre-recorded information. The compact disc was invented by Joop Sinjou and Toshi Tada Doi in 1979. It took the CD fifteen years to replace LP. Compact discs are now available in different generations. An optical disc is a flat, circular, usually polycarbonate disc on which data is stored in the form of pits and bumps within a flat surface, usually along a single spiral groove covering the entire recorded surface of the disc. This data is generally accessed using a laser light.

In 1979, two major electronic companies formed a consortium to develop a digital audio disc, which resulted in the introduction of the compact disc in the year 1983.

Though Optical Discs are more durable than audio/video data formats, they are prone to damage from daily usage and environmental factors. The information on an optical disc is stored sequentially on a continuous spiral track from the innermost track to the outermost track. An optical disc drive (ODD) on a computer is used to read or write an optical disc.

First generation optical discs were used for storing music and software. The laser disc format stored analog video while other disc formats were developed to store digital data.

These discs used infra-red laser as a reading device. The minimum size of a laser spot is proportional to the wavelength of the laser. Therefore, the wavelength is one of the factors limiting the information density on the disc. However, many factors affect density besides minimum spot size. For example, a multi-layered disc using infra-red would hold more data than an otherwise identical disc with a single layer.

Second generation optical discs store larger amounts of data, including TV-quality digital video. Most of such discs use a visible light laser (usually red). As you know, the shorter wavelength allows a tighter beam thereby allowing the pits and lands of the disc to be smaller. In the case of the DVD format, 4.7 GB of storage on a standard 12 cm, single sided, single layer disc is possible. Even smaller media such as the MiniDisc and DataPlay formats have capacities comparable to a much larger compact disc.

The use of short-wavelength visible light lasers for optical discs have enabled larger capacities, particularly for holding high-definition video. The third generation disks under development have the storage capacities of over one terabyte.

Compact disc eliminates the hisses, pops, and hums that degrade the music on the conventional LPs and magnetic tapes. This also helps to avoid one major problem of normal cassettes where the tape comes out of the track overflowing here and there, making a mess around the play head. In CD system, the play head does not physically touch the rotating disc and, therefore, the life of CD increases many times as compared to cassettes. There is no fear of the songs in the CD being lost or CD jamming in the player. The 1000th play of a compact disc will sound every bit as good as the first one, a feature that LPs and tapes cannot claim.

Itext Questions 33.1

1. List three devices used to listen music.

   ....

2. What does a compact disc offer?

   ....

3. Write two disadvantages of a compact disc.

   ....

33.1.1 Construction of Compact Disc

Fig. 33.1 shows the cross section of a compact disc. The disc consists of a reflective evaporated aluminum layer covered by a transparent protective plastic coating. The information layer of a compact disc is an optically flat mirror-like surface on which the microscopic steps ‘pits’ and ‘flats’ are raised. The disc contains at least 3 billion pits in a spiral track more than five kilometer long, and can record about one hour of continuous music.

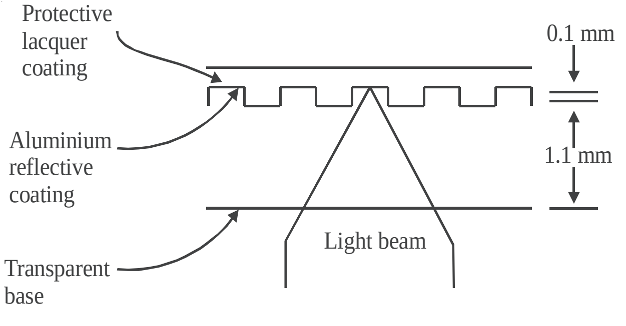
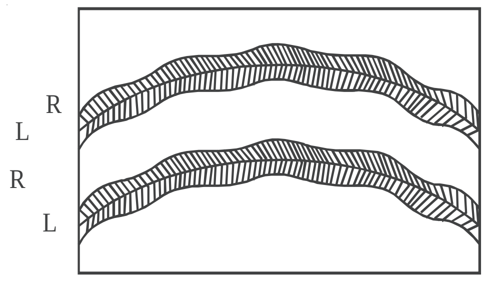


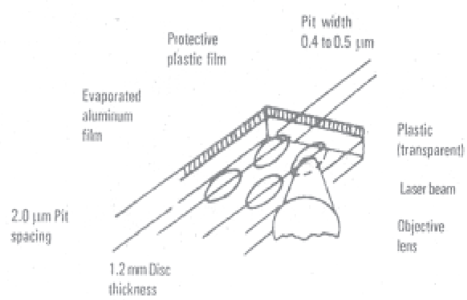
Fig. 33.1: Cross section of a compact disc

33.1.2 Structure

Sandwiched by a protective plastic coating, the silver metallic layer in the CD is etched with a spiral track of pits literally microscopic in size, using laser beam. The pitch of the spiral is 1.6 mm. Fig. 33.2 shows a comparison of the grooves in a conventional LP record and the pits of a compact disc.



(a)



(b)

Fig 33. 2: Comparison of the grooves in a) conventional LP record, and b) the pits of a CD

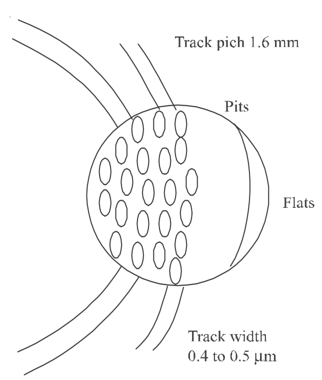


Fig 33.3: Magnified view of compact disc tracks

Fig. 33.3 shows a magnified view of a compact disc. It is composed of thousands of circular 'tracks' in the form of a continuous spiral from the inside to the outside of the disc. The tracks are similar to grooves. However, CD tracks consist of tiny pits or indentations in the disc material. The width of the pits is 0.4 to 0.5 μm (micro metre) with a depth of 0.1 μm. The distance between the spiral tracks is held constant at 1.6 μm, and is called *track pitch*. The combination of pits and flats (between the pits) is used to reproduce or pace the digitally recorded information.

The compact disc carries left and right channel information separately with two sets of information aligned successively on the disc. There is a fixed time interval between the two sets of information. The length of a CD's spiral track is about 6km and the total data capacity is about 780 MB (Mega Bytes)*. In fact, only one third of the CD's capacity is used to store digitised sound; the rest is used for error correction, subcodes, interdising, parity checks, synchronization as well as index details, which give the number of tracks and location of tracks on the disc.

There are 2,861,800 bits of non-audio information processed for every second of music – i.e. 10,301,500,000 bits for each hour of music. In all, a compact disc can contain a total of about 20 billion bits – to be precise 19,919,878,200 bits.

33.1.3 Shape, Size and Types of CD

The commonly used CD is 120 mm in diameter. It has 74 or 80 minute audio capacity and a 650 or 700 MB data capacity. CDs are also available in a number of shapes and sizes. The "business card" CD, which closely resembles the size of a business card, is most common.

As you know, the CD, an evolution of the gramophone, became a data storage medium. The technology was adapted for use as a data storage device, known as a CD-ROM. Depending on the application and the recording technology, CDs got several names. Some of these are described in following paragraphs.

(i) Audio CD

An audio CD is also known as Compact Disc Digital Audio (CDDA). The format is a two-channel 16-bit PCM encoded audio at 44.1 kHz sampling rate. The selection of the sample rate is made to achieve full reproduction of the audible frequency range. The CDDA standard is referred to as the "Red Book Standard"

A disc of 120 mm diameter provides 74-minutes playing time, which is much longer than what was possible on each side of long-playing vinyl records. The scanning velocity of this device is 1.2–1.4 ms^{-1} and is equivalent to approximately 500 rpm at the inside of the disc, and approximately 200 rpm at the outside edge. The disc slows down during its playback from beginning to end. With a scanning speed of 1.2 ms^{-1}, the playing time is 74 minutes, or around 650 MB of data on a CD-ROM. Even higher capacities on non-standard discs (up to 99 minutes) are available. But tighter squeezing of tracks worsens compatibility.

(ii) CD+Graphics

Computer Disc + Graphics (CD + G) is a special audio CD containing graphic data, in addition to the audio data. While the disc can be played on a regular audio CD player, the graphic output can be obtained only through a special CD + G player attached to a TV receiver or computer monitor. These graphics are mostly used to display lyrics for "karaoke" performers.

(iii) CD-Rom

During its initial period of existence, the Compact Disc was purely an audio format. However, in 1985, the CD-ROM standard was established, which defined a computer data storage medium using the same physical format as audio compact discs readable by a CD-ROM drive of a computer.

(iv) Video CD

Video CD (VCD) is basically a standard digital format for recording video on a CD. VCDs can be played by dedicated VCD players, DVD Video players and also by some video game consoles. The VCD standard is referred to as the "White Book Standard". The overall picture quality is intended to be comparable to VHS video but highly compressed video in VCD tends to be of lower quality than VHS video.

Super Video CD (Super Video Compact Disc or SVCD) format is used for storing higher quality video than VCD on standard CD. One recordable CD (CD-R disc) can hold up to one hour of SVCD format video.

(v) Photo CD

As the name suggests, photo CD format is used for digitizing and storing photos in a CD. The discs can hold nearly 100 high quality images, scanned prints and slides using special proprietary encoding. These CDs are intended to play on CD-i players, Photo CD players and any computer with the suitable software. The prints can be taken on photographic paper with a special machine.

Now let us study the technology involved in recording and playback of audio/video using a compact disk.

33.1.4 Analog and digital recording

You now know that sound/audio can be recorded on a record/disc in two ways: analog and digital. All conventional music reproduction systems, including tapes and LP records, are analog storage and retrieval systems. An analog signal is represented as a continuous flow of electricity (energy) that often functions as an electrical 'copy' of information being signalled. Even the speakers that reproduce sound and human ears which receive it are both analog. In fact, an analog signal is vulnerable to outside interference and distortions and fails to clearly represent the information it is carrying. That is why it is 'noisy'.

In digital format, we have signals as a string of bits positioned one after the other in the form of 'ON' and 'OFF' (1's and 0's).

In a compact disc, the audio is stored in the form of digital signals of 16 bits. You have studied the process of converting sound waves into electrical signals in the previous lesson. These electrical analogs can be used to create a permanent physical equivalent of sound wave-pattern, the undulations or wiggles in the record grooves. Wiggles cause motion repeatedly from side to side and undulate going alternately up & down or in and out.

Fig 33.4 shows how an electrical smooth (continuous) analog wave form is converted into a series of 1s and 0s to produce a series of values in binary code. If the voltage at a certain point in the wave is measured and found to be 6V, it will be encoded in binary as 110, 3V will be encoded as 011 and 5V as 101 and so on. The examples use three binary digits 'bits' in each case, which gives a small range of possible values.

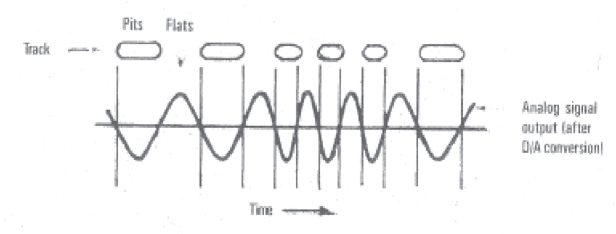


Fig. 33. 4: Track of pits and flats

Each sample is encoded with more bits to increase the accuracy of measurement. In compact disc, 16 bit string is used to encode the given information. So, when you have an audio signal in digital form, a stream of 'zeros' and 'ones' emerg from the digital output at a bit rate of 1.4112 million per second. Obviously, storing this huge information in permanent form is no easy task.

In compact disc, each sample is in 16-bit code/string, which gives a possible 65,536 (2^{16} read as 2 to the power 16) values. In other words, each sample is quantized to an accuracy of 1 part in 65,536 with a sampling rate of 44,100 per second. This enables the analog to digital converter to 'plot' audio waveform.

Digital recording technique has extremely low harmonic and inter-modulation distortions, compared to LP records. Wow and Flutter are virtually absent in a CD player. One advantage of digital recording is quite obvious; it is possible to insert extra information and manipulation can be done without affecting the original information.

33.2 Compact Disc (CD) Player

One basic difference between a phonograph and a CD player lies in their pick up mechanism. Phonograph records are played with a needle on top of the record which moves on the table top at the rate of 45 rpm ***The beginning of the record is at the outside edge, and the needle moves onwards as the music is played.***

A compact disc is played from the underside with light from a laser beam. The beginning of the CD is near the center. The light beam moves outward as the program advances. The CD player reproduces audio signals with extreme accuracy by extracting signal information from a disc using a laser optical read out with no physical contact between the disc and the signal pick up mechanism. The audio signals stored on CD are in a high density digital format.

The optical read out uses a laser beam. A laser, an acronym for Light amplification by Stimulated Emission of Radiation is a special light source which produces a narrow beam of concentrated, monochromatic coherent light. The laser used in CD players is generated by a small low powered, semiconductor diode, made of aluminum-gallium arsenide (AlGaAs), which emits an invisible (790 nm) wavelength of infra red light. The laser beam is focussed on the disc by the objective lens, which acts like the lens of a microscope and focusses the laser beam into a spot slightly less than 1 mm in diameter. The spot is then used to retrieve the information on the disc. The light beam is reflected off the microscopic pits and flats on the underside of the disc. The light reflected by the pits is not as bright as that reflected by the flat areas. These pit and flats are encoded in accordance with music or other audio. The amount of reflected light will change corresponding to the zeros and ones (0's and 1's) pattern recorded on the disc. The photo-detector output will give a serial binary data, from which the 16 bit of each of the samples will be recovered and by using a 16 bit digital to analog converter, we will get back to the original analog voice through speaker which we will hear. The audio signal passes through signal processing circuit before being played on the speakers.

The pits and flats representing the digital information are located at 1.1 mm from the transparent surface of base of the disc. The light beam passes through the transparent base material to retrieve the information. The rotation of the disc, combined with the pits and flats passing over the light beam, create a series of 'on' and off flashes of light being reflected into the system, thus modulating the light beam.

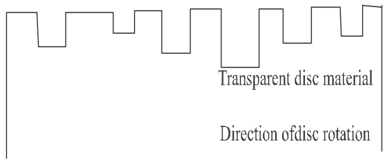


Fig 33. 5: A track of pits and flats.

Fig 33.5 shows a track of pits and flats. Lengths of pits and flats determine the information contained in the track. The pits and flats can vary in length from about 1 mm to 3 mm.

Each pit is only three fifth of a micrometer (about one hundredth of the breadth of your hair). With data so finely spaced on the disc, even a small particle of dust would block large amount of data and cause many problems.

The analog waveform shown below exhibits the pits and flats which represent the decoded signal after digital to analog conversion. The pits reflect less light than the flat area, and the lengths of the two vary to recreate original signals.

The information density of the CD is 50 to 100 times greater than that of conventional LP records. The CD is scanned by the servo controlled optical pick up at constant linear velocity (CLV) of 1.3 ms^{-1}. To get this scan rate, the rotational speed of the disc is progressively changed from 500 rpm at start upto 200 rpm at the outside edge of the disc. The block diagram of a compact disc player has been shown in Fig 33.6.

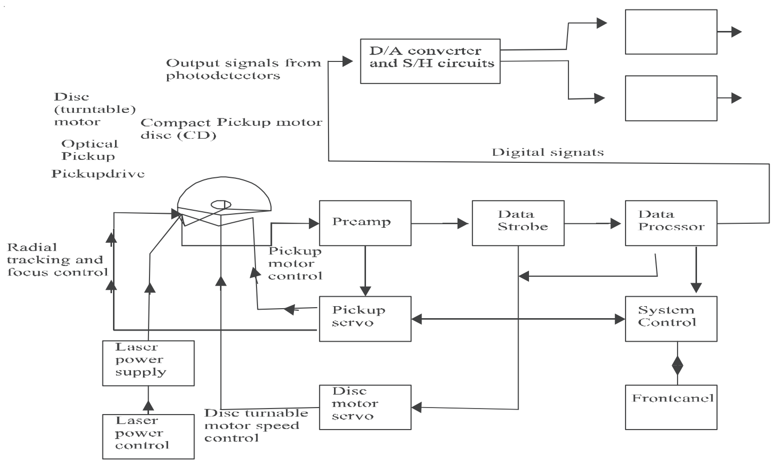


Fig 33. 6: Block diagram of a typical CD player

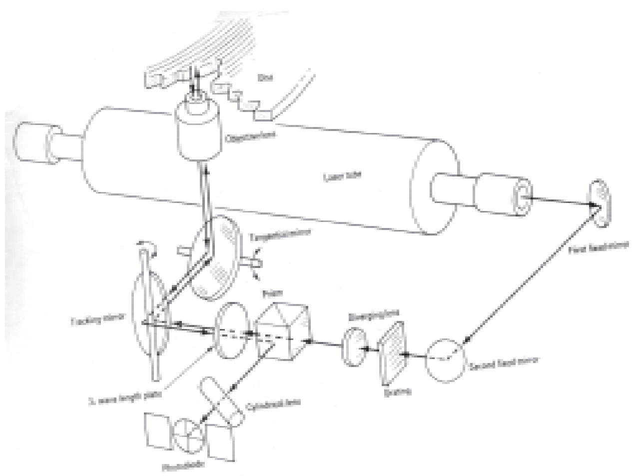


Fig.: 33.7 Construction of a C.D. Player

The number of songs in one CD depend on the duration of each song, but about seven Hindi songs come in one disc which gives one hour of uninterrupted quality sound. The compact disc spins at a high rate of variable speed between 500 rpm in the beginning and then upto 200 rpm in the end.

33.2.1 Advantages of Compact Disc

- Compact discs are available in two sizes; 8 cm and 12 cm diameter.

- Compact disc offers better sound quality with upto an hour's uninterrupted playing time.
- They are infinitely more durable than Vinyl disc (LPs).
- Since there is no friction, the CDs is much more durable.
- Wow and flutter are virtually non-existent in a CD player.
- Compact disc is made of plastic (polycarbonate), which is unbreakable.
- Handling a CD presents far less problems than analog records. For example, even if the disc is dirty, the laser beam can still operate properly because the beam is directed at the reflective aluminium layer beneath the surface (rather than at the surface).
- CDs allow selection of any desired section for play.

33.2.2 Disadvantages

- Pre-recorded CDs are costly
- CDs can not be re-used by erasing or overwriting.
- Old classical music may not be made available in CD format.

Intext Questions -33.2

1. Distinguish between the terms analog and digital.

   ....

2. Give two examples of analog and digital devices.

   ....

3. In what form, information (audio) is stored in a compact disc?

   ....

4. Write any two advantages of digital audio-recording.

   ....

5. Specify the range of speed of rotation of compact disc.

   ....

6. How will you calculate the stroring capacity of a compact disc?

   ....

33.3 Compact Disc and DVD (Digital Video Disc)

A video disc looks like an ordinary LP, but it plays pictures as well as music. Unlike video tape systems, it is specifically designed to play pre-recorded programmes, movies, concerts, vocational courses etc. Now-a-days, digital video disc (DVD) is the latest in video disc series: *VCR's* (which use magnetic tape), *Laser disc* based on laser vision and *digital video disc,* which is also called *Digital Versatile Disc*. It is capturing the market because its advantages go beyond picture quality; it delivers all sound effects expected in a theater. Digital storage is very versatile - text, videos and animation as well as sound can be stored on interactive discs, capturing an entire twelve volumes of encyclopedia on a small piece of plastic. 100 years of National Geographic magazine is available in 30 CDs. Similarly, old Indian classics are being digitised and CDs can act as useful tools for knowledge management.

33.3.1 Limitations of Traditional Video Recording Media

Video recording on magnetic media has shortcomings such as

- picture quality is poor and audio quality is also not satisfactory;
- dropouts, flicker (brightness variations, fluctuations slower than the persistence of vision) and distortions are common in a magnetic tape;
- the direct contact between magnetic tape and video head results in degraded quality of picture and audio is degraded after repeated use; and
- frequent head cleaning is necessary to minimize scratching and tracking problems.

33.3.2 Need of Video Disc

Laser Disc (LD) was the first commercial optical disc storage medium, and was used primarily for viewing movies at home. Laser Disc technology, using a transparent disc, was invented in 1958. The other type of videodisc in reflective mode was developed later and has several advantages over the transparent mode. While Laser Disc gained popularity in some countires, in Europe it remained an obscure format. The standard home video Laser Disc is 30 cm in diameter. Although LD has several features and properties similar to a CD/DVD, yet at most it an analog system. The video is stored in the composite domain with largely an analog sound.

Just as the audio CD eliminates the hisses, pops and hums, which degrade the music on analog records, LPs, cassette tapes, the video disc eliminates the dropouts, flickers and distortions that are common on analog video Home Systems, VCR, VDPs and tape recordings. Video discs need not be used solely for the storage of sound and pictures. It can store large amount of text or mixture of text, sound, graphics and moving pictures. This, together with random access and other capabilities of this system, has led to information storage, retrieval and transfer.

33.3.3 Types of Video Discs and Players

There are three types of video discs:

a) Contact Video Disc (CVD)

b) Optical Video Disc

c) Optical Digital Video Disc (DVD)

In an optical video disc, the tracks are monitored by optical laser beams. In most information applications, as opposed to entertainment, the industrial format optical disc is generally regarded as most suitable (because of its ability to present still pictures, hold frames of text and provide rapid access to any frame). Video discs can be used for storage of television pictures and sound, sound only, or for digital storage of data, or all these in combination. The Phillips/MCA disc for example, has 54,000 frames per side. But each television frame is fairly limited in the amount of information it can store. For television frames i.e. 6,000 - 7,000 pages per side of a disc is not comparable. Single frame cannot, therefore, be used to store complete page of text for viewing on domestic television receiver screen. Video disc can be used to store information in digital form. In these cases, the storage of a single side is approximately 10^{10} bits or roughly 1 million pages of 1250 characters, which is vastly more text than what can be used in a direct, television - compatible way.

Optical video discs have the digital information (video + audio) encoded on a standard video signal. The storage capacity of these discs is likely to be between 10^{10} and 10^{11} bits. The new DVD system uses the same technology as found in existing audio CD and CD-ROM (Compact disc read only memory) players. A single DVD standard for both video disc and CD-ROM application has been tried out. Another requirement was for the future DVD drives to read today's CD-ROM discs. Today's CD-ROM disc can hold about 650 MB of information (1 MB = 10^6 bites).

33.3.4 The Video-Disc Player

The video disc player is a very specialized form of photograph or record player. A video disc player plays a prerecorded video disc carrying both picture and sound through any standard TV set. The picture can be either black and white or coloured. The sound can be monaural on all players and stereo on some players (and even two channels independent or bilingual on some players).

The player circuit converts picture and sound information recorded on the disc into electrical signals (as discussed in lesson 32) that modulates a radio frequency (RF) unit (also known as VHF modulator). The output of RF unit in the player is applied to the TV set.

The video disc spins at a high speed compared with the conventional audio records and uses either an optical or capacitance pickup instead of the conventional stylus and needle. Typically, the video disc is played on both sides and has a playing time of 30 minutes per side with standard play. An extended play video disc is capable of storing one hour of information per side.

The advantage of using a disc as an information carrier over video tape is that disc can provide immediate access to any part of the program. Probably of greatest importance to the user is the low cost, which is made possible by using a production process similar to that of audio records. Also, both the video display and audio reproduction of a video are generally far superior to any video tape or cassette.

The disadvantage of the video discs compared to video tape or video cassettes is that the user cannot record on the video disc; he can only play back prerecorded one.

Working Principle of a Video Disc Player

The optical video disc is played from the bottom with a light from laser source. The beginning of the LV disc is near the center, and the beam scans outwards towards the edge as the program advances.

The light beam is focussed onto the bottom of the video disc through an objective lens. The lens is located in the player under the video disc. As the video disc is played from beginning to end, the objective lens moves from near the center of the video disc to the outside edge. The beam actually reflects off the microscopic pits beneath the bottom surface of the video disc. The pits are coded in accordance with the picture and sound information. The use of such an optical system allows many important playback features, such as forward and reverse play, slow or fast motion, and stopped motion (still picture).

An optical pick up ‘reads’ the reflection of tiny spots of light shining on a rotating disc. The character of reflection changes, depending on whether the beam falls on a pit formed on a reflecting layer or on a flat surface. This on-off reflection is captured by a photo-detector, which produces a string of on-off electrical signals that correspond to the zero’s and one’s digital code. The digital data is then ***converted into analog audio or video signals***. But DVD goes a step beyond CDs, taking advantage of recent technological advances to squeeze upto 488 minutes of full motion video data on the same 120 mm diameter disc that strained to hold 70 minutes of audio data just 15 years ago.

33.3.5: Digital Versatile Disc or Digital Video Disc

The most important hardware development in DVD player is new generation laser. Current CD players use infrared laser with a wavelength of 780 nm (10^{-9} m) or about one hundredth of the width of the human hair. The lasers in the new video disc player have a wavelength of 635 nanometer. The narrower wavelength means laser beam can focus on pits that are roughly half the size of the pits on current audio CD.

The improvement over the 1.6 μm track pitch of conventional audio CDs adds up. The length of a CDs spiral track is about 6km and the total data capacity is about 780 megabytes.

Tracks on the new DVD disc will be about 11 km long and will hold more than 4.7 gigabytes of data per side, that is, enough room to store 133 minutes of full motion video per side.

High quality sound is another promising feature of DVD. The DVD will have a lot of room for extra data, allowing more multiple language and sub title tracks. Users will be able to choose whether to listen to the original movie dialogue with or without subtitles or a dubbed version. This feature appeals to disc markers who will be able to put a number of languages on one disc, saving manufacturing and handling expenses.

The first DVD player hit the market in March 1997.

33.3.6. Advantages and Disadvantages of Video Disc

Compared to paper, microfilm and magnetic media, the video disc has the following advantages-

1. High storage capacity on both sides of the disc.
2. A durable storage media - no contact with the head, since information (Video + Audio) is scanned by laser beam.
3. Unaffected by dirt and scratches.
4. The availability of the relative inexpensive player which can operate under computer control and quickly access specified video images.
5. The materials from which the discs are prepared are less expensive than those of VCRs or conventional films.
6. The disc itself is light and compact and can be easily stored and transported.
7. Some discs have the further advantage of random access to various parts of the disc (in contrast to tapes and video cassettes).
8. Digital Video Disc or Digital Versatile Disc (DVD) has put down the VHS and laser video disks by providing
   - colours deeper and brighter;
   - edges sharper;
   - details crisper;
   - the DVD pictures are noticeably better than laser disc;
   - studio quality video images; and
   - theater like sound.
9. With a video tape recorder, favourite TV programmes can be recorded as they

happen to be played over and over later. Pre-recorded tapes (movies, concerts, phonography etc.) can also be bought, but these are expensive as they have to be recorded individually on 'real time'. Prerecorded compact video discs are mass produced and are, far cheaper than tapes.

Video disc has a disadvantage also, that is, the disc system currently available cannot record information. Only prerecorded disc available can be played through a specially designed laser scanned optical pick up system as in compact audio disc.

33.3.7 The Recordable CD

The technology has evolved from the stage where only pre-recorded CD containing audio and/or video were available. The blank recordable CD is now readily available at low cost. Audio-Video can be recorded using standalone CD recorders or with the help of computers having CD writers. A wide range of recordable CDs are in circulation. These include

(i) **Recordable CD:** (CD-R) recordings are designed to be permanent. The CD-R can store about 700mb/80 minutes of data. These are available in different maximum writable speeds viz. 48X, 52 X etc. Higher the speed, faster is the speed with which data can be stored on these CDs. The expected life of CD-R is from 20 to 100 years, depending on the quality of the discs, the quality of the writing drive and storage conditions.

(ii) **Rewritable CD:** (CD-RW) is a re-recordable medium. It uses a metallic alloy instead of a dye. The write laser in this case is used to heat and alter the properties (amorphous vs. crystalline) of the alloy and hence change its reflectivity. A CD-RW does not have as great a difference in reflectivity as a pressed CD or a CD-R. While earlier CD audio players can not read CD-RW discs, later CD audio players and stand-alone DVD players can.

(iii) **High Speed ReWritable CD:** Due to technical limitations, the original ReWritable CD could be written no faster than 4x speed. High Speed ReWritable CD has a different design that permits writing at speeds ranging from 4x to 12x.

Original CD-RW drives can only write to original ReWritable CD discs. High Speed CD-RW drives can typically write to both original ReWritable CD discs and High Speed ReWritable CD discs. Both types of CD-RW discs can be read in most CD drives. Even higher speed CD-RW discs, Ultra Speed (16x to 24x write speed) and Ultra Speed (32x write speed), are now available.

Intext Questions - 33.3

1. Write the full form of DVD.

   ....

2. Why is digital optical disc preferred to contact and optical disc (analogue)?

   ....

3. State the advantages of a DVD system.

   ....

4. Compare the specifications of compact audio disc with those of a DVD.

   ....

What You Have Learnt

- A compact disc is only 12 cm (4.7 inch) in diameter and it offers better sound quality with zero wow and flutter.
- Handling a compact disc presents no problem as they are immune to scratches, dirt and grease.
- Compact disc-Records do not wear out, have ultra hi-fi, and near perfect stereo sound.
- Compact disc encode the music digitally on light reflecting plastic.
- Audio compact disc eliminates the hisses, pops and hums that degrade the music on the analog records and cassette tapes.
- The digital video disc (DVD), or digital versatile disc, eliminates the dropouts, flickers and distortions that are common on analogue VHS tape recording.
- The digital video disc (DVD) will bring studio quality video images and theatre like sound into the home.
- Colours are deeper and brighter, edges sharper, details, crisper. The DVD picture is also noticeably better than optical laser disk.
- High quality sound is another feature of the promise of DVD besides superb picture quality.

Terminal Questions

1. What is the difference between a compact disc and the disc used in computer work?
2. Justify the need of a compact disc?
3. What are the advantages of compact disc over traditional audio recording/play back devices?
4. Give the construction, process of manufacture and working of a compact disc.
5. What are the differences between CD player and conventional long play record player or phonograph?
6. Why audio frequencies are not indicated in the electro-magnetic spectrum?
7. What are the drawbacks in the traditional LP sound recording system? How these are eliminated in the compact disc recording system?
8. Compare the specifications of compact disc and Long play record phonograph.
9. Describe the full form of the following VHS, VTR, DVD, CD,
10. What qualities do you prefer to select CD and DVD?
11. How compact disc is prepared?
12. Define bit? In how many bits the audio is encoded in disc?
13. What is the wavelength of laser used in a CD player?
14. From where does the LP record start and where does it end?
15. Where is the beginning and end of a compact disc?
16. What is the range of audiable frequencies?
17. In which format audio is recorded on LP record and in compact disc?
18. Write the names of the two types of video discs?
19. Why digital recording is preferred over its analogue counter part in Video disc?
20. In the latest new video disc player (DVD) which laser and of what wavelength is being used?
21. How much information a today's CD-ROM disc can store?

Answer to Intext Questions

33.1

1. (1) Radio/transistor (2) Tape reorder/player (3) Phonograph/LP Record Player
2. A compact disc offers better sound quality for upto and hour's uninterrupted playing time. It eliminates the hisses, pops and hums that degrade the music on the conventional records and cassettes tapes, wow and flutter are virtually non-existent in CD player.
3. One cannot erase and record audio on a compact disc of its own as is done in audio tapes. You can only play the prerecorded disc available. Secondly, it is very costly compared to audio cassettes. Many LPs contain recording (old classical) music that may never be available in CD format.

33.2

1. Analog means continuous variation of currents/voltage of sound waves in the electrical form. Digital means representation of information by combination of discrete binary units (0's and 1's)
2. Telephone, human voice, ears, speakers are all analog devices. Digital devices include - computers, digital audio tapes (DAT), digital cameras etc.
3. Information on a CD is stored in digital format.
4. There are no harmonic and intermodulation distortions. Free from wow and flutter. Free from hisses, pops and hums.
5. 200 rpm to 500 rpm. 500 rpm in the beginning to 200 rpm in the end.
6. 44,100 samples/(channel × second) × bytes/sample × 2 channel × 74 minutes × 60 seconds/minute

   = 783,216,000 bytes

   = 783 MB.

33.3

1. The full form of DVD is Digital Video Disc or Digital Versatile Disc.
2. a) More space to store extra data.

   b) Motion picture + sound both can be recorded simultaneously.

   c) Visuals, texts, and audio information can be stored on compact disc.

   d) Digital encoded information has low harmonic and intermodulation distortions.

3. Advantages include

i) Easy to handle and store than tape cartridges.

ii) It plays music as well as picture

iii) High-fidelity sound and perfect stereo system.

iv) Sufficient space to store extra information.

v) Colours are deeper and brighter

vi) Edges sharper.

vii) Details crisper.

viii) Studio quality video images and theatre like sound.

4.

	Compact Audio Disc		DVD
(i)	4.75 inch (12 cm) size	(i)	12 inch (30 cm)
(ii)	Stores audio	(ii)	Stores audio & Video
(iii)	Capacity to store information is less	(iii)	Capacity to store information and handle digital data is large
(iv)	Single side recording	(iv)	Both sides recording.

Senior Secondary Course
Physics
Student's Assignment – 9B

Maximum Marks: 50 | **Time :** $1\frac{1}{2}$ **Hours**

Instructions

- Answer All the questions on a seperate sheet of paper
- Give the following information on your answer sheet:
  - Name
  - Enrolment Number
  - Subject
  - Assignment Number
  - Address
- Get your assignment checked by the subject teacher at your study centre so that you get positive feedback about your performance.

Do not send your assignment to NIOS

1. Who was Leonardo da Vinci? (1)
2. Define angle of view? (1)
3. Give two properties of orthochromatic film. (1)
4. What makes a photo graphic film fast or slow? (1)
5. What determines the quality of magnetic tapes? (1)
6. Give an important feature of compact disc? (1)
7. What is the full form of DVD? (1)
8. Mention two methods of film development? (1)
9. Describe two characteristics of the tape? (2)
10. Describe any four common characteristics of all the video disc system? (2)
11. What are the main functions of a practical tape recorder? (2)
12. Describe the importance the depth of field and depth of focus? (2)
13. Describe the main features of different types of cameras? (4)
14. What is the disadvantage of video disc system? (4)
15. Describe the importance of the filters in photography? (4)
16. What are various lens defects? How these defects are minimised? (4)
17. Explain the structure and characteristics of the film? (4)

18. What is a transport system in photography? Explain the precautions which are necessary in a transport system? (4)

19. What do you mean by film processing? Describe various steps involved in the processing of exposed film? (5)

20. Justify the need of a compact disc? Describe the construction, process of manufacture and working of a compact disc? (5)

PHYSICS

MODEL QUESTION PAPER

SECTION – A (VERY SHORT ANSWER QUESTIONS)

Note: Answer all the questions.
Each question carries Two marks 13 x 2 = 26 Marks

1. Why does the car with a flattered tyre stops sooner than the one inflated tyres?
2. Modern air crafts fly at heights upwards of 10 km. Calculate the value of 'g' at that altitude. Given the radius of the earth is 6400 km and the value of 'g' on the surface of the earth is 9.8 ms^{-2}.
3. How does kerosene oil raise in the wick of a lantern ?
4. Why do two layers of cloth of equal thickness provide warmer covering than a single layer of cloth of double the thickness ?
5. Distinguish between transverse and longitudinal waves.
6. State Lenz's law.
7. When current drawn from a cell increases, the potential difference between the cell electrodes decreases, Why ?
8. Define total internal reflection and write the relation between critical angle and refractive index of the media ?
9. Calculate the focal length of a lens if the radii of curvature of its two surfaces are +20 cm and -25 cm. (u = 1.5) ?
10. An electron is accelerated through a P.D. of 182 volt. Calculate its associative wave length.
11. Differentiate between junction diode and zenor diode ?
12. Distinguish UPS from Invertor ?
13. What do you understand by terms film size and speed ?

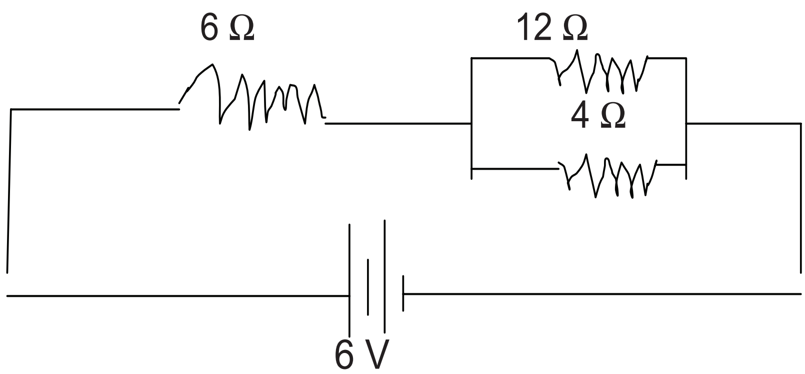
Note : Answer any Six Questions 6 x 5 = 30 Marks
Each question carries Five marks

14. State and prove work – energy theorem ? What happens to kinetic energy of a particle if the speed of the particle is doubled ?

15. State Bernoulli's theorem and write down the equation. Under what conditions Bernoulli's theorem is applicable to a fluid ?

16. Show that the motion of simple pendulum is simple harmonic and derive expression for its time period ?

17. For the circuit shown here, calculate the current flowing in 6 Ω resistor ?



18. Explain the defects in image formation of optical instruments ?
19. How does a p.n junction diode works as a half wave rectifier ?
20. What is an inverter ? Write how it works ?
21. Explain the various steps involved in audio recording and reproduction?

SECTION – C (LONG ANSWER QUESTIONS)

Note: Answer any Three Questions 3 x 8 = 24 Marks
Each question carries Eight marks

22. State Newton's second law of motion. Hence derive the equation of motion F = ma from it. A Constant force of magnitude 50N is applied to a body of mass 10 kg moving initially with a speed of 10 ms^{-1}. How long will it take the body to stop if the force acts in a direction opposite to its motion.

23.
   a. Define specific heats of gas
   b. Calculate C_p and C_v for argon. Given R = 8.3 J mol^{-1} k^{-1}.
   c. Derive the relationship between C_p and C_v.

24. Derive condition of balancing wheat stone bridge using Kirchhoff's Law.

25. Describe Rutherford's experiment of α – ray scattering and its findings.

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Intermediate (TOSS) Course

SENIOR SECONDARY COURSE

PHYSICS

LABORATORY MANUAL

Co-Ordinator

Neeraj Pratap Singh

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Foreword

Dear Learner,

I welcome you to the Physics Course of NIOS at the Senior Secondary level. It is through experiments only that you can understand the cause and effect relationship which is the essence of science. Therefore, experimentation is an important aspect of any curriculum of science subject. Experiments help in better understanding of the theoretical concepts involved in the subject.

The Academic Department of National Institute of Open Schooling has been very consciously active in updating the curriculum of various subjects. Hence the curriculum of Physics has also been revised. Consequently, the Laboratory Manual of Physics has been revised and updated to match with the theoretical contents of the revised course.

This Laboratory Manual will help you to determine the diameter of wire by screw gauge, to determine sped fie heat of solid. to find focal length of a convex mirror, to set up an astronomical telescope and do practically many other such experiments in the Laboratory by using the Lab equipments.

I hope, the Physics laboratory manual, in its revised form, will be more easy and useful to our learners and will make the learning joyful. We welcome suggestions for further improvement in the Manual.

I wish you a very bright future.

(D.S. Bist)
Chairman

A Note From the Director

Dear Learner,

The Academic Department at the National Institute of Open Schooling tries to bring you new programmes in accordance with your needs and requirements. After making a comprehensive study, we found that our curriculum is more functional, related to life situations and simple. However, the task before us was to make it more effective and useful for you. We invited leading educationists of the country and under their guidance, we have been able to revise and update the curriculum in the subject of Physics in the light of the National Curriculum Framework. 2005.

While updating the curriculum, we have also removed obsolete, outdated information and added new, relevant things and tried to make the learning material attractive and appealing for you.

I hope, you will find the new material interesting and exciting with lots of activities to do. Any suggestions for further improvement are welcome.

Let me wish you all a happy and successful future.

(Anita Priyadarshini)
Director (Academic)

A word with you

Dear Learner,

I hope you must be enjoying studying Physics from NIOS study material. Like any other branch of science, in Physics too you search for scientific truth by verifying the facts. Hence, learning by doing has an important role especially in Physics. The NIOS Physics curriculum at Senior Secondary tag is designed to encourage development of such skills in order to make learning effective. Therefore, lots of activities have been incorporated even in the study material of Physics course. In Book I of Physics you will find a list of experiments in the end. Some of these experiments are indeed very simple and you will be able to perform them even on your own. But for others, you may require some guidance. In this Physics laboratory manual we have tried to incorporate all the required guidelines to perform the experiments. This book is in addition to three core books which help you to over the theory portion of the curriculum.

There are three sections in this laboratory manual. In the beginning of each section. a few e of introduction have been given which discuss the importance and meaning of practical work in Physics, safety measures and precautions to be taken while in the laboratory, and the way you should maintain the Record Book. Each experiment in the manual has detailed instructions about how to perform the experiment and has observation tables in which you can record your data. Before starting an experiment, read the instructions given in the laboratory manual carefully and record the observations in the tables honestly.

I am sure, at the end of each experiment, you may like to assess our understanding about that experiment. For this purpose, a few questions have been given. For your convenience, the answers to these questions are also provided at the end of the manual in the appendix. Though the manual has the cope of recording your observations in the tables, you are required to maintain a record book as per the instructions given, as it carries weightage in the practical examination also. In case you have any doubts or problems while performing the experiments or otherwise, feel free to as our Physics Teacher or write to us.

We hope you will enjoy doing experiment. Wishing you an the success.

(Neeraj Pratap Singh)
COUR E CO-ORDINATOR

FORE WORD

The Open School Society was the first of its kind to be established in India. It was established in 1991 by the state Government. From 1991-2008 it offered classes up to upper primary level and in 2008-2009 class 10 (SSC), and seeing the need among the learners and the widespread acceptance and recognition, from 2010-11 Intermediate was also included in the distance learning mode of Open School. In the last seven year 5.3 lac learners have enrolled in various courses out of which 3.06 lac have successfully completed their courses. The aim of Telangana Open School Society is to provide high quality education. To this end we take great care in preparing curriculum. We also make available simplified study material and self-learning study material. This is provided to them free of cost. The study material is based on the blueprint which helps learners prepare well for the exams. The study material was prepared by eminent Professors, noted Lecturers and experienced Teachers. Every care has been taken to make our students well-versed in the subjects.

This Study Material is being reprinted in 2015-16 and is made availabale to the learners. Learners and teachers are invited to make use of this study material thus fulfilling the dream of makingTelangana a Golden Telangana (Bangaru Telangana). .

S. VENKATESWARA SHARMA
DIRECTOR, TOSS

CONTENTS

EXPERIMENT A

Like any other science subject, physics is a subject which can be learnt better by doing. In fact, the experiments form an integral part of the physics course at senior secondary stage.

A.1 THE OBJECTIVES OF PRACTICAL PHYSICS

We may start by asking "What are the objectives of laboratory work; why do it?" Laboratory work may serve to :

- ***demonstrate the principles covered in your study material*** in physics;
- provide ***familiarity with apparatus*** and enable them to handle the instruments and apparatus with purpose;
- learn ***how to do science experiments***;
- develop ***an attitude of perfection*** in practical tasks.

Seeing something demonstrated in practice is often a great help in understanding it. For example, intuitively one may feel that if a pendulum oscillates with 1^0 amplitude and then with 20^0 amplitude, the time period in the latter case will be much larger if not 20 times, at least 2 or 3 times. For Galileo it was a great fascination when he discovered, using his heart beats as a clock, that time period does not change with amplitude and this lead to development of pendulum clocks.

The second objective is perhaps more important. In any practical course you handle a number of instruments. In your later carrier you may be involved in scientific research, or in an industry. No practical course at senior secondary stage, or even at university stage, can include all instruments that different students may later use in such careers. A practical course trying to familiarise you with too many instruments will be boring and too heavy. Through a few instruments, a practical course prepares you to use instruments in general. There is a certain attitude of mind that a researcher or technician should adopt while handling any instrument, and this is what the course tries to instil, besides some basic skills. This is the attitude of perfection an attitude of trying to know in fine details how the instrument in hand works, how to handle it properly and then making genuine effort to handle it properly with all the relevant precautions. In the context of Indian industry, now poised to compete internationally, the importance of this objective can not be underestimated.

Padagogically the third objective is, perhaps, the most important. Practical work done honestly and properly trains you to be a good experimenter. It trains you in the scientific method - the method of systematic experimentation to seek new knowledge. It is not only important for the researcher, but also for every one else. We all face many situations in everyday life when we have to seek information through, what in everyday life is called 'trial and error' .

A.2 THE FORMAT OF THIS MANUAL

The experiments are presented in this manual in the form of self-instructional material in the following format:

1. ***Aim:*** It defines the scope of the experiment.
2. ***Objectives:*** The objectives of an experiment give you an idea about the skills or the knowledge that you are expected to develop after performing that experiment.
3. ***What you should know?:*** It highlights the concepts and background knowledge related to the experiment, which you must understand in order to do the experiment in a meaningful way.
4. ***Material required:*** It gives an exhaustive list of apparatus and other material required to perform the experiment.
5. *How to set up and perform the experiment?:* The steps are given in a sequential manner for setting up the apparatus and performing the, experiment. The precautions, wherever necessary, are incorporated while describing various steps.
6. ***What to observe?:*** A proper format of recording the observations, is suggested in each experiment.
7. ***Analysis of data:*** How to analyse your data, is suggested in each experiment; Quite frequently, it is combined with the previous heading, at serial number 6.
8. ***Result:*** It is the outcome of the observations and supports the aim set in the beginning.
9. ***Sources of error:*** Since all the experiments in physics involve measurements, your attention; is drawn in each experiment to major pitfalls specific to that experiment, if any, which may cause error in your measurements.
10. ***Check your understanding:*** At the end of each experiment, a few questions have been incorporated to consolidate what has been done and to check your own understanding about it. Before starting any experiment, you are advised to go through the detailed instructions given under it and plan your work accordingly. In case of any doubt, consult your tutor and get the clarification needed.

A.3 EXPERIMENTAL ERRORS

Look at the following table which summarises a few results of the determination of an accurate value for the speed of light - and incidentally it can tell a lot about experimental errors.

Date	*Investigator*	*Observed speed (c) km/s*	*Significant figures*
1875	Cornu	299990±200	4
1880	Michelson	29991O±50	5
1883	Newcomb	299860±30	5
1883	Michelson	299850±60	5
1926	Michelson	299796+4	6
The best value in 1982		299792.4590 ±0.0008	10

These results tell us that:

(a) no experiment gives the 100% correct value of a measurement.

(b) scientists aim to get closer and closer to the exact value.

(c) experimenters have to make a reasonable assessment of the accuracy of their experiment.

No meaning can be attached to the result of an experiment unless some estimate of the possible error is given. This means that all the figures given in the answer should be meaningful

The number of significant figures in a result are all those figures which are reliable and one last figures which is unreliable. Thus Cornu in 1875 could give only four significant figures. Probable error of his experiment being ±200, the 4th digit is unreliable. Again, Michelson in 1883 could only give five significant figures in his result, because he estimated his error as ± 60 km s^{-1}. In 1926, after spending over 50 years in measuring the speed of light, he could increase only one significant figure to his result - such a magnitude of effort is needed in making your measurements more accurate.

A.3.1 Different Kinds of Errors

We may consider errors of an experiment in the following two categories:

1. **Systematic errors :** These are errors of an experiment which will produce a result *which is always wrong in the same direction.* It can be an instrumental error, e.g. an old wooden scale has expanded by moisture and gives result of measuring length which is always too small. It could be due to an error of adjustment or setting of an instrument, or due to a simplified design of experiment meant for conveying a concept quickly in which this error has been neglected as insignificant Even a particular observer may have a tendency - a certain habit by which he tends to measure always too high a reading or vice-versa .

2. **Random errors:** These are errors in an experiment due to which the result of measurement pan be either more, or less, than the true value, e.g. parallax error in reading a scale - a limitation of the instrument as well as of the observer. In observing temperature by a thermometer, thickness of the thermometer may cause the error of -parallax and error may be there in measurement if one observer keeps his line of sight within ± 50° of the direction accurately perpendicular to scale (Fig. 5) and another within ± 20° of it. Due to random errors in repeat measurements the results are found to vary over a small range. Referring to figure l(a) if there is no systematic error, the results are spread around the true result (of course you never know it exactly). If there exists a systematic error, results of repeat measurements are spread away from the true result (Fig. 1 b).

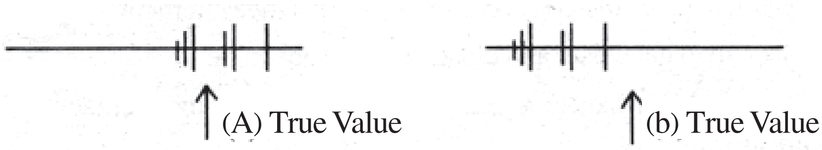


Fig 1 : Set of results (a) without systematic error and (b) with a systematic error

Here, it is convenient to make a distinction between the words accurate and precise in the context of errors. A result is said to be accurate if it is relatively free from systematic errors, and precise if the random errors are small. In practice, however, a more accurate experiment is generally more precise too.

You should make the habit of making at least three repeat observations of the same measurement and then finding their mean. In doing so positive and negative random errors tend to cancel each other. This will also enable you often to detect a major error in an observation and thus reject it. For example, if in an observation you happen to measure time of 9 oscillations of a pendulum when you intended to count 10, then it is significantly smaller than others, and you may reject it.

A.3.2 Fractional Error and Percentage Error

It is frequently useful to express an estimated error as a fraction of the mean value of an observed quantity, thereby to obtain some idea of the relative magnitude of the error. Thus, if the mean value is x and estimated error in it is Δx, then

$$\text{Fractional error} = \frac{\Delta x}{x}$$

$$\text{and percentage error} = \frac{\Delta x}{x} \times 100$$

Error in a particular measurement is an estimate only and is needed to be made to the first significant figure only.

The maximum error in any reading taken over a scale is usually taken to be *half of the distance between adjacent scale markings.* The *least count* of an instrument is the smallest value that it can measure. Thus the least count of a scale is the distance between adjacent scale markings. Maximum error in a reading is half of the least count.

Example 1: A scale is graduated in millimetres. Length of a pendulum is measured as 90.0 cm using it. Find the percentage error in this measurement

Solution: In measuring the length of a body by this scale, there is a possible error of 0.5 mm in judging the position of each end of the body, against the scale. The error in the length being measured (i.e. difference of the two readings) can be any where between 0 and 1 mm. The maximum error is thus 1 mm. Therefore, the percentage error is

$$\frac{1\text{mm}}{90.0}\times 100, \quad \text{or } 0.11\%, \ \text{or } 0.1\%$$

Similarly, in a length of 9.0 cm measured on the same scale, the percentage error would be ten times as big, i.e. 1 %. In a length of 4 cm or 5 cm measured on it, percentage error would be 20 times as big, i.e. 2%, and so on.

Example 2: A thermometer whose scale divisions are 0.20 C apart is used to measure a rise of temperature from 20.2^0C to 26.6^0C. Find the percentage error in this measurement

Solution: Each reading has an estimated error of 0.1^0C. Then estimated error in the rise of temperature, i.e. difference of these readings (6.4 ^{0}C) is 0.2^0C. Percentage error in the rise of temperature is

$$\therefore \ \frac{0.2^0\text{C}}{6.4^0\text{C}}\times 100 \ \text{ or } \ 3.1\% \ \text{ or } \ 3\%.$$

As a rule, when sum or difference of two observations is taken, the estimated absolute error in the result is the *sum of estimated absolute errors* of individual measurements.

A. 3.3 Percentage Error of a Product and a Quotient

Experiments in physics usually involve calculation of a result from more than one independent measurements. Calculation of the result is based on equations such as those in the following examples:

(a) Volume v of a rectangular body of length *I,* breadth *b* and height *h* is

$$V = l \times b \times h$$

Percentage error in v = % error in l + % error in b + % error in h.

(b) Even when a quotient is involved as

$$\rho = \frac{M}{V}$$

where ρ is the density of the material of a body whose mass is *m* and volume is *v,*

Percentage error in ρ = % error in m + % error in *v*.

(c) When a quantity appears in a formula to a higher power, as in volume v of a sphere of radius r,

$$V = \frac{4}{3}\pi r^3$$

then percentage error in $v = 3 \times$ % error in r.

(d) Resistivity p of the material of a wire of resistance *R,* length *1* "and radius *r;* is then percentage error in *r;* is

$$\rho = \frac{RA}{l} = \frac{R\times\pi r^2}{l}$$

= % error in *R* + 2(% error in *r)* + % error in *l.*

(e) In general if a quantity Z is expressed in terms of quantities A, B and C by the formula

$$z = k\frac{A^n B^n}{C^p}$$

where m, n and p may be whole numbers or fractions, and *k* is an exact constant (like π, 4/3, and so on),

then percentage error in Z

= *m* (% error in A) + *n* (% error in B) + *p* (% error in C)

Example 3 : We have following measurements for a wire

Parameter	Measurement	Estimated error	Percentage error
Resistance (R)	1250 ohm	$\pm$1 ohm	0.08%
Length (1)	2,50 m	$\pm$0.01 m	0.4%
Diameter (d)	0.34 mm	+0.0l mm	3%

Find the resistivity of the material of the wire and estimated error in the result.

Solution:

Radius of the wire = $\frac{d}{2} = 0.17 mm = \frac{0.17}{1000} m$

$$\rho = \frac{RA}{l} = \frac{R\times\pi r^2}{l} = \frac{1250\Omega\times\pi\left(\frac{0.17}{10000}\right)^2 m^2}{2.50 m}$$

= 4.54 þ 10^{-5} ohm metre

Percentage error in ρ = (0.08 + 0.4 + 2 × 3)%

= 6.48% – 6%

Estimated error in ρ = $4.54\times\frac{6.48}{100}\times10^{-5} = 0.29\times10^{-5}$ ohm metre.

Hence we write the result, rounding it off to one digit after the decimal, as under:

ρ = (4.5 $\pm$ 0.3) 10^{-5} ohm metre.

Note the rule of rounding off a result used above. If the figure after the last figure to be retained is 4 or less, it is neglected. If it is 5 or more, we increase one in the figure to be retained.

It may be noted in the above example that the percentage error of result 6.48 % has the biggest contribution from error in the measurement of diameter of the wire, 6%. If we want to make it a more precise experiment, it is the measurement of diameter that needs to be made more precise. Use of a finer micrometer screw gauge with smaller least count, many repeat measurements of d at various points along the length of the wire and taking their mean are, thus, the most important steps. Improving methods of measuring R and *l* in this experiment are not so useful.

A.4 GRAPHS IN PRACTICAL PHYSICS

Majority of experiments in physics require drawing of a graph showing how a physical quantity changes with changes in another. The former is called the *dependent variable* and the latter the *independent variable.* For example, you may have measured voltages that develop across a conductor when various currents are passed through it. Here the current *I,* being the independent variable, is plotted along horizontal axis (i.e. *x*-axis, or abscissa). The voltage *V* which develops across the conductor, being the dependent variable, is plotted along vertical axis (or *y*-axis, or the ordinate). Each pair of values is represented by a point on the graph. Points are marked as cross (x or +) or as a dot surrounded by a circle (.). Then a smooth line is passed closest to the points. Never imply join the points by a zig-zag line, which will indicate as if there was no error in any of the observations.

If the graph is a straight line passing through the origin, it indicates that the variable are proportional to each other. Relation between *V* and *I* for an eureka wire whose temperature does not significantly change during the experiment is such a relation (Fig. 2). Slope of the graph:

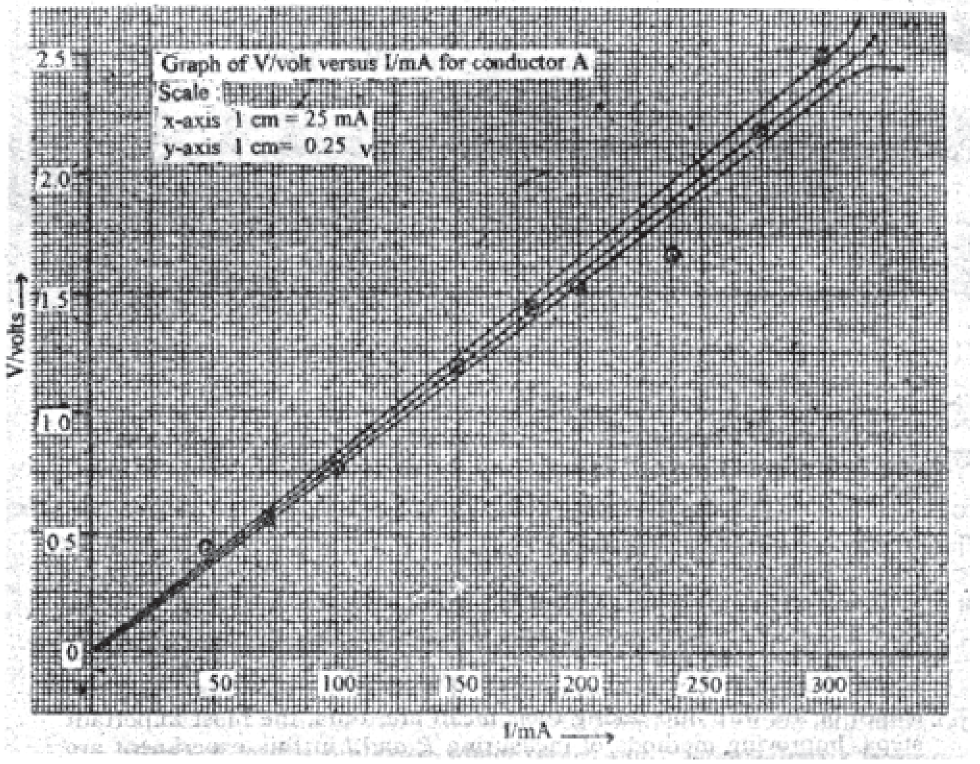


Fig. 2 Graph between *V* and *I*

$$\frac{\Delta V}{\Delta I} = \frac{\text{change in voltage}}{\text{change in current}} = R$$

gives the resistance of the wire. Value of slope thus found from the graph averages all the readings. Graph is also a good means of detecting the readings which need to be rejected, which may be widely off the smooth graph. Graph also provides a good means of estimating the error in the slope thus found. Draw two lines close to each other so that most of the points lie between them. Mean of their slopes is the best estimate of slope and half the difference between their slops is an estimate of the error in this slope.

Graph is often the best method to find out the kind of relation that exists between two variables. For example, a study of relation between *V* and *I* for a torch bulb may indicate that *V* is not proportional to *I*. The smooth graph is curved in which V increases much faster at higher values of current (Fig. 3).

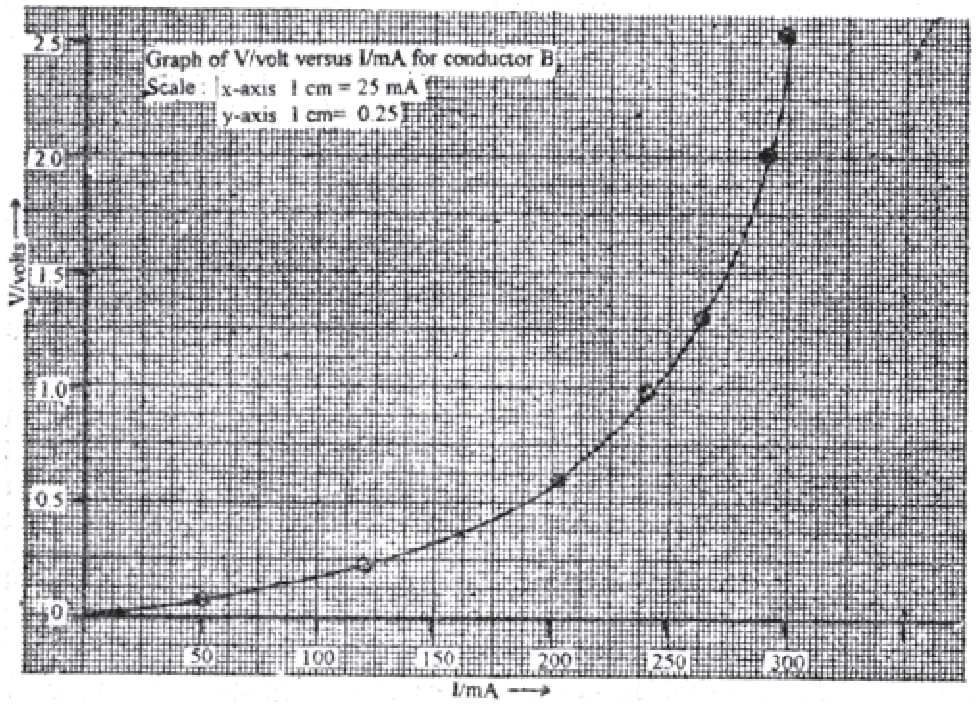


Fig. 3 Curved Graph between *V* and *I*

For plotting a graph of observations already taken, following points should be noted:

(i) Graphs are plots of numbers, rather than physical quantities. In physics, a symbol represents a physical quantity, with an appropriate unit. For example, the statement "the current is 1.5 ampere" can be expressed using symbols as *"I* = 1.5A". It would be meaningless to say "the current is *IA",* since *I* includes the unit ampere. So *I*/ A,, or *I*/mA*,* or *V*/volt, or *V*/m V is a pure number. These numbers are plotted on the graph.

(ii) When choosing the scales for the two axes, the following points must be considered:

(a) Choose scales so that the points are distributed as widely as possible; this means choosing a suitable scale and deciding on the numbers at the beginning of the scales, i.e. whether to choose the true origin (*x* -b, *y* = 0) or a false origin, e.g. (*x* = 5, *y* = 15).

(b) Choose simple scales to make calculations straight forward, e.g. don't choose 4 small divisions on X-axis to represent 9 mA. A better choice close to it is let 5 small divisions represent 10 mA.

(c) If the slope of the graph is to be measured, try to obtain an angle of 30^0 to 60^0 between the graph and the axes.

(iii) For investigating the relation between two physical quantities, readings must be taken for atleast 7 or 6 pairs of values of the two quantities. For taking these readings, the values of the independent variable should be spread over the entire range that the instruments given to you can provide.

Example 4: Following are readings of voltages across two conductors for various values of currents passing through them. State in which case the voltage is proportional to current, and find the resistance of this conductor.

Conductor A			Conductor B		
S. No.	I/(mA)	V (volt)	S. No.	I/(mA)	V/(volt)
1	0	0.00	1	0	0.00
2	50	0.45	2	50	0.]0
3	100	0.75	3	80	0.15
4	130	1.00	4	120	0.20
5	150	1.20	5	160	0.35
6	180	1.45	6	200	0.60
7	200	1.55	7	240	1.00
8	240	1.70	8	260	1.30
9	70	0.55	9	280	1.70
10	270	2.15	10	290	2.00
11	300	2.45	11	300	2.50

Solution: Let the mm graph paper available for each conductor be 12 cm x 18 cm in size. We may choose 20 mm to represent 50 mA on the *I-axis* and 20 mm to represent 0.50 volt on *V-axis* for both graphs, as the range for *V* as well as for *I* is same for both. Looking at the observations we find that V-scale needs to be of length 10 cm and *I-scale* of 12 cm. Thus we take *V-axis* along 12 cm side of graph and *I-axis* along longer side.

After plotting the points, it is clear that in case of conductor A (Fig. 2), $V \propto I$. In case of conductor B (Fig. 3), it seems that $V \propto I$ only upto about $I = 120$ mA and then V increases faster and faster as I increases.

In trying to find the slope of the best line through points plotted for conductor A, we find that most of the points lie between lines OA and OC. The reading (240 mA, 1.70V) is rejected, being too far from the best graph.

$$\text{Slope of straight line OA} = \frac{2.45\text{Volt}}{300\text{mA}} = 8.17\,\text{ohm}$$

$$\text{Slope of straight line OC} = \frac{2.30\text{Volt}}{300\text{mA}} = 7.67\text{ohm}$$

$\therefore$ R, the resistance of conductor, A = $\frac{8.17+7.67}{2} = 7.92\Omega$. Estimated error in the value of

$R = \frac{8.17-7.67}{2} = 0.25$ ohm. Rounding off to one digit after decimal, which is the first unreliable figure, we can write the result as R $= 7.9 \pm 0.3$ ohm

A 4.1 Converting a Curved Graph to a Straight Line

Not all graphs are straight lines. For example Boyle's law states that, "pressure of a fixed mass of a gas at constant temperature is inversely proportional to its volume". Thus, if in an experiment we measure pressures *(P)* corresponding to various volumes *(V)* of a gas and then plot *P* against *V,* a curve will be obtained by which it will be difficult to assert that the curve obtained verifies the Boyle's law for that gas.

A curved graph sometimes gives valuable information, but in general much more information is revealed from a straight line graph. So *whenever possible* we plot quantities which will yield a straight line graph. In the above example we may say that "pressure is *directly proportional to reciprocal of its volume".* Thus we may plot values of *P* against corresponding values of $1/V$ and see whether experimental points so obtained yield a straight line graph passing through the origin. If such a graph is obtained, the Boyle's law can be said to have been verified for that gas. Such conversion to straight line graph may, perhaps, not be possible for *V* versus *I* plot for a torch bulb, fig. 3.

Example 5: Following data was obtained for pressure and volume of an enclosed sample of air at constant temperature. Check graphically if this data verifies the hypothesis that "pressure is proportional to reciprocal of volume for air".

V/cm^3	50	40	35	30	25	22
P/mmHg	460	570	660	760	925	1050

Solution: First we calculate values of V^{-1} and rewrite the data as under.

V^{-1}/cm^3	0.02	0.0250	0.02860	0.0333	0.0400	0.0454
P/mmHg	460	570	660	760	925	1050

The range of values is x = 0.0200 to 0.0454 for V^{-1}/cm^{-3} and y = 460 to 1050 for P/mmHg. Thus to make a well spread out graph one may like to take a false origin at (x = .02 $y = 450$). However, we have to check whether or not the straight graph is obtained, and if so whether it passes through the true origin ($x = 0, y = 0$). Hence the ranges have to be treated as $x = 0$ to .0454 and $y = 0$ to 1050. Let the graph paper have dimensions 18 cm × 24 cm. Let 5 cm along x-axis represent 0.01 and 3 cm along y-axis represent 200. Thus x-axis needs a length of about 23 cm and y-axis about 16 cm, which are respectively taken along length and breadth of graph paper.

After-plotting the points (Fig. 4) we find that they indeed lie on a straight line, which passes through the origin ($x = 0, y = 0$). Hence the given hypothesis is verified for air.

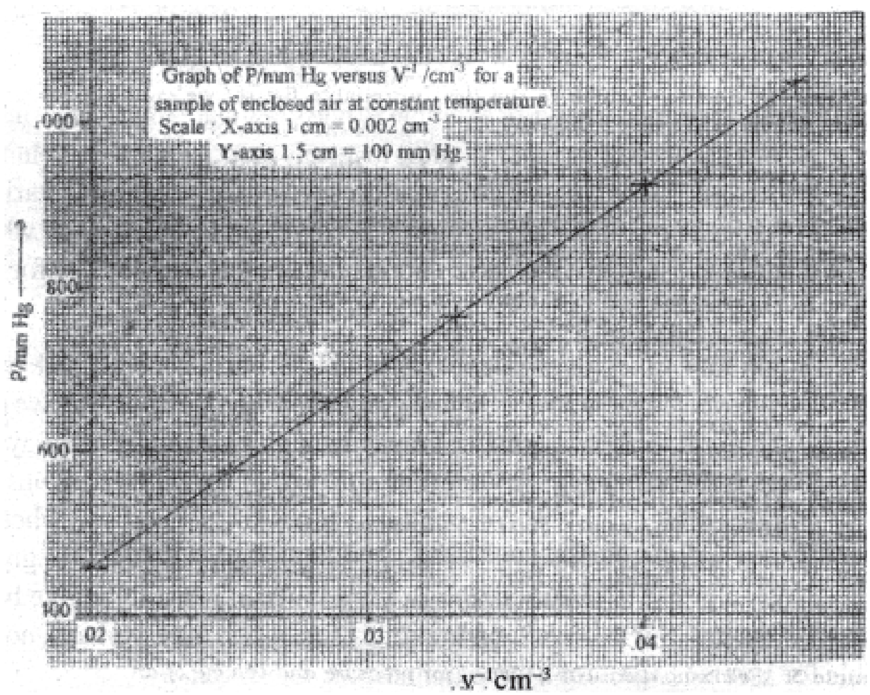


Fig. 4

A.4.2 Which is the Independent. Variable?

In the above discussions we have considered current I as the independent variable for study of relation between V and I. In actual performance of the experiment, choice of independent variable is often arbitrary. Thus instead of measuring voltages developed when current of your chosen values passes in the conductor, you may measure currents passing in the conductor when you apply your chosen voltages across it. This consideration applies to study of relation between p and v of a gas at constant temperature also and to almost all similar experiments .

For plotting a graph also, the choice of variable to be treated as in independent variable is often arbitrary. More important is the choice of scales for the two variables so that maximum portion of the area 'Of the graph paper is utilised. You can always make either the length or the breadth as the horizontal axis.

A.5 USE OF LOGARITHMS FOR CALCULATIONS IN PHYSICS

In order to obtain the final result from your observational, data, you have often to do calculations involving multiplications and divisions.

Such calculations can be done quickly and with less chance of a calculation error by using the logarithms.

To find the logarithm of a number you use a "***4 - figure table of logarithms***". The logarithm of a number consists of an integral part called ***characteristic,*** and a decimal part called the mantissa. Whereas the characteristic can be a positive or negative integer or zero, the mantissa is always positive.

If you look at a table of logarithms, it will be seen that rows of four figures are placed against each of the numbers from 10 to 99. These four figures form in each case the mantissa of a logarithm; the characteristic has to be supplied by you.

The characteristic of logarithm of any number between 1 and 10 is zero. For any number ≥ 10, it is a positive integer which is less by one than the number of figures to the left of the decimal point. For any number < 1, it is a negative integer whose magnitude is one more than the number of zeros which follow the decimal point Thus:

Characteristic of 7,47,300 is 5

Characteristic of 7,473 is 3

Characteristic of 74.73 is 1

Characteristic of 7.4 73 is 0

Characteristic of 0.7473 is -1 or $\overline{1}$ (read 'one bar')

Characteristic of 0.07473 is -2 or $\overline{2}$.

Characteristic of 0.007473 is -3 or $\overline{3}$

Example 6: Find log 7.4

Solution: In the column opposite the number 74 is mantissa 8692; the characteristic is 0.

Hence log 7.4 = 0.8692

Example 7: Find log 74.7

Solution: We find the first two figures 74 at the extreme left. Then move along the horizontal line to the number in the vertical column headed by the third figure 7 to obtain the mantissa 8733. The characteristic is 1, Hence log 74.7 = 1.8733.

Example 8. Find log 0.07473.

Solution: This number consists of four figures. To obtain the logarithm of a number consisting of four figures, it is necessary to use the mean difference columns at the extreme right of the page.

Mantissa of log 747 = .8733

Mean difference for 4th figure 3 = 2

Mantissa of log 7473 = .8735

$\therefore$ log 0.07473 = $\bar{2}.8735$

A.5.1 Antilogarithms

The number corresponding to a given logarithm is found by using the table of antilogarithms. First we use only the mantissa to find the figures of the required number. Then we locate the decimal point with the help of the characteristic.

Example 9 : Find the number whose log is 2.6057.

(For first 3 digits of mantissa) Antilog .605 = 4027

(For 4th digit of mantissa) Mean diff. for 7 = 7

= 4034

Hence, the number whose log is 2.6057 is 403.4

Similarly, the number whose log is 0.6057 is 4.034

the number whose log is $\bar{1}.6057$ is 0.04034

the number whose log is $\bar{2}.6057$ is 0.4034

1.5.2 Multiplication

To multiply two or more numbers together, ***add the logarithms of the numbers; the sum is the logarithm of the product***. While adding the logarithms care has to be taken that mantissa is always positive. Only the characteristic, which is the integer to the left of decimal point, is positive or negative. Infact, this convention makes the addition of logarithms easier than common positive and negative numbers, because four figures of each mantissa are added as positive numbers. Then in the characteristic only we have some positive and some negative integers to be added.

Example 10: Multiply $47.45 \times 0.006834 \times 1063$

Solution:

log 47.45 = 1.6763

log 0.006834 = $\bar{3}.834\ 7$

log 1063 = 3.0265

log (product) = 2.5375 $\therefore$ Product = 434.8

A.5.3 Division

Whereas for multiplication we add the logarithms, for division we *subtract the logarithm of the divisor from logarithm of the dividend. Then the difference obtained is the logarithm of the quotient.*

Example 11: Evaluate 0.4891 ÷ 256.8

Solution:

$$\log 0.4891 = \bar{1}.6894$$
$$\log 256.8 = 2.4096$$
- - - - - - - - - - - - - - - - - -
$$\log(\text{quotient}) = \bar{3}.2798 \qquad \therefore \text{ Quotient} = 0.001905$$

Notice that characteristic 2 subtracted from $\bar{1}$ gives $\bar{3}$, like the usual operation with positive and negative integers.

Example 12: Evaluate $\dfrac{51.32\times 0.4971\times 1.021}{69.84\times 42.98\times 3.982}$

Solution:

log 51.32	= 1.7103	log 69.84	= 1.8441
log 0.04971	= $\bar{2}$.6965	log 42.98	= 1.6333
log 1.021	= 0.0090	log 3.142	= 0.4972
log (numerator)	= 0.4158	log (denominator)	= 3.9746
	3.9746		
log(result)	= $\bar{4}$.4412	\ Result	= 0.0006446.

Notice that while subtracting log (denominator) from log (numerator), mantissas are treated as positive numbers. To subtract 9 from 3, we borrow 1 from characteristic 0 to make it 1; then 13-9 gives 4 in the first figure after decimal point.

A.6 PRECAUTIONS FOR READING SOME COMMON INSTRUMENTS

When you make a measurement with any instrument, it usually has a scale on which you read the position of end of an object, or a level, or a pointer, etc. For example:

(a) You have thermometer on the scale of which you observe the position of upper end of mercury thread inside.

(b) You have a metre scale on which you read the positions of the tips of a knitting needle to find its length. .

(c) You have a graduated cylinder in the scale of which you read the position of the surface of a liquid filled inside it to find its volume.

(d) You have an ammeter, or a voltmeter, or a galvanometer, or a multimeter, or a stop watch on the circular scale of which you read the position of a pointer.

The most general precaution in all the cases is that you keep your line of sight perpendicular to the scale of the instrument in order to eliminate *'parallax error'*. It requires a little practice to observe the reading with one eye, keeping the other eye closed. Then you have to keep the open eye in such a position that line joining the eye and the point whose reading is to be taken (i.e. your line of sight) is perpendicular to scale.

Referring to figure (5) for observing reading in a thermometer, with eye in position (a), you get correct reading 65°C. In position (b) you may get the reading as 64°C and in position (c) as 66°C. This so happens because whereas the scale is marked on the surface of the thermometer, the mercury thread is inside. The two can never be coincident.

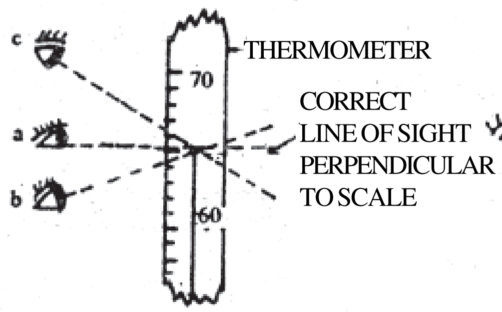


Fig.5: Correct tine of sight

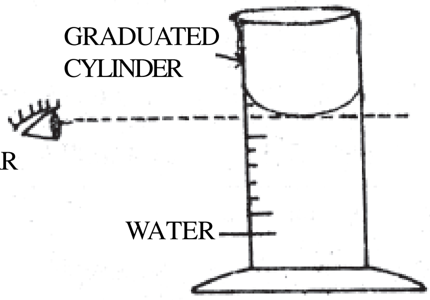


Fig.6: Surface of liquid in a measuring jar

Referring to fig 6, the surface of a liquid in a measuring jar or in a burette is never plane. It is concave upwards for water and most other liquids. You want to read the position of centre of the surface on the scale. Being lower than boundry, it is called lower miniscus. Your line of sight has to be horizontal and the length of the cylinder has to be vertical. If the cylinder is inclined to left in the diagram, you may get a too high reading. If it is inclined to right, you may get a too low reading. In similar manner for mercury filled in a glass burette or water filled in certain plastic vessels, where the surface is convex (fig. 7), you want to read the position of centre of the surface, called the upper miniscus.

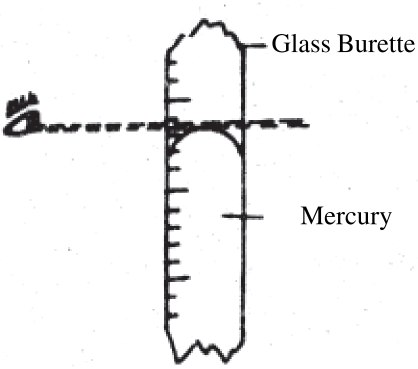


Fig.7: Surface of mercury in a vessel

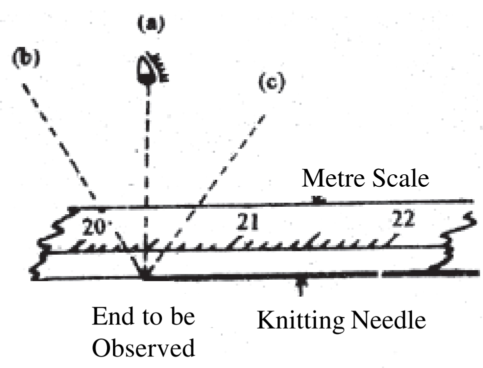


Fig.8: Taking reading on metre scats

While observing the position of end of the knitting needle on the metre scale, again, you have to keep the observing eye in a line perpendicular to scale, i.e. position (a) in fig 8, which gives the correct reading 20.5 cm. Positions of eye at (b) or at (c) will give you a wrong reading. The thinner is the edge of the scale, the smaller is this parallax error in positions (b) or (c) of the eye. Hence in some 30 cm scales, the edge is made quite thin.

A better method to use the metre scale with a thick edge is to keep it standing on the edge (Fig. 9). In this manner the end to be observed is quite close to the markings, thus making the parallax error small in case your line of sight is not perpendicular to scale. Moreover, the markings themselves function to some extent as direction guides, by which you can keep your eye at the correct position.

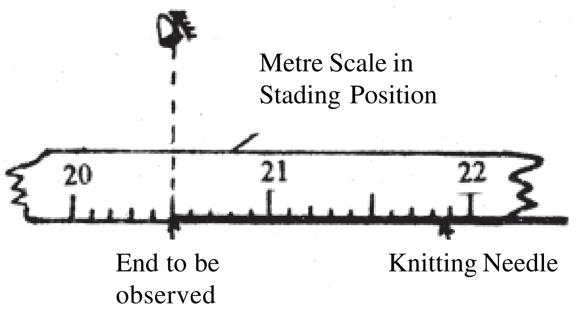


Fig.9: Metre scale in standing position

In case of a stop watch or a galvanometer, there is a pointer moving a little above the scale. In order to keep your line of sight perpendicular to the scale, sometimes you can see the image of your observing eye in the front glass of the instrument functioning as a partially reflecting mirror. In good electrical instruments, a mirror strip is built-in alongside the scale. Thus you see the image of the pointer in this, mirror-strip. You keep your observing eye in such a position that the pointer and its image coincide.

A.7 Physics Laboratory

In the physics laboratory, carelessness can lead to accidents causing injury to you or to your neighbour. Some instruments are costly. If such an instrument is damaged in an accident, it can paralyse the work of the whole class. Proper handling of apparatus and other materials can prevent majority of accidents. Remember the following points and act on them, while working in the physics laboratory.

(i) Put off the gas to extinguish the flame of a burner. Do not use any solid or liquid for this purpose (like putting a cap or pouring water as for extinguishing burning coal).

(ii) Do not throw any broken glass ware, etc. in the sink. Such things should be thrown into the waste basket.

(iii) Do not talk to other students in the laboratory while performing the experiment. In case you have any difficulty, consult your tutor. Of course, if you are a team of two or three students working on same experiment on the same apparatus, you can talk about the experiment among yourselves. Each member of the team should take turns to take observations.

(iv) Never test whether a wire is carrying current by touching it, Use a tester-screwdriver or/ a voltmeter of Appropriate range.

(v) Whenever a sharp instrument is used, be careful not to cut or puncher your skin, e.g. while using a pair of blades to make a narrow slit.

(vi) While using a delicate instrument, e.g. a sensitive galvanometer, be careful not to pass a high current in it, which may burn it out. While using it to find a null point, use a low resistance shunt or a high series resistance initially. When you approach the null point, then remove it to make the instrument sensitive and make fine adjustment of the null point.

(vii) Take care not to wet any instrument, unless it is part of the experiment itself.

Cuts and Burns

- For wound caused by a broken glass or any sharp edge, remove the glass piece from the wound; control the bleeding by pressing a clean cloth or handkerchief or by a steril surgical dressing. Apply a little dettol, or spirit, or burnol, or savlon and cover it with bandage.
- For wounds due to heat of a flame or due to touching a hot object, put the burnt portion under cold water for 15 min. to 30 min. Then apply burnol.

A.8 Maintenance of Record Book

Now, you are surely interested to know how to maintain the record book for experiments done by you. While performing an experiment, most probably you have acted on the steps as given in this manual. In some situations you may have followed a procedure a little different from that described in this manual, on the advice of your tutor. For writing the experiment in the record book, you may use the format having following sections:

- Aim of the experiment.
- **Apparatus and material** used for the experiment.
- **Procedure followed,** if it is slightly different from the one described in this manual.
- **Observations** which you take during the experiment.
- **Calculations** that you do after taking observations.
- **Result,** the final conclusion that you get on the basis of observations and calculations ..
- **Precautions** taken by you during performing the experiment.

SCHEME OF PRACTICAL EXAMINATION

Duration: 3 hours

There will be a practical examination of 20 marks apart from the theory examination.

The distribution of 20 marks is as follows:

(i)	Viva	3 Marks
(ii)	Record Book	3 Marks
(iii)	Two Experiments (7 marks each) (they should not be from the same group)	14 Marks

EXPERIMENT 1

Determine the internal diameter and depth of a cylinderical container (like tin can, calorimeter) using a vernier callipers and find its capacity. Verify the result using a graduated cylinder.

1.1 Objectives

After performing this experiment, you should be able to:

- determine the least count and zero error of a vernier callipers,
- determine the least count of a graduated cylinder,
- determine the internal diameter and depth of a cylinderical vessel by a vernier callipers,
- determine the capacity of a cylinder by a graduated cylinder.

1.2 What SHOULD YOU KNOW

The volume of a cylinder is given by the relation

$$V = \pi r^2 h = \pi\left(\frac{d}{2}\right)^2 h = \frac{1}{4}\pi d^2 h$$

where d = internal diameter of cylinder

r = internal radius of the cylinder

h = depth of cylinder

Material Required

A vernier callipers, a calorimeter, a graduated cylinder, a glass slab.

1.3 How to set up the Experiment

You would have studied about vernier callipers. It consists of a pair of calliperc having a vernier and main scale arrangement. The instrument has two jaws A and B. The vernier scale can easily slide along the edge of the main scale. The graduations of the vernier scale are so designed that a certain number of divisions of vernier scale, say 10, are coincident to 9 number of division of main scale. The difference between one smallest division of the main scale and one division of the vernier scale is known as *vernier constant* and is also the *least count* of the vernier device.

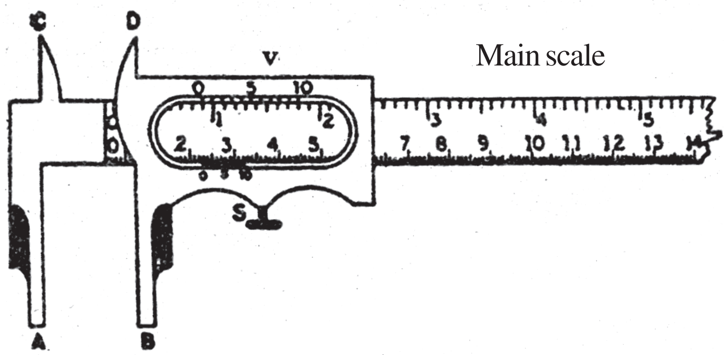


Fig. 1.1: Vernier Callipers

1.4 How to perform the Experiment

(a) Finding least count or vernier constant

(i) Observe the divisions on the vernier scale are smaller than those on the main scale. The *difference between one main scale division and one vernier division is called vernier constant or least count* of the vernier callipers.

(ii) Observe the number of vernier divisions *(n)* which match against one less number of divisions of main scale (n - 1).

(iii) Calculate the least count as under

1 division of vernier scale = $\frac{n-1}{n}$ division of main scale

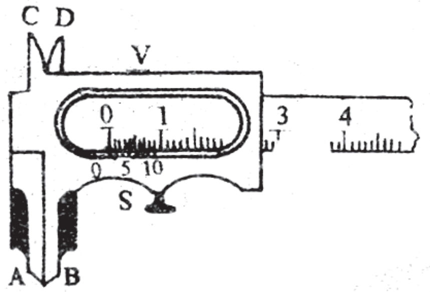
Least count = 1 main scale division - 1 vernier scale division

= 1 main scale division $-\frac{n-1}{n}$ main scale division

= 1/n main scale division.

(b) To find the zero error of the vernier scale

(iv) *With the jaws of the callipers closed, if the zero marks of the main scale does not coincide with the zero mark of the vernier scale, the instrument has a zero error.* If the zero mark of the vernier scale is on the left of the main scale's zero mark then the zero error is negative as shown in Fig. 1.2(a) and when it is on the right of the main scale's zero mark the zero error is positive [Fig. 1.2(b)].



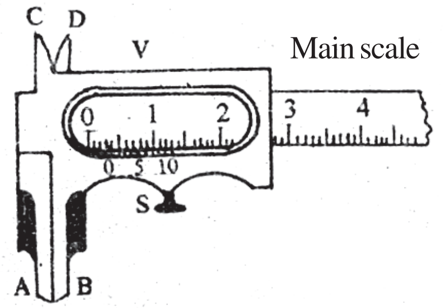


Fig. 1.2 (a): Negative zero error **Fig. 1.2 (b)**: Positive zero error

(v) If there is zero error, observe which vernier scale (v.s.) division best coincides with any main scale (ms) division with jaws of the callipers closed. The value of the zero error is the product of the best coinciding vernier division and least count of the vernier callipers when zero error is positive. On the other hand when zero error is negative, the coinciding vernier division is to be seen from the end of the vernier scale, backwards.

(vi) While observing which vernier scale division coincides with a main scale division, it may happen that none coincides. For example, 5 h may be a little ahead and 6th may be a little before a main scale division. *Observe, which one is closest to a main scale division.*

(c) To find the zero correction of the vernier scale

(vii) It is the negative of the zero error.

Zero correction = – (zero error)

Zero correction is added algebraically in the observed diameter to get the corrected diameter.

(d) Measuring internal diameter

(viii) To measure the internal diameter of the calorimeter, place the vernier callipers with the upper jaws inside the calorimeter as shown in the diagram (Fig. *1.1). The upper jaws of the vernier callipers should firmly touch the ends of a diameter of the calorimeter, but without deforming the calorimeter.*

(ix) Note the main scale reading immediately before the zero mark of the vernier and also note the division of the vernier which coincides with any of the main scale divisions.

(x) *Since the calorimeter may not be of precisely circular shape, take one more observation along a diameter perpendicular to previous one.*

(xi) Repeat the pair of observations at least three times and record them.

(e) Measuring depth

Next, let the end of the vernier callipers stand on its end on a glass slab, push down its depth gauge (the central moving strip), so that it also firmly touches the glass slab. Then note the zero error of its depth gauge.

(xiii) Next, set the vernier callipers with its end resting on the upper edge of the calorimeter and its depth gauge touching the bottom inside. Thus note the 'observed depth of the calorimeter. Calculated corrected depth by applying zero correction.

(f) Verification

(xiv) Next, in order to verify the capacity of calorimeter measured by vernier callipers, fill it completely with water. Pour this water in to an empty graduated cylinder and observe the volume of this water. Both values should be in agreement within experimental error.

1.5 OBSERVATIONS

One small division of main scale = ...mm

.... VS divisions = ... MS divisions

1 VS division = ... MS divisions

= .... mm

Least count = 1MS div − 1 VS div

= .... mm .... mm

= .... mm

= .... cm

Zero error for diameter measurement = (1) .... (2) .... (3) ....

Mean zero error = ... cm

Mean zero correction = − (Mean zero error) = ... mm

Table 1.1: For internal diameter of calorimeter

S.No.	M.S. reading y	Coincident V.S. div. n	V.S. reading $x = n \times$ V.C.	Observed value = $y + x$
1 (a)				
(b)				
2 (a)				
(b)				
3 (a)				
(b)				

Mean observed diameter = ...

d = Mean corrected diameter = ...

Zero error for depth measurement

Zero Error = (1) .... (2) .... (3) ....

Mean zero error = ...cm.

Mean zero correction = – (Mean zero error) = ...cm.

Table 1.2: For depth of calorimeter (h)

S.No.	M.S. reading y	Coincident V.S. div. n	V.S. reading $x = n \times$ V.C.	Observed value = $y + x$
1.				
2.				
3.				
4.				
5.				
6.				

Mean observed diameter = ...

d = Mean corrected diameter = ...

1.6 RESULT AND DISCUSSION

Internal volume of cylinder $= \frac{1}{4}\pi^2 dh$

$=$ ....

$=$ ....

Verification

Volume of calorimeter as measured by graduated cylinder = ...

1.7 SOURCES OF ERRORS

(i) None of the vernier divisions may be exactly coincident with a main scale division.

(ii) The vernier scale may be loose, and the caliberation may not be uniform. Similarly, vernier jaws may not be at right angles to its main scale. These are common small defects in cheaper instruments.

1.8 Check your Understanding

(i) What is vernier scale and why is it so called?

....

(ii) What is meant by vernier constant?

....

(iii) If the zero of V.S. is on the left of the zero of M.S. the zero error is positive or negative ?

....

(iv) How is zero error determined?

....

(v) What is the advantage of the vernier?

....

(vi) If zero error is - 0.03 cm, what is the value of zero correction?

....

(vii) How can you find the thickness of the bottom of a hollow cylinder by using vernier callipers?

....

EXPERIMENT 2

Determine the diameter of a given wire using a screw gauge

2.1 OBJECTIVES

After performing the experiment you should be able to:

- determine the least count of a screw gauge;
- determine the zero error of a screw gauge.
- determine the diameter of a wire using a screw gauge.

2.2 WHAT SHOULD YOU KNOW

(i) **Pitch:** The pitch of the screw is the distance through which the screw moves along the main scale in one complete rotation of the cap on which is engraved the circular scale.

(ii) **Least Count:** The least count of the screw gauge is the distance through which the screw moves when the cap is rotated through one division on the circular scale.

(iii) **Zero error and correction:** When the zero mark of the circular scale and the main scale do not coincide on bringing the studs in contact the instrument has zero error. The zero of the circular scale may be in advance or behind the zero of the main scale by a celtain number of divisions on circular scale. If the zero of the circular scale is ahead of the zero of main scale the zero error is negative (Fig. 2.3a). On the other hand if the zero of the circular scale is behind th'e zero of the pitch scale, the zero error is positive (Fig. 2.3b).

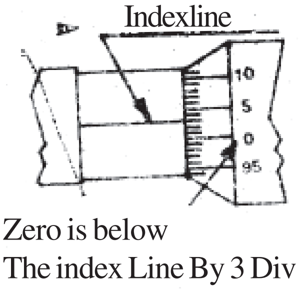


Fig. 2.3(a): Negative zero error

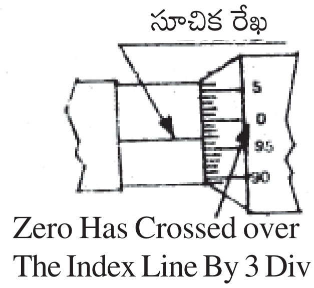


Fig. 2.3(b) : Positive zero error

(iv) **Back-lash error:** Owing to ill fitting or wear between the scr~ws and the nut, there is generally some space for the play of the screw, the screw may not move along the its axis for appreciable rotation of the head (or cap, on which circular scale is marked). The error so introduced is called back-lash errors. To *eliminate it you must advance the screw, holding it by the ratched cap,* when making final adjustment for finding zero error or the diameter of the wire.

Material Required

Given wire, screw gauge

2.3 HOW TO PERFORM THE EXPERIMENT

(i) **Measuring pitch:** To measure the pitch give several rotation to its cap and observe the distance through which screw moves. Calculate the pitch using the following formula

$$\text{Pitch} = \frac{\text{distance moved}}{\text{No.of complete rotations}}$$

(ii) **Measuring least count:** To measure the least count note the number of divisions on the circular scale and calculate

$$\text{Least count (L.C.)} = \frac{\text{Pitch of the screw}}{\text{No.of divisions on the circular scale}}$$

(iii) **Measuring zero error:** With the study in contact observe the numbers of divisions by which zero of the circular scale deviates from the zero of the main scale. This number multiplied by the least count gives the required zero error.

(iv) **Calculate the zero correction:** It is negative of zero error.

Zero correction = - zero error

Zero correction is added algebraically in the observed diameter of wire to get the corrected reading

(v) **Measuring diameter:** To measure the diameter of the wire move the screw back to make a gap between the studs. Insert the wire between the studs. Turn the screw forward by holding it from the ratchet cap and wire should be held gently between the two studs.

(vi) Read the neaerest division on the circular scale in line with the main scale and also find the complete rotations of the cap with the help of the main scale. Calculate the observed diameter:

Observed diameter = pitch $\times$ number of complete rotation + L.C. $\times$ circular scale reading

(vii) Repeat the experiment for 5 observations at different points of the wire along its length. Find the mean observed diameter and apply the zero correction to obtain correct diameter.

2.4 WHAT TO OBSERVE

Linear distance covered in 4 complete rotations = ... mm

Lin ar distance covered in 1 complete rotation = ... mm

$\therefore$ Pitch of the screw = ... mm = ...cm.

Number of division on circular scale = ...

$$\text{Least count} = \frac{\text{pitch}}{\text{No.of divisions on circular scale}} = \text{.............cm}$$

Zero error = (1) .... (2) .... (3) ....

Mean zero error = ...

Mean zero correction = - (Mean zero error)

= .... to be added algebraically.

Table 2.1 : Screw gauge readings for diameter

S.No.	Readings		Observed diameter
	Linear Scale m(div)	Circular Scale n(div)	= m $\times$ pitch + n $\times$ L.C.
1.			
2.			
3.			
4.			
5.			

Mean observed diameter = ... cm

Mean corrected diameter = D = ... cm

2.5 SOURCES OF ERRORS

(i) If the instrument be ere ed up tightly when finding zero error or taking reading of diameter of wire (perhap on account of defective on hard ratchet cap)it may compress the wire out of shape.

(ii) If the screw it not turned by holding the ratchet cap then the screw may compress the wire out of shape.

(iii) As mentioned earlier, to eliminate the back - lash error, the screw should always be turned in the same direction (i.e. in forward direction) when making the final adju tment Negligence of this procedure can co a major error.

2.6 CHECK YOUR UNDERSTANDING

(i) Why is this instrument called a screw gauge ?

....

(ii) What do you understand by pitch of a screw gauge?

....

(iii) What do you understand by least count of a screw guage ?

....

(iv) What is back-lash error and how it can be avoided ?

....

(v) What is the use of ratcher arrangement in a screw guate ?

....

(vi) If the zero of circular scale is ahead of the zero of main scale by 7 divisions of circular scale and least count is 0.005 mm. what is the zero error and the zero correction ?

....

EXPERIMENT 3

Determine the radius of curvature of a concave mirror using a spherometer.

3.1 OBJECTIVES

After performing this experiment you should be able to:

- find the least count of a spherometer;
- measure the bulge or depression of a spherical swface by spherometer and thus measure its radius of curvature;
- adjust the position of a needle in front of mirror such as to eliminate parallax between it and its real image;
- measure index correction and thus find correct radius of curvature of the muror.

3.2 WHAT YOU SHOULD KNOW

When a spherometer is placed on a curved surface such that all its legs are touching it, the middle leg will be a little higher or lower than the plane of the outer legs by a small amount *h* which is related to *R,* the radius of curture of the surface (Fig. 3.1).

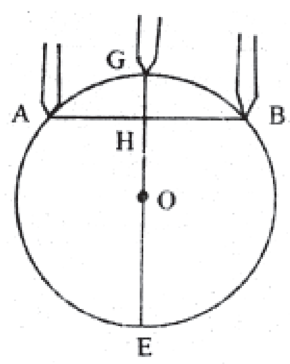


Fig. 3.1: Radius of curvature of the surface

GH = h

GOE = 2R

AH = *a*, the distance between the central leg and the outer leg.

From geometry

$AH \times HB = GH \times HE$

$a \times a = h(2R - h)$

$a^2 = 2Rh - h^2$

$2RH = a^2 + h^2$

$$R = \frac{a^2}{2h} + \frac{h^2}{2h}$$

$$\therefore R = \frac{a^2}{2h} + \frac{h}{2}$$

H is the centre of equilateral triangle tormed by the outer legs *A, B,* C, (Fig.3.2).

We have

$$\cos 30^{O} = \frac{AM}{AH}$$

$$\Rightarrow \frac{\sqrt{3}}{2} = \frac{l/2}{a} = \frac{l}{2a}$$

$$a = \frac{l}{\sqrt{3}}$$

$$R = \frac{l^2}{6h} + \frac{h}{2}$$

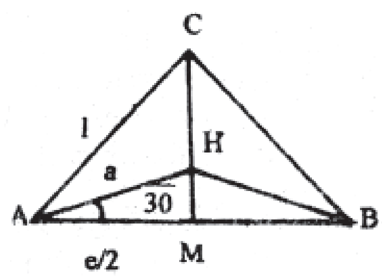


Fig. 3.2

Material Required

Spherometer, plane glass slab, concave mirror, half metre rod.

3.3 HOW TO PERFORIVI THE EXPERIMENT

(i) Examine the pherometer, noting carefully that the legs and the vertical cale are not shaky and that th central screw is not very loose.

(ii) Find the pitch of the screw by determiing the vertical distance covered in 4 or 5 rotations.

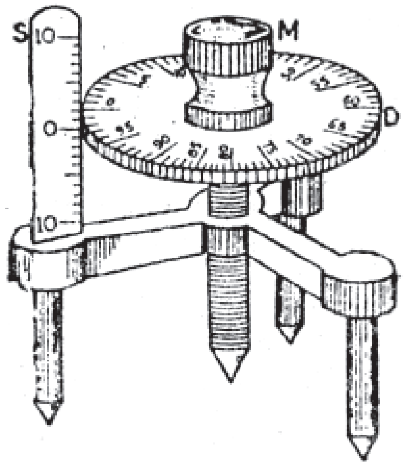
$$\text{Pitch} = \frac{\text{Distance moved}}{\text{No.of complete rotations}}$$

(iii) Find the least count by dividing the pitch by number of divisions on the circular scale

$$\text{Least count} = \frac{\text{Pitch of the screw}}{\text{No.of divisions on circular scale}}$$

(iv) Set the given concave mirror on a horizontal surface firmly and place the spherometer on it and adjust the central leg till it touches the surface. All the four legs touch the surface of the concave mirror.

(v) In order to eliminate back-lash error, proceed slowly as the central leg reach close to the mirror surface. Stop when central leg touches the mirror surface and the entire spherometer just rotates, hanging on the central leg.



Rig. 3.3 : Spherometer

(vi) Read the coincident division on the circular scale and also the main scale reading on the vertical scale. Thus find the total reading.

(vii) Now place the instrument on the surface of the plane glass slab and find how many complete turns have to be made to bring the tip of the central leg to the plane of the outer leg. Also read the coincident division on the circular scale. Thus fmd the total reading on the glass slab.

The difference between the above two readings gives *h*,

(viii) Press the spherometer gently on the notebook so as to get pricks of the feet which are pointed. Measure the distance between each pair of outer pricks and find their mean. This give *l*.

3.5 WHAT TO OBSERVE

(a) Table for Spherometer

Vertical distance covered in .... complete rotations = ... mm

Vertical distance covered in 1 complete rotations = mm

Pitch of the screw = ... mm = ... em

No. of division on the oircular scale = ...

$$\text{Least count} = \frac{\text{Pitch of the screw}}{\text{No.of divisions on circular scale}} = \text{................cm}$$

Table 3.1

S.No.	Cancular Mirror			Glass Slab		
	M.S. reading	Circular scale reading	Total reading	M.S. reading	Circular scale reading	Total reading

Mean = ...   Mean ....

h = Total reading on mirror - Total reading on slab = ... mm = ... cm

From the triangle of legs l_1 = ... cm, l_2 = ... cm, l_3 = ... cm

Mean l = ... cm.

3.6 Calculations and Result

Radius of curvature of mirror by the spherometer is

$$R = \frac{l^2}{64} + \frac{h}{2} = ...cm$$

3.6 Sources of Error

(i) By spherometer we find R of front surface of the mirror. But its back surface is polished.

(ii) Since l is very small, an error in it causes large percentage error in the result.

(iii) Back-lash error is eliminated only by the weight of the spherometer. Since it is a small weight, back-lash error may be only partially eliminated by it,

3.8 Check Your Understanding

i) Why is a spherometer so called ?

....

ii) What is pitch and how is it related with least count ?

....

iii) Why does a spherometer have three legs ?

....

iv) What is back - lash error and how it is avoided?

....

EXPERIMENT 4

To find the time period of a simple pendulum for small amplitudes and draw the graph of length of pendulum against square of the time period. Use the graph to find the length of the second's pendulum.

4.1 OBJECTIVES

After performing this experiment you should be able to:

- set up a simple pendulum swinging freely about a sharp point of suspension and measure its time period accurately;
- measure the length of the pendulum in hanging position;
- draw a graph between square of time period versus length of the pendulum and thus fmd the length of second's pendulum;
- comprehend that length of second's pendulum is specific to a certain place.
- appreciate that time period increases as length increases, and is proportional not to length but to square root oflength.

4.2 WHAT YOU SHOULD KNOW ?

A simple pendulum is a small heavy 'bob' B hanging by a light and 'nextenible string S(fig. 4.1). In '***equilibrium position*** ' string is vertical. While oscillating, *the 'amplitude of oscillation'* is the maximum angle that thrad make with the vertical (or sometime the maximum horizontal displacement of the bob). Its ***time period T,*** i.e., time taken for one oscillation depends on its ***length*** i.e. distance from point of suspension to C.G. of bob B (fig. 4.2):

$$T \propto \sqrt{l}$$

or $$T^2 \propto l$$

Thus graph between T^2 versus l is a straight line passing through the origin. T also increases if amplitude is large, but for small amplitudes it is constant.

Second's pendulum is one which takes one second to move from one end of the swing to other. Thus its time period is 2 s.

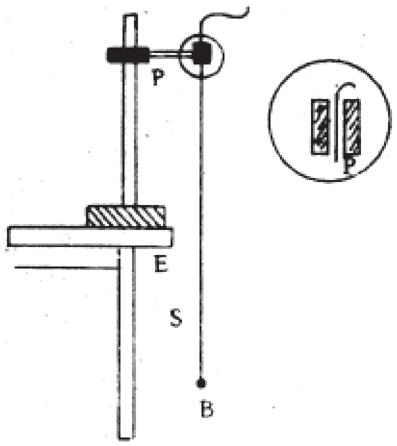


Fig. 4.1

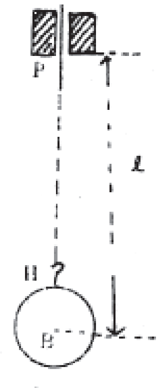


Fig. 4.2

Material Required

A spherical bob; stop watch (with least count of 0.1 econd or less), tall laboratory stand with clamp, split cork, fine thread, two small wooden blocks. metre scale .

4.3 HOW TO SET UP AND PERFORM THE EXPERIMENT

(i) Measure diameter of the bob with help of the metre scale and the two wooden block. Then tie one end of thread in the hook of the bob.

(ii) Pass the other end of the thread between two pieces of the split cork and clamp it in the clamp of the tand (Fig 4.1). The point P, where the thread comes out of the cork is thus a sharp point of suspension, whose po iti n does not change the pendulum swings. To ensure this, check up that two piece of the split-cork have sharp lower edges at P.

(iii) Make a length of about 125 em of this pendulum for the first set of readings. Measure the length from foot of the hook H to point of uspension P (fig 4,2), Add to it half the diameter of the, bob to obtain 1. the length of the pendulum. Length PH must be measaed ***with bob suspended,*** as the thread may have some elastic extension by the weight of the bob.

(iv) Adjust position of stand to bring this pendulum close to edge E of the table (Fig 4.1). On a white strip of paper stuck at the vertical end face of the table, mark a vertical line. The thread coincide with this line in its vertical position, when you see it from the front.

(v) Pull the bob to one side and release so that it oscillates with an amplitude of less than 4^0 (Fig 4.3). If height of P above table is about 60 cm, then maximum, displacement of thread from central mark is not more than about 4 cm.

(vi) With the help of stop watch, measure time of 20 oscillation. You should start the watch when thread crosses the central mark in a given direction and count 'zero'. At the count 'twenty' wnen thread crosses the central mark in the same direction, stop the watch. Take three consistent readings, least there is an error in counting. Then calculate time of one oscillation *T.*

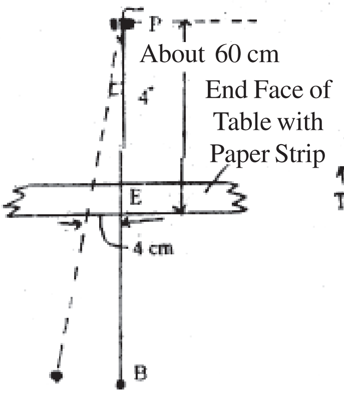


Fig. 4.3

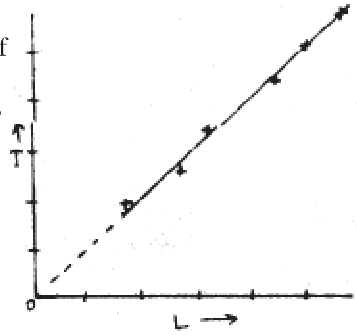


Fig. 4.4

(vii) Repeat steps (3) to (6) making shorter lengths of the pendulum upto about 20 cm.

viii) For each length calculate T^2 and plot a graph between T^2 verus l (Fig 4.4) From this graph find the value of l for $T^2 = 4s^2$.

4.4 What to Observe and Analysis of Data

Diameter of the bob = (1) .... (2) .... (3) ....

Mean diameter = ...

Radius of the bob, r = 1/2 (diameter)

Table 4.1 Measurement of time period

S.No.	Length PH	$l = PH + r$	Time of 20 oscillations				T	T^2
			1	2	3	Mean		

From T^2 versus l graph, l for $T^2 = 4S^2$ = is................

4.5 Result

i) T^2 versus l graph is found to be a straight line passing through origin. Hence, $T \propto \sqrt{l}$

ii) Length of second's pendulum at the place of the experiment is

a) by graph

b) by calculation ($T = 2\pi\sqrt{l/g}$, for seconds pendulum $T = 2s$ and obtain value of g at your place of experiment from a table of physical constants).

4.6 Sources of Error

i) If the stand is not quite rigid, it may cause horizontal movement of the point of suspension while the pendulum swings. This may affect the time period.

ii) Elasticity of thread may result in error in measurement of length of pendulum.

4.7 Check Your Understanding

i) Time period is defined as the time interval in which the pendulum makes one oacillation. To measure it why you are advised the indirect approach of first measuring time of 20 oscillations and then calculate time of one oscillation, instead of simply measuring the time of 1 oscillation by the stop watch ?

....

ii) How does it help in making accurate measurement of time period if you measure time of 50 oscillations instead of 20 oscillations ?

....

iii) If length of a pendulum is (a) decreased 1/9th (b) increased to 9 times its previous length. Then its time period becomes (Choose the correct answers in the two cases).

i) 1/9th   ii) 9 time   iii) $\frac{1}{81}$th   iv) 81 times   v) $\frac{1}{3}$rd   vi) 3 times

....

iv) Without changing the length of your pendulum, you carry it to another place where acceleration due to gravity is larger.

a) Does its time period change ? If so how ?

b) Does the length of seconds pendulum change ? If so how ?

....

EXPERIMENT 5

To find the weight of a given body using law of parallelogram of vectors.

5.1 Objectives

After performing this experiment, you should be able to:

- set up a point in equilibrium under the action of three forces;
- recognise **tension** in strings;
- sec that bodies always hang vertically under the action of gravity;
- recognise **weight** as a force due to the earth on any body;
- understand that if a number of forces act on a body simultaneously it is possible to find a single force which will produce the same effect is the ***resultant force***.

5.2 WHAT SHOlJLD YOlT KNOW

(i) According to Newton's Third Law of motion, tension in a string supporting a body is equal to the weight of the body.

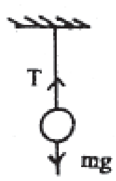


Fig. 5.1

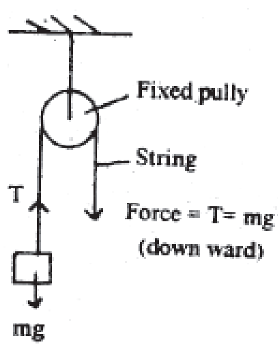


Fig. 5.2

The weight due to a body of mass m = mg (Fig. 5. 1). Therefore tension in the string is :

$$T = mg$$

(ii) A fixed pulley only changes the direction of force and not its value (Fig. 5.2).

(iii) Forces are *vectors* and they cannot be added arthimatically. ***Resultant force*** is a single force that produces the same effect as a combination of two or more forces. A body is said to be in *equilibrium* if the resultant force on it is zero.

(iv) ***Law of parallelogram of vectors:*** If two vectors acting simultaneously on a particle be represented in magnitude and direction by the two adjacent sides of a parallelogram drawn from a point, then their resultant is completely represented in magnitude and direction by the diagonal of that parallelogram drawn from that point.

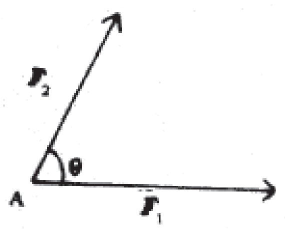


Fig. 5.3(A)

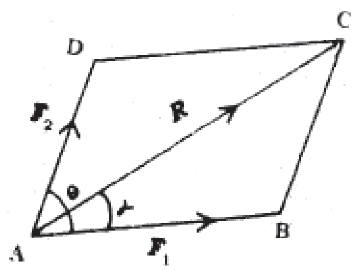


Fig. 5.3(B)

In Fig 5.3(a) F_1 and F_2 are two forces acting simultaneously on point object at A at an angle 6. They are represented in magnitude and direction by sides AB and AD of the parallelogramABCD.

The diagonal AC will represent *R* the resultant force.

$$R = F_1 + F_2$$

$$|R| = F_1^2 + F_2^2 + 2F_1F_2 \cos\theta$$

Also $\tan\alpha = \dfrac{F_2 \sin\theta}{F_1 + F_2 \cos\theta}$

Where a is the angle which the direction of the resultant, *R*, makes with the direction of F_1

If F_1 or F_2 change in magnitude or direction R will also change.

Material Required

Parallelogram law of forces apparatus (Gravesand's apparatus), plumb line, slotted weights, thin strong thread, white drawing, paper sheet, drawing pins, mirror strip, pencil, set square/ protractor, a body whose weight is to be determined.

5.3 How To Perform the Experiment

i) Set up the Gravesant's apparatus with its - board vertical arid stable on a rigid base. Check this with the help of a plumb line (Fig. 5.4).

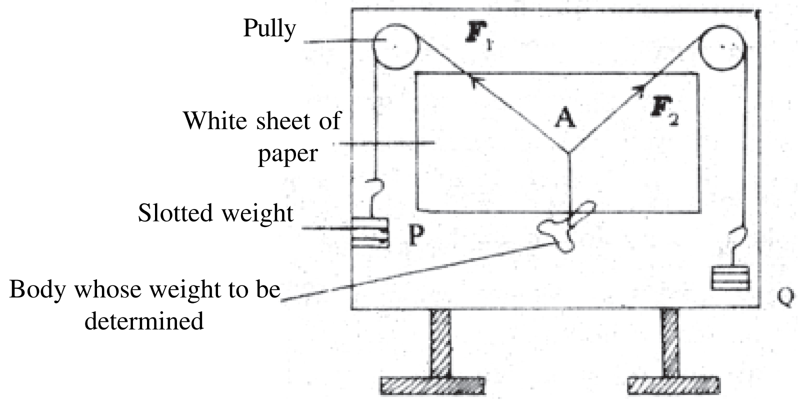


Fig. 5.4 : Grayesand's apparatus

(ii) ***Oil the axle of pulley so*** as *to* make them move freely.

(iii) Fix the white drawing sheet on the board with the help of pins.

(iv) Cut *a*/*m* long thread. Tie the hooks of the slotted weights at its ends.

(v) Pass the thread over the two pulleys. The hangers must hang freely and *they should* not *touch the board or pulley or ground.*

(vi) Cut 50 cm long thread. Tie the body whose weight is to be determined at one end of the string.

(vii) Knot the other end to the centre of 1m thread at A.

(viii) Adjust the three weights such that the junction A stays in equilibrium slightly below the middle of the paper. The *three forces are:*

F_1 - due to slotted weights P.

F_2 - due to slotted weights Q.

R – due to the weight of the body.

F_1 = P (slotted weight + Weight of hanger)

F_2 = Q (slotted weight + weight of hanger)

Perhaps with a given set of weights *P* and *Q* and body of unknown weight you find that central junction A can stay anywhere within a circle. Try to locate the centre of this area and bring the junction A there.

(ix) To mark the direction of the forces, place the plane mirror strip lengthwise under each thread in turn. Mark two points one on either ends of mirror strip by placing your eye in such a position that the image of the thread in strip is covered by the thread itself. *The points should be marked only weights are at rest.*

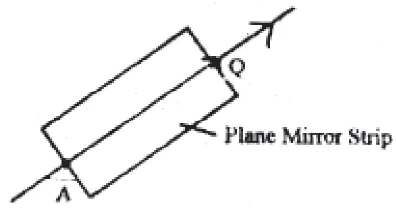


Fig. 5.5

x) Note the value of the weights P and Q. Do not forget to add the weight of the hanger along with each. Find weight of hanger by spring balance.

xi) Remove the sheet of paper. Join the marked points to show the direction of forces (Fig. 5.6).

xii) Choose a suitable scale to indicate the forces, so as to get a large parallelogram. From A mark off B such that $AB = \frac{Q}{n}$ and D such that $AD = \frac{P}{n}$ to represent forces due to n the weights and hanger. Here, n grown weight is represented by 1 cm.

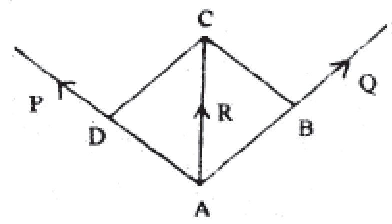


Fig. 5.6

The number n should be so chosen that the lengths AB and AD are accommodated in the drawing sheets.

An example will make these points clearer. In an experiment P = 150g and Q = 200 g and their directions were recorded as shown in Fig. 5.7. Choose a scale 1 cm = 50 g

$\therefore \; AD = \frac{150}{50} = 3cm$

and $AB = \frac{200}{50} = 4cm$

completing the parallelogram we measure and find that

AC is 4.4 cm

$\therefore \; R = 4.4 \times 50 = 220.0g$

or 220g

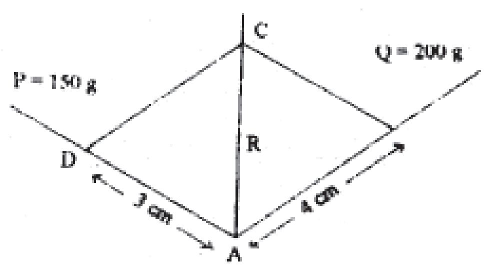


Fig. 5.7

The diagonal AC gives the value of resultant and hence in our case the unknown weight of the body.

xiii) Repeat the experiment twice again by changing weights in the hangers. Find the average value of the unknown weight.

5.4 What to Observe

i) Weight of hanger .... g

ii) Scale for drawing the prallelogram, 50 g = 1 cm (or any other), 1cm = $n\,g$.

Table 5.1 : Table for weight of the body

S.No.	Forces (slotted weight + hanger)		Diagonal AC y (cm)	Resultant Force $R = y \times n$ (g wt.)	Weight the given body
	P	Q			

Average weight = ... g

5.5 Result

Weight of the given body = ... g

5.6 Check Your Understanding

i) When do we say a body is at rest ?

....

ii) Why the thread junction does not come at rest at the same position always ?

....

iii) Why the suspended weights are kept away from board or table ?

....

iv) A student has value of P = 200 g, Q = 250 g and angle betweem them is (a) 90^0, (b) 60^0, (c) = 30^0 Find the resultant by drawing a suitable parallelogram. (Take 50 g = 1 cm).

....

v) For pulling down a tall tree why ropes are pulled in two different directions making an acute angle between them ?

....

EXPERIMENT 6

To study the Newton's law of cooling by plotting a graph between cooling time and temperature ditTerence between calorimeter and surroundings.

6.1 Objectives

After performing this experiment, you should be able to:

- establish that a body gains or looses heat because its temperature is below or above that of the surrounding;
- observe that the gain or loss of heat is not sudden but over a period of time, that is bodies take time to acquire a steady temperature;
- room temperature remains constant over a target period of time;
- heat lost by a hot body depends upon the nature of surf ace exposed, area of surface exposed and the difference between temperature of the body and room temperature.

6.2 What You Should Know

The rate of loss of heat from a vessel presumably depends on the area of the exposed surface, the nature of that surface, the temperature of the surface and the temperature of the surroundings, Newton's law of cooling states that the rate of loss of heat of a body is directly proportional to the difference of temperature between the body and the surrounding. The law however holds good only for small difference of temperature.

Rate of cooling $\propto$ difference of temperature between body and surrounding.

Consider a body of mass *m,* specific heat *s,* temperature *T* kept in a surrounding of temperature T_R. If it looses an amount ΔQ of heat in time Δt and thus its temperature is lowered by ΔT, then

$$\frac{\Delta Q}{\Delta t} = ms\frac{\Delta T}{\Delta t}$$

According to Newton's law of cooling

$$ms\frac{\Delta T}{\Delta t} \times (T - T_R)$$

Hence $\frac{\Delta T}{\Delta t} \propto (T - T_R)$, ms is a constant.

Material Required

Calorimeter with stirrer, thermometer with $\frac{1}{2}^0$ graduation, stop clock, heating device, water, oil (mustard or any other) about 100 ml, large metal box blackened inside and outside

6.3 HOW TO PERFORM THE EXPERIMENT

(i) Choose a clean, clear corner of the room.

(ii) Clean and dry the copper calorimeter but do not make its outside shining.

(iii) Note the room temperature and record it. Hold the thermometer and bring your eye in level with the upper tip of mercury thread to ensure correct reading.

(iv) Set up the apparatus as in Fig. 6.1.

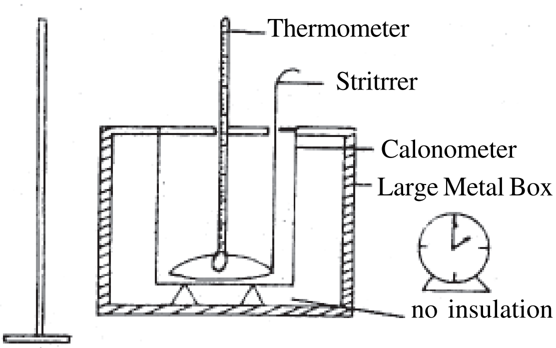


Fig. 6.1 : Newton's law apparatus

v) In case a double walled Newton's law apparatus is not available, use any large metal box blackened inside and outside. You can also just keep the copper calorimeter on the wooden table and work in any calm corner of the laboratory.

vi) Jeat water to about 80^0C.

vii) Fill the calorimeter about 2/3 with water.

viii) Place the thermometer in water.

ix) Set the stop clock at zero and note its least count

x) Start stirring the water in the calorimeter to make it cool uniformly.

xi) Just when temperature of water is at about 70^0 C note it and start the stop clock.

xii) Continue stirring and note temperature after every minute.

xiii) When fall of temperature becomes slower, note temperature at interval of two minutes, then five minutes and then ten minutes, till the temperature of water is close to room temperature.

xiv) Repeat the experument with oil in the same way. Fill the calorimeter about 2/3 with oil, as in case of water.

6.4 What to Observe

i) Least count of thermometer = ...

ii) Least count of stop watch = ...

iii) Room temperature at the beginning of exp. = T_1 =

iv) Room temperature at the end of exp. = T_2 =

v) Average Room temperature = $\frac{T_1 + T_2}{2} = T_R$

Table 6.1 : Temperatures at different times

Time (t) in (min)	T_W Temp. of water (^{0}C)	T_0 Temp. of oil (^{0}C)	$T_W - T_R$ (^{0}C)	$T_0 - T_R$ (^{0}C)
0				
1				
2				

6.5 Graph

i) Plot a graph between time and temperature of water. Take time along *x*-axis and temperature (T_w) along *y*– axis. It is called a 'cooling curve'.

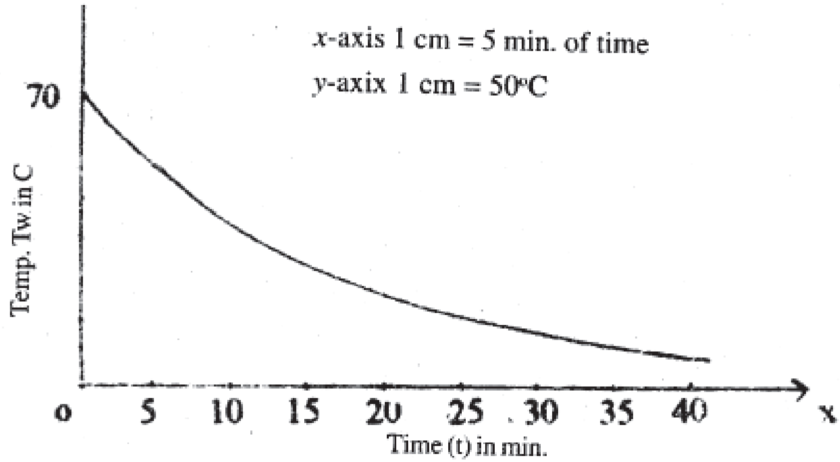


Fig. 6.2: Temperature - time graph

Similarly plot the graph for oil using-the same scale.

6.6 Result

The temperature falls quickly in the beginning and then slowly as difference of temperature (T_W–T_R) goes on decreasing. This is an agreement with Newton's Law of Cooling.

Note : Cooling is fast if the surface area of the calorimeter is large. Cooling is fast from black, painted surface and slow from polished metallic surface. Cooling is faster from good conductor vessels and slower from poor conductor ones. You can do simple changes in your apparatus and do the experiment to check this out as a project work.

Precautions

i) Stir the water/oil to allow uniform cooling.

ii) Room temperature should remain constant. Avoid any heat source near the experiment site so that room temperature remains constant.

iii) In case double walled calorimeter is not available, the room should be draught free.

6.7 Check Your Understanding

i) The two graphs water/oil are quite similar. Why ?

....

ii) Why do animals curl up and sleep in winter ?

....

iii) For same temperature difference with surrounding, you find that rate of cooling of oil is faster than That of water. Why ?

....

iv) Can the doctor's thermometer be used to perform the experiment ? Give reason for your answer.

....

v) Why should the liquid be stirred continuously ?

....

vi) Would the nature of graph change if a large calorimeter was taken ?

....

vii) Why should the same volume of liquid be taken in case of oil and water ? How does it help you in comparison of graph ?

....

EXPERIMENT 7

Determine the specific heat of a solid using the method of mixtures.

7.1 Objectives

After performing this experiment, you will be able to :

- understand the principle of heat exchange;
- verify heat is lost to the stnrounding whenever hot lxxlies are placed in cooler surroundings i.e. heat flows from higher temperatures to lower temperatures;
- appreciate that energy is always conserved and, therefore, heat energy is also conserved;
- recognise that different materials have different specific heats; and
- determine the specific heat of a solid.

7.2 What you Should Know ?

i) **Specific heat:** *The amount of heat required for a unit mass of substance to raise its temperature by* 1°C *is defined as specific heat*.

The unit of specific heat is cal gr^{l} $^{0}C^{-1}$ or J kg^{-1} $^{0}C^{-1}$ and it is read as calory per gram per degree celcius or Joule per kilogram per degree celcius.

ii) **Heat lost or gained by a body :** For a body of mass, specific heat s and change in tempeterure Δt,

Heat gaine = $ms\Delta t$ (Δt rise in temperature)

Heat lost = $ms\Delta t$ (Δt fall in temperature)

iii) Heat - exchange takes place between solids, liquids and surroundings. Whatever heat is lost by a hot body is taken up by the cooler ones in its contact because energy is conserved. This is known as ***princile of heat exchange*** which states that,

Heat gained by a cold body = heat lost by a hot body

This can be used to find the specific heat of specific heat of soilds and liquids.

iv) **Method of Mixture :** States that if a hot.solid is placed in a cold liquid with which it has no chemical reaction then the heat lost ***by the solid body is equal to heat gained by the liquid***, assuming there is no loss of heat to the sourroundings.

Meterial Required

Calorimeter with insulated box and stirrer, heating arrangement, brass bob, two thermometers, measuring glass cylinder, cotton thread, spring balance to find the mass of bob.

7.3 How to Perform the Experiment

i) Clean and weigh the calorimeter and stirrer using the spring balance.

ii) Place the calorimeter in its insulated box.

iii) Measure 60 mL of water using the measuring cylinder and pout it carefully in the calorimeter.

iv) Fix the thermometer in the stand and not the temperature of this cold water.

v) Tie a thread to the brass bob, heat it in boiling water for a few minutes. Note the temperature of boiling water by second thermometer already fixed in it, in another stand.

vi) Quickly transfer the brass bob into the water in the calorimeter; cover the lid; and stir.

vii) The temperature of water will rise and then become steady. Thereafter it slowly falls on account of loss of heat to the surrounding.

viii) Note the steady, final temperature of water.

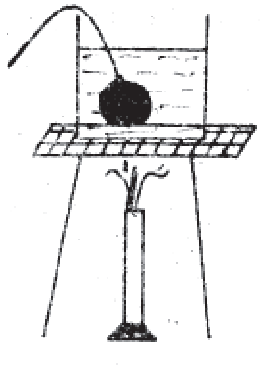


Fig. 7.1 : Shows careful heating of the brass bob before it is trasferred to the water in the calorimeter.

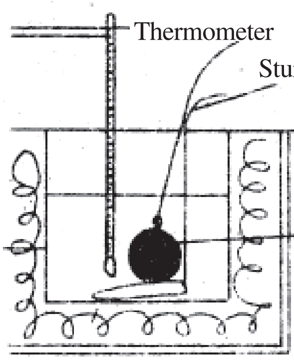


Fig. 7.2 : Show the arrangement of calorimeter box thermometer, stirrer when the ho bob is transferred in to the calorimeter.

7.4 What to Observe

i) Least count of measuring cylinder = ...

ii) Least count of spring balance = ...

iii) Mass of brass bob m_b = ...

iv) Mass of calorimeter and stirrer = m_c = ...

v) Least count of thermometer = ...

vi) Initial temperature of water in the calorimeter = t_1 = ...

vii) Temperature of boiling water = t_3 = ...

viii) Final temperature of water and bob = t_2 = ...

ix) Specific heat of copper = S_C (from the table) = 0.093 cal $g^{-1}\ {}^0C^{-1}$

x) Volume of cold water in the calorimeter = 60 mL (as given in the procedure)

mass of cold water = 60 g (density of water = 1g/mL)

7.5 How to Calculate

i) Heat *given* by hot brass bob = $m_b \times S \times (t_3 - t_2)$ cal

ii) Heat *taken* by water in calorimeter = $60 \times 1 \times (t_2 - t_1)$ cal

(Specific heat of water = 1cal g^{-1} 0 $^oC^{-1}$)

iii) Heat *taken* by calorimeter = $m_c \times S_c \times (t_2 - t_1)$ cal

We have from method of mixtures,

Heat *given* by hot body = heat *taken* by cold body

$m \times S \times (t_3 - t_2) = (60 + m_c \times S_c)(t_2 - t_1)$ cal

$$S = \frac{(60 + m_c s_c)(t_2 - t_1)}{m_b(t_3 - t_2)} = \text{.............calg}^{-1}\ {}^0\text{C}^{-1}$$

Note: It is intersting that this method can be adapted to do simple experimets at home. You can use a plastic cup to perform your experiment instead of a calorimeter. Take marble pieces for finding the specific heat of marble. You will need a laboratory thermometer to note temperatures. Weighing of the marble piece can be done at any grocery shop near your house. Amount of water can be worked out with an empty medicine bottle. Try, it is a lot of fun. Of course you ignore the heat taken by plastic cup. You can avoid second thermometer by taking temperature of boiling water as roughly 100^0C.

7.6 Check You Understanding

i) Can you find the specific heat of the brass bob by putting the cold brass bob in hot water in the calorimeter ? Explain ! Can you still find the final steady temperature ? Why ?

....

ii) Can you use this method to determine the specific heat of a wooden bob ? Explain.

....

iii) Why does the tap water not boil at 100^0C ?

....

iv) How do you measure the final temperature of the mixture ?

....

v) Why should the mixture be stired continuously ?

....

vi) A brass piece of 200 g at 100^0C is dropped into 500 ml of water at 20^0C. the final temperature is 23^0C. Calculate the specific heat of brass ?

....

vii) What is meant by the statement heat of marble is 0.215 cal $g^{-1}\,{}^0C^{-1}$ or that of Aluminimum is 900 $JKg^{-1}\,{}^0C^{-1}$?

....

viii) Can you use this 'method of mixture' for finding the specific heat of a liquid ? Explain.

....

ix) It is necessary that the solid bob should be spherical in shape ?

....

Suggested Activity :

Use this method to find the specific heat of any oil.

Hint :– Use given oil instead of water and repeat the experiment in the same way as you have done using brass - bob and water.

EXPERIMENT 8

To measure extensions in the length of a helical spring with increasing load

8.1 Objectives

After perfonning this experiment, you should be able to:

- suspend a spring vertically and set up the arrangement for measuring length corresponding to different loads; .
- measure the extension produced in the spring by a load suspended on it;
- draw a graph between load versus extension of the spring;
- calculate spring constant from the graph.

8.2 What you Should Know

It follows from Hooke's law that the gravitational force of load M suyspended in a spring and extension/produced in it by the load are proportional to each other.

$$\text{i.e. } \mathrm{Mg} \propto l$$

$$\Rightarrow \mathrm{M}g = \mu l$$

$$\text{or} \quad \mu = \frac{\mathrm{M}g}{l} \tag{8.1}$$

Here μ is the force in newton required to produce unit extension and is called ***spring constant*** of the spring. If we plot a graph between extension produced l (on y- axis)and load suspended Mg (on x-axis) then

$$\mu = \frac{\text{change in weight}}{\text{change in } l} = \frac{1}{\text{slope of graph}} \qquad (8.2)$$

Eq (8.2) gives the value of μ in the SI unit (Nm^{-1}).

Material Required

The spring, a pan which can be suspended below the spring, weight box, half -meter scale, laboratory stand, light aluminium strip with a pointer.

8.3 How to Step

Attach the scale in the laboratory stand in a vertical position. On the same stand suspend the spring. Suspend a light aluminium strip below it at which is stuck a light paper pointer (Fig. 8.1). At the lower end of the strip suspend the pan. When weights are added in the pan and spring extends, tip of the pointer moves down on the scale, without touching it. Position of the tip of the pointer can be read on the scale.

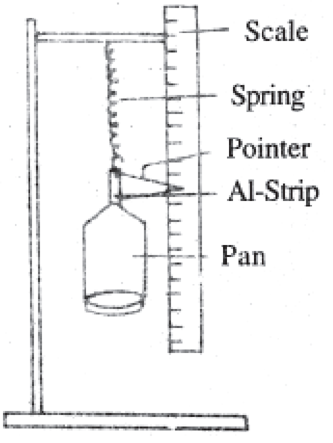


Fig. 8.1

8.4 How to Perform The Experiment

(i) Note the *zero reading* of pointer on the scale with no weights in the pan. Add a suitable weight, *M,* in the pan and note the new reading on the scale. Difference of the two readings gives extension, *I,* of the spring due to the weight M.

(ii) Gradually increase in steps the weights in the pan and note the position of . pointer for each load.

(iii) After an appropriate maximum load is reached, reduce the weights in same steps. Again note the position of pointer for each load. If the spring has not been permanently strained by your maximum load, the pointer will return to its previous position for each load. There can be some observational error. Hence find the mean of the two readings and then extension for each load.

(iv) Plot a graph between extension l (on y-axis) and 1oad M (on x-axis) (Fig 8.2). Draw the best straight line through the points plotted and the origin, which is also an observation - zero extension for zero load.

(v) Find the slope of the graph and then the constant μ.

$$\mu = \frac{\text{change in M}}{\text{change in } l} = \frac{1}{\text{slope of graph}}$$

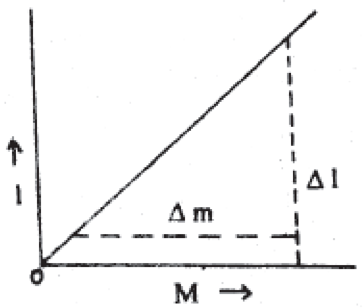


Fig. 8.3 Graph between M and l

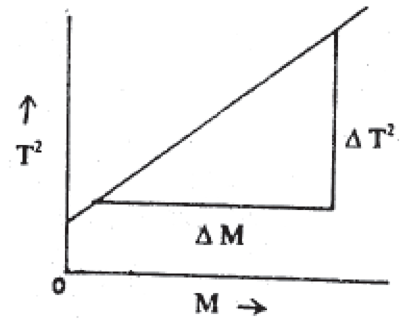


Fig. 8.3 Graph between M and T^2

8.5 What to Observe And Data Analysis

Table : Observations for extension versus load graph

S.No.	Load, M M/kg	Scale reading		Mean	Extension I/cm
		Load increasing	Load decreasing		

Slope of extension versus load graph = $\frac{\Delta l}{\Delta M}$ ....m kg^{-1}

Constant, μ = $(\text{slope})^{-1}$ = ...N m^{-1}

8.6 Result

i) Extension versus load graph is a straight line passing through origin. Thus extension is proportional to load, it.e Hook's law is found valid.

ii) Constant μ (weight suspended per unit extension) = ... Nm^{-1}.

8.7 Sources of Error

i) If pointer positions for equal loads for load decreasing are lower than those for load increasing, then a permanent extension of spring has occured by the maximum load applied. At that load, Hook's law breaks down.

ii) There can be friction between the pointer and the scale if they touch each other and their contact is not light enough. Then, for a given load, the pointer will come to rest in several positions.

8.8 Check Your Understand

i) Why should the oscillations be small ?

....

ii) Why should oscillations be only vertical ?

....

iii) How will the time period of large vertical oscillations, but within the elastic limit compare with that for small vertical oscillations?

....

iv) A spring, with a certian load suspended on it, is carried to the Moon. Thus the load decreases due to less gravitation of the Moon. What change occurs in its extension. Give reasons for your answer.

....

EXPERIMENT 9

To find the time required to empty a burette, filled with water, to 1/2 of its volume, to 1/4 of its volume, to 1/8 of its volume and so on. Then plot a graph between volume of water in the burette and time and thus study at each stage that the fractional rate of flow is same (analogy to radio-active decay).

9.1 Objectives

After petforming this experiment, you should be able to,

- observe how the volume of water in the burette varies with time as water flows out;
- plot a graph between volume of water versus time;
- interpret the graph to appreciate that the variation in the rate of flow of water as well as variation in volume of water in the burette with time are similar to variation of radio-activity of a radio-active isotope with time;
- find the fractional rate of flow of water at various stages and observe that it is constant.

9.2 What you Should Know

When a radio-active substance decays, the rate of radio-active decay (measured by intensity of radio-active radiation) decreases by same factor after equal intervals of time. The amount of undecayed substance left also decreases by the same factor after same intervals of time. Thus the fractional rate of decay;

$$= \frac{\text{rate of decay of the substance at any instant}}{\text{amount of undecayed substance left at that instant}}$$

remains constant with time.

In like manner, let water flow out through the narrow end of a burette to a thistle funnel and then to a sink. Then the rate of flow of water is proportional to level difference *h* between the thistle. funnel and water level in the burette at any time (Fig. 9.1) and hence to volume of water in the burette above the bottom mark. Thus, the fractional rate of flow :

$$= \frac{\text{rate of flow water}}{\text{volume of water in burette above the bottom mark}}$$

remains constant with time

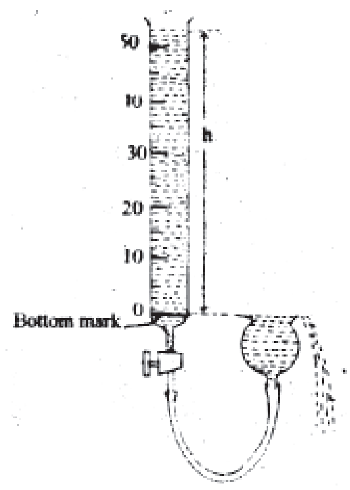


Fig. 9.1

Material Required

A 50 mL burette with a least count of 0.2 mL or 0.1 mL, a thistle funnel, rubber tube, two laboratory stands, stop clock.

9.3 How To Set Up

Fix the thistle funnel in one stand and the burette in the other. Connect their lower ends by rubber tube. Position the thistle funnel at a place where water overflowing from it falls in a sink, or a wide mouth vessel placed below it. Adjust the heights of the two stands, such that open mouth of thistle funnel is in level with bottom mark of the burette. This may be checked by filling some water in the burette, opening its stopper fully and then noting that water stops flowing out when water level in burette reaches the bottom mark (Fig. 9.2). This ensures that only pressure of water column in the burette above this mark, causes the flow of water during the xperiment. Put a cotton thread across the diameter of thistle funnel. This helps water to overflow with small level difference too, which may be stopped by surface tension of water.

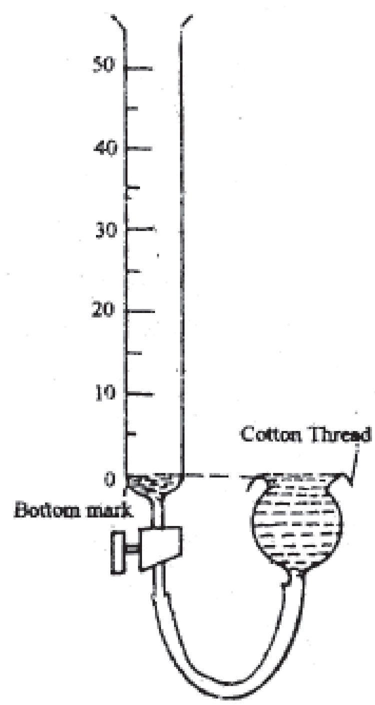


Fig. 9.2

9.4 How to Perform the Experiment

i) After setting up the apparatus as described above, you already have water in the burette upto the bottom mark and in the thistle funnel. Close the stopper and fill water in the burette upto a little above its upper mark (Fig. 9.1).

ii) Gently open the stopper a little so that water starts flowing slowly. At the same time start the stop watch. Water flow should be rather slow so that water flowing through narrow opening in the stopper does not become turbulent.

iii) As the water level reaches the upper mark of the burette, note the time shown in the stop clock, without stopping it.

iv) At every 5 mL fall of water, leyel note the time in the stop clock without stopping it. There is an inevitable time lag between observing water level reach a certain mark on the burette and then observing the time shown in the clock at that instant. But this time lag can be maintained approximately constant with some practice.

During these observations the stopper of the burette should not at all be disturbed. If you feel that water flow is much too slow or fast and there is need to alter it, then you have to start from step (I) again. The resistance to water flow by stopper must not be changed during these observations.

After water level comes down to a low value, e.g. 20 mL, then rate of flow becomes slow and you may like to note the tirre at every 2 mL fall of water level instead of 5 mL.

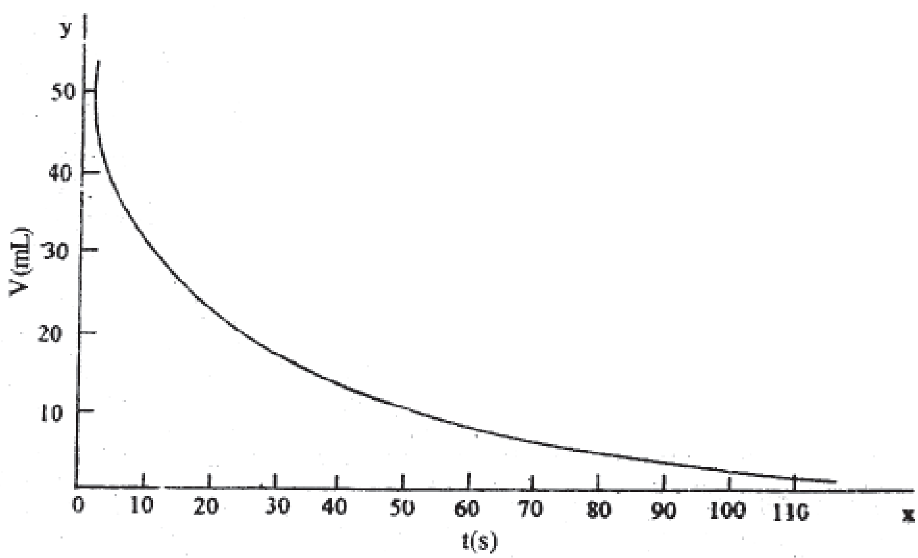


Fig. 9.3 : Graph between volume of water in the burette and observed time

v) Plot graph between volume of water in burette, V (along y-axis), versus observed time, t, in the stop clock (along x-axis) (Fig. 9.3).

vi) From the graph read values of t when V reduces to 40 mL, 20 mL, 10 mL, 5 mL and 2.5 mL. Calculate the time intervals T(1/2), T(1/4), T(1/8), T(1/16) taken to reach least four values from

$V = 40$ mL. Calculate half life of water flow in each case, i.e. time taken to reduce V to half values : $\frac{T(1/2)}{1}$, $\frac{T(1/4)}{2}$, $\frac{T(1/8)}{3}$, $\frac{T(1/16)}{4}$.

vii) Draw tangents to the graph at each of these five values of *v*, and find the slopes $\frac{\Delta V}{\Delta t}$ = rate of flow.

viii) At each of these five values of V, find the fractional rate of flow water :

$$= \frac{\text{rate of flow of water at an instant}}{\text{volume of water in the burette at that instant}}$$

9.5 What to Observe

Table 9.1: Observing V versus *t*

V/mL	50	45	40	35	30	25	20	18	15	14	12
t/s											
V/mL	11	10	9	8	7	6	5	4	3	2	1
t/s											

9.6 Analysis of Data

Table 9.2: Half life of water How and fractional rate of flow

V/mL	t/s	time interval From V = 40 mL	half life of water flow	Rate of flow = slope	Fractional rate of flow (FRF)
40					
20					
10					
5					
2.5					

Mean half life = ... Mean FRF = ...

9.7 Result

i) At any stage of flow, it takes the same time to reduce v to h value. Half life of water flow in this experiment = ... s.

ii) Fractional rate of flow of water is constant during the experiment. Its value in this experiment = ... s^{-1}.

9.8 Sources of Error

i) Time lag between observing a certain value of V in the burette and then observing the corresponding time t in the stop clock, may not be same for all readings.

ii) If water flow is even slightly turbulent during higher values of V in the beginning, then the fractional rate of flow wioll be too low at that time.

9.9 Check Your Understanding

i) Why doea fractional rate of flow at low values of V tend to differ from its constant value during the experiment ?

....

ii) Why could fractional rate of flow at high values of V some times differ from its constant value during the experiment ?

....

iii) Why do need to attach a thistle funnel in the lower end of burette in level with its bottom mark?

....

iv) Which time interval should be larger

a) for flow of water out of the burette from V = 50 mL to 40 mL.

b) for flow of water out of the burette from V = 40 mL to 30 mL.

....

v) Intensity of radio-active radiation from a given sample of carbon - 14 decays in a manner similar to water flow in this experiment. Identify the physical quantities in this experiment corresponding to,

a) intensity of radio-active radiation in the sample,

b) number of carbon - 14 atoms yet undecayed in the sample at a point of time,

c) half lifw of radio - active decay.

....

vi) a) Roughly in how many half lives do you expect nearly complete decay of radio-activity of carbon - 14 (i.e. to less than 1% of initial intensity) in a given sample ?

b) Extrapolate your V versus t graph and state in how many half lives does V reduce to about 1% of initial value.

....

PART - B

B.1 Introduction

The eye and the ear, the two most important of our sense-organs, receive stimuli in the form of waves, viz. light (electromagnetic waves) and sound (mechanical waves). The study of wave-phenomena is, therefore, of utmost importance.

Optics, the study of light energy, has provided us with tools like spectrometers; aids of vision like microscopes, telescopes, spectacles, photographic camera and toys like kaleidoscopes. All those things, not only have given us a new insight into the microcosmos and macrocosmos, but also have improved quality of our life immensely.

All this has become possible through the study of light energy and its effect on matter. Moreover, the study of light energy is easy and interesting and requires very simple and low cost apparatus.

General Instructions on Optical Experiments

(i) While looking at the object and image-pins your eyes should be kept at least 25 cm away from the nearest pin.

(ii) The pins should be held vertical and parallax should be removed between the concerned pins, tip to tip.

(iii) Line diagrams should be drawn for image formation indicating the rays with arrow-heads.

B.2 Optical Bench

An optical bench is a 1 m, or 1.5 m, or 2 m long horizontal bed made of wood or iron (Fig. 1). The bench is supported on two levelling screws on either end and carries a metre-scale laid down along its length usually on one side. Three or four uprights are provided with the bench with a provision to hold a pin or a bus-holder in an upright. An upright can be fixed at any desired position on the bench and the position of the pin (or mirror/lens) held in it, can be read with the help of a line-mark in the middle of its base.

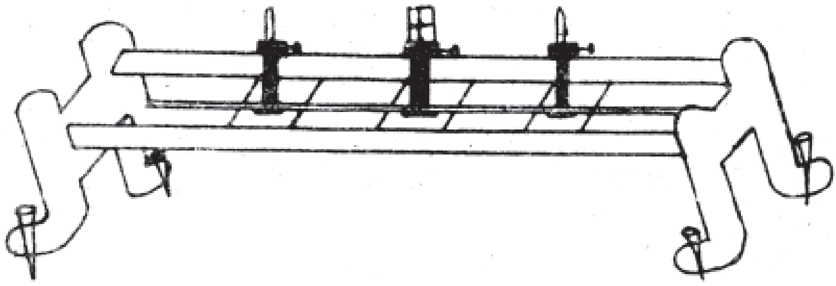


Fig. B.1

Setting of Optical Bench

(i) Level the bench with the help of a spirit level and the levelling screws. For this, place the spirit level along the length, on the base of an upright and bring the bubble in the spirit level to its middle mark by adjusting the corresponding levelling screws. Then place the spirit-level transverse to the length of the bed and make the same adjustment again. Make sure by placing the spirit-level on other uprights also that the bed is thoroughly levelled.

(ii) Fix the lens/mirror and pins in Uprights as per requirement of the experiment Adjust their vertical heights such that the tips of the pins and the centre of the lens/mirror be on the same horizontal line parallel to the bed of the- bench.

Bench Correction

In making measurements with optical bench we measure the distance between the index lines on the uprights and take it as the distance between the tip of the pin and the pole of a mirror (or the optical centre of a lens). The index-line on the upright may not give the exact position of the tip of the pin or the pole of the mirror. This causes an error in measurement called bench error. A correction for the error is to be done which is determined through a separate experiment and, applied in all measurements.

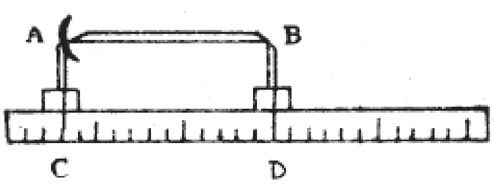


Fig. B.2

Bench Correction = – (Bench error)

– (Measured distance – Actual distance)

= Actual distance – Measured distance

To find bench correction the mirror (or lens) and the piri-tip are set at a fixed distance on the optical bench, making use of a knitting needle.

Length of the knitting needle, then, gives the actual distance between the pin and the mirror (or lens) and the observed distance can be read between the index lines of the corresponding uprights. For the setting in Fig B.2

Bench Correction = AB – CD

quite often bench correction is also called 'index-correction'.

B.3 METHOD OF PARALLAX

Relative shift in the position of a body, with respect to another body, on viewing it from two different positions is called parallax. More is the separation between the bodies more is the parallax between them. In Fig. 3 as the eye is moved from O to A, the pin X moves towards the left of X and oh moving the eye from O to B, it moves towards the right. But when X and Y are one above the other, no parallax is observed as we look at them from different positions. (Fig. 4).

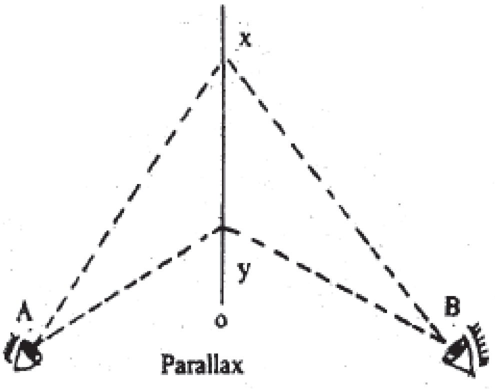


Fig. B.3

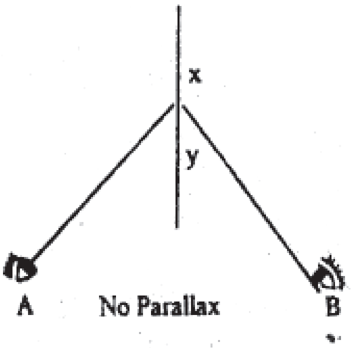


Fig. B.4

Method of parallax is used to locate the position of a real image. When on moving the eye from one side to other the tip of image pin is found to remain coincident with the tip of the image we say that there is no parallax between them and hence the image-pin gives the position of the real image.

EXPERIMENT 10

To determine (i) the wavelength of sound produced in an air column, (ii) the velocity of sound in air t room temperature using a resonance column and a tuning

10.1 Objectives

After performing this experiment, you should be able to:

- set the resonance tube apparatus;
- determine the first and second positions of resonance;
- determine the wavelength of sound waves in air;
- calculate the velocity of sound waves in air; and
- understand the phenomenon of resonance.

10.2 What Should You Know

You know that air columns in pipes or tubes of fixed lengths have their specifIc natural frequencies. For example, in a closed organ pipe (closed at one end) of length L_1 when the air column is set into vibration with a tuning fork of a particular frequency, it vibrates in resonance with the tuning fork. The superposition of the waves travelling down the tube and the reflected waves travelling up the tube produce (longitudinal) standing waves which must have a node at the closed end o the tube and an antinode at the open end (Fig 10.1).

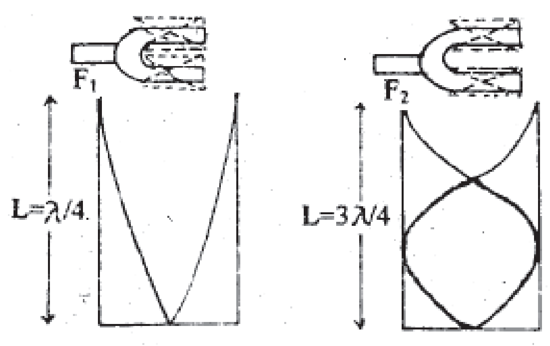


Fig. 10.1: Longitudinal standing waves of different frequencies in a tube

The resonance frequencies of a pipe or tube (air column) depend on its length L. Only a certain number of wavelengths can be "fitted" into the tube given the condition that there should be a node at the closed end and an anti-node at the open end. But you know that the distance between a node and an anti-node is $\lambda/4$ and therefore, resonance occurs when the length of the tube (air column) is nearly equal to an odd number of $\lambda/4$ i.e.

$$L = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4} ..... etc$$

Or, in general, $L = \frac{n\lambda}{4}$, where $n = 1, 3, 5$ ..... (10.1)

Where λ is the wavelength of the sound. You know that the relation between the wavelength and frequency of the sound source is

$$v = f\lambda \qquad ...(10.2)$$

Combining (10.1) and (10.2) we get, for a closed pipe,

$$f_n = \frac{nv}{4L}, \qquad n = 1, 3, 5.... \qquad (10.3)$$

The lowest frequency of ($n = 1$) is called the fundamental frequency and higher frequencies are called overtones. Hence, an air column of length L has particular resonance frequencies and will be in resonance with the corresponding driving frequencies.

It is clear from equation (10.3) that the three parameters involved in the resonance condition of an air column are f, v and L . To study resonance in this experiment, the length L of the air column will be varied for a given driving frequency (the wave velocity in air is relatively constant).

From condition (10.1) we see that the difference in the tube (air column) lengths for successive condition of resonance is

$$\Delta L = L_2 - L_1 = \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

$$= L_3 - L_2 = \frac{5\lambda}{4} - \frac{3\lambda}{4} = \frac{\lambda}{2}$$

where L_1 is the length of the air column at first resonance, L_2 at second resonance and so on.

$$\therefore \lambda = 2L \qquad ...(10.4)$$

We can determine the wavelength of sound waves by measuring ΔL. Then by knowing frequency f of the driving tuning fork, the velocity of sound in air at room temperature can be calculated using the relation :

$$\Delta v = f\lambda = 2f(L_2 - L_1) \qquad ...(10.5)$$

Material Required

Resonance tube apparatus, tuning forks, rubber mallet or block, meter stick (if measurement scale not on resonance tube) and therm otneter.

10.3 How to Perform the Experiment

(i) Note the room temperature.

(ii) Note the frequency of the tuning forks.

(iii) The resonance tube apparatus is shown in Fig.10.2. Set it in vertical position with the help of levelling screws attached to its base and spirit level. Fill the reservoir with water and raise it to adjust the water level in the long tube to a point near the top. Do not overfill the reservoir otherwise it will overflow when you lower it. Practice lowering and raising the water level in the tube to get the "feel" of the apparatus.

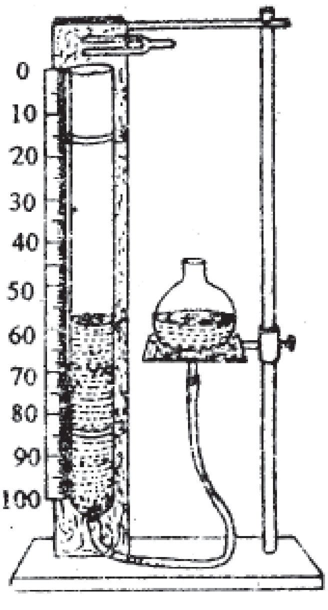


Fig. 10.2 : The resonance tube apparatus

(iv) With the water level in the tube near the top, take the tuning fork and set it into oscillations by striking it with a rubber mallet or on a rubber block, whichever is available. **Never strike the tuning fork on a hard object** (e.g. a table). This may damage the fork and cause a change in its characteristic frequency. Hold the vibrating the fork horizontally slightly above the opening of the tube so that the sound is directed down the tube. (Note that a tuning fork has directional sound-propagation characteristics. Experiment with a vibrating fork and your ear, to determine these directional characteristics).

(v) Lower the reservoir to a low position on the support rod. Adjust the water level in the tube to fall in steps of 1 cm, controlling it with the help of pinch cork. Bring the tuning fork at top of the tube each time. Continue till a loud sound is heard.

(vi) Now raising and lowering the water level in steps of 1mm try to locate the position at which maximum sound is heard. This is first resonance position.

(vii) Determine the exact position of the water level on the scale, (while noting the position, measure the length from the top of the tube) for the first resonance. Repeat the experiment thrice.

(viii) Repeat this procedure for the second resonance position, at around three times the length of air column for first resonance.

(ix) Compute the average lengths of air column for first and second resonances. Then compute wavelength from the difference between them. Using the known frequency of the fork, calculate the velocity of sound.

10.4 What to observe

Temperature of air = ...

Table 10.1 : Table for resonance positions

S.No.	Source requency Hz	First position of resonance				Second position of resonance			
		1 (cm)	2 (cm)	3 (cm)	Average L_1(cm)	1 1 (cm)	2 2 (cm)	3 3 (cm)	Average L_2(cm)
1									
2									
3									
4									

10.5 Calculations

(a) Length of air column for 1st resonance L_1 = ... cm.

Length of air column for IInd resonance L_2 = ... cm.

$\Delta L = L_2 - L_1$ = ... cm = ...m.

(b) Velocity of sound in air = $2f\,\Delta L$ = ...ms^{-1}

(c) Correct velocity of sound in air at room temperature (from tables) = ...

(d) Percent error in the result = $\dfrac{\text{observed value - correct value}}{\text{correct value}} \times 100$

= ....%

10.6 Result

(i) Wavelength of waves in air column = ... m.

(ii) The velocity of sound in air at temperature .... is found to be ms^{-1}. The correct value is .... and percentage error is ....

10.7 Check your Understanding

(i) A 128 Hz sound source is held over a resonance tube. What are the first and second lengths of air column at which resonance will occur at a temperature of 20°C? (The velocity of sound in air is temperature-dependent and is given by the relationship $V_t = 331.4 + 0.6\,t\ ms^{-1}$ where t is the air temperature in degree Celsius?

....

(ii) Why do you use the difference in lengths, of resonating air column for the first and second position, for calculating the wavelength and the velocity of sound? Explain.

....

(iii) Suppose that the laboratory temperature were 5° C higher than the temperature at which you prepared this experiment, what effect would this have had on the length of the resonating air column for each reading? Explain.

....

EXPERIMENT 11

To compare the frequencies of two tuning forks by finding the first and second resonance positions in a resonance tube.

11.1 Objectives

After performing this experiment, you should be able to:

- use the resonance tube apparatus;
- determine the first and second position of resonance;
- compare the frequencies of the given tuning forks.

11.2 What should you know

From the previous experiment, you know that an air column can be driven to resonance using a vibrating tuning fork. Resonance occurs when the length of the air column is equal to an odd multiple of $\lambda/4$. We found that if ΔL is the difference in the lengths of air column for successive conditions of resonance, then the wavelength of sound waves is given by

$$\lambda = 2\,\Delta L \qquad ...(11.1)$$

If f is the frequency of the sound source, the velocity of sound is

$$v = f\lambda \qquad ...(11.2)$$

Since the velocity of sound is constant in a given condition, for two tuning forks of frequencies f_1 and f_2 we have

$$f_1\lambda_1 = f_2\lambda_2 \qquad ...(11.3)$$

or $$\frac{f_1}{f_2} = \frac{\lambda_2}{\lambda_1}$$

Combining this equation with equation (11.1), we get

$$\frac{f_1}{f_2} = \frac{\Delta L_2}{\Delta L_1} \qquad ...(11.4)$$

Material Required

Resonance tube apparatus, tuning forks, robber mallet or block, meter stick (if measurement scale not attached to the resonance tube).

11.3 How to perform the Experiment

(i) Follow the procedural steps (i) to (viii) given in experiment No. 11.

(ii) Repeat the experiment for the second tuning fork.

(ill) Record the position for the first and second resonance for the two tuning forks in the observation table.

(iv) For each length of resonating air column, calculate the average of the three readings taken.

(v) Calculate the difference (ΔL) between length of resonating air column for the second and the first position for the two tuning forks.

(vi) Calculate the ratio of ΔL's for the two tuning forks.

11.4 What to Observe

S.No.	Tuning fork	First position of resonance				Second position of resonance			
		1	2	3	Average	1	2	3	Average
1 2 3	First								
1 2 3	Second								

11.5 Calculations

(i) Difference between the positions of first and second resonance for the first tuning fork = ... cm.

(ii) Difference between the positions of first and second resonance for the second tuning fork =............................... cm.

(iii) $\frac{f_1}{f_2} = \frac{\Delta L_2}{\Delta L_1}$ = ...

11.6 Result

The ratio of frequencies of the given tuning forks is found to be ....

11.7 Check your Understanding

(i) Should a tuning fork be set into oscillation by striking it with a rubber mallet / block or any other object? Explain.

....

(ii) For a resonance tube apparatus with a total tube length of 1 m, how many resonance positions would be observed when the water level is lowered through the total length of the tube for a tuning fork with a frequency of (a) 500 Hz, (b) 1000 Hz? (Velocity of sound in air = 347 ms^{-1}).

....

(iii) A sound source is held over a resonance tube, and resonance occurs when the surface of the water in the tube is 10 em below the source. Resonance occurs again when the water is 26 cm below the source. If the temperature of the air is 20°C, calculate the source frequency. Velocity of sound in air at temperature *t* in degree celsius, is $V_t = 331.4 + 0.6$ ms^{-1}.

....

EXPERIMENT 12

To establish graphically the relation between the tension and length of the string of a sonometer resonating with the given tuning fork. Use the graph to determine the mass per unit length of the string.

12.1 Objectives

After perfonning this experiment, you should be able to;

- set the length, of sonometer wire which resonates with the given tuning fork;
- determine the length of a string vibrating in resonance with the given tuning fork for different values of tension;
- establish graphically a relation between length and tension; and
- determine th mass per unit length of the string.

12.2 WHAT SHOULD YOU KNOW

You know that a stretched string that is set into vibrations produces musical sound. When a string stretched between two points is plucked, several modes of oscillation may be present. However, the simplest mode of vibration with lowest frequency for a given length of a string is called the fundamental mode of vibration and its frequency is given by

$$f = \frac{1}{2L}\sqrt{\frac{F}{\mu}} \qquad (12.1)$$

- Where *L is* the length of the vibrating segment, *F* is the tension in string and *n* is the mass per unit length of the string. For a given frequency and a given string, *f* and μ are constant and we have,

$$\sqrt{F} \propto L \ \ (f,\ \mu \ \text{ constant}) \qquad \ldots. \ (12.2)$$

This means that the tension *(F)* applied to the String, varies as the square of the length *(L)* necessary for resonance.

In this experiment, we shall establish the above relation by the use of a sonometer. A sonometer consists essentially of one or two piano wires stretched over a sounding box. The tens ion is applied by means of a hanger and weights suspended from each wire, by passing the wire over to a pulley and the effective length is regulated by movable bridges. The general appearance of a sonometer is shown in Fig. 12.1.

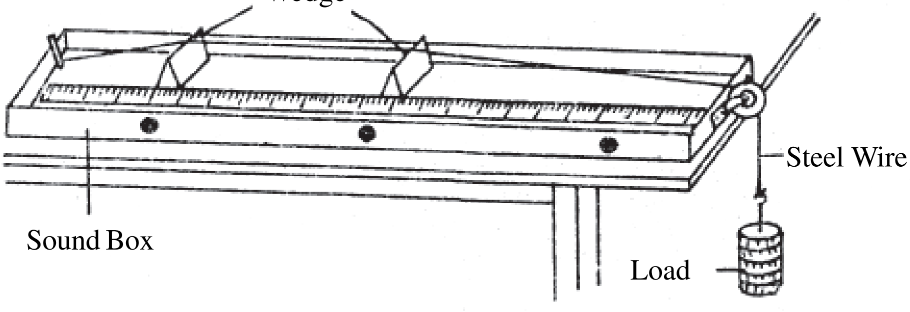


Fig. 12.1 A sonometer

Material Required

Sonometer, weight hanger and slotted weights (ten $^1/_2$ kg weights), tuning fork, rubber mallet or block, meter-stick (if sonometer does not have length scale), 2 sheets of cartesian graph paper.

12.3 How to Perform The Experiment

(i) Place the sonometer near the end of the laboratory table so that the weight hanger attached to the wire hangs freely.

(ii) Set the two bridges near the ends of the wire so as to utilize most of the length. Add weights to the -weight hanger. (Caution: *Keep your feet clear of the suspended weights incase the wire breaks or comes loose and the weights falls).*

(iii) Fold a small paper strip in V-shape and place it as a rider in the middle of the string.

(iv) Sound the tuning fork by striking it with a rubber mallet or on a rubber block. ***Never strike the tuningfork against a hard object*** (e.g. a table). ***This may damage the fork and change its characteristic frequency***. Place the base of the vibrating fork on the top of the sonometer and observe the vibrations of the paper rider. Then, vary the vibrating length of the string by sliding its bridge until the string resonates with the vibrating tuning fork. This you ensure by noting that a loud sound is heard and the paper rider flutters vigorously and falls. Measure the vibrating length of the string, that is the length between the two bridge and record thi length. Remember that the string vibrate in one segment in fundamental mode of vibration.

(v) Change the tension in the wire by adding $^1/_2$ kg weight to the hanger and repeat procedure (iv).

(vi) Repeat the experiment for 6 or more values of tension.

12.4 What to Observe

Frequency of tuning fork = ...

Variation oflength with tension.

Table 12.1 : Table for tension and length

S.No.	Total suspended mass (Kg)	Tension F(N)	$\sqrt{F}$	Length L (m)
1				
2				
3				
4				
5				
6				

12.5 Analysis of Data

(i) Riot F versus L for the given tuning fork and join the points. From the shape of the curve, guess the possible relationship between F and L. Can you use this curve to estimate the correct relationship between the two quantities ?

(ii) Plot $\sqrt{F}$ (along *y*-axis) versus L for the given tuning fork and draw the straight line that best fits the data. Determine the slope of the line. this slope is equal to $2f\sqrt{\mu}$. Divide the slope by 2f and square the value obtained. This gives μ , the mass per unit length of the string.

12.6 Result

(i) Plot of $\sqrt{F}$ versus L is found to be a straight line. This means that tension in the string varies as the square of the length of the string vibrating in its fundamental mode.

(ii) From the slope of the straight line, mass per unit length of the string = ... Kg/m.

12.7 Check Your Understanding

(i) Show that both sides of equation (12.1) have the same dimension.

....

(ii) What is the purpose of the sound board in a sonometer ?

....

(iii) A wire of mass 0.0003kg/m and 0.5m long is vibrating 200 times per second. What must be the tension in newtons ? What mass hung on the wire would produce this tension ?

....

iv) If a wire 50.8 cm long produces a note of 128 Hz, a similar wire 25.4 cm long string at the same tension, should produce a note of .... Hz.

....

v) Two wire strings have the same vibrating length and are under the same tension, but one string has a linear mass density twice that of the other. Will the fundamental frequency of the string with the greater mass density be half that of the other ? Explain.

....

EXPERIMENT 13

To find the value of v for different values of u in case of a concave mirror and find its focal length (f) by plotting graph between $\frac{1}{u}$ and $\frac{1}{v}$.

13.1 Objectives

After performing this experiment, you should be able to :

- set up an optical bench;
- determine bench correction;
- determine approximate focal length of the mirror;
- determine $'v'$ for different value of u ;
- plot a graph between $\frac{1}{u}$ and $\frac{1}{v}$.
- interpret the graph and compute the focal length of the given concave mirror.

13.2 What Should You Know

You know that for a concave mirror the reciprocal of its focal length (f) is equal to the sum of the reciprocals of image distance (v) and the object distance (u)

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{v} = -\frac{1}{u} + \frac{1}{f} \quad \ldots(13.1)$$

Comparing equation (13.1) with standard equation of a straight line, namely, $y = mx + c$ we find that graph between $\frac{1}{v}$ and $\frac{1}{u}$ should be a straight line with a slope of (-1) and intercepts on $y-$ axes equal to $\frac{1}{f}$, From this we can find the focal length of the given mirror.

Material Required

Concave mirror, optical bench with three uprights, mirror holder, two pins, knitting needle, metre rod, spirit level.

13.3 How to Set-Up the Experiment

(i) Fix an upright at zero cm mark on the optical bench and put mirror holder in it.

(ii) Place the other two uprights holding pins on the optical bench at different positions.

(iii) Level the optical bench with the help of spirit level and levelling screws.

(iv) Fix the mirror in mirror-holder and *adjust the tips of the pins so that they are in the same horizontal line as the pole of the mirror* (See Fig. 13.1).

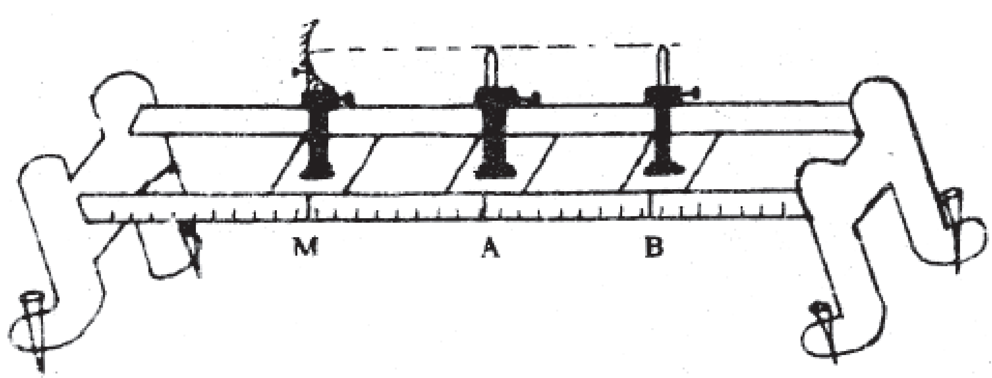


Fig. 13.1 Experimental set-up

13.4 How to Perform the Experiment

(a) **Determination of bench - correction**

(i) Place the knitting needle along the metre scale. Read the position of its two ends, *avoiding error due to parallax.* Find the length of the knitting needle *l*.

(ii) Using knitting needle, adjust the object-pin, so that the distance between the pole of the mirror and the tip of the pin is l. Now read the position of the mirror and the object-pin A, on the scale of the optical bench. Find the observed length of knitting needle as measured on the optical bench-scale, l_1.

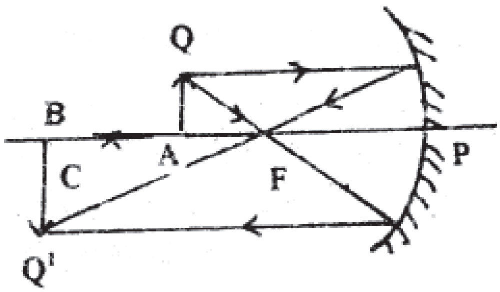


Fig. 13.2 Ray diagram

(iii) Find bench correction $(l - l_1)$ for pin A.

(iv) Repeat the same procedure for image pin 'B' also.

(b) Determination of approximate focal length of the mirror

(v) Take out the mirror from mirror-holder and hold it in such a way so that a clear distinct image of a distant object is obtained on the wall.

(vi) Measure the distance between the mirror and the wall with the help of a metre scale. This gives the approximate focal length, f_1 of the mirror.

(C) Determination of *v* for different values of *u*

(vii) Fix the mirror again in the mirror - holder.

(viii) Fix the object - pin A at a point between, f_1 and $2f_1$ but so that looking into the mirror, you will see a clear real, inverted and highly enlarged image of A.

(ix) Position the image - pin B beyond $2f_1$, so that there is no parallax between the tip of B and the tip of image of A.

(x) Fix pin B.

(xi) Repeat the procedure (ii) and (iii) for different positions of pin A between f_1 and $2f_1$ abd seeing that it is enlarged.

(xii) Record the observations in tabulated form as shown in table 13.1.

(xiii) Find the values of $\frac{1}{u}$ and $\frac{1}{v}$ for each observation, by taking u and v in metres.

(xiv) Plot a graph with $\frac{1}{u}$ on x−axis and $\frac{1}{v}$ on y−axis, taking *scone scale on both axes and start from zero on either axes*,

(xv) Read the intercept on y−axis. Reciprocal of it gives the focal length.

13.5 What to observe

(a) Determination of bench correction

Length of the knitting needle l = ... cm.

Observed separation between the mirror and pin A

on optical bench scale, when they are separated by l i.e., l_1 = ... cm.

Observed separation between the mirror and P in B, l_2 = ... cm.

Bench correction for $u = (l - l_1)$ cm $= x_1$ = ... cm.

Bench correction for $v = (l - l_2)$ cm $= x_2$ = ... cm.

(b) Rough focal length of the mirror

f_1 = ... cm, ... cm, ... cm.

Mean value of rough focal length = ... cm.

Table 13.1 : Observations for *u* and *v*

Sl. No.	Position of			Object distance		Image distance		1/u	1/v
	Mirror cm cm	object Neddle A cm	Image Neddle B cm	Observed value cm	Corrected value(u) cm	Observed value cm	Corrected value(v) cm	m^{-1}	m^{-1}
1									
2									
3									
4									
5									
6									

13.6 Analysis of Data

The graph between $\frac{1}{u}$ and $\frac{1}{v}$ is shown in the adjoining diagram.

y coordinate of point D - OD = ___________ m^{-1}

$$\Rightarrow f = \frac{1}{OD} = ...m =$$

x-coordinate of the point C = OC = ___________ m^{-1}

Slope = –OD/OC = ...

13.7 Conclusions

(i) Graph between $\frac{1}{u}$ and $\frac{1}{v}$ is a straight line with a slope = ...

(ii) Focal length of the given concave mirror = ... m.

13.8 Sources of Error

(i) Most often error in measurement occurs due to error of parallax. So parallax should be removed carefully.

13.9 Check Your Understanding

(i) What do you mean by parallax ? How is it removed between the tips of a pin and the real image of another pin ?

....

(ii) How does the size of the image Change as the object is moved away from a concave mirror ?

....

(iii) When will you get a virtual image of an object in a concave mirror ?

....

(iv) What is the importance of determining rough focal length before starting the actual experiment ?

....

(v) You are given a round piece of mirror. How will you identify whether the mirror is plane, concave or convex.

....

(vi) Why do we use small spherical mirror ?

....

(vii) Can you determine the focal length of a concex mirror using this method ? Explain.

....

(viii) Suggest any other alternative graphical methods for the determination of 'f' in this experiment.

....

(ix) In this experiment if you are given a candle and a screen in place of the two pins. Can you still perform this experiment ? Explain.

....

(x) If you are given only one pin in this experiment. Can you find the focal length of the mirror? Explain.

....

EXPERIMENT 14

To find the focal length (f) of a convex lens by plotting graph between $\frac{1}{u}$ and $\frac{1}{v}$.

14.1 Objectives

After performing this experiment you should be able to :

- set up an optical bench ;
- determine bench correction;
- determine approximate focal length of the lens;
- determine 'v' for different values of 'u';
- plot a graph between $\frac{1}{u}$ and $\frac{1}{v}$; and
- interpret the graph and compute the focal length of the lens.

14.2 What Should You Know

You know that the relation between the object distance u and the image distance v for a convex lens placed in air is

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{v} = -\left(\frac{1}{u}\right) + \frac{1}{f} \qquad ...(14.1)$$

Comparing equation (14. 1) with the standard equation of a straight line, i.e., $y = mx + C$, we find that on plotting a graph between $\frac{1}{u}$ and $\frac{1}{v}$ we will get a straight line with slope (−1) and intercept $\left(\frac{1}{f}\right)$ on y-axis.

Material Required

Convex lens, optical bench with uprights, lens holder, two pins, three knitting needle, metre rod, spirit level.

14.3 How to Set-Up The Experiment

(i) Fix an upright at 50 cm mark and put lens holder and lens in it.

(ii) Place the other two uprights holding pins on the optical bench, one on either side of the lens.

(iii) Level the optical bench with the help of spirit level and levelling screws.

(iv) Adjust the centre of the lens and the tips of the pins in the same horizontal line as shown in the diagram 14.1.

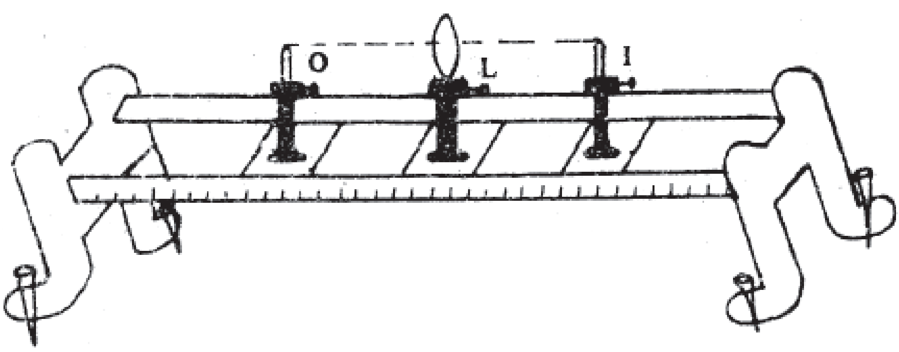


Fig. 14.1 Experimental setup

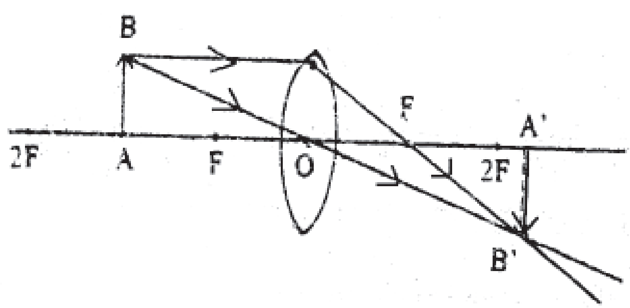


Fig. 14.2 Ray diagram

14.4 How to Perform the Experiment

(A) **Determination of bench correction**

(i) Place the knitting needle along the metre scale. Read the position of its two ends, avoiding error due to parallax. Find the length of the knitting needle 'l'.

(ii) Adjust the position of the object pin O, so that the distance between the centre of the lens and the tip of the pin is l. Read the position of the lens and the object pin O on the scale of the optical bench.

Find the observed length of the knitting needle on the optical bench scale l_1.

(iii) Determine bench correction $(l - l_1)$ for the object pin O.

(iv) Repeat the same procedure for image pin I also and find the bench correction $(l - l_1)$ for it.

(B) Determination of approximate focal length of the lens

(v) Take out the lens from lens holder and hold it in such a way so that a clear distinct image of a distant object is obtained on the wall.

(vi) Measure the distance between the lens and the wall with the help of a metre scale.

(vii) Record the approximate focal length f_1 of the lens.

(C) **Determination of v for different values of u**

(viii) Fix the lens again in the lens holder on optical bench.

(ix) Fix the object pin O between f_1 and $2f_1$ with respect to the lens. See from the other side of the lens so that a clear, real, inverted enlarged image of O is formed by the lens.

(x) Move the image - pin I, beyond $2f_1$ and remove parallax between the tip of the image of O and the tip of I by moving your eyes to the left and then to the right side of the image and seeing that the two tips remain in contact as you move your eye. Also observe on other side of the lens that parallax between the tip of pin O and tip of inverted image of pin I has been removed, (i.e. I functions as object).

(xi) Fix pin I also. Measure the separation between the uprights of L and O (i.e. u) and L and I (i.e. v) on the scale of optical bench.

(xii) Repeat the steps (ii) to (iv) for different positions of object pin O five or six times. Keep it beyond f_1 every time and see that the image formed is inverted.

(D) **Plotting the graph and calculation of f**

(xiii) Calculate the value of $\frac{1}{u}$ and $\frac{1}{v}$ for each observation by taking u and v in metres.

(xiv) Plot graph with $\frac{1}{u}$ on x−axis and $\frac{1}{v}$ on y−axis. Take same scale for both axes. Start from zero on either axes. In this graph plot also the points with values of u and v interchanged, because you observed removal of parallax on other side of the lens as well, when pin I functions as object.

(xv) Read the intercept on any axis. Reciprocal of it gives the focal length.

14.5 What to Observe

(A) Determination of Bench Correction

Length of the knitting needle l = ...cm.

Observed separation between the lens and object - pin O on optical benched scale when they are separated by l, i.e. l_1 = ... cm.

Observed separation between the lens and the image - pin when they are separated by l, i.e., l_2 = ... cm.

Bench correction for object distance $x = (l - l_1)$ cm. Bench correction for image distance $y = (l - l_2)$ cm.

(B) Rough focal length of the mirror

f_1 = __________ cm, _____________ cm, ____________ cm

Mean value of rough focal length = ... cm.

(C) Observations for *u* and *v*

Sl. No.	Position of Lens O cm	Position of Object Needle A cm	Position of Image Needle A′ cm	Object distance Observed Value OA cm	Object distance Corrected Value OA′ cm	Image distance Observed Value OA′ cm	Image distance Corrected Value OA′ cm	1/u m^{-1}	1/v m^{-1}
1									
2									
3									
4									
5									
6									

14.6 Analysis of Data

The graph between $\frac{1}{u}$ and $\frac{1}{v}$ is shown in Fig. 14.3 x-coordinate of point C,

OC = ... m^{-1} $\Rightarrow f = \frac{1}{OC}$ = __________ m = a

y - coordinate of point D, OD = ... m^{-1}

$$f = \frac{1}{OD} \quad m = b$$

Mean $f = \frac{a+b}{2} m$

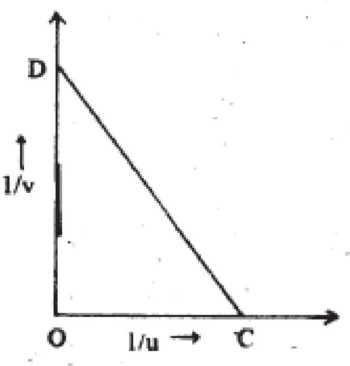


Fig. 14.3

14.7 Conclusions

(i) Graph between $\frac{1}{u}$ and $\frac{1}{v}$ is a straight line with a slope = −1 (because $a \approx b$)

(ii) Focal length of the given convex lens f = ... cm.

14.8 Sources of Error

Lens has some thickness which has been neglected in this experiment.

14.9 Check Your Understanding

(i) Give some practical uses of lenses.

....

(ii) You have a plano - convex lens having $\mu = 1.5$ and R the radius of curvature of its spherical surface. What is the value of its focal length in terms of R.

....

(iii) Power of a lens is - 2.5 Dioptre (a) what is the focal length of the lens ? (b) Is it a converging or a diverging lens.

....

(iv) Can you perform the experiment using a candle and a screen. How ?

....

(v) If a lens of $\mu = 1.5$, be immensed in water ($\mu = \frac{4}{3}$), how will its focal length change ?

....

(vi) What is the position of the object for which image formed by a convex lens is of the same size as the object ?

....

(vii) Is the image formed by a convex lens always real ?

....

(viii) How will you determine the focal length of a convex lens using one pin and a plane mirror ?

....

EXPERIMENT 15

Find the focal length of a convex mirror using a convex lens

15.1 Objectives

After performing the experiment you should be able to:

- set up an optical bench so as to obtain a real image with a convex mirror using a convex lens;
- select a suitable convex lens for performing the experiment;
- determine bench correction;
- determine approximate, focal length of the convex lens;
- determine the radius of curvature of the convex mirror; and
- determine the focal length of the convex mirror.

15.2 WHAT SHOULD YOU KNOW

You know that a convex mirror always forms virtual image of a real object and hence the value of v (i.e. the position of the image) cannot be obtained directly. Therefore, convex lens is used to enable us to form a real image due to the combination.

Let an object O be placed between f and $2f$ of a convex lens L and its image be formed at I, which we locate by removing parallax between the image pin and the image of O (Fig. 15.1).

Now keeping the position of O and L fixed we place the convex mirror between L and I at such a position so that the image of O is formed just above it (Fig. 15.2). This happens when the rays retrace their path, i.e. when the rays falls on the mirror normally. Obviously this means that MI is the radius of curvature of the mirror.

Since, $R = 2f$

$$\therefore\ f = \frac{\text{MI}}{2}.$$

Material Required

Convex mirror, convex lens (having focal length greater than that of the mirror but not greater than twice of that of the mirror), Optical bench with four uprights, knitting needle, metre-rod, spirit level.

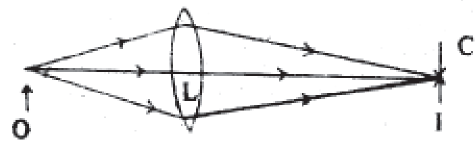


Fig. 15.1

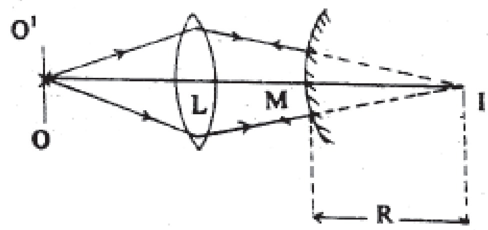


Fig. 15.2

15.3 How to Set-Up The Experiment

(i) Level the optical bench with the help of spirit level and levelling screws.

(ii) Mount the lens L in the middle of the bench and one pin on either side of it. Adjust the centre of the lens and tips of the pins in the same horizontal line.

(iii) Replace the pin I with mirror M. Check by moving M close to L that the combination of M and L behaves as a concave mirror and we receive an inverted image of O. In case inverted image is not obtained and combination still behaves as a convex mirror, then replace the lens with another convex lens of shorter focal length.

15.4 How to Perform The Experiment

(i) Find the approximate focal length f_1 of the convex lens.

(ii) Find the index-correction between the mirror M and the image needle I.

(iii) Place the object needle O at a distance greater than f_1 and remove parallax between the tip of O and its real inverted image by lens-mirror combination, by adjusting the position of mirror M.

(iv) Fix the positions of O and L and M note their positions.

(v) Remove the mirror from its upright and mount the image needle I in its place. Without disturbing O and L remove parallax between the inverted image of O and the tip of the image needle I. Note the position of I.

(vi) The distance MI is observed radius of curvature of the convex mirror.

(vii) Repeat the experiment 4-5 times by changing distance between object needle and convex lens.

(viii) Find mean R and then $f = \frac{R}{2}$.

15.5 What to Observe

(i) Approximate focal length of the convex lens f_1

= (i)................. cm, (ii)................. cm, (iii)................. cm,

Mean value of f_1 = ... cm

(ii) Real length of the knitting needle l = ... cm.

Observed length of the knitting needle between convex mirror M.

and image needle I, l_1 = ... cm.

Index correction $x = (l - l_1)$ .... cm.

(iii) Measurement of Radius of curvature of the mirror.

S.No.	Position of upright at				Observed	Corrected
	O (cm)	L (cm)	M (cm)	I (cm)	radium R_1 (cm)	$R = R_1 + x$ (cm)
1						
2						
3						
4						
5						

Mean R = ... cm

15.6 Result And Discussion

Mean focal length of the convex mirror $f = \frac{R}{2} =$ ....cm

Thus, focal length of the given convex mirror is ....cm.

15.7 Sources of Error

(i) If the image of pin O by lens alone at I is highly magnified it may not be possible to locate its position with precision. In several positions of pin I, parallax may be too small to observe.

15.8 Check Your Understanding

(i) How will you find out the focal length of a convex mirror using a spherometer ?

....

(ii) Why do we always get a virtual diminished image from a convex mirror ?

....

(iii) A convex mirror is used as a rear - view mirror in auto - mobiles. Why ?

....

(iv) Instructions in this experiment advise that focal length of convex lens should be more than that of convex mirror. If you have a lens against this advice i.e. of focal length f_1 less than that of convex mirror (f), then can this experiment be done? If so, how ?

....

(v) A convex mirror always forms a virtual image of a real object but it can form a real image of a virtual object. Explain with the help of an example.

....

EXPERIMENT 16

Determine the focal length of a concave lens by combining it with a suitable convex lens.

16.1 OBJECTIVES

After performing this experiment you should be able to:

- select a suitable convex lens which forms a converging combination with the given concave lens;
- set-up an optical bench for lens-formula;
- determine bench correction;
- determine approximate focal length of the convex lens and that of the combination;
- determine v for different values of *u* for the convex lens as well as for the combination;
- calculate the focal length of the combination, focal length of the convex lens and focal length of the concave lens.

16.2 What Should You Know

If two lenses of fecal lengths f_1 and f_2 are kept in contact, the focal length F of the combination is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \qquad \ldots(16.1)$$

As per new cartesian sign convention focal length of a concave lens is negative and the focal length of a convex lens is positive. Hence if the first lens is convex and the second is convave then the focal length of the combination of these two lenses is given by

$$\frac{1}{F} = \frac{1}{f_1} - \frac{1}{f_2} \Rightarrow F = \frac{f_1 f_2}{f_2 - f_1} \qquad \ldots(16.2)$$

where f_1 and f_2 are now magnitudes of the focal lengths.

Equation (16.1) clearly show that if f_2 is more than f_1, the focal length of the combination will be positive and hence it will behave as a converging (convex) lens.

Using two pin method, determine the focal length of the convex lens f_1 and the focal length of the combination F. The focal length of the concave lens may be determine using the formula

$$f_2 = \frac{f_1 F}{f_1 - F} \qquad \ldots(16.3)$$

Material Required

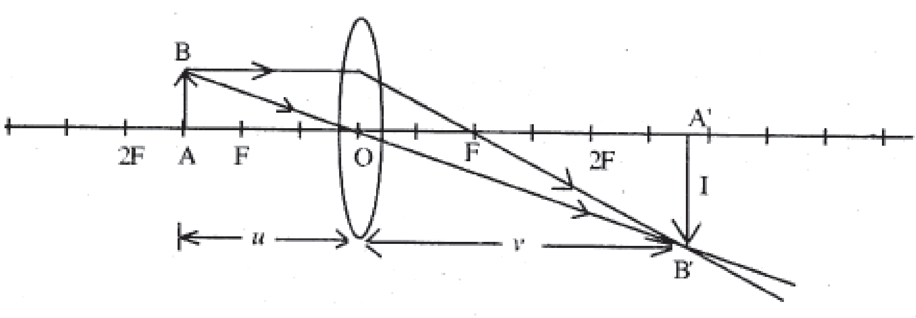
Optical bench with three uprights, knitting needle, two pins, lens holder, concave lens, convex lens, cellotape, spirit level, half metre rod.

Note : Lenses should be so chosen so that the focal length of the combination should not be greater than 20 cm, e.g. 10 cm and - 20 cm.

16.3 How to Set-up The Experiment

(i) Level the optical bench with the help of spirit level and leveling screws.

(ii) Check that the convex lens in contact with the given concave lens forms an enlarged image of a nearby object. If it makes a diminished image, change the convex lens with another one of shorter focal length.



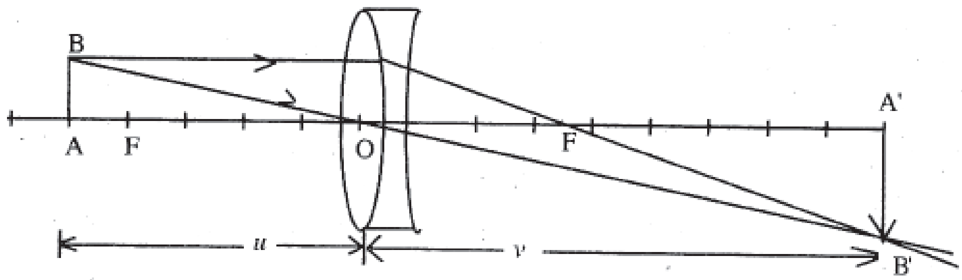


Fig. 16.1 Ray Diagram

(iii) Fix the convex lens in the middle of the optical bench and place one pin on either side of it. Adjust the centre of the lens and the tips of the pins in the same horizontal line.

16.4 How To Perform The Experiment

(i) Determine the rough focal length of the convex lens with the help of metre scale, by forming the image of a distant object on the wall.

(ii) Fix the lens in the lens holder in the middle upright and place the object - pin AB at a distance greater than rough focal length on one side of the lens.

(iii) Move the image pin and remove parallax between its tip of and the image of AB through the lens i.e. A'B' .

(iv) Note the index corrected values of *u* and *v*.

(v) Repeat the experiment for four or five different values of *u*.

(vi) Put the concave lens in contact with the convex lens. Fix them together with the help of cellotape at the rim.

(vii) Repeat the procedure for determining the focal length of a convex lens as described in steps (ii), (iii), (iv) and (v) for the combination.

16.5 What to observe

(i) Approximate focal length of the convex lens = ... cm

Approximate focal length of the combination = ... cm

Real length of knitting needle l = ... cm

Observed length of knitting needle between convex lens and object - pin l_2 = ... cm.

Observed length of knitting needle between convex lens and image - pin l_2 = ... cm.

Index correction for object-pin, $x = (1 - l_1)$ .... cm.

Index correction for object-pin, $y = (1 - l_2)$ .... cm.

The index correction is always added to the measured value to get the corrected values.

(ii) Focal length of Convex lens

S.No.	Position of uprights			Observed distances		Corrected distances		
	Object Neddle (cm)	Convex Lens O (cm)	Image (cm)	OA cm	OA' cm	u = OA + X cm	v = OA' + Y cm	f_1 = uv/u–v cm
1								
2								
3								
4								
5								

Mean f_1 = ...

(iii) Focal length of the lens combination

S.No.	Position of uprights			Observed distances		Corrected distances		f_1 = uv/u–v cm
	Object Needle (cm)	LensCom-bination (cm)	Image (cm)	OA cm	OA' cm	u = OA + X cm	v = OA' + Y cm	
1								
2								
3								
4								
5								

Mean F = ...cm.

16.6 Calculations

Focal length of concave lens f_2 (with its sign) $= -\frac{Ff_1}{f_1 - F}$ = ...cm

16.7 Result

Focal length of the given concave lens = ... cm

16.8 Sources of Error

(i) The lens has some thickness whereas the theory is strictly applicable to thin lenses.

16.9 Check Your Understanding

(i) What are the factors on which the focal length of a lens depends ?

....

(ii) Out of red and violet colour lights, which travels faster in (i) air, (ii) water ?

....

(iii) Is the focal length of a lens more for red light or for violet light ?

....

(iv) Can you determine rough focal length of a concave lens ?

....

(v) What is the minimum distance between an object and its real image formed by a lens ?

....

(vi) In the experiment you performed, the focal length of the convex lens should be smaller than the focal length of the concave lens. How will you check this ? Why is it necessary ?

....

(vii) It is difficult to mount two thick lenses in contact in the same upright. Can you perform the experiment holding the lenses in separate uprights. Explain.

....

EXPERIMENT 17

To draw a graph between the angle of incidence (i) and angle of deviation (δ) for a glass prism and to determine the refractive index of the glass of the prism using this graph.

17.1 Objectives

After performing this experiment, you should be able to :

- draw emergent rays corresponding to rays incident on the face of a prism at different angles ;
- determine the angle of deviation (δ) for various values of angle of incidence (i);
- determine the angle of prism;
- plot the variation of angle of deviation (δ) with angle of incidence (i) and hence determine the angle of minimum deviation (δ_m).
- determine the refractive index of the glass of the prism.

17.2 What should you know

You know that when light travels from one medium to another in which its speed is different, the direction of travel of the light is, in general, changed, when light travels from the medium of lesser speed to the medium of greater speed, the light is bent away from the normal. If light travels from a medium of greater speed to one of lesser speed, the light is bent towards the normal. The ratio of the sine of the angle of incidence in vacuum (*i*) to the sine of the angle of refraction (*r*) in a substance is equal to the ratio of speed of light (v_1) in the vacuum to the speed of light in (v_2) in the substance.

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = n \qquad \text{...(17.1)}$$

where the constant n is called the refractive index of the substance.

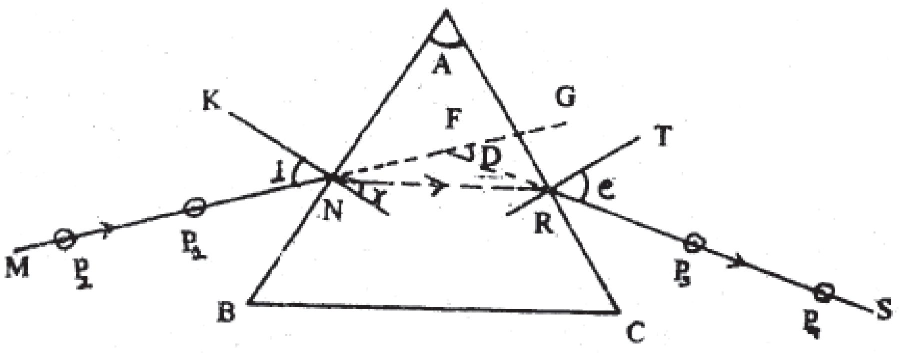


Fig. 17.1 Refraction through glass prism

If a ray MN of light (Fig 17.1) is incident on one surface of a prism ABC, the ray is bent at both the first and the second surface. The emergent ray RS is not parallel to the incident ray but is deviated by an amount that depends upon the refracting angle A of the prism the refractive index n of its material and also on the angle of incidence (i) at the first sufrace. As the angle of incidence is, say, decreased from a large value, the angle of deviation decreases at first and then increases and is minimum when the ray passes through the prism symmetrically as in Fig. 17.1. The angle of deviation, δ_m, is then called the angle of minimum deviation. For this angle of minimum deviation δ_m, there is a simple relation between the refracting angle A, the angle of minimum deviation δ_m, there is a simple relation between the refracting angle A, the angle of minimum deviation δ_m, and the refractive index n. The relation is

$$n = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\frac{A}{2}} \qquad \text{...(17.2)}$$

Material Required

Drawing board, white paper, prism, pins, pencil, scale, protractor, drawing pins.

17.3 How to perform the Experiment

(i) Fix a sheet of a white paper on the drawing board.

(ii) Draw line AB representing a face of the given prism. At a point N on this line, draw normal KN and a line MN at angle z repreesnting an incident ray. Do not keep i less than 30^0 as the ray may get totally reflected inside the prism.

(iii) Place the prism on the sheet so that its one face coincides with the line AB. Refracting edge A of the prism should be vertical.

(iv) Fix two pins P_1 and P_2 on the line MN. Looking into the prism from the opposite refracting surface AC, position your one-eye such that feet of P and P_2 appear to be one behind the other. Now fix two pins P_3 and P_4 in line with P_1 and P_2 as viewed through the prism.

(v) Remove the pins and mark their positions. Put a scale along side AC, remove the prism and then draw a long line representing surface AC. Draw line joining P_3 and P_4. Extend lines P_2 P_1 and P_4 P_3 so that they intersect at F. Measure the angle of incidence *i* (angle MNK), angle of deviation D (angle RFG) and angle of prism (angle BAG).

(vi) Repeat the experiment for at least five different angles of incidence between 30^0 and 60^0 at intervals of 5^0.

17.4 What To Observe

Table : Variation of angle of deviation with angle of incidence

S.No	Angle of incidence (i) degrees	Angle of deviation (d) degrees	Angle of prism (A) degrees
1.			
2.			
3.			
4.			
5.			

17.5 Analysis of Data

Plot a graph between i and δ keeping δ along y-axis. From the graph, find the angle of minimum deviation, δ_m from the graph. Calculate the refractive index of the glass of the prism using these values in Equation (17.2).

$$n = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin(A/2)} = \frac{\sin \text{..........}}{\sin \text{..........}} = \frac{\text{......}}{\text{......}} = \text{......}$$

m = ... degree

δ_m = ... degree

17.6 Result

The refractive index of glass of the prism = ...

17.7 Precaution

Common prisms are usually quite small with sides of 2.5 cm or 3 cm. So drawing the boundary of the prism and then measuring angle A does not lead to accurate value of A. Therefore, it is suggested that you draw a long line for faces AB and AC with a ruler and place the prism touching the ruler.

17.8 Check your Understanding

(i) A prism made of glass ($\mu = 1.5$) and refracting angle 60^0 is kept in minimum deviation position. What is the value of angle of incidence ?

....

(ii) What is the condition for the angle of minimum deviation ? In particular, what is the relation of the transmitted ray to the base of the prism ?

....

(iii) Find the index of refraction of a 60^0 prism that produces minimum deviation of 50^0.

....

(iv) Is the refractive index of glass prism different for different wavelengths ? Explain.

....

(v) A prism, $n = 1.65$, has a refracting angle of 60^0. Calculate the angle of minimum deviation.

....

EXPERIMENT 18

To compare the refractive indices of two transparent liquids using a concave mirror and a single pin.

18.1 Objectives

After performing this experiment, you should be able to :

- learn and understand that when a ray of light travels from a rarer medium to a denser medium, it bends towards the normal at the point of incidence;
- learn and understand that a concave mirrror with liquid filled in its cavity behaves like a concave mirror of smaller focal length and radius of curvation.
- Understand that one method of determining refractive index of a liquid can be the comparison of real radius of curvature of a concave mirror and its apparent radius of curvature after filling the liquid in its cavity; and
- Compare the refractive indices of two different transparent liquids.

18.2 What You Should Know

(i) When the object is placed on the centre of curvature of the concave mirror, the real inverted image is formed at the centre of curvature (i.e. at the same point).

(ii) When a ray of light falls normally on the concave mirror, it retraces its path backwards along the same line.

(iii) Refractuve index of a liquid

$$= \frac{\text{Real radius of curvature of a mirror}}{\text{Its apparent radius of curvature after filling its cavity with the transparent liquid}}$$

Material Required

A vertical clamp stand, plumb line and a metre scale, a pin, a concave mirror and the experimental liquids.

18.3 How to Set up The Experiment

(i) Put the concave mirror on a horizontal plate form (Table).

(ii) Put the vertical clamp stand near the concave mirror and clamp the object pin horizontally in the vertical rod of the stand. Adjust the tip of the object pin just vertically above the centre of the concave mirror as shown in figure 18.1.

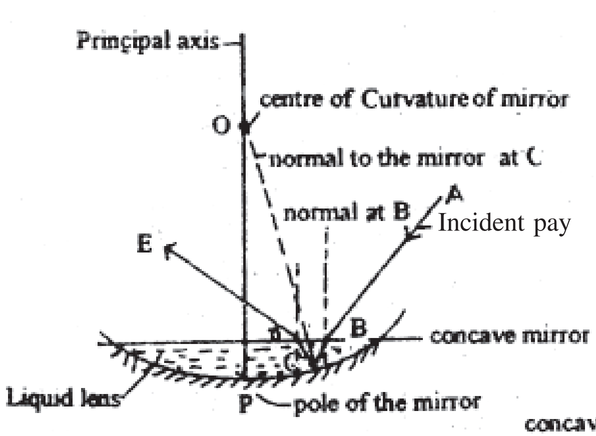


Fig. 18.1 : Ray diagram

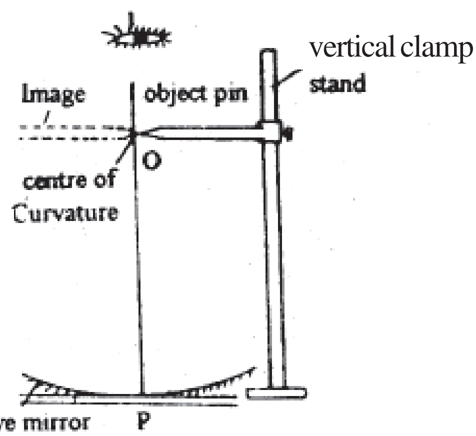


Fig. 18.2 : Showing the path ABODE of a ray of light

18.4 How to Perform the Experiment

(i) Fix the object pin in some position on the vertical stand sufficiently above the concave mirror.

(ii) Put your one eye vertically above the pin looking for the real inverted image of the pin in the concave mirror.

(iii) Move your eye slightly on to either side to find the parallax between the object pin and its real image.

(iv) Move the object pin on the vertical stand to a higher or lower position so as to coincide it with the image position. Now adjust carefully to remove the parallax between the object pin and its image. This makes the height of the image and the object pin above the concave mirror to be the same.

(v) Measure, the height of the tip of the object pin from the pole (centre) of the concave mirror with the help of a plumb line and metre scale. This gives you h_1 = real radius of curvature of the concave mirror.

(vi) Now fill the hollow cavity of the concave mirror with the given transparent experimental liquid (say, water). Wait for a minute so that the liquid becomes stationary and its level horizontal.

(vii) Again look for the image of the object pin in the concave mirror containning liquid. The image now appears to be formed nearer to the concave mirror than the object pin. Move the object pin on the vertical stand downwards towards the mirror to again coincide the image and the object pin. Remove the parallax between the two as before. This gives you h_2 = apparent radius of curvature of the combination of pf concave mirror and the liquid lens which is equal to the distance between the object pin and the pole of the concave mirror. Measure this.

(viii) Repeat the procedure thrice and calculate the mean value of h_1, and h_2.

(ix) Now, calculate the refractive index (n) of the liquid using the formula

$$n = \frac{h_1}{h_2} = \frac{\text{Distance of the object pin without liquid in the concave mirror}}{\text{Distance of the object pin with liquid in the concave mirror}}$$

(x) Repeat the observation for h_2 with another transparent liquid and compare their refractive indices.

(xi) Find out percentage error in your results :

The standard value of Refractive Inded of liquid = x(from the book)

Measured value = n = ...

Error $= n - x =$ ....

Percentage Error $\left(\frac{n-x}{x}\right)\times 100 =$ ....

18.5 What to Observe

Distance of the object pin from the mirror						
		when mirror is empty		when mirror is filled with liquid		Refractive Index of given liquid
Liquid	S. No.	h_1 cm	mean(h_1) cm	h_2 cm	mean(h_2) cm	$n = h_1/h_2$
Water	i)					
	ii)					
	iii)					
oil (turpe-time)	i)					
	ii)					
	iii)					

18.6 Result And Discussion

The refractive index of water = n_1 = ...

The refractive index of turpentine oil = a, = ...

Ratio of $\frac{n \text{ for water}}{n \text{ for oil}} = \frac{n_1}{n_2} =$ ....

Standard value of n for water = ...

Percentage error = ...

Standard value of n for oil = ...

Pertanage error = ...

It is noteworthy that oil may be a denser optical medium ($n_2 > n_1$), but it may have less density.

18.7 Sources of Error

(i) If the tip of the object pin is not touching the time of its image while removing the parallax between them, there may be difficulty in judging the correct position of non-parallax. The error may also arise in the values of h_1 and h_3 if the object pin is not horizontal.

(ii) The distances h_1 and h_2, are measured from the pole of the mirror to the tip of the object pin. However , when transparent liquid is filled in the cavity of the concave mirror, the pole gets slightly shifted upwards which cause an error in the measurements of h_2 and hence in the result.

(iii) If the platform, on which the concave mirror is placed is not exactly horizontal, its principal axis will not be vertical but slightly oblique. This will lead to errors in the values of h_1 and h_2 measured vertically.

18.8 Ways to Minimize the Errors

(i) Use a vertical clamp stand with a horizontal base to place the mirror,

(ii) Use a plumb line to measure the distances h_1, and h_2 from the tip of the object pin to the mirror to eliminate any error due to non-horzontality of the object pin.

18.9 Check Your Understanding

i) Where is the image formed when the object pin is placed at the centre of curvature of the concave mirror ?

....

ii) Where is the image formed when the object pin is placed beyond the centre of curvautre on the principal axis of the concave mirror ?

....

iii) Where is the image formed of the object pin is placed at a distance less than half the radius of curvature of the concave mirror? Explain.

....

iv) You have adjusted the position of the object pin after removing parallax in finding the distance h_1 with empty concave mirror. Now filling the concave mirror with any transparant liquid, to which side is the image displaced towards the concave mirror or away from the concave mirror ?

....

v) When you move the object pin towards the mirror, does the position of image remain fixed or the image also moves ?

....

vi) Suppose, the object pin is at a distance of 30 cm from the concave mirror and its image is at a distance of 20 cm from the concave mirror. How much distance the object pin is be moved towards to concave mirror to coincide with the image.

(a) 10 cm (b) less than 10 cm (c) more than 10 cm.

....

vii) When you fill a concave mirror with refractive index 1.3, the valve of h_2 measured is 25 cm. What will be the valve of h_2 when the same concave mirror is filled with a liquid of refreactive index 1.25.

....

viii) Can you use this method to find the refreactive index of mercury ? Explain.

....

EXPERIMENT 19

To set up an astronomical telescope and find its magnifying power.

19.1 Objectives

After performing this experiment you should be able to :

- correctly place an eye lens and an objective lens on the optical bench so that these make an astronomical telescope;
- point this telescope to a distant object and adjust positions of eye lens and objective lens so as to see a sharp image of the object ;
- estimate with some precision the height of enlarged image of a distant object as seen through telescope, against a scale with bold marks seen directly; and
- calculate the magnifying power of the telescope.

19.2 What you should know

Astronomical telescope consists of two converging lenses. One is the objective lens O (Fig. 20.1) of a long focal length f_0. The other is the eye lens E of short focal length f_e . A distant object is seen through it by keeping the objective lens towards that object. For simplicity, assume that the axis of the telescope EO points towards the base A of the distant object AB situated for beyond the figure. The objective lens makes a real, inverted and diminished image A' B' of that object.

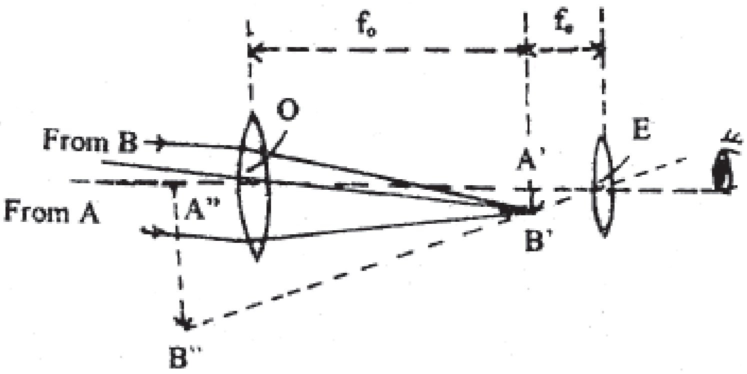


Fig. 19.1 : Ray diagram of telescope

As the rays enter the eye lens, A'B' functioning as the new object, its virtual magnified image A"B" is formed. Thus you observe fine details in A"B" by the eye lens. the image A'B' is at the focus of lens O and also is approximately at the focus of lens E. Therefore, separation between the lenses is

$$OE = f_0 = f_e \qquad (19.1)$$

Magnifying power of the telescope is

$$m = \frac{\text{angle subtended by the image A''B'' at E}}{\text{angle subtended by tech object AB at O}}$$

$$= \frac{\angle A'EB'}{\angle A'OB'} = \frac{A'B'/f_e}{A'B'/f_0} = \frac{f_0}{f_e} \qquad (19.1)$$

In order to observe the image of distant object through the telescope, your eye should not be too close to the eye lens E. This lens makes a real image of lens O at I (Fig. 19.2). It is just beyond the outer focal point F_e of the lens E.

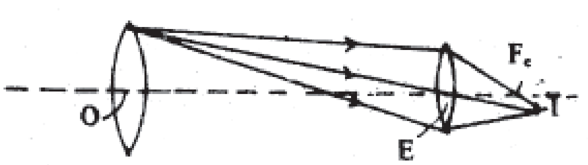


Fig. 19.2

All light rays entering through O and passing through lens E, also pass through this image. This is called the exit pupil of the telescope. Pupil of your eye must coincide with this image in order to receive all the light coming through objective and the eye lens. This enables you to see all the objects that the telescope is capable of seeing at one time.

Material Required

An optical bench with three lens-uprights, objective lens (f = 50cm to 80 cm, diameter - 50 mm), eye lens (f = 5 cm to 10cm diameter = 20 mm to 50 mm), circular carboard diaphram (O.D. - 50 mm, central hole diameter - 15mm), a scale with bold marks, metre scale.

Note :

1. Both lenses must be made of a good opthalmic or optical glass and not cheap ones made of window glass. It ensures that the image A"B" (Fig. 19.1) has enough details and these are seen clearly by lens E.
2. It is preferable that the lenses are plano convex. If so the plane sides of both the lenses will be kept towards your eye. But double convex lenses will also make a good telescope, if these are of good glass.
3. If the diameter of eye elens is too small to be fixed in the upright of the optical bench (e.g. 20 mm) then it must be fitted in the centre of a circular frame of O.D. = 50 mm. You can improvise such a frame of card board too, as shown in Fig. 20.3. C_2 is a circular disc of diameter 50 mm. It has a hole equal to the lens, which holds the lens. C_1 and C_3 are discs of same O.D., but with smaller holes and prevent the lens from slipping out of the disc C.

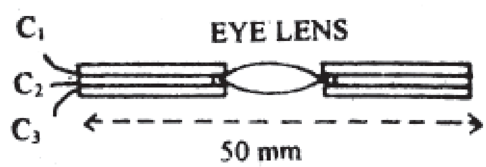


Fig. 19.3

19.3 How to Perform the Experiment

(A) Setting up the Telescope

(i) Find the focal length of the objective Lens f_0, by focussing the image of a distant bright object on a

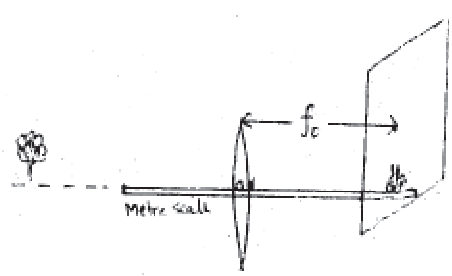


Fig. 19.4

screen, or on a wall of your laboratory and measuring its distance from the lens (Fig. 19.4). Similarly, find the focal length of eye lens f_e. These are only approximate values.

(ii) Calculate appoximate distance between the two lenses, $f_0 + f_e$ for telescope making.

(iii) Fix the eye lens in one upright and keep it at the 10 cm mark on the optical bench.

(iv) Mark a small cross (x) in the centre of the objective lens. Fix it on another upright. Adjust the height of its centre above optical bench equal to that of the eye lens. Then keep it on the optical bench at a distance $f_0 + f_e$ from the eye lens.

(v) Fix the diaphram D in the third upright. Adjust the height of its centre above optical bench equal to that of the eye lens. Then keep it on the optical bench at a distance slightly more than f_e from the eye lens on the side opposite to the objective lens (Fig. 19.5). You should now see the image of cross mark on objective lens made by eye piece at the centre of the diagphram. Make fine adjustments in the position of diaphram vertically, horizontally and along length of the optical bench. Thus you locate the exit pupil of the telescope.

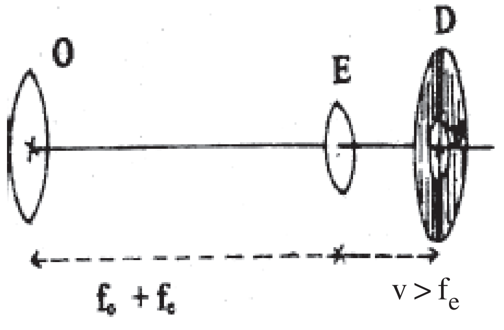


Fig. 19.5

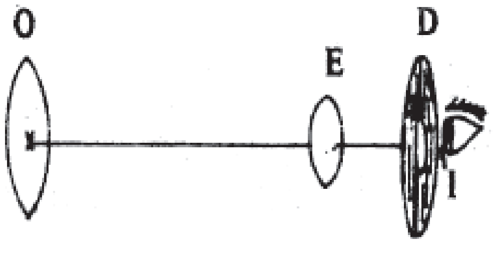


Fig. 19.6

(vi) Now point this telescope to any distant object. Keep your eye at the hole in diaphram D (Fig. 19.6) and look at in inverted image of the object. You will have to move the diaphram a little forward. You may also have to adjust the position of lenses O and E a little in order to focus a sharp image of the object.

(B) Finding the Magnifying Power

(vii) Keep the scale with bold marks vertical in front of the telescope at a distance of atleast 10m. If your laboratory is not long enough, do this part of experiment in the corridore.

(viii) Adjust the position of eye lens so that the final virtual image of the scale is roughly at the same distance as the scale seen directly. For this adjustment you may look by one eye (say the right eye) into the telescope and by the other eye look directly at the scale. When proper adjustment is done, you see the scale and its magnified image together, as if stuck to each other.

(ix) Your scale with bold marks is such that it can be seen clearly by your left eye at a distance of upto 20 m. Observe on it the size of the enlarged image of one smallest division see through the telescope by the right eye (Fig. 19.7). Ratio of the size of this enlarged image to size of the division gives the magnifying power of the telescope.

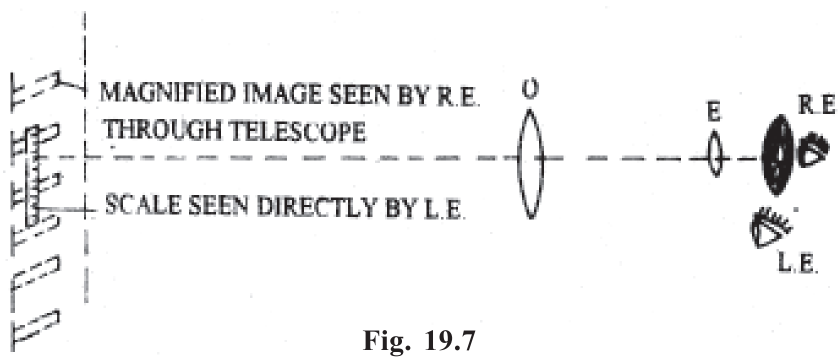


Fig. 19.7

(x) Repeat the observation of step (9) for two divisions of the scale, three divisions of the scale, and so on. Thus obtain a few more measured values of magnifying power. Find the mean of all these values.

Note :

(i) If the scale is not placed distant enough, the magnifying power obtained by you may be larger than the theoretical vlaue $\frac{f_0}{f_e}$. Compare your result with the theoretical value and account for the difference.

(ii) If you normally wear spectacles for distance vision, do not remove them for this experiment. However, distance between the pupil of your eye and the spectacle being around 2 cm, you have to move the diaphram forward by about 2 cm after locating the exit pupil of the telescope.

19.4 Observations and Calculations

(A) Setting up the Telescope

Approximate focal length of objective, f_0 = ... cm.

Approximate focal length of eye lens, f_e = ... cm.

Position of eye lens on the optical bench = ... cm.

Position of objective on the optical bench = ... cm.

Position of diaphram on the optical bench = ... cm.

(B) **Measuring Magnifying Power**

S.No.	No. of small divisions observed(n)	No.of small divisions seen directly which match with magnified image (n')	Magnifying power $m = \frac{n'}{n}$
1			
2			
3			
4			

Mean value of m = ...

(C) **Verification**

Theoretical magnifying power, $\frac{f_0}{f_e}$ = ...

19.5 Conclusion

(i) Inverted magnified image of a distant object is seen through the astronomical telescope.

(ii) Observed magnifying power of the telescope = ...

(iii) $\frac{f_0}{f_e}$ = ...

19.6 Sources of Error

i) f_0 and f_e have been measured only approximately.

ii) Expression $m = \frac{f_0}{f_e}$ is valid only for the case when object - and its final virtual image are both at infinity. But it is not so in the experiment.

iii) Lenses used in the experiment are not achromatic. Thus image seen in the telescope made in the experiment is not quite sharp as it would be in a standard telescope using achromatic lenses, Thus magnifying power cannot be found quite accurately.

19.7 Check Your Understanding

i) An astronomical telescope is made using an objective lens of $f_0 = 80$ cm and eye lens of $f_e = 100$ mm. Find its magnifying power when the distant object and final image, both are at infinity.

....

ii) What is the distance between the objective lens and eye lens of the Telescope in Q.1 ? If you observe an object at a distance of 8 m from the objective lens, how much must be the distance between these lenses ?

....

iii) What is exit pulpil of an astronomical telescope ?

....

iv) Why is it necessary to keep the pulpil of your eye at the exit pupil of the telescope ?

....

v) At what distance from eye lens is the exit pupil of the telescope in Q.1 ?

....

vi) Design a telescope of magnifyrng power 25, in which the distance between objective lens and eye lens is only 52 cm.

....

vii) A newspaper is kept erect, as it is kept to read comfortably at close distance. But, it is being seen from a distance by an astronomical telescope, so that words are seen clear. Then, will it be read comfortably ? Give reason for your answer.

....

viii) A certain head-line in a newspaper can be read comfortably by unaided eye at a maximum distance of 4m. We make an astronomical telescope of magnifying power 10 using non-achromatic lenses, as in this experiment. By this telescope we try to read the same words at a distance of 40m, keeping them inverted. Will the words be read comfortably through the telescope ? Give reason for your answer.

....

PART C

C.1 Introduction

In this part you will be concerned with experiments which illustrate basic principles of electricity. This is, perhaps, the single most important gift of modern science to mankind. Let us discuss some issues which concern almost, all the experiments in this part.

C.2 Dry Cell

A dry cell is the simplest source of electric current for your experiments. A single new cell has an e.m.f. of a little over 1.5 V. A new battery of 6 cells may have an e.m.f. of 9.2 V. But when it provides current in a circuit, the p.d. at its terminals is much less, because it has a high internal resistance.

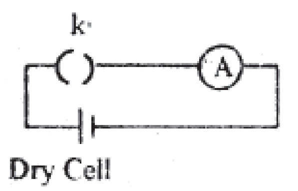


Fig. 1

Condition of a dry cell is best judged by its short -circuit, current, i.e. the amount of current supplied by it when its terminals are joined directly to an ammeter (Fig. 1). of course for a very short time. When the short-circuit current is about 25% or 20% of that for a new cel1. then the cell needs to be rejected. It cannot be recharged and used over again.

C.3 Lead Accumulator

As its name indicates. it is the kind of cell which accumulates electric energy, e.m.f. of a fully charged cell is about 2.08 V. When its e.m.f. falls to about l.9 V, it must be recharged. If you continue to use it still, then it gets 'SULPHATED' when its e.m.f. falls to about 1.8 V and then it cannot be recharged.

During the process of charging it, if you continue to charge it even after it is fully charged, water in its electrolyte continues to decompose into O_2 and H_2. This kind of 'OVER-CHARGING' is harmless, except that "water level" falls in the cell. Thus you need to check the water level in a cell frequently and 'top' it with distilled water. A good practice is to check the water level every time you recharge it, or atleast once a month. If thus maintained. this cell can be easily re-used 500 times or even 1000 times. Even then there is a time limit of about 3 years or 4 years on its life-span.

Unlike a dry cell. you never test the short-circuit current of a lead-accumulator. Its' internal resistance is quite low. Thus. if its terminals are directly connected for a while. a very heavy current passes in the circuit. which can damage the cell. With this heavy current when you break the circuit, the tiny self-inductance of wires will cause a strong spark to jump across the point where you break the circuit.

A good indicator of the condition of a lead accumulator is its e.m.f. Another is the density of H_2SO_4 in it.

C.4 Rheostat

A rheostat is the simplest device to control the current in an electric circuit. It consists of a resistance wire wrapped in a single layer on a tube of a non-conducting material. Both ends of the wire are fixed into terminals A and B (Fig. 2). A third terminal can make contact anywhere on the wire with the help of a sliding contact. It can be used in two ways.

(a) As a variable resistor: When it is connected in series in a circuit by terminals A & C or by terminals B & C, it functions as a variable resistor, which can be used to control the current in the circuit.

(b) As a potential divider: Apply the p.d. of a battery across terminals A and B, thus passing a current in the entire length of the wire. Then depending on the position of the sliding contact, the terminal C provides any desired potential difference between A and C.

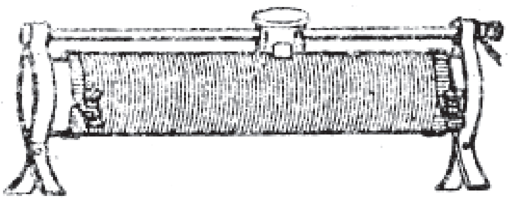


Fig. 2

An important precaution while using a rheostat is to see that the wire is clean along the line where sliding contact touches it. Also the brushes of the sliding contact should not be loose. They should make a firm contact with the wire, so that the contact resistance between terminal C and wire may be negligible.

C.5 RESISTANCE BOX

A resistance box is a device which provides you a standard resistance of any value upto a certain maximum. For example. it may have resistance wires of 1. 2. 2, 5, 10, 20, 20 and 50 ohm in series. Each resistance has its own plug key in parallel with it (Fig. 3).

To obtain a desired resistance a suitable combination of keys is kept open and the rest are closed. The keys which are closed are counted as zero, the resistance of their plugs being negligible. The current which enters at terminal A, passes only through those resistance wires

whose keys are open. Thus resistances of wires corresponding to open keys are added up to find the resistance provided by that combination. In this manner this design of resistance box can provide any standard resistance upto 110 ohm in steps of 1 ohm.

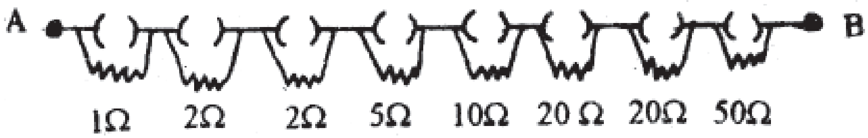


Fig. 3

An important precaution in using a resistance box is, that all the plug keys must be quite clean. If they are not clean, each closed key will have some contact resistance and these can add up to produce an error of a few ohms. If in the resistance of, say, 5Q, you want the error to be not more than 0.01 Q, then resistance of each closed key should not exceed about 0.001 Q. The keys can be cleaned by a liquid cleaner which is meant to clean and shine metallic surfaces (e.g. Brasso). A sand paper should not be used for this purpose. The sand paper makes the surface rough, which results in contact between the plug and brass blocks at a few points only.

C.6 GENERAL INSTRUCTIONS FOR MAKING CIRCUIT CONNECTIONS

In electricity experiments, you often have a circuit diagram. You are required to connect various pieces of apparatus by copper wires according to that diagram for performing the experiment. The ends of copper wire may have an oxide layer on them. Thus on connecting an end to a terminal, resistance of this oxide layer may add an extra resistance in the circuit. To eliminate this contact resistance, ends of each copper wire should be cleaned by sand paper, to remove the oxide layer. Check whether the surfaces of the screws of the terminals are also clean. If not, clean them by a liquid cleaner (e.g. Brasso). Sand paper does make the surface of wires rough. But copper being a soft metal, when screw presses on the wire, contact is established over a substantial area.

When you connect a few cells in series to obtain an e.m.f. more than what one cell can provide, then positive of each cell connects to negative of the adjacent cell (Fig. 4). But in case of a circuit element like ammeter or voltmeter, the situation is the exact opposite. The terminal marked (-) is to be connected to the terminal marked (-) on the battery.

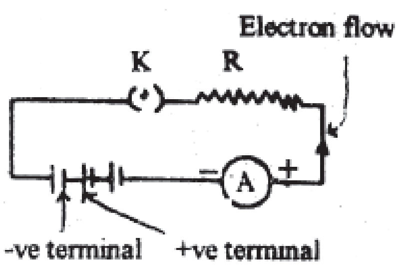


Fig. 4

The flow of current in a circuit is actually drift of electrons only (except in electrolytes or semi-conductors). The terminal marked (-) n a cell provides electrons to circuit and (+) receives them back (Fig. 4). However, we state the direction of current to be opposite to the direction of electron flow, i.e. we find it convenient to talk in terms of the conventional.current, in which we imagine positive charge flowing in the circuit (Fig. 5).

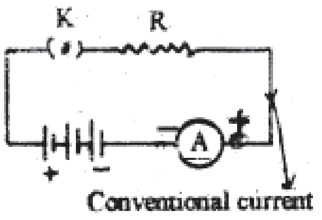


Fig.5

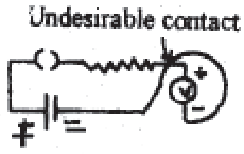


Fig.6(a)

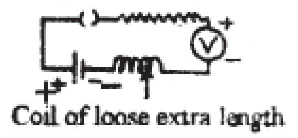


Fig.6(b)

In making electrical connections it is preferable to use wires insulated by a double layer of cotton (DOC wires). If wire of two different parts of the circuit happen to touch each other (Fig. 6a), still they do not get electrically connected due to this insulation. Even then it is a good precaution to layout your circuit in such a way that such undesired contact of wires does not take place.

If there is a loose extra leagth of wire in some part of the circuit, it may be wound into a coil (Fig. 6b). In an a.c. circuit, such loose extra length of wire may be double-folded and then wound into a non-inductive coil.

EXPERIMENT 20

To verify the law of combination (series and parallel) of resistances using ammeter -voltmeter method and coils of knon resistances

20.1 Objectives

After performing the experiment you should be able to:

- determine the least count of an ammeter and a voltmeter:
- make connections of an electrical circuit according to a circuit diagram;
- understand the concepts of series and parallel combination of resistances;
- know the function of various components used in the circuit;
- recognise the sources of error in the electrical circuits; and
- understand voltage or potential difference and. current relationship.

20.2 What should you know

You know that according to Ohm's law. when a steady current I flows through a conductor the potential difference across its ends is directly proportional to it. provided that the physical conditions remain the same.

$$V \propto I \text{ or } V = RI$$

When two or more resistances are connected in series then the net resistance of such a combination is equal to the sum of the individual resistances.

If two resistances rand r, are connected in series, then net resistance $R,$ is given by the relations

$$R_S = r_1 + r_2$$

When two or more resistances are connected in parallel the reciprocal of the total resistance of such combination is equal to the sum of the reciprocals of the individual resistances. For two resistances and r_2 connected in parallel, the net resistance R_p of the combination is given by

$$\frac{1}{R_p} = \frac{1}{r_1} + \frac{1}{r_2}$$

Material Required

A battery, an ammeter, a voltmeter, rheostat, one way key, sand paper, coils of known resistance and connecting wires.

Note: It is advisable to select the ammeter and voltmeter of lowest available range.

20.3 How to perform the experiment

1. Determine the least count of the voltmeter and ammeter, and note the zero, error, if any
2. Draw the electrical circuit as shown in the Fig. 20.1 in your copy and make connections according to it. Make sure that connections are neat and tight and insulation from ends of the wires is properly removed by sand paper.
3. Insert the key K, slide the rheostat contact and thus see that ammeter and voltmeter are working properly.
4. Observe the zero error of each instrument by making the current-zero by taking out the key K. Then again insert the key K.
5. Adjust the sliding contact of the rheostat such that either ammeter or voltmeter gives full scale deflection reading. Deflection in the other instrument also should be more than half of the full scale deflection.
6. Note down the value of potential difference V from voltmeter and current I from ammeter.
7. Take atleast three sets of independent observations.
8. Repeat the whole experiment for parallel arrangement as shown in Fig. 21.2.

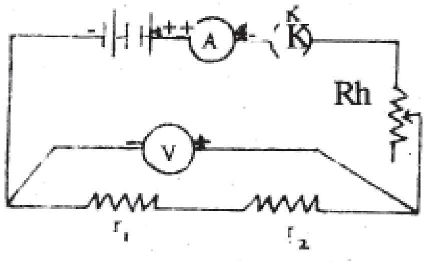


Fig.20.1: Series combination of resistances

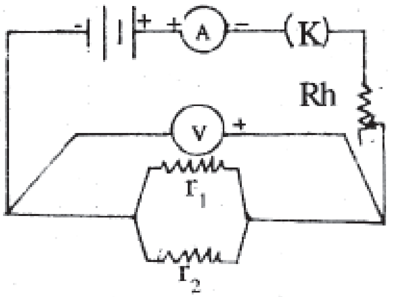


Fig.20.2: Parallel combination of resistances

20.4 What To observe

(i) Least count of the given ammeter = ... ampere (A)

Least count of the given voltmeter = ... volt(V)

(ii) Zero error in the ammeter = ... ampere.

Zero error in the voltmeter = ... volt.

Zero correction for ammeter = ... A

Zero correction of voltmeter = ...V.

Marked value of resistance r_1 = ... ohm.

Marked value of resistance r_2 = ... ohm.

Table 20.1 : Table for mean resistance

Resistance wire/coil	No.of obs	Ammeter Reading		Voltmeter Reading		$\frac{V}{I} = R$ Ω	Mean resistance Ω
		obsd. (A)	corrected (A)	obsd. (V)	Corrected (V)		
r_1 and r_2 in series	1						
	2						
	3						
r_1 and r_2 in parallel	1						
	2						
	3						

20.5 Calculations

(i) **In Series:**

(a) Experimental value of R_S = ... ohm

(b) Theoretical value of $R_S = r_1 + r_2$ = ... ohm

(c) Difference (if any) = ... ohm

(b) In parallel :

(a) Experimental value of R_p = ... ohm.

(b) Theoretical value of $R_p = R_p = \frac{r_1 r_2}{r_1 + r_2}$ = ... ohm

(c) Difference (if any) = ... ohm.

20.6 Result

(i) Within limits of experimental error, experimental and theoretical values of R_s are same. Hence law of resistances in series is verified.

(ii) Within limits of experiment error, experimental and theoretical values of R_p are same. Hence law of resistances in parallel is verified.

20.7 Sources of Error

(i) The connections may be loose.

(ii) There may be some insulations at the ends of connecting wires left over even after cleaning them by sand paper.

20.8 Check Your Understanding

(i) Why are thick connecting wires used in an electrical circuit?

....

(ii) What would happen if some student connects voltmeter in series?

....

(iii) Why should not a large value of current pass through a conductor while doing an experiment?

....

(iv) How do you come to know if a conductor obeys the Ohm's Law?

....

(v) What could be the possible reasons for ammeter showing nearly zero reading and voltmeter showing battery voltage ?

....

(vi) If you are getting full batter voltage across voltmeter and no deflection in ammeter. What changes will you make to set the circuit right ?

....

(vii) If by mistake some students connects ammeter across the series / parallel combination of resistance and voltmeter in series in the circuit, what reading will be shown by ammeter and voltmeter.

....

EXPERIMENT 21

To compare the e.m.f.'s of to given primary cells by using a potentiometer

21.1 Objectives

After performing the experiment you should be able to:

- make connections of an electrical circuit according to a circuit diagrams;
- know difference between voltmeter and potentiometer;
- know how to find null point on the wire;
- recognize the sources of error in the electrical circuit;
- understand the role of rheostat in controlling the current in an electric circuit; and
- find e.m.f of a given cell with the help of a standard cell.

21.2 What should You Know

You know that a voltmeter is a device used for measuring the terminal potential difference of a cell. But in the process of measuring, it draws a small current from the cell. A potentiometer is an instrument used for measuring without drawing any current, the potential drop across two points in a circuit, or e.m.f. of a cell. It is also used for comparing the e.m.f s of two given cells.

If E_1 and E_2 are the e.m.f s of the two given cells and l_1 and l_2 are the two balancing lengths respectively on the potentiometer then

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

Material Required

A potentiometer with atleast 4 m wire, an ammeter, a galvanometer, a voltmeter, a resistance box, a jockey, sandpaper, a one way key, a Leclanche cell, a Daniell cell, a two way key and rormectine; wires.

21.3 How To perform the Experiment

i) Draw the circuit diagram in your copy as given in Fig. 21.1.

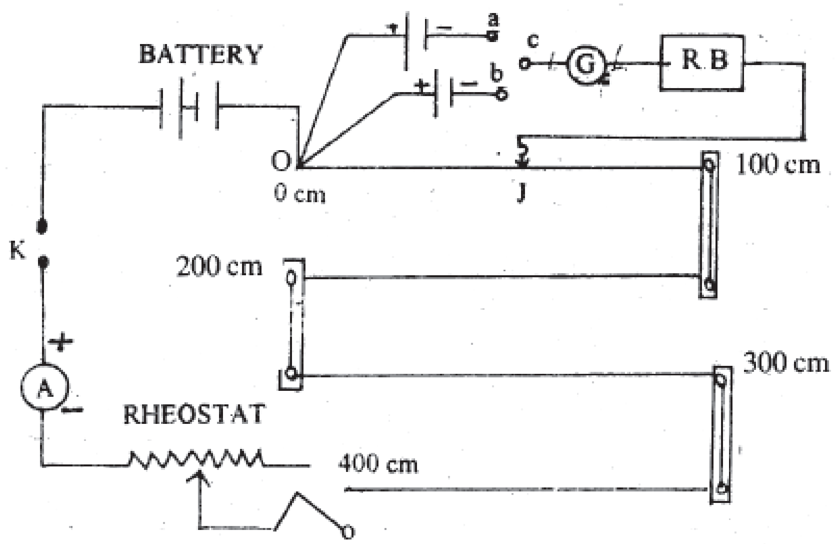


Fig. 22.1

(ii) Make the connections as shown in the circuit. *Be sure to remove the insulations from the ends of connecting wires with sandpaper.*

(iii) Make sure that the negative end of the ammeter is connected with the negative terminal of the battery. The positive terminal of the battery should always be connected to the zero end of the potentiometer.

(iv) Always keep the key, K, open while making connections.

(v) Make the resistance in the rheostat minimum by drawing current for full scale deflection of the ammeter from the battery.

(vi) Close the one-way key (K) and take out a 1000Ω plug from the resistance box for safety of the galvanometer while first searching approximate po ition of null point. Insert the plug between the terminals a and *c* to connect the cell E_1, in the circuit. E_1, is the Lec1anche cell.

(vii) Now, gently press the jockey at the zero end of the potentiometer and note the deflection in the galvanometer. Press the jockey at the other end of the potentiometer wire. If the two deflections in the galvanometer are in the opposite direction then the connections are correct. In case the two deflections are in same directions, then potential drop across the potentiometer is less than E_1 Then current in potentiometer has to be increased.

(viii) Now, gently slide the jockey over the potentiometer wire till the galvanometer shows no deflection. This position of jockey is approximate position of null point. Put back the 1000Ω plug in the resistance box and make fine adjustment of null point, since the galvanometer becomes more sensitive with zero resistance in the resistance box. Note this position of null point as first position and now move the jockey 5 cm beyond this position and locate the second position of this null point by sliding back the jockey and take mean of these positions as l_1.

(ix) Take down the ammeter reading and note the length l_1 for the cell E_1.

(x) Disconnect the cell *B* by removing the plug from gap *ac* and insert the plug between gap *bc to* connect th cell E_2 and repeat the process.

(xi) Obtain an accurate position of null point for the second cell E_2 also by making resistance zero in the resistance box and note the length l_2, Make sure that the ammeter reading remains precise) the same as that for cell E_1, when you measured l_1.

(xii) Change the current in the circuit by adjusting the rheostat and obtain at least three sets of observations similarly. If the null point for E_1 in first set was on first or second wire, you must decrease the current for subsequent sets so that this null point shifts to 3rd or 4th wire.

21.4 What To observe

Least count of the ammeter = ... ampere.

Sl. No.	Ammeter Reading	Balancing point for E_1			Balancing point for E_2			$\frac{E_1}{E_2} = \frac{l_1}{l_2}$
		1 (cm)	2 (cm)	Mean l_1 (cm)	1 (cm)	2 (cm)	Mean l_2 (cm)	
1								
2								
3								

21.5 Result

The ratio of emfs, $\frac{E_1}{E_2}$ = ...

21.6 Sources of Error

(i) The potentiometer wire may not be of uniform cross-section throughout its length.

(ii) The e.m.f. of the auxiliary battery may not be constant during the experiment.

(iii) Contact resistances at the ends of the wires of potentiometer may not be negligiable due to rusting and a considerable amount of voltage may drop across them.

21.7 Check Your Understanding

(i) What do you understand by the e.m.f. of a cell?

....

ii) What is a potentiometer? What is its principle?

....

iii) What is potential gradient along the potentiometer wire?

....

iv) On what factor does the potential gradient depend?

....

v) Why is the uniform thickness of potentiometer wire so important?

....

vi) Why do we use a rheostat in the battery circuit?

....

vii) Why do we not want the balance point to be on the first or second wire?

....

viii) What material is preferred to make potentiometer wire and why?

....

ix) What will you do to get balance point on 3rd and 4th wire of potentiometer?

....

x) You are given Leclanche and Daniel cells for comparing their emfs. For which cell would you prefer to find the balance point first and why ?

....

EXPERIMENT 22

Determine the specific resistance of the material of two given wires using a metre bridge.

22.1 Objectives

After performing the experiment, you should be able to :

- find the least count of a screw guage;
- know the difference between resistance and specific resistance;
- identify the factors on which resistivity of a wire depends;
- make the connections of an electrical circuit;
- know the connections of an electrical circuit;
- find the position of balance point on the wire; and
- know the sources of error in an electrical circuit

22.2 What Should you Know

Metre bridge is the practical form of Wheatstone's bridge where P

$$\frac{P}{Q} = \frac{R}{S}$$

P and Q are called ratio arms R is adjustable and S is the unknown resistance. For a wire of uniform area of cross - section, if null point obtained at length l (Fig. 22.1)

$$\frac{P}{Q} = \frac{l\sigma}{(100-l)\sigma} = \frac{1}{(100-l)}$$

as the total length of the wire of metre bridge is 100 cm, where σ is resistance per unit length of the bridge wire. Therefore,

$$S = \frac{(100-l)}{l} R$$

Material

A metre bridge, a galvanometer, a jockey, a Leclanche cell, a one way key, a resistance box, a metre scale, sandpaper, connecting wires and screw gauge.

22.3 How to Perform The Experiment

(i) Draw the circuit diagram given below in your notebooks and make the connections according to the circuit diagram.

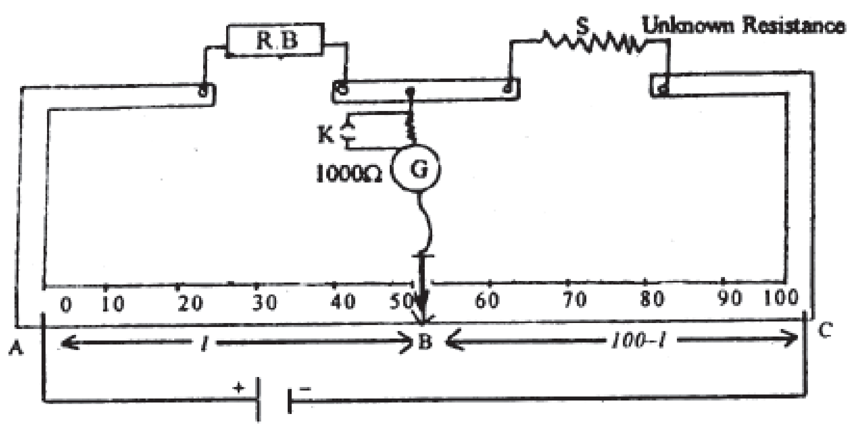


Fig. 23.1: Null position on the meter bridge wire

(ii) Remove the insulations from the ends of the connecting wires with the help of sand paper and make neat, clean and tight connections.

(iii) Make sure that the resistance in the resistance box is of same order of magnitude as the unknown resistance S.

(iv) To check whether the connections of the circuit are correct, take out a plug from the resistance box to introduce suitable resistance in the circuit. Open the key K. Now the 1000Ω resistor makes galvanometer safe. Touch the jockey gently, first at the left and then at the right end of the metre bridge wire. If the deflections in the galvanometer are in opposite directions, the connections are correct.

(v) Now choose an appropriate resistance *R* from the resistance box. This is the rough position of null point. Now close the key K and then make fine adjustment of null point. Slide the jockey on the metre bridge wire gently by touching and lifting it again and again till the galvanometer reads zero nearly in the middle of the wire.

(vi) Record the lengths of both parts of the wire in the observation table.

(vii) Repeat the above steps two time more by selecting the suitable value of *R* for getting null point between 30 cm and 70 cm.

(viii) Now cut the resistance wire S at the points where it leaves binding tenninals. Straighten it by stretching and remove 3 kinks.

(ix) Measure the diameter of the wire by a screw guage atleast the different points. At each point, the diameter should be measured in two mutually perpendicular directions.

(x) Repeat the whole experiment for second wire of different material.

22.4 What to Observe

i) Measurement of resistance S :

No.of obsv.	Resistance R(ohm)	Position of null point AB = l (cm)	BC = (100-l)(cm)	$S = \frac{(100-l)}{l} R$ ohm
1				
2				
3				

Mean value of the resistance of the wire -

S = ... ohm

Note: In another identical table record observations to find resists S' of your second wire.

ii) Length of the first wire (L) = ... cm.

Length of the second wire (L') = ... cm.

iii) Pitch of the screw gauge (P) = ... cm.

Number of divisions on circular scale = 100.

Least count (a) $= \frac{P}{100}$ = ... cm.

Zero error (e) = ... cm.

Zero correction *(-e)* = ... cm.

iv)

Sl. No.	Reading along one direction			Reading along mutually perpendicular direction			Mean Obs.dia	Corrected diameter
	MSR	CSR	Obsd.dia	MSR	CSR	Obsd.	$d_0 = \frac{(d_1 + d_2)}{2}$	$d = d_0 - e$
	s_1	n_1	$d_1 = s_1 + n_1 a$	s_2	n_2	$d_2 = s_2 + n_2 a$		
1								
2								
3								

Note: In another identical table record observation to find diameter *d′* of econd wire.

Mean corrected diameter *(d)* of first wire = ... cm.

(d') of second wire .... cm.

(v) Specific resistance of the material of the given wires-

For first wire $\rho = S\frac{\pi d^2}{4l}$ = ... ohm metre.

For second wire $\rho = S_1\frac{\pi d'^2}{4l}$ = ... ohm metre.

Standard value of specific resistance of the material of the given wires-

ρ_0 = ... ohm m.

ρ'_0 = ... ohm m.

22.5 Conclusion

The specific resistance of the material of the given wires -

ρ = ... ohm m.

ρ' = ... ohm m.

22.6 Sources of Error

(i) The instrument screws may have much contact resistance.

(ii) The plugs may not be clean and tight enough giving rise to contact resistance.

(iii) The wire of the metre bridge may not have uniform crossectional area.

22.7 Check Your Understanding

(i) Why should the metre bridge wire have uniform thickness?

....

(ii) What are end resistances?

....

(iii) What is null point?

....

(iv) Why is it advised to keep the null point between 30 cm and 70 cm?

....

(v) Why should the moving contact of Jockey not be pressed too ha or should not be scratched along the wire?

....

(vi) Why should the current be passed only while taking an observation?

....

(vii) It has been advised to connect a high resistance (1000 ohm) series with the galvanometer while trying to find the null point. Why?

....

EXPERIMENT 23

Determine the internal resistance of a primary cell using a potentiometer

23.1 OBJECTIVES

After performing this experiment, you should be able to:

- explain the principle of operation of a potentiometer and the meaning of 'null point';
- explain the necessary conditions for obtaining, null point on the potentiometer wire;
- obtain null point on the potentiometer wire for a given cell / given arrangement making the required adjustments, if necessary;
- investigate the dependence of l_2 on R and give explanation for the same; and
- compute internal resistance of the cell from the observed data.

23.2 What Should You Know

(i) A cell is characterised by its e.m.f. ε. When current is drawn from a cell, there is a movement (flow) of ions in the electrolyte between the electrodes of the cell. Resistance offered by the electrolyte to the flow of ions in it is called the internal resistance of the cell and is denoted by r:

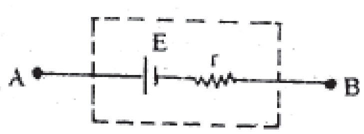


Fig. 23.1

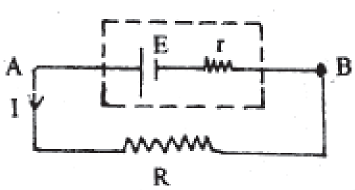


Fig. 23.2

(ii) Schematically, internal resistance r of a cell is shown as part of a cell of *emf* ε whose terminals A and B only are available to us for making connections (Fig 23.1)

(iii) When a resistance R is put across a cell of e.m.f. S and internal resistance r (23.2), the current drawn from the cell will be

$$I = \frac{E}{R+r}$$

and the terminal potential difference V across the terminal A and B of the cell and hence across *R* will be

$$V = IR = \left(\frac{\varepsilon}{R+r}\right)r$$

$$\Rightarrow V\ (R+r) = \varepsilon r$$

$$\Rightarrow r = \left(\frac{\varepsilon}{V} - 1\right)R \qquad \text{...(23.1)}$$

iv) When a constant current is maintained in a wire of uniform cross-sectional area, potential difference between any two points on the wire is directly proportional to the length of the wire between the two points.

v) Null point is a condition which refers to zero deflection shown by a galvanometer connected in an electrical network. On either side of the null point the galvanometer deflection is on opposite side of zero.

vi) In the circuit arrangement shown in Fig. 23.3 if l_2, is the length of the potentiometer wire between the terminal P and the null point when the cell is in open circuit then

$$E \propto l_1 \quad \text{or} \quad E = kl_1 \qquad \text{...(23.2)}$$

If the null point is obtained at a length l_2 when the cell is in close circuit then

$$V \propto l_2 \quad \text{or} \quad V = kl_2 \qquad \text{...(23.3)}$$

From (1), (2) and (3) we get

$$\frac{E}{V} = \frac{l_1}{l_2} \quad \text{and} \quad r = \left(\frac{l_1}{l_2} - 1\right)R$$

Material Required

A 4m wire/10m wire potentiometer, a battery, two one-way keys, a rheostat of low resistance, a high resistance box RB (H), a low resistance box RB (L), a voltmeter, a Leclanche cell, a jockey, a galvanometer, connecting wires, sand paper.

23.3 How to sep up the Experiment

(i) Clean the ends of the connecting wires with the sand paper and make tight connections as per the circuit diagram shown in Fig. 23.3.

(ii) Before connecting a key in the circuit, remove the plug from it.

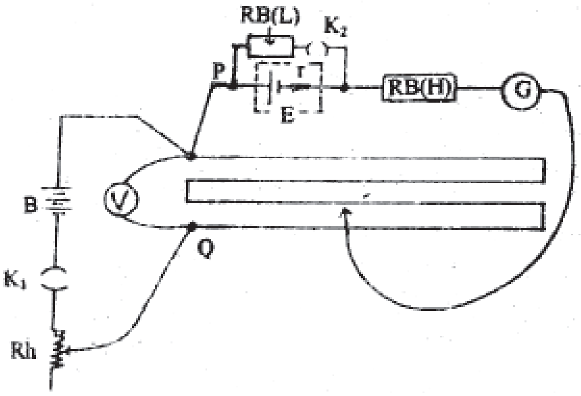


Fig. 23.3 : Circuit diagram of a potentiometer

23.4 How to perform the Experiment

(i) After having assembled the circuit, check it once again with the circuit diagram.

(ii) Keep the rheostat resistance at its maximum and then insert the plug in key K_1.

(iii) Take out some high resistance plug (say 5000Ω) from the resistance box RB(H).

(iv) Place the jockey J first at terminal P of the potentiometer wire and then at terminal Q of the potentiometer wire. The galvanometer deflection must be on opposite sides of zero in the two cases. If it is so, the null point will be obtained somewhere on the potentiometer wire. If the galvanometer deflection is on one side of the zero only, adjust the rheostat to a lower resistance value till you get deflection on opposite sides of the zero. Rheostat should be so adjusted that the null point is preferably on the last wire of the potentiometer.

Note: To get null point somewhere on the potentiometer wire, the voltmeter reading must be greater than the *emf* of the experimental cell.

(v) Starting from the terminal P gently slide the jockey J along the potentiometer wire till you get zero deflection in the galvanometer. This is a rough adjustment of null point, because with 5000Ω resistance in series galvanometer is quite insensitive. This step is necessary for safety of the galvanometer.

(vi) Now make resistance 0 ohm in the resistance box RB(H) and adjust the Jockey J again. if required. to make fine adjustment of null point position. Measure the distance of this null point (called the balancing length l_1 from the terminal P along the potentiometer wire and record it. Take 2 or 3 observations for l_1, in this manner.

(vii) Take out 5000 Ω plug resistance again from the resistance box RB(H). Take out some resistance R (say 5 Ω) from the resistance box RB (L) and insert the plug in key K_2. Repeat steps (v) and (vi) above to obtain null point Measure the distance of this null point (called the balancing length 1) from the terminal P along the potentiometer wire and record it In this manner take 2 or 3 observations for 1_2 also.

(viii) Repeat step (vii) for several R's say 6Ω, 7Ω, 8Ω, 9Ω and 10Ω. All through the observations, the voltmeter reading should remain constant. Adjust rheostat. if required. to keep the voltmeter reading constant. For this purpose battery B *should be fully charged.* Also during these observations key K_2 should be closed for as little time as possible.

(ix) In the end repeat measurement of l_1 with K_2 open to check up if emf of cell changed in the process of doing the experiment. Take l_1 as the mean of all the readings taken in the beginning and in the end.

23.5 What to Observe

Voltmeter reading = ... volts

S.No.	Balancing length l_1 (Key k_2 open)				Balancing length l_2 (Key k_2 open)			$r = f\left[\left(\frac{l_1}{l_2}\right)-1\right]R$
	Length increas-ing cm	Length decreas-ing cm	Mean cm	R Ω	Length increas-ing cm	Length decreas-ing cm	Mean cm	Ω
1				5				
2				6				
3				7				
5				8				
5				9				
6				10				
7								
8								

23.6 Result

1. For R = 5Ω

   r =

2. For R = 6Ω

   r =

3. For R = 7Ω

   r =

4. For R = 8Ω

   r =

5. For R = 9Ω

   r =

6. For R = 10Ω

   r =

   Internal resistance of the given Leclanche cell lies between .... and ....

   when it is shunted with a resistance of between .... and ....

23.7 Sources of Error

(i) Primary cells cannot deliver large currents for long duration. This is due to the increase in their internal resistance. So while finding balancing length l_2 for a particular *R,* if the key K_2 is kept closed for a longer duration, l_2 will be affected. Hence calculated value of internal resistance will not be exact,

(ii) Calculation of *r* is based on the measured values of l_1 and l_2 for some value of *R*. Error in measurement of l_1 and l_2, will introduce error in *r.*

23.8 Check Your Understanding

(i) Carefully look at the observations recorded by you in the Observation Table. You notice that as *R* is increased, l_2, increases-Give an explanation for this.

As *R* approaches infinity, what value will l_2 approach?

....

ii) Suggest some other method of finding internal resistance of a primary cell.

....

iii) For the given primary cell used by you, why is the calculated value of the internal resistance for different values of R not be same?

....

iv) It is known that the *emf* of the primary cell is proportional to the null/balancing length l_1, On what factors does the constant of proportionality depend?

....

v) What factors govern the accuracy of a measurement using a potentiometer?

....

vi) For finding internal resistance of a cell, which potentiometer will you prefer - a 4 m wire potentiometer or a 10m wire potentiometer? Give reason for your answer.

....

vii) What is the material of the wire used in a potentiometer?

....

viii) Why should potentiometer wire be of uniform area of cross-section?

....

ix) In the formula $V = \varepsilon - Ir$, what does the term *'Ii'* represent?

....

x) Can the terminal potential difference of a cell be greater than the emf of the cell? Explain your answer.

....

23.9 Suggested Activities

(i) Replace the Leclanche cell with a 1.5V dry cell which has almost been consumed. Obtain null point for balancing length l_2 for $R = 5$ ohm. Keep the jockey J at the position of the null point for some time. Does the galvanometer deflection remain zero throughout? Repeat this observation for $R = 50\Omega$. Explain your observations.

(ii) Internal resistance of a cell puts an upper limit on the current that can be drawn from the cell. For this reason a number of cells may be joined in series and/or parallel to get the desired *emf* and internal resistance. Take two identical dry cells. Using the circuit diagram of figure find the internal resistance for their series and parallel combination.

By comparing balancing lengths l_1, for their series and parallel combination comment on the *emf* of the series and parallel combination of cells.

EXPERIMENT 24

Determine the inductance and resistance of a given coil(inductor) using a suitable series resistance and an AC voltmeter

24.1 Objectives

After performing this experiment you should be able to:

- explain the principle behind the experimental determination of Land *r;*
- select appropriate value of *R* and give justification for the same;
- observe and record the voltmeter reading with due regard to the least count of the voltmeter; and
- compute the value of self inductance and resistance of the inductor from the recorded data using the method of vector addition.

24.2 What Should You Know

(i) Depending upon its number of turns, area of cross-section of each turn, length of the coil and the permeability of the material of the core, every coil has certain self-inductance L.

(ii) In addition to its self-inductance, every coil has certain resistance *r*. For a given coil the value of *r* depends on the length of the wire, its area of cross-section (or thickness) and the resistivity of the material of the wire used for making the coil.

Fig. 24.1 Symbol of on inductor

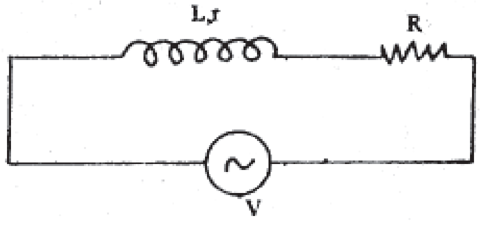


Fig. 24.2 Circuit diagram

(iii) Symbol of an inductor is as shown in Fig. 24.1. Here L and *r* stand for the self inductance and resistance of the inductor respectively.

(iv) Refer to the circuit arrangement shown in fig.24.2

The *rms* voltages across the inductor and the series resistor R, as measured by an AC voltmeter will not be in phase and therefore cannot be added straight away to get the applied rms voltage.

ie $V_{applied} = V_L + V_R$

Instead, V applied is the vector sum of V_L and V_R.

Material Required

A step - down transformer (Its secondary windings to be used as an inductor), a resistance box, a voltmeter (range 0-15V), a step down transformer (220-12V AC 50 Hz), connecting wires, a key, sand paper.

24.3 How to set up the Experiment

Clean the ends of the connecting wire with the sand paper and make tight connections as per the arrangement / circuit diagram shown in Fig. 24.3.

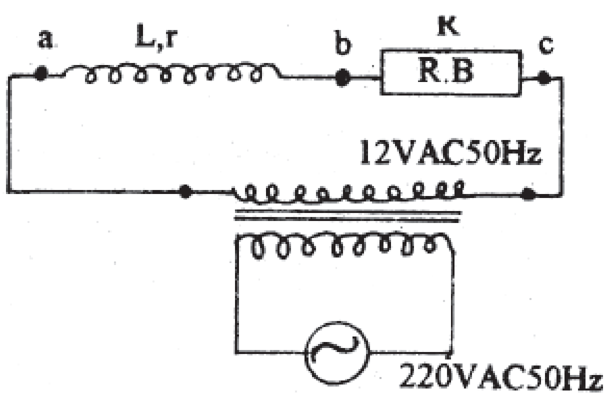


Fig. 24.3

24.4 How to Perform The Experiment

(i) After having assembled the circuit, check it once again with the circuit diagram.

(ii) Before inserting the plug in the key, take out $R = 200$ ohm plug from the resistance box.

(iii) Insert the plug in the key. Put the voltmeter first across the inductor and then across the resistance box. If needed, adjust *R* till the voltmeter reading is of the same order.

(iv) Read and record voltmeter readings V_L and V_R across L and R respectively. Put voltmeter across the series combination of L and R and read and record V.

(v) Repeat step (iv) above for 5 different values of R and record your observations in the observation table.

24.5 What to Observe

Lease count of AC voltmeter = ...

S.No.	Resistance R in series with the inductor (ohm)		Voltemeter Reading	
		across the inductor V_L (volt)	across the resistor R V_R(volt)	across the series combination of inductor and resistor $V_{applied}$ (volt)
1				
2				
3				
4				
5				
6				

24.6 Result and Discussion

Let us first learn how to add two vectors V_L and V_R to get $V_{applied}$. For example, let $V_R = 8.2$ Volts, $V_L = 6.8$ Volts and $V_{applied} = 12.2$ volts. It will be convenient to represent V_R by a vector whose length is 8.2 cm. Similarly V_L and $V_{applied}$ can also be represented by vectors of lengths 6.8 cm and 12.2cm respectively.

Draw a line AB = V_R = 8.2 cm (Fig. 24.4). From B drawn an arc of radius BC - V_L = 6.8 cm with the help of a compass. From A draw an arc of radius AC = $V_{applied}$ = 12.2cm. Here C will be the point of intersection of the arcs as shown join A and B with C. Extend AB and drop a perpendicular CD on it from C.

$$\frac{AB}{BD} = \frac{R}{r} \quad \text{and} \quad \frac{CD}{BD} = \frac{X_L}{r}$$

Thus, r can be calculated from the first equation and thus X_L can be calculated from the second equation. Further $X_L = \omega L$ where $\omega = 2\pi f$ and $f = 50$ Hz for AC mains. Thus self inductance L of the coil can also be calculated.

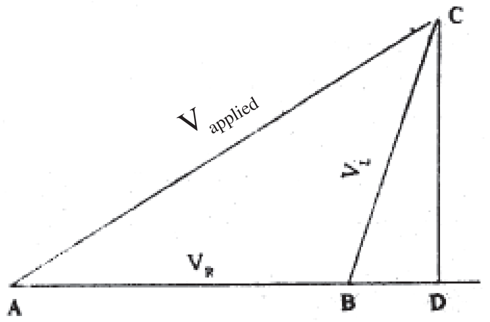


Fig. 24.4

Calculations :

S.No.	r	X_L	L
1			
2			
3			
4			
5			
6			

Result :

The mean value of self inductance (L) of coil = ...

The mean value of internal resistance (r) of the coil = ...

24.7 Sources of Error

(i) There may be error in the measurement of V_R, V_L and $V_{applied}$ because of the finite least count of the voltmeter used,

(ii) During the course of measurement of V_L and V_R the applied voltage $V_{applied}$ may change due to fluctuations in the AC main voltage.

24.8 Check Your Understanding

i) On what factors does the self inductance of a coil depend?

....

ii) A coil of resistance R and inductance L is unwound and its wire is straightened. What will happen to its L and R ?

....

iii) An inductor put across a 6V DC source draws a current of 1A and across a 6V 50 Hz AC source draws a current of $\frac{1}{2}$ A . What is the impedance and the inductive reactance of the coil?

....

iv) How can the DC resistance of an inductor be determined experimentally ?

....

v) An AC voltmeter connected between *a* and *b* (Fig. 24.5) reads 30 volts and when connected between *b* and *c* reads 40 volts. How much will it read when connected between *a* and *c* ? Assume the inductor to be a pure inductor.

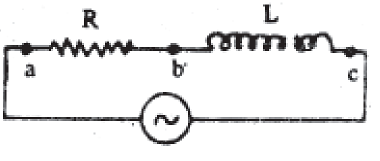


Fig. **24.5**

....

vi) In the experiment you have performed, can we replace the AC source by a DC source ?

....

vii) A current of 1A is drawn from a 10V DC source when an inductor of inductance L and resistance r is connected to it. Will the current be more or less when the 10V DC source is replaced with a 10V AC 50Hz source ?

....

viii) A coil connected across 6V 50Hz source draws 1A current from the source. What will happen to the current when the 6V 50Hz source is replaced with a 6V 100Hz source ?

....

ix) Look at the observation table and answer why $V_{applied} = V_R + V_L$?

....

x) What is the phase difference between V_R and V_L? Is it 90^0, or less than 90^0, or more than 90^0?

....

EXPERIMENT 25

Study decay of current in a RC circuit while charging the capacitor, using a galvanometer and find the time constant of the circuit.

25.1 Objectives

After performing this experiment you should be able to:

- observe galvanometer deflection versus time for a given set of R and C values;
- record the variation of charging/discharging current shown by the galvanometer deflection with time;
- plot galvanometer deflection versus time using appropriate scale; and
- compute the time constant and $T_{1/2}$ graphically and compare them with those calculated using the values of R and C.

25.1 What Should you Know

(i) Capacitance C of a capacitor is defined as the ratio of charge Q-to-electric potential difference V.

(ii) Each capacitor is characterised by its capacitance and the maximum voltage it can withstand. Thus a 1000 μF 10V capacitor can be charged to a maximum potential difference of 10 volts.

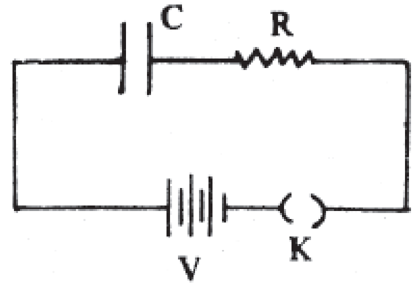


Fig. 25.1

(iii) Refer to the circuit shown here (Fig. 25.1). Let the capacitor be uncharged initially. On closing the key at $i = 0$ the charging current I in the circuit decreases exponentially with time from its initial value $I_0 = VIR$ to zero as $I_0 = I_0 e^{-e/RC}$.

(iv) From here it follows that in a time t = RC, called the time constant, the charging current becomes

$$I = I_0 e^{-1} = \frac{I_0}{e} = \frac{I_0}{2.72}.$$

or $$I = 0.37\, I_0.$$

(v) Is also follows from here that $I = \frac{I_0}{2}$ in a time $t = T_{1/2}$ (called half-life) such that

$$\frac{I}{I_0} = \frac{1}{2}\, e^{-T^{1/2}/RC}$$

or $e^{+T_{1/2}/RC} = 2.$

$$\Rightarrow \frac{T_{1/2}}{RC} = (\log_{10^2})\, RC = 2.303 \log_{10^2}$$

$$\Rightarrow T_{1/2} = 2.30(\log_{10^2})\, RC = 2.303 \times 0.3010 RC.$$

Material Required

Electrolytic capacitor 2000µF 10V, a high value resistance box RB(H). A3V/9V battery, single keys, a stop watch, connecting wires, sand paper.

25.3 How To set up theExperiment

Clean the ends of the connecting wires with the help of sand paper. Connect the circuit shown in Fig. 25.2.

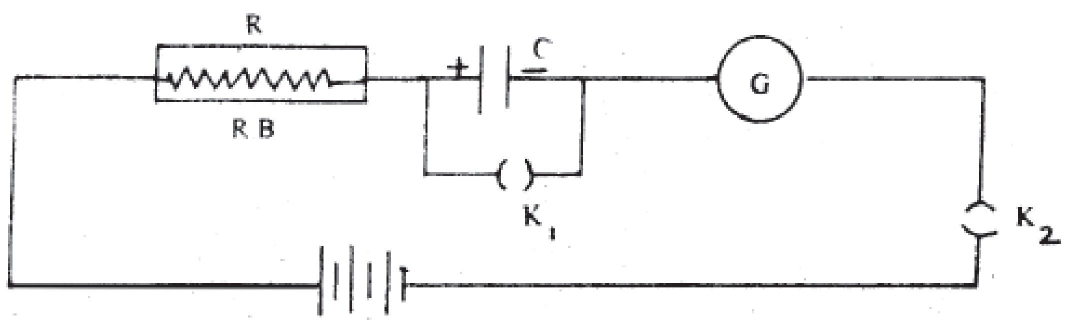


Fig. 25.2

While making connections take care to connect the positive terminal of the 2000 μF 10V, capacitor to the positive terminal of the battery. Also take care to remove plugs from the keys before connecting them in the circuit.

25.4 How To Perform The Experiment

i) Check the circuit for the connection by comparing it with the circuit diagram.

ii) Note that the galvanometer pointer is at '0'. If needed, adjust it to bring it to 0 (consult Laboratory technician).

iii) Close key K_2.

iv) Introduce a high value resistance (say 10,000Ω) in the circuit from the resistance box. This is done to keep the galvanometer deflecting within its scale when key K_2 is closed.

v) Now close key K_2 also, and adjust the resistance box to get full scale deflection in the galvanometer. Record R, the resistance offered by the resistance box in the observation table.

vi) Keep the stop watch ready. As you remove the plug from the key K_1 start the stop watch at the same time (say $t = 0$). From this time on ward the capacitor will start charging will start charging.

vii) Record the time every time when the galvanometer deflection becomes 24 divisions, 20 divisions 16 divisions .... 4 divisions, 3 divisions, 2 divisions.

viii) Plot galvanometer deflection θ along Y–axis against time t along axis as shown below (Fig. 25.3).

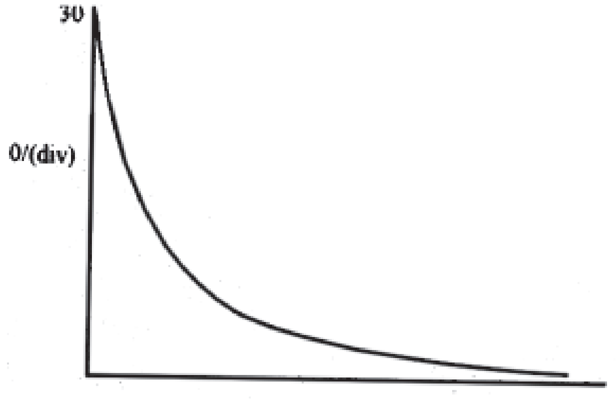


Fig. 25.3 : Galvanometer deflection (Q) verses time (t). time/(s)

ix) From the graph find $T_{1/2}$ the "time" in which the galvanometer deflection reduces to 50% of its initial value and compare it with 0.69 RC. Choose several initial values e.g. 30 div, 20 div. 10 div., 6 div. For each initial value find $T_{1/2}$. If these value of $T_{1/2}$ are equal within experimental error, find their mean.

x) From the graph find the time in which the charging current hence galvanometer deflection falls to 0.368 times its initial value i.e. θ falls from initial value of 30 div to (.362) (30) i.e., 11 divisions, or 22 divisions to 8 divisions, or 16 to 6, or 11 to 4, approximately and compare it with RC.

xi) The value of RC i.e. time constant should be sufficiently large to record the observations properly.

25.5 What to Observe

i) Resistance offered by the resistance box, R = ...

ii) Capacitance of the capacitor, C = ...

iii) Least count of the stop watch = ...

S.No.	Charging current in galvanometer divisions.	Time in second				From graph	
		Set I	Set II	Set III	Mean	Half life (S)	Time Constant (S)
1.	30						
2.	24						
3.	20						
4.	16						
5.	12						
6.	10						
7.	8						
8.	6						
9.	4						
10.	3						
11.	2						

Mean half life = ...

Mean time constant = ...

RC = ...

$0.693 \times RC$ = ...

25.6 Result And Discussion

i) For any initial current, it takes the same time to reach its half value.

ii) Mean half life for R = ... Ω, C = ... μF is = ... s.

Theoretical half life $0.693 \times RC$ = ... sec.

iii) Mean time constant for R = ... Ω and C = ... μF is ....sec.

Theoretical time constant = ... s.

25.7 Sources of Error

i) There may be some error in the calculation of RC time constant and $T_{1/2} = 0.693$ RC on account of the following:

(a) R should also include galvanometer resistance which though small may not be negligible.

(b) Electrolytic capacitors have large tolerance i.e. their actual capacitance may differ from the printed value by 20%.

(ii) There may be error in recording galvanometer deflection and in recording time using stop watch on account of finite least count of these instruments.

25.8 Check Your Understanding

i) Capacitors of capacitance 100 μF and 220μF are charged one by one by connecting them to the same battery. Which of them will charge to a higher potential difference?

....

ii) What type of capacitor is preferably used for studying the RC time constant?

Why ?

....

iii) Time constant of a given Rand C is found to be 40 seconds. What will be the new time constant if:

(a) another identical capacitor is put in parallel with the first?

(b) another identical resistor is put in series with the first?

....

iv) Which graph in the Fig. 25.4 corresponds to larger time constant? Why?

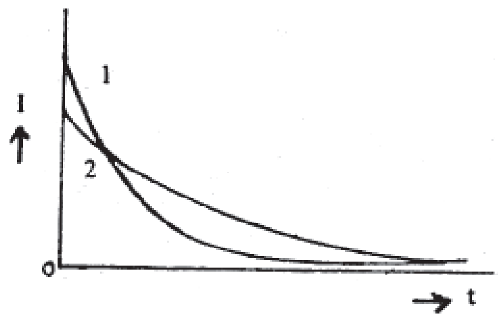


Fig. 25.4

v) What does the area under the current verses time curve represent?

....

vi) Why do we use large values of R and C for studying the charging of the capacitor ?

....

vii) For studying charging of a 1000 μF capacitor through a resitstor, you are given two resistors of values 10KΩ, 100KΩ. Which of the resistors will you prefer ?

....

viii) Given below are three different combinations of R and C.

(A) R = 100 KΩ C = 1000 μF

(B) R = 68 KΩ C = 1000 μF

(C) R = 220 KΩ C = 100 μF

(a) Which combination gives you the longest time constant ?

(b) Which combination gives you largest discharging current at $t = 0$ when each capacitor charged to the same potential difference is discharged through its respective R ?

....

ix) Can we study the discharging of a capacitor through a resistor for the purpose of finding the RC time constant by measuring the fall of the potential difference across the capacitor with time with the help of a voltmeter ? why ?

....

25.9 Suggested Activities

(i) To study discharging of a capacitor charged to 10V(say) through a voltmeter of range (0 - 10V).

(ii) Charging a 2000μF 10V uncharged capacitor through a 100KΩ resistor by connecting it to another 2000 μF 10V capacitor charged to 9 Volts.

EXPERIMENT 26

To draw the characteristic curve of a forward biased pn junction diode and to determine the static and dynamic resistance of the diode.

26.1 Objectives

After performing this experiment, you should be able to :

- identify the cathode and anode of pn Junction diode;
- find from the data sheet the maximum safe current that can be passed through the diode being used;
- know the difference between static and dynamic resistances of a diode;
- know the knee voltage of the diode; and
- choose meters of proper range for the experiment.

26.2 What should You know

A p-n junction diode consists of p −type and n −type materials forming a junction as shown in Fig. 26.1(a)

In the p −type material there is an impurity of a III group element which gives rise to holes in it. The current flows in it due to motion of these ! holes. In the n-type material there is an impurity of a V group element which gives rise to free electrons in it. The current flows in it due to motion of these electrons.

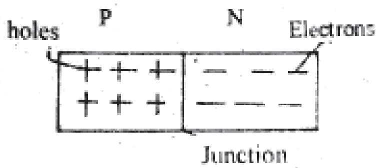


Fig. 26.1(a) p-n junction diode

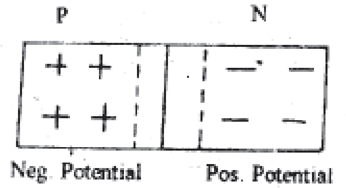


Fig. 26.1(b) Due to recominination of holes and electrons P-region becomes negatively changed an N-region becomes (positively very charged)

Both the materials are electrically neutral. Holes from p-type and electrons from n type, being free, combine with each other" at the junction. Due to this combination of holes and electrons, the p-type material develops a negative potential and n-type acquires positive potential as shown in Fig. 26.1 (b). This potential difference across the junction pulls the holes and electrons apart and stops their further combination.

For forward biasing the diode, p-type side of the junction called the 'Anode' is connected to the positive pole of the battery and n-type side called the 'Cathode' is connected to the negative pole of battery as shown in Fig. 26.2. Under the-effect of this external applied potential difference- the holes and electrons are pushed towards each other. When the applied voltage exceeds the contact PD across, the junction, they start combining with each other and current starts flowing. It rises rapidly with increase of applied voltage. If the polarity of battery is reversed the holes and electrons are pulled still apart and no current flows in the diode.

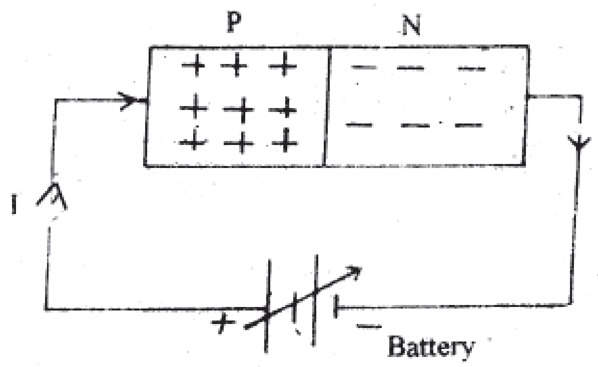


Fig. 26.2

Fig 26.2: pn-junction is forward biased by the battery. The positive pole of battery supplies positive charge to P-region and negative pole supplies negative charge to N-region which combine at the junction and a current start flowing.

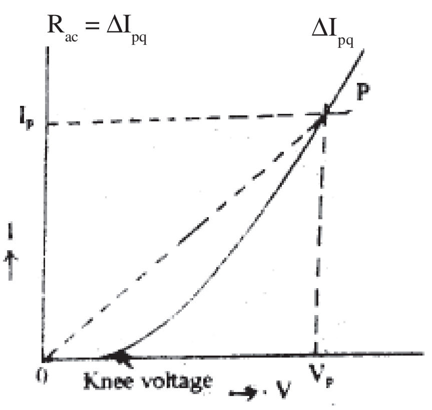
In this experiment we have to study, how the current varies with the applied voltage, we shall see that the current remains zero till the applied the voltage approaches contact PD called the 'knee' voltage. On increasing the applied voltage beyond this point, the current flowing through the diode increases rapidly. A graph plotted between 'V and I' is not a straight line as is seen in Fig. 26.3. It is called the characteristics of the diode. In such cases where the (V vs l) graph is not a straight line, we define two resistances. The static resistance or DC resistance and dynamic resistance or AC resistance. If we take a point P on the curve and note the applied voltage V_P and current I_P corresponding to this point, then the static resistance or R_{dc} at point P is defined as

$$R = \frac{V_P}{I_P}$$

The value of this resistance varies from point to point and is not constant.

If we take two points P and Q close to each other on the straight part of the curve and find the corresponding incremental voltage ΔV_{pq} and ΔI_{pq} from the curve as shown in Fig. 26.4, then R dynamic or R_{ac} is defined as

$$R_{ac} = \frac{\Delta V_{pq}}{\Delta I_{pq}}, \quad R_{ac} = \frac{\Delta V_{PQ}}{\Delta I_{PQ}}$$



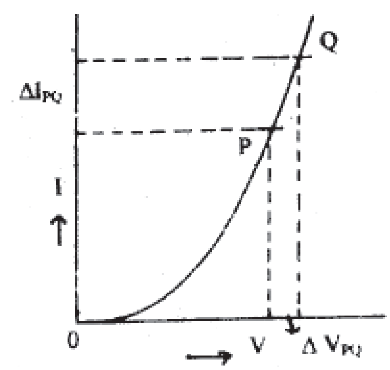


Fig. 26.3 : R_α at $R_{DC} = \frac{V_p}{I_p}$, which is the slope of line OP. It will have different values for different positions of P.

Fig. 26.3: $R_{ac} = \frac{\Delta V_{PQ}}{\Delta I_{PQ}}$ This will be nearly constant for straight part of the curve. It is much less than R_{DC}.

This resistance is nearly constant for the straight part of the curve. The dynamic resistance of a diode is much lower than the static resistance. It is this resistance which a diode offers to AC when it is used as a rectifier to convert AC into DC.

The knee voltage of a diode depends on the material used for id fabrication. For Silicon diode ifs value is 0.7 V and for Germanium diode it's value is 0.3V.

The commonly used diodes in the laboratory are OA 79 and 1N4007JOA79 is Ge diode which is sealed in a glass tube. 1N4007 is a Silicon diode sealed in plastic casing. The distinguishing No. is printed on their casing. There are two axial leads. On one side there is a coloured ring as shown in Fig. 26.5(a) and Fig. 26.5(b). This ring indicates the cathode lead which is connected to the n-type material in the diode. The other lead connected to p-type material is anode. From the data sheet we find that I_{max} for OA 79 is 30 *ma* at 1.5V. For IN4007, I_{max} is 1 amp at 1.5V. The symbol of the diode is given in Fig. 26.5(c).

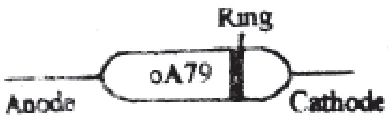


Fig. 26.4(a)

Fig. 26.4(b)

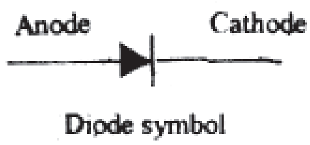


Fig. 26.4(c)

Material Required

A Ge diode 0A79 0 - 1.5V voltmeter, 0-30 ma meter 25 ohm rheostat, 2V lead accumulator, one-way key and connecting wires etc.

26.3 How To Perform The Experiment

(i) Set the zero of both the meters

(ii) Record the least count of both the meters.

(iii) Make the connections as shown in diagram 26.5.

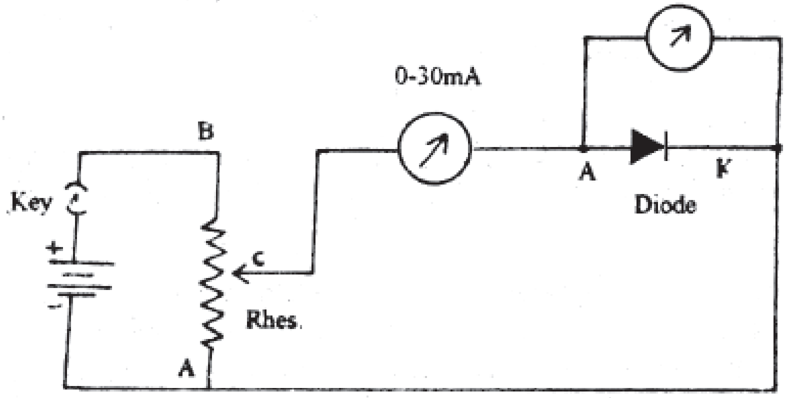


Fig. 26.5

(iv) Bring the movable point C of the rheostat nearest to the point A and insert key. Readings in both the meters will.be zero. Now move point C slowly towards B so that the reading in the volt meter is on a scale mark and record the readings of mA and volt meter in the observation table.

(v) In this manner move point C towards B in small steps and each time take readings of mA and voltmeter. Take the readings in steps of say 0.1 volt till the current passing through the diode is around 25 to 30 mA.

(vi) Now plot a graph from these readings, which will look like the one given in Fig. 26.3.

26.4 What to Observe

Zero error in voltmeter = Nil

Zero error in mA meter = Nil

Least count of voltmeter = V/div

Least count of mA meter = mA/div

S.No.	Voltmeter Divn.	Reading V	mA meter Divn.	Reading mA
1				
2				
.				
.				
.				
15				

26.5 Analysis And Conclusion

(i) From the graph plotted from the observations recorded in the table, you will find that the current through the diode is zero while potential difference across it is low. Find the voltage (the knee voltage) at which the current just starts flowing.

(ii) Take 3 points A, B and C on the graph. Find the voltage and current corresponding to these points and calculate the value of static resistances at these points. Are they equal?

(iii) Take three pairs of points close to A. B and C. Points near A should be at equal distances on either sides of A. and so on. Find the incremental voltage and currents at these points. From these values of incremental voltage and currents find dynamic resistances at these points. Are they equal?

(iv) What conclusions do you draw about the static and dynamic resistances at different points on the graph?

26.6 SOURCES OF ERROR

(i) They may be contact resistances particularly if any connections remains loose.

(ii) Zero error of the meters may not be accurately eliminated.

(iii) Starting deflection may be too small and more than 70% of full scale.

(iv) Each time the pointer of ammeter may not be on a scale mark.

(v) Ammeter is measuring current of voltmeter and diode.

26.7 Check Your Understanding

i) Which of the two resistances of a diode is higher and why?

....

ii) Why the dynamic resistance is nearly constant while the static resistance is different at different point of the V-I characteristic ?

....

iii) Why should a sensitive voltmeter be used in this experiment ?

....

iv) Why should the points near the point A or B or C on the graph for finding dynamic resistance be at equal distances from A ?

....

EXPERIMENT 27

To draw the characteristic of an NPN transistor in common emitter mode. From the characteristics find out (i) the current gain (β) of the transistor and (ii) the voltage gain A_v with a load resistance of 1 kΩ.

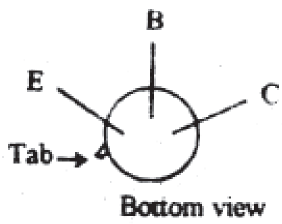
27.1 Objectives

After performing this experiment, you should be able to:

- understand how to forward bias a p-n junction and how to reverse bias it;
- identify the leads of the transistor,
- find out from data sheet the type of transistor, the maximum safe current voltage and maximum power dissipation for the transistor;
- know what is meant by CE mode;
- know that the transistor is a current operated device;
- define current gain (β) of a transistor;
- define the voltage gain (A); and
- know the factors on which A_v depends.

27.2 What should you know

You have already learnt in theory that a transistor has three leads. To identify them hold it up side down. There is a small tab projecting out of the casing. The lead adjacent to this tab is emitter lead. The other two leads taken in clock wise direction are respectively base and collector leads as shown in Fig. 27.1. In some transistors there is a coloured dot marked on the casing. The lead near this mark is collector The other two leads taken in anti clockwise order are respectively base and emitter leads as shown in Fig. 27.2.



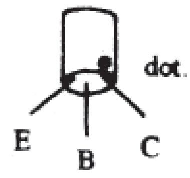
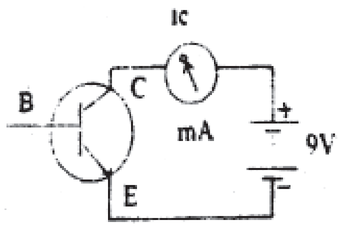


Fig. 27.1 **Fig. 27.2**

While using a transistor the collector is always reverse biased. Normally no current flows in the collector emitter circuit as shown in fig 27.3. But on passing a small base current by forward biasing the base emitter junction as shown in Fig. 27.4. a strong I_c starts flowing. Thus we see that a transistor is a current operated device and ***a small base current gets amplified in the collector circuit. In*** fig. 27.4, we see that the emitter is included in- both the base and the collector circuits. Hence it is called a common emitter circuit.



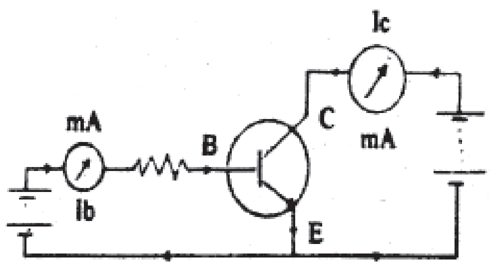
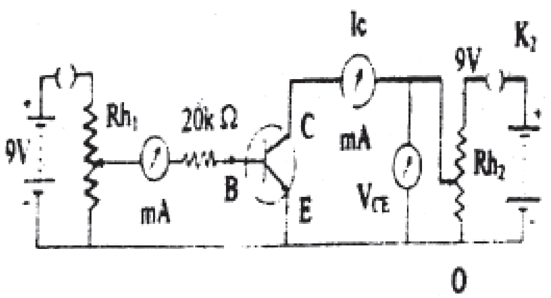


Fig. 27.3 **Fig. 27.4**

The incremental ratio $\delta I_c / \delta I_b$ is the current amplification factor 'β' of the transistor. We have to find out 'β' from the characteristics curves as explained later, To keep I_c constant, that is independent of variation of I_c a high resistance of 20k ohm or more is included in series with the base as shown in the circuit given in Fig. 27.5.



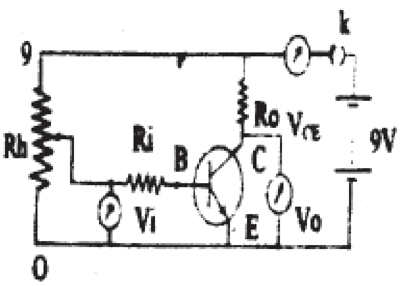


Fig. 27.5 **Fig. 27.6**

When the input signal supplied to a transistor changes by a small amount, it produces a large change in output The ratio of change in output voltage to the corresponding change in input voltage is called voltage gain A_v produced by the transistor.

To obtain voltage gain A_v from a transistor a load resistance R_o is to be connected in series with the collector and a suitable resistance R_i in senes with the base. To determine the voltage gain a circuit shown in Fig. 27.6 is used. Briefly, the voltage gain A_v produced by the transistor can be found as given below.

If δV_i is the change in input voltage, then change in base current produced by it is given by

$$\delta I_i = \delta I_b = \frac{\delta V}{R_i}$$

Therefore, corresponding change in collector current δI_C is given by

$$\delta I_C = \beta \times \delta I_b = \beta \frac{\delta V_i}{R_i}$$

The output voltage δV_0 will be the change in voltage drop across the load resistance R_0. Therefore,

$$\delta V_0 = \delta I_0 \times R_0 = \beta \times \delta V_i \times \frac{R_0}{R_i}$$

(or)

or $$A_V = \frac{\delta V_0}{\delta V_i} = \beta \times \frac{R_0}{R_i}$$

From this expression we see that the value of A_v the voltage gain produced depends on β, R_0 and R_i.

β for CL100 is around 150, so keep the value of A_V partically measurable that is around 20, the value of R_0 is taken as 1000ohm or 500 ohm and R_i used is 4000 ohm.

Material Required

One 1.5 V and one 9 V batteries or stabilised battery eliminator with 9V and 1.5V output terminals, medium power NPN transistor CL 100 or equivalent mounted on board for making connections. 0-30 mA DC meter, 0-300 micro amp DC meter, 0-10 V DC voltmeter, 0-1.5 V DC voltmeter, two 1000 ohm rheostats. two one way keys, 20 k ohm, 4 k ohm. 2 k ohm. 1 k ohm and 0.5 k ohm carbon resistors with tenninals and connecting wires or leads.

27.3 How to Set up the Experiment

Select a medium power transistor so that it can withstand a high current without damage. Here. the CL100 has been recommended for the experiment. Identify it's leads and see that they are correctly connected to the three terminals on the board. Draw the diagram Fig. 27.5 on your copy and place all the required equipment on the table as shown in the diagram. Then complete the connections with the wire. Move the wipers of rheostats to 0 end and insert the keys. All the meters should indicate zero reading.

Now set the wiper of rheostat-2 to the middle. The collector voltmeter will show 4 volt and collector current will be zero. Now move the wiper of rheostat-1 slowly upward. The base current will increase uniformly as indicated by the micro ammeter and the collector current will also rise. Take care that it does not go beyond 30 mA. The circuit has been set correctly.

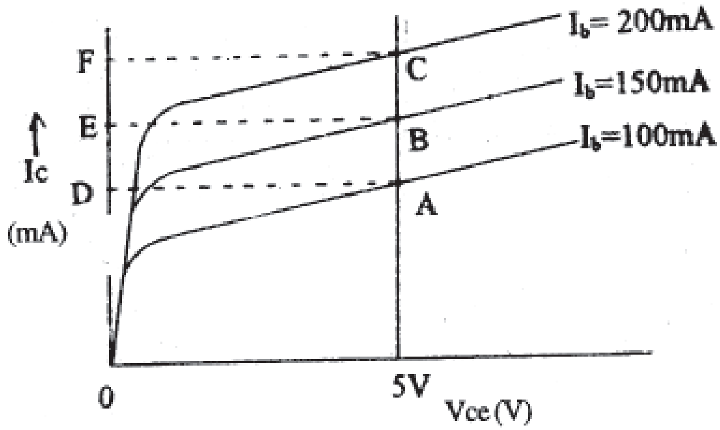


Fig. 27.7

27.4 How to Perform The Experiment to Find The current Gain

(i) Note the least count of the meters.

Least count of mircro ammeter = ... μA/div

Least count of volt meter = ... V/div

Least count of milli-ammeter = ... A/div

(ii) To start with, the wipers of both the rheostats are at zero position. Move the wiper of rheostat-l so that the I_0 becomes 100 μA. Leave it there. Now move the wiper of rheostat - 2 slowly in small steps, take the readings of V_{ce} and I_c and record them in table No.1 given below. You will note that at first I_c rises rapidly and then it becomes nearly constant against variation of V_{ve}. Take the readings up to 9 V. Similarly repeat the observations with I_0 set to 150 and 200 μA and record the observations in table No.2 and 3.

Table 1 :

I_b = 100 μA

V_{ce}(V)	0	.1	.2	.3	.5	.75	1	2	3	4	5	6	7
I_C(mA)													

Table 2

$I_b = 150\ \mu A$

V_{ce}(V)												
I_C(mA)												

Table 3

$I_b = 200\ \mu A$

V_{ce}(V)												
I_C(mA)												

(iii) Plot graphs from the data recorded in above three tables. The graphs obtained and shown in fig. 27.7. These are the characteristics of CLI 00 in CE mode. At low V_{ce} a fraction of charge carriers injected into the base region are collected by the collector and hence I_c, is small. As V_{ce} increases more and more carriers get collected, hence I_c rises rapidly. When all the carriers have been collected I_c becomes nearly constant. This explains the shape of the characteristics curves.

(iv) To find the current amplification factor β of the transistor draw a vertical line perpendicular to V_{ce} axis at say - 5V point. Let it cut the three curves at A, Band C as shown in Fig. 27.7. Now from points A, B and C draw perpendiculars on the I_c axis. Let these meet the axis at points D, E and F as shown in Fig. 27.7.

(v) In going from points A to B the base current changes by

$$\delta I_b = 150 - 100 = 50\mu A = \frac{50}{1000}\text{ mA}$$

(vi) The collector current changes by DE mA, therefore,

$$\delta I_C = \text{DE mA}$$

$$\beta = (\text{DE} \times 1000)50$$

(vii) Similarly calculate β for variation of currents from B to C and A to C. Find the mean value of β.

27.5 To Find the Voltage Gain

(i) To determine the voltage gain *A* produced by the transistor with 1k ohm load resistance R_0, connect the circuit as shown in Fig. 28.6. Keep the wiper of rheostat at zero. Keep R_i = 4 k ohm.

(ii) Insert key K_2, to apply voltage of 9V to collector. Then insert K_1, and move the wiper of rheostat slowly upward till the reading of V_{ce} say 5V. Now increase or decrease V. by say 0.05 V, or 0.1 V, or 0.2 V. For this least count of voltmeter V_i should be small. This gives the change in input voltage that is δV_i, Note the corresponding change in V_{ce}, which gives δV_o. Record there readings in table 4 given below. Repeat this process five or six times and record the observations in table 4.

Table 4

Load resistance R_0 = ...ohm.

Input resistance R_i = ... ohm.

δV_i (V)	
δV_o (V)	
$A = \delta V_0 / \delta V_i$	

(iii) *Calculate the voltage gain for all the sets of readings recorded in table 4. You will see that* A_v is about the same for all the sets. The deviation occurs when the output voltmeter readings are near 0 or 9 volts.

(iv) You can also verify that the experimental value of A_V is $= \beta \dfrac{R_0}{R_i}$.

27.6 Check Your Understanding

i) What happens to the transistor, when we pass 30 mA current for a long time with 9V V_{ce} ?

....

ii) From the data sheet we find that CL100 can pass I_c = 150 mA and it can safely withstand 50 V between collector and emitter. Can we pass 150 *mA* at 50 V through it? If not, why ?

....

iii) What will happen if R_o is 10k ohm and R_i is 500 ohm? How many readings of $8V_i$ with your meter having a L.C. of .01 V /div. can be taken? Given that β is 200.

....

iv) From your experimental curves (Fig. 27.7) find out how will β change with V_{ce}.

....

v) Is it possible to do this experiment without a separate battery of 1.5V for base circuit ? If so how?

....

EXPERIMENT 28

To draw the lines of force due to a bar magnet keep (i) N-pole pointing to magnetic north of the arth (ii) S-pole pointing to magnetic north of the earth. Locate neutral points.

28.1 Objectives

After performing this experiment you should be able to:

- find the N and S-pole of a bar magner;
- define magnetic meridian;
- locate the position of poles in a bar magnet;
- know the condition for getting a neutral point; and
- place a bar magnet in proper orientation.

28.2 What Should You know

The common bar magnet is a magnetised piece of iron. It has maximum attracting power near the ends. These are called the poles. To find which end is N and which is S, it is suspended freely with the help of a thread tied in the middle (Fig. 28.1)

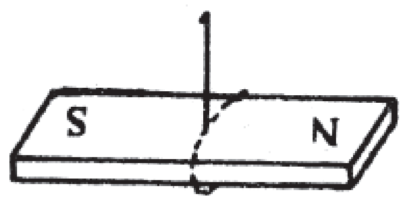


Fig. 28.1
Frely suspended magnetic needle

After some time it will come to rest in N -S direction. The end which points toward geographic North is called N-pole and the other is S-pole The line joining N and S passing through the middle of magnet is usual its magnetic axis.

At a point in space around the bar magnet, where there are two equal opposite magnetic field cancelling each other, there is a neutral point Here there will be no magnetic field. In our experiment, one of the two fields is produced by the bar magnet and the other is earth's horizontal magnetic field. These two combine together to give the neutral point.

The lines of force are the paths on which a hypothetical N -pole set free will move in the given magnetic field. These are supposed to come out of N-pole and enter the S-pole and form closed lines.

These are

curves around the bar magnet (Fig. 28.2). The line of symmetry AB, which is a straight line of force passing through the poles is the magnetic axis of the magnet.

Earth's magnetic field being uniform in the small region of your laboratory, gives parallel lines of force.

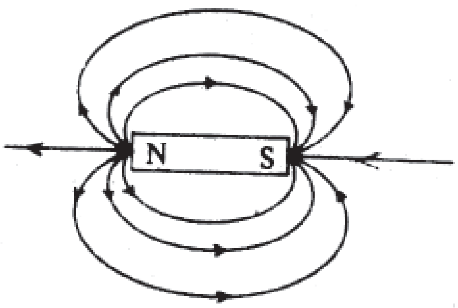


Fig. 28.2

Material Required

Two bar magnets, compass needle, white paper, drawing board, drawing pins, pencil, chalk.

28.3 How to Set up the Experiment

(i) Find the N-pole of the bar magnet and mark the end with ink.

(ii) Fix a white paper on the drawing board.

(iii) Draw a line in pencil through the middle of paper along the short edge for performing the I part of experiment i.e. N-pole of magnet toward north as shown in Fig. 28.3. For the II part of the experiment line will have to be drawn parallel to long edge as shown in Fig. 28.4.

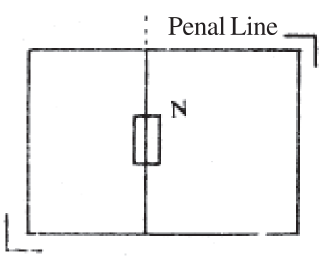


Fig. 28.3

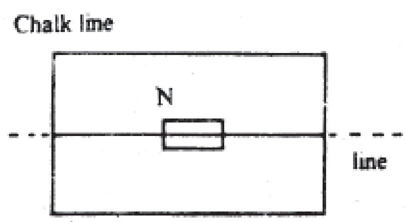


Fig. 28.4

(iv) Place the magnet in the middle of line also shown above.

(v) Take a small compass box and place it on a wooden table. Place a metre rod beside it so that it is parallel to the needle. Remove the compass and draw a line with a chalk. This line gives the magnetic meridian at the place.

(vi) Place the drawing board such that the line on paper in pencil is parallel to the line drawn in chalk on the table, as shown in two cases in Figures 28.3 and 28.4.

28.4 How to Perform The Experiment

a) N-Pole facing North

(i) After placing the magnet as shown in Fig. 28.3 mark the boundary of board in chalk, so that its position is not displaced during the experiment. If at all it accidentally gets displaced, it can be put back in its original position.

(ii) Take a .small compass box. Place it near the N -pole of the bar magnet with it pointer pointing towards the pencil dot marked near the N-pole (Fig. 28.5). Mark the dot on the other side of needle. Move the compass box to the second marked dot, again mark a dot near the far end of needle. Repeat this process till you reach the S-pole. You will get a chain of dots which can be joined by a smooth curved line, as shown in Fig. 28.6 .

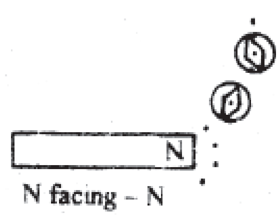


Fig. 28.5

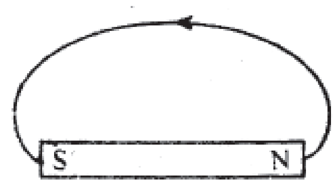


Fig. 28.6

(iii) Join these dots with free hand. This gives the line of force. Mark arrow head on it pointing away for N-pole as shown.

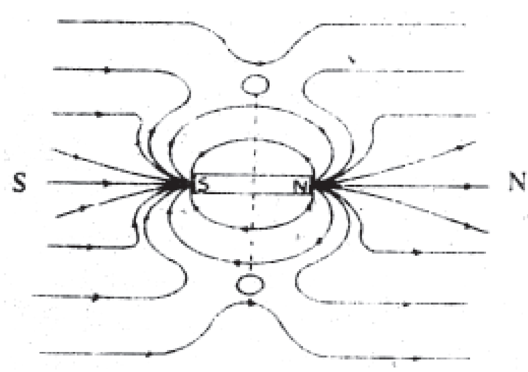


Fig. 28.7

(iv) Draw such lines for different starting points and you will get large number of lines of force around the magnet. Their shape will be as shown in Fig. 28.7.

These lines will not cut each other. You will get two regions on the equatorial line shown by small circles in Fig. 28.7, where there will be no line of force. These are the neutral points. There are two neutral points, one on each side of the magnet. If you place the compass here in the circle with its centre at the neutral point, the needle wire not point in any fIxed direction. It can come to rest in any orientation. That shows that no force is acting on it If magnet is properly placed, each of these points will be equi-distant from the two poles and lie exactly on equatorial line.

b) N-facing South

(i) For drawing the magnetic 'field in this case and locating neutral points place the drawing board with pencil line on paper parallel to long edge of board, along the N-S line of earth, as shown in the Fig. 28.4.

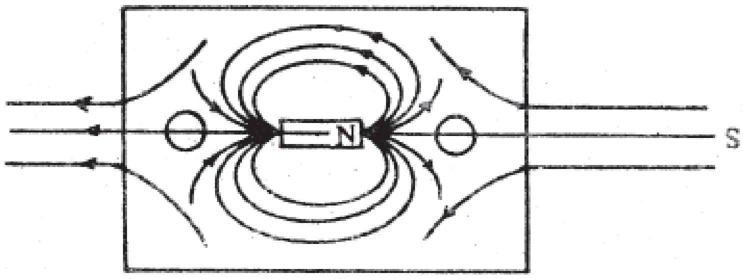


Fig. 28.8

(ii) Now follow the same procedure as in the last experiment The lines of force will look as shown in Fig. 28.8 above.

Here we see that the two neutral points are located on the axial line of the magnet. Because it is at these points where the earth's horizontal fIeld and the magnetic fIeld of magnet balance each other.

28.5 WHAT TO OBSERVE

a) N-pole of magnet towards north

(i) In this case, each, of the two neutral points is equi-distant from the poles.

(ii) They are symmetrically located on the equatorial line.

(iii) On the neutral points, the compass needle come to rest in every position. It does not align itself in any fIxed direction.

(iv) The directions of lines here are opposite. b) N-pole of magnet towards south

(v) In this case the neutral points lie on the axial line. They a symmetrically located.

Other things are same as in (a) part.

28.6 Sources of Error

(i) The magnet may not be placed symmetrically not the line in pencil on paper.

(ii) The N-S line drawn on the table may not be correct.

Due to both these errors the field drawn is not symmetrical about the line in pencil drawn on the paper.

28.7 Check Your Understanding

(i) What is magnetic equator of earth?

....

(ii) What type of magnetic pole is located at geographic north pole of the earth ?

....

(iii) Can you get a neutral point in a single magnetic field?

....

EXPERIMENT 29

To determine the internal resistance of a galvanometer by half deflection method, and to convert it into a volt meter of a given range, say (0-3V), and verify it.

29.1 Objectives

After performing this experiment you should be able to:

- know the type of meter simply by looking at the dial and distinguish between a galvanometer, a voltmeter and an ammeter;
- notice zero reading error and to get it corrected by laboratory technician;
- determine the least count of the meters;
- know, what is meant by full scale deflection current of a galvanometer;
- use a rheostat as a variable resistance and as a potentiometer; and
- know the function of a shunt.

Material Required

A battery, a galvanometer (pointer type), a voltmeter of suitable range, 25 ohm - 3 A rheostat, 5000 ohm resistance box, 100 ohm resistance box, two one-way keys, D.C.C. copper wire for making connections and sand paper.

Whenever we record a deflection on the scale of a meter, there is always an uncertainty of ± 0.5 division in a reading, which results in an error of 1 division in the observed deflection. Therefore, for accurate results from the observations on deflection instruments, as far as possible, you should choose a meter of such range that the deflections produced by the current or potential difference to be measured is 70% or more on the scale.

29.2 What Should You Know

In this experiment you will use a Galvanometer and a D.C. voltmeter. On the dials of these meters you will see the following marking below the scale. $\underline{G}$. $\underline{V}$. The letters G, V respectively stand for Galvanometer and Voltmeter. The under line below the letters means that these instruments are meant for D.C. only.

For determination of galvanometer resistance G the circuit is connected as shown in Fig. 29.1 below.

Let the current flowing through the Galvanometer be I and corresponding deflection in it be θ. Then connect the resistance S in parallel with galvanometer and adjust its value so that Battery the deflection in galvanometer becomes half, i.e. θ/2. Now, the current flowing through the galvanometer is I/2 and remaining I/2 is by-passed by the resistance S connected across G. Because the current divides equally between G and S, therefore,

$$G = S \qquad ...(29.1)$$

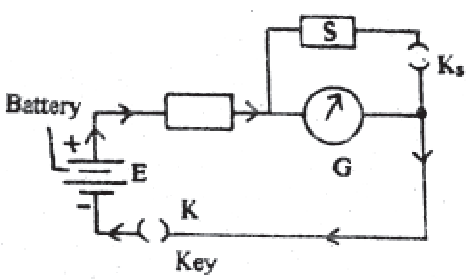


Fig. 29.1

The resistance S connected across a part of circuit to reduce current in that part only, is called the shunt.

Another important constant of a Galvanometer is I_g, ***the full*** scale ***deflection*** current. I_g is that much current-which deflects the Galvanometer pointer from O to maximum deflection on its scale conversion of a Galvanometer into a voltmeter or an ammeter we must know I_g also. To find the value of I_g again refer to Fig. 29.1. Let the EMF of the battery be E and the value of the resistance connected inseries with the Galvanometer and battery be R. Then, the current I flow through the galvanometer which produces a deflection θ in it, is given

$$I = \frac{E}{R+G} \qquad ...(29.2)$$

Therefore, I_g the current required to produce a full scale deflection n division will be given by

$$I_g = \frac{E}{(R+G)} \times \frac{n}{\theta} \qquad ...(29.3)$$

To convert a Galvanometer into a voltmeter of desired range say (0- V volts), a suitable high resistance R_s is connected in series with the Galvanometer as shown in Fig. 29.2 below.

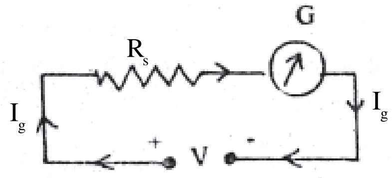


Fig. 29.2: Connecting a galvanometer into a voltmeter

The value of resistance R_s is such that if a PD of V volt is connected across the combination of R_s and G a current I flows through it and produces a full scale deflection in the galvanometer. Applying Ohm's law we get

$$(R_S + G) = \frac{V}{I_g} \qquad \ldots(29.4)$$

$$R_S = \frac{V}{I_g} - G \qquad \ldots(29.5)$$

29.3 How to Perform the Experiment

(a) **To determine G and I of galvanometer**

(i) Set the needle to zero in the galvanometer and voltmeter. (ii) Note the least count of voltmeter.

(iii) Measure the emf of lead accumulator with voltmeter and record at the top of observation table.

(iv) Place the equipment as shown in Fig. 29.1 and connect them with pieces of DCC wire whose ends have been properly cleaned with sand paper. Take out 5 k ohm key from the resistance box R and insert key K.Adjust R so that the deflection in G is more than 20 (70% of number of divisions in the galvanometer scale) and divisible by 2, say 22.

Now insert the shunt key K_s as well. Deflection in galvanometer will fall. Adjust the value of S by taking out various keys from it till the deflection in galvanometer is $\frac{\theta}{2}$, i.e. 11 in this set. Record the values of R, θ, and S in observation table (1). Now repeat the process with different values of R to get deflections 24, 26 etc. and reducing the deflection from θ to $\frac{\theta}{2}$ in each case. You will see that the value of S will come out to be same in each case. Record R, S and θ in table below and calculate I_g using equation (29.3).

b) Conversion of a galvanometer into a voltmeter of range V

(iv) After having determined the internal resistance G and full scale deflection current I_g of the given galvanometer, calculate the series resistance R_s by using equation (29.5). Connect this resistance in series with the galvanometer. The galvanometer will become a voltmeter of range V. To check the correctness of conversion of th Galvanometer, compare it with a standard voltmeter using the circuit shown in Fig. 29.3.

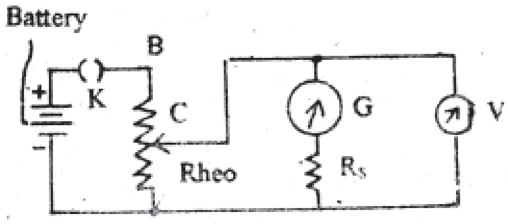


Fig. 29.3

(vii) Keep the moving tenninal C of the rheostat near terminal A and insert the key K. Now move the terminal C towards terminal B and note the readings of standard voltmeter and converted voltmeter in steps of 0.5 V. Record these readings in table (2). Find the difference between the readings of two meters. If it is zero then the conversion is OK.

29.4 What to Obeserve

Table 1 :

No. of divisions in galvanometer scale n = ...

Least count of voltmeter = ... V/div

Emf of batter, E = ... V

Table - 1

S. No.	Volume of R ohm	Deflection θ in galvo	Value of S for half deflection ohm	G = S ohm	$I_g = \frac{En}{(R+G)\theta}$ A
1	22 div.				
2	24 div.				
3	26 div.				
4	28 div.				

Mean value of G = ... ohm

Mean value of I_g = ... amp

Table 2:

Least count of converted voltmeter K_1 = ... volt/div

Least count of standard voltmeter K_2 = ... volt/div

S.No.	Reading of Voltmeters				Difference
	Converted		Standard		$V_S - V_C$
	θ div.	$V_C = K_1\theta$	θ div.	$V_S = K_2\theta$	
1					
2					
3					
4					

Note: I/1 is called the Ohm's per volt of the voltmeter. It gives the resistance required to convert its; galvanometer into a voltmeter of range one volt. Ohm's per volt is a measure of sensitivity of voltmeter. Higher the Ohm's/volt better the voltmeter. Ordinary volt meters used in Lab are of 1000 ohm/V. Meter of 10,000 ohm/V is 10 times better. Why?

29.5 Result

Resistance of galvanometer =............ ohm

Fun scale deflection current of galvanometer =............ µA

Series resistor r_s to make it a voltmeter of range = ... ohm .

Maximum difference of readings taken by converted and original voltmeter = ...

29.6 Sources of Error

(i) The ends of connecting wires may not be clean thus causing contact resistance.

(ii) The keys of resistance box may not be tight enough and may have contaminated surface if not cleaned by a cleaning liquid.

(iii) If deflection with key K_s open, is less then 70% of full scale, percentage error of the experiment shall be quite large.

(iv) There may be parallax error in observing deflection.

(v) In half deflection method the total current is assumed constant but in fact it increases when shunt is connected.

29.7 Check Your Understanding

i) An ammeter of range 10 mA and negligible resistance is to be used as a voltmeter of 10V range.

How will you do it ?

....

ii) A 0.3 V voltmeter is of 1 mA full scale deflection. How will you convert it into an ammeter of 3A range?

....

iii) Voltmeter is connected .... to measure P.D.

iv) Ammeter is connected .... to measure current.

v) A series resistance alters the current in .... but a shunt reduces the current in ....

Answers to Check Your Understanding

Experiment 1

(i) A vernier scale is a scale with divisions slightly smaller than those on the main scale and is moveable along the main scale. It is no named after the name of its inventor Pierr- Vernier.

(ii) Vernier constant is the difference between the length of one main scale division and one vernier division. It is the least count of the instrument, because we can measure a length with this much precision.

(iii) Negative

(iv) By adjusting the lower jaws for zero thickness (or the depth gauge for zero depth), observe the vernier reading and multiply it by vernier constant.

(v) Vernier scale enables is to observe the position of its zero mark on the main scale with a precision of a fraction ($\frac{1}{10}$, or $\frac{1}{20}$, or $\frac{1}{50}$) of the main scale division,

(vi) + 0.03 cm.

(vii) First measure the inside depth of the hollow cylinder by using its depth gauge. Next measure its outside depth using the lower jaws. Substract the former from the latter to get the thickness of the bottom.

Experiment 2

(i) Because it measures the fraction of smallest division on the main scale accurately with the help of a screw.

(ii) Pitch of a screw gauge is the distance through which the screw move along its axis in one complete rotation.

(iii) Least count is the distance through which the screw moves along its axis in a rotation of one circular scale division.

$$\text{Least count} = \frac{\text{Pitch of the screw}}{\text{No. of divisions in the circular scale}}$$

(iv) Back-lash error is the error in circular scale reading caused by no movement of screw along its axis while we rotate it. It is due to play in the screw. It can be avoided by taking care to only advance the screw every time final adjustment is made for finding zero error or the diameter of the wire.

(v) Ratchet arrangement prevents you from accidentally pressing hard on the fixed stud by the screw while measuring zero error, or on the wire while measuring diameter of the wire.

(vi) Zero error = -0.035 mm

Zero correction = + 0.035 mm.

Experiment 3

(i) Because, it is used for the measurement of radii of curvature of spherical surfaces. .

(ii) Pitch of a screw is the distance between two consecutive threads of the screw and is equal to the linear distance moved by the screw when it is given a full rotation. Pitch divided by number of divisions on circular scale gives least count.

(iii) Three legs provide the most stable structure to stand on any surface.

(iv) A screw has back-lash error when it can rotate a little without moving forward.

It is due to its being loose fit in the threads of spherometer in which it moves. It is also a necessity that it may be loose fit, otherwise it may not move. It is avoided by leting the spherometer hang on the screw for every reading.

Experiment 4

(i) Chance error of measuring a time interval by stop watch, which depends on your personal skill, remains the same whatever is the length of the time interval. By taking 20 oscillations, the fractional error (i.e. percentage error) in the measurement is smaller by a factor 1/20, as the time interval is 20 times longer.

(ii) When you measure time of 50 oscillations, instead of 20 you measure a time interval 2.5 times longer. Thus percentage error in measuring this time interval (and also the calculated time of one oscillation) is smaller by a factor 1/2.5,

(iii) (a) 1/3rd (b) 3 times.

(iv) (a) Time period changes. Because bob accelerates faster, T decreases. (b) Length of second's pendulum also changes. It increases - a longer pendulum will be required for same time period of 2 s.

Experiment 5

(i) A body is said to be at rest if it does not change its position relative to its surroundings with the passage of time.

(ii) The junction may not come to rest at the same position due to friction.

(iii) The weights are kept away from the table or board so as to avoid effect of friction.

(iv) (a) 320 g wt.

(b) 390 g wt. (c) 443 g wt.

(v) The resultant force is almost equal to sum of the individual forces and when it falls down, it does not fall on any of the workers.

Experiment 6

(i) Cooling curves are similar because the rate of cooling depends on the temperature difference between calorimeter and surroundings.

(ii) Animals curl up to sleep during winter. By doing so they reduce the surface area of exposed body and avoid loss of heat.

(iii) Mass and specific heat of oil are less. Thus for same loss of heat in one second, its fall of temperature is more.

(iv) No. The doctor's thermometer cannot be used because of low range of temperature (say upto 44°C approximately only). Also it has to be given a jerk to lower its reading.

(v) The liquid is stirred continuously so that exchange of heat is done soon and equilibrium temperature is obtained.

(vi) No. Because its range is only from 35°C to 43°C and its reading will not decrease with cooling of calorimeter.

(vii) So that the comparison is possible and effect of density and specific heat on cooling can be observed.

Experiment 7

(i) Yes. This method-can be used. In this case hotter water and calorimeter will give heat to colder solid brass hob. However, it will be (difficult to find the stead) final temperature of the mixture. Because, the temperature of water with bob dipped in it, will keep on falling continuously.

(ii) No, Wood is bad conductor of heat. It can not acquire uniform temperature throughout.

(iii) The pure water boils at 100^0C only when the atmospheric pressure is 76 cm of mercury.

(iv) The temperature of the water during stirring initially rises; becomes maximum and steady for some time and then starts falling again due to heat losses by radiation. This steady maximum temperature of the water is the final temperature of the mixture.

(v) The mixture is stirred continuously to keep the temperature uniform throughout.

(vi) Specific heat of water = 1 cal g^{-1} °C^{-1} Let the specific heat of brass = S

Heat lost by brass piece = 200 × S × (100 – 23)

Heat gained by water = 500 × 1 × (23 – 20). Assuming no loss of heat to the surrounding,

$$S = \frac{500 \times 3}{200 \times 77} = \frac{15}{157} = 0.098 \text{ Cal / g}^{-1}/\,^{o}C^{-1}$$

(vii) For marble of 1 gm to raise its temperature by unity, 0.215 cals of heat are required. Similarly; 1 kg of Aluminium requires 900 J of I heat to raise its temperature by one degree celcius.

(viii) Yes. Instead of water, the given liquid is used. In this case, however, the specific heat of the material of solid bob is taken as known.

(ix) No. It can be of any shape.

Experiment 8

(i) If the oscillations are too large, maximum extension of the spring during a downward swing can be beyond the elastic limit.

(ii) We are concerned with oscillations which occur in the suspended mass M due to elastic force of the spring only? If there is a horizontal component of motion, somewhat like a pendulum, then gravitational force makes the motion complicated.

(iii) These will be equal. The oscillations are S .H.M. If these are within elastic limit, i.e. maximum extension during a downward swing is within elastic limit of the spring. For a simple harmonic motion, time period is independent of amplitude.

(iv) Extension decreases due to smaller, gravitational force pulling down the spring.

Experiment 9

(i) At low values of *V* the force of surface tension becomes comparable to pressure of water column which causes the flow of water.

(ii) At high values of V, if there is turbulent flow of water in the narrow stopper of the burette, fraction rate of flow could be too

(iii) This ensures that only pressure of the water column in the burette above the bottom mark causes the flow of water through the narrow stopper of the burette.

(iv) (b) is larger. Rate of flow of water at V = 40 ml is 4/5th of that at V = 50 ml because fractional rate of flow is same.

(v) (a) Rate of flow of water.

(b) Volume of water, V, in the burette at any point of time.

(c) Half life of water flow: T (1/2) or T (1/4)/2, etc.

(vi) (a) About 7 half-lives.

Experiment 10

(i) 0.67 m and 2.01 m.

(ii) Equation (1) says that from even one length, we can determine the wavelength and hence the velocity of sound. But the antinode does not occur exactly at the open end of the tube. It is at a slight distance above it. This is approximately equal to 0.3 D where *D* is the internal diameter of the tube. Therefore, the real length of the resonating air column is not equal to length of air column *I,* but *is* $I + e$. Taking the difference in the lengths of resonating air columns for two positions this end correction.

(iii) For a given source of sound, frequency is constant and hence wavelength is directly proportional to the velocity of sound. Since the velocity increases with temperature, wavelength will also increase accordingly. Now length of resonating air column $L = n\lambda/4$. Hence, if the temperature is 5°C more, length of air column for each resonance will increase.

Experiment 11

(i) A tuning fork should be set into oscillation by striking it with a rubber mallet / block whichever is available. Striking the tuning fork with any hard object may damage the fork and cause a change in its characteristic frequency.

(ii) (a) 3; (b) 6

(iii) 1073 Hz.

Experiment 12

(i) Ten ion F has the dimensions of MLT^{-2} and μ has the dimension of μ/L or ML^{-1}. Therefore, RHS of equation (12.1) has the dimension of

$$\frac{1}{L}\left[\frac{MLT^{-2}}{ML^{-1}}\right] = T^{-1}$$

Left hand side of the equation is frequency which has the dimension of T^{-1}. Thus both sides of the given equation have the same dimensions.

(ii) Soundboard communicates the vibrations of tuning fork the string. When natural frequency of the string is same as that of tuning fork, resonance takes place and paper rider flutters vigorously and falls.

(iii) 12N, 1.225 kg.

(iv) 256Hz.

(v) For constant F and L, the fundamental frequency of a string $f \times \frac{1}{\sqrt{\mu}}$ (See Eqn. 13.1 in the text). Therefore, the fundamental frequency of the string with greater mass density could be not half but $\frac{1}{\sqrt{2}}$ times the fundamental frequency of the other.

Experiment 13

(i) Relative shift in the position of a body with respect to another body, on viewing it from two different stand-points, is called parallax. Parallax between the tip of the real image of a pin and the tip of another pin is removed by moving the image-pin on the optical bench till we find that their tips remain coincident as we see them from different positions by moving our head side-ways.

(ii) As we move an object away from a concave mirror between its pole and focus the size of its virtual image increases. On placing it at a point beyond focus the image formed is real and the size of the real image decreases as we move the object from focus to infinity.

(iii) We will get a virtual image from a concave mirror when the object is positioned between the focus and the pole of the mirror.

(iv) Rough focal-length is determined so that the object pin may be placed between f and $2f$. Thus we will manage to keep our image-pin beyond $2f$ and the real image of object pin may be formed on it.

(v) Place an object very close to the mirror. If its image in the mirror is enlarged, the mirror is concave if the image is diminished in size, the mirror is convex.

(vi) We use spherical mirrors of aperture (diameter) small in comparison to focal length, because the mirror formula is applicable only for paraaxial rays.

(vii) No. Because the image formed by a convex mirror is always virtual.

(viii) We could also determine f by plotting graphs between (i) on y-axis (uv) and (ii) on x-axis ($u + v$). Slope of this straight line graph passing through origin is the focal length.

(ix) Yes. Because the real image of candle may be obtained on screen and thus the value of u and v may be accurately determined.

(x) Yes. We can obtain the real image of a pin on itself when it is placed at the centre of curvature. Thus we can determine R.

Then $f = \frac{R}{2}$

Experiment 14

(i) Lenses are used in (i) spectacles, (ii) microscopes, (iii) telescopes, (iv) Photo-cameras etc.

(ii) $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R}\right) = \frac{0.5}{R} = \frac{1}{2R}$

$\Rightarrow f = 2R$

(iii) a) $P = -2.5\ m^{-1},\ f = \frac{1}{P} = \frac{-1}{2.5},\ m = -40m.$

(b) Negative sign of focal length indicates that the lens is a diverging (concave) lens.

(iv) Yes. Because the image formed by a convex lens in this experiment is real, we can use a candle in place of object pin and a translucent screen in place of image-pin.

(v) $\frac{1}{f} = (1.5 - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

When in water $\frac{1}{f_1} = \left(\frac{1.5}{4/3} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

$$= \left(\frac{9}{8} - 1\right)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$\frac{f_1}{f} = \frac{0.5}{1/8} = 4$$

$$\Rightarrow f_1 = 4f$$

i.e. in water the focal length will be four-times the value in air.

(vi) The image is same size as object when the object is placed at 2f

(vii) No. The image will be virtual when the object is placed between focus and optical centre of the lens.

(viii) If the object pin is placed at the focus of the lens, rays from any point of it will emerge out as parallel beam (Fig. 14.4). Hence if the lens is backed by a plane mirror the rays will retrace their path and hence the real and inverted image of the object pin will be formed at the same position. Thus f can be measured.

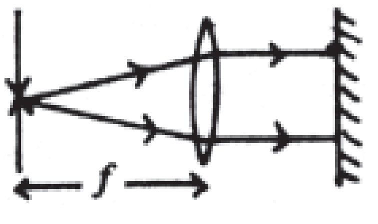


Fig. 14.4

Experiment 15

(i) Radius of curvature of a spherical mirror may be determined using the formula $R = \frac{l^2}{6h} + \frac{h}{2}$ where l = average distance between the legs of the spherometer and h = height of the spherical surface above any planner section (measured by spherometer), then f= $f = \frac{R}{2}$

(ii) The magnification for a convex mirror is given by $M = -\left(\frac{f}{u+f}\right)$

The formula shows that the image formed will be virtual and diminished.

(iii) A convex mirror is used as a rear-view mirror in automobiles, because, the erect, diminished images formed in the mirror help in seeing the wider portion of the rear-traffic.

(iv) Yes. Referring to Fig. 16.1, if OL is slightly more than f_1 image distance LI can be as large as we like and more than R. Hence, experiment can be done even if $f_1 > R/2$, However, if f_1 is too small, precision of the experiment is less as the image of O at I becomes highly magnified. Procedure for doing the experiment remains the same even if $f_1 < R/2$.

(v) Ordinarily when we place a real object in front of a convex mirror its virtual image is formed behind the mirror. But in case of the present experiment we are forming the real image of a virtual object by the convex mirror. The virtual object is image at I formed by the lens, but ray forming that image are reflected by the mirror before reaching I.

Experiment 16

(i) Focal length of a lens depends on

(a) refractive index of the material of the lens.

(b) refractive index of the surrounding medium.

(c) radii of curvature of the surfaces of the lens.

(d) wavelength of light used.

(ii) (a) In air red and violet colour lights travel with the- same speed.

(b) In water red light travels faster than violet light.

(iii) Focal length is more for red light, because $\frac{1}{F} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ and $\mu = A + \frac{B}{\lambda_2}$ (Cauchy's formula). Red light has larger wavelength λ and hence smaller μ. Therefore, for red light the lens shows larger focal length.

(iv) No. Because, the image formed by a concave lens is virtual.

(v) Minimum distance between an object and its real image formed by a lens = 4f.

(vi) (i) The combination of the two lenses in contact should form an enlarged image of a near-by object. This ensure that the focal length of the convex lens is smaller than the focal length of the concave lens.

(ii) This is necessary because we want to form a real image with the combination.

(vii) Yes. When we mount the lenses in two separate uprights the real image formed by the convex lens serves as the virtual object for the concave lens which finally forms its real image. By measuring *u* and v. focal length can be calculated. .

Experiment 17

(i) In minimum deviation

$$A = 2r$$

$$\Rightarrow r = \frac{60}{2} = 30^0$$

$$\mu = \frac{\sin i}{\sin r} \Rightarrow \sin i = \mu \sin r$$

$$= 1.5 \times \frac{1}{2} = 0.75$$

$$i = \sin^{-1}(0.75)$$

(ii) The angle of minimum deviation occurs for a particular wavelength when a ray of that wavelength passes through the prism symmetrically, i.e. parallel to the base of the prism.

(iii) 1.64

(iv) The index of refraction is slightly different for different wavelengths. When the incident beam is not monochromatic, each wavelength (colour) is refracted differently because the wave velocity is slightly different for different wavelengths in a material medium! Here different wavelengths for different colours refers to their wavelengths in air (or in vacuum). But the frequencies of the waves are unchanged, when they enter from one medium to another. Thus we can also take of different for different frequencies !(for different colours).

(v) 51.2^0

Experiment 18

(i) At the centre of curvature i.e. at the object pin itself.

(ii) Below the object pin at a smaller distance than the radius of curvature.

(iii) No real image is formed. A virtual and erect image is formed behind the mirror.

(iv) Towards the concave mirror, because

$h_2 < h_1$ (Since $n > 1$ and $n = \frac{h_1}{h_2}$).

(v) Image also moves. The image moves away from the concave mirror. The two coincide in between.

(vi) $\frac{1}{v} + \frac{1}{u} = \frac{1}{f} = \frac{2}{R}$ (Mirror formula)

$\frac{1}{-20} + \frac{1}{-30} = \frac{2}{R}$ (using modem sign convention)

$\frac{-3-2}{60} = \frac{2}{R} \Rightarrow \frac{-5}{60} = \frac{2}{R} \Rightarrow R = -24cm$

The two will meet at centre of curvature. Therefore the object pin is to move a distance of (30 – 24) – 6 cm to meet its image at centre of curvature.

The answer is (b).

(vii) $\frac{n_a}{n_b} = \frac{h_1}{h_{2a}} \bigg/ \frac{h_1}{h_{2b}}$

$\Rightarrow \frac{n_a}{n_b} = \frac{h_{2b}}{h_{2a}} \Rightarrow \frac{1.3}{1.2} = \frac{x}{25} \Rightarrow \frac{25 \times 1.3}{1.25}$ cm

i.e. $x = -26$ cm.

(viii) No. Mercury is non-transparent and nearly a perfect reflector. The refractive index of Mercury is ∞.

Experiment 19

(i) $m = \frac{f_0}{f_e} = \frac{80cm}{100mm} = \frac{80cm}{10cm} = 8.$

(ii) Distance between objective lens and eye lens $= f_0 + f_e$

= 80 cm + 10 cm

= 90 cm.

When object is kept at 8 m from objective lens, let the distance of image made by it be *v*. Then, u = –800 cm and by lens formula we have

$$\frac{1}{v} - \frac{1}{(-800)} = \frac{1}{80} \Rightarrow v = 88.9cm.$$

Therefore, distance between objective lens and eye lens = $v + f_e$

$= 88.9 + 10\text{cm}$

$= 98.9\text{cm}.$

(iii) Exit pupil of a telescope is the real image of the objective lens made by the eye lens.

(iv) It is necessary for us to keep the pupil of our eye at the exit pupil of telescope so that all the light coming through objective lens and eye lens enters the eye.

This enables us to see all the objects that the telescope is capable of seeing at one time.

(v) Let distance of exit pupil from eye lens be v. Since the objective lens at a distance of 90 cm is functioning as object here, $u = -5$ cm. Thus by using lens formula, we have

$$\frac{1}{v} - \frac{1}{(-90)\text{cm}} = \frac{1}{10} \Rightarrow v = 11.2\,\text{cm}.$$

(vi) Let f_0 and f_e be focal lengths of objective lens and eye lens of the desired telescope. Then

M = $f_0 / f_e = 25$

and distance between the lenses = $f_0 + f_e = 52$

Solving equations (1) and (2) for f_o and f_e we get

$f_o = 50$ cm and $f_e = 2$ cm.

(vii) The final image in the astronomical telescope is inverted. Thus the words of the newspaper will be seen inverted, which cannot be read comfortably.

(viii) Distance of newspaper is 10 times of that at which the words be read by unaided eye. Also the telescope magnifies 10 times. Hence, words will be seen as big as by unaided eye at 4 m distance. Had the telescope been perfect the words could be read. But ordinary lenses are used, the final image is slightly blurred Hence, the words cannot be read in the given situation. In fact, the advantage in clarity by the telescope is always less than its magnifying power.

Experiment 20

(i) Resistance of thick connecting wires is small and negligible.

(ii) Current in the circuit will become much less than what it was before inserting the voltmeter. Thus functioning of the circuit will change.

(iii) Large current may heat up the wire. Thus its resistance may change.

(iv) If the graph between current passing in it and potential difference across it is a straight line passing through the origin, it obeys Ohm's law.

(v) Perhaps the voltmeter has been connected in series with the battery and the combination of resistances being investigated.

(vi) Voltmeter, wrongly connected in series with the combination of resistances, will be removed from there and then connected in parallel with the combination of resistances.

(vii) Since voltmeter is a high resistance instrument, and is Connected in series all the battery voltage will be applied at it and it will show the battery e.m.f. Even then very small current will pass in the circuit, which ammeter may not be able to measure. Its needle will stay at close to zero-mark.

Experiment 21

(i) e.m.f. of a cell is the potential difference' across its terminals when no current is drawn from the cell.

(ii) Potentiometer is a device for measuring potential difference between two points without drawing any current. When a current is passed through a wire of uniform connection, then potential difference across any segment of the wire is proportional to the length of that segment.

(iii) Potential gradient along the potentiometer wire is the potential drop per unit length.

(iv) Potential gradient depends on:

(a) current passing through the wire. Greater the current, greater is the potential gradient.

(b) material of the wire. Greater the resistivity, greater is the potential gradient

(c) Cross-section of the wire. Greater the cross-sectional area smaller is the potential gradient.

(v) If a portion of the wire is thinner, than others, then potential drop in every cm of that portion is more than the other portions. Thus the proportionality relation between potential difference and length does not hold in this wire and it cannot be used for a potentiometer.

(vi) Rheostar enables us to so adjust the current that potential difference across the entire length of potentiometer wire is a little more than the largest of the potential differences to be compared.

(vii) The smaller the length l_1 or l_2, the greater is percentage error in the result.

(viii) Eureka (or constantan) is preferred because its resistivity changes only little by change of temperature.

(ix) Current in the wire is decreased. It decreases potential gradient and thus increases the length across which potential difference equals the potential difference being measured.

(x) Balance point is found first for the leclanche cell because it is of higher e.m.f. After its balance point is found within the length of potentiometer wire, the balance point for second cell of smaller e.m.f. must be within the length of the wire.

Experiment 22

(i) In the derivation of the formula $S = \left(\frac{100-l}{l}\right)R$, it has been assumed that resistance per unit length of the metre bridge wire is constant throughout. For a wire of varying crossectional area, this will not be true.

(ii) Usually a small contact resistance in series with the wire exists at each end due to loose fixing, of the ends of wire to the screws. This is called end resistance.

(iii) When position of jockey on the wire of metre bridge has been so chosen that potential difference across galvanometer in zero, this position is called null point.

(iv) So that the lengths l & $(100-l)$ are comparable. The wheat stone bridge is more sensitive when all the four resistances are of the same order of magnitudes.

(v) It may cause variation in the crossectional area, thereby using a variation in the resistance per unit length of the metre-bridge wire.

(vi) If the current through the wire is passed continuously, it would get heated causing an increase in its resistance. This may change the value of the ratio $\left(\frac{l}{100-l}\right)$, thus changing the null-point.

(vii) Galvanometer is a sensitive instrument. Initially when jockey is far from the null point then current through the galvanometer may be high causing deflection beyond the maximum deflection mark on -the scale. A sudden flow of high current may damage the galvanometer. To allow a small and safe value of current to flow through the galvanometer when it is far from the null point, a high series resistance is connected. Alternatively, a shunt is connected across the galvanometer to by-pass a major portion of the current.

Experiment 23

(i) As R increases, the current drawn from cell decreases. Since $V = \varepsilon = I_r$ the term *(Ir)* decreases thereby making V larger. Since $V \propto l_2$ therefore l_2 increases. As R approaches infinity, V approaches *E* and l_2 approaches Zr

(ii) By measuring p.d. of the cell for two different values of current drawn from it. Internal resistance of the cell and the *emf* of the cell can be calculated from the following equations

$V_1 = \varepsilon - I_1 r$

$V_2 = \varepsilon - I_2 r$

(iii) Internal resistance of a cell depends on the current drawn from it. Since for different R, the current drawn from the cell is different, the calculated value of internal resistance will also be different.

(iv) This constant of proportionality, called the potential gradient along the potentiometer wire depends on current in it and its resistance per unit length.

(v) Smaller is the potential gradient, greater is the accuracy (precision) of a measurement using a potentiometer.

(vi) A 10- m wire potentiometer will be preferred. Other factors remaining the same, potential gradient along the 10-m wire potentiometer will be smaller.

(vii) It is an alloy called constantan.

(viii) It is because only for uniform area of cross-section the potential difference across any two points on the potentiometer wire is proportional to the length of the wire between the points.

(ix) Term Ir gives the potential drop across the cell itself.

(x) Yes, When a current I is forced into a cell in a direction opposite to what the cell supplies, its terminal potential difference will be $V = E + Ir$.

Experiment 24

(i) It depends on the number of turns, length of the coil, radius of each turn and the permeability of the core.

(ii) Its R will remain unchanged whereas its L will diminish to almost zero.

(iii) Impedance = 12 ohm, inductive reactance = 10.4 ohm approximately.

(iv) (a) By measuring it straightaway using a multimeter.

(b) By applying a known DC p.d. across the inductor and measuring the current in it.

(v) 50 volts.

(vi) No. By a DC source only internal resistance r of the coil can be measured and not its inductance L.

(vii) Current will be less.

(viii) Current will decrease.

(ix) Because V_R and V_L are not in phase.

(x) Less than 90°. [Phase difference is 90° in the case of a resistor and a pure inductor]. Referring to Fig. 24.4 it is equal to angle $\angle CBD$.

Experiment 25

(i) Both will charge to the same applied potential difference.

(ii) Electrolytic capacitor because of their large capacitance.

(iii) (a) 80 seconds (as C gets doubled)

(b) 20 seconds (as R gets halved)

(iv) Curve 2 corresponds to larger time constant. Because it takes longer for it to decrease to half its initial value.

(v) Area under the current verses time curve gives the total charge given to the capacitor.

(vi) The time constant RC should be large enough so that it is manually possible to observe and record the fall in charging current with time.

(vii) With 1000 μF capacitor a l00kΩ resistor will be preferred as the combination gives a time constant of 100 seconds which is fairly large .

(viii) (a) combination (A) gives the longest time constant.

(b) combination (B) gives largest discharging current at $t = 0$ because of smallest R.

(ix) Yes. Because in that case the capacitor will also discharge through the voltmeter also combined resistance of that resistor and voltmeter in parallel has to be considered.

Experiment 26

(i) Dynamic resistance of a diode is much smaller and DC resistance is much higher. It is because for some initial voltage across the diode, no current flows through it. When current starts flowing then for a small incremental voltage, there is a large incremental current.

(ii) Dynamic resistance is reciprocal of the slope of the V-I characteristic (I being plotted along y-axis). The slope is constant along straight portion of the characteristic and so is the dynamic resistance. Static resistance keeps changing along the graph because slopes of lines from origin to different points on the graph are different.

(iii) Current drawn by voltmeter is an error in current reading of the mA -metre, which measures total current passing in the voltmeter and the diode. Hence voltmeter should be sensitive and draw very small current.

(iv) The ratio of incremental current/incremental voltage gives average slope of the graph between the two points. This will be equal to slope of the graph at A, if Ais their mid-point, even in the case when slope of the graph is changing along the graph.

Experiment 27

(i) The transistor heats up and can be damaged.

(ii) The transistor can withstand either $Ic = 150$ mA or $V_{ce} = 50$V. If both are simultaneously applied, the transistor will damage immediately.

(iii) Voltage gain will be very large, roughly about 4000. No reading with δV_i of 0.01 V can be taken as δV_{ce} can be at the most 4 V.

(iv) "You have to take several vertical lines, say at $V_{ce} = 4$V, 5 V, 6 V, 7 V, 8 V, and 9V. Then work according to steps 27.4 (iv) and (v) for each value of V_{ce}.

(v) Yes, it is possible to do this experiment without a separate battery for base circuit. We can take a fraction of P.D. of the 9V battery of collector circuit by a rheostat RG_1 of 1000 ohm in series with a resistance of 5 k ohm and feed it to the base through R This can be done for finding current gain as well as for finding voltage gain.

Experiment 28

(i) It is a locus of the points on the surface of earth which are equidistant from the two magnetic poles of the earth.

(ii) Magnetic S pole is located near the geographical North pole of the earth.

(iii) Neutral points cannot be found in a single magnetic field.

Experiment 29

(i) Resistance of 1000 ohms in series.

(ii) A shunt resistance of 0.1 ohm in parallel.

(iii) In parallel.

(iv) In series.

(v) Entire circuit, only the device across-which shunt is connected.

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