विध्न विचारत भीरु जन, नहीं आरम्भे काम, विपति देख छोड़े तुरंत मध्यम मन कर श्याम।
पुरुष सिंह संकल्प कर, सहते विपति अनेक, 'बना' न छोड़े ध्येय को, रघुबर राखे टेक।।

रचितः मानव धर्म प्रणेता
सद्गुरु श्री रणछोड़दासजी महाराज

STUDY PACKAGE

This is TYPE 1 Package please wait for Type 2

Subject : PHYSICS

Topic : THERMAL & CHEMICAL EFFECTS OF CURRENT

Teko® CLASSES .....the support

Index

Student's Name :______________________

Class :______________________

Roll No. :______________________

ADDRESS: R-1, Opp. Raiway Track,
New Corner Glass Building, Zone-2, M.P. NAGAR, Bhopal
☎ : (0755) 32 00 000, 98930 58881, www.tekoclasses.com

THERMAL AND CHEMICAL EFFECTS OF CURRENT

Q.1 What are the SI units of electrical energy and electric power? What is the practical unit of electrical energy?

Sol. The S.I. unit of electrical energy is joule and that of electrical power is watt. The practical unit of electrical energy is kilo watt-hour.

Q.2 What is the cause of heating effect of current?

Sol. When a potential difference is applied across a conductor, the free electrons are accelerated due to the electric field. These electrons collide frequently with the ions in the conductor and lose their kinetic energy. which appears as heat energy.

Q.3 Write two characteristics of the wire of an electric heater.

Sol. Two characteristics of a heater wire are:
(1) It should have high melting point.
(2) It should have low resistance.

Q.4 What are the various factors on which the heat produced in a conductor depends?

Sol. The various factors on which the heat produced in a conductor depends are
(a) the current through the conductor,
(b) resistance of the conductor,
(c) the time for which the currents is passed through the conductor.

Q.5 State Joule's law of heating.

Sol. Heat produced in a conductor of resistance R, when a current flows through it for time t, is given by $H = I^2Rt$. This is called Joule's law.

Q.6 Define S.I. unit of electrical power.

Sol. S.I. unit of electric power is watt. The power consumed by an electric circuit is said to be one watt, if a potential difference of one volt applied across it produces a current of one ampere in that circuit.

Q.7 Convert kWh into joules.

Sol. I kWh $= 10^3 W \times 60 \times 60 s = 3.6 \times 10^6$ J

Q.8 Of the two bulbs in a house, one glows brighter than the other. Which of the two has larger resistance?

Sol. The resistance of the dimmer bulb is larger.

Q.9 What is an electrolyte?

Sol. Substances which conduct electricity because a fraction of their molecules dissociate into positive and negative ions are called electrolytes. The most common examples are acids, bases and salts which ionize when dissolved in water.

Q.10 What is electrolysis?

Sol. The process of chemical decomposition of a conducting liquid (electrolyte) into its components when a current is passed through it is called electrolysis.

Q.11 What are anions and cations?

Sol. Anion: It is a negatively charged ion formed by addition of electrons to atoms or molecules. In electrolysis, anions are attracted to the positive electrode (anode).
Cation: It is a positively charged ion formed by removal of electrons from atoms or molecules. In electrolysis, cations are attracted to the negative electrode (cathode).

Q.12 State Faraday's laws of electrolysis.

Sol. **Faraday's First Law:** The mass of a substance deposited or liberated at an electrode is proportional to the quantity of charge that passes through the electrolyte, i.e.,

$$m \propto Q$$
$$\text{or } m = ZQ = zIt$$

The constant z is called the electrochemical equivalent (E.C.E.) of the substance.

Faraday's Second Law: If the same quantity of charge is passed through several electrolytes, then the masses of the various substances deposited at the respective electrodes are proportional to their chemical equivalents (equivalent weights). Thus if m_1 and m_2 are the masses of two substances deposited and E_1 and E_2 are their respective chemical equivalents, then $\frac{m_1}{m_2} = \frac{E_1}{E_2}$.

Q.13 Define electrochemical equivalent of an element.

Sol. Electrochemical equivalent of an element is the mass of the element released from a solution of its ion when a current of one ampere flows for one second during electrolysis.

Q.14 What is Faraday constant?

Sol. Faraday constant is the quantity of charge required to liberate one equivalent weight of a substance. It is equal to 96500 C.

Q.15 Write some uses of electrolysis.

Sol. Some of the important uses of electrolysis are:
(a) Electroplating (b) Purification of metals
(c) Electrotyping (d) Medical applications etc.

Q.16 What is electroplating?

Sol. Electroplating is the process in which a layer of some metal is deposited on any other surface by the process of electrolysis. The anode is made of the metal to be deposited and the cathode is made of the substance which is to be electroplated.

Q.17 State two reasons, why electrolytes have lower electrical conductivity than metallic conductors in general.

Sol. (a) The ionic density in electrolytes is very small as compared to the free electron density in metals.
(b) The mobility of free electrons in metal is much higher than the mobility of ions in electrolytes.

Q.18 What are strong electrolytes? Give examples.

Sol. Those electrolytes which are completely ionised in their solutions are called strong electrolytes. For example HCI, NaCI etc.

Q.19 What are weak electrolytes? Give examples.

Sol. Some electrolytes are ionised to a small extent in their solutions. For example, NH_4Cl. Such electrolytes are called weak electrolytes.

Q.20 If pure water is used, no electrolysis takes place. Why?

Sol. Pure Water does not undergo electrolysis as it does not dissociate into constituent ions. Therefore water is acidified before electrolysis.

Q.21 How does a voltmeter differ from a voltameter?

Sol. Voltmeter is a device which is used to measure potential difference between two points, while voltameter is a vessel containing an electrolyte with two electrodes immersed in it. Current can be measured with voltameter.

Q.22 Write the SI unit of electrochemical equivalent.

Sol. The SI unit of electrochemical equivalent (E.C.E.) is kg per coulomb.

Q.23 Name the electrodes on which hydrogen and oxygen are liberated during the electrolysis of water.

Sol. During the electrolysis of water, hydrogen is liberated at the cathode and oxygen is liberated at the anode.
At the cathode the reaction is: $4H_2O + 4e^- \longrightarrow 4H^- + 2H2$
At the anode the reaction is': $2H_2O \longrightarrow 4H^+ + 4e^- + O_2$

Q.24 Why does molten sodium chloride conduct electricity? Explain.

Sol. Sodium chloride in an ionic compound. Even in solid state it has Na^+ and Cl^- ions. When it is melted, ions are free to move and became charge carriers. So NaCl in molten state conducts electricity.

Q.25 Is electrolysis possible with alternating current?

Sol. No, electrolysis is not possible with a.c. For electrolysis current should pass continuously only in one direction. In case current reverses its direction periodically, no deposition on the electrodes will take place.

Q.26 What is the difference between a fuse wire and a heater wire?

Sol. The melting point of a fuse wire is very low while that of a heater wire is very high.

Q.27 What is an electrochemical cell ?

Sol. An electrochemical cell is a system in which a chemical reaction produces an e.m.f. Thus a cell converts chemical energy into electrical energy.

Q.28 Distinguish between primary and secondary cells.

Sol. A primary cell is one in which the chemical reaction that produces the emf is not reversible. Thus a primary cell cannot be recharged. A secondary cell is one in which the chemical reaction is reversible. Thus a secondary cell can be recharged.

Q.29 What is an accumulator or a storage cell? Write names of two storage cells.

Sol. A secondary cell is also called an accumulator or a storage cell. In these cells the chemical reaction is reversible. So they can be recharged.
Two secondary cells are: (a) Lead-acid cell (b) Ni-Fe cell.

Q.30 Describe briefly a simple voltaic cell ?

Sol. A simple voltaic cell consists of a glass vessel containing dilute sulphuric acid which acts as electrolyte. A copper rod and a zinc rod are immersed in the acid.

Action: Zinc atoms in contact with sulphuric acid give up electrons : $Zn \longrightarrow Zn^{++} + 2e^-$

The Zn^{++} ions pass into the electrolyte. As a result the zinc electrode is left negatively charged and acts as cathode.

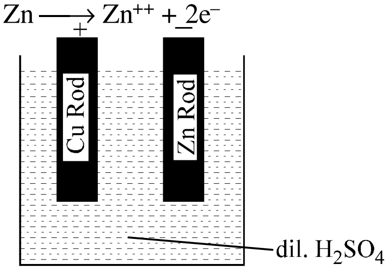
Sulphuric acid and water dissociate as

$$H_2SO_4 + H_2O \longrightarrow 2H^3O^+ + SO_4^-$$

Due to high concentration of Zn^{++} ions near the cathode, the H_3O^+ ions are pushed towards the copper electrode, where they get discharged by removing electrons from the copper atoms:-

$2H_3O^+ + 2e^- \longrightarrow 2H_2O + H_2$

The copper electrode is thus left positively charged and acts as anode.



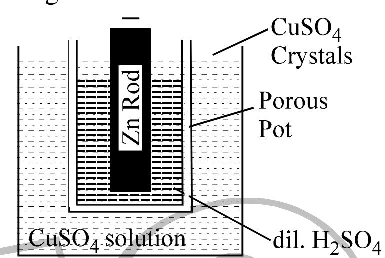
Voltaic Cell

Q.31 Describe with the help of a labelled diagram the construction and working of a Daniel cell.

Sol. Deniel Cell: It consists of a zinc electrode immersed in dilute sulphuric acid (or acidulated zinc sulphate solution) and a copper electrode in copper sulphate solution, with a membrane (porous pot) through which ions can pass from one solution to the other. At the former electrode zinc ions pass into the solution and at the other electrode copper ions are deposited, according to the following reactions :

$Zn \longrightarrow Zn^{++} + 2e^-$

$Z^{++} + CuSO_4 \longrightarrow ZnSO_4 + Cu^{++}$ and $Cu^{++} + 2e^- \longrightarrow Cu$



Deniel Cell

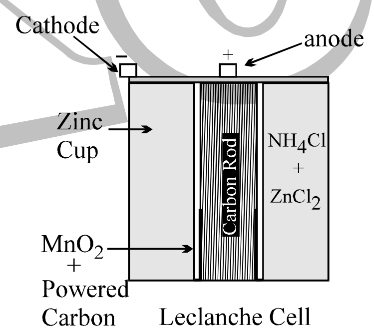
The emf of the cell is 1.1 V. Zinc rod is amalgamated to avoid local action. This cell is not very useful due to polarization.

Q.32 Draw a labelled diagram to show the components of a Leclanche cell and write the reactions taking place inside the cell.

Sol. Laclanche cell has two forms - wet and dry. Figure shows the labelled diagram of a dry Laclanche cell.

When an external circuit is connected across the cell, zinc atoms in contact with the electrolyte ionize, losing two electrons per atom. The electrons flow into the metal wire circuit and Zn^{++} ions pass into the solution. The zinc is thus the cathode:

$Zn \longrightarrow Zn^{++} + 2e^-$



Leclanche Cell

The ammonium ions of the electrolyte remove electrons from the carbon anode, to which electrons flow in from the external circuit. One thus has

$$2NH_4^+ + 2e^- \longrightarrow 2NH_3 + H_2$$

at the anode.

The hydrogen is neutralized by MnO_2 at the anode, and in the body of the electrolyte, the Zn^{++} ion combines with the Cl^- ions to form $ZnCl_2$, so that the overall chemical reaction is

$Zn + 2NH_4Cl + MnO_2 \longrightarrow ZnCl_2 + 2NH_3 + H_2O + Mn_2O_3 + Q$

Q being the energy released in the reaction.

Q.33 What is the emf of a dry cell.

Sol. E.M.F.of a dry cell is 1.5V.

Q.34 What is local action in a voltaic cell?

Sol. In a voltaic cell, impurities like carbon etc. lying on the surface of the zinc rod, on coming in contact with the acid form minute cells. Due to these minute cells some internal currents are set up in the zinc rod which results in wastage of zinc. This phenomenon is called local action.

Q.35 What do you mean by polarisation in cells?

Sol. In a primary cell, hydrogen is produced which migrates to the anode and covers it in the form of bubbles. As a result the current decreases and finally stops. This phenomenon is called polarization.

Q.36 You are given a primary and a secondary cell of the same emf. From which cell will you be able to draw larger current and why?

Sol. The secondary cell will provide larger current as the internal resistance of a secondary cell is less than that of a primary cell.

Q.37 Name the depolariser in Laclanche cell.

Sol. Manganese dioxide (MnO_2)

Q.38 Can you use the Leclanche cell for supplying steady current?

Sol. Leclanche cell can not be used for supplying steady current for a long time. The emf of this cell falls due to partial polarisation.

Q.39 State the transformation of energy in a photo cell.

Sol. In a photo cell light energy is transferred into electrical energy.

Q.40 What is thermoelectric effect (Seebeck effect) ?

Sol. If two wires of different metals are joined at the ends and the two junctions are maintained at different temperatures, then a current starts flowing through the wires. This is called Seebeck effect. The emf developed in the circuit is called thermo-emf.

Q.41 What is thermo electric series? Mention the first and the last members of the series.

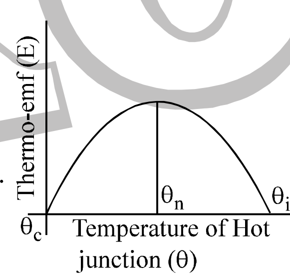
Sol. Seebeck arranged a number of metals in the form of a series according to the following criteria:
(i) Current flows through the cold junction from the metal which appears earlier in the series to the metal which appears later.
(ii) Greater the separation of the two metals in the series, greater is the thermo-emf generated.
First member of the series -Sb
Last member of the series -Bi

Q.42 What is the order of thermo-emf?

Sol. The order of thermo-emf is 10^{-6} V

Q.43 Draw the graph showing the variation of thermo-emf of a thermocouple with the temperature difference of its junctions. How does its neutral temperature vary with the temperature of the cold junction?

Sol. Neutral temperature is independent of the temperature of the cold junction.



Q.44 What is thermoelectric power? Write its S.I. unit.

Sol. The rate of change of thermo-emf with temperature, $\left(\frac{dE}{d\theta}\right)$, is called thermoelectric power or Seebeck coefficient. It's S.I. unit is volt/Kelvin

Q.45 Define neutral temperature and temperature of inversion.

Sol. If the temperature of the hot junction of a thermocouple is gradually increased, the thermo-emf first increases and attains a maximum value. This temperature is called neutral temperature (θ_n)
If the temperature is further increased, the emf decreases to become zero again and then it changes direction. The temperature at which the thermo-emf changes direction is called temperature of inversion (θ)

Q.46 Thermo-emf is given by the expression
$E = \alpha\theta + (1/2)\beta\theta^2$
Write the expression for thermoelectric power (Seebeck coefficient)

Sol. $E = \alpha\theta + (1/2)\beta\theta^2$
Thermo electric power $S = \frac{dE}{d\theta} = \alpha + \beta\theta$

Q.47 What is Peltier effect?

Sol. If a current is passed through a junction of two dissimilar metals, heat is either absorbed or evolved at the junction. On reversing the direction of current, the heating effect is also reversed. This phenomenon is called Peltier effect.

Q.48 Define Peltier coefficient.

Sol. Peltier coefficient is defined as the amount of heat absorbed or evolved per second at a junction when a current of I A is passed through it.

Q.49 What is Thomson effect?

Sol. The production of an electric potential gradient along a conductor as a result of a temperature gradient along it is called Thomson effect. Thus points at different temperatures in a conductor are at different potentials.

Q.50 What is a Thermopile?

Sol. Thermopile is a series combination of thermocouples. It is used to detect and measure the intensity of heat radiation.

Q.51 Mention some applications of thermoelectric effect.

Sol. Some of the important applications of thermoelectric effect are:
(a) Power generation (b) Measurement of temperature (c) Remgeration.

Q.52 Name the carriers of current in the following voltameters:
(a) Copper electrodes in $CuSO_4$ solution.
(b) Platinum electrodes in dilute sulphuric acid.

Sol. (a) Cu^{++} and SO^{--} ions. (b) H^+ and OH^- ions.

Q.53 Write the expression which gives the relation of the thermoelectric emf of a thermocouple with the temperature difference of its cold and hot junctions.

Sol. $E = \alpha\theta + (1/2)\beta\theta^2$ where a and β are constants.

Q.54 Give one practical application of thermoelectricity.

Sol. Measurement of temperature.

Q.55 Why is an electrolyte dissociated when dissolved in liquids ?

Sol. The ionic bonds between the ions of the solute are made weak by polar molecules of liquids. Therefore the ions of electrolyte (solute) get dissociated.

Q.56 How is the electrical conductivity of an electrolyte affected by increase of temperature?

Sol. The electrical conductivity of an electrolyte increases with the increase in temperature.

Q.57 Write one main difference between primary and secondary cells.

Sol. The primary cells can not be recharged while in secondary cells reversible reactions take place so that they can be recharged.

Q.58 What is the direction of the thermoelectric current at the hot junction of an iron-copper thermocouple?

Sol. From copper to iron.

Q.59 What is the relation between temperature of cold junction, neutral temperature and inversion temperature?

Sol. $$\theta_n = \frac{\theta_i + \theta_c}{2}$$

where θ_n is neutral temperature, θ_c is temperature of cold junction, and θ_i is inversion temperature.

Q.60 Name the thermocouple which is used to measure a temperature of 300 K.

Sol. Copper-Constatantan thermocouple.

Q.61 How are metals purified by electrolysis process?

Sol. For purification of metals by electrolysis, anode is made of the impure metal and cathode of pure metal. The electrolyte used is any soluble salt of pure metal. When current is passed through the electrolyte, pure metal gets deposited on the cathode.

Q.62 Describe briefly a lead-acid accumulator, giving its charging and discharging chemical equations.

Sol. Lead-acid accumulator is a secondary cell which can be recharged by passing a current through it in the reverse direction. The chemical process that occurred at the electrodes are then reversed and the cell recovers its original state.

The electrodes consist of alternating parallel plates of lead dioxide (positive electrode) and spongy lead (negative electrode) insulated from each other. They are immersed in an electrolyte of dilute sulphuric acid.

Reactions: H_2SO_4 dissociates into H^+ and SO^{--} ions.

During discharging:

At Cathode: $Pb + SO_4^{--} \longrightarrow PbSO_4 + 2e^-$

At anode: $PbO_2 + 2H^+ + 2e^- \longrightarrow PbO + H_2O$

$PbO + H_2SO_4 \longrightarrow PbSO_4 + H_2O$

During charging:

At cathode: $PbSO_4 + 2H^+ + 2e^- \longrightarrow Pb + H_2SO_4$

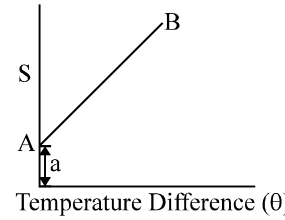
At anode: $PbSO_4 + SO_4^{--} + 2H_2O \longrightarrow PbO_2 + 2H_2SO_4 + 2e^-$

Q.63 Plot a graph showing the variation of thermoelectric power with temperature difference between the hot and the cold junctions.

Sol. Thermo electric power S is given by

$S = \alpha + \beta\theta$

The graph is shown in figure



Q.64 Which one has lower internal resistance–a secondary cell or a primary cell?

Sol. Secondary cell.

Q.65 Seebeck effect is reversible. What does it mean ?

Sol. It means that if the hot and the cold junctions are interchanged, the emf changes sign and the circulating current reverses direction.

Q.66 What are the units in which the thermoelectric coefficients α and β are generally expressed?

Sol. α: μ V/°C

β: μ V/°C^2

Q.67 At room temperature, what is the order of the ratio of the conductivity of an electrolyte to-that of a conductor?

Sol. 10^{-5} to 10^{-6}

Q.68 Name a liquid which allows current through it but does not dissociate into ions.

Sol. Mercury

Q.69 On what factors does the magnitude of thermo-emf depend?

Sol. The magnitude of thermo-emf depends on two factors:

(a) Nature of the metal~ forming the thermo couple.

(b) Temperature difference between the two junctions.

Q.70 Derive the relation between Faraday constant and Avogadro number.

Sol. Faraday constant (F) is the amount of charge required to liberate 1 equivalent weight of a substance by electrolysis. So the amount of charge required to liberate 1 mole of the substance is Fp where p is valency of the substance.

The charge required to liberate one atom of substance is, therefore $\dfrac{Fp}{N}$

Now, the charge on each ion is pe, where e is electronic charge. Thus $\dfrac{Fp}{N} = pe$; $F = Ne$

Q.71 Are all pure liquids bad conductors of electricity ?

Sol. No. For example, mercury is a good conductor.

Q.72 Define International Ampere.

Sol. International ampere is defined as the steady current, which when passed through a silver voltameter, deposits 0.001118 g of silver in one second on the cathode.

Q.73 Define chemical equivalent and electrochemical equivalent of a substance.

Sol. The electrochemical equivalent of a substance is defined as the mass of the substance deposited on anyone of the electrodes when one coulomb of charge passes through the electrolyte.

The chemical equivalent of a substance is defined as the ratio of atomic weight to the valency.

Q.74 Derive the relation connecting chemical equivalent and electrochemical equivalent of an element.

Sol. From Faraday's first law of electrolysis, we have m = zit, where z is the electrochemical equivalent (ece). Now we consider two substances having chemical equivalents E_1 and E_2. When the same quantity of charge is passed through the electrolytes containing them, let the masses of the two substances liberated be m_1 and m_2 respectively.

Then, from Faraday's second law $\dfrac{E_1}{E_2} = \dfrac{m_1}{m_2}$

But $m_1 = z_1it$ and $m_2 = z_2it$ where z_1 and z_2 are the ece's of the two substances. So,

$$\frac{E_1}{E_2} = \frac{m_1}{m_2} = \frac{z_1u}{z_2u}$$

or E/z = Constant. The constant is denoted by F and is called Faraday constant: E/z = F

Q.75 What is the relation between Peltier coefficient and Seebeck coefficient?

Sol. $\pi = TS$ where π is the peltier coefficient, S is the Seebeck coefficient and T is the temperature of the cold junction.

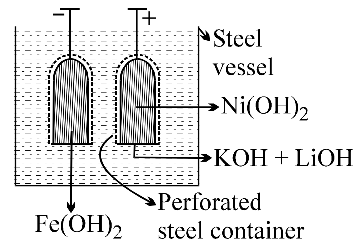
Q.76 Why do some covalent salts (which are not ionic in solid state) become conducting when dissolved in water?

Sol. The dielectric constant of water is large (81). It weakens the attraction between the atoms of covalent salts. In some cases, the salts ionise and conduct electricity.

Q.77 With the help of a suitable diagram, explain the construction and working of an alkali accumulator.

Sol. Alkali Accumulator:

This accumulator consists of a steel vessel containing a 20% solution of KOH with 1% LiOH. LiOH makes it conducting. Perforated steel grid is used as anode. The anode is stuffed with nickel hydroxide. Another perforated steel grid stuffed with finely divided iron hydroxide is used as cathode. To lower the internal resistance traces of mercury oxide are used in it.



Alkali Accumulator

Working:-

Potassium hydroxide dissociates as

(a) $2KOH \longrightarrow 2K^+ + 2OH^-$

During charging, anode is connected to the positive terminal and cathode to the negative terminal of a d.c. source. Inside the cell the current flows from anode to cathode. Hydroxyl ions are attracted towards anode where they lose their charge and form nickel peroxide:

(b) $Ni(OH)_2 + 2OH \longrightarrow Ni(OH)_4$

The positive ions move towards cathode and then react with $Fe(OH)_2$ to form iron:

(c) $Fe(OH)_2 + 2K \longrightarrow Fe + 2KOH$

The complete reaction during charging is given by adding (a) (b) & (c):

$Ni(OH)_2 + Fe(OH)_2 \longrightarrow Ni(OH)_4 + Fe$

During discharging, the current flows from cathode to anode inside the cell and reaction is given by

$Ni(OH)_4 + Fe \longrightarrow Ni(OH)_2 + Fe(OH)_2$

Q.78 What is a button cell? Write its main components and reactions taking place at anode and cathode?

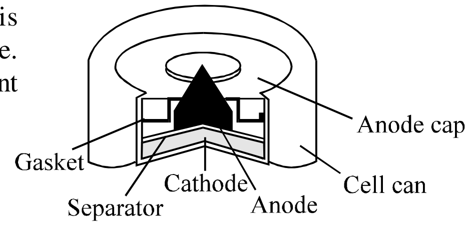
Sol. Button Cell:-

The button cell is a solid state miniature dry cell, which is widely used in electronic watches, cameras etc. It is also known as silver oxide zinc cell. Some other button cells are mercury cell, Lithium cell, Alkaline cell.

Main parts of a button cell are

(a) Anode can (b) Cathode can (c) Separator (d) Gasket.

Silver Oxide zinc cell is shown in figure. The anode is amalgamated zinc powder with gelatinised KOH electrolyte. Cathode is of silver oxide and it is separated by an absorbent cellulosic material. Reactions taking place inside the cell are:



Button Cell

At Cathode: $Ag_2O + H_2O + 2e^- \longrightarrow 2Ag^+ 2OH^-$

At anode: $Zn + 2OH^- \longrightarrow ZnO + H_2O + 2e^-$

The emf of the cell is 1.60 V. It has a high energy output per unit weight and a constant voltage level.

Q.79 Which has higher internal resistance–lead accumulator or alkali accumulator?

Sol. Alkali accumulator has higher internal resistance.

Q.80 What are the advantages of alkali accumulator over lead accumulator?

Sol. (i) Alkali accumulator is not damaged if it is not charged for a long time.

(ii) Excess charging or discharging do not damage it.

Q.81 State the condition in which terminal voltage across a secondary cell is equal to its e.m.f.

Sol. In open circuit, i.e., when no current flows through the cell.

MAGNETIC PROPERTIES OF MATTER

Summary with Applications

Atomic currents, magnetic dipoles, and magnetization

In a simple model, an orbiting electron has a magnetic moment proportional to its orbital angular momentum,

$$m = -\frac{e}{2m_e}L \qquad ....(1)$$

and a singular contribution due to the spin angular momentum,

$$m = \frac{e}{m_e}S \qquad ....(2)$$

The magnetization in a material is the magnetic moment per unit volume:

$$M = \frac{<\sum m_i>}{\Delta V} \qquad ....(3)$$

Diamagnetism

In diamagnetism materials, magnetic dipole moments are induced in molecules by the magnetic field, and the vectors M and B have opposite directions.

Paramagnetism

The permanent magnetic moment of an unpaired electron in a paramagnetic substance tends to become aligned with the magnetic field. The vectors M and B are parallel and are related by Curie's law

$$M = \frac{CB}{\mu_0 T} \qquad ....(4)$$

valid except at low temperatures and high fields.

Ferromagnetism

Molecular magnetic dipoles in a magnetic domain tend to be aligned in a ferromagnetic material. If the domains are oriented preferentially by applying a magnetic field, the sample has a large magnetization. The magnetization can persist in hard magnetic materials to form a permanent magnet.

Magnetic intensity H

The magnetic intensity H is defined by the relation

$$B = \mu_0 (H + M) \qquad ....(5)$$

For a linear medium with permeability μ, the relation can be expressed as $B = \mu H$. For a Rowland ring, H is due to the macroscopic current in the windings. The relation between B and H for ferromagnetic materials is nonlinear, and hysteresis effects are present.

The magnetic field of the earth

Outside its surface, the earth's magnetic field is approximately a dipole field. Large changes in the field occur over geological time intervals.

Magnetic field in magnetic materials – Hysteresis

The field of a long solenoid is directly proportional to the current. Indeed the field B_0 inside a solenoid is given by

$$B_0 = \mu_0 nI$$

This is valid if there is only air inside the coil. If we put a piece of iron or other ferromagnetic material inside the solenoid, the field will be greatly increased, often by hundreds or thousands of times. This occurs because the domains in the iron become preferentially aligned by the external field. The resulting magnetic field is the sum of that due to the current and that due to the iron. It is sometimes convenient to write the total field in this case as sum of two terms :

$$B = B_0 + B_M \qquad \text{................(6)}$$

Here, B_0 refers to the field due only to the current in the wire (the "external field"); it is equal to the field that would be present in the absence of a ferromagnetic material. Then B_M represents the additional field due to the ferromagnetic material itself; often $B_M >> B_0$.

The total field inside a solenoid in such a case can also be written by replacing the constant μ_0 by another constant, μ, characteristic of the material inside the coil:

$$B = \mu nI \qquad \text{................(7)}$$

μ is called the magnetic permeability of the material. For ferromagnetic materials μ is much greater than μ0. Φορ all other materials, its value is very close to μ_0 #. The value of μ, however, is not constant for ferromagnetic materials; it depends on the value of the external field B_0, as the following experiment shows.

Measurements on magnetic materials are generally done using a torus, which is essentially a long solenoid bent into the shape of a circle (Figure –1), so that practically all the lines of B remain within the torus. Suppose the torus has an iron core that is initially unmagnetized and there is no current in the windings of the torus. Then the current I is slowly increased, and B_0 increases linearly with I. The total field B also increases, but follows the curved line shown in the graph of Figure –2. (Note the different scales: $B >> B_0$) Initially (point a), no domains are aligned. As B_0 increases, the domains become more and more aligned until at point b, nearly all are aligned. The iron is said to be approaching saturation. (Point b is typically 70 percent of full saturation; the curve continues to rise very slowly, and reaches 98 percent saturation only when B_0 is increased by about a thousand fold above that at point b; the last few domains are very difficult to align). Now suppose the external field B_0 is reduced by decreasing the current in the coils. As the current is reduced to zero, point c in Figure – 3, the domains do not become completely unaligned. Some permanent magnetism remains. If the current is then reversed in direction, enough domains can be turned around so B = 0 (point d). As the reverse current is increased further, the iron approaches saturation in the opposite direction (point e). Finally, if the current is again reduced to zero and then increased in the original direction, the total field follows the path efgb, again approaching saturation at point b.

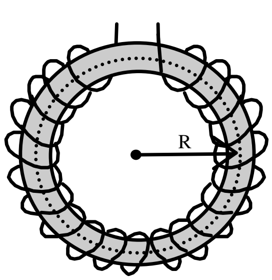


Figure – 1
Iron–core
torus

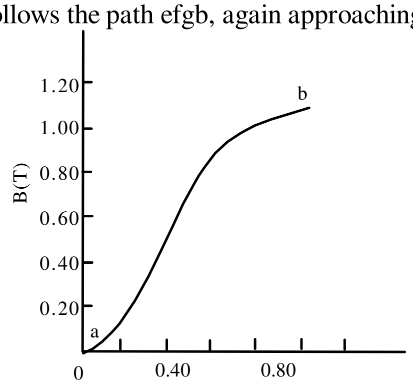


Figure – 2
Total magnetic field of an iron-core torus as a function of the external field B_0.

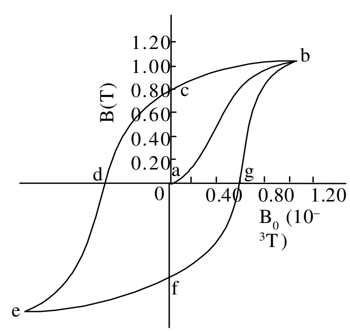


Figure – 3
Hysteresis Curve

Notice that the field did not pass through the origin (point a) in this cycle. The fact that the curves do not retrace themselves on the same path is called hysteresis. The curve bcdefgb is called a hyteresis loop. In such a cycle, much energy is transformed to thermal energy (friction) due to realigning of the domains; it can be shown that the energy dissipated in this way is proportional to the area of the hysteresis loop.

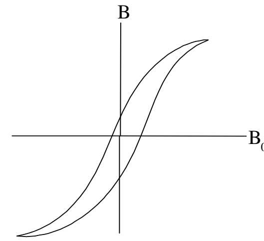


Figure – 4
Hysteresis Curve for soft iron

At point c and f, the iron core is magnetized even though there is no current in the coils. These points correspond to a permanent magnet. For a permanent magnet, it is desired that ac and af be as large as possible. Materials for which this is true are said to have high retentivity, and may be referred to as "hard". On the other hand, a hysteresis curve such as that in Figure –4 occurs for so-called "soft iron" (it is soft only from a magnetic point of view). This is preferred for electromagnets since the field can be more readily switched off, and the field can be reversed with less loss of energy. Whether iron is "soft" or "hard" depends on how it is alloyed, heat treatment, and other factors.

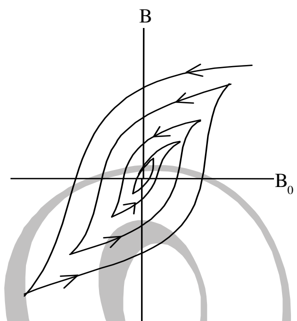


Figure – 5
Successive hysteresis loops during demagnetization

A ferromagnetic material can be demagnetized – that is, made unmagnetized. This can be done by reversing the magnetizing current repeatedly while decreasing its magnitude. This results in the curve of Figure – 5. The heads of a tape recorder are demagnetized in this way; the alternating magnetic field acting at the heads due to a demagnetizer is strong when the demagnetizer is placed near the heads and decreases as it is moved slowly away.

\# *All materials are slightly magnetic. Non-ferromagnetic materials fall into two classes: paramagnetic, in which μ is very slightly larger than μ_0; and diamagnetic, in which μ is very slightly less than μ_0. Paramagnetic materials apparently contain atoms that have a net magnetic dipole moment due to orbiting electrons, and these become slightly aligned with an external field just as the galvanometer coil experiences a torque that tends to align it. Atoms of diamagnetic materials have no net dipole moment. However, in the presence of an external field, electrons revolving in one direction are caused to increase in speed slightly, whereas those revolving in the opposite direction are reduced in speed; the result is a slight net magnetic effect which actually opposes the external field.*

ELECTROMAGNETIC WAVES

The generation of em Waves

To begin our study of electromagnetic waves (em waves), let us consider the situation shown in Figure. We see there a dipole consisting of two oppositely charged balls and the electric field the dipole generates. When the voltage source is a battery, the field is an electrostatic one and does not change. Suppose, however, that the battery is replaced by an ac voltage source. Then the charges on the balls will vary sinusoidally. The charge on the top ball will vary as

$$q = q_0 \cos 2\pi ft \qquad \text{.................(1)}$$

The equal magnitude charge on the bottom ball is oppositely in sign and will vary in the same way. Thus the dipole continually reverses polarity, undergoing f cycles per second. What does this imply for the electric field outside the dipole?

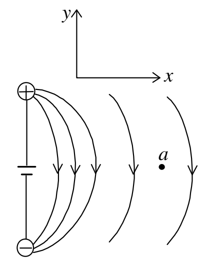


Figure (1)
A portion of the instaneous electric field close to two charged balls. If the charges oscillate back and forth between the balls, the electric field at point a will alternately point up and down.

Close to the dipole – at point *a*, for example – the field reverses in step with the charge reversal. Hence the field at *a* oscillates in the y direction and varies in a sinusoidal fashion with the same frequency as the source. Its equation is

$$E_y = E_{oy} \cos 2\pi ft \qquad \text{.................(2)}$$

What about the electric field far from the source, however? How does it behave?

We can think of the electric field as being the disturbance sent out by the dipole source much the same way on a string is the disturbance sent down the string by an oscillating source. At a certain instant, the field sent out along the x-axis is as shown in Figure(2). The field shows the history of the charge on the dipole. The downward directed fields were sent out when the top of the dipole was positive; the upward directed field were sent out one half cycle later, when the top of the dipole was negative.

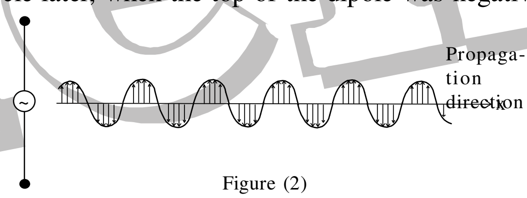


Figure (2)
The alternating charges on the dipole antenna send an electric field disturbance out into space.

In the case of a radio station, the dipole (or antenna) is often simply a long wire. If you visit a radio transmitting site, you will see the antenna as a long wire stretched between two towers or as a vertical wire held by a single tower. Charges are placed on the antenna by an ac voltage from a transformer system. The electric field wave sent out by the antenna blankets the earth around it, as in the Figure(3). At a point such as *a* in the path of the wave, the electric field reverses periodically as the wave passes. The frequency of the oscillating electric field at *a* is the same as the frequency of the source.

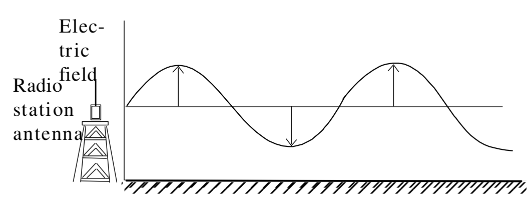


Figure (3)
The electric field wave from the antenna blankets an area even quite distance from the station.

Thus we see that an electric field wave is sent out by the oscillating dipole, the transmitting antenna. We should notice that, like all waves, the electric field wave obeys the following relation between frequency *f* and wavelength λ

$$\lambda = \frac{\nu}{f} \qquad \text{................(3)}$$

where ν is the speed at which the wave travels out through space. Further, we notice that the quantity that vibrates, namely the electric field vector, is always perpendicular to the direction of propagation. Hence the electric field wave is a transverse wave .

It is easy to see that a radio station's antenna necessarily generates a magnetic field wave as it generates an electric field wave. To see this, refer to Figure given below. At the radio station, charges are sent up and down the antenna in the Figure (4a) to produce the alternating charges we have been discussing. This charge movement constitutes an alternating current in the antenna, and because a magnetic field circles a current, an oscillating magnetic field is produced, as shown in the Figure (4b). As with the oscillating electric field, the magnetic field, the magnetic field travels out along the x-axis as a transverse wave. Because the direction of the current oscillates, so too does that of the magnetic field.

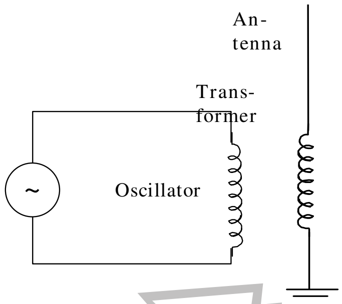


Figure (4a)
(a) As charge rushes up and down the antenna.

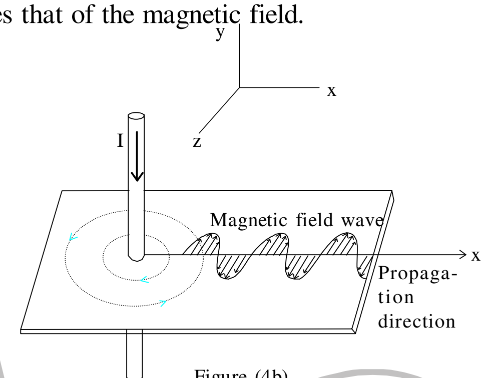


Figure (4b)
(b) A magnetic field wave is sent out as shown.

Notice, however, that the magnetic field is in the z direction, while the electric field is in the y-direction. As shown in the Figure(5), the magnetic field id perpendicular to both the electric field and the direction of propagation. The two waves are drawn in phase (that is, they reach maxima together). That this is true is not obvious; it is the result of detailed computations.

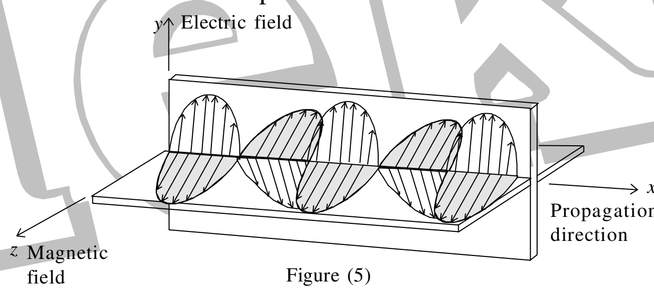


Figure (5)
In an em wave, the magnetic field wave is perpendicular to both the electric field wave and the direction of propagation.

As we see, em waves are transverse waves and are much like waves on a string and other transverse-waves. However, em waves consist of oscillating electric and magnetic fields, not of material particles. As such, they can travel through empty space (vacuum). And, as we shall see, they carry energy along their direction of propagation. Later we shall show that em waves travel through vacuum with the speed of light, which we designate by *c*. You will recall that, in the SI, the speed of light in vacuum is defined to be $c = 2.998 \times 10^8$ m/s.

There is one other feature of em wave generation that we should point out. Notice that the charges that oscillate up and down the antenna are accelerating. It turns out that whenever a charge undergoes acceleration, it emits em radiation; the larger the acceleration (or deceleration) of the charge, the more energy it emits as em radiation. Thus, if a fast-moving charged particle undergoes an impact, it will emit a burst of em radiation as it suddenly stops.

Types of Electromagnetic Waves

As we discuss at greater length later, radio-type waves were foreseen by a 34 year old Scottish physicist, James Clerk Maxwell, in 1865, many years before the first radio was invented. Maxwell used the then known facts about electricity to show that em radiation should exist. Furthermore, he was able to prove that these waves should have a speed of 3×10^8 m/s in vacuum. This was an astonishing prediction because the speed he found was a well known speed, the speed of light in vacuum, *c*. Thus Maxwell was led to surmise that light waves are one form of em waves. Today we know that there are a variety of em waves that cover a wide range of wavelengths; we refer to this as the em wave spectrum.

The basic difference between the various types of em waves are the result of their different wavelengths. Since all electromagnetic radiation travels through vacuum with the speed of light, the relation $\lambda = v/f$ becomes $\lambda = c/f$ for electromagnetic radiation. Hence a difference in λ implies a difference in the frequency of the radiation. The various types of electromagnetic radiation are shown in Figure(11). Examine this chart carefully to become familiar with the wavelength ranges involved. Let us now discuss briefly the nature of each type of radiation.

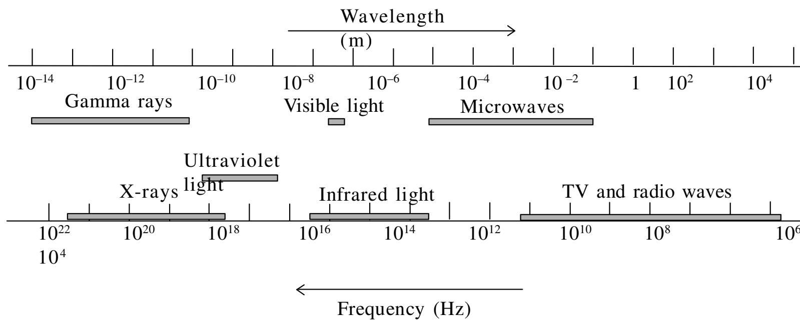


Figure (11)
Types of electromagnetic radiation. The bars indicate the approximate wvaelength range of each type of radiation.

Radiowaves

We have already discussed radio waves in some detail. Their wavelengths range from 1 m or so to more than about 3×10^6m for the waves sent out by ac power lines. If one wished to obtain a wave with $\lambda = 10^8$ km, which is the distance from the earth to the sun, how frequently should one reverse the charges on the antenna?

Microwaves

Microwaves are short-wavelength radio waves. They are sometimes called *radar waves*. The shortest wavelength given in Figure for microwaves (10^{-3}m) represents the lower limit of wavelengths that can be generated electronically at present. Notice that, at a frequency of 10^{12}Hz, light can travel only 0.03 cm during one oscillation. Since material particles and energy cannot travel faster than the speed of light, only an antenna shorter than 0.03 cm can be charged during this short time. This should indicate why very short wavelength waves are difficult to produce electronically.

Infrared waves

Infrared waves have wavelengths between those of visible light, 7×10^{-7} m, and microwaves. Infrared radiation is readily absorbed by most materials. The energy contained in the waves is also absorbed, of course, and appears as thermal energy. For this reason, infrared radiation is also called *heat radiation*. The earth receives from the sun a large amount of infrared radiation as well as light. Warm objects of all types radiate infrared rays.

Light waves

The wavelengths of the visible portion of electromagnetic radiation extend only from about 4×10^{-7} to 7×10^{-7}m, and we call this wavelength range *light*. We classify various wavelength regions in this range by the names of colours. The sensitivity of the normal human eye to wavelengths in this region is shown in Figure(12). See also Colour Plate II, which shows the light spectrum in colour. You should learn the approximate wavelengths of the various colours. The "antenna" that generates light waves is charge accelerating within an atom.

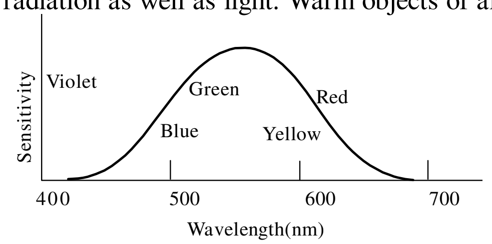


Figure (12)
Sensitivity curve for the eye. The human eye is most sensitive to greenish yellow light

Ultraviolet waves

Ultraviolet waves are radiation with wavelengths shorter than visible violet light but still stronger than about 10nm. At the shorter wavelengths, they are not distinct from x-rays.

X-ray waves

X-rays are electromagnetic radiation with $\lambda \leq 10$nm. Usually, this classification is reserved for the radiation given off by electrons in atoms that have been bombarded.

Gamma rays waves

Gamma rays (γ-rays) are electromagnetic radiation given off primarily by nuclei and in nuclear reactions. They differ from x-rays only in their manner of production.

Notice that the spectrum of electromagnetic radiation encompasses waves with wavelengths extending from longer than 10^6m to shorter than 10^{-18}m. Even though these waves are all electromagnetic waves, they differ considerably in their mode of interaction with matter.

POLARIZATION OF LIGHT

Many optical devices make use of the fact that light is a transverse vibration. As we shall see, this fact is important when light is transmitted through certain materials.

It is also a factor when light is reflected. It is fundamental to the behaviour of light that concerns us in this section.

We know that light is em radiation. It consists of waves such as the one shown in Figure - 1. The electric field vector is sinusoidal and perpendicular to the direction of propagation. If the wave is travelling along the x -axis, the electric field vibrates up and down at a given point in space as the wave passes by. There is a magnetic field wave perpendicular to the page and in step with the electric field. We call a wave such as this a plane polarized wave. It derives its name from the fact that the electric field vector vibrates in only one plane, the plane of the page in this case.

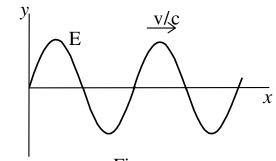
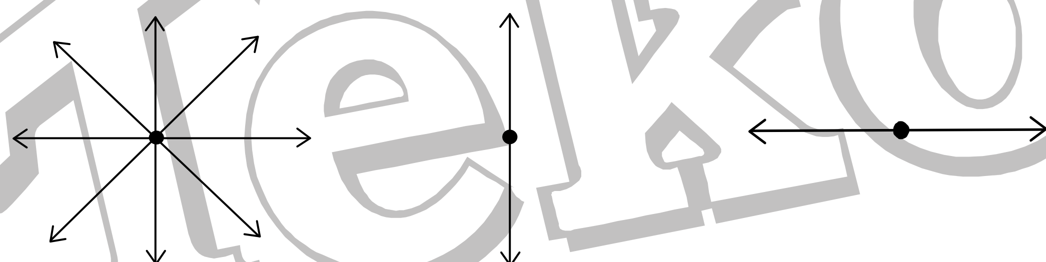


Figure -
The electric field vector vibrates in a single plane when a beam of light is plane-polarized

Most light consists of many, many waves like the one in Figure - 1 in which all vibrational planes are perpendicular to. If the direction of propagation is to the right, the electric field vectors must all vibrate perpendicular to the x-axis. However, they need not all vibrate in the plane of the page, and actually most of them do not. Let us stand at the end of the x-axis in Figure – 1 and look back along it towards the coordinate origin, in other words, with the wave travelling straight towards us. The great multitude of waves coming towards us give rise to many individual electric field vectors that are randomly oriented, as in Figure 2(a). If the waves were plane - polarized vertically, that is, in the plane of the page in Figure - 1, the approaching vectors would appear as shown in Figure – 2(b). For a horizontally plane - polarized wave, the vectors would appear as in Figure – 2(c).



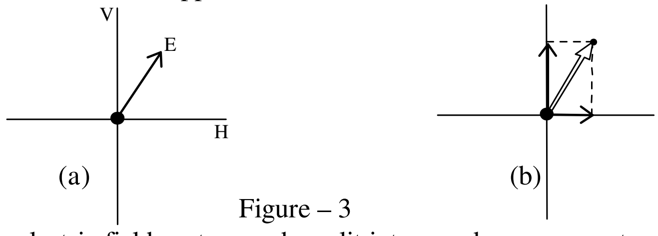
Unpolarized (a) Vertically Polarized (b) Horizontally Polarized (c)

Figure – 2

If narrow beam of light is coming straight out of the page, the electric-field vibration will be as shown for three types of beams

Unpolarized light can be conveniently plane - polarized using a polarizing sheet. This is a sheet of transparent plastic in which special needle like crystals of iodoquinine sulfate have been embedded and oriented. The resulting sheet allows light to pass through it only if the electric field vector is vibrating in a specific direction. Hence, if unpolarized light is incident upon the sheet, the transmitted light will be plane polarized and will consist of the sum of the electric field vector components parallel to the permitted direction.

Any vector can be thought of as consisting of two perpendicular components. Hence, if the electric field is oriented as shown in Figure 3(a), it can be thought of as consisting of a vertical and horizontal component, as shown in 3(b). If we pass light that is vibrating at the angle shown in Figure 3(a)(b) through a polarizing sheet whose transmission direction is vertical, the vertical component of the vibration will pass through and the horizontal component will be stopped.

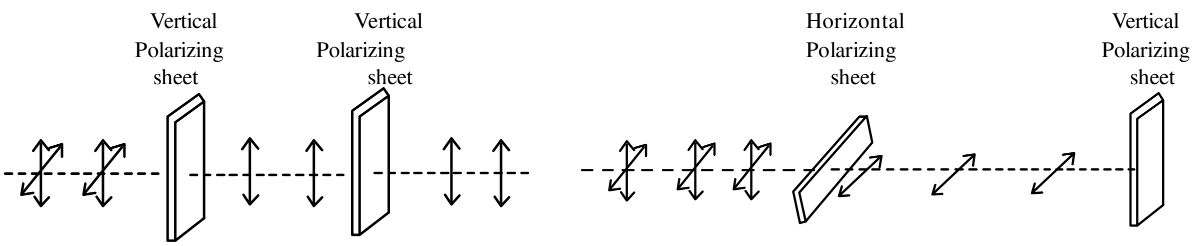


(a) (b)

Figure – 3

The electric field vector can be split into x and y components.

Consider what happens when unpolarized light is passed through two polarizing sheets as shown in Figure 4. In part (a), the polarizer (the first sheet) allows only the vertical vibrations to pass. These are also transmitted by the analyzer (the second sheet) since it too is vertical. In part (b), however, the polarizer has been rotated through 90^0 and now allows only horizontal vibrations to pass. These are completely stopped by the vertically oriented analyzer. Therefore (almost) no light comes through the combination. In this latter case we say that polarizer and analyzer are **crossed**.

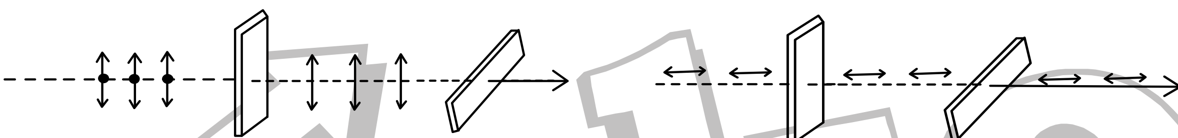


(a) (b)

Figure - 4

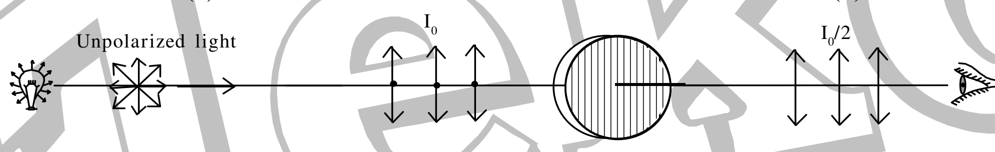
(a) the unpolarized light is polarized by the first polarizing sheet (the polarizer).

(b) The second polarizing sheet (the analyzer) and the polarizer are crossed, and the beam is completely stopped by the analyzer.

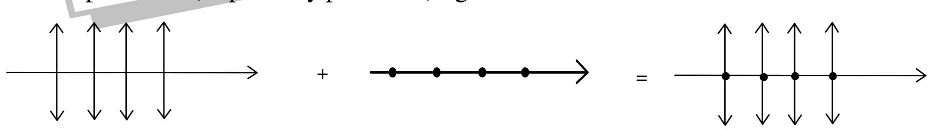


Light (transverse wave)
(a)

Sound (longitudinal wave)
(b)



In case of interference of polarized lights the interfering waves must have same plane of polarization otherwise unpolarized (or partially polarized) light will result.



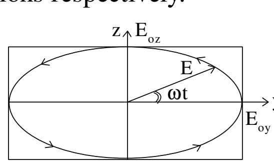
Plane polarised light with vibration in the plane of paper

Plane polarised light with vibration perpendicular to the plane of paper

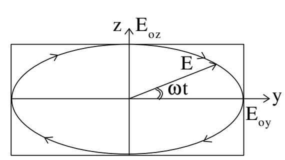
Un polarised light

The devices such as polaroids or Nichol prism are called polarizer when used to produce plane polarized light and analyzer when used to analyzed (i.e., identify) the given light.

Apart from partially and plane (i.e., linearly) polarized, light can also be circularly or elliptically polarized that too left handed or right handed. Elliptically and circularly polarized lights result due to super position of two mutually perpendicular plane polarized lights differing in phase by ($\pi/2$) with unequal or equal amplitudes of vibrations respectively.



Left handed Elliptically Polarised Light
(A)



Right handed Elliptically Polarised Light
(B)

Methods of Obtaining Plane Polarized Light

(A) By Reflection :

In 1811, Brewster discovered that when light is incident at a particular angle on a transparent substance, the reflected light is completely plane polarized with vibrations in a plane perpendicular to the plane of incidence. This specific angle of incidence is called polarizing angle θ_p and is related to the refractive index μ of the material through the relation –

$$\tan \theta_p = \mu \qquad \text{................(1)}$$

known as "Brewster law."

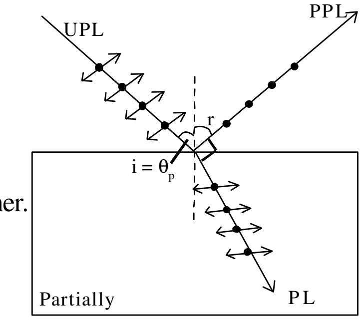
In case of polarization by reflection –

(i) For $i = \theta_p$, reflected light is partially polarized.

(ii) For $i = \theta_p$, reflected and refracted rays are perpendicular to each other.

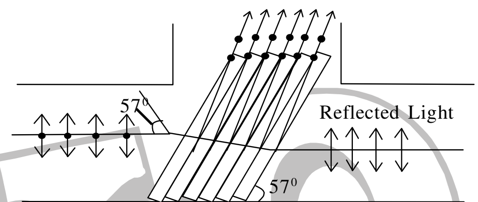
(iii) For $i <$ or $> \theta_p$, both reflected and refracted light becomes partially polarized.

(iv) For glass $\theta_p = \tan^{-1}(3/2) \simeq 57^0$ while for water $\theta_p = \tan^{-1}(4/3) \simeq 53^0$.



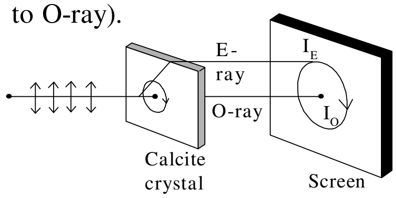
(B) By Refraction :

In this method a pile of glass plates is formed by taking 20 to 30 microscope slides and light is made to be incident at polarizing angle (57^0). In accordance with Brewster law the reflected light will be plane polarized with vibrations perpendicular to the plane of incidence (which is here plane of paper) and the transmitted light will be partially polarized. And as in one reflection about 15% of the light with vibration perpendicular to plane of paper is reflected, after passing through a number of plates as shown in the Figure emerging light will become plane polarized with vibrations in the plane of paper.

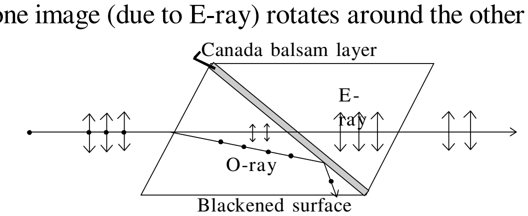


(C) By Double Refraction :

It was found that in certain crystals such as calcite, quartz and tourmaline etc., incident unpolarized light splits up into two light beams of equal intensities with perpendicular polarizations. One of the ray behaves as ordinary light and is called O-ray (ordinary - ray) while the other does not obey laws of refraction and is called E-rays (extraordinary ray) this why when an object is seen through these crystals we usually see two images of an object and if the crystal is rotated one image (due to E-ray) rotates around the other (due to O-ray).



(A)

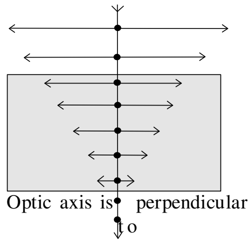


(B)

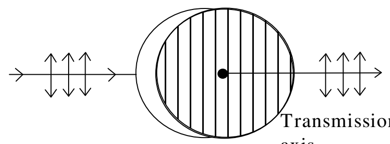
By using the phenomenon of double refraction and isolating one ray from the other we can obtain plane polarized light which actually happens in a Nichol prism. Nichol prism is made up of calcite crystal and in it E-ray is isolated form O-ray through total internal reflection of O-ray at Canada balsam layer and then absorbing it at the blackened surface as shown in Figure.

(D) By Dichroism :

Some crystals such as tourmaline and sheets of Iodosulphate of quinone has the property of strongly absorbing the light with vibrations perpendicular to a specific direction (called transmission axis) transmitting the light with vibration parallel to it. This selective - absorption of light is called dichroism. So if unpolarized light passes through proper thickness of these, the transmitted light will be plane polarized with vibrations parallel to transmission axis. Polaroids work on this principle.

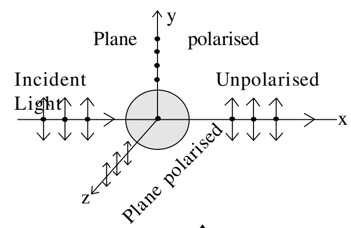


Tourmaline crystal
(A)



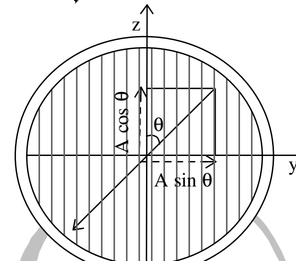
Poloroid
(B)

(E) By Scattering :



When light is incident on atoms and molecules, the electrons absorb the incident light and reradiate it in all directions. This process is called scattering. It is found that scattering light in directions perpendicular to the direction of incident light is completely plane polarized while transmitted light is unpolarized. Light in all other directions is partially polarized.

Intensity of Light Emerging From a Polaroid



If plane polarized light of intensity I_0 $(=KA^2)$ is incident on a polaroid and its vibrations of amplitude A makes an angle θ with the transmission axis, then component of vibrations parallel to transmission axis will be A cosθ while perpendicular to it A sin θ. Now as polaroid will pass only those vibrations which are parallel to its transmission axis, i.e., A cos θ. So the intensity of emergent light will be

$$I = K(A\cos\theta)^2 = KA^2\cos^2\theta$$

or $$I = I_0\cos^2\theta \qquad [\text{as } i_0 = KA^2] \qquad \text{..........(2)}$$

This law is called "Malus law". From this it is clear that –

(1) If the incident light is unpolarized than as vibrations are equally probable in all directions (in a plane perpendicular to the direction of wave motion), θ can have any value from 0 to 2π and hence

$$(\cos^2\theta)_{av} = \frac{1}{2\pi}\int_0^{2\pi}\cos^2\theta\, d\theta = \frac{1}{2}\,x\,\frac{1}{2\pi}\int_0^{2\pi}(1+\cos 2\theta)\, d\theta$$

i.e. $$(\cos^2)_{av} = \frac{1}{2}\,x\,\frac{1}{2\pi}\left[\theta+\frac{1}{2}\sin 2\theta\right]_0^{2\pi} = \frac{1}{2}$$

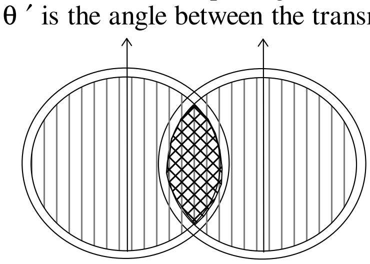
so from eq. (2), we have, $I = \dfrac{1}{2}I_0$

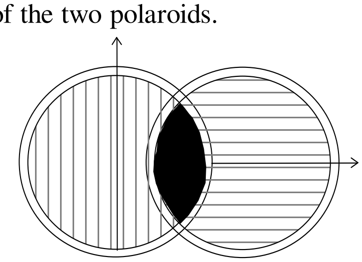
i.e., If an unpolarized light is converted into plane polarized light (say by passing it through a polaroid or a Nichol – prism), intensity becomes half.

(2) If light of intensity I_1 emerging from one polaroid called polarizer is incident on a second polaroid (usually called analyzer) the intensity of the light emerging from the second polaroid in accordance with Malus law will be given by

$$I_2 = I_1\cos^2\theta'$$

where θ ′ is the angle between the transmission axis of the two polaroids.


Parallel polaroids
(A)


Crossed polaroids
(B)

So if the two polaroids have their transmission axis parallel to each other, i.e. $\theta' = 0$.

$$I_2 = I_1 \cos^2\theta = I_1$$

And if the two polaroids are crossed, i.e. have their transmission axes perpendicular to each other, $\theta' = 90^0$.

$$I_2 = I_1 \cos^2 90^0 = 0$$

So if an analyzer is rotated from 0 to 90^0 with respect to polarizer, the intensity of emergent light changes from maximum value I_1 to minimum value zero.

Identification of given Light

Polaroid or Nichol prism is used to examine whether a given light is unpolarized partially - polarized or plane polarized. For this, the given light is passed through a polaroid (called analyzer) and the polaroid is rotated about the incident light and emergent light is seen. Then if –

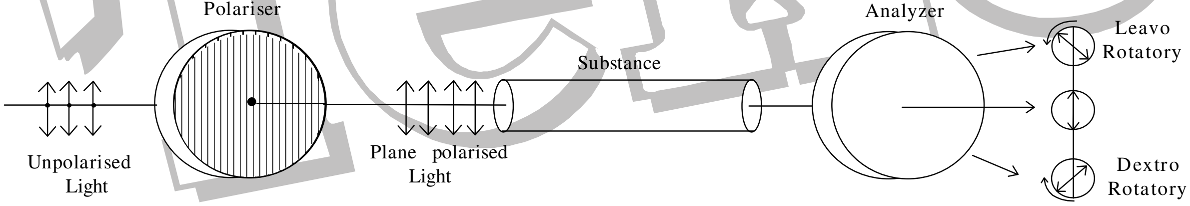
(a) There is no variation in intensity of emergent light in any position, the incident light will be unpolarized as in case of unpolarized light the vibration of same amplitude are equally probable in all directions.

(b) There is a variation in intensity of emergent light with minimum not equal to zero, the incident light will be partially polarized as in partially polarized light vibrations exist in all directions but are more in some directions than in others.

(c) There is variation in intensity of emergent light with minimum equal to zero, the incident light is plane (or linearly) polarized as in plane polarized light vibrations are confined along one direction only and so transmission axis of analyzer will become parallel and perpendicular to vibrations twice in its one complete rotation giving rise to maximum and zero intensity twice in each rotation.

Optical Activity

When plane polarized light passes through certain substances, the plane of polarization of light is rotated about the directionof propagation of light through a certain angle. This phenomenon is called optical activity or optical rotation and substances optically active.



Polarimeter

If the optically active substance rotates the plane of polarization clockwise (looking against the direction of light), it is said to be dextrorotatory or right handed. However, if the substance rotates the plane of polarization anti clock wise it is called laevo–rotatory or left handed.

The optical activity of a substance is related to the asymmetry of the molecule or crystal as a whole, e.g., solution of cane sugar is dextrorotary due to asymmetrical molecular structure while crystals of quartz are dextro or levo rotatory due to structural asymmetry which vanishes when quartz is fused.

Optical activity of a substance is measured with the help of, polarimeter in terms of specific rotation which is defined as the rotation produced by a solution of length 10cm (1 dm) and unit concentration (i.e., 1 g/cc) for given wavelength of light at a given temperature,

i.e., $$[\alpha]^{\lambda}_{t^0C} = \frac{\theta}{LC}$$

where θ is the rotation in length L at concentration C.

PRINCIPLES OF COMMUNICATION

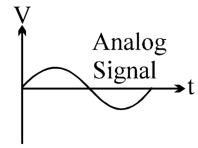
Very Short and Short-Answer questions

Q.1 What do you mean by Communication?

Sol. Communication is the processing, sending and receiving various information with the help of suitable devices and transmission medium.

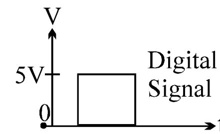
Q.2 What is an analog signal?

Sol. A continuously varying signal (voltage or current) is called an analog signal.



Q.3 What is a digital signal?

Sol. A voltage or current signal that can have only two discrete values is called a digital signal, for example, a square wave.



Q.4 What are the various types of communication systems?

Sol. There are two types of communication systems:
(a) Analog communication system: It makes use of analog signals.
(b) Digital communication system: It makes use of digital signals.

Q.5 What do you mean by radio communication?

Sol. Radio communication involves transmitting and receiving a message in the form of a radio wave signal in between two stations without connecting them with wire.

Q.6 What is modulation?

Sol. The process of superimposing electrical audio signals on high frequency carrier waves is called modulation.

Q.7 Distinguish between the terms modulating wave, carrier wave and modulated wave.

Sol. Modulating waves: The audio signal to be transmitted over long distances is called modulating wave.
Carrier wave: A high frequency wave, over which audio signals are to be superimposed, is called carrier wave.
Modulated wave: The resultant wave produced by superimposing the audio signal on a high frequency carrier wave is called modulated wave.

Q.8 What are the various methods of modulation?

Sol. There are three methods of modulation:
(a) Amplitude modulation (b) Frequency modulation (c) Phase modulations

Q.9 What is amplitude modulation?

Sol. Amplitude modulation: When the amplitude of high frequency carrier waves is changed in accordance with the intensity of the modulating wave, it is called amplitude modulation.

Q.10 What is frequency modulation?

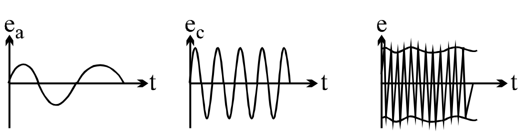
Sol. Frequency modulation: When the audio signal is superimposed on the high frequency carrier wave in a manner that the amplitude of the modulated wave is same as that of the carrier wave but its frequency is modified in accordance with the intensity of the modulating wave, it is called frequency modulation.

Q.11 What is phase modulation?

Sol. Phase modulation: The process in which the phase of the carrier wave is varied in accordance with the modulating wave is called phase modulation.

Q.12 Show graphically amplitude modulation.

Sol.



(i) Signal (ii) Carrier (iii) AM Wave

Q.13 Define modulation factor(modulation index,depth of modulation).

Sol. Modulation factor is defined as the ratio of the change of amplitude of the carrier wave to the amplitude of the normal carrier wave, i.e.,

$$m_a = \frac{\text{Amplitude change of carrier wave}}{\text{Amplitude of normal carrier wave}}$$

Q.14 What is the value of bandwidth in amplitude modulation?

Sol. In amplitude modulation, bandwidth is twice the signal frequency.

Q.15 Define the term frequency deviation.

Sol. In frequency modulation the maximum variation of the frequency of modulated wave from the carrier frequency is called frequency deviation.

Q.16 What are the limitations of amplitude modulation?

Sol.(i) The efficiency of amplitude modulation is low.

(ii) Messages cannot be transmitted over long distances using amplitude modulation.

(iii) The reception is generally noisy.

Q.17 Write an expression for the modulation index for frequency modulation.

Sol. Modulation index in case of frequency modulation is given by

$$m_f = \frac{\delta}{f_s}$$

where δ is frequency deviation and f_s is modulating frequency.

Q.18 Can the value of modulation index be greater than unity?

Sol. Yes, in case of frequency modulation the value of modulation index can be greater than unity.

Q.19 Write the advantages of frequency modulation.

Sol.(i) Frequency modulation transmission is highly efficient.

(ii) Frequency modulation can be used for the stereo sound transmission due to the presence of a large number of sidebands.

Q.20 Give two disadvantages of frequency modulation.

Sol.(i) The frequency modulation transmitting and receiving equipments are very complex as compared to those used in amplitude modulation transmission.-

(ii) A.wider frequency channel is required in frequency modulation transmission.

Q.21 What is the importance of modulation index?

Sol. The modulation index determines the strength and quality of the transmitted signal. For strong and clear reception the modulation index must be high.

Q.22 What do you mean by bandwidth?

Sol. The frequency range in which a transmitting system makes transmission is called bandwidth.

Q.23 Give expressions for bandwidth in

(a) AM transmission (b) FM transmission

Sol (a) AM transmission:

Bandwidth = 2 × maximum frequency of modulating signal.

(b) FM transmission:

Bandwidth = 2n × frequency of modulating signal

where n is the number of significant sidebands.

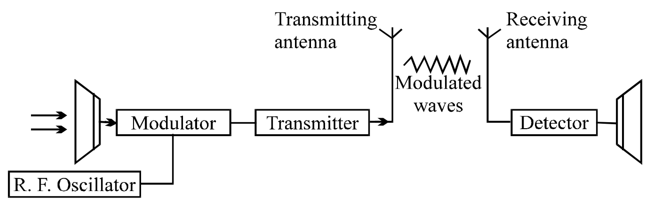
Q.24 What is demodulation?

Sol. The reverse process of modulation, i.e. the process of recovering the audio signal from the modulated wave is known as demodulation or detection.

Q.25 What is pulse amplitude modulation?

Sol. The process of modulation in which the amplitude of the pulses is varied in accordance with the modulating signal is called pulse amplitude modulation.

Q.26 Draw a sketch to illustrate the basic elements required to transmit and receive an audio signal.



Q.27 What is sampling?

Sol. The process of generating pulses of zero width and of amplitude equal to the instantaneous amplitude of the analog signal is called sampling.

Q.28 Write three merits of digital communication.

Sol.(i) Digital signals are easy to receive.

(ii) Digital signals do not get distorted by the noise.

(iii) Digital signals can be stored as digital data.

Q.29 What is modem?

Sol. The name modem is a contraction of the terms modulator and demodulator. As the name implies, both functions are included in a modem.

Q.30 What is an artificial satellite?

Sol. An artificial object placed in an orbit around the earth or any other planet is called an artificial satellite.

Q.31 What is a geostationary satellite?

Sol. A satellite whose period of revolution around the earth is same as that of earth about its own axis, i.e., 24 hours, is called a geostationary satellite and the orbit is called synchronous or geostationary orbit.

Q.32 Write three merits of satellite communication.

Sol.(i) Satellite communication covers wide area.

(ii) Satellite communication can be used for establishing mobile communication with greater ease.

(iii) In remote and hilly areas it is most cost-effective.

Q.33 What do you mean by remote sensing?

Sol. Remote sensing is the process of obtaining and recording information from a distance without physical contact.

Q.34 What is a passive satellite?

Sol. A satellite which is used to reflect the signals back to the earth is called a passive satellite.

Q.35 What is an active satellite?

Sol. A satellite equipped with electronic devices to receive the signal from the earth, process it, amplify it and then retransmit it back to the earth is called an active satellite.

Q.36 What is transmission medium?

Sol. It is a link which transfers information from the information source to the destination.

Q.37 Name various transmission media used in communication systems?

Sol. (a) Two wire lines (b) Coaxial cables (c) Radio link (d) Fibre link

Q.38 What are the two types of two-wire line?

Sol.(a) Parallel wire line: In this two metallic wires run parallel to each other in an insulation coating, for example, PVC insulation.

(b) Twisted power line: It consists of two insulated copper wires twisted, around each other.

Q.39 What is the main drawback of 2-wire line.

Sol. At microwave frequencies, the energy losses in a 2-wire line become very large. The attenuation of signals increases with the length of the wire. Therefore, the 2-wire line is used for transmission of signals over a small distance.

Q.40 What is a coaxial cable?

Sol. A coaxial cable consists of a central copper wire surrounded by a PVC insulation over which there is a sleeve of copper mesh. Finally it is covered with an outer thick PVC material.

Q.41 What is the use of copper mesh in a coaxial cable?

Sol. In a coaxial cable, when the central copper wire carries the signal, the copper mesh shields it electrically from the external electrical disturbances.

Q.42 What is an optical fibre?

Sol. It is a device which is based on the phenomenon of total internal reflection. It consists of a very thin glass or quartz fibre which is coated with a material of lower refractive index.

Q.43 What is the use of optical fibres?

Sol. The optical fibres are used to transmit light signals from one place to another without any appreciable loss in the intensity of light.

Q.44 What are the two types of optical fibres?

Sol. The optical fibres are of the following two types:

(a) Monomode optical fibre

(b) Multimode optical fibre

Q.45 What is cladding?

Sol. The glass coating of relatively lower refractive index, surrounding the glass case in optical fibre is called cladding.

Q.46 What do you mean by angle of acceptance in optical fibre?

Sol. The maximum angle of incidence in air for which light is totally reflected at the glass core-cladding interface is called the angle of acceptance.

Q.47 Write an expression for the angle of acceptance in an optical fibre.

Sol. If i is the angle of acceptance then

$$\sin i = \sqrt{\mu_1^2 - \mu_2^2}$$

Where μ_1 is the refractive index of glass core and μ_2 is the refractive index of cladding.

Q.48 What is optical communication?

Sol. The phenomenon of transmission of information from one place to another using optical carrier waves is called optical communication.

Q.49 What does LASER stands for?

Sol. The term LASER stands for

Light amplification by stimulated emission of radiation.

Q.50 Write the main characteristics of a laser beam?

Sol. The main characteristics of a laser beam are - highly monochromatic, highly coherent and perfectly parallel. A laser beam can be sent to a far off place and be reflected back without any significant loss of intensity.

Q.51 What is stimulated emission?

Sol. If an atom or a molecule is in an excited state, it may make a transition to a lower energy state by the 'impact' of another photon of the required energy. This process is known as stimulated emission, to distinguish it from spontaneous emission which occurs on its own.

Q.52 What do you mean by optical pumping?
Sol. It is the process of raising atoms from a lower energy state to a higher energy state by induced absorption.

Q.53 What is light modulation?
Sol. The process of modulating a light beam from an optical source in accordance with the information signal is called light modulation.

Q.54 Why do we need modulation.
Sol. Audio signals are weak signals. So they can not be transmitted directly over large distances. Moreover the wavelength associated with audio signals is very large. Hence antenna of large dimensions ($-\lambda$) is required. To overcome these difficulties, modulation is needed. .

Q.55 Which modulation is used for commercial broadcasting of voice signal?
Sol. Amplitude modulation.

Q.56 Which modulation is used in TV broadcast and why?
Sol. TV broadcast requires larger bandwidth and hence frequency modulation is used.

Q.57 What is the approximate dimension of an antenna?
Sol. Of the order of the wavelength of the signal.

Q.58 What is FAX?
Sol. The electronic transmission of a document to a distant place via telephone line is known as FAX or fascimile.

Q.59 Name the layer of earth's atmosphere which is most useful in long distance radio communication. Why?
Sol. Ionosphere. It reflects the radio waves back to the earth.

Q.60 What is the highest frequency that can be reflected back by the ionosphere?
Sol. 30MHz.

Q.61 Distinguish between ground wave and sky wave?
Sol. Audio signals emitted from a certain location on the earth can be received at another location by two different ways- .
(i) If the waves travel along the surface of the earth from one place to another, it is called ground wave. Ground wave transmission is limited to 1500KHz.
(ii) If the wave is transmitted towards the sky and reaches another location after getting reflected from the ionosphere, it is called sky wave. Sky wave transmission is limited to a frequencyof 30MHz.

Q.62 What is the frequency range of UHF band?
Sol. Ultra high frequency (UHF) band has frequency ranging from 300MHz to 3000MHz.

Q.63 Which waves are used for long distance radio telecast?
Sol. Short waves are used for long distance radio telecast as they can be easily reflected back to the earth by the ionosphere.

Q.64 What is amplitude modulated (AM) Band?
Sol. Amplitude modulated band consists of radiowaves of frequencies less than 30MHz.

Q.65 Is it necessary to use satellites for long distance TV transmission? Give one reason.
Sol. TV signals cannot be sent directly to large distances. Further, TV signals have very high frequencies which are not reflected by the ionosphere. Therefore the signals from the broadcasting station are beamed towards a geostationary satellite, which relays them back to the earth. Since the satellite is high above, it covers large distances on the earth.

Q.66 Write an expression for the distance upto which the TV signals can be directly received from a TV tower of height h.

Sol. distance $d = \sqrt{2hR}$
Where R is radius of the earth and h is the height of the antenna.

Q.67 Which part of the electromagnetic spectrum is used in operating a radar?
Sol. Microwaves ($10^9 - 10^{12}$ Hz)

Q.68 What do you understand by HF and MF bands?
Sol. HF stands for high frequency band (3–30 MHz).
MF stands for medium frequency band (300–3000 kHz).

Q.69 Why is ground wave transmission limited to a frequency of 1500 kHz.
Sol. The attenuation of ground waves increase with increase in frequency due to interaction with objects in its path. So ground wave transmission is limited to a frequency of 1500 kHz.

Q.70 Why sky waves are not used in the transmission of TV signals?
Sol. TV signals have frequency much higher than 30 MHz. Such high frequency signals cannot be reflected by the ionosphere. Therefore, sky waves are not used in the transmission of TV signals.

Q.71 What is FM Band?
Sol The electromagnetic waves in the frequency range 80 MHz to 200 MHz constitute frequency modulated (FM) band.

Q.72 What is a geostationary satellite?
Sol. A satellite which appears to be fixed at a place above the earth is called a geostationary satellite. It has the time period of revolution around the earth equal to the rotational period of the earth about its axis, i.e., 24 hour

Q.73 Name the electromagnetic wave used in satellite communication.
Sol. Microwave.

Q.74 Name two primary requirements for optical transmission.
Sol. (i) Optical source (ii) Optical fibre.

Q.75 What is the bandwidth required to telecast picture through a TV channel?
Sol. 4.7MHz per channel.

Q.76 What is an optical source? Name any two optical sources.
Sol. Light source used in optical communication is called an optical source. Examples- LED and LASER.

Q.77 Write three advantages of LASER over LED as optical source.
Sol.(i) Low beam divergence (ii) Greater transmission distance (iii) High modulation rate

Q.78 What is an optical detector? Name three optical detectors.
Sol. It is a device that generates electrical signals when light falls on it. Examples - Silicon photodiode, avalanche photodiode, photo transistor, etc.

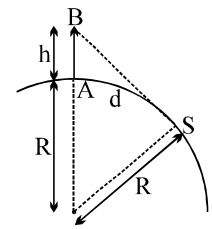
Q.79 What do you mean by sensitivity and responsivity of a detector?
Sol. Sensitivity is a measure of the ability of a detector and determines how weak a signal can be detected. The ability of the detector to respond quickly to the changing light pulses is called responsivity.

Q.80 What is photonics?
Sol. Photonics is a subject that deals with generation and detection of photons.

Q.81 What is LED?
Sol. An LED works on the process of spontaneous emission when a p-n junction is forward biased. If a p-n junction diode is forward biased, energy is released due to recombination of electrons and holes. In case of silicon and germanium diodes, the energy released is in infrared region. However, if the diode is made of gallium arsenide or indium phosphide, the energy released is in visible range.

Q.82 Derive an expression for the distance upto which the TV, signals can be directly received from a TV tower of height h.

Sol. The figure shows a TV transmitting antenna of height AB = h located at A on the surface of the earth of radius R. The signal transmitted can be received within a circle of radius AS on the surface of the earth. Now in the right angled triangle OBS.



$$OB^2 = OS^2 + BS^2$$

Now,

$$BS \approx AS = d. \text{ So,}$$

$$(R+h)^2 = d^2 + R^2$$

$$d^2 = h^2 + 2hR$$

Since $h << R$, neglecting h^2 we have $d^2=2hR$

or $d = \sqrt{2hR}$

LONG-ANSWER QUESTIONS

Q.1 Why is modulation necessary in a communication system?

Sol. Modulation is necessary in a communication system due to the following reasons:

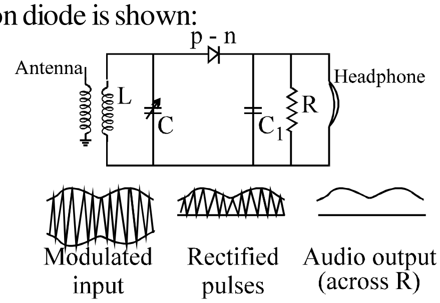
(a) Antenna Length: It can be shown theoretically that in order to transmit a signal effectively, the length of the transmitting antenna should be of the order of the wavelength of the signal.The audio frequencies range from 20 Hz to 20 kHz: If they are transmitted directly, the length of the required antenna would be very large. For example, for a frequency of 20 kHz, the antenna length would be $(3 \times 10^8)/(20 \times 10^3)$ = 15,000 metres, which is too large. Thus it is not practicable to transmit audio signals directly.
A carrier wave, on the other hand, has a much higher frequency, say 1000 kHz. This would require an antenna of about 300 metres length, which can be conveniently installed.

(b) The energy of a wave depends on its frequency-greater the frequency of a wave, greater is the energy possessed by it. The audio signal frequencies are low and hence their energies are small. Therefore, they cannot be transmitted over large distances directly. However, superimposing them on high frequency carrier waves makes it possible to transmit them over long distances.

(c) Long distance transmission is carried out without wires, i.e., the signal is radiated into space. At low audio frequencies the efficiency of radiation is not good. After modulation the transmission is at high carrier frequencies, which is quite efficient.

Q.2 Draw a circuit diagram for demodulation (detection) and explain its working.

Sol. The basic circuit using a junction diode is shown:



The input circuit consists of a parallel combination of an inductor L and a variable capacitor C. This circuit is called tuning circuit which is used to select the desired modulated radio frequency. The output of the diode is a series of positive half cycles of radio frequency current pulses. The peaks of these pulses vary in accordance with the modulating audio signal. This rectified output is fed to the parallel combination of a capacitor C_1 and a resistor R. The capacitor C_1 acts as a bypass for carrier waves and the audio frequency voltage appears across the resistor R.

Q.3(a) Explain the use of a geostationary satellite for long distance communication.

(b) Explain remote sensing.

Sol.(a) For long distance transmission, microwaves are used as carrier waves since they can pass through the atmosphere without significant loss of energy. This is due to their small wavelengths. Signals from the broadcasting station are beamed towards an artificial earth satellite which reflects them back to the earth. Since the satellite is at a large height, it can send back the signals to a large part of the earth's surface. For a satellite to be useful for sending signals to particular regions, its orbit must be such that it appears stationary relative to the earth's surface. Such a satellite is called a geostationary satellite. Its time period is 24 hours. It can be shown that the height of such a satellite above the earths' surface is about 36,000 km. Communication links all around the earth have been established by putting many geostationary satellites in the equatorial plane at this height.

(b) Remote sensing. It is the technique of obtaining information about an object or some region from a large distance. For this purpose a remote sensing satellites, also called an active satellite, is used. Such a satellite is equipped with various instruments (such as cameras, microwaves scanners etc.) to enable it to record and send the desired information. The satellite is placed in sun-synchronous orbit around the earth. This makes it possible to have similar lighting conditions every time it passes over the particular region of the earth. Constant lighting angles help the observations about that region to be more standard and easier to interpret. In recent years, satellite remote sensing has become very important. One major application is to gather information (e.g. temperature, nature, size etc.) about remote, inaccessible regions of the earth and to estimate the damage caused by floods, droughts, etc.

Q.4 State the principle of an optical fibre. Explain in brief the various types of optical fibres.

Sol. Optical fibres are based on the phenomenon of total internal reflection.

Consider a ray BO incident on the glass core from air at an angle i such that the ray of light inside the core meets the core-cladding interface at an angle greater than the critical angle for it. As a result, the ray of light undergoes total internal reflection. The path of ray is shown in figure A. Different types of optical fibres are-

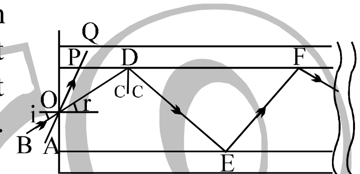


Figure A

1. Monomode optical fibre - It has a narrow core of diameter about 5 mm surrounded by a relatively big cladding (125 mm in diameter). In such optical fibres, there is practically no loss in the intensity of the output light signal.

2. Multimode optical fibre - These are further classified as-

(i) Step index multimode fibre: In this type of optical fibre the diameter of the core is about 50 mm which is very large in comparison with monomode optical fibre.

Figure B shows the path of two light waves of wavelength λ_1 and λ_2. Since the refractive index of a material depends on the wavelength, the two light waves will reach the other end following different and unequal paths. As a result a faulty and distorted signal is obtained.

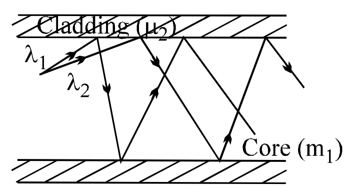


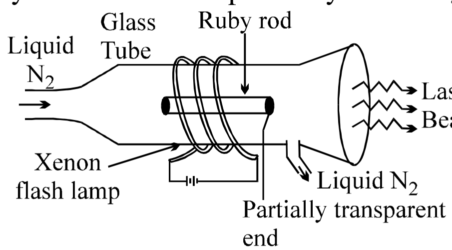
Figure B

(ii) Graded index multimode fibre: In this type of optical fibre, the refractive index decreases smoothly from its centre to the outer surface of the fibre. As such, there is no boundary between the core and cladding. At the centre, the refractive index is 1.52, which decreases to 1.48 at the outer surface. In a graded index multimode fibre, all the light waves, regardless of their wavelength, arrive at other end of the fibre at the same time.

Q.5 State the principle of LASER. Explain the experimental arrangement and theory of ruby laser with the help of energy level diagram.

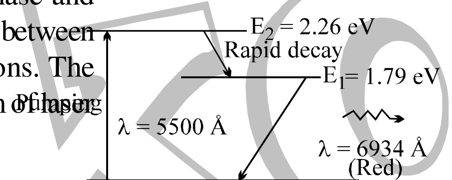
Sol. LASER is based on the principle that in the atomic systems possessing metastable states, one can cause population inversion and then the process of stimulated emission can be used to produce highly coherent, highly monochromatic and perfectly parallel beam of light.

Ruber Laser is a solid state laser. The main component of it is a ruby rod. Ruby is a crystal of aluminium oxide doped with 0.05% of chromium oxide. These rods are about 5 cm in length and 0.5 cm in diameter. The end faces of the rod are made parallel and coated with silver, such that one face becomes fully reflecting while the other face is partially reflecting so as to allow the laser beam to emerge out of the ruby rod. The ruby rod is placed along the axis of a Xenon flash tube. The flash tube provides the necessary pumping energy to the ruby rod. The rod is kept cool by circulating liquid nitrogen around it.



Ruby laser is a three energy level system. The three energy levels of chromium ion are the ground state E_0 the metastable state E_1 and a higher energy level E_2. Initially the atoms are distributed in various energy levels. When the Xenon lamp is switched on, it produces a flash intense light of wavelength 5500Å which acts as pumping radiation for chromium ions. The atoms are raised from the ground state to the higher energy state E_2. The electrons cannot stay in excited state for more than 10^{-8} s and they drop to either energy level E_1 or directly to ground state E_0. The energy released during the process is lost to ruby rod and before it raises its temperature it is cooled by liquid nitrogen. In a short duration there is population inversion i.e., state E_1 (metastable) becomes more populated.

Now, once a photon is produced due to transition from the metastable state E_1 to the ground state E_0, it stimulates the emission of another photon of the same energy, phase and direction. The emitted photons suffer multiple reflection between the two polished ends and stimulate further emissions. The process of amplification continues till an intense beam of laser emerges out from the partially coated face of the rod.



Q.6 Write short notes on
(a) Modem (b) Fax.

Sol.(a) MODEM: As the name implies, a modem can perform both the functions of modulation and demodulation. In the transmitting mode, modem converts digital data into analog signal for use in modulating a carrier by a signal. At the receiver end reverse of it takes place. Thus modems are placed at both the ends of communication circuits. Operation of modem are classified into the following three modes:

(i) Simplex mode - This type of modem provides transmission in only one direction.

(ii) Half duplex mode - This type of modem are able to transfer data in both directions. The flow of data in one direction takes place at one time and in the opposite direction at a second time. It requires one transmission bidirectional channel.

(iii) Full duplex mode - In this mode of operation, transmission takes place in both directions at the same time. In this case two transmission channels are required.

(b) FAX (FASCIMILE). The electronic transmission of a document to a distant place via telephone line is known as fascimile or Fax. In fascimile transmission an exact reproduction of a document is produced at the receiving end.

In order to send Fax copy of some document, the sender dials in the phone number of Fax machine at the receiver's end. At the sender's end Fax machine is in transmitting mode while at the receiver end it is in receiving mode. In the receiving mode, only the printer is active to receive the incoming signal. When the document is fed into the machine, the scanner scans the document. When an intense beam of light falls on the scanned document, the amount of light that bounces back is detected by the sensor. When ink is present, little light is.reflected which creates a pulse of low voltage while from the blank paper a pulse of high voltage is produced. A modem inside the Fax corverts these digital pulses into analog signals which are then transmitted via the telephone link. The modem at the other end converts back the analog signal into digital pulses which are printed by the printer of the Fax and produce Fax copy of the original document.