तत् त्वं पूषन् अपावृणु

केन्द्रीय विद्यालय संगठन

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SUBJECT - PHYSICS
CLASS - XII

INDEX

CHAPTER 1 - ELECTRIC CHARGES AND FIELDS

GIST OF THE LESSON

- Electric charge
- Basic properties of electric charge
- Coulomb's law
- Electric field
- Electric field lines
- Electric flux
- Electric dipole
- Dipole in a uniform electric field
- Gauss's law
- Applications of Gauss's law

SUMMARY

- **Electric Charge:** It is the intrinsic property of the elementary particle of matter which gives rise to electric force between various objects.
- **SI Unit of electric charge:** coulomb (C)
- **Properties of charge:**

1. **Additive in nature:** The total charge on an isolated system is equal to the algebraic sum of the charges on individual bodies of the system.
2. **Conservation of charge:** The charge of an isolated system remains constant. Charge can neither be created nor destroyed in isolation.
3. **Quantization of charge:** The total charge on a body is the integral multiple of fundamental charge.

$$Q = \pm ne, \text{ where } e = 1.6 \times 10^{-19} \text{ C}$$

- **Bodies can be charged by:**
- Friction
- Induction
- Conduction
- **Coulomb's law:** It states that the force of interaction between two point charges is directly proportional to the product of magnitude of charges and inversely proportional to the square of the distance between them.

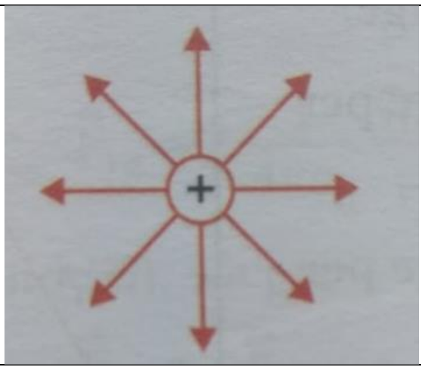
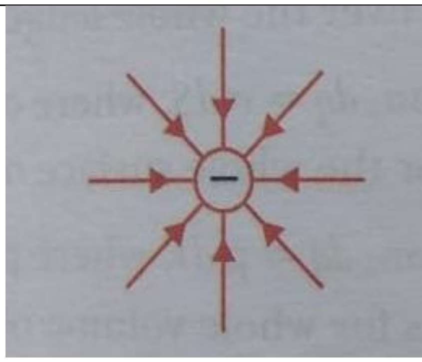
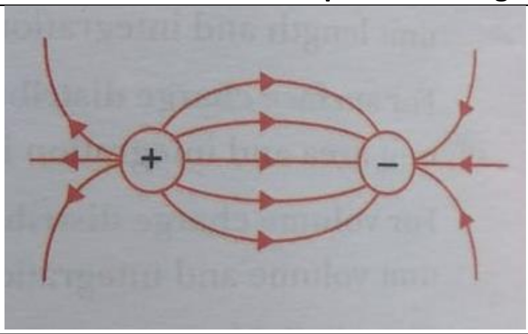
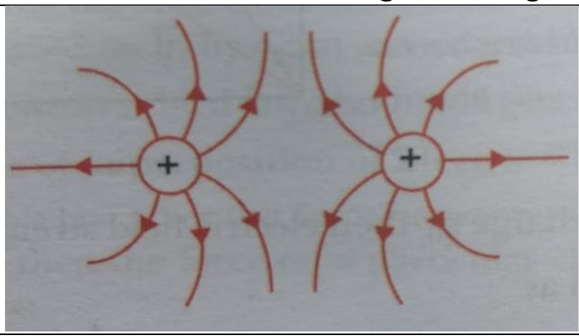
$$F = \frac{kq_1q_2}{r^2} \qquad \text{where, } k = 9 \times 10^9 \text{ Nm}^2\text{C}^{-2}$$

- **Electric field:** It is the region or space around the charge within which its electrostatic force of interaction can be experienced by some other charge.
- **Electric field intensity:** It is equal to the force experienced by a unit positive charge placed at that point, without disturbing the position of source charge.

$$\vec{E} = \frac{\vec{F}}{q_o} = \frac{kq}{r^2}$$

- **SI unit: NC^{-1}**
- **Electric field lines:** It is the path straight of curved in the electric field such that the tangent at any point to it gives the direction of electric field at that point.
- **Properties of electric field lines:**

1. The lines of force are continuous curve without any break.
2. The lines of force start at positive charge and end at negative charge.
3. No two electric lines of force intersect each other. Because if they intersect, then at the point of intersection, there will be two tangents which will denote two different directions of electric field at single point, which is not possible.

	
Electric field line due to positive charge	**Electric field line due to negative charge**
	
Electric field line due to electric dipole	**Electric field due to two like charges**

- **Electric Dipole:** A system of two equal and opposite charges separated by a small distance is called electric dipole.
- **Electric Dipole moment:** It is equal to the product of the magnitude of either charge and the distance between the charges.
- **SI Unit:** C-m

$\vec{p} = q\,(\overrightarrow{2a})$ where, q = magnitude of charge and 2a=length of dipole

-q ______________________ +q

← 2a →

- **Electric field due to electric dipole:**

(a) On axial line: E = $\frac{2pr}{4\pi\epsilon_0 (r^2-a^2)^2}$

(b) On equatorial line: E = $\frac{p}{4\pi\epsilon_0 (r^2 + a^2)^{3/2}}$

- **Torque on a dipole in uniform electric field:**

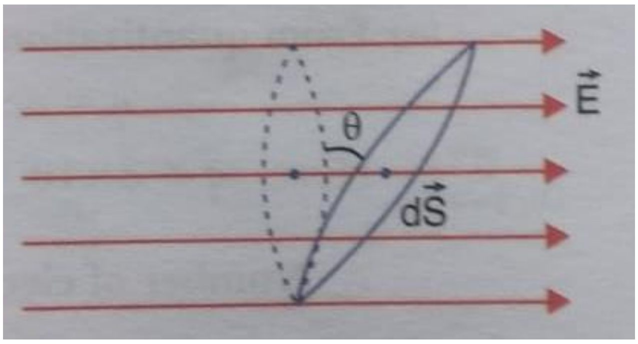
$$\tau = pE\sin\theta$$

In vector form: $\vec{\tau} = \vec{p} \times \vec{E}$

- **Electric flux:** It is equal to the total number of electric field lines passing through the given surface normally.

$$\phi = \vec{E} \cdot \vec{dS}$$

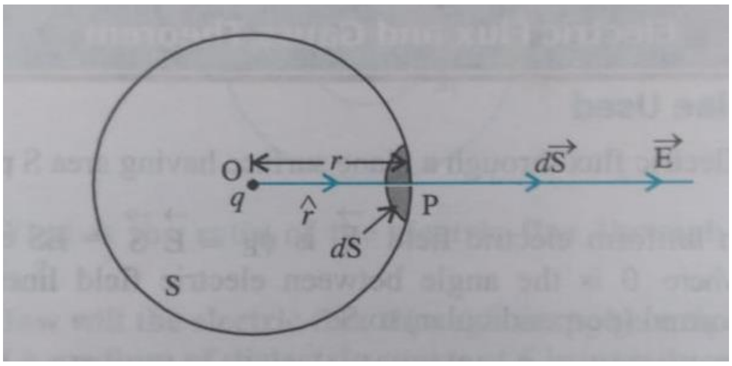
- **SI unit: Nm^2C^{-1}**



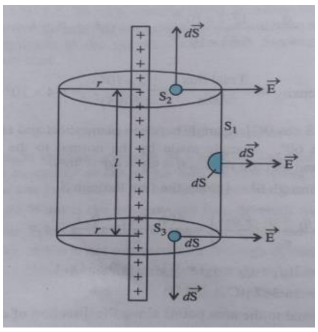
- **Gauss's theorem:** It states that the total electric flux through a closed surface is $1/\epsilon_0$

times the net charge enclosed by closed surface.

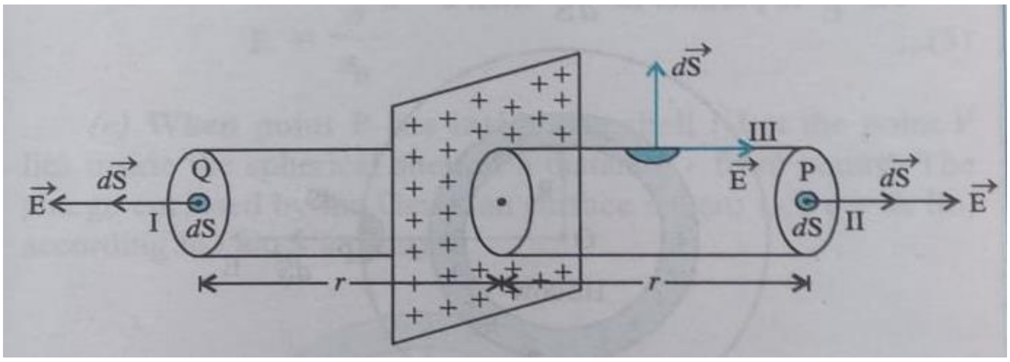
$$\phi = \oint \vec{E} \cdot \vec{dS} = q/\epsilon_0$$



- **Electric field due to infinitely long straight wire:** E = $\frac{\lambda}{2\pi\epsilon_0 r}$



Electric field due to uniformly charged infinite plane sheet: E = $\frac{\sigma}{2\epsilon_0}$

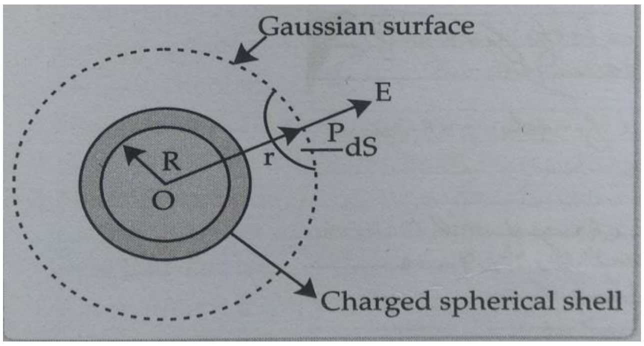


- **Electric field due to uniformly charged thin spherical shell:**

(i) **Inside:** E=0

(ii) **At surface:** E = $\frac{q}{4\pi\epsilon_0 R^2}$

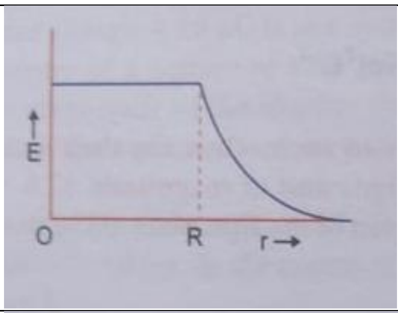
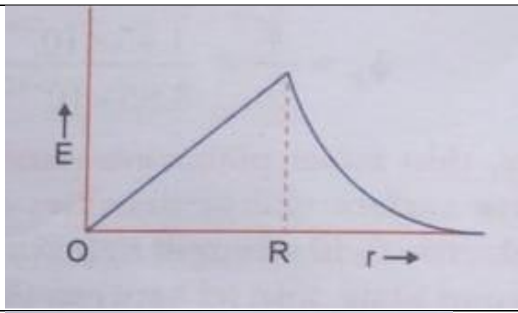
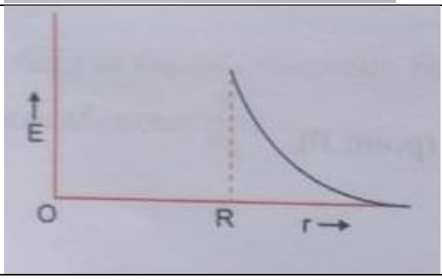
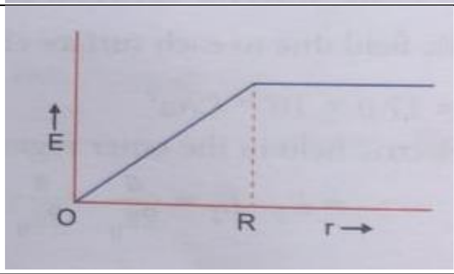
(iii) **Outside:** E = $\frac{q}{4\pi\epsilon_0 r^2}$

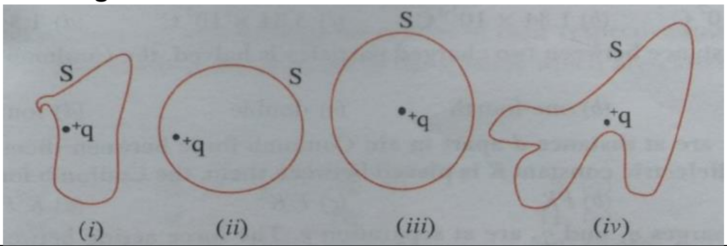
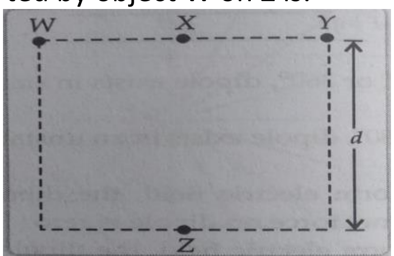


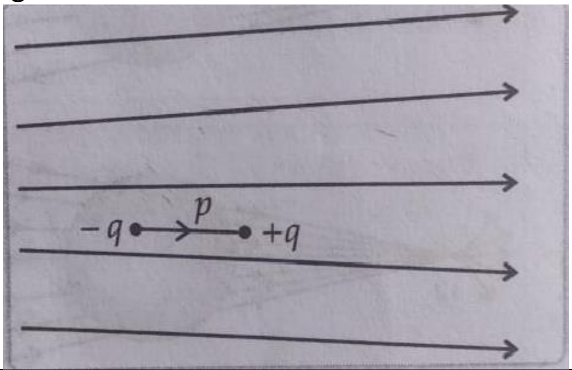
SECTION – A

(1 MARK - MCQ)

1	Which of the following is not a property of field lines?			
	(a)	Field line are continuous curve	(b)	Two field lines cannot cross each other
	(c)	Field lines start at positive charges and end at negative charges	(d)	They form closed loops
2	Gauss's law is valid for			
	(a)	Any closed surface	(b)	Only regular closed surfaces
	(c)	Any open surface	(d)	Only irregular closed surfaces
3	The electric field due to a uniformly charged sphere of radius R as a function of the distance from its centre is represented graphically by:			

	(a)		(b)	
	(c)		(d)	

4	The electric flux through the surface 			
	(a)	In Fig (iv) is the largest	(b)	In Fig (iii) is the least
	(c)	In Fig (ii) is same as Fig(iii) but is smaller than Fig. (iv)	(d)	Is the same for all the figures
5	An object has charge of 1 C and gains 5.0×10^{18} electrons. The net charge on the object becomes:			
	(a)	- 0.80 C	(b)	+ 0.80 C
	(c)	+ 1.80 C	(d)	+ 0.20 C
6	The magnitude of electric field due to a point charge 2q, at distance r is E. Then the magnitude of electric field due to a uniformly charged thin spherical shell of radius R with total charge q at a distance r/2 (r >>R) will be:			
	(a)	E/4	(b)	0
	(c)	2E	(d)	4E
7	Four objects W, X, Y & Z, each with charges +q are held fixed at four points of a square of side d as shown in the figure. Objects X and Z are on the mid points of the sides of the square. The electrostatic force exerted by object W on object X is F. Then the magnitude of the force exerted by object W on Z is: 			
	(a)	F/7	(b)	F/5
	(c)	F/3	(d)	F/2

8	Electric charge between two bodies can be produced by:			
	(a)	Sticking	(b)	Rubbibg
	(c)	oiling	(d)	Passing AC current
9	Law stating that “force is directly proportional to product of charges and inversely proportional to square of the separation between them” is called			
	(a)	Newton’s law	(b)	Coulomb’s law
	(c)	Gauss’s law	(d)	Ohm’s law
10	When a body is charged by conduction, its mass			
	(a)	Remains same	(b)	Increases
	(c)	decreases	(d)	Increases or decreases
11	A hemisphere is uniformly charged positively. The electric field at a point on a diameter away from the centre is directed:			
	(a)	Perpendicular to the diameter	(b)	Parallel to the diameter
	(c)	At an angle tilted towards the diameter	(d)	At an angle tilted away the diameter
12	The figure shows electric field lines in which an electric dipole p is placed as shown. Which of the following statement is correct? 			
	(a)	The dipole will not experience any force	(b)	The dipole will experience a force towards the right
	(c)	The dipole will experience a force towards the left	(d)	The dipole will experience a force upwards
13	Suppose a closed square loop whose area is $2\hat{\imath} - 5\hat{\jmath}$ is placed in an electric field of $3\hat{l} + 2\hat{J}$, then what will be the electric flux?			
	(a)	$(6\hat{l} - 10\hat{J})$ Vm	(b)	-4 Vm
	(c)	4 Vm	(d)	Zero
14	Which of the flowing is called as “The number of electric force lines that pass through a unit region”?			
	(a)	Density	(b)	Electric flux
	(c)	Electric field	(d)	nothing
15	A +q charge is placed in the centre of a cubical box. The total flux coming out of a wall has a value of:			
	(a)	$q/ 6\epsilon_o$	(b)	q/ ϵ_o
	(c)	$6q/ \epsilon_o$	(d)	$q/3\ \epsilon_o$
16	An electron having charge e and mass m is moving in a uniform electric field E. Its acceleration will be			
	(a)	eE/m	(b)	eE^2/m
	(c)	e^2/m	(d)	mE/e

17	If $\oint \vec{E} \cdot \overrightarrow{dS} = 0$ over a surface, then				
	(a)	The electric field inside the surface and on it is zero	(b)	The electric field inside the surface is necessarily uniform	
	(c)	The number of flux lines entering the surface must be equal to the number of flux lines leaving it	(d)	Surface area is zero	
18	When the distance between two charged particles is halved, the Coulomb force between them becomes				
	(a)	One half	(b)	One forth	
	(c)	double	(d)	Four times	
19	Two charges are at distance d apart in air. Coulomb force between them is F. If a dielectric material of dielectric constant K is placed between them, the Coulomb force now becomes:				
	(a)	F/K	(b)	FK	
	(c)	F/K^2	(d)	K^2F	
20	Three charges +4q, Q and q are placed in a straight line of length l at point at distance 0, l/2 and l respectively. What should be Q in order to make the net force on q to be zero?				
	(a)	-q	(b)	-2q	
	(c)	-q/2	(d)	4q	
21	Electric dipole moment is				
	(a)	Scalar	(b)	Vector	
	(c)	Vector directed from -q to +q	(d)	Vector directed from +q to -q	
22	Electric field due to an electric dipole is				
	(a)	Spherically symmetric	(b)	Cylindrically symmetric	
	(c)	Asymmetric	(d)	None of these	
23	When an electric dipole is held at an angle in uniform electric field, the net force and torque on dipole is				
	(a)	Force=0, torque=0	(b)	Force≠0, torque≠0	
	(c)	Force=0, torque≠0	(d)	Force≠0, torque=0	
24	The dimensional formula of permittivity of free space is				
	(a)	$[M^{-1}L^{-3}T^4A^2]$	(b)	$[ML^2T^2A]$	
	(c)	$[M^{-1}L^{-2}T^{-2}A]$	(d)	$[M^{-1}L^{-2}T^{-2}A^2]$	
25	Whan a body becomes negatively charged, its mass				
	(a)	decreases	(b)	Increases	
	(c)	Remains same	(d)	None of these	

Solution of MCQ

Q.No.	Ans	Q.No.	Ans	Q.No.	Ans	Q.No.	Ans	Q.No.	Ans
1	d	6	c	11	a	16	a	21	c
2	a	7	b	12	c	17	c	22	b
3	b	8	b	13	b	18	d	23	c
4	d	9	b	14	b	19	a	24	a
5	d	10	d	15	a	20	a	25	b

Assertion and Reason Type Questions

Directions: In each of the following questions, a statement of assertion (A) is followed by a statement of reason (R). While answering questions, choose the correct one and mark it as

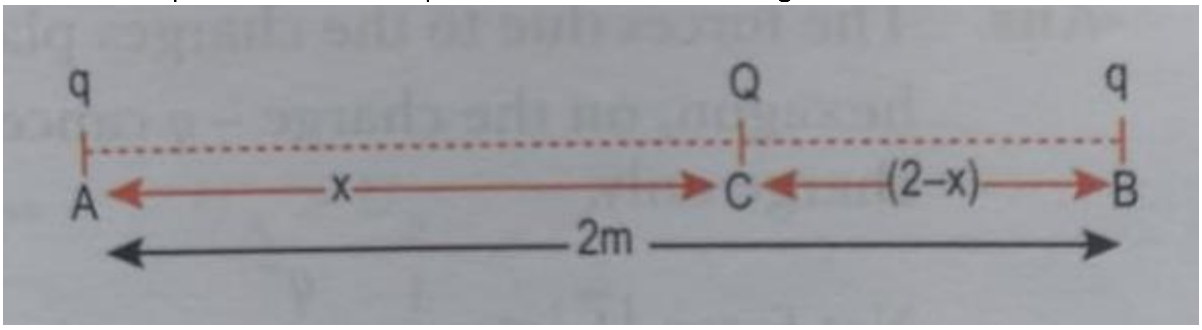
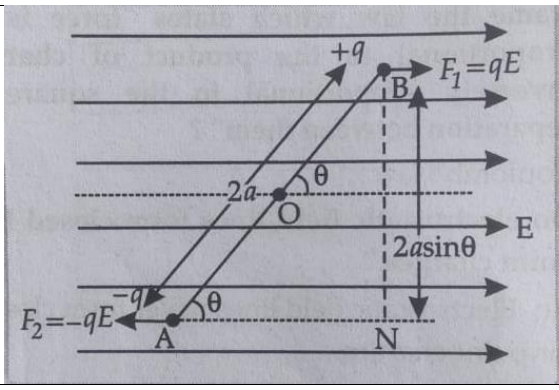
(a) If both assertion (A) and reason (R) are true and reason (R) is the correct explanation of the assertion (A).
(b) If both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of the assertion (A).
(c) If assertion (A) is true and reason (R) is false.
(d) If both assertion (A) and reason (R) are false/assertion (A) is false but reason (R) is true.

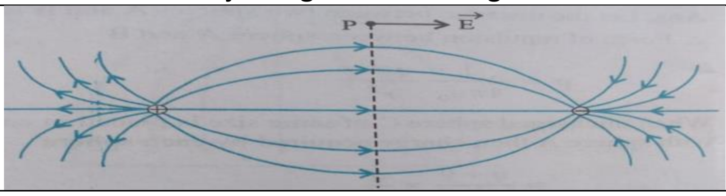
1(a)	Assertion: A metallic shield in the form of a hollow shell may be built to block an electric field. Reason: In a hollow spherical shield, the electric field inside it is zero at every point.
2(d)	Assertion: The Coulomb force is dominating force in the universe. Reason: The Coulomb force is weaker than the gravitational force.
3(a)	Assertion: Gauss's law cannot be used to calculate the electric field near an electric dipole. Reason: Electric dipole don't have symmetrical charge distribution.
4(b)	Assertion: If a conductor is given charge then no excess inner charge appears. Reason: Electric field inside the conductor is zero.
5 (c)	Assertion: Electrons in an atom are held due to coulomb forces. Reason: The atom is stable only because centripetal force due to Coulomb's law is balanced by centrifugal force.
6 (c)	Assertion: A point charge is brought in an electric field. The field at nearby point will increase, whatever be the nature of the charge. Reason: The electric field is independent of the nature of charge.
7 (c)	Assertion: Net electric field inside a conductor is zero. Reason: Total positive charge equals to total negative charge in a charged conductor.
8 (b)	Assertion: When the inverse square law is not obeyed, Gauss's law shows deviation. Reason: The conservation of charges leads to Gauss's law.
9 (a)	Assertion: In a non-uniform electric field, a dipole will have translator as well as rotatory motion. Reason: In a non-uniform electric field, a dipole experiences a force as well as torque.
10 (d)	Assertion: Electric lines of force cross each other. Reason: The resultant electric field at a point is the superposition of the electric fields at that point.

Solution of Assertion and Reason Type

Q.No.	Ans	Q.No.	Ans
1	a	6	c
2	d	7	c
3	a	8	b
4	b	9	a
5	c	10	d

SECTION-B (2 MARKS)

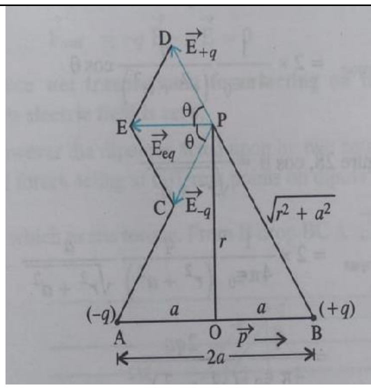
Q1	Two identical conducting balls A and B have charges –Q and +3Q respectively. They are brought in contact with each other and then separated by a distance d apart. Find the nature of the Coulomb force between them.
Ans	Final charge on balls A and B = (3Q-Q)/2 = Q The nature of the coulomb force between them is repulsive.
Q2	The sum of two-point charges is 7μC. They repel each other with a force of 1N when kept 30 cm apart in free space. Calculate the value of each charge.
Ans	Given, q_1+q_2 = 7μC = 7 x 10^{-6} C Therefore, q_2 = 7μC = 7 x 10^{-6} - q_1 F = k q_1 q_2/r^2 $1 = x = \frac{9 \text{ x } 10^9 \ x\, q_1}{(0.30)^2} x\,(7 \text{ x } 10^{-6} - q_1)$ q_1 = 5 μC and q_2 = 2 μC
Q3	Two identical point charges, q each, are kept 2 m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of charge Q. 
Ans	System is in equilibrium, therefore net force on each charge of system will be zero. $\frac{qQ}{4\pi\epsilon_0\, x^2} = \frac{qQ}{4\pi\epsilon_0\, (2-x)^2}$ X = 1 m
Q4	Derive an expression for the torque acting on an electric dipole, when it is held in a uniform electric field. Identify the orientation of the dipole in the electric field, in which it attains a stable equilibrium.
Ans	

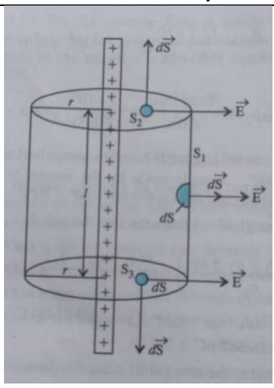
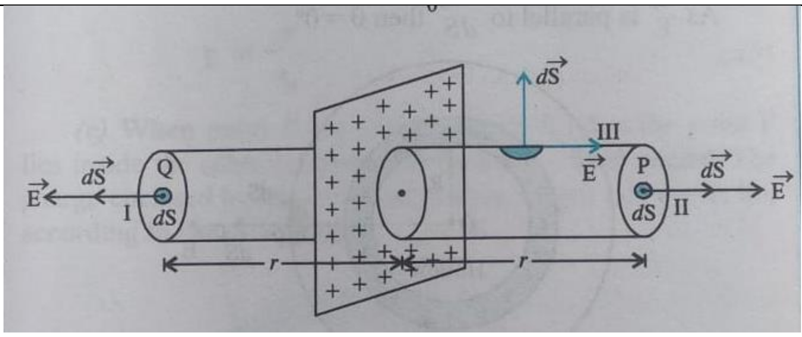
	An electric dipole AB consisting of charge +1 and –q and of length 2a is placed in uniform electric field E making an angle ϴ with the direction of electric field. Force acting of -q = -qE Force acting of +q = +qE Net force = -qE + qE = 0 Torque = force x perpendicular distance Torque = qE x 2asin ϴ = pEsin ϴ
Q5	How many electronic charges form a charge of one coulomb?
Ans	Here, q = 1 C e = 1.6 x 10^{-19} C according to quantization of charge, q = ne n = $\frac{q}{e} = \frac{1}{1.6 \text{ x } 10^{-19}}$ = 6.25 x 10^{18} electrons
Q6	Two-point charges each of 1C separated by 1 m distance experiences a force of $9 \text{ x } 10^{9}\ N$. How much force is experience by them if they are immersed in water, keeping the distance of separation between them same? Dielectric constant of water = 80.
Ans	Dielectric constant = K = $\frac{F}{F_m}$ Therefore, Fm = F/K = 9 x $\frac{10^9}{80}$ = 1.125 x 10^{8} N
Q7	How much electric field strength is required to just support a water drop of mass 0.001 kg and having a charge 1.6 x 10^{-19} C?
Ans	Given, m = 0.001 kg, q = 1.6 x 10^{-19} C Force on drop due to electric field = weight of drop qE = mg E = mg/q = $\frac{0.001\ x\ 9.8}{1.6 \text{ x } 10^{-19}}$ = 6.125 x 10^{16} NC^{-1}
Q8	Two-point electric charges of unknown magnitude and sign are separated by distance d. The electric field intensity is zero at a point not between two charges but on the line joining them. Write the essential condition for this to happen.
Ans	(i) The two charges must have opposite signs. (ii) The magnitude of the charge lying near the point of zero electric field intensity must be smaller than the magnitude of other charge.
Q9	A system has two charge q_1=2.5 x 10^{-7} C and q_2 = -2.5 x 10^{-7} C located a points A(0,0,-15) cm and B (0,0,+15) cm respectively. Find the total charge and electric dipole moment of the system.
Ans	Total charge = $q_1 + q_2$ = 2.5 x 10^{-7} + (-2.5 x 10^{-7}) = 0 Distance between two charges = 2a = 15+ 15 = 30 cm = 0.30 m Electric dipole moment = q(2a) = 2.5 x 10^{-7} x 0.30 = 7.5 x 10^{-8} Cm Direction of electric dipole moment is B to A.
Q10	Two-point charges +q and -q are placed at a distance d apart. Draw the lines on which the resultant field is parallel to the line joining the two charges.
Ans	

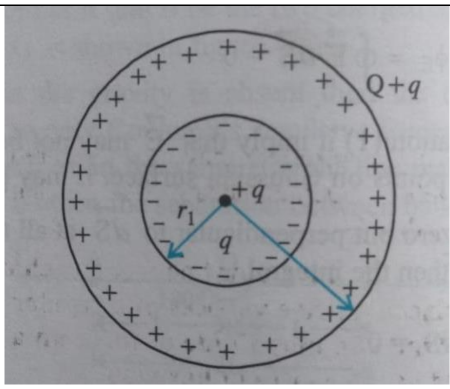
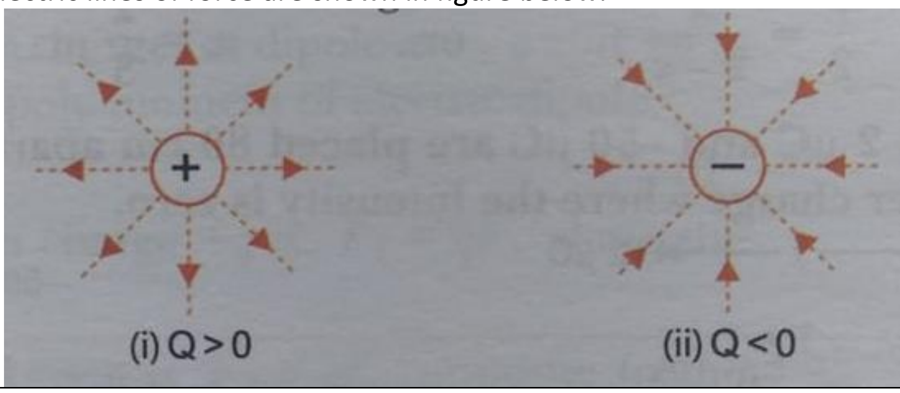
Q11	A spherical gaussian surface encloses a charge of 8.85 x 10^{-8} C. (i) Calculate the electric flux passing through the surface. (ii) If the radius of the Gaussian surface is doubled, how would the flux changes?
Ans	(i) Electric flux = q/ ϵ_o = 8.85 x 10^{-8}/8.85 x 10^{-12} = 10^4 Nm^2C^{-1} (ii) When the radius will be doubled, the charge enclosed in the surface will remain constant. Therefore, the flux will remain same.
Q12	An electric flux of -3 x 10^{-14} Nm^2C^{-1} passes through a spherical Gaussian surface is caused by a point charge. Compute the point charge's value.
Ans	Electric flux = q/ ϵ_o q = (electric flux) x ϵ_o = (-3 x 10^{-14}) x 8.85 x 10^{-12} = - 2.655 x 10^{-25} C
Q13	Why can't you compute the field of a cube using Gauss' law?
Ans	Because the electric field of a cube fluctuates along any segment of the Gaussian surface, Gauss law cannot be used to calculate its field. In this case, Gauss' law is applied to all closed surface of any shape. Furthermore, when the charge distribution is symmetrical, the validity of this law is determined.
Q14	On which factors does the electric flux through a closed Gaussian surface depend upon?
Ans	(i) Net charge enclosed by the surface. (ii) The permittivity of the medium.
Q15	Consider the electric field $\vec{E} = 6\hat{\imath} + 2\hat{\jmath} + \hat{k}$, calculate the electric flux through a surface of area 20 units in Y-Z plane.
Ans	Given, $\vec{E} = 6\hat{\imath} + 2\hat{\jmath} + \hat{k}$ $d\vec{S}$ = 20 $\hat{\imath}$ electric flux = $\vec{E} \cdot d\vec{s}$ = 120 units

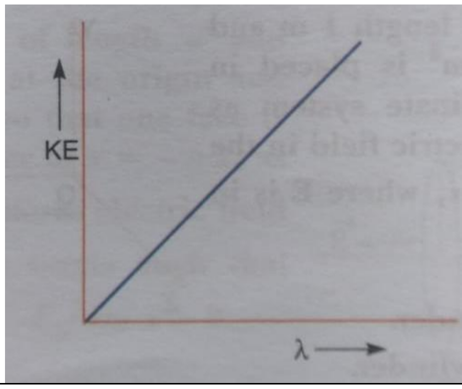
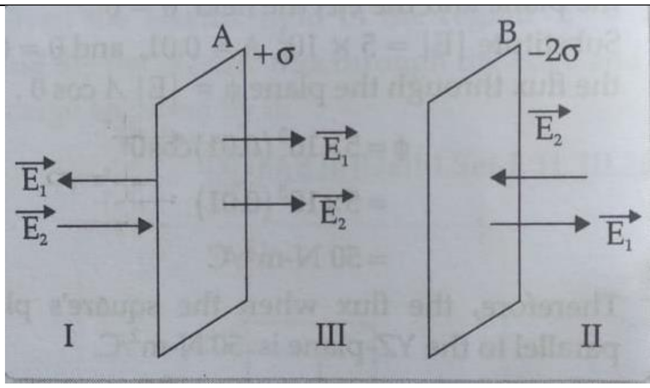
SECTION-C (3 MARKS)

Q1	If a body gives out 10^9 electrons every second, how much time is required to get a total charge of 1 C from it?
Ans	Given, number of electrons per second = 10^9 Suppose 't' is the time taken to get charge of 1 C, then total number of electrons in time 't' will be = (n) = 10^9 x t Total charge = 1 = ne = 10^9 x t x 1.6 x 10^{-19} Therefore, t = 1/(10^9 x 1.6 x 10^{-19}) = 6.25 x 10^9 sec or 198.18 years.
Q2	Two identical spheres, having charges of opposite sign attract each other with a force of 0.180 N when separated by 0.5 m. The spheres are connected by conducting wire, which then removed, and thereafter they repel each other with a force of 0.036 N. What were initial charges on the spheres.
Ans	Suppose, initial charges are q_1 and q_2. Given force between charges, F=0.108 N Distance, d = 0.5 m Force of interaction between two charges, F = $\frac{kq_1q_2}{r^2}$ Therefore, q_1q_2 =Fr^2/k = 0.108x$(0.5)^2$/(9X10^9) = 3 x 10^{-12} ---------- (i) When spheres are connected with conducting wire, charge on each sphere will be Q=($q_1 + q_2$)/2 -------(ii)

	Then the force will be 0.036N. $Q^2 = Fr^2/k = 0.036 \times (0.5)^2/(9 \times 10^9) = 3 \times 10^{-12}$ -------- (iii) From eq. (i), (ii) & (iii) $q_1 = 3 \times 10^{-6}$ C and $q_2 = 1 \times 10^{-6}$ C
Q3	Derive an expression for electric field intensity at any point on the equatorial line of dipole.
Ans	 Consider an electric dipole consisting of two charges -q and +q at points A and B separated by distance 2a. Let P be a point at a distance ‘r’ from the centre of dipole ‘O’. Electric field at point P, due to +q, $\vec{E}1 = \frac{kq}{BP^2}$ along BP Components of E1: Along BA = $\frac{kq}{BP^2}$ cosΘ Along OP = $\frac{kq}{BP^2}$ sinΘ Electric field at point P, due to -q, $\vec{E}2 = \frac{kq}{AP^2}$ along PA Components of E2: Along BA = $\frac{kq}{BP^2}$ cosΘ Along PO = $\frac{kq}{BP^2}$ sinΘ Therefore, net electric field along BA=E_x = 2 x $\frac{kq}{BP^2}$ cosΘ net electric field along OP=E_y = ($\frac{kq}{BP^2}$ sinΘ) – ($\frac{kq}{BP^2}$ sinΘ) = 0 Therefore, net electric field E=E_x = 2 x $\frac{kq}{BP^2}$ cosΘ = 2 x $\frac{1}{4\pi\epsilon_0}$ x $\frac{1}{(r^2+a^2)^2}$ x $\frac{1}{\sqrt{r^2+a^2}}$ E = $\frac{1}{4\pi\epsilon_0}$ x $\frac{p}{(r^2+a^2)^{\frac{3}{2}}}$

Q4	Derive an expression for electric field intensity due infinitely long charged wire.
Ans	 Consider an infinitely long charged wire having linear charge density λ. Electric field intensity is to be determined at a distance r from the wire. To apply Gauss' theorem, imagine a hypothetical cylindrical Gaussian surface having radius 'r' and length 'l' as shown in figure. The charge enclosed by the cylinder, q = λ l According to Gauss's theorem, $\phi = \oint \vec{E} \cdot \overrightarrow{dS} = q/\epsilon_o = \lambda l/\epsilon_o$ $\oint \vec{E} \cdot \overrightarrow{dS} = \int_I \vec{E} \cdot d\vec{s} + \int_{II} \vec{E} \cdot d\vec{s} + \int_{III} \vec{E} \cdot d\vec{s} = q/\epsilon_o = \lambda l/\epsilon_o$ $\oint \vec{E} \cdot \overrightarrow{dS} = \int_I EdScos0 + \int_{II} EdScos90 + \int_{III} EdScos90 = q/\epsilon_o = \lambda l/\epsilon_o$ $E(2\pi rl) = \lambda l/\epsilon_o$ $E = \lambda/(2\pi\epsilon_o r)$ ---------------- (Derived)
Q5	Derive an expression for electric field intensity due to thin infinite plane sheet of charges.
Ans	 Consider a thin infinite plane sheet having charge density σ. Electric field intensity is to be determined at a distance r from the sheet. To apply Gauss' theorem, imagine a hypothetical cylindrical Gaussian surface having cross-sectional area S and length 2r piercing the sheet as shown in figure. The charge enclosed by the cylinder, q = σ A According to Gauss's theorem, $\phi = \oint \vec{E} \cdot \overrightarrow{dS} = q/\epsilon_o = \sigma S/\epsilon_o$ $\oint \vec{E} \cdot \overrightarrow{dS} = \int_I \vec{E} \cdot d\vec{s} + \int_{II} \vec{E} \cdot d\vec{s} + \int_{III} \vec{E} \cdot d\vec{s} = q/\epsilon_o = \sigma S/\epsilon_o$ $\oint \vec{E} \cdot \overrightarrow{dS} = \int_I EdScos0 + \int_{II} EdScos0 + \int_{III} EdScos90 = q/\epsilon_o = \sigma S/\epsilon_o$ $ES+ES = 2ES = \sigma S/\epsilon_o$

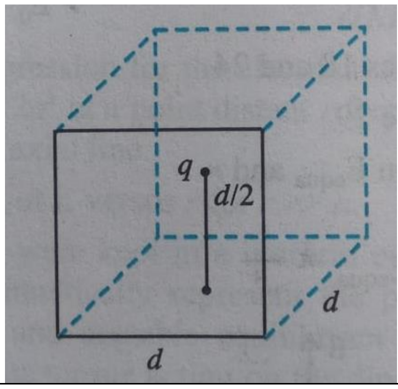
	$E = \sigma / 2\epsilon_0$ ----------**(Derived)**
Q6	A spherical conducting shell of inner radius r_1 and outer radius r_2 has a charge 'Q'. A charge q is placed at the centre of shell. (i) What is the surface charge density on the (a) inner surface (ii) outer surface of cell? (ii) Write an expression for electric field at a point x >r_2 from centre of the shell.
	 The charge +q at centre of shell induces charge -q on the inner surface of shell and charge +q on the outer surface of shell. (i) (a) surface charge density on inner surface = $\frac{q}{4\pi r1^2}$ (b) surface charge density on outer surface = $\frac{Q+q}{4\pi r2^2}$ (ii) electric field at a point x>r_2 = $\frac{q+Q}{4\pi\epsilon o\ x^2}$
Q7	The electric field E due to any point charge near it is defined as E= $\lim_{q\to 0}\left(\frac{F}{q}\right)$ where q is the test charge and F is the force acting on it. What is the physical significance of $\lim_{q\to 0}$ in this expression? Draw the electric field lines of point charge Q when (i) Q>0 and (ii) Q<0.
Ans	The physical significance of $\lim_{q\to 0}$ in the definition of electric field E = $\lim_{q\to 0}\left(\frac{F}{q}\right)$ The point test charge q produces its own electric field; hence it will modify the electric field strength to be measured. Therefore, the test charge used to measure the electric field must be too small. The electric lines of force are shown in figure below. 
Q8	(a) An infinitely long positively charged straight wire has a liner charge density λ $Cm^{-1.}$ An electron is revolving around the wire as its centre with constant velocity in a circular lane perpendicular to the wire. Deduce the expression for its kinetic energy.

<table>
<tr><td></td><td>(b) Plot a graph of kinetic energy as a function of charge density λ.</td></tr>
<tr><td>Ans</td><td>Electric field due to infinitely long charged wire,
$E = \lambda / (2\pi\epsilon_o r)$
The revolving electron experiences an electrostatic force and provides necessary centripetal force.
$eE = mv^2/r$
$e\lambda / (2\pi\epsilon_o r) = mv^2/r$
Kinetic energy = $mv^2/2 = e\lambda / (4\pi\epsilon_o r)$

</td></tr>
<tr><td>Q9</td><td>Two large charged place sheets of charge densities σ and -2 σ C/m^2 are arranged vertically with a separation of d between them. Deduce expressions for the electric field at points.
(i) To the left of the first sheet
(ii) To the right of the second sheet
(iii) Between the two sheets</td></tr>
<tr><td>Ans</td><td>

Electric field due to sheet A, $E_1 = \frac{\sigma}{2\epsilon_0}$
Electric field due to sheet B, $E_2 = \frac{-\sigma}{\epsilon_0}$

The electric field in the region left of first sheet
$E_I = E_1 - E_2$
$E_I = \frac{\sigma}{2\epsilon_0} - \frac{\sigma}{\epsilon_0} = \frac{-\sigma}{\epsilon_0}$ -------------- towards right

The electric field in the region right of the second sheets
$E_I = E_1 + E_2$
$E_I = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{\epsilon_0} = \frac{3\sigma}{2\epsilon_0}$ -------------- towards right</td></tr>
</table>

	The electric field in the region between the sheets $E_I = E_2 - E_1$ $E_I = \frac{\sigma}{\epsilon_0} - \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{2\epsilon_0}$ -------------- towards left
Q10	A point charge q is at a distance of d/2directly above the centre of a square of side d as shown in fig. Use Gauss's law to obtain the expression for electric flux through square. If the point charge is now moved a distance d from the centre of the square and the side of square is doubled, then how the electric flux will be affected? 
Ans	According to Gauss's law, total electric flux through the cube, $\phi_E = q/\epsilon_o$ Therefore, flux through each of six faces of square = $\phi_E/6 = q/6\epsilon_o$ When the charge is moved to a distance d and the side of the square ids doubled, then the side of the imaginary cube will be 2d, however the charge enclosed remains the same. Hence, the total flux through the cube and therefore the flux through the square remains same as before.

SECTION-D (5 MARKS)

Q1	(i) State Gauss's law. (ii) Derive expression for electric field due to uniformly charged thin spherical shell: (a) At point inside the shell (b) At the surface of shell (c) At the point outside the shell (iii) Plot the graph showing the various of electric field with distance.
Ans	It states that the total electric flux through a closed surface is $1/\epsilon_o$ times the net charge enclosed by closed surface. $\phi = \oint \vec{E} \cdot \overrightarrow{dS} = q/\epsilon_o$ Consider a think spherical shell of radius R and charge q is uniformly distributed over the surface of shell. Let P is at a distance 'r' from centre of the shell.

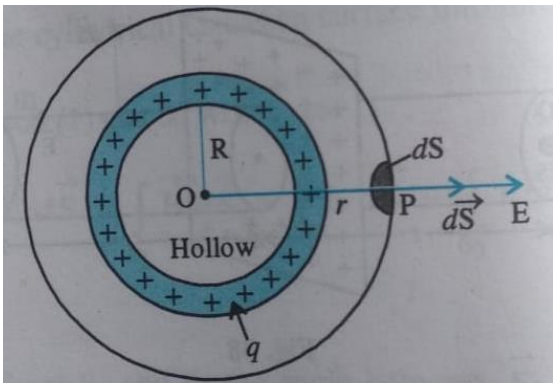
(i) Inside the shell, r<R

According to Gauss's law

$$\phi = \oint \vec{E} \cdot \overrightarrow{dS} = q/\epsilon_o$$

$$\phi = \int EdS\,cos0 = 0$$

therefore, E=0



(ii) At the surface of the shell, r=R

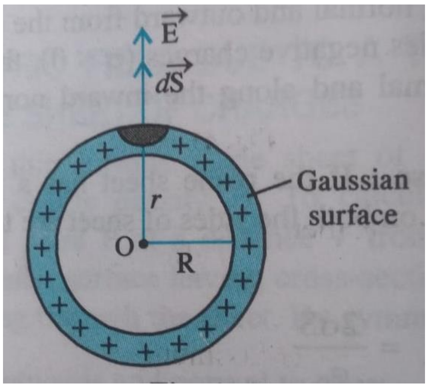
According to Gauss's law

$$\phi = \oint \vec{E} \cdot \overrightarrow{dS} = q/\epsilon_o$$

$$\phi = \int EdS\,cos0 = q/\epsilon_o$$

therefore, $E \times 4\pi R^2 = q/\epsilon_o$

$E = q/4\pi\epsilon_o R^2$



(iii) At the point outside the shell, r>R

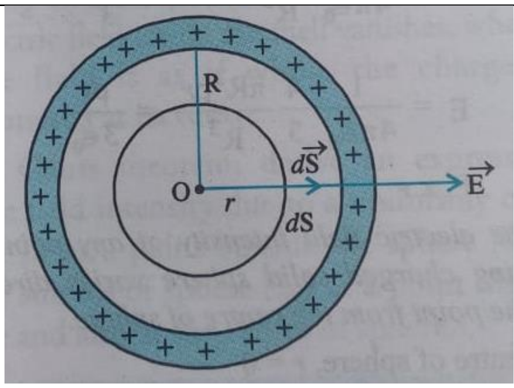
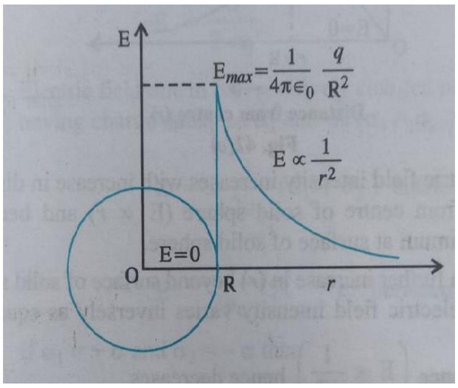
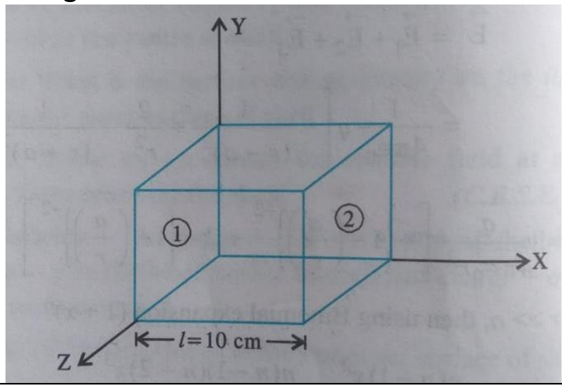
According to Gauss's law

$$\phi = \oint \vec{E} \cdot \overrightarrow{dS} = q/\epsilon_o$$

$$\phi = \int EdS\,cos0 = q/\epsilon_o$$

therefore, $E \times 4\pi r^2 = q/\epsilon_o$

$E = q/4\pi\epsilon_o r^2$

	 
Q2	(i) Define electric flux and write its SI unit. (ii) Electric field in fig given below is directed along +X-direction and given by E_x=5Ax + B, where E is in NC^{-1} and x in metre. A and B are constants with dimensions. Taking A=10 $NC^{-1}m^{-1}$ and B = 5 NC^{-1}. Calculate a) The electric flux through the cube b) Net charge enclosed in cube 
Ans	(i) Electric flux: It is equal to the total number of electric field lines passing through the given surface normally. $$\phi = \vec{E} \cdot \vec{dS}$$ SI unit: Nm^2C^{-1} (ii) The electric field is acting only in X-direction and its Y and Z components are zero. So, the flux passes only through faces (1) and (2). Magnitude of electric field at face(1), (x=0)

	$E_1 = 5Ax + 2B = (5 \times 10 \times 0) + (2 \times 5) = 10\ NC^{-1}$ Flux, $\phi_1 = E_1 l^2 \cos\Theta = 10 \times (0.10)^2 \times \cos 180^o$ $\phi_1 = -0.1\ Nm^2C^{-1}$ Magnitude of electric field at face(2), (x=10 cm) $E_1 = 5Ax + 2B = (5 \times 10 \times 0.1) + (2 \times 5) = 15\ NC^{-1}$ Flux, $\phi_2 = E_2 l^2 \cos\Theta = 15 \times (0.10)^2 \times \cos 0^o$ $\phi_1 = 0.15\ Nm^2C^{-1}$ Net flux though the cube, $\phi_C = \phi_1 + \phi_2 = 0.05\ Nm^2C^{-1}$ Total charge enclosed with in cube= $\epsilon_0 \phi_C = 4.43 \times 10^{-13}$ C

SECTION-E

CASE STUDY BASED QUESTION (4 marks)

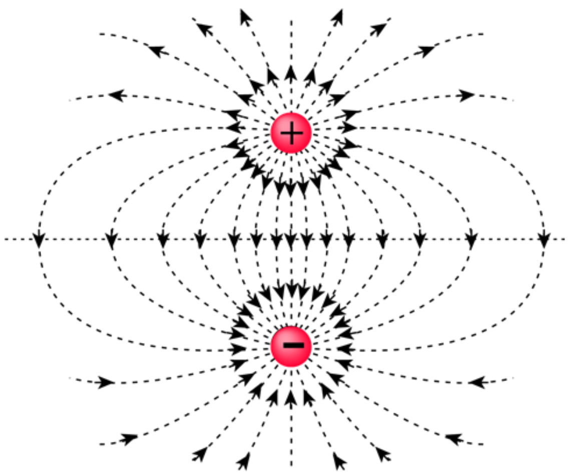
1

ELECTRIC DIPOLE

An **electric dipole** is the separation of opposite sign charges (usually by a very small distance), typically introduced by a simple case of two charges, both with equal magnitude but opposite charge.

Electric dipoles are common in nature, so the analysis of them has many practical applications. Dipoles are usually found in molecular structures caused by non-uniform charge distribution of protons and electrons, and are used to find the polarity of a system which is useful in understanding many chemical phenomena such as the normal force (the reason we don't fall through objects), surface tension, solubility, and melting/boiling points.

The electric field of an electric dipole can be constructed as a vector sum of the point charge fields of the two charges:



(i) **What is electric dipole moment?**

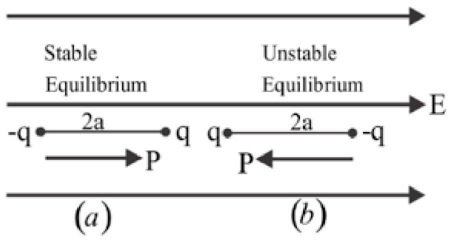
Ans: It is equal to the product of either charge and the distance between the two charges.

(ii) **Write the SI unit of electric dipole moment.**

Ans: Coulomb-metre (C-m)

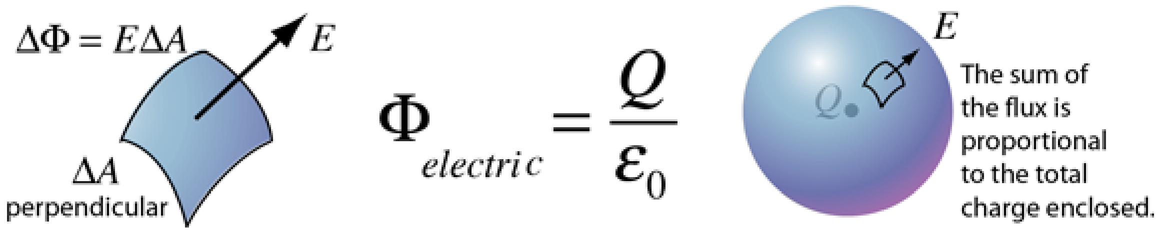
(iii) Depict the orientation of the dipole in (a) stable, (b) unstable equilibrium in a uniform electric field.

Ans:



GAUSS'S LAW

The total of the electric flux out of a closed surface is equal to the charge enclosed divided by the permittivity.



The electric flux through an area is defined as the electric field multiplied by the area of the surface projected in a plane perpendicular to the field. Gauss's Law is a general law applying to any closed surface. It is an important tool since it permits the assessment of the amount of enclosed charge by mapping the field on a surface outside the charge distribution. For geometries of sufficient symmetry, it simplifies the calculation of the electric field.

Another way of visualizing this is to consider a probe of area A which can measure the electric field perpendicular to that area. If it picks any closed surface and steps over that surface, measuring the perpendicular field times its area, it will obtain a measure of the net electric charge within the surface, no matter how that internal charge is configured.

(i) Define electric flux?

Ans: The number of electric lines of force (or electric field lines) that intersect a given area normally.

(ii) Write the SI unit of electric flux.

Ans: Nm^2C^{-1}

(iii) A spherical rubber balloon carries a charge that is uniformly distributed over its surface. As balloon is blown up and increases in size, how does the total electric flux coming out of the surface change? Give reason.

Ans: Since, flux = q/ϵ_o As charge remains unchanged when size of balloon increases, electric flux through the surface remains unchanged.

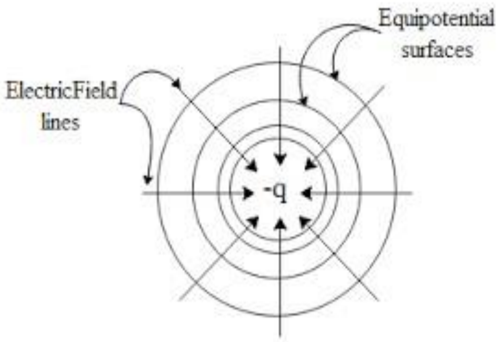
CHAPTER 2 - ELECTRIC POTENTIAL AND CAPACITANCE

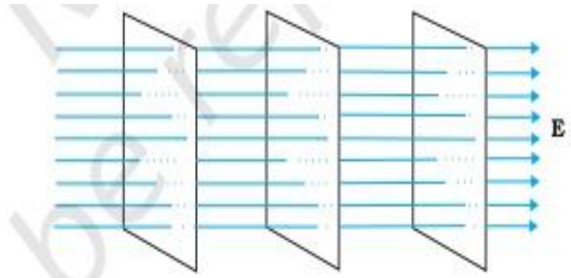
GIST OF THE LESSON

- Electric potential & potential difference
- Electric potential due to a point charge, a dipole and systemof charges
- Equipotential surface
- Electrical potential energy of a system of two-point charges and of electric dipole in an electrostatic field.
- Conductors and insulators, free charges and bound charges inside a conductor.
- Dielectrics and electric polarization,
- Capacitors and capacitance,
- Combination of capacitors in series and in parallel,
- Capacitance of a parallel plate capacitor with and without dielectric medium between theplates,
- Energy stored in a capacitor (no derivation, formulae only).

SUMMARY

- Electrostatic Potential: Work done per unit positive Test charge to move it from infinity to that point in an electric field. It is a scalar. SI unit: J/C or V $V = W/q_0$
- Electric potential at a distance 'r' from a point charge Q
  $V(r) = Q/4\pi\epsilon_0 r$
- Definition of 1 Volt: The electrostatic potential at any point in an electric field is said to be one volt when one joule of work is done in bringing one-unit charge from infinity to that point.
  $V = W/q$, $1V = 1J/1C$
- Relation between Electric field intensity & Potential: The electric field intensity at any point is the negative gradient potential at that point.
  $E = - dV/dr$
- Work done $W = q\Delta V = q\ (V_A - V_B)$
- Potential energy of two point charges Q_1 and Q_2 separated by a distance r:
  $U = k\ Q_1Q_2/r$
- Potential energy of an electric dipole of dipole moment p kept in a uniform electric field E is: $U = -\vec{p}.\vec{E}$
  Stable equilibrium: dipole parallel to electric field, $\theta = 0^0$
  Unstable equilibrium: dipole anti parallel to electric field, $\theta = 180^0$
- Equipotential surfaces: The surfaces on which the potential is same at every point.





GURE 2.10 Equipotential surfaces for a uniform electric field.

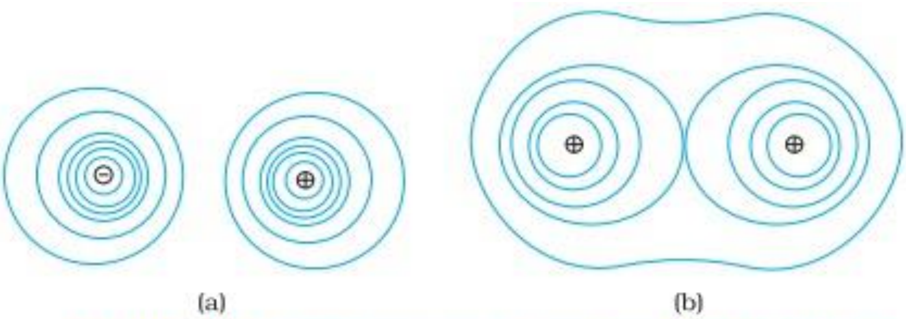
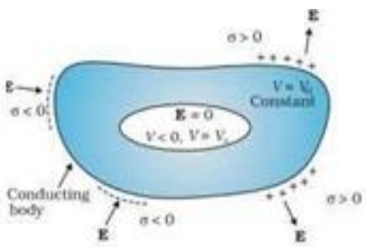


FIGURE 2.11 Some equipotential surfaces for (a) a dipole, (b) two identical positive charges.

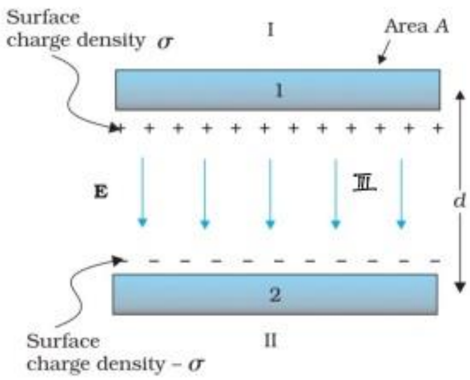
- Properties of equipotential surface:
- Work done in moving a charge between any two points on an equipotential surface is zero
- The field lines are normal to the equipotential surface
- No two equipotential surfaces intersect.
- Equipotential surfaces are closer where electric field is stronger.

- Electrostatics of conductors
    1. Inside a conductor Electrostatic field is zero
    2. On the surface E is always Normal to the surface
    3. No excess charge resides inside the conductor
    4. Charge distribution on the surface is uniform if the surface is smooth
    5. Electric field is zero in the cavity of hollow conductor and potential remains constant which is equal to that on the surface.



- Capacitance: Ability to store charge. Mathematically, it is the ratio of charge stored to potential applied. It is a scalar quantity. S I unit is Farad.
- Capacitance is said to be 1Farad when a charge of 1C increases the potential difference between the plates by 1 Volt.
- Parallel plate capacitor

Consider the following setup; two conducting plates of area A with charge Q and –Q respectively and surface charge density σ= Q/A are separated by a distance d.



Let us calculate the Electric field in the three regions-

$$E_I = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

$$E_{II} = \frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = 0$$

$$E_{III} = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon\sigma} = \frac{\sigma}{\varepsilon_0}$$

We know,

$$|E| = \frac{\Delta V}{r}$$

$$\frac{\sigma}{\varepsilon_0} = \frac{\Delta V}{d}$$

$$\Delta V = \frac{\sigma d}{\varepsilon_0}$$

$$C = \frac{Q}{V} = \frac{\sigma A}{V} = \frac{\sigma A \varepsilon_0}{\sigma d}$$

$$\boxed{C = \frac{A\varepsilon_0}{d}}$$

- Parallel plate capacitor with dielectric

Consider a case where a dielectric medium of dielectric constant K and thickness t is placed b/w the plates of a capacitor of plate separation d (d>t)

Let us calculate the electric field at the 3 points-

$$E_{p_1} = \frac{\sigma}{\varepsilon_0}$$

$$E_{p_2} = \frac{\sigma}{\varepsilon_0}$$

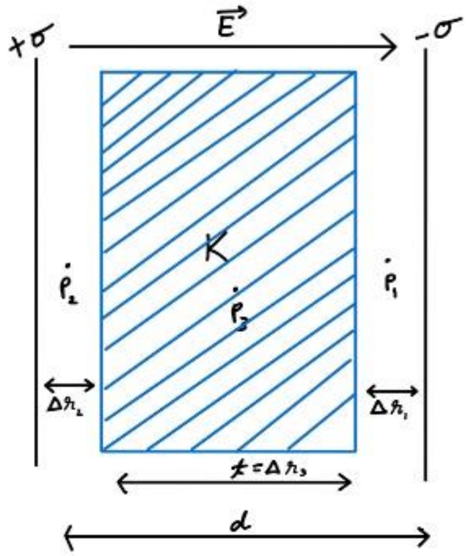
$$E_{p_3} = \frac{\sigma}{k\varepsilon_0}$$

$$\Delta V = Ep_1\Delta r_1 + Ep_2\Delta r_2 + Ep_3\Delta r_3$$

$$= Ep_1(\Delta r_1 + \Delta r_2) + Ep_3\Delta r_3$$

$$= \frac{\sigma}{\varepsilon_0} \times (d - t) + \frac{\sigma}{k\varepsilon_0} t$$

$$\Delta V = \frac{\sigma}{\varepsilon_0} \times \left(d - t + \frac{t}{k}\right)$$



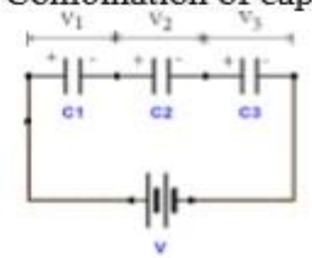
$$C = \frac{Q}{V}$$

$$C = \frac{\sigma A \varepsilon_0}{\sigma(d - t + t / K)}$$

$$C = \frac{A\varepsilon_0}{(d - t + t / K)}$$

- Grouping of capacitors

Combination of capacitors: Series



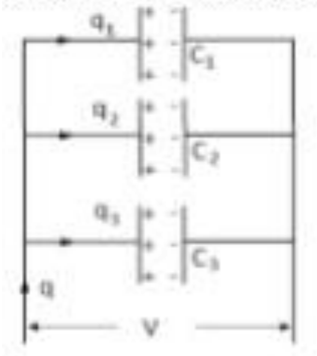
Charge Q stored is same in all capacitors
Potential divides among the capacitors

$$\frac{1}{C} = \sum_{i=1}^{n} \frac{1}{C_i}$$

When 'n' identical capacitors C are connected in series,

$$C_{series} = \frac{C}{n}$$

Combination of capacitors: Parallel



Potential difference V is same for all capacitors,
Charge Q $= q_1 + q_2 + q_3$

$$c = \sum_{i-1}^{n} c_i$$

When 'n' identical capacitors C are connected in parallel,

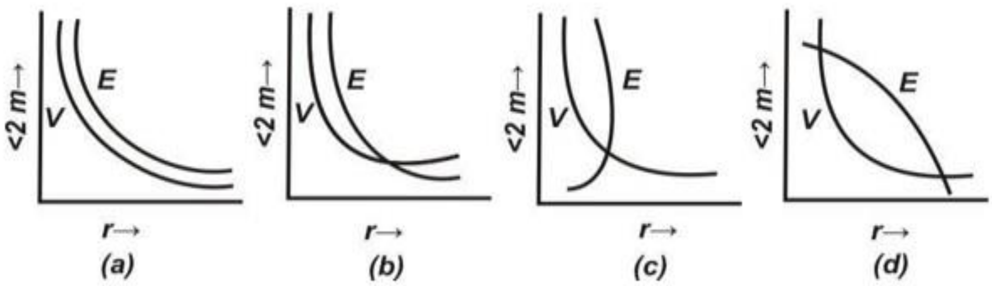
$$C_p = nC$$

- Energy stored in a capacitor

  $U = ½\, CV^2 = Q^2/2C$

MCQs

1. The variation potential V with r & electric field E with r for a point charge is correctly shown in the graphs



2. Capacitance of a parallel plate capacitor can be increased by
   (a) Increasing the distance between the plates
   (b) Decreasing the distance between the plates
   (c) Decreasing the area of plates
   (d) Increasing the thickness of the plates
3. A capacitor of capacitance C has a charge Q and stored energy W. If the charge is increased to 2Q, the stored energy will be
   (a) W/2 (b) 4W (c) 2W (d) W
4. A battery is used to charge a capacitor till the potential difference between the plates become equal to the emf (V) of the battery. The ratio of the energy stored in the capacitor to the work done by the battery will be
   (a) ½ (b) 2 (c) ¼ (d) 4

5. The electric potential V at any point (x,y,z) in space is given by $V = 3x^2$ where x,y,z are all in metre. The electric field at the point (1m,0,2m) is
   (a) 6V/m along -x axis
   (b) 6V/m along +x axis
   (c) 1.5V/m along -x axis
   (d) 1.5V/m along +x axis
6. A parallel plate capacitor with oil in between the plates (dielectric constant of oil is 2) has a capacitance 'C'. If the oil is removed, what will be the new capacitance
   (a) $C/\sqrt{2}$ (b) C/2 (c) $2C$ (d) $\sqrt{2}\,C$

7. Energy stored in a capacitor is given by
   (a) $U = \frac{1}{2} C^2V$ (b) $U = \frac{1}{2} CV^2$ (c) $U = CV^2$ (d) $2CV^2$
8. In series combination of capacitors, potential drops across the individual capacitors is

   a) inverse ratio of charges stored b) direct ratio of capacitors

   c) inverse ratio of capacitors d) none of these
9. The electric field between the plates of a fully charged capacitor is E. If a material of dielectric constant K is introduced between the plates, the electric field at a point between the plates

   a) becomes zero b) remains unchanged

   c) becomes E/K d) becomes EK

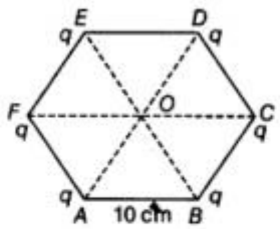
10. Three condensers of capacity 2 μF, 4 μF and 8 μF respectively, are first connected in series and then connected in parallel. The ratio of the equivalent capacitance in the two cases will be

    (a) 7 : 3 (b) 3 : 7

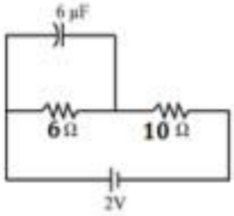
    (c) 49 : 4 (d) 4 : 49

SHORT ANSWER TYPE(2MARKS)

1. Write the expression for the potential energy of an electric dipole in an external electric field. Hence write the conditions for stable and unstable equilibrium.
2. A regular hexagon of side 10cm has charge 5ηC at all vertices. Calculate the potential at the centre.



3. Find the charge on the 6 ηF capacitor shown in the figure.



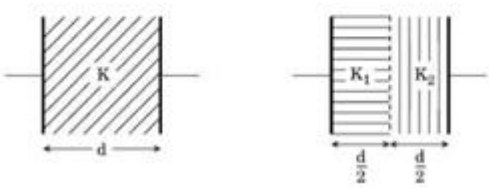
4. A capacitor of unknown capacitance is connected across a battery of V volts. The charge stored in it is 360 ηC. When the potential is reduced by 120V, the charge stored in it becomes 120 ηC. Calculate the potential V and capacitance C.

5.

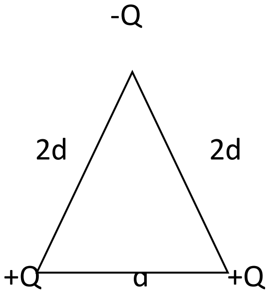
(i) Two circular metal plates, each of radius 10cm are kept parallel to each other at a distance of 1mm. What kind of capacitor do they make?

(ii) If the radius of each of the plates is increased by a factor of √2 and distance of separation reduced to half, calculate the ratio of capacitance in both case

6. Find the ratio of the potential differences that must be applied across the parallel and series combination of two identical capacitors so that energy stored, in two cases, becomes the same.
7. A parallel plate capacitor having plate area $100cm^2$ and separation 1.0mm holds a charge of 0.12ηC when connected to a 120V battery. Find the value of dielectric constant of material filling the gap.
8. A capacitor 200 pF is charged by a 300V battery. The battery is disconnected and the charged capacitor is connected to another uncharged capacitor 100pF. Calculate the difference in the final and initial energy stored.
9. The space between the plates of a parallel plate capacitor is completely filled in two ways. In the first case, it is filled with a slab of dielectric constant K. In the second case, it is filled with two slabs of equal thickness and dielectric constants K1 and K2 respectively as shown in the figure. The capacitance of the capacitor is same in the two cases. Obtain the relationship between, K, K1 and K2

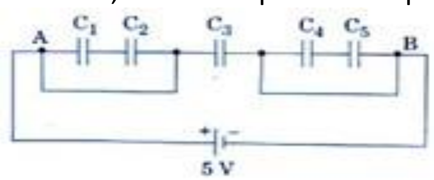


10. What is the total potential energy of the configuration shown here?



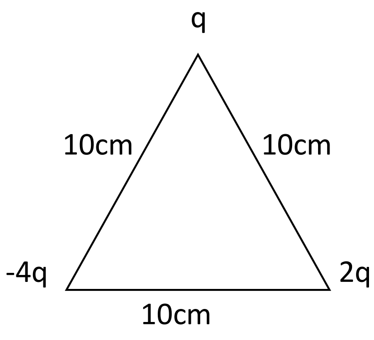
SHORT ANSWER TYPE(3MARKS)

1. A parallel plate is charged by a battery. When the battery remains connected, a dielectric slab is inserted in the space between the plates. Explain what changes if any, occur in the values of
   (a) its capacitance
   (b) electric field between the plates and energy stored in the capacitor be affected? Justify your answer giving necessary mathematical expression for each case.
2. A parallel plate capacitor is charged by a battery to a potential. The battery is disconnected and a dielectric slab is inserted to completely fill the space between the plates. How will
   (a) its capacitance
   (b) electric field between the plates and energy stored in the capacitor be affected? Justify your answer giving necessary mathematical expression for each case.
3. In the figure given below, find the equivalent capacitance between A and B

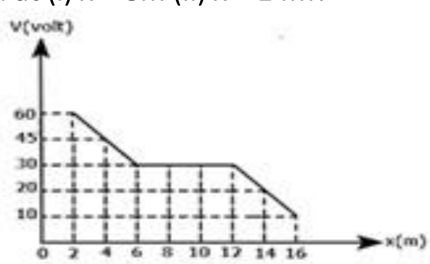


C1 = C5 = 8µF, C2 = C3 = C4 = 4 µF

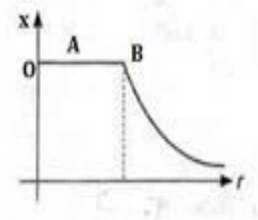
   (i) Calculate effective capacitance between A and B
   (ii) Maximum charge supplied by the source
   (iii) The energy stored in the network
4. Two point charges +Q1 and -Q2 are placed at a distance ‘r’ apart. Obtain the expression for the amount of work done to place a third charge Q3 at the midpoint of the line joining the two.
5. Calculate the work done to dissociate the system of three charges placed at the vertices of a triangle as shown. Given: $q = 1.6 \times 10^{-10}$ C



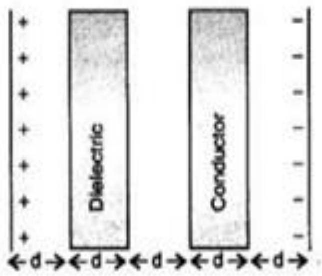
6. The variation of potential with distance from a fixed point is as shown in the figure. What is the electric field at (i) x = 8m (ii) x = 14m?



7. A graph showing variation between two physical quantities ‘x’ with ‘r’, where ‘r’ is the distance from the center of a charged conducting sphere.
   (i) Name the physical quantity ‘x’
   (ii) What does the distance ‘OB’ represent?
   (iii) At what point the electric field of this conducting sphere (a) minimum (b) maximum? Write the values

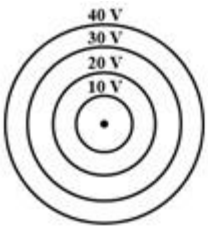


8. What should be the charge on a sphere of radius 4cm, so that when it is brought in contact with another sphere of radius 2cm carrying a charge of 10ηC? there is no transfer of charge from one to another.
9. Figure shows a parallel plate capacitor of charge densities +σ and – σ. A dielectric slab of constant K and a conducting slab both are of thickness ‘d’ are inserted in between the plates.



Find the potential difference between the plates. Plot the graph between the E and x taking x=0 at +ve plate and x = 5d at -ve plate.

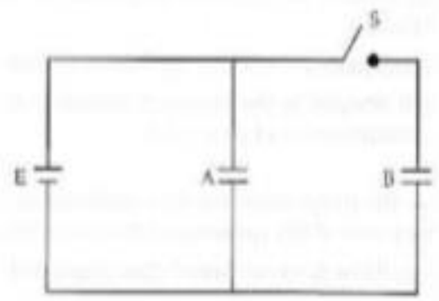
10.
   (a) Two isolated metal spheres A and B have radii R and 2R respectively and same charge q. Find which of the two spheres has greater (i) capacitance (ii) energy density just outside the spheres.
   (b) Concentric equipotential surfaces due to a point charge at the centre are shown. Identify the polarity of the charge and draw the field lines.



LONG ANSWER TYPE QUESTIONS (5 MARKS)

1. Explain briefly the process of charging a parallel plate capacitor when it is connected across DC battery. A capacitor of capacitance 'C' is charged to 'V' volts by a battery. After sometime battery is disconnected and distance is doubled. Now a dielectric slab of constant, 1 < K < 2, is introduced to fill the gap between the plates. How will the following get have affected?
   (i) the electric field between the plates
   (ii) the energy stored in the capacitor. Justify your answer by writing necessary expressions.

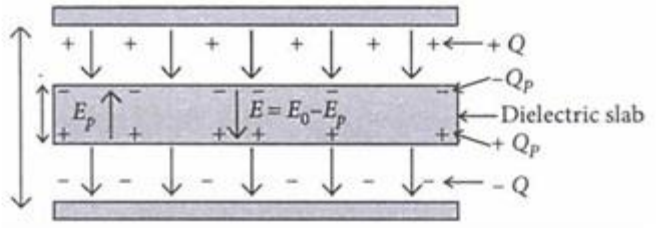
2. Two identical parallel plate capacitors A and B are connected to a battery V volt with a switch 'S' closed. The switch is now opened and the free space between the plates of the capacitor is filled with a medium of dielectric constant K. Find the ratio of the total energy stored in both capacitors before and after the introduction of the dielectric.



3.
(a) Does the capacitance C of a capacitor increase, decrease or remain same when (i) the charge on it is tripled (ii) the potential difference across the plates is halved? Justify your answer.
(b) Two metal spheres A and B of radius 'r' and '2r' whose Centre are separated by a distance '6r' are given charges Q each and are potential V_1 and V_2 respectively. Find the ratio of V_1 to V_2.
(c) If the spheres are now connected by a wire, what amount of charge will flow through the wire?

CASE STUDY BASED QUESTIONS

1. A dielectric slab is a substance that does not allow the flow of charges through it but permits them to exert electrostatic forces on one another.
   When a dielectric slab is placed between the plates, the field E_o polarises the dielectric. This induces charge $-Q_p$ on the upper surface and $+Q_p$ on the lower surface of the dielectric. These induced charges set up a field E_p inside the dielectric in the opposite direction of external field E.



(i) In a parallel plate capacitor, the capacitance increases from 4ηF to 80ηF on introducing a dielectric medium between the plates. What is the dielectric constant of the medium?

(a) 10 (b) 20 (c) 50 (d) 80

(ii) A parallel plate capacitor with air between the plates has a capacitance of 8 pF. The separation between the plates is now reduced by half and the space between them is filled with a medium of dielectric constant 5.

Calculate the value of capacitance of the capacitor in the second case.

(a) 20 pF (b) 40 pF (c) 60 pF (d) 80 pF

(iii) A dielectric introduced between the plates of a parallel plate capacitor with battery remain connected

(a) decreases potential difference between the plates

(b)decreases the electric field between the plates

(c) increases the charge on the plates

(d) all the above

(iv) A parallel plate capacitor of capacitance 1 pF has separation between the plates d. When the distance of separation becomes 2d and wax of dielectric constant x is inserted in it the capacitance becomes 2 pF. What is the value of x?

(a) 2 (b)8 (c) 4 (d) 1

2. The surface on which all points have the same potential is called the equipotential surface. On the equipotential surface, to move a charge from one point to another, no work is required.

Equipotential Points: The same electric potential points on the electric field are called equipotential points.

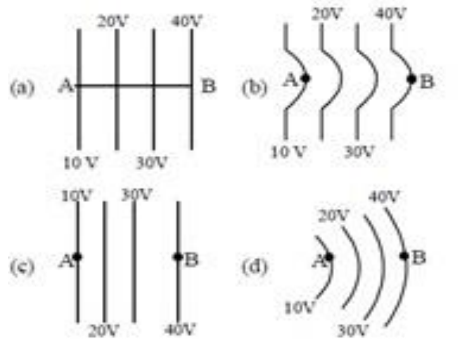
The line or curve connecting the points is known as an equipotential line.

The surface on which the point lies is called the equipotential surface. The volume in which the points are filled is known as an equipotential volume.

In an equipotential surface, if a point charge is said to move from point VA to VB, then the work done in moving the charge is given by,

W = q0 (VA –VB)

As VA – VB is said to be zero and the total work done, W = 0.



(i) Which of the above figures represent uniform electric field?
(a) fig (a) only (b) fig (a & c) (c) fig (b & d) (d) all the above

(ii) A charge +Q is moved from point A to point B. Choose the correct statement:
(a) Work done in fig(d) is the least
(b) Work done in fig (a) is greater than that in other cases
(c) Work done in fig (a) & (c) are equal but greater than that in fig (b & d)
(d) Work done in all three cases is equal

(iii) A charge -3ηC is taken from a point P to point Q where potential difference is 2.4V. Calculate the work done
(a) 0 J (b) 7.2 J (c) – 7.2 J (d) -7.2 ηJ

(iv) Suppose a charge +20 ηC is trapped at the Centre of a uniformly charged conducting sphere of radius 5cm and surface charge density 15 ηC/cm^2. What is the work done required to move the 20 ηC to the surface?
(a) 100 ηJ (b) 300 ηJ (c) Zero (d) 25 ηJ

ASSERTIONS AND REASONS

Directions: These questions consist of two statements, each printed as Assertion (A) and Reason (R). While answering these questions, you are required to choose any one of the following four responses.

A) Both A and R are true and R is the correct explanation of A
B) Both A and R are true but R is not the correct explanation of A.
C) A is true but R is false.
D) A is false and R is also false.

1. ASSERTION - For a uniform electric field E along the x -axis, the equipotential surfaces are planes parallel to the y-z plane.
REASON - Electric field is in the direction in which the potential increases.
2. ASSERTION - Work done in moving a charge between any two points in an electric field is independent of the path followed by the charge, between these points.
REASON - Electrostatic force is a non-conservative force.
3. ASSERTION - If the distance between parallel plates of a capacitor is halved and dielectric constant is three times, then the capacitance becomes 6 times.
REASON - Capacity of the capacitor does not depend upon the nature of the material.

4. ASSERTION - A non-polar molecule is one in which the centers of positive and negative charges are separated.

   REASON - Non polar molecules have a permanent dipole moment.

5. ASSERTION - When a dielectric is inserted between the plates of a capacitor, capacitance increases.

   REASON - The dielectric is polarized by the field.

6. ASSERTION - A capacitor with large capacitance can hold large amount of charge Q at a relatively.

   REASON - The charge of the capacitor leaks away due to the reduction in insulating power of the intervening medium.

7. ASSERTION - When capacitors are connected in series net capacitance decreases.

   REASON - In series combination, charges on the two plates are the same on each capacitor.

8. ASSERTION - The total charge stored in a capacitor is zero.
   REASON - The field just outside the capacitor is σ/ε_0 . (σ is the charge density).

9. ASSERTION - Two equipotential surfaces cannot cut each other.
   REASON - Two equipotential surfaces are parallel to each other.

10. ASSERTION - Electric field inside a conductor is zero.
    REASON - The potential at all the points inside a conductor is same.

Answers of Assertion Reason

1. C　2. C　3. C　4. D
5. A　6. B　7. C　8. C
9. C　10. B

MCQs ANSWERS

1. (b) E is proportional to $1/r^2$, V is proportional to 1/r

2. (b) $C = \epsilon_0 A/d$

3. (d) 4W $U = Q^2/2C$

4. (a) ½.
   If V is the emf of the battery, Work done = $QV = CV^2$. The energy stored = ½ CV^2

5. (a) 6V/m along -x axis
   Electric potential $V = 3x^2$
   $E = -dV/dx$ E =
   $-6x$
   At the point (1,0,2)
   Electric field $E = 6 \times 1 = -6V/m$

6. (b) C/2

7. (b) 1/2 CV^2

8. (c)

9. (c)

10. (d)

SHORT ANSWER TYPE (2 MARKS) ANSWER

1. U = - pE cos θ
For stable equilibrium, θ = 0

For unstable equilibrium, θ = 180

2. Potential V = 6 k q/r = 2.7×10^6 V

3. Current through the circuit I = 2/(6+10) = 1/8 A

Voltage across 6Ω resistor, V'= IR = 6/8 V

Charge on the capacitor, Q = CV' = 4.5 µC

4. Parallel plate capacitor (ii) $r' = \sqrt{2}r$. $A' = 2A$. $But\ d' = d/2$. $So\ C' = 4C$.
∴ $Ratio, C/C'$ = ¼

5. Work done = - (PE)
$W = k\ (q1q2 + q1q3 + q2q3)/r$

6. Substituting, W = 2.3×10^{-8} J

For identical capacitors: $Cs = C/2$; $Cp = 2C$

$Us = Up$, $1/2CsVs^2 = 1/2CpVp^2$.

∴ Vp/Vs = ½

7. $C = Q/V = 10^{-9}\ F. From\ the\ formula, C = K\varepsilon oA/d, K = 11.3$

8. $Ui = 1/2C_1\ V_2^2 = 9 \times 10^{-6}\ J$
Common potential after both capacitors connected,
$Vcommon = (C1V1+C2V2)/\ (C1+C2) = 200V$
$Uf = 1\ 2CpVcom^2 = 1/2300pF\ x\ (200)^2 = 6 \times 10\text{-}^2\ J$
Difference in energy = (9 – 6) x 10^{-2} J = 3 x 10^{-2} J

9.

Case 2 is a series combination

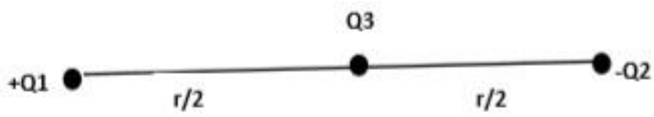
$C_1 = K\frac{\varepsilon_0 A}{d}$; $C_2 = (\frac{2K_1K_2}{K_1+K_2})\frac{\varepsilon_0 A}{d}$

$Since, C_1 = C_2\ ; K = \dfrac{2K_1K_2}{K_1+K_2}$

10. $U = k\,Q.Q/d + kQ.(-Q)/2d + k(-Q).Q/2d = 0$

SHORT ANSWER TYPE (3 MARKS) ANSWER

1. (i) Capacitance increases as C' = KC (K>1)
   Potential difference remains same as battery remain connected.
   So E =V/d remain same
   (iii) Energy, U = 1/2 CV^2; U' = KU
2. (a) The capacitance increases as the dielectric constant K>1.
   Potential difference V= CQ. As C increases and Q remains the same since the battery is disconnected, the p.d. between the plates decreases.
   (b) Electric field E = V/d where V is the p.d. and d the separation between the plates. As V decreases and d remains the same, electric field also decreases. (c)Energy stored in a capacitor U = 1/2 CV^2.
   As Q is constant and C increases, U decreases.
3. Since C1, C2 are short circuited, the net charge on them = 0 Similarly, net charge on C4 and C5 =0 So effective capacitance = C3 = 4µF Then, Q = CV = 4µF x 5 = 20 µC Energy stored, U = 1/2 CV^2 = 50µJ
4.



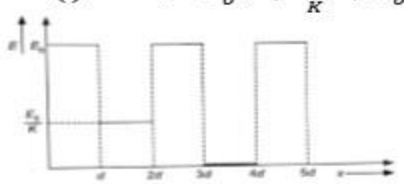
$$W = k\frac{Q_1Q_3}{r/2} - \frac{Q_3Q_2}{r/2} = 2k\left(\frac{Q_1Q_3 - Q_3Q_2}{r}\right)$$

5. Work done = - (PE)
   W = k $(q_1q_2+q_2q_3+q_3q_1)/r$

   Substituting, W = 2.3 x 10^{-8} J

6. E = −dV/dx
   (i) At x = 8m, V is constant. E = 0
   (ii) At x = 14m, V is gradually decreasing.
   E = − (10−30)/(16−12) = 5 V/m
7. (i) Electric potential
   (ii) OB = radius of the sphere
   (iii) E max is at surface (x = radius)
   at B, E imin is x < radius
8. For no transfer of charge, V1 = V2
   Hence $kq_1/r_1 = kq_2/r_2$; then q_1 = 20µC
9.

(i) $V = E_o d + \frac{E_o d}{K} + E_o d + 0 + E_o d = 3E_o d + \frac{E_o d}{K}$



10.

(a) (i) $C \propto R$; Capacitance of sphere B is greater

(ii) $energy\ density = \frac{U}{Volume} = \frac{Q^2/2C}{\frac{4}{3}\pi R^3}$. On solving, $\frac{U_A}{U_B} = 16:1$

(b) Negative charge.

LONG ANSWER TYPE

1. Hint: C1 = C; V1 = V and Q1 = CV When battery is disconnected, Q remains same.
   So after distance is doubled and battery disconnected, C2 = KC/2
   C1V1 = C2V2 ;
   Electric field E1 = Vd and E2 = E1/K
2. When switch is connected, $U_A = U_B = \frac{1}{2}CV^2$
   Total energy $U_i = 2\left(\frac{1}{2}CV^2\right) = CV^2$
   After the introduction of dielectric slab and switch opened, $C_A = C_B = KC$
   P.D across A = V; P.D across B = V/K (since Q remains same for A and B)
   $U_A = \frac{1}{2}KCV^2$; $U_B = \frac{1}{2K}CV^2$
   On adding final energy, $U_f = \left(\frac{K^2+1}{K}\right)\frac{1}{2}CV^2$
   Ratio, $\frac{U_f}{U_i} = \left(\frac{K^2+1}{2K}\right)$
3. (a) No change in capacitance since C does not depend on Q or V
   (b) V = kQ/r. So the ratio V1:V2 = 2:1
   (c) When connected by a wire, the potentials become equal.
   On equating, Q1′ = Q2′/2. Charge flowing = Q/3 (electric charge is conserved. 2Q = Q1′+ Q2′ = 3 Q2′/2.)

CASE STUDY QUESTIONS

1. (i) 20 (C′ = KC)
(ii) 80 pF
(iii) increases the charge on the plates (Battery connected V remains same)
(iv) 4

2. (I) fig (a) only
(ii) Work done in all three cases is equal
(iii) -7.2 μJ
(iv) Zero (the potential inside a charged sphere is uniform)

Chapter 3 – Current Electricity

SYLLABUS (2022 – 23)		
Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, temperature dependence of resistance, Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's rules, Wheatstone bridge.		
	Page No.	***Dropped Topics/ Chapters***
Rationalised Content	*102–103*	*3.7 Resistivity of Various Materials (delete Tables 3.1 and 3.2 and Carbon resistors, Colour code for carbon resistor)*
	107–109	*3.10 Combinations of Resistors – Series and Parallel*
	112–113	*Example 3.5*
	120–124	*3.15 Meter Bridge* *3.16 Potentiometer*
	127–131	*Exercises 3.3, 3.4, 3.10, 3.12, 3.14–3.23*

GIST of the Chapter

1. **Electric current :** Current is defined as the rate of flow of electric charge through a cross-section of the conductor.
   $I = \frac{dq}{dt}$, for steady current $I = \frac{q}{t} = \frac{ne}{t}$

2. **Current density** : Current density at a point inside the conductor is defined as the amount of current flowing per unit area around that point of the conductor.
   $j = \frac{I}{A}$, current density is a vector quantity. SI unit of *j* is Am^{-2}.

3. **Drift velocity :** The average velocity with which free electrons get drifted towards the positive end of the conductor under the given external electric field is called the drift velocity. $\overrightarrow{v}_d = -\frac{e\overrightarrow{E}}{m}\tau$
   where *e* is the charge on electron, *m* is the mass of the electron, $\overrightarrow{E}$ is the electric field applied and τ is the relaxation time. The –ve sign shows that drift velocity of electrons is in a direction opposite to that of the external electric field.

4. Relationship between current and drift velocity
   $I = nAev_d$ where *n* is the number density of electrons and *A* is the area of cross-section of the conductor.

5. **Mobility :** It is defined as the magnitude of drift velocity per unit electric field.
   $$\mu = \frac{|\overrightarrow{v}_d|}{E} = \frac{e}{m}\tau$$
   The SI unit of mobility is $m^2\,V^{-1}\,s^{-1}$ and its dimensional formula is $[M^{-1}L^0\,T^2\,A^1]$
6. **Ohm's law :** It states that the current (I) flowing through a conductor is directly proportional to the potential difference (V) across the ends of the conductor, provided physical conditions of the conductor such as temperature remains constant.

$$V \propto I, V = IR$$

Where 'R' is the resistance (property which opposes the flow of charges) offered by the conductor. SI unit of resistance is ohm (Ω) and its dimensional formula is $[ML^2\, T^{-3} A^{-2}]$.

7. **Ohmic and non-ohmic conductors :** Those conductors which obey Ohm's law are known as ohmic conductors, e.g. metals. For ohmic conductors, the graph between current and potential difference is a straight line passing through the origin.
   Those conductors which do not obey Ohm's law are known as non-ohmic conductors e.g. diode valve, junction diode. For non-ohmic conductor the graph between current and voltage is not linear.

8. $R = \rho \frac{l}{A} = \left(\frac{m}{ne^2\tau}\right)\frac{l}{A}, where\ \rho = \frac{m}{ne^2\tau}$
   where *m* is the mass of electron, *e* is charge of electron, *n* is the number density of electrons, *t* is the relaxation time, *l* is the length of conductor and *A* is its area of cross section, *ρ* is the specific resistance or resistivity of the conductor.

9. **Resistivity :** It is the resistance offered by the conductor of unit length and unit cross-sectional area. It is denoted by *ρ*. SI unit of resistivity is Ωm and its dimensional formula is $[ML^3\, T^{-3} A^{-2}]$.

10. **Vector form or microscopic for of Ohm's law :**
    $\vec{J} = \sigma \vec{E}$, where σ is the conductivity of the material.

11. **Conductivity :** The reciprocal of resistivity is known as conductivity or specific conductance. It is denoted by symbol σ . The SI unit of conductivity is $\Omega^{-1} m^{-1}$ or $S\, m^{-1}\ or\ mho\ m^{-1}$ and its dimensional formula is $[M^{-1} L^{-3} T^3\, A^2]$
    $$\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m} = ne\mu$$

12. **Effect of temperature on resistance and resistivity**
    The resistance of a metallic conductor increases with increase in temperature while for semiconductor the resistance decreases with temperature. The resistance of a conductor at temperature t°C is given by $R_t = R_0\,(1 + \alpha t)$
    where R_t is the resistance at t °C, R_0 is the resistance at 0°C and α is the temperature coefficient.
    For metals, α is positive i.e., resistance increases with rise in temperature.
    For insulators and semiconductors, α is negative i.e., resistance decreases with rise in temperature.

13. **Joule's Law of Heating** : According to Joule's heating effect of current, the amount of heat produced (H) in a conductor of resistance R, carrying current I for time t is
    $$H = I^2\, Rt\ (in\ joule)$$

14. **Electric power :** It is defined as the rate at which work is done by the source of emf in maintaining the current in the electric circuit.
    $$Electric\ power = \frac{electric\ work\ done}{time\ taken}, P = VI = I^2 R = \frac{V^2}{R}$$

15. **Electric energy :** It is defined as the total electric work done or energy supplied by the source of emf in maintaining the current in an electric circuit for a given time.

$Electric\ energy = H = P \times t$. The SI unit of electrical energy is joule (J).
The commercial unit of electric energy is kilowatt-hour (kWh),
$1\ kWh = 3.6 \times 10^6\ J$ = one unit of electricity consumed.

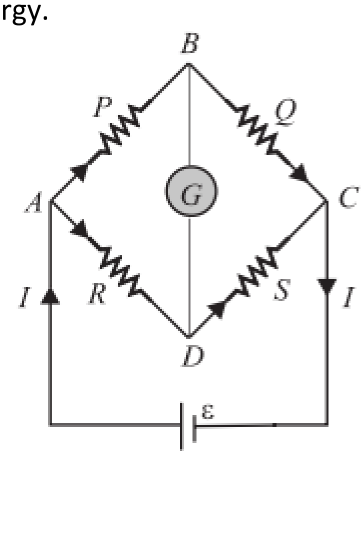
16. **Electromotive force (emf) of a cell** : It is defined as the potential difference between the two terminals of a cell in an open circuit i.e., when no current flows through the cell. It is denoted by symbol ε.
The emf of a cell depends upon the nature of electrodes, nature and the concentration of electrolyte used in the cell and its temperature.

17. **Terminal potential difference** : It is defined as the potential difference between two terminals of a cell in a closed circuit i.e., when current is flowing through the cell.
$$V = \varepsilon - Ir, where\ r\ is\ the\ internal\ resistance\ of the\ cell.$$
During charging of a cell the terminal potential difference becomes greater than the emf of the cell.

18. **Internal resistance of a cell** : It is defined as the resistance offered by the electrolyte and electrodes of a cell when the current flows through it. Internal resistance of a cell depends upon the distance between the electrodes, nature of the electrolyte, nature of electrodes, Area of the electrodes immersed in the electrolyte. $Internal\ resistance, r = R\left(\frac{\varepsilon}{V} - 1\right)$

19. **Kirchhoff 's Rules:**
    (a) **Junction rule or current law:** At any junction, the sum of the currents entering the junction is equal to the sum of currents leaving the junction.
    Kirchhoff's junction rule supports the conservation of charge.
    (b) **Loop rule or voltage law**: The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero.
    Kirchhoff's loop rule supports the conservation of energy.

20. **Wheatstone bridge :** It is an arrangement of four resistances P, Q, R and S connected as shown in the figure. Their values are so adjusted that the galvanometer (connected across one diagonal) shows no deflection. This condition of bridge is then said to be balanced Wheatstone bridge. For balanced Wheatstone bridge, the points B and D are at the same potential and
$$\frac{P}{Q} = \frac{R}{S}$$



Important Formulas

1. Electric current, $I = \frac{charge}{time} = \frac{q}{t} = \frac{ne}{t}$

2. Ohm's law $V = IR$

3. Drift velocity

$$\vec{v}_d = -\frac{e\vec{E}}{m}\tau, \quad \tau = avreage\ relaxation\ time$$

4. Current in terms of drift velocity (v_d), $I = neAv_d$

5. Resistance

$$R = \rho\frac{l}{A} = \frac{m}{ne^2\tau}$$

6. Resistivity or specific resistance, $\rho = R\frac{A}{l} = \frac{m}{ne^2\tau}$

7. Conductivity $= \frac{1}{resistivity}\ or\ \sigma = \frac{1}{\rho}$

8. Current density,

$$j = \frac{current}{Area} = \frac{I}{A} = env_d$$

9. Relation between current density and electric field, $\vec{J} = \sigma\vec{E}\ \ or\ \vec{E} = \rho\vec{J}$

10. Mobility, $\mu = \frac{v_d}{E} = \frac{e\tau}{m}$

11. Temperature coefficient of resistance, $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$

If $t_1 = 0°\ and\ t_2 = t°C, then$

$$\alpha = \frac{R_t - R_o}{R_o\ t} \quad or \quad R_t = R_o(1 + \alpha t)$$

12. For a cell of internal resistance r, the emf is , $\varepsilon = V + Ir = I(R + r)$

13. Terminal potential difference of a cell,

$$V = IR = \frac{\varepsilon R}{R + r}$$

14. Terminal potential difference when a current is being drawn from the cell, $V = \varepsilon - Ir$

15. Terminal potential difference when the cell is being charged, $V = \varepsilon + Ir$

16. Internal resistance of a cell,

$$r = R\left[\frac{\varepsilon - V}{V}\right]$$

17. Heat produced by electric current,

$$H = I^2Rt\ joule = \frac{I^2Rt}{4.18}\ cal \qquad or, H = VIt\ joule = \frac{VIt}{4.18}cal$$

18. Electric power,

$$P = \frac{W}{t} = VI = I^2R = \frac{V^2}{R}$$

19. Electric energy, $W = Pt = VIt = I^2Rt$

20. Kirchhoff's laws of electrical networks

a. $\sum I = 0$ or total incoming current = total outgoing current (junction rule)

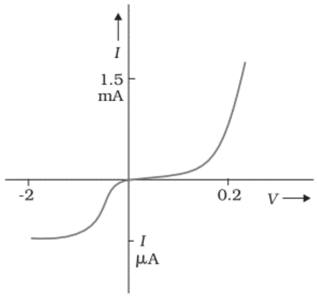
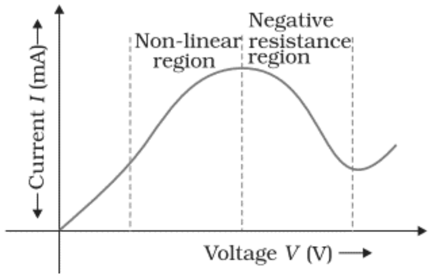
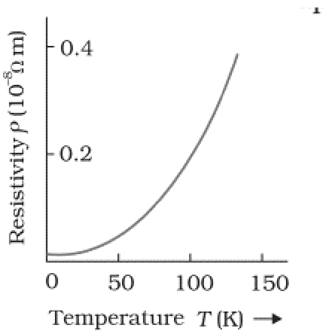
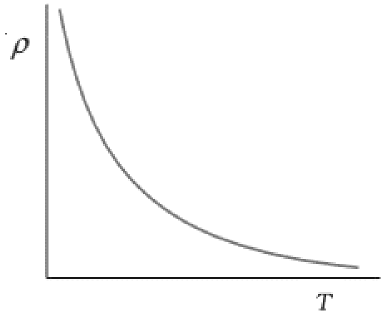
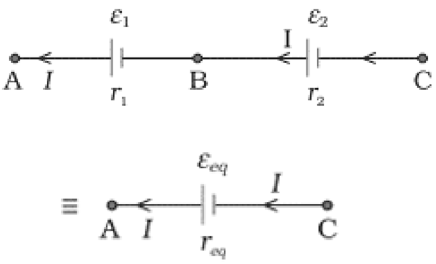
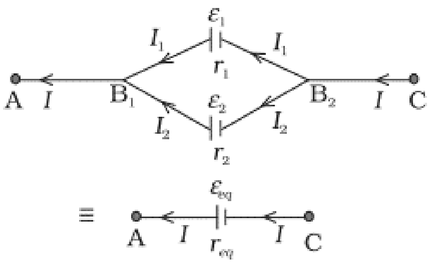
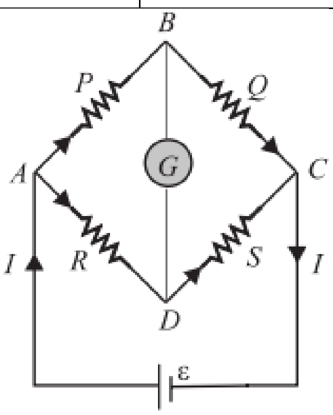
b. $\sum \varepsilon = \sum IR = 0$ (loop rule)

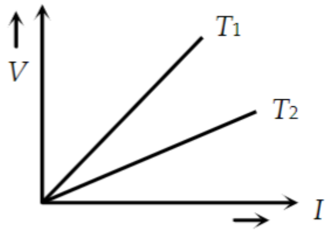
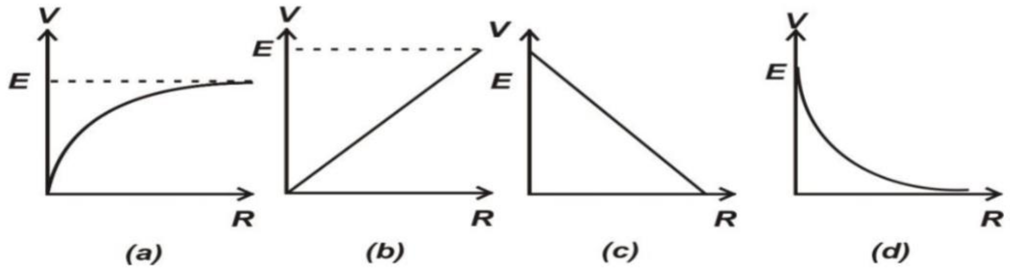
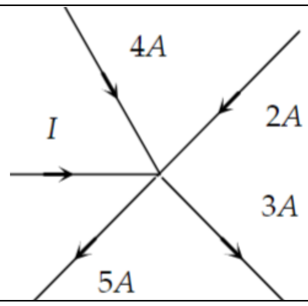
21. For a balanced Wheatstone bridge,

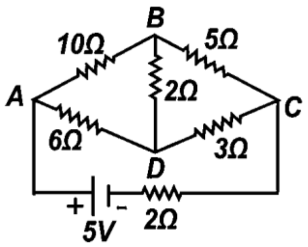
$$\frac{P}{Q} = \frac{R}{S}$$

IF X is unknown resistance $\frac{P}{Q} = \frac{R}{X}\ \ or\ X = \frac{RQ}{P}$

Important Diagrams/Graphs

 (1) Non Ohmic conductor – p n junction diode characteristics	 (2) Non Ohmic conductor - Variation of current versus voltage for GaAs.
 (3) Resistivity ρ_T of a metal as a function of temperature T	 (4) Resistivity ρ_T of a semiconductor as a function of temperature T
 (5) Two cells of emf ε_1 and ε_2 connected in series	 (6) Two cells of emf ε_1 and ε_2 connected in parallel
 (7) Wheatstone bridge	

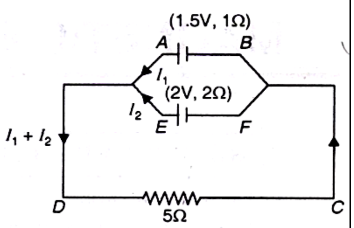
	MULTIPLE CHOICE QUESTIONS (MCQ's)
Q1.	The voltage Vand current I graph for a conductor at two different temperatures T_1 and T_2 are shown in the figure. The relation between T_1 and T_2 is (a) $T_1 = T_2$ (b) $T_1 > T_2$ (c) $T_1 < T_2$ (d) $T_2 = T_1^2$ 
Q2.	Two wires of same material have length L and 2L and cross–sectional areas 3A and A respectively. The ratio of their specific resistance would be (a) 1 : 3 (b) 3: 1 (c) 1 : 6 (d) 1 : 1
Q3.	Drift velocity v_d varies with the intensity of electric field as per the relation (a) v_d = constant (b) $v_d \propto E$ (c) $v_d \propto E^2$ (d) $v_d \propto 1/E$
Q4.	A cell of emf E and internal resistance r is connected across an external resistor R. The graph showing the variation of Potential difference across R versus R. 
Q5.	For a cell, the terminal potential difference is 3.6 V, when the circuit is open. If the potential difference reduces to 3 V, when cell is connected to a resistance of 5 Ω, the internal resistance of cell is (a) 8Ω (b) 2Ω (c) 1Ω (d) 4Ω
Q6.	A cell supplies a current of 0.9 A through a 2Ω resistor and a current of 0.3 A through 7Ω resistor. The internal resistance of the cell is (a) 2.0 Ω (b) 1.5Ω (c) 1.0Ω (d) 5Ω
Q7.	Kirchhoff's II law for the electric network is based on: (a) Law of conservation of charge (b) Law of conservation of energy (c) Law of conservation of angular momentum (d) Law of conservation of linear momentum
Q8.	In the given current distribution what is the value of I (a) 3A (b) 8 A (c) 2A (d) 5A 

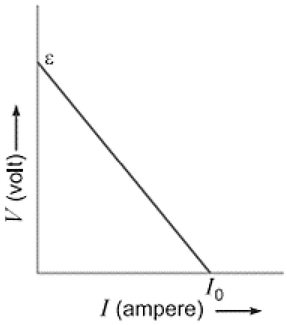
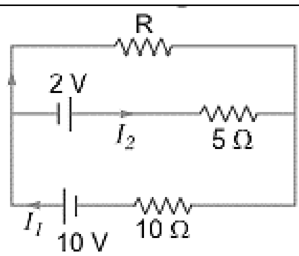
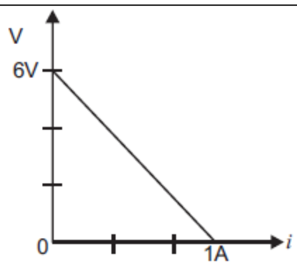
Q9.	What will be the electric current through branch BD of the electric network:  (a) 0.6 A (b) 0 A (c) 1 A (d) 10 A
Q10.	The ratio of current density and electric field is called: (a) Resistivity (b) Mobility (c) conductivity (d) Drift velocity

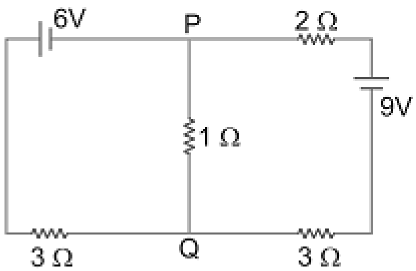
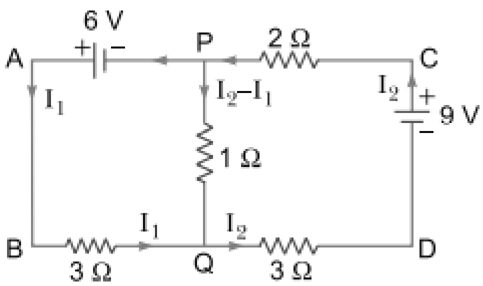
	ASSERTION REASON TYPE QUESTIONS
	Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:
	(a) Both A and R are true, and R is the correct explanation of A. (b) Both A and R are true, and R is NOT the correct explanation of A. (c) A is true but R is false. (d) A is false and R is also false.
Q11.	**Assertion (A) :** For a given conductor, electric current does not vary even if it's cross sectional area varies. **Reason (R)** : A conductor remains uncharged when current flows through it.
Q12.	**Assertion (A) :** A direction is associated with electric current. **Reason (R):** It does obey vector law of addition.
Q13.	**Assertion (A):** When a wire is stretched to double of its length, its resistivity doubles. **Reason (R):** The resistivity is directly proportional to the length of the conductor.
Q14.	**Assertion (A):** Ohm's law is applicable for all conducting elements. **Reason (R):** Ohm's law is a fundamental law.
Q15.	**Assertion (A):** Kirchhoff's junction law follows from the conservation of charges. **Reason:** Kirchhoff's loop law follows from the conservation of energy.
Q16.	**Assertion (A) :** Terminal voltage of a cell is greater than the emf of a cell during charging of the cell. **Reason (R):** Terminal voltage is the potential difference in open circuit condition.
Q17.	**Assertion (A)**: The resistivity of the alloy increases rapidly with increase of temperature. **Reason (R):** Alloys usually have much lower temperature coefficients of resistance than pure metals.

Q18.	**Assertion (A)**: A low voltage supply, from which high currents are to be withdrawn, must have very low internal resistance. **Reason (R):** Maximum current drawn from a source is inversely proportional to internal resistance.
Q 19.	**Assertion (A):** Instead of single 12 V battery, in a car eight dry cells of 1.5 V connected in series is generally used. **Reason:** Internal resistance of the combination of the cells becomes very low.
Q20.	**Assertion (A):** Current is passed through a metallic wire, heating it red. When cold water is poured on half of its portion, then the rest of the half portion becomes hotter. **Reason (R):** Resistances decrease due to decrease in temperature and so current through wire increases.

	<u>TWO MARKS QUESTIONS</u>
Q21.	Two conducting wires X and Y of same diameter but different materials are joined in series across a battery. If the number density of electrons in X is twice that in Y, find the ratio of drift velocity of electrons in the two wires.
Ans.	In series the current will be same $so, I_x = I_y = neAv_d$ For same diameter, cross-sectional area is same $A_x = A_y = A$ $\therefore n_x eAv_{dx} = n_y eAv_{dy}$ Given $n_x = 2n_y$ $\therefore \frac{v_{dx}}{v_{dy}} = \frac{n_y}{n_x} = \frac{1}{2}$
Q22.	The number density of free electrons in a copper conductor estimated is $8.5 \times 10^{28}\ m^{-3}$. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is $2.0 \times 10^{-6}\ m^2$ and it is carrying a current of 3.0 A.
Ans.	$n = 8.5 \times 10^{28} m^{-3}, l = 3m, A = 2 \times 10^{-6} m^2, e = 1.6 \times 10^{-19} C\ and\ I = 3\ A$ $Drift\ velocity, v_d = \frac{I}{neA} = \frac{3}{1.6 \times 10^{-19} \times 8.5 \times 10^{28} \times 2 \times 10^{-6}}\ ms^{-1}$ $v_d = \frac{3}{16 \times 85 \times 2 \times 10}$ $= 1.1 \times 10^{-4} ms^{-1}$ $\therefore Required\ time, t = \frac{l}{v_d} = \frac{3}{1.1 \times 10^{-4}}$ $or\ \ t = 2.73 \times 10^{4} s$

Q23.	A conductor of length 'l' is connected to a dc source of potential 'V'. If the length of the conductor is tripled by gradually stretching it keeping 'V' constant, how will (i) drift speed of electrons and (ii) resistance of the conductor be affected. Justify your answer.
Ans.	We know that $$v_d = -\frac{eE}{m}\tau = -\frac{eV}{ml}\tau \quad or\ v \propto \frac{1}{l}$$ ∴ When length is tripled, the drift velocity becomes one-third. New Resistance $$R' = \frac{\rho l'}{A'} = \frac{\rho 3l}{\frac{A}{3}} = 9R$$ Hence, the new resistance will be 9 times the original.
Q24.	Two wires A and B of the same material and having same length, have their cross sectional areas in the ratio 1 : 6. What would be the ratio of heat produced in these wires when same voltage is applied across each?
Ans.	$Given, \frac{A_A}{A_B} = \frac{1}{6}$ $$H = \frac{V^2}{R}t \quad and\ R = \rho\frac{l}{A}$$ $$H_A = \frac{V^2 t}{\frac{\rho l}{A_A}} \quad and\ H_B = \frac{V^2 t}{\frac{\rho l}{A_B}}$$ $$\Rightarrow \frac{H_A}{H_B} = H_A = \frac{V^2 t}{\rho l}A_A \times \frac{\rho l}{V^2 t A_B} = \frac{A_A}{A_B} = \frac{1}{6}$$
Q25.	Two cells of emf 1.5 V and 2 V and internal resistances 1Ω and 2Ω, respectively, are connected in parallel to pass a current in the same direction through and external resistance of 5Ω. Using Kirchhoff's laws calculate the current through each branch of the circuit. 
Ans	Applying Krichhoff's loop rule ABCDA $$5(I_1 + I_2) + I_1 = 1.5$$ $$or, 6I_1 + 5I_2 = 1.5 \qquad \dots\dots\dots(1)$$ In loop CDEFC $$5(I_1 + I_2) + 2I_2 = 2$$ $$or, 5I_1 + 7I_2 = 2 \qquad \dots\dots.(2)$$ Solving (1) and (2) $$I_1 = \frac{1}{34}A\ and\ I_2 = \frac{9}{34}A$$

Q26.	Plot a graph showing variation of voltage Vs the current drawn from the cell. How can one get information from this plot about the emf of the cell and its internal resistance?
Ans	Graph of voltage Vs current  $V = \varepsilon - Ir \Rightarrow r = \dfrac{\varepsilon - V}{I}$ At $I = 0, V = \varepsilon$ When $V = 0, \qquad I = I_o, r = \dfrac{\varepsilon}{I_0}$ The y- intercept gives the emf of the cell and the slope of graph gives the internal resistance.
Q27.	Two cells of emf 10 V and 2 V and internal resistance 10 Ω and 5 Ω respectively, are connected in parallel as shown. Find the effective voltage across R. 
Ans.	The effective voltage across R is given by $\dfrac{\varepsilon_{eq}}{r_{eq}} = \dfrac{\varepsilon_1}{r_1} + \dfrac{\varepsilon_2}{r_2}$ $and, \quad \dfrac{1}{r_{eq}} = \dfrac{1}{r_1} + \dfrac{1}{r_2}$ $or \dfrac{1}{r_{eq}} = \dfrac{1}{10} + \dfrac{1}{5} = \dfrac{3}{10}$ $\therefore \ \varepsilon_{eq} = \left(\dfrac{10}{10} - \dfrac{2}{5}\right) \times \dfrac{10}{3} = 2\ V$
Q28.	The plot of the variation of potential difference across a combination of three identical cells in series, versus current is as shown below. What is the emf and internal of each cell? 
Ans	Let ε be emf and r the internal resistance of each cell. The equation of terminal potential difference $V = \varepsilon_{eff} - ir_{int} = \varepsilon - ir_{int}$ ...... (1) where r_{int} is effective (total) internal resistance. From fig., when $i = 0, V = 6.0\ V$ From (1),

	$$6 = 3\varepsilon - 0 \;\; or\; \varepsilon = \frac{6}{3} = 2\,V = emf\ of\ each\,cell$$ And, when $i = 1\,A,\;\; V = \;0\,V$ $$0 = 6 - 1(r_{int}) \quad or\, r_{int} = 6\,\Omega$$ $$now\, r_{int} = r + r + r \quad or\, r = \frac{r_{int}}{3} = \frac{6}{3} = 2\,\Omega$$
Q29.	The potential difference across a resistor 'r' carrying current 'I' is Ir. (i) Now if the potential difference across 'r' is measured using a voltmeter of resistance 'R_V', show that the reading of voltmeter is less than the true value. (ii) Find the expression for the percentage error in measuring the potential difference by a voltmeter.
Ans.	(i) $V = Ir$ (without voltmeter R_V) $$V' = I\frac{rR_V}{r + R_V}$$ $$= \frac{Ir}{1 + \frac{r}{R_V}}$$ $$\Rightarrow V' < V$$ (ii) Percentage error $$\frac{\Delta V}{V} \times 100\ \% = \frac{V - V'}{V} \times 100\ \% = \left(\frac{r}{r + R_V}\right) 100\%$$
Q30.	Find the magnitude and direction of current in 1Ω resistor in the given circuit 
Ans	For the closed loop APQBA $$-6 - 1(I_2 - I_1) + 3I_1 = 0$$ $$or, 4I_1 - I_2 = 6 \qquad \ldots(1)$$ For loop PCDQP $$2I_2 - 9 + 3I_2 + 1(I_2 + I_1) = 0$$ $$or, -I_1 + 6I_2 = 9 \qquad \ldots(2)$$  By solving equation 1 and 2 $$I_1 = \frac{45}{23}A\;\; and\; I_2 = \frac{42}{23}A$$ $$\therefore\, current\ through\ the\ 1\Omega\ is = I_2 - I_1 = -\frac{3}{23}A$$

	THREE MARKS QUESTIONS
Q31.	Define current density. Deduce the relation connecting current density and conductivity of the conductor, when electric field E, is applied to it.
Ans	Current density at a point inside the conductor is defined as the amount of current flowing per unit area around that point of the conductor. $$j = \frac{I}{A}$$ current density is a vector quantity. SI unit of *j* is Am^{-2}. If E is the magnitude of electric field in a conductor of length *l*, then the potential difference across its end is $$V = El$$ Also, from Ohm's law $$V = IR = \frac{I\rho l}{A} \quad or, El = \frac{I\rho l}{A} \; or \; E = j\rho$$ Where $j = \frac{I}{A}$, is the current density. As the direction of current density $\vec{j}$ is same as that of electric field $\vec{E}$, we can write the above equation as $$\boxed{\vec{E} = \rho\vec{j}}$$ $$or, \boxed{\vec{j} = \sigma\vec{E}}$$ $$where\ \sigma = conductivity = \frac{1}{\rho}$$
Q32.	(a) Derive an expression for drift velocity of free electrons. (b) How does drift velocity of electrons in a metallic conductor vary with increase in temperature? Explain
Ans	(a) When a potential difference is applied across a conductor, an electric field is produced, and free electrons are acted upon by an electric force (Fe). Due to this, electrons accelerate and keep colliding with each other and acquire a constant (average) velocity v_d called drift velocity. Electric force on electron $\overrightarrow{F_e} = -\ e\vec{E}$ If m is the mass of electron, then its acceleration $$\overrightarrow{a} = \frac{\overrightarrow{F_e}}{m} = -\frac{e\,\overrightarrow{E}}{m}$$ Now, according to the equation of motion for constant accelerated motion $$v = u + at$$ Here u = thermal velocity = 0, t = τ = relaxation time and v= drift velocity = v_d $$\therefore \overrightarrow{v_d} = -\frac{e\,\overrightarrow{E}}{m}\tau$$ (b) With rise of temperature, the rate of collision of electrons with ions increases, so relaxation time decreases. As a result, the drift velocity of electrons decreases with the rise of temperature.

<table>
<tr><td>Q33.</td><td>A potential difference V is applied across the ends of copper wire of length l and diameter D. What is the effect on drift velocity of electrons if

(a) V is halved?
(b) l is doubled?
(c) D is halved?</td></tr>
<tr><td>Ans</td><td>Drift velocity,

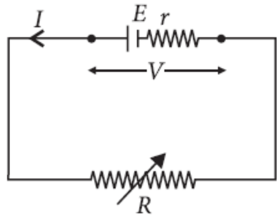
$$v_d = \frac{I}{neA} = \frac{V}{RneA} = \frac{V}{neA\left(\frac{\rho l}{A}\right)} = \frac{V}{ne\rho l}$$

(i) As $v_d \propto V$, when V is halved the drift velocity is halved.

(ii) As$v_d \propto \frac{1}{l}$, when l is doubled the drift velocity is halved.

(iii) As v_d is independent of D, when D is halved drift velocity remains unchanged.</td></tr>
<tr><td>Q34.</td><td>A cell of emf ‘E’ and internal resistance ‘r’ is connected across a variable load resistor R. Draw the plots of the terminal voltage V versus (i) R and (ii) the current I.

It is found that when $R = 4\ \Omega$, the current is $1\ A$ and when R is increased to $9\ \Omega$, the current reduces to $0.5\ A$. Find the values of the emf E and internal resistance r.</td></tr>
<tr><td>Ans</td><td>Given situation is shown in the figure



$$I = \frac{E}{R+r}$$

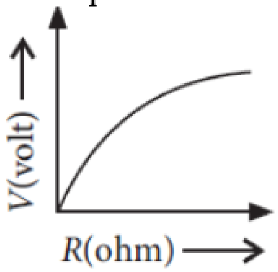
Terminal voltage

$$V = E - Ir = E - \frac{E}{R+r}r = \frac{ER}{R+r}$$

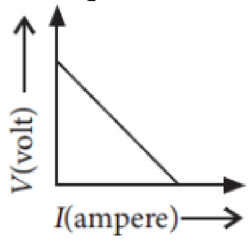
Terminal voltage

$$V = E - Ir = E - \frac{E}{R+r}r = \frac{ER}{R+r}$$

Graph: V vs R



Graph: V vs I



When $R = 4\Omega, I = 1A$

$$\therefore 1 = \frac{E}{4+r} \quad or\ E = 4 + r \qquad ....(i)$$

When $R = 9\Omega, I = 0.5\ A$

$$\therefore \frac{1}{2} = \frac{E}{9+r} = \frac{4+r}{9+r} \qquad [usig\ (i)]$$

$$or\ 9 + r = 8 + 2r \quad or\ r = 1\ \Omega$$

From eq (i)

$$E = 4 + r = 4 + 1 = 5\ V$$</td></tr>
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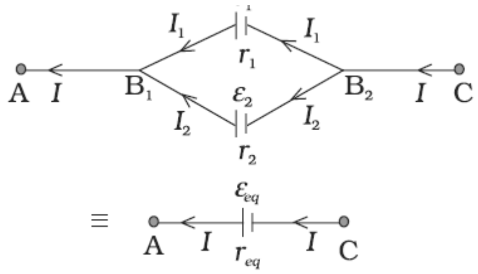
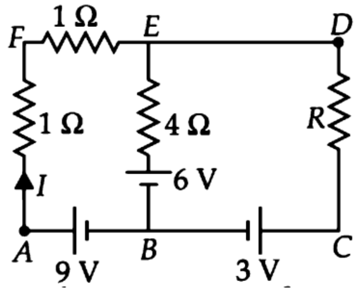
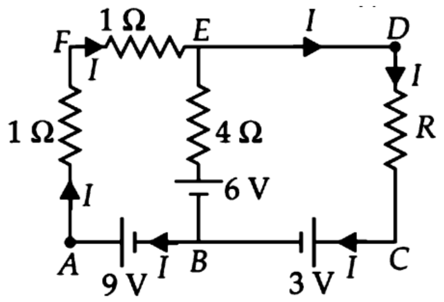
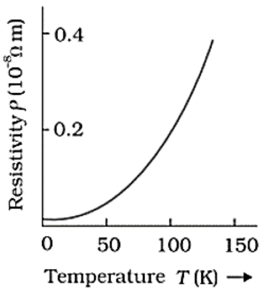
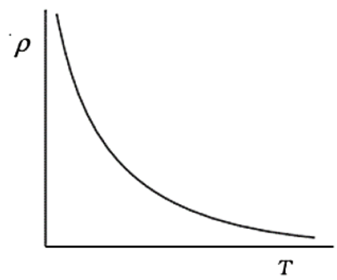
Q35.	Two cells of emf E_1 and E_2 have internal resistance r_1 and r_2. Deduce an expression for equivalent emf of their parallel combination.
Ans.	 Consider a parallel combination of the cells. I_1 and I_2 are the currents leaving the positive electrodes of the cells. At the point B_1, I_1 and I_2 flow in whereas the current I flow out. Since as much charge flows in as out, we have $I = I_1 + I_2$ Let V (B_1) and V (B_2) be the potentials at B_1 and B_2, respectively. Then, considering the first cell, the potential difference across its terminals is V (B_1) – V (B_2). Hence, $V = V(B_1) - V(B_2) = \varepsilon_1 - I_1 r_2$ $\Rightarrow I_1 = \frac{\varepsilon_1 - V}{r_1}$ For the second cell $V = V(B_1) - V(B_2) = \varepsilon_2 - I_2 r_2$ $\Rightarrow I_2 = \frac{\varepsilon_2 - V}{r_2}$ $Now, I = I_1 + I_2$ $I = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2} = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$ $or\ V = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} - I\left(\frac{r_1 r_2}{r_1 + r_2}\right)$ $or, V = \varepsilon_{eq} - I r_{eq}$ $where\ \varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$ $and\ r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$ $or, in\ simpler\ way\ \boxed{\frac{I}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}} \qquad and, \boxed{\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}}$
Q36.	Using Kirchhoff's rules determine the value of unknown resistance R in the circuit so that no current flows through 4Ω resistance. Also find the potential difference between A and D. 

Ans	As no current flows through 4Ω, the current in various branches as shown in the figure. Applying Kirchhff's loop rule to the closed loop AFEBA, we get  $$-I - I - 4 \times 0 - 6 + 9 = 0$$ $$or\ 9 - 6 - 2I = 0\ or\ 2I = 3$$ $$or, I = \frac{3}{2}A \quad \ldots\ldots(i)$$ Again, applying Kirchhoff's loop rule to the closed loop BEDCB, we get $$6 + 4 \times 0 - IR - 3 = 0\ or\ IR = 3$$ $$R = \frac{3}{I} = 3 \times \frac{2}{3} = 2\Omega \quad using\ (i)$$ Potential difference between A and D = Potential difference A and E $$\therefore V_{AD} = 2I = 2 \times \frac{3}{2} = 3V$$
Q37.	Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons.
Ans	Consider a conductor of a length *l* and of uniform area of cross section *A*. ∴ Volume of the conductor = *Al* If *n* is the number density of electrons, then the total number of free electrons in the conductor = *Aln*. If *e* is the charge on each electron, the total charge on all the free electrons in the conductor, ***q=Alne*** Now, let a constant potential difference *V* be applied across the ends of the conductor. The electric field setup across the conductor is then given by, $$E = \frac{V}{l}$$ Due to this field the free electrons present in the conductor will begin to move with a drift velocity v_d and the time taken by the free electrons to cross the conductor will be, $$t = \frac{l}{v_d}$$ Hence the current $$I = \frac{q}{t} = \frac{Alne}{l/v_d}$$ $$\therefore I = neAv_d\ \ or \frac{I}{A} = j = nev_d \Rightarrow j \propto v_d$$
Q38.	Show, on a plot, variation of resistivity of (i) a conductor, and (ii) a typical semiconductor as a function of temperature. Using the expression for the resistivity in terms of number density and relaxation time between the collisions, explain how resistivity in the case of a conductor increases while it decreases in a semiconductor, with the rise of temperature.

Ans



Resistivity ρ_T of a metal as a function of temperature T



Resistivity ρ_T of a semiconductor as a function of temperature T

We know that

$$\rho = \frac{m}{ne^2\tau}$$

Where m is mass of electron n = charge density, τ = relaxation time, e = charge on the electron.

(i) In case of conductors with increase in temperature, relaxation time decreases, so resistivity increases.

(ii) In case of semiconductors with increase in temperature number density (n) of free electrons increases, hence resistivity decreases.

Q39. The following table gives the length of three copper wires, their diameters, and the applied potential difference across their ends. Arrange the wires in increasing order according to the following:

(i) the magnitude of the electric field within them,

(ii) the drift speed of electrons through them, and

(iii) the current density within them

Wire No.	Length	Diameter	Potential difference
1	L	3d	V
2	2L	d	V
3	3L	2d	2V

Ans (i)

$$E_1 = \frac{V}{L}, E_2 = \frac{V}{2L}, E_3 = \frac{2V}{3L}$$

$$\Rightarrow E_2 < E_3 < E_1$$

(ii)

$$|\vec{v}_d| = \frac{eE}{m}\tau \quad or\ v_d \propto E$$

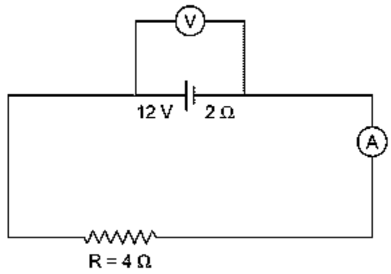
$$\Rightarrow v_{d_2} < v_{d_3} < v_{d_1}$$

(iii) $I = neAv_d$

$$current\ density, j = \frac{I}{A} = nev_d \ \ or\ j \propto v_d \quad \Rightarrow j_2 < j_3 < j_1$$

Q40. (a) The potential difference applied across a given resistor is altered so that the heat produced per second increases by a factor of 9. By what factor does the applied potential difference change?

(b) In the figure shown, an ammeter A and a resistor of 4 Ω are connected to the terminals of the source. The emf of the source is 12 V having an internal resistance of 2 Ω. Calculate the voltmeter and ammeter readings.



Ans (a) Heat produced per second (power), $P = I^2R = \frac{V^2}{R}$

Given,

$$P' = 9P$$

$$\therefore \frac{V'^2}{R} = 9 \times \frac{V^2}{R} \quad or\ V' = 3V$$

∴ potential difference increases by factor of 3

(b) Given emf, E = 12 V

Internal resistance, $r = 2\Omega$, external resistance $R = 14\Omega$

Ammeter reading,

$$I = \frac{E}{R+r} = \frac{12}{4+2} = \frac{12}{6}A = 2A$$

Voltmeter reading

$$V = E - Ir = 12 - (2 \times 2) = 8\,V$$

FIVE MARKS QUESTIONS

Q41 (a) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductor depend?

(b) Why alloys like constantan and manganin are used for making standard resistors?

(a) Consider a conductor of length l and cross-sectional area A. When a potential difference V is applied across its ends, the current produced is I. If n is the number of electrons per unit volume in the conductor and v_d the drift velocity of electrons, then

$$I = neAv_d$$

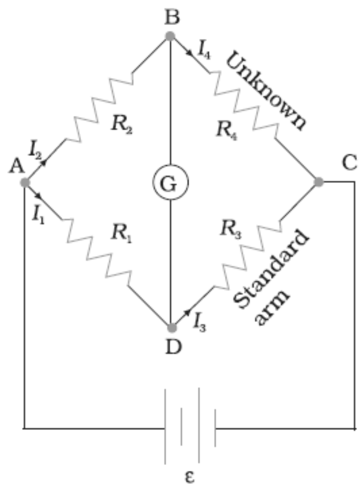
If τ is the relaxation time and E is the electric field strength, then drift velocity,

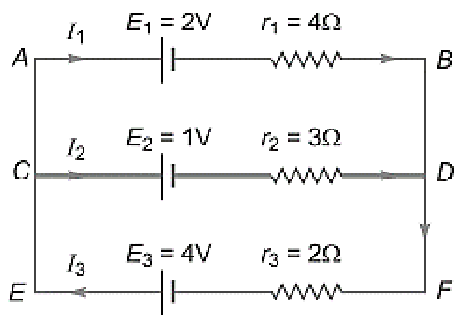
If τ is the relaxation time and E is the electric field strength, then

$$\vec{v}_d = -\frac{e\vec{E}}{m}\tau$$

where E is the applied field and τ is the relaxation time. If applied field is due to a potential difference V across a conductor of length l then,

	$E = -\frac{V}{l} \qquad \therefore v_d = \frac{eV}{ml}\tau$ Also, $I = neAv_d or, I = neA\frac{eV}{ml}\tau = \left(\frac{ne^2A\tau}{ml}\right)V$ According to Ohm's law $V = IR$ ∴ comparing above two equations R = $\frac{ml}{ne^2A\tau} = \rho\frac{l}{A} \qquad or\ \rho = \frac{m}{ne^2\tau}$ Clearly, resistivity of a conductor is inversely proportional to number density of electrons and relaxation time. (b) Resistivity of the material of a conductor depends upon the relaxation time, i.e., temperature and the number density of electrons. This is because constantan and manganin show very weak dependence of resistivity on temperature.
Q42.	(a) Derive an expression for drift velocity of electrons in a conductor. Hence deduce Ohm's law. (b) A wire whose cross-sectional area is increasing linearly from its one end to the other, is connected across a battery of V volts. Which of the following quantities remain constant in the wire ? (i) drift speed, (ii) current density, (iii) electric current and (iv) electric field Justify your answer
Ans	(a) Let an electric field E be applied to the conductor. Electric force on electron $\vec{F_e} = -e\vec{E}$ If m is the mass of electron, then its acceleration $$\vec{a} = \frac{\vec{F_e}}{m} = -\frac{e\vec{E}}{m}$$ Now, according to the equation of motion for constant accelerated motion $$v = u + at$$ Here u = thermal velocity = 0, t = τ = relaxation time and v= drift velocity = v_d $$\therefore \vec{v_d} = -\frac{e\vec{E}}{m}\tau$$ Now the amount of charge with number density n, crossing area A, in time Δt will be $$= neAv_d\Delta t = I\Delta t$$ $$\Rightarrow I = neAv_d$$ $$or\ I = neA\left(\frac{eE}{m}\tau\right) = \frac{ne^2A\tau}{m}E$$ $$or\ I = \left(\frac{1}{\rho}A\right)\frac{V}{l} \qquad \left(\because \rho = \frac{m}{ne^2} and\ E = \frac{V}{l}\right)$$ $$or, I = \frac{V}{R}\ or\ V = IR\ \left(\because R = \rho\frac{l}{A}\right)$$ This is Ohm's law. (b) Current density will remain constant in the wire. All other quantities, depend on the cross-sectional area of the wire

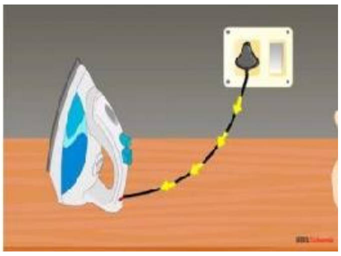
Q43.	(a) Define mobility. Deduce the relationship between the mobility and the current flowing in a conductor. (b) The number density of electrons in copper is $8.5\times\ 10^{28}m^3$. Determine the current flowing through a copper wire of length $0.2\ m$, area of cross-section $1\ mm^2$, when connected to a battery of 3 V. Given the electron mobility = $4.5\times 10^{-6}m^2V^{-1}s^{-1}$ and charge on electron = $1.6\times\ 10^-19\ C$.
Ans	(a) Mobility μ is defined as the magnitude of the drift velocity per unit electric field. $$\mu=\frac{\lvert v_d\rvert}{E}\quad \mu=\frac{q\tau}{m}$$ SI unit of Mobility is $m^2s^{-1}V^{-1} or\ ms^{-1}N^{-1}C$ Relation between current and mobility $$I=Anev_d\ \ and\ v_d=\mu E$$ $$\therefore \boxed{I=Ane\mu E}$$ (b) Here $\mathrm{n}=8.5\times\ 10^{28}m^3, l=0.2m, A=1mm^2=10^{-6}m^2$, $$V=3V,\mu=4.5\times10^{-6}m^2V^{-1}s^{-1}$$ Electric field in the copper wire, $$E=\frac{V}{l}=\frac{3}{0.2}=15\ Vm^{-1}$$ Current = $I=Ane\mu E=10^{-6}\times8.5\times10^{28}\times1.6\times10^{-19}\times4.5\times10^{-6}\times15$ $$=0.918\ A$$
Q44.	(a) State Kirchhoff's loop rule. (b) Draw a circuit diagram showing balancing of Wheatstone bridge. Use Kirchhoff's rules to obtain the balance condition in terms of the resistances of four arms of Wheatstone Bridge.
Ans	(a) Kirchhoff's second law or Voltage rule or Loop rule: The algebraic sum of all the potential drops and emfs along any closed path in a network is zero
	(b) Wheatstone bridge is a measuring instrument used to determine the resistance of unknown resistor by applying Kirchhoff's rules. It is a network of four resistor arranged in the form of a quadrilateral as shown in the figure. It is also known as a bridge circuit. The bridge is said to be balanced when no current pass through the galvanometer. Under this condition the ratios.  $$\frac{R_2}{R_1}=\frac{R_4}{R_3}$$ **Derivation of balanced condition** Considering the circuit and if the cell has negligible internal resistance, we can adjust the bridge such that current through the galvanometer is zero. In this case, the Kirchhoff's junction rule applied to junctions D and B gives $I_1=I_3\ and\ I_2=I_4$

	Now applying Kirchhoff's loop rule to closed loop ADBA gives $$-I_1R_1 + 0 + I_2R_2 = 0 \qquad (\because I_g = 0)$$ $$or \frac{I_1}{I_2} = \frac{R_2}{R_1} ------------ (1)$$ and from closed loop CBDC $$I_4R_4 + 0 - I_3R_3 = 0 \quad (\because I_g = 0) \qquad or \qquad I_2R_4 + 0 - I_1R_3 = 0$$ $$\Rightarrow \frac{I_1}{I_2} = \frac{R_4}{R_3} ------------ (2)$$ From eq (1) and (2) $$\frac{R_2}{R_1} = \frac{R_4}{R_3}$$
Q45.	(a) State the two Kirchhoff's laws. Explain briefly how these rules are justified. (b) Using Kirchhoff's rules, calculate the current in the arm AC of the given circuit. 
Ans	(a) **Kirchhoff's junction rule:** The algebraic sum of currents meeting at any junction is zero, i.e., $\sum I = 0$ This law is based on the law of conservation of charge. When currents in a circuit are steady, charges cannot accumulate or originate at any point of the circuit. So whatever charge flows towards the junction in any time interval, an equal charge must flow away from that junction in the same time interval. **Kirchooff's loop rule:** The algebraic sum of potential differences across circuit elements of a closed circuit is zero, i.e., $\sum V = 0$ This is cosequence of conservation of energy. (b) From Kirchhoff's first law, $I_3 = I_1 + I_2 \qquad ...(i)$ Applying Kirchooff's second law in loop ABDCA $$-2 - 4I_1 + 3I_2 + 1 = 0 \Rightarrow 4I_1 - 3I_2 = -1 \qquad ...(ii)$$ Applying Kirchoff 's second law to loop ABFEA $$-2 - 4I_1 - 2I_3 + 4 = 0 \Rightarrow 4I_1 + 2I_3 = 2 \; or \; 2I_1 + I_3 = 1$$ Using (i) we get $$\Rightarrow 2I_1 + (I_1 + I_2) = 1 \; or \; 3I_1 + I_2 = 1 \qquad ...(iii)$$ Solving (ii) and (iii), we get $$I_1 = \frac{2}{13}A, I_2 = I - 3I_1 = \frac{7}{13}A \qquad so, I_3 = I_1 + I_2 = \frac{9}{13}A$$

CASE STUDY - BASED QUESTIONS

Q46. **Case Study – Heating effect of current**

Whenever an electric current is passed through a conductor, it becomes hot after some time. The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating. Thus, the electrical energy supplied by the source of emf is converted into heat. In purely resistive circuit, the energy expended by the source entirely appears as heat. But if the circuit has an active element like a motor, then a part of energy supplied by the source goes to do useful work and the rest appears as heat. Joule's law of heating forms the basis of various electrical appliances such as electric bulb, electric room heater, electric press etc.



(i) Which of the following is correct statement?

(a) Heat produced in a conductor is independent of the current flowing.

(b) Heat produced in a conductor varies inversely as the current flowing.

(c) Heat produced in a conductor varies directly as the square of the current flowing.

(d) Heat produced in a conductor varies inversely as the square of the current flowing.

(ii) A 25 W and 100 W are joined in series and connected to the mains. Which bulb will glow

brighter? Why?

(iii) If the coil of a heater is cut to half, what would happen to heat produced? Explain.

(iv) Explain how electrical fuse works based on heating effect of current.

Ans (i) (c) Heat produced in a conductor varies directly as the square of the current flowing.

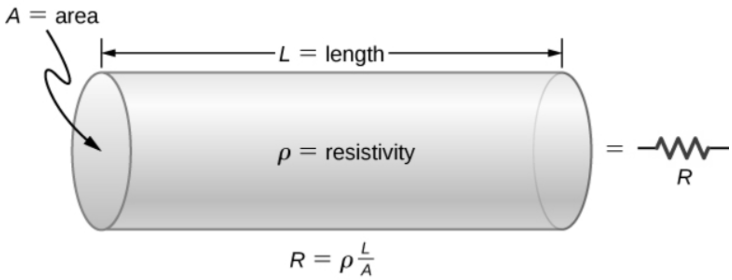
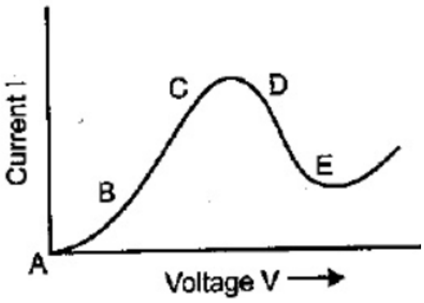
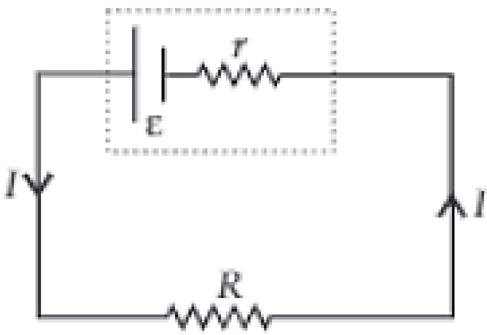
(ii) In series I remains same, now $P = I^2R$, 100 W will have more resistance hence will glow brighter.

(iii) $R \propto l \; and \; H = I^2Rt \therefore$ if the coil is cut to half, the heat produced will becomes half.

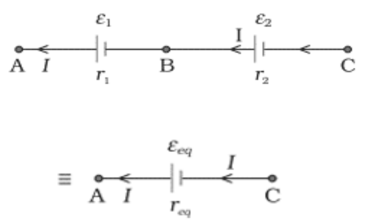
(iv) Electrical fuse works on the principle of heating effect of electric current. When a current more than the rated amount passes through a fuse, it melts due to excessive heating and breaks the circuit and the current stops flowing.

Q47. **Case Study – Resistance and Resistivity**

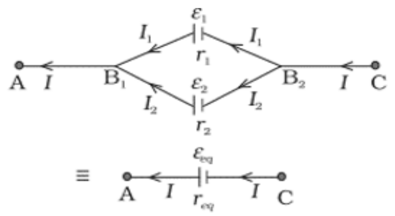
Resistance is a measure of the opposition to current flow in an electrical circuit. Resistance is measured in ohms. Resistivity is the electrical resistance of a conductor of unit cross-sectional area, and unit length. Resistivity is the characteristic property

	of each material and is useful in comparing various materials based on their ability to conduct electric currents. The resistance of the material depends on the length, cross-section and area of conductor whereas the resistivity depends on the nature and temperature of the material.  (i) What will happen to the resistance and resistivity of a material if the radius of the cross-section is doubled keeping all other parameters constant? (ii) A copper wire having the same size as steel wire have: (a) more resistance (b) less resistance (c) same resistance (d) none of the above (iii) How does the resistivity if a conductor varies with temperature? (iv) Graph showing the variation of current versus voltage for a material GaAs is shown in the figure. Identify the region of (i) negative resistance (ii) where Ohm's law is obeyed. 
Ans	(i) Resistance becomes ¼ but the resistivity remains same. (ii) (b) less resistance (iii) Resistivity of the conductor increases with the increase of temperature. (iv) DE – negative and Ohm's law is obeyed in region BC.
Q48.	**<u>Case Study – Relation between V, ε and r of a cell</u>** Emf (ε)of a cell is the maximum potential difference between two electrodes of the cell when no current is drawn from the cell. Internal resistance (r) is the resistance offered by the electrolyte of a cell when the electric current flows through it. The internal resistance of a cell depends upon the following factors: 

	(A) distance between the electrodes (B) nature and temperature of the electrolyte (C) nature of electrodes (D) area of electrodes. For a freshly prepared cell, the value of internal resistance is generally low and goes on increasing as the cell is put to more and more use. The potential difference between the two electrodes of a cell in a closed circuit is called terminal potential difference and its value is always less than the emf of the cell in a closed circuit. It can be written as $V = \varepsilon - Ir$ (i) When will be the terminal potential difference of two electrodes of a cell is equal to emf of the cell? (ii) A cell of emf ε and internal resistance r gives a current of 0.5 A with an external resistance of 12 Ω and a current of 0.25 A with an external resistance of 25 Ω. What is the value of internal resistance of the cell? (iii) An external resistance R is connected to a cell of internal resistance r, the maximum current flows in the external resistance, when (a) R = r (b) R < r (c) R> r (d) R= 1/r (iv) While charging of a cell, the terminal voltage will be greater than the emf of a cell. Why?
Ans	(i) under open circuit condition (I=0) the terminal potential difference of two electrodes of a cell is equal to emf of the cell (ii) As $I = \frac{\varepsilon}{R+r}$ In first case $0.5 = \frac{\varepsilon}{12+r} \quad or\ \varepsilon = 6 + 0.5r \quad ...(i)$ In second case $0.25 = \frac{\varepsilon}{25+r} \quad or\ \varepsilon = 6.25 + 0.25r \quad ...(ii)$ From (i) and (ii), $r = 1\Omega$ (iii) (a) R=r (iv) As during charging the current is driven through the battery in the opposite direction, a terminal voltage can be higher than EMF.
Q49.	**Case Study – Combination of Cells** A single cell provides a feeble current. To get higher current in a circuit we use combination of cells. Cells can be joined in series and in parallel and in a mixed way. Two cells are said to be connected in series when negative of one cell in connected to the positive of the other cell and so on. Cells are said to be connected in parallel when positive terminal of each cell is connected to one point and negative terminal of each cell is connected to another point. In mixed grouping of cells certain number of cells are joined in series and all such rows are connected in parallel with each other.



Two cells of emf ε_1 and ε_2 connected in series



Two cells of emf ε_1 *and* ε_2 connected in parallel

(i) Two identical cells when connected in series or in parallel, supply the same amount of current through an external resistance of 2Ω. What will be the internal resistance of each cell?

(ii) What will be the total emf of the combination of cells, when ‘n’ identical cells each of emf E are connected in parallel?

(iii) Out of ‘n’ cells, each having emf ‘E’ and internal resistance ‘r’, two are connected in series and rest in parallel. What will be the total internal resistance of the combination?

(iv) In parallel combination of ‘n’ cells, we obtain

(a) more voltage (b) more current (c) less voltage (d) more current

Ans

(i) In series $I_s = \frac{2E}{2+2r}$

In parallel $I_p = \frac{E}{2+\frac{r}{2}} = \frac{2E}{4+r}$

Since $I_s = I_p$, equating both the equations, r= 2Ω

(ii) E

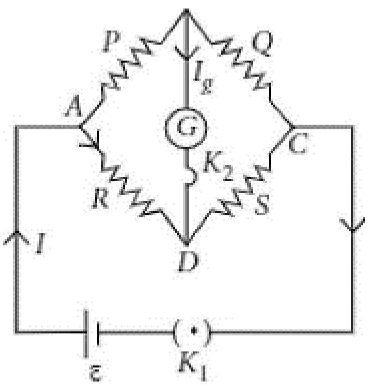
(iii) nr

(iv) (b) more current

Q50. **Case Study – Wheatstone Bridge and its application**

Wheatstone bridge is an arrangement of four resistances P, Q, P and S connected as shown in the figure. Their values are so adjusted that the galvanometer G shows no deflection. The bridge is then said to be balanced when this condition is achieved happens. In the setup shown here, the points B and D are at the same potential, and it can be shown that

$$\frac{P}{Q} = \frac{R}{S}$$



This is called the balancing condition. If any three resistances are known, the fourth can be found. The practical form of Wheatstone bridge is slide wire bridge or Meter bridge. Using

$$S = \frac{100 - l}{l} \times R$$

	the unknown resistance can be determined as where l is the balancing length of the Meter bridge (i) In a Wheatstone bridge circuit, P = 5 Ω, Q = 6 Ω, R = 10 Ω and S = 5 Ω. What is the value of additional resistance to be used in series with S, so that the bridge is balanced? (ii) When will be a Wheatstone bridge considered most sensitive? (iii) What will be the change in the balance point if the galvanometer and the cell are interchanged? (iv) The percentage error in measuring resistance with a meter bridge can be minimized by adjusting the balancing point close to (a) 0 (b) 20 cm (c) 50 cm (d) 80 cm
Ans.	(i) 7 Ω in series makes resistance S= 12 Ω and bridge becomes balanced as $\frac{P}{Q} = \frac{R}{S}$ (ii) A Wheatstone bridge is said to have maximum sensitivity when it is in balanced state and the magnitude of resistors attached in the bridge are of the same magnitude. (iii) Balanced condition will not change. (iv) (c)50 cm

Correct options of MCQs and A-R based questions

MCQs		Assertion-Reason based questions	
Question No.	**Correct Option**	**Question No.**	**Correct Option**
1	(b) $T_1 > T_2$	**11**	(b) Both A and R are true, and R is NOT the correct explanation of A.
2	(d) 1 : 1	**12**	(c) A is true but R is false.
3	(b)) $v_d \propto E$	**13**	(d) A is false and R is also false.
4	(a)	**14**	(d) A is false and R is also false.
5	(c) 1Ω	**15**	(b) Both A and R are true, and R is NOT the correct explanation of A.
6	(d) 5Ω	**16**	(c) A is true but R is false.
7	(b) Law of conservation of energy	**17**	(d) A is false and R is also false.
8	(c) 2A	**18**	(a) Both A and R are true, and R is the correct explanation of A
9	(b) 0A	**19**	(d) A is false and R is also false.
10	(c)conductivity	**20**	(a) Both A and R are true, and R is the correct explanation of A

CHAPER 4 - MOVING CHARGES AND MAGNETISM

GIST OF THE CHAPTER.

- CONCLUSION OF OERSTED EXPERIMENT : Moving charges or currents produced a magnetic field in the surrounding space.
- Magnetic field , Lorentz force – The force on an electric charge due to both electric and magnetic field can be written as - $\vec{F}$ = q [$\vec{E}$ + ($\vec{v}$ x $\vec{B}$)]. = **F**electric + **F**magnetic .
- $\vec{F}_{magnetic}$ = q ($\vec{v}$ x $\vec{B}$) . The direction of the force is perpendicular to both $\vec{v}$ and $\vec{B}$.
- Magnetic force on negative charge is opposite to that of a positive charge.
- Force due to magnetic field becomes zero if velocity and magnetic field are parallel or anti parallel .
- The magnetic force is experienced by only a moving charge.
- A straight conductor of length l and carrying a steady current I experiences a force $\overrightarrow{F}$ in a uniform external magnetic field $\vec{B}$. $\vec{F}$ = I $\vec{l}$ x $\vec{B}$; where I$\vec{l}$I = length of the conductor and its direction is given by the direction of the current .
- MOTION IN A MAGNETIC FIELD :
  (a) If a charge particle enters parallel or antiparallel to the direction of magnetic field it follows straight line path.
  (b) If a charge particle enters perpendicularly to the magnetic field (θ = 90^0) , then F = Bqv and charge executes a circular orbit in a plane normal to $\vec{B}$.
  The radius of the circular path is given as r = $\frac{mv}{Bq}$.
  If ω is the angular frequency then , $2\pi\nu$ = Bq/m . Time period of revolution is T = $2\pi/\omega$ = $\frac{2\pi m}{Bq}$.
  (c) If $0^0 < \theta < 90^0$, the path of the charge particle is helix . v cosθ is responsible for linear motion while v sinθ is responsible for circular motion . Hence , trajectory is a helical path . The radius of circular path followed by it is r = $\frac{mv\,sin\theta}{Bq}$ and the pitch of the helical path is $\frac{2\pi mv\,cos\theta}{Bq}$.

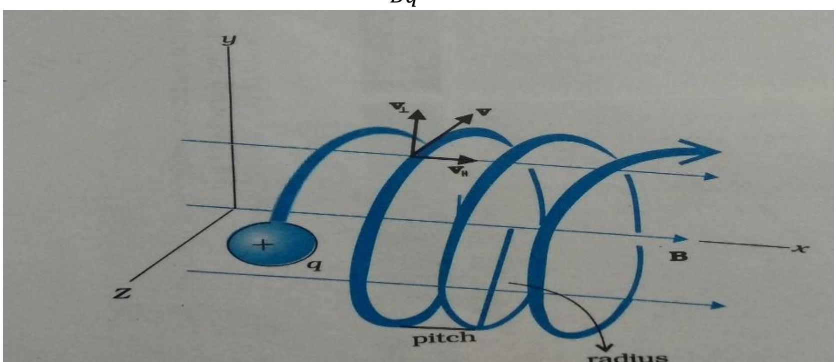
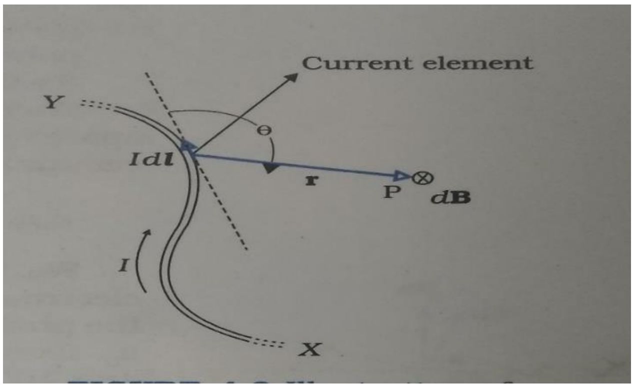


FIGURE 4.6 Helical motion

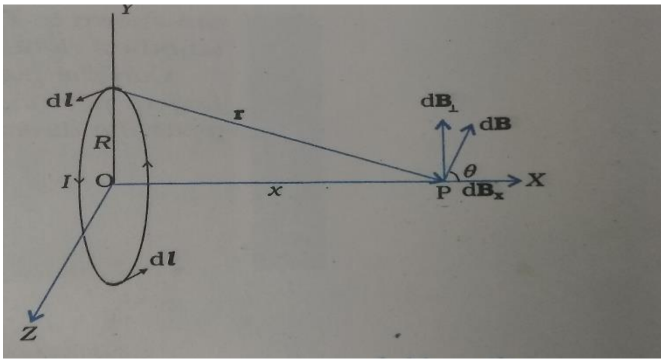
- BIOT SAVART LAW : It gives the magnetic field $\overrightarrow{dB}$ due to an element $\overrightarrow{dl}$ carrying a steady current I at a point P at a distance r from the current element is

$\overrightarrow{dB} = \frac{\mu 0}{4\pi} I \frac{\vec{dl} \, X \, \vec{r}}{r^3}$. To obtain the total field at P , this vector expression is integrated over the entire length of the conductor.



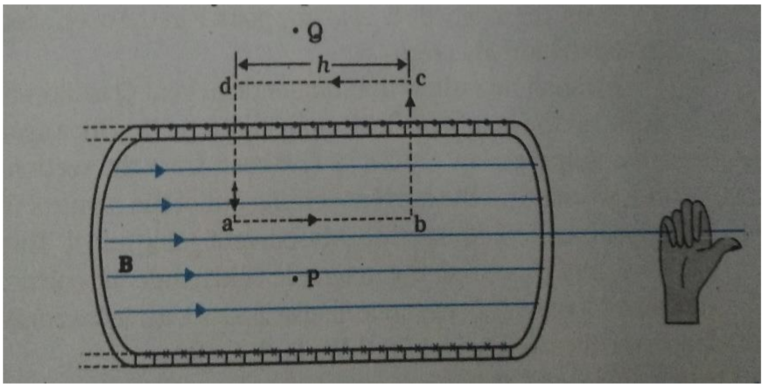
- The magnitude of the magnetic field due to a circular coil of radius R carrying current I at an axial distance x from the centre is given as –

$$B = \frac{\mu 0 \, I \, R^2}{2\,(x^2+R^2)^3/2}.$$

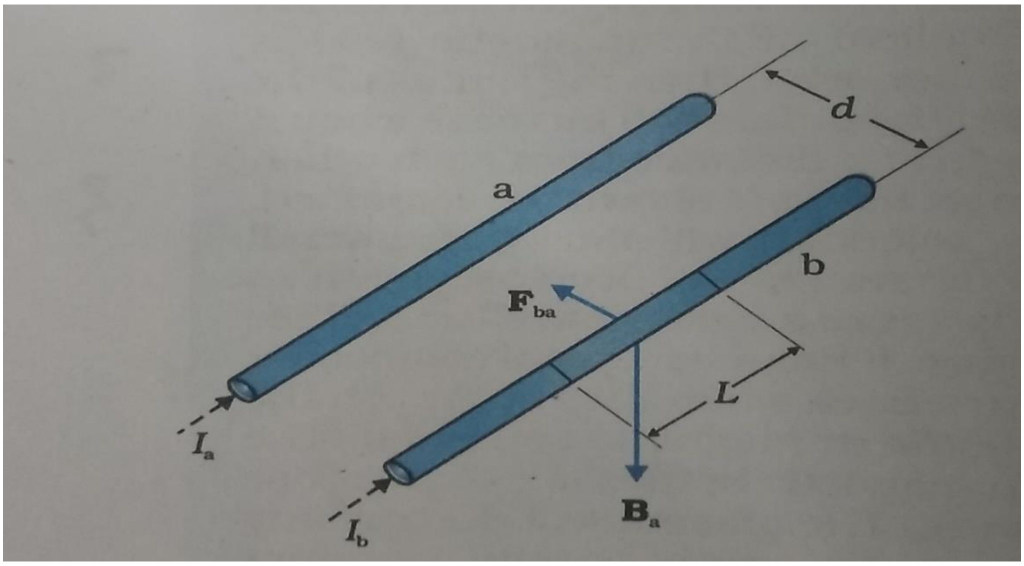


At the centre this reduces to $B = \frac{\mu 0 \, I}{2R}$.

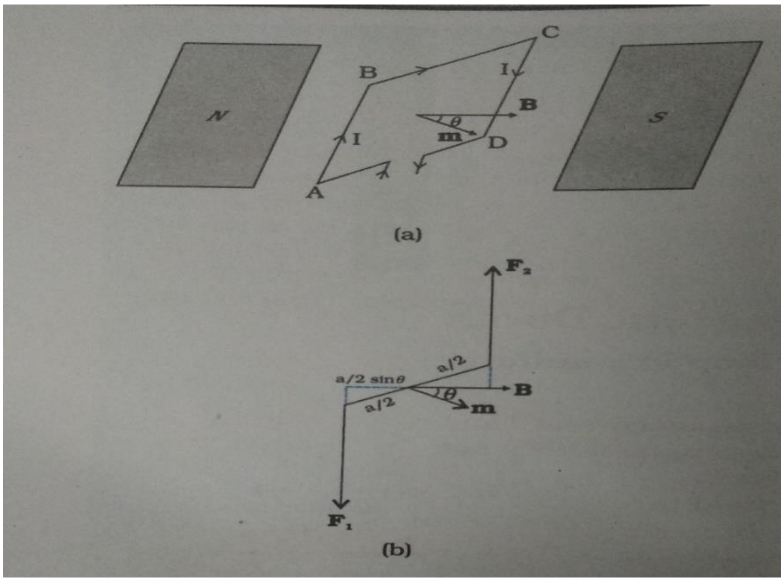
- AMPERE'S CIRCUITAL LAW : Considering an open surface S bounded by a loop C . Then Ampere's circuital law states that $\oint \vec{B} \,.\, \vec{dl} = \mu 0$ I , where I refers to the current passing through S . The sign of I is determined from the right hand rule .
  If $\vec{B}$ is directed along the tangent to every point on the perimeter L of a closed curve and is constant in magnitude along perimeter then . BL = $\mu 0 \, I_e$, where I_e is the net current enclosed by the closed circuit .
- APPLICATIONS :
  (a) The magnitude of the magnetic field at a distance R from a long straight wire carrying current I is given by $B = \frac{\mu 0 \, I}{2\pi R}$.
  The field lines are circles concentric with the wire.
  (b) The magnitude of the magnetic field B inside a long solenoid carrying a current I is B = $\mu 0$n I , where n is the number of turns per unit length .



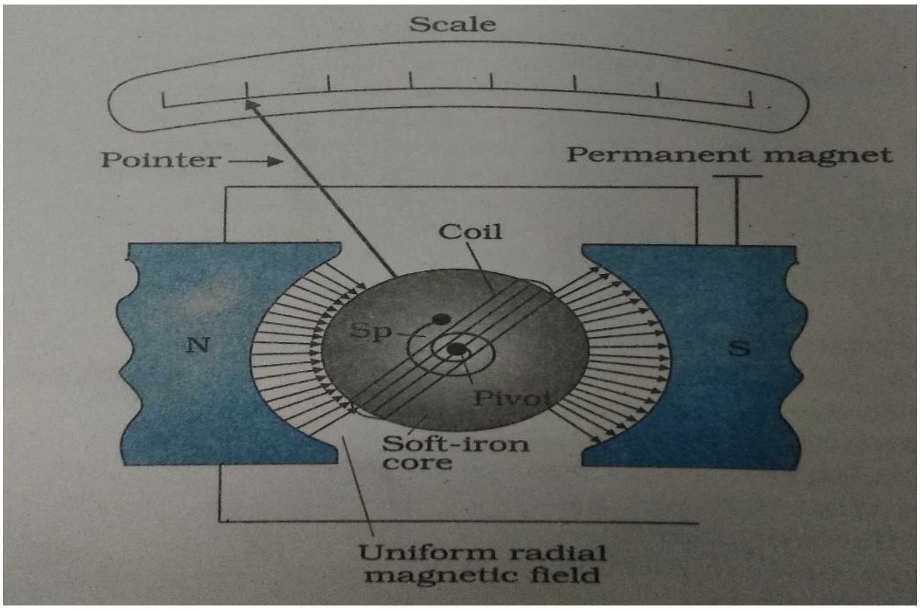
- FORCE BETWEEN TWO PARALLEL CURRENTS , THE AMPERE: Force per unit length between parallel infinitely long current carrying straight conductor is given by
  F/L = $\mu0$ $I_1I_2/2\pi d$, where I_1 and I_2 are currents in the two parallel conductors separated by distance 'd' .



- 1 Ampere – 1 Ampere is the value of that steady current which when maintained in each of the two very long , straight , parallel conductors of negligible cross – section , and placed 1 m apart in vacuum , would produce on each of these conductors a force equal to 2 x 10^{-7} N per metre of length.
- Parallel currents attract and anti parallel currents repel.
- A planar loop carrying current I , having N closely wound turns and N area A possesses a magnetic moment $\vec{m}$, where $\vec{m}$ = N I $\vec{A}$. The direction of magnetic moment is given by the right hand thumb rule : curl the palm of your right hand along the loop with the fingers pointing in the direction of the current . The thumb sticking out gives the direction of $\vec{m}$ (and $\vec{A}$) .
- When this loop is placed in a uniform magnetic field $\vec{B}$, the force $\vec{F}$ on it is zero. And the torque on it is given as τ = $\vec{m}$ x $\vec{B}$.

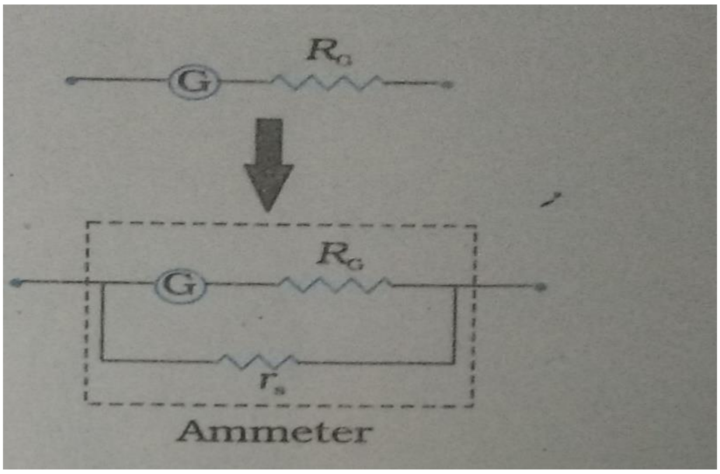


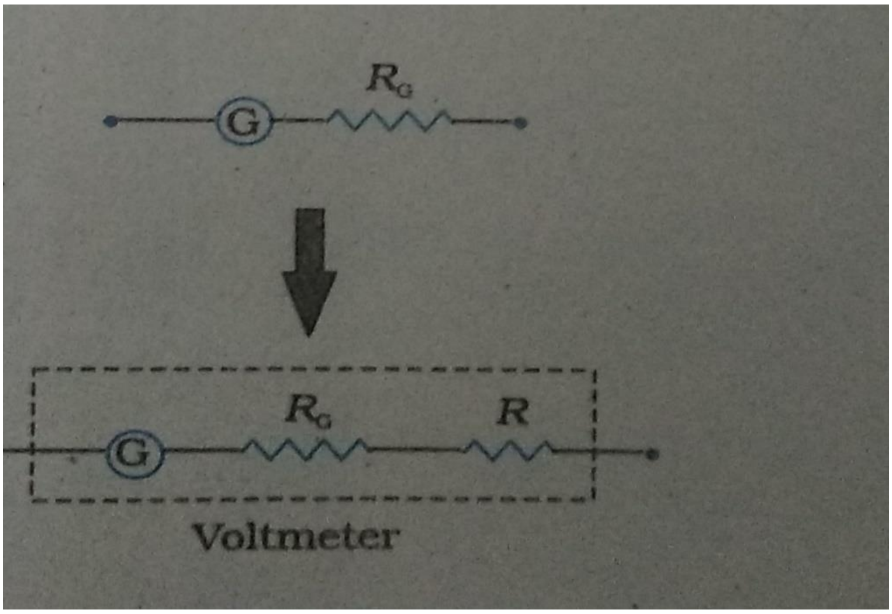
- MOVING COIL GALVANOMETER : It is a sensitive instrument used for detecting small electric current.



- Principle – it works on the principle that when a current carrying coil is placed in a magnetic field , it will experience a torque.
- In a moving coil galvanometer ,the torque is balanced by a counter torque due to spring i.e $k\phi$ = NIAB , where ϕ is the equilibrium deflection and k is the torsion constant of the spring.
- Figure of Merit of a galvanometer : it is defined as the current that produces a deflection of one scale division in the galvanometer and it is given by I/α = k/NAB.
- Current Sensitivity : It is defined as deflection produced in the galvanometer when a unit current flows through it. It is given as $I_s = \phi /I$ = NBA/k.
- Voltage Sensoitivity : It is defined as the deflection produced in the galvanometer when a unit potential difference is applied acoss its ends. It is given as $V_s = \phi /V$ = NBA/k R.

- A moving coil galvanometer can be converted into a ammeter by introducing a shunt resistance r_s of small value in parallel. It can be converted ito voltmeter by introducing a resistance of a large value in series .





MULTIPLE CHOICE QUESTIONS (1 MARK)

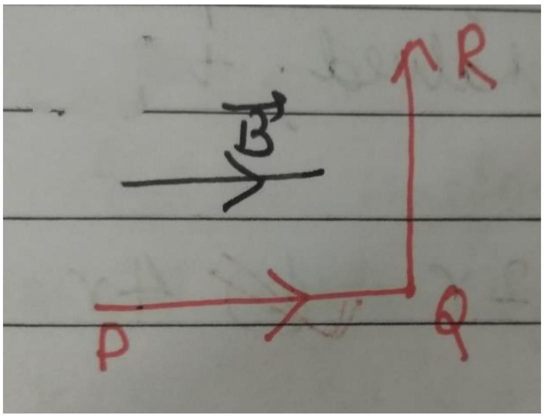
1. Consider the following statements regarding the observations of Oersted for a current in a straight wire placed near a compass needle –
   I. Alignment of compass needle is tangential to a circle which has the straight wire as its centre and plane perpendicular to the wire.
   II. Orientation of the needle is independent of the direction of the current in the wire.
   III. Deflection in the compass needle increases on increasing current or bringing the needle ncloser to the wire.

   Which of the statement(s) given above is /are correct?

   (a) I and II only.

(b) II and III only.
(c) I and III only.
(d) I , II and III.

2. The magnetic force on a charge is zero when –
   (a) Charge is not moving.
   (b) Charge has velocity parallel or antiparallel to magnetic field.
   (c) Both (a) and (b) .
   (d) None of these.
3. Which of the following units is not used for magnetic field –
   (a) Weber/m^2 .
   (b) Weber.
   (c) Gauss.
   (d) Tesla.
4. The force on a charge particle due to a magnetic field can act –
   (a) On charge which is at rest .
   (b) On a charge which is moving in the direction of the magnetic field .
   (c) On a charge moving in the opposite direction of the magnetic field .
   (d) On a charge moving in the perpendicular direction to that of the magnetic field .
5. α and β particle are projected with the same velocity v perpendicular to the magnetic field , then –
   (a) α particle will experience more force as compared to that of β .
   (b) α particle will experience less force as compared to that of β .
   (c) Both α and β will experience equal force .
   (d) None of these.
6. An electron experiences a force $(4\hat{\imath} + 3\hat{\jmath}) \times 10^{-13}$ N in a uniform magnetic field when its velocity is redirected and becomes $(1.5\hat{\imath} - 2\hat{\jmath}) \times 10^{7}$ m/s , the magnetic force of the electron is zero . The magnetic field vector is –
   (a) $-0.075\hat{\imath} + 0.1\hat{\jmath}$
   (b) $0.1\hat{\imath} + 0.075\hat{\jmath}$
   (c) $0.075\hat{\imath} - 0.1\hat{\jmath} + \hat{k}$
   (d) $0.075\hat{\imath} - 0.1\hat{\jmath}$
7. A wire PQR is bent as shown in figure and is placed in a region of uniform magnetic field B. The length of PQ = QR = l . A current I ampere flows through the wire as shown. The magnitude of the force on PQ and QR will be



(a) BIl , 0
(b) 2BIl , 0
(c) 0 , BIl
(d) 0 ,0.

8. Electron of mass m and charge q is travelling with speed v enters a magnetic field B perpendicularly. It describes a circle of radius r. If the speed of the electron is doubled and magnetic field is halved ; the resulting path would have the radius –
(a) 2r
(b) 4r
(c) r/4
(d) r/2.

9. A proton and an alpha particle are projected normally into the magnetic field with the same speed . What will be the ratio of radius of the trajectories of the proton and alpha particle ?
(a) 2:1
(b) 1:2
(c) 4:1
(d) 1:4.

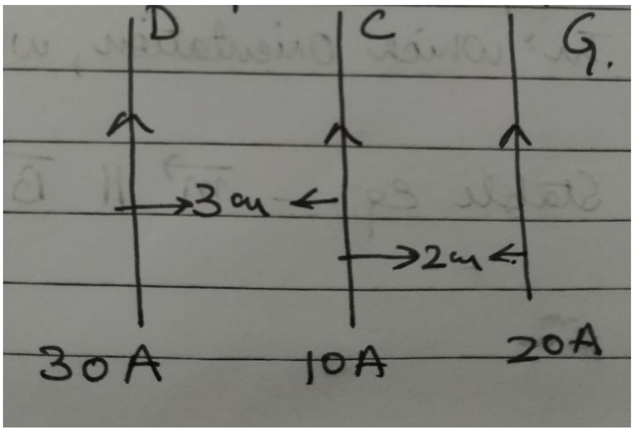
10. Consider the situation given in table-

Motion of charge particle in magnetic field		Effect on the charge particle
(I)	Charge particle enters parallel to the magnetic field	(p) describes helical path.
(II)	Charge particle's velocity makes an angle Θ (0^0 < Θ < 180^0) with the magnetic field.	(q) describes circular path.
(III)	Charge particle's velocity is perpendicular to the magnetic field.	(r) experiences no force .

Choose the correct option –
(a) I – (p) , II – (q) , III – (r).
(b) I – (r) , II – (q) , III – (p).
(c) I – (r) , II – (p) , III – (q).
(d) I – (q) , II – (r) , III – (p).

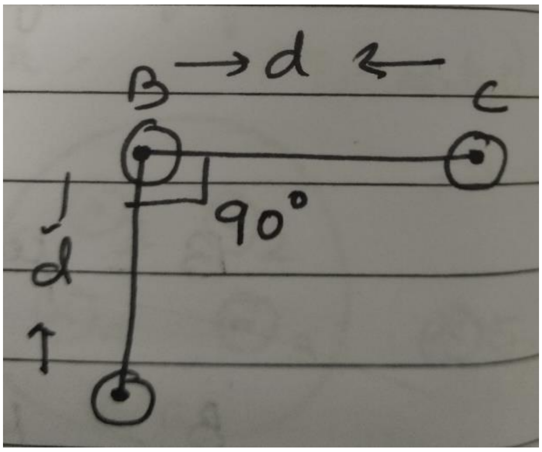
11. A proton with velocity of 4 x 10 ^{5} m/s enters a uniform magnetic field of 0.3 T . The velocity vector makes an angle of 60^0 with the magnetic field . The pitch of the helix is –
(a) 0.012 cm
(b) 1.2 cm.
(c) 4.4 cm.
(d) 0.044 cm.

12. Which particle will have minimum frequency of revolution when projected with same velocity perpendicular to the magnetic field ?
   (a) Li^+
   (b) Electron.
   (c) Proton.
   (d) He^+.
13. Two long conductors , separated by a distance d carrying current I_1 and I_2 in the same direction . They exert force F on each other. Now the current in one of them is increased to two times and its direction is reversed . The distance is also increased to 3d . The new value of the force between them is =
   (a) -2F
   (b) F/3
   (c) -2F/3
   (d) -F/3.
14. A solenoid has 1000 turns per meter length . If a current of 5A is flowing through it , then magnetic field inside the solenoid is –
   (a) $2\pi \times 10^{-3}$ T.
   (b) $2\pi \times 10^{-5}$ T .
   (c) $4\pi \times 10^{-3}$ T.
   (d) $4\pi \times 10^{-5}$ T.
15. A solenoid 1.5 m long and 0.4 cm in diameter possess 10turns per cm length. A current of 5 A flows through it. The magnetic field at the axis inside the solenoid is –
   (a) $2\pi \times 10^{-3}$ T.
   (b) $2\pi \times 10^{-5}$ T.
   (c) $4\pi \times 10^{-2}$ T.
   (d) $4\pi \times 10^{-3}$ T.
16. Three long , straight parallel wires carrying current are arranged as shown in figure. The force experienced by a 25 cm length of wire is –



   (a) 10^{-3} N.
   (b) 2.5×10^{-3} N.
   (c) Zero.
   (d) 1.5×10^{-3} N.

17. An arrangement of three straight wires placed perpendicularly to the plane of paper carrying same current 'I' along the same direction is shown in figure. Magnitude of force per unit length on the middle wire B is given by –



(a) $\frac{\mu 0\, I d^2}{2\pi d}$
(b) $\frac{2\mu 0 I^2}{\pi d}$
(c) $\frac{\sqrt{2}}{\pi d}\mu 0 \mathrm{I}^2$
(d) $\frac{\mu 0 I\text{^}2}{\sqrt{2}\,\pi d}$

18. An ammeter reads upto 1A . Its internal resistance is 0.081 ohm . To increase the range to 10 A , the value of shunt is –
(a) 0.03 ohm
(b) 0.3 ohm
(c) 0.9ohm
(d) 0.09 ohm.

ANSWER KEY (MCQS)

1	C
2	C
3	B
4	D
5	A
6	A
7	C
8	B
9	B
10	C
11	C
12	A
13	C
14	A
15	A
16	C

17	D
18	D

ASSERTIONS AND REASONS

In the following questions , a statement of Assertion (A) is followed by a statement of Reason (R) , mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of the assertion .
(b) If both assertion and reason are true but reason is not correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

1. ASSERTION : A charge , whether stationary or in motion produces a magnetic field .
   REASON : Moving charges produce only magnetic field in the surrounding space.
2. ASSERTION : If a proton and an alpha particle enter a uniform magnetic field perpendicularly with the same speed , the time period of revolution of alpha particle is double that of proton.
   REASON : In a magnetic field , the period of revolution of a charged particle is directly proportional to the mass of the particle and is inversely proportional to charge of the particle.
3. ASSERTION : The resistance of an ideal voltmeter should be infinite .
   REASON : The lower resistance of voltmeter gives a reading lower than the actual potential difference across the terminals.
4. ASSERTION : Magnetic field interacts with a moving charge and not with a stationary charge .
   REASON : A moving charge produces a magnetic field .
5. ASSERTION : Magnetic field cannot change kinetic energy of a moving charge .
   REASON : Magnetic field cannot change the velocity vector.

ANSWER KEY (ASSERTION – REASON)

1	d
2	a
3	a
4	a
5	c

SHORT ANSWER I TYPE QUESTIONS (2 MARKS)

1. (a) Write the expression for Lorentz force.
   (b) The magnetic force acting on a charge particle q moving with velocity $\vec{v}$ in magnetic field $\vec{B}$ is given by $\overrightarrow{F}$ = q ($\vec{v}$ X $\vec{B}$). Which pair of vectors are always at right angle to each other?
   Sol : (a) $\vec{F}$ = q ($\vec{E}$ + $\vec{v}$ x $\vec{B}$), is Lorentz force .
   (b) $\vec{F}$ and $\vec{v}$; $\vec{F}$ and $\vec{B}$.

2. An electron is moving northwards with a velocity of 3 x 10^7 m/s in a uniform magnetic field of 10 T directed eastwards. Find the magnitude and direction of the force on the electron.

Sol : F = Bqv sin θ

= 10 x 1.6 x 10^{-19} x3 x 10^7 sin 90^0

= 4.8 x 10^{-11} N. (directed upward).

3. Derive an expression for the force experienced by a current carrying straight conductor placed in the magnetic field . Under what condition is this force maximum?

Sol : for derivation refer to NCERT textbook.

Force is maximum for θ = 90^0 .

4. A wire of length l carries a current I along the X – axis . A magnetic field $\vec{B}$ = B_0 ($\hat{\imath}$ + $\hat{\jmath}$ + $\hat{k}$) Tesla exists in space. Find the magnitude of the magnetic force on the wire.

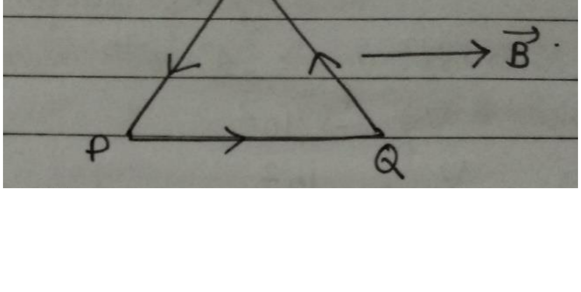
Sol : $\overrightarrow{F}$ = I ($\vec{l}$ x $\vec{B}$)

= I [l $\hat{\imath}$ x B_0 ($\hat{\imath}$ + $\hat{\jmath}$ + $\hat{k}$)]

= ($\hat{k}$ - $\hat{\jmath}$) B_0 I l.

F = $\sqrt{2}$ B_0IL.

5. Figure shows a triangular loop PQR carrying current I . The triangle is equilateral with side equal to l . If a uniform magnetic field B exists parallel to PQ , then find the force acting the three wires respectively.

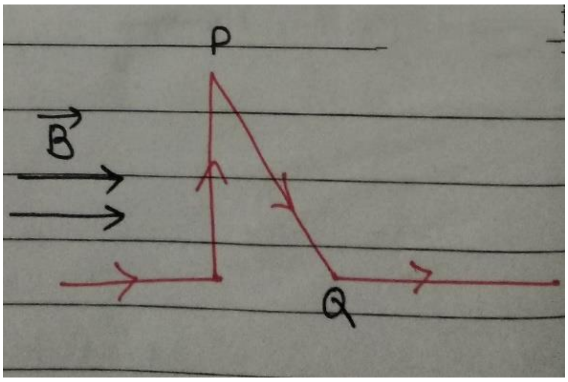


Sol : $F_{PQ} = 0$ ($\theta = 0^0$)

$F_{QR} = \frac{\sqrt{3}}{2}$ ILB ($\theta = 120^0$) .

$F_{RP} = \frac{\sqrt{3}}{2}$ ILB

6. Find the magnitude of the magnetic force on the segment PQ placed in a magnetic field of 0.025 T if a current of 5 A flows through it as shown in figure.

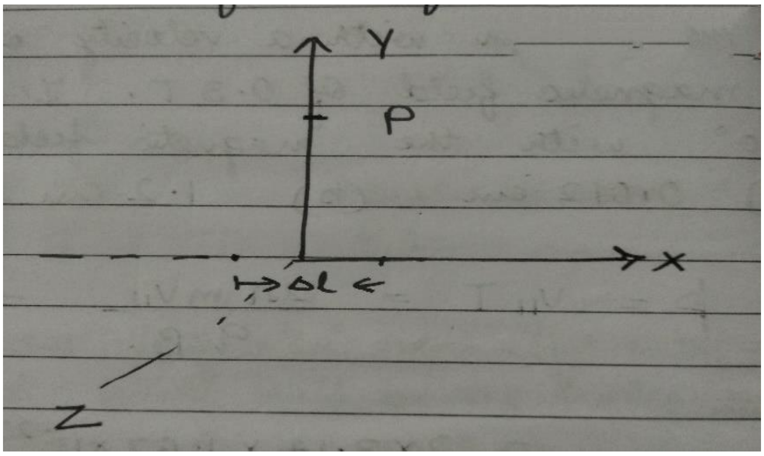


Sol : F_{PQ} = ILB sin θ

= 5 x .30 x 0.25 x sin 60^0

= 0.32 N

7. An element $\Delta l = \Delta\, x\hat{\imath}$ is placed at the origin (as shown in figure) and carries a current I = 2 A . Find out the magnetic field at a point P on the Y – axis at a distance 1 m due to element Δx = w cm . Also give the direction of the field produced.



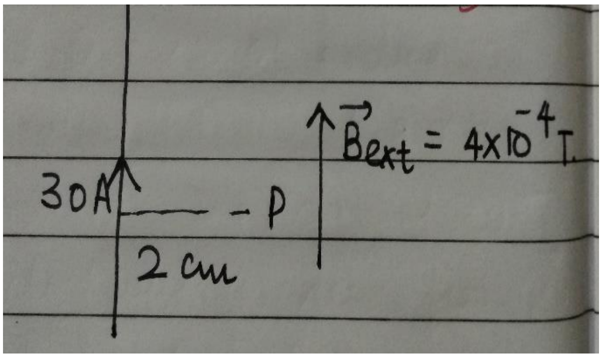
Sol : $\overrightarrow{dB} = \frac{\mu 0}{4\pi}\, I\, (\overrightarrow{dl} \times \vec{r}\,)/ r^3$

$\overrightarrow{dl} \times \vec{r}$ = w $\hat{\imath} \times \hat{\jmath}$ = w $\hat{k}$

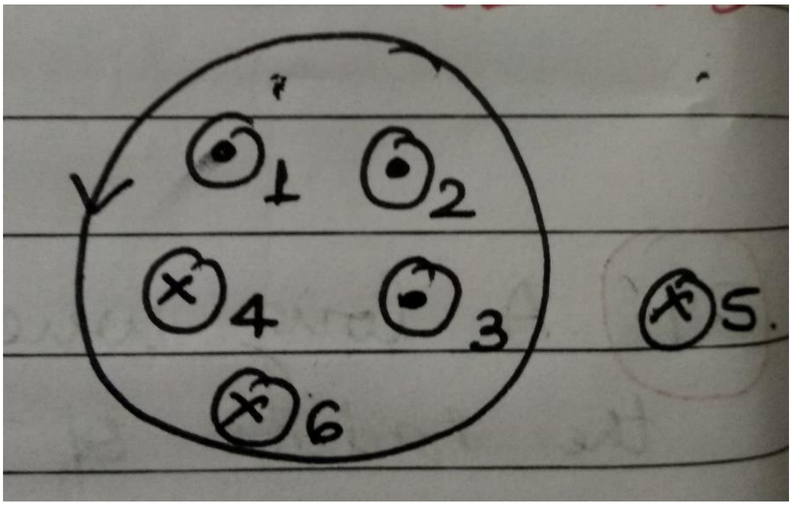
$\overrightarrow{dB}$ = 2 x 10^{-7} w $\hat{k}$ T

PRACTICE QUESTIONS (2 Marks).

1. A long straight wire carrying current of 30 A is placed in an external magnetic field of 4×10^{-4} T parallel to the current . Find the magnitude of the resultant magnetic field at a point 2 cm away from the wire.



2. Six wires of current I_1 = 1 A , I_2 = 2 A , I_3 = 3 A , I_4 = 1 A , I_5 = 5 A and I_6 = 4 A cut the page perpendicularly at the points 1 , 2 ,3 , 4 and 6 respectively as shown in figure . Find the value of $\oint \vec{B} \cdot \vec{dl}$ around the closed path.



3. A solenoid of length l having N turns carries a current I . Deduce the expression for the magnetic field in the interior of the solenoid.

4. To increase the current sensitivity of a moving coil galvanometer by 50 % , its resistance becomes twice its initial resistance . By what factor does its voltage sensitivity changes?

5. A galvanometer has a resistance of 100 ohm . When a current passes through the galvanometer . 1% of the current goes through the coil and rest through the shunt . Find the resistance of the shunt.

SHORT ANSWER II TYPE QUESTIONS (3 MARKS)

1. A proton and an alpha particle enter at right angle into a uniform magnetic field of intensity B . Calculate the ratio of their radii of their paths when they enter the field with (i) same momentum and (ii) same kinetic energy.

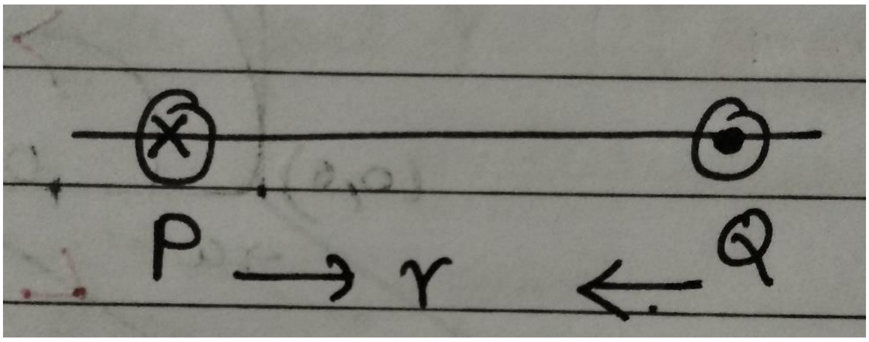
   Sol : r = mv/Bq

   $R_p = m_p v_p / Bq_p$ $\quad$ $(r)\alpha = m\alpha v\alpha / Bq\alpha$

   $R_p / r\alpha$ = 2q/2 = 2: 1.

   (ii) for same K.E ; ratio of radius is 1 :1.

2. Two parallel wires P and Q placed at a separation of r cm , carry currents I_1 = 5 A and I_2 = 2 A in opposite direction as shown in figure . Find the point on the line PQ where the resultant magnetic field is zero.

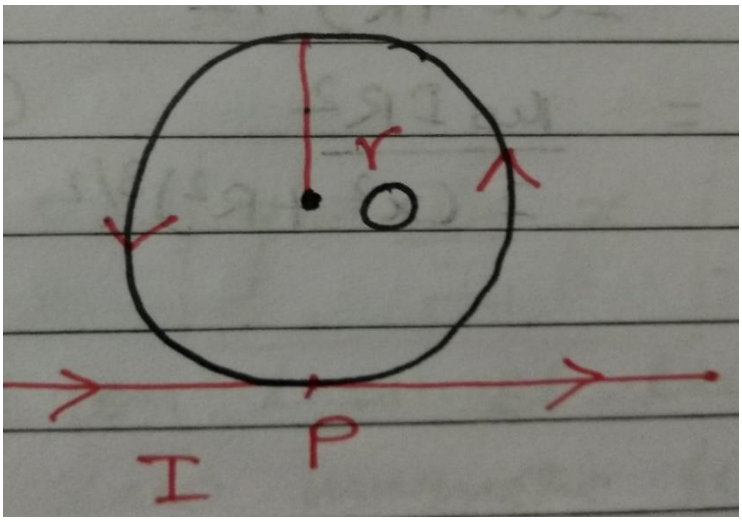


   Sol : $B_{OQ} = B_{OP}$; $\frac{\mu 0\ I}{2\pi x} = \frac{\mu 0\ I'}{2\pi\ (r+x)}$

   $\frac{2}{x} = \frac{5}{6+x}$

   X = 4 cm.

3. What is the magnitude and direction of magnetic field at the centre O of the circular portion if a current I is passed through the wire.



   Sol : B_1 = Magnetic field due to straight wire.

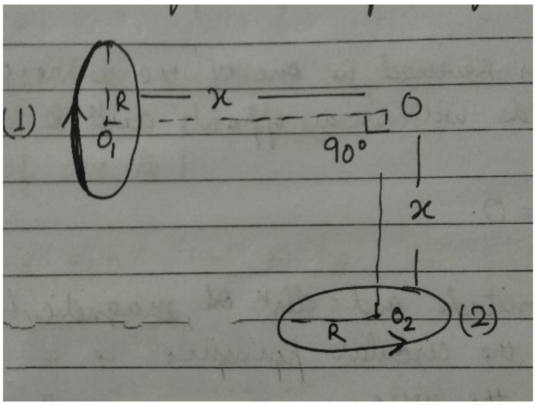
   $= \frac{\mu 0\ I}{2\pi r}$ (directed perpendicular and out of the plane)

   B_2 = Magnetic field due to circular loop.

   $= \frac{\mu 0\ I}{2r}$ (directed perpendicular and out of the plane)

$B_{net} = \frac{\mu 0\, I}{2r} \left(1 + \frac{1}{\pi} \right)$.

4. Two small identical circular loops marked (1) and (2) carrying equal currents are placed with their geometrical axes perpendicular to each other as shown in figure . Find the magnitude and direction of the net magnetic field produced at O.



Sol : $B_1 = \frac{\mu 0 I R^2}{2\,(x^2+R^2)^3/2}$ (directed along OO_1) = B

$B_2 = \frac{\mu 0 I R^2}{2(x^2+R^2)\text{^}3/2}$ (directed along O_2O). = B

$B_{net} = \sqrt{2B^2} = \sqrt{2}\,\frac{\mu 0 I R^2}{2(R^2+x^2)}$.

.

5. A galvanometer gives full scale deflection with a current of 0.006 A . By connecting it to 4990 ohm resistance it can be converted into voltmeter of range 0 – 30 V. If connected to $\frac{2n}{249}$ ohm resistance , it becomes an ammeter of range 0 – 1.5 A . Find the value of n .

Sol : $(R + G)\, I_g = V$

$(4990 + G)\, 0.006 = 30$

$G = 10\ \Omega$

$I_g G = (I - I_g)\, S$

$0.06 = (1.5 - 0.006)\, \frac{2n}{249}$

$n = 5$.

6. An ammeter of resistance 0.80 ohm can measure current up to 1 A .
   (a) What must be the shunt resistance to enable the ammeter to measure current up to 5 A ?
   (b) What is the combined resistance of the ammeter and the shunt ?

Sol : (a) $I_g = 1$ A , $G = 0.80\ \Omega$

$I_g G = (I - I_g)\, S$

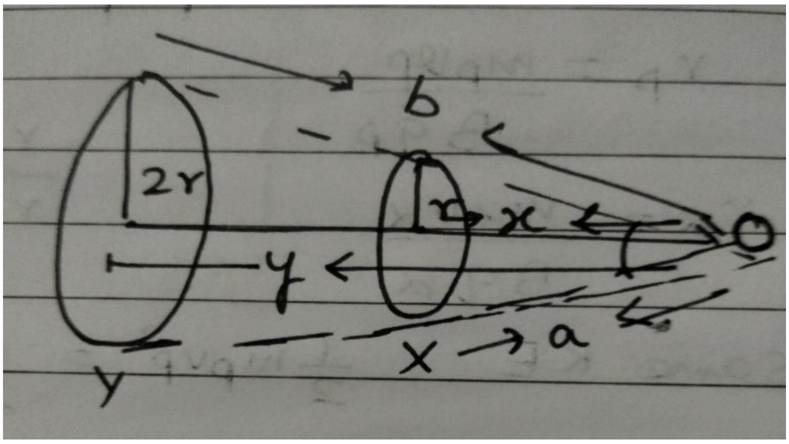
$S = 0.20\ \Omega$

R_{eq} (b) $1/ R_{eq} = 1/G + 1/S$

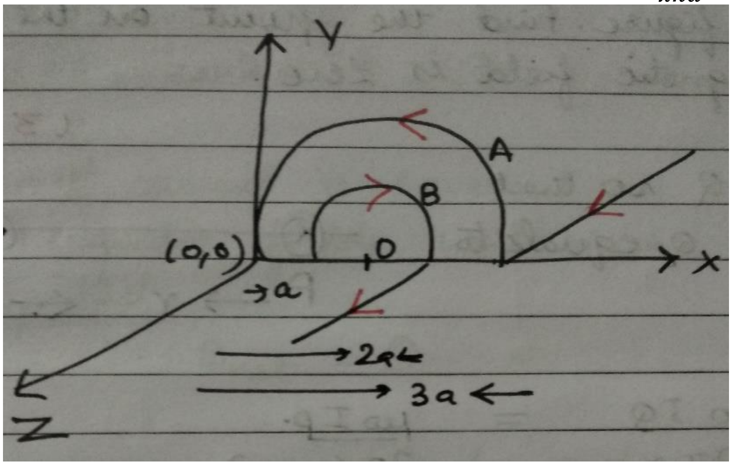
$R_{eq} = 0.16\Omega$

PRACTICE QUESTIONS (3 MARKS)

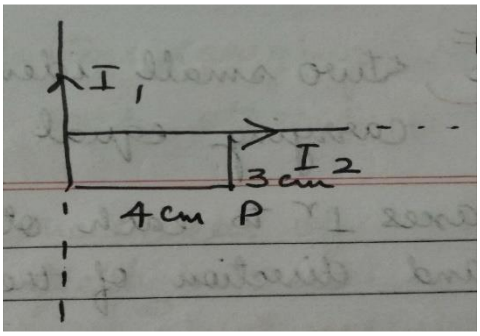
7. Two circular coils X and Y having equal number of turns and carrying equal currents in same sense are placed coaxially such that they subtend the same solid angle at O. If B be the magnetic field at O due to smaller coil X , then find –
   (a) Magnetic field at O due to larger coil Y .
   (b) Total magnetic field at O.



8. In the given figure , net magnetic field at O will be $\frac{\mu 0}{x\pi a}\sqrt{4+\pi^2}$. Find the value of x .

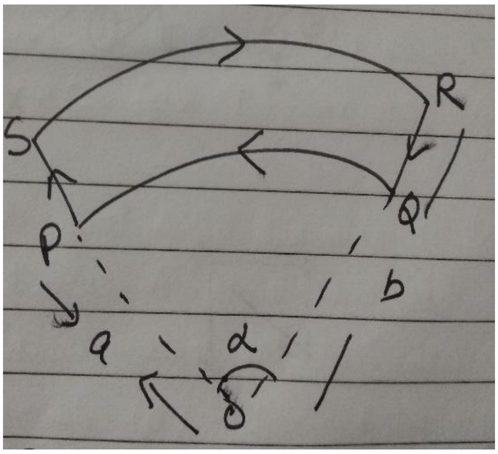


9. Two infinitely long insulated wires are kept perpendicular to each other . They carry current I_1 = 2 A and I_2 = 1.5 A.

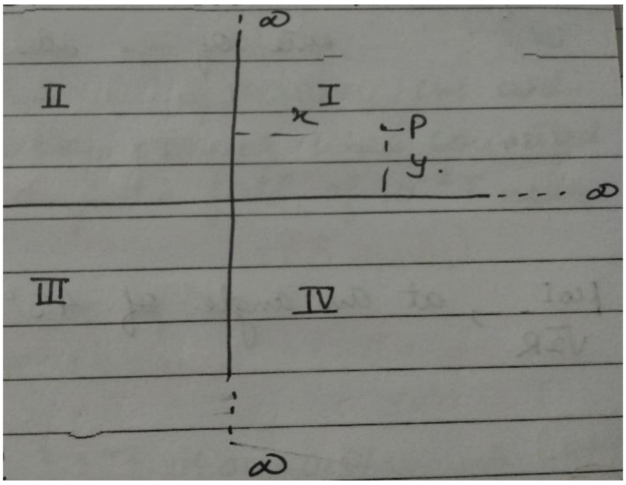


   (a) Find the magnitude and direction of the magnetic field at P.
   (b) If the direction of current is reversed in one of the wires , what would be the magnitude of the field ?

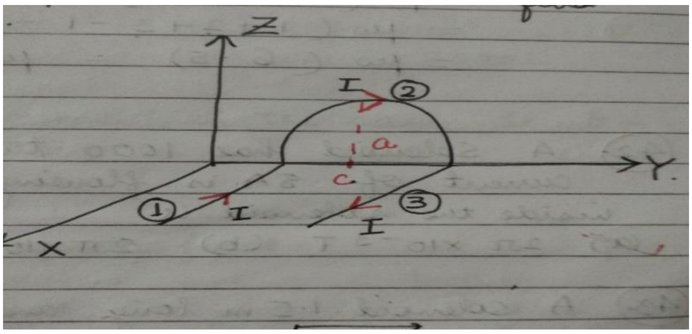
10. Figure shows a current loop having two circular segments and joined by two radial lines . Find the magnetic field at the centre O.



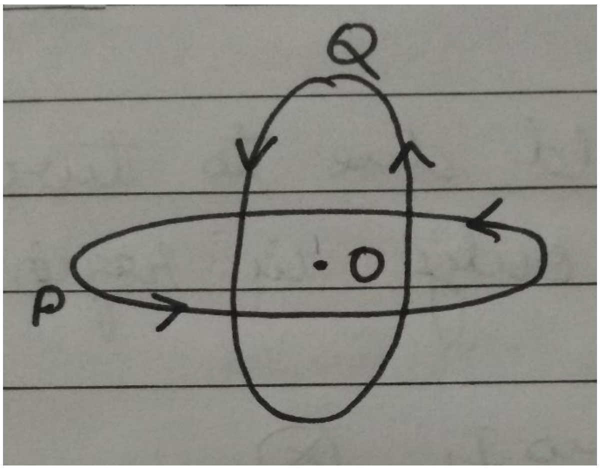
11. Two insulating infinitely long conductors carrying current I_1 and I_2 lie mutually perpendicular to each other in the same plane as shown in figure . Find the locus of the point at which the net magnetic field is zero.



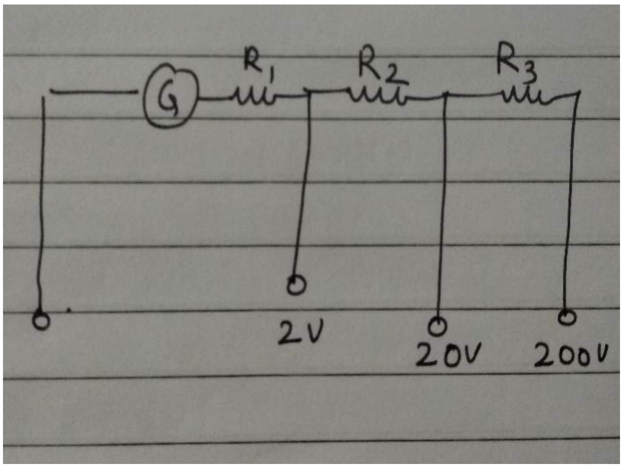
A long wire bent as shown in figure carries current I . If the radius of the semi circular portion is 'a' then find the magnetic field at the centre C .



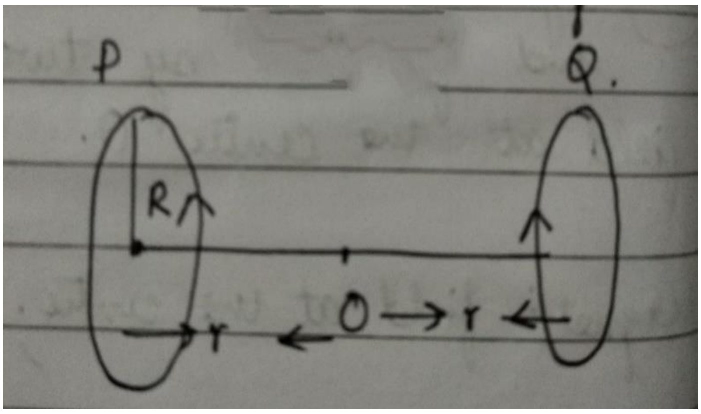
12. Two identical circular coils P and Q each of radius R and carrying current 'I' are kept in perpendicular plane such that they have a common centre as shown in figure. Find the magnitude and direction of the net magnetic field at the common center of the two coils .



13. A copper wire having resistance of 0.01 ohm per meter is used to wind a 400 turn solenoid of radius 1 cm and length 20 cm . Find the emf of a battery which when connected across the solenoid would produce a magnetic field of 10^{-2} T near the center of the solenoid .
14. A rectangular loop of area A having N turns and carrying a current 'I' is held in a uniform magnetic field B .
    (a) Deduce the expression for the maximum torque experienced by the loop .
    (b) In which orientation , will the loop be in stable equilibrium.
15. Define current sensitivity and voltage sensitivity of galvanometer . Increasing the current sensitivity may not necessarily increase the voltage sensitivity of a galvanometer . Justify your answer .
16. A multirange voltmeter can be constructed by using a galvanometer in the circuit as shown in figure . We want to construct a voltmeter that can measure 2 V , 20 V and 200 V using galvanometer of resistance 10 ohm and that produces a maximum deflection for current of 1 mA . find the value of R_1 , R_2 and R_3 that have to be used .



17. Two identical circular loops P and Q each of radius r and carrying current I are kept in the parallel planes having a common axis passing through O . The direction of current in P is clockwise and in Q is anticlockwise as seen from O , which is equidistant from the loops P and Q . Find the magnitude of net magnetic field at O.



CASE STUDY BASED QUESTIONS (4 MARKS)

PARAGRAPH 1 : AMPERE'S CIRCUITAL LAW .

Just as Gauss's law is an alternative form of coulomb's law in electrostatics , similarly we have Ampere's law as an alternative form of Biot – Savart's law in magnetostatics. Ampere found that magnetic lines of force of straight current carrying conductor are concentric circles in a plane perpendicular to the conductor . Ampere's law is stated with reference to the loops of magnetic lines of force. We consider a loop to be made up of a number of small line elements . Consider one such element of length dl . Let B_i be the tangential component of the field at this element . We multiply it by element length dl and add all such products . When the lengths of these elements become small and their number gets larger , this summation tends to an integral . Ampere's law states that the line integral of the magnetic field $\vec{B}$ around any closed path is equal to μ_0 times the net current I passing through the closed loop .

$$\oint \vec{B} \, . \, \vec{dl} = \mu_0 \, I \, .$$

The closed loop is called Amperian loop . Ampere's law is valid for any arbitrary closed loop and holds only for steady currents . However , it is useful for calculating the magnetic field in highly symmetrical situations where $\vec{B}$ is tangential to loop and has non zero constant B or $\vec{B}$ is normal to the loop or B vanishes .

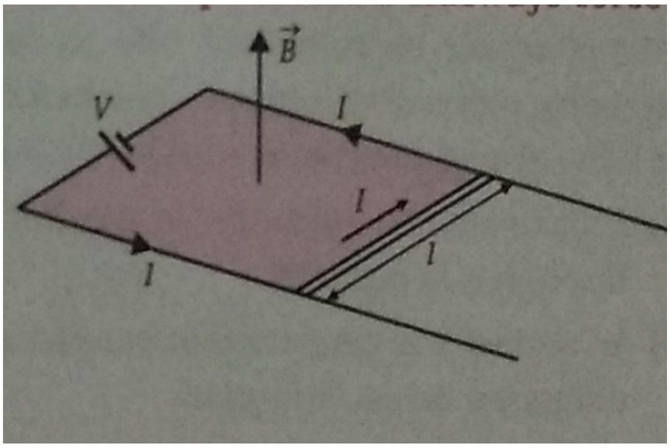
Answer the following questions –

1. Only the current inside the Amperian loop contributes in
   (a) Finding magnetic field at any point on the Amperian loop .
   (b) Line integral of magnetic field .
   (c) In both of the above .
   (d) In neither (a) nor (b) .
2. An electric current passes through a long wire . At a distance 5 cm from the wire , the magnetic field is B . The field at 20 cm from the wire would be
   (a) B/2
   (b) B/3
   (c) B/4
   (d) B/5.

3. 1 A current flows through an infinitely long straight wire . The magnetic field produced at a point 1 m away from it is
   (a) 2 x 10^{-3} T
   (b) 2π x 10^{-3} T
   (c) 2 x 10^{-7} T
   (d) 2π x 10^{-7} T.
4. A long straight wire of circular cross section (radius a) carries current I and the current I is uniformly distributed across the cross – section . Which of the following plots represents the variation of magnitude of magnetic field B with distance r from the centre of the wire?
5. A steady current is flowing through a cylindrical conductor .
   (a) The magnetic field in the vicinity of the conductor is zero.
   (b) The electric field in the vicinity of the conductor is zero .
   (c) The magnetic field at the axis of the conductor is zero .
   (d) The electric field at the axis of the conductor is zero.

PARGRAPH 2 : FORCE ON A CURRENT CARRYING CONDUCTOR IN A MAGNETIC FIELD .

When a conductor carrying current is placed in an external magnetic field , it experiences a mechanical force . A current carrying conductor when placed in a magnetic field experiences a sideways force as the force experienced by the moving electron is transmitted to the conductor as a whole . A conductor of length l carrying a current I held in magnetic field $\vec{B}$ at an angle θ with it , experience a force given by F = I l B sinθ . In vector form it is give as $\vec{F}$ = I $\vec{l}$ x $\vec{B}$. The direction of force is perpendicular to both $\vec{l}$ and $\vec{B}$ and is given by Fleming's left hand rule .



Answer the following questions –

1. Ignoring friction , air resistance and electrical resistance , the magnitude and direction of the net force on the conducting bar is
   (a) Il B , to the right
   (b) IlB , to the left .
   (c) 2 IlB , to the right .

(d) 2 IlB , to the left .

2. If the bar has mass m , find the distance d that of the bar must move along the rails from rest to attain speed v .
   (a) $\frac{3v^2m}{2IlB}$
   (b) $\frac{5v^2m}{2\,IlB}$
   (c) $\frac{v^2m}{IlB}$
   (d) $\frac{v^2m}{2\,IlB}$
3. A force acting on a conductor of length 5 m carrying current of 8 A kept perpendicular to the magnetic field of 1.5 T is
   (a) 100 N
   (b) 60 N
   (c) 50 N
   (d) 75 N
4. A straight wire of mass 200 g and length 1.5 m carries a current of 2 A . It is suspended in mid air by a uniform horizontal magnetic field B . The magnitude of B (in Tesla) is
   (a) 2
   (b) 1.5
   (c) 0.55
   (d) 0.65

PARAGRAPH 3 : USING GALVANOMETER AS AN AMMETER AND VOLTMETER .

A galvanometer is a device used to detect current in an electric circuit . It cannot as such be used as an ammeter to measure current in a given circuit. This is because galvanometer is a very sensitive device , it gives a full scale deflection for a current of the order μA . Moreover , for measuring currents , the galvanometer has to be connected in series and it has a large resistance , this will change the value of current in the circuit . To overcome these difficulties , we connect a small resistance called shunt resistance in parallel with the galvanometer coil, so that most of the current passes through the shunt . Now to use galvanometer as a voltmeter , it has to be connected in parallel with the circuit element across which we need to measure potential difference . Moreover , it must draw a very small current , otherwise it will appreciably change the voltage which we are measuring . To ensure this a large resistance R is connected in series with the galvanometer.

Answer the following questions :

1. A sensitive galvanometer can be converted into an ammeter or a voltmeter by connecting a proper resistance to it . Which of the following statements is true ?

(a) A voltmeter is connected in parallel and current through it is negligible .
(b) An ammeter is connected in parallel and potential difference across it is small.
(c) A voltmeter is connected in series and potential difference acrss it is small.
(d) An ammeter is connected in series in a circuit and the current through it is negligible.

2. By mistake a voltmeter is connected in series and an ammeter is connected in parallel with a resistance in an electrical circuit. What will happen to the instruments ?

(a) Voltmeter is damaged.
(b) Ammeter is damaged
(c) Both are damaged.
(d) None is damaged.

3. Two identical galvanometer are converted into an ammeter and milliammeter . Resistance of the shunt of milliammeter through which the current passes through will be

(a) More
(b) Equal
(c) Less
(d) Zero

4. A voltmeter has resistance of G ohm and range of V volt . The value of resistance used in series to convert it into voltmeter of range n V volt is

(a) n G
(b) (n-1) G
(c) G/n
(d) G/(n-1).

ANSWER KEY (CASE STUDY BASED QUESTIONS)

PARAGRAPH 1

1. b
2. c
3. C
4. c

PARAGRAPH 2

1. a
2. d
3. b
4. d

PARAGRAPH 3

1. a
2. d
3. a
4. b

LONG ANSWER TYPE QUESTIONS (5 MARKS)

1. (a) State Biot Savart's law expressing it in the vector form. Use it to obtain the expression for the magnetic field along an axial point , distance d from the centre of a circular coil of radius a carrying current I .
   (b) Find the ratio of the magnitude of the magnetic field of this coil at the centre and at an axial point for which d = a $\sqrt{3}$.

2. Two long straight parallel conductors carrying steady current I_1 and I_2 separated by a distance d. If the currents are flowing in the same direction , show how the magnetic field set up in one produces an attractive force on the other . Obtain the expression for this force. Hence define one Ampere.

3. With the help of diagram . explain working of a moving coil galvanometer . What is the function of-

(a) uniform radial field .

(b) soft iron core.

4. Explain how a galvanometer can be converted into an ammeter of a given range . Derive the expression for shunt resistance and current for full scale deflection . Find the effective resistance of the ammeter.

5. Explain how a galvanometer can be converted into a voltmeter to read a maximum potential difference of V volts . Can one use voltmeter to measure the emf of a cell ? Justify your answer .

NOTE : FOR DERIVATION PART REFER TO NCERT TEXT BOOK PART 1.

CHAPTER 5 - MAGNETISM AND MATTER

GIST OF THE LESSON

Properties of magnets

(i) Attractive property
(ii) Directive Property
(iii) Like poles attract and unlike poles repel.
(iv) Magnet poles cannot be isolated i.e. always exists in pairs.

Magnetic Field Lines

It is defined as the **imaginary** curve the tangent to which at any point gives the direction of the magnetic field at that point.

Properties:

(i)The magnetic field lines of a magnet are the imaginary lines making closed continuous loops.

(ii) The tangent to the magnetic field lines at any point gives the direction of the magnetic field at that point.

(iii) Two magnetic field lines cannot intersect each other.

(iv) The crowded magnetic field lines represent the stronger field and vice versa.

Magnetic Dipole and Dipole Moment

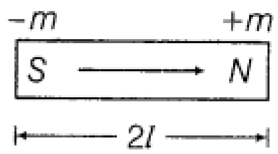
Two unlike magnetic poles of equal strength separated by a small distance makes a dipole moment.

If strength of each pole of a magnet is 'm' and magnetic length '2l' then

Magnetic dipole moment (M) is given by,

M=mx2l

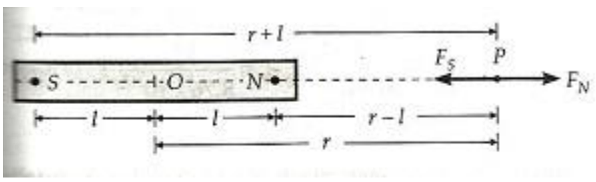
Its direction is from south pole to north pole.



Its unit is A/m^2

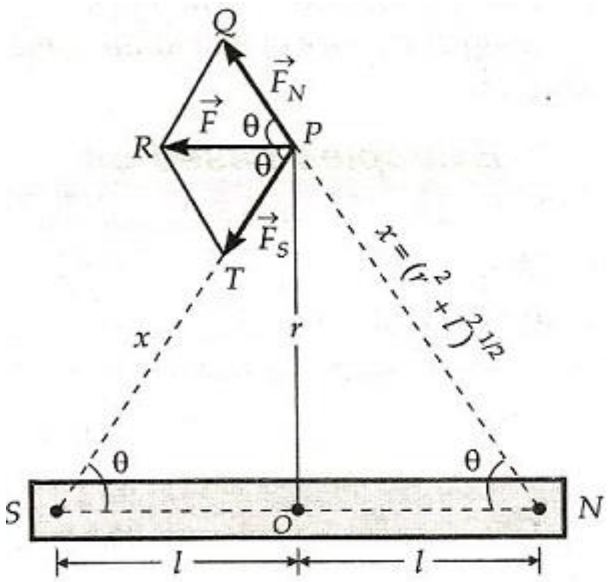
Magnetic Field Intensity due to a magnetic dipole (Bar Magnet)

a. Along its Axis



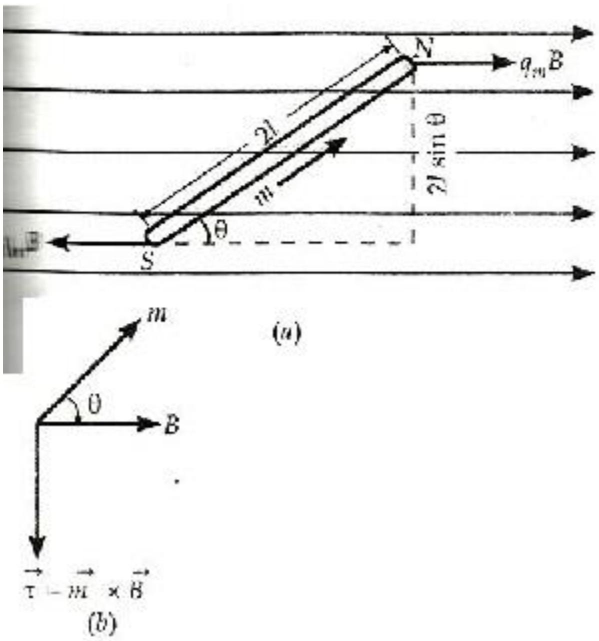
$$\vec{B} = \frac{\mu_o}{4\pi}\frac{2m}{r^3}$$

b. Perpendicular to its Axis



$$\vec{B} = \frac{\mu_o}{4\pi}\frac{m}{r^3}$$

Torque on a bar magnet placed in uniform external electric field:



a) The net force on it is zero.
b) The torque on it is $\vec{m} \times \vec{B}$
c) Torque on dipole will be minimum when θ = 0°
d) d) Torque on dipole will be maximum when θ = 90°. When a bar magnet of dipole moment $\vec{m}$ is placed in a uniform magnetic field $\vec{B}$, then-
e) Its potential energy is $-\vec{m}.\vec{B}$ where we choose the zero of energy at the orientation when $\vec{m}$ is perpendicular to $\vec{B}$.

MAGNETIC PROPERTIES OF MATERIALS

Diamagnetic Substances -

Diamagnetic substances are magnetized weakly when placed in an external magnetic field in a direction that is opposite to the applied field. The type of magnetism that is exhibited by these substances is known as diamagnetism. Examples of diamagnetic substances are copper, gold, antimony, bismuth, silver, lead, silicon, mercury, etc.

The electron's orbital motion gives rise to an orbital magnetic moment. In addition to this, the electrons tend to spin around their own axis, creating a spin magnetic moment. Electrons in an atom can have a clockwise or anticlockwise spin. In a similar way, the electrons can revolve around the nucleus in a clockwise or anticlockwise direction.

In the case of diamagnetic substances, the magnetic moments of atoms and the orbital magnetic moments have been oriented in such a manner that the vector sum of an atom's magnetic moment becomes zero.

Characteristics

- In a diamagnetic substance, the magnetic moment of every atom is calculated to be zero.
- An external magnetic field can repel them weakly.
- If diamagnetic substances are placed in a non-uniform magnetic field, then the substances move towards the weaker side of the field from the stronger side.
- When these substances are placed in an external magnetic field, they get weakly magnetized in the direction that is opposite to the direction of the field.
- Magnetic susceptibility turns out to be negative in diamagnetic substances.

Paramagnetic Substances

Substances that get magnetized weakly when placed in an external magnetic field in the same direction as the direction of the externally applied field are known as paramagnetic substances. These substances are different from ferromagnetic and diamagnetic substances. They have a tendency to move from the weaker to the stronger part of the magnetic field. Some examples of paramagnetic substances are calcium, lithium, tungsten, aluminium, platinum, etc.

In a paramagnetic substance, each atom has a permanent magnetic dipole moment because of the way they spin, the magnetic moments are oriented. However, the direction of magnetic moments can have random orientations when there is thermal motion. Due to which the net magnetic moment of this substance is zero.

Characteristics

- Every atom in this substance is considered as a magnetic dipole that has a resultant magnetic moment.
- The external magnetic field creates a weak attraction to these substances.
- They move from weaker to the stronger part of the field when placed in a non-uniform field.
- These substances lose their magnetism when the external magnetic field is removed.

Ferromagnetic Substances

Substances that get magnetized strongly in an external magnetic field in a direction which is the same as the direction of the externally applied field are known as ferromagnetic substances. These types of substances retain their magnetic moment even after the removal of the magnetic field. Ferromagnetic substances tend to move from weaker to stronger parts of the external field. Some examples of ferromagnetic substances are iron, cobalt, and nickel.

In the ferromagnetic substances spin, magnetic moments have a large contribution. These substances consist of a large number of small units that are known as domains. These domains experience torque when a ferromagnetic substance is exposed to an external magnetic field. Due to this, the domains rotate and remain parallel to the direction of the field.

Characteristics

- A large number of small domains make ferromagnetic substances.
- These substances do not lose their magnetism when the external magnetic field is removed.
- These substances become paramagnetic when they are heated above the curie point.
- The external magnetic field strongly attracts ferromagnetic substances.
- These ferromagnetic materials tend to move from the weaker to the stronger part of the field when the magnetic field is non-uniform.
- If a rod of ferromagnetic substance is placed in a uniform magnetic field, the rod comes to rest with its length being parallel to the direction of the field.

IMPORTANT TOPICS:

Bar magnet, bar magnet as an equivalent solenoid (qualitative treatment only), magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis (qualitative treatment only), torque on a magnetic dipole (bar magnet) in a uniform magnetic field (qualitative treatment only), magnetic field lines. Magnetic properties of materials- Para-, dia- and ferro - magnetic substances with examples, Magnetization of materials, effect of temperature on magnetic properties.

Multiple Choice Questions

1. Which among these is not attracted by magnets?

   a. Cobalt b. Iron c. Copper d. Nickel

Ans.: c Copper

2. The pole strength of a bar magnet depends upon
   a. Nature of the material of the magnet only
   b. Area of cross section of the magnet only
   c. Both a and b
   d. None

   Ans : c Both a and b

3. SI unit of magnetic pole strength is
   a. A-m
   b. A/m
   c. A/m^2
   d. A/m^{-2}

   Ans: c. A-m

4.The direction of magnetic dipole moment of a bar magnet is

   a. From north pole to south pole
   b. From south pole to north pole
   c. Perpendicular to the axis of the Bar magnet
   d. None

   Ans: b From south pole to north pole.

5 . The ratio of magnetic field induction due to short bar magnet on axial line and equatorial line for the same distance is

   a. 1:2
   b. 1:3
   c. 2:3
   d. 2:1

   Ans: d 2:1

6. The SI unit of magnetic field induction

   a. Weber
   b. Tesla
   c. Gauss
   d. Both b and c

   Ans b Tesla

7. The magnetic field induction at a point on the equatorial line of ………………………………

Ans: $B = \frac{\mu_o}{4\pi} \frac{M}{r^3}$

8. The magnetic moment at a point on the axial line of a short magnet is………………… Ans:

$$B = \frac{\mu_o}{4\pi} \frac{2M}{r^3}$$

9. A magnetic bar of M magnetic moment is placed m the field of magnetic strength B, the torque acting on it is :

(a) $\vec{M} . \vec{B}$
(b)$-\vec{M} . \vec{B}$
(c) $\vec{M} \times \vec{B}$.
(d) $\vec{B} \times \vec{M}$

Ans: c

10. If the magnetic field is not uniform, the bar magnet will experience

a. Resultant force only

b. Resultant torque only

c. Both translational and rotational

d. Can't say.

Ans: c

11. Which of the following is ferromagnetic:

a. Aluminium

b. Quartz

c. Nickel

d. Bismuth

Ans. c

12 Which of the following is paramagnetic:

a. Manganese

b. Iron

c. Copper

d. Water

Ans: a.

13. If the magnetic moment of the atoms of a substance is zero, the substance is called

a. Diamagnetic

b. Paramagnetic

c. Ferromagnetic

d.None of these

Ans: a

14. The magnetic material having negative magnetic susceptibility are

a. Non magnetic

b. Diamagnetic

c. Paramagnetic

d. ferromagnetic

Ans: b

15.The magnetic susceptibility for diamagnetic material is

a. Small and negative

b. Large and negative

c. small and positive

d. large and positive

Ans: a

16.Susceptibility is small and positive for

a. Paramagnetic

b. Ferromagnetic

c. non magnetic

d. Diamagnetic

Ans. (a)

17. Ferromagnetic own their properties due to

a. Filled inner shells

b. Vacant inner sub- shell

c. Partially filled inner sub shell

d. All the sub shells equally filled

Ans: c

18. Magnetism in a substance is caused by

a. Orbital motion of the electrons

b. Spin motion of the electrons only

c. Spin and orbital both

d. None of these.

Ans: b

ASSERTION AND REASON:

(A)Both Assertion (A) and Reason (R) are true and Reason is the correct explanation of Assertion.

(B)Both Assertion (A) and Reason (R) are true and Reason is not the correct explanation of Assertion.

(C) Assertion (A) is true, but Reason is false.

(D)Assertion (A) is false, but Reason is true.

Assertion: Ferro-magnetic substances become paramagnetic above Curie temp. Reason: Domains are destroyed at high temperature.

(Ans: A)

Assertion: Diamagnetic materials can exhibit magnetism. Reason: Diamagnetic materials have permanent magnetic dipole moment.

(Ans: C)

Assertion: The poles of magnet cannot be separated by breaking into two pieces. Reason: The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

(Ans: B)

Assertion: We can make a analogy that a bar magnet resembles with solenoid. Reason: This was proved by calculating the axial field of a finite solenoid and at large distance it resembled that a bar magnet.

(Ans A)

Assertion: Gauss's law of magnetism is different from that for electrostatics. Reason: Isolated magnetic poles are not known to exist.

(Ans: A)

<u>SHORT QUESTIONS (2 and 3 marks)</u>

1. The magnetic moment of a circular coil carrying current I, having N turns each of radius r, is M. Find the magnetic moment of the same coil if it is unwound and rewound into a coil having 2N turns for the same current.

Ans: 2M

2. Out of the magnetic materials, A has relative permeability slightly greater than unity while B has less than unity. Identify the nature of the materials A and B. Will their susceptibility be positive or negative?

Ans: Magnetic material A is paramagnetic, its susceptibility will be positive and B is diamagnetic, its susceptibility will be negative.

3.The susceptibility of magnetic materials is -2.6×10^{-5}. Identify the type of magnetic material and state its two properties.

Ans: Diamagnetic.

Properties: (i)Tendency to move from stronger to weaker part of the external magnetic field. (ii) It gets feebly magnetized in the direction opposite to applied magnetic field.

4.Give two points to distinguish between a paramagnetic and a diamagnetic substance.

Ans. Refer to the Gist.

5.The relative magnetic permeability of magnetic material is 800.Identify the nature of magnetic material and state its two properties.

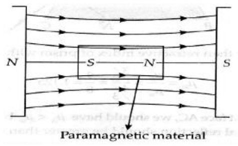
Ans: ferromagnetic. Properties

(i) Its get strongly magnetized when placed in an external magnetic field

(ii) It has strong tendency to move region from region of weak magnetic field to strong magnetic field, i.e.it gets strongly attracted to a magnet.

6.The susceptibility of a magnetic material is 0.9853. Identify the type of magnetic material. Draw the modification of the field pattern keeping a piece of this material in a uniform magnetic field.

Ans: Paramagnetic



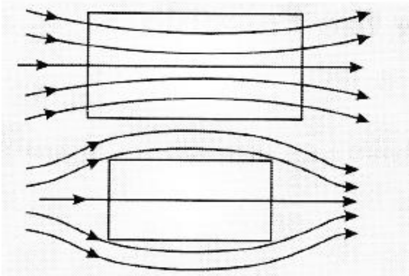
7. Define magnetic susceptibility of a material. Name two elements, one having positive susceptibility and the other having negative susceptibility. What does negative susceptibility signify?

Ans: Magnetic susceptibility: It is defined as the intensity of magnetisation per unit magnetising field. It has no unit. Iron has positive susceptibility while copper has negative susceptibility. Negative susceptibility of a substance signifies that the substance will be repelled by a strong magnet or opposite feeble magnetism induced in the substance.

8. Show diagrammatically the behaviour of magnetic field lines in the presence of (i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature?

Ans: A paramagnetic material tends to move from weaker to stronger region of the magnetic field passing through it.

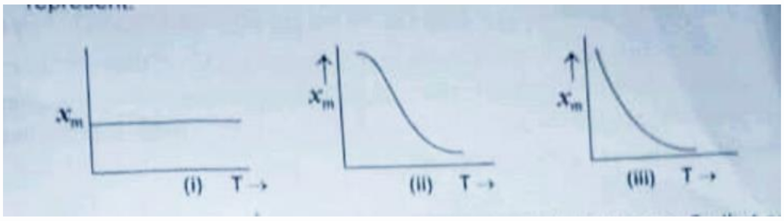
A diamagnetic material tends to move from stronger to weaker regions of the magnetic field and hence decreases the number of lines of magnetic field passing through it.



9. A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field. Find the work done to rotate the loop by 30° about an axis perpendicular to its plane?

Ans: Rotation of loop by 30° about an axis perpendicular to its plane does not change the angle between magnetic moment and magnetic field. Hence, no work is done.

10. Three curves are shown in figures. Indicate what magnetic substance they represent.



Ans(i) diamagnetic, (ii) Ferromagnetic, (iii) paramagnetic.

11.Draw the magnetic field lines for a current carrying solenoid when a rod made of (a) copper (b) aluminium (c) iron, is inserted within the solenoid.

Ans:

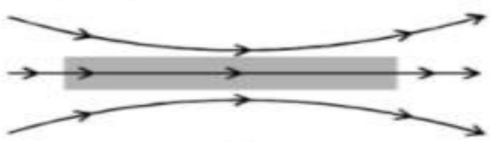
cu is diamagnetic

(a)

al s paramagnetic

(b)

Fe is ferro magnetic



(c)

12.Define the term magnetic dipole moment. Write the expression for magnetic field intensity along its axis and perpendicular to the axis.

Ans: Magnetic dipole moment of a magnetic dipole is defined as the product of its pole strength and magnetic length. It is a vector quantity and directed from S-pole to N-pole.

13.A bar magnet of magnetic moment 5 Am^2 has 20 cm apart. Calculate its pole strength.

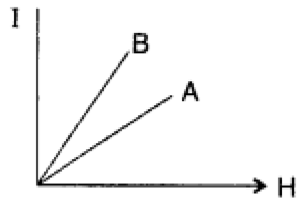
Ans: pole strength= magnetic moment/length

5/0.20=25 Am.

14.A steel wire of length l ha a magnetic moment m. It is bent into a semi-circular arc. What is new Magnetic moment?

Ans: New magnetic moment= pole strength x 2r=2m/π.

15. The figure shows the variation of intensity of magnetisation versus the applied magnetic field intensity, H, for two magnetic materials A and B :



(a) Identify the materials A and B.
(b) Why does the material B, has a larger susceptibility than A, for a given field at constant temperature?
Ans:
As $\chi_m = \frac{I}{H}$
Slope of the line gives magnetic susceptibilities.
For magnetic material B, it is giving higher +ve value.
So material is 'ferromagnetic'.
For magnetic material A, it is giving lesser +ve value than 'B'.
So material is 'paramagnetic'.(b) Larger susceptibility is due to characteristic 'domain structure'. More number of magnetic moments get aligned in the direction of magnetising field in comparison to that for paramagnetic materials for the same value of magnetising field.

16. A bar magnet is placed in the position of stable equilibrium in a uniform magnetic field of induction B. (i) How much is the potential energy of the magnet? (ii) If it is rotated through an angle 180°, then what will be the amount of work done?

Ans (i) In stable equilibrium, U=-mBcos0=-mB

(ii) When the dipole is rotated through 180 then

Work done=-mB(Cos180-Cos 0) =2mB

17.Why is a current carrying loop is considered as a magnetic dipole?

Ans: Like a bar magnet/magnet dipole, a current loop possesses magnetic moment M = NIA. In an external magnetic field, the current loop experiences a torque and aligns its axis parallel to magnetic field.

18. A magnetised needle in a uniform magnetic field experiences a torque but no net force. an iron nail near a bar magnet, however, experience a force of attraction in addition to a torque. Why?

Ans: In the first case, magnetic field is uniform, and forces on the two ends of the needle are equal and opposite. So net force is zero. However, a torque act on it. In case of iron nail, there is an induced magnetism. The induced(say) south pole in the nail, being closer to the north pole of the bar magnet, experiences a large attractive force than the induced north pole. So the nail experiences both net attractive and a torque.

19.A coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current I remaining the same. Calculate the ratio of the magnetic moments of the new coil and the original coil.

Ans: 1:2

20. A bar magnet of magnetic moment 6 J/T is aligned at 60° with a uniform external magnetic field of 0.44 T. Calculate (a) the work done in turning the magnet to align its magnetic moment (i) normal to the magnetic field, (ii) opposite to the magnetic field, and (b) the torque on the magnet in the final orientation in case (ii).

Ans: a (i) W= -MB (cos90-cos60) = 1.32J

(ii) 3.96J;

f) Torque=0

21. How does pole strength and magnetic moment of each part of a bar magnet change if it is cut into two parts?

Ans: The pole strength becomes half and the magnetic moment becomes half.

CASE BASED QUESTIONS:

1.When the atomic dipoles are aligned partially or fully, there is a net magnetic moment in the direction of the field in any small volume of the material. The actual magnetic field inside material placed in magnetic field is the sum of the applied magnetic field and the magnetic field due to magnetisation. This field is called magnetic intensity (H). $H=B/\mu_0-M$, where M is the magnetisation of the material, μ_0 is the permittivity of vacuum and B is the total magnetic field. The measure that tells us how a magnetic material responds to an external field is given by a dimensionless quantity is appropriately called the magnetic susceptibility: for a certain class of magnetic materials, intensity of magnetisation is directly proportional to the magnetic intensity.

(i) Magnetization of a sample is

(a) volume of sample per unit magnetic moment | (b) net magnetic moment per unit volume

(c) ratio of magnetic moment and pole strength | (d) ratio of pole strength to magnetic moment

(ii) Identify the wrongly matched quantity and unit pair.

(a) Pole strength	Am
(b) Magnetic susceptibility	dimensionless number
(c) Intensity of magnetisation	A m-I
(d) Magnetic permeability	Henry/ m

(iii) A bar magnet has length 3 cm, cross-sectional area 2 cm^2 and magnetic moment 3 Am^2. The intensity of magnetisation of bar magnet is

(a) 2×10^5 A/m | (b) 3×10^5 A/m

(c) 4×10^5 A/m | (d) 5×10^5 A/m

(iv) A solenoid has core of a material with relative permeability 500 and its windings carry a current of 1 A. The number of turns of the solenoid is 500 per metre. The magnetization of the material is nearly

(a) 2.5×10^3 A m^{-1} | (b) 2.5×10^5 A m^{-1}

(c) 2.0×10^3 A m^{-1} | (d) 2.0×10^5 A m^{-1}

(v) The relative permeability of iron is 6000. Its magnetic susceptibility is

(a) 5999 | (b) 6001

(c) 6000 x 10^{-7} | (d) 6000 x 10^7

Ans: (i) b (ii) c (iii) d (iv) b (v) a.

2. In small fields, ferromagnetic materials typically have much larger susceptibility, therefore larger permeability than paramagnetic materials. Ferromagnetic results because spontaneous self-aligning, cooperative interaction among relatively large number of iron atoms in region called domains. As a result of molecular interactions, the molecular magnetic moments in each domain are aligned parallel to one another. In other words, each domain is spontaneously magnetized to saturation even in the absence of any external magnetic field. The directions of magnetization in different domains are random, so that the resultant magnetization is zero and the specimen is unmagnetized.

(I) What changes will occur in specimen on placing it inside a solenoid and increasing magnetizing intensity?

a. Intensity of magnetization decreases

b. Intensity of magnetization increases

c. Magnetic susceptibility of specimen increases.

d. Magnetic susceptibility of specimen decreases

(ii) With increase in temperature, magnetic susceptibility of a ferromagnetic material

a. Decreases

b. Increases

c. Remains constant

d. First increases and decreases.

(iii)For a diamagnetic material which of the option is correct?

a. Magnetic susceptibility>0

b. Magnetic susceptibility<0

c. Magnetic susceptibility=0

d. Magnetic susceptibility =1

(iv) The property possessed by ferromagnetic substance only is

a. Hysteresis

b. Susceptibility

c. Directional property

d. Attracting a magnetic substance.

Ans: 1.b 2.a 3.a 4.d

3. Every substance shows some kind of magnetic behaviour at a time. This magnetic behaviour is shown because these substances are made up of charged particles like electrons and protons. It is how the electrons are arranged by themselves in the atoms and how groups of these atoms behave that tell us the magnetic properties of the material. These atoms (or the group of atoms) as a result become a magnetic dipole or a minibar magnet that can align according to the magnetic field that has been applied. The resultant effect of these dipoles determines the magnetic properties of the magnetic materials. To study the magnetic properties of magnetic materials, we generally keep the material in a uniform magnetic field, and then the magnetic field is varied. Based on their behaviour, the magnetic materials can be classified into three major types: Diamagnetic, Paramagnetic and Ferromagnetic substances.

(i)The universal (or inherent) property among all these substances is

a. Diamagnetism b. Paramagnetism c. Ferromagnetism d. Both a and b

(ii) Magnetic susceptibility of a diamagnetic substance

a. decrease with temperature b. increase with temperature

c. first increases and then decreases d. is not affected by temperature

(iii) The value of the magnetic susceptibility for a superconductor is

a. zero b. infinity c. +1 d. -1

(iv) Water is example of

a. Diamagnetic b. Paramagnetic c. Ferromagnetic d. Superconductors

(v). If a ferromagnetic material is inserted in a current carrying solenoid, the magnetic field of solenoid

a. largely increases b. slightly increases c. largely decreases d. slightly decreases.

Ans: 1a; 2 b; 3d; 4a; 5a.

PRACTICE QUESTIONS

MCQS:

1.The magnetic field lines inside a bar magnet is

a. from north to south pole of the magnet

b. from south to north pole of the magnet

c. does not exist

d. depends on the area of cross section of the bar.

2. If the magnetizing field on a ferromagnetic material is increased its permeability

a. is decreased b.is increased c. is unaffected d. may be increased or decreased

3. If a ferromagnetic material is inserted in a current carrying solenoid, the magnetic field of solenoid

a. largely increases b. slightly increases c. largely decreases d. slightly decreases.

4.In which type of material susceptibility does not depend on temperature?

a. Diamagnetic b. Paramagnetic c. Ferromagnetic d. All of them

ASSERTION AND REASON:

Both Assertion (A) and Reason (R) are true and Reason is the correct explanation of Assertion.

Both Assertion (A) and Reason (R) are true and Reason is not the correct explanation of Assertion.

Assertion (A) is true, but Reason is false.

Assertion (A) is false, but Reason is true.

5. Assertion: Ferro-magnetic substances become paramagnetic above Curie temp.
Reason: Domains are destroyed at high temperature.

6.Assertion: Diamagnetic materials can exhibit magnetism.
Reason: Diamagnetic materials have permanent magnetic dipole moment.

7.Assertion: We can make a analogy that a bar magnet resembles with solenoid.
Reason: This was proved by calculating the axial field of a finite solenoid and at large distance it resembled that a bar magnet.

8. The permeability of a material is 0.9983. Name the type of magnetic materials it represents.

9. How does pole strength and magnetic moment of each part of a bar magnet change if it is cut into two parts?

10.Which of the following substances are paramagnetic: Bi, Al, Cu, Ni?

SHORT ANSWER TYPE QUESTIONS(2marks)

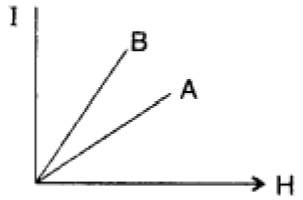
11.Define magnetic susceptibility of a material. Name two elements, having positive susceptibility and having negative susceptibility. What does negative susceptibility signify?

12. Show diagrammatically the behaviour of magnetic field lines in the presence of

(i) paramagnetic and (ii) diamagnetic substances. How does one explain this distinguishing feature?

Long Type Questions(3marks)

13. The figure shows the variation of intensity of magnetisation versus the applied magnetic field intensity, H, for two magnetic materials A and B:



(a) Identify the materials A and B.
(b) Why does the material B, has a larger susceptibility than A, for a given field at constant temperature?

14. A magnetised needle of magnetic moment 4.8×10^{-2} J/T is placed at 30°with the direction of uniform magnetic field of magnitude 3×10^{-2} T. Calculate the torque acting on the needle.

15 When the atomic dipoles are aligned partially or fully, there is a net magnetic moment in the direction of the field in any small volume of the material. The actual magnetic field inside material placed in magnetic field is the sum of the applied magnetic field and the magnetic field due to magnetisation. This field is called magnetic intensity (H). $H=B/\mu_0-M$, where M is the magnetisation of the material, μ0 is the permittivity of vacuum and B is the total magnetic field. The measure that tells us how a magnetic material responds to an external field is given by a dimensionless quantity is appropriately called the magnetic susceptibility: for a certain class of magnetic materials, intensity of magnetisation is directly proportional to the magnetic intensity.

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(d) Magnetic permeability Henry/ m

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(a) 2×10^5 A/m (b) 3×10^5 A/m

(c) 4×10^5 A/m (d) 5×10^5 A/m

(iv) A solenoid has core of a material with relative permeability 500 and its windings carry a current of 1 A. The number of turns of the solenoid is 500 per metre. The magnetization of the material is nearly

(a) 2.5×103 A m^{-1} (b) 2.5×105 A m^{-1}

(c) 2.0×103 A m^{-1} (d) 2.0×105 A m^{-1}

(v) The relative permeability of iron is 6000. Its magnetic susceptibility is

(a) 5999 (b) 6001

(c) 6000 x 10^{-7} (d) 6000 x 10^{7}

CHAPTER 6: ELECTROMAGNETIC INDUCTION

Gist of Lesson:-

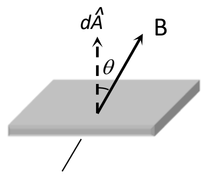
- The phenomenon of producing induced current due to change in magnetic flux is called EMI

Magnetic Flux :-

The total number of magnetic lines of force passing normally through an area placed in a magnetic field is equal to the magnetic flux linked with that area.

For elementary area *dA* of a surface flux linked $d\phi = B\,dA\cos\theta$ or $d\phi = \vec{B}\cdot d\vec{A}$

So, Net flux through the surface $\boldsymbol{\phi = \oint \vec{B}\cdot d\vec{A} = BA\cos\theta}$



For *N*-turns coil $\phi = NBA\cos\theta$

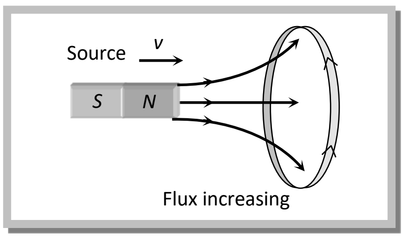
- Magnetic flux is a scalar quantity.
- S.I. unit is *weber* (*wb*),
- CGS unit is *Maxwell* or *Gauss* × cm^2;
- $1\,wb = 10^8$ *Maxwell* .
- Other units : *Tesla* × m^2 $= \frac{N \times m}{Amp} = \frac{Joule}{Amp} = \frac{Volt \times Coulomb}{Amp} = Volt \times sec$ = *Ohm* × *Coulomb* = *Henry* × *Amp*.
- Dimensional formula [ϕ] = [$ML^2T^{-2}A^{-1}$]
- **Maximum and Zero flux**

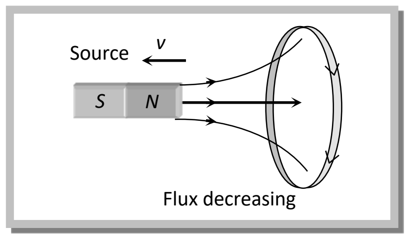
If $\theta = 0^o$, *i.e.* plane is held perpendicular to the direction of magnetic field then flux from the surface is maximum and if $\theta = 90^o$ *i.e*. plane is held parallel to the direction of magnetic field then flux linked with the surface is zero.

Faraday's Experiments:-

- First experiment

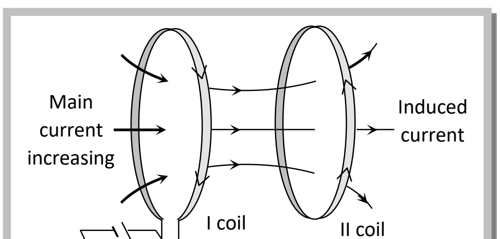
A coil is arranged to link some of the magnetic flux from a source *S*. If relative motion occurs between coil and source *S* such that flux linked with the coil changes, a current is induced in it.





- **Second experiment**

Two coils are arranged so that a steady current flows in one and some of its magnetic flux links with the other. If the current in the first coil changes a current is induced in the second.



❖ Faraday's Laws :-

➢ **First Law**

Whenever the number of magnetic lines of force (magnetic flux) passing through a circuit changes (or a moving conductor cuts the magnetic flux) an emf is produced in the circuit (or emf induces across the ends of the conductor) called induced emf. The induced emf persists only as long as there is change or cutting of flux.

➢ **2nd law**

The induced emf is given by rate of change of magnetic flux linked with the circuit *i.e.* $e = -\frac{d\phi}{dt}$. For *N* turns $e = -\frac{N\,d\phi}{dt}$; Negative sign indicates that induced emf (*e*) opposes the change of flux.

❖ **Induced current :** If circuit is closed, then induced current is given by $i = \frac{e}{R} = -\frac{N}{R}.\frac{d\phi}{dt}$; where *R* is the resistance of circuit

❖ **Lenz ' Law :- Induced current opposes the factor due to which it produced.**

❖ <u>**MOTIONAL EMF**</u> : The EMF induced due to motion of a conducter in B.

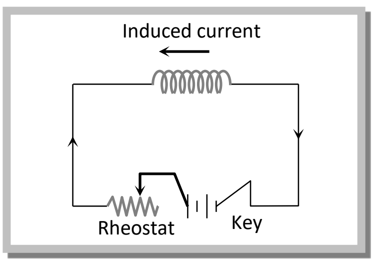
e = -dΦ /dt=-dB.A/dt=-BdA/dt=-Bldx/dt Or e=-Blv & i =Blv/R

➢ **Force**: F =ilB= -B(Blv/R)l =B^2 v l^2/R

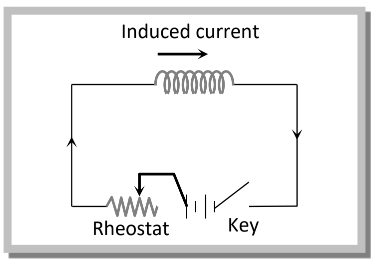
➢ **Power :** P =FV=B^2 r^2 l^2/R

❖ Self-Induction

Whenever the electric current passing through a coil or circuit changes, the magnetic flux linked with it will also change. As a result of this, in accordance with Faraday's laws of electromagnetic induction, an emf is induced in the coil or the circuit which opposes the change that causes it. This phenomenon is called 'self induction' and the emf induced is called back emf, current so produced in the coil is called induced current.



Main current increasing



Main current decreasing

➢ **Coefficient of self-induction:** If no magnetic materials are present near the coil, number of flux linkages with the coil is proportional to the current *i*. *i.e.*, $N\phi \propto i$ or $N\phi = Li$ (*N* is the number of turns in coil and $N\phi$ – total flux linkage) where $\boldsymbol{L = \frac{N\phi}{i}}$ = coefficient of self-induction.

If *i* = 1 *amp*, *N* = 1 then, *L* = ϕ *i.e.,* the coefficient of self induction of a coil is equal to the flux linked with the coil when the current in it is 1 *amp*.

➢ By Faraday's second law induced emf $e = -N\frac{d\phi}{dt}$. Which gives $\boldsymbol{e = -L\frac{di}{dt}}$; If $\frac{di}{dt} = 1\,Amp\ /\ sec$ then |*e*|= *L*.

Hence coefficient of self induction is equal to the emf induced in the coil when the rate of change of current in the coil is unity.

➢ **Units and dimensional formula of '*L*'**

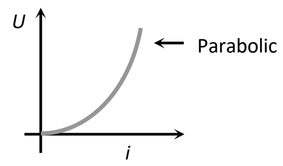
Practical Unit is henry (***H***).

It's dimensional formula [*L*] = $[ML^2T^{-2}A^{-2}]$

➢ **Dependence of self-inductance (*L*):** '*L*' does not depend upon current flowing or change in current flowing but it depends upon number of turns (*N*), Area of cross section (*A*) and permeability of medium (μ). (Soft iron has greater permeability. Hence greater self inductance *L*)

❖ **Magnetic potential energy of inductor:** In building a steady current in the circuit, the source emf has to do work against of self-inductance of coil and whatever energy consumed for this work stored in magnetic field of coil this energy called as magnetic potential energy (*U*) of coil

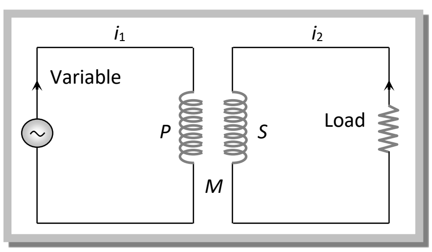
$U = \int_0^i Li\,di = \frac{1}{2}Li^2$; Also $U = \frac{1}{2}(Li)i = \frac{N\phi i}{2}$



Energy density is given as $U = \frac{1}{2}\frac{B^2}{\mu_0}$.

❖ Mutual Induction

Whenever the current passing through a coil or circuit changes, the magnetic flux linked with a neighbouring coil or circuit will also change. Hence an emf will be induced in the neighbouring coil or circuit. This phenomenon is called 'mutual induction'. The coil or circuit in which the current changes is called 'primary' while the other in which emf is set up is called 'secondary'.



In case of mutual inductance for two coils situated close to each other, total flux linked with the secondary due to current in the primary is $N_2\phi_2$ and $N_2\phi_2 \propto i_1 \Rightarrow$ $\boldsymbol{N_2\phi_2 = Mi_1}$ where N_1 - Number of turns in primary; N_2 - Number of turns in secondary; ϕ_2 - Flux linked with each turn of secondary; i_1 - Current flowing through primary; M- Coefficient of mutual induction or mutual inductance.

According to Faraday's second law emf induces in secondary $e_2 = -N_2\frac{d\phi_2}{dt}$; $\boldsymbol{e_2 = -M\frac{di_1}{dt}}$; If $\frac{di_1}{dt} = \frac{1Amp}{sec}$ then $|e_2| = M$. Hence coefficient of mutual induction is equal to the emf induced in the secondary coil when rate of change of current in primary coil is unity.

- Units and dimensional formula of M are similar to self-inductance (L)
- **Dependence of mutual inductance**

(a) Number of turns (N_1, N_2) of both coils

(b) Coefficient of self inductances (L_1, L_2) of both the coils

(c) Area of cross-section of coils

(d) Magnetic permeability of medium between the coils (μ_r) or nature of material on which two coils are wound

(e) Distance between two coils (As $d\uparrow = M\downarrow$)

(f) Orientation between primary and secondary coil (for 90° orientation no flux relation $M = 0$)

(g) Coupling factor 'K' between primary and secondary coil

- **Calculation of mutual inductance between two coils**

If two coils (1 and 2) also called primary and secondary coils are placed close to each other (maximum coupling); N_1 and N_2 = Number of turns in primary and secondary coils respectively, ϕ_2 = Flux linked with each turn of secondary, $N_2\phi_2$ = Total flux linkage with secondary coils; M = Mutual inductance between two coil

So $N_2\phi_2 = Mi_1 \Rightarrow N_2(B_1A_2) = Mi_1 \Rightarrow \boldsymbol{M = \frac{B_1N_2A_2}{i_1}}$

Multiple Choice Questions: -

1. The magnetic flux linked with a coil, in *webers*, is given by the equations $\phi = 3t^2 + 4t + 9$. Then the magnitude of induced e.m.f. at t = 2 *second* will be **[KCET (Engg./Med.) 2000; CPMT 2003]**

(a) 2 *volt* (b) 4 *volt* (c) 8 *volt* (d) 16 *volt*

2. The magnetic flux linked with a coil at any instant '*t*' is given by $\phi = 5t^3 - 100t + 300$, the *emf* induced in the coil at *t* = 2 second is

(a) – 40 *V* (b) 40 *V* (c) 140 *V* (d) 300 *V*

3. Faraday's laws are consequence of conservation of

(a) Energy (b) Energy and magnetic field (c) Charge (d) Magnetic field

4. In a coil of area 20 cm^2 and 10 turns with magnetic field directed perpendicular to the plane changing at the rate of 10^4 *T/s*. The resistance of the coil is 20 Ω. The current in the coil will be

(a) 10 *A* (b) 20 *A* (c) 0.5 *A* (d) 1.0 *A*

5. A coil having an area of 2 m^2 placed in a magnetic field which changes from 1 to 4 *weber*/m^2 in 2 *seconds*. The e.m.f. induced in the coil will be

(a) 4 *volt* (b) 3 *volt*

(c) 2 *volt* (d) 1 *volt*

(a) 4 *volt* (b) 3 *volt* (c) 2 *volt* (d) 1 *volt*

6. To induce an e.m.f. in a coil, the linking magnetic flux

(a) Must decrease (b) Can either increase or decrease

(c) Must remain constant (d) Must increase

7. A magnetic field of 2×10^{-2} *Tesla* acts at right angles to a coil of area $100\, cm^2$ with 50 turns. The average *emf* induced in the coil is 0.1 *V*, when it is removed from the field in time *t*. The value of *t* is

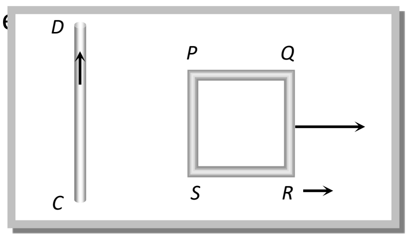
(a) 0.1 second (b) 0.01 second (c) 1 second (d) 20 second

8. A cylindrical bar magnet is kept along the axis of a circular coil. If the magnet is rotated about its axis, then

(a) A current will be induced in a coil (b) No current will be induced in a coil

(c) Only an e.m.f. will be induced in the coil (d) An e.m.f. and a current both will be induced in the coil

9. A square loop *PQRS* is carried away from a current carrying long straight conducting wire *CD* (figure). The direction of induced current in the



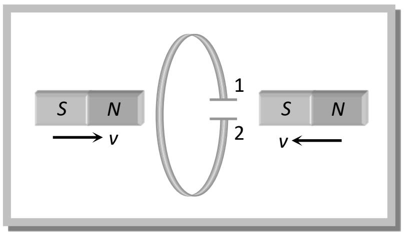
(a) Anticlockwise

(b) Clockwise

(c) Some times clockwise sometimes anticlockwise

(d) Current will not be induced

10. The north and south poles of two identical magnets approach a coil, containing a condenser, with equal speeds from opposite sides. Then



(a) Plate 1 will be negative and plate 2 positive

(b) Plate 1 will be positive and plate 2 negative

(c) Both the plates will be positive

(d) Both the plates will be negative

Ans. 1 (d) ,2 (b) ,3 (a),4 (a),5(b),6(b),7 (a),8(b),9(b),10(b)

1 Mark Questions :-

Q1. When is the magnetic flux crossing a given surface area held in a magnetic field maximum?
Ans: When area is held perpendicular to the direction of magnetic field.

Q2. What is the basic cause of induces emf?
Ans: Change in magnetic flux linked with the circuit.

Q3. Write an expression for self-inductance of a long solenoid.
Ans: $L=\mu_0 N^2 A/l$ where symbols have usual meanings

Q4. How does the mutual inductance of a pair of coil change when distance between the coils is increased?
Ans: Decreases

Q5. How does the mutual inductance of a pair of coil change when an iron sheet is placed between the two coils?
Ans: Increases

Q6. What is SI Unit of mutual inductance of two coils?
Ans: Henry

Q7. What is electromagnetic induction?
Ans: Phenomena of production of induced emf due to change of magnetic flux linked with a closed circuit.

Q8. What are the dimensions of self-inductance?
Ans: $M^1L^2T^{-2}A^{-2}$

Q9. What are the dimensions of Mutual-inductance?
Ans: $M^1L^2T^{-2}A^{-2}$

Q10. A metallic rod held horizontally along East-West direction is allow to fall under gravity. Will there be an emf induced across its ends?

Ans: Yes, this is because horizontal component of the earth's magnetic field along N^{-S} is intercepted by the falling rod.

Q11. On what factors does the magnitude of emf induced in the circuit due to magnetic field depend?

Ans: Rate of change of magnetic flux.

Q12. When current in coil changes with time, how is the back emf induced in the coil related to it?

Ans: Back emf induced in the coil opposes the change in the current.

Q13. Define 1 henry.

Ans: One(1) henry is self-inductance of the coil in which 1 volt emf is produced when the rate of change of current in the coil is 1 A/s.

Assertion-Reason Type Questions-

These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If the Assertion is incorrect but Reason is correct.

1. **Assertion :** Induced emf will always occur whenever there is change in magnetic flux.
   Reason : Current always induces whenever there is change in magnetic flux.
2. **Assertion :** Lenz's law violates the principle of conservation of energy.
   Reason : Induced emf always opposes the change in magnetic flux responsible for its production.
3. **Assertion :** Acceleration of a magnet falling through a long solenoid decreases.
   Reason : The induced current produced in a circuit always flow in such direction that it opposes the change to the cause that produced it.
4. **Assertion :** An induced emf appears in any coil in which the current is changing.
   Reason : Self induction phenomenon obeys Faraday's law of induction.
5. **Assertion :** An emf can be induced by moving a conductor in a magnetic field.
   Reason : An emf can be induced by changing the magnetic field.
6. Assertion :Inductance coil are made of copper.
   Reason : Induced current is more in wire having less resistance.
7. Assertion: Lenz's law violates the principle of conservation of energy.
   Reason : Induced e.m.f. opposes always the change in magnetic flux responsible for its production.

8. Assertion : In the phenomenon of mutual induction, self induction of each of the coils persists.

Reason : Self induction arises when strength of current in same coil changes. In mutual induction, current is changing in both the individual coils.

Ans. 1 (c) ,2 (a),3(a),4(b),5(b),6(a),7(d),8(b)

Two Marks Questions

Q1. Name the SI Unit of (a) Magnetic Flux (b) Magnetic Induction

Ans: (a) Weber (b) Tesla

Q2. What are the factors on which self-inductance of a coil depend?

Ans: (a) Number of turns

(b) Area of a cross-section

(c) Permeability of core material

Q3. Distinguish between self-induction and Mutual Induction

Ans: **Self-induction:** It is the property of a coil by virtue of which the coil opposes any change in the strength of current flowing through it by inducing an emf in itself.

Mutual Induction: It is the property of two coils by virtue of which each opposes any change in the strength of current flowing through the other by developing an opposing an emf.

Q4. Distinguish between coefficient of self-inductance and coefficient of mutual inductance.

Ans: **Coefficient of self-inductance:** It is numerically equal to the amount of magnetic flux linked with the coil when unit current flows through the coil.

Coefficient of mutual inductance: Of two coils is equal to the emf induced in one coil when rate of change of current through the other coil is unity.

Q5. What emf will be induced in a 10H inductor in which current changes from 10Amp to 7Amp in 9×10^{-2}seconds?

Ans: $e = -L\frac{dI}{dt}$

$= \frac{-10(7-10)}{9\times10^{-2}}$

$= 333.3V$

Q6. What is the self-inductance of a solenoid of length 40cm., area of cross-section $20cm^2$ and total number of turns 800.

Ans: $L=\mu_0N^2A/l$

$= \frac{4\pi\times10^{-7}(800)^2\times20\times10^{-4}}{0.4}$

$$= 4.02 \times 10^{-3} H$$

Q7. Current in the circuit falls from 5.0 A to 0.0A in 0.1 sec. if an average emf of 200volt is induced calculate the self-induction of the current?

Ans. $\frac{d\Phi}{dt} = \frac{0.0-5.0}{0.1}$ = -50A/S

$L = -\frac{e}{\frac{d\Phi}{dt}} = \frac{200}{-(-50)}$ = 4H

Q 8. A pair of adjacent coil has a mutual inductance of 1.5 H if the current in the one coil changes from 0 to 20 A in 0.5 sec what is the change of magnetic flux linkage with the other coil

Ans. $\Phi_2 = MI_1$

change in magnetic flux $\Delta\Phi_2 = M\Delta I_1 = 1.5(20-0)$ = 20 A

$\Delta\Phi_2 = 1.5 \times 20 = 30$ Weber

Q9. Two spherical bobs, one metallic and the other of glass of the same size are allow to fall freely from the same height above the ground which of the two would reach earlier and why?

Ans: Glass, No effect of EMI in glass.

Q10. Two identical loops, one of copper and the other of Aluminium are rotated with the same angular speed in the same magnetic field. Compare (a) the induces emf (b) the current produced in the two coils.

Ans: (a) emf same (area and time period same)
(b) Current in copper is more as copper has less resistance.

Q11. A plane loop of rectangular shape is moved within the region of a uniform magnetic field acting perpendicular to its plane. What is the direction and magnitude of the current induced in it?

Ans: No current, hence no direction.

Q 12. A bar magnet falls from a height h through a metal ring. Will its acceleration be equal to g. Give reason for your answer?

Ans: Acceleration will be less than g as current induces opposes the motion of the magnet.

Q.13 Two identical loops, one of copper and other of aluminium, are rotated with same angular speed in the same magnetic field. Compare:

i) The induced e.m.f.

ii) The current produced in the two coils.

Justify your answer

Ans. EMF will be same. Induced current is more in copper.

Q.14 A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer.

Ans. Yes, emf will be induced in the rod as there is change in magnetic flux.
When a metallic rod held horizontally along east-west direction, is allowed to fall freely under gravity i.e. fall from north to south , the intensity of magnetic lines of earth's magnetic field changes through it i.e. the magnetic flux changes and hence the induced emf in it.

Three Marks Questions

Q1. State an explain Faraday's Laws of EMI.
Ans . First Law :-Whenever the number of magnetic lines of force (magnetic flux) passing through a circuit changes (or a moving conductor cuts the magnetic flux) an emf is produced in the circuit (or emf induces across the ends of the conductor) called induced emf. The induced emf persists only as long as there is change or cutting of flux.
2nd Law:-

The induced emf is given by rate of change of magnetic flux linked with the circuit *i.e.* $e = -\frac{d\phi}{dt}$. For *N* turns $e = -\frac{N\,d\phi}{dt}$; Negative sign indicates that induced emf (*e*) opposes the change of flux.

Q2. Derive a relation for coefficient of Self-inductance of a long solenoid.
Ans. We are considering a solenoid with n turns with length l . The area of cross section is AA. The solenoid carriers current I and B is the magnetic field inside the solenoid.
The magnetic field B is given as,
$B=\mu_0 nI$
Where, μ_0 is the permeability of free space, n is the number of turns and I is the current in the solenoid and L is the length.
The magnetic flux is the product of the magnetic field and area of the cross section.
Here the magnetic flux per turn is given as,
$\varphi=B\times A$

Substituting the values in the above expression,
$\varphi=\mu_0 nI\ A/l$
Hence there is n number of turns, the total magnetic flux is given as,

$$\varphi= \mu_0 n^2 I\ A/l \qquad \text{…………………(1)}$$

If LL is the coefficient of self-inductance of the solenoid, then
$\varphi=LI$...........(2)
Comparing the two equations we get,

$$LI=\mu_0 n^2 IA/l$$

So the expression for the coefficient of self-inductance is

$$L = \mu_0 n^2 A/l$$

Q3. Prove that the magnitude of the emf induced in a conductor of length l when it moves at v m/s perpendicular to a uniform magnetic field B is Blv

Ans. The emf induced in a straight conductor of length *l* moving with velocity v perpendicular to a magnetic field B is $E = Blv$

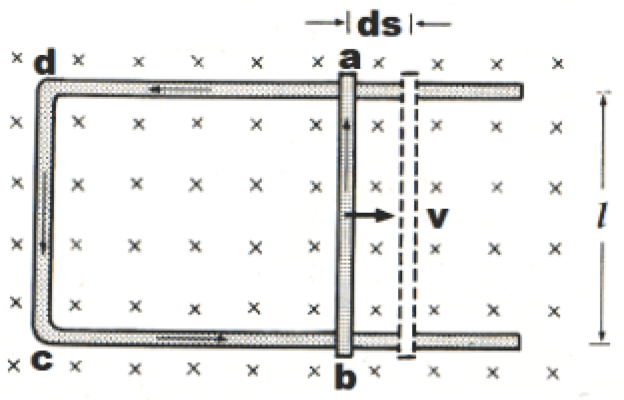


Fig. 5

Proof.

$$F = lIB$$

Because of this side-thrust, an external force provided by some working agent is required to maintain the motion. The work done by this agent is the work done on the circulating charge. There is a direct conversion here of mechanical energy to electrical energy.

The distance moved in time t is

$$ds = v\,dt$$

and the work done is

$$dW = F\,ds = lIB \cdot v\,dt$$

Now the product of I and dt is the charge dq displaced in this time, so

$$dW = Blv\,dq$$

or

$$dW/dq = Blv$$

Since E = dW/dq,

E = Blv

Q4. (i) Define mutual Inductance
(ii) A pair of adjacent coils has a mutual inductance of 1.5H. If the current in one coil changes from 0 to 20 A in 0.5 second, what is the change of flux linkage with the other coil? (Hint: 30 weber)

Q5. State Lenz's law. Show that Lenz's law follows from principle of conservation of energy.
Ans. Lenz's law states that the polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produces it.
Yes and its justification

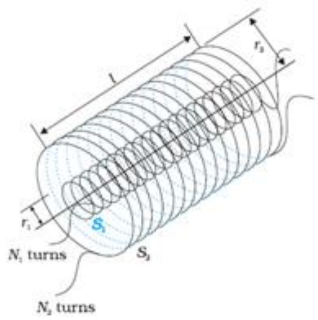
Long Answer Type Question (5 Marks)

Ques. (1) (a)Define the term mutual inductance between the two coils. Obtain the expression for mutual inductance of a pair of long solenoids each of length '*l*' and radii r_1 and r_2 (r_2>>r_1). Total numbers of turns in the two coils are N_1 and N_2 respectively.

(b) A long solenoid with 15 turns per cm has a small loop of area 2cm^2 placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2A to 4 A in 0.1 second, what is the induced emf in the loop while the current is changing? (Hint: 7.5 µV)

Ans. (a) The mutual-inductance between two coils is defined as the number of the flux linkages in one coil when unit current flows through the nearby coil .Fig shows two long, coaxial solenoids of length l with number of turns per unit length n_1 and n_2 and radii r_1 and r_2 respectively.

Total number of turns $N_1 = n_1$ l and $N_2 = n_2$ l



If I_2 be the current flowing in the outer solenoid,
From the definition of mutual inductance

$$M_{12} = \frac{N1\emptyset_1}{I_2} = \frac{N_1 A_1 B_2}{I_2} = \frac{N_1 A_1 \mu_0 n_2 I_2}{I_2} = \mu_0 N_1 N_2 \, l \, A_1 = \frac{\mu_0 n_1 n_2 A_1}{l}$$

(b) using formula e= 7.5 µV

Case Study Based Questions: -

1. Self-Induction: - When a current I flow through a coil, flux linked with it is $\phi = LI$, where L is a constant known as self-inductance of the coil. Any change in current sets up an induced emf in the coil. Thus, the self-inductance of a coil is the induced emf set up in it when the current passing through it changes at the unit rate. It is a measure of the opposition to the growth or the decay of current flowing through the coil. Also, the value of self-inductance depends on the number of turns in the solenoid, its area of cross-section, and the permeability of its core material.

(i) The inductance in a coil plays the same role as
(a) inertia in mechanics
(b) energy in mechanics
(c) momentum in mechanics
(d) force in mechanics

(ii) A current of 2.5 A flows through a coil of inductance 5 H. The magnetic flux linked with the coil is
(a) 0.5 Wb
(b) 12.5 Wb
(c) zero
(d) 2 Wb

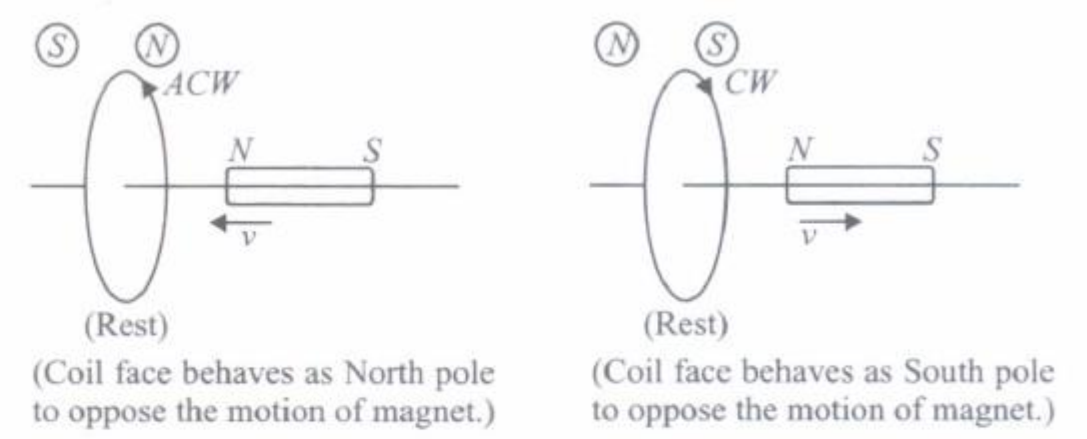
(iii) The inductance L of a solenoid depends upon its radius R as
(a) $L \propto R$
(b) $L \propto 1/R$
(c) $L \propto R^2$
(d) $L \propto R^3$

(iv) The unit of self-inductance is
(a) Weber ampere
(b) $Weber^{-1}$ ampere
(c) Ohm second
(d) Farad

(v) The induced emf in a coil of 10 henry inductance in which current varies from 9 A to 4A in 0.2
second is
(a) 200 V
(b) 250 V
(c) 300 V
(d) 350 V

Ans.: - 1 (a) 2(b) 3 (c) 4 (c) 5 (b)

2. Lenz's law states that the direction of induced current in a circuit is such that it opposes the change which produces it. Thus, if the magnetic flux linked with a closed circuit increases, the induced current flows in such a direction that magnetic flux is created in the opposite direction of the original magnetic flux. If the magnetic flux linked with the closed-circuit decreases, the induced current flows in such a direction so as to create magnetic flux in the direction of the original flux.



(i) Which of the following statements is correct?

(a) The induced e.rn.f is not in the direction opposing the change in magnetic flux so as to oppose the cause
(b) The relative motion between the coil and magnet produces change in magnetic flux.
(c) Emf is induced only if the magnet is moved towards coil.
(d) Emf is induced only if the coil is moved towards magnet

(ii)The polarity of induced emf is given by

(a) Ampere's circuital law
(b) Biot-Savart law
(c) Lenz's law
(d) Fleming's right hand rule

(iii) Lenz's law is a consequence of the law of conservation of

(a) charge (b) mass (c) momentum (d) energy

(iv) Two identical circular coils A and B are kept in a horizontal tube side by side without touching each other. If the current in coil A increases with time, in response, the coil B.

(a) is attracted by A (c) is repelled
(c) is repelled (d) rotates

Ans. 1(b) ,2 (c) 3(d) 4 (c)

Practice Questions

1. Define self-inductance of a coil. Write its S.I. unit.

2. What is meant by back emf ? When current in a coil changes with time, how is the back emf induced in the coil related to it ?

3. Define Mutual inductance of a coil. Write its S.I. unit.

4. What is motional electromotive force (motional emf)?

5. Use the expression for Lorentz force acting on the charge carriers of a conductor to obtain the expression for the induced emf across the conductor of length moving with velocity through a magnetic field acting perpendicular to its length.

6. A metallic rod of length is rotated with a frequency, with one end hinged at the centre in a uniform magnetic field as shown. Derive an expression for- (a) induced emf and induced current in the rod (b) magnitude and direction of the force acting on the rod (c) power required to rotate the rod

7. Derive the expression for the self-inductance of a long solenoid of cross sectional area A, length l , and having turns n per unit length.

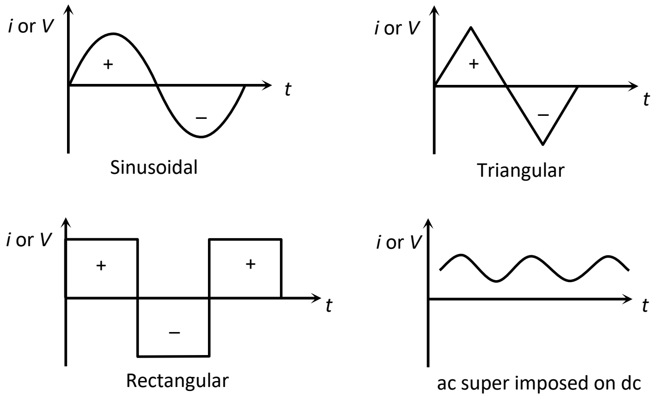
8. Derive an expression for the self-inductance of a circular aired coil. Name the three factors on which the self- inductance of a coil depends.

9. (i) Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other.
(ii) Write the factors on which the mutual inductance of a pair of solenoids depends.

CHAPTER 7: ALTERNATING CURRENT

(1) An alternating quantity (current *i* or voltage *V*) is one whose magnitude changes continuously with time between zero and a maximum value and whose direction reverses periodically.

(2) Some graphical representation for alternating quantities



(3) **Equation for *i* and *V* :** Alternating current or voltage varying as sine function can be written as

$$i = i_0 \sin\omega t = i_0 \sin 2\pi\nu t = i_0 \sin \frac{2\pi}{T} t$$

and $V = V_0 \sin\omega t = V_0 \sin 2\pi\nu t = V_0 \sin\frac{2\pi}{T} t$

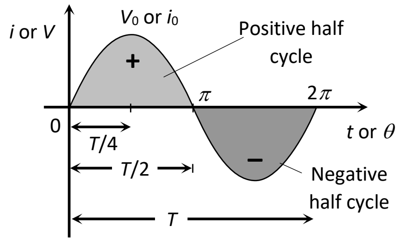


Fig. 24.2

where *i* and *V* are Instantaneous values of current and voltage,

i_0 and V_0 are peak values of current and voltage

ω = Angular frequency in rad/sec, ν = Frequency in Hz and T = time period

Important Values of Alternating Quantities

(1) Peak value (i_o or V_0) : The maximum value of alternating quantity (i or V) is defined as peak value or amplitude.

(2) Mean square value ($\overline{V^2} or\ \overline{i^2}$) : The average of square of instantaneous values in one cycle is called mean square value. It is always positive for one complete cycle. e.g. $\overline{V^2} = \frac{1}{T}\int_0^T V^2 dt = \frac{V_0^2}{2}$ or $\overline{i^2} = \frac{i_0^2}{2}$

(3) Root mean square (r.m.s.) value : Root of mean of square of voltage or current in an ac circuit for one complete cycle is called r.m.s. value. It is denoted by Vrms or irms

$$i_{rms} = \sqrt{\frac{i_1^2+i_2^2+\ldots}{n}} = \sqrt{\overline{i^2}} = \sqrt{\frac{\int_0^T i^2 dt}{\int_0^T dt}} = \frac{i_0}{\sqrt{2}} = 0.707\ i_0 = 70.7\%\ i_0$$

Similarly

$V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707V_0 = 70.7\%$of V_0 $\left[\langle sin^2(\omega t)\rangle = \langle cos^2(\omega t)\rangle = \frac{1}{2}\right]$

(4) Mean or Average value (i_{av} or V_{av}) : The average value of alternating quantity for one complete cycle is zero.

The average value of ac over half cycle (t = 0 to T/2)

$i_{av} = \frac{\int_0^{T/2} i dt}{\int_0^{T/2} dt} = \frac{2i_0}{\pi} = 0.637i_0 = 63.7\%$ of i_0,

Similarly $V_{av} = \frac{2V_0}{\pi} = 0.637V_0 = 63.7\%$ of V_0.

(5)Power in ac Circuits

In dc circuits power is given by P = Vi. But in ac circuits, since there is some phase angle between voltage and current, therefore power is defined as the product of voltage and that component of the current which is in phase with the voltage.

Thus $P = Vicos\varphi$; where V and i are r.m.s. value of voltage and current.

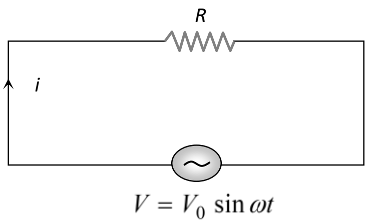
(1) Instantaneous power : Suppose in a circuit $V = V_0\, sin\,\omega\, t$ and $i = i_0\, sin(\omega t + \varphi)$ then $P_{\text{instantaneous}} = Vi = V_0 i_0\, sin\,\omega\, t\, sin(\omega t + \varphi)$

(2) Average power: The average of instantaneous power in an ac circuit over a full cycle is called average power. It's unit is watt i.e.

$$P_{av} = V_{rms} i_{rms}\, cos\,\varphi = \frac{V_0}{\sqrt{2}}.\frac{i_0}{\sqrt{2}} cos\,\varphi = \frac{1}{2} V_0 i_0\, cos\,\varphi = i_{rms}^2 R = \frac{V_{rms}^2 R}{Z^2}$$

where, cos Ø= Resistance(R) / Impedance (Z) is called the power factor 0f AC circuit

Resistive Circuit (*R*-Circuit)



(1) Current :$i = i_0\, sin\,\omega\, t$

(2) Peak current : $i_0 = \frac{V_0}{R}$

(3) Phase difference between

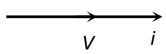
voltage and current : ϕ = 0°

(4) Power factor : $cos\,\varphi = 1$

(5) Power : $P = V_{rms} i_{rms} = \frac{V_0 i_0}{2}$

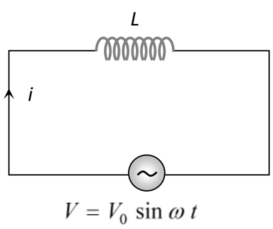
(6) Time difference : T.D. = 0

(7) Phasor diagram : Both are in same phase



Inductive Circuit (L-Circuit)

(1) Current : $i = i_0\, sin\left(\omega t - \frac{\pi}{2}\right)$



(2) Peak current :

$i_0 = \frac{V_0}{X_L} = \frac{V_0}{\omega_L} = \frac{V_0}{2\pi\nu L}$

(3) Phase difference between

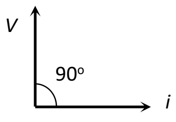
voltage and current $\varphi = 90^o$ (or $+\frac{\pi}{2}$)

(4) Power factor : $cos\,\varphi = 0$

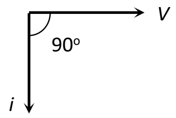
(5) Power : P = 0

(6) Time difference : $\text{T.D.} = \frac{T}{4}$

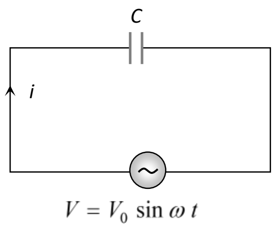
(7) Phasor diagram : Voltage leads the current by $\frac{\pi}{2}$



or



Capacitive Circuit (C-Circuit)



(1) Current : $i = i_0\,sin\left(\omega t + \frac{\pi}{2}\right)$

(2) Peak current :

$i_0 = \frac{V_0}{X_C} = V_0\omega C = V_0(2\pi\nu C)$

(3) Phase difference between

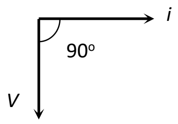
voltage and current : $\varphi = 90^o$ (or $-\frac{\pi}{2}$)

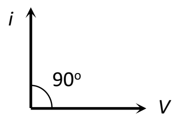
(4) Power factor : $cos\,\varphi = 0$

(5) Power : P = 0

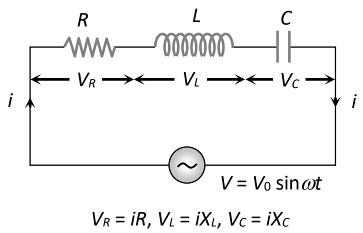
(6) Time difference : $\text{TD} = \frac{T}{4}$

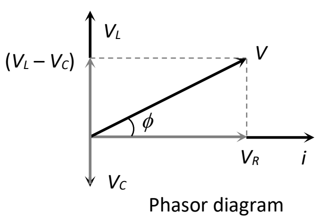
(7) Phasor diagram : Current leads the voltage by $\pi/2$





Series RLC-Circuit





(1) Equation of current : $i = i_0\,sin(\,\omega t \pm \varphi)$; where $i_0 = \frac{V_0}{Z}$

(2) Equation of voltage : From phasor diagram

$V = \sqrt{V_R^2 + (V_L - V_C)^2}$

(3) Impedance of the circuit :

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

(4) Phase difference : From phasor diagram

$$tan\,\varphi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} = \frac{\omega L - \frac{1}{\omega C}}{R} = \frac{2\pi \nu L - \frac{1}{2\pi\nu C}}{R}$$

(5) If net reactance is zero : Means $X = X_L - X_C = 0$

$\Rightarrow X_L = X_C$. This is the condition of resonance

(6) At resonance (series resonant circuit)

(i) $X_L = X_C \Rightarrow Z_{min} = R$ i.e. circuit behaves as resistive circuit

(ii) $V_L = V_C \Rightarrow V = V_R$ i.e. whole applied voltage appeared across the resistance

(iii) Phase difference : $\phi = 0^o \Rightarrow$ p.f. = $\cos\phi = 1$

(iv) Power consumption $P = V_{rms}\, i_{rms} = \frac{1}{2} V_0 i_0$

(v) Current in the circuit is maximum and it is $i_0 = \frac{V_0}{R}$

(vi) These circuit are used for voltage amplification and as selector circuits in wireless telegraphy.

(7) Resonant frequency (Natural frequency)

At resonance $X_L = X_C \Rightarrow \omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}} \frac{rad}{sec} \Rightarrow \nu_0 = \frac{1}{2\pi\sqrt{LC}} Hz(\text{or} cps)$

(Resonant frequency doesn't depend upon the resistance of the circuit)

Wattless Current

Average power is given by

$P_{av} = E_{rms} = I_{rms} \cos\theta$

Here the $I_{rms} \cos\phi$ contributes for power dissipation. Therefore, it is called wattless current.

AC Generator or Dynamo

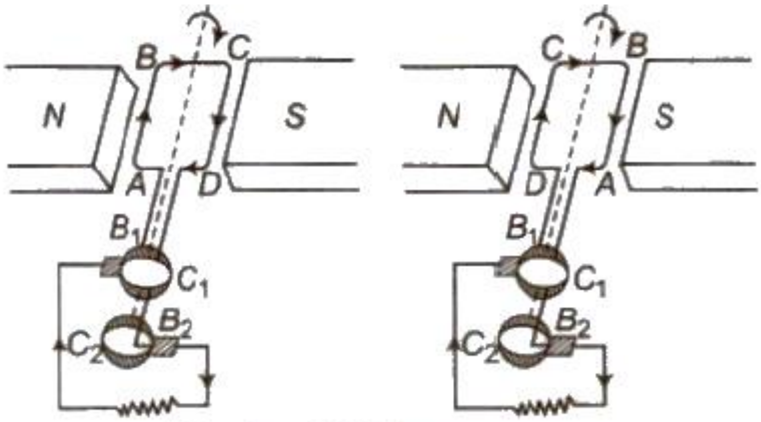
It is a device which converts mechanical energy into alternating current energy.

Its working is based on electromagnetic induction.

The induced emf produced by the AC generator is given by

$e = NBA\omega \sin \omega t = e_o = \sin \omega t$

The parts of an AC generator



Working of AC dynamo

(i) **Armature** It is rectangular coil of insulated copper wire having a large number of turns.

(ii) **Field Magnet**s These are two pole pieces of a strong electromagnet.

TRANSFORMER

(i)Vs/Vp = Ns/Np

(ii)efficiency η = (VsIs/ Vp Ip) ×100

for ideal transformer η = 100%

iii) For ideal transformer Vs/Vp = Ns/Np = Ip/Is

MCQ

1.If a current *I* given by $I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$ flows in an ac circuit across which an ac potential of $E = E_0 \sin \omega t$ has been applied, then the power consumption *P* in the circuit will be

(a) $P = \frac{E_0 I_0}{\sqrt{2}}$ (b) $P = \sqrt{2} E_0 I_0$

(c) $P = \frac{E_0 I_0}{2}$ (d) *P* = 0

1Ans :D

2.Voltage and current in an ac circuit are given by $V = 5\,sin\left(100\pi t - \frac{\pi}{6}\right)$ and $I = 4\,sin\left(100\pi t + \frac{\pi}{6}\right)$

(a) Voltage leads the current by 30^o

(b) Current leads the voltage by 30^o

(c) Current leads the voltage by 60^o

(d)Voltage leads the current by 60^o

2Ans : C

3.The power factor of LCR circuit at resonance is

(a) 0.707 (b) 1

(c) Zero (d) 0.5

3Ans : B

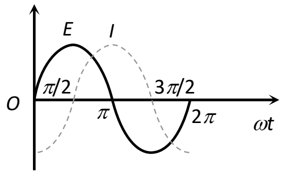
4.In a series circuit R = 300 Ω, L = 0.9 H, C = 2.0 μF and ω = 1000 rad/sec. The impedance of the circuit is

(a) 1300 Ω (b) 900 Ω

(c) 500 Ω (d) 400 Ω

Ans : C

5.The variation of the instantaneous current (I) and the instantaneous emf (E) in a circuit is as shown in fig. Which of the following statements is correct



(a) The voltage lags behind the current by π / 2

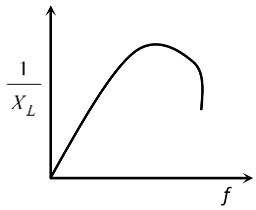
(b) The voltage leads the current by π / 2

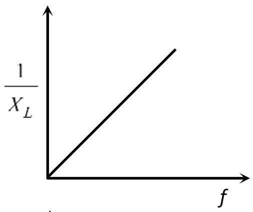
(c) The voltage and the current are in phase

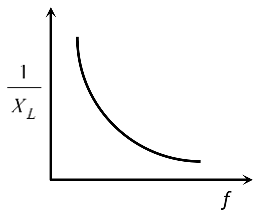
(d) The voltage leads the current by π

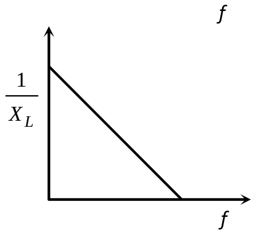
5.Ans : B

6.In pure inductive circuit, the curves between frequency f and reciprocal of inductive reactance 1/XL is

(a) 

(b) 

(c) 

(d) 

6Ans : C

7.The large-scale transmission and distribution of electrical energy over long distances is done with the use of

(a) Dynamo (b) Transformers (c) Generator (d) Capacitor

7Ans : B

8.In an LCR series circuit, the capacitor is changed from C to 4C. To keep the resonant frequency same, the inductance must be changed by?

(a) 2L (b) L/2 (c) 4L (d) L/4

8Ans : D

9.The reading of an ammeter in an alternating current is 4A. The peak value of current in the circuit is

(a) 4 A (b) 8 A (c) 4√2 A (d) √2 A

9.Ans :C

10. In a purely resistive AC circuit, the current

(a) is in phase with the e.m.f.

(b) leads the e.m.f. by a difference of π radians phase

(c) leads the e.m.f. by a phase difference of π /2 radians

(d) lags behind the e.m.f. by phase difference of π /4 radian

10.Ans : A

11. The core of a transformer is laminated, so as to

(a) make it light weight (b) make it robust and strong (c) increase the secondary voltage (d) reduce energy loss due to eddy current

11.Ans : D

12. The ratio of no. of turns of primary coil to secondary coil in a transformer is 2:3. If a cell of 6 V is connected across the primary coil, then voltage across the secondary coil will be

(a) 3 V (b) 6 V (c) 9 V (d) 12 V

12Ans C

13. In a transformer, the no. of turns of primary and secondary coil are 500 and 400 respectively. If 220 V is supplied to the primary coil, then ratio of currents in primary and secondary coils is

(a) 4:5 (b) 5:4 (c) 5:9 (d) 9:5

13Ans : A

14.Power factor is maximum in an LCR circuit when

(a) $X_L = X_C$ (b) $R = 0$

(c) $X_L = 0$ (d) $X_C = 0$

14Ans : A

15 A coil of 200Ω resistance and 1.0 H inductance is connected to an ac source of frequency $200/2\pi\ Hz$. Phase angle between potential and current will be

(a) 30° (b) 90°

(c) 45° (d) 0°

15Ans :C

ASSERTION AND REASON

Directions: In the following questions, two statements are given- one labeled Assertion (A) and the other labelled Reason. Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below

(a) Both Assertion and Reason are true and Reason is the correct explanation of Assertion

(b) Both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

(c) Assertion is true but Reason is false

. (d) Assertion is false but Reason is true

1.Assertion : In series LCR circuit resonance can take place.

Reason : Resonance takes place if inductance and capacitive reactance are equal and opposite.

1.Ans : A

2.Assertion : A bulb connected in series with a solenoid is connected to ac source. If a soft iron core is introduced in the solenoid, the bulb will glow brighter.

Reason :On introducing soft iron core in the solenoid, the inductance increases.

2.Ans : D

3.Assertion : Capacitor serves as a block for dc and offers an easy path to ac.

Reason :Capacitive reactance is inversely proportional to frequency

3.Ans : A

4.Assertion : The alternating current lags behind the emf by a phase angle of, $\pi/2$ when AC flows through an inductor.

Reason : The inductive reactance increases as the frequency of AC source increases.

4.Ans :B

5.Assertion : The power is produced when a transformer steps up the voltage.

Reason : In an ideal transformer VI = constant.

5.Ans : A

6.Assertion : Choke coil is preferred over a resistor to control the current in an AC circuit.

Reason : Power factor of an ideal inductor is zero.

6.Ans : A

7.Assertion : Average value of ac over a complete cycle is always zero.

Reason: Average value of ac is always defined over half cycle.

7.Ans : B

8.Assertion : An electric lamp connected in series with a variable capacitor and ac source, its brightness increases with increase in capacitance.

Reason :Capacitive reactance decrease with increase in capacitance of capacitor.

8Ans : A

9.Assertion : An inductance and a resistance are connected in series with an ac circuit. In this circuit the current and the potential difference across the resistance lag behind potential difference across the inductance by an angle $\pi/2$.

Reason :In LR circuit voltage leads the current by phase angle which depends on the value of inductance and resistance both.

9Ans : B

10.Assertion : A capacitor of suitable capacitance can be used in an ac circuit in place of the choke coil.

Reason :A capacitor blocks dc and allows ac only.

10Ans : B

TWO MARKS QUESTIONS :

1.Why is the use of AC voltage preferred over DC voltage? Give two reasons

1.ANS : It is easy to maintain and change the voltage of AC electricity for transmission and distribution

· AC can be stepped up and back down with transformers quite easily whereas DC cannot as transformers rely on a constantly changing EMF

· Plant cost for AC transmission is much more lower than equivalent DC transmission

2.How much average power over a complete cycle, does an AC source supply to a capacitor?

2.ANS :Power dissipated in ac circuit, P=VrmsIrmscosϕ where cosϕ=Z/R

For an ideal capacitor R=0 cosϕ=ZR=0

P=VrmsIrmscosϕ = VrmsIrms×0=0 (zero).

i.e. power dissipated in an ideal capacitor is zero.

3.Define the term rms value of the current. How is it related to the peak value?

3.ANS :That steady current which, when flows through a resistor of known resistance for a given period of time than as a result the same quantity of heat is produced by the alternating current when flows through the same resistor for the same period of time is called **R.M.S** or effective value of the alternating current. In other words, the R.M.S value is defined as the square root of means of squares of instantaneous values. In a complete cycle, the square root of the average value of the square of alternating current is called the root mean square (RMS) value of alternating current

$I_{rms}=I_0/\sqrt{2}$

.$=0.707I_0$

Where I_0 is the peak value of current.

4.The instantaneous current and voltage of an AC circuit are given by I =(10 sin 300t) A and V= (200 sin 300t) V. What is the power dissipation in the circuit?

4.ANS:The instantaneous current ad voltage of an AC circuit are given.

- I = 10 sin 300 t A
- V = 200 sin 300 t volt

The average power loss over a cycle is given by.

P = V / CosΘ

Where V and I are the rms value of voltage and current.

Here phase difference Φ = 0°

The average power loss over a complete cycle

P = 10 / √2 x 200 /√2 x cos0°

P = 1000 W

Hence the power dissipation in the circuit is 1000 W

5.Prove that an ideal inductor does not dissipate power in an a.c. circuit

5.ANS:The instantaneous EMF is given by E=EoSinωt

the instantaneous current in the inductor is given by I=Iocosωt

the instantaneous power in the inductor is given by P=EI

=EoIocosωtsinωt

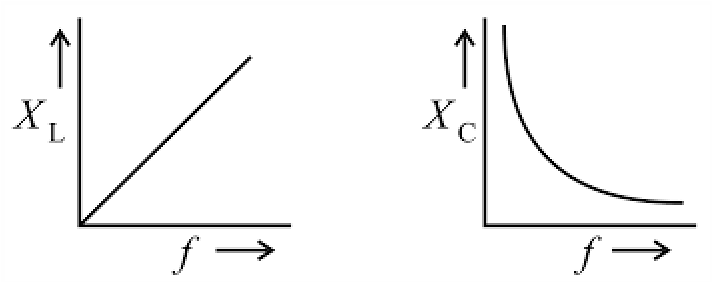
= 2EoIosin2ωt

the average power over the complete cycle Pav=2EoIosin2ωt=0

hence,an ideal inductor does not dissipate power

6. Draw a graph showing variation of reactance of (i)Capacitor (ii)Inductor with frequency

6.ANS :



7.In an AC circuit, the rms voltage is 100√2V. Find the peak value of voltage and its means value during a positive half cycle.

7.ANS:

***Ev*=1002*V*,*E*0=?,*Em*=?**

E*0=√2*Ev*=√2(100/√2)=200*V

***Em*=2*E*0/ *π* =2X200/3.14**

=127.4*V*

8.A capacitor of capacitance 100μF and the coil of resistance 50Ω and inductance 0.5 H are connected in series with a 110 V, 50Hz AC source. Find the rms value of the current

8.ANS: $X_L = \omega L = 2 \times 3.14 \times 50 \times 0.5\ \Omega = 157\Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{2 \times 3.14 \times 50 \times 100 \times 10^{-6}}\Omega$$

$$= \frac{1000}{31.4}\ \Omega = 31.85\ \Omega$$

$$\text{Impedance, } Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{2500 + (157 - 31.85)^2}\Omega$$

$$= 134.77\ \Omega$$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{110}{134.77}A$$

$$= 0.816A$$

9.Resonance frequency of a circuit is v . If the capacitance is made 4 times the initial value, then the resonance frequency will become.

9.ANS

As we know,

Resonance frequency of a circuit

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$\text{ie, } f \propto \frac{1}{\sqrt{C}}$$

$$\Rightarrow \frac{f'}{f} = \frac{\sqrt{C}}{\sqrt{4C}} = \frac{1}{2}$$

$$\Rightarrow f' = \frac{f}{2}$$

10. Mention the two characteristics properties of the material suitable for making the core of transformer

10.ANS:

The characteristic properties of the material suitable for making the core of a transformer are as follows:

→ low coercivity and low retentivity

→ low hysteresis loss

→ High magnetic susceptibility

→ High permeability

→ High resistivity

THREE MARKS QUESTIONS :

1.An inductor 200 mH, capacitor 500 µF, resistor 10 W are connected in series with a 100 V, variable frequency a.c. source. Calculate the (i) frequency at which the power factor of the circuit is unity. (ii) current amplitude at this frequency.

1.ANS:

Given:-$L = 200 \times 10^{-3} \mu$

$C = 500 \times 10^{-6} F$

$R = 10\Omega$ $V = 100V$

i) For unity power factor

Z=R

$$X_C = X_L \Rightarrow \frac{1}{\omega C} = \omega L$$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{200 \times 10^{-3} \times 500 \times 10^{-6}}}$$

$\omega = 100Hz$

ii)Current amplitude at this frequency will be

$$I = \frac{V}{R} = \frac{100}{10} = 10A$$

2.A 15µF capacitor is connected to 220 V, 50 Hz source. Find the capacitive reactance and the rms current

2.ANS:

Given : $C = 15 \times 10^{-6}$ F

Rms value of voltage $V_{rms} = 220$ V

Frequency of source $f = 50$ Hz

Capacitive reactance $X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times 15 \times 10^{-6}} = 212.3\Omega$

Rms value of current $I_{rms} = \frac{V_{rms}}{X_C} = \frac{220}{212.3} = 1.04$ A

Peak value of current $I_o = \sqrt{2}I_{rms} = \sqrt{2} \times 1.04 = 1.465$ A

Since $X_C \propto \frac{1}{f}$

So capacitive reactance gets halved if the frequency is doubled.

Also, $I_{rms} \propto \frac{1}{X_C} \propto f$

Socurrent becomes doubled if the frequency is doubled.

3.An electric lamp is having a coil of negligible inductance and is connected in series with a capacitor, and an a.c source is glowing with a certain brightness. How will the brightness

of a lamp change on reducing the
(i) capacitance, and
(ii) the frequency? Justify your Answer
3.ANS:

> Capacitive reactance and frequency has an inverse dependent ($X_c \propto 1/f$).
>
> Thus, as the frequency of the a.c. source increases, the capacitive reactance decreases. Therefore, the bulb glows with more brightness because more current flows through it.

4.An alternating voltage given by V=140 sin314t is connected across a pure resistor of 50 ohms.Find Frequency,V_{rms} and I_{rms}
4.ANS:

Given V = 140 sin 314*t*, R = 50Ω

(1) Comparing with $V = V_0 \sin \omega t$

Thus, $V_0 = 140$ V

ω = 314

2πν = 314

$$v = \frac{314}{2 \times 3.14} Hz = 50Hz$$

(2) $$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{140}{\sqrt{2}} = 98.99V$$

$$I_{rms} = \frac{V_{rms}}{R} = \frac{98.99}{50} = 1.97A$$

5.Draw a sketch of the basic elements of an a.c. generator. State its principle and briefly explain its working.
5.ANS:

(a) <u>Principle:</u>

It works on the principle of Faraday's law of electromagnetic induction. Whenever a coil is rotated in a uniform magnetic field about an axis perpendicular to the field, the magnetic flux linked with coil changes and an induced emf is set up across its ends.

Working:

When the coil starts rotating with the arm AB moving up and the arm CD moving down, cutting the magnetic lines of force, then according to Fleming's right-hand rule and the induced current is set up in these arms along the direction of AB and CD. So an effective induced current flowing in the direction of ABCD is obtained.

If there are large number of turns in the coil, the current generated in each turn adds upto give a large quantity of current through the coil.

After half rotation of the coil, its arm CD starts moving up and AB moving down. As a result, the direction of the induced currents gets reversed in the coil in the direction of DCBA. Thus after every half rotation the polarity of the current in the respective arm changes. Such a current, which changes its direction after equal intervals of time, is called to get a direct current a split ring type commutator must be used in place of slip ring commutator.

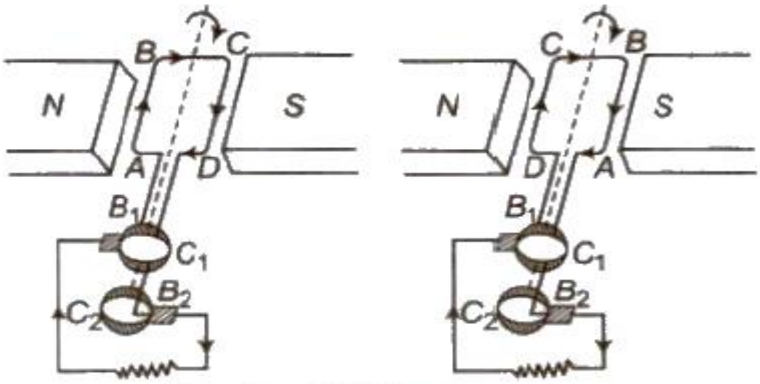
emf induced in a coil

Consider a coil of N turns and area A being rotated at a constant angular velocity ω in a magnetic field of flux density B, its axis being perpendicular to the field.

When the normal to the coil is at an angle θ to the field, the flux through the coil is BAN cosθ = BAN cos(ω)t, since θ = ωt

The induced emf produced by the AC generator is given by

$e = NBA\omega \sin \omega t = e_o = \sin \omega t$



Working of AC dynamo

FIVE MARKS QUESTIONS :

1.(a) Derive the relationship between the peak and the rms value of current in an a.c. circuit.
(b) Describe briefly, with the help of a labelled diagram, working of a step-up transformer. A step-up transformer converts a low voltage into high voltage. Does it not violate the principle of conservation of energy? Explain

1.ANS: a) $i_{rms} = \sqrt{\frac{i_1^2+i_2^2+...}{n}} = \sqrt{\overline{i^2}} = \sqrt{\frac{\int_0^T i^2 dt}{\int_0^T dt}} = \frac{i_0}{\sqrt{2}}$= 0.707 i_0 = 70.7% i_0

b) When alternating current source is connected to the ends of primary coil, the current changes continuously in the primary coil; due to which the magnetic flux linked with the secondary coil changes continuously, therefore the alternating emf of same frequency is developed across the secondary.

Let Np be the number of turns in primary coil,

NS the number of turns in secondary coil and f the magnetic flux linked with each turn.

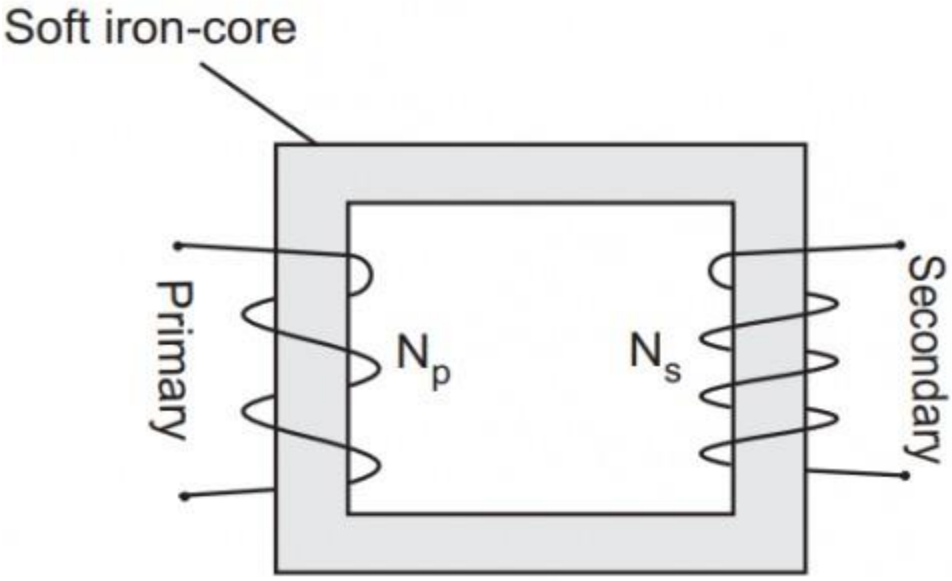
We assume that there is no leakage of flux so that the flux linked with each turn of primary coil and secondary coil is the same.

According to Faraday's laws the emf induced in the primary coil If the resistance of primary coil is negligible, the emf (εp) induced in the primary coil, will be equal to the applied potential difference (Vp) across its ends. Similarly if the secondary circuit is open, then the potential difference VS across its ends will be equal to the emf (εS) induced in it; therefore where r = NS/Np is called the transformation ratio. If ip and iS are the instantaneous currents in primary and secondary coils and there is no loss of energy; then For about 100% efficiency, Power in primary = Power in secondary

In step up transformer, $N_s > N_p \rightarrow r > 1$;

So $V_S > V_p$ and $i_S < i_p$

i.e., step up transformer increases the voltage.



Two coils on separate limbs of the core

The law of conservation of energy cannot be violated at all. The fact that voltage and current get "stepped" in opposite directions (one up, the other down) makes perfect sense when power is equal to voltage times current, and realize that transformers cannot produce power, only convert it. Any device that could output more power than it took in would violate the Law of Energy Conservation

2.Show that a series L-C-R circuit at resonance behaves as a purely resistive circuit. Compare the phase relation between current and voltage in series L-C-R circuit for a) $X_L < X_C$ b) $X_L > X_C$ C) $X_L = X_C$ using phasor diagrams

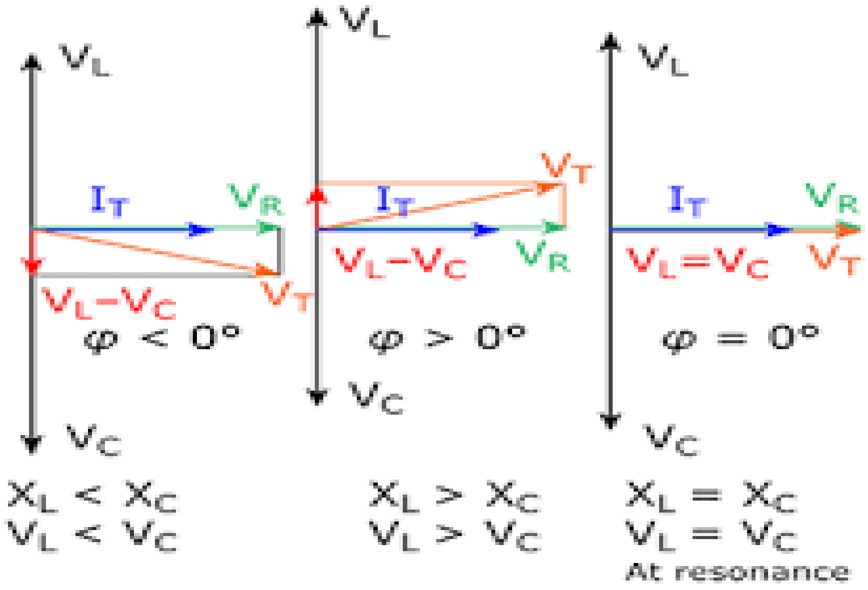
2.ANS: At resonance,

XL=XC

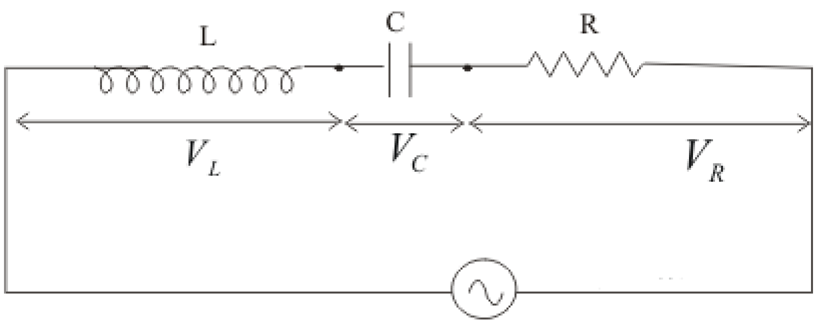
Z=[(XL−XC)2+R2]$^{1/2}$

Z=R

Hence, series LCR circuit at resonance behaves as purely resistive circuit.



3.The given circuit diagram shows a series LCR circuit connected to a variable frequency 230 V source. Here L=5.0 H, C=80 μ F, R=40 Ω



(a) Determine the source frequency, which drives the circuit in resonance.
(b) Obtain the impedance of the circuit and the amplitude of current at the resonating frequency.
(c) Determine the rms potential drops across the three elements of the circuit.
(d) How do you explain the observation that the algebraic sum of the voltage of the three elements obtained in (c) is greater than the supplied voltage?

3.ANS:

(a)

The resonance frequency is given by

$\omega=1/\sqrt{LC}=1/\sqrt{5\times80\times10^{-6}}=50rad/s$

The resonant frquency is 50 rad/s.

(b)

At resonance, $\omega L=1/\omega C$

$\Rightarrow Z=R=40\Omega$

The peak voltage, Vo=2V

Io=2V/Z

Io=8.13A

(c)

Potential drop across inductor,

VL(rms)=I×ωRL

$I=I_0/2=2V/2Z=23/40$ A

⇒Vrms=1437.5V

Potential drop across capacitor,

(Vc)rms=I×1/ ωRC=1437.5V

Potential drop across resistor,

(VR)rms=I×R=230V

Potential drop across the LC combination

$V_{LC}= I(XL-XC)$

at resonance XL=XC $\Rightarrow V_{LC}=0$ V

CASE STUDY

PASSAGE – I

A fresh man physics lab is designed to study the transfer of electrical energy from one circuit to another by means of a magnetic field using simple transformers. Each transformer has two coils of wire electrically insulated from each other but wound around a common core of ferromagnetic material. The two wires are close together but do not touch each other. The primary coil is connected to a resistor such as a light both. The AC source produces an oscillating voltage and current in the primary coil that produces an oscillating magnetic field in the core material. This in turn induces an oscillating voltage and AC current in the secondary coil. Students collected the following data comparing the number of turns per coil (N), the voltage (V) and the current (I) in the coils of three transformers.

	Primary coil			Secondary coil		
	N_1	V_1	I_1	N_2	V_2	I_2
Transformer 1	**100**	**10 V**	**10 A**	**200**	**20 V**	**5 A**
Transformer 2	**100**	**10 V**	**10 A**	**50**	**5 V**	**20 A**
Transformer 3	**100**	**10 V**	**10 A**	**100**	**5 V**	**20 A**

1. The primary coil of a transformer has 100 turns and is connected to a 120V AC source. How many turns are in the secondary coil if there is a 2400V across it?

   a) 5 b) 50 c) 200 d) 2000

2. A transformer with 40 turns in its primary coil is connected to a 120 V AC source. If 20 watts of power is supplied to the primary coil, how much power is developed in the secondary coil?

   a) 10 W b) 20 W c) 80 W d) 160 W

3. Which of the following is a correct expression for R, the resistance of the load connected to the secondary coil?

   a) $\left(\frac{V_1}{I_1}\right)\left(\frac{N_2}{N_1}\right)$ b) $\left(\frac{V_1}{I_1}\right)\left(\frac{N_2}{N_1}\right)^2$ c) $\left(\frac{V_1}{I_1}\right)\left(\frac{N_1}{N_2}\right)$ d) $\left(\frac{V_1}{I_1}\right)\left(\frac{N_1}{N_2}\right)^2$

4. The primary coil of a given transformer has 1/3 as many turns as in its secondary coil. What primary current is required to provide a secondary current of 3.0mA?

   a) 1.0mA b) 6.0mA c) 9.0mA d) 12.0mA

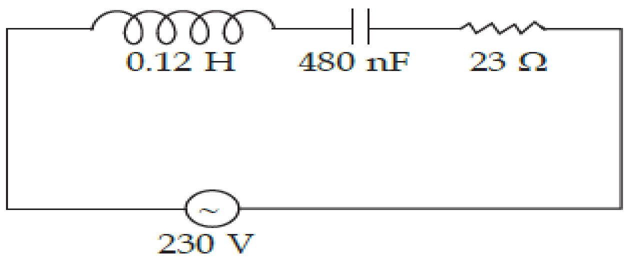
5. A 12V battery is used to supply 2.0mA of current to the 300 turns in the primary coil of a given transformer. What is the current in the secondary coil if N_2 = 150 turns?

   a) 0 A b) 1.0mA c) 2.0mA d) 4.0 A

Answers : 1 – d ; 2 – c ; 3 – b ; 4 – b ; 5 – a

PASSAGE – II

Resonant Series LCR Circuit. When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. We cannot have resonance in a RL or RC circuit. A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is Connect to a 230 V variable frequency supply.



(i) Find the value of source for which current amplitude is maximum.
(a) 222.32 Hz
(b) 550.52 Hz
(c) 663.48 Hz
(d) 770 Hz

(ii) The value of maximum current is
(a) 14.14 A
(b) 22.52 A
(c) 50.25 A
(d) 47.41 A

(iii) The value of maximum power is
(a) 2200 W
(b) 2299.3 W
(c) 5500 W
(d) 4700 W

(iv) At resonance which of the following physical quantity is maximum?
(a) Impedance
(b) Current
(c) Both (a) and (b)
(d) Neither (a) nor (b)

(i) c
(ii) a
(iii) b
(iv) b

CHAPTER 8 : ELECTROMAGNETIC WAVES

Gist of the Chapter

Displacement Current The current which comes into play in the region in which the electric field and the electric flux is changing with time. It is given by

$$I_d = \epsilon_0 \frac{d\phi_e}{dt}$$

Need for Displacement Current Ampere's circuital law for conduction current during charging of a capacitor was found inconsistent. Therefore, Maxwell modified Ampere's circuital law.
The displacement current produces in space due to change of electric flux linked with the surface. This reveals that, varying electric field is the source of magnetic field.

Maxwell's Equations of Electromagnetic Waves Maxwell's equations are the basic laws of electricity and magnetism. These equations give complete description of all electromagnetic interactions.
There are four Maxwell's equations which are explained below:

MAXWELL'S EQUATIONS

1. $\oint \mathbf{E} \cdot d\mathbf{A} = Q/\varepsilon_0$ (Gauss's Law for electricity)
2. $\oint \mathbf{B} \cdot d\mathbf{A} = 0$ (Gauss's Law for magnetism)
3. $\oint \mathbf{E} \cdot d\mathbf{l} = \frac{-d\Phi_B}{dt}$ (Faraday's Law)
4. $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$ (Ampere – Maxwell Law)

Electromagnetic Waves are coupled oscillating electric and magnetic fields created by accelerating charges that propagate forward in space.

Electromagnetic waves are transverse in nature, i.e. electric and magnetic fields are perpendicular to each other and to the direction of wave propagation. Electromagnetic waves are not deflected by electric and magnetic fields.

E (electric field) and B (magnetic field) in electromagnetic waves are in same phase.

The energy in electromagnetic wave is divided on an average equally between electric and magnetic fields.

Electromagnetic Spectrum The systematic sequential distribution of electromagnetic waves in ascending or descending order of frequency or wavelength is known as electromagnetic spectrum. The range varies from 10^{-12} m, to 10^4 m, i.e. from γ-rays to radio waves.

Elementary facts about the uses of electromagnetic waves

Radio waves

(i) In radio and TV communication.

(ii) In astronomical field.

Microwaves

(i) In RADAR communication.

(ii) In analysis of molecular and atomic structure.

(iii) For cooking purpose.

Infrared waves

(i) In knowing molecular structure. (ii) In remote control of TV VCR, etc.

Ultraviolet rays

(i) Used in burglar alarm. (ii) To kill germs in minerals.

X-rays

(i) In medical diagnosis as they pass through the muscles not through the bones.

(ii) In detecting faults, cracks, etc., in metal products,

γ-rays

(i) disinfection in industries (ii) In radiotherapy.

TABLE 8.1 DIFFERENT TYPES OF ELECTROMAGNETIC WAVES

Type	Wavelength range	Production	Detection
Radio	> 0.1 m	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials
Microwave	0.1m to 1 mm	Klystron valve or magnetron valve	Point contact diodes
Infra-red	1mm to 700 nm	Vibration of atoms and molecules	Thermopiles Bolometer, Infrared photographic film
Light	700 nm to 400 nm	Electrons in atoms emit light when they move from one energy level to a lower energy level	The eye Photocells Photographic film
Ultraviolet	400 nm to 1nm	Inner shell electrons in atoms moving from one energy level to a lower level	Photocells Photographic film
X-rays	1nm to 10^{-3} nm	X-ray tubes or inner shell electrons	Photographic film Geiger tubes Ionisation chamber
Gamma rays	$<10^{-3}$ nm	Radioactive decay of the nucleus	-do-

MCQs

1. Which physical quantity is same for X-rays, red light and radio waves in vacuum?
   (a) wavelength (b) frequency (c) speed (d) none of these.
2. 10 cm is the wavelength corresponding to which part of electromagnetic wave?
   (a) X ray (b) Gamma (c) Microwave (d) Visible light
3. Which part of electromagnetic spectrum has largest penetrating power?
   (a) x-ray (b) visible (c) gamma (d) radio
4. Which part of electromagnetic spectrum is absorbed from sunlight by ozone layer?
   (a) x-ray (b) ultra violet (c) gamma (d) radio
5. Which of the following has the shortest wavelength?
   (a) Microwaves (b) Ultraviolet rays (c) X-rays (d) radio

6. If E and B represent electric and magnetic field vectors of the electromagnetic wave, the direction of propagation of electromagnetic wave is along

   (a) E (b) E×B (c) B×E (d) B

7. The ratio of contributions made by the electric field and magnetic field components to the intensity of an EM wave is

   (a) C:1 (b) $C^2: 1$ (c) 1:1 (d) $\sqrt{C}: 1$

Assertion and Reasoning

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

1. **Assertion :** Electromagnetic wave are transverse in nature.
   Reason : The electric and magnetic fields in electromagnetic waves are perpendicular to each other and the direction of propagation.
2. **Assertion:** Electromagnetic waves exert radiation pressure.
   Reason : Electromagnetic waves carry energy.
3. **Assertion:** Electromagnetic waves carry energy and momentum.
   Reason : Electromagnetic waves cannot be polarised.
4. **Assertion :** Ultraviolet radiation plays an important role in maintaining the average temperature of earth.
   Reason : Ultra violet radiations are sometimes referred to as heat waves
5. **Assertion :** The velocity of electromagnetic waves depends on electric and magnetic properties of the medium.
   Reason : Velocity of electromagnetic waves in free space is constant.

Very Short Answer Type

1. Write two properties of electromagnetic waves.
2. What are electromagnetic waves? Are these waves transverse or longitudinal?
3. How are electromagnetic waves produced?
4. The small ozone layer on top of the stratosphere is crucial for human survival. Why? Give the wavelength range of the associated electromagnetic wave.
5. In a plane em wave, the electric field oscillates sinusoidally at a frequency of $2.0 \times 10^{10} Hz$ and amplitude 24 v/m.
   (a) What is the wavelength of the wave.
   (b) What is the amplitude of the oscillating magnetic field?

6. Show that the average energy density of the Electric field equals the average energy density of the magnetic field.
7. Professor CV Raman surprised his students by suspending freely a tiny light ball in a transparent vacuum chamber by shining a laser beam on it. Which property of EM waves was he exhibiting? Give one more example of this property.
8. Frequency of radiation emitted from transition between two very close energy levels Hydrogen atom which is known as LAMB Shift is 1057MHz. Which part of EM spectrum does the transition belong and write one of its use.
9. Sketch a schematic diagram depicting electric and magnetic fields for an electromagnetic wave propagating along X-direction. Write two properties of EM wave.
10. Name the following constituent radiations of electromagnetic spectrum which-
    a. Are used in satellite communication/in radar and geostationary satellite.
    b. Are used to study crystal study of solids.
    c. Are similar to the radiations emitted during decay of radioactive nuclei.
    d. are used for water purification/are absorbed by sunlight by ozone layer.

Short Answer Type

1. A capacitor made up of two parallel plates each of plate area A and separation d, is being charged by an external ac source. Show that the displacement current inside the capacitor is same as the current charging the capacitor. What are the magnitudes of conduction and displacement currents when it is fully charged?
2. A capacitor made of two circular plates each of radius 12 cm and separated by 5 mm is being charged by an external source. The charging current is constant and equal to 0.15 A.
   (a) Calculate the capacitance and the rate of change of potential difference between the plates
   (b) Obtain the displacement current across the plates.
   (c) Is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain
3. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of $2.0 \times 10^{10}\ Hz$ and amplitude 48 V/m
   (a) What is the wavelength of the wave?
   (b) What is the amplitude of the oscillating magnetic field?
   (c) Show that the average energy density of the E field equals the average energy density of the B field.

Case Based Question

The electromagnetic spectrum consists of visible light, x- rays, gamma rays, microwaves, ultraviolet rays, radio waves and infrared waves. The waves used in radio and television communication are the radio waves having frequency range 500 kHz to 1000MHz. In the ultrahigh frequency bands cellular phone uses the radio waves to transmit the voice. Microwaves are the waves having short wavelength. In aircraft navigation, for the radar system microwaves are used due to their short wavelength. Infrared waves are also called as heat waves. Infrared radiation has most importance in maintaining earth's surface temperature through greenhouse effect. The infrared waves have vast application in real life such as infrared detectors are used for military purposes and also to see the growth of crops. The waves which are visible to human eye are the visible rays. Visible rays are having frequency range as $4*10^{14}$ Hz to $7*10^{14}$ Hz. The huge source of ultraviolet light is the sun. Ultraviolet rays have wavelength range from $4*10^{-7}$m to $6*10^{-10}$m. X-rays are the rays having most importance in medical applications which are having wavelength range 10nm to 10^{-4} nm. X-rays are used to destroy the living tissue and organisms in medical field. Then gamma rays are the rays having wavelength range as 10^{-10}m to 10^{-14}m which are the high frequency radiations mostly produced in nuclear reactions. Gamma rays are also used to destroy cancer cells in medical field.

1. TV waves range from…………………………………..
   (a) 54Hz to 890Hz (b) 54 MHz to 890 MHz (c) 500 kHz to 1000 MHz (d) 1KHz to 1MHz
2. The domestic application of microwave is
   (a) TV (b) Refrigerator (c) Oven (d) Radio
3. Why infrared waves are called heat waves?
4. The part of the electromagnetic wave that can be detected by the human eye is
   (a) 900 – 400 nm (b) 200 – 400 mm (c) 700 – 400 mm (d) 700 – 400 nm

Long Answer Type

1. Suppose that the electric field part of an electromagnetic wave in vacuum is

$$E = 3.1\frac{N}{C} cos\, cos\, [(1.8\, rad/m)y + (5.4 \times 10^{8}\, rad/s)t]\hat{\imath}$$

(a) What is the direction of propagation?
(b) What is the wavelength λ?
(c) What is the frequency ?
(d) What is the amplitude of the magnetic field part of the wave?
(e) Write an expression for the magnetic field part of the wave?

ANSWERS

MCQs

1. (c) Speed
2. C
3. C
4. (B) Ultraviolet
5. C
6. b
7. b

Assertion and Reasoning

1. a
2. a
3. c
4. d
5. b

Short Answer Type 2 marks

1. All EMW travel with the speed of light in vacuum.
   EMW can travel through vacuum.
2. Electromagnetic Waves are coupled oscillating electric and magnetic fields created by accelerating charges that propagate forward in space. Transverse.
3. Oscillating charges produce oscillating electric field which then produce oscillating magnetic field. The oscillating magnetic field in turn produces oscillating electric field and the disturbance moves forward in space.
4. Because it blocks harmful UV radiations coming from the sun. 400 nm to 1 nm.
5. Use speed = frequency × wavelength. Then $B_o = \frac{E_O}{C}$
6. Average energy density of the E field is $E_{av} = \frac{1}{2}\varepsilon_0 E_{rms}^2$ and average energy density of the B field is $B_{av} = \frac{1}{2\mu_0} B_{rms}^2$. Use $\frac{E_0}{B_0} = c$ and $c^2 = \frac{1}{\mu_0\varepsilon_0}$. Also use the relation $E_{rms} = \frac{E_0}{\sqrt{2}}\ and\ B_{rms} = \frac{B_0}{\sqrt{2}}$
7. Radiation Pressure, tail of comet
8. 1057 MHz is around $10^9 Hz$.
9. Diagram. Any two properties.
10. Radio, X ray, Gamma, UV

Short Answer Type 3 marks

1. Let the applied alternating voltage be $V = V_O \sin \sin \omega t$.
   At any instant, the conduction current

$$I = \frac{dq}{dt} = \frac{d(CV)}{dt} = \frac{d(CV_O \sin \sin \omega t\ )}{dt} = \omega CV_O \cos \cos \omega t\ = I_O \cos \cos \omega t$$

   Displacement current

$$I_d = \epsilon_0 \frac{d\emptyset_e}{dt} = \epsilon_O \frac{d(EA)}{dt} = \epsilon_O \frac{d(\frac{q}{\epsilon_O A}A)}{dt} = \frac{dq}{dt} = I = I_O \cos \cos \omega t$$

   Both currents are zero when fully charged.

2. $C = \frac{\epsilon_O A}{d} = 80.1\, pF \quad \frac{dQ}{dt} = C\frac{dV}{dt} \quad \therefore \quad \frac{dV}{dt} = \frac{I}{C} \quad 2nd\ part\ I(conduction) = I(displacement)\ 3rd\ part{:}\ yes\ provided\ by\ current\ we\ mean\ sum\ of\ both\ currents.$

3. Use speed = frequency × wavelength. Then $B_o = \frac{E_O}{C}$.

   Average energy density of the E field is $E_{av} = \frac{1}{2}\varepsilon_0 E_{rms}^2$ and average energy density of the B field is $B_{av} = \frac{1}{2\mu_0} B_{rms}^2$. Use $\frac{E_0}{B_0} = c$ and $c^2 = \frac{1}{\mu_0 \varepsilon_0}$. Also use the relation $E_{rms} = \frac{E_0}{\sqrt{2}}\ and\ B_{rms} = \frac{B_0}{\sqrt{2}}$

Case based Question 4 marks

1. c
2. c
3. Infrared waves can produce vibrations in entire atoms or molecules of a substance. This vibration increases internal energy and consequently the temperature of the substance. This is why infrared waves are often called heat waves.
4. d

Long Answer type 5 marks

1. a) Check sign of kx and ωt within the argument of the given expression

   b) find k by comparing

   c) use the relation between speed, frequency and wavelength.

   d) find electric field amplitude and use relation $\frac{E_0}{B_0} = c$

   e) the form of equation for magnetic field part is same as that of E field

CHAPTER 9: RAY OPTICS

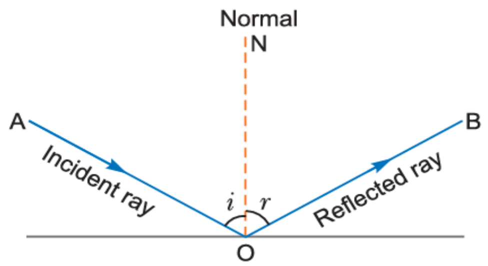
Points to ponder

1. Optics: The study of nature and propagation of light is called optics.

Ray optics deals with particle nature of light whereas wave optics considers light as a wave.

2. Reflection of Light: When a light ray incident on a smooth surface bounces back to the same medium, it is called reflection of light.

Laws of Reflection



(i) Angle of incidence is equal to the angle of reflection. i.e., i = r

(ii) The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.

These laws hold for any reflecting surface whether plane or curved.

There is no change in wavelength and frequency during reflection.

Spherical Mirror: A spherical mirror is simply a part cut off from the surface of a hollow sphere which has been made smooth and silver polished on one side.

Spherical mirrors are of two types:

(i) Concave mirror: If outer side or bulging side of the spherical surface is silver polished, it is called a concave mirror.

(ii) Convex mirror: If inner side of a spherical surface is silver polished, it is called a convex mirror.

Relation between focal length and radius of curvature: The distance between centre (C) of spherical surface and its pole (P) is called the radius of curvature. It is denoted by R.

The rays parallel to the principal axis (CP) after striking the mirror meet at a point (F) (in concave mirror) or appear to be meeting at a point F (in convex mirror). This point is called the principal focus (F) of mirror.

The distance of focus (F) from pole (P) of a mirror is called the focal length of the mirror.

It is denoted by f. The focal length f is half of the radius of curvature. i.e., $\boldsymbol{f = \frac{R}{2}}$

Mirror formula: The mirror formula is $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ where ***u*** = distance of object from mirror; ***v***= distance of image from mirror; and ***f*** = focal length of mirror.

Magnification produced by mirror: The ratio of the size of image to the size of object is called linear magnification produced by the mirror

Magnification: $M = \frac{h_i}{h_o}$

Where h_i is the height of image and h_o is the height of object

3. Refraction of Light: When a ray of light enters from one transparent medium into another, there is a change in speed and direction of the ray in the second medium. This phenomenon is called refraction of light.

Laws of refraction:

(i) The incident ray, the refracted ray and the normal to the surface separating the two media, all lie in the same plane.

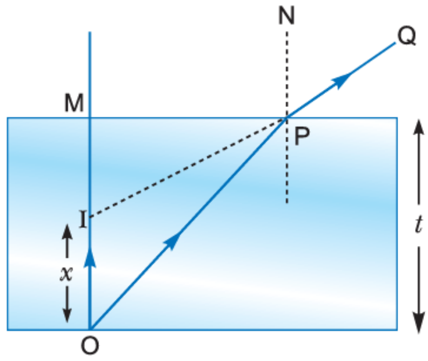
(ii) Snell's Law: For two media, the ratio of sine of angle of incidence to the sine of the angle of refraction is constant for a beam of particular wavelength, i.e.,

$$\frac{\sin i}{\sin r} = constant = n_{21} = \frac{n_2}{n_1}$$

where n_1 and n_2 are absolute refractive indices of I and II media respectively.

The frequency of light remains unchanged while passing from one medium to the other

Formation of image due to refraction: According to Snell's law, if $n_2 > n_1$, $i > r$. That is, if a ray of light enters from rarer medium to a denser medium, it is deviated towards the normal and if $n_2 < n_1$, $i <$ r that is, if the ray of light enters from denser to a rarer medium it is deviated away from the normal.



Accordingly, if the ray of light starting from object **O**, in the given diagram in a denser medium travel along **OP**, it is deviated away from the normal along **PQ**. The ray **PQ** appears to come from **I**. Thus, **I** is the virtual image of **O**. It can be shown that

$$n = \frac{Real\ depth}{Apparent\ depth}$$

4. Critical Angle: When a ray of light is incident on the interface from denser medium to rarer medium, it is deviated away from the normal. When angle of incidence is increased, angle of refraction also increases and at a stage it becomes 90°.

The angle of incidence in denser medium for which the angle of refraction in rarer medium is 90° is called the critical angle (C) for the pair of media

If $\mathbf{n_1}$ and $\mathbf{n_2}$ are refractive indices for rarer and denser media, then

$$\frac{Sin\ i}{Sin\ r} = \frac{n_1}{n_2}$$

$$\frac{Sin\ C}{Sin\ 90} = \frac{n_1}{n_2}$$

$$n1 = 1\ (air)\ n2 = n$$

$$sin\ C = \frac{1}{n}$$

5. Total Internal Reflection: When angle of incidence in the denser medium is greater than the critical angle, the incident ray does not refract into a rarer medium but is reflected back into the denser medium. This phenomenon is called total internal reflection.

The conditions for total internal reflection are

(i) The ray must travel from a denser into a rarer medium.

(ii) The angle of incidence i> critical angle C.

The critical angle for water-air, glass-air and diamond-air interfaces are 49°, 42° and 24° respectively

6. Thin Lens Formula: If u and v are object and image distances from a lens of focal length f, then thin lens formula is $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

This equation holds for convex and concave lenses both, but proper signs of ***u, v*** and ***f*** are to be used according to sign convention of coordinate geometry. Focal length of a convex lens is taken as positive and of a concave lens is taken as negative.

7. Refraction through a spherical surface

The portion of a refracting medium, whose curved surface forms the part of a sphere, is known as spherical refracting surface.

Sign conventions for spherical refracting surface are the same as those for spherical mirrors.

Spherical refracting surfaces are of two types:

Convex refracting spherical surface

Concave refracting spherical surface

When the object is situated in rarer medium, the relation between **n_1** (refractive index of rarer medium) **n_2** (refractive index of the spherical refracting surface) and *R* (radius of curvature) with the object and image distances is given by

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

When the **object is** situated in denser medium, the relation between ***n_1, n_2, R, u** and **v*** can be obtained by interchanging ***n_1*** and ***n_2***. In that case, the relation becomes

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

8. Lens Maker's Formula: If R_1 and R_2 are the radii of curvature of first and second refracting surfaces of a thin lens of focal length f, then lens makers formula is

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

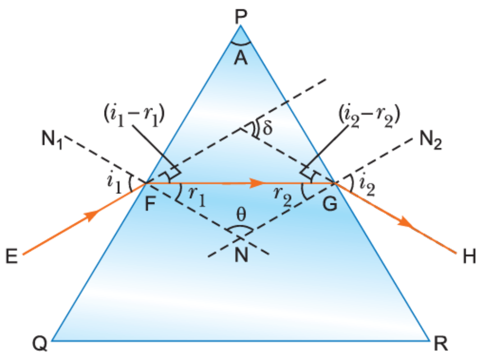
9. Power of a Lens: The power of a lens is its ability to deviate the rays towards its principal axis.

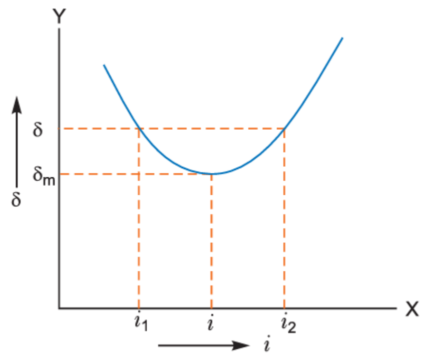
It is defined as the reciprocal of focal length in metres.

Power of a lens, $P = \frac{1}{f}$. Its unit is diopter and is represented as **'D'**.

Thin Lenses in Contact: If two or more lenses of focal lengths f_1, f_2 are placed in contact, then their equivalent focal length F is given by $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} +$ **....** The power of combination $P = P_1 + P_2 + \ldots$

10. Refraction Through a Prism: A prism is a transparent medium enclosed by two plane refracting surfaces. Let EF be the monochromatic ray incident on the face PQ of prism PQR of refracting angle A at angle of incidence i1.





This ray is refracted along FG, r_1 being angle of refraction. The ray FG is incident on the face PR at angle of incidence r_2 and is refracted in air along GH. Thus GH is the emergent ray and i2 is the angle of emergence. The angle between incident ray EF and emergent ray GH is called angle of deviation δ.

For a prism if A is the refracting angle of prism, then $r_1 + r_2 = A$ ...(i) and

$i_1 + i_2 = A + \delta$ ...(ii)

Clearly, deviation $i_1 + i_2 - A = \delta$, i_1 and i_2 may be inter-changed, therefore, there are two values of angles of incidence for same deviation δ. If n is the refractive index of material of prism, then from Snell's law

$$n = \frac{Sin\, i_1}{Sin\, r_1} = \frac{Sin\, i_2}{Sin\, r_2}$$

If angle of incidence is changed, the angle of deviation δ changes as shown in fig. For a particular angle of incidence, the deviation is minimum. This is called angle of minimum deviation δ_m.

Minimum deviation: At minimum deviation the refracted ray within a prism is parallel to the base. Therefore, $i_1 = i_2 = i$ ***(say)*** $r_1 = r_2 = r$ ***(say)*** Then from equations (i) and (ii),

$r + r = A$ or $r = \frac{A}{2}$ ...(iv)

$i + i = A + \delta_m$ so, $i = \frac{A + \delta_m}{2}$

∴ The refractive index of material of prism

$$n = \frac{Sin\, i}{Sin\, r} = \frac{Sin\left(\frac{A + \delta_m}{2}\right)}{Sin\left(\frac{A}{2}\right)}$$

For a thin prism, viz. A ≤ 10° $\delta_m = (n - 1)\, A.$

11. Optical Instruments (Microscopes and Telescopes): A microscope is an optical instrument to see very small objects.

(i) Simple Microscope: It consists of a convex lens of small focal length f. If **β** = angle subtended by an image on eye **α** = angle subtended by an object on eye, when object is at a distance of distinct vision (**D**) Magnifying power,

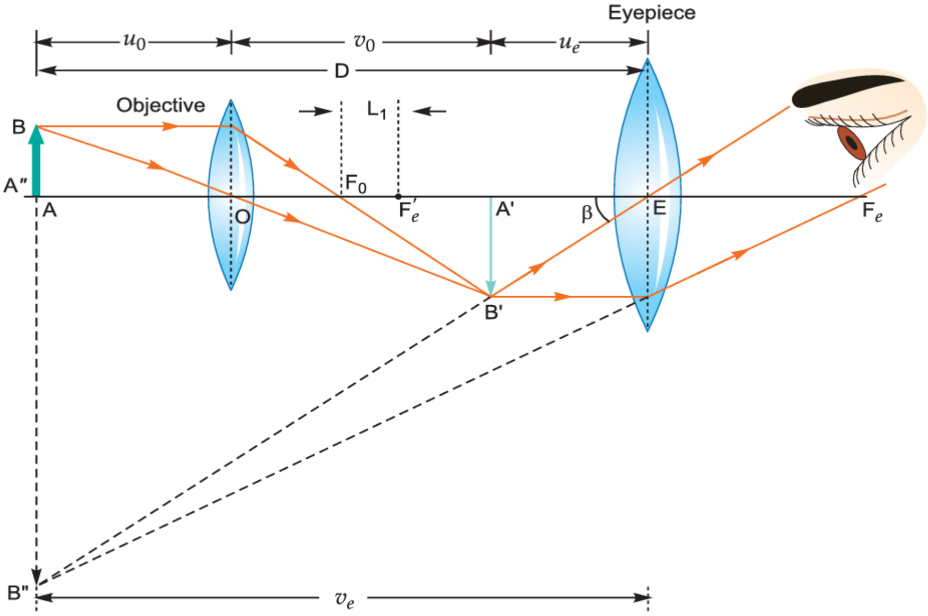
$$M = \frac{\beta}{\alpha} = \left(\frac{D}{v}\right)\left(1 + \frac{v}{f}\right)$$

If the final image is at **∞, v = ∞** then, $M = \frac{D}{f}$, If the final image is at a distance of distinct vision, $M = 1 + \frac{D}{f}$

(ii) Compound Microscope: A compound microscope essentially consists of two co-axial convex lenses of small focal lengths. The lens facing the object is called an objective lens while that towards eye is called the eye lens (eyepiece).

∴ Magnifying power of microscope,

$$M = \frac{\beta}{\alpha} (= m_o \times m_e) = \frac{v_o D}{u_o v_e}\left(1 + \frac{v_e}{f_e}\right)$$



Separation between lenses, $L = v_0 + u_e$

Special cases:

(*a*) When final image is formed at a distance of distinct vision, $v_e = D$

$$M = -\frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) \text{ and } L = v_0 + u_e$$

The distance between second focal point of objective and first focal point of eye lens is called the tube length denoted by L,then

$$\frac{v_o}{u_o} = \frac{L}{f_0}$$

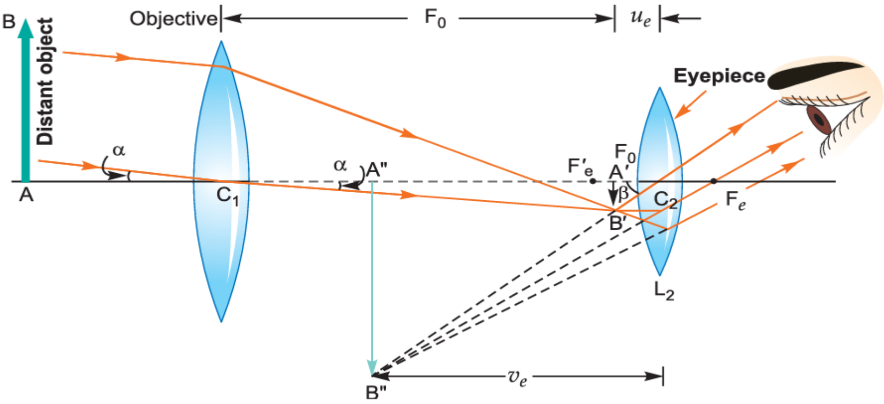
So, $$M = -\frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

(*b*) When final image is formed at infinity, $v_e = \infty$, then

$$M = -\frac{v_o}{u_o} \times \frac{D}{f_e}$$

$$= -\frac{L}{f_o} \cdot \frac{D}{f_e} \text{ and } L = v_o + f_e$$

(iii) Astronomical Telescope (Refracting Telescope): It is used to see magnified images of distant objects. An astronomical telescope essentially consists of two co-axial convex lenses. The lens facing the object has a large focal length and a large aperture and is called objective, while the lens towards eye has a small focal length and small aperture and is called eye lens.



The magnifying power of telescope is

$$M = \frac{\text{Angle subtended by final image at eye}}{\text{Angle subtended by object on eye}} = \frac{\beta}{\alpha}$$

$$= (m_0 \times m_e) = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{v_e}\right)$$

and Length of telescope $L = f_0 + u_e$

where u_e = distance of real image from eye lens

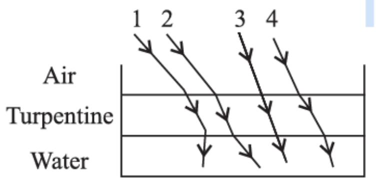
v_e = distance of final image A′ B′ from eye lens

f_0 = focal length of objective, f_e = focal length of eye lens

Reflecting Telescope: In this telescope, a concave mirror is used as an objective in place of a convex lens.

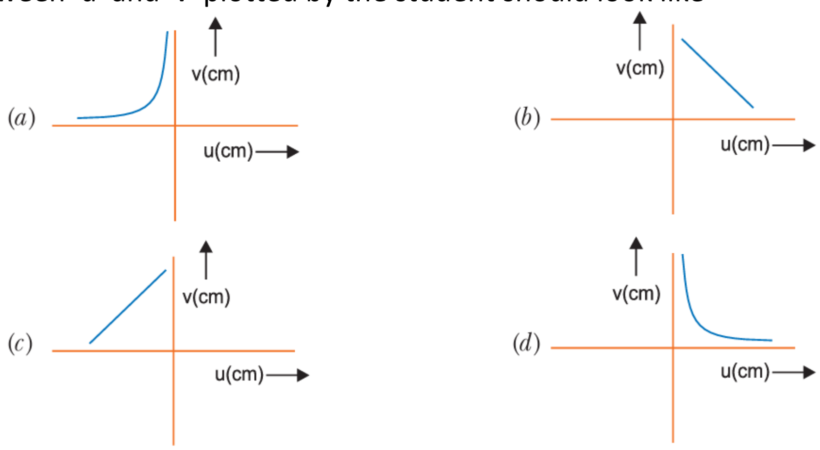
It is free from chromatic aberration and it has larger resolving power than refracting telescope.

	MULTIPLE CHOICE QUESTIONS
1.	An equiconvex lens of focal length 15 cm is cut into two halves. Find the focal length of each part? (a) -30cm (b) -20cm (c) 30cm (d) -15cm
2.	Mirage is a phenomenon due to (a) refraction of light (b) total internal reflection of light (c) diffraction of light (d) none of these.
3.	How does the focal length of a convex lens changes if mono chromatic red light is used instead of violet light? (a) Focal length is increased when red light is used (b) Focal length is decreased when red light is used (c) Focal length remains the same when red light is used (d) does not depends on colour of light.
4.	A glass lens is immersed in water. What will be the effect on the power of lens? (a) increase (b) decrease (c) constant (d) can't say
5.	From a point source, a light fall on a spherical glass surface (n = 1.5 and radius of curvature = 10 cm). The distance between point source and glass surface is 50 cm. The position of image is (a) 25 cm (c) 100 cm (b) 50 cm (d) 150 cm

6.	How does the magnifying power of a telescope change on increasing the linear diameter of its objective? (a) Power increases on increases diameter (b) Power decreases on decreases diameter (c) Power remains constant on increases diameter (d) Power doesn't depend on diameter
7.	An object approaches a convergent lens from the left of the lens with a uniform speed 5 m s^{-1} and stops at the focus. The image (a) moves away from the lens with a uniform speed 5 m s^{-1}. (b) moves away from the lens with a uniform acceleration. (c) moves away from the lens with a nonuniform acceleration. (d) moves towards the lens with a non-uniform acceleration.
8.	What is the magnification and focal length of a plane mirror. (a) +1,∞ (b)+1,0 (c)-1,∞ (d)-1,0
9.	A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen, (a) half the image will disappear (b) complete image will disappear (c) intensity of image will decrease (d) intensity of image will increases.
10.	The optical density of turpentine is higher than that of water while its mass density is lower. Figure shows a layer of turpentine floating over water in a container. For which one of the four ray's incidents on turpentine in figure, the path shown is correct?  (a) 1 (b) 2 (c) 3 (d) 4
11.	An astronomical telescope has a large aperture to: (a) increase span of observation (b) have low dispersion (c) reduce spherical aberration (d) have high resolution
12.	A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will (a) become zero (b) become infinite (c) become small, but non-zero (d) remain unchanged
13.	A concave mirror of focal length 15 cm forms image having twice the linear dimensions of the object. The position of the object, when the image is virtual, will be (a) 22.5 cm (b) 7.5 cm (c) 30 cm (d) 45 cm
14.	A short pulse of white light is incident from air to a glass slab at normal incidence. After travelling through the slab, the first colour to emerge is (a) blue (b) green (c) violet (d) red
15.	Why is refractive index in a transparent medium greater than one? (a) Because speed of light in vacuum is always less than speed in transparent medium

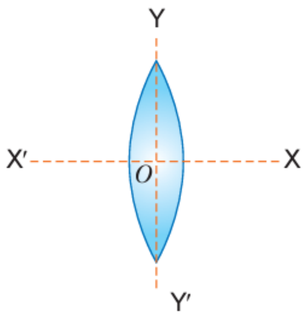
(b) Because the speed of light in vacuum is always greater than the speed in a transparent medium
(c) Frequency of wave changes when it crosses medium
(d) None of the above

16. A student measures the focal length of a convex lens by putting an object pin at a distance 'u' from the lens and measuring the distance 'v' of the image pin. The graph between 'u' and 'v' plotted by the student should look like



17. Which of the following is not due to total internal reflection?
(a) Working of optical fibre
(b) Difference between apparent and real depth of a pond
(c) Mirage on hot summer days
(d) Brilliance of diamond

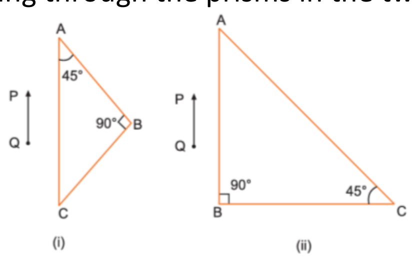
18. An equiconvex lens is cut into two halves along (i) XOX' and (ii) YOY' as shown in the figure. Let f, f' and f'' be the of the focal lengths of complete lens of each half in case (i) and of each half in case (ii) respectively. Choose the correct statement from the following :

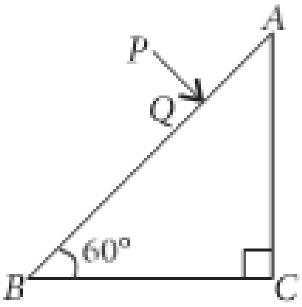
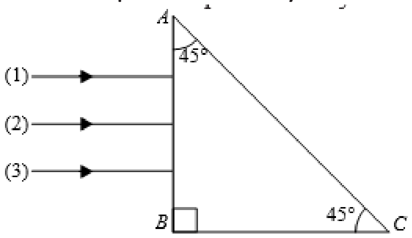


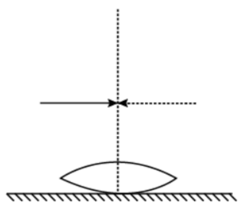
(a) f' = 2 f and f'' = f
(b) f' = f and f'' = f
(c) f' = 2 f and f'' = 2 f
(d) f' = f and f'' =2 f

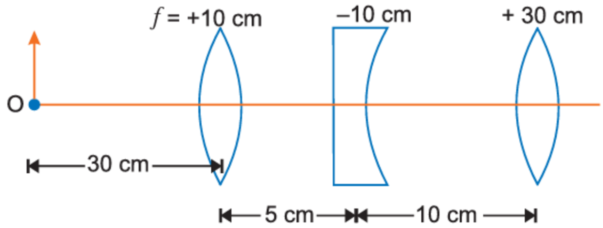
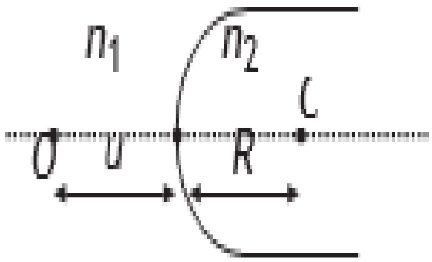
19. If the focal length of objective lens is increased then magnifying power of
(a) microscope will increase but that of telescope decrease
(b) microscope and telescope both will increase
(c) microscope and telescope both will decrease
(d) microscope will decrease but that of telescope will increase

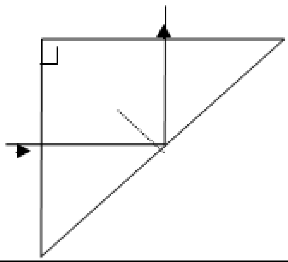
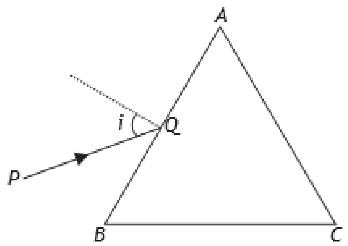
20.	For relaxed eye, the magnifying power of a microscope is (a) $\frac{v_0}{u_0} \times \frac{D}{f_e}$ (b) $\frac{v_0}{u_0} \times \frac{f_e}{D}$ (c) $\frac{u_0}{v_0} \times \frac{D}{f_e}$ (d) $\frac{u_0}{v_0} \times \left(-\frac{D}{f_e}\right)$
	For question numbers 21-30, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below. (a) Both A and R are true and R is the correct explanation of A (b) Both A and R are true but R is NOT the correct explanation of A (c) A is true but R is false (d) A is false and R is also false
21.	Assertion (A): Higher is the refractive index of a medium or denser the medium, lesser is the velocity of light in that medium. Reason (R): Refractive index is inversely proportional to velocity.
22.	Assertion (A): Convergent lens property of converging remains same in all media. Reason (R): Property of lens whether the ray is diverging or converging is independent of the surrounding medium.
23.	Assertion(A): The focal length of the mirror is *f* and distance of the object from the focus is *u*, the magnification of the mirror is *-f* / *u-f*. Reason(R): Magnification $= \frac{\text{Size of image}}{\text{Size of object}}$
24.	Assertion(A): Diamond glitters brilliantly. Reason(R): Diamond does not absorb sunlight.
25.	Assertion(A): The mirrors used in search lights are parabolic and not concave spherical. Reason(R): In a concave spherical mirror the image formed is always virtual.
26.	**Assertion**(A)**:** Plane mirror may form real image. **Reason**(R)**:** Plane mirror forms virtual image, if object is real.
27.	Assertion(A): Endoscopy involves use of optical fibres to study internal organs. Reason (R): Optical fibres are based on phenomena of total internal reflection.
28.	Assertion (A): If optical density of a substance is more than that of water, then the mass density of substance can be less than water. Reason (R): Optical density and mass density are not related.
29.	Assertion (A): Microscope magnifies the image. Reason (R): Angular magnification for image is more than object in microscope.
30.	Assertion (A): A double convex lens (μ = 1.5) has focal length 10 cm. When the lens is immersed in water (μ= 4/3) its focal length becomes 40 cm. Reason (R): $1/f = (\mu_{gm} - 1)(1/R_1 - 1/R_2)$
	SHORT ANSWERS (2 MARKS)
31.	When a monochromatic light travels from one medium to another its wavelength changes but frequency remains the same. Explain.
32.	When red light passing through a convex lens is replaced by light of blue colour, how will the focal length of the lens change?
33.	Under what condition does a biconvex lens of glass having a certain refractive index act as a plane glass sheet when immersed in a liquid?

34.	How does the angle of minimum deviation of a glass prism vary, if the incident violet light is replaced by red light?
35.	A compound microscope is used because a realistic simple microscope does not have magnification. Explain.
36.	Two thin lenses of power –4 D and 2 D are placed in contact coaxially. Find the focal length of the combination.
37.	For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which media would the velocity of light be minimum?
38.	A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Give reason.
39.	An optical instrument uses an objective lens of power 100 D and an eyepiece of power 40 D. The final image is formed at infinity when the tube length of the instrument is kept at 20 cm. Identify the optical instrument.
40.	What is the angle of incidence for maximum deviation through a prism?
41.	A spherical convex surface of radius of curvature 20 cm, made of glass (n = 1.5) is placed in air. Find the position of the image formed, if a point object is placed at 30 cm in front of the convex surface on the principal axis.
42.	Calculate the radius of curvature of an equi-concave lens of refractive index 1.5, when it is kept in a medium of refractive index 1.4, to have a power of –5D?
43.	A lens is placed in the path of a beam of light which converges to the point O in the absence of the lens. The distance between the lens and the point is 15 cm, what distance from the point O will the beam converge if the lens is a concave lens of focal length 25 cm.
44.	State the conditions for total internal reflection to occur.
45.	A right-angled crown glass prism with critical angle 41° is placed before an object, PQ in two positions as shown in the figures (i) and (ii). Trace the paths of the rays from P and Q passing through the prisms in the two cases. 

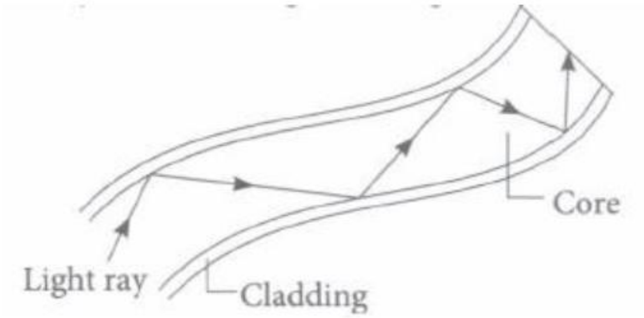
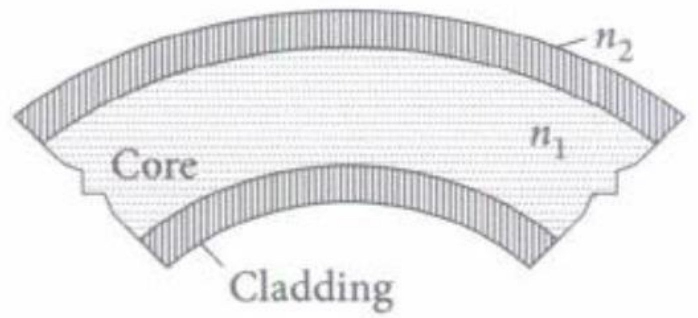
46.	A ray *PQ* incident normally on the refracting face *BA* is refracted in the prism *BAC* made of material of refractive index 1.5. Complete the path of ray through the prism. From which face will the ray emerge? Justify your answer. 
47.	You are given two converging lenses of focal lengths 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece.
48.	Draw a schematic arrangement of a reflecting telescope (Cassegrain) showing how rays coming from a distant object are received at the eye-piece. Write its two important advantages over a refracting telescope.
49.	Why are convex mirrors used as side view mirrors in vehicles?
	SHORT ANSWERS (3 MARKS)
50.	Draw ray diagrams to show how specially designed prisms make use of total internal reflection to obtain inverted image of the object by deviating rays (i) through 90° and (ii) through 180°.
51.	The refractive index of a material of a concave lens is n1. It is immersed in a medium of refractive index n2. A parallel beam of light is incident on the lens. Trace the path of emergent rays when (i) n2 = n1 (ii) n2>n1 (iii) n2< n1.
52.	(i) What is total internal reflection? Under what conditions does it occur? (ii) Find a relation between critical angle and refractive index. (iii) Name one phenomenon which is based on total internal reflection.
53.	A convex lens made up of glass of refractive index 1.5 is dipped, in turn, in (i) a medium of refractive index 1.65, (ii) a medium of refractive index 1.33. (a) Will it behave as a converging or a diverging lens in the two cases? (b) How will its focal length change in the two media?
54.	Three rays (1, 2, 3) of different colours fall normally on one of the sides of an isosceles right-angled prism as shown. The refractive index of prism for these rays is 1.39, 1.47 and 1.52 respectively. Find which of these rays get internally reflected and which get only refracted from *AC*. Trace the paths of rays. Justify your answer with the help of necessary calculations. 

55.	State the laws of reflection and refraction.
56.	(i) Draw a schematic labelled ray diagram of a reflecting type telescope. (ii) Write two important advantages justifying why reflecting type telescopes are preferred over refracting telescopes. The objective of a telescope is of larger focal length and of larger aperture (compared to the eyepiece). Why? Give reasons.
57.	A ray of light passing through an equilateral triangular glass prism from air undergoes minimum deviation when angle of incidence is $3/4^{th}$ of the angle of prism. Calculate the speed of light in the prism.
58.	(a) A small telescope has an objective lens of focal length 140 cm and an eyepiece of focal length 5.0 cm. Find the magnifying power of the telescope for viewing distant objects when (i) the telescope is in normal adjustment, (ii) the final image is formed at the least distance of distinct vision. (b) Also find the separation between the objective lens and the eye piece in normal adjustment.
59.	Draw a labelled ray diagram of an astronomical telescope in the near point position. Write the expression for its magnifying power.
60.	Draw a ray diagram showing the image formation by a compound microscope when the final image is formed at the near point. Write the expression for its magnifying power.
61.	A symmetric biconvex lens of radius of curvature R and made of glass of refractive index 1.5, is placed on a layer of liquid placed on top of a plane mirror as shown in the figure. An optical needle with its tip on the principal axis of the lens is moved along the axis until its real, inverted image coincides with the needle itself. The distance of the needle from the lens is measured to be x. On removing the liquid layer and repeating the experiment, the distance is found to be y. Obtain the expression for the refractive index of the liquid in terms of x and y. 
62.	An illuminated object and a screen are placed 90 cm apart. Determine the focal length and nature of the lens required to produce a clear image on the screen, twice the size of the object.
63.	A fish in a water tank sees the outside world as if it (the fish) is at the vertex of a cone such that the circular base of the cone coincides with the surface of water. Given the depth of water, where fish is located, being '*h*' and the critical angle for water-air interface being 'i_c', find out by drawing a suitable ray diagram the relationship between the radius of the cone and the height '*h*'

64.	A biconvex lens of glass of refractive index 1.5 having focal length 20 cm is placed in a medium of refractive index 1.65. Find its focal length. What should be the value of the refractive index of the medium in which the lens should be placed so that it acts as a plane sheet of glass?
65.	Find the position of the image formed of an object ‘O’ by the lens combination given in the figure. 
	LONG ANSWERS (5 MARKS)
66.	(a) Draw a ray diagram to show refraction of a ray of monochromatic light passing through a glass prism. Deduce the expression for the refractive index of glass in terms of angle of prism and angle of minimum deviation.
67.	(a) Derive the mathematical relation between refractive indices n_1 and n_2 of two media and radius of curvature R for refraction at a convex spherical surface. Consider the object to be a point source lying on the principle axis in rarer medium of refractive index n_1 and a real image formed in the denser medium of refractive index n_2. Hence, derive lens maker’s formula. (b) Light from a point source in air falls on a convex spherical glass surface of refractive index 1.5 and radius of curvature 20 cm. The distance of light source from the glass surface is 100 cm. At what position is the image formed?
68.	a) A point object ‘*O*’ is kept in a medium of refractive index n_1 in front of a convex spherical surface of radius of curvature *R* which separates the second medium of refractive index n_2 from the first one, as shown in the figure. Draw the ray diagram showing the image formation and deduce the relationship between the object distance and the image distance in terms of n_1, n_2 and *R*.  (b) (i) When the image formed above acts as a virtual object for a concave spherical surface separating the medium n_2 from n_1 ($n_2 > n_1$), draw this ray diagram and write the similar (similar to (a)) relation. (ii) Hence obtain the expression for the lens maker’s formula.

69.	(i) Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism. (ii) A ray of light incident normally on one face of a right isosceles prism is totally reflected as shown in figure. What must be the minimum value of refractive index of glass? Give relevant calculations. 
70.	(a) A ray *PQ* of light is incident on the face *AB* of a glass prism *ABC* (as shown in the figure) and emerges out of the face *AC*. Trace the path of the ray. Show that $\angle i + \angle e = \angle A + \angle \delta$ where δ and *e* denote the angle of deviation and angle of emergence respectively.  Plot a graph showing the variation of the angle of deviation as a function of angle of incidence. State the condition under which $\angle\delta$ is minimum. (b) Find out the relation between the refractive index (μ) of the glass prism and $\angle A$ for the case
71.	Define magnifying power of a telescope. Write its expression. A small telescope has an objective lens of focal length 150 cm and an eye piece of focal length 5 cm. If this telescope is used to view a 100 m high tower 3 km away, find the height of the final image when it is formed 25 cm away from the eye piece.
72.	Draw a ray diagram to show the working of a compound microscope. Deduce an expression for the total magnification when the final image is formed at the near point. In a compound microscope, an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye piece has a focal length of 5 cm and the final image is formed at the near point, estimate the magnifying power of the microscope.
73.	(i) Define power of a lens. Write its units. (ii) Deduce the relation $1/f = 1/f_1 + 1/f_2$ for two thin lenses kept in contact coaxially.
74.	Derive the 'mirror equation' using the ray diagram for the formation of a real image by a concave mirror.

75.	(i) Draw a labelled ray diagram to obtain the real image formed by an astronomical telescope in normal adjustment position. Define its magnifying power. (ii) You are given three lenses of power 0.5 D, 4 D and 10 D to design a telescope. (a) Which lenses should be used as objective and eyepiece? Justify your answer. (b) Why is the aperture of the objective preferred to be large?
	CASE BASED QUESTIONS
76.	A prism is a portion of a transparent medium bounded by two plane faces inclined to each other at a suitable angle. A ray of light suffers two refractions on passing through a prism and hence deviates through a certain angle from its original path. The angle of deviation of a prism is, {(δ) = μ - 1} A, through which a ray deviates on passing through a thin prism of small refracting angle A. If μ is refractive index of the material of the prism, then prism formula is, $\mu = \frac{\sin(A+\delta m)/2}{\sin A/2}$ (i) For which colour, angle of deviation is minimum? (a) red (b) yellow (c) violet (d) blue (ii) When white light moves through vacuum (a) all colours have same speed (b) different colours have different speed (c) violet has more speed than red (d) red has more speed than violet (iii) The deviation through a prism is maximum when angle of incidence is (a) 45^o (b) 70^o (c) 90^o (d) 60^o (iv) What is the deviation produced by a prism of angle 6°? (Refractive index of the material of the prism is 1.644). (a) 3.864^o (b) 4.595^o (c) 7.259^o (d) 1.252^o (v) A ray of light falling at an angle of 50° is refracted through a prism and suffers minimum deviation. If angle of prism is 60°, then the angle of minimum deviation is (a) 45^o (b) 75^o (c) 50^o (d) 40^o
77.	An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It makes use of total internal reflection. These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length.

	 (i) Which of the following is based on the phenomenon of total internal reflection of light? (a) sparkling of diamond (b) optical fibre (c) instrument used by doctors for endoscopy (d) all of these (ii) A ray of light will undergo total internal reflection inside the optical fibre, if it (a) goes from rarer medium to denser medium (b) is incident at an angle less than critical angle (c) strikes the interface normally (d) is incident at an angle greater than critical angle (iii) If in core, angle of incidence is equal to critical angle, then angle of refraction will be (a) 0° (b) 45° (c) 90° (d) 180° (iv) In an optical fibre (shown), correct relation for refractive indices of core and cladding is  (a) n1 = n2 (b) n1 < n2 (c) n1 > n2 (d) n1 + n2 =2 (v) If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre is (a) 3 x 10^8 ms^{-1} (b) 1.5 x 10^8 ms^{-1} (c) 6 x 10^8 ms^{-1} (d) 45 x 10^8 ms^{-1}
78.	Power (P) of a lens is given as the reciprocal of focal length (P=1/f) where f should be in meter and P is in Dioptre. For convex power is positive and concave power is –ve. When two or more lenses are kept in contact then power of the combined lens is given as P= P1 + P2+P3 …….

(i) A convex and a concave lens is separated by distance d are then put in contact then the focal length of the combination
(a) becomes 0 (b) remain the same (c) decreases (d)increases.

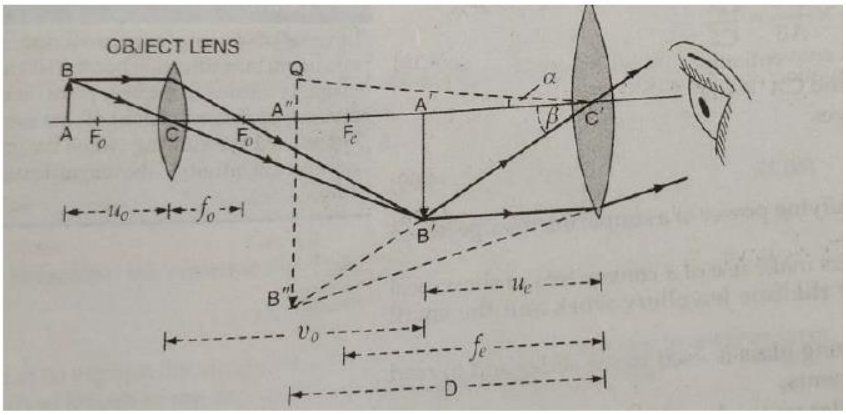
(ii) The two lenses of power +1.5D and +1.0D are placed in contact then the effective power of the combination will be
(a)2.5D (b)1.5 D (c) 0.5D (d)3.25D

(iii) If the power of the lens is 5D then what is the focal length of the lens?
(a)10cm (b) 20cm (c)15cm (d) 5cm

(iv) Two thin lens of focal length +10cm and -5cm are kept in contact, the power of the combination is?
(a)-10D (b)-20D (c)10D (d)15D

(v) A convex lens of focal length 25cm is placed coaxially in contact with a concave lens of focal length 20cm the system will be;
(a) converging in nature (b) diverging in nature
(c) can be converging or diverging (d) None of the above.

79. A compound microscope consists of two lenses. A lens of short aperture and short focal length facing the object is called the object lens and another lens of short focal length but large aperture is called the eye lens. Magnifying power is defined as the ration of angle subtended by the final image at the eye to the angle subtended by the object is seen directly, when both are placed at least distance of distinct vision



(i) An objective lens consists of
(a) Short aperture and short focal length (b)large aperture and large focal length
(c)short aperture and large focal length (d)large aperture and short focal length

(ii) An eyepiece consists of
(a) short aperture and short focal length (b) large aperture and large focal length
(c) short aperture and large focal length (d) large aperture and short focal length

(iii) Formula of magnifying power
(a) M= (β/α) (b) M=(α/β)
(c) M=(1+(α/β)) (d) M=(1+(β/α))

(iv) A compound microscope with an objective of 1.0 cm, focal length and eyepiece 2.0 cm. Focal length of a tube is 20 cm. Calculate the magnifying power of the microscope

(a) 270 (b) 27 (c)140 (d) 14

(v) Final image formed by compound microscope

(a) inverted (b) Erect (c)virtual (d)highly diminished

80. Total internal reflection is the phenomenon of reflection of light into denser medium at the interface of denser medium with rarer medium. For this phenomenon to occur necessary condition is that light must move from denser to rarer and angle of incidence in denser medium must be greater than critical angle for the pair of media in contact. Critical angle depends on nature of medium and wavelength of light. We can show that μ=1/sinC (where C is the critical angle).

(i) critical angle for glass air interface, where μ for glass is 3/2, is

(a)41.8^{o} (b) 60^{o} (c)30^{o} (d)15^{o}

(ii) Critical angle for water air interface is 48.60, then what is the refractive index of water

(a)1 (b)3/2 (c)4/3 (d)3/4

(iii) Critical angle for air water interface for violet colour is 49^{o} its value for red colour will be

(a)49^{o} (b)50^{o} (c)48^{o} (d)can't say

(iv) Which of the following is not due to total internal reflection?

(a) working of optical fibre

(b)difference between real depth and apparent depth of a pound.

(c)mirage on hot summer day

(d) brilliance of diamond

(v) critical angle of glass is θ1 and that of the water is θ2 critical angle for water and glass surface would be (μg > μw)

(a) less than θ2 (b) between θ1 and θ2 (c)greater then θ2 (d)less than θ1.

81. The whole class was excited as they were on their way to Kavalur in Tamil Nadu, an observatory, housing the largest telescope in India. The teacher was explaining type of telescope, the diameter of the objective (2.34m) and other details. The children were looking forward to see through the telescope.

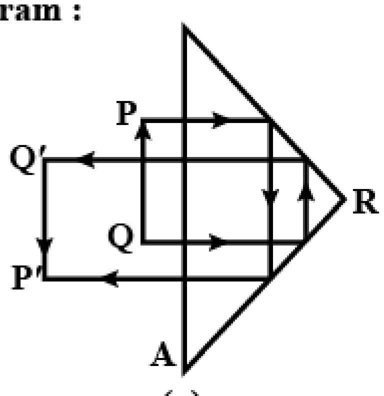
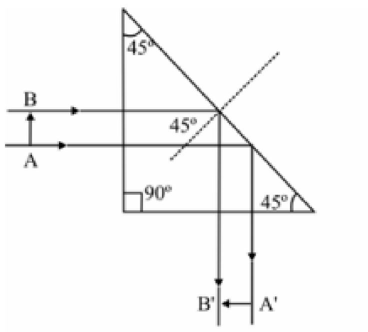
	(i) What type of telescope is the teacher referring to (a) Binocular (b) Refracting type telescope (c) Reflecting type telescope (d) Compound microscope (ii) In astronomical compare to eye piece, objective lens has (a) negative focal length (b) zero focal length (c) small focal length (d) large focal length (iii) If fo is the focal length of the objective and fe is the focal length of the eyepiece, then magnification of a refracting (M) telescope can be determined as (a) M = fo/fe (b) M = fo + fe (c) M = fo - fe (d) M = fe/fo (iv) A telescope can make stars look (a) bigger (b) brighter (c) smaller (d) all of above (v) A telescope that uses two converging lenses is called (a) reflecting telescope (b) refracting telescope (c) simple telescope (d) compound microscope

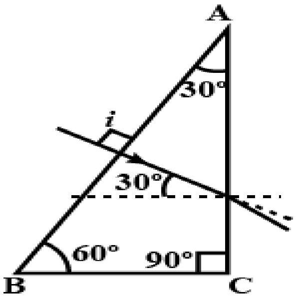
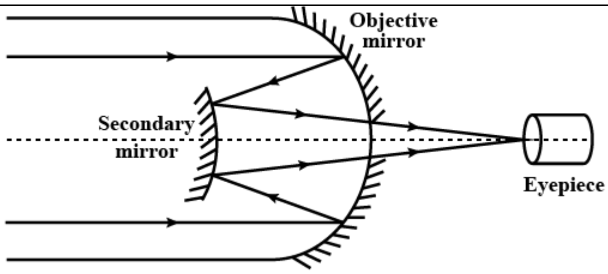
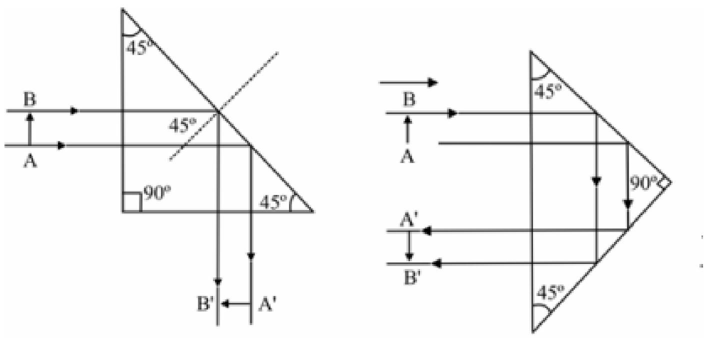
Answers

1.	(c)	2.	(b)	3.	(a)	4.	(b)	5.	(b)
6.	(d)	7.	(c)	8.	(a)	9.	(c)	10.	(b)
11.	(d)	12.	(b)	13.	(b)	14.	(d)	15.	(b)
16.	(a)	17.	(b)	18.	(d)	19.	(d)	20.	(a)

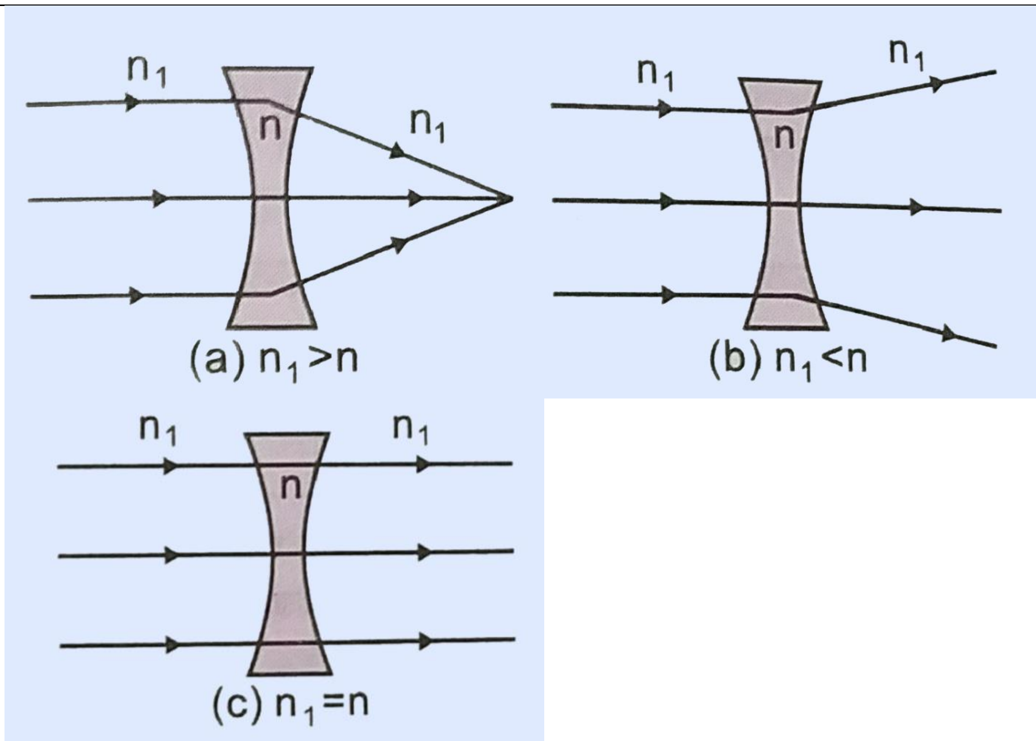
21.	(a) : Both assertion and reason are true and reason is the correct explanation of assertion. According to Snell's law it shows that higher is the refractive index of a medium or denser the medium, lesser is the velocity of light in that medium.
22.	(d) : A convex lens made of glass behaves as a convergent lens when placed in air or water. However when the same lens is immersed in carbon disulphide (m = 1.63), it behaves as a divergent lens. Therefore when a convergent lens is placed inside a transparent medium of refractive index greater than that of material of the lens, it behaves as a divergent lens. Behaviour of a lens depends on the refractive index of a surrounding medium.
23.	(a)
24.	(b)
25.	(c)
26.	(b)
27.	(a) : An endoscope is made of optical fibres. Its core is made of optically denser material. Its outer cladding is made of optically rarer material. It is based on total internal reflection.

28.	(a) : Optical density and mass density are not related to each other. Mass density is mass per unit volume. It is possible that mass density of an optically denser medium be less than that of an optically rarer medium (optical density is the ratio of the speed of light in two media). e.g., turpentine and water. Mass density of turpentine is less than that of water but its optical density is higher.
29.	(a) : Microscope is an optical instrument which forms a magnified image of a small nearby object and thus, increases the visual angle subtended by the image at the eye so that the object is seen to be bigger and distinct. Therefore, angular magnification for image is more than object.
30.	(a)
31.	Whenever light passes from one medium to another medium this ratio will always remain constant. Because both velocity and wavelength changes will compensate each other to give the final ratio equal for both mediums. Hence we can say that there will be no change in the frequency. The frequency will remain constant.
32.	Focal length of the lens decrease when red light is replaced by blue light.
33.	When the refractive index of the biconvex lens is equal to the refractive index of the liquid in which lens is immersed then the biconvex lens behaves as a plane glass sheet. In this case, $f \to \infty$.
34.	$\delta_{violet} > \delta_{red}$ When incident violet light is replaced with red light, the angle of minimum deviation of a glass decreases.
35.	Compound microscope is used because a realistic simple microscope does not have adjustable magnification. The magnification in a compound microscope can be adjusted according to the requirements.
36.	Net power $P = P_1 + P_2 = -4 + 2 = -2$ D Focal length f = 100/ P = 100/-2 = -50 cm.
37.	Refractive index, μ =c/v = sin i/ sinr As sin15° < sin25° < sin35° So, $v_A < v_B < v_C$ Hence in medium *A,* velocity of light is minimum.
38.	The lens will act as a diverging lens as the refractive index of water is greater than that of lens.
39.	Here focal length of objective lens f0=1/P0=1/100=0.01 m = 1.0 cm , focal length of eyepiece fe=1/Pe=1/50m=0.02m=2.0 cm length of the tube L = 25 cm and final image is being formed at infinity. (a) The instrument is a compound microscope because both f0 and fe ,are small and comparatively speaking f0<fe (b) Magnification produced m =- =(- L/ f0).(D/fe)=−312.5
40.	When the angle of incidence is 90 degrees, the maximum deviation occurs. Because the incoming light beam “grazes” down the prism surface, this is known as grazing incidence.
41.	Use formula for refraction through spherical surface, we get v = -180
42.	R = ? μ2=1.5 μ1=1.4 Power (P) = -5D

	$1/f=-5$ according to Lens maker's formula : $1/f=(\mu 2/\mu 1-1)(1/R1-1/R2)$ $-5=(1.5/1.4-1)(1/-R-1/R)$ $R=1/35m$ $=100/35cm=2.857cm$
43.	**As a lens is placed in the path of the convergent beam, the point P would lie on the right of the lens and acts as a virtual object.** **Object distance, $u=12$ cm** **(a) Focal length, $f=20$ cm (Convex Lens) Using the lens formula, $1/f=1/v-1/u$** **we have, $1/20=1/v-1/12 \Rightarrow v=7.5$ cm** **It is located at 7.5 cm from the lens and it is a real image.** **(b) Focal length, $f=-16$ cm (Concave Lens)** **Applying lens formula, we have** **$1/-16=1/v-1/12$** **$v=48$ cm** **It is located at 48 cm from the lens and it is a real image.**
44.	The ray coming from the object has to pass from denser to rarer medium and angle of incidence is greater than the critical angle.
45.	**Diagram :**  (a)  (a)
46.	The incidence angle is given as, $\sin i_c=2/3$ $\sin i_c=0.66$

	So, ic>30∘ Thus, the light will emerge out from face AC. 
47.	Magnification of a compound microscope is given by: M=MoMe≈ (-L/fo)(25/fe) Substituting values, 30=L×25/1.25×5 L=7.5 cm
48.	 Advantages : (a) Parabolic mirror is used to remove the spherical aberration. (b) No chromatic aberration in mirror. (c) Light mechanical support is required, because mirror weighs much less than a lens of equivalent optical quality.
49.	Convex mirrors are used as side view mirrors in a car to see the traffic behind. This is because of the following reasons: The image formed in a convex mirror is highly diminished due to which a convex mirror gives a wide field of view of the traffic behind the vehicle.
50.	 (a) (b)

51.



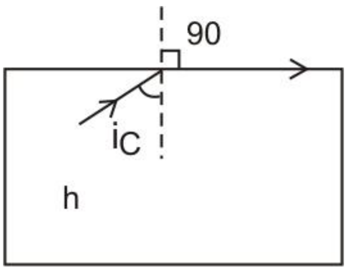
52. i) When light travels from optically denser medium to rarer medium, for the angle of incidence greater than the critical angle, the incident ray reflects back to the denser medium. This is called total internal reflection.

Condition for total internal reflection

(a) The light should travel from denser medium to rarer medium

(b) The angle of incidence should be greater than the critical angle.

ii)



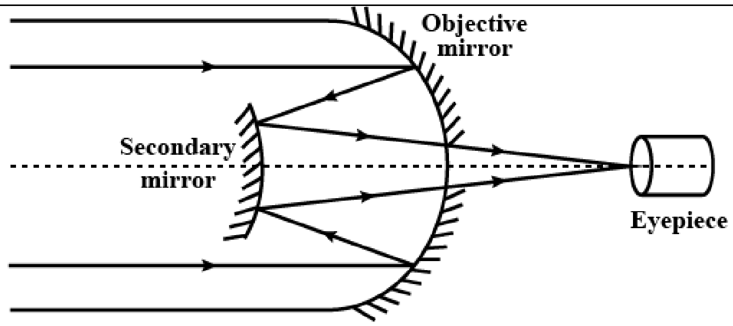
The angle of incidence corresponding to $r = 90^o$ is called the critical angle.

By snells law

$$\sin i_c = \frac{1}{n}$$

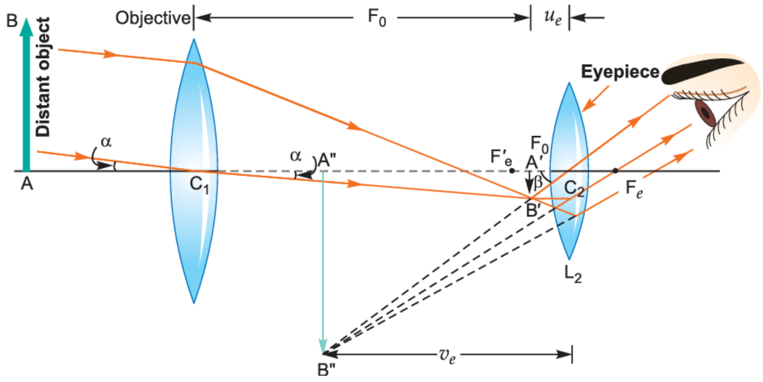
	$n = \frac{1}{\sin i_c}$ iii) Mirage is based on total internal reflection.
53.	(i) When the lens is in air, its focal length is 1/f=(1.5−1)(1/R1−1/R2)=(1/2)(1/R1−1/R2) (ii) When the lens is dipped in medium of μ=1.65, 1/f1=(1.5/1.65−1)(1/R1−1/R2)=(−0.15/1.65)(1/R1−1/R2) on solving, f1=-5.5f ∴The lens behave as concave lens of focal length −5.5f (iii) When the lens is liquid in medium of μ=1.33 1/f2=(1.5/1.33−1)(1/R1−1/R2)=(0.17/1.33)(1/R1−1/R2) on solving, f2=3.9f ∴ The lens behaves as convex lens of focal length 3.9f
54.	**Critical angle for ray 1:** **sin(C1)=1/μ1=1/1.39** **C1=sin−1(1/1.39)=46.00°** **For ray 2:** **sin(C2)=1/μ2** **C2=sin−1(1/1.47)=42.86°** **Similarly for ray 3:** **Sin(C3)=1/μ3=1/1.52** **C3=sin−1(1/1.52)=41.13°** **The ray 1 will get reflected completely from side AC at angle 46°. And ray 2 \and 3 will be refracted as their angle is less than the ray 1.**
55.	Laws of reflection : the angle of reflection is equal to the angle of incidence, the incident ray, the reflected ray, and the normal to the surface all lie in the same plane.

<table>
<tr><td></td><td>Laws of refraction :
The incident ray refracted ray, and the normal to the interface of two media at the point of incidence all lie on the same plane. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. This is also known as Snell's law of refraction.</td></tr>
<tr><td>56.</td><td>



(ii) Advantages : (a) Parabolic mirror is used to remove the spherical aberration. (b) No chromatic aberration in mirror. (c) Light mechanical support is required, because mirror weighs much less than a lens of equivalent optical quality. (iii) In normal adjustment, magnifying power of the telescope M = F0/Fe.
If focal length of the objecctive lens is large in comparison to the eyepiece, magnifying power increases</td></tr>
<tr><td>57.</td><td>Here, Angle of prism, A=60o
Angle of incidence, i=3/4×60
i+e=A+δ
e is emergence angle where δ is deviation angle
At minimum deviation δ=δmin
i=e
2i=A+δmin
2×45=60+δmin
δmin=30
By prism law,

μ= sin(A+δm) /2
sinA/2
putting values
μ=1.41
Let v be velocity of light in prism
v=c/μ=2×108 m/s</td></tr>
<tr><td>58.</td><td>(a) Focal length of the objective lens, fo=140cm
Focal length of the eyepiece, fe=5cm
Least distance of distinct vision, d=25cm
When the telescope is in normal adjustment, its magnifying power is given as-
m=fo/fe=28
(b) Focal length of the objective lens, fo=140cm
Focal length of the eyepiece, fe=5cm
Least distance of distinct vision, d=25cm
When the final image is formed at d, its magnifying power is given as-
m=(fo/fe)(1+fe/d)=33.6</td></tr>
</table>

<table>
<tr><td>59.</td><td>


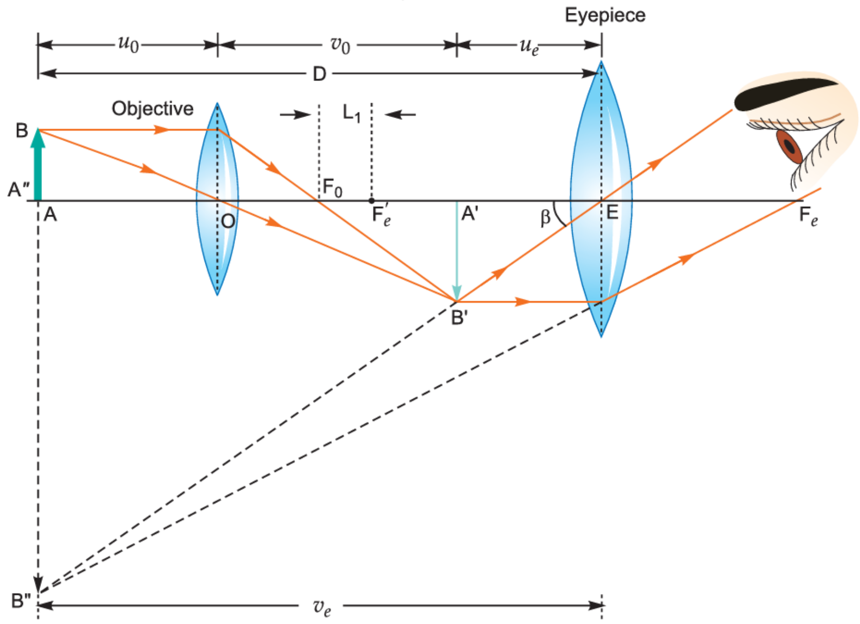
The magnifying power of telescope is

$$M = \frac{\text{Angle subtended by final image at eye}}{\text{Angle subtended by object on eye}} = \frac{\beta}{\alpha}$$

$$= (m_0 \times m_e) = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{v_e}\right)$$

and Length of telescope $L = f_0 + u_e$
where u_e = distance of real image from eye lens
v_e = distance of final image A′ B′ from eye lens
f_0 = focal length of objective, f_e = focal length of eye lens
</td></tr>
<tr><td>60.</td><td>

$$M = \frac{\beta}{\alpha}(= m_o \times m_e) = \frac{v_o D}{u_o v_e}\left(1 + \frac{v_e}{f_e}\right)$$



Separation between lenses, $L = v_0 + u_e$
</td></tr>
<tr><td>61.</td><td>
Given, refractive index of lens, μg = 1.5
The distance of the needle from the lens in the first case = The focal length of the combination of convex lens and plano- concave lens formed by the liquid, f =x
And, the distance measured in the second case = Focal length of the convex lens, f1=y
If the focal length of plano-concave lens formed by the liquid be f2, then
1/f=1/f1+1/f2

⇒ 1/f2=1/x−1/y
</td></tr>
</table>

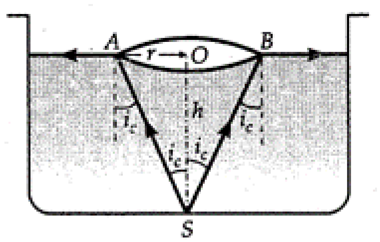
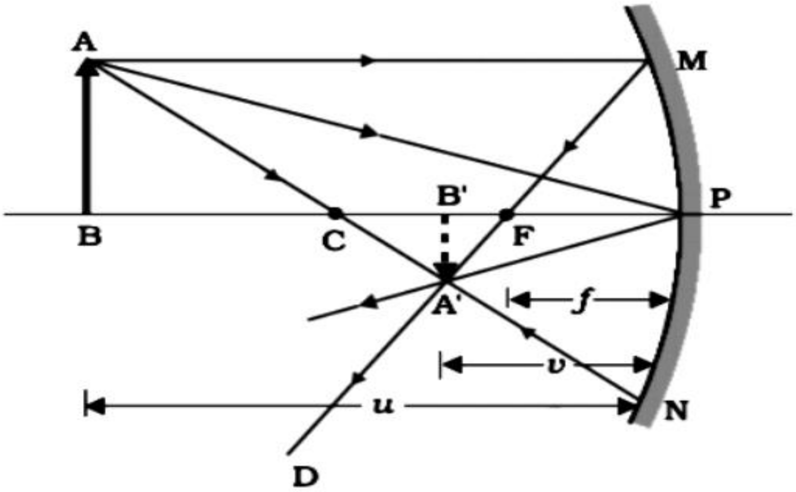
	$=y-x/xy$ or $f_2=xy/y-x$ Now, refractive index of lens, $\mu=1.5$, radius of curvature of one surface= R and radius of curvature of other surface = - R $\therefore 1/f_1=(\mu_g-1)(1/R-1/-R)$ $1/y=(1.5-1)(2R) \Rightarrow R=y$ And, if refractive index of liquid is μ_l, Radius of curvature on the side of plane mirror $=\infty$ Radis of curvature on the side of lens =- R $\therefore \quad y-x/xy=(\mu_l-1)(1/-R-1/\infty)=(\mu_l-1)(-1/y)$ $\mu_l = 2x-y/x$
62.	Since the image is formed on the screen, it is a real image. Let the distance of the object from the lens be x. Then, distance of the image from the lens be (90-x) magnification, $m=v/u$ According to new Cartesian coordinate system, $u=-x, v=+(90-x)$ and $m=-2$ $\therefore -2=90-x/-x$ $\Rightarrow x=30cm$ $\therefore u=-30cm$ and $v=+(90-30)=60cm$ Also, $-1/u+1/v=1/f$ Putting values $\Rightarrow F=20cm$ (convex lens).
63.	Here B is a fish situated at a depth from the water surface and R is the radius of the cone. By definition of critical angle, we have: $\sin i_c=1/n$, where n is the refractive index of water But, $\sin i_C = \frac{CA}{BA} = \frac{R}{\sqrt{R^2+h^2}}$ Hence, $\frac{1}{n} = \frac{R}{\sqrt{R^2+h^2}} \Rightarrow R = \frac{h}{\sqrt{n^2-1}}$ 
64.	$n_g = n_m = 1.5$
65.	For 1st lens, $u_1=-30cm, f_1=+10cm, v_1=?$ As $1/v_1-1/u_1=1/f_1 \therefore 1/v_1-1/-30=110$

	Image formed by first lens serves as object for second lens at a distance =(15−5)=10cm to the right of second lens, and the object is virtual Therefore, for second lens, $u_2=10cm, v_2=?\ f_2=-10cm$. As $1/f_2=1/v_2-1/u_2 \therefore -1/10=1/v_2-1/10$ $\therefore 1/v_2=0, v_2=\infty$ The virtual image is found at infinity to the right of 2nd lens. This acts as an object for 3rd lens. Therefore, for 3rd lens, $u_3=\infty, v_3=?$ $f_3=+30cm$ As $1/v_3-1/u_3=1/f_3$ $\therefore 1/v_3-1/\infty=1/30$ or $v_3=30cm$ The final image is formed at 30cm to the right of third lens.
66.	Refer textbook
67.	(b) It is given that $n_1=1$ $n_2=1.5$ $R=20cm$ $u=-100cm \quad v=?$ Now using following relation $n_2/v-n_1/u=(n_2-n_1)/R$ putting values we get $v=100cm$
68.	Refer textbook
69.	(ii) We know that light incident normally on one face of right isosceles prism is totally reflected. $\mu=1/\sin(c)$ (Total internal reflection) C is a critical angle, which is 45 $\mu=1/\sin(45)$ $\mu=\sqrt{2}$ Thus minimum value of refractive index is 1.414
70.	Refer textbook
71.	The magnifying power of a telescope is measured by the ratio of angle (β) subtended by the final image on the eye to the angle (α) subtended by object on eye. If the telescope is in normal adjustment, i.e., the final image is at infinity. Formula : $M=f_o/f_e$ since $f_o=150cm, f_e=5cm$ $\therefore M=15/0.5=30$ If tall tower is at distance 3 km from the objective lens of focal length 150 cm. It will form a image at distance v_o So, $1/f_o=1/v_o-1/u_o$ $1/150cm=1/v_o-1/-3km$ $v_o=1.5m$ Magnification $m_o=h_1/h_o=v_o/u_o$

	putting values hi=0.05m.
72.	Given, fo=1.25cm,fe=5cm,uo=−1.5cm,D=25cmfo=1.25cm,fe=5cm,uo=-1.5cm,D=25cm Calculate vo using formula 1/fo=1/vo−1/uo1fo Then, substituting the values, we get Magnification, m=(vo/uo)|(1+D/fe)=30
73.	Power of lens : It is the reciprocal of focal length of a lens. $P = \frac{1}{f}$ (f is in metre) Unit of power of lens : Dioptre
74.	 From Fig., the two right-angled triangles A′B′F and MPF are similar. (For paraxial rays, MP can be considered to be a straight line perpendicular to CP.) Therefore, $\frac{B'A'}{PM} = \frac{B'F}{FP}$ or $\frac{B'A'}{BA} = \frac{B'F}{FP}$ ($\because$ PM = AB) ------------------- (1) Since ∠APB = ∠APB′, the right angled triangles A′BP and ABP are also similar. Therefore, $\frac{B'A'}{BA} = \frac{B'P}{BP}$ ------------------- (2) Comparing Eqns. (1) and (2) we get, $\frac{B'F}{FP} = \frac{B'P - FP}{FP} = \frac{B'P}{BP}$ ----------- (3) Equation (3) is a relation involving magnitude of distances. We now apply the sign convention. We note that light travels from the object to the mirror MPN. Hence this is taken as the positive direction. To reach the object AB, image A′B′ as well as the focus F from the pole P, we have to travel opposite to the direction of incident light. Hence, all the three will have negative signs. Thus, B′ P = −v, FP = −f, BP = −u Using these in Eq. (3), we get, $\frac{-v+f}{-f} = \frac{-v}{-u}$ or $\frac{v-f}{f} = \frac{v}{u}$ $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

75.	(ii) (a) For a telescope, power of objective = 0. 5 D Power of eyepiece = 10 D This choice would give higher magnification as $m = \frac{f_o}{f_e}$ b) Aperture of the objective is preferred to be large so as to have high resolving power and larger light gathering power to obtain brighter image
76.	(i) a (ii) a (iii) a (iv) a (v) d
77.	(i) d (ii) b (iii) c (iv) c (v) b
78.	(i) c (ii) a (iii) b (iv) a (v) b
79.	(i) a (ii) d (iii) a (iv) a (v) a
80.	(i) a (ii) c (iii) d (iv) b (v) b
81.	(i) c (ii) d (iii) a (iv) c (v) b

CHAPTER 10: WAVE OPTICS

SYLLABUS: Wavefront and Huygen's principles, refection and refraction of a plane wave at a plane surface using wavefront; proof of laws of reflection and refraction using Huygen's principle, Interference, Young's double slit experiment and expression for fringe width; coherent sources, and sustained interference of light; diffraction due to a single slit, width of central maxima

SUMMARY OF IMPORTANT TOPICS;

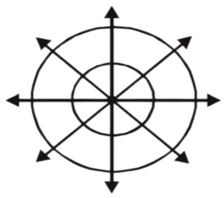
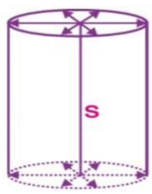
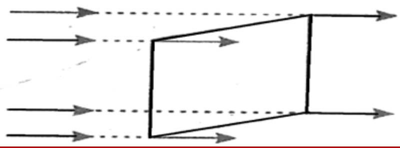
Wavefront and Huygen's principle: -

Wavefront: wavefront is a set or locus of all points of a medium vibrating in the same phase at a given instant.

- The direction of propagation of wave is perpendicular to the wavefront.

  Or
- Incoming rays are perpendicular to the wavefront.

Different shapes of wavefront based on different sources of light;

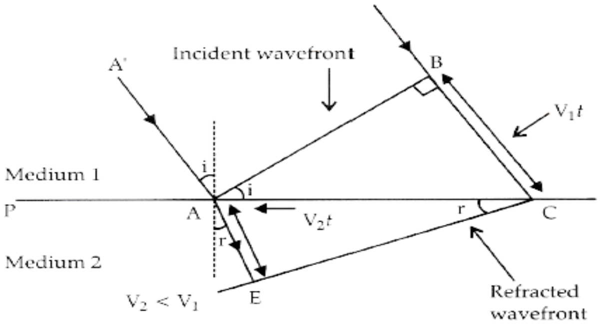
Source	Wavefront	Shape of wavefront
Point source	Spherical	
Linear source	Cylindrical	
Plane source	Plane wavefront	
Point source far away	Plane wavefront	

Huygen's principle:

- Every point of a wavefront (primary wavefront) becomes a source of disturbance called secondary wavelets, which travel in all direction with the speed of light in the medium.
- A surface touching these secondary wavelets tangentially in the forward direction at any instant, gives the new wavefront which is known as secondary wavefront.

Proof of laws of refraction of light by Huygen's principle:

From the figure,



AB= incident wavefront

EC= refracted wavefront

∠i= angle between incident wavefront AB and interface PP'

∠r= angle between refracted wavefront EC and interface PP'

If the medium2 is optically denser than the medium 1 and t is the time in which disturbance from B reaches C. This is the same time in which disturbance from A reaches E where

Distance AE<BC

$$\Delta AEC \text{ is congruent to } \Delta ABC$$

$$Sin\ i = \frac{BC}{AC}$$

$$Sin\ r = \frac{AE}{AC}$$

$$\frac{Sin\ i}{sin\ r} = \frac{BC}{AC} \times \frac{AC}{AE} = \frac{BC}{AE}$$

BC= Distance travelled by wave at B in time t in medium 1

AE= distance travelled by wave at A in time t in medium 2

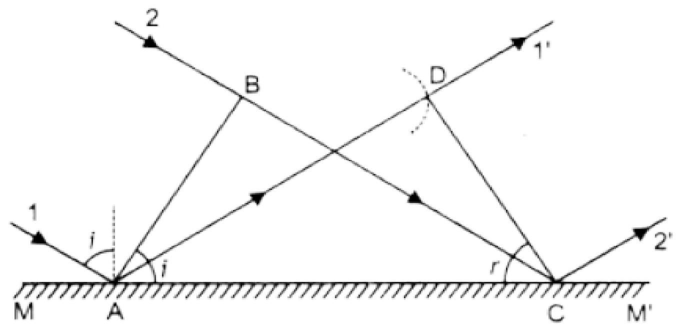
Therefore, $\frac{\boldsymbol{Sin\ i}}{\boldsymbol{sin\ r}} = \frac{V_1t}{V_2t}$

$\frac{\boldsymbol{Sin\ i}}{\boldsymbol{sin\ r}} = \frac{V_1}{V_2}$ = constant

Which is Snell's law:-

- And it is Clear from the figure that the incident wavefront AB normal to the interface PP' and refracted wavefront EC all lie in the same plane. This is the second law of refraction.

Proof of law of reflection of light by Huygen's principle



AB=incident wavefront

CD=reflected wavefront

$\angle i$ = angle between incident wavefront AB with interface MM'

∠r= angle between reflected wavefront CD with interface MM's

The disturbance produced by B strikes at C in time t.

BC=Vt.

And also, the disturbance from A will also travel the same distance

Vt in same time to strike at D.

That is, AD=BC=Vt

And ΔABC IS congruent to ΔACD

Therefore, $\angle i = \angle r$

Hence the law of reflection is proved

Principle of superposition

The resultant displacement of a particle at any instant is the vector sum of the individual displacements caused to the particle by two or more waves. Let Y1 and Y2 be the displacements of the particle at any instant caused by the two waves. Then the resultant displacement of the particle at that instant is $\vec{Y} = \vec{Y}1 + \vec{Y}2$

Constructive superposition:

when two waves of same wavelength superimpose on each other in phase, then the superposition is said to be constructive.

That is, $\vec{Y} = \vec{Y}1 + \vec{Y}2$

Destructive superposition:

when two waves of same wavelength superimpose on each other out of phase then the superposition is said to be destructive

That is, $\vec{Y} = \vec{Y}1 + (-\vec{Y}2)$

Resultant wave of two waves:

let the two waves from two coherent sources be

$\vec{Y}1$= a sin ωt and

$\vec{Y}2$= b sin (ωt+ϕ)

Then the resultant of these waves is given by

- $\vec{Y}$= R sin (wt+θ) where R is the amplitude of the resultant wave. And R= $\sqrt{a^2 + b^2 + 2ab\cos\phi}$
- Intensity of the resultant wave is I = (I_a + I_b +2 $\sqrt{I_a I_b}$ cos ϕ)

Coherent Source: Two sources are said to be coherent if they emit wave of same frequency (or wave length) and are either in phase or have constant initial phase difference.

Interference: The phenomenon of re-distribution of light energy due to the superposition of light wave from two coherent. Sources are known as interference of light.

The resultant wave of two waves

Y1 = a sin ωt and

Y2 = b sin (ωt + ϕ) from two coherent sources.

After being super imposed is given by

Y = R sin (ωt + ϕ) ---------①

Where R is the resultant amplitude.

R= $\sqrt{a^2 + b^2 + 2ab\cos\phi}$ ----------②

Intensity of resultant wave:

$I = I_a + I_b + 2\sqrt{I_a . I_b}\ \cos\phi$ ------------③

Where` I_a and I_b are the intensities of 1st wave and 2nd wave

Condition for Constructive Interference: Occurs when the amplitude and hence the intensity is maximum.

i.e., equation --- ③

$I = I_{max}$ if $\cos\phi$ = +1

Or

ϕ = 0 ,2π, 4π

Or

In general, ϕ= n (2π) where n=0,1,2,3...

Thus, Constructive Interference takes place if the phase difference between the two superimposing waves is an integral multiple of 2π

Since path difference $\Delta x = \frac{wavelength}{2\pi}$ Phase difference

Path difference for the Constructive Interference

$$\Delta x = \frac{\lambda}{2\pi} \text{ x n } 2\pi$$

$$\Delta x = n\lambda$$

From equation (3) the maximum intensity is

$I_{max} = I_a + I_b + 2\sqrt{I_a I_b}$

$I_{max} = (\sqrt{I_a} + \sqrt{I_b})^2$

And from ②

R $_{max} = \sqrt{a^2 + b^2 + 2ab}$

R $_{max} = \sqrt{(a+b)^2}$

R $_{max}$ = a+b

Special cases: If a=b and $I_a = I_b$

$I_{max} = 4 I_a$

R $_{max}$ = 2 a

Condition for destructive Interference: Occurs when the amplitude and hence the intensity is minimum.

$I = I_{min}$ if $\cos\phi$ = minimum

Or ϕ = π, 3 π, 5 π...

Or in general ϕ = $\left(n + \frac{1}{2}\right) 2\pi$, n=0, 1, 2, ...

Path difference for destructive interference

$$\Delta x = \frac{\lambda}{\cancel{2\pi}} \text{ x } \left(n + \frac{1}{2}\right) \cancel{2\pi}$$

$$\Delta x = \lambda\left(n + \frac{1}{2}\right)$$

from ②

R $_{min}$ = $\sqrt{a^2 + b^2 - 2ab}$

R $_{min}$ = $\sqrt{(a-b)^2}$

R $_{min}$ = $a - b$

From----③

$I_{min} = \sqrt{I_a + I_b - 2\sqrt{I_a I_b}}$

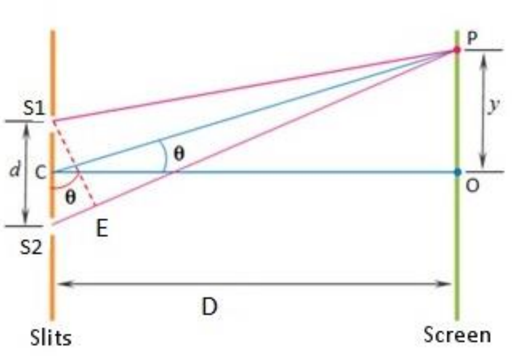
$I_{min} = \left(\sqrt{I_a} - \sqrt{I_b}\right)^2$

Special Cases: If a=b, $I_a = I_b$

R $_{min}$ **= 0**

I_{min} **= 0**

Young's Double Slit Experiment:



At 'O' we get central maxima, here path difference ($S_2P - S_1P$) = 0

At 'P' which is at Y height from O, path difference ($S_2P - S_1P$) $= \frac{yd}{D}$

Condition for P to be a bright spot

$\frac{yd}{D}$ = 0, λ, 2λ, ……. nλ.

∴ n^{th} bright spot will be formed at a distance $Y_n = \frac{nD}{d}\lambda$ from 'O'

<u>Condition for P to be a dark spot</u>

$\frac{yd}{D} = \frac{\lambda}{2}, \frac{3\lambda}{2}, \ldots, (2n+1)\frac{\lambda}{2}$

n^{th} Dark spot will be formed at a distance

$$Y_n = \frac{(2n+1)\frac{\lambda}{2}D}{d} = \frac{(2n+1)\lambda D}{2d}$$

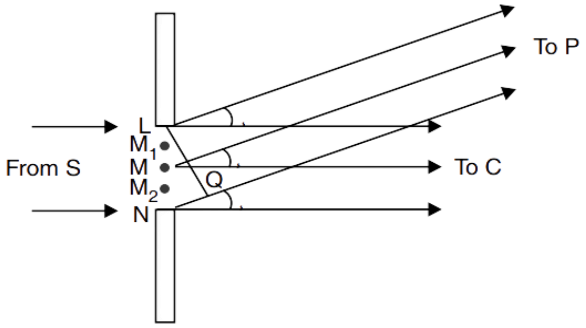
Width of the Bright fringe: - β= distance between two consecutive dark fringes

$$\beta = \frac{3\lambda D}{2d} - \frac{\lambda D}{2d}$$

$$\beta = \frac{2\lambda D}{2d}$$

$$\beta = \frac{\lambda D}{d}$$

Diffraction: It is defined as the bending of light around the corners of an obstacle or aperture into the region where we should expect shadow of the obstacle.



If width of the opening = a

θ is the angle of elevation of point P from principal axis.

Path difference between ray from L and ray from N = LQ = a sin θ

a sin θ= λ

∵ for first maxima $\theta = \frac{\lambda}{a}$ (∴ sin θ = θ) sin θ <<<1

It is observed that when path difference = λ, 2 λ,.... (2n – 1) λ then P is a dark point.

When a sin θ = $\frac{3\lambda}{2}$,......... (2n+1) $\frac{\lambda}{2}$, then P is a bright point.

Elevation angle for first bright fringe $\theta_{1D} = \frac{3\lambda}{2a}$

- Height of first dark fringe $x_{1D} = \frac{3\lambda D}{2a}$
- Elevation angle for first dark fringe $\theta_{1D} = \frac{\lambda}{a}$
- Width of the bright fringe = $\frac{D\lambda}{a}$

- Width of the dark fringe = $\frac{D\lambda}{a}$
- Width of the central fringe = $\frac{2D\lambda}{a}$
- There is no gain or loss of energy in interference or diffraction, which is consistent with the principle of conservation of energy. Energy only redistributes in these phenomena.

Sustained interference and conditions for sustained interference:

Interference pattern is said to be sustained if the positions of the constructive interference (i.e., bright fringes) and destructive interference (dark fringes) remain fixed on the screen.

To have sustained interference following conditions must be fulfilled.

1. Two sources must be coherent.
2. Two sources should emit waves continuously.
3. Two coherent sources of light should be close to each other.
4. The amplitude of two waves emitted by the two coherent sources of light should be equal to get complete contrast between in dark and bright fringes.
5. Two coherent sources of light should be narrow.
6. The distance of the screen from the coherent sources of light should not be small.
7. The light should be monochromatic to eliminate.
8.

A) OBJECTIVE QUESTION (MCQ) (1 mark each)

1. Two light sources are said to be coherent if they produce waves

A. Of equal wavelength
B. Of equal frequency
C. Of equal velocity
D. Of equal frequency and having constant phase difference between them.

Answer: option D

2. What is the shape of wavefront from distant source of light?

A. Planar
B. Spherical
C. Cylindrical
D. Depends on shape of the source

Answer: option A

3. There are two points on same wavefront separated by a distance λ/2. What will be the phase difference between these two points?

A. π
B. π/2
C. π/4
D. 0

Answer: option D

4. The wavefront of a linear source of light
    A. Spherical
    B. Plane
    C. Cylindrical
    D. Reflected type

Answer: option B

5. When the distance between the slit and the screen in Young's double slit experiment is doubled then
    A. Fringe width becomes double
    B. Fringe width becomes half
    C. Fringe width remains unchanged
    D. Fringe width becomes thrice

Answer: option A

6. Two coherent light beams of intensities I and 4I are superposed. The maximum and the minimum possible intensities in the resulting beam is
    A. 5I and 3I
    B. 9I and I
    C. 9I and 3I
    D. 5I and I

Answer: option B

7. How can the fringe width increase in Young's double-slit experiment?

A. By decreasing the width of the slit
B. By reducing the separation of slits
C. By reducing the wavelength of the slits
D. By decreasing the distance between slits and the screen

Answer: option B

8. What happens to the interference pattern if the two slits S_1 and S_2 in Young's double experiment are illuminated by two independent but identical sources?
A. The intensity of the bright fringes doubled
B. The intensity of the bright fringes becomes four times
C. Two sets of interference fringes overlap
D. No interference pattern is observed

Answer: option D

9. A single slit diffraction pattern is obtained using a beam of red light What happened if the red light is replaced by the blue light?
A. There is no change in diffraction pattern.
B. Diffraction fringes become narrower and crowded.

C. Diffraction fringes become broader and farther apart.
D. The diffraction pattern disappears.

Answer: option B

10. **The energy of the wave travels in a direction ______ to the wavefront.**

A. Parallel
B. Perpendicular
C. Both A and B
D. None

Answer: option B

B) Assertion and reasons: (1 mark each)

Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
A. If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
B. If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
C. If the Assertion is correct but Reason is incorrect.
D. If both the Assertion and Reason are incorrect.

1. **Assertion:** No interference pattern is detected when two coherent sources are infinitely close to each other.
Reason: The fringe width is inversely proportional to the distance between the two sources.

Answer: Option A

2. **Assertion:** In Young's double slit experiment if wavelength of incident monochromatic light is just doubled, number of bright fringes on the screen will increase.
Reason: Maximum number of bright fringes on the screen is inversely proportional to the wavelength of light used

Answer: option A

3. **Assertion:** Diffraction takes place for all types of waves mechanical or non-mechanical, transverse or longitudinal.
Reason: Diffraction's effects are perceptible only if wavelength of wave is comparable to dimensions of diffracting device.

Answer: option B

4. **Assertion (A):** Interference obeys the law of conservation of energy.
Reason (R): The energy is redistributed in case of interference

Answer: option A

5. **Assertion (A):** We cannot get diffraction pattern from a wide slit illuminated by monochromatic light.
   Reason (R): In diffraction pattern, all the bright bands are not of the same intensity.

Answer: option B

C) Very short question (1 mark each)

1. What are the conditions for two sources to be coherent?

Answer: Two sources are said to be coherent if they produce waves of same frequency and having a constant phase difference between them.

2. Define wavefront.

Answer: wavefront is a locus of points of a medium vibrating in the same phase at an instant.

3. What will be effect on the fringes if Young' s experiment is immersed in water?

Answer: Fringe width would decrease.

4. State two conditions to obtain sustained interference of light.

Answer: The two conditions for obtaining sustained interference of light are

(a) the two light sources should be coherent

(b) the two light sources should be narrow and placed close to each other.

5. What will be the effect on the width of the central maxima if the slit is made narrower?

Answer: when the slit is made narrower the width of central maxima increases. Since width of the maxima=$\frac{2\lambda D}{d}$.

6. The Ratio of intensities of two waves is in the ratio of 1:25 what is the ratio of their amplitudes?

Answer: 1:5

7. Why are coherent sources required to create interference of light?

Answer: Coherent sources are required for sustained interference. If sources are incoherent, the intensity at a point will go on changing with time.

8. Differentiate between a ray and a wavefront.

Answer: A wavefront is a surface of constant phase. A ray is a perpendicular line drawn at any point on wavefront and represents the direction of propagation of the wave.

9. What is interference of light?

Answer: The phenomenon of redistribution of light energy due to the superposition of light waves from two coherent sources is known as interference of light.

10. What is diffraction?

Answer: Diffraction is bending of waves around sharp edges into the geometrically shadowed region.

D) Short answer questions (2 marks each)

1. **In young's double slit experiment how is the fringe width change when**
(a) Light of smaller frequency is used
(b) Distance between the slits is decreased?
Answer.
(a) If light of smaller frequency is of higher wavelength is used the fringe width will increase.
(b) If distance between the slits is decreased i.e. Fringe width will increase.

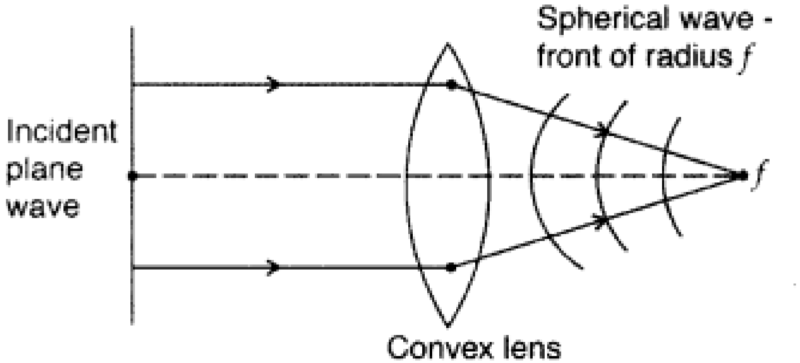
2. **Write two points of difference between interference and diffraction?**
Answer.

S.No.	Interference	Diffraction
1	Interference occurs due to superposition of light coming from two coherent sources.	It is due to the superposition of the waves coming from different parts of the same wave front.
2	All bright fringes are of equal intensity	The intensity of bright fringes decreases with increasing distance from the central bright fringes.

3. **Can white light produce interference? What is the nature?**

Answer: White light produces interference but due to different colour present in white light interference pattern overlaps the central bright fringe for all the colours is at the position, so its colour is white. The white central bright fringe is surrounded by few coloured rings.

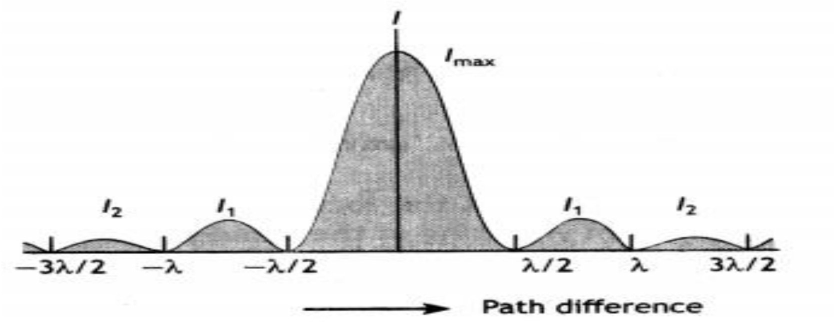
4. Draw a diagram to show refraction of a plane wave front incident in a convex lens and hence draw the refracted wave front.
Answer:



5. Define diffraction of light. Draw an intensity distribution graph for diffraction due to a single-slit.

Answer: Diffraction is bending of waves around sharp edges into the geometrically shadowed region.

The intensity distribution for a single-slit diffraction pattern is as shown.



6. State Huygens' Principle.

Answer:

Huygens principle states that

(a) Each point on a wavefront is a source of secondary waves which travel out with the same velocity as the original waves.

(b) The new wavefront is given by the forward locus of the secondary wavelets, which give rise to a new secondary wavefront.

7. **In a double-slit experiment using the light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1°. What is the spacing between the two slits?**

Answer:

Wavelength of the light, λ = 600 nm

The angular width of the fringe formed, $\theta = 0.1^0 = \frac{0.1\,\pi}{180}$

Spacing between the slits, $d = \frac{\lambda}{\theta} = \frac{(600\times10^{-9}\times180)}{(0.1\times3.14)} = \frac{108000\times10^{-9}}{0.314}$

$d = 3.44 \times 10^{-4}$ m

8. **A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Find the width of the slit.**

Answer:

Wavelength of the beam of light, λ = 500 nm

Distance between the slit and the screen, D= 1 m

Distance of the first minimum from the centre of the screen, x = 2.5 mm = 2.5 x 10^{-3} m

First minima, n = 1

Consider the equation, nλ = $\frac{xd}{D}$

⇒ d = $\frac{n\lambda D}{x}$

= $\frac{(1\times 500\times 10^{-9}\times 1)}{(2.5\times 10^{-3})}$

= 200 x 10^{-6} m

9. When light travels from a rarer medium to a denser medium it loses its speed. Does this imply a reduction in energy carried by the light wave? Give reason for your answer.

Answer: No, this does not imply the reduction in energy. Because energy of any wave depends upon its frequency, which remains same whenever light passes from one medium to another.

10.Light of wavelength 5000 A° is incident normally on a slit of width 2.5×10−4 cm. Find The angular position of second minimum from the central maximum.

Answer:

We know that,

Angular width of central maximum = $\frac{2\lambda}{a}$

where, λ =wavelength of light,

a=width of single slit,

So, sinθ= $\frac{2\lambda}{a}$

where λ = 5000 A° = **5000 x 10^{-10}m**

a = 2.5 x 10^{-6} m ⟹ **sinθ =** $\frac{2\times 5000\times 10^{-10}}{2.5\times 10^{-6}}$

=> sinθ = $\frac{10000\times 10^{-10}}{2.5\times 10^{-6}}$

=> sinθ = $\frac{10}{25}$

=> sinθ = $\frac{2}{5}$

θ = $\sin^{-1}(\frac{2}{5})$

E) short answer question (3mark each)

1. Describe Young's double slit experiment to produce interference pattern due to a monochromatic source of light. Write the expression for the fringe width.

Answer: refer the summary notes.

2. State Huygens' Principle and using this principle, prove law of reflection of light.

Answer: refer the summary notes.

3. (a) The ratio of the widths of two slits in Young's double slit experiment is 4 : 1. Evaluate the ratio of intensities at maxima and minima in the interference pattern. (b) Does the appearance of bright and dark fringes in the interference pattern violate, in any way, conservation of energy? Explain.

Answer: (a)

Here $\frac{a1}{a2} = \sqrt{\frac{W_2}{W_1}} = \sqrt{\frac{4}{1}} = \frac{2}{1}$

$$\frac{I_{\max}}{I_{\min}} = \left|\frac{2a_2 + a_2}{2a_2 - a_2}\right|^2 = 9:1$$

b) There is NO violation of the conservation of energy. The appearance of the bright and dark fringes is simply due to a 'redistribution of energy'

4.(a)When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the center of the shadow of the obstacle. Explain why.

(b) State Two points of difference between the interference pattern obtained in Young's double slit experiment and the diffraction pattern due to a single slit.

Answer(a): The waves diffracted at the edge of circular obstacle produce constructive interference at the centre of the shadow; producing a bright spot.

(b): **Interference:** A double-slit interference pattern has equally spaced dark and bright bands.

- The peak intensity of the bright bands remains the same.
- **Diffraction:** A single slit diffraction pattern has a central bright maximum that's twice as wide as other maxima.
- The intensity falls as we go to the successive maxima away from the centre on either side.

5. State Huygens' principle and using this principle, prove the laws of refraction of light.

Answer: refer the summary notes.

F) Long answer question (5 marks each)

1.

(a) State Huygens's principle for constructing wavefronts?
(b) Using Huygens's principle deduce the laws of reflection of light?
(c) What changes in diffraction pattern of a single slit will you observe? When the monochromatic source of light is replaced by a source of white light?

Answer: refer summary notes for (a) and (b)

(C)

(1) The diffracted light consists of different colours.
(2) It results in overlapping of different colours.

2(a). Define a wavefront. How is it different from a ray?

(b) depict the shape of the wavefront

(i) light emerging from a point source.

(ii) light emerging out of a convex lens when a point source is kept at its focus.

(iii) using Huygens construction of secondary wavelets, draw a diagram showing the passage of a plane wavefront from a denser medium into a rarer medium.

Answer:(a) refer summary note and Q.no. 8 from very short answer question.

(b) Refer the table in the summary notes.

3.(i)Define diffraction of light.

(ii)State one feature by which the phenomenon of interference can be distinguished from that of diffraction.

(iii) A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 'a'. If the distance between the slits and the screen is 0.8 m and the distance of 2nd order maximum from the centre of the screen is. 15 mm, calculate the width of the slit.

Answer: i) refer the summary notes.

(ii) In interference all the maxima are of equal intensity.

In a diffraction pattern, the central fringe is of maximum intensity while the intensity of secondary maxima falls rapidly.

(iii)Given, $\lambda = 600$ nm $= 6 \times 10^{-7}$ m,

D = 0.8 m, $Y_2 = 15 \times 10^{-3}$ m

To calculate: Width of the slit 'd'

Calculations: $Y_2 = \frac{5}{2} \times \frac{\lambda D}{d}$

d= $\frac{5}{2} \times \frac{(6 \times 10^{-7} \times 0.8)}{15 \times 10^{-3}}$

∴ Distance, d = 8×10^{-5} = 80 μm

Case Based Question:

According to superposition principle, the resultant displacement produced due the number of waves at a particular point is the vector sum of displacement produced by each vector at that point. The two sources of light are said to be coherent only when the phase difference between the light waves produced by them is zero or constant. The point at which two waves are in phase or if trough of one wave coincides with the trough of other or crest of one wave coincides with the crest of other then the resultant intensity produced at that point will be larger and amplitude also maximum. Such points are the points where constructive interference takes place. While there are some points where two light waves are not in phase with each other and crest of one wave coincides with the trough of other and vice versa due to which resultant intensity at that point is minimum and amplitude also get decreased. Such points are the points where destructive interference takes place. For constructive interference, the path difference is equal to integral multiple of wavelengths and resultant intensity will be maximum at those points. While for destructive interference, the path difference is (n + $\frac{1}{2}$) multiple of wavelengths and where resultant intensity is zero. When light is passed around the sharp edges of an obstacle it gets bended and may enters into the geometrical shadow of that obstacle such a phenomenon of light is called as diffraction of light. In interference, there are equally spaced alternate bright and dark bands are possible. While in diffraction, the there is a only one bright central Maxima and around both sides of the central Maxima the intensity of the light decreases as we go away from that central Maxima.

Questions:

Q 1.) For coherent sources of light, the phase difference must be___

a) one

b) zero

c) either zero or constant

d) 90°

Q 2.) If the phase difference is 0, +2π, -4π then the interference should be

a) constructive interference

b) destructive interference

c) both a and b

d) diffraction of light

Q 3.) For destructive interference

a) path difference is (n +1/2) times wavelength

b) phase difference is π, -3π, +5π

c) path difference is integral multiple of wavelengths

d) both a and b

Q 4.) The interference and diffraction of light explains which nature of light?

Answer key:

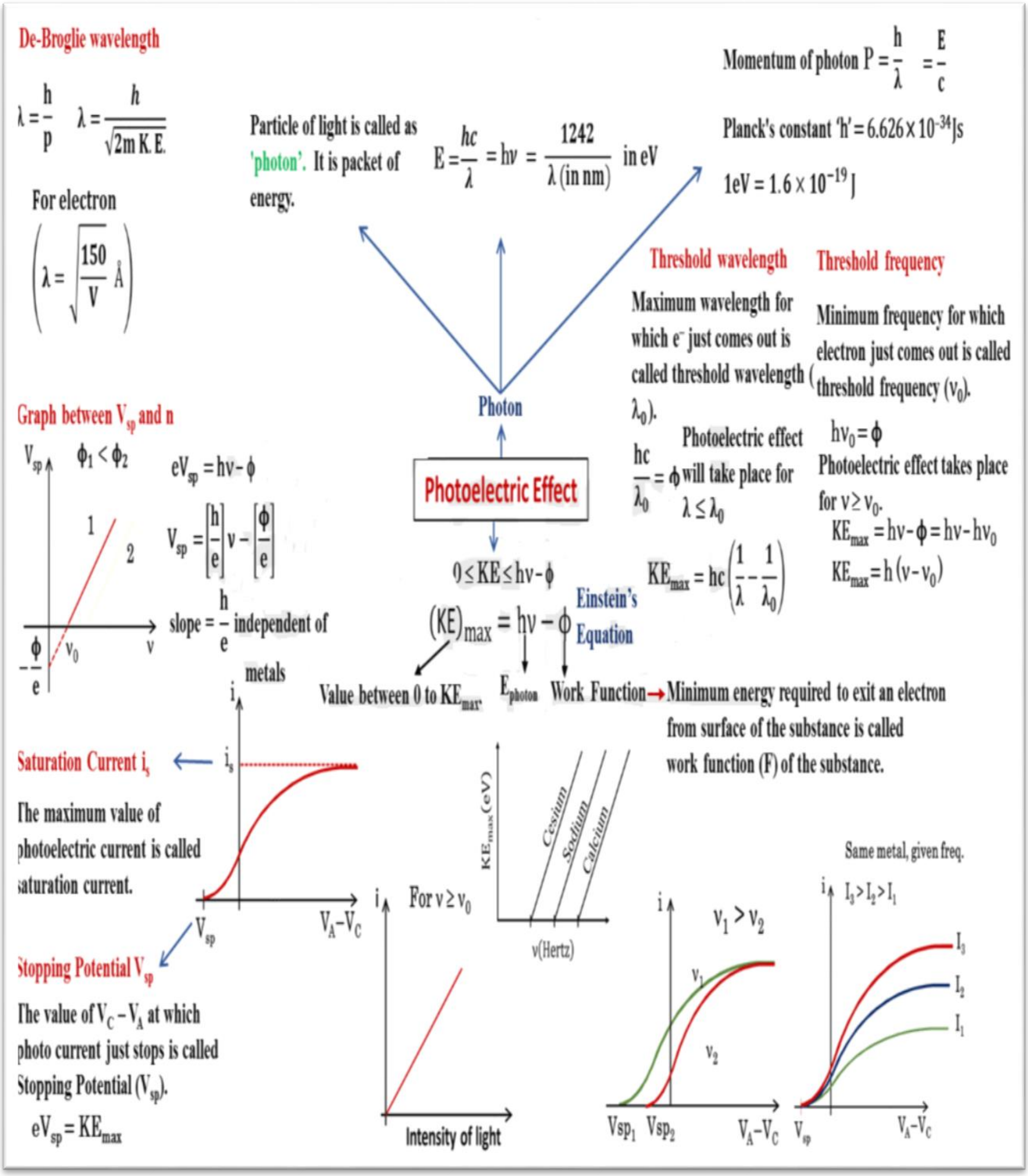
Q 1.) c) either zero or constant

Q 2.) a) constructive interference

Q 3.) d) both a and b

Q 4.) The phenomenon of interference of light and diffraction of light explains the wave nature light.

Important formulae & Diagrams



Photoelectric Effect

The phenomenon of emission of electrons from a metal surface, when radiations of suitable frequency is incident on it, is called photoelectric effect.

Terms Related to Photoelectric Effect

(i) Work Function (ϕ) The minimum amount of energy required to eject one electron from a metal surface is called its work function. Its dimensional formula is [$ML^2 T^{-2}$] and unit is J or eV.

(ii) Threshold Frequency (ν_0) The minimum frequency of light which can eject photoelectron from a metal surface is called threshold frequency of that metal. Its dimensional formula is [T^{-1}] and unit is Hz.

(iii) Threshold Wavelength (λ_0) the maximum wavelength of light which can eject photoelectron from a metal surface is called threshold wavelength of that metal. Relation between work function, threshold frequency and threshold wavelength

$$\phi = h\nu_0 = \frac{hc}{\lambda_{max}}$$

Hallwachs and Lenard's detailed study of Photoelectric effect:

• In 1888, Lenard observed that when ultraviolet light falls on zinc metal, metal becomes positively charged. With the discovery of electrons, it was established that this is due to emission of electrons. The current produced by these photoelectrons is called photoelectric current.

• When the frequency of the incident light is smaller than a certain minimum value, it is called the threshold frequency. Below this frequency, no emission of electrons take place.

- **Hertz and Lenard's experiment**: This experiment led the formation of quantum theory of light as wave theory could not explain photoelectric effect.
- **Experimental outcome**: It showed that intensity of light has linear relationship with photoelectric current at a potential higher than the stopping potential.

Laws of Photoelectric Effect

- For a given material and a given frequency of incident radiation, the photoelectric current or number of photoelectrons ejected per second is directly proportional to the intensity of the incident light.
- For a given material and frequency of incident radiation, saturation current is found to be proportional to the intensity of incident radiation, whereas the stopping potential is independent of its intensity.
- For a given material, there exists a certain minimum frequency of the incident radiation below which no emission of photoelectrons takes place. This frequency is called threshold frequency. Above the threshold frequency, the maximum kinetic energy of the emitted photoelectrons or equivalent stopping potential is independent of the intensity of the incident light but depends upon only the frequency (or wavelength) of the incident light.
- The photoelectric emission is an instantaneous process. The time lag between the incidence of radiations and emission of photoelectrons is very small, less than even 10^{-9}s.

Einstein’s Photoelectric Equation

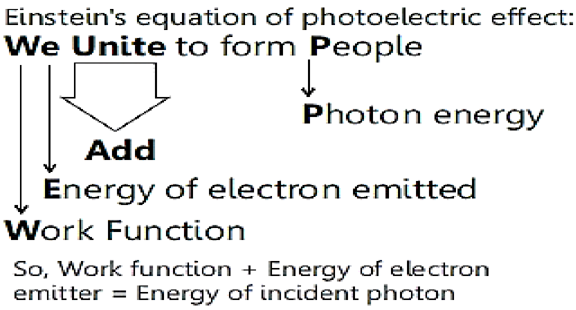
The maximum kinetic energy of photoelectrons

$$K_{max} = h\nu - \phi$$

$$K_{max} = h\nu - h\nu_0 = h(\nu - \nu_0)$$

where, ν is frequency of incident light and ν_0 is threshold frequency.

This can be written as $\phi + K_{max} = h\nu$



Stopping Potential

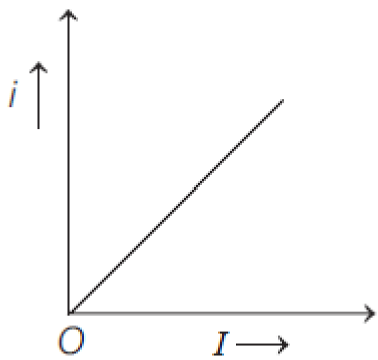
The minimum negative potential given to anode plate at which photoelectric current becomes zero is called stopping potential (V_0). Maximum kinetic energy of photoelectrons is given by

$$K_{max} = eV_0 = h(\nu - \nu_0) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$$

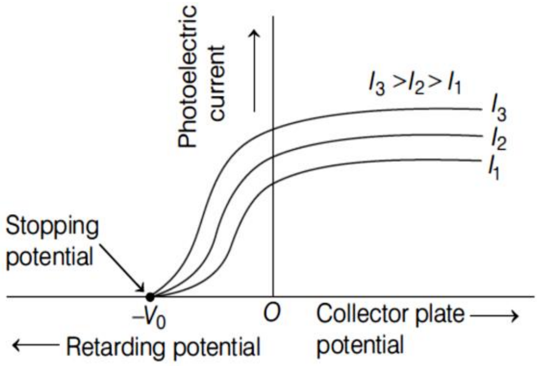
where, λ is the wavelength of incident radiation and λ_0 is the threshold wavelength of metal surface.

Graphs related to Photoelectric Effect

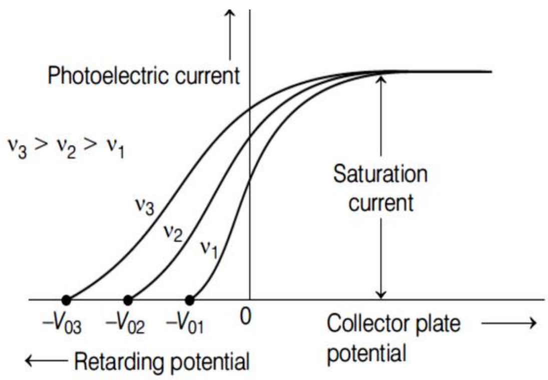
(i) Photoelectric current (i) versus intensity of incident light (I).



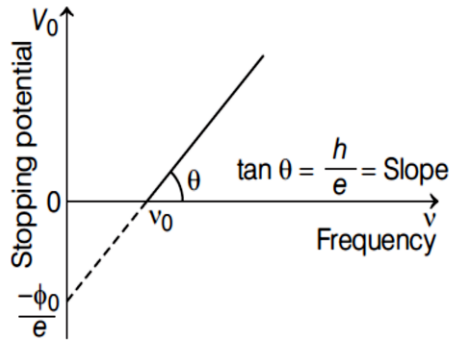
(ii) Variation of photoelectric current (I) versus potential for different intensities but constant frequency



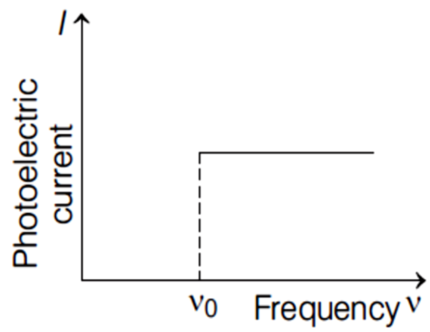
(iii) Variation of photoelectric current (I) versus potential for different frequencies but constant intensity of incident radiation



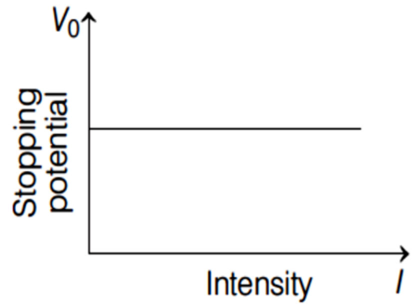
(iv) Frequency (v_0) versus stopping potential (V_0)



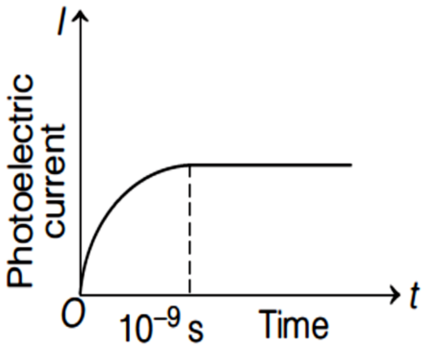
(v) Frequency (v) versus photoelectric current (i)



(vi) Intensity versus (I) stopping potential (V_0)



(vii) Photoelectric current (I) versus time lag (t)



Planck's Quantum Theory (Particle Nature of Light: The Photon)

According to this theory, the energy of an electromagnetic wave is not continuously distributed over the wavefront, instead of an electromagnetic wave travel in the form of discrete packets or bundles of energy called quanta. One quantum of light radiation is called a photon.

The energy of each photon is $E = h\upsilon$ where h is Planck' s constant and n is frequency of radiation.

The momentum of a photon, $p = \frac{hc}{\lambda}$

Characteristic Properties of Photons

Different characteristic properties of photons are given below:

- In interaction of radiation with matter, radiation behaves as if it is made up of particles called photons.
- A photon travels at a speed of light c in vacuum (3×10^8 m / s)
- Photons travel in a straight line.
- Irrespective of the intensity of radiation, all the photons of a particular frequency n or wavelength l have the same energy and momentum.
- Energy of a photon depends upon frequency of the photon, so the energy of the photon does not change when photon travels from one medium to another.
- Wavelength of the photon changes in different media, so velocity of a photon is different in different media.

- Photons are not deflected by electric and magnetic fields. This shows that photons are electrically neutral.
- In a photon-particle collision (such as photoelectron collision), the energy and momentum are conserved. However, the number of photons may not be conserved in a collision.
- It has zero rest mass, i.e., the photon exists at rest.

Dual nature of radiation

A wave is associated with every moving particle called matter or de-Broglie wave.

de-Broglie Wavelength

- If a particle of mass m is moving with velocity v, then wavelength of de-Broglie wave associated with it is given by

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

- For charged particles accelerated through a potential V

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$$

- For electron

$$\lambda = \frac{h}{\sqrt{2meV}} = \frac{12.27}{\sqrt{V}}\ A^0$$

- For a gas molecule of mass m at temperature T kelvin, its de-Broglie wavelength is given by $\lambda = \frac{h}{\sqrt{3mkT}}$

where k is the Boltzmann constant.

Multiple Choice Questions (1mark)

1. A particle is dropped from a height H. The de Broglie wavelength of the particle as a function of height is proportional to

(a) H (b) $H^{1/2}$ (c) H^0 (d) $H^{-1/2}$

2. The wavelength of a photon needed to remove a proton from a nucleus which is bound to the nucleus with 1 MeV energy is nearly

(a) 1.2 nm (b) 1.2×10^{-3} nm (c) 1.2×10^{-6} nm (d) 1.2×10^{1} nm

3. A photoelectric cell is illuminated by a point source of light 1 m away. The plate emits electrons having stopping potential V. Then:

(a) V decreases as distance increase

(b) V increases as distance increase

(c) V is independent of distance (r)

(d) V becomes zero when distance increases or decreases

4. In a photoelectric experiment, the stopping- potential for the incident light of wavelength 4000 Å is 2 volts. If the wavelength be changed to 3000 Å, the stopping-potential will be:

(a) 2 volt (b) less than 2 volt (c) zero (d) more than 2 volt.

5. A proton, a neutron, an electron and an a-particle have same energy. Then their de Broglie wavelengths compare as

(a) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$ (b) $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$

(c) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$ (d) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

6. The number of photoelectrons emitted for light of frequency ν (higher than the threshold frequency ν_0) is proportional to:

(a) threshold frequency (b) intensity of light (c) frequency of light (d) $\nu - \nu_0$

7. The phenomenon which shows quantum nature of electromagnetic radiation is:

(a) photoelectric effect. (b) Tyndall effect. (c) interference. (d) reflection and refraction.

8. Kinetic energy of electrons emitted in photoelectric effect is

(a) directly proportional to the intensity of incident light.

(b) inversely proportional to the intensity of incident line.

(c) independent of the intensity of incident light.

(d) independent of the frequency of light.

9. Photoelectrons emitted from a metal have

(a) different speeds starting from 0 to certain maximum. (b) same kinetic energy.

(c) same frequency. (d) Both (B) & (C)

10.Photons are

(a) electrically neutral and not deflected by electric or magnetic field.

(b) electrically neutral and deflected by magnetic field.

(c) electrically charged and not deflected by electric or magnetic field.

(d) electrically charged and not deflected by electric field.

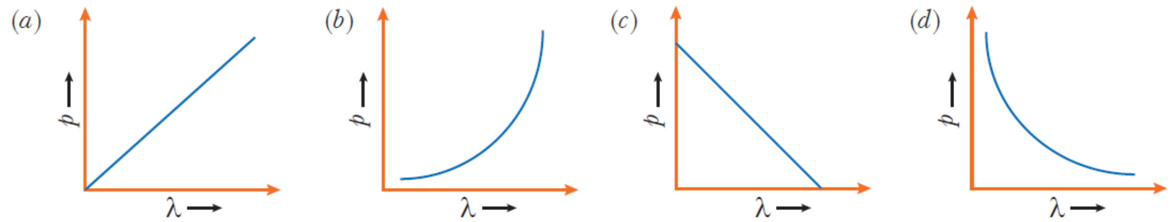
11.Rest mass of the photon is

(a) minimum. (b) maximum. (c) zero. (d) cannot be predicted

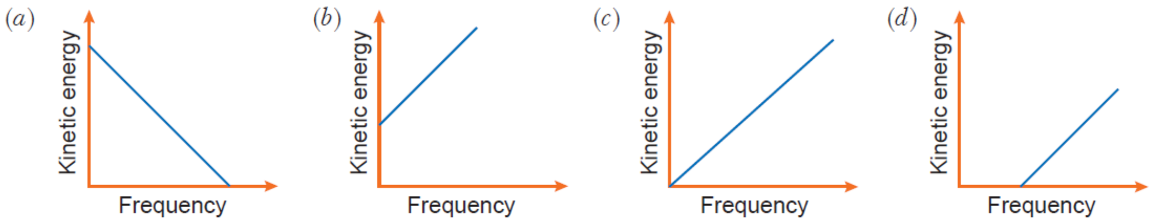
12. If an electron and a photon propagate in the form of waves having same wavelength, it implies that they have same:

(a) speed (b) momentum (c) energy (d) all the above

13. Which of the following figures represent the variation of particle momentum and the associated de-Broglie wavelength?



14. According to Einstein's photoelectric equation, the graph between the kinetic energy of photoelectrons ejected and the frequency of incident radiation is



15. Two particles A_1 and A_2 of masses m_1, m_2 ($m1 > m2$) have the same de Broglie wavelength. Then

(a) their momenta are the same

(b) their energies are the same

(c) energy of A_1 is less than the energy of A_2

(d) energy of A_1 is more than the energy of A_2

1. (*d*) 2. (*b*) 3. (c) 4. (d) 5. (b) 6. (b) 7. (a) 8. (c) 9. (a) 10. (a) 11. (c) 12. (b) 13. (d) 14. (d) 15. (a ,c)

ASSERTION AND REASON BASED MCQS (1mark)

Directions: In the following questions, a statement of **Assertion (A)** is followed by a statement of **Reason (R).**

Mark the correct choice as:

(A) Both (A) and (R) are true, and (R) is the correct explanation of (A).

(B) Both (A) and (R) are true, but (R) is not the correct explanation of (A).

(C) (A) is true, but (R) is false.

(D) (A) is false, but (R) is true.

Q. 1. Assertion (A): The energy (E) and momentum (p) of a photon are related as p = E/c

Reason (R): The photon behaves like a particle.

Ans. Option (A) is correct.

Q. 2. **Assertion (A):** Photoelectric effect demonstrates the particle nature of light.

Reason (R): The number of photoelectrons is proportional to the frequency of light.

Ans. Option (C) is correct.

Q. 3. Assertion (A): Kinetic energy of photoelectrons emitted by a photosensitive surface depends upon the frequency of incident photon.

Reason (R): The ejection of electrons from metallic surface is possible with frequency of incident photon below the threshold frequency.

Ans. Option (C) is correct.

Q. 4 Assertion (A): de-Broglie equation is significant for microscopic particles.

Reason (R): de-Broglie wavelength is inversely proportional to the mass of a particle when velocity is kept constant.

Ans. Option (A) is correct.

Q. 5 Assertion (A): de-Broglie wavelength of a gas molecule is inversely proportional to the square root of temperature.

Reason (R): The root mean square velocity of gas molecules depends on temperature.

Ans. Option (A) is correct. So, $V_{rms} \propto \sqrt{T}$ Again de-Broglie wavelength, $\lambda = h/mv$

So, $\lambda \propto 1/\sqrt{T}$

CASE STUDY BASED MCQS (4mark)

Case I: Read the passage given below and answer the following questions

Photoelectric Effect: Photoelectric effect is the phenomenon of emission of electrons from a metal surface, when radiations of suitable frequency fall on them. The emitted electrons are called photoelectrons and the current so produced is called photoelectric current**.**

1. With the increase of intensity of incident radiations on photoelectrons emitted by a photo tube, the number of photoelectrons emitted per unit time is

(a) increases (b) decreases (c) remains same (d) none of these

2. It is observed that photoelectron emission stops at a certain time t after the light source is switched on. The stopping potential (V) can be represented as

(a) $2(KE_{max}/e)$ (b) (KE_{max}/e) (c) $(KE_{max}/3e)$ (d) $(KE_{max}/2e)$

3. If the frequency of incident light falling on a photosensitive metal is doubled, the kinetic energy of the emitted photoelectron is

(a) unchanged (b) halved (c) doubled (d) more than twice its initial value

4. The photoelectric cut off voltage in a certain experiment is 1.5 V. The maximum kinetic energy of photoelectrons emitted is

(a) 2.4 eV (b) 1.5 eV (c) 3.1 eV (d) 4.5 eV

Ans: 1(a) 2. (b) 3. (d) (If the frequency of incident radiation is doubled, then

K' = 2hv – ϕ = 2(hv – ϕ) + ϕ = 2K + ϕ K' > 2K) 4. (b)

Case II: Read the passage given below and answer the following questions

de-Broglie Wavelength: According to de-Broglie, a moving material particle sometimes acts as a wave and sometimes as a particle or a wave associated with moving material particle which controls the particle in every respect. The wave associated with moving particle is called matter wave or de-Broglie wave where wavelength called de-Broglie wavelength, is given by $\lambda = \frac{h}{mv}$

1. If a proton and an electron have the same de Broglie wavelength, then

(a) kinetic energy of electron < kinetic energy of proton

(b) kinetic energy of electron = kinetic energy of proton

(c) momentum of electron = momentum of proton

(d) momentum of electron < momentum of proton

2. Which of these particles having the same kinetic energy has the largest de Broglie wavelength?

(a) Electron (b) Alpha particle (c) Proton (d) Neutron

3. The wavelength of matter wave is independent of
(a) mass (b) velocity (c) momentum (d) charge

4. When the velocity of an electron increases, its de Broglie wavelength

(a) increases (b) decreases (c) remains same (d) may increase or decrease

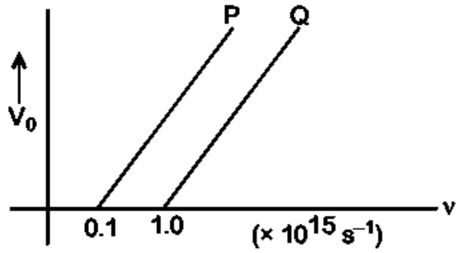
Ans: 1. (c) 2. (a) 3. (d) 4. (b)

VERY SHORT ANSWER TYPE QUESTIONS (VSA) (1mark)

Q. 1. Name the phenomenon which shows the quantum nature of electromagnetic radiation.

Ans. "Photoelectric effect" shows the quantum nature of electromagnetic radiation.

Q. 2 The figure shows the variation of stopping potential V_0 with the frequency ν of the incident radiations for two photosensitive metals P and Q. Which metal has smaller threshold wavelength? Justify your answer.



Ans: Since $\lambda = \frac{c}{v}$ metal Q has smaller threshold wavelength.

Q.3 In photoelectric effect, why should the photoelectric current increase as the intensity of monochromatic radiation incident on a photosensitive surface is increased? Explain.

Ans: The photoelectric current increases proportionally with the increase in intensity of incident radiation. Larger the intensity of incident radiation, larger is the number of incident photons and hence larger is the number of electrons ejected from the photosensitive surface.

Q. 4 The stopping potential in an experiment on photoelectric effect is 1.5 V. What is the maximum kinetic energy of the photoelectrons emitted?

Ans: $K_{max} = eV_s = e\,(1.5V) = 1.5\ eV = 1.5 \times 1.6 \times 10^{-19}\ J = 2.4 \times 10^{-19}\ J$

Q. 5 What is the stopping potential of a photocell, in which electrons with a maximum kinetic energy of 6 eV are emitted?

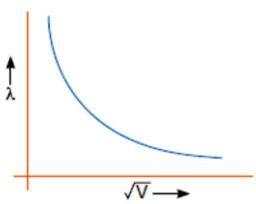
Ans. $E_k = eV_0 \Rightarrow 6\ eV = eV_0 \Rightarrow V_0 = 6\ V$ The stopping potential V_0= 6 volt (Negative).

Q. 6 An electron and a proton have the same kinetic energy. Which one of the two has the larger de Broglie wavelength and why?

Ans: An electron has the larger wavelength **Reason**: de-Broglie wavelength in terms of kinetic energy is $\lambda = \frac{h}{\sqrt{2mE_K}}$ for the same kinetic energy.

Q. 7 Show on a graph the variation of the de Broglie wavelength (λ) associated with an electron, with the square root of accelerating potential (V).

Ans: We know $\lambda = \frac{12.27}{\sqrt{V}}\dot{A}$



Q.8 Two metals A and B have work functions 4 eV and 10 eV respectively. Which metal has the higher threshold wavelength?

Ans: Work function $W = h\nu_0 = \frac{hc}{\lambda}$ $\lambda \propto \frac{1}{W}$ threshold wavelength of metal A is higher.

SHORT ANSWER QUESTIONS (2mark)

Q. 1 Write three characteristic features in photoelectric effect which cannot be explained on the basis of wave theory of light, but can be explained only using Einstein's equation.

Ans. The three characteristic features which cannot be explained by wave theory are:

(i) Kinetic energy of emitted electrons is found to be independent of the intensity of incident light.

(ii) There is no emission of electrons if frequency of incident light is below a certain frequency (threshold frequency).

(iii) Photoelectric effect is an instantaneous process.

Q. 2 A proton and an electron have same velocity. Which one has greater de Broglie wavelength and why?

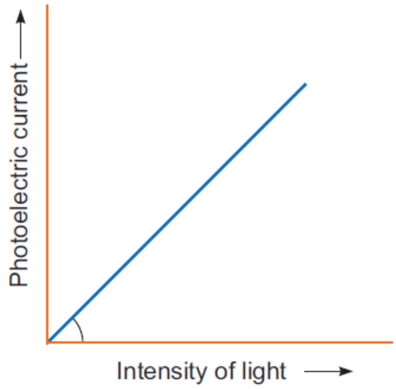
Ans: de Broglie wavelength (λ) is given as $\lambda = \frac{h}{mv}$ given $v_p = v_e$ since $m_p > m_e$ $\lambda \propto \frac{1}{m}$ hence $\lambda_p < \lambda_e$ Thus, electron has greater de Broglie wavelength, if accelerated with same speed.

Q. 3 Plot a graph showing the variation of photoelectric current with intensity of light. The work function for the following metals is given:

Na: 2.75 eV and Mo: 4.175 eV. Which of these will not give photoelectron emission from a radiation of wavelength 3300 Å from a laser beam? What happens if the source of laser beam is brought closer?

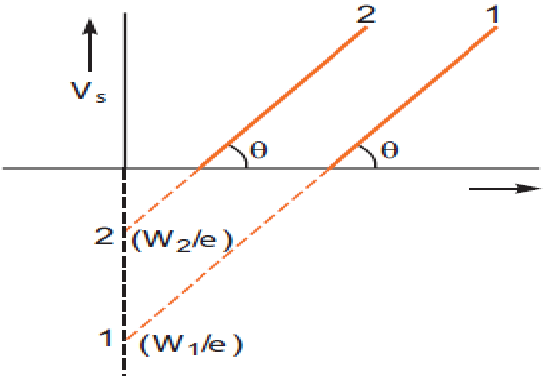
Ans. Energy of photon $E = \frac{hc}{\lambda} joule = \frac{hc}{e\lambda} eV = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times3.3\times10^{-7}} eV = 3.76eV$

Since W_0 of M_o is greater than E, ∴ Mo will not give photoemission. There will be no effect of bringing source closer in the case of MO. In case of Na, photocurrent will increase.



Q. 4 Plot a graph showing the variation of stopping potential with the frequency of incident radiation for two different photosensitive materials having work functions W1 and W2 (W1>W2). On what factors does the (i) slope and (ii) intercept of the lines depend?

Ans. The graph of stopping potential Vs and frequency (ν) for two photosensitive materials 1 and 2 is shown in fig.



(i) Slope of graph $tan\theta = \frac{h}{e} = const$

(ii) Intercept of lines depend on the work function.

Q. 5 If light of wavelength 412·5 nm is incident on each of the metals given below, which ones will show photoelectric emission and why?

Metal	Work Function (eV)
Na	1.92
K	2.15
Ca	3.20
Mo	4.17

Ans. The energy of the incident photon

$$E = hv = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{412.5 \times 10^{-9}} J = 3eV$$

Metals having work function less than energy of the incident photon will show photoelectric effect. Hence, only Na and K will show photoelectric emission.

SHORT ANSWER QUESTIONS–II (3mark)

Q. 1 Using photon picture of light, show how Einstein's photoelectric equation can be established.

Write two features of photoelectric effect which cannot be explained by wave theory.

Ans. In the photon picture, energy of the light is assumed to be in the form of photons each carrying energy.

When a photon of energy 'hv' falls on a metal surface, the energy of the photon is absorbed by the electrons and is used in the following two ways:

(i) A part of energy is used to overcome the surface barrier and come out of the metal surface. This part of energy is known as a work function and is expressed as $\phi_0 = h\nu_0$.

(ii) The remaining part of energy is used in giving a velocity 'v' to the emitted photoelectron

which is equal to the maximum kinetic energy of photo electrons

(iii) According to the law of conservation of energy,

$$hv = \phi_0 + \frac{1}{2}mv_{max}^2$$

$$hv = hv_0 + \frac{1}{2}mv_{max}^2$$

$\Rightarrow KE_{max} = h\nu - h\nu_0$

or $KE_{max} = h\nu - \phi_0$

This equation is called Einstein photoelectric equation.

Features which cannot be explained by wave theory:

(i) The process of photoelectric emission is instantaneous in nature.

(ii) There exists a 'threshold frequency' for each photosensitive material.

(iii) Maximum kinetic energy of emitted electrons is independent of the intensity of incident light.

Q.2 A proton and an alpha particle are accelerated through the same potential. Which one of the two has (i) greater value of de Broglie wavelength associated with it and (ii) less kinetic energy? Give reasons to justify your answer.

Ans. (i) de Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mqV}}$$

For same V, $\lambda \propto \frac{1}{\sqrt{mq}}$

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha q_\alpha}{m_p q_p}} = \sqrt{\frac{4m_p}{m_p}\cdot\frac{2e}{e}}$$

$$= \sqrt{8} = 2\sqrt{2}$$

Clearly, $\lambda_p > \lambda_\alpha$.

Hence, proton has a greater de-Broglie wavelength.

(ii) Kinetic energy, $K = qV$

For same V, $K \propto q$

$$\frac{K_p}{K_\alpha} = \frac{q_p}{q_\alpha} = \frac{e}{2e} = \frac{1}{2}$$

Clearly, $K_p < K_\alpha$.

Hence, proton has less kinetic energy.

Q. 3. Define the terms (i) 'cut-off voltage' and (ii) 'threshold frequency' in relation to the phenomenon of photoelectric effect. Using Einstein's photoelectric equation show how the cut-off voltage and threshold frequency for a given photosensitive material can be determined with the help of a suitable plot/graph.

Ans. (i) Cut off or stopping potential is that minimum value of negative potential at anode which just stops the photo electric current.

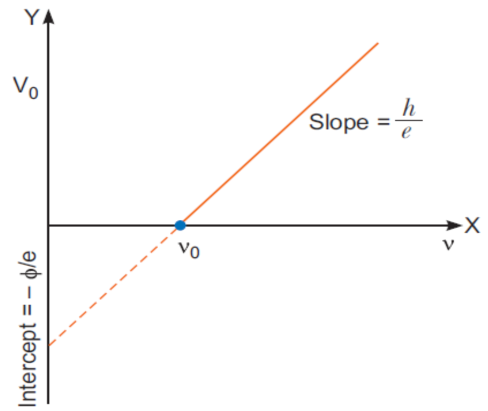
(ii) For a given material, there is a minimum frequency of light below which no photo electric emission will take place, this frequency is called as threshold frequency. By Einstein's photo electric equation

$$KE_{max} = \frac{hc}{\lambda} - \phi = h\nu - h\nu_0$$

$$eV_0 = h\nu - h\nu_0$$

$$V_0 = \frac{h}{e}\nu - \frac{h}{e}\nu_0$$

Clearly, $V_0 - \nu$ graph is a straight line.



Q. 4. An α-particle and a proton are accelerated from rest by the same potential. Find the ratio of their de- Broglie wavelengths.

Ans:

de-Broglie wavelength $\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$

For -particle, $\lambda_\alpha = \frac{h}{\sqrt{2m_\alpha q_\alpha V}}$

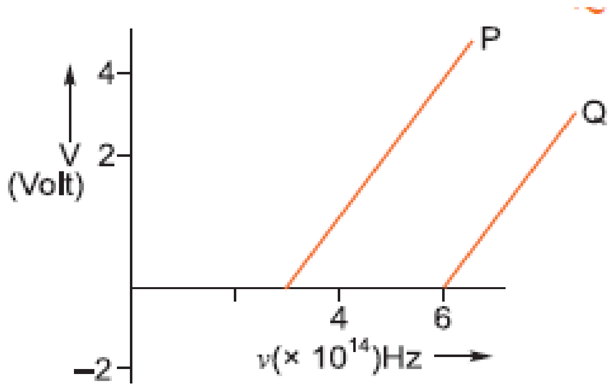
For proton, $\lambda_p = \frac{h}{\sqrt{2m_p q_p V}}$

$\therefore \quad \frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p q_p}{m_\alpha q_\alpha}}$

But $\quad \frac{m_\alpha}{m_p} = 4, \frac{q_\alpha}{q_p} = 2$

$\therefore \quad \frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{1}{4} \cdot \frac{1}{2}} = \frac{1}{\sqrt{8}} = \frac{1}{2\sqrt{2}}.$

Q. 5. In the study of a photoelectric effect the graph between the stopping potential V and frequency n of the incident radiation on two different metals P and Q is shown below:



(i) Which one of the two metals has higher threshold frequency?

(ii) Determine the work function of the metal which has greater value.

(iii) Find the maximum kinetic energy of electron emitted by light of frequency 8×10^{14} Hz for this metal.

Ans

(*i*) Threshold frequency of *P* is 3×10^{14} Hz.
Threshold frequency of *Q* is 6×10^{14} Hz.
Clearly *Q* has higher threshold frequency.

(*ii*) Work function of metal *Q*, $\phi_0 = h\nu_0$

$$= (6.6 \times 10^{-34}) \times 6 \times 10^{14} \text{ J}$$

$$= \frac{39.6 \times 10^{-20}}{1.6 \times 10^{-19}} \text{eV} = \mathbf{2.5\ eV}$$

(*iii*) Maximum kinetic energy, $K_{max} = h\nu - h\nu_0$

$$= h(\nu - \nu_0)$$

$$= 6.6 \times 10^{-34} (8 \times 10^{14} - 6 \times 10^{14})$$

$$= 6.6 \times 10^{-34} \times 2 \times 10^{14} \text{ J}$$

$$= \frac{6.6 \times 10^{-34} \times 2 \times 10^{14}}{1.6 \times 10^{-19}} \text{eV}$$

$$\therefore \quad K_{max} = 0.83 \text{ eV}$$

LONG ANSWER QUESTIONS (5mark)

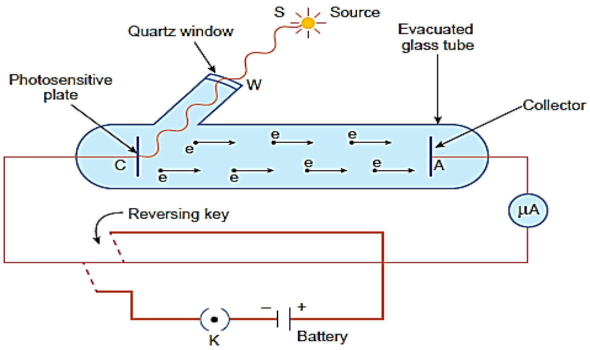
Q. 1. Describe an experimental arrangement to study photoelectric effect.

Ans. Experimental study of Photoelectric Effect: The apparatus consists of an evacuated glass or quartz tube which encloses a photosensitive plate C (called emitter) and a metal plate A (called collector). A transparent window W is sealed on the glass tube which can be covered with a filter for a light of particular radiation. This will allow the light of particular wavelength to pass through it. The plate A can be given a desired positive or negative potential with respect to plate C, using the arrangement as shown in figure.

Working:

When a monochromatic radiation of suitable frequency obtained from source S fall on the photosensitive plate C, the photoelectrons are emitted from C, which gets accelerated towards the plate A (collector) if it is kept at positive potential. These electrons flow in the outer circuit resulting in the photoelectric current. Due to it, the micro ammeter shows a deflection. The reading of micro ammeter measures the photoelectric current.

This experimental arrangement can be used to study the variation of photoelectric current with the following quantities.



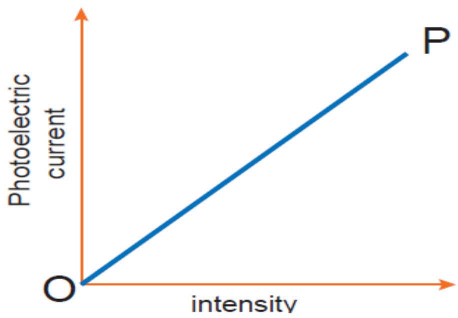
Q 2: Explain the effect of

(i) intensity of light on photoelectric current,

(ii) potential on photoelectric current and

(iii) frequency of incident radiation on stopping potential

Ans: (i) Effect of intensity of the incident radiation: By varying the intensity of the incident radiations, keeping the frequency constant, the photoelectric current varies linearly with the intensity of the incident radiation. Also, the number of photoelectrons emitted per second is directly proportional to the intensity of the incident radiations.

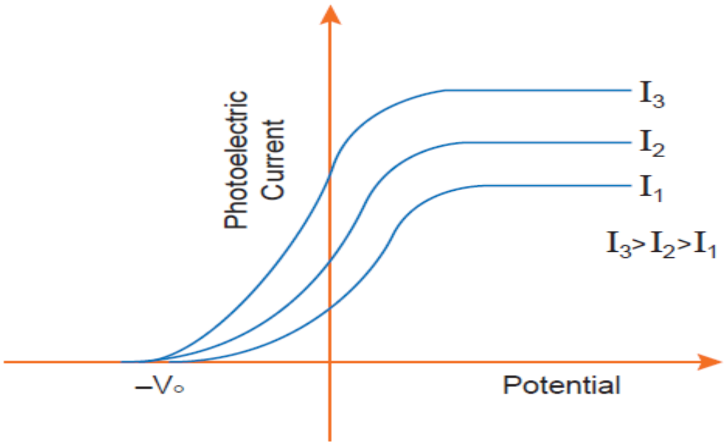


(ii) Effect of potential of plate A w.r.t place C:

the photoelectric current increases gradually with the increase in positive potential of plate A. At one stage for a certain positive potential of plate A, the photoelectric current becomes maximum or saturates. After this if we increase the positive potential of plate A, there will be no increase in the photoelectric current. This maximum value of current is called saturation current: The saturation current corresponds to the state when all the photoelectrons emitted from C reach the plate A. Now apply a negative potential on plate A w.r.t. plate C. We will note that the photoelectric current decreases, because the photoelectrons emitted from C are repelled and only energetic photoelectrons are reaching the plate A. By increasing the negative potential of plate, A, the photoelectric current decreases rapidly and becomes zero at a certain value of negative potential V0 on plate A. This maximum negative potential V0, given to the plate A w.r.t. plate C at which the photoelectric current becomes zero is called stopping potential or cut off potential.

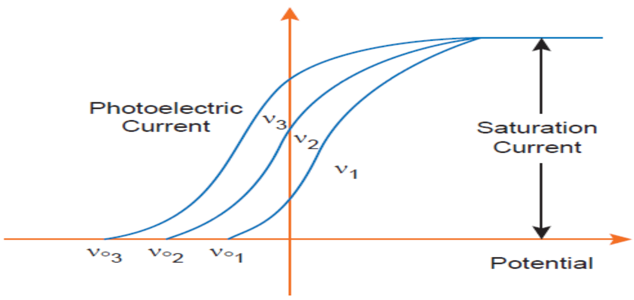
$$K_{max} = eV_0 = \frac{1}{2}mv_{max}^2$$

The value of stopping potential is independent of the intensity of the incident radiation. It means, the maximum kinetic energy of emitted photoelectrons depends on the radiation source and nature of material of plate C but is independent of the intensity of incident radiation.



(iii) Effect of frequency of the incident radiation:

When we take the radiations of different frequencies but of same intensity, then the value of stopping potential is different for radiation of different frequency. The value of stopping potential is more negative for radiation of higher incident frequency. The value of saturation current depends on the intensity of incident radiation but is independent of the frequency of the incident radiation.



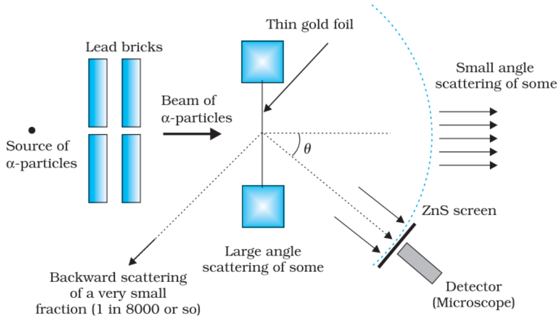
CHAPTER 12 : ATOMS

Gist of the lesson

Thomson's Model

Atom is a spherical cloud of positive charge with electron embedded into it, like seeds in watermelon.

α-Particle Scattering Experiment and Rutherford nuclear model of atom



Conclusions

1. Only about 0.14% of incident α-particle scatter by more than 1°.
2. About 1 in 8000 deflected by more than 90°.
3. Size of nucleus to be about 10^{-15}m to 10^{-14}m.
4. For large impact parameter the α-particle goes nearly undeviated.
5. In case of head on collision, the impact parameter is minimum and α- particle rebound back ($\theta = \pi$).

Rutherford's Model

According to Rutherford most of the mass of atom and all its positive charge are concentrated in a tiny space of the order of 10^{-14}m, called nucleus and electrons revolves around it. Centripetal force is obtained from electrostatic attraction between electron and nucleus.

Drawbacks

(i) Stability of atom

(ii) Line spectrum of atoms

IMPACT PARAMETER

It is Perpendicular distance of the initial velocity vector of the α- particle from the centre of nucleus.

$$b = \frac{Ze^2 \cot(\frac{\theta}{2})}{4\pi\varepsilon_0 E}$$

Electron Orbit

Radius (r) = $\frac{e^2}{4\pi\varepsilon_0 m v^2}$

Kinetic energy (K) = $\frac{e^2}{8\pi\varepsilon_0 r}$

Potential energy (U) = - $\frac{e^2}{4\pi\varepsilon_0 r}$

Total energy (E) = K+U= - $\frac{e^2}{8\pi\varepsilon_0 r}$

BOHR'S MODEL

Bohr combined classical and quantum concepts and gave the theory in terms of three postulates.

1. An electron can revolve only in certain stable orbits without emission of radiant energy.
2. Electron can revolve only in those orbits in which angular momentum is integral multiple of $(\frac{h}{2\pi})$

L= $mv_n r_n = \frac{nh}{2\pi}$, n =1,2,3……

3. When an electron makes a transition from one of the specified non radiator orbit to another lower energy orbit then radiate energy equal to the difference of energy equal to final and initial state.

Bohr's model is applicable for hydrogen and hydrogen like elements only.

Limitations of Bohr's Model

1. Bohr's model is applicable for single electron atom/ions.
2. Bohr's model correctly predict the frequencies of the light emitted by hydrogen like atom but unable to explain the relative intensities of light

DIFFERENT QUANTITIES FOR HYDROGEN LIKE ELEMENTS

Radius of the n^{th} orbit:

$r_n = \left(\frac{\varepsilon_0 h^2}{\pi m e^2}\right)\frac{n^2}{Z} = \mathbf{0.529}\frac{n^2}{Z}A \rightarrow r_n \propto \frac{n^2}{Z}$

Speed of electron in n^{th} orbit:

$V_n = \frac{e^2}{2h\varepsilon_0}\frac{Z}{n} \rightarrow V_n \propto \frac{Z}{n}$

Energy of electron in n^{th} orbit:

$E_n = = \frac{me^4}{8\varepsilon_0^2 h^2}\left(\frac{Z^2}{n^2}\right) J$ *or* $E_n = -\frac{13.6Z^2}{n^2}$ eV

$$\rightarrow E_n \propto \frac{Z^2}{n^2}$$

Time period of revolution of electron in n^{th} orbit:

$T = \left(\frac{4\varepsilon_0 h^3}{me^4}\right)\frac{n^3}{Z^2} = \frac{n^3}{Z^2}(\mathbf{1.51\ X\ 10^{-16}}s)$

$$\rightarrow T \propto \frac{n^3}{Z^2}$$

HYDROGEN SPECTRUM

1. Lyman series

$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$, n =2,3,4……∞ lies in UV region

2. Balmer series

$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$, n =3,4,5……∞ lies in visible region

3. Paschen series

$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right)$, n =4,5,6……∞ lies in near IR region

4. Barcket series

$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$, n =5,6,7……∞ lies in IR region

5. Pfund series

$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right)$, n =6,7,8……∞ lies in far IR region

Rydberg constant

$R = \frac{me^4}{8\varepsilon_0 h^3 c} = \mathbf{1.07\ X 10^7 m^{-1}}$

DE BROGLIE'SEXPLANATION OF BOHR'S SECOND POSTULATE OF QUANTISATION

De-Broglie explained second postulate of Bohr's atomic model by assuming an electron has wave nature.

The circumference of orbit should be integer multiple of de-Broglie wavelength of electron in nth orbit.

$2\pi r_n = n\lambda$, $n = 1,2,3 \ldots \ldots \ldots$ $mv_n r_n = \frac{nh}{2\pi}$

This is quantum condition proposed by Bohr for an angular momentum of an electron.

Excitation energy: The energy required to raise the electron from its ground state to some higher energy level is called excitation energy.

Excitation potential: The potential difference through which the electron in an atom has to be accelerated, so as to just raise it from its ground state to the excited state, is called excitation potential.

Ionisation energy: The energy required to knock an electron completely out of an atom is called ionisation energy.

Ionisation potential: The potential difference through which the electron in an atom has to be accelerated so as to just ionise it, is called ionisation potential. The ionisation potential is numerically equal to the ionisation energy.

IMPORTANT FORMULAE

1. Radius of stationary orbits

For H-atom, Z=1 $r_n = \frac{n^2h^2\varepsilon_0}{\pi me^2} = 0.53\frac{n^2}{Z}$ Å

2. Orbital speed, $V_n = \frac{Ze^2}{2nh\varepsilon_0}$

3. Energy of n^{th} orbit,

$$E_n = -\frac{me^4}{8\varepsilon_0^2 n^2 h^2} = -\frac{13.6}{n^2}\ \text{eV}$$

4. Time period of revolution of electron in stationary orbits $T \propto \frac{n^3}{Z^2}$

5. Frequency of revolution of electron, $f \propto \frac{Z^2}{n^3}$

6. Kinetic energy of electron, $KE = \frac{Ze^2}{8\pi\varepsilon_0 r}$

7. Total energy, $E = \frac{-Ze^2}{8\pi\varepsilon_0 r}$

8. Bohr's second postulate

$$L_n = mv_n r_n = \frac{nh}{2\pi}$$

9. Bohr's third postulate

$$h\nu = E_i - E_f$$

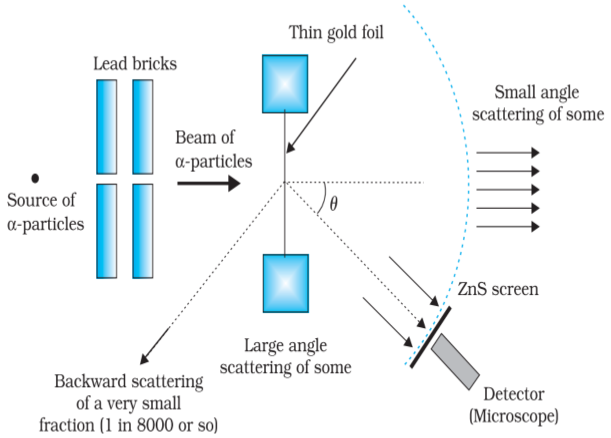
10.

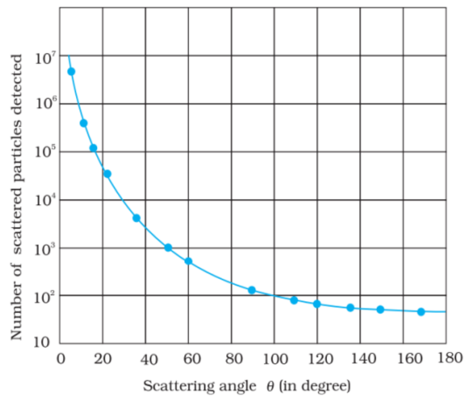
$$TE = -KE\ ,\quad PE = 2TE$$

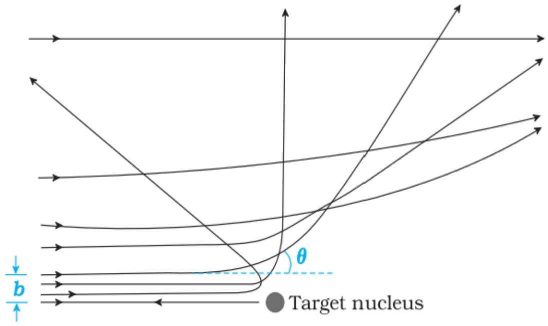
11. Rydberg's constant

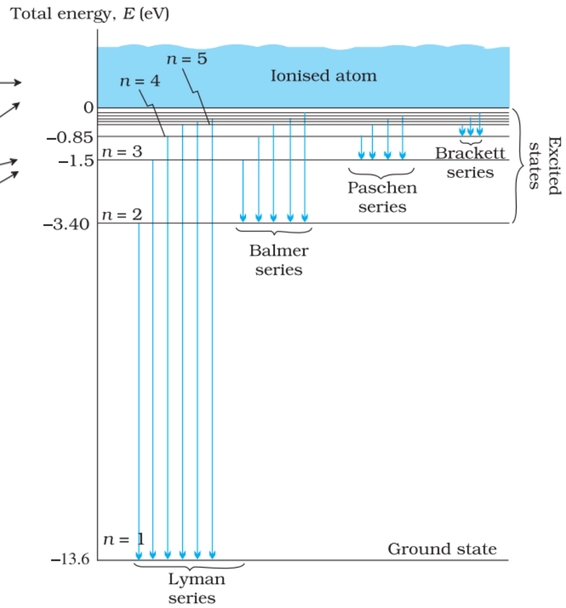
$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]\ ;\quad R = \frac{me^4}{8\varepsilon_0^2 h^3 c}$$

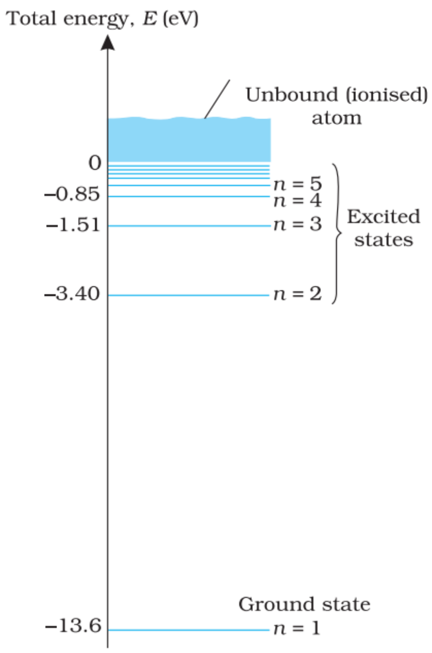
Important figures

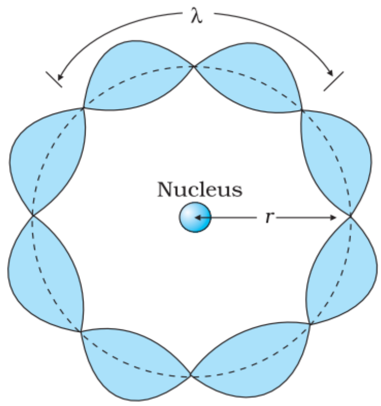












Multiple Choice Questions

1. Which of the following statements is not correct according to Rutherford model?
(a) Most of the space inside an atom is empty.

(b) The electrons revolve around the nucleus under the influence of Coulomb force acting on them.
(c) Most part the mass of the atom and its positive charge are concentrated at its centre.
(d) The stability of atom was established by the model.

2. In Rutherford's α -particle scattering experiment, what will be correct angle for α scattering for an impact parameter b = 0 ?
(a) 90° (b) 270° (c) 0° (d) 180°

3. The atomic model based on quantum theory was purposed by:
(a) Planck (b) Sommerfeld (c) Bohr (d) Thomson

4. According to Bohr's postulates, which of the following quantities take discrete values?
(a) Kinetic energy (b) Potential energy (c) Linear momentum (d) Angular momentum

5. The characteristics spectrum of an atom is observed as
(a) Emission line spectrum (b) Emission band spectrum
(c) Absorption line spectrum (d) Absorption band spectrum

6. De Broglie's hypothesis gave an explanation for Bohr's quantized orbits by bringing in wave particle duality. According to this, the orbit correspond to circular standing wave in which the circumference of orbit is
(a) An integral multiple of wavelength (b) Always equal to wavelength
(c) Independent of wavelength (d) An integral multiple of frequency

7. The ratio between Bohr radii is
(a) 1 : 2 : 3 (b) 2 : 4 : 6 (c) 1 : 4 : 9 (d) 1 : 3 : 5

8. The series of the hydrogen spectrum which has least wavelength
(a) Lyman series (b) Balmer series (c) Paschan series (d) Barckett series

9. The energy of hydrogen atom in its n^{th} orbit is E_n =13.6 eV. The energy required for sending electron from 1^{st} orbit to 2^{nd} orbit will be:
(a) 12.2 eV (b) 10.2 eV (c) 13.6 eV (d) 3.4 eV

10. In Bohr's model of hydrogen atom, radius of the first orbit of an electron is r_0. Then, radius of the third orbit is:
(a) $r_0/3$ (b) r_0 (c) $3r_0$ (d) $9r_0$

11. When an electron jumps from the fourth orbit to the second orbit, one gets the
(a) second line of Paschen series (b) second line of Balmer series
(c) first line of Pfund series (d) second line of Lyman series

12. For ionising an excited hydrogen atom, the energy required (in eV) will be
(a) a little less than 13.6 eV (b) 13.6 eV
(c) more than 13.6 eV (d) 3.4 or less

13*. Taking the Bohr radius as a_0 =54 pm, the radius of Li^{++} ion in its ground state, on the basis of Bohr's model, will be about

(a) 53 pm (b) 27 pm (c) 18 pm (d) 13 pm

14*. Which of the following parameters is the same for all hydrogen-like atoms and ions in their ground states?

(a) Radius of the orbit (b) Speed of the electron

(c) Energy of the atom (d) Orbital angular momentum of the electron

15*. When an atomic gas or vapour is excited at low pressure, by passing an electric current through it then

(a) emission spectrum is observed (b) absorption spectrum is observed

(c) band spectrum is observed (d) both (b) and (c)

Ans

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
(d)	(d)	(c)	(c)	(a)	(a)	(c)	(a)	(b)	(d)
11.	12.	13.	14.	15.					
(b)	(b)	(c)	(b)	(a)					

Assertion-Reason Question

For the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Both A and R are true, and R is correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) Both A and R are false.

16. Assertion: Electron is revolving round the nucleus.

Reason: If the electrons were stationary, they would fall into the nucleus due to the electrostatic attraction and the atom would be unstable.

17. Assertion: Thomson's model of the atom is known as a plum pudding model.

Reason: Thomson's model of the atom is supposed to be round in shape.

18. Assertion: According to electromagnetic theory an accelerated particle continuously emits radiation.

Reason: According to classical theory, the proposed path of an electron in Rutherford atom model will be parabolic.

19. Assertion: Bohr's theory of hydrogen atom could not completely explain the fine structure of hydrogen spectrum.

Reason: In the spectrum of hydrogen, certain spectral lines are not single lines but a group of closed lines with slightly different frequencies.

20. Assertion: The electron in the hydrogen atom passes from energy level n= 4 to the n=1 level. The maximum and minimum numbers of photon that can be emitted are six and one respectively.
Reason: The photons are emitted when electron make a transition from the higher energy state to lower energy state.

Ans

16.	17.	18.	19.	20.
(a)	(c)	(c)	(a)	(b)

One Mark Question (VSA)

1. In Bohr's theory of model of hydrogen atom, name the physical quantity which equals to an integral multiple of $\frac{h}{2\pi}$? [Ans: Angular momentum of electron]
2. Which series comes in ultra-violet and visible region of hydrogen spectrum? [Ans- Lymen series and Balmer series]
3. What is Bohr's quantization condition? [Ans- L= mvr = n$\frac{h}{2\pi}$ where n=1,2,3 .....]
4*. Write the expression for Bohr's radius in hydrogen atom. [Ans- $r_n = \frac{\varepsilon_0 h^2 n^2}{\pi m e^2}$]
5*. What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom? [Hint: $r_n \propto n^2$, Ans - $\frac{r_2}{r_1} = \frac{4}{1}$]
6*. The kinetic energy of alpha – particle incident on gold foil is doubled. How does the distance of closest approach change?

7. The total energy of an electron in the first excited state of the hydrogen atom is about -3.4 eV. What is the potential energy of the electron in this state? [Hint : P.E. = 2 E]

Short Answer (SA – 2 Marks)

1. Write two important limitations of Rutherford nuclear model of the atom.
Ans. Two important limitations of Rutherford Model are:
(i) Electron orbiting around the nucleus, continuously radiate energy due to the acceleration. Hence the atom will not remain stable.
(ii)As electron spirals inwards; its angular velocity and frequency change continuously, therefore it should emit a continuous spectrum. But an atom like hydrogen always emits a discrete line spectrum.

2. Which is easier to remove: orbital electron from an atom or a nucleon from a nucleus?
Ans. It is easier to remove an orbital electron from an atom. The reason is the binding energy of orbital electron is a few electron-volts while that of nucleon in a nucleus is quite

large (nearly 8 MeV). This means that the removal of an orbital electron requires few eV energy while the removal of a nucleon from a nucleus requires nearly 8 MeV energy.

3. Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by the particle of mass 200 times that of the electron but having the same charge? (Given Rydberg's constant, $R = 10^7\ m^{-1}$)
Ans The minimum energy, required to free the electron from the ground state of the hydrogen atom, is known as Ionization Energy.
Since $E_0 \propto m$ Therefore, Ionization Energy will become 200 times.

4.* When is Hα line in the emission spectrum of hydrogen atom obtained? Calculate the frequency of the photon emitted during this transition.

AnsThe line with the longest wavelength of the Balmer series

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$$

where λ = wavelength

$R = 1.097\times10^7\ m^{-1}$ (Rydberg constan

When the electron jumps from the orbit with $n = 3$ to

we have

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \frac{1}{\lambda} = \frac{5}{36}R$$

The frequency of photon emitted is given by

$$\nu = \frac{c}{\lambda} = c \times \frac{5}{36}R$$

$$= 3 \times 10^8 \times \frac{5}{36} \times 1.097 \times 10^7\ \text{Hz}$$

$$= \mathbf{4.57 \times 10^{14}\ Hz}$$

5*. The ground state energy of hydrogen atom is – 13.6 eV. If an electron makes a transition from an energy level – 1.51 eV to – 3.4 eV, calculate the wavelength of the spectral line emitted and name the series of hydrogen spectrum to which it belongs.

Ans Energy difference = Energy of emitted photon

$$= E_1 - E_2$$

$$= -1.51 - (-3.4) = 1.89\ eV = 1.89 \times 1.6 \times 10^{-19}\ J$$

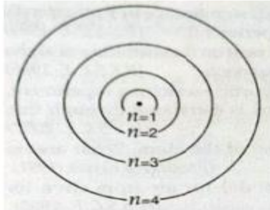
$$\lambda = \frac{hc}{E_1 - E_2}$$

$$= \frac{6.6\times10^{-34} \times 3\times10^8}{1.89\times1.6\times10^{-19}} = \frac{19.8}{3.024}\times10^{-7}$$

$$= 6.548 \times 10^{-7}\ m = \mathbf{6548\ Å}$$

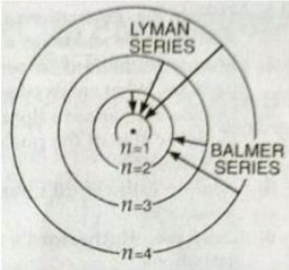
This wavelength belongs to Balmer series of hydrogen spectrum.

(SA –II 3 Marks)



1. In the Fig. for the stationery orbits of the hydrogen atom, mark the transitions representing the Balmer and Lyman series.

Ans



2. What is the minimum energy (in eV) required to remove an electron from the ground state of doubly ionised Li atom (Z = 3)? [Hint: $E_n = -\frac{13.6}{n^2} Z^2$]

Ans 122.4 eV

3. Calculate the impact parameter of a 5MeV alpha particle scattered by 90° when it approaches a gold nucleus (Z=79).

Ans

$$b = \frac{K Z e^2 \cot\left(\frac{\theta}{2}\right)}{KE}$$

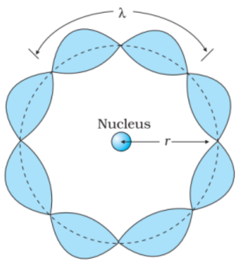
$$b = \frac{9\times10^9 \times 79 \times (1.6\times10^{-19})^2 \times \cot 45^\circ}{5\times1.6\times10^{-13}}$$

$$= 2.27 \times 10^{-14}\ \text{m} \ ; \quad b = 2.3 \times 10^{-14}\ \text{m}$$

4. Using de-Broglie's hypothesis, explain with the help of a suitable diagram, Bohr's second postulate of quantization of energy levels in a hydrogen atom.

Ans According to de Broglie's hypothesis,

$\lambda = h/mv$ ....(i)



According to de Broglie's condition of stationary orbits, the stationary orbits are those which contain complete de Broglie wavelength.

$2\pi r = n\lambda$ ....(ii)

Substituting value of l from (ii) in (i), we get

$2\pi r = n(h/mv)$

=> $mvr = n(h/2\pi)$ ....(iii)

This is Bohr's postulate of quantisation of energy levels.

5*. Using Bohr's postulate, obtain the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?

Ans

Total energy of electron in Bohr's stationary orbit—K.E which is due to velocity and P.E. due to position of electron.

From the first postulate of Bohr's atom model,

$$\frac{mv^2}{r} = \frac{KZe^2}{r^2} \qquad \therefore \qquad \frac{1}{2}mv^2 = \frac{1}{2}\frac{KZe^2}{r}$$

i.e., K.E. of electron $= \frac{1}{2}mv^2 = \frac{KZe^2}{2r}$ ...(*i*)

Potential due to the nucleus $= \frac{KZe}{r}$

$\therefore$ P.E. of electron = Potential × Charge

$$= \frac{KZe(-e)}{r} = \frac{-KZe^2}{r} \qquad ...(ii)$$

P.E. of electron in the orbit, E= K.E + P.E

$$= \frac{KZe^2}{2r} + \left(\frac{-KZe^2}{r}\right) = \frac{1}{2}\frac{KZe^2}{r} - \frac{KZe^2}{r}$$

$$= -\frac{KZe^2}{2r}$$

Putting the value of $r = \frac{n^2h^2}{4\pi^2 mKZe^2}$,

we get **(By *Bohr's formula*)**

$$E = -\frac{KZe^2}{2} \times \frac{4\pi^2 mK^2Ze^2}{n^2h^2} = -\frac{2\pi^2 mK^2Z^2e^4}{n^2h^2}$$

Energy is negative implies that the electron- nucleus is a bound or attractive system.

6*. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

Ans Let r be the radius of the orbit of a hydrogen atom. Forces acting on electron are centrifugal force (F_c) and electrostatic attraction (F_e)

At equilibrium, $F_c = F_e$

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \qquad \text{[for H-atom, } Z = 1]$$

According to Bohr's postulate

$$mvr = \frac{nh}{2\pi} \qquad \Rightarrow \qquad v = \frac{nh}{2\pi mr}$$

$$m\left(\frac{nh}{2\pi mr}\right)^2 \cdot \frac{1}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \qquad \Rightarrow \qquad \frac{mn^2h^2}{4\pi^2m^2r^2.r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$r = \frac{n^2h^2\varepsilon_0}{\pi me^2} \qquad \Rightarrow \qquad \therefore \qquad r \propto n^2$$

7. Determine the distance of closest approach when an alpha particle of kinetic energy 4.5 MeV strikes a nucleus of Z = 80, stops and reverses its direction.

Ans Let r be the centre to centre distance between the alpha particle and the nucleus (Z = 80). When the alpha particle is at the stopping point, then

$$K = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r}$$

or $$r = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2Ze^2}{K}$$

$$= \frac{9\times10^9\times2\times80\,e^2}{4.5\text{ MeV}} = \frac{9\times10^9\times2\times80\times(1.6\times10^{-19})^2}{4.5\times10^6\times1.6\times10^{-19}}$$

$$= \frac{9\times160\times1.6}{4.5}\times10^{-16} = 512\times10^{-16}\text{m}$$

$$= \mathbf{5.12\times10^{-14}\ m}$$

8. Explain briefly how Rutherford scattering of α- particle by a target nucleus can provide information on the size of nucleus.

CASE BASED QUESTIONS/ SOURCE BASED QUESTIONS

Case 1

The trajectory traced by an α- particle depends on the impact parameter, b of collision. The impact parameter is the perpendicular distance of the initial velocity vector of the α- particle from the centre of the nucleus. A given beam of α- particle has a distribution of impact parameter b, so that the beam is scattered in various directions with different probabilities. (In a beam, all particles have nearly same kinetic energy.) It is seen that an α- particle close to the nucleus suffers large scattering.

1. What is the significance of impact parameter?

2. Draw a plot showing the number of particle scattered versus the scattering angle.

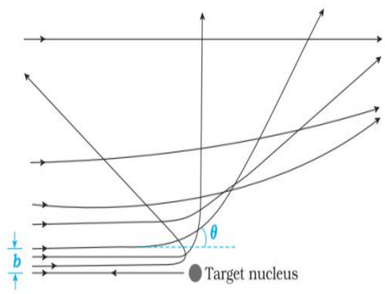
3. If an α- particle collides head on with the nucleus, calculate is impact parameter?

OR

In G-M scattering experiment, the trajectory of α- particle in Coulomb's field of a heavy nucleus is shown in figure.

(a) What do 'b' and 'θ' represent in figure?

(b) What will the value of 'b' for (i) $\theta = 0°$, and (ii) $\theta = 180°$



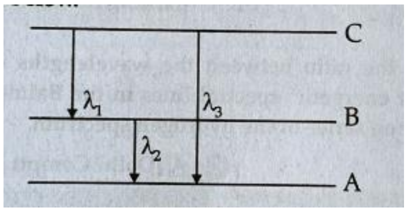
Case 2

The Bohr model is a big part of Physics history. Neils Bohr proposed his model in 1913. It states that electrons orbit the nucleus at set distances. The model was an expansionλ on the Rutherford model overcame. Neils Bohr's model was based on his observations of the atomic emissions spectrum of the hydrogen atom. His findings said that the electron can move to a higher-energy orbit by gaining an amount of energy equal to the difference in energy between the higher-energy orbit and the initial lower-energy orbit. But time and research has proven and changed the Bohr model; Making this model one of the most famous models in Physics history.

1. State Bohr's Postulate to define stable orbits in hydrogen atom.
2. State limitation of Bohr's atomic model.
3. Use Bohr's model of hydrogen atom to obtain the relationship between the angular momentum and magnetic moment of revolving electron.

OR

Find a relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown below.



[Ans $E_C - E_B = \frac{hc}{\lambda_1}$, $E_B - E_A = \frac{hc}{\lambda_2}$, $E_C - E_A = \frac{hc}{\lambda_3}$

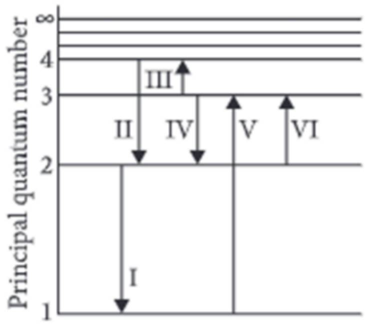
And $E_C - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$

Therefore $\frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = \frac{hc}{\lambda_3}$, so $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$]

Case 3

Electron Transition for Hydrogen Atom

Bohr's model explains the spectral lines of hydrogen atomic emission spectrum while the electron of the atom remians in ground state, its energy is unchanged. When the atom absorbs one or more quanta of energy, the electron moves from the ground state orbit to an excited state orbit that is further away.



The given figure shows an energy level diagram of hydrogen atom. Several transition are marked as I, II, III, IV and V. The diagram is only indicative and not scale.

1. What will be the nature of spectrum when electron moves from ground state orbit to exited state?
2. Which of the transistion beongs to Lyman series?
3. Calculate the wave length of second member of Lyman series. [Hint : n_i =3 , n_f = 1]

OR

Calcuate the shortest wave length og Balmer series. [Hint: $n_i = \infty$, n_f = 2]

CHAPTER 13: NUCLEI

Nucleus

In every atom, the positive charge and mass are densely concentrated at the central core of the atom, which forms its nucleus. More than 99.9% mass of the atom is concentrated in the nucleus.

Atomic Mass Unit (amu)

The unit of mass used to express mass of an atom is called atomic mass unit. Atomic mass unit is defined as 1/12th of the mass of carbon (${}^{12}_{6}C$) atom.

1 amu or 1 u=1.660539 $\times 10^{-27}$ kg

(1) Mass of proton (m_p)=1.00727 u

(2) Mass of neutron (m_n)=1.00866 u

(3) Mass of electron (m_e)=0.000549 u

Relation between amu and MeV

1 amu=931 Mev

Composition of Nucleus

The composition of a nucleus can be described by using the following.

(1) **Atomic Number (Z)** :Atomic number of an element is the number of protons present inside the nucleus of an atom of the element.

Atomic number (Z) = Number of protons = Number of electrons (in a neutral atom)

(2) **Mass Number (A)**: Mass number of an element is the total number of protons and neutrons inside the atomic nucleus of the element.

Mass number (A)= Number of protons(Z) +Number of neutrons(N)

= Number of electrons +Number of neutrons

A=Z+N

Size of Nucleus

According to the scattering experiments, nuclear sizes of different elements are assumed to be spherical, so the volume of a nucleus is directly proportional to its mass number. If R is the radius of the nucleus having mass number A, then

$4/3\pi R^3 \propto A$

- ⇨ $R \propto A^{1/3}$
- ⇨ $R = R_0 A^{1/3}$

where. R_0= 1.2x10^{-15} m is the range of nuclear size. It is also known as nuclear radius.

Nuclear Density

Density of nuclear matter is the ratio of mass of nucleus and its volume.

$\rho = m/(4/3\pi R_0^3)$ => ρ = $2.38 \times 10^{17} kg/m^3$

where, m = average mass of one nucleon and R_o=1.2 fm = 1.2×10^{-15}m

=>The nuclear density (ρ) does not depend on A (mass number).

Mass Defect

The sum of the masses of neutrons and protons forming a nucleus is more than the actual mass of the nucleus. This difference of masses is known as mass defect.

$\Delta m = Zm_p + (A-Z)m_n - M$

where, Z= atomic number, A= mass number, m_p = mass of one proton, m_n= mass of one neutron and M= mass of nucleus.

Mass-Energy Relation

Einstein's mass-energy equivalence equation is given by

$E = mc^2$ (E is the energy and c is the speed of light =3×10^8 m/s and m = mass of nucleus)

Nuclear Forces

Short ranged (2-3 fm) strong attractive forces which hold protons and neutrons together in against of coulombian repulsive forces between positively charged particle is called nuclear force. The nuclear force between neutron-neutron, proton-neutron and proton-proton is approximately the same. The nuclear force does not depend on the electric charge.

Nuclear Energy

When nucleons form a nucleus, the mass of nucleus is slightly less than the sum of individual masses of nucleons. This mass is stored as nuclear energy in the form of mass defect. Also, transmutation of less stable nuclei into more tightly bound nuclei provides an excellent possibility of releasing nuclear energy.

Two distinct ways of obtaining energy from nucleus are Number of nucleons given below

Nuclear Fission

The phenomenon of splitting of heavy nuclei (usually A>230) into lighter nuclei of nearly equal masses is known as nuclear fission, e.g.

$$_{92}U^{235} + {}_0n^1 \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\ {}_0n^1 + Q$$

Nuclear Fusion

The phenomenon of fusing or combining of two lighter nuclei into a single heavy nucleus is called nuclear fusion, e.g.

$$_1H^1 + {}_1H^1 \longrightarrow {}_1H^2 + e^1 + v + 0.42\ MeV$$

[The energy released during nuclear fusion is known as thermonuclear energy.]

Binding Energy

The binding energy of a nucleus is defined as the minimum energy required to separate its nucleons and place them at rest at infinite distance apart. Using Einstein's mass-energy relation, $\Delta E = (\Delta mc^2)$, the binding energy of the nucleus is

$\Delta E = [Zm_p + (A-Z)m_n - M]c^2$

Average Binding Energy Per Nucleon of a Nucleus

It is the average energy required to extract a nucleon from the nucleus to infinite distance. It is given by total binding energy divided by the mass number of the nucleus.

Binding energy per nucleon=$\frac{\text{Total binding energy}}{Number\ of\ nucleons}$

Binding Energy Curve

It is a plot of the binding energy per nucleon versus the mass number A for a large number of nuclei as shown below:

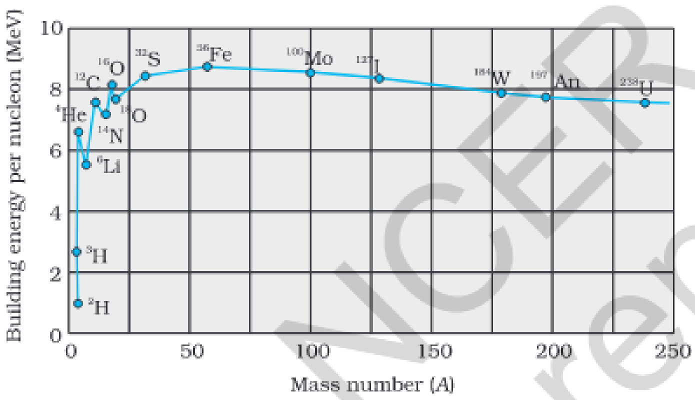


FIGURE 13.1 The binding energy per nucleon as a function of mass number.

Binding energy per nucleon as a function of mass number :It is used to explain phenomena of nuclear fission and fusion.

Nuclear Stability

The stability of a nucleus is determined by the value of its binding energy per nucleon. The constancy of the binding energy in the range 30 < A<170 is a consequence of the fact that the nuclear force is short-ranged.

Nuclear Chain Reaction

In a nuclear fission, more neutron are produced compared to those which are absorbed, hence a strong possibility of chain reaction with each of the produced neutron arises initiating another fission reaction.

<u>(i) Controlled Chain Reaction</u> :The chain reaction can be controlled and maintained steadily by absorbing a suitable number of neutrons at each stage, so that on an average one neutron remains available for exciting further fission such a reaction is called controlled chain reaction. e.g. Nuclear reactor.

(ii) Uncontrolled Chain Reaction : During fission reaction, neutron released again absorbed by the fissile isotopes, the cycle repeats to give a reaction that is self sustaining leading to large amount of radiation. Such a reaction is called uncontrolled chain reaction. e.g. Atom bomb.

[1 marks]

1.The nucleus of an atom consists of

a)electrons and protons
b)electrons, protons and neutrons
c)electrons and neutrons
d)neutrons and protons

Ans: a) The nucleus is defined as the part of the atom consisting of protons and neutrons.

2.1 MeV equals:

a)1.6 x 10^{-19} J
b) 1.6 x 10^{-22} J
c) 1.6 x 10^{-13} J
d) 1.6 x 10^{-9} J

Ans: c) 1 eV = (charge of an electron x 1V)

= (1.6 x 10^{-19} C x 1 V)

= (1.6 x 10^{-19} J)

1 MeV = 1.0 x 10^{6} eV

Therefore 1 MeV = 1.6 x 10^{-13} J

3.What is the source of energy in stars?

a)fusion b)chemical reaction c)gravitational collapse d)fission

Ans: a) In stars, nuclear fusion happens. This keeps it glowing.

4.Two spherical nuclei have mass numbers 216 and 64 with their radii R_1 and R_2 respectively. The ratio R_1 and R_2 is:

a) 3:2 b) 1:3 c)1:2 d)2:3

Ans: a) $R_1/R_2 = (A_1/A_2)^{1/3} = (216/64)^{1/3} = 3:2$

5. The neutrons as discovered by

a)Marie Curie b) Pierre Curiec)Rutherford d) James Chadwick

Ans: d) by James Chadwick in 1932

6. Select the pairs of isotopes & isotones from the following:

i. $^{13}C_6$ ii.$^{14}N_7$ iii. $^{30}P_{15}$ iv. $^{31}P_{15}$

Ans: Isotopes-iii &iv, isotones-I & ii

7. Light energy emitted by stars is due to

a)breaking of nuclei
b)joining of nuclei
c)burning of nuclei
d)reflection of solar light.
Ans: b) Joining of nuclei in fusion.

8.Nuclear fusion is possible

a)only between light nuclei
b)only between heavy nuclei
c)between both light and heavy nuclei
d)only between nuclei, which are stable against decay.
Ans: a) Fusion is possible between light nuclei.

9.Which of the following is an essential requirement for initiating nuclear fusion:

a)critical mass

b)thermal neutrons

c)high temperature

d)critical temperature

Ans: c) High temperature is essential for initiating fusion reaction.

10. The nuclear forces are:
a)charge dependent

b)spin dependent

c)charge independent

d)long range

Ans: c) charge independent since it is a nuclear phenomenon

11.Which is a non central force:
a)Electrostatic force

b)Nuclear force

c)Gravitational force

d)None of the above

Ans: b) Nuclear force

12.For Uranium nucleus, how does its mass vary with its volume?

a.m ∞ V   b)m ∞ √V   c) m ∞ 1/V   d) m ∞ V^2

Ans. a) m ∞ V

13.Order of magnitude of density of uranium nucleus (m_p= 1.67 x 10^{-27} kg) is

a) 10^{20} kg/m^3 b) 10^{11} kg/m^3 c) 10^{14} kg/m^3 d) 10^{17} kg/m^3

Ans. d) 10^{17} kg/m^3

14.If a star can convert all the He nuclei completely into oxygen nuclei, the energy released per oxygen nucleus is

[mass of Helium nucleus is 4.0026 amu and mass of oxygen nucleus is 15.9994 amu]

a) 7.6 MeV   b)56.12 MeV   c)10.24 MeV   d)23.9 MeV

Ans: c) 10.24 MeV

15. Fast neutrons can easily be slowed down by

a)using lead shielding
b)passing them through water containing protons
c)elastic collisions with heavy nuclei
d)applying a strong electric field.

Ans) b)passing them through water containing protons with comparable masses

[2 marks]

1. How the size of a nucleus is experimentally determined? Write the relation between the radius and mass number of the nucleus. Show that the density of nucleus is independent of its mass number.

Ans.The size of the nucleus is experimentally Determined using Rutherford's α-scattering experiment and the distance of closed approach and impact parameter.

The relation between radius and mass number of nucleus is,

$R = R_oA^{1/3}$, where R_o = 1.2 fm

Nuclear density, ρ= Mass of nucleus / Volume of nucleus

$= mA / (4/3)\pi(R_oA^{1/3})^3$

M= mass of each nucleon

$\rho = mA / (4/3)\pi R_o^3A$

$= m / (4/3)\pi R_o^3$

it is clear that ρ does not depend on mass number.

2.Why is it necessary to slow down the neutrons, produced through the fission of $^{235}_{92}U$ nuclei(by neutrons) to sustain a chain reaction? What type of nuclei is (preferably) needed for slowing down fast neutrons?

Ans: Average kinetic energy of neutrons produced in nuclear fission of $_{92}U^{235}$ is nearly 2MeV whereas the chances of absorption of neutrons average kinetic energy of nearly 0.024 MeV is high by U nuclei. So. there is a need to slow down the fast neutrons using appropriate substance namely moderator, into slow thermal neutrons.
Nuclei have comparable mass to that of neutrons should be preferable be used to slow down fast neutrons.It is due to the fact that the elastic collision between fast neutrons and slow moving protons in paraffin lead to interchange the velocities.

3.Show that nuclear density is independent of mass number.

Ans: Let the volume of a nucleus be V ,the mass of the nucleus be M and the mass of a nucleon be m

$V = {}^4/_3\pi r^3$

$\rho = M/V$

So, $M = {}^4/_3\pi r^3\rho$

Let's replace the r^3 from the equation

$r = r_0 A^{1/3}$

$r^3 = r_o{}^3A$

$M = {}^4/_3\pi r_o{}^3A\,\rho$

but M = Am

So, $Am = {}^4/_3\pi r_o{}^3A\,\rho$

Therefore,

Rearranging we get, $\rho = 3m/(4\pi r_o{}^3)$

This means that the density does not dependent on A or r - it is related to constant values - it is therefore a constant value.

4. Why is the binding energy per nucleon found to be constant for the nuclei in the range of mass number (A) lying between 30 and 170?

(B) When a heavy nucleus with mass number A = 240 breaks into two nuclei, A = 120, energy released in' this process.

Ans: (A) Nuclear forces are short ranged. For a particular nucleon inside a sufficiently large nucleus will be under the influence of some of its neighbors which come within the range of the nuclear force. The property that a given nucleon influences only nucleons close to it is also referred to as saturation property of the nuclear force.

(B) The binding energy per nucleon of the parent nucleus is less than those of the two daughter nuclei. It is this increased binding energy that gets released in this process.

5.In the fusion reaction

$_1H^2 + {}_1H^2 \longrightarrow {}_2He^3 + {}_0n^1$, the masses of deuteron, helium and neutron expressed in amu are 2.015, 3.017 and 1.009 respectively. If 1 kg deuterium undergoes complete fusion, find the amount of total energy released.

Ans:1amu = 931.5 MeV/c^2

$\Delta m = 2(2.015) - (3.017 + 1.009) = 0.004 amu$

1 amu = 931.5 MeV/c^2

Hence,

E = 0.004×931.5 MeV = 3.724 MeV

E = 3.726×1.6×10^{-13}J = 5.96×10^{-13}J

For 1 kg of Deuterium available,

moles = 1000g/2g = 500

N = 500 N_A = 3.01×10^{26}

Energy released = (N/2) × 5.95×10^{-13}J

= 8.95×10^{13}J

[3 marks]

1.Assuming the nuclei to be spherical in shape, how does the surface area of a nucleus of mass number A_1 compared with that of a nucleus with mass number A_2 ?

Ans: Nuclear radius , R = $R_oA^{1/3}$

∴.surface area, S = 4πR^2

= 4π$(R_oA^{1/3})^2$ = 4π$R_o \cdot A^{2/3}$

∴.Ratio of surface area, $S_1/S_2 = (A_1/A_2)^{2/3}$

2. Define Nuclear forces and gives their important characteristics/properties.

Ans.The nucleus of an atom has a number of protons and neutrons (nucleons) which are held together by the forces known as Nuclear forces in the tiny nucleus, inspite of strong force of repulsion between protons.

Characteristics/Properties of nuclear forces:

1. Nuclear forces are strongest forces in nature.
2. Nuclear forces are short range forces.
3. Nuclear forces are basically strong attractive forces but contain a small component of repulsive forces.
4. Nuclear forces are saturated forces.
5. Nuclear forces are charge independent
6. Nuclear forces are spin- dependent
7. Nuclear forces are exchange forces

3. Define atomic mass unit (a.m.u.) and calculate its value in SI unit of mass. Also find energy equivalent in MeV corresponding to it.

Ans. Atomic mass unit is defined as $\frac{1}{12}$th of mass of one $^{12}_{6}C$ atom.

According to Avogadro's hypothesis number of atoms in 12 g of $^{12}_{6}C$ is equal to Avogadro number. i.e 6.023x10^{23} .

Therefore the mass of one carbon atom $^{12}_{6}C = \frac{12}{6.023x10^{23}}$ = 1.99 x10^{-23}g = 1.99 x10^{-26}kg

Or, 1a.m.u. = $\frac{1}{12}$x1.99 x10^{-26}=1.665x10^{-27}kg

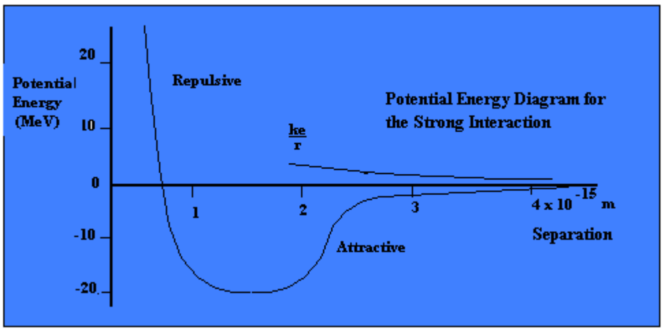
Energy equivalent of 1 a.m.u ,

Δm = 1 a.m.u = 1.665×10^{-27}kg

$E = \Delta m C^2$ J = $1.665 \times 10^{-27} \times (3 \times 10^8)^2 / 1.6 \times 10^{-13}$ MeV = 931.5 MeV

4. Sketch a graph showing the variation of potential energy of a pair of nucleons as a function of their separation. Write three characteristic properties of nuclear force which distinguish it from the electrostatic force.

Ans:



Nuclear force

i) Strongest short range force which operate up to distance of 2-3 fm.

ii) it does not obey inverse square law

iii) it exhibit charge independent character.

Electrostatic force

i) It is not very short range force necessarily.

ii)It obey inverse square law.

iii)It depend on the nature of charge, like charge repel whereas opposite charge attract each other

5. Explain mass defect and binding energy.

An atomic nucleus is a stable structure. The nucleus is bound by very strong short range forces called nuclear forces. Certain amount of work has to be done to separate the nucleons to such a distance that there is no interaction. This work done therefore measures binding energy of the nucleus.

On the basis of Einstein's theory of mass energy equivalent it was found that the rest mass of a nucleus is always slightly less than the sum of the free neutrons and protons comprising the nucleus. This indicates that some mass disappears when a nucleus is formed. This difference in the masses is called the mass defect. It is this mass defect, which appears in the form of binding energy.

$$\therefore \Delta m = \left[Zm_p + \left((A - Z)m_n\right) - m_n\right]$$

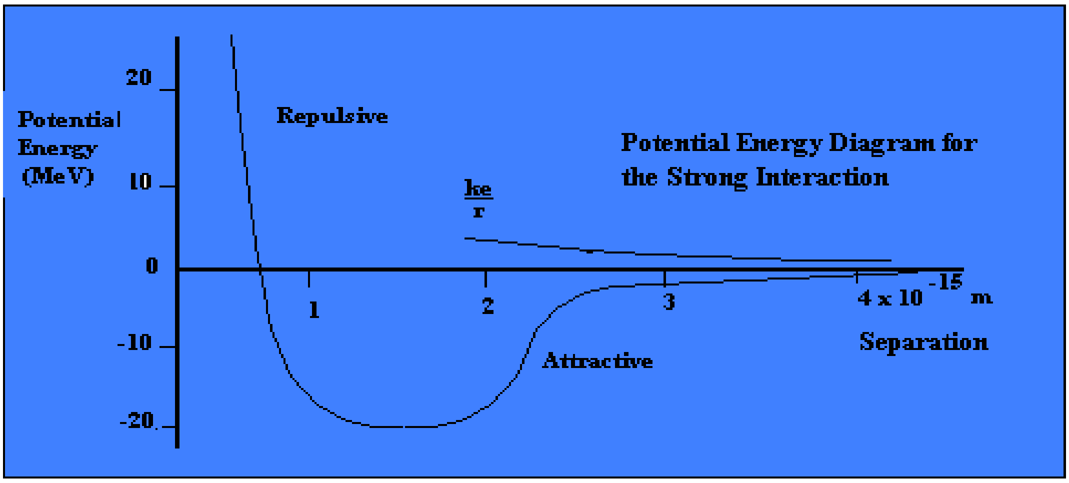
where Δm is the mass defect, m_p is mass of a proton, m_n is mass of a neutron, m_N is mass of nucleus $_ZX^A$.

B.E = $(\Delta mc^2) = [Zm_p + (A-Z)m_n]c^2$

6. Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions, which you can draw regarding the nature of nuclear forces.

Ans: Conclusions:

1. At large distances $r > r_0$, potential energy is –ve therefore force is attractive.
2. At small distance $r < r_0$, potential energy is +ve so force is repulsive.



7. Define the Q-value of a nuclear process. When can a nuclear process not proceed spontaneously? If both the no. of protons and the no. of neutrons are conserved in a nuclear reaction, in what way is mass converted into energy (vice – versa)in the nuclear reaction?

Ans: The Q- value of a nuclear process refers the energy release in the nuclear process which can be determined using Einstein's mass energy relation, $E = mc^2$ .The Q- value is equal to the difference of mass of products and the reactance multiplied by square of velocity of light.

The nuclear process does not proceed spontaneously when Q- value of a process is –ve or sum of masses of products in greater than sum of masses of reactant.

Mass defect occurs in nucleus which converts into energy=$mc^2$and produces binding energy. This energy binds nucleons together.

8.If a nucleus $_{26}Fe^{56}$ splits into two nuclei of $_{13}Al^{28}$, would the energy be released or needed for this purpose to occur? Given m($_{26}Fe^{56}$) = 55.934944&m ($_{13}Al^{28}$) = 27.98191, 1u = 931MeV/c^2 .Calculate the energy in MeV.

Ans: $m(_{26}Fe^{56}) + Q \longrightarrow 2\,(_{13}Al^{28})$

Δm = 2 x (27.98191)u - 55.934944 u

= 0.02888 u

Energy released, = 0.02888 x 931MeV = 26.88728 MeV

9.Why is the mass of a nucleus always less than the sum of the masses of its constituents, neutrons and protons? If the total number of neutrons and protons is a nuclear reaction is conserved , how then is the energy absorbed or evolved in the reaction? Explain.

Ans: The nucleus can be broken into its constituent parts only if this amount of energy is supplied to it from outside. This energy comes from conversion of some of the mass of the nucleus into energy by the formula $E = mc^2$. That is why the mass of a nucleus is always less than the sum of masses of its constituent neutrons and protons.

The number of neutrons and protons is conserved but their masses are not conserved. Some of the mass of every nucleon is converted to energy and given out as heat and radiations.

10. Find the energy equivalent of 1 amu in terms of MeV.

The unit in which atomic and nuclear masses are measured is called atomic mass unit (a.m.u).
1 a.m.u is defined as $1/12^{th}$ of the mass of an atom of ${}_6C^{12}$ isotope.
It can be shown that
1 a.m.u = 1.66×10^{27} kg.
According to Einstein, mass energy equivalence
$E = mc^2$
Where m = 1.66×10^{-27} kg.
C = 3×10^8 m/sec ,we get
E = 1.49×10^{-10} J (1Mev = 1.6×10^{-13} J)

$$\text{or } E = \frac{1.49 \times 10^{-10} \text{ J}}{1.6 \times 10^{-13}} \text{Mev}$$

E = 931.25 Mev
Hence a change in mass of 1a.m.u (called mass defect) releases an energy equal to 931 Mev.

1 amu = 931 Mev is used as a standard conversion.

[Assertion-Reasoning Type Questions]

Answer: (a)Both are correct and reason is correct explanation of assertion.
Answer: (b)Both are correct but reason is not the correct explanation of assertion.
Answer: (c)Assertion is correct but Reason is wrong.
Answer: (d)Both Assertion and Reason are wrong.

1.Assertion: Nuclear density is almost same for all nuclei.
Reason: The radius (r) of a nucleus depends only on the mass number (A) as $r \propto A^{1/3}$.

Answer: a)

2.Assertion: Fast moving neutrons do not cause fission of a uranium nucleus.
Reason: A fast moving neutron spends very little time inside the nucleus.

Answer: (a)

3.Assertion: Nuclear force between neutron-neutron, proton neutron and proton-proton is approximately the same.

Reason: The nuclear force doesn't depend on the electric charge.

Answer: (a) Since, nuclear force is charge independent, hence assertion is correct.

4.Assertion: Binding energy per neutron is constant for mass number in the range 30< A< 170

Reason :Nuclear force is short ranged force and saturation of force occurs for greater distances.

Answer: (a)

CASE STUDY BASED QUESTION:

Einstein was the first to establish the equivalence between mass and energy. According to him, whenever a certain mass (Δm) disappears in some process the amount of energy released is $E = \Delta m\ c^2$, where c is the velocity of light in vacuum =3×10^8 m/s. The reverse is also true i.e. whenever energy E disappears an equivalent mass $\Delta m = E/c^2$ appears.

Read the above passage and answer any 04 from the following –

i) What is the energy released when 1a.m.u mass disappears in a nuclear reaction?

a) 1.49×10^{-10} J b) 1.49×10^{-7} J c) 1.49×10^{10} J d) 1.49×10^{-10} MJ

Ans: (a)

ii)Which of the following process releases energy?

a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

Ans: (c)

iii)Which process is used in today's nuclear power plant to harness nuclear energy?

a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

Ans: (a)

iv)Which process releases energy in Atom Bomb?

a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

Ans: (a)

v)Which of the following is used as Moderator in a Nuclear Reactor?

a)Deuterium Water b)Normal Water c)Mineral Water d)Soft water

Ans: (a)

CHAPTER 14 : SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

GIST OF THE LESSON:

1. Classification of Conductors, Semiconductors and Insulators:

(a) On the basis of Conductivity (σ) or Resistivity ρ(=1/σ):-

The solids are classified as follows:

(i) **Conductors**: They have very low resistivity(ρ) in the range $10^{-2} – 10^{-8}$Ω-m.

(ii) **Semiconductors**: They have resistivity in the range $10^{-5} – 10^{6}$ Ω-m.

(iii) **Insulators**: They have high resistivity in the range $10^{11} – 10^{19}$ Ω-m.

(b) On the Basis of Energy Bands:-

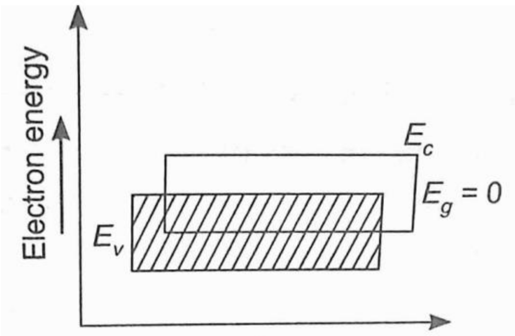
Inside the crystal, each outermost shell electron has a unique position and no two electrons have the same set of quantum states. Because of this, each electron has a different energy level. These different energy levels constitute and energy band.

Valence band: The energy band which includes the energy levels of the valence electrons, is called the valence band.

Conduction band: The energy band which includes the higher energy levels which may or may not be occupied by electrons, is called conduction band.

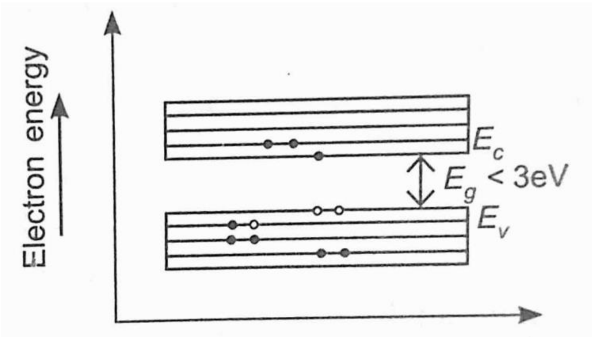
Energy band gap (Energy gap E_g): The gap between the top of the value band (E_v) and bottom of conduction band (E_c) is called the energy gap (E_g). On the basis of energy bands, conductors, semiconductors and insulators can be classified as follows:

(i) **Metals or Conductors:** The conduction and valence band can easily move into the conduction band. Therefore, the electrons from valence band can easily move into the conduction band. Therefore, the resistance of the metals is low or the conductivity is high.



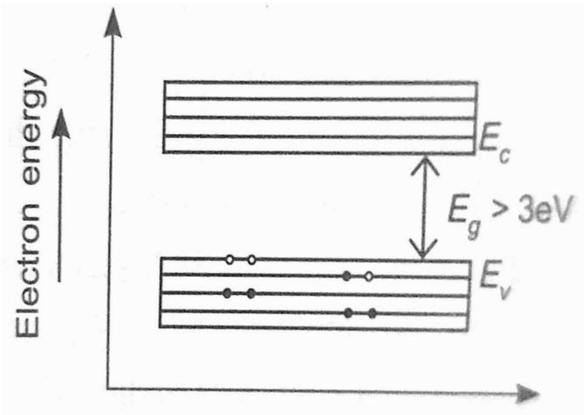
(ii) **Semiconductors:** E_g< 3eV (small energy b and gap)

At T= 0K, the conduction band is empty and the semiconductors behaves like an insulator. But the room temperature, electrons gain thermal energies and cross the small E_g (energy gap) easily and either the conduction band, and can move in the conduction band.

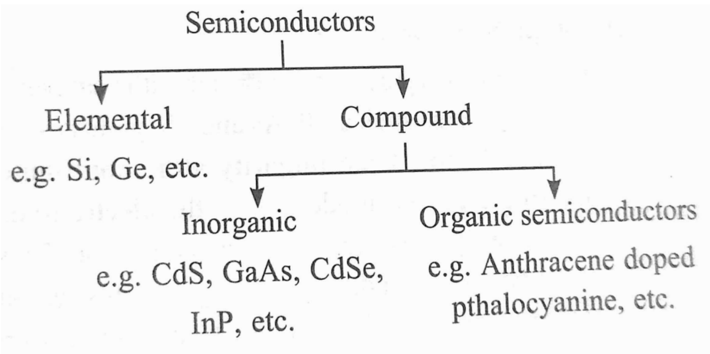


(iii) Insulators: E_g> 3eV (large energy band gap)

The conduction band is empty. Due to large E_g (energy gap), the electrons cannot be excited from valence band to conduction band by thermal excitation.



2. Types of semiconductors



3. Intrinsic semiconductors (Pure Si or Ge)

In these semiconductors, due to the thermal excitation, the electrons move from the valence band to conduction band, leaving behind a vacancy in the valence band called hole. The hole in the valence band behaves as an apparent free particle with effective positive charge.

Therefore, the number of electrons in the conduction band is equal to the number of holes in the valence band.

∴ $n_e = n_h = n_i$

Here n_e = free electron density (concentration)

n_h = free hole density (concentration)

n_i = intrinsic carrier concentration

When an external field is applied, the holes moves towards the negative potential giving current due to hole and the electrons move towards the positive potential and give rise to current due to electron.

Thus, the total current (I) is the sum of the current due to electron (I_e) and current due to hole (I_h).

$I = I_e + I_h$

The two processes occur simultaneously, i.e, the process of generation of conduction electrons and holes, and the process of recombination of electrons and holes due to their collision.

4. Extrinsic Semiconductors

The conductivity of a semiconductor can be improved by adding a suitable impurity in specific amounts. Such materials are called extrinsic semiconductors. The deliberate addition of impurities is called *doping,* and such materials are also known as doped semiconductors.

The added impurities are called dopants. The size of the dopant and the semiconductors atoms should be nearly the same, so that it does not distort the original or pure semiconductors lattice.

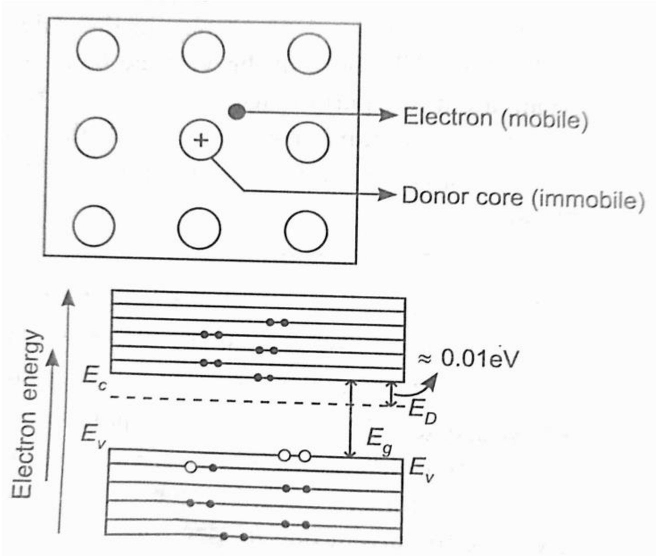
The following are two types of dopants that are used in the tetravalent (Si or Ge) doping.

(i) Pentavalent (valency5): Arsenic (As), Antimony (Sb), phosphorus (P), etc.

(ii) Trivalent (valency 3): Indium (In), Boron (B), Aluminum (Al), etc.

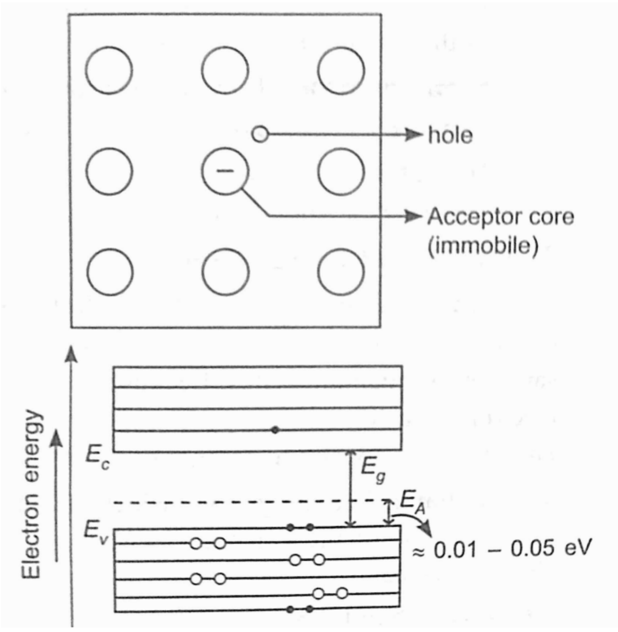
(a) *n*-type Semiconductor

The doping of a pure semiconductor with pentavalent impurity atoms such as P, As and Sb, yield n-type semiconductor. Each impurity atom contributes one free electron in addition to the electron-hole pairs already existing in the semiconductor. Thus, in a *n*-type semiconductor, $n_e > n_h$. For this reason, electrons are called the majority charge carriers and holes are called the minority charge carriers in a *n*-type semiconductor. Each impurity atom is called a donor as it donates one free electron to the semiconductors.



(b) ***p*-type Semiconductor:**

The doping of a pure semiconductor with trivalent impurity atoms such as *B* and Al, yields p-type semiconductor. Each impurity atom contributes one hole in addition to the electron-hole pairs already existing in the semiconductor. Thus, in a p-type semiconductor, $n_h > n_e$. For this reason, holes are called the majority charge carriers and electrons are called the minority charge carriers in a p-type semiconductor.



Each impurity atom is called an acceptor because it accepts one electron in the valence band to become ionised as negatively charged. The holes introduced into the semiconductor by the acceptor impurity have energy which is 0.04 eV above the highest energy level of the valence band as shown in the above figure.

Charge carriers in Semiconductors: Intrinsic or pure semiconductors conduct due to electrons and holes whose number density is same, i.e. $n_e = n_h = n_i$. Here n_i is called the number density of intrinsic carriers. In a doped semiconductor, whether *p*-type or n-type, the number density of charge carriers is related as

$$n_i^2 = n_e n_h$$

5. *p-n* junction diode

A p-n junction consists of wafers of *p*-type and n-type semiconductors fused together or grown on each other.

(a) Depletion region

(i) It is a region near the *p*-n junction that is depleted of any mobile charge carrier. It consists of immobile ion cores.

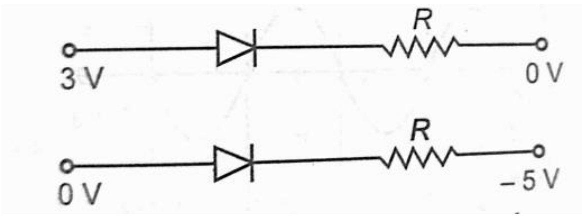
(ii) The depletion width depends on:

(i) the type of biasing, and (ii) extent of doping

(b) Potential Barrier (V_B): Due to the accumulation of immobile ion cores in the junction, a potential difference is developed which prevents the further movement of majority charge carriers across the junction.

6. Forward biasing of a *p-n* junction

(a) A *p-n* junction is said to be forward biased when *p*-region is maintained at a higher potential with respect to the n-region as shown below.

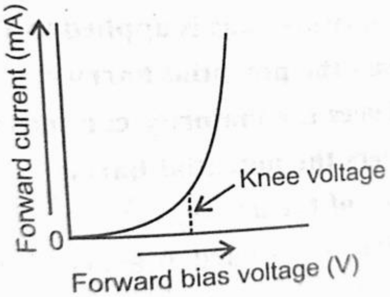


(b) When forward biased, majority charge carriers in both the regions are pushed through the junction. The depletion region's width decreases and the junction offers low resistance, and potential difference across the junction becomes $V_B - V$.

(c) Forward characteristics of *p-n* junction diode:

It is a graphical relation between the forward bias voltage applied and the forward current flowing through the diode. As long as the forward bias voltage is less than the barrier potential, no current flows. But when a forward bias voltage(V) is greater than barrier potential applied, an almost linear forward bias voltage current (≈ a few mA) flow due to the flow of majority carriers. For diodes, we define a quantity, called dynamic resistance, as the ration of small change in voltage ΔV to a small change in current ΔI,

This forward voltage at which flow of current increasing quickly is known as knee voltage.

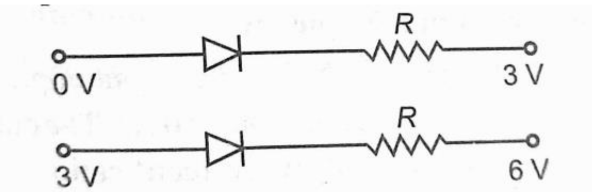


i.e. $r_d = \frac{\Delta V}{\Delta I}$

p-n

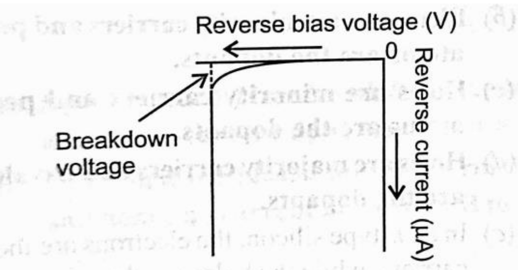
7. Reverse biasing of a *p-n* junction

(a) A *p-n* junction is said to be reverse biased when its *p*-region is maintained at a lower potential with respect to its *n*-region as shown below.



(b) When the junction is reverse biased, the majority charge carriers in both the regions are pushed away from the junction. The depletion regions width increases and the potential difference across the junction becomes, $V + V_B$.

(c) **Reverse characteristics of a junction diode:** It is a graphical relation between the reverse bias voltage applied and the reverse current flowing (if any) the diode. In this case, the majority carriers in both *p*-region and n-region move away from the junction so that no majority current flows. However, minority carriers cross over the junction constituting a small current (≈ a few μA) which is called minority current which almost remains constant with the change in bias. It is called reverse saturation current. As the magnitude of the reverse bias voltage is increased, the leakage current also rises gradually. At a particular reverse bias voltage, the reverse current increases abruptly (i.e. it becomes very large suddenly). The reverse bias voltage at which the reverse current rises abruptly, is called **Breakdown voltage)**.

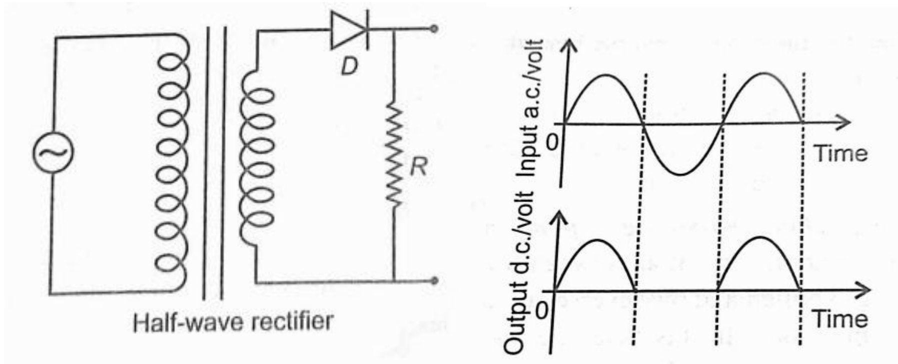


8. *p*-n junction as a rectifier

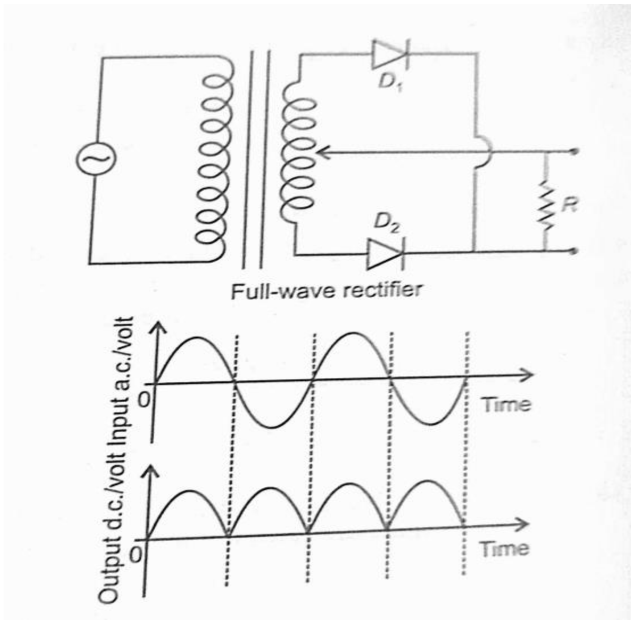
Rectification: It is the process of conversion of ac into dc. A single *p*-n junction, or two or four *p*-n junctions can be used for this purpose.

Principle: A *p-n* junction diode conducts in forward bias and does not conduct in the reverse bias.

(a) Half-wave rectifier: A single *p-n* junction can be used for half-wave rectifier. It conducts only during alternative half-cycle of the input ac voltage. As a result, the output voltage does not change in polarity. The average of the voltage from a half-wave rectifier is low.



(b) Full-wave Rectifier: It is achieved using two *p-n* junctions. It conducts for both halves of the cycle. The average voltage of a full-wave rectifier is more than that of a half-wave rectifier, for the same rms value of ac voltage.



MULTIPLE CHOICE QUESTIONS (1 MARK)

1. The usual semiconductors are
(a) Germanium and silicon
(b) Germanium and copper
(c) Silicon and glass
(d) Glass and carbon

2. The energy gap between the valence and conduction bands of a substance is 6 eV. The substance is a

(a) Conductor

(b) Semiconductor

(c) Insulator

(d) Superconductor

3. In a *n*- type semiconductor, which of the following statements is true?

(a) Electrons are majority carriers and trivalent atoms are the dopants.

(b) Electrons are minority carriers and pentavalent atoms are dopants.

(c) Holes are minority carriers and pentavalent atoms are dopants.

(d) Holes are majority carriers and trivalent atoms are dopants.

4. The conductivity of a semiconductor increases with increase in temperature because

(a) Number density of free current carriers increases.

(b) Relaxation time increases.

(c) Both number density of carriers and relaxation time increase.

(d) Number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.

5. When an electric field is applied across a semiconductor

(a) Electron moves from lower energy level to higher energy level in the conduction band

(b) Electron moves from higher energy level to lower energy level in the conduction band

(c) Holes in the valence band move from higher energy level to lower energy level

(d) Holes in the valence band more from lower energy level to higher energy level.

6. A piece of copper and another of germanium are cooled from room temperature to 77 K. The resistance of

(a) Each of these decreases

(b) Copper strip increases and that of germanium decreases.

(c) Copper strip decreases and that of germanium increases

(d) Each of these increases

7. The breakdown in a reverse biased *p-n* junction diode is more likely to occur due to

(a) Large velocity of the minority charge carriers if the doping concentration is small

(b) Large velocity of the minority charge carriers if the doping concentration is large

(c) Strong electric field in a depletion region if the doping concentration is small.

(d) Strong electric field in the depletion region if the doping concentration is large.

8. At equilibrium, in a *p*-*n* junction diode the net current is
(a) Due to diffusion of majority charge carriers
(b) Due to drift of minority charge carriers.
(c) Zero as diffusion and drift currents are equal and opposite.
(d) Zero as no charge carriers cross the junction.

9. The impurity atoms to be mixed in pure silicon to form *p*-type semiconductor are, of
(a) Phosphorus
(b) Germanium
(c) Antimony
(d) Aluminum

10. The manifestation of band structure in solid is due to
(a) Heisenberg's uncertainty principle
(b) Pauli's exclusion principle
(c) Bohr's correspondence principle
(d) Boltzmann's law

VERY SHORT ANSWER QUESTIONS (1 MARK)

11. Name the charge carriers in *n*-type semiconductors.

12. How does the width of depletion region of a *p*-*n* junction vary if doing concentration is increased.

13. Draw a *p*-*n* junction with reverse bias.

14. Why are elemental dopants for Silicon or Germanium usually chosen from group 13 or group 15?

15. At what temperature would an intrinsic semiconductor behave like a perfect insulator?

16. Give the ratio of number of holes and number of conduction electrons in an intrinsic semiconductor.

17. In half wave rectification, what is the output frequency of input frequency is 25 Hz?

18. What type of extrinsic semiconductor is formed when

(i) Germanium is doped with indium?
(ii) Silicon is doped with bismuth?

19. When a voltage drop across *p-n* junction diode is increased from 0.70 V to 0.71 V, the change in the diode current is 10mA. What is the dynamic resistance of diode.

20. What happens to the width of depletion layer of *p-n* junction when it is

    (i) Forward biased
    (ii) Reverse biased?

SHORT ANSWER QUESTIONS (2 MARK)

21. What is meant by doping of an intrinsic semiconductor? Name the two types of atoms used for doping of Ge/Si.

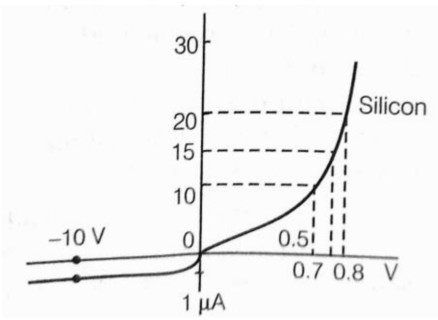
22. Explain the formation of the barrier potential in a *p-n* junction.

23. (i) Explain the formation of energy bands in crystalline solids.

    (ii)Draw the energy band diagrams of (a) a metal and (b) a semiconductor

24. A student wants to use two *p-n* junction diodes to convert alternating current into direct current. Draw the labelled circuit diagram she would use and explain how it works?

25. The *V*-I characteristic of a silicon diode is as shown in figure. Calculate the resistance of the diode at (i) I = 15 mA and (ii) V= - 10V



26. Distinguish between 'intrinsic' and 'extrinsic' semiconductors?

27. Explain, with the help of a circuit diagram, the working of a *p-n* junction diode as a half-wave rectifier.

28. Draw energy band diagram of *n*-type and *p*-type semiconductor at temperature T>0K. Mark the donar and acceptor energy level with their energies.

29. Distinguish between a metal and an insulator on the basis of energy band and diagram.

LONG ANSWER QUESTIONS (3 MARK)

30. Explain with the help of a diagram, how depletion region and potential barrier are formed in a junction diode.

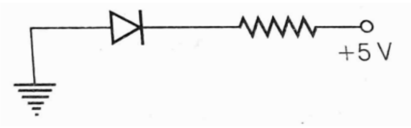
31. Draw *V-I* characteristic of a *p-n* junction diode. Answer the following questions, giving reasons:
(i) Why is the current under the reverse bias almost independent of the applied potential up to a critical voltage?

(ii)Why does the reverse current show a sudden increase at the critical voltage?

32. Draw a block diagram of a full-wave rectifier with capacitor filter, Draw input and output (filtered) voltage of rectifier.

33. With the help of a circuit diagram explain the working of a *p-n* junction diode as a full-wave rectifier. Also draw its input and output waveforms.

34. (i) In the following diagram, is the junction diode forward biased or reverse biased?



(ii)Draw the circuit diagram of a full wave rectifier and state how it works?

35. (i) Explain with the help of a diagram the formation of depletion region and barrier potential in a *p-n* junction.

(ii)Draw the circuit diagram of a half-wave rectifier and explain its working.

VERY LONG QUESTIONS (5 MARK)

36. (i) Explain with the help of suitable diagram, the two processes which occur during the formations of a *p-n* junction diode. Hence, define the terms (i) depletion region and (ii) potential barrier.

(ii) Draw a circuit diagram of a *p-n* junction diode under forward bias and explain its working.

37. (i) State briefly the processes involved in the formation of *p-n* junction, explaining clearly how the depletion region is formed.

(ii) Using the necessary circuit diagrams, show how the *V-I* characteristics of a *p-n* junction are obtained in:-
(a) forward biasing
(b) reverse biasing

38. (i) Explain with the help of diagram, how a depletion layer and barrier potential are formed in a junction diode.

(ii) Draw a circuit diagram of full-wave rectifier. Explain its working and draw input and output waveforms.

Assertion-Reasoning MCQs

Direction. Each of these questions contains two statements Assertion (A) and Reasons (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true, but R is not the correct explanation of A

(c) A is true, but R is false

(d) A is false and R is also false

39. **Assertion** The energy gap between the valence band and conduction band is greater in silicon than in germanium.

Reason Thermal energy produces fewer minority carriers in silicon than in germanium.

40. **Assertion** The total current I in a semiconductor is the sum of electron current and hole current.

Reason In a semiconductor, I_h arises due to the motion of holes towards positive potential and free electrons under an applied electric field.

41. **Assertion** The resistivity of a semiconductor decreases with temperature.

Reason The atoms of a semiconductor vibrates with larger amplitudes at higher temperature thereby increasing its resistivity

42. **Assertion** A hole on *p*-side of a *p*-*n* junction moves to *n*-side just an instant after drifting of charge carriers occurs across junction.

Reason Drifting of charge carriers reduces the concentration gradient across junction.

43. **Assertion :** When two semi conductor of p and n type are brought in contact, they form p-n junction which act like a rectifier.

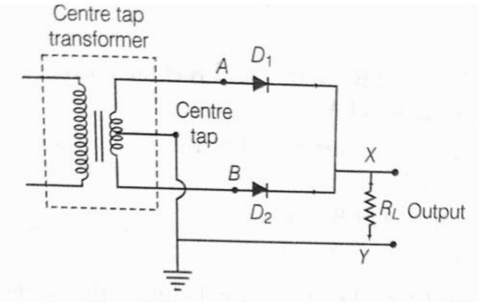
Reason : A rectifier is used to convent alternating current into direct current.

44. **Case Based MCQ**

Direction Read the following passage and answer the questions that follows

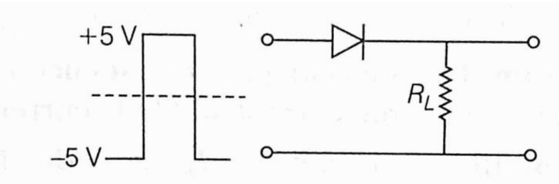
Full Wave Rectifier The process of converting alternating voltage/current into direct voltage/current is called **rectification.** Diode is used as a rectifier for converting alternating current/voltage into direct current/voltage.

Diode allows current to pass only, when it is forward biased. So if an alternating voltage is applied across a diode, the current flows only in that part of the cycle when the diode is forward biased. This property is used to rectify the current/voltage.

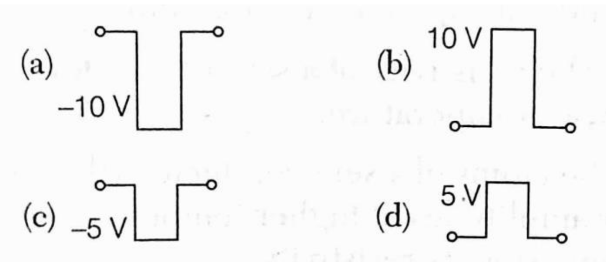


Circuit diagram of full wave rectifier

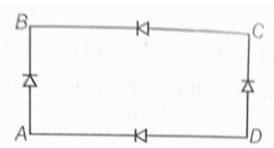
(i) If in a *p-n* junction, a square input signal of 10 V is applied as shown



Then, the output across R_L will be



(ii) In figure, the input is across the terminals A and C and the output is across *B* and *D.* Then, the output is



(a) zero

(b) same as the input

(c) half wave rectified

(d) full wave rectified

(iii) Which of the following is not true about a rectifier circuit?

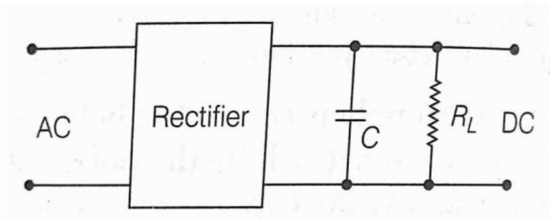
(a) It can convert DC to AC

(b) It can convert AC to DC

(c) It can shift voltage level

(d) None of these

(iv) In the given circuit,



Capacitor C is used

(a) for storing potential energy

(b) as a bypass to DC component to get AC is R_L.

(c) to remove sparking

(d) as a bypass to AC component to get DC in R_L.

(v) The ratio of output frequencies of half-wave rectifier and a full wave rectifier, when an input of frequency 200 Hz is fed at input, is

(a) 1:2

(b) 2:1

(c) 4:1

(d) 1:4.

ANSWERS

MULTIPLE CHOICE QUESTIONS (1 MARK)

1. (a) Germanium and silicon

2. (c) Insulator

3. (c) Holes are minority carriers and pentavalent atoms are dopants.

4. (d) number density of current carriers increases, relaxation time decreases but effect of decrease in relaxation time is much less than increase in number density.

5. (a) electrons moves from lower energy level to higher energy level in the conduction band.

   (c) holes in the valence band move from higher energy level to lower energy level.

6. (c) copper strip decreases and that of germanium increases.

7. (a) large velocity of the minority charge carriers if the doping concentration is small.

   (d) strong electric field in the depletion region if the doping concentration is large.

8. (c) zero as diffusion and drift currents are equal and opposite.

9. (d) aluminum

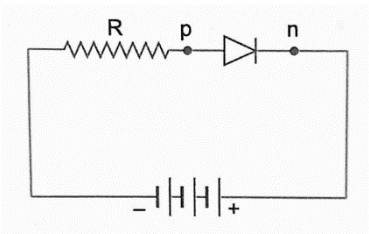
10. (b) Pauli's exclusion principle.

VERY SHORT ANSWER QUESTIONS (1 MARK)

11. Free electrons

12. When doping concentration is kept high in *p*-*n* junction, then there will be less space for electron to travel and equilibrium is achieved by recombination between charge carriers in nearby region. So, depletion width is decreased with doping.

13. The *p*-*n* junction with reverse bias is shown in fig.



14. The size of dopants atoms should be such as not to distort the pure semiconductor lattice structure and yet easily contribute a charge carrier on forming covalent bonds with Si or Ge.

15. An intrinsic semiconductor behaves as a perfect insulator at temperature 0 K.

16. Ratio, 1:1

17. For a half wave rectifier, the output frequency is equal to the input frequency. SO, the frequency after rectification is 25 Hz.

18. (i) Indium is trivalent, so germanium doped indium is a *p*-type semiconductor.

(ii) Bismuth is pentavalent, so silicon doped bismuth is an *n*-type semiconductor.

19. Dynamic resistance = $\Delta V / \Delta I$ = 0.71-0.70/10 X 10^{-3} = 0.01/10^{-2} = 1Ω.

20. (i) When forward biased, the width of depletion layer decreases.

(ii) When reverse biased, the width of depletion layer increases.

SHORT ANSWER QUESTIONS (2 MARK)

21. When some desirable impurity is added to intrinsic semiconductors deliberately to increase its conductivity, then this process is called doping and the impurity are called dopants. Two types of dopants(atoms) are used in doping

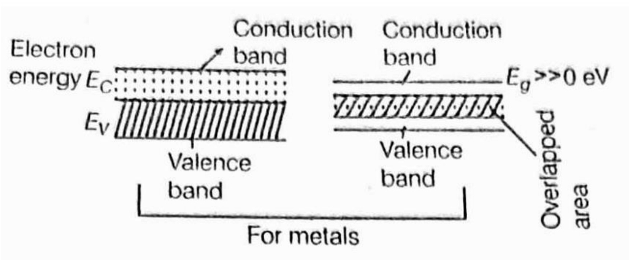
(i) Trivalent atoms having 3 valence electrons e.g. indium, Boron, Aluminum, etc.

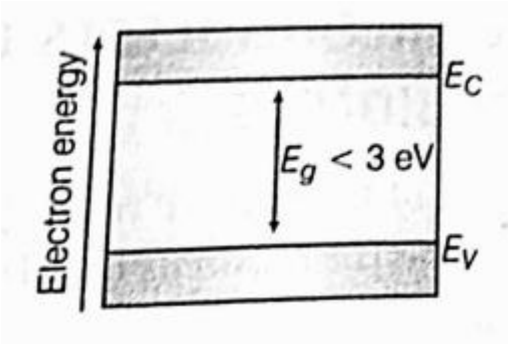
(ii) pentavalent atoms having 5 valence electrons e.g., Arsenic, Antimony, phosphorus, etc.

22. Depletion region is the small region in the vicinity of the junction which is depleted of free charge carriers. Width of depletion region is of the order of 10^{-6} m. The potential difference developed across the depletion region is called the potential barrier.

23. (i) Since, isolated atoms have discrete energy levels. In a crystalline solid, due to the presence of a large number of atoms, interatomic interactions take place. Due to this, energy levels get modified to energy bands.

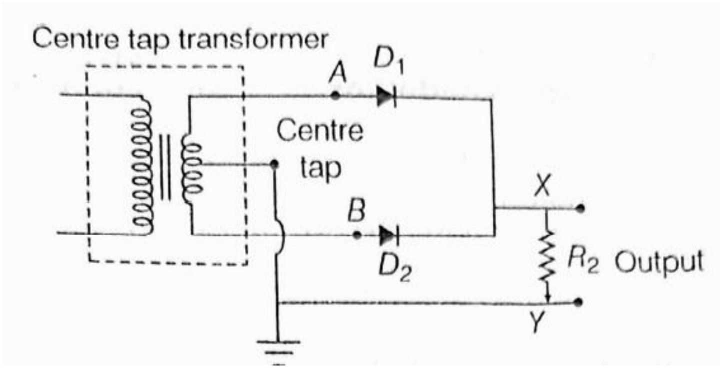
(ii)





For Semiconductors

24 – A rectifier is used to convert alternating current into direct current, as below:



Working:

During the positive half cycle of the input AC, the diode D_1 is forward biased and the diode D_2 is reverse biased. The forward current flows through diode D_1.

During the negative half cycle of the input AC, the diode D_1 is reverse biased and diode D_2 is forward biased. Thus, current flows through diode D_2. Thus, we find that during both the halves, current flows in the same direction.

25. (i) From the given curve, we have

Voltage, V = 0.7 V for current,

I = 15 mA for voltage,

∴Resistance, $V/I = 0.7/ 15 \times 10^{-3} = 47\Omega$

(ii) For V = -10 V, we have

$I = -1\ \mu A = -1 \times 10^{-6}$ A

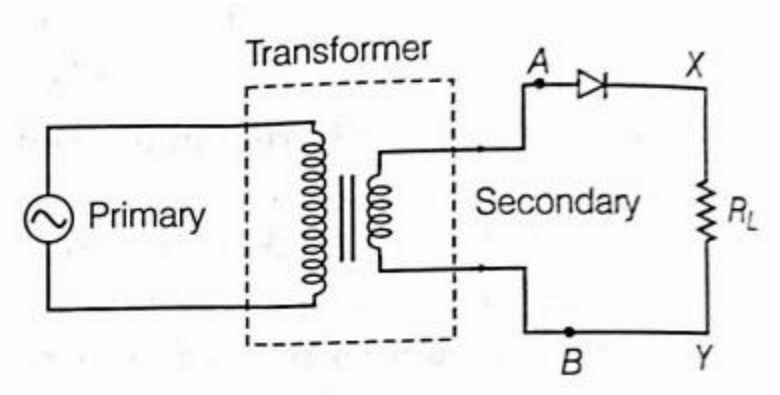
$R = 10/ 1 \times 10^{-6} = 1.0 \times 10^{7}\ \Omega$.

26.

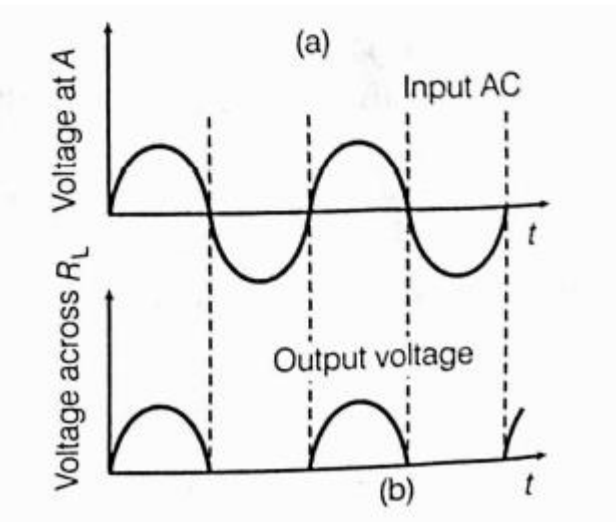
Intrinsic semiconductor	Extrinsic semiconductor
It is a pure semiconductor material with no impurity atoms in it.	It is prepared by doping a small quantity of impurity atoms to the pure semiconductor.
The number of free electrons in the conduction band and the number of holes in valence band exactly . $n_e = n_h = n_i$	The number of free electrons and holes is never equal. There is an excess of is electrons $n_e > n_i$ in *n*-type semiconductors and excess of holes $n_e > n_i$ in *p*-type semiconductors.

27 .

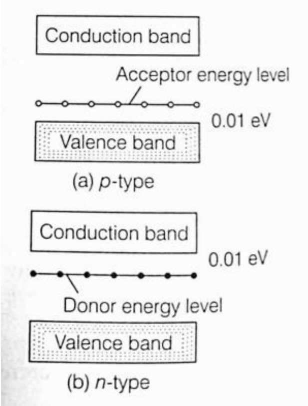
***p-n* Junction Diode as a Half-Wave Rectifier:** AC voltage to be rectified is connected to the primary coil of a step down transformer. Secondary coil is connected to he diode through resistors R_L, across which output is obtained.



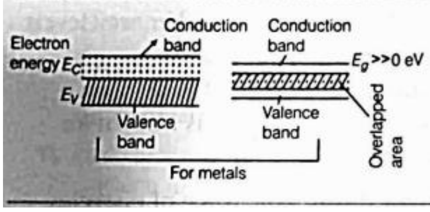
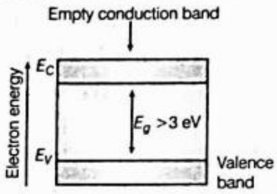
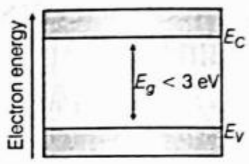
Working: During positive half cycle of the input AC, the *p-n* junction becomes low and current flows. Hence, we get output in the load. During negative half cycle of the input AC, the *p-n* junction is reverse biased. Thus, the resistance of *p-n* junction is high and current does not flow. Hence, no output in the load. So, for complete cycle of AC, current flows through the load resistance in the same direction.



28. The required energy band diagram is shown below:-



29. – Difference between Conductor, insulator and semiconductor:-

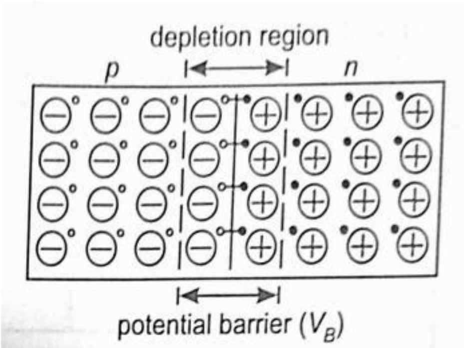
Conductor (Metal)	Insulator	Semiconductor
In conductor, either there is no energy gap between the conduction band which is partially filled with electrons and valence band or the conduction band and valence band overlap each other.	In insulator, the valence band is completely filled, the conduction band is completely empty and energy gap between conduction band and valence band is quite large that small energy from any other source cannot overcome it.	In semiconductor also, like insulators the valence band is completely filled and the conduction band is empty but the energy gap between conduction band and valence band, unlike insulators is very small.
Thus, many electrons from below the fermi level can shift to higher energy levels above the fermi level in the conduction band and behave as free electrons by acquiring a little more energy from any other sources.	Thus, electrons are bound to valence band and are not free to move and hence, electric conduction is not possible in this type of material.	Thus, at room temperature, some electrons in the valence band acquire thermal energy greater than energy band gap and jump over to the conduction band where they are free to move under the influence of even a small electric field and acquire small conductivity.
		

30. Two process that take place during the formation of *p-n* junction are diffusion and drift of charge carriers.

In a *n*-type semiconductor, the concentration of electrons is more than that of holes. Similarly, in a *p*-type semiconductor, the concentration of holes is more than that of electrons. Formation of depletion region during formation of *p-n* junction and due to the concentration gradient across p and n-sides, holes diffuse from p-side to n-side (p→n) and electrons diffuse from n-side to p-side (n→p).

The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralize each other.

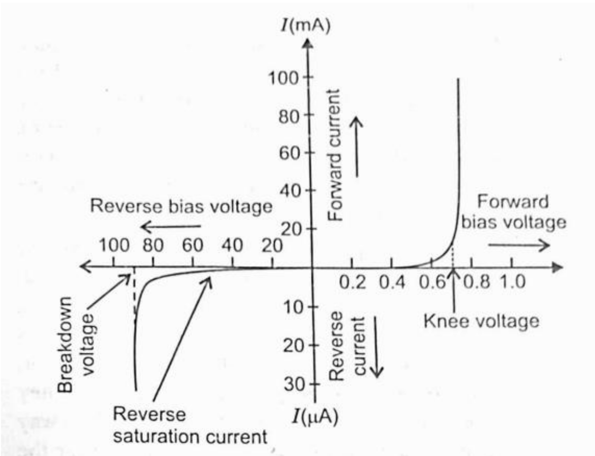
Thus, near the junction, positive charge is built on *n*-side and negative charge on *p*-side.



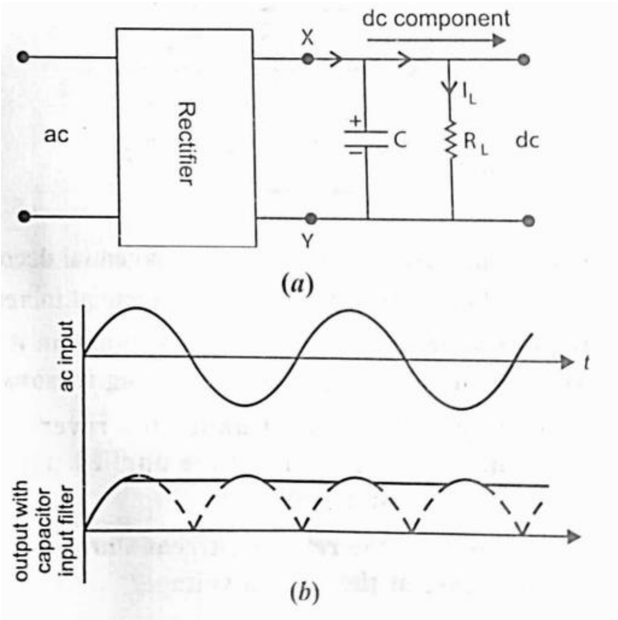
This sets up up potential difference across the junction and an internal electric field E_i directed from *n*-side to *p*-side. The equilibrium is established when the field E_i becomes strong enough to stop further diffusion of the majority charge carriers (However, it helps the minority charge carriers to drift across the junction). The region on either side of the junction which becomes less danced of charge carrier depleted(free) from the mobile charge carriers is called **depletion region** or depletion layer.The potential difference developed across the depletion region is called the **potential barrier.**

31**.** (i) The reverse current is not limited by the magnitude of applied voltage, but it is limited due to the concentration of minority carriers on either side of the junction.

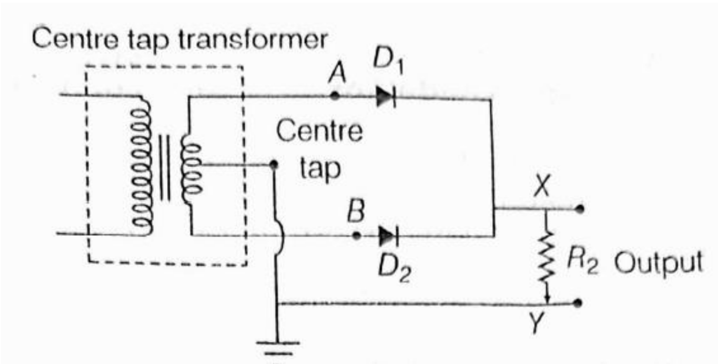
(ii) at the critical voltage ,the electric field across the junction is high enough to pull valance electrons from the host atoms.as a result ,a large no. of electrons are available for the conduction which shows a sudden increase of the reverse current at breakdown voltage.



32.



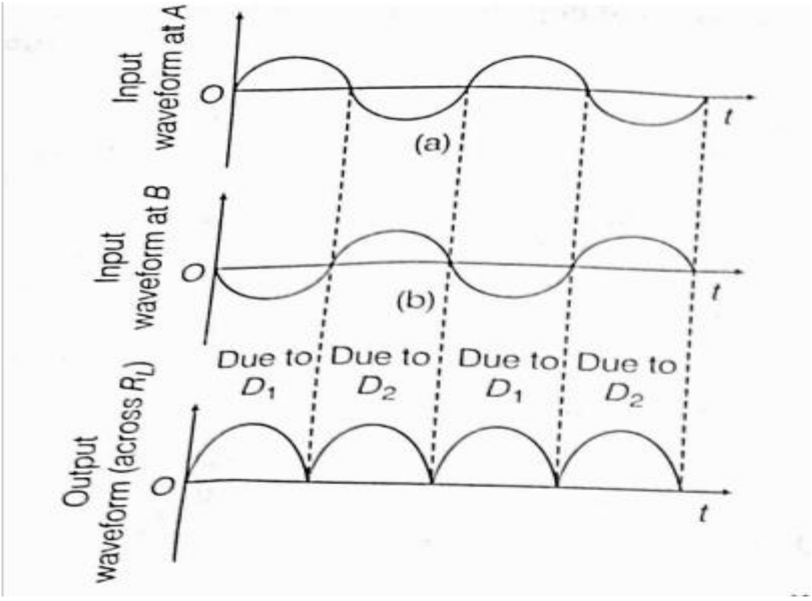
33. A rectifier is used to convert alternating current into direct current, as below:



Working:

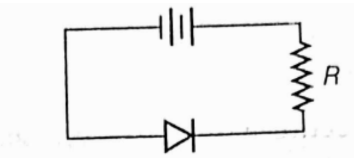
During the positive half cycle of the input AC, the diode D_1 is forward biased and the diode D_2 is reverse biased. The forward current flows through diode D_1.

During the negative half cycle of the input AC, the diode D_1 is reverse biased and diode D_2 is forward biased. Thus, current flows through diode D_2. Thus, we find that during both the halves, current flows in the same direction.



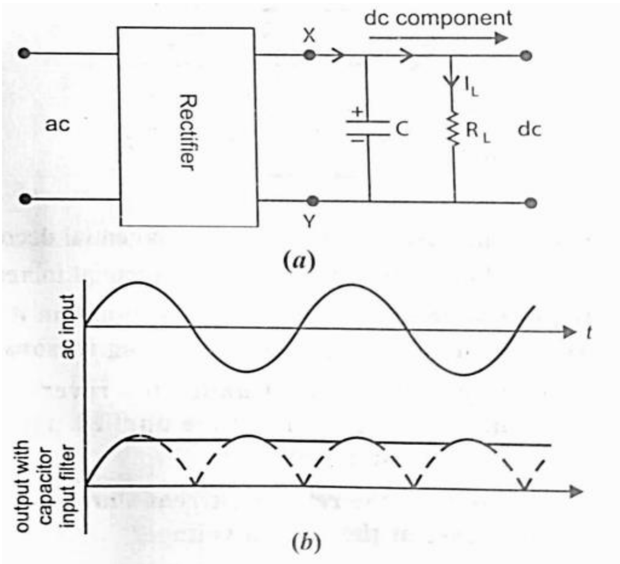
34. (i)

The circuit above can be redrawn as follows



As, the *p*-section is connected to negative terminal of the battery, the diode shown is reverse biased.

(ii) A rectifier is used to convert alternating current into direct current, as below:

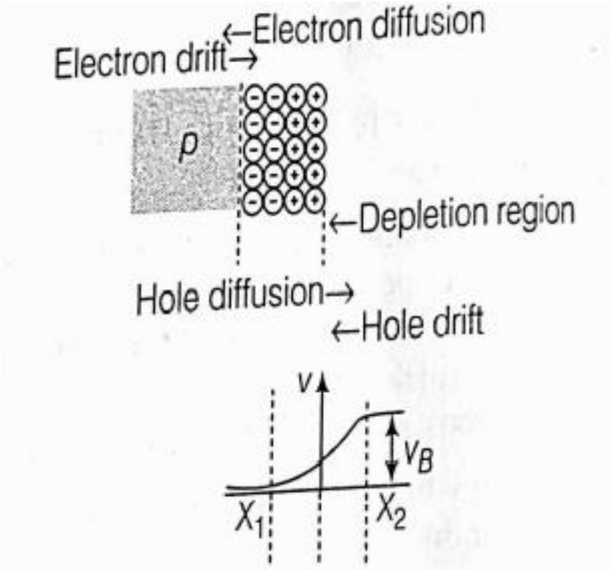


Working:

During the positive half cycle of the input AC, the diode D_1 is forward biased and the diode D_2 is reverse biased. The forward current flows through diode D_1.

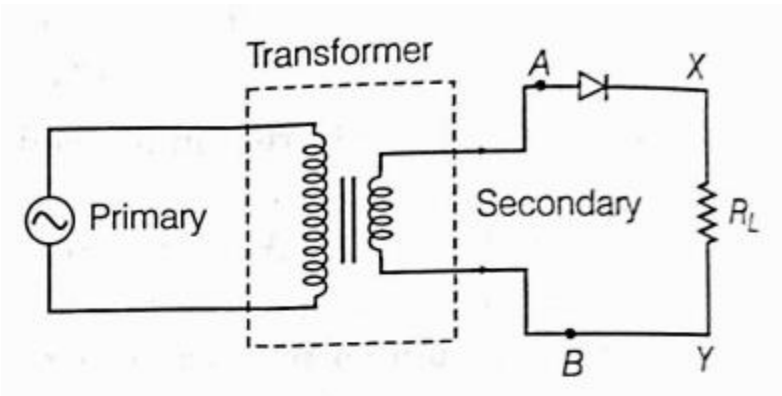
During the negative half cycle of the input AC, the diode D_1 is reverse biased and diode D_2 is forward biased. Thus, current flows through diode D_2. Thus, we find that during both the halves, current flows in the same direction

35. (i) The small region in the vicinity of the junction which is depleted of free charge carriers and has only immobile ions is called **depletion region**

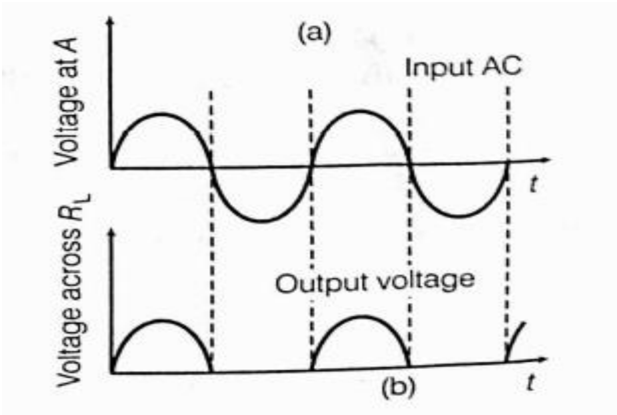


The accumulation of negative charges in the *p*-region and positive charge in the *n*-region sets up a potential difference across the junction. This acts as a barrier and is called barrier potential V_B.

(ii) ***p-n*** **Junction Diode as a Half-Wave Rectifier:** AC voltage to be rectified is connected to the primary coil of a step down transformer. Secondary coil is connected to he diode through resistors R_L, across which output is obtained.



Working: During positive half cycle of the input AC, the *p-n* junction becomes low and current flows. Hence, we get output in the load. During negative half cycle of the input AC, the *p-n* junction is reverse biased. Thus, the resistance of *p-n* junction is high and current does not flow. Hence, no output in the load. So, for complete cycle of AC, current flows through the load resistance in the same direction.



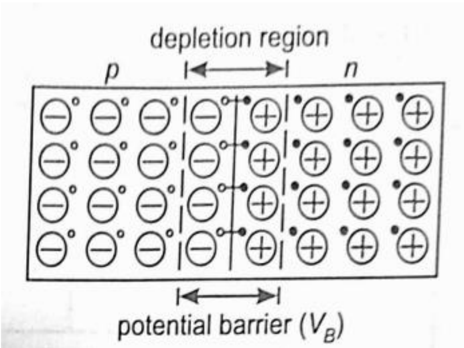
VERY LONG ANSWER TYPE QUESTION (5 MARK)

36. (i) Two process that take place during the formation of *p-n* junction are diffusion and drift of charge carriers.

In a *n*-type semiconductor, the concentration of electrons is more than that of holes. Similarly, in a *p*-type semiconductor, the concentration of holes is more than that of electrons. Formation of depletion region during formation of *p-n* junction and due to the concentration gradient across p and n-sides, holes diffuse from p-side to n-side (p→n) and electrons diffuse from n-side to p-side (n→p).

The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralize each other.

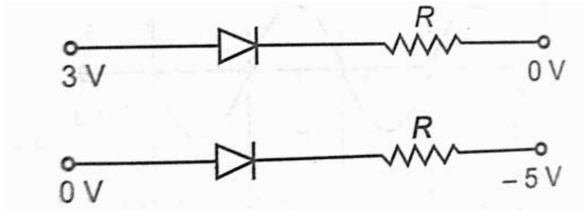
Thus, near the junction, positive charge is built on *n*-side and negative charge on *p*-side.



This sets up up potential difference across the junction and an internal electric field E_i directed from *n*-side to *p*-side. The equilibrium is established when the field E_i becomes strong enough to stop further diffusion of the majority charge carriers (However, it helps the minority charge carriers to drift across the junction). The region on either side of the junction which becomes depleted(free) from the mobile charge carriers is called **depletion region** or depletion layer.The potential difference developed across the depletion region is called the **potential barrier.**

(ii) **Forward biasing of a *p-n* junction**

(a) A *p-n* junction is said to be forward biased when *p*-region is maintained at a higher potential with respect to the n-region as shown below.

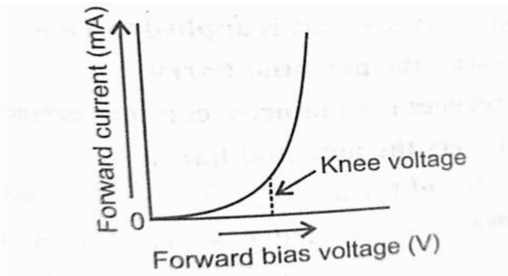


(b) When forward biased, majority charge carriers in both the regions are pushed through the junction. The depletion region's width decreases and the junction offers low resistance, and potential difference across the junction becomes $V_B - V$.

Forward characteristics of *p-n* junction diode:

It is a graphical relation between the forward bias voltage applied and the forward current flowing through the diode. As long as the forward bias voltage is less than the barrier potential, no current flows. But when a forward bias voltage(V) is greater than barrier potential applied, an almost linear forward bias voltage current (≈ a few mA) flow due to the flow of majority carriers. For diodes, we define a quantity, called dynamic resistance, as the ration of small change in voltage ΔV to a small change in current ΔI,

This forward voltage at which flow of current increasing quickly is known as knee voltage.



p-n i.e. $r_d = \frac{\Delta V}{\Delta I}$

37. (i) A p-n junction consists of wafers of *p*-type and n-type semiconductors fused together or grown on each other.

(a) Depletion region

(i) It is a region near the *p*-n junction that is depleted of any mobile charge carrier. It consists of immobile ion cores.

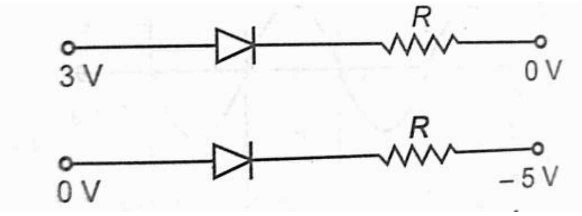
(ii) The depletion width depends on:

(i) the type of biasing, and (ii) extent of doping

(b) Potential Barrier (V_B): Due to the accumulation of immobile ion cores in the junction, a potential difference is developed which prevents the further movement of majority charge carriers across the junction.

(ii). (a) **Forward biasing of a *p-n* junction**

A *p-n* junction is said to be forward biased when *p*-region is maintained at a higher potential with respect to the n-region as shown below.



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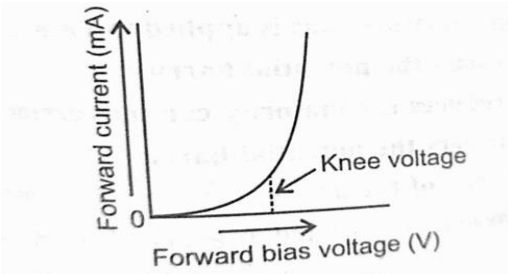
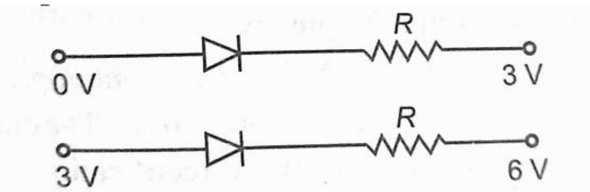


p-n i.e. $r_d = \frac{\Delta V}{\Delta I}$

(b) Reverse biasing of a *p-n* junction

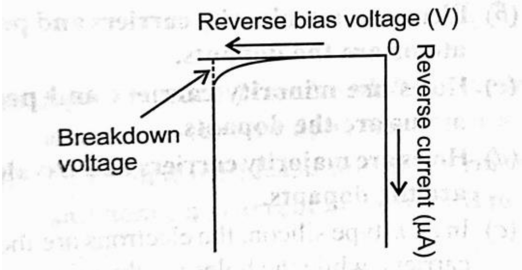
A *p-n* junction is said to be reverse biased when its *p*-region is maintained at a lower potential with respect to its *n*-region as shown below.



When the junction is reverse biased, the majority charge carriers in both the regions are pushed away from the junction. The depletion regions width increases and the potential difference across the junction becomes, $V + V_B$.

Reverse characteristics of a junction diode: It is a graphical relation between the reverse bias voltage applied and the reverse current flowing (if any) the diode. In this case, the majority carriers in both *p*-region and n-region move away from the junction so that no majority current flows. However, minority carriers cross over the junction constituting a small current

(≈ a few µA) which is called minority current which almost remains constant with the change in bias. It is called reverse saturation current. As the magnitude of the reverse bias voltage is increased, the leakage current also rises gradually. At a particular reverse bias voltage, the reverse current increases abruptly (i.e. it becomes very large suddenly). The reverse bias voltage at which the reverse current rises abruptly, is called **Breakdown voltage)**.



38. (i) Two process that take place during the formation of *p-n* junction are diffusion and drift of charge carriers.

In a *n*-type semiconductor, the concentration of electrons is more than that of holes. Similarly, in a *p*-type semiconductor, the concentration of holes is more than that of electrons. Formation of depletion region during formation of *p-n* junction and due to the concentration gradient across p and n-sides, holes diffuse from p-side to n-side (p→n) and electrons diffuse from n-side to p-side (n→p).

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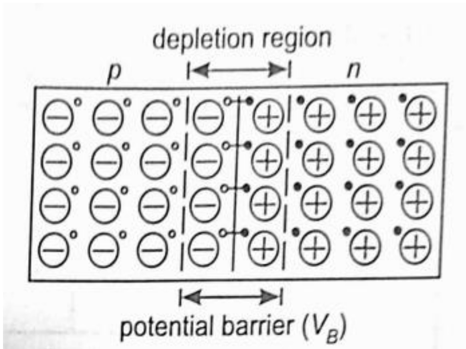

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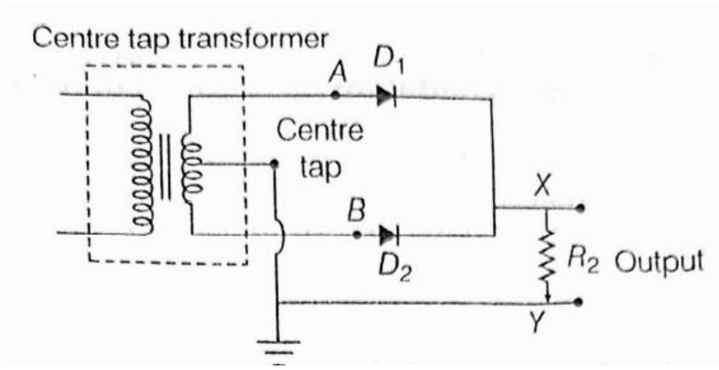

Working:

During the positive half cycle of the input AC, the diode D_1 is forward biased and the diode D_2 is reverse biased. The forward current flows through diode D_1.

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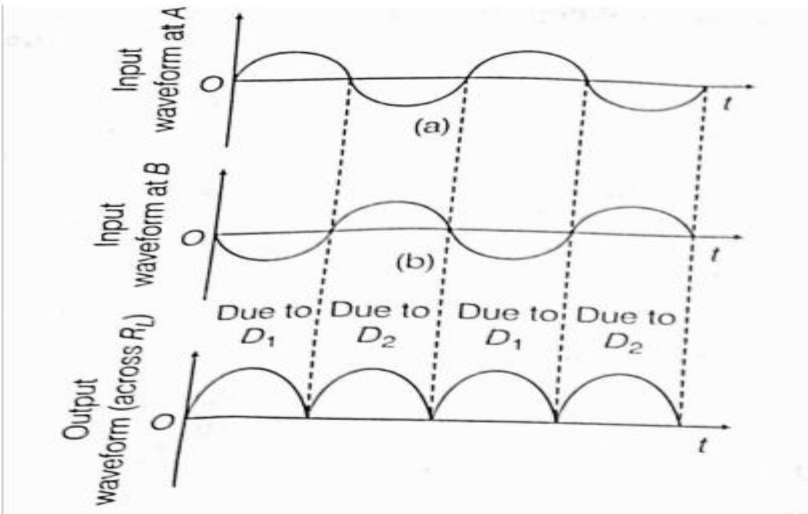


39. (b)

40. (c)

41. (c)

42. (d)

43. (b)

44. (i) (d)

    (ii) (d)

    (iii) (a)

    (iv) (d)

    (v) (a)

BLUE PRINT, SAMPLE PAPER & MARKING SCHEME 2022-23

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

BLUE PRINT SAMPLE PAPER-1 (SESSION 2022-23)

CLASS – XII (PHYSICS)

BLUE PRINT Time : 3 hrs

Class : XII Max. Marks:70

PHYSICS

S.No	UNIT	MCQ (1 MARK)	SA I (2 MARKS)	SA II (3 MARKS)	LA (5 MARKS)	CASE STUDY	TOTAL	MARKS
1	ELECTROSTATICS	2(2)	2(1)		5(1)		9(4)	16
2	CURRENT ELECTRICITY	2(2)	-		5(1)		7(3)	
3	MAGNETIC EFFECTS OF CURRENT AND MAGNETISM	3(3)	2(1)	3(1)	-		8(5)	17
4	ELECTROMAGNETIC INDUCTION AND A.C.	3(3)		6(2)	-		9(5)	
5	E.M.WAVES	1(1)	2(1)		-		3(2)	18
6	OPTICS	2(2)	4(2)		5(1)	4(1)	15(6)	
7.	DUAL NATURE OF MATTER AND RADIATIONS	2(2)	-	3(1)	-		5(3)	12
8.	ATOMS AND NUCLEI	2(2)	2(1)	3(1)	-		7(4)	
9.	ELECTRONIC DEVICES	1(1)	2(1)			4(1)	7(3)	07
	TOTAL	**18(18)**	**14(7)**	**15(5)**	**15(3)**	**8(2)**	**70(35)**	**70**

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

SAMPLE PAPER-1 (SESSION 2022-23)

CLASS – XII (PHYSICS)

MAX. MARK: 70 TIMES ALLOWED: 3 HOURS

General Instructions:

(1) There are 35 questions in all. All questions are compulsory

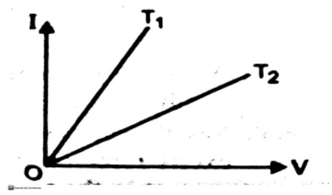
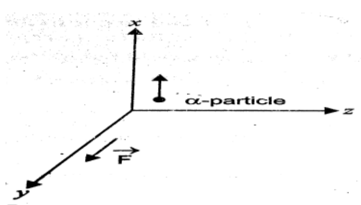
(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.

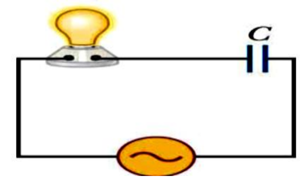
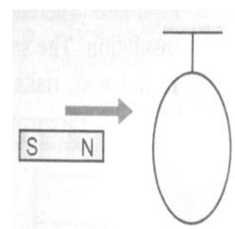
(3) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.

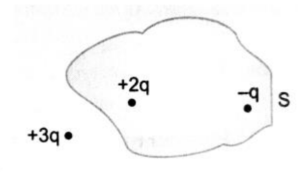
(4) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.

5. Use of calculators is not allowed.

SECTION A

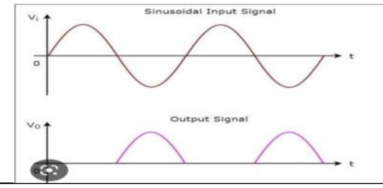
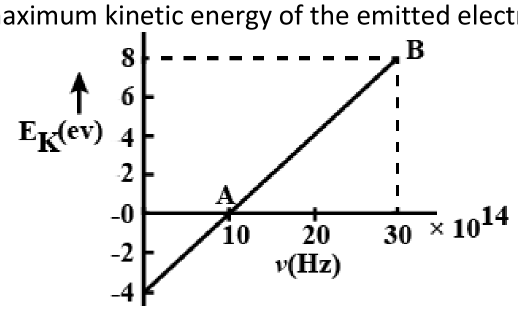
Q.NO.		MARKS
1	The force experienced by a unit positive test charge placed at a point is called (i)The magnetic field at that point (ii)The gravitational field at that point (iii)The electrical field at that point (iv)The nuclear field at that point	1
2	The electric potential on the axis of an electric dipole at a distance' r' from its centre is V .Then the potential at a point at the distance 2r on its equatorial line will be (i) 2V. (ii) -V (iii) V/2. (iv) Zero	1
3	V-I graph for a metallic wire at two different temperatures T1 and T2 is as shown in figure. (i) T1=T2 (ii) T1>T2. (iii) T2>T1. (iV) T1=T2=0  	1
4	A beam of alpha particles projected along + x-axis, experiences a force due to a magnetic field along the + y axis .What is direction of magnetic field. (i) along +z axis (ii) along -z axis (iii) along - y axis. (iv) along -x axis  	1
5	An electron does not suffer any deflection while passing through a region of uniform magnetic field what is direction of magnetic field. (i) perpendicular to direction of motion of electron (ii) parallel of direction of electron (iii) may be both above cases (iv) None of the above cases	1

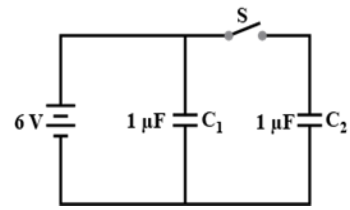
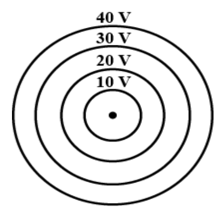
6	What are units of magnetic permeability? (i) Tesla (ii) Tesla/ampere (iii) Tesla metre/ ampere (iv) Tesla/metre^2	1
7	A capacitor is connected in series with an electric bulb with an AC source as shown in figure . What happen when capacitance of capacitor is increased (i)Glow of bulb enhanced (ii) Glow of blub reduces (iii) glow of bulb remains same (iv) None of the above 	1
8	Identify the part of electromagnetic spectrum which is (i) suitable for radar system used in aircraft navigation (ii) adjacent to the low frequency end of electromagnetic spectrum. (i) Gamma rays, X-rays (ii) X-rays, Gamma rays (iii) Radiowaves, Microwaves (iv) Microwaves,Radiowaves	1
9	Copper ring is suspended by a thread in a vertical plane . One end of a magnet is brought horizontally towards the ring . How will the position of ring be affected?  (i) Ring will move away from the magnet (ii) Ring will move upwards (iii) Ring will move downwards (iv) Ring will move towards the magnet	1
10	A small ink dot on a paper is viewed through a glass slab of thickness 10 cm ; and refractive index 1.5. By what distance would the dot appear to be raised? (i) 5cm. (ii) 6.67cm. (iii) 7.67 cm. (iv) 3.33cm	1
11	The work function of Aluminum is 4.2 eV. Find the threshold wavelength for the photoelectric emission. (i) 2062.5A° (ii) 3000A° (iii) 2955A° (iv) 4125A°	1
12	The radius of the innermost electron orbit of hydrogen atom is 0.529 A°. The radius of the n = 2 orbit is (i) 2.116A° (ii) 1.058 A° (iii) 0.529A° (iv) 4.669 A°	1
13	Which of the following best define nuclear forces? i) The attraction between protons and neutrons ii) Repulsion between protons and neutrons iii) The attraction between protons and electrons iv) The attraction between electrons and neutrons	1
14	The instantaneous current from an AC source is given by I = 5 sin 314. What is The RMS value of the current. (i) 5A. (ii) 7.07 A. (iii) 314A. (iv) 3.54A	1

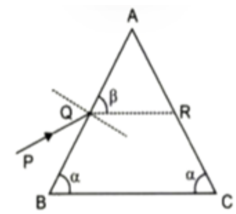
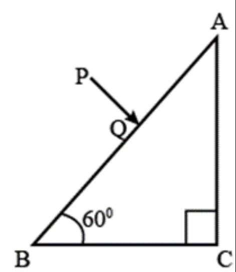
15	Given figure shows 3 point charges. What is the electric flux due to this configuration through the surface S (i) q/2ε (ii) 2q/ ε (iii) q/ ε. (iv) 0  	1
16	Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below. a) Both A and R are true and R is the correct explanation of A b) Both A and R are true and R is NOT the correct explanation of c) A is true but R is false d) A is false and R is also false ASSERTION (A): The electrical resistivity of a semiconductor increases on doping. REASON(R): Doping always increases the number of electrons in the semiconductor.	1
17	Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below. a) Both A and R are true and R is the correct explanation of A b) Both A and R are true and R is NOT the correct explanation of c) A is true but R is false d) A is false and R is also false ASSERTION: In young's double slit experiment , bright and dark fringes are obtained on screen REASON: Young's double slit experiment show wave nature of light.	1
18	Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below. a) Both A and R are true and R is the correct explanation of A b) Both A and R are true and R is NOT the correct explanation of A c) A is true but R is false d) A is false and R is also false ASSERTION: Photoelectric current increases with increase in intensity of incident radiations incident on emitter plate. REASON: Number of photons per second decreases with increase in intensity.	1

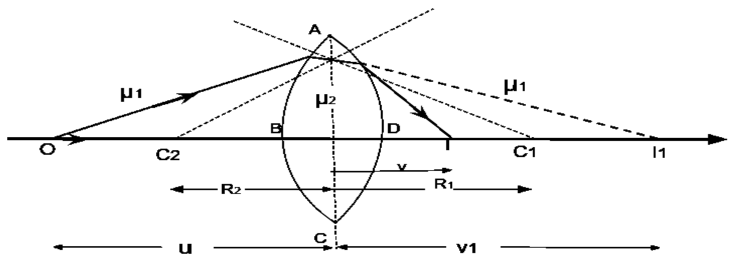
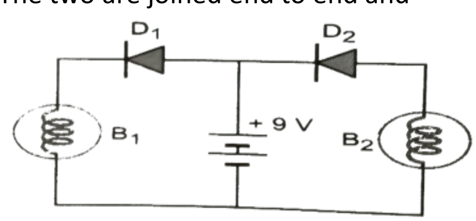
Section- B

19	(i) What oscillates in em waves . (ii) What is the physical quantity which is same for X-rays of wavelength 1 A°, red light of wavelength 6800A°, radio waves of wavelength 500 m.	2
20	To identical specimens of magnetic materials Nickel and Aluminum are kept in non uniform magnetic field . Draw the magnetic field lines in both cases . How magnetic susceptibility of nickel and Aluminum are different to each other.	2
21	The short wavelength limit for Balmer series of hydrogen spectrum is 3646.8A°. Calculate the short wavelength limit for Paschen series of the hydrogen spectrum.	2

22	A magician during the show makes a glass lens of refractive index 1.5 disappear in a trough of liquid .What is the refractive index of the liquid? Is the liquid water? justify your answer.	2
23	Differentiate p-type and n-type semiconductor on the basis of energy band diagrams .Why are they neutral although having different unequal no. of free electron and holes? OR Observe below waveform and identify the electronic device. How it works.  	2
24	In a single slit diffraction experiment, the width of the slit is reduced to half its original width. How would this affect the size and intensity of the central maximum? How diffraction fringe pattern obtained on screen is different from interference pattern obtained on screen?	2
25	Using Gauss's law in electrostatics derive an expression for electric field due to uniformly charged infinite plane sheet.	2
	SECTION-C	
26	State Biot-Savart's law. Obtain expression for magnetic field at the centre of the circular coil carrying current.	3
27	(i) State Faraday's law of electromagnetic induction. (ii) What do you understand by the term self inductance ?	3
28	An AC source generating a voltage $V=V_0$ sinwt is connected to a LCR circuit in series.With the help of suitable phasor diagram, Obtain the relation for impedance in an AC series LCR circuit.. OR What does the term "Wattless current or Idle current" mean? How this term is related to power factor?	3
29	In an experiment on photoelectric effect, the graph between maximum kinetic energy and frequency of emitted photoelectron for metal surface is found to be straight line.Calculate (i) threshold frequency. (ii) work function of a metal in electron volt. (iii) maximum kinetic energy of the emitted electron by light of frequency 30 × 10^14  hz	
30	X-rays of wavelength 0.82 A° fall on a metal plate. Find the de_Broglie wavelength associated with photoelectron emitted. Calculate work function of the metal.	3

	SECTION D	
31	(i) Why is the electrostatic potential inside a charged conducting shell constant throughout the volume of the conductor? (ii) Figure shows two identical capacitors, C_1 and C_2, each of 1 mF capacitance connected to a battery of 6 V. Initially switch S is closed. After sometimes S is left open and dielectric slabs of dielectric constant K = 3 are inserted to fill completely the space between the plates of the two capacitors. How will the (a) charge and (b) potential difference between the plates of the capacitors be affected after the slabs are inserted?  (i) Concentric equipotential surfaces due to a charged body placed at the centre are shown. Identify the polarity of the charge and draw the electric field lines due to it.  (ii) (a) Define electric flux. Write its SI unit. (b) “Gauss’s law in electrostatics is true for any closed surface, no matter what its shape or size is.” Justify this statement with the help of a suitable example.	
32	(i) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. (ii) Two cells of emfs 1.5 V and 2.0 V having internal resistances 0.2 Ω and 0.3 Ω respectively are connected in parallel. Calculate the emf and internal resistance of the equivalent cell. **OR** (i) State the two Kirchhoff’s rules used in the analysis of electric circuits and explain them. (ii) Derive the equation of the balanced state in a Wheatstone bridge using Kirchhoff’s laws.	

33	 (i) How would the diffraction pattern of a single slit be affected when: (a) the width of the slit is decreased? (b) the monochromatic source of light is replaced by a source of white light? (ii) A ray of light incident on the face AB of an isosceles triangular prism makes an angle of incidence 'i' and deviates by angle β as shown in the figure. Show that in the position of minimum deviation ∠α = ∠β. Also find out the condition when the refracted ray QR suffers total internal reflection. **OR** i) Write two points of difference between the phenomena of interference and diffraction. ii) A ray PQ incident normally on the refracting face BA is refracted in the prism BAC made of material of refractive index 1.5. Complete the path of ray through the prism. From which face will the ray emerge? Justify your answer. 	
	Section E	
34	**Case Study : Lens Maker Formula** **Read the following paragraph and answer the questions** The lens makers formula relates the focal length of a lens to the refractive index of its material and the radii of curvature of its two surfaces . This formula is used to manufacture a lens of particular focal length from the glass of a given refractive index. For this reason , it is called the lens makers formula.	

	 (i) An unsymmetrical double convex thin lens forms the image of a point object on its axis. Will the position of the image change if the lens is reversed? (ii) Will the focal length of a lens for red light be more, same or less than that for blue light? (iii) The radii of curvature of both the surfaces of a lens are equal. If one of the surfaces is made plane by grinding, then will the focal length of lens change? Will the power change? **OR** A convex lens made of a material of refractive index n_1 is kept in a medium of refractive index n_2. Parallel rays of light are incident on the lens. Complete the path of rays of light emerging from the convex lens if: (i) $n_1 > n_2$ (ii) $n_1 < n_2$.	
35	**Case Study : Biasing of Diode** **Read the following paragraph and answer the questions** When the diode is forward biased, it is found that beyond forward voltage $V = V_k$, called knee voltage, the conductivity is very high. At this value of battery biasing for p-n junction, the potential barrier is overcome and the current increases rapidly with increase in forward voltage. When the diode is reverse biased, the reverse bias voltage produces a very small current about a few microamperes which almost remains constant with bias. This small current is reverse saturation current. (i) In the following diagram, which bulb out of B_1 and B_2 will glow and why? (ii)What happens to the width of depletion layer of a p-n junction when it is (a) forward biased, (b) reverse biased? (iii) Two semiconductor materials X and Y shown in the alongside figure, are made by doping a germanium crystal with indium and arsenic respectively. The two are joined end to end and connected to a battery as shown.  (a) Will the junction be forward biased or reverse biased? (b) Sketch a V-I graph for this arrangement. OR Draw V-I characteristics for forward and reverse biased diode.	

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

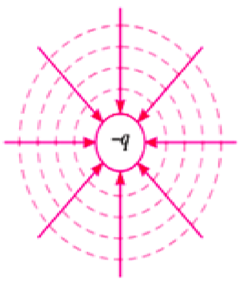
MARKING SCHEME SAMPLE PAPER-1 (SESSION 2022-23)

CLASS – XII (PHYSICS)

MAX. MARK: 70 TIMES ALLOWED: 3 HOURS

	Section-A	
1	(iii)	
2	(iv)	
3	(iii)	
4	(ii)	
5	(ii)	
6	(iii)	
7	(i)	
8	(iv)	
9	(i)	
10	(iv)	
11	(iii)	
12	(i)	
13	(i)	
14	(iv)	
15	(iii)	
16	(d)	
17	(a)	
18	(c)	
	SECTION-B	
19	(i)Electric and magnetic fields (ii)Speed	1,1
20	Nickel is more ferromagnetic than aluminium.	1,1

21	818.9 nm.	2
22	Same refractive index. Give justification from lens maker's formula .	1,1
23	Difference They are formed out of mixing neutral semiconductor and neutral dopes. Or Electronic device is Half wave rectifier . Give working.	1, 1 1,1
24	Double size and ¼ th intensity Difference between both patterns	½ + ½ 1
25	Derivation	2
	SECTION-C	
26	Statement Derivation	1,2
27	Faraday's law Expression for self inductance.	1+2
28	Correct expression Or Correct expression	3
29	Threshold frequency= 3×10^14 per second Work function=1.25 eV Kinetic energy= 3×10^-19 J	1,1,1
30	Wavelength=0.999A°	1.5 1.5
31	(i) Since E = 0 inside the conductor & has no tangential component on the surface. Therefore no work is done in moving charge inside or on the surface of the conductor and potential is constant. (ii) When switch S is closed, p.d. across each capacitor is 6V $V_1 = V_2 = 6$ V $C_1 = C_2 = 1$ μF ∴ Charge on each capacitor $q_1 = q_2 = CV = (1\ \mu F) \times (6\ V) = 6\ \mu C$	2,.5,.5,1,1

	When switch S is opened, the p.d. across C_1 remains 6 V, while the charge on capacitor C_2 remains 6 μC. After insertion of dielectric between the plates of each capacitor, the new capacitance of each capacitor becomes $C'_1 = C'_2 = 3 \times 1$ μF = 3 μF (i) Charge on capacitor C_1, $q'_1 = C'_1 V_1 = (3\ \mu F) \times 6\ V = 18\ \mu C$ Charge on capacitor C_2 remains 6 μC (ii) Potential difference across C_1 remains 6 V. Potential difference across C_2 becomes $V'_2 = \frac{q_2}{C'_2} = \frac{6\ \mu C}{3\ \mu C} = 2V$ **OR** **(i) For a single charge the potential ig given as** $V = \frac{KQ}{r}$ This shows that V is constant if r is constant. Greater the radius smaller will be the potential. In the given figure, potential is increasing. This shows that the polarity of charge is negative (– q). The direction of electric field will be radially inward. The field lines are directed from higher to lower potential.  **(ix)** (a) Definition + SI unit According to Gauss theorem, the electric flux through a closed surface depends only on the net charge enclosed by the surface and not upon the shape or size of the surface. For any closed arbitrary shape of the surface enclosing a charge the outward flux is the same as that due to a spherical Gaussian surface enclosing the same charge. Justification: This is due to the fact that electric field is radial and the electric field $E \alpha \frac{1}{R^2}$. Thus, electric field at each point inside a charged thin spherical shell is zero.	
32	(i) Derivation for $\rho = \frac{m}{ne^2\tau}$ (ii) $E_1 = 1.5V$, $r_1 = 0.2\ \Omega$ $E_2 = 2.0\ V$, $r_2 = 0.3\ \Omega$ emf of equivalent cell E= 1.7V	2,2,1

<table>
<tr><td></td><td>Internal resistance of equivalent cell r = 0.12Ω</td><td></td></tr>
<tr><td>33</td><td>

i) From the relation ϴ= λ/a we find that if the width of the slit (a) is decreased, then for a given wavelength, sin θ is large and hence θ is large. Hence diffraction maxima and minima are quite distant on either side of θ.

ii) With monochromatic light, the diffraction pattern consists of alternate bright and dark bands. If white light is used central maximum is white and on either side, the diffraction bands are coloured.

Proving α = β

Finding i_c **= A- (9o⁰ – β)**

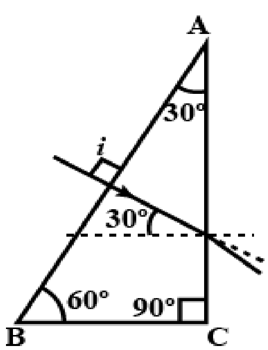
OR

<table>
<tr><td>Interference</td><td>Diffraction</td></tr>
<tr><td>It is due to the superposition of two waves coming from two coherent sources.</td><td>It is due to the superposition of secondary wavelets originating from different parts of the same wavefront.</td></tr>
<tr><td>The width of the interference bands is equal</td><td>The width of the diffraction bands is not the same</td></tr>
<tr><td>The intensity of all maxima (fringes) is same</td><td>The intensity of central maximum is maximum and goes on decreasing rapidly with increase in order of maxima.</td></tr>
</table>

Path of emergent ray

Naming the face

Justification



</td><td>1,1,2,1</td></tr>
<tr><td>34</td><td>No, the reversibility of the lens makes equation. For convex lens,
$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = -(n-1)\left(\frac{1}{R_2} - \frac{1}{R_1}\right)$</td><td>1,1,1.5,.5</td></tr>
</table>

	On reversing the lens, values of R_1 and R_2 are reversed and so their signs. Hence, for a given position of object (u), position of image (v) remains unaffected As the refractive index for red is less than that for blue , $\frac{1}{f} \alpha \ (n-1)$ parallel beams of light incident on a lens will be bent more towards the axis for blue light compared to red. Thus the focal length for red light will be more than that for blue Focal length of lens $\frac{1}{f} = (n-1)\ (\frac{1}{R} + \frac{1}{R})$ f = $\frac{R}{2(n-1)}$ When one surface is made plane $\frac{1}{f} = (n-1)\ (\frac{1}{R} + \frac{1}{\infty})$ f' = $\frac{R}{(n-1)}$ = 2f . That is, the focal length will be doubled. As P $= \frac{1}{f}$, so power will be halved OR In case (i) $n_1 > n_2$, the lens behaves as convergent lens. In case (ii) $n_1 < n_2$, the lens behaves as a divergent lens	
35	Bulb B_1 will glow as diode D_1 is forward biased. (a)When forward biased, the width of depletion layer decreases. (b) When reverse biased, the width of depletion layer increases. (a) Reverse biased (b) V-I characteristics	1, .5,.5,1,1

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

BLUE PRINT SAMPLE PAPER-2 (SESSION 2022-23)

CLASS – XII (PHYSICS)

Sl. No.	Name of the Chapter	MCQ (1 Mark)	VSA (2 Marks)	SA (3 Marks)	LA (5 Marks)	Case study(4Marks)	Total
1	Electric Charges and Field	1			1		6
2	Electrostatic Potential and Capacitance	2		1			5
3	Current Electricity				1		5
4	Moving Charges and Magnetism	3	1				5
5	Magnetism and Matter					1	4
6	Electromagnetic Induction	1		1			4
7	Alternating Current	2	1				4
8	Electromagnetic Waves	1	1				3
9	Ray Optics and Optical Instruments	2		1	1		10
10	Wave Optics		1	1			5
11	Dual Nature of Radiation and Matter		1	1			5
12	Atoms	2	1				4
13	Nuclei	1	1				3
14	Semiconductor Electronics: Materials, Devices and SimpleCircuits	3				1	7
		18	7	5	3	2	70

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

SAMPLE PAPER-2 (SESSION 2022-23)

CLASS – XII (PHYSICS)

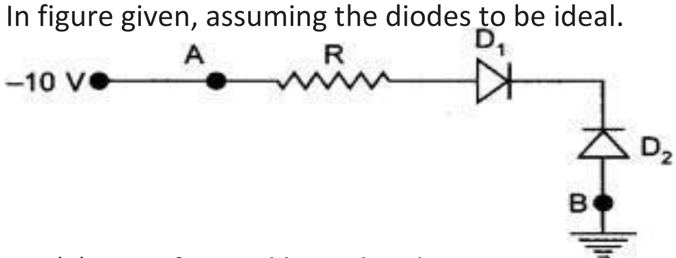
MAX. MARK: 70 TIMES ALLOWED: 3 HOURS

General Instruction:

- There are 35 questions in all. All questions are compulsory.
- This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
- Section A 18 MCQ of 1 mark each, section B contains seven questions of two marks each, Section C contains five questions of 3 marks each, Section D contains Three long questions of 5 marks each And Section E contains two case study base questions of 4 marks each.
- There is no overall choice. However, an internal choice has been provided in section B, C, D and E. you have to attempt only one of the choices in such questions.
- Use of calculators or any other electronics devices are not allowed.

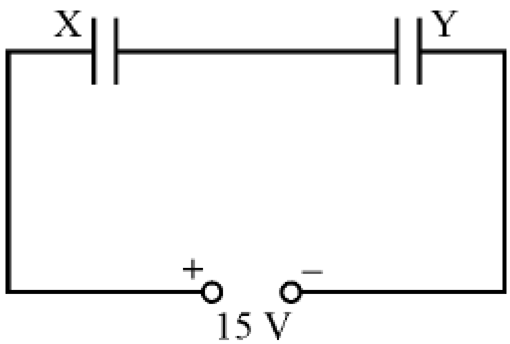
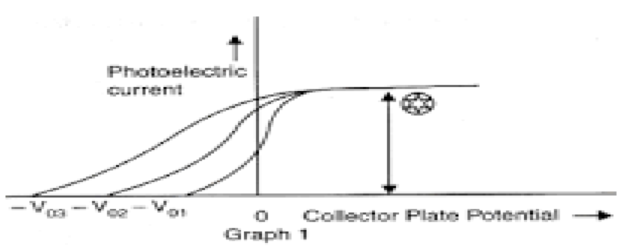
SECTION A:

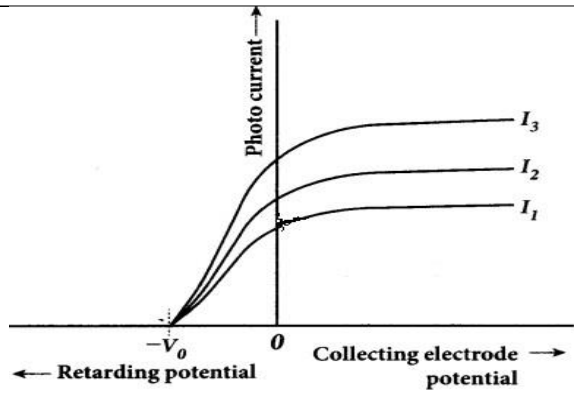
Q. No.		MARKS
1.	What is the flux through a cube if q is at one corner of the cube? (a) q/ϵ_0 b)$2q/\epsilon_0$ c) $q/8\epsilon_0$ d) $q/4\epsilon_0$	1
2	A parallel plate air capacitor having a capacitance 'C' is half-filled by a medium of dielectric constant 5. What % change will be there in the capacitance of the capacitor? (a) 200% increase (b) 400% decrease (c) 400% increase (d) 66.6% increase	1
3	An electric charge 10^{-3} μC is placed at the origin (0,0) of (x, y) co-ordinate system. Two points A and B are situated at ($\sqrt{2}$, $\sqrt{2}$) and (2,0) respectively. The potential difference between the points A and B will be: (a) 4.5 V (b) Zero (c) 2.0V (d) 9.0V	1
4	An electron is moving in a region of electric field and magnetic field, it will gain energy from, (a) Electric Field (b) Magnetic Field (c) Both (d) none of these	1
5	To convert a galvanometer into an ammeter of given range, a____resistance is connected in____ with the galvanometer. (a) Low, series (b) low, parallel (c) high, parallel (d)High, parallel	1

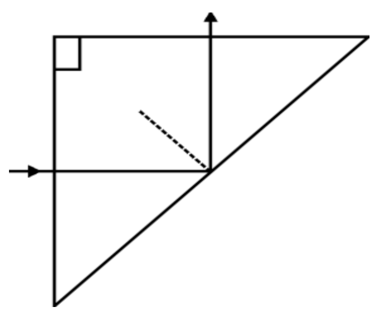
6	In the α- particle scattering experiment, the shape of the trajectory of the α-particles depend upon: (a) only on impact parameter (b) only on the source of α - particles. (c) both impact parameter and source of α-particles (d) impact parameter and the screen material of the detector.	1
7	Lenz's law of electromagnetic induction is as per law of conservation of: (a) Energy b) angular momentum c) charge d) mass	1
8	In an AC circuit V and I are given by $V = 50 \sin 50t$ Volt and $I = 100 \sin (50t + \pi/3)$ mA. The power dissipated in the circuit (a) 2.5 kW b) 1.25 kW c) 5.0 kW d) 500 W	1
9	The output of a step-down transformer is measured to be 24 V when connected to a 12 W light bulb. The value of the peak current is (a) $1/\sqrt{2}$ A b) 2 A c) $2\sqrt{2}$ A d) 18 A	1
10	Which of the following E M wave has the highest wave length? (a) X- Ray (b) Micro Wave (c) U-V Rays (d) Infrared Rays	1
11	When a ray is refracted, which of the following does not change (a) Frequency b) wavelength c) velocity d) amplitude	1
12	A person standing in front of a mirror finds his image larger than himself. This implies that the mirror is: (a) Convex (b) parabolic (c) plane (d) concave	1
13	Find the ratio of maximum wavelength of minimum wavelength for the lines of Balmer series in hydrogenspectrum. (a) 5/9 b) 9/5 c) 5/36 d) 1/4	1
14	In figure given, assuming the diodes to be ideal.  (a) D1 is forward biased and D2 is reverse biased and hence current flows from A to B. (b) D2 is forward biased and D1 is reverse biased and hence no current flows from B to A and viceversa.	1

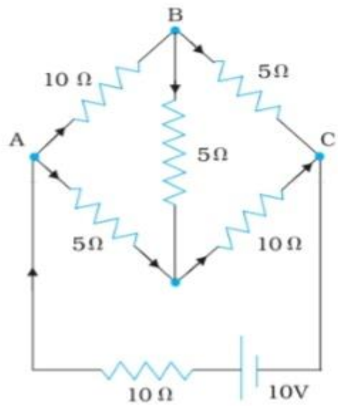
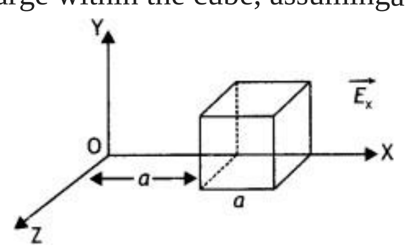
	(c) D1 and D2 are both forward biased and hence current flows from A to B. (d) D1 and D2 are both reverse biased and hence no current flows from A to B and vice versa.	
15	Which of the following statements is incorrect for the depletion region of a diode? (a) There the mobile charges exist. (b) Equal number of holes and electrons exist, making the region neutral. (c) Recombination of holes and electrons has taken place. (d) None of these	1
16	**Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Selectthe correct answer to these questions from the codes (a), (b), (c) and (d) as given below.** **Both A and R are true and R is the correct explanation of A** **Both A and R are true and R is NOT the correct explanation of A** **A is true but R is false** **A is false and R is also false** **Assertion (A)**: When a pure semiconductor is doped with a pentavalent impurity, the number ofconduction electrons is increased while the number of holes is decreased. **Reason (R):** Some of the holes get recombined with the conduction electrons as the concentration ofthe conduction electrons is increased	1
17	**Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Selectthe correct answer to these questions from the codes (a), (b), (c) and (d) as given below.** **Both A and R are true and R is the correct explanation of A** **Both A and R are true and R is NOT the correct explanation of A** **A is true but R is false** **A is false and R is also false** **Assertion (A)**: The voltage sensitivity may not necessarily increase on increasing the currentsensitivity. **Reason (R)**: Current sensitivity increases on increasing the number of turns of the coil	1
18	**Two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Selectthe correct answer to these questions from the codes (a), (b), (c) and (d) as given below.** **Both A and R are true and R is the correct explanation of A** **Both A and R are true and R is NOT the correct explanation of A** **A is true but R is false**	1

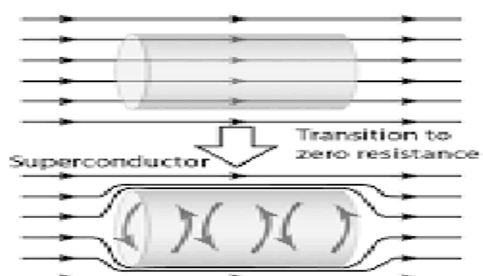
	A is false and R is also false **Assertion (A**): Initially, it was believed that mass and energy are conserved separately in a nuclear reaction. **Reason (B):** According to Einstein, one can convert mass-energy into other forms of energy	
	SECTION B (VERY SHORT QUESTIONS)	
19	An α particle and a β particle are projected with the same velocity perpendicular to a magnetic field. Which one will experience more force?	2
20	The power factor of an a.c. circuit 0.5. What is the phase difference between voltage and current inthe circuit?	2
21	Arrange the following electromagnetic waves in the descending order of their wavelength: Microwave, infrared rays, ultraviolet radiation, Y- rays.	2
22	In a single slit detraction experiment, first minimum of red light (660nm) coincides with the first maximum of some other wavelength λ. Calculate λ.	2
23	The radius of the first electron of the hydrogen atom is 5.3x10 -11 m. What is the radiusof the second orbit. **(OR)** The ground state energy of hydrogen atom is -13.6eV. What are the kinetic energy and potential energy of the electron in this state.	2
24	Write two main observations of photoelectric effect experiment which could only be explained by Einstein's photoelectric equation.	2
25	Define the' distance of closest approach. An a-particle of kinetic energy 'K' is bombarded on a thingold foil. The distance of the closest approach is 'r'. What will be the distance of closest approach for an α- particle of double the kinetic energy? **OR** Write two important limitations of Rutherford nuclear model of the atom.	2
	SECTION C (SHORT ANSWER TYPE QUESTION)	

26	Two parallel plate capacitors X and Y have the same area of plates and same separation betweenthem. X has air between the plates while Y contains a dielectric medium of εr = 4.  (i) Calculate capacitance of each capacitor if equivalent capacitance of the combination is 4 µF. (ii) Calculate the potential difference between the plates of X and Y. (iii) Estimate the ratio of electrostatic energy stored in X and Y.	3
27	Derive expression for self- inductance of a long air-cored solenoid of length l, cross-sectional area A and having number of turns N. **OR** Define mutual inductance. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with theother coil?	3
28	The graph shown in fig 1 and 2 are for the phenomenon of photoelectric effect  	3

	 (i) Identify which of the characteristics of(intensity/frequency) incident light, isbeing kept constant in each case. (ii) A metal has a work function of2eV and is illuminated by monochromatic lightof wavelength500nm (a) calculate the threshold wavelength (b) the stopping potential **OR** (i) Sketch the graph showing the variation of stopping potential with frequency ofincident radiation for two photo sensitive materials A and B having threshold frequencies νA >νB. (ii) In which case is the stopping potential more and why? (iii)Does the slope of the graph depend on the nature of the material? Explain.	
29	The work function of cesium is 2.14 eV. Find (a) the threshold frequency for caesium, (b) the wavelength of the incident light if the photocurrent is brought to zero by a stopping potentialof 0.60 V.	3
30	Define the term ‘critical angle’ for a pair of media. A point source of monochromatic light ‘S’ is keptat the centre of the bottom of a cylinder of radius 15.0 cm. The cylinder contains water (refractive index 4/3) to a height of 7.0 cm. Draw the ray diagram and calculate the area of water surface through which the light emerges in air.	3

	SECTION D (LONG ANSWER TYPE QUESTION)	
31	(a) Two thin lenses are placed coaxially in contact. Obtain the expression for the focal length of thiscombination in terms of the focal lengths of the two lenses. (b) A glass convex lens has a power of + 10 D +10D. When this lens is totally immersed in a liquid, it acts as a concave lens of focal length 50 c m 50cm. Calculate the refractive index of theliquid. Given. $^{a}n_{g} = 1.5$ **OR** (I) Plot a graph to show variation of the angle of deviation as a function of angle of incidence for light passing through a prism. Derive an expression for refractive index of the prism in terms of angle of minimum deviation and angle of prism. (II) A ray of light incident normally on one face of a right isosceles prism is totally reflected asshown in fig. What must be the minimum value of refractive index of glass? Give relevant calculations. 	5
32	(i) Define the term drift velocity. (ii) On the basis of electron drift, derive an expression for resistivity of a conductor in terms of number density of free electrons and relaxation time. On what factors does resistivity of a conductordepend? (iii) Why alloys like constantan and manganin are used for making standard resistors? **OR** (i) State kirchhoff's loop rule. (ii) Determine the current in each branch of the network shown in figure:	5

		
33	(a) Use Gauss's law to derive the expression for the electric field ($\vec{E}$) due to a straight uniformlycharged infinite line of charge λ Cm^{-1}. (b) Define electric flux and write its SI unit. The electric field components in the figure shown are: $E_x = \alpha x$, $E_y = 0$, $E_z = 0$ where $\alpha = 100N/cm$. Calculate the charge within the cube, assuminga = 0.1m.  **OR** **(i)** Derive an expression for the electric field at any point on the equatorial line of an electric dipole. **(ii)** Two identical point charges q each are kept 2m apart in air. A third point charge Q of unknown magnitude and sign is placed on the line joining the charges such that the system remains in equilibrium. Find the position and nature of Q.	
	SECTION E (CASE STUDY BASE QUESTION)	
34	Read the following paragraph and answer the questions. A p-n junction is a single crystal of Ge or Si doped in such a manner that one half portion of it acts as p-type semiconductor and other half functions as n-type	

	semiconductor. As soon as junction is formed, the holes from the p-region diffuse into the n-region and electrons from -region diffuse into p-region. This results in the development of potential barrier VB across the junction which opposes the further diffusion of electrons and holes through the junction. The small region in the vicinity ofthe junction which is depleted of free charge carriers and has only immobile ions is called the depletion region. (a) Why is germanium preferred over silicon for making semiconductor devices? (b) Which type of biasing results in a very high resistance of a p n junction diode. Drawa diagram showing this bias. (c) How does the width of the depletion region of a pn junction vary, if the reverse biasapplied to it decreases? (d) Name the 2 important processes involved in the formation of a p n junction.	
35	There exists a perfect diamagnet, namely, a superconductor. This is a metal at very low temperatures. In this case χ = –1, μr = 0, μ= 0. The external magnetic field is totally expelled. Interestingly, this material is also a perfect conductor. However, there exists no classical theory which ties these two properties together. A quantum-mechanical theory by Bardeen, Cooper, andSchrieffer (BCS theory) explains these effects. The BCS theory was proposed in1957 and was eventually recognised by a Nobel Prize in physics in 1970.  	

1. The value of magnetic susceptibility for a superconductor is
   (a) Zero
   (b) Infinity
   (c) +1
   (d) -1
2. Superconductors are
   (a) Insulators
   (b) Semiconductors
   (c) Conductors
   (d) Perfect conductors
3. Resistance of a superconductor is
   (a) Infinite
   (b) Zero
   (c) Maximum
   (d) Minimum
4. Which of the following is a property of superconductors?
   (a) Meissner Effect
   (b) Hall Effect
   (c) Photoelectric effect
   (d) Doppler effect

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

MARKING SCHEME SAMPLE PAPER-2 (SESSION 2022-23)

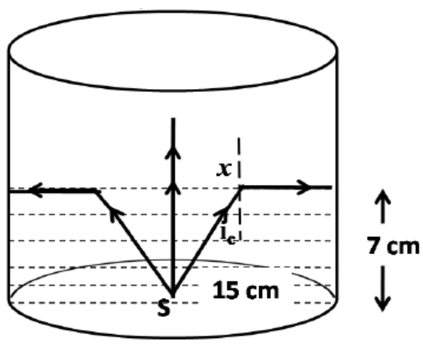
CLASS – XII (PHYSICS)

MAX. MARK: 70

1	Ans (c)
2	(d) 66.6% increase (Hint: Series combination of 2 capacitors of spacing d/2)
3	(b) Zero
4	$b)\ electric\ field$
5	$b)\ low, parallel$
6	Ans (a) only on impact parameter
7	Ans (a) Energy
8	Ans (a)
9	Ans (b)
10	Ans (b) micro-wave
11	Ans (a)
12	Ans (d)
13	Ans (b)
14	Ans (d)

	In circuit, A is at −10V and B is at 0V. So, B is positive than A. So, D2 is in forward bias and D1 is in reverse bias so no current flows from A to B or B to A
15	Ans (a) There the mobile charges exist
16	Ans (a) Both are correct and reason is correct explanation of Assertion
17	Ans (a) Both are correct and reason is correct explanation of Assertion
18	Ans (b) Both A and R are true and R is the correct explanation of A
19	$\vec{F} = q(\vec{v} \times \vec{B})$ (2) F α q α particle has more charge than βparticle. Hence α particle will experience moreforce.
20	Phase difference = 60˚ 2
21	microwave> Infrared > Ultraviolet > Y-Rays (2)
22	For diffraction minimum, sin Ɵ= n λ /d For diffraction maximum, sin Ɵ=(2n+1) λ /2d Λ= 2x660/3=440 nm (2)
23	r_n α n^2. $r_2/r_1=4$ (1) $r_2=2.12\times10^{-10}$m (1) OR K= +ve of total energy. K= 13.6eV (1) Potential energy= -13.6-13.6=-27.2eV (1)
24	(i) There in minimum frequency required for the incident light to produce photoelectric effect. (1) (ii) Stopping potential does not change with intensity of light. (1)

25	It is the distance of charged particle from the centre of the nucleus, at which the whole of the initial kinetic energy of the (far off) charged particle gets converted into the electric potential energy of thesystem. (½) Distance of closest approach (r) is given by, $r = 2Ze^4/4\pi\varepsilon_0 K$ ½ Therefor when K is doubled r becomes r/2 1 OR According to Rutherford model, electron orbiting around the nucleus, continuously radiates energydue to the acceleration; hence the atom will not remain stable. (1) As electron spirals inwards; its angular velocity and frequency change continuously; therefore itwill emit a continuous spectrum (1)
26	(i) Let Cx = C, Cy= 4C (1) For series combination C = CxCy / (Cx+Cy) 4 μF = 4C/5 C = 5 μF Cx = 5 μF, Cy = 20 μF (ii) Total charge Q = CV = 4 μF *15V = 60 μC (1) Vx = Q/ Cx = 60/5 = 12 V Vy = Q/ Cy =60/20 = 3 V (iii) Ex/ Ey = $(½ Q^2/CX) / (½ QY^2/CY)$ = 20/5 = 4:1 (1)
27	Derivation (2) OR Mutual inductance is numerically equal to the magnetic flux linked with a coil when the unit currentpasses through the neighbouring coil. Given M = 1.5 H, dl = 20 – 0 = 20 A,dt = 0.5 s, Φ = ? Φ = – Mdl/dt Φ = – 1.5 × 20/0.5 = – 60 Wb (1)

28	a) Intensity, frequency (1) b) $\lambda_0 = hc/\Phi_0 = 6.18\times10^{-7}$m (2) OR 1) graph (1) 2) V0=h/e (v-v0) V0 is more for B (1) 3) Slope = h/e so it does not depend on the material (1)
29	$\lambda = h/\sqrt{2mqv} = h/\sqrt{2mK}$ $m_d > m_p$ (1) for the same λ we must have $K_p > K_d$ (1) i.e proton has more kinetic energy (1)
30	For an incident ray, travelling from an optically denser medium to optically rarer medium, the angleof incidence, for which the angle of refraction is 90°, is called the critical angle. 1 $\mu = \frac{1}{\sin i_c}$ $i_c = \sin^{-1}\left(\frac{1}{\mu}\right)$ (2)  $\mu = \frac{1}{\sin i_c}$ $\sin i_c = \frac{3}{4}$ $\cos i_c = \frac{\sqrt{7}}{4}$ $\tan i_c = \frac{3}{\sqrt{7}}$ From figure, $\tan i_c = \frac{x}{7} \Rightarrow \frac{3}{\sqrt{7}} \Rightarrow \frac{x}{7} \Rightarrow x = 3\sqrt{7}$cm Area = $\pi x^2 = 63\pi$ cm^2
31	Diagram (1) Derivation (2)
32	i) Average velocity acquired by the electrons in the conductor in the presence of external electricfield. (1)

	We know that vd = - eEr/m Where E = V/l vd = - eVr/ml Current I = nAe vd = nAe^2 Vr / ml I/V = nAe^2 r / ml 1/R = nAe^2 r / ml RA/l = m/ ne^2r ρ = m/ ne^2r (2) (ii) Resistivity of the material of a conductor depends on the relaxation time, i.e., temperature and the number density of electrons. (1) (iii)Because constantan and manganin show very weak dependence of resistivity on temperature (1) **OR** Kirchhoff's loop rule (2) Current in Branch AB = $\frac{4}{17}$ Amp Current in branch BC = $\frac{6}{17}$ Amp Current In branch CD = $\frac{-4}{17}$ Amp Current in branch AD = $\frac{6}{17}$ Amp Current in branch BD = $\frac{-2}{17}$ Amp Total Current = $\frac{4}{17}+\frac{6}{17}-\frac{4}{17}+\frac{6}{17}-\frac{2}{17} = \frac{10}{17}$ Amp (3)

33	(a) Derivation (3) (b) Electric Flux is the dot product of the electric field and area vector.$\Phi = \oint \vec{E} \cdot \vec{ds}$ SI Unit: Nm^2/C or V-m For a given case $\Phi = \Phi 1 - \Phi 2 = [Ex(atx= 2a) - Ex(atx = a)]a^2$ $= [\alpha(2a)-\alpha(a)]a^2 = \alpha a^3$ $= 10^4 \times (0.1)^3 = 10\ Nm^2/C$ But $\Phi = q\varepsilon_0$ $\therefore q = \varepsilon 00\Phi = 8.854 \times 10^{-12} \times 10$ C = 8.54 Pc (2)
34	a. This is because the energy gap for Ge (E=0.7 eV) is smaller than the energy gapfor Si (E=1.1 eV). b. Reverse Bias, figure c. if the reverse bias decreases the width of the depletion region decreases. d. Drift and Diffusion
35	(i) b (ii) d (iii) b (iv) a

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

BLUE PRINT SAMPLE PAPER-3 (SESSION 2022-23)

CLASS – XII (PHYSICS)

MAX. MARK: 70 TIMES ALLOWED: 3 HOURS

UNIT NAME	TOTAL WEIGHTAGE	1MARK	2 MARKS	3 MARKS	4 MARKS	5 MARKS
ELECTROSTATICS	16	2	1	----------	----------	1*
CURRENT ELECTRICITY		2	1*	1	----------	--------
MAGNETIC EFFECTS OF CURRENT , MAGNETISM	17	----------	1	1	----------	1*
ELECTROMAGNETIC INDUCTION , ALTERNATING CURRENT		1	1*	-----------	1	------
ELECTROMAGNETIC WAVES	18	--------	--------	1*	--------	-------
OPTICS		5	1	1	---------	1*
DUAL NATURE OF MATTER AND RADIATION	12	4	1	-------------	-------------	--------
ATOMS AND NUCLEI		3	--------	1*	----------	---------
ELECTRONIC DEVICES	7	1	1	----------	1	----
TOTAL	70	18	7	5	2	3

. * internal choice is given

KENDRIYA VIDYALAYA SANGATHAN, GUWAHATI REGION

SAMPLE PAPER-3 (SESSION 2022-23)

CLASS – XII (PHYSICS)

MAX. MARK: 70 TIMES ALLOWED: 3 HOURS

General Instructions:

(1) There are 35 questions in all. All questions are compulsory

(2) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.

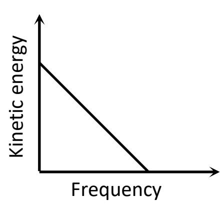
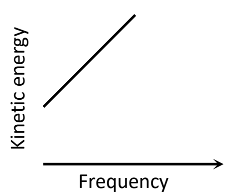
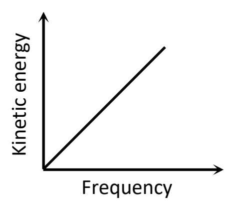
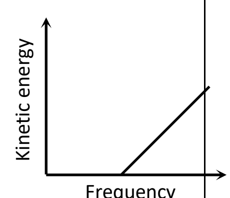
(3) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.

(4) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.

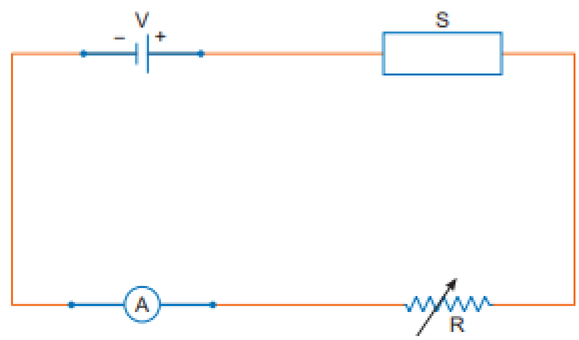
5. Use of calculators is not allowed.

Section – A

All questions are compulsory. In case of internal choices, attempt any one of them.		
1.	Which of the following is not a property of field lines? (a) Field lines are continuous curves without any breaks (b) Two field lines cannot cross each other (c) Field lines start at positive charges and end at negative charges They form closed loops	1
2.	What is angle between electric field and equipotential surface? 90° always (b) 0° always (c) 0° to 90° (d) 0° to180	1
3.	The plates of a parallel plate capacitor are 4 cm apart, the first plate is at 300 V and the second plate at – 100 V. The voltage at 3 cm from the second plate is 200 V (b) 400 V (c) 250 V (d) 500 V	1
4.	In a pure inductive circuit, the current (a) lags behind the applied emf by an angle π (b) lags behind the applied emf by an angle π / 2 (c) leads the applied emf by an angle π / 2 (d) and applied emf are in same phase	1
5.	If the focal length of objective lens is increased then magnifying power of (a) microscope will increase but that of telescope decrease (b) microscope and telescope both will increase (c) microscope and telescope both will decrease (d) microscope will decrease but that of telescope will increase	1
6.	Focal length of a convex lens of refractive index 1.5 is 2 cm. Focal length of lens, when immersed in a liquid of refractive index of 1.25 will be	1

	(a) 10 cm (b) 7.5 cm (c) 5 cm (d) 2.5 cm	
7.	In Young's experiment, monochromatic light is used to illuminate the slits A and B. Interference fringes are observed on a screen placed in front of the slits. Now if a thin glass plate is placed in the path of the beam coming from A, then (a) the fringes will disappear (b) the fringe width will increase (c) the fringe width will decrease (d) there will be no change in the fringe width	1
8.	Two waves having the intensities in the ratio of 9 : 1 produce interference. The ratio of maximum to minimum intensity is (a) 10 : 8 (b) 9 : 1 (c) 4 : 1 (d) 2 : 1	1
9.	A photoelectric cell is illuminated by a point source of light 1 m away. The plate emits electrons having stopping potential V. Then: (a) V decreases as distance increase (b) V increases as distance increase (c)) V is independent of distance (r) (d) V becomes zero when distance increases or decreases	1
10.	The work-function for a metal is 3 eV. To emit a photoelectron of energy 2 eV from the surface of this metal, the wavelength of the incident light should be: (a) 6187 Å (b) 4125 Å (c) 12375 Å (d) 2486 Å	1
11.	According to Einstein's photoelectric equation, the graph between the kinetic energy of photoelectrons ejected and the frequency of incident radiation is a.  b.  c.  d. 	1
12.	Two particles A1 and A2 of masses m1, m2 (m1 > m2) have the same de Broglie wavelength. Then (a) their momenta are the same (b) their energies are the same (c) energy of A1 is less than the energy of A2 (d) energy of A1 is more than the energy of A2	1
13.	The ratio of the speed of the electrons in the ground state of hydrogen to the speed of light in vacuum is 1/2 (b) 2/237 (c) 1/137 (d) 1/237	1
14.	When an electron in an atom goes from a lower to a higher orbit, its (a) kinetic energy (KE) increases, potential energy (PE) decreases (b) KE increases, PE increases (c) KE decreases, PE increases (d) KE decreases, PE decreases	1

15.	The ratio of wavelengths of the last line of Balmer series and the last line of Lyman series is (a) 1 (b) 4 (c) 0.5 (d) 2	1
	Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses. (a) Both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion. (b) Both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion. (c) Assertion is correct, Reason is incorrect (d) Both Assertion and Reason are correct	1
16.	**Assertion :** When bodies are charged through friction, there is a transfer of electric charge from one body to another, but no creation or destruction of charge. **Reason :** This follows from conservation of electric charges.	1
17.	**Assertion :** The focal length of the convex mirror will increase, if the mirror is placed in water. **Reason :** The focal length of a convex mirror of radius R is equal to , f = R/2.	1
18.	**Assertion :** When two semi conductor of p and n type are brought in contact, they form p-n junction which act like a rectifier. **Reason :** A rectifier is used to convent alternating current into direct current.	1
	<u>Section – B</u>	
19.	Two wires, one of copper and the other of manganin, have same resistance and equal thickness. Which wire is longer? Justify your answer. **OR** First a set of n equal resistors of R each are connected in series to a battery of emf E and internal resistance R. A current I is observed to flow. Then the n resistors are connected in parallel to the same battery. It is observed that the current is increased 10 times. What is n?	2
20.	A long straight wire *AB* carries a current of 4 A. A proton *P* travels at 4×10^6 m/s parallel to the wire 0.2 m from it and in a direction opposite to the current. Calculate the force which the magnetic field due to the current carrying wire exerts on the proton. Also specify its direction.	2
21.	The current flowing through a pure inductor of inductance 2 mH is i =15 cos 300 t ampere. What is the (*i*) rms and (*ii*) average value of current for a complete cycle? **OR**	2

	When an ac source is connected to an ideal inductor show that the average power supplied by the source over a complete cycle is zero.	
22.	An object is kept in front of a concave mirror of focal length 15 cm. The image formed is real and three times the size of the object. Calculate the distance of the object from the mirror.	2
23.	An α-particle and a proton of the same kinetic energy are in turn allowed to pass through a magnetic field *B* , acting normal to the direction of motion of the particles. Calculate the ratio of radii of the circular paths described by them.	2
24.	In the following diagram 'S' is a semiconductor. Would you increase or decrease the value of R to keep the reading of the ammeter A constant when S is heated? Give reason for your 	2
25.	Plot a graph comparing the variation of potential 'V' and electric field 'E' due to a point charge 'Q' as a function of distance 'R' from the point charge.	2
	Section -C	
26.	State Kirchhoffs's rules for electrical networks. Use them to explain the principle of Wheatstone bridge for determining an unknown resistance.	3
27.	A thin convex lens having two surfaces of radii of curvature R_1 and R_2 is made of a material of refractive index μ_2. It is kept in a medium of refractive index μ_2. Derive, with the help of a ray diagram, the lens maker's formula when a point object placed on the principal axis in front of the radius of curvature R_1 produces an image *I* on the other side of the lens	3
28.	(a) Draw the plot of binding energy per nucleon (*BE*/*A*) as a function of mass number *A*. Write two important conclusions that can be drawn regarding the nature of nuclear force.	3

	(b) Use this graph to explain the release of energy in both the processes of nuclear fusion and fission. **OR** Calculate the longest wavelengths belonging to Lyman and Balmer series. In which region of hydrogen spectrum do these transitions lie? [Given R = 1.1×10^{7} m^{-1}]	
29	Name the parts of the electromagnetic spectrum which is (a) suitable for radar systems used in aircraft navigation. (b) used to treat muscular strain. (c) used as a diagnostic tool in medicine. Write in brief, how these waves can be produced. **OR** Identify the following electromagnetic radiations as per the wavelengths given below. Write one application of each. (a) 10^{-3} nm (b) 10^{-3} m (c) 1 nm	3
30.	Describe the path of a charged particle moving in a uniform magnetic field with initial velocity (i) parallel to (or along) the field. (ii) perpendicular to the field	3
	Section –D	
31.	An electric dipole of dipole moment p is held in a uniform electric field E. (i) Prove that no translatory force acts on the dipole. (ii) Hence prove that the torque acting on the dipole is given by pE sin θ, indicating the direction along which it acts. (iii) How much work is required in turning the electric dipole, from the position of most stable equilibrium to the position of most unstable equilibrium? **OR** (a) State Gauss's law. Use it to deduce the expression for the electric field due to a uniformly charged thin spherical shell at points (i) inside and (ii) outside the shell. (b) Two identical metallic spheres *A* and *B* having charges +4*Q* and –10*Q* are kept a certain distance apart. A third identical uncharged sphere C is first placed in contact	5

	with sphere *A* and then with sphere *B*. Spheres A and B are then brought in contact and then separated. Find the charges on the spheres *A* and *B*.	
32.	a. Derive the expression for force per unit length between two long straight parallel current carrying conductors. Hence, define one ampere. b. An α-particle and a proton moving with the same speed enter the same magnetic field region at right angles to the direction of the field. Show the trajectories followed by the two particles in the region of the magnetic field **OR** (a) With the help of a diagram, explain the principle and working of a moving coil galvanometer. (b) Why is it necessary to introduce a cylindrical soft iron core inside the coil of a galvanometer? (c) What is the importance of a radial magnetic field ?	5
33.	(a) Draw a ray diagram for the formation of image by a compound microscope. Define its magnifying power. Deduce the expression for the magnifying power of the microscope. (b) Explain: (i) why must both the objective and the eyepiece of a compound microscope have short focal lengths? (ii) while viewing through a compound microscope, why should our eyes be positioned not on the eyepiece but a short distance away from it for best viewing? **OR** (a) A monochromatic source of light of wavelength λ illuminates a narrow slit of width d to produce a diffraction pattern on the screen. Obtain the conditions when secondary wavelets originating from the slit interfere to produce maxima and minima on the screen. (b) How would the diffraction pattern be affected when (i) the width of the slit is decreased? (ii) the monochromatic source of light is replaced by white light?	5
	SECTION - E	
34	**CASE STUDY : ENERGY BAND GAP** From Bohr's atomic model, we know that the electrons have well defined energy levels in an isolated atom. But due to interatomic interactions in a crystal, the	4

	electrons of the outer shells are forced to have energies different from those in isolated atoms. Each energy level splits into a number of energy levels forming a continuous band. The gap between top of valence band and bottom of the conduction band in which no allowed energy levels for electrons can exist is called energy gap. (i) Give the ratio of the number of holes and number of conduction electrons in an intrinsic semiconductor. (ii) How does the energy gap of an intrinsic semiconductor vary, when doped with a trivalent impurity/ pentavalent impurity? (iii) How does the forbidden energy gap of an intrinsic semiconductor vary with increase in temperature? (iv) Give reason, why, a p-type semiconductor crystal is electrically neutral?	
35	**CASE STUDY: TRANSFORMER** A transformer is an electrical device which is used for changing the a.c. voltages. It is based on the phenomenon of mutual induction i.e. whenever the amount of magnetic flux linked with a coil changes, an e.m.f is induced in the neighboring coil. For. an ideal transformer, the resistances of the primary and secondary windings are negligible. It can be shown that Es/Ep=Ip/Is=ns/np=k where the symbols have their standard meanings. 1. What is difference between step up and step-down transformer? 2. Which quantity remains constant in an ideal transformer? 3. Show that transformation ratio of step-down transformer is less than one. 4. Mention two types of energy loss in transformer.	4

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MARKING SCHEME SAMPLE PAPER-3 (SESSION 2022-23)

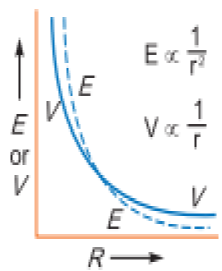
CLASS – XII (PHYSICS)

MAX. MARK: 70

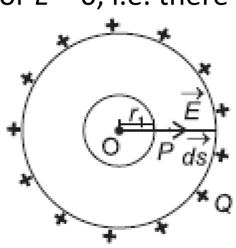
Marking Scheme

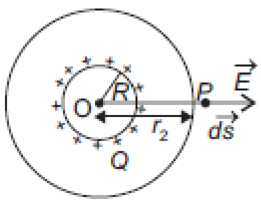
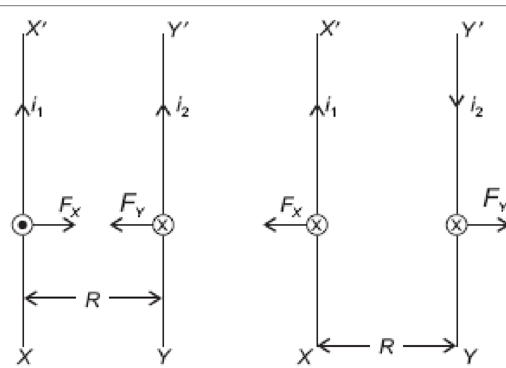
Section – A

Q No.		Marks
1	D	1
2	A	1
3	**A**	1
4	B	1
5	D	1
6	C	1
7	D	1
8	C	1
9	C	1
10	D	1
11	D	1
12	A & C	1
13	C	1
14	C	1
15	B	1
16	A	1
17	D	1
18	B	1
	Section – B	
19	Copper Reason: Let l1 and l2 be lengths of copper and manganin wires having same resistance R and thickness i.e., area of cross-section (A). Since $\rho_1 <<< \rho_2$ So, $l_1 >>> l_2$ i.e., copper wire would be long **OR**	2

	When n resistors are in series, $I = \dfrac{E}{R + nR}$; When n resistors are in parallel, $\dfrac{E}{R + \dfrac{R}{n}} = 10I$ $\dfrac{1+n}{1+\dfrac{1}{n}} = 10 \Rightarrow \dfrac{1+n}{n+1}n = 10 \quad \Rightarrow \quad n = \mathbf{10.}$	
20	Given, $I = 4$ A, $r = 0.2$ m, $v = 4\times10^{6}$ m/s Magnetic field at Point P due current carrying straight wire AB $B = \dfrac{\mu_0}{2\pi}\dfrac{I}{r}$ Force acting on the moving proton in the magnetic field $F = Bqv \sin\theta$ Therefore $F = \dfrac{\mu_0}{2\pi}\dfrac{I}{r}\times qv\sin\theta$ $= \dfrac{2\times10^{-7}\times4\times1.6\times10^{-19}\times4\times10^{6}\sin 90}{0.2}$ $= \mathbf{2.56 \times 10^{-18}\ N}$	2
21	I (rms) = 7.5√2 A , 0 **OR** For an ideal inductor phase difference between current and applied voltage = π/2 ∴ Power, P = Vrms Irms cos ϕ = Vrms Irms cos . 2 0 r = Thus the power consumed in a pure inductor is zero.	2
22	By using Mirror equation u = -20 cm	2
23	Radius $r = \dfrac{mv}{qB} = \dfrac{\sqrt{2mK}}{qB}$ $K_\alpha = K_{proton}$ $M_\alpha = 4\,M_p$ $q_\alpha = 2q_p$	2
24	The value of R would be increased. On heating, the resistance of semiconductor (S) decreases.	2
25	The graph of variation of potential and electric field due to a point charge Q with distan from the point charge is shown in figure. 	2

	Section – C	
26	Rules Working	1.5 1.5
27	Derivation of Lens makers formula	3
28	Binding energy curve The two important conclusions regarding the nature of nuclear force ar given below. (*i*) The nuclear force is attractive and sufficiently strong to produce a binding energy of a few MeV per nucleon. (*ii*) The constancy of the binding energy in the wide range of mass numbe $30<A<170$ indicate that nuclear force is a short-range force. (*b*) (*i*) According to the binding energy curve, a very heavy nucleu ($A > 170$), has lower binding energy per nucleon compared t nuclei of middle mass number ($30<A<170$). Thus, if a heavy nucleus breaks into two nuclei of mass number between 3 and 170, nucleons get more tightly bound. This implies energ would be released in the process. (nuclear fission) (*ii*) When two light nuclei ($A \le 10$) join to form a heavier nucleus, th binding energy per nucleon of fused heavier nucleus increases. Again i indicates that energy would be released in the process (nuclear fusion) OR The transition corresponding to longest wavelength in the Lyman series, i.e. $n_i = 2$ and $n_f = 1$ $\therefore \quad \frac{1}{\lambda} = R\left(1-\frac{1}{4}\right)=\frac{3}{4}R$ $\Rightarrow \quad \lambda = \frac{4}{3R}=\frac{4}{3\times1.1\times10^7}\text{m}$ $= 1.21 \times 10^{-7}\text{ m}$ $\lambda = 121\text{ nm}$ The transition corresponding to longest wavelength in the Balmer series i.e. $n_i = 3$ and $n_f = 2$ $\therefore \quad \frac{1}{\lambda} = R\left(\frac{1}{4}-\frac{1}{9}\right)=\frac{5}{36}R$ $\Rightarrow \quad \lambda = \frac{36}{5R}=\frac{36}{5\times1.1\times10^7}$ $= 6.545 \times 10^{-7}\text{ m}$ $\lambda = 655\text{ nm}$ The first transition lies in the ultraviolet region and the second one belongs to visible region.	
29	(a) Microwaves Production: Klystron/magnetron/Gunn diode (any one) (b) Infrared radiations Production: Hot bodies/vibrations of atoms and molecules (any one) (c) X-rays	

	Production: Bombarding high energy electrons on metal target/X-ray tube/Inner shell electrons **OR** (a) γ-rays. Use: In treatment of cancer. (b) Microwaves. Use: In radar system for aircraft navigation. (c) X-rays. Use: As a diagnostic tool for the detection of fractures.	
30	Parallel – no effect of magnetic field Derivation for radius with dia	1 2
Section – D		
31	I net force = 0 Ii derivation ii (iii) $\because W = -pE(\cos\theta_2 - \cos\theta_1)$ Stable equilibrium corresponds to $\theta_1 = 0°$ Unstable equilibrium corresponds to $\theta_2 = 180°$. $\therefore \quad W = -pE(\cos 180° - \cos 0°) = -pE(-1-1) = 2pE$ **OR** : (a) Gauss's Law states that the net outward flux through any closed surface is equal to $\frac{1}{\varepsilon_0}$ times the charge enclosed by the closed surface. (i) When the point *P* is inside the shell. In this case, the Gaussian surface lies inside the spherical shell and hence no charge is enclosed by it. $\oint \vec{E}.\vec{ds} = \oint E.ds\cos 0 = E\oint ds = E \times 4\pi r_1^2 \quad ...(i)$ and by Gauss's law $\oint \vec{E}.\vec{ds} = \frac{1}{\varepsilon_0} \times 0 = 0 \quad ...(ii)$ (since no charge is enclosed) $\therefore$ From (i) and (ii), we have $E \times 4\pi r_1^2 = 0$ or *E* = 0, i.e. there is no electric field inside a charged spherical shell.  (ii) When the point *P* lies outside the shell	1 2 2 1 1.5 1.5

	$\therefore \quad \oint \vec{E}.\vec{ds} = \oint E.ds = E\oint ds = E \times 4\pi r_2^2 \quad \ldots(i)$ Also, by Gauss's law $\oint \vec{E}.\vec{ds} = \frac{1}{\varepsilon_0}.Q \quad \ldots(ii)$ From (*i*) and (*ii*), we get $E \times 4\pi r^2 = \frac{1}{\varepsilon_0}.Q \Rightarrow E = \frac{1}{4\pi\varepsilon_0}.\frac{Q}{r^2} \quad [\because r = r_2]$  Initial charge on the sphere *A* = + 4 *Q* Initial charge on the sphere *B* = – 10 *Q* Since, all the three spheres are identical, they have the same capacity. When uncharged sphere *C* is placed in contact with *A*, the total charge is equally shared between them. $\therefore$ Charge on C after contact with *A* = $\frac{0+4Q}{2}$ = 2 *Q* and charge on *A* after contact with *C* = 2 *Q*. When sphere *C* carrying a charge 2 *C* is placed in contact with B, again charges are equally shared between *C* and *B*. Charge on C after it is in contact with *B* = $\frac{(2-10)Q}{2}$ = – 4 *Q* Now, when sphere A with a charge of 2 Q is placed in contact with B, with charge – 4 Q. Charge on *A* $= \frac{2-4}{2} = -Q$ and charge on *B* $= -1\ Q$	1
32	Let XX' and YY' be the two long parallel straight conductors carrying currents i_1 and i_2 respectively in the same direction and placed in vacuum or air at a distance R metre apart.  The magnitude of magnetic field at each point on Y' due to current i_1 in XX' is given by $B_1 = \frac{\mu_0}{2\pi} \cdot \frac{i_1}{R}$ According to the right-hand palm rule, A . the direction of $\vec{B_1}$ is perpendicular to the plane of paper, directed inward.	

The conductor YY', carrying current i_2 is situated in magnetic field B_1 produced by the current i_1 in XX'. Therefore, the length of YY' experiences a force which is given by

$$F_Y = i_2 B_1 l = i_2 \frac{\mu_0}{2\pi} \cdot \frac{i_1}{R} \cdot l$$

$\therefore$ Force per unit length of YY' is given by

$$\frac{F_Y}{l} = \frac{\mu_0}{2\pi} \cdot \frac{i_1 i_2}{R}$$

Fleming's-left hand rule shows that the direction of this force is towards XX'.

Similarly, the force experienced per unit length of XX' due to current in YY' is given by

$$\frac{F_X}{l} = \frac{\mu_0}{2\pi} \cdot \frac{i_1 i_2}{R}$$

According to the Fleming's-left hand rule, the direction of force will be towards YY'. Thus, the wires attract.

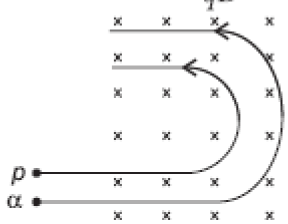
Now, let $i_1 = i_2 = 1$ ampere, $R = 1$ metre, $\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1}

$$\therefore \quad \frac{F}{l} = \frac{4\pi \times 10^{-7} \times 1 \times 1}{2\pi \times 1} = 2 \times 10^{-7} \text{ newton/metre}$$

Thus, "one ampere is the current which when flowing in each of the two infinitely long parallel conductors placed 1 m apart in vacuum or air from each other produces between them a force of interaction of exactly 2×10^{-7} newton per metre of length."

B.

$$r = \frac{mv}{qB}$$



OR

(a) **Principle:** A current carrying loop placed in a uniform magnetic field experiences a torque.

Working: A coil free to rotate in a uniform magnetic field about a fixed axis experiences a torque when current is passed through it.

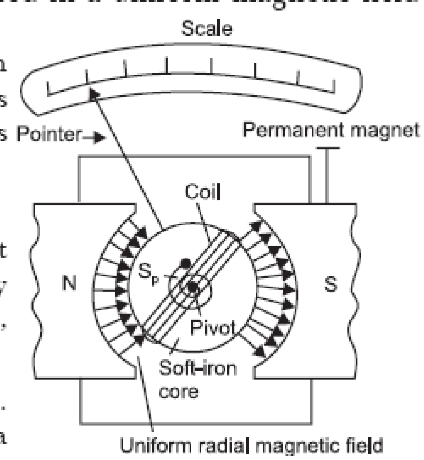
$$\tau = NIAB$$

A spring S_p provides a counter torque $k\phi$ that balances the magnetic torque. For a steady angular deflection ϕ and in equilibrium,

$$k\phi = NIBA$$

where, k is torsional constant of the spring. The deflection ϕ is taken on a scale by a pointer attached to the spring.

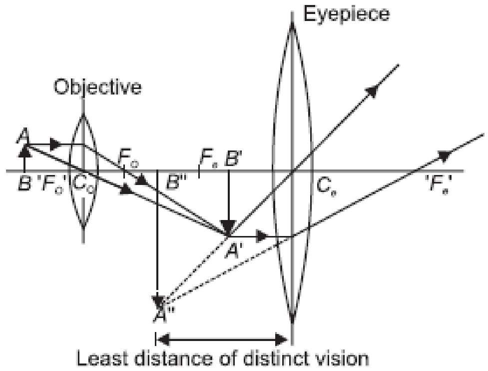
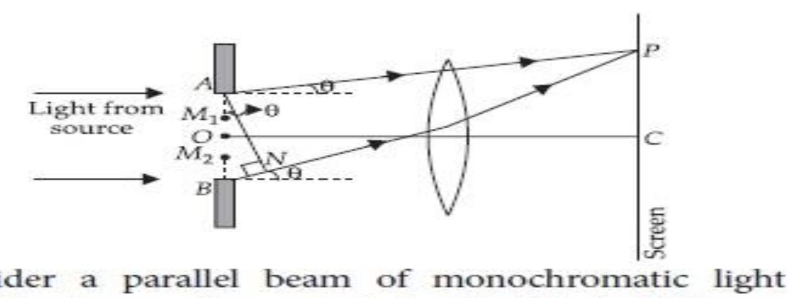
$$\phi = \left(\frac{NAB}{k}\right) I$$



A moving coil galvanometer

(b) (i) On introducing a soft iron cylindrical core, the magnetic field becomes more radial and its strength increases.

As $I_s = \frac{NBA}{k}$ and $V_s = \frac{NBA}{kR}$

	(c) With a radial magnetic field sin θ = 1 in the expression for the torque. Hence, we can calibrate a scale	
33	 (a) Magnifying power: It is the ratio of angle subtended by the final image at the eye to the angle subtended by the object at the eye when both are at the least distance of distinct vision. $\because \quad m_o = \frac{h_I}{h_o} = \frac{L}{f_o}$ $m_e = 1 + \frac{D}{f_e}$ $m = m_o \times m_e = \frac{-L}{f_o}\left(1+\frac{D}{f_e}\right)$ or $\quad m = \frac{v_o}{\lvert u_o \rvert}\left(1+\frac{D}{f_e}\right)$ (b) (i) To achieve a large magnification of small object, the eyepiece and the objective must have short focal lengths. (ii) If we place our eyes too close to the eyepiece, the area of the pupil of the eye is less than the area of the eye-ring. So, our eyes will not collect much of the light and our field of view will get reduced. **OR** (a)  Consider a parallel beam of monochromatic light is incident normally on a single slit AB of width a as shown in the figure. According to Huygens principle every point of slit acts as a source of secondary wavelets spreading in all directions. The mid point of the slit is O.	

	A straight line through O perpendicular to the slit plane meets the screen at C. At the central point C on the screen, the angle θ is zero. All path differences are zero and hence all the parts of the slit contribute in phase. This gives maximum intensity at C. Consider a point P on the screen. The observation point is now taken at P. Secondary minima : Now we divide the slit into two equal halves AO and OB, each of width $\frac{a}{2}$. For every point, M_1 in AO, there is a corresponding point M_2 in OB, such that $M_1M_2 = \frac{a}{2}$. The path difference between waves arriving at P and starting from M_1 and M_2 will be $\frac{a}{2}\sin\theta = \frac{\lambda}{2}$. $a\sin\theta = \lambda$ In general, for secondary minima $a\sin\theta = n\lambda$ where $n = \pm1, \pm2, \pm3......$ Secondary maxima : Similarly it can be shown that for secondary maxima $a\sin\theta = (2n+1)\frac{\lambda}{2}$ where $n = \pm1, \pm2........$ (b) (i) Linear width of central maxima, $W = \frac{2D\lambda}{d}$ Angular width of central maxima, $\theta_n = \frac{W}{D} = \frac{2\lambda}{d}$ So, when the width of the slit (d) is decreased, the angular width θn increases, and the diffraction pattern is spread out. (ii) When a monochromatic source of light is replaced by a source of white light, the following changes are observed in the diffraction pattern: • Differaction pattern is coloured. As the fringe width is directly proportional to the wavelength, so, the fringe width of red colour is wider than that of violet colour. • The central maximum is white.	
34	(i) 1 (ii) Decreases (iii) no effect (iv) because impurity atoms added to the semiconductor are electrically neutral.	1 1 1 1
35	1For a step up transformer ns>np; For a step-down transformer ns>np; 2 Power 3 Es<Ep; k<1 4 Eddy current loss, flux leakage.	1 1 1 1