SENIOR SECONDARY COURSE

PHYSICS

3

(CORE MODULES)

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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 memorising 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 20^{th} 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

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

3

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

30. Photography Camera
31. Film Exposing and Processing
32. Audio-Video Recording
33. Compact Disc for Audio-Video Recording

CONTENTS

MODULE - IXA

ELECTRONICS AND COMMUNICATIONS

30A

ELECTRONICS IN DAIL 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.

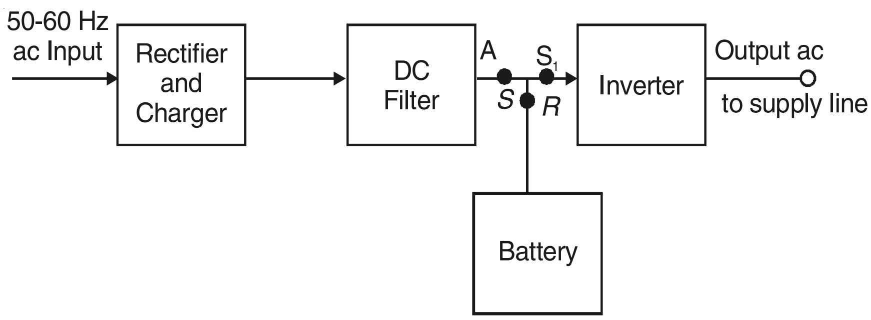


Fig. 30.1 : ***Block diagram of an inverter***

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 ***SS′***. 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.)

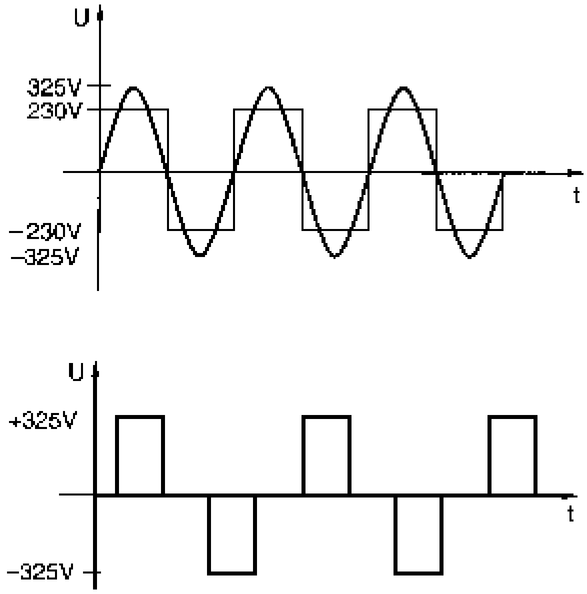


Fig. 30.2: Square wave voltage with duty cycle 25% for 230 V_{rms}

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

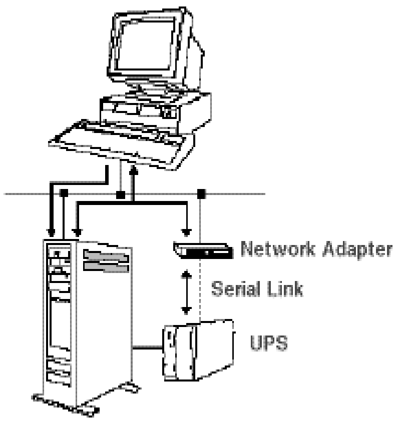


Fig. 30.3 : *A UPS connected to a CPU.*

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.

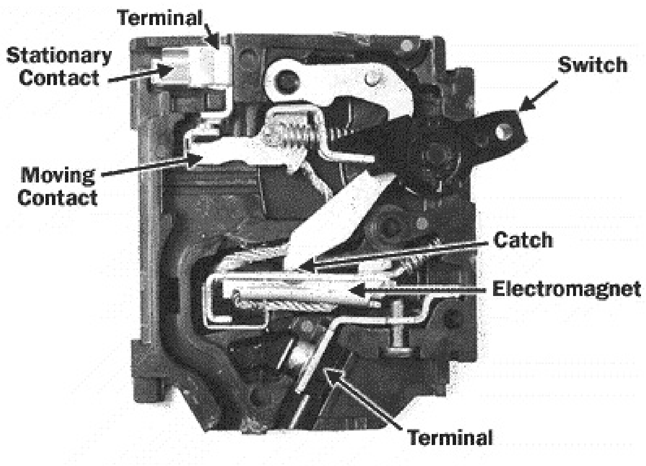


Fig. 30.5: An electromagnet type MCB

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.

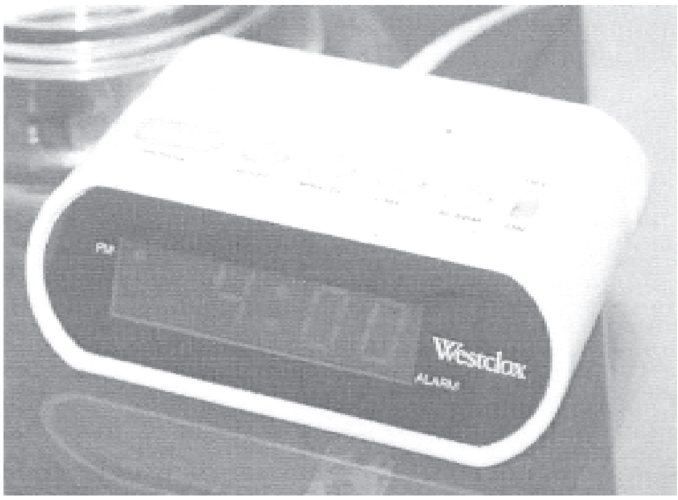


Fig. 30.6: A Digital Clock

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.

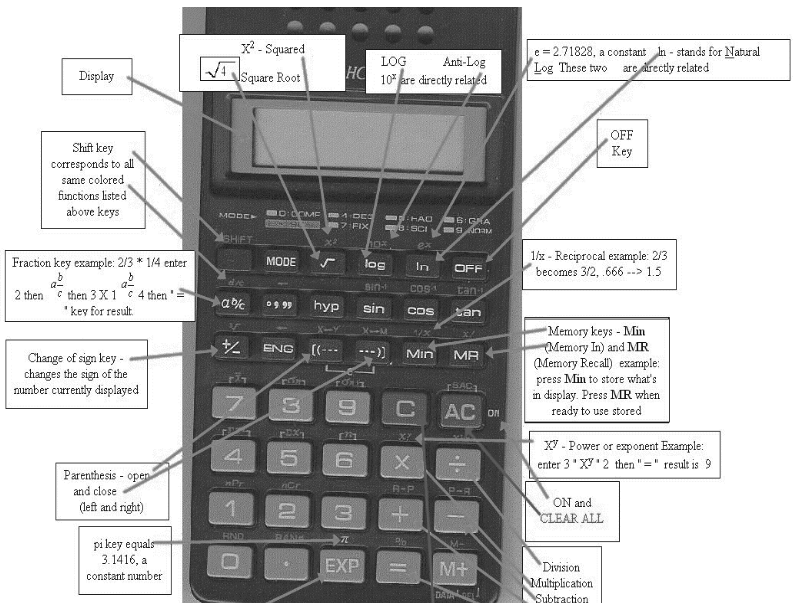


Fig. 30.7: Front Panel of a scientific calculator

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.

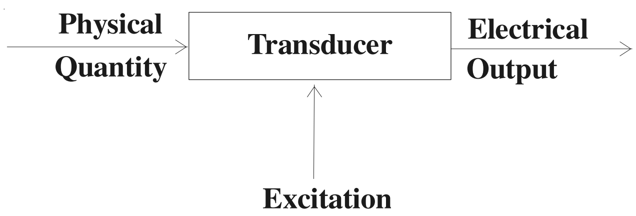


Fig. 30.9: Function of a typical trainsducer

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

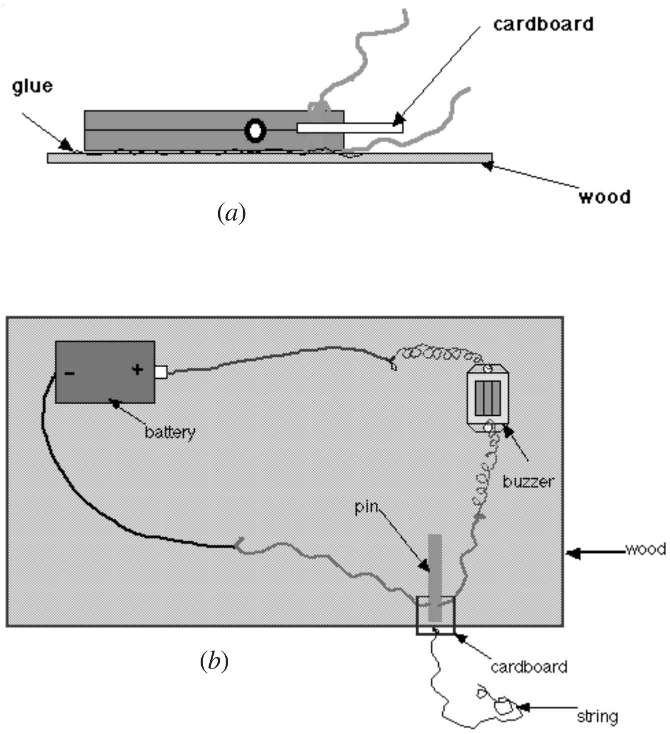


Fig. 30.10: Burglar Alarm

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.

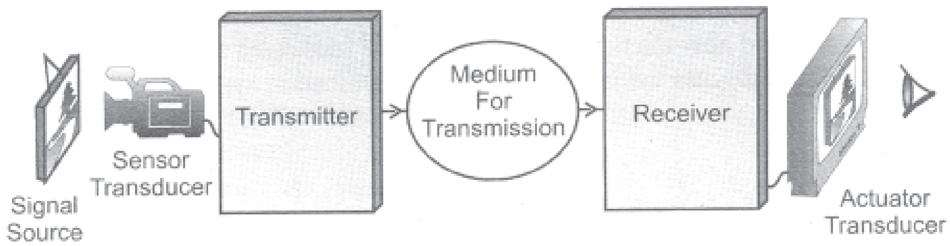


Fig. 31.1 : A schematic arrangement for the communication system.

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.

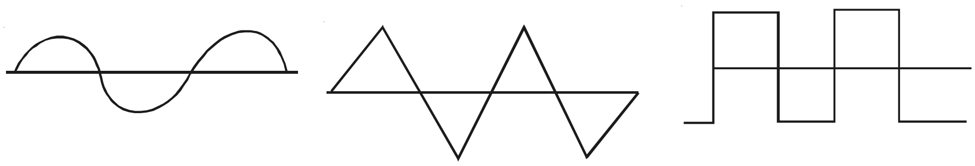


Fig. 31. 2 : *Examples of (a) continuous (sinusoidal) and (b) discrete signals.*

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.

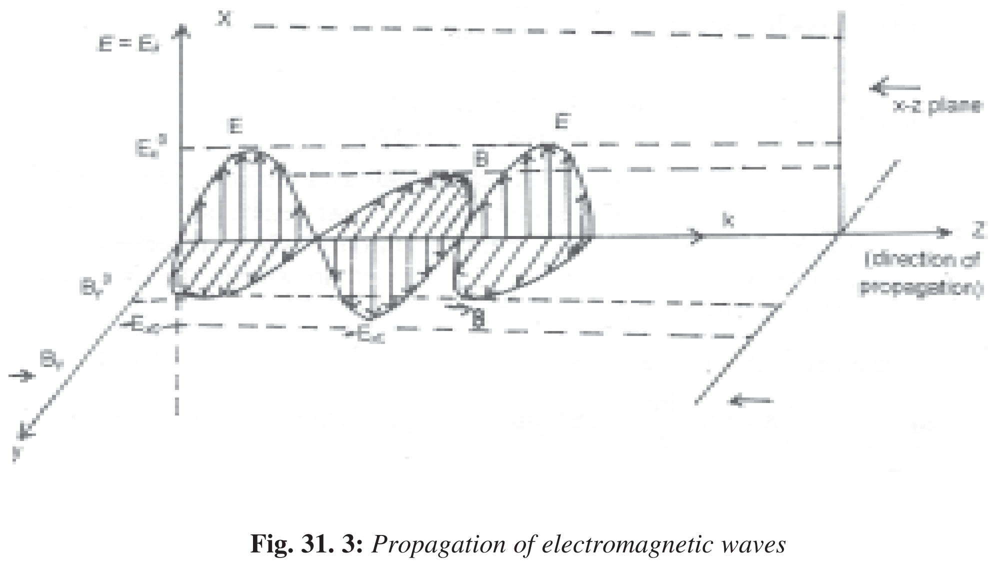


Fig. 31. 3: *Propagation of electromagnetic waves*

Mathematically we can express these as E =E_0sin(kz – ωt) and H = $H_o$sin(kz – ωt). 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

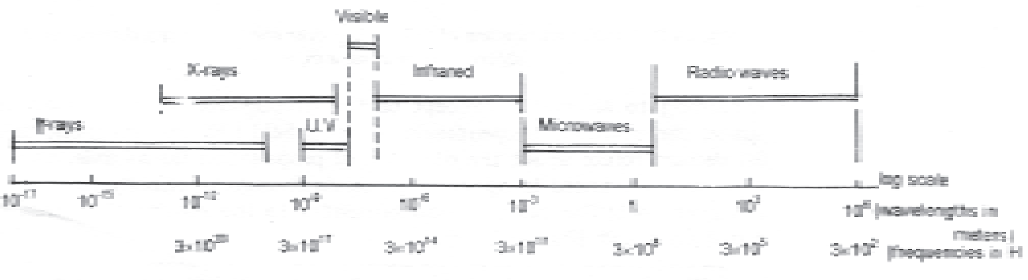


Fig. 31. 4: *The electromagnetic spectrum: The wave values of length correspond to vacuum (or air) The boundaries between successive regions of the spectrum are not sharply defined.*

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 = νλ, where c = 3 x 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)	3 - 30 MHz	100 – 1 m	short wave radio
Very High Frequency (VHF)	30 – 300 MHz	10 – 1 m	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?

....

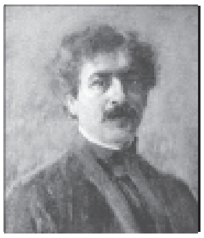
2. Calculate the wavelength of a radio wave of frequency of 30 MHz propagating in space.

....

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

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 $2N$ 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

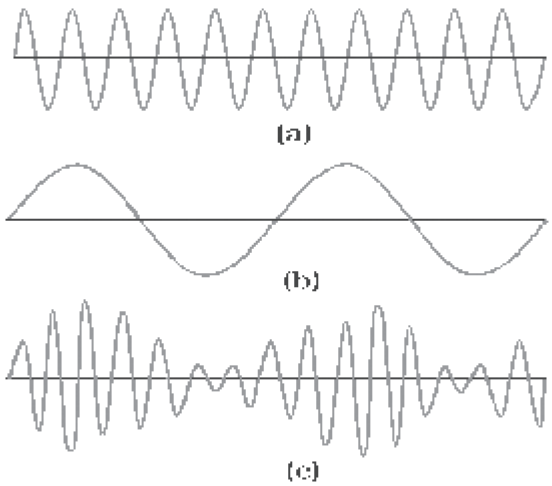


Fig. 32.1: Modulation of a carrier wave by a modulating signal: (a) a sinusoidal carrier wave of high frequency, (b) a modulating signal (message or information signal) of low frequency, (c) amplitude modulated carrier wave.

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

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

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

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

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

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

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.

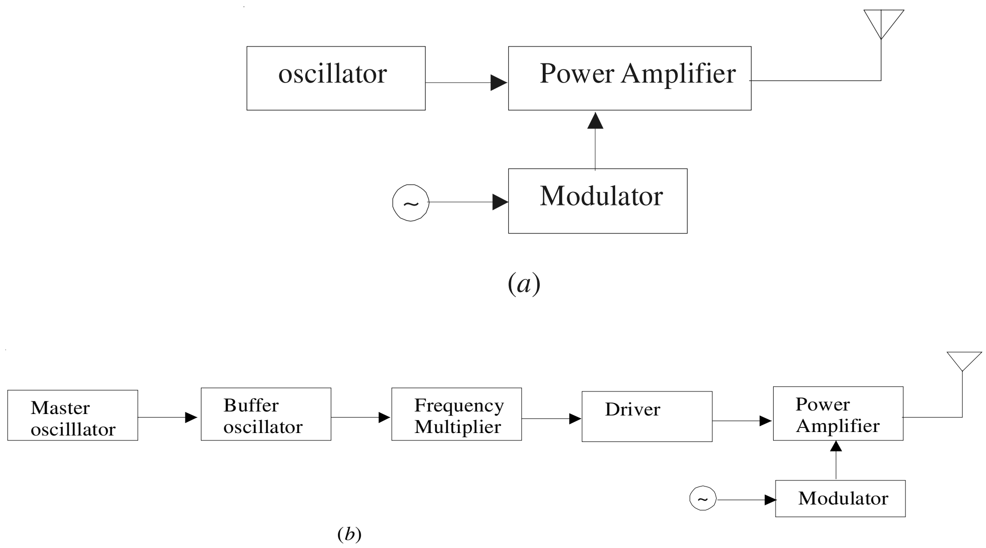


Fig. 32.2 Block diagram of a) a basic and b) practical AM transmitter

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).

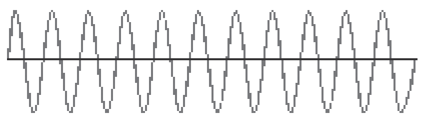


Fig. 32.3: Frequency modulated career wave

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.

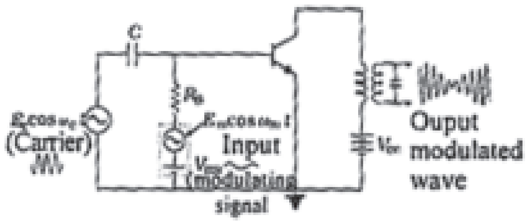


Fig.32.4: Circuit diagram of a demodulator

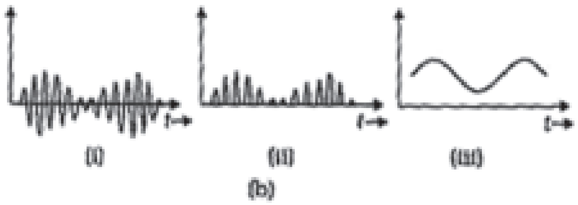


Fig. 32.5: The modulated wave form (i) input (iii) output

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.

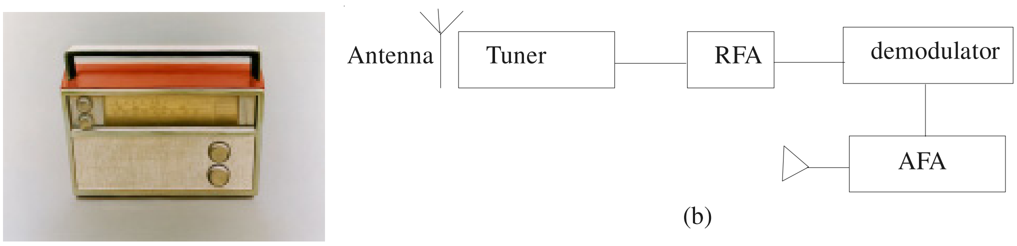


Fig. 32.6 : (a) a radio, and b) block diagram of a radio receiver circuit

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.

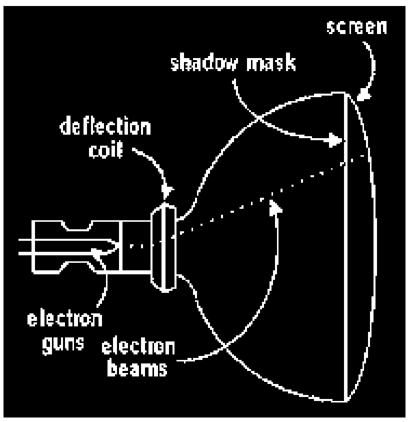


Fig. 32.7: Schematic diagram of CRT in a television set

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.

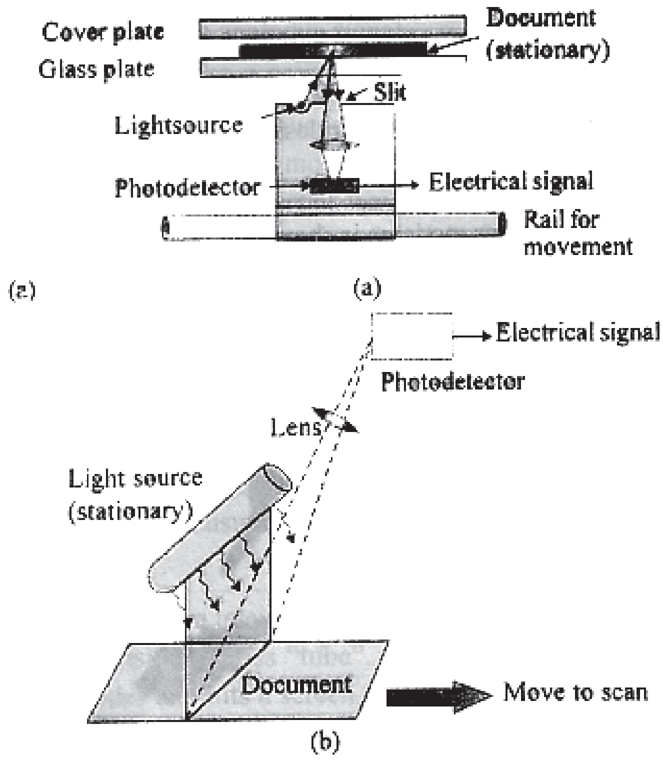


Fig. 32.7 : a) Fixed document scanner, b) Movable document scanner

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 X 10^{14} Hz, while that at a wavelength of 6 cm is 5 x 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)

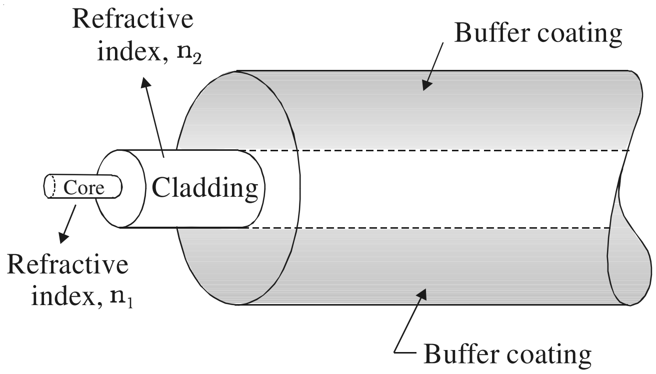


Fig. 33.2: A typical optical fibre with a doped silica core and a pure silica cladding.

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)

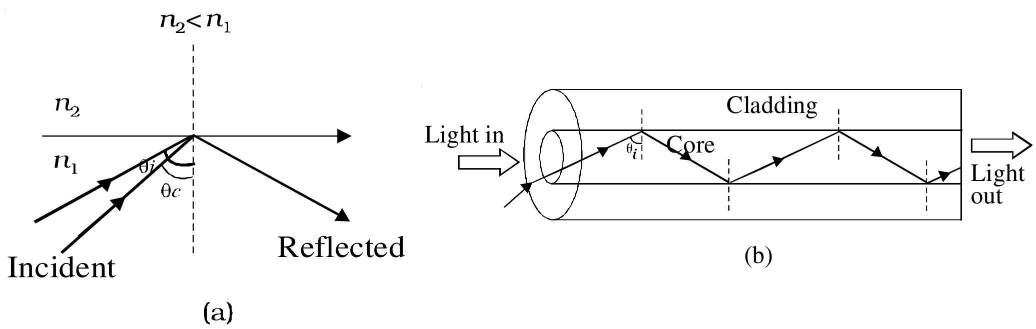


Fig. 33.3: (a)Total internal reflection (b) Ray confinement in actual optical fibre

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 infarred 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.

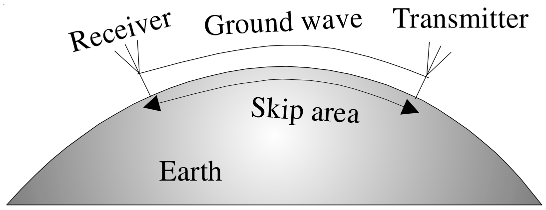


Fig. 33.4: Ground wave propagation

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.

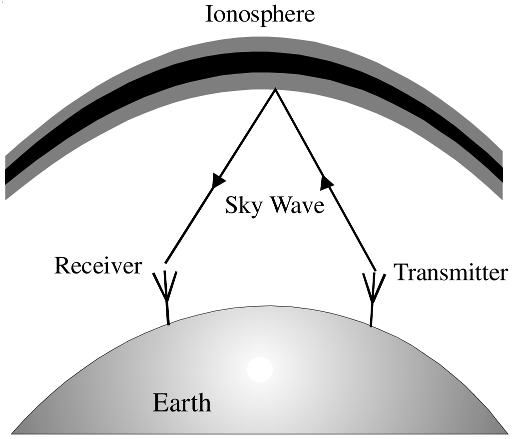


Fig. 33.5: Skywave propagation

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.

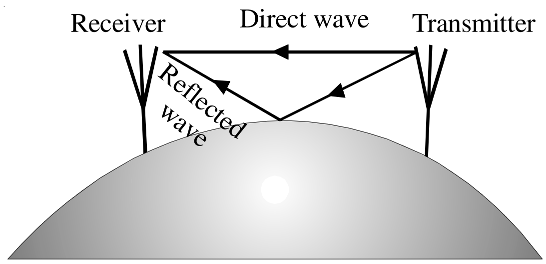


Fig. 33.6: Space-wave propagation

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.

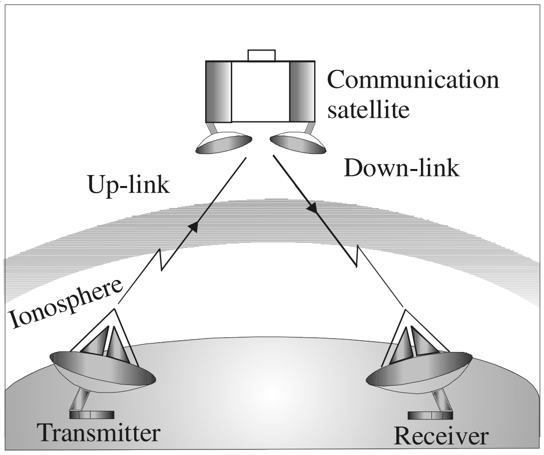


Fig. 33.7: Satellite communication.

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”.

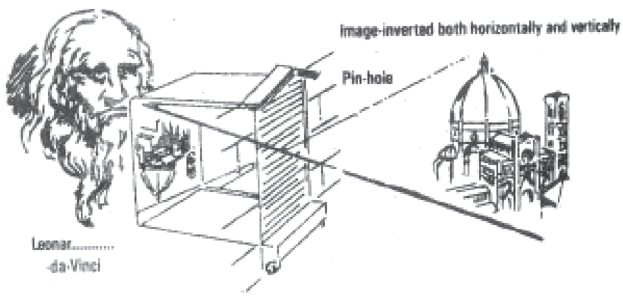


Fig. 30.1 : Principle of pin-hole camera

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 :

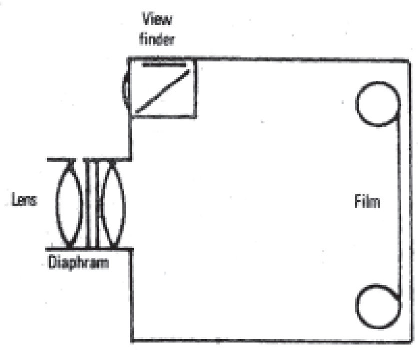


Fig. 30.2 : Schematic diagram of a lens camera

(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*.

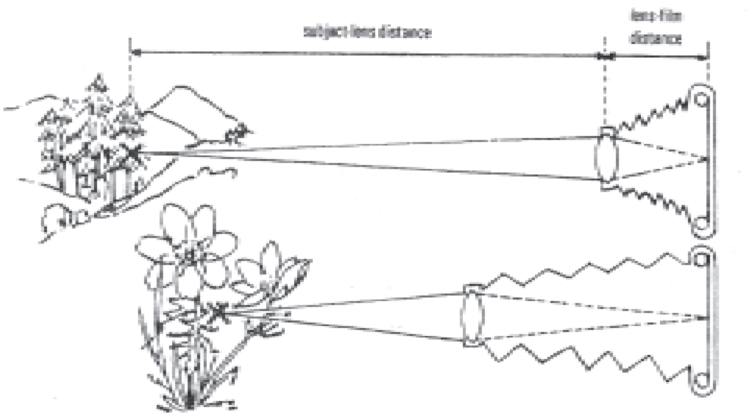


Fig. 30. 3 : Typical object to lens distance and lens to film distance

(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).

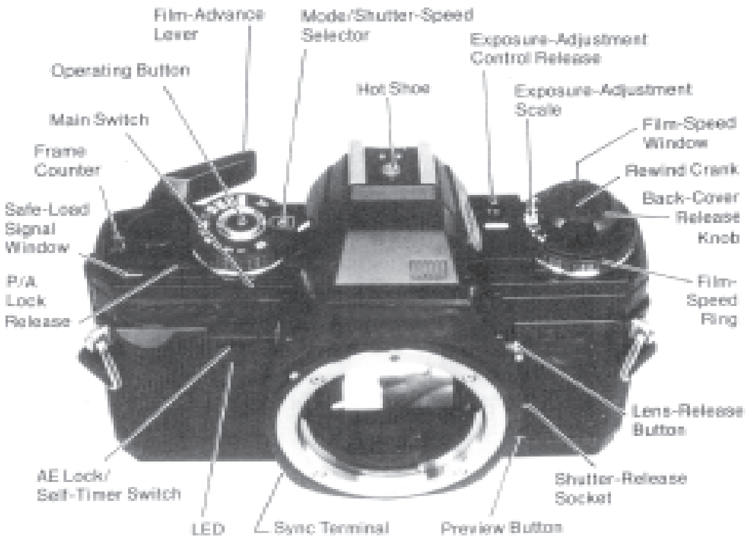


Fig 30. 4 : Parts of a non-digital modern photographic camera.

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.

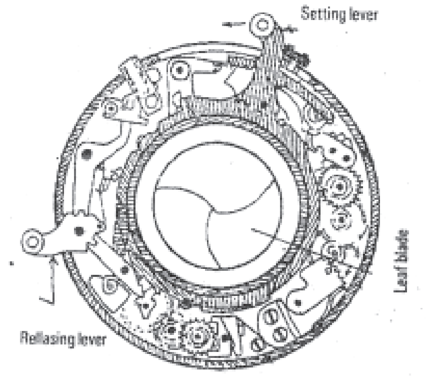
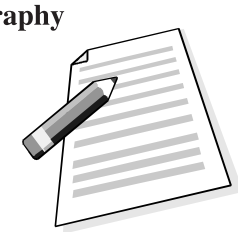


Fig 30. 5 : Diagram of focal plane shutter

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.

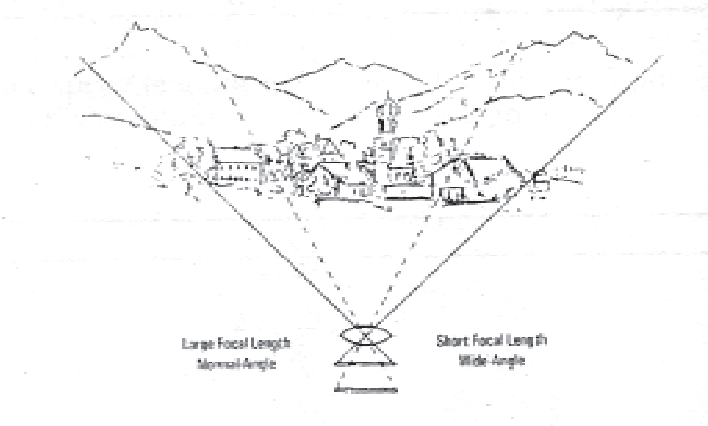


Fig. 30.6: The wide-angle takes in more than the normal lens

(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.

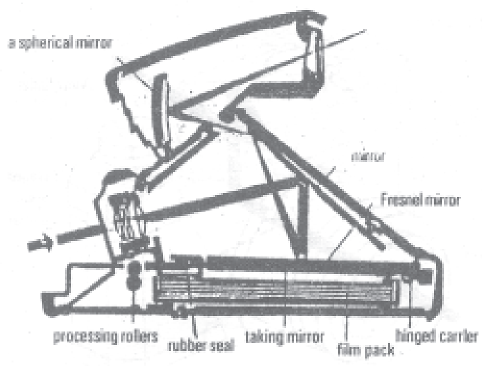


Fig 30. 7 : Line diagram of a poloroid camera

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.

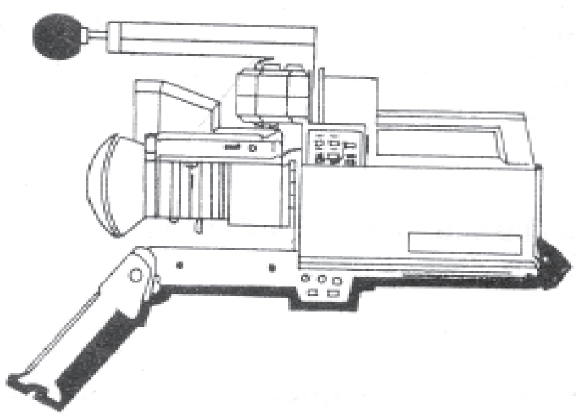


Fig 30.8 : Schematic diagram of a video camera showing different parts

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.

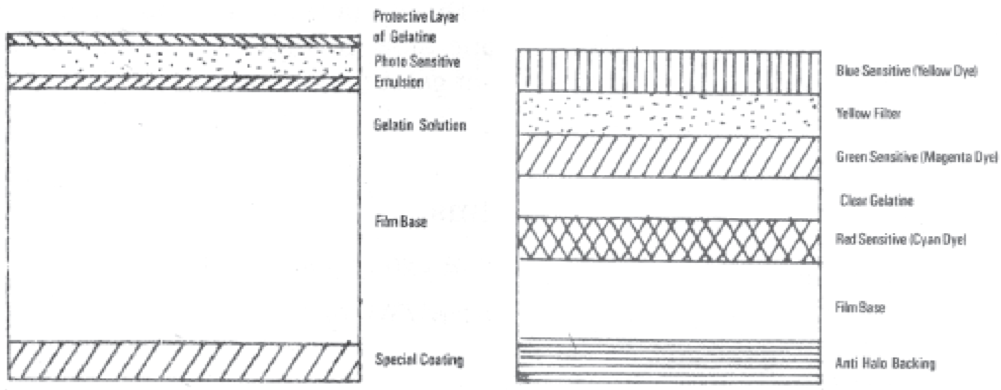
31.1 The Photographic Film

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.

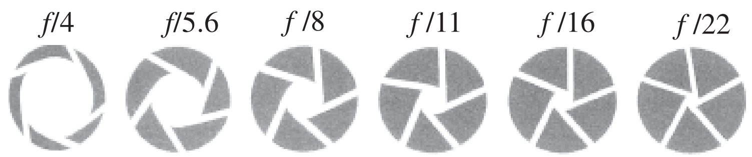


Fig. 31.2 : Pictorial representation of *f*-number sizes

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 $\times$ 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 $(1/100^{th})$ 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)

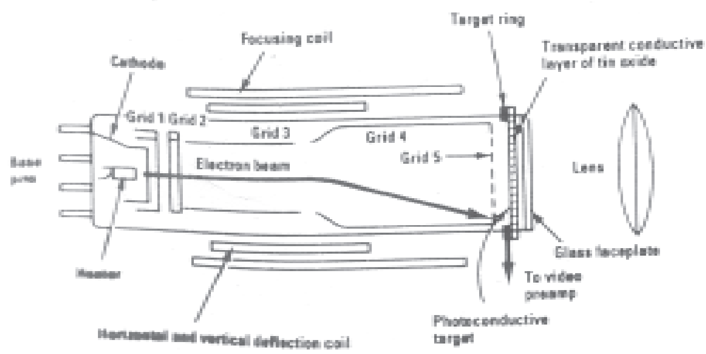


Fig 32.1: A cross-sectional view of a conventional monochrome vidicon tube.

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.

Notes

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.

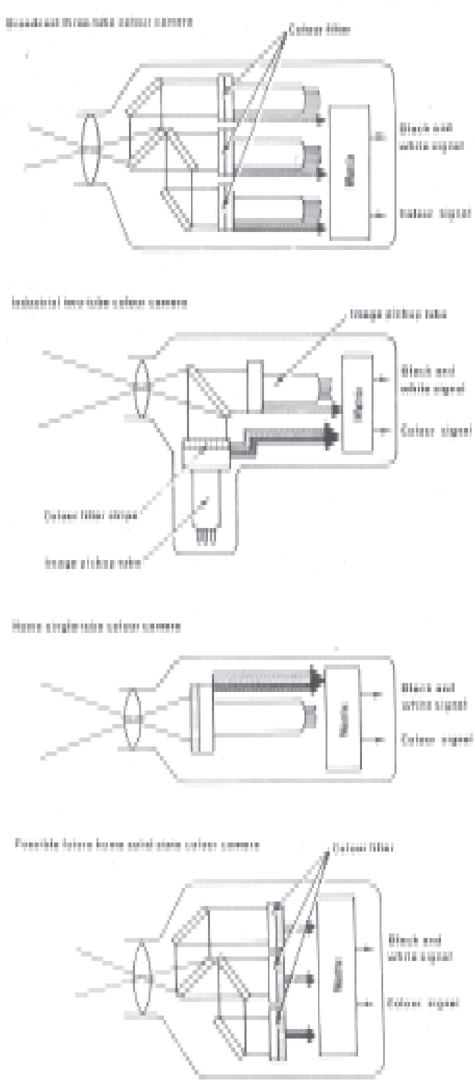


Fig 32.2 : A colour camera

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.

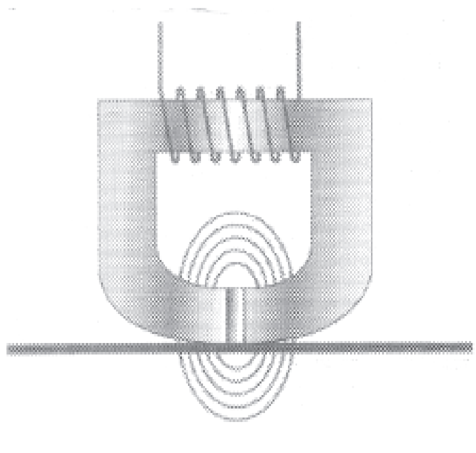


Fig 32. 5: A high frequency eraser

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).

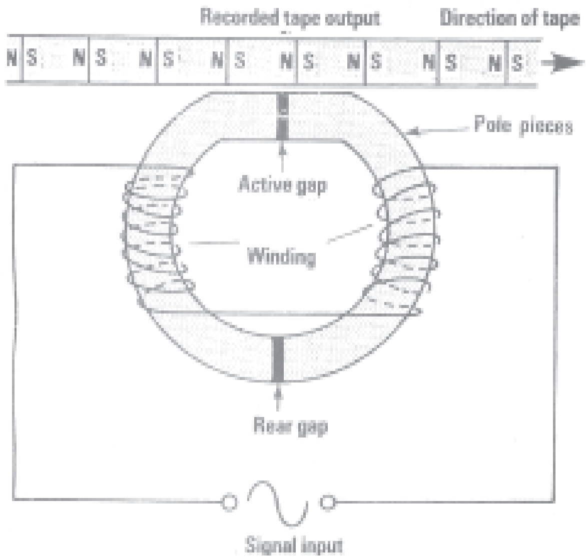


Fig 32.6: A recording head

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.

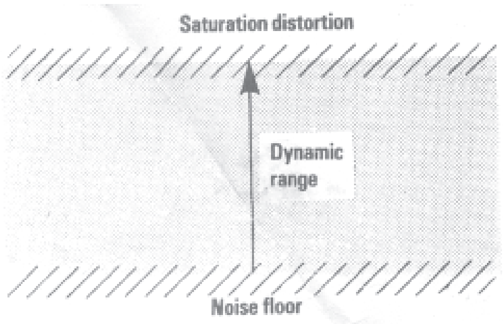


Fig. 32.7 : Dynamic range in recording is limited by background noise and at the tape saturation

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

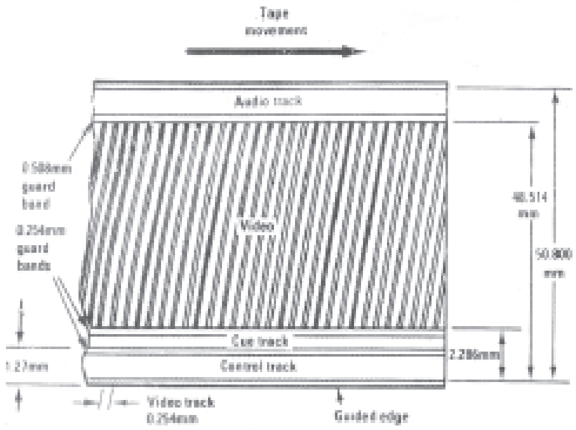


Fig. 32.8 : Recording parameters of the quadruple video recording format

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.

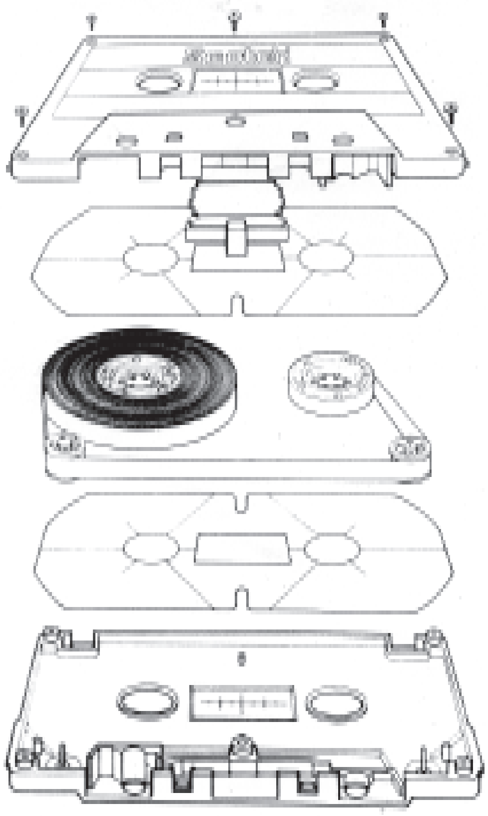


Fig. 32.9 : Cartridge or Cassette

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.

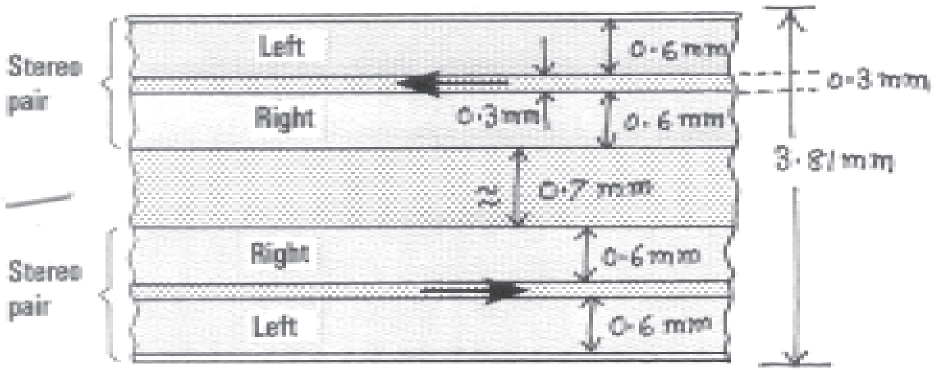


Fig. 32.10 : Magnified view of compact cassette tape

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.

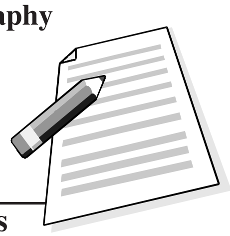
Video tape Recorder (VTR) is a device which when connected to a television set, can be used to record both sound and picture on magnetic tape. The tape is normally enclosed in a cartridge (a video cassette). Video tape recorders can also be used to 'play back' these tapes, whether they have been prepared 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 → electrical variations → orginial audio/video.

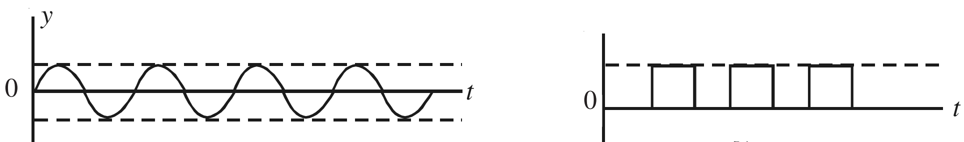
Terminal Exercise

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)



(*a*) (b)

   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.

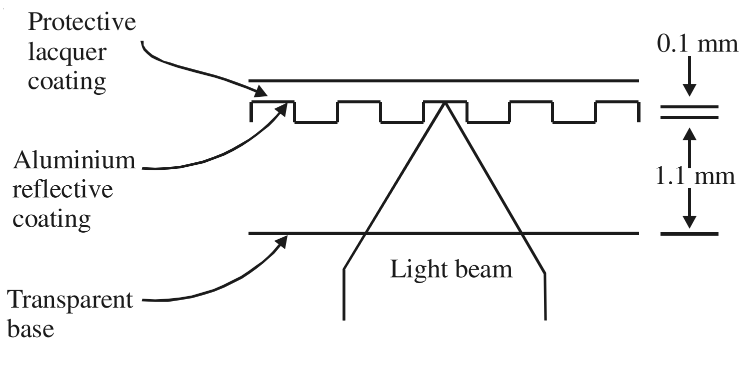
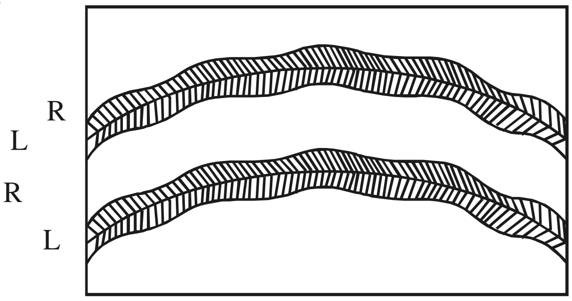


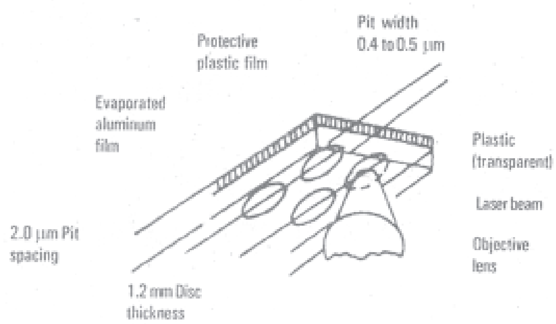
Fig. 33.1: Cross section of a compact disc

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

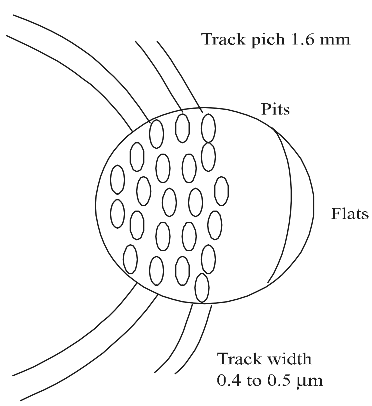


Fig 33.3: Magnified view of compact disc tracks

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.

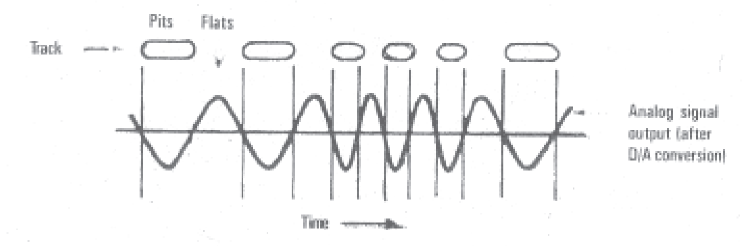


Fig. 33. 4: Track of pits and flats

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.

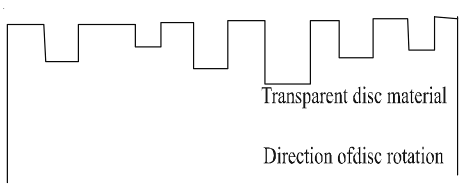


Fig 33. 5: A track of pits and flats.

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.

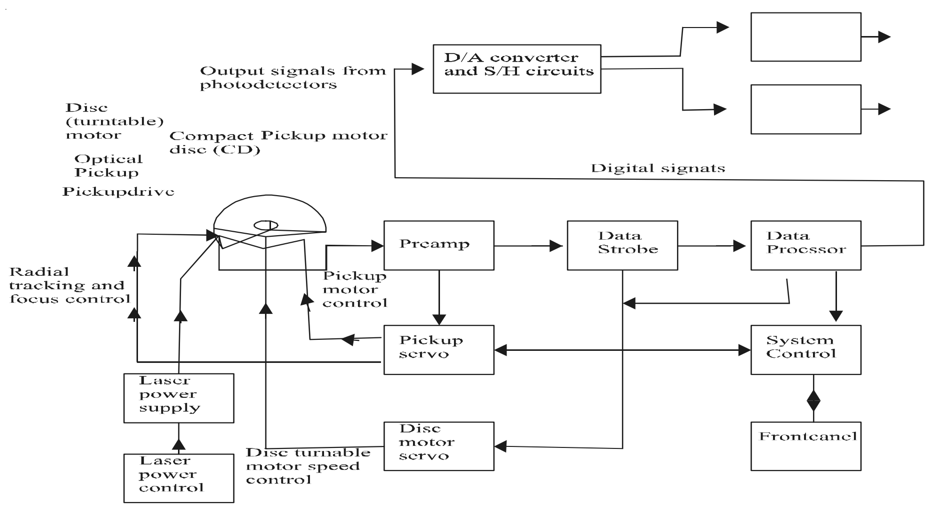


Fig 33. 6: Block diagram of a typical CD player

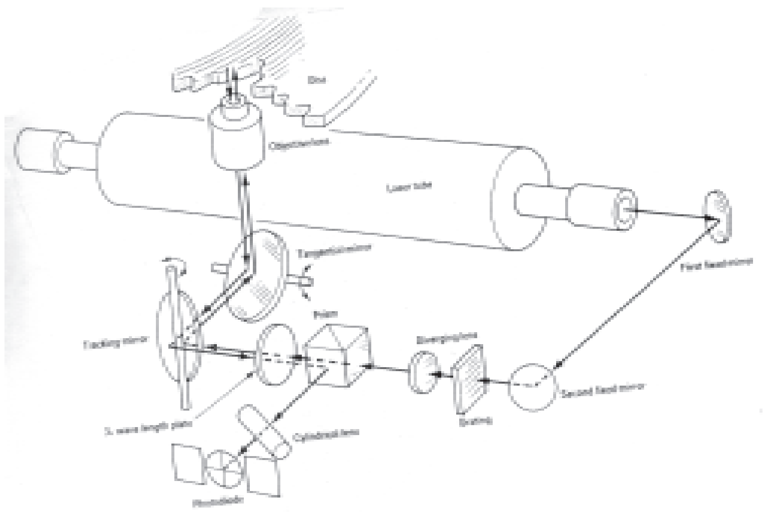


Fig.: 33.7 Construction of a C.D. Player

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)

Design of Question Paper

Subject Physics (2007) **Class: Senior Secondary**

Paper Marks 100 **Duration : 3Hrs.**

[A] Objective Wise Weightage :

	Knowledge (k)	**Understanding** (u)	**Applications** (A)	**Total**
% weight	30%	50%	20%	100%
Marks allotted	24	40	16	80
No. of Questions	7	13	6	26

[B] Weight of Various Types of Questions :

	Essey (5 marks)	**SA I** (4 Marks)	**SA II** (2 marks)	**VSA** (1 mark)	**Total**
% weight	30.25%	45%	17.5%	6.25%	100%
Marks allotted	25(20+5)	36(32+4)	14(12+2)	5(4+1)	80(68+12)
No. of Questions	5(4+4)	9(8+1)	7(6+1)	5(4+1)	26(22+4)

[C] Distribution of marks on Various Modules.

Module Number	**Module Name**	**Marks.**
1.	Motion, force And energy	14
2.	Mechanics of solids And fluids	06
3.	The rural Physics	08
4.	Oscillations And waves	05
5.	Electricity And Magnetism	14
6.	Optics And optical Instruments	07
8.	Semiconductors And Their Applications.	07
9.	Optional Modules : (A) Electronics And Communication system. (B) photography And Audio videography	12 12

[D] Difficulty Level

	Essey	**Average**	**Difficult**
Percent Weight	30%	50%	20%
Marks Allotted	24	40	16
No. of Questions	7	13	6

Note : Some internal choise is given in application questions.

BLUE PRINT

Subject : Physics | Class : Senior Secondary
Maximum Marks : 80 | Time : 3 hours

Sl. No.	Form of Questions / Content Module	Knowledge			Understanding				Application			Skill		Total
		E	SA (I)	SA (II)	VSA	E	SA I	SA II	VSA	E I	SA II	SA	VSA	
1.	Motion, froce And Energy		4(1)				4(1)	2(1)			4(1)			14(4)
2.	Mechanics of Solids And fluids.		4(1)									2(1)		6(2)
3.	Thermal Physics			2(1)		5(1)			1(1)					8(3)
4.	Oscillations And Waves						4(1)		1(1)					5(2)
5.	Electricity And Magnetics		4(1)			5(1)				5(1)				14(3)
6.	Optics And Optical Instruments		4(1)					2(1)					1(1)	7(3)
7.	Atoms And Nuclei					5(1)						2(1)		7(2)
8.	Semiconductors And their Application				1(1)		4(1)	2(1)						7(3)
9.	Optional Modules* 1. Electronics And Communications 2. Photography And Audio Vieo graphy	5(1)					4(1)		1(1)			2(1)		12(4)
	Total	5(1)	16(4)	2(1)	1(1)	15(3)	16(4)	6(3)	3(3)	5(1)	4(1)	6(3)	1(1)	80(26)

Summary

Essay(E)	**Marks per Question**	**No. of Question**	**Marks**
Essay (E)	5	5	25
Short Answer (SAI)	4	9	36
Short Answer (SAII)	2	7	14
Very Short Answer (VSA)	1	5	5
		26	80

Sample Question Paper - 1
Senior Secondary Physics

Maximum Marks: 80 **Time : 3 Hours**

Instruction :

1. All the questions from section A are compulsory, however in some questions internal choice is given.
2. From section B, questions of one module of your choice only are to be attempted.
3. Draw neat, clean labelled diagrams whenever necessary.
4. Use log tables if need be.

SECTION A : CORE MODULES.

1. What type of biasing is used in a zener diode as a regulator? 1
2. A fly sits on the objective of a telescope, will you be able to see its image through the age piece? 1
3. Why do we observe extreme temperatures on moon whereas uwe have moderate global temperature on earth ? 1
4. On an average human heart beats 75 times a minute. What is its beat period? 1
5. Draw carnot's cycle neatly. ? For each stage on the diagram indicate the thermidynamic process followed. 2
6. Draw a labelled diagram of a nuclear reactor. 2
7. Two soap bubbles A and B are blown at the ends of a narrow pipe, such that A is twice in radius than B. As time passes, the size of which of the bubbles will increase. Why? 2
8. In young's double slit experiment what happens When :

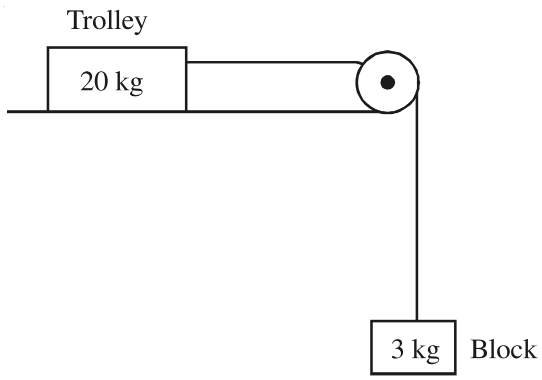
   (*i*) the seperation between the source slits is decreased.

   (*ii*) a mercury lamp is used instead of a sodium lamp. 2
9. With the help of a sympolic diagram explain how the function of NAND gate may be realised using a NOT gate and AND gate. 2
10. A car and a loaded truck are moving on a straight road with same momentum. If equal slopping forces are applied on both. Which of them will come to a stop in smaller distance? Justify your answer. 2
11. State the law of parallelogram of vecttors. Obtain the expression for resultant of two vectors P and Q inclimed at an angle θ. 4
12. A solid sphere of mass M and radius R is allowed to roll down an inclined plane of inclination θ. 4

    (a) Under what contidion will it roll without slipping,

    (b) show that if it is rolling without slipping, force of friction on it will be $\frac{2}{7}$ Mg sing θ.
13. A projectile breaks up into two equal parts when it is at the highest point in its trajectory. If one of the piecas returns to the starting point, at what distance from the starting point will the other piece hit? Give your answer in terms of the range R of the projectile. Explain. 4

Calculate (*i*) the aceleration (*ii*) Tension in the string of the block and trolley system shown in figure. Coefficient of kinetic friction between the trolley and the surface is $\frac{1}{25}$. Take pulley as frictionless, string as massless and g = 10 $m\ s^{-2}$.



14. State and explain

    (*i*) Hookes Law

    (*ii*) Pascalls Law 4

15. A string is clamped at its both ends. The transverse displacement of the string is given by

    $$y(x,t) = 0.06\ \sin\left(\frac{2\pi}{3}x\right)\cos(120\pi t)$$

    When *x* and *y* are in metes and time in seconds. The length of the string is 150 *cm* and to mass is 30*g*. Answer the following question :

    (*i*) Is the wave on the string a travelling wave or a stationary wave?

    (ii) Find the wavelength and frequency of the system

    (iii) What will be the tensions in the string? 4

16. Name the two main defects of images formed by lenses. What spherical are the causes of thesee defects? Give one method used for the correction of each of these defects 4

17. With the help of a neat labelled diagram explain the construction and working of a moving coil galvanometer. How can it be converted into a voltmeter of given range? 4

18. With the help of a suitable circuit diagram explain the working of a *p-n-p* transistor as an amplifier in common emitter configuration. 4

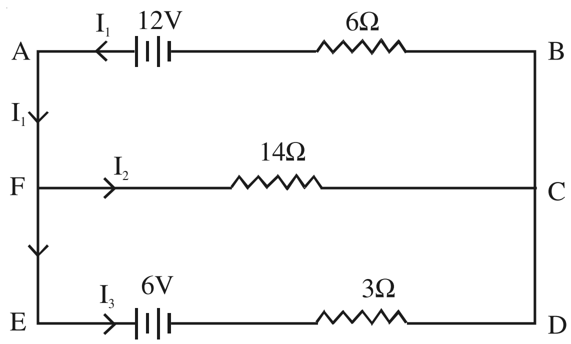
19. Write the relation between pressume, volume and root mean square speed of a gas. using the relation deduce the law of equipartition of energy. Applying law of equipartition of energy to find the value of CP/CV for a diatomic gas 5

20. Applying kirchhott's rules to the given network and find.

    (*a*) Values of I_1, I_2 and I_3

    (*b*) Potential difference between A and B.

    (*c*) Net energy supplied by the two batteries shown is the circuit. 5



or

A coil of wire when connected to a 100 vdc source draws 1A current. The same coil when connected to a 100 *v*, 50 H*z ac* source draws only 0.5A. Explain. Also calculate the resistace, reactance and impedance of the coil.

21. An air filled parallel plate capacitor with capacitance C is charged by a V volt battery and then the battery is disconnected. Now the seperation between its plates is doubles. How will the following quantities be affected?

    (*a*) capacitance (b) chare (c) potential difference between the plates (d) strength of dectrostatic field between the plates (e) electrostatic potential energy stored in the capacitor per units volume. 5

22. Draw a graph showing variation in binding energy per nucleon with mass number of various elements upto mass number 20. Using this graph explain the release of energy in fusion. 5

<u>Section (B)</u>

Optional Module – A :

Electronics And Communication Systems.

23. Describe the meaning of modulation. Give three points to emphasize the need of modulation in long distance transmission of signals. Name a method of modulating

    (*i*) an analogue signal (*ii*) a digital signal. 5

24. State the function of an inverter. Giving its block diagram explain its working principle. Give its two applications. 4

25. The tank circuit of an oscillator consists of an inductor L = 50 *m*H and a capacitor C = 0.2 *uf*. What will be the frequency of the oscllator. 2

26. Give one point of difference between LCD and LED. 1

Optional Module – B :

(Photography And Audio Video Graphy.)

27. With the help of a suitable diagram explain the principle, construction and working of a photographic camera. 5

28. Name the instrument which converts (*i*) sound into electrical signals. (*ii*) Electrical signals into sound. Name the essential processes involved in the working of a tape recorder. Draw block diagram of any one of these. 4

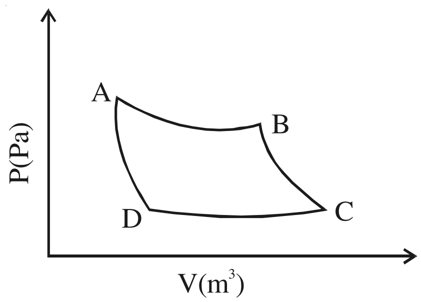
29. In a photography camera, what is meant by aperture setting $f\frac{f}{8}$ and a shutter speed of $\frac{1}{60}$ s. 2

30. Which defect of camera lens may be reduced by the use of small aperture? 1

Marking Scheme For Sample Paper
Senior Secondary Physics.
Section - A

Maximum Marks: 80 **Time : 3 Hours**

<table>
<tr><th>Q. No.</th><th>Expected Value point</th><th>Marks.</th></tr>
<tr><td>1.</td><td>Reverse</td><td>1</td></tr>
<tr><td>2.</td><td>No.</td><td>1</td></tr>
<tr><td>3.</td><td>Because moon has no atmosphere
Green house gases like CO_2 maintain moderate global temperature on earth.</td><td>½
½</td></tr>
<tr><td>4.</td><td>$\frac{1}{75}$ min or $\frac{60}{75}$ s or 0.8s</td><td>1</td></tr>
<tr><td>5.</td><td>



Correct diagram
AB – isothermal expansion.
BC – adiabalie expansion.
CD – isotheronal compression.
DA – adiabalic compression</td><td>1

1</td></tr>
<tr><td>6.</td><td>

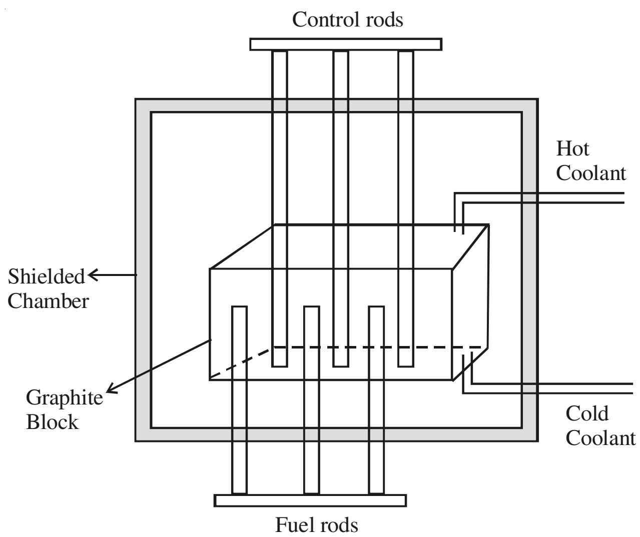


diagram
Labelling</td><td>1
1</td></tr>
<tr><td>7.</td><td>Excess Pressure in a soap bubble = $\frac{4T}{r}$
$\therefore$ A pressure in A is less than the pressure in B
fluids flow flow from higher to lower pressures.
$\therefore$ size of A will increase</td><td>½
½
½
½</td></tr>
</table>

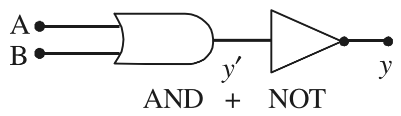
8. In young's double slit experiment fringe width w = $\frac{D\lambda}{d}$ ½

(i) When seperation between the source shts, ve; d decreases fringe width w increases ½

(ii) Sodium lamp is a mono chromatic source where as mercury lamp is a polychromatic source. ½

Due to inter ference only a few coloured fringes will be seen around a central white bright fringe.

9. NAND Gate is refresented as



A	B	y′	y
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0

½+½+1

10. The loaded truck has more mass ∴ it has lesser kinetic energy ½

∵ Kinetic energy = $\frac{p^2}{2m}$ and P is same for both the vehicles ½

According to Work – Energy theorem

$k\varepsilon = f.v$ ½

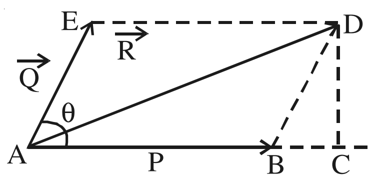
as F is same $x \propto \kappa\varepsilon$ a ∴ Truck will come to stop in smaller distance ½

11. The law of parallelogram of vectors states; "If two vectors may be represented in magnitude and direction by the two adjacent sides of a parallelogram then the magnitude and direction of the resultant vector will be given by the diogonal of the parallelogram passing through the common origin."**(figure)** 1

In right ΔACD

$|AD|^2 = |AC|^2 + |CD|^2$

$= \left|\overline{AB} + \overline{BC}\right|^2 + |CD|^2$ 1



$\Rightarrow |R|^2 = (|P| + |Q|\cos\theta)^2 + (|Q|\sin\theta)^2$

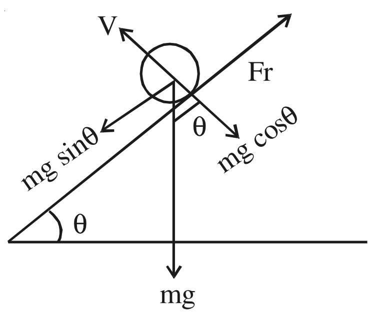
$= |P|^2 + |Q|^2 + 2|P||Q|\cos\theta + |Q|\sin\theta.$ 1

i.e. $|R|^2 = |P|^2 + |Q|^2 + 2|P||Q|\cos\theta.$

$\Rightarrow |R| = \sqrt{|P|^2 + |Q|^2 + 2|P||Q|\cos\theta}$ 1

12. (*a*) The sphere rolls without shiping when v_{cm} = RW ½

(*b*)



½

$mg.\sin\theta - fr = ma$ ½

$T = RFr = I\frac{a}{R}$ ½

$\Rightarrow f_r = \frac{Ia}{R_2}$ ½

$mg\sin\theta = \left(m + \frac{I}{R^2}\right)a$ ½

$a = \left(\frac{a\sin\theta}{1 + \frac{I}{mR^2}}\right)$

as for sprere

$T = \frac{2}{5}mR^2$ ½

$= \frac{\frac{2}{5}mR^2}{R^2}\left(\frac{g\sin\theta}{1 + \frac{2}{5}\frac{mR^2}{mR^2}}\right) = \frac{2}{5}\frac{mg\sin\theta}{7/5} = \frac{2}{7}mg\sin\theta.$ 1

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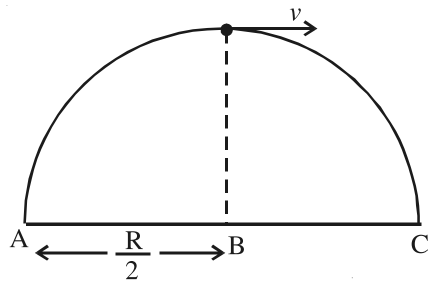
13. 

Let the speed of the projectile at the highest point (efore splitting into two halves be v.
As a single piece it might have travelled a horizontal distance $\frac{R}{2}$ in reaching the highest point. ½

On splitting , a piece of mass $\frac{m}{2}$ returning bacle to the starting point (A) must also have speed v (as it also has to travel a distance $\frac{R}{2}$ horizontally). 1

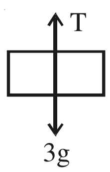
According to conservation of momentum, the other piece must have a speed = V_1 (say)

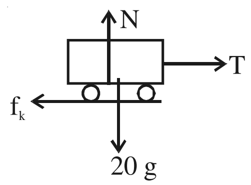
$mv = \frac{m}{2}v^1 - \frac{m}{2}v \Rightarrow v^1 = 3v$ 1½

Hence this piece coill fall at a horizontal distance of $\frac{3}{2}R$ from or a distance of 2R from A. 1

or

½+½





$3g - T = 3a$ ½

$T - fk = 20a$ ½

$N = 20g$ ½

$T - ukn = 20a$ ½

$T - 0.04 \times 20g = 20a$ ½

a = 0.96 ms^{-2}, T = 27.1 n ½+½

14. (*a*) Hooke's Law of elasticity statis, "Withins elastic limits stress is directly proportional to strain."

i.e. $\frac{stress}{strain} = E$

where *E* is a constant for the given material and is called as coefficient of elasticity of the material. The coefficient of elasticity is a scolar quantity and has limit nm^{-2}. 1

(*b*) Pascal's Law of hydrostatics states; "Pressure applied on any part of a confined liquid is transmitted equally in all direction." 1

Thus a force F applied on an area A results in a pressure $p = \frac{F}{A}$ which is transmitted through the liquid equally in all direction and acts normally on an exposed surface. If the area of the surface is 10 A them the force due to the pressure on the surface = 10A.P = 10F. This way effect of force may be multiplied by increasing surface.

Pressure also is a scolar Quantity and its SI unit is Nm^{-2} (pascal). 1

15. (*i*) Stationary wave 1

(*ii*) 2v = 120 ⇒ v = 60 Hz 1

$\frac{2\pi}{\lambda} = \frac{2\pi}{3} \Rightarrow \lambda = 3m$ 1

(*iii*) 648n 1

16. (*i*) The two main defects of images formed by spherical lenses are :

(*a*) Chromatic aberration (*b*) Spherical aberration 1

(*ii*) (*a*) Chromatic aberration is caused by the dispersion in various parts of the lens due to which white light from a point source do not get focussed at one point, rather dispersed rays of different colours are focussed at different points.

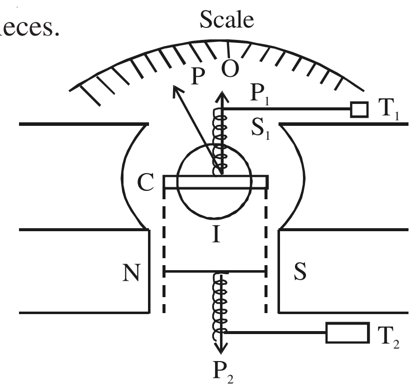
(*b*) Spherical aberration is caused by the spherical shape of lens surfaces due to which the paraxial rays are focussed at a distant position and marginal rays at a near by position. 2

(*iii*) Suitable lens combinations may be formed to minimize these defects. 1

or any other suitable answer.

17. **Construction**

NS – strong permanent magnet with cylimelical pole pieces. 1



I – Cylindirical soft iron core fixed cooxially with the cylindricl air gap between the pole pieces, to provide radial field. 1

C – a rectangular coil of large number of turns of insulated copper wire mounted on an insulated for me.

S_1 and S_2 ⇒ hair spring with the help of which the coil is kept in position at pirots P_1 and P_2. The springs also help as lead for current terminal T_1 to T_2 through the coil.

P ⇒ Pointer attached to the centre of cal to move on horizontal scale.

Working : When current is passed through the coil it experiences a torgue T_1 = BINA and gets deflected. As the coil turns the springs are twisted and apply a restoring torgue

$T_1 = CO$. At equilibrium.

BINA = CO.

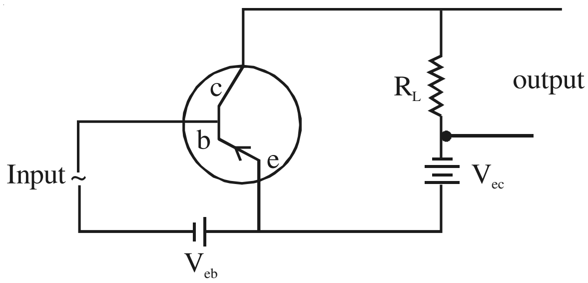
$$I = \frac{C}{BNA}\theta = K\theta$$

Thus more current is passed more deflection is shown by the pointer. On reversing current the direction of deflection of the pointer on the scale is also reversed.

To convert the galvanometer of resistance R*g*, which shows full scale deflection for current Ig, into a voltmeter of range O – V volts we will have to connect a high resistance

$R = \left(\frac{V}{Ig} - Rg\right)$, in series with the galvanometer coil, make it end zero and colibrate for measuring voltages. 1

18.



Correct symbol of pnp transistor	½
Correct orientation of transistor	½
Correct biasing of *eb* and *cb* junction.	½+½
Working of transistor as amplifier.	
Small change in base current results in large change in collector current.	½
$R_{eb} < R_{bc}$ resistance	½
Current gain and gain both are greater than 1 hence substantial voltage gain.	½
Input and output graphsor idea of phase reversal.	½

19. $PV = \frac{1}{3}mn\overline{C}^2$ 1

$$= \frac{2}{3}.n.\frac{1}{2}m\overline{C}^2$$

$$= \frac{2}{3}.n.(k\varepsilon\ of\ 1\ molecule)$$

also. PV = *u*Rt

$\therefore$ *u*RT = $\frac{2}{3}n$ ER

$$\frac{3}{2}\frac{uRT}{n}$$

ER = $= \frac{3}{2}.\frac{RT}{n/u} = \frac{3}{2}\frac{RT}{N}\ where\ \frac{R}{N} = k$

= Boltzmann constant = $\frac{3}{2}RT$ 1

In deriving relation (1) a monoatomic molecule having three degrees of freedom was cousidered

$\therefore$ Energy associated with each degree of freedom = $\frac{1}{2}RT$. ½

The energy of 1 mole of a diatomic gas at TK

$E_T = 5 \times \frac{1}{2} RT.\ N$

$= \frac{5}{2}RT.$ ½

And at (T + 1) k

$E_{T+1} = \frac{5}{2}R(T+1)$

$\therefore$ Cv = Energy required to raise the temperature of 1 mole of gas by 1k = $E_{T+1} - E_T = \frac{5}{2}R$. ½

also CP = Cv + R.

$= \frac{7}{2}R.$ ½

$\therefore f = \frac{Cp}{cv} = \frac{7R/2}{5R/2} = \frac{7}{2} = 1.4$ ½

---

20. (a) $I_1 = \frac{5}{6}A, I_2 = \frac{1}{2}A., I_3 = \frac{1}{3}A$ 1+1+1

(b) VA – VB = 7v 1

(c) 8 watt. 1

OR

At dc it is the renstance of the wire only which ultimately hinders the current.

$\therefore R = \frac{100}{1} = 100\Omega$ 1

In ac in addition to resistance reactance of the coil also becaome effective and hence impedence of the coil 1

$z = \frac{100}{0.5} = 200\Omega$ 1

$z^2 = X_l^2 + R^2 \Rightarrow X_2 = \sqrt{Z^2 - R^2} = \sqrt{100 \times 300} = 173.2\Omega$ 1

$X_l = 2\pi vl \Rightarrow L = \frac{XL}{2\pi v} = \frac{173.2}{2 \times 3.14 \times 50} = \frac{173.2}{314} = 0.55H$ 1

21. (a) $C = \frac{\varepsilon_o}{d}$ as d is doubled C will be halved. 1

(b) One the capacitor is charged and battery removed the charge on the plates will stay unaltered. 1

(c) $V = \frac{Q}{C}$ as Q remains same and C is halved V will be doubled. 1

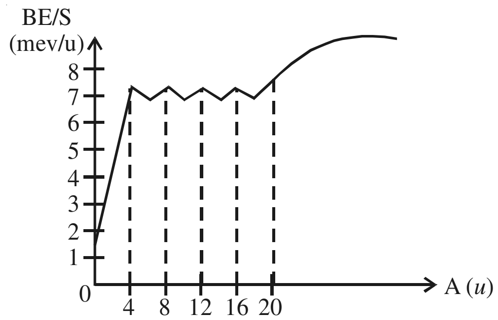
(d) $E = \frac{v}{d}$ as v and d both are doubled E stays unaltered 1

(e) Energy density $\frac{1}{2}\varepsilon E^2$ which is a constant for the given set up is electriostalic potential energy started per umit volume remains cost. 1

22. Correct indication A quantities and their units on axes . 1

Peaks at internals of 4v. 1

Rise from 1.1 mer/u to 7.7 Mev/u for A = 1 to A = 4 1



In fusion reaction 4 protons fuse together to form a helium nucleus in accordance with the following reaction 1

${}_1^1H \Rightarrow {}_2^4He + 2\,{}_{+1}^{o}t + 25.6$ Mev 1

Total B. ε of four nucleous in ${}_2^4H$ $4 \times 7.7 = 30.8$ Mev

Total B. ε of four protons 4×1.1 4.4 Mev

∴ in the fusion reaction energy rebased = 26.4 Mev

Nearly 1 Mev energy is corresponding to two positions. 1

Section (B) : (i) Electronics And Communication Systems.

23. Modulation is the process of translating the low frequency messege signal into high frequency waves in such a way that the information contained in the original signal remains intact. 1

Long distance transmission can not be done on low frequencies because of the following problems :

(*i*) Size of antenna : For effective transmission minimum height of antenna required is $\frac{\lambda}{4}$.

The upper limit of andable frequencies 20 RH*z* corresponds to a wavelength 15 R*m*. Such long antennas are practicable. 1

(*ii*) Effective Power Radialed By An Antenna : Studies have shown that effective power irradiated by an antenna $\propto \left(\frac{l}{\lambda}\right)^2$. Thus less the wavelength (or more the frequency) more powerful is radiated signal. 1

(*iii*) Mixing UB of signal from different transmitter : A very large number of transmitters operate at the same time. If all of them transmit at the same base-band the information coill get mixed up and no clear imformation will be received. 1

So modution is a must for long distance transmission of signals.

Amplitude Modulation (AM) or frequency Modulation (FM) is used for analogue signals. ½

Pulse code Modulation (PCM) is used for digital signals.

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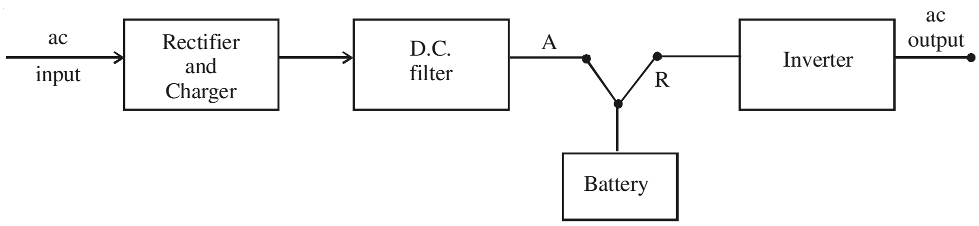
24. 

1

Inverter is a power device through which *dc* power may be converted into ac of desired frequency and voltage. — 1

The block diagram showing the basic working of an inserter is given above.

AC input is rectified, filtered and then through a relay R given to a battery to charge it. An overcharge protection circuit is used for the saflit of the battery. — ½

When there is a load shedding the relay R connects the battery to the inverting circuit, which consists of oscillator which converts *dc* from the battery into *ac* at 220v, 50 Hz. The output of the inverter is used to run our household appliances. — ½

Two applications of inverter are :

(i) As stand by system for small power applications. — ½

(ii) For un interrupted power supply system which is very important in computers and circuits having memory systems. — ½

or any other correct applications.

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25. $v = \dfrac{1}{2\pi\sqrt{LH}}$ — ½

$= \dfrac{1}{2\pi\sqrt{50\times10^{-3}\times.2\times10^{-6}}}$ — ½

$= \dfrac{10^4}{2\pi}\text{Hz}$ — 1

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26. LED gives oft light but LCD controls light — 1

(*ii*) Photography And Audio Videography.

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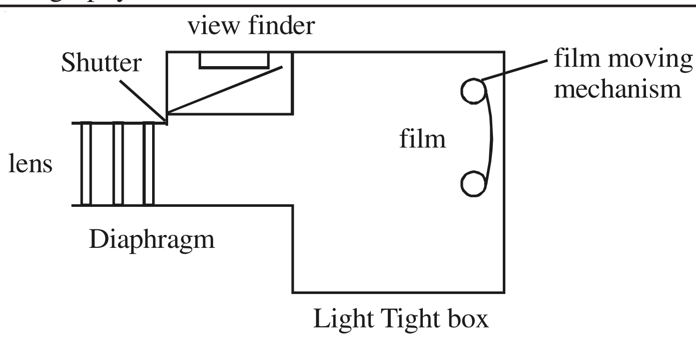
27. Diagram — 1

Labelling — 1

Description — 1

Principle — 1

Working — 1



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28. The instrument which converts (*i*) sound into electrical signals is microphone — ½

The essential processes involved in the working of a tape recorder are :

(*a*) Recording — ½

(*b*) Reproduction — ½

(*c*) Elasure — ½

	Block diagram of any one of the above	½
	Aperture setting, in photographic Camera, is done in terms of *f*–number.	½
	$f - \text{number} = \dfrac{\textit{focal length of the lens.}}{\textit{working diameter of the lens}}$	½
	$f - \text{number} = \dfrac{f}{8}$ implies an average value of aperture.	½
	For right exposure of the film the aperturs of the lens is to be correctly matched with the right shutter speed which is the time for which the light is allowed to enter the camera. A shutter speed of $\dfrac{1}{60}$ & sinplies that the shutter opens for $\dfrac{1}{60}$ s to enter light in the camera.	½
29.	Spherical aberration	1

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Lesson No.	Lesson Name	Content			Language		Illustrations		What You Have Learnt	
		Difficult	Interesting	Confusing	Simple	Complex	Useful	Not useful	Very helpful	Not helpful
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31A.										
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33A.										

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