Class-12

PHYSICS

GENERAL EDUCATION DEPARTMENT

SAMAGRA SHIKSHA, KERALA

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CHAPTERS

CHAPTER- 1

ELECTRIC CHARGES AND FIELDS

Focus Area

1.2 Electric charge

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Points to Remember

*Electric charge is an intrinsic property of matter and is carried by elementary particles like electrons, protons, positrons etc.

*Basic properties of electric charge

(1) Quantisation: The electric charge of any system is always an integer multiple of the fundamental charge,

$$Q = \pm ne$$

where **n** is an integer and **e** is the electronic charge.

(2) Additivity: The total charge of a system is the algebraic sum of the charges.

(3) Conservation: The total charge of an isolated system is conserved.

*Coulomb's Law: The force of attraction or repulsion between two electric charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them.

$$F = \frac{1}{4\pi\ \varepsilon_0}\ (\frac{q_1\ q_2}{r^2})$$

*Electric field: is a region where an electric charge experiences a force.

Intensity of electric field E is the force per unit charge placed at a point

E = F/q is a vector quantity and its unit is N/C or V/m

*Electric field due to a point charge, $E = \frac{1}{4\pi\,\varepsilon_0}\left(\frac{q}{r^2}\right)$

Electric field lines

* The imaginary lines around a charge are called electric field lines.

* Electric field lines start from positive charge and end on negative charge.

* Electric field lines never intersect each other, since electric field has only one direction at a point.

* Electric Flux: is the total number of electric lines of force passing normal to the surface. Unit of electric flux is Nm^2/C

* Electric dipole: Two equal and opposite charges separated by a very small distance constitute an electric dipole.

* Dipole moment of an electric dipole is the product of one of the charges and the distance between them. It is a vector quantity and its unit is Cm.

The direction of dipole moment is from negative charge to positive charge

* Electric field at a point on the axis of a dipole.

$E = \frac{1}{4\pi\,\varepsilon_0}\frac{2P}{r^3}$

*Electric field at a point on the equatorial line of a dipole

$E = \frac{1}{4\pi\,\varepsilon_0}\frac{P}{r^3}$

*Torque experienced by a dipole in a uniform electric field

$\boldsymbol{\tau} = \mathbf{P} \times \mathbf{E} = PE\sin\theta$

* Gauss's Law: The total normal electric flux over a closed surface in free space is $\frac{1}{\varepsilon_0}$ times the charge enclosed by the surface.

* Electric field due to an infinitely long straight uniformly charged wire is $E = \frac{\lambda}{2\pi\varepsilon_0\, r}$ where λ is the linear charge density (charge per unit length)

*Electric field due to a uniformly charged infinite plane sheet of charge is $E = \frac{\sigma}{2\varepsilon_0}$

*Electric field due to a uniformly charged spherical shell $E = \frac{\sigma}{\varepsilon_0}\frac{R^2}{r^2}$

Sample questions

(1) What are the basic properties of an electric charge ?

(2) How many electrons are present in 1C of charge?

(3) Electric lines of force never intersect. Why?

(4) Unit of electric flux is ---------------

(5) State Gauss's law in electrostatics.

(6) Torque experienced by a dipole placed in a uniform electric field is---------------

(7) Unit of electric field is -----------------------------

(8) What are the characteristics of electric lines of force?

(9) Derive the expression for the electric field at a point on the axis of a dipole.

(10) Derive the expression for the electric field due to a uniformly charged plane sheet.

(11) Derive the expression for the electric field due to a uniformly charged spherical shell.

Answers

(2) Number of electrons in 1 C of charge , n =Q/e =1/1.6x10^{-19}= 6.25x10^{18}

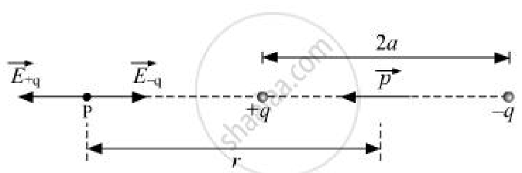
(3) Electric lines of force never intersect, if they intersect it would mean that there are two directions of electric field at point, that is not possible.

(4)Nm^2/C

(6) $\boldsymbol{\tau}$ = PE sin θ

(7) N/C or V/m

(9)



AB is an electric dipole of two point charges −q and +q separated by small distance 2a.
P is a point along the axial line of the dipole at a distance r from the midpoint O of the electric dipole.
The electric field at the point P due to +q is,

$$E_{+q} = \frac{1}{4\pi\epsilon_0}\left[\frac{q}{((r-a)^2)}\right]$$

The electric field at the point P due to −q is,

$$E_{-q} = \frac{1}{4\pi\epsilon_0}\left[\frac{q}{((r+a)^2)}\right]$$

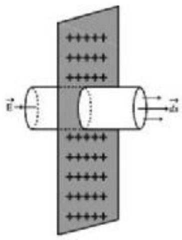
Therefore, the resultant electric field (E)at P is,

$$\text{E} = E_{+q} + E_{-q} = \frac{q}{4\pi\epsilon_0}\left[\frac{1}{((r-a)^2)} - \frac{1}{((r+a)^2)}\right] = \frac{q}{4\pi\epsilon_0}\left[\frac{4ar}{((r^2-a^2)^2)}\right]$$

If r>>a $\quad E = \left[\frac{4qa}{4\pi\epsilon_0 r^3}\right] = \frac{1}{4\pi\epsilon_0}\frac{2P}{r^3}$

Where P= q.2a is the dipole moment.

(10)



Consider an infinite thin plane sheet of positive charge with a uniform charge density σ on both sides of the sheet. Let a point be at a distance **a** from the sheet at which the electric field is required. Consider a gaussian cylinder of area of cross section **A**.

Electric flux through the gaussian surface $\emptyset = E \times 2A$ ....(i)

According to gauss's theorem $\emptyset = q / \varepsilon_0$

Here, Charge enclosed by the gaussian surface,

$$q = \sigma A$$

Therefore $\emptyset = \sigma A / \varepsilon_0$..............(ii)

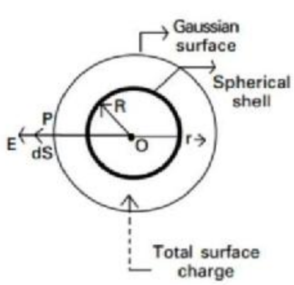
From (i) and (ii)$\Rightarrow E \times 2A = \sigma A / \varepsilon_0$

ie, $E = \sigma / 2\varepsilon_0$

The direction of electric field for positive charge is in the outward direction and perpendicular to the plane of infinite sheet.

The direction of electric field for negative charge is in the inward direction and perpendicular to the plane of infinite sheet.

(11)



Consider a uniformly charged spherical shell. Let the total charge on it is 'q' and radius is R.

Surface charge density $\sigma = q / 4\pi R^2$

Field at a point outside the shell

Consider a point at a distance r outside the sphere. Imagine a Gaussian surface with r as radius where r > R

By Gauss's theorem, total flux $\emptyset = \frac{1}{\epsilon_0} q$ ……….…….(i)

Also $\emptyset = 4\pi r^2 E$ ……………………………...……(ii)

From (i) and (ii) $4\pi r^2 E = \frac{1}{\epsilon_0} q$

ie: $E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$

On the surface of the sphere r = R

Ie : $E = \frac{1}{4\pi\epsilon_0} \frac{q}{R^2}$

Inside the sphere q = 0, E = 0

CHAPTER-2

ELECTROSTATIC POTENTIAL AND CAPACITANCE

Focus Area

2.2 Electrostatic Potential

2.3 Potential due to a point charge

2.11 Capacitors and capacitance

2.12 The parallel plate Capacitor

2.14 Combination of capacitors

2.15 Energy stored in a Capacitor

Points to remember

*Electrostatic Potential

Potential at a point in an electric field is the work done in bringing a unit positive charge from infinity to that point against the electric field. Unit of potential is volt. It is a scalar quantity.

*Potential at a point due to a point electric charge $V=\frac{1}{4\pi\ \varepsilon_0}\ (\frac{q}{r})$

Relation between electric field and potential $E = \frac{-dV}{dr}$

*Capacitors and capacitance

(1)A capacitor is a device which can store electrical energy.

(2) A capacitor is an arrangement of conductors to increase the capacitance.

(3) Capacitance is the ratio of charge imparted to the rise in potential $C=\frac{Q}{V}$

(4) Unit of Capacitance is farad (F)

(5) Capacitance of a parallel plate Capacitor is $C=\frac{\varepsilon_0\ \varepsilon_r\ A}{d}$

Where ϵ_0 is the permittivity of free space, ϵ_r is the relative permittivity and A is the area of each plate, d is the distance between the plates.

*Combination of Capacitors

When three capacitors are connected, the effective capacitance is given by,

(1) Capacitors in Series, $\frac{1}{C_S}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$

(2) Capacitors in Parallel, $C_P=C_1+C_2+C_3$

If two capacitors are connected in series, the effective capacitance $C_S = \frac{C_1 C_2}{C_1+C_2}$

*Energy stored in a capacitor is the work done in charging it.

$$U=\frac{1}{2}CV^2$$

$$=\frac{1}{2}QV$$

$$=\frac{1}{2}\frac{Q^2}{C}$$

Sample Questions

(1) Define potential at a point.

(2) What is the relation connecting electric field and potential difference?

(3) The potential on the surface of a sphere is 10V. What is the potential at the centre of the sphere?

(4) Derive an expression for potential at a point due to a point charge.

(5) Derive the expression for the capacitance of a parallel plate capacitor.

(6) Derive the expression for the effective capacitance

(1) if three capacitors are connected in series.

(2) if three capacitors are connected in parallel.

(7) Derive an expression for the Energy stored in a capacitor.

(8) The total capacitance of two capacitors is 4 μF when connected in series and 18 μF when connected in parallel. Find the capacitance of each capacitor.

(9) The ratio of effective capacitance of two equal capacitors connected in series to that when connected in parallel is -------------------

(10) Assuming the earth to be an isolated conducting sphere of radius 6400 km, What is the capacitance of the earth?

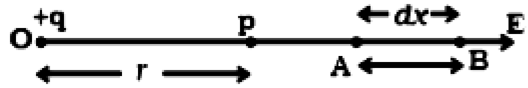
Answers

(2) $E = \frac{-dV}{dr}$

(3) 10V

(4) Let +q be an isolated point charge situated in air at O. P is a point at a distance r from +q.

Consider two points A and B at distances x and x + dx from the point O (Fig.)



The potential difference between A and B is, dV = −E dx

The force experienced by a unit positive charge placed at A is

$$E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{q}{x^2}$$

$$\therefore \quad dV = -\frac{1}{4\pi\varepsilon_o}\frac{q}{x^2} \cdot dx$$

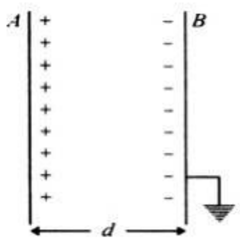
The negative sign indicates that the work is done against the electric force.

The electric potential at the point P due to the charge +q is the total work done in moving a unit positive charge from infinity to that point,

$$V = -\int_{\infty}^{r} \frac{q}{4\pi\varepsilon_o x^2} \cdot dx = \frac{q}{4\pi\varepsilon_o r}$$

(5) Let the plate A be given a charge +Q.

Due to electrostatic induction a charge -Q will appear on the nearer side of B and +q on the farther side.



The induced potential will get neutralized due to flow of electrons from the earth. Thus the plate A has +Q charge and B has -Q charge, uniformly distributed on the inner surface of the plates.

The surface charge density of each plate , $\sigma = Q/_A$

By Gauss's theorem, the electric intensity E between the plate is

$E = \sigma/_{\varepsilon_0}$

Potential difference between the plates, V = E x d = $\sigma d/_{\varepsilon_0}$

But $\sigma = Q/_A$

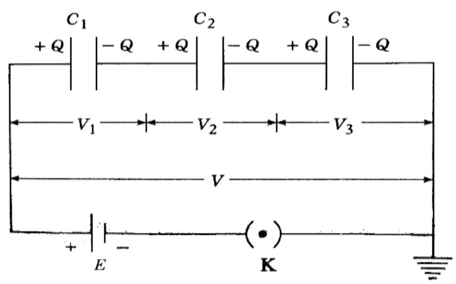
Therefore, V = $\frac{Qd}{\varepsilon_0 A}$

The capacitance of the capacitor, C = $Q/_V = \frac{Q}{\frac{Qd}{\varepsilon_0 A}} = \frac{\varepsilon_0 A}{d}$

When a dielectric is introduced between the plates of a capacitor $C = \frac{\varepsilon_0 \varepsilon_r A}{d}$

(6) (i)

Capacitors in series:



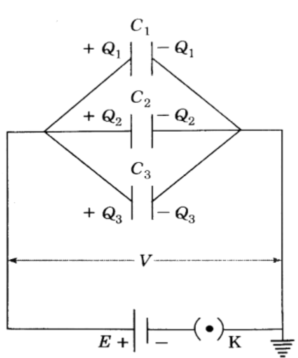
Capacitors in series

When capacitors are connected in series, the charge remains the same, but voltages are different, The total voltage.
V = V_1+V_2+V_3.
we know that C=Q/V

V=Q/C
therefore,
Q/C = Q/C_1 + Q/C_2 + Q/C_3
$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

C_s is the resultant capacitance when capacitors are connected in series.

(ii) **Capacitors in parallel**:



Capacitors in parallel

when capacitors are connected in parallel, then charge is different but voltage remains the same.

The total charge Q is given by

$Q = Q_1 + Q_2 + Q_3$
we know that C = Q/V

Q = CV
therefore,
$C_P V = C_1 V + C_2 V + C_3 V$

$C_P = C_1 + C_2 + C_3$
is the resultant capacitance when capacitors are connected parallel.

7. Consider a capacitor of capacitance C and potential difference V between the plates.
Suppose the capacitor is being charged gradually.
Let the charge on one plate be **+q** and **-q** on the other at any instant during charging and v, the potential at that instant.

Now, at any stage the charge on capacitor is q.

The amount of work done in giving an additional charge dq to the capacitor is
dW= V dq

Total work done in giving a charge Q to the capacitor is

$$W=\int_0^Q v\, dq = \frac{1}{C}\int_0^Q q\, dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q = \frac{1}{2}CV^2$$

The work is stored as the potential energy.
$U = \frac{1}{2} CV^2$
Other forms, $U = \frac{1}{2} QV$ and $U = \frac{1}{2}\frac{Q^2}{C}$

(8) $C_s = 4\ \mu F$ $C_p = C_1 + C_2 = 18\mu F$ $4 = C_1 C_2 / 18$

$C_1 C_2 = 72$ $C_1 - C_2 = 6$

Therefore $C_1 = 12\ \mu F$

and $C_2 = 6\ \mu F$

9) 1:4

10) $C = 4\pi\epsilon_0 R = 0.71 mF$

CHAPTER-3

CURRENT ELECTRICITY

Focus Area

3.4 Ohm's Law

3.9 Electrical energy, power

3.10 Combination of Resistors-Series and Parallel

3.11 Cells, Emf, Internal resistance

3.13 Kirchhoff's Rules

3.14 Wheatstone's Bridge

3.15 Meter Bridge

3.16 Potentiometer

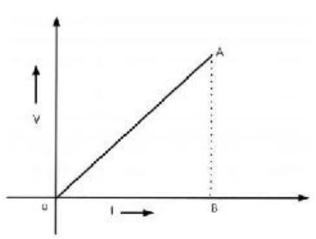
Points to Remember

*Ohm's Law: At constant temperature the current flowing through a conductor is directly proportional to the potential difference between its ends.

V=IR

* V-I Graph: A graph can be drawn with current(I) along the x-axis and potential difference along the y-axis

$$\text{Resistance}(R) = \frac{AB}{OB}.$$



It is a straight line. The slope of the graph gives the resistance.

Unit of resistance is ohm (Ω)

Reciprocal of resistance is conductance. Its unit is mho or Siemens

*Resistivity

(1) The resistance of a conductor is proportional to the length of the conductor.

(2) The resistance is inversely proportional to the area of cross section

$$R = \frac{\rho l}{A}$$

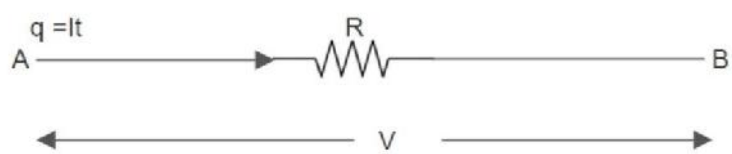
Resistivity ρ is the resistance offered by a conductor of length 1m and area of cross section $1m^2$

Unit of resistivity is ohm metre(Ωm)

*Resistance varies with temperature. In the case of metals resistance increases with temperature.

$R_t = R_0 (1+ \alpha t)$ where R_t is the resistance at t^0 C and R_0 is the resistance at 0^0C and α is the temperature coefficient of resistance

*Electric Power: The power of an electrical appliance is the rate at which the electrical energy is converted into other forms of energy. As the charge moves from A to B, it loses electric potential energy QV. In other words qV joules of electrical energy is converted in to heat in t seconds.



Electric Power = qV/t = ItV/t=VI J/s or W

Electric Power = $VI = I^2R = V^2/R$

Unit of electric power is watt (W)

*Electrical Energy

The loss of electrical potential energy in maintaining current in a circuit is called electrical energy consumed in the circuit.

Electrical energy consumed in t seconds, $W = VIt = I^2Rt = V^2t/R$ joules

Unit of electrical energy is Ws or J

*Commercial unit of electrical energy is kWh or unit

$1kWh = 3.6x10^6$ J

*Joules Law:

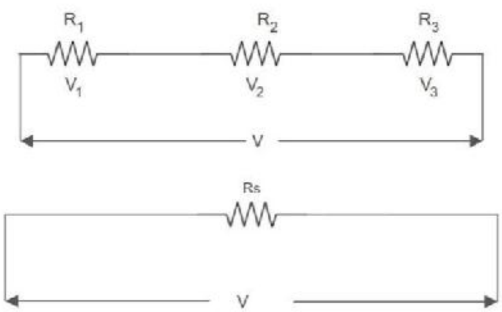
Heat produced(H) in a conductor when a current flows through it is

(1) directly proportional to the square of the intensity of current I^2
(2) Directly proportional to the resistance R
(3) Directly proportional to the time t

$H = I^2Rt$ joules

*Combination of resistors

(1) in series



The total potential difference

$V = V_1 + V_2 + V_3$

$= IR_1 + IR_2 + IR_3$

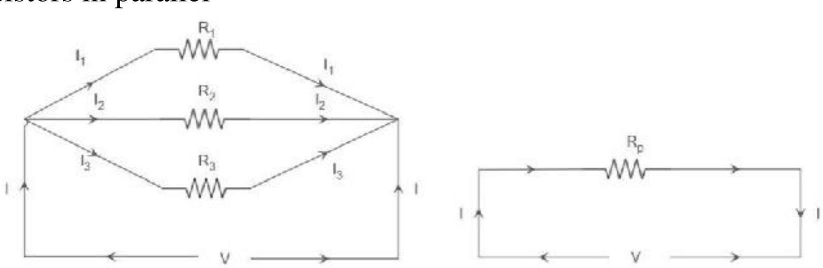
$= I(R_1 + R_2 + R_3)$

In series circuit current remains the same. If Rs is the effective resistance of the combination

$V = I R_s$

$R_s = R_1 + R_2 + R_3$

(2) Resistors in parallel



$I = I_1 + I_2 + I_3$

$= V/R_1 + V/R_2 + V/R_3$

$= V (1/R_1 + 1/R_2 + 1/R_3)$

If R_p is the effective resistance of the combination

$I = V (1/R_p)$

$1/R_p = 1/R_1 + 1/R_2 + 1/R_3$

If there are two resistances only,

R_p = Product/sum

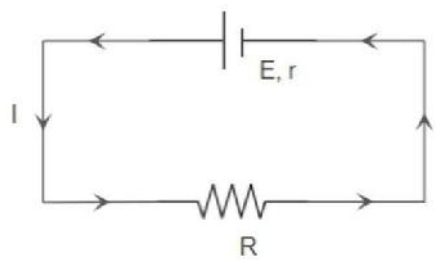
$R_p = R_1R_2 / R_1+R_2$

*EMF of a cell

EMF is the source of electrical energy and is the terminal potential difference when the circuit is open. It is always greater than the potential difference.

*Internal resistance of a cell:

The resistance offered by the material of a cell when an electric current flows through it, is called internal resistance of the cell(r). A fresh cell has low internal resistance and increases with long use.



Current I = E/ (R+r)

E = IR + Ir

E = V + Ir

Where V is the terminal potential difference, Ir is the 'lost volt' which is the potential drop across the internal resistance.

E = V + Ir

= V + (V/R)r

$= V\left(1 + \frac{r}{R}\right)$

$\frac{E}{V} = \left(1 + \frac{r}{R}\right)$

$\frac{r}{R} = \left(\frac{E}{V} - 1\right)$

$r = R\left(\frac{E}{V} - 1\right)$ $r = R\left(\frac{E-V}{V}\right)$

*Internal resistance of a cell increases with external resistance.

*Factors affecting internal resistance

(1) Nature of the electrolyte

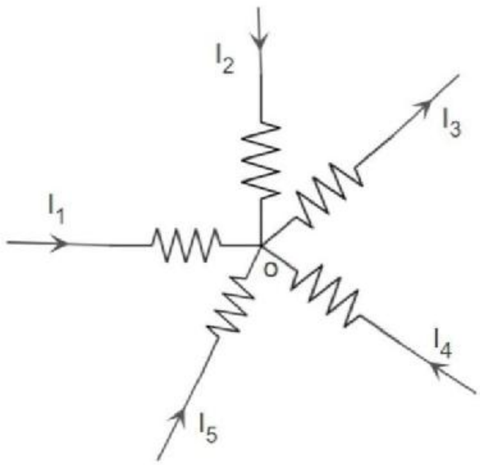
(2) Nature of the electrodes

(3) Area of the plates immersed in the electrolyte

(4) Distance between the plates

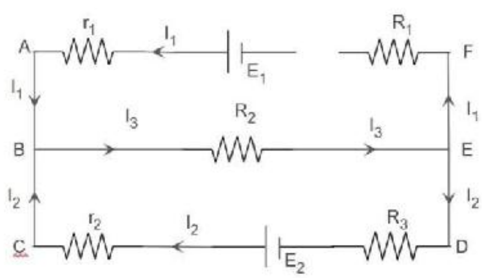
*KIRCHHOFF'S RULES

First Law: The algebraic sum of the currents meeting at any junction is zero. The current flowing towards the junction is positive and leaving the junction is negative



$I_1 + I_2 - I_3 + I_4 + I_5 = 0 \Rightarrow \Sigma I = 0$

Second Law: In any closed network the algebraic sum of the product of current and resistance is equal to the algebraic sum of the EMF'S in that network



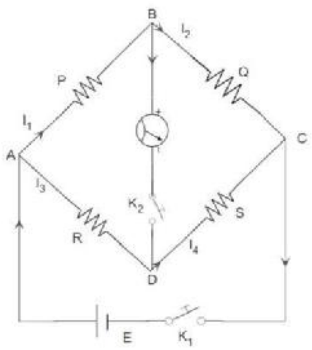
$$\Sigma IR = \Sigma E$$

(i) For the circuit ABEFA, $I_1 r_1 + I_3 R_2 + I_1 R_1 = E_1$

(ii) For the circuit ACDFA, $I_1 r_1 - I_2 r_2 - I_2 R_3 + I_1 R_1 = E_1 - E_2$

(iii) For the circuit CBEDC, $I_3 R_2 + I_2 R_3 + I_2 r_2 = E_2$

*WHEATSTONE'S BRIDGE -Balancing condition



Let P,Q,R and S are four resistors connected to form a network ABCD. Between A and C, a cell of emf E is connected through a key K_1. A sensitive galvanometer is connected between B and D through key K_2. Applying Krichoff's first law to the junctions B and D.

$I_1 - I_g - I_2 = 0$

$I_3 + I_g - I_4 = 0$

Applying Kirchhoff's second law to the circuits ABDA and BCDB,

$I_1 P + I_g G - I_3 R = 0$ where G is the resistance of the galvanometer

$I_2 Q - I_4 S - I_g G = 0$

The resistances are so adjusted that, the galvanometer shows null deflection

ie ; $I_g = 0$

Then $I_1 = I_2$, $I_3 = I_4$

Also $I_1 P = I_3 R$

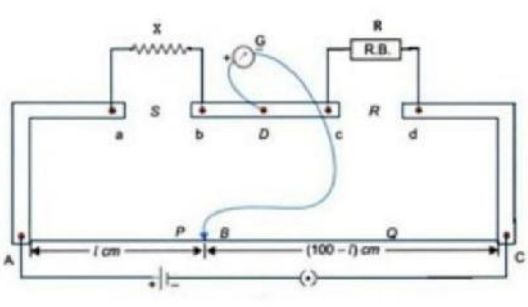
$I_2 Q = I_4 S$

From the last two equations we have

P/Q= R/S

*This is the balancing condition for a Wheatstone's bridge

Meter Bridge



Practical version of Wheatstone's bridge is a meter bridge. It is used to measure unknown resistance. It consists of a uniform wire of length 1 m fixed between two terminals A and B. There are two L shaped copper strips with an I shaped copper strip between them. There are two gaps S and R. A jockey is arranged for sliding contact. The entire arrangement is fixed on a wooden board The unknown resistance is connected in gap S and a known resistance in R. With a suitable resistance in the box the balancing length l_1 is determined. By interchanging X and R the balancing length l_2 is again determined. Then,

$$l = (l_1 + l_2)/2$$

By the principle of Wheatstone's bridge $X / R = \frac{l\sigma}{(100-l)\sigma}$

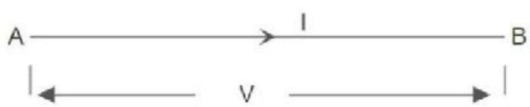
Where σ is the resistance per unit length of the wire

ie; $X=Rl/(100-l)$

*Potentiometer

Principle: When a steady current flows through a conductor of uniform area of cross-section, the potential difference across any portion of the conductor is proportional to its length.

ie; $V \propto l$

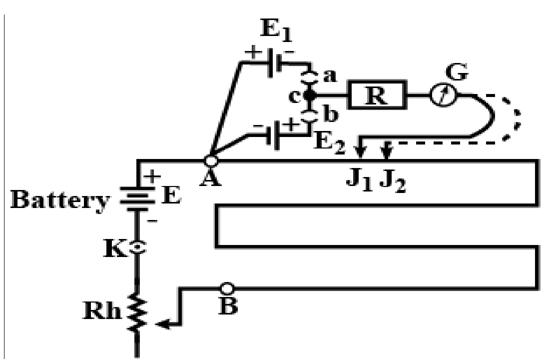


$V = I R$ $\qquad R = \frac{\rho\, l}{A}$

$V = \frac{I\, \rho\, l}{A}$ $\qquad = \left(\frac{I\,\rho}{A}\right) l \Rightarrow V \propto l$ since ρ, I and A are constants

This is the principle of a potentiometer

*Comparison of EMF's



Primary circuit is closed. Cell of emf E_1 is introduced into the secondary circuit and the balancing length AJ_1 is determined (l_1)

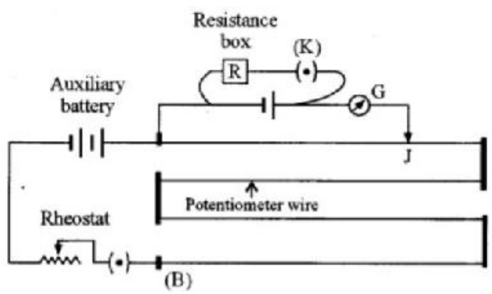
$E_1 \propto l_1$

Similarly for the second cell of emf E_2, the balancing length AJ_2 is measured as l_2

$E_2 \propto l_2$

Hence $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

To determine internal resistance of a cell



Primary circuit is closed. A cell of emf E and internal resistance r is included in the secondary circuit. K is opened and the balancing l_1 is determined.

$E \propto l_1$

A suitable resistance (say 1Ω) is included in the resistance box R and K is closed, the balancing length l_2 is determined.

The terminal potential difference across the resistance

$\frac{E\,R}{(R+r)} \propto l_2$

Dividing the above equations

$\frac{E}{\frac{E\,R}{(R+r)}} = \frac{l_1}{l_2} \quad \Rightarrow \frac{R+r}{R} = \frac{l_1}{l_2} \quad \Rightarrow 1 + \frac{r}{R} = \frac{l_1}{l_2}$

$r = R\left(\frac{l_1 - l_2}{l_2}\right)$

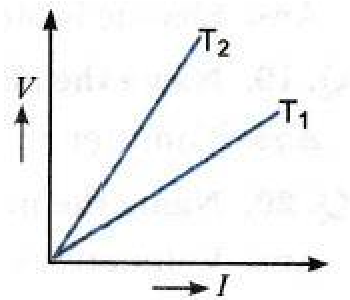
Sample Questions

(1) State Ohm's law

(2) You are given n wires, each of resistance 2 **Ω** . What is the ratio of maximum to minimum resistance possible with these wires?

(3) The effective resistance of two wires is10 **Ω** ,when connected in series and 2.4 **Ω** when connected in parallel. Find the value of individual resistances.

(4) The V-I graph of a conductor at two different temperatures T_1 and T_2 are given. At what temperature is the resistance high?



(5) You are given three resistors of resistances 1 Ω , 2 Ω, 3 Ω . How will you combine them to get an equivalent resistance of

(a)11/3 Ω (b)11/5 Ω (c) 6 Ω (d) 6/11 Ω

(6) Two wires of equal lengths, one of copper and the other of manganin, have the same resistance. Which wire is thicker?

(7) Derive the expression for the effective resistance of three resistors of resistances R_1, R_2 & R_3

(a) connected in series and (b) connected in parallel

(8) Derive the expression for the internal resistance of a cell.

(9) Derive the balancing condition of a Wheatstone's bridge

(10) Explain the meter bridge experiment to find the unknown resistance.

(11) Explain the potentiometer experiment to compare the EMF s of two cells

(12) Explain the potentiometer experiment to find the internal resistance of a cell.

CHAPTER 4

MOVING CHARGES AND MAGNETISM

Focus Area

4.2 Magnetic Force

4.5 Magnetic Field due to a current element, Biot-Savart's Law

4.6 Magnetic field on the axis of a circular current loop

4.7 Ampere's Circuital Law

4.8 The solenoid and the toroid

Points to Remember

*A charge q moving with a velocity **v** through a magnetic field **B** experiences a magnetic force.

F= q(**v** x **B**). This force is called magnetic Lorentz Force. **F = q v B sin*θ*** where θ is the angle between **B** and **v**.

The direction of the force is given by the direction of motion of the right handed screw imagined to rotate from **v** to **B**

*The Lorentz force on a charged particle in the presence of electric and magnetic field is

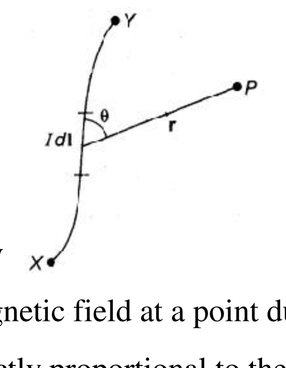
F=q(vx**B+E**)

*A current carrying conductor placed in a uniform magnetic field will experience a force.

Magnetic force F =B I L sinθ

*Magnetic effect of electric current-

A current carrying conductor produces magnetic field around it. The direction of the magnetic field is given by Right hand grip rule or Maxwell's cork screw rule. The magnitude of the magnetic field is given by Biot- Savart's law.



*Biot-Savart's law

The magnetic field at a point due to a current element is

(1) directly proportional to the strength of the current I

(2) directly proportional to the length of the element dl

(3) directly proportional to sinθ, where θ is the angle between the element and the line joining the point and the midpoint of the element.

(4) inversely proportional to the square of the distance r^2 between the element and the point.

$dB = \frac{k\, I\, dl \sin\theta}{r^2}$, where $k = \frac{\mu_0}{4\pi}$

*Magnetic field on the axis of a circular current loop

$dB = \left(\frac{\mu_0}{4\pi}\right) \left(\frac{2\pi\, nI\, a^2}{(a^2+x^2)^{\frac{3}{2}}}\right)$

*Ampere's Circuital law: The line integral of the magnetic field around a closed path in free space is equal to μ_0 times the total current enclosed by the path.

$$\int B.dl = \mu_0 I$$

*Solenoid.

A Solenoid is a coil wound in a helical form. When a current flows through a solenoid it behaves like a bar magnet and the magnetic field is established inside the solenoid. Outside the solenoid there is no magnetic field. The magnetic field produced by a solenoid is $\mu_0 n I$ where μ_0 is the permeability of free space, n is the number of turns per unit length of the solenoid and I is the current.

*Toroid

An endless solenoid is called a toroid. The magnetic field produced by a toroid is $\mu_0 n I$

Where μ_0 is the permeability of free space, **n** is the number of turns per unit length of the toroid and

I is the current.

Sample questions

(1) State Biot-Savart's law

(2) Write down the expression for the magnetic field produced by a current carrying solenoid.

(3) What is the principle of an electric motor?

(4) State Ampere's circuital law.

(5) The number of turns on a 25 cm long solenoid is 250. If 5A current is passed through it, calculate the magnetic field on the axis of the solenoid

(6) A charge of 2C is moving with a velocity 4000 m/s in a magnetic field of 0.5 T at an angle 30^0 with the field. Find the force on the charge.

(7) An electron is moving in a circular path with a speed of 3×10^6 m/s in a uniform magnetic field of magnitude 2×10^{-4} T. Find the radius of the path.

(8) Derive the expression for the magnetic field produced by a current carrying circular loop.

(9) By applying Ampere's circuital law, derive the expression for the magnetic field due to a current carrying solenoid.

(10) State Fleming's left hand rule.

Answers

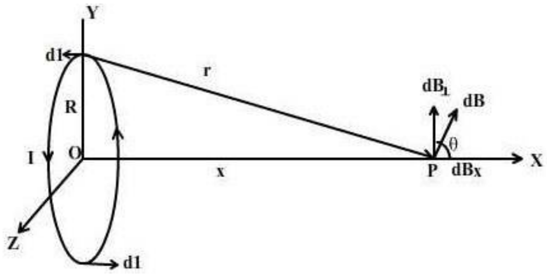
(3) Current carrying conductor placed in a uniform magnetic field will experience a force.

(5) $B = \frac{\mu_0 N I}{l}$

(6) $F = qvB \sin\theta$

(7) $\frac{mv^2}{r} = qvB$

(8)



Consider a circular coil of radius **R** with centre **O**. Let current **I** be flowing in the coil. Let P be a point on the axis of the circular coil at a distance x from its centre O.
Consider two small elements of the coil each of length **dl** at diametrically opposite edges as shown in figure
As per the figure, $r = \sqrt{R^2 + x^2}$
According to Biot- Savart's law, the magnetic field at P due to current element dl is,
$dB = \frac{\mu_0}{4\pi} \frac{I|dl \times r|}{r^3} = \frac{\mu_0}{4\pi} \frac{Idl}{(x^2+R^2)}$
The direction of dB is perpendicular to the plane formed by **dl** and **r**
Resolve dB into two mutually perpendicular components dB cosθ and dB sinθ.
But vertical components dB sinθ due to the diametrically opposite elements cancel each other as they are in opposite directions. But the horizontal components get added up as they are in the same direction
Also

$$cos\theta = \frac{R}{(x^2+R^2)^{\frac{1}{2}}}$$

The resultant field at P $B = \int dBcos\theta$

$$B = \int \frac{\mu_0}{4\pi} \frac{Idl\, R}{(x^2 + R^2)^{\frac{3}{2}}} = \frac{\mu_0}{4\pi} \frac{I\, R}{(x^2 + R^2)^{\frac{3}{2}}} \int dl = \frac{\mu_0}{4\pi} \frac{I\, R}{(x^2 + R^2)^{\frac{3}{2}}} 2\pi R$$

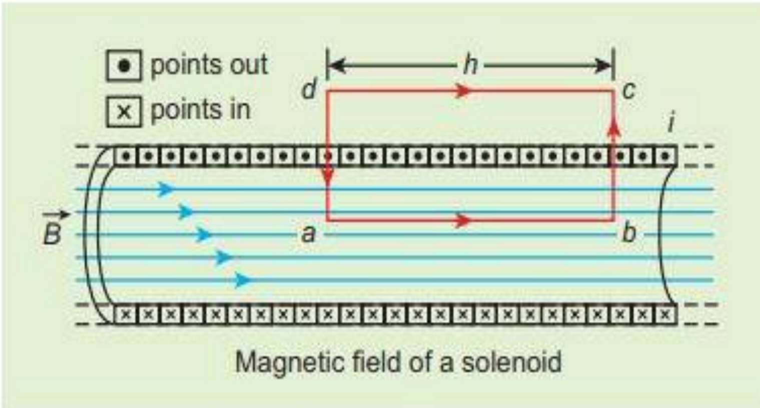
$$B = \frac{\mu_0}{4\pi} \frac{2\pi I\, R^2}{(x^2 + R^2)^{\frac{3}{2}}}$$

If there are n turns in the coil

$$B = \frac{\mu_0}{4\pi} \frac{2\pi nI\, R^2}{(x^2+R^2)^{\frac{3}{2}}}$$

$B = \frac{\mu_0}{4\pi}\frac{2\pi n I}{R}$ This is the field at the centre of the coil as x=0

9) Consider a solenoid of length L having N turns. The diametre of the solenoid is assumed to be much smaller when compared to its length and the coil is wound very closely.



Magnetic field of a solenoid

In order to calculate the magnetic field at any point inside the solenoid, we use Ampere's circuital law. Consider a rectangular loop **abcd** as shown in Figure. Then from Ampère's circuital law,

$\oint B.dl = \mu_0 \text{I}$

The left hand side of the equation is

$$\oint_C \vec{B}\cdot d\vec{l} = \int_a^b \vec{B}.d\vec{l} + \int_b^c \vec{B}.d\vec{l} + \int_c^d \vec{B}.d\vec{l} + \int_d^a \vec{B}.d\vec{l}$$

Since the elemental lengths along bc and da are perpendicular to the magnetic field which is along thexis of the solenoid, the integrals

$$\int_b^c \vec{B}.d\vec{l} = \int_b^c |\vec{B}||d\vec{l}|\cos 90^\circ = 0$$

$$\int_d^a \vec{B}.d\vec{l} = 0$$

Since the magnetic field outside the solenoid is zero, the integral $\int_c^d B\,.dl = 0$

For the path along **ab**, the integral is

$$\int_a^b \vec{B}.d\vec{l} = B\int_a^b dl\cos 0^\circ = B\int_a^b dl$$

where the length of the loop ab as shown in the Figure is **h**. But the choice of length of the loop ab is arbitrary. We can take very large loop such that it is equal to the length of the solenoid L. Therefore the integral is

$$\int_a^b \vec{B}.d\vec{l} = BL$$

Let N I be the current passing through the solenoid of N turns, then

$$\int_a^b \vec{B}.d\vec{l} = BL = \mu_\circ NI \Rightarrow B = \mu_\circ \frac{NI}{L}$$

The number of turns per unit length is given by *N/L* = *n*, Then

$B = \frac{\mu_0 \text{ nL I}}{L} \qquad = \mu_0$ n I

Since *n* is a constant for a given solenoid and μ_0 is also constant.

For a fixed current I, the magnetic field inside the solenoid is also a constant.

(10) Stretch the forefinger, middle finger and the thumb of the left hand in mutually perpendicular directions. If the forefinger represents the direction of the magnetic field and middle finger represents the direction of current then the thumb gives the direction of force on the conductor.

CHAPTER 5

MAGNETISM AND MATTER

Focus Area:

5.3 Magnetism and Gauss's Law

5.4 The Earth's Magnetism

5.5 Magnetisation and Magnetic Intensity

Points to Remember:

- In a magnet each line of force starts from a north pole and reaches the South Pole externally and then goes from south to north internally. Thus magnetic line of force is a continuous curve.
- A magnet always exists as a dipole. A north pole and a south pole separated by a small vector distance constitute a magnetic dipole
- According to Gauss's theorem in magnetism, the surface integral of magnetic flux over a closed surface is zero. This is because magnetic monopoles do not exist.
- $\int B.dS = 0$
- A freely suspended magnet comes to rest itself roughly along the geographic north-south direction. This means that there is a magnetic field around the earth.
- The vertical plane passing through the geographic north and south poles is called geographic meridian and the vertical plane passing through the magnetic north and south poles is called magnetic meridian.
- The angle between geographic meridian and magnetic meridian of the earth is called declination or angle of variation.
- The angle which the direction of total intensity of earth's magnetic field makes with the horizontal is called dip or inclination. It is denoted by θ. Angle of dip varies from place to place. At the poles, the value of dip is 90° and at the equator it is zero.
- The horizontal component of earth's magnetic field is called horizontal intensity. It is denoted by B_h. $B_h = B\cos\theta$

  This gives the relation between dip and horizontal intensity.

  The vertical component is, $B_v = B\sin\theta$ and $B = \sqrt{B_v^2 + B_h^2}$

$$\tan\theta = \frac{B_v}{B_h}$$

- The ability of a magnetic field to magnetize a material medium is called its magnetic intensity H. Its magnitude is measured by the number of ampere-turns flowing round unit length of a solenoid, required to produce that magnetic field. i.e. H = ni.
- When a material is placed in a magnetic field, it gets magnetized. The magnetic moment per unit volume is called magnetisation.

  $M = \frac{\text{magnetic moment}}{\text{volume}}$, S.I unit of magnetisation is A/m.

- When a magnetic material is magnetized by placing it in a magnetic field, the resultant field inside the material is the sum of the field due to the magnetisation of the material and the original magnetizing field. This resultant field is called magnetic induction or magnetic flux density **B**. S.I unit is tesla (T) or weber/m^2.
- **Relation between M, B and H,**

$$B = \mu_0 H + \mu_0 M$$

- The ease with which a specimen of a magnetic material can be magnetized is called its magnetic susceptibility and is equal to the ratio of intensity of magnetisation M to the magnetic intensity H.

$$\chi = \frac{M}{H}$$

- Relation between Susceptibility and Permeability, $\mu_r = (1+\chi)$

Sample Questions

1. Name the three independent quantities conventionally used to specify the earth's magnetic field?
2. Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero. The above law is attributed to which of the following statement?
   a. Absence of magnetic monopoles b. Absence of electrostatic monopoles c. Stationary charges do not produce magnetic field.
3. In the magnetic meridian of certain place, the horizontal component of the earth's magnetic field is 0.26 G and the dip angle is 60^0, what is the magnetic field of earth at this location?

4. A closely wound solenoid of 800 turns and area of cross section 2.5×10^{-4} m^2 carries a current 3A. Calculate a) Value of H b) Associated magnetic moment ?
5. The resulting magnetic field inside a material is the sum of flux density in vacuum produced by the same magnetic intensity and the flux density due to the magnetisation of the medium, write the relation connecting them?

Answers

1. i) Angle of Dip or Magnetic inclination ii) Magnetic declination iii) Horizontal component of magnetic field of earth B_H
2. a) Absence of magnetic monopoles
3. $B_h = B\cos\theta$, 0.52 G
4. i) H = NI, 2400 A/m ii) M= NIA , 0.6 JT^{-1}
5. $B = \mu_0 H + \mu_0 M$

CHAPTER 6

ELECTROMAGNETIC INDUCTION

Focus area

6.4 Faraday's Law of Induction

6.5 Motional Electromotive Force

6.6 Eddy Currents

6.7 AC Generator

Points to Remember

- Whenever the magnetic flux linked with a closed circuit changes, an e.m.f is induced in the circuit. The resulting current is called induced current. This phenomenon is called electromagnetic induction
- Faraday's Laws of electromagnetic induction:

(i) Whenever the magnetic flux linked with a closed circuit changes, an e.m.f is induced in the circuit. The induced e.m.f lasts as long as the flux change lasts.

(ii) The magnitude of the induced e.m.f is proportional to the rate of change of magnetic flux.

$E \alpha \frac{d\phi}{dt}$ or $E = \text{a constant} \times \frac{d\phi}{dt}$ The constant is taken to be one. $\therefore E = \frac{d\phi}{dt}$

- **Lenz's law :**

The direction of the induced e.m.f is such that it opposes the cause producing the change of flux.

Induced e.m.f, $E = -\frac{d\phi}{dt}$, the negative sign indicates that the induced e.m.f opposes the flux change.

- **Motional e.m.f :**

Consider a straight conductor PQ of length l moving normal to a uniform magnetic field B with a velocity v as shown in figure. The electrons in the conductor will experience a force $F = Bev$ and they move towards the end Q. This makes the end P to become positively charged. As a result a uniform electric field E is developed which is directed from P to Q. Now the electrons experience an electric force $F = eE$.The charge separation takes place until the magnetic force is balanced by electric force.

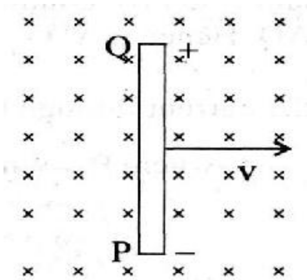
$Bev = eE$ or $E = Bv$

Let V be the potential difference between the ends of the conductor PQ. Then, $E = \frac{V}{l}$

$\therefore \frac{V}{l} = Bv$ or $V = Blv$

This equation gives induced e.m.f between the ends of the conductor.

If the velocity vector makes an angle θ with the direction of the magnetic field, then the induced e.m.f is, $V = Blv \sin\theta$



- **Eddy Current**

  Whenever the magnetic flux linked with a block of metal changes, an emf is induced in it. The induced currents flow in closed paths which look like eddies. Such currents are called eddy currents or Foucault currents. The direction of current is given by Lenz's law. The effect of eddy current depends on the resistance of the path through which it flows. Eddy current heat the metal and thus energy is wasted in the form of heat.

- **Application of eddy currents**

  1. Electromagnetic damping: To bring the coil in a moving coil galvanometer quickly to its equilibrium position, the coil is wound on a metallic frame. When a steady current is passed through the coil, eddy currents are induced in the metal frame, which produce damping called electromagnetic damping. Thus the coil comes to rest without oscillations.

  2. Induction furnace: This is used to extract a metal from its ore. When the metal ore is placed in a varying magnetic field, produced by a high frequency alternating current, eddy currents are induced in it. This heats the metal ore and it melts.

  3. Electric brakes: Metal drums are coupled with the wheels of the train. When a strong magnetic field is applied suddenly to a rotating drum, eddy currents are set up in it and the drum get stopped.

  4. Induction motor: This is an a.c motor used in fan. Using two single phase a.c having a phase difference of $\pi/2$, a rotating magnetic field can be produced. A metallic cylinder, called rotor is placed in the rotating magnetic field. The rotor rotates due to the large eddy currents induced in it.

  5. Speedometer: When a vehicle moves, a magnet rotates inside an aluminum cylinder. The changing magnetic field induces eddy current in the cylinder and drags it through certain angle which indicates the speed of the vehicle on a calibrated scale.

- **AC Generator**

A generator is a device which converts mechanical energy into electrical energy. It works on the principle of electromagnetic induction. The basic elements of an a.c generator are (i) a field magnet (ii) the armature (iii) the slip rings (iv) the graphite brushes. The armature consists of rectangular coil of insulated copper wire wound on a laminated soft iron core. It is capable of rotation about an axis normal to a uniform magnetic field produced by the field magnet. The ends of the coil are connected to the copper rings R_1 and R_2 called slip rings. B_1 and B_2 are two graphite brushes which press lightly against each ring. These brushes are connected to the external load.

Working: When the coil rotates with an angular velocity ω within the magnetic field B, the magnetic flux linked with the coil in a time t is, $\phi = BAN\cos\omega t$, where A is the area of the coil and N is the number of turns in the coil. The magnetic flux changes according to the value of ωt.

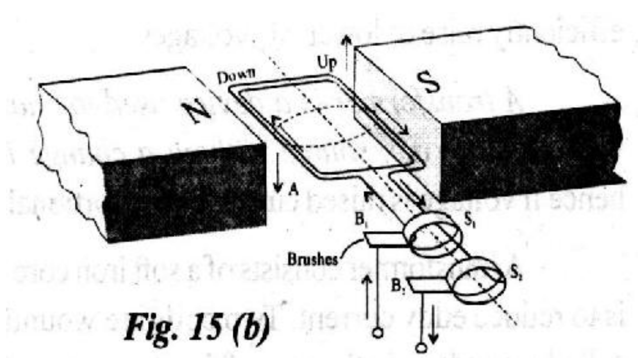


Fig. 15 (b)

The instantaneous e.m.f

$$E = -\frac{d\phi}{dt} = -\frac{d}{dt}(NBA\cos\omega t)$$

$$E = NBA\omega \sin\omega t$$

$$E = E_0 \sin\omega t, \text{ where } E_0 = NBA\omega \text{ called peak value of e.m.f.}$$

Sample Questions

1. Find the magnitude of emf induced in a 200 turns coil with cross sectional area $0.2 m^2$, if the magnetic field through the coil changes from 0.1 Wb/m^2 to 0.5 Wb/m^2 at a uniform rate over a period of 0.05 seconds?
2. A conductor moves in a direction parallel to the magnetic field. Which of the following statement is correct?

   i) There is a voltage developed between the ends of the conductor

   ii) No voltage developed between the ends of the conductor

3. A jet plane is travelling towards west at 1800 kmph. If the horizontal component of the earths's magnetic field at that place is $5x10^{-4}$ T and angle of dip is 30^0, find the emf induced between the ends of the wings having a span of 25 m?

4. A train moving north-south direction with a speed of 108 kmph. Find the amount of emf generated between the wheels if the length of axle be 2m. Assume that the vertical component of Earth's field is 8×10^{-5} Wb/m^2 ?

5. State Faraday's law of electromagnetic induction? Express them mathematically.

6. State the factors on which the induced emf in a coil rotating in a uniform magnetic field depends? Explain the working of ac generator?

7. What are eddy currents? Write any two applications of eddy currents?

Answers

1. Magnetic flux linked with the coil, $\Phi_1 = NAB_1$, $\Phi_2 = NAB_2$

$$\Phi_2 - \Phi_1 = 16 \text{ Wb}$$

$$\text{Induced emf} = \Phi_2 - \Phi_1 / t = 320 \text{ V}$$

2. v x B = 0, No magnetic field developed.

3. $V = Blv$, $\tan\theta = \frac{B_v}{B_h}$, $B_v = 2.88 \times 10^{-4}$ T

$V = 3.6$ V

4. $V = Blv$, 0.0048 V

5. $E \alpha \frac{d\phi}{dt}$, $\therefore E = \frac{d\phi}{dt}$

6. i) Total number of turns ii) Magnetic field iii) Area of the coil iv) speed of rotation of coil.

CHAPTER 7

ALTERNATING CURRENT

Focus Area:

7.2 A.C Voltage applied to a resistor

7.3 Representation of AC current and voltage by rotating vectors- Phasors

7.4 AC voltage applied to an inductor

7.9 Transformers

Points to Remember:

- Consider a coil of N turns and area A rotating with an angular velocity ω about an axis normal to a uniform magnetic field B. Let the normal to the coil makes and angle θ with the direction of B. When time t=0, the plane of the coil is perpendicular to the magnetic field. The magnetic flux linked with the coil is,

$$\phi = NBA\cos\theta = NBA\cos\omega t$$

The e.m.f induced in the coil is, $E = -\frac{d\phi}{dt} = -\frac{d}{dt}(NBA\cos\omega t)$

$$E = NBA\omega \sin\omega t$$
$$E = E_0 \sin\omega t$$

Where $E_0 = NBA\omega$ called peak value.

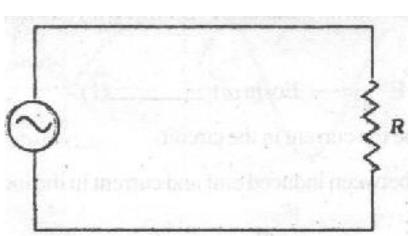
The instantaneous value of current is represented by, $I = I_0 \sin\omega t$

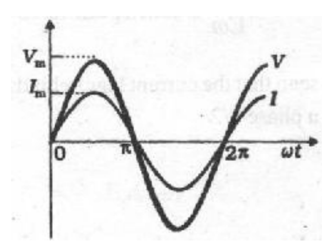
Where $I_0 = \frac{E_0}{R}$, R is the resistance of the coil.

- **Phasor diagram**

Alternating current and voltage are represented by phasors. A phasor is a directed straight line having a constant amplitude and phase. It is a rotating vector. The length of the phasor is proportional to the amplitude of the alternating current or e.m.f. The projection of the Phasor on the vertical axis gives the instantaneous value of the alternating current or e.m.f.

- **a.c circuit containing resistor only**





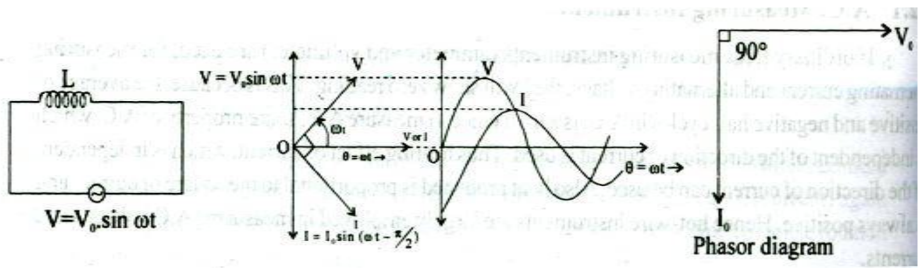
Let an alternating e.m.f $E = E_0 \sin\omega t$ be applied to a circuit containing a resistor of resistance R as shown in figure. The instantaneous current through the circuit is,

$$I = \frac{E}{R} = \frac{E_0}{R}\sin\omega t = I_0 \sin\omega t$$

$I_0 = \frac{E_0}{R}$, is peak value of current.

When a.c is passing through a pure resistor, the current and e.m.f are in the same phase

- **a.c circuit containing inductor only**



Let an alternating e.m.f $E = E_0 \sin\omega t$ be applied across an inductor of inductance L. According to Lenz's law the induced e.m.f is, $E = -L\frac{dI}{dt}$. Hence to maintain an a.c through the inductor, the applied e.m.f is, $E = +L\frac{dI}{dt}$

Then, $L\frac{dI}{dt} = E_0 \sin\omega t$ or $dI = \frac{E_0}{L}\sin\omega t\, dt$

Integrating, $I = \frac{E_0}{L}\int \sin\omega t\, dt = \frac{E_0}{L}\left(-\frac{\cos\omega t}{\omega}\right)$

$I = \frac{E_0}{L\omega}\sin(\omega t - \frac{\pi}{2})$ Put $I_0 = \frac{E_0}{L\omega}$, the peak value of current.

$\therefore I = I_0 \sin(\omega t - \frac{\pi}{2})$

Thus when a.c is passing through an inductor, the current lags behind the voltage by π/2.

- **Inductive reactance X_L**

The peak value of current is, $I_0 = \frac{E_0}{L\omega}$.

Here Lω is the opposition offered by the inductor against the flow of a.c. It is called inductive reactance denoted by X_L. Its unit is ohm (Ω).

$$X_L = L\omega$$

But, $\omega = 2\pi f$. Then, $X_L = L.2\pi f$

For a given inductor L is constant, $X_L \alpha f$. The variation of frequency with X_L is shown in the figure.

For direct current, $f = 0$. Then X_L=0. The reactance offered by a pure inductor in a dc circuit is zero. (Inductor is an easy path for dc)

- **Power consumed in pure inductive circuit**

Instantaneous power, $P = E_0 \sin\omega t \times I_0 \sin(\omega t - \frac{\pi}{2})$

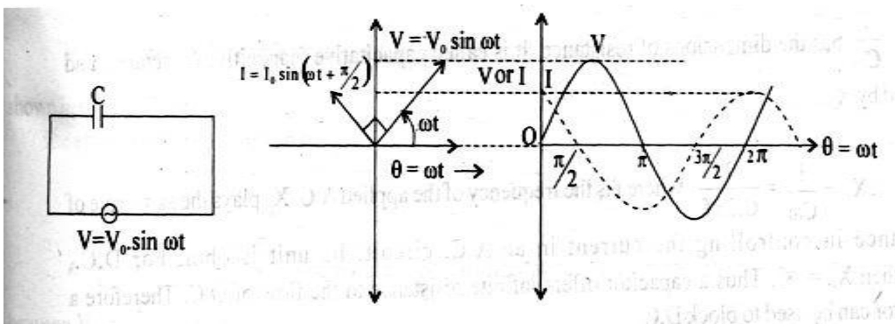
$$P = -E_0 I_0 \sin\omega t \cos\omega t = -\frac{E_0 I_0}{2}\sin 2\omega t$$

Average power over one complete cycle is, $P = \dfrac{\int_0^T -\frac{E_0 I_0}{2}\sin 2\omega t}{\int_0^T dt} = -\dfrac{E_0 I_0}{T}\int_0^T \sin 2\omega t$

The value of $\int_0^T \sin 2\omega t = 0$. Then the average power P=0.

Thus the average power consumed by an inductor over one complete cycle is zero.

- **a.c circuit containing capacitor only**



Let an alternating e.m.f $E = E_0 \sin\omega t$ be applied across a capacitor of capacitance C. The plates of the capacitor get charged positively and negatively alternately during every half cycle of a.c. Let the charge on the plates at any instant be q. Then, $E = \frac{q}{C}$

$$\frac{q}{C} = E_0 \sin\omega t \quad \text{or} \quad q = E_0 C \sin\omega t$$

Instantaneous current is, $I = \dfrac{dq}{dt} = \dfrac{d}{dt}(E_0 C \sin\omega t)$

$$I = E_0 C\omega \cos\omega t = \frac{E_0}{1/C\omega}\sin(\omega t + \frac{\pi}{2})$$

Put $I_0 = \dfrac{E_0}{1/C\omega}$, the peak value of current.

$\therefore I = I_0 \sin(\omega t + \frac{\pi}{2})$

Thus when a.c is passing through capacitor, the current leads the voltage by π/2.

- **Capacitive reactance X_C**

The peak value of current is, $I_0 = \dfrac{E_0}{1/C\omega}$.

Here $\frac{1}{C\omega}$ is the opposition offered by the capacitor against the flow of a.c. It is called capacitive reactance denoted by X_C. Its unit is ohm (Ω).

$$X_C = \frac{1}{C\omega}$$

But, $\omega = 2\pi f$. Then, $X_C = \frac{1}{C.2\pi f}$

For a given capacitor C is constant, $X_C \ \alpha\ \frac{1}{f}$. The variation of frequency with X_C is shown in the figure. For direct current, $f = 0$. Then, $X_C = \infty$ .i.e. a capacitor blocks d.c but allows a.c to pass through it.

- **Power in a pure capacitor**

  Instantaneous power, $P = E_0 \sin\omega t \times I_0 \sin(\omega t + \frac{\pi}{2})$

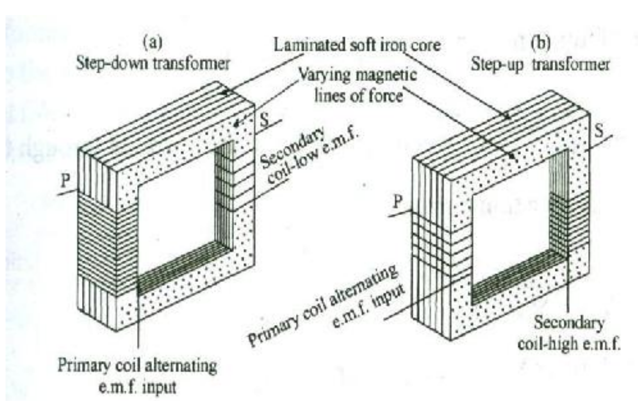
$$P = E_0 I_0 \sin\omega t \cos\omega t = \frac{E_0 I_0}{2} \sin 2\omega t$$

Average power over one complete cycle is, $P = \frac{\int_0^T \frac{E_0 I_0}{2} \sin 2\omega t}{\int_0^T dt} = \frac{E_0 I_0}{T} \int_0^T \sin 2\omega t$

The value of $\int_0^T \sin 2\omega t = 0$. Then the average power P=0.

Thus the average power consumed by a capacitor over one complete cycle is zero.

- **Transformer**



A transformer is a device used to change an alternating potential difference or current. It works on the principle of mutual induction. There are two types of transformers

1. Step-up transformer: increases the alternating voltage.
2. Step-down transformer: decreases the alternating voltage.

A transformer consists of two coils, which are not connected to one another in any way. These two coils are wound on the same iron core. The coil connected to the source of a.c is called primary coil and the other is called secondary coil.

In step-up transformer, the primary coil consists of less number of turns and of thick insulated wires. The secondary coil consists of thin wires of large number of turns. In step-down transformer, the primary coil consists of large number of turns of thin copper wires. The secondary coil is made up of thick wires and of less number of turns.

Working: When an alternating e.m.f is applied to the primary coil, the resulting current produces a changing magnetic flux which coupled to the secondary coil and induces an alternating e.m.f in it. Let ϕ_1 and ϕ_2 be the magnetic flux linked with the primary and secondary coil respectively. N_1 and N_2 are the number of turns in the primary and secondary.

The e.m.f induced in the primary is, $E_1 = -N_1 \frac{d\phi_1}{dt}$

The e.m.f induced in the secondary is, $E_2 = -N_2 \frac{d\phi_2}{dt}$

Dividing the above equations, $\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$, called transformer ratio.

For a step-up transformer $N_2 > N_1$ and $E_2 > E_1$

For a step-down transformer $N_2 < N_1$ and $E_2 < E_1$

If I_1 and I_2 are the currents in the primary and secondary and there is no power loss,

$$E_1 I_1 = E_2 I_2$$

Such a transformer is called an ideal transformer. In an actual transformer there is always loss of power and hence the output is always less than the input power.

$$\frac{E_2}{E_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1}$$

The efficiency of a transformer is, $\eta = \frac{\text{output power}}{\text{input power}} = \frac{E_2 I_2}{E_1 I_1}$

- **Energy losses in a transformer**

1. Copper loss: Insulated copper wires used for making the primary and secondary of the transformer have resistance and so heat is produced. This loss is called copper loss and can be reduced by using thick wires.
2. Iron loss: The alternating magnetic flux induces eddy currents in the iron core. This causes heating of the core. This loss is called iron loss and can be minimized by laminated cores.
3. Flux leakage loss: The magnetic flux due to the current in the primary may not completely linked to the secondary, if the core has air gap or badly designed. This is called flux leakage and there is loss of energy.

4. Hysteresis loss: When the iron core is subjected to cycle of magnetization the core gets heated up due to hysteresis. This loss is called hysteresis loss and can be reduced by using a core having low hysteresis loop.

Sample Questions:

1. A choke coil in series with a lamp is connected to an ac voltage line. What happened to the intensity of the light from the lamp?

2. An electric lamp, connected in series with a capacitor and an ac source, is glowing with certain brightness. How does the brightness of the lamp change on increasing the capacitance?

3. Which of the following statement is true regarding the reactance of an ac circuit containing capacitance or inductance?

(i) The Resistance R depends on the frequency of applied ac voltage

(ii) The Reactance of the circuit depends on the frequency of ac voltage

4. The emf from a 60 cycle generator has peak value of voltage 180 V. Write the general equation for instantaneous emf from the source?

5. In a purely inductive ac circuit, L = 25 mH and the rms voltage is 150 V. Find the inductive reactance and rms current in the circuit if the frequency is 60 Hz.?

6. A power transmission line feeds input power at 2300V to a step-down transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary in order to get output power at 230 V?

7. Explain the principle of working of a transformer. Mention various energy losses in a transformer?

8. An ideal inductor is connected across 220V-50 Hz and 220V -100Hz supplies. Will the current flowing through it in each cases be same or different?

9. Explain the working of an ac generator?

Answers

1. Since inductive reactance $X_L = L\omega$, The intensity of light decreases upon connecting the inductor

2. The reactance $X_C = \frac{1}{C\omega}$, The brightness increases with the value of C. Because the value of X_c decreases on increasing C

3. (ii) The Reactance of the circuit depends on the frequency of ac voltage

4. $E = 180 \sin(120\pi t)$

5. $X_L = L.2\pi f$, 9.42 Ω

6. Using transformer equation, $\frac{E_2}{E_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1}$, N_2 = 400 turns

8. Different in each due to the difference in frequencies .

CHAPTER - 8

ELECTROMAGNETIC WAVES

Focus area:

8.2 Displacement current.

8.3 Electromagnetic waves.

A stationary charge creates an electric field.

A moving charge produces an electric field and a current, which in turn produces a magnetic field.

The current which flows in a conductor due to the flow of charge is conduction current.

The current due to a changing electric field is called displacement current.

When an AC is applied across the plates of a condenser, a time varying electric field is created and the displacement current is produced in the dielectric between the plates.

Displacement current is given by the equation $I_d = \epsilon_0 \frac{d\varphi_E}{dt}$

The generalized ampere's circuital theorem is

$$\oint B.dl = \mu_0 \; i_c + \mu_0 \; \epsilon_0 \frac{d\varphi_E}{dt}$$

Points to remember

Electromagnetic waves are transverse in nature

They do not require a medium for their propagation

They travel with the speed of light in vacuum

When they enter a medium, their speed is reduced.

They are composed of electric field and magnetic field.

The electric field vector and magnetic field vector are mutually perpendicular to each other and also perpendicular to the direction of propagation of the wave.

They are produced when charged particles are accelerated .

The speed c is given by the equation $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

The speed of an electromagnetic wave is also given by c= E/B

The speed of electromagnetic waves in a medium is given by $v = \frac{1}{\sqrt{\mu \epsilon}}$

The whole arrangement of electromagnetic waves in increasing order of wave length is called electromagnetic spectrum.

It ranges from the shortest gamma rays ($0.001 A^0$) to the longest radio waves (1000 m)

For an electromagnetic wave travelling in the z direction,

the electric field vector is given by $E_x = E_o \sin(kz - \omega t)$

The magnetic field vector is given by $B_Y = B_o \sin(kz - \omega t)$

The velocity is related to ω and k as $v = \omega/k$

Sample questions

1 The speed of electromagnetic wave is the highest in --------------

2 The relation between electric field vector and magnetic field vector in an electromagnetic wave is c=

3 An electromagnetic wave is produced when a -------------------- is accelerated.

4 Which of the following is the possible frequency of visible light?

(a) 10^6Hz (b) 10^{10}Hz (c) 10^{14}Hz (d) 10^{18}Hz

5 Match suitably

A	B
X rays	cell phone
Ultra violet rays	Radiation therapy
Infrared waves	radar
Microwaves	radiograph
Radio waves	Sun burn
Gamma rays	Remote control

6. Which of the following is not an electromagnetic wave?

(X rays, gamma rays , β rays, microwaves)

7. The magnetic field of a plane electromagnetic wave travelling in the positive Z-direction is described by

(i) $B_Y = B_o \sin(kz-\omega t)$ (ii) $B_Y = B_o \sin(kz+\omega t)$

(iii) $B_Y = B_o \sin(ky-\omega t)$ (iv) $B_Y = B_o \sin(kx-\omega t)$

8. If μ and ϵ are the permeability and permittivity of a medium, the velocity of light in that medium is given by--------------------

9. James Clerk Maxwell introduced the concept of displacement current.

(a) What do you mean by displacement current?

(b) Write down the expression for it.

10. An electromagnetic wave is propagating along the X- direction with a frequency 5×10^9Hz in free space.

(a) Name the electromagnetic wave.

(b) Write any two of its applications.

11. Write at least three important uses of the following.

(a) ultraviolet rays (b) gamma rays (c) X rays

Answers

1 Vacuum

2 $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$

3 charged particle

4 10^{14}Hz

5 Match suitably

A	B
X rays	radiograph
Ultra violet rays	Sun burn
Infrared waves	Remote control
microwaves	cell phone
Radio waves	radar
Gamma rays	Radiation therapy

6. β rays

7. $B_Y = B_o \sin(kz-\omega t)$

8. $v = \frac{1}{\sqrt{\mu \in}}$

9. (a) Displacement current is the current produced when electric flux continuously changes.

(b) $I_d = \epsilon_0 \frac{d\varphi_E}{dt}$

10. (a) microwaves.

(b) They are used for communication, microwave oven for cooking.

11 (a) **ultraviolet rays**

They are used to kill germs in water purifiers

Used in the detection of finger prints.

Vitamin D is produced by ultraviolet rays

(b) **gamma rays**

They are used for the treatment of cancer (radiation therapy)

Used for sterilizing surgical instruments.

To detect cracks in metallic casting.

(c) **X rays**

They are used to study the structure of atoms and molecules.

To take the photograph of internal organs such as bones (radiograph)

To detect hidden materials.

CHAPTER 9

RAY OPTICS

Focus Area

9.2 Reflection of light by spherical mirrors

9.3 Refraction

9.5 Refraction at a spherical surface and by lenses

9.6 Refraction through a prism.

Points to remember

Concave mirror can form real and virtual images and its focal length is negative.

Convex mirror always form virtual images which are erect and diminished. Its focal length is positive.

Concave mirrors are used by dentists, used as parabolic reflectors in vehicles and torches, solar cooker, shaving mirror and also used in reflecting telescope.

Convex mirror is used as rear view mirror in vehicles, street light reflectors etc.

Radius of curvature of a spherical mirror is twice its focal length. R=2f

Sign convention

All the distances are measured from the pole of the mirror or optic centre of the lens.

Distances measured in the same direction of incident ray are positive, and those measured opposite to the direction of incident ray are negative.

Heights measured upward with respect to the principal axis are positive and downwards

are negative.

The relation between object distance u, image distance v, and the focal length f is $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

This is mirror formula

Magnification is the ratio of the height of the image to the height of the object.

If magnification is negative, the image formed is real and inverted.

If magnification is positive, the image formed is virtual and erect.

When light enters from one medium to another medium, its straight line path is deviated . This is refraction

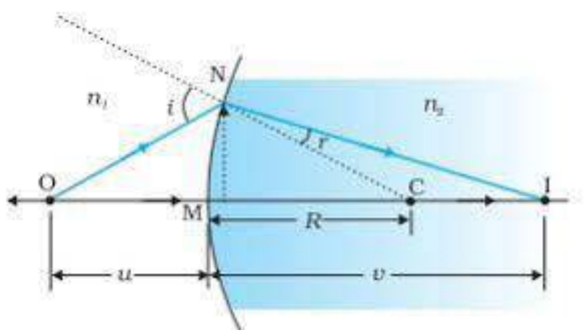
Snell's law of refraction $_1n_2$= sin i/ sin r where n is the refractive index of the second medium with respect to the first medium.

$_1n_2 = n_2/n_1$

Absolute refractive index n is also the ratio of velocity of light in air (or vacuum) to the velocity of light in that medium.

Rivers and ponds appear shallow due to refraction.

When a point object O is kept at a distance 'u' in a medium of refractive index n_1 from a spherical surface of radius of curvature R and refractive index n_2. If its point image I is formed at a distance 'v' from the spherical surface, then $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2-n_1}{R}$



Lens is a transparent medium bounded by two spherical surfaces.

Lens maker's formula $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

A converging lens of refractive index n_2 kept in a medium of refractive index n_1 . If $n_2 < n_1$ it acts as a diverging lens(concave)

And it acts as a converging lens itself if $n_2 > n_1$

An air bubble in water acts as a diverging lens (concave lens)

Focal length of a convex lens is positive and that of a concave lens is negative.

If two thin lenses of focal length f_1 and f_2 are combined together the effective focal length f is given by $\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{f}$

Power of a lens is the reciprocal of focal length expressed in metre $P=\frac{1}{f}$

The unit of power is dioptre (D).

Power of a convex lens is positive and that of a concave lens is negative.

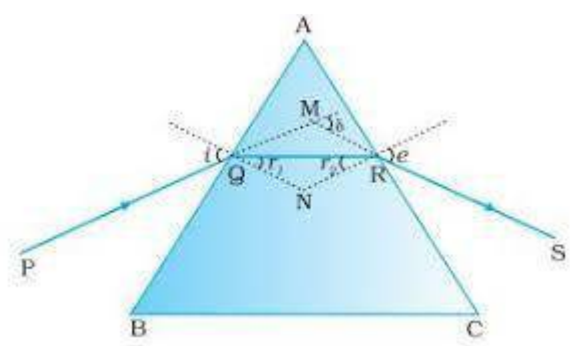
Law of distances of a lens is $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

When a ray of light enters a prism, it deviates towards the base of the prism.

If the angle of incidence is increased, angle of deviation d first decreases, reaches a minimum value D and then increased.

If i and e are the angle of incidence and angle of emergence, r_1 and r_2 are the angles of refraction, then deviation $d= i + e - A$ and the angle of the prism $A= r_1 + r_2$.

The relation between the angle of the prism A, angle of minimum deviation D and the refractive index n is given by $n=\frac{sin\frac{A+D}{2}}{sin\frac{A}{2}}$



Sample questions

1 A mirror which always form a virtual, diminished and erect image is------------------------------

2 Draw a diagram showing the image formation by convex mirror when an object is kept at a distance from the mirror.

3 An object is kept at a distance of 40cm from a concave mirror of focal length 20cm. Find the distance of the image formed.

4 A ray of light entering from one medium to another medium suffers no bending. Is this statement true? Justify your answer.

5 The speed of light in a medium is 1.73×10^8m/s. Find the refractive index of the medium.

6 For refraction at a spherical surface separating two media of refractive indices n_1 and n_2 the relation between object distance u and image distance and radius of curvature R is given by

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Arrive at the expression for lens maker's formula.

7 A convex lens of focal length 15 cm is combined with a concave lens of focal length 20cm. Find the focal length of the combination and say whether the combination act as a convex lens or concave lens. Justify.

8 Arrive at the equation $n = \frac{\sin\frac{A+D}{2}}{\sin\frac{A}{2}}$ for a prism.

9 A ray of light is incident on one face of an equilateral prism at an angle of 50^0. Find the angle of emergence *e* and the angle of deviation (n=1.5)

10. Draw the variation of angle of deviation with angle of incidence(graph)

Answers

1 Convex mirror.

2

3 Given u= -40cm, f= -20cm v= ? $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$ $\frac{1}{v}=\frac{1}{-20}-\frac{1}{-40}$ $\frac{1}{v}=\frac{1}{40}-\frac{1}{20}$ $\frac{1}{v}=-\frac{1}{40}$

v= - 40 cm. The image is formed at a distance 40 cm from the mirror. The image and object are at the same position.

4 A ray of light entering from one medium to another medium deviates from the straight line path if it is falling obliquely . But if the light ray is falling normally on a surface it suffer no bending.

5 Absolute refractive index of the medium is given by

$$n=\frac{speed\ \ of\ light\ in\ air\ or\ vacuum}{speed\ \ of\ light\ in\ the\ medium}=\frac{3x10^8}{1.73x10^8}=1.73$$

6 Consider double convex lens of refractive index n_2 bounded by two spherical surfaces of radii of curvature R_1 and R_2 kept in a medium of refractive index n_1.

A point object O is kept at a distance u from the lens and its image I' is formed at a distance v' from the lens

For the first surface $\frac{n_2}{v_1}-\frac{n_1}{u}=\frac{n_2-n_1}{R_1}$

For the second surface, this image I' will act as the virtual object and its final image I is formed at a distance v.

Equation for the second surface $\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2}$

Adding the above equations we get $\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

Dividing throughout by u we get $\frac{1}{v} - \frac{1}{u} = \frac{n_2 - n_1}{n_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

If the object is at infinity, the image is at the focus

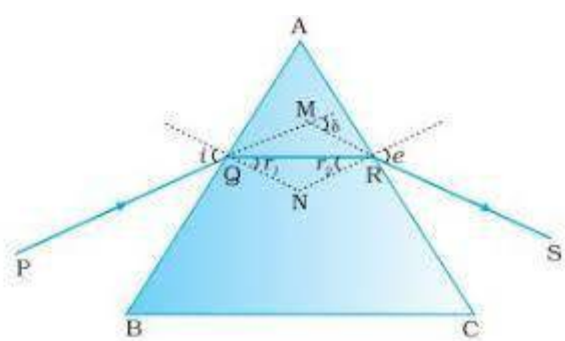
When u= ∞ , v= f The above equation becomes $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_2} - \frac{1}{R_1}\right]$ This is lens maker's formula.

7 When two thin lenses are combined, the effective focal length is given by $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f}$

Given f_1=15cm =0.15m ; f_2= -20 cm = -0.2m $\frac{1}{0.15} - \frac{1}{0.20} = \frac{1}{F}$ $6.666 - 5.00 = \frac{1}{f}$ =1.66

f=0.60m =60cm. Since the focal length of the combination is positive, the combination acts as a convex lens of focal length 60cm

8



ABC is an equilateral prism of refractive index n. PQ is an incident ray, QR is the refracted ray and RS is the emergent ray. N is a normal. The angle of incidence in the first face is i . r_1 is the angle of refraction the angle of emergence in the second face is e . and r_2 is the angle of refraction. The angle of deviation is δ

In the quadrilateral AQNR sum of the angles is 360^0

$A + Q + N + R = 360^0$

$A + 90^0 + N + 90^0 = 360^0$

$A + N = 180^0$ -----------------(1)

In the Δ QNR $r_1 + r_2 + N = 180^0$-----------------(2)

Comparing (1) & (2) $A = r_1 + r_2$-------------------(3)

In the Δ QMR $(i - r_1) + (e - r_2) = \delta$

$i + e - (r_1 + r_2) = \delta$ -------------------------(4)

$i + e - A = \delta$ from (3)

When the angle of incidence is increased, angle of deviation δ first decreases reaches a minimum value D and then increased

When the deviation is minimum, (δ =D), i = e = i and $r_1 = r_2 = r$

(3) and (4) becomes A= 2r and 2i- A=D r=A/2 i =(A+D)/2

Refractive index n= sin i/ sin r $n = \frac{sin\frac{A+D}{2}}{sin\frac{A}{2}}$

9) $n = \frac{sin\ i_1}{sin\ r_1}$ $\sin r_1 = \frac{sin\ i_1}{n}$ $\sin r_1 = \frac{sin 50}{1.5} = 0.511$

$r_1 = sin^{-1}(0.511) = 30.730^0$ $A = r_1 + r_2$ $60 = 30.730 + r_2$

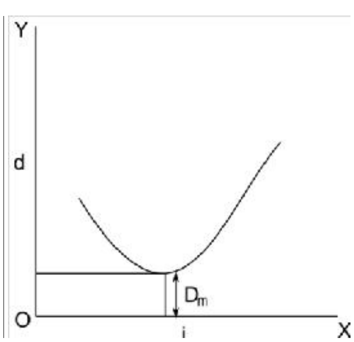
$r_2 = 60 - 30.730 = 29.27$ $n = \frac{sin\ i_2}{sin\ r_2}$ $1.5 = \frac{sin\ i_2}{sin 29.27}$

$sin\ \ i_2 = 1.5\ sin 29.27 = 0.7333$ $i_2 = sin^{-1}(0.733) = 47.14$

The angle of emergence is 47.14^0

The angle of deviation d= $i_1 + i_2 - A$= 50+47.14 – 60 = 97.14 – 60 = 37.14^0

10)



CHAPTER 10

WAVE OPTICS

Focus area

10.2 Huygen's principle

10.3 Refraction and reflection of plane waves using Huygen's principle.

10.4 Polarisation

Points to remember

Every source of light sends out disturbance throughout the medium in the form of waves. The locus of all points which are equidistant from the source vibrate in same phase and is called wavefront.

Each point on the wavefront is a source of secondary disturbance.

For a point source the wave front is spherical

If the source is an extended one, the wavefront is cylindrical

If the source is at infinity, the wave front is plane.

To explain reflection on the basis of wave theory, we have to prove that angle of incidence is equal to angle of reflection. $i = r$

To explain refraction on the basis of wave theory, we have to prove that $\sin i/\sin r = {}_1n_2$

Polarisation is the phenomenon which clearly shows that light is a transverse wave.

In the case of an ordinary light there is vibration in all directions perpendicular to the direction of propagation.

Polarisation is the restriction of vibration of light in a single plane.

When a beam of light is passed through a tourmaline crystal, the vibration of light is restricted in crystallographic axis of the crystal. If a second crystal is held with its crystallographic axis parallel to the first, light emerges through the second crystal. If their crystallographic axes are perpendicular to each other, light does not emerge from the second crystal. First crystal is the polariser and second crystal is the analyser.

Malus' law states that the intensity of light coming out of the analyser is proportional to the square of the cosine of the angle between the polariser and analyser. $I= I_0 \cos^2\theta$

Polaroids are thin plastic sheets used to produce polarised light. Such polaroids are used in sun glasses to control intensity of light, 3D films, display boards in calculator and mobile phones etc.

When light get reflected from a transparent surface, both reflected light and transmitted light are partially polarised with their plane of polarisation mutually perpendicular to each other.

For a particular angle of incidence called Brewster's angle or polarising angle reflected light is completely polarised.

tan of Brewster's angle gives refractive index of the medium ($n=\tan i_B$)

We can prove that for Brewster's angle, reflected ray and transmitted are mutually perpendicular to each other.

Sample questions

1 If the wave front is plane, the source of light is --------------

2 Angle between plane of vibration and plane of polarisation is

(a) 30^0 (b) 60^0 (c) 45^0 (d) 90^0

3 Which of the following represents Brewster's law ?

(a) $n=\sin i_B$ (b) $n=\tan^{-1} i_B$ (c) $n=\tan i_B$ (d) $n=\cos i_B$

4 Sound waves cannot be polarised. Why?

5 For what angle between the crystallographic axes of polariser and analyser will be the intensity of the emergent light becomes one-fourth the incident light?

6 Explain refraction on the basis of Huygen's principle.

7 Prove that if the angle of incidence on a transparent medium is Brewster's angle, the reflected ray and transmitted ray are mutually perpendicular to each other.

Answers

1 at infinity.

2 (d) 90^0

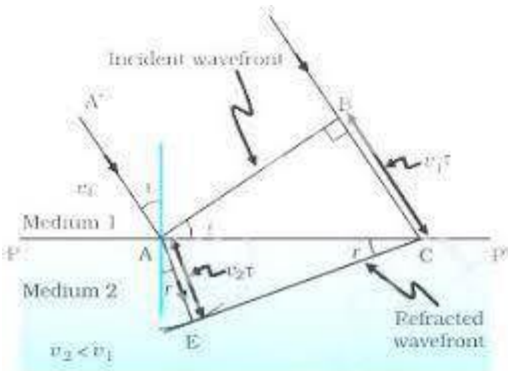
3 (c) n=tan i_B

4 Sound waves are longitudinal waves, which cannot be polarised.

5 According to Malus' law $I = I_0 \cos^2\theta$ when $\theta=60^0$ $\cos\theta = ½$

$I = I_0 (½)^2 = I_0/4$

6



Consider a plane wavefront AB incident on a surface PP' separating two media with speed of light v_1 and v_2

Let i be the angle of incidence. Let τ be the time taken by light to travel from B to C with a velocity v_1. Then the length BC= $v_1 \tau$.

By this time light travel a distance AE with velocity v_2 through the second medium so that the distance AE= $v_2\tau$

In order to draw the shape of the refracted wavefront, draw a sphere of radius AE with centre A. The tangent CE drawn from C is the refracted wavefront

Considering the ΔABC sin i= BC/AC----------------------(1)

Considering the ΔAEC sin r= AE/AC---------------------(2)

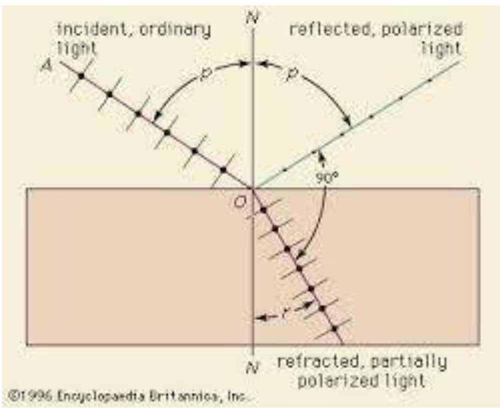
Dividing these equation

sini/ sinr= BC/AE= $v_1 \tau$ / $v_2\tau$ = v_1 / v_2 which is a constant $_1n_2$

this the refractive index of the second medium with respect to the first.

sin i/ sin r = $_1n_2$. This is Snell's law.

7



AO is an unpolarised light incident on a transparent medium of refractive index n with angle of incidence i=p where p is the Brewster's angle or polarising angle. Let r be the angle of refraction.

Then according to Snell's law

n= sini/ sinr= sinp/sinr--------------------(1)

According to Brewster's law at polarising angle

n=tanp =sinp/cosp----------------------(2)

comparing (1) and (2)

sinp/sinr= sinp/cosp

sinr=cosp

$(r+p)=90^0$

Hence the angle between reflected ray and transmitted ray is 90^0

CHAPTER 11

DUAL NATURE OF RADIATION AND MATTER

Focus Area

11.3 Photoelectric effect

11.6 Einstein's Photoelectric equation, energy quantum of radiation

11.7 Particle nature of light: The photon

11.3 Photoelectric effect

Points to Remember

- The phenomenon of photoelectric emission was discovered in 1887 by Heinrich Hertz.
- Photoelectric effect is the emission of electrons from metals and other substances when an electromagnetic radiation of suitable frequency falls on them.
- The electrons emitted are called photoelectrons.
- The current that results from the flow of photoelectrons is called photo electric current.
- The substance which emits photoelectrons is called photosensitive substance.
- The alkali metals like lithium, potassium, caesium etc. are photosensitive to visible light.
- The metals like copper, zinc, cadmium, magnesium etc. are sensitive only to ultraviolet light,

x-ray and Gamma ray.

- There will not be any photoelectric emission if the incident frequency is less than the threshold frequency.
- The velocity of the emitted electrons is increased with increase in frequency of incident radiation.
- The kinetic energy of the photoelectrons depend on the frequency of the incident light.
- If the intensity of light is increased keeping the frequency same, then more photons are incident on the metal with the result that more electrons are ejected .

- The photoelectric current is directly proportional to the intensity of the incident radiation.
- The energy of quantum or photon of radiation is $h\upsilon$.
- The number of electrons emitted is directly proportional to the intensity of incident radiation.
- The minimum amount of energy required to liberate an electron from a metal surface known as work function of that metal.
- Work function is measured in electron volt (eV).
- The work function of different metals are different.

- The work function of pure metal varies from 2 to 6 eV.
- Work function depends on nature of the metal, its purity and the condition of it's surface.
- Einstein's photoelectric equation is

$$h\nu = \phi_o + \frac{1}{2} mv^2_{max}$$

$$h\nu = h\nu_o + \frac{1}{2} mv^2_{max}$$

Where ν_o = Threshold frequency.
ν = Frequency of radiation
h = Planck's constant.

- Energy of photon is E=hυ
- Momentum of photon is P=hυ/c
- Photons are electrically neutral
- When a photon collide with a particle, the total energy and total momentum are conserved.
- Photons are not deflected by electric or magnetic fields.

Sample Questions

1) When the surface of an alkali metal is illuminated with yellow monochromatic light of sufficient frequency, electrons are ejected.

a) Name the phenomenon

b) Who discovered this phenomenon?

c) Instead of alkali metal, if copper is used and instead of yellow monochromatic light, white light is used, what will be the observation?

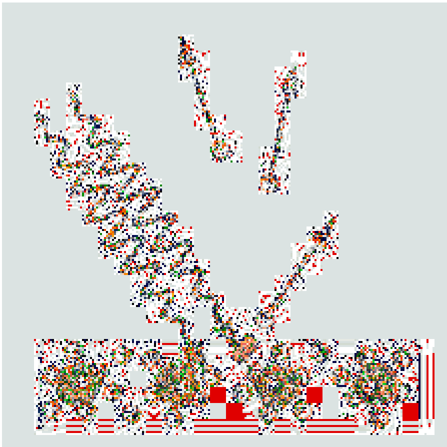
d) Can we use white light for ejecting electrons from an aluminum surface?

2) Write some elements which respond only to ultraviolet light for the ejection of electrons.

3) What is threshold frequency? What are the factors that affect threshold frequency?

4) Explain Hallwachs' and Lenard's experimental observations.

5) Mark the photon and electron in the figure given below



6) Why there is no electron emission below threshold frequency?

7) What is the effect of emission of photoelectrons on intensity of light?

8) What happens to the energy of the photon incident on metal surface?

9) Pick out the odd one out

(Interference , Diffraction ,Polarization, Photoelectric effect).

10) Work function of a metal is 4.6 eV . What is meant by it?

11) Why are alkali metals most suitable for photoelectric emission?

12) The threshold frequency of a material is $2x10^{14}$ Hz. What is its work function?

13) Write Einstein's Photoelectric equation and explain each term.

14) If the frequency of a radiation is $6x10^{14}$ Hz. Find it's energy

Answers

1)a. Photoelectric effect

b) Heinrich Hertz.

c) Electrons are not ejected from the metal surface.

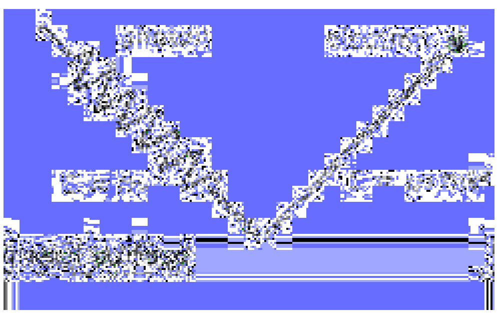
d) No, Electrons are not ejected from the metal surface because the frequency different colours of white light is less than the threshold frequency.

2) Copper, Zinc, Cadmium, Magnesium

3) The minimum energy required to eject the electrons from the metal surface is called threshold energy and the frequency corresponding to this energy is threshold frequency. It depends on the nature of the metal surface.

4) Wilhelm Hallwachs and Philipp Lenard conducted a detailed study of the phenomenon of photoelectric emission. Lenard observed that when ultraviolet radiations were allowed to fall on the emitter plate of an evacuated glass tube enclosing two electrodes (metal plates), current flows in the circuit. As soon as the ultraviolet radiation is stopped, the current flow is also stopped. Thus, light falling on the surface of the emitter causes current in the external circuit. Hallwachs observed that the uncharged zinc plate became positively charged when it is irradiated by ultraviolet light. Also positive charge on a positively charged zinc plate gets enhanced when it is illuminated by ultraviolet light. From the experimental observations he concluded that zinc plate emits negatively charged particles under the action of ultraviolet light.

5)



6) There is a minimum amount of energy required to eject electron.

7) When intensity of incident radiation is increased, photoelectric current is also increased.

8) A part of the energy is used to eject electron from the metal surface and the remaining part is converted to the kinetic energy of the ejected electrons.

9) Photoelectric effect

10) The minimum energy required to eject an electron from that metal surface 4.6 eV.

11) Less energy is needed to eject electrons, as the size of the alkali metal is comparatively large and hence the threshold energy is less.

12) W = $h\upsilon_0$ = 13.2×10^{-20} J

13)

$$h\nu = \phi_o + \frac{1}{2} m v^2_{max}$$

$$h\nu = h\nu_o + \frac{1}{2} m v^2_{max}$$

Where ν_o = Threshold frequency.
ν = Frequency of radiation
h = Planck's constant.

m is the mass of electron and v the velocity of the emitted electron.

14) E= $h\upsilon$ = $6.65 \times 10^{-34} \times 6 \times 10^{14}$ = 39×10^{-20} J

CHAPTER 12

ATOMS

Focus area

12.4 Bohr model of the hydrogen atom

12.6 de Broglie's explanation of Bohr's second postulate of quantisation

Points to remember

*Electron in a stable orbit does not radiate energy.

*A stable orbit is that in which the angular momentum of an electron about the nucleus is an integral multiple of h/2π

The electron can absorb energy only if it jumps from a lower to a higher orbit and radiate only if it jumps from a higher orbit to a lower orbit.

The energy emitted or absorbed is a photon of frequency υ and energy E=h υ

Angular momentum of the revolving electron L= nh/2π where n=0,1,2,3...

The energy of the electron in the n^{th} orbit $E_n = \frac{-me^4}{8\epsilon_0^2 \; n^2h^2}$

Sample questions

1 According to Bohr postulates, angular momentum of an electron is an integral multiple of -------------

2 The velocity of an electron in an orbit is --------------

(a) Inversely proportional to the radius

(b) Directly proportional to the radius

(c) Independent of the radius

(d) Directly proportional to square of the radius

3 If the circumference of the fourth orbit of an atom is 16

A^0, the wavelength of the electron in that orbit will be

(a) 2 A^0 (b) 4 A^0 (c) 5 A^0 (d) 8 A^0

4 The highest energy of an electron possible in an atom is ------------

5 Write down important postulates proposed by Bohr about hydrogen atom.

6 Deduce the expression for the velocity and radius of the n^{th} orbit of hydrogen atom from Bohr's postulates.

7 Arrive at an expression for total energy of an electron in the n^{th} orbit of hydrogen atom.

8. The radius of the innermost orbit of hydrogen atom is $5.3x10^{-11}$m. What are the radii of the orbit with n=2 and n=3

Answers

1 h/2π

2 Inversely proportional to the radius

3 4 A^0

4 zero

5 Bohr postulates

(i) Electron in an atom can revolve in certain stable orbits without the emission of radiant energy

(ii) Electrons revolves only in those orbits for which the angular momentum is an integral multiple of h/2π

(iii) Electrons radiate energy when it undergo a transition from an orbit of higher energy to one of lower orbit and this energy is the energy difference between these two orbits. The frequency of emitted photon is given by $\upsilon = (E_2 - E_1)/h$

6 By Bohr postulates angular momentum mvr = nh/2π-----------(1)

Centripetal force for circular motion of the electron is obtained from the electrostatic force between nucleus and electron

$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0}\frac{e^2}{r^2}$ -------------------(2)

Dividing the above equations (1)/ (2) $v = \frac{e^2}{2\epsilon_0 nh}$

Hence the velocity of electron in an orbit is inversely proportional to the principal quantum number of the orbit

When n=1 $r = 5.29 \times 10^{-11}$m is called Bohr radius.

7. Kinetic energy of electron $K = \frac{1}{2} mv^2$

$$K = \frac{e^2}{8\pi\epsilon_0 r}$$

Potential energy $U = \frac{-e^2}{4\pi\epsilon_0 r}$

Total energy is the sum of kinetic energy and potential energy

TE = KE + PE = K + U = $\frac{e^2}{8\pi\epsilon_0 r} - \frac{e^2}{4\pi\epsilon_0 r} = \frac{e^2}{4\pi\epsilon_0 r}\left[\frac{1}{2} - 1\right] = \frac{-e^2}{8\pi\epsilon_0 r}$

Substituting the value of r

Total energy $TE = \frac{-me^4}{8\epsilon_0^2 n^2 h^2}$

Substituting the values of constants $E_n = \frac{-13.6}{n^2} eV$

The negative sign in the equation shows that the electron is bound to the nucleus.

8 Radius of the orbit $r \alpha n^2$ $r_1 = 5.3 \times 10^{-11}$m

$r_2 \alpha 2^2$

$r_3 \alpha 3^2$

Comparing $r_2 = 4 r_1 = 2.12 \times 10^{-10}$m

Comparing $r_3 = 9 r_1 = 4.77 \times 10^{-10}$m

CHAPTER 13

NUCLEI

Focus Area

13.6 Radioactivity

13.7 Nuclear Energy

Points to Remember

- Henry Becquerel discovered radioactivity.
- Radioactivity is the phenomenon of spontaneous disintegration of the heavy nucleus of an atom by the emission of radiation.
- Radioactivity is a nuclear phenomenon.
- It is an irreversible process and is unaffected by physical or chemical conditions of the element.
- Three types of radioactive decay occur in nature; They are alpha decay, beta decay and gamma decay.
- Alpha particle is equivalent to Helium nucleus.
- Beta particles are electrons or positrons.
- The rate of disintegration of a radioactive substance is directly proportional to the number of atoms present at that instant in the sample.
- The time taken by a radioactive substance to disintegrate half of its initial amount is called half life period of that substance.
- Disintegration per unit time is called activity.
- SI unit of activity is becquerel.(Bq)
- 1Bq=One decay /second.
- 1 curie $=3.7\times10^{10}$ decay /second
- 1 rutherford $=10^{6}$ decay /second.
- Mean life is the average life time of all the atoms present in the sample

Sample Quetions

1) Define the activity of a given radioactive substance. Write its SI unit.
2) How is the mean life of a radioactive sample related to its half-life?
3) Two nuclei have mass numbers in the ratio 1: 8. What is the ratio of their nuclear radii?
4) Draw a plot representing the law of radioactive decay. Define the activity of a sample of a radioactive nucleus. Write its SI unit.

Answers

1)The activity of a sample is defined as the rate of disintegration taking place in the sample of radioactive substance. SI unit of activity is becquerel (Bq).
1 Bq =1 disintegration/second

2)

Mean life, $t_m = \frac{1}{\lambda}$, where λ is decay constant.

But half-life, $T_{1/2} = \frac{\ln 2}{\lambda}$

$\Rightarrow \quad \lambda = \frac{\ln 2}{T_{1/2}}$

$$\Rightarrow \quad t_m = \frac{T_{1/2}}{\ln 2} = \frac{T_{1/2}}{0.693}$$

$$t_m = 1.443\ T_{1/2}$$

3)

Radius of nucleus, $R = R_0 A^{1/3}$

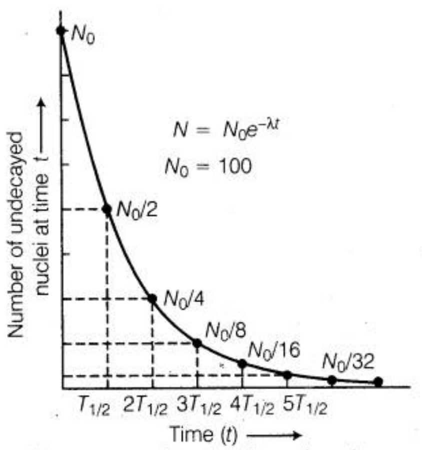
where, $R_0 =$ constant, $A =$ mass number

$$\therefore \quad \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$$

$$R_1 : R_2 = 1 : 2$$

4)

The curve representing the law of radioactive decay is shown as below:



Decay curve for a radioactive element **(1)**

13.7 Nuclear Energy

Points to remember

- The core of the nuclear reactor consists of uranium (U^{235}) in the form of cylindrical rods. These rods are dipped inside a liquid which is the moderator.

- Whenever one neutron strikes this uranium rod nuclear fission reaction starts and 3 fast moving neutrons are produced.
- Because of the moderator these 3 neutrons undergo elastic collision as a result they slow down before they strike the second rod.
- Geometry of the core is such that only one out of 3 neutrons which are emitted strike the next rod making the reaction a controlled one.
- When the control rods are inserted inside they will absorb all the extra neutrons. Since there are no neutrons, nuclear fission reaction will stop.
- Large amount of energy is also released in the core.
- In order to extract the energy from the core water at very high pressure is passed through it.
- As hot water passes through it produces steam in the steam generators.
- This steam is used to run the turbines which in turn produce electricity.
- This process will continue until all the fissionable uranium atoms are used up. Then the rods have to be replaced in the nuclear reactor.

Sample Questions

1) Name any two materials which are used as a moderator in nuclear reactor.

2) Explain nuclear fusion.

3) What is nuclear fission .Give an example.

Answers

1) Heavy water, Graphite

2) The process of combining of two lighter nuclei to form a heavy nucleus is called nuclear fusion.

Three deuteron nuclei (${}_1H^2$) fuse to form a Helium nucleus (${}_2He^4$) and 21.6 MeV is energy released

$${}_1H^2 + {}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4 + {}_1H^1 + {}_0n^1 + 21.6\,\text{MeV}$$

In this process, a large amount of energy is released.

Nuclear fusion takes place at very high temperature about 10^7 K and at very high pressure 10^6 atmosphere.

3) The process of the splitting of a heavy nucleus into two or more lighter nuclei is called nuclear fission.

When a slow moving neutron strikes with a uranium nucleus ${}_{92}U^{235}$, it splits into ${}_{56}Ba^{141}$ and ${}_{36}Kr^{92}$ along with three neutrons and a lot of energy.

$${}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} \doteq 3\,{}_0n^1 + \text{energy}$$

CHAPTER 14

SEMICONDUCTOR ELECTRONICS: MATERIALS DEVICES AND SIMPLE CIRCUITS

Focus area

14.7 Application of junction diode as a rectifier

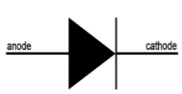
14.9 Digital Electronics and logic gates

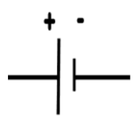
Points to Remember

- ✓ A device which convert AC in to DC is known as rectifier.
- ✓ A diode conducts only in forward bias.
- ✓ Half wave rectifier converts only one half of the AC into DC.
- ✓ A single p-n junction diode is used for half wave rectification
- ✓ A full wave rectifier give output voltage to both positive and negative half cycle of ac

Sample Questions

1. The symbol of a diode is

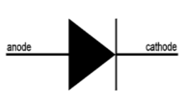




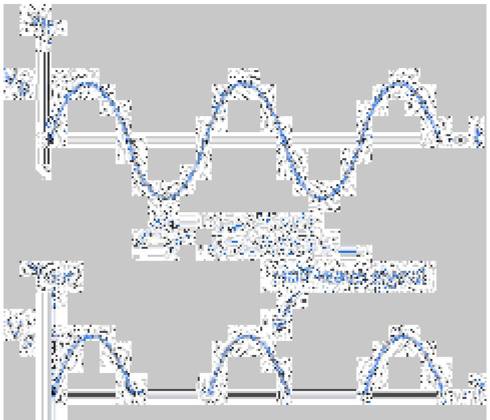
2. Draw the rectified output of half wave rectifier.
3. How does a diode act as a rectifier? Explain with the help of a diagram.
4. Draw the circuit diagram of a full wave rectifier using two diodes.
5. How can we rectify both positive and negative half cycles of AC using a full wave rectifier? Draw the output wave form.

Answers

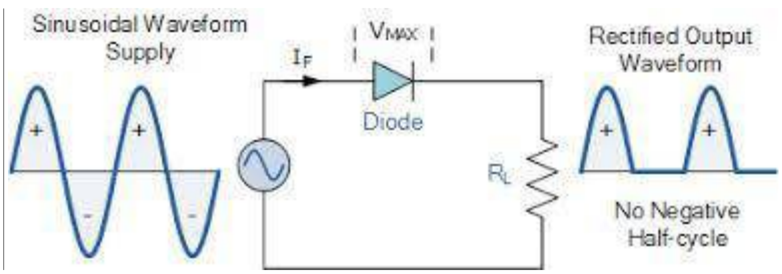
1)



2)

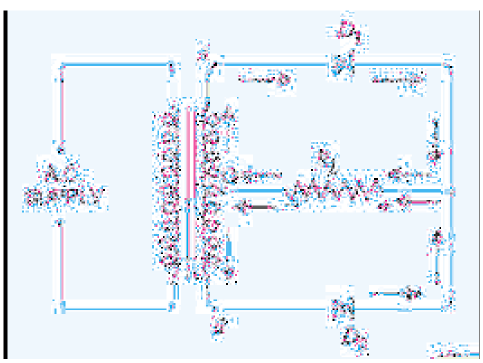


3)

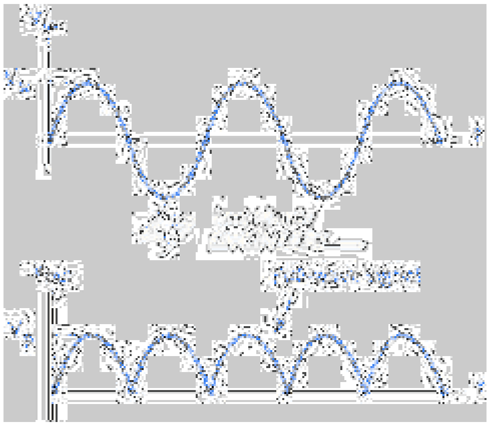


A half wave rectifier converts only one half of the AC into DC. A single PN junction diode is used for half wave rectification. It conducts only during alternate half cycle of the input AC voltage (the diode is forward biased). As a result the voltage output does not change in polarity.

4)



5) A full wave rectifier give output rectified voltage corresponding to both the positive and negative cycles of the AC. During positive half cycle diode D_1 gets forward biased and conducts while D_2 being reverse biased and is not conducting. We get an output voltage across R. During negative half cycle diode D_1 does not conduct, but diode D_2 conducts by giving an output voltage across R.



14.9 DIGITAL ELECTRONICS AND LOGIC GATE

Points to Remember

- Digital electronic involves circuits and systems in which there are only two possible states which are represented by two voltage levels- high and low (1 or 0)
- Continuously varying quantities such as voltage and current through a resistance are analog signals.
- Circuits giving two discrete levels of voltage or current (0 and 1) are called digital circuits.
- Logic gates are digital circuits which either allows a signal or to pass through or stop it.
- Truth table is a table that shows all the possible input and output combination for the logic gate.

Sample Questions

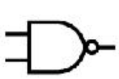
1) Match the following

GATES SYMBOL

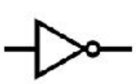
AND

NAND

OR



NOT



NOR

2) Write the truth table for NAND Gate

3) The truth table shown is for (OR ,AND ,NAND,NOT)

[illegible]		[illegible]
[illegible]	[illegible]	[illegible]
0	0	0
0	1	0
1	0	0
1	1	1

Answers

1) NOR

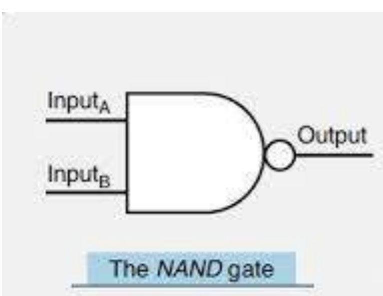
OR

AND

NAND

NOT

2)



The *NAND* gate

Input		Output
A	B	
0	0	1
0	1	1
1	0	1
1	1	0

3) AND GATE

GENERAL EDUCATION DEPARTMENT

SAMAGRA SHIKSHA, KERALA