KENDRIYAVIDYALAYASANGATHAN
RANCHI REGION

STUDY MATERIAL

SUBJECT: PHYSICS
SUB-CODE: 042
CLASS: XII
SESSION: 2023-24

OUR PATRON

SH DP PATEL
DEPUTY COMMISSIONER
KENDRIYA VIDYALAYA SANGATHAN REGIONAL OFFICE RANCHI

COORDINATORS	
SH. SURESH SINGH	ASSISTANT COMMISSIONER, KVS, RO RANCHI
SMT. SUJATA MISHRA	ASSISTANT COMMISSIONER, KVS, RO RANCHI
SH. BALENDER KUMAR	ASSISTANT COMMISSIONER, KVS, RO RANCHI

CONVENER **Sh. R.C. Gond, Principal, KV Patratu**

ACKNOWLEDGEMENT

We are happy to provide useful study material in the subject of Physics keeping in view the academic progress of the students.

Our important objective is to help them to achieve their goals with ease and convenience.

Firstly, we would like to thank Sri. D. P. PATEL, Hon'ble Deputy Commissioner, KVS RO Ranchi and Assistant Commissioner Mrs. Sujata Mishra who showed their concern for students and suggested to prepare the material.

Again, we would like to thank Sh. R.C. Gond, Principal, KV Patratu who guided us throughout to prepare the material.

This study material provides conceptual clarity and application expertise. It gives a positive direction to the thinking of the students. Our main objective is to reduce stress and pressure of board exams amongst the students and instill interest in them and dedication to score higher from the very beginning.

We, the editorial team feel proud to contribute in the study material to enrich the subject related information and look for better performance of students in the coming year.

With best wishes.

Regards "Editorial Team"

CONTRIBUTORS

S. NO.	NAME OF PGT PHYS MR./MRS.	NAME OF KV	TOPIC/CHAPTER
1	JAYANT KUMAR SINHA	RANCHI CRPF	Electric charges and fields
2 3	BACHCHAN KUMAR JHA PANKAJ KUMAR CHAUDHARY	RANCHI NO.I (HEC)	Electrostatic potential and capacitance
4	A.K SINGH	KV GOMOH	Current Electricity
5	MANISH ROY	RANCHI DEEPATOLI	Moving Charges and magnetism
6	DR. UMA CHARAN MANDAL	RANCHI HINOO	Magnetism and Matter
7	UJJWAL KUMAR THAKUR	RAMGARH	Electromagnetic Induction
8	MD. MUKHTAR ALAM	KV NO 3 BOKARO	Alternating Current
9	VIJAY NARAYAN SINGH	KV BOKARO THERMAL	Electromagnetic wave
10	PARTEEK KUMAR	KV LATEHAR	Ray Optics and optical instruments
11	SATYENDRA NARAYAN SINGH KIRAN K SOREN	CHANDRAPURA CTPS	Wave Optics
12	DR. KARUNA SAGAR SINGH	RANCHI HINOO	Dual nature of matter and radiation
13	KAMAL SEN JEET	KV PATRATU	Atoms
14	DR. NIDHI RANI ROMOLA SORENG	DHANBAD OLD DVS BLDG. KV TATANAGAR	Nuclei
15 16	SHAMBHU KUMAR PAUL SANJEEV KUMAR	BOKARO NO.I BOKARO NO.1	Semiconductor Electronics: materials, Devices and simple circuits
16	ABHISHEK SHARMA	KV SURDA	Compilation and editing

CLASS XII (2023-24)
PHYSICS (THEORY)

Time: 3 hrs. **MAXIMUM MARKS 70**

	CHAPTER	MARKS
UNIT1	**ELECTROSTATICS** Chapter–1: Electric Charges and Fields Chapter–2: Electrostatic Potential and Capacitance	**16**
UNIT-2	**Current Electricity** Chapter–3: Current Electricity	
UNIT-3	**Magnetic Effects of Current and Magnetism** Chapter–4: Moving Charges and Magnetism Chapter–5: Magnetism and Matter	**17**
UNIT-4	**Electromagnetic Induction and Alternating Currents** Chapter–6: Electromagnetic Induction Chapter–7: Alternating Current	
UNIT-5	**Electromagnetic Waves** Chapter–8: Electromagnetic Waves	**18**
UNIT-6	**Optics** Chapter–9: Ray Optics and Optical Instruments Chapter–10: Wave Optics	
UNIT-7	**Dual Nature of Radiation and Matter** Chapter–11: Dual Nature of Radiation and Matter	**12**
UNIT-8	**Atoms and Nuclei** Chapter–12: Atoms Chapter–13: Nuclei	
UNIT-9	**Electronic Devices** Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuit	**7**

INDEX

CHAPTER-1
ELECTRIC CHARGES AND FIELDS

1. Charge- Charge is the property associated with matter due to which it produces and experiences electric and magnetic effect.

2. Conductors and Insulators Those substances which readily allow the passage of electricity through them are called conductors, e.g. metals, the earth and those substances which offer high resistance to the passage of electricity are called insulators, e.g. plastic rod and nylon.

3. Transference of electrons is the cause of frictional electricity.

4. Additivity of Charges Charges are scalars and they add up like real numbers. It means if a system consists of n charges $q_1, q_2, q_3, \dots, q_n$, then total charge of the system will be $q_1 + q_2 + \dots + q_n$.

5. Conservation of Charge The total charge of an isolated system is always conserved, i.e. initial and final charge of the system will be same.

6. Quantisation of Charge Charge exists in discrete amount rather than continuous value and hence, quantised.Mathematically, charge on an object, $q=\pm ne$where, n is an integer and e is electronic charge. When any physical quantity exists in discrete packets rather than in continuous amount, the quantity is said to be quantised. Hence, charge is quantised.

7. Units of Charge

(i) SI unit coulomb (C)

(ii) CGS system

(a) electrostatic unit, esu of charge or stat-coulomb (stat-C)

(b) electromagnetic unit, emu of charge or ab-C (ab-coulomb)

1 ab-C = 10 C, 1 C = 3 x 10^9 stat-C

8. Coulomb's Law It states that the electrostatic force of interaction or repulsion acting between two stationary point charges is given by

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

where, q_1 and q_2 are the stationary point charges and r is the separation between them in air or vacuum.

Also, $$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N-m}^2/\text{C}^2$$

where, ε_0 = permittivity of free space = $8.85419 \times 10^{-12}\ \text{C}^2/\text{N-m}^2$

The force between two charges q_1 and q_2 located at a distance r in a medium other than free space may be expressed as

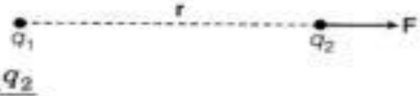
$$F = \frac{1}{4\pi\varepsilon} \cdot \frac{q_1 q_2}{r^2}$$

where, ε is **absolute permittivity** of the medium.

Now, $$\frac{F_{\text{vacuum}}}{F} = \frac{\frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}}{\frac{1}{4\pi\varepsilon} \cdot \frac{q_1 q_2}{r^2}} = \frac{\varepsilon}{\varepsilon_0} = \varepsilon_r$$

where, ε_r is called **relative permittivity** of the medium also called **dielectric constant** of the medium.

In vector form,



$$\mathbf{F} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{|\mathbf{r}|^2}\,\hat{\mathbf{r}} \quad \text{or} \quad |\mathbf{F}| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

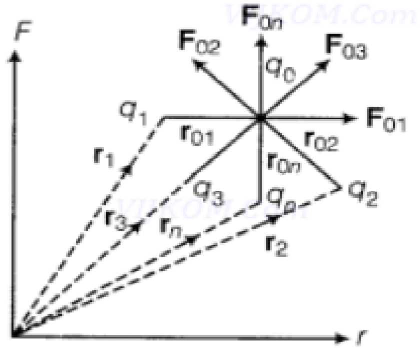
9. Electrostatic forces (Coulombian forces) are conservative forces.

10. Principle of Superposition of Electrostatic Forces This principle states that the net electric force experienced by a given charge particle q_0 due to a system of charged particles is equal to the vector sum of the forces exerted on it due to all the other charged particles of the system.

i.e. $\mathbf{F}_0 = \mathbf{F}_{01} + \mathbf{F}_{02} + \mathbf{F}_{03} + \ldots + \mathbf{F}_{0n}$

$$\mathbf{F}_0 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_0}{|\mathbf{r}_{01}|^3}\mathbf{r}_{01} + \frac{q_2 q_0}{|\mathbf{r}_{02}|^3}\mathbf{r}_{02} + \ldots + \frac{q_n q_0}{|\mathbf{r}_{0n}|^3}\mathbf{r}_{0n}\right]$$

where, $\mathbf{r}_{01} = \mathbf{r}_0 - \mathbf{r}_1$, $\mathbf{F}_{01}$ = force on q_0 due to q_1.



Superposition of electrostatic forces

Similarly, $\mathbf{r}_{0n} = \mathbf{r}_0 - \mathbf{r}_n$; $\mathbf{F}_{0n}$ = force on q_0 due to q_n

$\therefore$
$$\mathbf{F}_0 = \frac{q_0}{4\pi\varepsilon_0}\left[\sum_{i=1}^{n}\frac{q_i}{|\mathbf{r}_{0i}|^3}\mathbf{r}_{0i}\right]$$

Net force in terms of position vector,

$$\mathbf{F}_0 = \frac{q_0}{4\pi\varepsilon_0}\left[\sum_{i=1}^{n}\frac{q_i}{|\mathbf{r}_0 - \mathbf{r}_i|^3}(\mathbf{r}_0 - \mathbf{r}_i)\right]$$

11. Electrostatic Force due to Continuous Charge Distribution

The region in which charges are closely spaced is said to have continuous distribution of charge. It is of three types given as below:

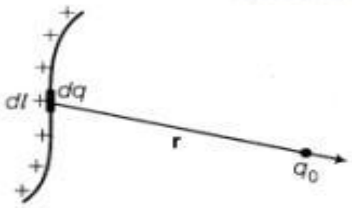
(i) Linear Charge Distribution

$$dq = \lambda\, dl$$

where, λ = linear charge density

$$d\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_0(dq)}{|\mathbf{r}|^2}\hat{\mathbf{r}} \Rightarrow d\mathbf{F} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q_0(\lambda\, dl)}{|\mathbf{r}|^2}\hat{\mathbf{r}}$$

Net force on charge q_0, $\mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_l \frac{\lambda\, dl}{|\mathbf{r}|^2}\hat{\mathbf{r}}$

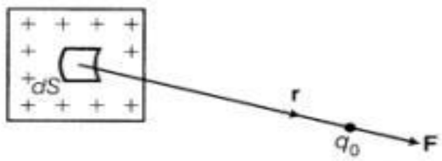


(ii) Surface Charge Distribution

$$dq = \sigma\, dS$$

where, σ = surface charge density

Net force on charge q_0, $\mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_S \frac{\sigma\, dS}{|\mathbf{r}|^2}\hat{\mathbf{r}}$

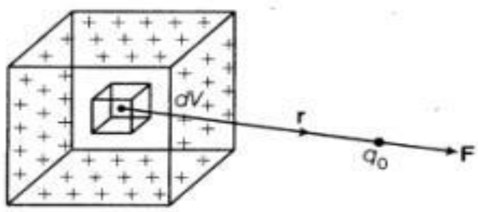


(iii) Volume Charge Distribution

$$dq = \rho\, dV$$

where, ρ = volume charge density

Net force on charge q_0, $\mathbf{F} = \frac{q_0}{4\pi\varepsilon_0}\int_V \frac{\rho\, dV}{|\mathbf{r}|^2}\hat{\mathbf{r}}$



12. Electric Field Intensity The electric field intensity at any point due to source charge is defined as the
force experienced per unit positive test charge placed at that point without disturbing the source charge. It is expressed as

$$\mathbf{E} = \lim_{q_0 \to 0} \frac{\mathbf{F}}{q_0}$$

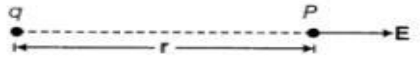
Here, $q_0 \to 0$, i.e. the test charge q_0 must be small, so that it does not produce its own electric field.

SI unit of electric field intensity (**E**) is N/C and it is a vector quantity.

13. Electric Field Intensity (EFI) due to a Point Charge

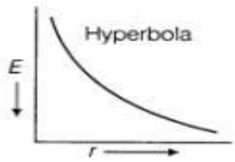
Electric field intensity at *P* is, then

$$\mathbf{E} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{|\mathbf{r}|^2} \hat{\mathbf{r}}$$



The magnitude of the electric field at a point *P* is given by

$$|\mathbf{E}| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q}{r^2}$$



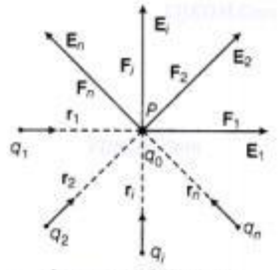
If $q > 0$, i.e. positive charge, then E is directed away from source charge. On the other hand if $q < 0$, i.e. negative charge, then E is directed towards the source charge.

$$\mathbf{E} \propto \frac{1}{r^2}$$

14Electric Field due to a System of Charges : Same as the case of electrostatic force, here we will apply principle of superposition, i.e.

$$\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2 + \mathbf{E}_3 + \ldots + \mathbf{E}_n$$

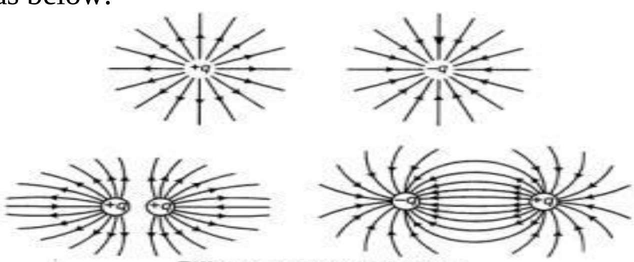
$$\Rightarrow \qquad \mathbf{E} = \frac{1}{4\pi\varepsilon_0} \sum_{i=1}^{n} \frac{q_i}{|\mathbf{r}_i|^2} \hat{\mathbf{r}}_i$$



15.

Electric Field Lines Electric field lines are away of pictorially mapping the electric field around aconfiguration of charge(s). These lines start on positive charge and end on negative charge. The tangent on these lines at any point gives the direction of field at that point.

16. Electric field lines due **to positive and negative charge** and their combinations are shown as below:

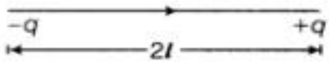


Different electric field lines

17. Electric Dipole Two-point charges of same magnitude and opposite nature separated by a small distance altogether form an electric dipole.

18. Electric Dipole Moment The strength of an electric dipole is measured by a vector quantity known as electric dipole moment (p) which is the product of the charge (q) and separation between the charges (2l).

19. Electric Field due to a Dipole Electric field of an electric dipole is the space around the dipole in which the electric effect of the dipole can be experienced.



$$\mathbf{p} = q \times 2\mathbf{l}$$

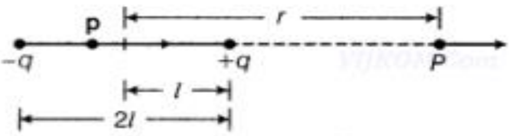
$$\Rightarrow \quad |\mathbf{p}| = q\,(2l)$$

Direction Its direction is from negative charge ($-q$) to positive charge ($+q$).

SI unit Its SI unit is C-m.

NOTE The line joining the two charges $-q$ and $+q$ is called the dipole axis.

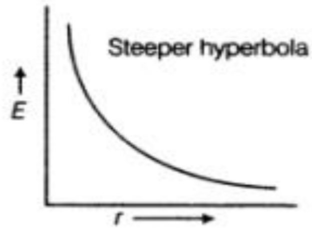
(i) Electric Field at any Point on the Axial Line/End-on Position of Electric Dipole



$$\mathbf{E}_{\text{axial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\mathbf{p}r}{(r^2 - l^2)^2}$$

When $l << r$, $\mathbf{E}_{\text{axial}} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\,\mathbf{p}}{r^3} \Rightarrow |\mathbf{E}_{\text{axial}}| = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2|\mathbf{p}|}{r^3}$

$$\mathbf{E} \propto \frac{1}{r^3}$$

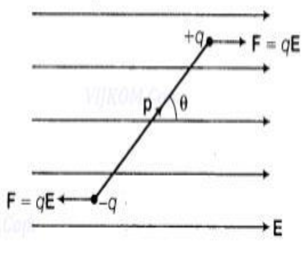


The direction of electric field at any point on axial line is along the direction of electric dipole moment.

20. When $l << r$, $\frac{|\mathbf{E}_{\text{axial}}|}{|\mathbf{E}_{\text{equatorial}}|} = 2$ –

21. Torque on an electric dipole placed in a uniform electric field (E) is given by

$\tau = \mathbf{p} \times \mathbf{E} \Rightarrow |\tau| = pE\sin\theta$



22. Minimum torque experienced by electric dipole in electric field, when $\theta = 0°$ or π

$$\tau = \tau_{\min} = 0$$

23. Maximum torque $\tau = \tau_{\max}$, when $\sin\theta = 1 \Rightarrow \theta = \pi/2$

$$\tau_{\max} = pE$$

24. Dipole is in stable equilibrium in uniform electric field when angle between p and E is 0° and in unstable equilibrium when angle θ= 180°.

25. Net force on electric dipole placed in a uniform electric field is zero.

26. There exists a net force and torque on electric dipole when placed in non-uniform electric field.

27. Work done in rotating the electric dipole from θ_1 to θ_2 is

$W = pE(\cos\theta_1 - \cos\theta_2)$

28. Potential energy of electric dipole when it rotates from $\theta_1 = 90°$ to $\theta_2 = 0$ $U = pE(\cos 90° - \cos\theta) = -pE\cos\theta = -\mathbf{p}\cdot\mathbf{E}$

29. Work done in rotating the dipole from the position of stable equilibrium to unstable equilibrium, i.e. when $\theta_1 = 0°$ and $\theta_2 = \pi$.

$W = 2\,pE$

30. Work done in rotating the dipole from the position of stable equilibrium to the position in which dipole experiences maximum torque, i.e. when $\theta_1 = 0°$ and $\theta_2 = 90°$.
W = pE
31. **Electric flux**. The electric flux through a small surface Δs defined as the electric lines of force passing through that are when held normally to the lines of force.
Mathematically-- **φ =** E. Δs
where E is the electric field and AS is the area vector representing the elementary surface area.
Unit. In SI, unit of electric flux is newton metre^2 coulomb^{-2} (Nm^2 C^{-2}).
32. Gauss' theorem. It states that the total outward electric flux through a closed surface is $\frac{1}{\epsilon_o}$ times the charge enclosed |by the closed surface.
Mathematically**:** $\varphi = \vec{E}.\, \vec{dS} = \frac{q}{\epsilon_0}$
where q is charge enclosed by the closed surface.
33. Gaussian surface. Any closed surface around the charge distribution (maybe a point charge, a line charge, a surface charge or a volume charge) so that Gauss' theorem can be conveniently applied to find
electrical field due to it is called the gaussian surface.
34.Electric field due to infinitely long straight wire of linear charge density λ
E = $\frac{\lambda}{2\pi\varepsilon_o r}$
where r is perpendicular distance of the observation point from the wire.
35. Electric field due to an infinite plane sheet of charge of surface charge density σ
Electric field between two infinite plane parallel sheets of charge of
surface charge density σ and -σ : **E =** $\frac{\sigma}{2\epsilon_0}$
36. Electric field due to spherical shell of surface charge density σ **and radius R:**

E= $(1/4\pi\varepsilon_0)(q/r^2)$**' for r>R (outside the shell)**
E= 0, for r<R (inside the shell)
E= $\frac{1}{4\pi\epsilon_0}\frac{q}{R^2}$**' for r=R (at the surface)**
Here, $q = 4\pi R^2 \sigma$

37. Electric field due to a solid sphere of volume charge density ρ and radius R:
E= $(1/4\pi\varepsilon_0)(q/r^2)$ **for r>R (outside the sphere)**
E= $\frac{1}{4\pi\epsilon_0}\frac{qr}{R^3}$ **for r<R (inside the sphere)**

E= $\frac{1}{4\pi\epsilon_0}\frac{q}{R^2}$**' for r=R (at the surface)**
Here, $q = \frac{4\pi}{3} R^3\rho$

Very Short Answer type questions (MCQ). - (1marks)
1. Force between two point charges kept at a distance 'r' is F. The distance between them, if the force between them reduces to F/3:
(a) 3√r (b) 3r (c) 2√r (d) none of these
2. If the amounts of electric flux entering and leaving an enclosed surface respectively are ϕ1 and ϕ2, the electric charge inside the surface will be:
(a) (ϕ2 – ϕ1)/ Ɛo (b) (ϕ2 + ϕ1)/ ε_0 (c) (ϕ2 – ϕ1) Ɛo (d) (ϕ2 + ϕ1) Ɛo
3. Electric field varies as r^{-3} due to:
(a) a point charge (b) an infinite line charge.
(c) an electric dipole (d) an infinite plane sheet of charge.

4. An electric field dipole is placed inside a hollow sphere at its center. Then,
a) the electric flux through the sphere is zero.
b) the electric field is zero at every point on the surface of the sphere.
c) the electric field is non-zero at every point on the surface of sphere.
d) none of these.

5. The electric field due to a infinitely long straight charged conductor varies as
(a) 1/r (b) $1/r^3$ (c) $1/r^{-2}$ (d) $1/r^2$

6. A hollow insulated conducting sphere is given a positive charge of 10 μC. What will be the electric field at the centre of the sphere, if its radius is 2 m:
(a) zero (b) 5 μC m^{-2} (c) 20 μC m^{-2} (d) 32 μC m^{-2}

7. A charge q is placed at the centre of the line joining two exactly equal positive charges Q. the system of three charges will be in equilibrium, if q is equal to:
(a) –Q/4 (b) +Q (c) –Q (d) Q/2

8. Two parallel large thin metal sheets have equal surface charge densities 26.55 $x10^{-12}$ C^2/Nm^{-2} opposite sign. The electric field between the sheets is
(a) 1.5 N/C (b) 1.5 x 10^{-10} N/C (c) 3 N/C (d) is zero

9. Torque acting along on electric dipole of dipole moment p placed in uniform electric field E is:
(a) **P** x **E** (b) **P** . **E** (c) **P** x(**E** x **P**) (d) **E** x **P**

10. An electric field required to keep a water drop of mass m just to remain suspended, when charged with one electron is:
(a) e m / g (b) m g / e (c) e m g (d) mg

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** : Electric lines of force never cross each other.
Reason : Electric field at a point superimpose to give one resultant electric field.
Answer A

2. **Assertion** : The Coulomb force is the dominating force in the universe.
Reason : The Coulomb force is weaker than the gravitational force.
Answer D

3. **Assertion** : If there exists coulomb attraction between two bodies, both of them may not be charged.
Reason : In coulomb attraction two bodies are oppositely charged.
Answer B

4. **Assertion** : The property that the force with which two charges attract or repel each other are not affected by the presence of a third charge.
Reason : Force on any charge due to a number of other charge is the vector sum of all the forces on that charge due to other charges, taken one at a time.
Answer B

5. **Assertion** : On going away from a point charge or a small electric dipole, electric field decreases at the same rate in both the cases.
Reason : Electric field is inversely proportional to square of distance from the charge or an electric dipole.
Answer D

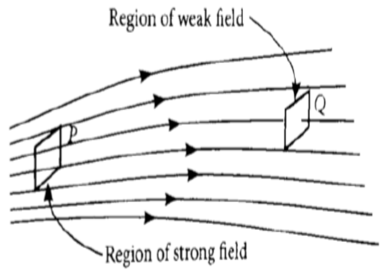
6. Assertion (A): The surface densities of two spherical conductors of different radii are equal. Then the electric field intensities near their surface are also equal.
Reason (R) : Surface density is equal to charge per unit area.
Answer B
7. Assertion : On bringing a positively charged rod near the uncharged conductor, the conductor gets attracted towards the rod.
Reason : The electric field lines of the charged rod are perpendicular to the surface of conductor.
Answer B

Short Answer type questions (2marks)

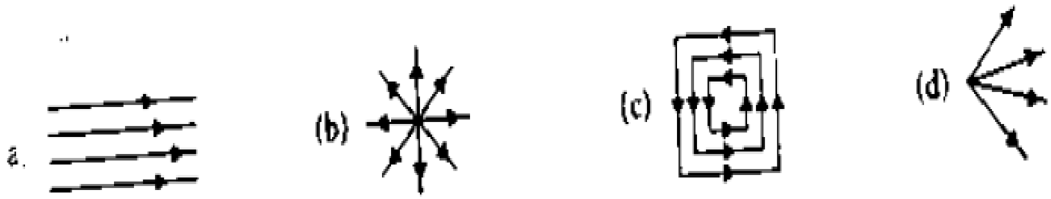
1. Two point charges, q $=8\times10^{-8}$ C and Q= -2×10^{-8} C are separated by a distance of 10 cm in air. What is the net electric field at the mid- point between the charges.
Ans. 3.6x 10^5N/C
2. The electrostatic force on a small sphere of charge 0.4μC due to another small sphere of charge −0.8μC in air is 0.2 N.
(a) What is the distance between the two spheres?
(b) What is the force on the second sphere due to the first?
3. Is Coulomb's law in electrostatics applicable in all situations?
4. The force between two equal point charges kept at a distance d apart in air is F. If now the distance between them is doubled and their charges are also doubled, what would happen to force between them?
Ans. There is no change in force
5. Compare the electric flux in a cubical surface of side 10 cm and a spherical surface of radius 10 cm, when a change of 5μC is enclosed by them.
Ans. Electric flux will be same in both the cases
6. Define electric flux. Write its S.I. unit. A charge q is enclosed by a spherical surface of radius R. If the radius is reduced to half, how would the electric flux through the surface change?
7. Two small identical electrical dipoles AB and CD, each of dipole moment '**P**' are kept at an angle of 120° as shown in the figure. What is the resultant dipole moment
of this combination? If this system is subjected to electric field (**E**) directed along + X direction, what will be the magnitude and direction of the torque acting on this?

Case Study Question 1:

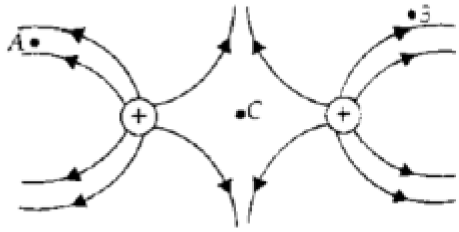
Electric field strength is proportional to the density of lines of force i.e., electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in given figure, the electric field at P is stronger than at Q.



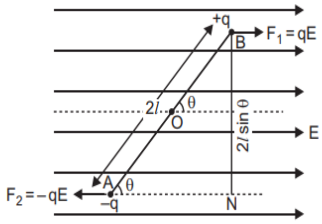
(i) Electric lines of force about a positive point charge are
(a) radially outwards (b) circular clockwise
(c) radially inwards (d) parallel straight lines
(ii) Which of the following is false for electric lines of force?
(a) They always start from positive charge and terminate on negative charges.
(b) They are always perpendicular to the surface of a charged conductor.
(c) They always form closed loops.
(d) They are parallel and equally spaced in a region of uniform electric field.
(iii) Which one of the following patterns of electric line of force is not possible in field due to stationary charges?



(iv) Electric field lines are curved
(a) in the field of a single positive or negative charge
(b) in the field of two equal and opposite charges.
(c) in the field of two like charges.
(d) both (b) and (c)
(v) The figure below shows the electric field lines due to two positive charges. The magnitudes EA, EB and EC of the electric fields at point A, B and C respectively are related as



(a) EA>EB>EC (b) EB>EA>EC (c) EA=EB>EC (d) EA>EB=EC
Answers: (i) a (ii) (c) (iii) (c) (iv) (d) (v) (a)
Case Study Question 2:
When electric dipole is placed in uniform electric field, its two charges experience equal and opposite forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However these forces are not collinear, so they give rise to some torque on the dipole. Since net force on electric dipole in uniform electric field is zero, so no work is done in moving the electric dipole in uniform electric field. However some work is done in rotating the dipole against the torque acting on it.



(i) The dipole moment of a dipole in a uniform external field Ē is B. Then the torque τ acting on the dipole is
(a) **τ = P x E** (b) **τ = P. Ē** (c) **τ** = 2(**p** + **Ē**) (d) **τ = (P + E)**
(ii) An electric dipole consists of two opposite charges, each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 105 NC^{-1}. The maximum torque on the dipole is
(a) 0.2 x 10^{-3} Nm (b) 1 x 10^{-3} Nm (c) 2 x 10^{-3} Nm (d) 4 x 10^{-3} Nm
(iii) Torque on a dipole in uniform electric field is minimum when θ is equal to
(a) 0°. (b) 90° (c) 180° (d) Both (a) and (c)
(iv) When an electric dipole is held at an angle in a uniform electric field, the net force F and torque τ on the dipole are
(a) **F= 0, τ = 0**. (b) **F≠0, τ≠0** (c) **F=0, τ ≠ 0** (d) **F≠0, τ=0**
(v) An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle with the direction of the field. Assuming that potential energy of the dipole to be zero when 0 = 90°, the torque and the potential energy of the dipole will respectively be
(a) pEsinθ, -pEcosθ (b) pEsinθ, -2pEcosθ (c) pEsinθ, 2pEcosθ (d) pEcosθ, – pEsinθ
Answers: (i) (a) (ii) (c) (iii) (d) (iv)(c) (v) (a)

LONG ANSWER TYPE QUESTIONS (3 marks) :

1. Three point charges q, -4q and 2q are placed at the vertices of an equilateral triangle ABC of side '*l*'.Obtain the expression for the magnitude of the resultant electric force acting on the charge q.
2. Derive an expression for the electric field intensity at a point on the equatorial line of an electric dipole of dipole moment P and length 2a . What is the direction of the field?
3. State Gauss's law in electrostatics. Using this law derive an expression for the electric field due to a uniformly charged infinite plane sheet.
4. An electric dipole is kept in a uniform electric field. Derive an expression for the net torque acting on it and write its direction. State the conditions under which the dipole is in (i) stable equilibrium and (ii) unstable equilibrium.
5. State Gauss's law in electrostatics. Use this law to derive an expression for the electric field due to an infinitely long straight wire of linear charge density λ Cm^{-1}.

LONG ANSWER TYPE QUESTIONS (5 marks) :

1. Define electric dipole moment. Write its S.I unit. Derive an expression for dipole field intensity at any point on the equatorial line of an electric dipole. Draw the graph between electric field and distance when r>>a

2. A charge is distributed uniformly over a ring of radius'a'. Obtain an expression for the electric field intensity E at a point on the axis of the ring. Hence show that for points at large distances from the ring, it behaves like a point charge.

3. Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r, for r≦ R and r ≧

CHAPTER-2

ELECTROSTATIC POTENTIAL AND CAPACITANCE

SUMMARY

1 Electric Potential : The work done in moving unit positive charge from infinity to a particular point in electrostatic field.

$$\boldsymbol{V = \frac{W}{Q}}$$

2 Electric potential due to point charge : $\boldsymbol{V = \frac{1}{4\pi\varepsilon 0}\frac{q_1\, q_2}{r}}$

3 Electric potential due to electric dipole:

$$\boldsymbol{V = \frac{p\cos\theta}{4\pi\varepsilon 0 r^2}}$$

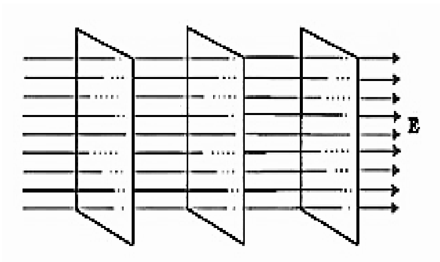
4 Potential along axial line due to dipole $\boldsymbol{V = \frac{p}{4\pi\varepsilon 0 r^2}}$

5 Potential on equatorial line of electric dipole $\boldsymbol{V = 0}$ $[\boldsymbol{\theta = 90}°]$

6 Relation between electric potential and electric field $\boldsymbol{E = -\frac{dv}{dr}}$

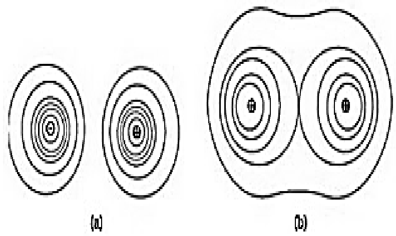
7 Equipotential Surface- an equipotential surface is a surface, every point of which is at the same electric potential .

8 No work is done in moving a charge between two points on an equipotential surface.



9 For a uniform electric field E, say, along the x -axis, the equipotential surfaces are planes normal to the x -axis, i.e., planes parallel to the y-z plane.

10 Equipotential surfaces for (a) a dipole and (b) two identical positive charges are shown in Fig.



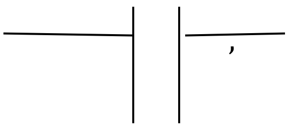
11 Electrostatic Potential Energy $\boldsymbol{U = \frac{1}{4\pi\varepsilon 0}\frac{q_1 q_2}{r}}$

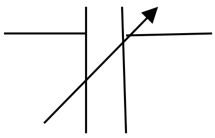
Potential energy of a dipole in external electric field :

$\boldsymbol{U = -pE\cos}\Theta$

12 **Capacitors and capacitance** : Capacitor is used to store electrical energy. $\boldsymbol{C = \frac{Q}{V}}$ SI unit of C is Farad(F)

13 Parallel Plate capacitor:





Variable capacitor

14 Capacitance of Capacitor: Without dielectric slab $\mathbf{C_0} = \boldsymbol{\frac{\varepsilon_0 A}{d}}$

With dielectric constant(K) completely fitted

$$\boldsymbol{C = K\frac{\varepsilon_0 A}{d}} = \text{K } C_0$$

With dielectric constant (K) not completely fitted

$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{k}}$$

15 **Grouping of Capacitors**

Series: Equivalent Capacitance $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots \ldots \ldots + \frac{1}{C_n}$

Note- In case of series connection charge remains same on each capacitor.

(B)Parallel: Equivalent Capacitance

$$Cp = C_1 + C_2 + C_3 + \cdots \ldots + C_n$$

Note- in case of parallel connection voltage remain same across each capacitor.

16 Electrostatic Shielding- The cavity inside the conductor remains shielded from outside electric influence. It is due to the fact that electric field vanishes inside the cavity of hollow conductor. This is known as electrostatic shielding.

17 Polarisation- It is defined as dipole moment per unit volume.

Electrostatic energy stored in capacitor

$$U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = \frac{1}{2}QV .$$

VSA (MCQ)

Q1. Two capacitors of capacitance 6 µF and 4 µF are put in series across a 120 V battery. What is the potential difference across the 4 µF capacitor?

(a) 72 V (b) 60 V (c) 48 V (d) zero

Q2. Two conducting spheres of radii r_1 and r_2 are equally charged. The ratio of their potential is

(a) $(r_1/r_2)^2$ (b) $(r_1r_2)^2$ (c) (r_1/r_2) (d) (r_2/r_1)

Q3. Consider a uniform electric field in the z-direction. The potential is a constant

(a) for any x for a given z (b) for any y for a given z

(c) on the x-y plane for a given z (d) all of these

Q4. Which of the following statement is true?

(a) Electrostatic force is a conservative force.

(b) Potential at a point is the work done per unit charge in bringing a charge from any point to infinity.

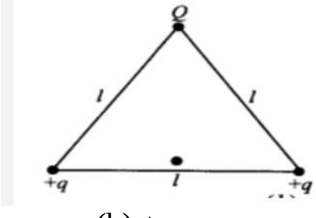
(c) Electrostatic force is non-conservative

(d) Potential is the product of charge and work.

Q5. Two metal plates form a parallel plate capacitor. The distance between the plates is d. A metal sheet of thickness d/2 and of the same area is introduced between the plates. What is the ratio of the capacitance in the two cases?

(a) 2 : 1 (b) 3 : 1 (c) 2 : 1 (d) 5 : 1

Q6. Three charges Q, +q and +q are placed at the vertices of an equilateral triangle of side l as shown in the figure. If the net electrostatic energy of the system is zero, then Q is equal to



(a) -q (b) +q (c) zero (d) –q/2

Q7. A capacitor is charged by a battery. The battery is removed and another identical uncharged capacitor is connected in parallel. The total electrostatic energy of resulting system

(a) increases by a factor of 4. (b) decreases by a factor of 2.

(c) remains the same. (d) increases by a factor of 2.

Q8. The electric potential V at any point O (x, y, z all in metres) in space is given by $V = 4x^2$

volt. The electric field at the point (1 m, 0, 2 m) in volt/metre is
(a) 8 along negative x-axis (b) 8 along positive x-axis
(c) 16 along negative x-axis (d) 16 along positive z-axis

Q9. The electrostatic force between the metal plates of an isolated parallel plate capacitor C having a charge Q and area A, is
(a) proportional to the square root of the distance between the plates.
(b) linearly proportional to the distance between the plates.
(c) independent of the distance between the plates.
(d) inversely proportional to the distance between the plates

Q10. A parallel plate air capacitor is charged to a potential difference of V volts. After disconnecting the charging battery the distance between the plates of the capacitor is increased using an insulating handle. As a result the potential difference between the plates
(a) increases (b) decreases (c) does not change (d) becomes zero

Answers : 1-a , 2- b , 3- d , 4 -a , 5 - c , 6 - d , 7 - b , 8 - a , 9 - C , 10 - a

Assertion and Reason Questions

Directions: These questions consist of two statements, each printed as Assertion and R 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.

Q1. Assertion : Two equipotential surfaces cannot cut each other.
Reason : Two equipotential surfaces are parallel to each other.

Q2. Assertion: The electric potential at any point on the equatorial plane of a dipole is zero.
Reason: The work done in bringing a unit positive charge from infinity to a point in equatorial plane is equal for the two charges of the dipole.

Q3.Assertion : For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.
Reason : The net work done by a conservative force on an object moving along a closed loop is zero.

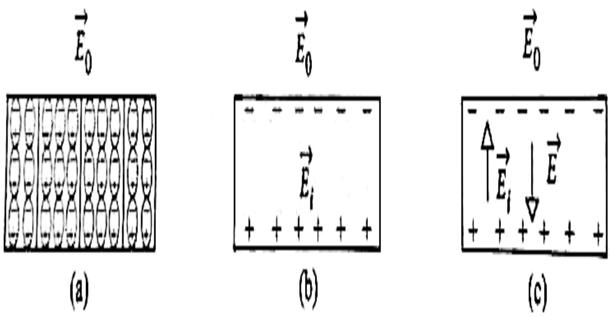
Q4. Assertion : Work done in moving a charge between any two points in an electric field is independent of the path followed by the charge, between these points.
Reason: Electrostatic force is a non-conservative force.

Q5. Assertion : Electric field inside a conductor is zero.
Reason: The potential at all the points inside a conductor is same.

Ans : 1 -C , 2- D , 3 - A , 4 - C , 5 - B

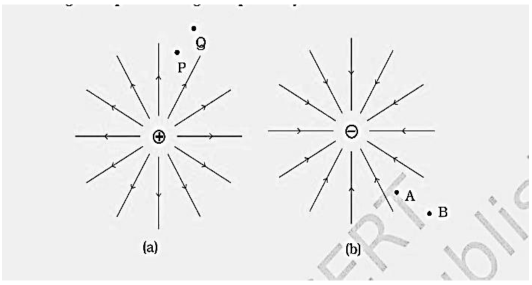
Case based question- 2:

Case 1- When an insulator is placed in an external field, the dipoles become aligned. Induced surface charges on the insulator establish a polarization field $\bar{E}i$ in its interior. The net field $\bar{E}$ in the insulator is the vector sum of $\bar{E}$, and $\bar{E}i$ as shown in the figure.



On the application of external electric field, the effect of aligning the electric dipoles in the insulator is called polarisation and the field Ē; is known as the polarisation field.
The dipole moment per unit volume of the dielectric is known as polarisation (P).
For linear isotropic dielectrics, $P = \chi E$, where χ = electrical susceptibility of the dielectric medium.
(i) Which among the following is an example of polar molecule?
(2) O_2 (b) H (c) N2 (d) HCI
(ii) When air is replaced by a dielectric medium of constant K, the maximum force of attraction between two charges separated by a distance
(a) Increases K times (b) remains unchanged (c) decreases K times (d) increases 2K times.
(iii) Which of the following is a dielectric?
(a) Copper (b) Glass (c) Antimony (Sb) (d) None of these
(iv) For a polar molecule, which of the following statements is true?
(a) The centre of gravity of electrons and protons coincide.
(b) The centre of gravity of electrons and protons do not coincide.
(c) The charge distribution is always symmetrical.
(d) The dipole moment is always zero.
(v) When a comb rubbed with dry hair attracts pieces of paper. This is because the
(a) Comb polarizes the piece of paper
(b) Comb induces a net dipole moment opposite to the direction of field
(c) Electric field due to the comb is uniform
(d) Comb induces a net dipole moment perpendicular to the direction of field
Answer: (i) (d) (ii) (c) (iii) (b) (iv)(b) (v) (a)

Case based question- 2



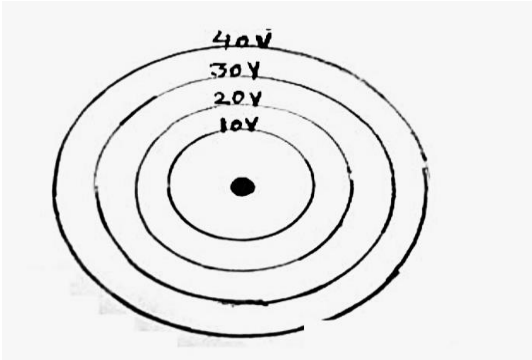
Work done in bringing a unit positive test charge from infinity to the point P, against the repulsive force of charge Q (Q > 0), is the potential at P due to the charge Q.
By definition is the potential at P due to the charge Q is given by $V(r) = Q/4\pi\varepsilon^0 r$
Equation is true for any sign of the charge Q, though we considered Q > 0 in its derivation.
For Q < 0, V < 0, i.e., work done (by the external force) per unit positive test charge in bringing it from infinity to the point is negative. This is equivalent to saying that work done by the electrostatic force in bringing the unit positive charge form infinity to the point P is positive.
Since for Q < 0, the force on a unit positive test charge is attractive, so that the electrostatic force and the displacement (from infinity to P) are in the same direction.] Finally, we
Eq. is consistent with the choice that potential at infinity be zero.
Figures (a) and (b) show the field lines of a positive and negative point charge respectively.
(a) Give the signs of the potential difference (VP – VQ) ; (VB – VA).
(b) Give the sign of the potential energy difference of a small negative charge between the points Q and P; A and B.
(c) Give the sign of the work done by the field in moving a small positive charge from Q to P.
(d) Give the sign of the work done by the external agency in moving a small negative charge from B to A.
(e) Does the kinetic energy of a small negative charge increase or decrease in going from B to A?

Answer : *(a) As $V \propto 1/r$, VP > VQ . Thus, (VP – VQ) is positive. Also VB is less negative than VA . Thus, VB > VA or (VB – VA) is positive.*

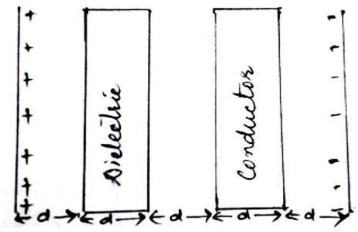
(b) A small negative charge will be attracted towards positive charge. The negative charge moves from higher potential energy to lower potential energy. Therefore the sign of potential energy difference of a small negative charge between Q and P is positive.
Similarly, (P.E.)A > (P.E.)B
and hence sign of potential energy differences is positive.
(c) In moving a small positive charge from Q to P, work has to be done by an external agency against the electric field. Therefore, work done by the field is negative.
(d) In moving a small negative charge from B to A work has to be done by the external agency. It is positive.
(e) Due to force of repulsion on the negative charge, velocity decreases and hence the kinetic energy decreases in going from B to A

LONG ANSWER TYPE QUESTIONS

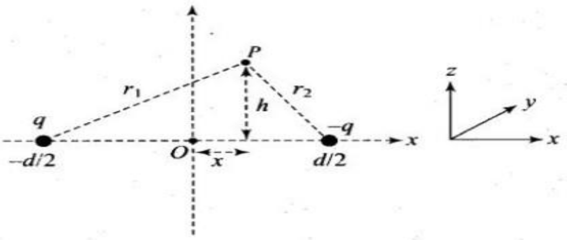
Q1(a) Two isolated metal spheres A and B have radii R and 2R respectively, and same charge q. Find which of the two spheres have greater :
(i) Capacitance and (ii) energy density just outside the surface of the spheres.
(b) (i) Show that the equipotential surfaces are closed together in the regions of strong field and far apart in the regions of weak field. Draw equipotential surfaces for an electric dipole
(ii) 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.



Q2. (a) Two point charges of magnitude +q and -q are placed at (-d/2, 0, 0) and (d/2, 2, 0), respectively. Find the equation of the equipotential surface where the potential is zero .
(b) Given two parallel conducting plates of area A and charge densities + σ & -σ.
A dielectric slab of constant K and a conducting slab of thickness d each are inserted in between them as shown. (i) Find the potential difference between the plates.
(ii) Plot E versus x graph, taking x=0 at positive plate and x=5d at negative plate.



Answer :
Q1. (a) (i) $C_A = 4\pi\varepsilon_0 R$, $C_B = 4\pi\varepsilon_0(2R)$ $C_B>C_A$
(ii) $u = 1/2\ \varepsilon_0 E$ $E= \sigma/\varepsilon_0 = Q/A\ \varepsilon_0$, $u \propto 1/A^2$ $\therefore$ $U_a>U_b$
(b) (i) $E = -dV/dr$ For same change in dV, E α 1/dr
where 'dr' represents the distance between equipotential surfaces. Diagram of equipotential surface due to a dipole
(ii) Polarity of charge – negative Direction of electric field – radially inward
Q2. Answer



The potential at the point P due to charges is given by

$$V_P = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} + \frac{1}{4\pi\varepsilon_0}\frac{(-q)}{r_2}$$

If net electric potential at this point is zero, then

$$0 = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0}\frac{q}{r_2} \Rightarrow \frac{1}{r_1} = \frac{1}{r_2} \text{ or } r_1 = r_2$$

$$r_1 = \sqrt{(x + d/2)^2 + h^2} \text{ and } r_2 = \sqrt{(x - d/2)^2 + h^2}$$

or $\quad (x - d/2)^2 + h^2 = (x + d/2)^2 + h^2$

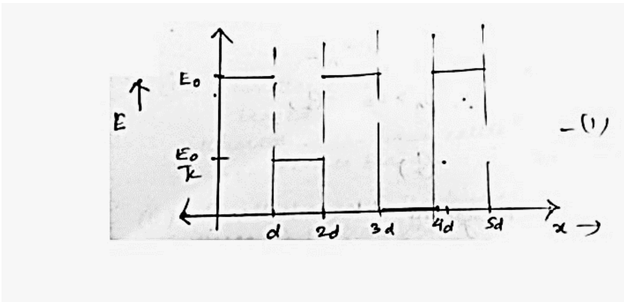
$\Rightarrow \quad x^2 - dx + d^2/4 = x^2 + dx + d^2/4$

or $\quad 2dx = 0 \Rightarrow x = 0$

The equation of the required plane is $x = 0$, i.e., y–z plane.

(b) (i) $V = E^0d + E^0d/k + 0 + E^0d = 3E^0d + E^0d/k$

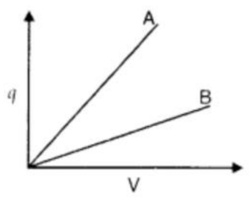
(ii) Graph



SHORT ANSWER QUESTION

Q1. What is the work done in moving a test charge q through a distance of 1 cm along the equatorial axis of an electric dipole?

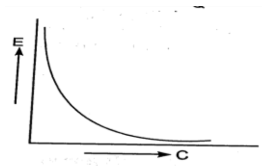
Q2. The given graph shows variation of charge 'q' versus potential difference 'V' for two capacitors C1 and C2. Both the capacitors have same plate seperation but plate area of C2 is greater than that of C1. Which line (A or B) corresponds to C1 and why?



Q3. Net capacitance of three identical capacitors in series is 1 µF. What will be their net capacitance if connected in parallel? Find the ratio of energy stored in the two configurations if they are both connected to the same source.

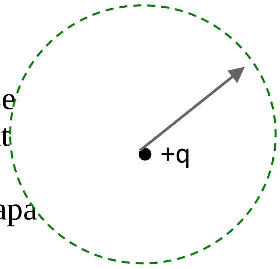
Q4. What is an equipotential surface? List it's properties.

Q5. Two charges of 4µC each are placed at the corners of A and B of an equilateral triangle ABC of side length 0.2m in air. What will be the electric potential at the third corner C?



Q6. Two capacitors of capacitances 3µF and 6µF are charged to potential of 2V and 5V respectively. These two charged capacitors are connected in series. Find the potential across each of the two capacitors?

Q7. The graph shown here shows the variation of total energy (E) Stored in capacitor against the value of the capacitance (C) itself.
Which of the two: the charge on capacitor or
The potential used to charge it , is kept constant for this graph ?



Q8.Draw equipotential surfaces corresponding to a field that uniformly increase
but remains constant along Z-direction. How are the surfaces different from that
electric field along Z-direction?

Q9. A metal plate is introduced between the plates of a charged parallel plate capa
its effect on the capacitance of the capacitor?

Q10 What is the amount of work done in moving a point charge Q around circular arc of radius 'r' at the centre of which another point charge ' q ' is located ?

Answer:

Q1.Since potential for equatorial axis , V = 0 ∴ W = qV = 0

Q2. Line B corresponds to C1

Reason: Since slope (q/v) of 'B' is less than that of 'A'

Q3.

Let C be the capacitance of each capacitor, then in series

$$\frac{1}{C_s} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} = \frac{3}{C}$$

or $C = 3C_s = 3 \times 1\ \mu F = 3\ \mu F$

When these capacitors are connected in parallel, net capacitance, $C_p = 3\,C = 3 \times 3 = 9\ \mu F$

When these two combinations are connected to same source the potential difference across each combination is same.

Ratio of energy stored,

$$\frac{U_s}{U_p} = \frac{\frac{1}{2}C_s V^2}{\frac{1}{2}C_p V^2} = \frac{C_s}{C_p} = \frac{1\,\mu F}{9\,\mu F} = \frac{1}{9}$$

$U_s : U_p = 1 : 9$

For a point charge, the equipotential surfaces are concentric spherical shells.

Q5. We know V = kq/r where $k = 1/4\pi\varepsilon^0 = 9\times10^9$ and r = 0.2m

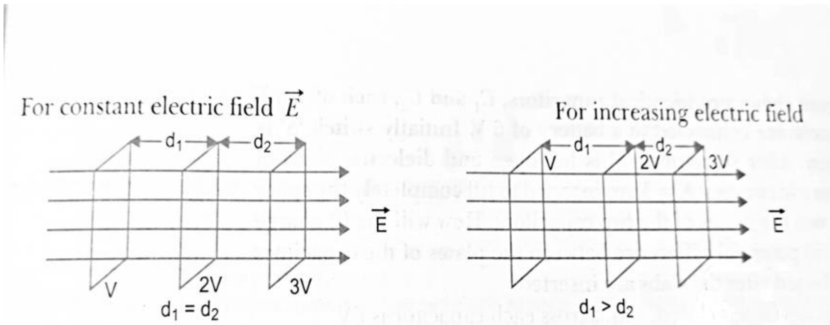
∴ Voltage at C=2 kq/r = $=36\times10^4$ V

Q7. The given graph represents , E ∝ 1/C

This is satisfied by the expression , $E = q^2/2C \propto 1/C$ for constant q .

That is , the charge q is kept constant .

Q8.



Difference: For constant electric field , the equipotential surfaces are equidistant for same potential difference between these surfaces ; while for increasing electric field , the separation between these surfaces decreases , in the direction of increasing field , for the same potential difference between them .

Q9. If t is thickness of metal plate , then $C = \varepsilon^0 A/[d - t(1-1/k)]$

For metal plate k= ∞ , $C = \varepsilon^0 A/(d - t)$

Obviously , effective separation between the plates is decreased from d to (d -t) .
Q10. The potential of points A and B are same being equal to

. $V_a = V_b = (1/4\pi\varepsilon_0)q/r$

Where r is the radius of the circle .

. Work done $W = q(V_a - V_b) = q \times 0 = 0$.

SHORT ANSWER -QUESTIONS (03 marks)

Q1. Describe schematically the equipotential surfaces corresponding to
(a) A constant electric field in the Z- direction
(b) A field that uniformly increases in magnitude but remain in a constant direction (say, Z)
(c) Single positive charge at the origin .
Q2. 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 its (i) capacitance (ii) electric field between the plates and (iii) energy stored in the capacitor be affected? Justify your answer.
Q3. (a) A comb run through one's dry hair attracts small bits of paper . Why?
(b) Ordinary rubber is an insulator. But special rubber tyres of aircraft are made slightly conducting. Why is this necessary?
(c) Vehicles carrying inflammable materials usually have metallic ropes touching the ground during motion. Why?
Q4. (a) For what position of an electric dipole in a uniform electric field its potential energy is (i) minimum and (ii) maximum.
(b) If the electric potential equals to zero at a point ,must the electric field be zero at that point ?
Q5. Deduce an expression for the electric potential due to an electric dipole at any point on its axis. Mention one contrasting feature of electric potential of a dipole at a point as compared to that due to a single charge
Answer Q1. (i) planes parallel to x-y plane
(ii) Planes parallel to x-y plane,except that planes which is differing by a fixed potential get closer as field increases.
(iii) concentric spheres with centre at the origin.
Q2.(i) Let 'C' be capacity of the parallel plate capacitor charged to a potential V of the battery. When the battery is disconnected, the charge on the capacitor remains the same.
(ii) Capacitance: The capacitance of capacitor becomes K times the original value , $C=C^oK$
(iii) Electric field: Electric field is reduced by K times , $E = V/d = V^\circ/Kd = E^o/K$
(iv) Energy stored: The energy stored in the capacitor is reduced by K times

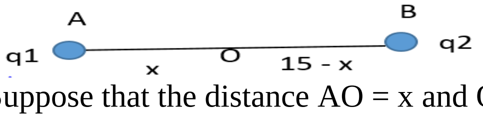
$U = CV^2/2 = 1/2\, KC^o(V/K)^2 = 1/2 C^oV^{o2}/K = U^o/K$

Q3. (a) This is because the comb gets charged by friction.
(b) To enable them to conduct charge produced by friction to the ground.
(c) To enable them to conduct charge produced by friction to the ground .
Q4.(i) minimum at $\theta = 90\ degree$ (ii) Maximum at $\theta = 0\ degree$
Q5 Deuduction u= -p.E=pE cos θ

NUMERICALS

1. Two point charges of 3 x10 $^{-8}$C and -2 x10 $^{-8}$ Care placed 15 cm apart in air. At what point on the line joining the two charge is the electric potential zero? Take the potential at infinity to be zero.

Ans. Given, $q_1 = 3 \times 10^{-8}$C, $q_2 = -2 \times 10^{-8}$C, r = 15 cm, x=?
Let O be the point, where the electric potential is zero due to the two charges (fig.)



Suppose that the distance AO = x and OB = 15-x

Electric potential at point O due q1

$V_1 = \frac{q1}{4\pi\varepsilon 0\ x} = \frac{9 \times 10^9 X\ 3\ X\ 10^{-8}}{x} = \frac{270}{x}$

Electric potential at point O due q2

$V_2 = \frac{q1}{4\pi\varepsilon 0\ (15-x)} = \frac{9 \times 10^9 X\ 2 \times 10^{-8}}{x} = \frac{280}{15-x}$

Since the electric potential at point O is zero, we have

$V1 + V_2 = 0,$ $\frac{280}{15-x} = \frac{270}{x}$

x = 9cm from q_1

2. (i) Two capacitor of capacitances 5μF and 10μFare charge to 16V respectively. What is the common potential when they are connected in parallel?

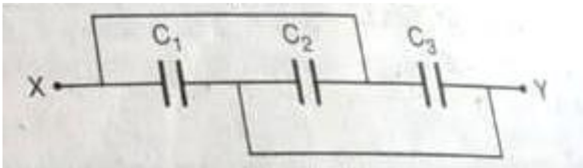
Ans: Given $C_1 = 5 \times 10^{-6}$, $C_2 = 10 \times 10^{-6}$, V1 = 16V, V2 =13V

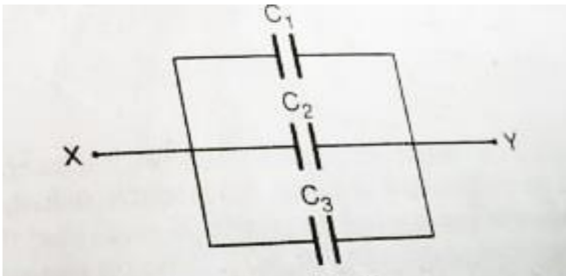
Charge on the capacitor C_1, $q1 = C_1V1= 5 \times 10^{-6} \times 16 = 80 \times 10^{-6}$ C

Charge on the capacitor C_2, $q2 =C_1V2= 10 \times 10^{-6} \times 13 = 130 \times 10^{-6}$ C

$V = \frac{q1+ q2}{C1+C2} = \frac{80\ X\ 10^{-6}+\ 130\ X\ 10^{-6}}{5\ X\ 10^{-6}+\ 10\ X\ 10^{-6}} = 14V$

(ii) There capacitor C1, C2 and C3 of capacitance 3μF, 2μF and 5μF respectively are connected as shown in fig. find the equivalent capacitor of the combination between point X and Y.





Ans: The given circuit is like below fig.

Given C1 = 3μF, C2 = 2μF, C3 =5μF

So C1, C2 and C3 are in parallel, so that equivalent capacitance between X and Y

Cp = C1 + C2 + C3 = 3 +2 +5 = 10μF

3. Calculate the equivalent capacity in the given figure across the point.M & N
(Ans. 12μF)

Hint- Capacitance between MD and DC are in series

Their equivalent capacitance $C1=\frac{8*8}{8+8} = 4\mu F$

Equivalent capacitance across $MC=\frac{8*8}{8+8} = 4\mu F$

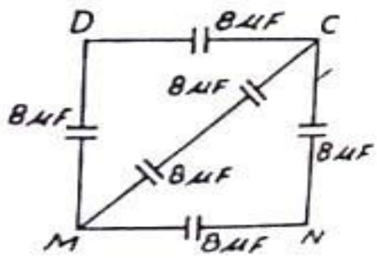
Therefore $C_2=4\mu F$

Now C_1 and C_2 are in parallel so its equivalent capacitance $C_3=C_1+C_2=8\mu F$

Now c3+8μF are in series

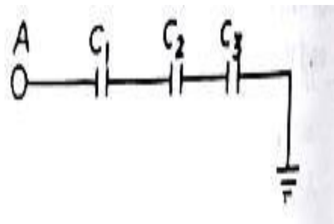
Therefore $C_4=\frac{8*8}{8+8} =4\mu F$

Therefore equivalent capacitance across MN =(4+8) μF =12μF



4. . In the figure shown calculate the potential difference across the capacitor C_2 if C_1=20μF; C_2=30F; C_3=15F and the potential of point A is 90V.

(Ans.20V)



Since the condensers are in series hence,

$\frac{1}{C} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3}$ or $C= \frac{C1C2C3}{C2C3+C1C3+C1C2} = \frac{20}{3}F$

Therefore, charge q=CV=(20/3)*90=600 coulomb.

Hence, P.D across the condenser C_2, $V2 = \frac{q}{C2} = 20V$

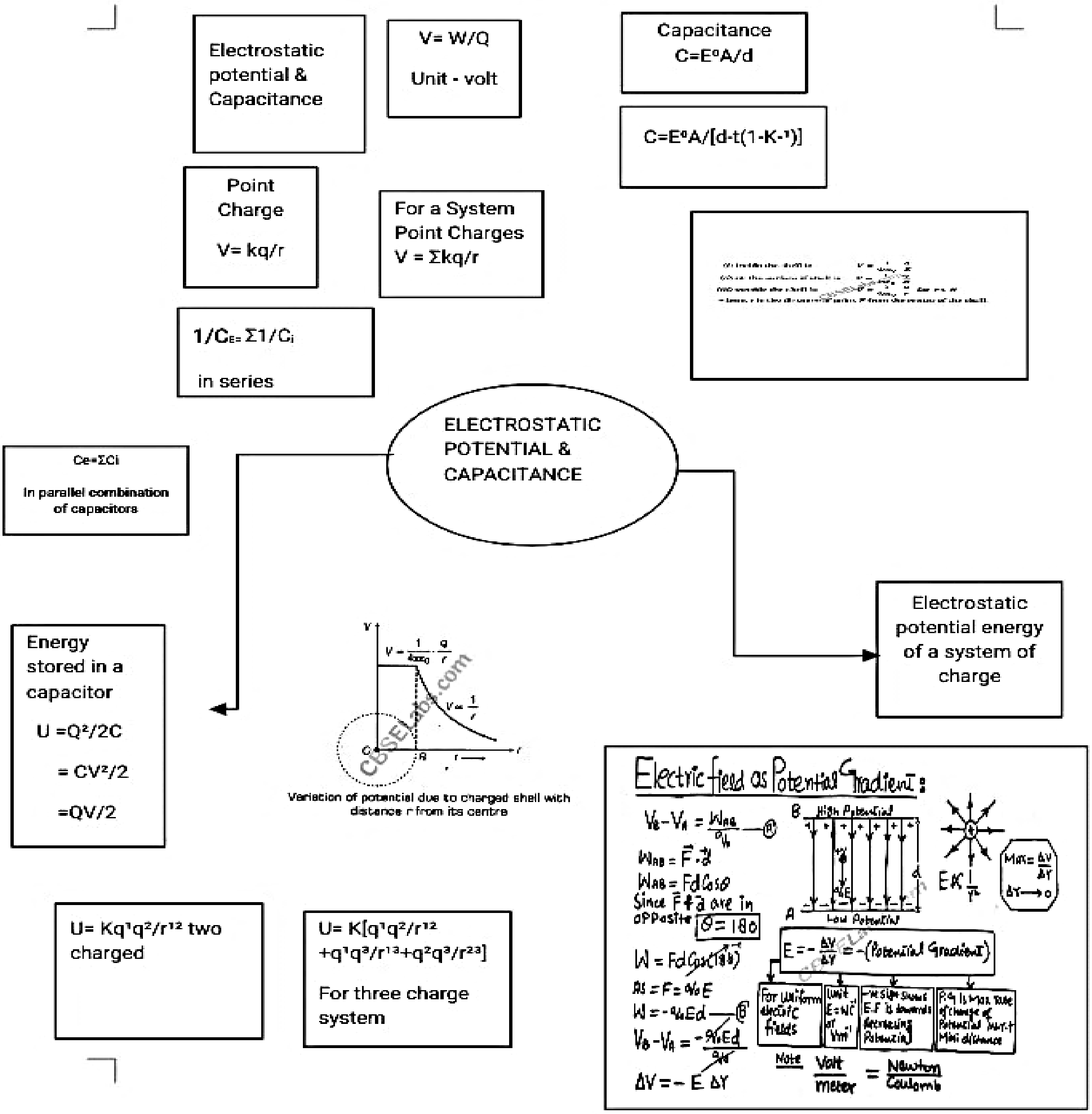
5. A 800 pF capacitor is charged by a 100V battery. After sometime, the battery is disconnected. The capacitor is then connected to another 800pF capacitor. What is the electrostatic energy stored.

Ans: Given $C_1 = 800 \times 10^{-12}$, 800×10^{-12}, $V_1 = 100V$, $C_2 = 800 \times 10^{-12}C$, $V_2 = 0$, U=?

$V = \frac{C1V1 + C2V2}{C1+C2} = \frac{8\ X\ 10^{-10}\ X\ 100}{(800+\ 800)10^{-12}} = 50V$

Electric energy (U) $= \frac{(C1+C2)V^2}{2} = \frac{(800+800)10^{-12}\ X\ (50)^2}{2} = 2 \times 10^{-6}$ J.

MIND MAP

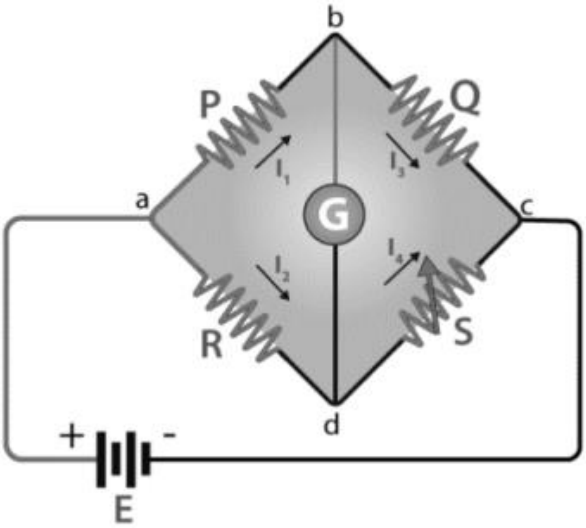


CHAPTER-3
CURRENT ELECTRICITY

SUMMARY

Electric current. It is the rate of flow of electric charge through a conductor.
Mathematically - I= Q/t
Unit. In SI, the unit of electric current is ampere (A).
1 ampere (A) = 1 coulomb per second (C S^{-1})
Ohm's law -It states that physical conditions remaining unchanged, the current flowing through a conductor is always directly proportional to the potential difference across its two ends.
Mathematically - $V \propto I$ or $V=RI$
Here, R is called resistance of the conductor.
Unit. The unit of resistance is ohm (Ω)
1 ohm (Ω) = 1 volt/ampere (V/A)
Resistance of a conductor. The resistance of a conductor of length l and area of cross-section A is given by $R = \rho\, l/A$
Here, ρ is resistivity of the material of the conductor.
Resistivity. The resistivity of the material of a conductor is the resistance offered by a wire of this material of unit length and unit area of cross-section. It is also known as specific resistance of the material of the conductor. Unit. **The SI unit of resistivity is ohm metre (Ω m)**
Conductance. The reciprocal of the resistance of a conductor is called its conductance (G).
Thus, $G=1/R$ **Unit. The SI unit of conductance is ohm^{-1} (Ω^{-1}) or siemen (S). ohm^{-1} is also written as mho.**
Conductivity. The reciprocal of the resistivity of the material of a conductor is called its conductivity. Thus, $\sigma=1/\rho$
Unit. The SI unit of conductivity is siemen /metre (S/m). ohm^{-1} $metre^{-1}$ is also written as mho /metre'.
Drift velocity. It is the velocity with which a free electron in the conductor gets drifted under the influence of the applied external electric field.
Mathematically - $\boldsymbol{v_d = eE\tau/m = I/neA}$
Here, τ is average relaxation time and n is number of free electrons per unit volume in the conductor. The other symbols have their usual meanings.
Temperature coefficient of resistance. It is defined as the change in resistance per unit resistance per degree rise in temperature.
If resistance increases linearly up to temperature θ, then temperature coefficient,
$\alpha = (R_t - R_0)/R_0\theta$ **Unit. The unit of temperature coefficient is $°C^{-1}$.**
E.M.F. The work done per unit charge by the source in taking the charge from its one terminal to the other is called the electromotive force or e.m.f. of the source.
$I= E/(R + r)$
It is equal to the potential difference between the two terminals of the source, when no current is drawn from it.
Internal resistance. The resistance offered by the electrolyte of the cell, when the electric current flows through it, is known as internal resistance of the cell.
If V is potential difference across the two terminals of a cell, when a current I is drawn from it, then
$V = E - Ir = E\,[1 - r/(R+r)]$
Here, E is e.m.f. of the cell and R, the external resistance in the circuit.
Mathematically- $r = R\,(E/V - 1)$

For n cell in series, I = $nE/(R+nr)$
For n cells in parallel, I = $nE/(nR+r)$
Heat produced by electric current, H = $I^2 Rt$
Electric power, P = W/t = VI = I^2R = V^2/R
Electric energy, W = Pt = VIt =



Kirchhoff's Laws. These laws are used to analyse electric circuits.
First law, It states that the algebraic sum of the currents meeting at a point (junction) in an electrical circuit is always zero. $\Sigma I = 0$
Second law. It states that in any closed loop of an electrical circuit, the algebraic sum of the e.m.fs. is equal to the algebraic sum of the products of the resistances and the currents flowing through them.
$\Sigma E = \Sigma IR$
Wheatstone bridge. It is an arrangement of four resistances used to determine an unknown resistance.
In a balanced Wheatstone bridge,
$P/Q = R/S$
where P, Q, R and S are resistances in the four arms of the Wheatstone bridge.(3)

MULTIPLE CHOICE QUESTIONS

Q1A metal rod of length 10 cm and a rectangular cross-section of 1cm x ½ cm is connected to a battery across opposite faces. The resistance will be
(a) Maximum when the battery is connected across 1cm x ½ cm faces.
(b) Maximum when the battery is connected across 10 cm x 1cm faces.
(c) Maximum when the battery is connected across 10 cm x ½ cm faces.
(d) Same irrespective of the three faces.
Ans-(a) Maximum when the battery is connected across 1cm x ½ cm faces.
2. 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.
Ans. (B)Law of conservation of energy.
3. In a Whetstone's bridge, all the four arms have equal resistance R. If resistance of the galvanometer arm is also R, then equivalent resistance of the combination is-
(A) R (B)2R
(C)R/2 (D)R/4
Ans. (A) R
4. Drift velocity vd varies with the intensity of electric field as per the relation :
(A) $v_d \propto E$ (B) $v_d \propto 1/E$
(C) v_d = constant (D) $v_d \propto E^2$
Ans. (A) $v_d \propto E$
5. Two electric bulbs whose resistances are in the ratio of 1:2 are connected in parallel to a constant voltage source the power dissipated in them have the ratio-
(A)1:2 (B)1:1
(C)2:1 (D)1:4

Ans. ©2:1

6. EMF of a cell depends:

(A) nature of electrolyte (B) metal of electrode
(C) both (A) and (B) (D) None of these

Ans.- (C) both (A) and (B)

7. A 12 cm wire is given shape of of a a right angled triangle PQR having sides PQ = 3 cm , QR= 4cm and RP= 5 cm. The resistance between two ends (PQ, QR, RP) of the respective sides are measured one by one by a multimeter. The resistances will be in the ratio

(A) 27:32:35 (B) 9:16:25 (C) 4:3:5 (D) 3:4:5

Ans. (A) 27:32:35

8. What is the effect on the product of resistivity and conductivity of a conductor when its temperature is increased?

(A) may increase or decrease. (B) increases (C) decreases. (D) remains constant

Ans. (D) remains constant

9. Specific resistance of a conductor increases with :–

(A) increase in temperature. (B) increase in cross–sectional area
(C) increase in cross–sectional area and decrease in length. (D) decrease in cross–sectional

Ans. (A) increase in temperature.

10. The resistance of an ideal ammeter is

(a) Infinite (b) Very high (c) Small (d) Zero

Ans. (d) Zero

ASSERTION REASON TYPE QUESTIONS

The questions given below consist of an Assertion and a Reason. Use the following key to choose the appropriate answer.

(a) If both Assertion and Reason are true and the reason is 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 the Reason is false.

(d) If Assertion is false, but the Reason is true.

1.Assertion: Electric appliances with metal body has three electrical connection but an electrical bulb has two electrical connection.

Reason: Three pin connections reduce chance of electric shock.

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

2. Assertion: EMF of battery increases with time.

Reason: Internal resistance increases with time.

Ans.(d) If Assertion is false, but the Reason is true.

3. Assertion : Voltmeter is connected in parallel with the circuit.

Reason : Resistance of a voltmeter is very large.

Ans. (b) If both Assertion and reason are true, but Reason is not correct explanation of the Assertion.

4. Assertion: Kirchhoff's junction law follows from the conservation of charges.

Reason: Kirchhoff's loop law follows from the conservation of energy.

Ans. (b) If both Assertion and reason are true, but Reason is not correct explanation of the Assertion.

5. Assertion : Though the direction of electric current is well defined, yet it is treated as a scalar.

Reason : Electric current does not follow the laws of vector addition.

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

CASE BASED QUESTION

Q1. Read the passage given below and answer the following questions

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

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

(a) Doubled (b) Halved (c) Remains same (d) Becomes four times.
Ans. (a) Doubled

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

(a) 100 W (b) 25 W (c) Both bulbs will glow brighter (d) None will glow brighter
Ans. (b) 25 W

(iv) A rigid container with thermally insulated wall contains a coil of resistance 100 Ω, carrying 1A. Change in its internal energy after 5 min will be

(a) 0 Kj (b) 10 kJ (c)20 kJ (d) 30 kJ
Ans. (d) 30 kJ

(v) The heat emitted by a bulb of 100 W in 1 min is

(a) 100 J (b) 1000 J (c) 600 J (d) 6000 J
Ans. (d) 6000 J

Q2 Read the passage given below and answer the following questions

An electrocardiogram records the electrical signals in your heart. It's a common and painless test used to quickly detect heart problems and monitor your heart's health. During an ECG, up to 12 sensors (electrodes) will be attached to your chest and limbs. The electrodes are sticky patches with wires that connect to a monitor. They record the electrical signals that make your heart beat. A computer records the information and displays it as waves on a monitor or on paper. It works on the principle that a contracting muscle generates a small electric current that can be detected and measured through electrodes suitably placed on the body. The voltage is in the range of 1mV ~ 5 mV. Using this information and concepts of current electricity, answer any four of the following questions:

(i). The voltage range in which an ECG works is

(a) 1-2 V (b) 1-10 V (c) 1-5 V (d) 1-5 mV
Ans. (d) 1-5 mV

(ii). What is the purpose of the probes connected to the human body while taking an ECG?

(a) They supply current to the heart. (b) They detect current when the heart muscles contract.
(c) Both a and b (d) None of these.
Ans. (b) They detect current when the heart muscles contract.

(iii). How much current can a human body withstand?

(a) More than 10 mA (b) Less than 10 mA (c) More than 1A (d) Less than 100 mA

Ans. (b) Less than 10 mA

(iv). Drift velocity is of the order of

(a) about 10^{-6} ms^{-1} (b) about 10^{4} ms^{-1} (c) about $10^{-4}ms^{-1}$ (d) None of these

Ans. (c) about $10^{-4}ms^{-1}$

(v). The resistance of a wet human body is

(a) 10 Ω (b) 100 Ω (c) 1000 Ω (d) 500 Ω

Ans. (c) 1000 Ω

SHORT ANSWER TYPE QUESTIONS (2 MARKS)

Q.1 How does the mobility of electrons in a conductor change, if the potential difference applied across the conductor is doubled, keeping the length and temperature of the conductor constant?

Ans. Mobility is defined as the magnitude of drift velocity per unit electric field.

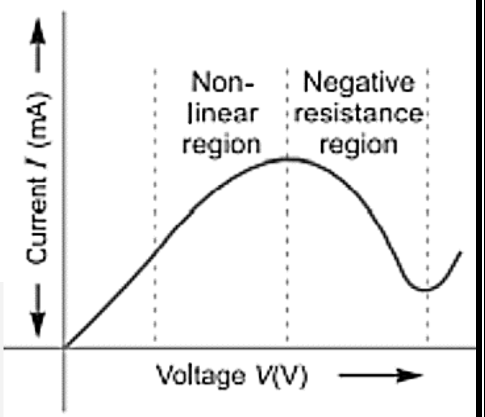
$\mu = vd/E = eE\tau/mE = e\tau/m$

$\mu \; \alpha \; \tau$ At constant temperature and length, there is no change in relaxation time i.e., $t \propto 1/T$

Also, it does not depend on potential difference. Hence, on changing the potential difference, there is no change in mobility of electrons.

Q.2 Plot a graph showing variation of current versus voltage for the material GaAs.

Ans- The variation of electric current with applied voltage for GaAs is as shown



Q.3 Two wires, one of copper and the other of manganin, have same resistance and equal thickness.Which wire is longer? Justify your answer.

Ans- 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).

Resistance of copper wire, $R = \frac{\rho_1 l_1}{A}$

Resistance of manganin wire $R = \frac{\rho_2 l_2}{A}$

$\Rightarrow \quad \rho_1 l_1 = \rho_2 l_2$ (As ρl = constant)

Since $\rho_1 <<< \rho_2$

So, $l_1 >>> l_2$

i.e., copper wire would be longer.

Q.4 Nichrome and copper wires of same length and same radius are connected in series. Current I is passed through them. Which wire gets heated up more? Justify your answer

Ans.

Nichrome wire gets heated up more.

Heat dissipated in a wire is given by

$$H = I^2Rt$$

$$H = I^2 \frac{\rho l}{A} t \quad \left(\because R = \frac{\rho l}{A}\right)$$

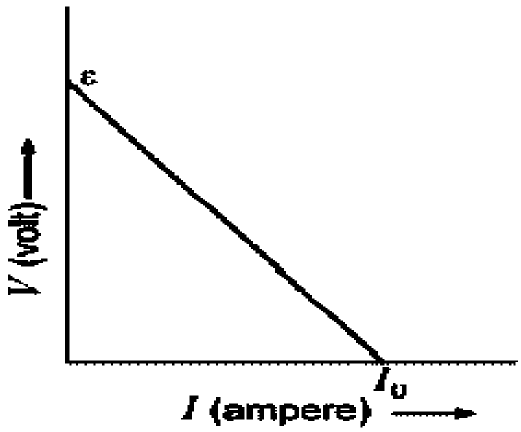
Here, radius is same, hence area (A) is same. Also, current (I) and length (l) are same.

$\therefore \quad H \propto \rho$

But $\rho_{nichrome} > \rho_{copper}$

$\therefore \quad H_{nichrome} > H_{copper}$

Q.5 Why are alloys used for making standard resistance coils?
Ans. Alloys have (i)low value of temperature coefficient and the resistance of the alloy does not vary much with rise in temperature. (ii) high resistivity, so even a smaller length of the material is sufficient to design high standard resistance.
Q.6 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



$$V = \varepsilon - Ir \Rightarrow r = \frac{\varepsilon - V}{I}$$

At $I = 0, V = \varepsilon$

When $V = 0$, $I = I_0,\ r = \frac{\varepsilon}{I_0}$

The intercept on y-axis gives the emf of the cell. The slope of graph gives the internal resistance.

Q.8 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 current is same,

So, $I_X = I_Y = I = neAv_d$

For same diameter, cross-sectional area is same

$A_X = A_Y = A$

$\therefore \quad I_X = I_Y \Rightarrow n_x eAv_x = n_y eAv_y$

Given $n_x = 2n_y \Rightarrow \frac{v_x}{v_y} = \frac{n_y}{n_x} = \frac{n_y}{2n_y} = \frac{1}{2}$

Q.9 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.

(i) We know that $v_d = -\frac{eV\tau}{ml} \propto \frac{1}{l}$

When length is tripled, the drift velocity becomes one-third.

(ii) $R = \rho \frac{l}{A}$, $l' = 3l$

New resistance

$$R' = \rho\frac{l'}{A'} = \rho \times \frac{3l}{A/3} = 9R \quad \Rightarrow \quad R' = \mathbf{9R}$$

Hence, the new resistance will be 9 times the original.

Q.10 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 (i) V is halved? (ii) l is doubled? (iii) D is halved?

Ans.

Drift velocity, $v_d = \frac{I}{neA} = \frac{V/R}{neA} = \frac{V}{neA\left(\frac{\rho l}{A}\right)} = \frac{V}{ne\rho l}$

(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.

LONG ANSWER TYPE QUESTIONS (3Marks)

Q.1. Define internal resistance of a cell. What are the factors those affect it?

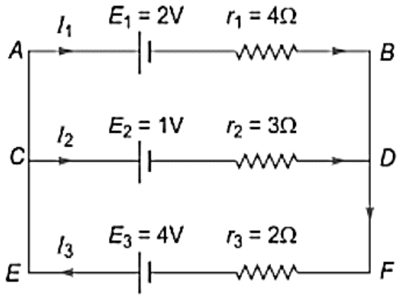
Ans. The opposition offered by the electrolyte of the cell to the flow of electric current through it is called the internal resistance of the cell.

Factors affecting Internal Resistance of a cell:

Larger the separation between the electrodes of the cell, more the length of the electrolyte through which current has to flow and consequently a higher value of internal resistance. Greater the conductivity of the electrolyte, lesser is the internal resistance of the cell. i.e. internal resistance depends on the nature of the electrolyte. The internal resistance of a cell is inversely proportional to the common area of the electrodes dipping in the electrolyte. The internal resistance of a cell depends on the nature of the electrodes.

Q.3. Write Kirchoff's rules. What kind of conservation do they represent? Use these rules to write the expressions for the currents I_1, I_2 and I_3 in the circuit diagram shown.

Ans. Kirchhoff’s Rule:
Junction Rule:-The algebraic sum of currents meeting at a point is zero.It is in accordance with conservation of charge
ii) Loop rule:-The algebraic sum of potential difference around a closed loop is zero.It is in accordance with conservation of energy.



Kirchhoff’s Rules:

(*i*) The algebraic sum of currents meeting at any junction is zero, *i.e.*,

$$\Sigma I = 0$$

(*ii*) The algebraic sum of potential differences across circuit elements of a closed circuit is zero, *i.e.*, $\Sigma V = 0$

From Kirchhoff’s first law

$I_3 = I_1 + I_2$ ...(*i*)

Applying Kirchhoff’s second law to mesh *ABDCA*

$$-2 - 4I_1 + 3I_2 + 1 = 0$$

$\Rightarrow \quad 4I_1 - 3I_2 = -1$ ...(*ii*)

Applying Kirchoff’s second law to mesh *ABFEA*

$$-2 - 4I_1 - 2I_3 + 4 = 0$$

$\Rightarrow \quad 4I_1 + 2I_3 = 2$ or $2I_1 + I_3 = 1$

Using (*i*) we get

$\Rightarrow \quad 2I_1 + (I_1 + I_2) = 1$

or $\quad 3I_1 + I_2 = 1$ ...(*iii*)

Solving (*ii*) and (*iii*), we get

$$I_1 = \frac{2}{13}\text{ A}, I_2 = 1 - 3I_1 = \frac{7}{13}\text{ A}$$

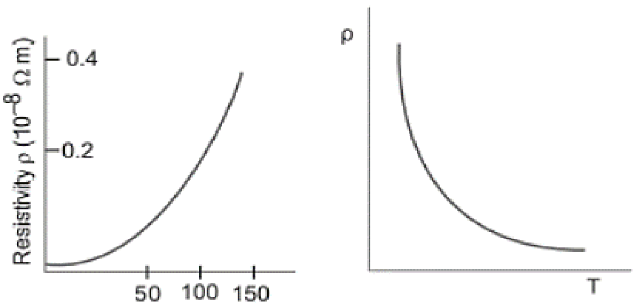
so, $\quad I_3 = I_1 + I_2 = \frac{9}{13}$**A**

4.(a) Out of 40 and 60 Watt bulb , which has greater resistance ?
(b) 60 Watt and 100 Watt bulbs are connected parallel to 220 Volt supply. Which bulb will glow more? (c) 100 Watt and 200 Watt bulbs are connected series to 220 Volt supply. Which bulb will glow more?

Ans. (a) 40 Watt has greater resistance because $P \propto 1/R$. (b) 100 Watt bulb will glow more. $H = V^2t/R$ & $P \propto 1/R$. (c) 100 Watt bulb will glow more. $H = I^2Rt$ & $P \propto 1/R$.

Q.5. 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- We know that, $\rho = \boldsymbol{m/ne^2\,\tau}$
Where m is mass of electron, t = charge density, τ = relaxation time e = charge on the electron.
In case of conductors with increase in temperature, relaxation time decreases, so resistivity increases. In case of semiconductors with increase in temperature number density (n) of free electrons increases, hence resistivity decreases.



LONG ANSWER TYPE QUESTIONS (5Marks)

Q.1. Make circuit diagram of Wheatstone Bridge and obtain condition for balance.

Ans.

Wheatstone Bridge:

Currents through the arms are assumed by applying Kirchhoff's Junction Rule.

Applying Kirchhoff's Loop Rule for:

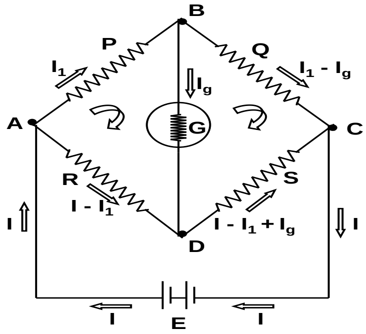
Loop ABDA:

$-I_1.P - I_g.G + (I - I_1).R = 0$

Loop BCDB:

$-(I_1 - I_g).Q + (I - I_1 + I_g).S + I_g.G = 0$

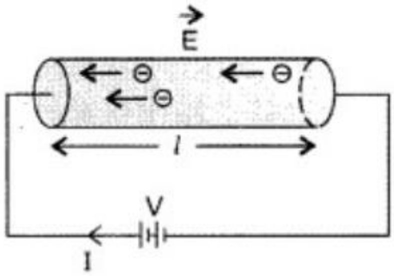
When $I_g = 0$, the bridge is said to balanced.



By manipulating the above equations, we get $\boxed{\dfrac{P}{Q} = \dfrac{R}{S}}$

Q.2.(a) (i)Why do the 'free electrons', in a metal wire, 'flowing by themselves', not cause any Current flowing in the wire? (ii)Explain the term 'drift velocity' of electrons in a conductor. Derive the expression of drift velocity Hence obtain the expression for the current through a conductor in terms of 'drift velocity'

(b) Use the above expression to show that the 'resistivity', of the material of a wire, is proportional to the Relaxation time



Answer: (a) (i) The free electrons, in a metal, (flowing by themselves), have a random distribution of their velocities. Hence the net charge crossing any cross section in a unit time is zero.

(ii) The drift velocity equals the average (time dependent) velocity acquired by free electrons, under the action of an applied (external) electric field.

Its unit is m/s and dimensions $[LT^{-1}]$

Let n be the number of free electrons per unit volume of the conductor. Acceleration= a= eE/m

$V_d = [(U_1 + a\tau_1) + (U_2 + \tau_2) + \ldots\ldots(U_n + a\tau_n)]/n$

$= [(U_1 + U_2 + \ldots + U_n]/n + [a(\tau_1 + \tau_2 + \ldots\ldots + \tau_n)]/n = 0 + a\tau$ $\qquad V_d = eE\tau/m$

$$t = \frac{1}{v_d} \qquad \text{where } [v_d \text{ is drift velocity of electrons}$$

$$\therefore \quad I = \frac{Q}{t} = \frac{nAle}{\frac{l}{v_d}} = neAv_d \qquad \therefore \boxed{I = neAv_d}$$

(b) We know from above

$$I = -neA\, v_d \qquad \ldots(i)$$

$$\text{Also we know, } v_d = \left(\frac{e\vec{E}}{m}\right)\tau \qquad \ldots(ii)$$

Putting the value of v_d in equation (i) from equation (ii) we have

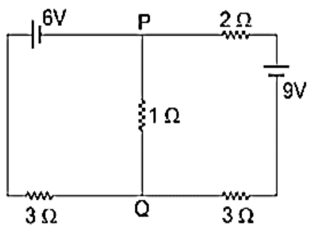
$$I = -neA\frac{eE}{m}\tau \qquad \left[\because E = \frac{V}{l}\right.$$

$$\text{or} \quad \frac{E}{I} = -\frac{m}{ne^2A\tau} \qquad \left[\because \rho = \frac{RA}{l}\right.$$

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

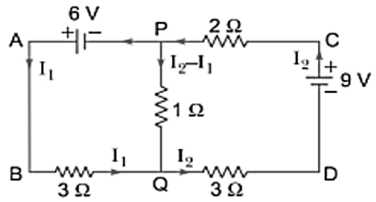
$$\rho \propto \frac{1}{\tau}$$

NUMERICALS (3 MARKS)



Q. 1 Find the magnitude and direction of current in 1Ω resistor in the given circuit.

ANS:



For the mesh *APQBA*

$$-6 - 1(I_2 - I_1) + 3I_1 = 0$$

or $$-I_2 + 4I_1 = 6 \qquad ...(i)$$

For the mesh *PCDQP*

$$2I_2 - 9 + 3I_2 + 1(I_2 - I_1) = 0$$

or $$6I_2 - I_1 = 9 \qquad ...(ii)$$

Solving (*i*) and (*ii*), we get

$$I_1 = \frac{45}{23}\text{A} \quad \text{and} \quad I_2 = \frac{42}{23}\text{A}$$

$\therefore$ Current through the 1 Ω resistor $= (I_2 - I_1) = \frac{-3}{23}$**A**

Q.2 Using the concept of free electrons in a conductor, derive the expression for the conductivity of a wirein terms of number density and relaxation time. Hence obtain the relation between current density and the applied electric field E.

Ans.

The acceleration, $\vec{a} = -\frac{e}{m}\vec{E}$

The average drift velocity is given by, $v_d = -\frac{eE}{m}\tau$

(τ = average time between collisions or relaxation time)

If *n* is the number of free electrons per unit volume, the current *I* is given by

$$I = neA|v_d|$$

$$= \frac{e^2A}{m}\tau n\,|E|$$

But $I = |j|\,A$ **(where** j**= current density)**

Therefore, we get

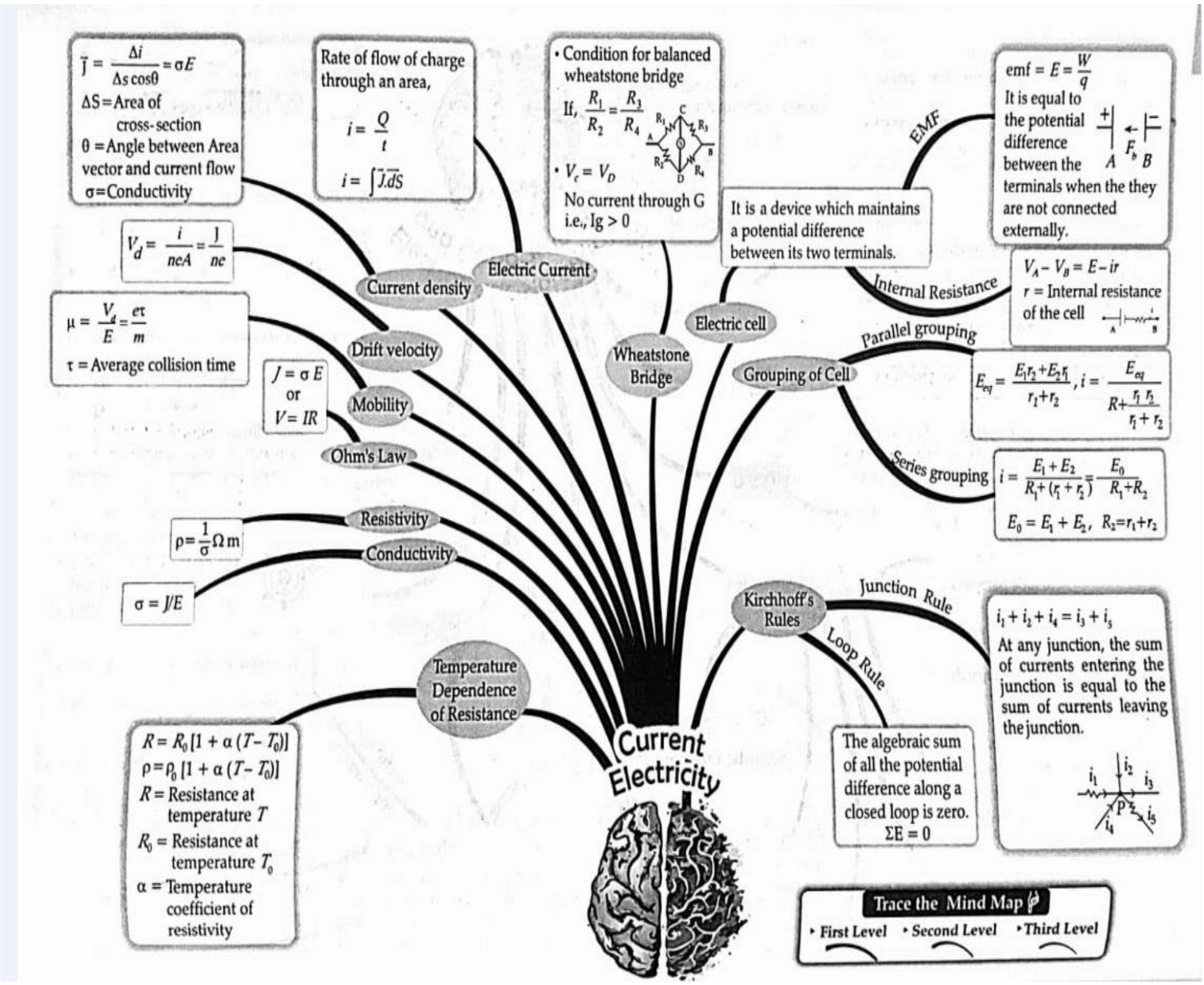
$$|j| = \frac{ne^2}{m}\tau\,|E|.$$

The term $\frac{ne^2}{m}\tau$ **is conductivity.**

$$\therefore \sigma = \frac{ne^2\tau}{m}$$

$$\Rightarrow \qquad J = \sigma E$$

MIND MAP

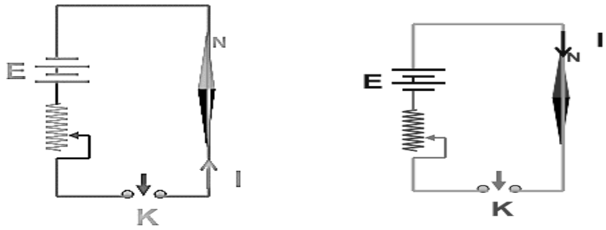


Current Electricity
Current density
Electric Current
Drift velocity
Mobility
Ohm's Law
Resistivity
Conductivity
Temperature Dependence of Resistance
Wheatstone Bridge
Electric cell
Grouping of Cell
Kirchhoff's Rules
EMF
Internal Resistance
Parallel grouping
Series grouping
Junction Rule
Loop Rule
J = Δi / Δs cosθ = σE
ΔS = Area of cross-section
θ = Angle between Area vector and current flow
σ = Conductivity
Rate of flow of charge through an area,
i = Q/t
i = ∫J.dS
Condition for balanced wheatstone bridge
If, R1/R2 = R3/R4
Vc = VD
No current through G
i.e., Ig > 0
Vd = i/neA = J/ne
μ = Vd/E = eτ/m
τ = Average collision time
J = σE or V = IR
ρ = 1/σ Ωm
σ = J/E
R = R0 [1 + α (T − T0)]
ρ = ρ0 [1 + α (T − T0)]
R = Resistance at temperature T
R0 = Resistance at temperature T0
α = Temperature coefficient of resistivity
emf = E = W/q
It is equal to the potential difference between the terminals when the they are not connected externally.
It is a device which maintains a potential difference between its two terminals.
VA − VB = E − ir
r = Internal resistance of the cell
Eeq = (E1r2 + E2r1)/(r1 + r2), i = Eeq / (R + r1r2/(r1 + r2))
i = (E1 + E2)/(R1 + (r1 + r2)) = E0/(R1 + R2)
E0 = E1 + E2, R2 = r1 + r2
i1 + i2 + i4 = i3 + i5
At any junction, the sum of currents entering the junction is equal to the sum of currents leaving the junction.
The algebraic sum of all the potential difference along a closed loop is zero.
ΣE = 0
Trace the Mind Map
First Level
Second Level
Third Level

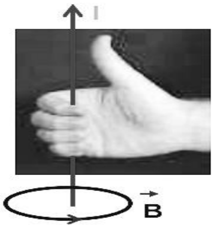
CHAPTER-4
MOVING CHARGES AND MAGNETISM

<u>Magnetic Effect of Current</u>: An electric current (i.e. flow of electric charge) produces magnetic effect in the space around the conductor called strength of Magnetic field or simply Magnetic field.

<u>Oersted's Experiment</u>: When current was allowed to flow through a wire placed parallel to the axis of a magnetic needle kept directly below the wire, the needle was found to deflect from its normal position**.** When current was reversed through the wire, the needle was found to deflect in the opposite direction to the earlier case.

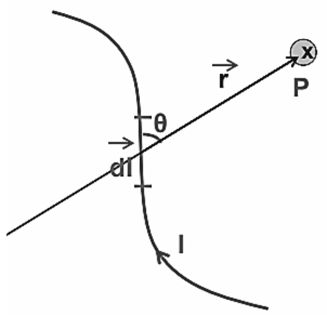


Right Hand Thumb Rule or Curl Rule: If a current carrying conductor is imagined to be held in the right hand such that the thumb points in the direction of the current, then the tips of the fingers encircling the conductor will give the direction of the magnetic lines of force.



<u>Biot – Savart's Law:</u> The strength of magnetic field dB due to a small current element d l carrying a current I at a point P distant r from the element is directly proportional to I, d l, sin θ and inversely proportional to the square of the distance (r2) where θ is the angle between d l and r.

i) dB α I   ii) dB α d l   iii) dB α sin θ   iv) dB α 1 / r²



$$dB \propto I\, dl \sin\theta / r^2$$

$$dB = \mu_0 I\, dl \sin\theta / 4\pi r^2$$

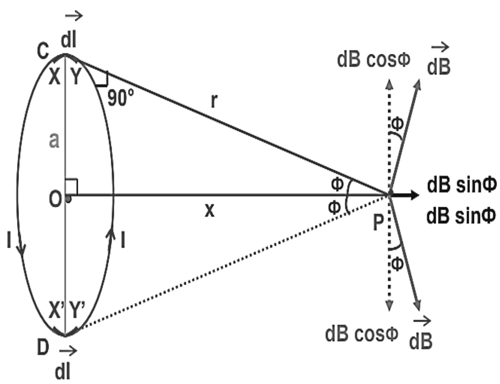
$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,\vec{dl} \times \hat{r}}{r^2}$$

Biot – Savart's Law in vector form:

$$\vec{dB} = \frac{\mu_0}{4\pi}\frac{I\,\vec{dl} \times \vec{r}}{r^3}$$

Value of $\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1} or Wb m^{-1} A^{-1}.
Direction of dB is same as that of direction of dl x r which can be determined by Right Hand Screw Rule. It is emerging at P' and entering at P into the plane of the diagram. Current element is a vector quantity whose magnitude is the vector product of current and length of small element having the direction of the flow of current. (I dl)

<u>Magnetic Field due to a Circular Loop carrying current:</u>1) At a point on the axial line: The plane of the coil is considered perpendicular to the plane of the diagram such that the direction of magnetic field can be visualized on the plane of the diagram. At C and D current elements XY and X'Y' are considered such that current at C emerges out and at D enters into the plane of the diagram.



$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl \sin\theta}{r^2} \quad \text{or} \quad dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

dB is resolved into components dB cosΦ and dB sinΦ .

Due to diametrically opposite current elements, cosΦ components are always opposite to each other and hence they cancel out each other. SinΦ components due to all current elements dl get added up along the same direction (in the direction away from the loop).

$$B = \int dB \sin\Phi = \int \frac{\mu_0 \; I \, dl \sin\Phi}{4\pi \; r^2} \quad \text{or} \quad B = \frac{\mu_0 I \,(2\pi a)\, a}{4\pi\,(a^2 + x^2)\,(a^2 + x^2)^{1/2}}$$

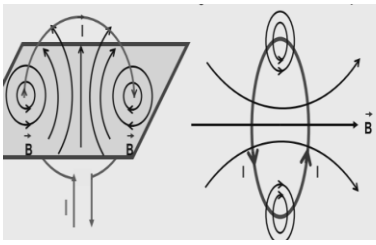
$$B = \frac{\mu_0 I a^2}{2(a^2 + x^2)^{3/2}}$$

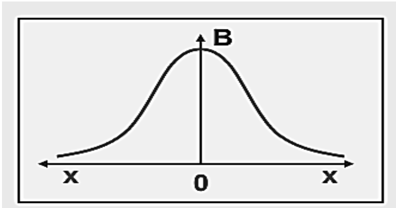
(μ_0 , I, a, sinΦ are constants, ∫dl = 2πa and r & sinΦ are replaced with measurable and constant values.)

Special Cases: i) At the centre O, x = 0. $\therefore \; B = \frac{\mu_0 I}{2a}$

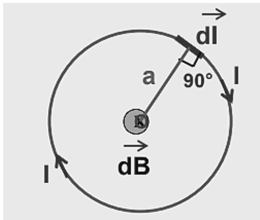
ii) If the observation point is far away from the coil, then a << x. So, a^2 can be neglected in comparison with x^2 . $\therefore \; B = \frac{\mu_0 I a^2}{2 x^3}$

Different views of direction of current and magnetic field due to circular loop of a coil:





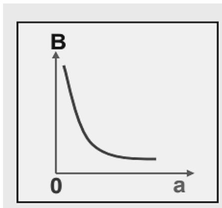
2) **B at the centre of the loop:** dB The plane of the coil is lying on the plane of the diagram and the direction of current is clockwise such that the direction of magnetic field is perpendicular and into the plane.
The angle θ between dl and a is 90° because the radius of the loop is very small and since sin 90° = 1



$$dB = \frac{\mu_0 \; I \, dl \sin\theta}{4\pi \quad a^2} \qquad dB = \frac{\mu_0 \; I \, dl}{4\pi \; a^2}$$

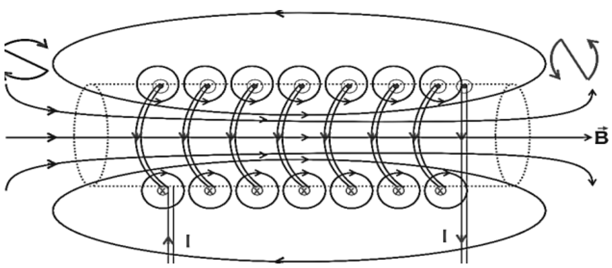
$$B = \int dB = \int \frac{\mu_0 \; I \, dl}{4\pi \; a^2}$$

(μ_0 , I, a are constants and ∫dl = 2πa) $\quad B = \frac{\mu_0 I}{2a}$

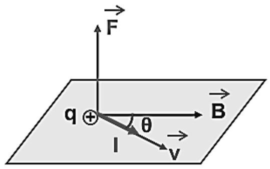


Magnetic Field due to a Solenoid:

TIP: When we look at any end of the coil carrying current, if the current is in anti-clockwise direction then that end of coil behaves like North Pole and if the current is in clockwise direction then that end of the coil behaves like South Pole.

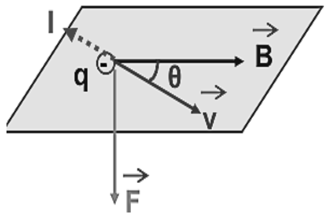


Lorentz Magnetic Force: A current carrying conductor placed in a magnetic field experiences a force which means that a moving charge in a magnetic field experiences force.



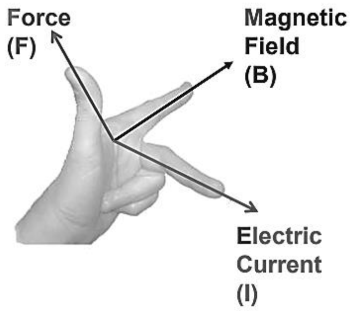
$$\vec{F}_m = q(\vec{v} \times \vec{B}) \qquad \vec{F}_m = (q\,v\,B\sin\theta)\,\hat{n}$$

where θ is the angle between $\vec{v}$ and $\vec{B}$



Special Cases: i) If the charge is at rest, i.e. v = 0, then Fm = 0. So, a stationary charge in a magnetic field does not experience any force.
ii) If θ = 0° or 180° i.e. if the charge moves parallel or anti-parallel to the direction of the magnetic field, then **Fm = 0**.
iii) If θ = 90° i.e. if the charge moves perpendicular to the magnetic field, then the force is maximum. **Fm(max) = q v B**

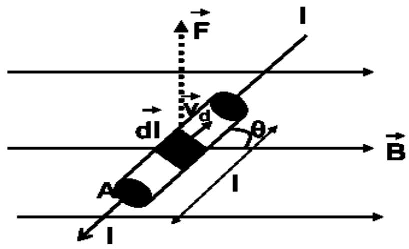
Fleming's Left Hand Rule: Force (F) Magnetic Field (B) Electric Current (I) If the central finger, fore finger and thumb of left hand are stretched mutually perpendicular to each other and the central finger points to current, fore finger points to magnetic field, then thumb points in the direction of motion (force) on the current carrying conductor. **TIP: Remember the phrase 'e m f' to represent electric current, magnetic field and force in anticlockwise direction of the fingers of left hand.**



Force on a moving charge in uniform Electric and Magnetic Fields: When a charge q moves with velocity v in region in which both electric field E and magnetic field B exist, then the Lorentz force is F = qE + q (v x B) or F = q (E + v x B)

Force on a current-carrying conductor in a uniform Magnetic Field:
Force experienced by each electron in the conductor is

$$\vec{f} = -e(\vec{v}_d \times \vec{B})$$



If n be the number density of electrons, A be the area of cross section of the conductor, then no. of electrons in the element dl is n A dl. where I = neAvd and -ve sign represents that the direction of dl is opposite to that of vd) or F = I l B sin θ - Force experienced by the electrons in dl is

$$d\vec{F} = n\,A\,dl\,[-e(\vec{v}_d \times \vec{B})] = -\,n\,e\,A\,v_d\,(d\vec{l} \times \vec{B})$$

$$= I\,(d\vec{l} \times \vec{B})$$

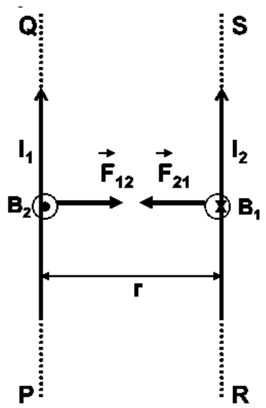
$$\vec{F} = \int d\vec{F} = \int I\,(d\vec{l} \times \vec{B})$$

$$\boxed{\vec{F} = I(\vec{l} \times \vec{B})} \quad \text{or} \quad \boxed{F = I\,l\,B\sin\theta}$$

Forces between two parallel infinitely long current-carrying conductors:
Magnetic Field on RS due to current in PQ is

Force acting $B_1 = \dfrac{\mu_0 I_1}{2\pi r}$ **on RS due to current I_2 through it is**

$$F_{21} = \frac{\mu_0 I_1}{2\pi r} I_2\, l \sin 90^\circ \quad \text{or} \quad F_{21} = \frac{\mu_0 I_1 I_2\, l}{2\pi r}$$



B_1 acts perpendicular and into the plane of the diagram by Right Hand Thumb Rule. So, the angle between l and B1 is 90˚ . l is length of the conductor. $F_{21} = \mu_0 I_1 I_2 l / 2\pi r$ B_2 $\mu_0 I_1 I_2 l / 2\pi r$
Magnetic Field on PQ due to current in RS is

$$B_2 = \frac{\mu_0 I_2}{2\pi r}$$

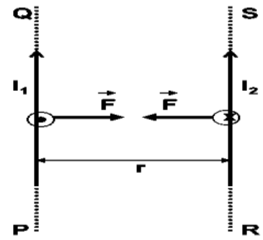
Force acting on PQ due to current I1 through it is

$$F_{12} = \frac{\mu_0 I_2}{2\pi r} I_1 l \sin 90^\circ \quad \text{or} \quad F_{12} = \frac{\mu_0 I_1 I_2 l}{2\pi r}$$

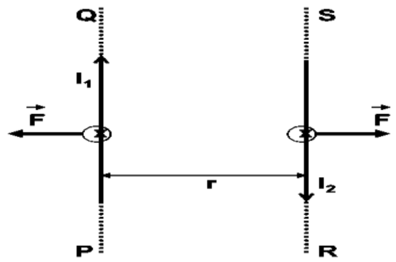
$$\boxed{F_{12} = F_{21} = F = \frac{\mu_0 I_1 I_2 l}{2\pi r}}$$

Force per unit length of the conductor is

$$\boxed{F / l = \frac{\mu_0 I_1 I_2}{2\pi r}} \text{ N / m}$$



By Fleming's Left Hand Rule, the conductors experience force towards each other and hence attract each other.



By Fleming's Left Hand Rule, the conductors experience force away from each other and hence repel each other.

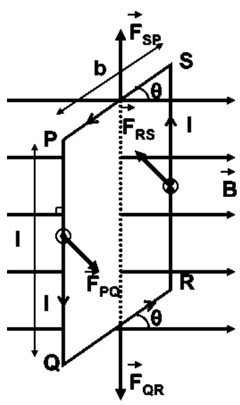
<u>Definition of Ampere:</u>

Force per unit length of the conductor is $F / l = \frac{\mu_0 I_1 I_2}{2\pi r}$ N / m

When $I_1 = I_2 = 1$ Ampere and r = 1 m, then F = 2 x 10^{-7} N/m.

One ampere is that current which, if passed in each of two parallel conductors of infinite length and placed 1 m apart in vacuum causes each conductor to experience a force of 2 x 10-7 Newton per metre of length of the conductor.

Torque experienced by a Current Loop (Rectangular) in a uniform Magnetic Field:



Let θ be the angle between the plane of the loop and the direction of the magnetic field. The axis of the coil is perpendicular to the magnetic field.

$$\vec{F}_{SP} = I(\vec{b} \times \vec{B})$$

$$|\vec{F}_{SP}| = I\, b\, B \sin\theta$$

$$\vec{F}_{QR} = I(\vec{b} \times \vec{B})$$

$$|\vec{F}_{QR}| = I\, b\, B \sin\theta$$

Forces F_{SP} and F_{QR} are equal in magnitude but opposite in direction and they cancel out each other. Moreover they act along the same line of action (axis) and hence do not produce torque.

$$\vec{F}_{PQ} = I(\vec{l} \times \vec{B})$$

$$|\vec{F}_{PQ}| = I\, l\, B \sin 90^\circ = I\, l\, B$$

$$\vec{F}_{RS} = I(\vec{l} \times \vec{B})$$

$$|\vec{F}_{RS}| = I\, l\, B \sin 90^\circ = I\, l\, B$$

Forces F_{PQ} and F_{RS} being equal in magnitude but opposite in direction cancel out each other and do not produce any translational motion. But they act along different lines of action and hence produce torque about the axis of the coil.

$$\tau = F_{PQ} \times PN \qquad \text{(in magnitude)}$$

$$\tau = I\,l\,B\,(b\cos\theta)$$

$$\tau = I\,lb\,B\cos\theta$$

$$\tau = I\,A\,B\cos\theta \qquad (A = lb)$$

$$\tau = N\,I\,A\,B\cos\theta \qquad \text{(where N is the no. of turns)}$$

If Φ is the angle between the normal to the coil and the direction of the magnetic field, then $\Phi + \theta = 90°$ i.e. $\theta = 90° - \Phi$

So, $\tau = I\,A\,B\cos(90° - \Phi)$ $\tau = N\,I\,A\,B\sin\Phi$

NOTE: One must be very careful in using the formula in terms of cos or sin since it depends on the angle taken whether with the plane of the coil or the normal of the coil.

<u>Torque in Vector form:</u>

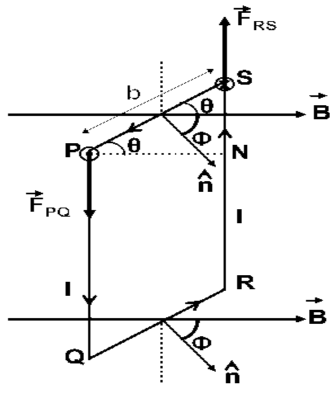
$$\tau = N\,I\,A\,B\sin\Phi$$

$$\vec{\tau} = (N\,I\,A\,B\sin\Phi)\,\hat{n} \quad \text{(where } \hat{n} \text{ is unit vector normal to the plane of the loop)}$$

$$\boxed{\vec{\tau} = N\,I\,(\vec{A} \times \vec{B})} \quad \text{or} \quad \boxed{\vec{\tau} = N\,(\vec{M} \times \vec{B})}$$

$$\text{(since } \vec{M} = I\vec{A} \text{ is the Magnetic Dipole Moment)}$$

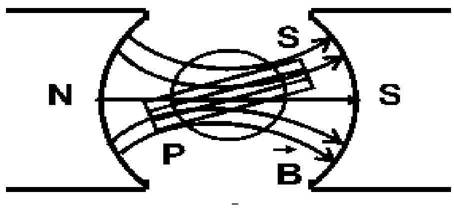
Note: 1) The coil will rotate in the anticlockwise direction (from the top view, according to the figure) about the axis of the coil shown by the dotted line.
2) The torque acts in the upward direction along the dotted line (according to Maxwell's Screw Rule). 3) If $\Phi = 0°$, then $0 = \tau$.
4) If $\Phi = 90°$, then τ is maximum. i.e. $\tau_{max} = N\,I\,A\,B$
5) Units: B in Tesla, I in Ampere, A in m^2 and τ in Nm.
6) The above formulae for torque can be used for any loop irrespective of its shape.



<u>Moving Coil or Suspended Coil or D' Arsonval Type Galvanometer:</u>

Torque experienced by the coil is $\tau = N\,I\,A\,B\sin\Phi$
Restoring torque in the coil is $\tau = k\,\alpha$ (where k is restoring torque per unit angular twist, α is the angular twist in the wire)
At equilibrium, $N\,I\,A\,B\sin\Phi = k\,\alpha$ $I = k\,N\,A\,B\sin\Phi\,\alpha$
The factor $\sin\Phi$ can be eliminated by choosing Radial Magnetic Field.

<u>Radial Magnetic Field</u>: N S B P S The (top view PS of) plane of the coil PQRS lies along the magnetic lines of force in whichever position the coil comes to rest in equilibrium.
So, the angle between the plane of the coil and the magnetic field is 0°. or the angle between the normal to the plane of the coil and the magnetic field is 90°. i.e.
$\sin\Phi = \sin 90° = 1$



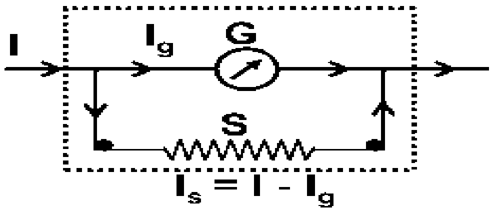
Current Sensitivity of Galvanometer: It is the defection of galvanometer per unit current.

$$\boxed{\frac{\alpha}{I} = \frac{N\,A\,B}{k}}$$

Voltage Sensitivity of Galvanometer: It is the defection of galvanometer per unit voltage.

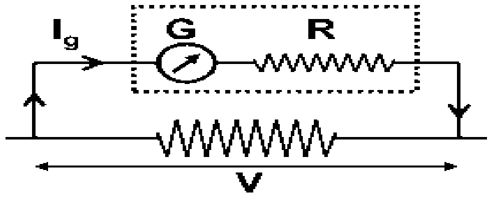
$$\boxed{\frac{\alpha}{V} = \frac{NAB}{kR}}$$

Conversion of Galvanometer to Ammeter:
Galvanometer can be converted into ammeter by shunting it with a very small resistance. Potential difference across the galvanometer and shunt resistance are equal.



$$\therefore \; (I - I_g)\, S = I_g\, G \qquad \text{or} \qquad S = \frac{I_g\, G}{I - I_g}$$

Conversion of Galvanometer to Voltmeter:
Galvanometer can be converted into voltmeter by connecting it with a very high resistance. Potential difference across the given load resistance is the sum of p.d across galvanometer and p.d. across the high resistance.

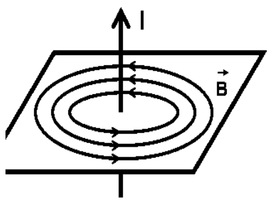


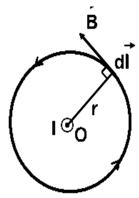
$$\therefore \; V = I_g (G + R) \qquad \text{or} \quad R = \frac{V}{I_g} - G$$

<u>**Ampere's Circuital Law:**</u> The line integral $\oint \vec{B} \cdot \vec{dl}$ for a closed curve is equal to μ_0 times the net current I threading through the area bounded by the curve. Current is emerging out and the magnetic field is anticlockwise.

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I$$

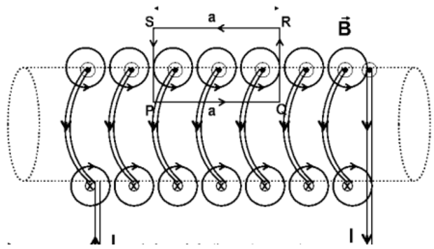
Proof:





$$\oint \vec{B} \cdot \vec{dl} = \oint B \, . \, dl \cos 0°$$
$$= \oint B \, . \, dl = B \oint dl$$
$$= B (2\pi r) = (\mu_0 I / 2\pi r) \times 2\pi r$$
$$\boxed{\oint \vec{B} \cdot \vec{dl} = \mu_0 I}$$

Magnetic Field at the centre of a Straight Solenoid:



$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I_0$$

$$\oint \vec{B} \cdot \vec{dl} = \oint_{PQ} \vec{B} \cdot \vec{dl} + \oint_{QR} \vec{B} \cdot \vec{dl} + \oint_{RS} \vec{B} \cdot \vec{dl} + \oint_{SP} \vec{B} \cdot \vec{dl}$$
$$= \oint B \, . \, dl \cos 0° + \oint B \, . \, dl \cos 90° + \oint 0 \, . \, dl \cos 0° + \oint B \, . \, dl \cos 90°$$
$$= B \oint dl = B.a \qquad \text{and} \quad \mu_0 I_0 = \mu_0 n a I \qquad \therefore \; \boxed{B = \mu_0 n I}$$

(where n is no. of turns per unit length, a is the length of the path and I is the current passing through the lead of the solenoid)

****

MULTIPLE CHOICE QUESTIONS

Q1 A current-carrying straight wire creates a magnetic field at a point P. If the wire is bent into a semicircular loop, what will be the magnetic field at point P?

a) Zero b) Same as before c) Doubled d) Halved

Q2 The magnetic field inside a long solenoid carrying current is:

a) Zero b) Uniform and parallel to the axis of the solenoid

c) Non-uniform d) Circular

Q3 The phenomenon of electromagnetic induction is based on:

a) The motion of charged particles b) The interaction of magnets and non-magnetic materials

c) The creation of magnetic fields d) The change in magnetic field intensity

Q4 The magnetic field lines around a straight current-carrying conductor:

a) Form closed loops b) Radially point outward from the wire

c) Radially point inward towards the wire d) Are straight lines

Q5 The magnetic field inside a current-carrying conductor is:

a) Zero b) Uniform and directed along the conductor

c) Non-uniform d) Circular

Q6 The force experienced by a charged particle moving in a magnetic field is maximum when the angle between the velocity of the particle and the magnetic field is:

a) 0° b) 45° c) 90° d) 180°

Q7 A current-carrying conductor placed in a magnetic field experiences a force. This is a manifestation of:

a) Ampere's law b) Faraday's law c) Lenz's law d) Lorentz force

Q8 A particle with a positive charge is moving in a straight line parallel to a magnetic field. The force experienced by the particle is:

a) Zero b) Maximum c) Minimum d) Undefined

9 The magnitude of the force experienced by a charged particle moving in a magnetic field is directly proportional to:

a) The velocity of the particle b) The charge of the particle

c) The strength of the magnetic field d) The mass of the particle

10. When a current-carrying conductor is placed in a magnetic field, the direction of the force experienced by the conductor is given by:

a) Lenz's law b) Ampere's law c) Fleming's left-hand rule d) Fleming's right-hand rule

****

ASSERTION- REASON QUESTION

Given below (Q.1 to Q. 5) are two statements labeled as Assertion (A) and Reason(R)
Select the most appropriate answer from the options given below:
(i) Both A and R are true and R is the correct explanation of A
(ii) Both A and R are true but R is not the correct explanation of A.
(iii) A is true but R is false.
(iv) A is false and R is also false.

1.Assertion (A): To increase the range of an ammeter, we must connect a suitable high resistance in series with it.

Reason (R): The ammeter with increased range should have high resistance

2.Assertion (A): A proton projected into a perpendicular magnetic field moves with constant kinetic energy.

Reason (R): The magnetic force acting on the particle is perpendicular to its velocity.

3.Assertion (A): The voltage sensitivity of a galvanometer cannot be increased by increasing its number of turns.

Reason (R): On increasing the number of turns (N), the weight of the coil also increases.

4.Assertion (A): A radial magnetic field is used in a moving coil galvanometer
Reason (R): The radial field maximizes the torque on the coil.
5.Assertion (A): A galvanometer gives greater deflection for greater current
Reason (R): The torque in the loop is directly proportional to the strength of current in it.
****

CASE STUDY-1 GALVANOMETER

1.The galvanometer consists of a coil, with many turns, free to rotate about a fixed axis, in a uniform radial magnetic field. There is a cylindrical soft iron core which not only makes the field radial but also increases the strength of the magnetic field. The galvanometer can be used in a number of ways. It can be used as a detector to check if a current is flowing in the circuit. In this usage the neutral position of the pointer (when no current is flowing through the galvanometer) is in the middle of the scale and not at the left end. Depending on the direction of the current, the pointer's deflection is either to the right or the left. The galvanometer cannot as such be used as an ammeter to measure the value of the current in a given circuit. This is for two reasons: (i) Galvanometer is a very sensitive device, it gives a full-scale deflection for a current of the order of μA. (ii) For measuring currents, the galvanometer has to be connected in series, and as it has a large resistance, this will change the value of the current in the circuit.

1. A moving coil galvanometer is an instrument, which
(A) is used to measure emf of a cell (B) is used to measure potential difference
(C) is used to measure resistance
(D) is a deflection type coil which gives deflection when current flows through its coil

2. To make the field radial in a moving coil galvanometer
(A) number of turns of the coil is kept same (B) magnet is taken in the shape of horse- shoe
(C) poles are of very strong magnet (D) poles are cylindrically cut

3. The deflection in the galvanometer is
(A) directly proportional to the torsional constant of the spring
(B)directly proportional to the number of turns of the coil
(C) inversely proportional to the area of the coil
(D) inversely proportional to the current in the coil

4. To increase the current sensitivity of the galvanometer, we should decrease
(A) strength of magnet (B) torsional constant of spring
(C) number of turns in coil (D) area of the coil

5. Galvanometer constant doesn't depend on the following factors
(A) number of turns of the coil (B) area of the coil
(C) current passing through the coil (D) magnetic field

CASE STUDY 2. AURORA BOREALIS

During a solar flare, a large number of electrons and protons are ejected from the sun. Some of them get trapped in the earth's magnetic field and move in helical paths along the field lines. The field lines come closer to each other near the magnetic poles. Hence the density of charges increases near the poles. These particles collide with atoms and molecules of the atmosphere. Excited oxygen atoms emit green light and excited nitrogen atoms emits pink light. This phenomenon is called Aurora Borealis in physics

i) Charge particles move in helical paths when the field (B) makes _______angle with the velocity of the particles
a) $0 < \theta < 90^0$ b) only 90^0 c) 0^0 d) 180^0

ii) When an excited atom comes to a lower energy state,
a) It absorbs energy b) it emits energy c) it oscillates d) N either absorbs nor radiates energy

iii) The colour of the radiation depends on the __________of the radiation
a) Wavelength b) speed c) amplitude d) none of these

iv) Earth's magnetic field is strongest near the _____

a) Poles b) equator c) neither poles nor equator

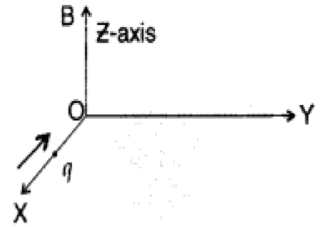
****

SA -I(2 Marks)

1.An ammeter of resistance 0.6 Ω can measure current upto 1.0 A. Calculate
(i) The shunt resistance required to enable the ammeter to measure current upto 5.0 A
(ii) The combined resistance of the ammeter and the shunt.

2. I)Write the expression, in a vector form, for the Lorentz magnetic force $\vec{F}$due to a charge moving with velocity $\vec{V}$ in a magnetic field $\vec{B}$. What is the direction of the magnetic force?
II)Using the concept of force between two infinitely long parallel current carrying conductors, define one ampere of current.

3. Using Ampere's circuital law, obtain an expression for the magnetic field along the axis of a current carrying solenoid of length l and having N number of turns.



4.A charge 'q' moving B along the X-axis with a velocity v is subjected to a uniform magnetic field B acting along the Z-axis as it crosses the origin O. (Delhi 2009)
(i) Trace its trajectory.
(ii) Does the charge gain kinetic energy as it enters the magnetic field? Justify your answer.

5. A steady current (I_1) flows through a long straight wire. Another wire carrying steady current (I_2) in the same direction is kept close and parallel to the first wire. Show with the help of a diagram how the magnetic field due to the current I_1 exerts a magnetic force on the second wire. Write the expression for this force.

6.A circular coil of closely wound N turns and radius r carries a current I. Write the expressions for the following : (i) the magnetic field at its centre (ii) the magnetic moment of this coil

7. A proton and a deuteron, each moving with velocity $\vec{\mathbf{v}}$ enter simultaneously in the region of magnetic field $\vec{\mathbf{B}}$ acting normal to the direction of velocity. Trace their trajectories establishing the relationship between the two.

8. Draw the magnetic field lines due to a current passing through a long solenoid. Use Ampere's circuital law, to obtain the expression for the magnetic field due to the current I in a long solenoid having n number of turns per unit length.

9.(i) State Biot – Savart law in vector form expressing the magnetic field due to an **B** element **dl** carrying current I at a distance **r** from the element.
(ii) Write the expression for the magnitude of the magnetic field at the centre of a circular loop of radius r carrying a steady current I. Draw the field lines due to the current loop.

10. Find the condition under which the charged particles moving with different speeds in the presence of electric and magnetic field vectors can be used to select charged particles of a particular speed.

****

LA-I (3 Marks)

1.A long straight wire of a circular cross-section of radius 'a' carries a steady current 'I'. The current is uniformly distributed across the cross-section. Apply Ampere's circuital law to calculate the magnetic field at a point V in the region for
(i) $r < a$ and (ii) $r > a$.

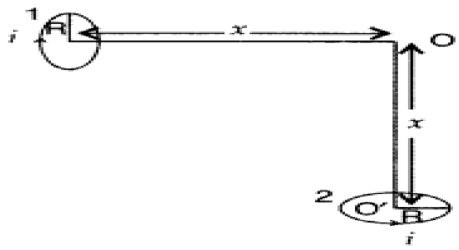
2. State the underlying principle of working of a moving coil galvanometer. Write two reasons why a galvanometer can not be used as such to measure current in a given circuit. Name any two factors on which the current sensitivity of a galvanometer depends.

3. (a) Draw a schematic sketch of a moving coil galvanometer and describe briefly its working.
(b) "Increasing the current sensitivity of a galvanometer does not necessarily increase the voltage sensitivity." Justify this statement.

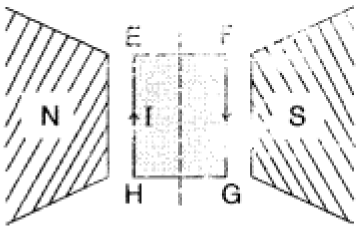
4. A uniform magnetic field **B** is set up along the positive x-axis. A particle of charge 'q' and mass 'm' moving with a velocity v enters the field at the origin in X-Y plane such that it has velocity components both along and perpendicular to the magnetic field **B**. Trace, giving reason, the trajectory followed by the particle. Find out the expression for the distance moved by the particle along the magnetic field in one rotation.
5. (a) Why is the magnetic field radial in a moving coil galvanometer? Explain how it is achieved.
(b) A galvanometer of resistance 'G' can be converted into a voltmeter of range (0 – V) volts by connecting a resistance 'R' in series with it. How much resistance will be required to change its range from 0 to V/2?
****

LA -II(5 Marks)

1. (a) Using Biot-Savart's law, derive an expression for the magnetic field at the centre of a circular coil of radius R, number of turns N, carrying current i.
(b) Two small identical circular coils marked 1, 2 carry equal currents and are placed with their geometric axes perpendicular to each other as shown in the figure. Derive an expression for the resultant magnetic field at O.



2. (a) Two straight long parallel conductors carry currents I_1 and I_2 in the same direction. Deduce the expression for the force per unit length between them.
Depict the pattern of magnetic field lines around them.
(b) A rectangular current carrying loop EFGH is kept in a uniform magnetic field as shown in the figure.(i) What is the direction of the magnetic moment of the current loop?
(ii) When is the torque acting on the loop (A) maximum, (B) zero?



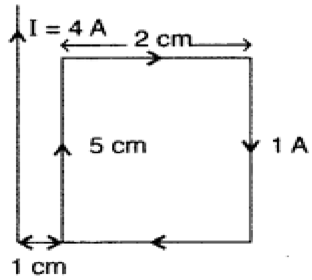
3. (a) State the principle of the working of a moving coil galvanometer, giving its labelled diagram. (b) "Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity." Justify this statement (c) Outline the necessary steps to convert a galvanometer of resistance RG into an ammeter of a given range.
4. Find the magnetic field at a point on the axis of a circular coil carrying current and hence find the magnetic field at the centre of the circular coil carrying current.
5. A proton and an alpha particle having the same kinetic energy are, in turn, passed through a region of uniform magnetic field, acting normal to the plane of the paper and travel in circular paths. Deduce the ratio of the radii of the circular paths described by them.
****

NUMERICALS- (3 Marks)

1. A closely wound solenoid of 2000 turns and cross sectional area 1.6×10^{-4} m^2 carrying a current of 4.0 A is suspended through its centre allowing it to turn in a horizontal plane. Find
(i) the magnetic moment associated with the solenoid,
(ii) magnitude and direction of the torque on the solenoid if a horizontal magnetic field of 7.5×10^{-2} T is set up at an angle of 30° with the axis of the solenoid.
2. (a) Define the current sensitivity of a galvanometer.
(b) The coil area of a galvanometer is 16×10^{-4} m^2. It consists of 200 turns of a wire and is in a magnetic field of 0.2 T. The restoring torque constant of the suspension fibre is 10^{-6} Nm per degree. Assuming the magnetic field to be radial, calculate the maximum current that can be measured by the galvanometer if the scale can accommodate 30° deflection.

3. A wire AB is carrying a steady current of 12A and is lying on the table. Another wire CD carrying 5A is held directly above AB at a height of 1 mm. Find the mass per unit length of the wire CD so that it remains suspended at its position when left free. Give the direction of the current flowing in CD with respect to that in AB.
4.Two identical coils, each of radius 'R' and number of turns 'N' are lying in perpendicular planes such that their centres coincide. Find the magnitude and direction of the resultant magnetic field at the centre of the coils, if they are carrying currents 'I' and $\sqrt{3}I$ respectively.

5.A rectangular loop of wire of size 2 cm × 5 cm carries a steady current of 1 A. A straight long wire carrying 4 A current is kept near the loop as shown in the figure.
If the loop and the wire are coplanar, find
(i) the torque acting on the loop and
(ii) the magnitude and direction of the force on the loop due to the current carrying wire.



****

ANSWERS

MCQ

1.Answer: b) Same as before
2. Answer: b) Uniform and parallel to the axis of the solenoid
3. Answer: d) The change in magnetic field intensity
4. Answer: a) Form closed loops
5. Answer: b) Uniform and directed along the conductor
6. Answer: c) 90°
7. Answer: d) Lorentz force
8. Answer: a) Zero
9. Answer: a) The velocity of the particle
10. Answer: d) Fleming's right-hand rule

ASSERTION- REASON QUESTIONS

Solution: 1. IV 2. I 3. II 4. I 5. I

CASE STUDY -1

Solution: 1. D 2. D 3. B 4. B 5. C

CASE STUDY -2

Solution: 1) A 2) B 3) A 4) A

SA-1

1. Ans:

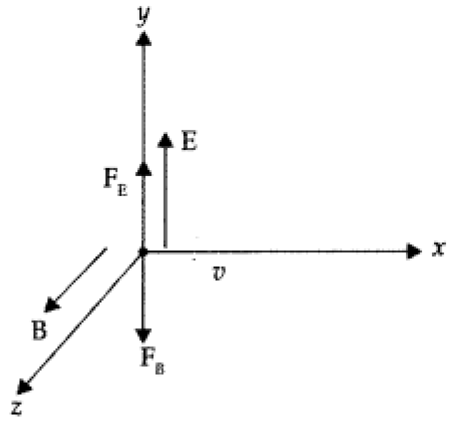
(i) Shunt Resistance, $S = \frac{R_A i_g}{i - i_g} = \frac{0.6 \times 1}{4} = 0.15\ \Omega$

(ii) Total Resistance, $\frac{1}{R_{total}} = \frac{1}{0.6} + \frac{1}{0.15} = \frac{25}{3}$

$$R_{total} = \frac{3}{25}\ \Omega = \mathbf{0.12\ \Omega}$$

2. Ans: (i) $\vec{F} = q(\vec{v} \times \vec{B})$

This force is normal to both the directions of velocity $\vec{V}$ and magnetic field $\vec{B}$.

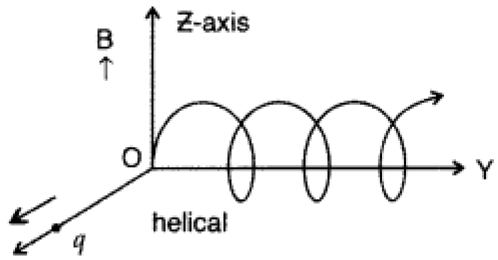


$$F = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

3. Ans: Derive $B = \mu_0 n I_0$

4. Ans:

(i)

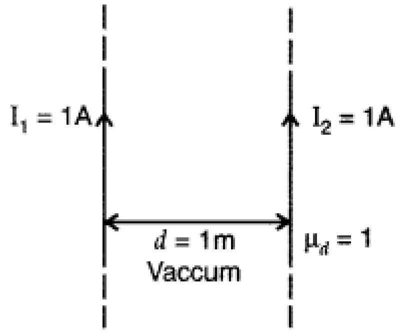


(ii) K.E does not change irrespective of the direction of the charge as

Power delivered, $\vec{F}\cdot\vec{v} = q(\vec{v}\times\vec{B})\cdot\vec{v} = 0$

[$\because$ scalar triple product $(\vec{v}\times\vec{B})\cdot\vec{v} = 0$]

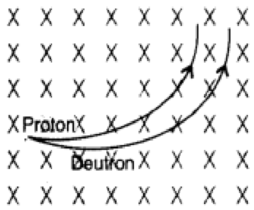
5.Ans: REFER TO SUMMARY



$$F = \frac{\mu_0 \times 1 \times 1}{2\pi \times 1}$$

$$\therefore \quad F = \frac{\mu_0}{2\pi} = \mathbf{2 \times 10^{-7}\ N}$$

7. Ans:



8

Ans:REFER TO SUMMARY

9. Ans: REFER TO SUMMARY

10. Ans: Condition: The velocity $\vec{v}$ of the charged particles, the **E** and **B** vectors, should be mutually perpendicular.

It means that the forces on q, due to **E** and **B** must be oppositely directed.

Force due to electric field $= q\vec{E}$ and

Force due to electric field $= q(\vec{v} \times \vec{B})$

The **required condition** is $q(\vec{v} \times \vec{B})$

$$\Rightarrow \quad q\vec{E} = -q(\vec{v} \times \vec{B}) \Rightarrow v = \frac{\mathbf{E}}{\mathbf{B}}$$

LA—1(3 Marks)

1.Answer

Let r be the perpendicular distance of point P from the axis of the cylinder, where r > a.
Here **B** and d **l** are acting in the same direction.
Applying Ampere's circuital law, we have

$$\oint \vec{B}.d\vec{l} = \mu_0 I \Rightarrow \oint B\,dl \cos\theta = \mu_0 I$$

$$\Rightarrow B\int_0^{2\pi r} dl = \mu_0 I \qquad ...[\because \cos 0 = 1$$

$$\Rightarrow B.2\pi r = \mu_0 I \qquad \Rightarrow B = \frac{\mu_0 I}{2\pi r} \qquad \therefore B \propto \frac{1}{r}$$

When the point P lies inside the wire :
Here r ≤ a. We have two possibilities:
According to Ampere circuital law,
(i) "Whenever the current floras only through the surface of the wire, B = 0 as current in the closed path will be zero."
(ii) "Wherever in the case when current is uniformly distributed through the cross-section of conductor, current through the closed path will be :
I' = Current per unit area of the wire × area of the circle of radius r

$$= \frac{I}{\pi a^2} \times \pi r^2 = \frac{Ir^2}{a^2}$$

Applying *Ampere's circuital law,*

$$\oint = \vec{B}.d\vec{l} = \mu I'$$

$$\Rightarrow B \times 2\pi r = \mu_r \mu_0 \times \frac{Ir^2}{a^2}$$

$$\Rightarrow B = \frac{\mu_r \mu_0}{2\pi}\frac{Ir}{a^2} \qquad \therefore B \propto r$$

2.Answer:
(i) Moving coil galvanometer works on the principle of a torque experienced by a current carrying coil placed in a magnetic field, whose magnitude is a function of current passing through the coil.
(ii) The galvanometer cannot be used to measure the value of the current in a given circuit due to the following two reasons:
(a) Galvanometer is a very sensitive device. It gives a full scale deflection for a small value of current.
(b) The galvanometer has to be connected in series for measuring currents and as it has a large resistance, this will change the value of the current in the circuit.
(iii)

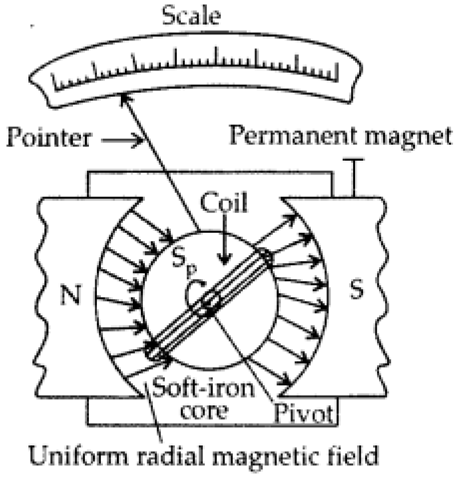
$$\text{Current sensitivity, } I_s = \frac{\alpha}{I} = \frac{NBA}{K}.$$

It depends on the number of turns N of the coil, torsion constant and the area A of the coil.
3.Answer:
(a)
Principle : "If a current carrying coil is freely suspended/pivoted in a uniform magnetic field, it experiences a deflecting torque."
Working: As the pivoted coil is placed in a radial magnetic field, hence on passing current I through it, a deflecting torque acts on the coil which is given by, τ = NAIB

**...where [N = total number of turns in the coil,
A = area of coil, B = magnetic field.**

The spring S_p attached to the coil provides the counter torque and in equilibrium state balances

the deflecting torque. If φ is steady angular deflection then counter torque is kφ.
…where [k = torsional constant of the spring



In equilibrium state,

$$NAIB = k\phi \qquad \Rightarrow \quad \phi = \left(\frac{NAB}{k}\right)I$$

Thus, deflection is directly proportional to the current flowing in the coil.
(a) (i) Uniform radial magnetic field. It keeps the magnetic field line normal to the area vector of the coil.
(ii) Soft iron core in galvanometer. The cylindrical soft iron core, when placed inside the coil of a galvanometer, makes the magnetic field stronger and radial in the space between it and pole pieces, such that whatever the position of the rotation of the coil may be, the magnetic field is always parallel to its plane.
(b) (i) Current sensitivity is defined as the deflection produced in the galvanometer when unit current is passed through its coil.

$$I_s = \frac{\phi}{I} = \frac{nBA}{k} \text{ radian/ampere or division } A^{-1}$$

…where [**n = Number of turns in the galvanometer.**
k = Restoring couple per unit twist or torsional constant.

(ii) Voltage sensitivity is defined as the deflection produced in the galvanometer when unit voltage is applied across the coil of the galvanometer.

$$V_s = \frac{\phi}{V} = \left(\frac{nBA}{k}\right) \times \frac{1}{R} \text{ radian/volt or div. } V^{-1}$$

…where [R = Resistance of the coil

Since $V_s = \frac{I_s}{R}$, increase in current sensitivity

does not necessarily increase the voltage sensitivity. It may be affected by the resistance used.
(b) Current sensitivity is defined as the deflection produced in the galvanometer when unit current is passed through its coil.

$$I_s = \frac{\theta}{I} = \frac{nBA}{k} \text{ radian/ampere or division } A^{-1}$$

...where $\left[\begin{array}{l} n = \text{Number of turns in the galvanometer.} \\ k = \text{Restoring couple per unit twist or torsional constant.} \end{array}\right.$

Voltage sensitivity is defined as the deflection produced in the galvanometer when unit voltage is applied across the coil of the galvanometer.

$$V_s = \frac{\theta}{V} = \frac{nBR}{kR} \text{ radian/volt or div. } V^{-1}$$

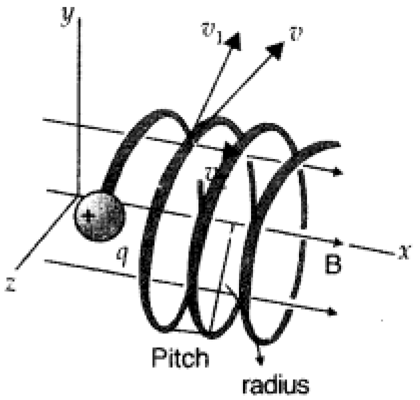
...where [R = Resistance of the coil

Since $V_s = \frac{I_s}{R}$, increase in current sensitivity may not necessarily increase the voltage sensitivity. It may be affected by the resistance used.

4.Answer:

Since the velocity of the particle is inclined to x-axis, thererfore, the velocity has a component along B, this component remains unchanged as the motion along the magnetic field will not be affected by the magnetic field. The motion in a plane perpendicular to B is as before a circular one, thereby producing a helical motion, which is its trajectory.

If r is the radius of the circular path of a particle, then a force of mv^2/r, acts perpendicular to the path towards the centre of the circle and is called the centripetal force. If the velocity v is perpendicular to the magnetic field B, the magnetic force is perpendicular to both v and B and acts like a centripetal force. It has a magnitude qvB. Equating the two expressions (for centripetal force)



$mv^2/r = qvB$, which gives $r = mv/qB$ …(i) for the radius of the circle described by the charged particle.

$$\text{We have, } T = \frac{2\pi}{w} = \frac{2\pi}{v/r} = \frac{2\pi m}{qB} \qquad \ldots(ii)$$

There is a component of the velocity parallel to the magnetic field (denoted by v_{11}), it will make the particle move along the field and the path of the particle would be a helical one.

The distance moved along the magnetic field in one rotation is called pitch p.

Using equation (ii), we have

$$p = v_{\parallel}T = 2\pi m v_{\parallel}/qB$$

5.Answer:

(a) The magnetic field in a moving coil galvanometer is made ‘radial’ to keep the magnetic field ‘normal’ to the area vector of the coil. It is done by taking the cylindrical soft iron core. The

torque acting on the coil is maximum (sin θ = 1, when, θ = 90°)
(b) Given : resistance of galvanomter = G Ω
Range of voltmeter (R_L) = (0 – V) volts
Resistance to be connected in parallel = R

$$R' = ?, \quad \text{where range is } \left(0 - \frac{V}{2}\right) \text{ Volts}$$

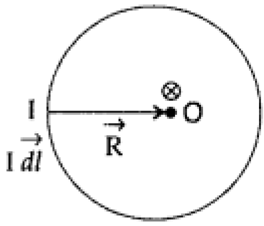
$$\text{In the first case, } i_g = \frac{V}{R+G} \quad \ldots(i)$$

$$\text{In the second case } i_g = \frac{V/2}{R'+G} \quad \ldots(ii)$$

[i_g is the maximum current which can flow through galvanometer]
From equation (i) and (ii), on solving we get

$$\mathbf{R' = \left(\frac{R-G}{2}\right)}$$

<u>LA -II(5 Marks)</u>
1.Answer:
(a) Consider a circular loop of wire of radius R carrying current I. The entire loop can be divided into a large number of small current elements.



According to Biot-Savart's law, magnetic field due to current element 'Idl' at the centre O of a coil is

$$\vec{dB} = \frac{\mu_0}{4\pi} I \frac{(d\vec{l} \times \vec{R})}{R^3}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{R^2} \qquad (\because \sin 90° = 1)$$

so $d\vec{l} \perp \vec{R}$
Magnetic field due to whole coil is

$$B = \frac{\mu_0 I}{4\pi R^2}\int dl \quad \text{or} \quad B = \frac{\mu_0 I}{4\pi R^2} . l$$

$$\Rightarrow \quad B = \frac{\mu_0 I}{4\pi R^2} . 2\pi R \quad \text{or} \quad B = \frac{\mu_0 I}{2R}$$

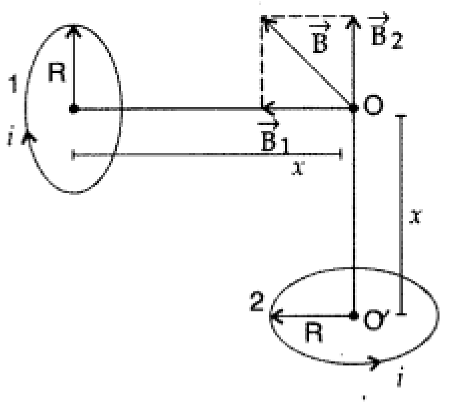
In case of N number of turns

$$B = \frac{\mu_0 NI}{2R}$$

(*b*) Field at 'O' due to 1st loop is

The direction of d $\vec{l}$ is along the tangent

$$B_1 = \frac{\mu_0 I R^2}{2(x^2 + R^2)^{3/2}}$$



$\vec{B_1}$ is directed towards the centre of the loop.
Field at 'O' due to 2^{nd} loop is

$$B_2 = \frac{\mu_0 I R^2}{2(x^2 + R^2)^{3/2}}$$

$\vec{B_2}$ is directed away from the centre of the loop because current flows in second loop is anticlockwise.

As $\vec{B_1} \perp \vec{B_2}$, so the net field at O is

$$B = \sqrt{B_1^2 + B_2^2} \quad \text{or} \quad B = \frac{\mu_0 I R^2 \sqrt{2}}{2(x^2 + R^2)^{3/2}}$$

In case $x >> R$ $\quad \therefore \quad B = \frac{\mu_0 I R^2 \sqrt{2}}{2x^3}$

2.Answer:
(i) Magnetic moment will be out of the plane from the surface HEFG.
(ii) Torque
(A) Torque is maximum when MII B i.e., when it gets rotated by 90°.
(B) Torque is minimum when M and B are at 270° to each other.

In equilibrium state,

$$NAIB = k\phi \qquad \Rightarrow \quad \phi = \left(\frac{NAB}{k}\right) I$$

Thus, deflection is directly proportional to the current flowing in the coil.
(a) (i) Uniform radial magnetic field. It keeps the magnetic field line normal to the area vector of the coil.
(ii) Soft iron core in galvanometer. The cylindrical soft iron core, when placed inside the coil of a galvanometer, makes the magnetic field stronger and radial in the space between it and pole pieces, such that whatever the position of the rotation of the coil may be, the magnetic field is always parallel to its plane.
(b) (i) Current sensitivity is defined as the deflection produced in the galvanometer when unit

5. Answer:

Given : $E_p = E = E$

We know, $\frac{mv^2}{r} = qvB$

or $r = \frac{\sqrt{2mE}}{qB}$ $\quad \because \quad E = \frac{1}{2}mv^2$

$$r_p = \frac{\sqrt{2m_pE}}{q_pB} \text{ and } r_\alpha = \frac{\sqrt{2m_\alpha E}}{q_\alpha B} \quad \left[\begin{array}{l} \because m_\alpha = 4m_p \\ q_\alpha = 2q_p \end{array}\right.$$

$$\frac{r_p}{r_\alpha} = \frac{\sqrt{2m_pE}}{q_pB} \times \frac{q_\alpha B}{\sqrt{2m_\alpha E}} = \sqrt{\frac{m_p}{m_\alpha}} \times \frac{q_\alpha}{q_p}$$

$$= \sqrt{\frac{m_p}{4m_p}} \times \frac{2q_p}{q_p} = \frac{1}{2} \times 2 = 1$$

$\boldsymbol{r_p : r_a :: 1 : 1}$

Numericals- (3 Marks)

1.Answer:

Given : $n = 2000$ turns, $A = 1.6 \times 10^{-4}$ m^2

$I = 4.0$ A, $B = 7.5 \times 10^{-2}$ T

$\theta = 30°$, $\quad \left(\sin 30° = \frac{1}{2}\right)$

(*i*) Magnetic moment (M)

$M = NIA = (2000) \times (4) \times (1.6 \times 10^{-4})$

$= \mathbf{1.28\ Am^2}$

(*ii*) Magnitude of torque

$$\vec{\tau} = \vec{M} \times \vec{B} = MB \sin\theta$$

$= (1.28) \times (7.5 \times 10^{-2}) \times \frac{1}{2}$

$= \mathbf{48 \times 10^{-3}\ Nm}$

(iii) Direction of torque is perpendicular to both the planes of the solenoid and the magnetic field.

2.Answer:

Sensitivity of a galvanometer: A galvanometer is said to be sensitive, if it gives a large deflection, even when a small current passes through it.

(*i*) Current sensitivity, $\frac{\phi}{I} = \frac{nAB}{k}$ $\quad \ldots(\mu A^{-1})$

(*ii*) Voltage sensitivity, $\frac{\phi}{V} = \frac{nAB}{kR}$ $\quad \ldots(\mu V^{-1})$

(*b*) $A = 16 \times 10^{-4}$ m^2, $\quad N = 200$ turns, $B = 0.2$ T,

$k = 10^{-6}$ Nm per degree

$\theta = 30° = \frac{30 \times \pi}{180} = \frac{\pi}{6}$ Rad

As $NABI = k\theta$

$\therefore \quad 200 \times (16 \times 10^{-4}) \times (0.2) \times I = 10^{-6} \times \frac{\pi}{6}$

$\therefore \quad I = \frac{\pi \times 10^{-6}}{6 \times 200(16 \times 10^{-4}) \times (0.2)}$

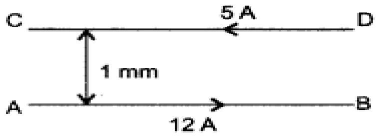
$= 8.17 \times 10^{-6}$ A $= \mathbf{8.17\ \mu A}$

3) Answer:
Given :
Current in the wire AB (I_1) = 12 A,
Current in wire CD (I_2) = 5 A
Separation between two wires (d) = 1 mm
= 10^{-3} m
Let 'm' be the mass of wire CD of length (L),

hence $\frac{m}{L} = ?$ $F_{mag} = I(\vec{l} \times \vec{B})$

Now the magnetic field due to wire (AB) on wire (CD) is

$$\vec{B} = \frac{\mu_0}{4\pi} \times \frac{2I_1}{d}$$



$F_{weight} = mg$

To balance

$F_{weight} = F_{mag}$ $mg = I_2 (\vec{L} \times \vec{B})$

$$\frac{m}{L} = \frac{I_2 \times \vec{B}}{g} = \left(\frac{I_2}{g} \times \frac{\mu_0}{4\pi} \times \frac{2I_1}{d}\right)$$

$$= \frac{5}{10} \times \frac{\mu_0}{4\pi} \times \frac{2 \times 12}{1 \times 10^{-3}}$$

$$= \frac{5}{10} \times 10^{-7} \times \frac{2 \times 12}{10^{-3}}$$

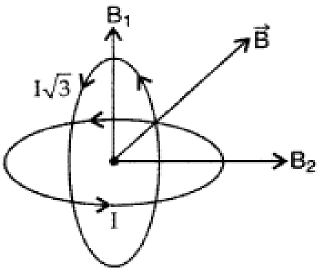
$$= 1.2 \times 10^{-3} \text{ kg m}^{-1}$$

Direction of current in CD should be opposite to that of AB.

4. Answer:

$$B_1 = \frac{\mu_0 2\pi NI}{4\pi R} = \frac{\mu_0 NI}{2R}$$

$$B_2 = \frac{\mu_0 2\pi NI\sqrt{3}}{4\pi R} = \frac{\mu_0 NI\sqrt{3}}{2R}$$



So, **Resultant magnitude,**

$$\mathbf{B} = \sqrt{B_1^2 + B_2^2} = \frac{\mu_0 NI}{2R}\sqrt{1+3} = \frac{\mu_0 NI}{R}$$

and **Direction** is *clockwise.*

5.Answer:

(i) τ (Torque on the loop) = MB sin θ

As $\vec{M}$ and $\vec{B}$ are parallel, hence τ = 0

(*ii*) Force acting on the loop, |F|

$$= \frac{\mu_0 I_1 I_2}{2\pi} l \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$= 2 \times 10^{-7} \times 4 \times 1 \times 5 \times 10^{-2}\left(\frac{1}{10^{-2}} - \frac{1}{3 \times 10^{-2}}\right)$$

$$= \frac{40 \times 10^{-9}}{10^{-2}}\left[1 - \frac{1}{3}\right] \text{N} = 40 \times 10^{-7} \times \frac{2}{3} \text{N}$$

$$= \frac{80}{3} \times 10^{-7} \text{ N} = 26.66 \times 10^{-7} \text{ T} \approx \mathbf{2.67\ \mu N}$$

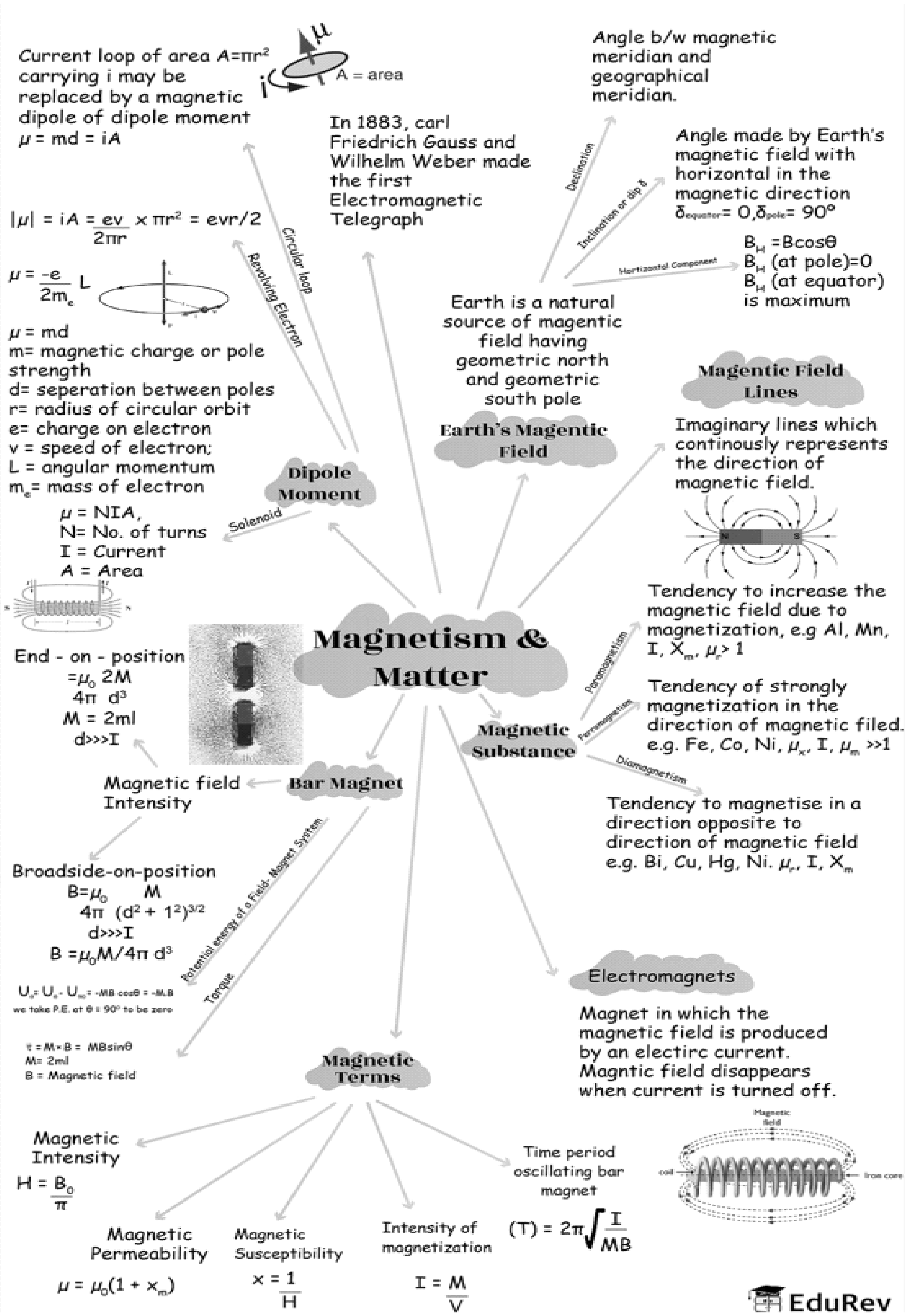
Direction : Towards the conductor/Attractive

Net force on the loop will act towards the long conductor (attractive) if the current in its closer side is in the same direction as the current in the long conductor, otherwise it will be repulsive.

****

CHAPTER-5
MAGNETISM AND MATTER

MIND MAPS



SUMMARY

Magnetic dipole: An arrangement of two unlike poles of equal strength and separated by a small distance ts called magnetic dipole. In SI, the unit of magnetic pole strength is ampere metre (A m). The distance between the two magnetic poles is called the magnetic length of the magnetic dipole. It is denoted by 2 | , a vector from south to north pole of the magnetic dipole.
Magnetic dipole moment: The product of the pole strength of the either magnetic pole and the magnetic length of the magnetic dipole is called its magnetic dipole moment. It is denoted by $\vec{M}$ Mathematically - $\vec{M}$ =m ($2\vec{l}$) Here, m is pole strength of the magnetic dipole. The SI unit of magnetic dipole moment is ampere/metre^2 (A m^2).
Current loop and magnetic dipole: A current loop of area A carrying current I behave as a magnetic dipole having magnetic dipole moment, M=IA
Torque on a magnetic dipole in a magnetic field: When a magnetic dipole of magnetic dipole moment M is placed in a uniform magnetic field of strength B_- making an angle 4 with the direction of magnetic field, it experiences a torque, which is given by
$|\vec{\tau}| = |\vec{M} \times \vec{B}| = MB \sin\theta$
Potential energy stored in a magnetic dipole on rotating inside a magnetic field: The work done in rotating a magnetic dipole against the torque acting on it, when placed in magnetic field is stored inside the magnetic dipole in the form of its potential energy.
When the magnetic dipole is rotated from its initial position θ_1, to the final position θ_2, then the potential energy stored is given by $U=MB(\cos\theta_2 - \cos\theta_1)$
Magnetic intensity: It is defined as the ratio of magnetic induction in vacuum to the absolute magnetic permeability of free space. It is given by $H = B_0 \mu_0$
where $\mu_0 = 4\pi \times 10^{-7}$ tesla metre/ampere is absolute permeability of vacuum.
Magnetic intensity is also known as H-field or magnetising field strength.
The unit of magnetic intensity i.e. A/ m is also equivalent to N /m2 T or N/Wb or J/m-3 T
Intensity of magnetisation: It is defined as the magnetic dipole moment developed per unit volume or the pole strength developed per unit area of cross-section of the specimen.
It is given by $I = M/V = m/a$
Here, V is volume and A is area of cross-section of the specimen. In SI, the unit of intensity of magnetisation is ampere/metre (A/m}).
Magnetic induction: It is defined as the number of magnetic lines of induction (magnetic field lines inside the material) crossing per unit area normally through the magnetic material.
If H is the strength of the magnetising field, then magnetic induction is given by $B= \mu_0 (H+I)$ In SI, the unit of the strength of magnetising field is ampere/ metre (A/ m) and that of magnetic induction is tesla (T) or weber /metre^2 (Wb/ m^2)
Magnetic susceptibility: The magnetic susceptibility of a material is defined as the ratio of the intensity of magnetisation (I) and the strength of magnetising field (H). It is given by $\chi_m = IH$
The magnetic susceptibility has no units.
Magnetic permeability: The magnetic permeability of a material is defined as the ratio of the magnetic induction (B) of the material to the strength of magnetising field (H).
It is given by $\mu_m = B\ H$
In SI, the unit of magnetic permeability is tesla metre/ ampere (T m/ A).
Diamagnetic substances: Those substances, which when placed in a magnetic field are feebly magnetised in a direction opposite to that of the magnetising field.
Paramagnetic substances: Those substances, which when placed in a magnetic field are feebly magnetised in the direction of the magnetising field.
Ferromagnetic substances: Those substances, which when placed in a magnetic field are strongly magnetised in the direction of the magnetising field.

MULTIPLE CHOICE QUESTIONS:

1. The dimensional formula for magnetic element aa

(a)$M^0L^2T^0A$ (b) $M^0LT^0A^2$ (c) $M^\circ L^2T^0A^2$ (d)M^0L^0TA.

2. A bar magnet of moment M is bent into arc, its moment

(a) decreases (b) increases (c) does not change (d) may change.

3. A bar magnet is cut into two equal halves by a plane parallel to the magnetic axis of the following physical quantities the one which remains unchanged is

(a) pole strength (b) magnetic moment
(c) intensity of magnetizatim (d) moment of inertia

4. A magnetic field in produced and directed along У-axis. A magnet is placed along y-axis. The direction of torque on the magnet is

(a) in th X-Y plane (b) along Y-axin (c) along Z-axis (d)Torque will be zero

5. The permeability of a material is 0.9 The material is

(a) diamagnetic (b) paramagnetic (c) ferromagnetic (d) non-magnetic.

6. The magnetic susceptibility of a diamagnet substance is

(a) ∞ (b) zero (c) small but negative (d) small but positive

7. The value of susceptibility for superconductor is

(a) 0 (b) infinity (c)+1 (d)-1.

8. The curie law is obeyed by

(a)At all temperature. (b) above the curie temperature
(c)below the curie temperature (d) At the curie temp.

9. The following one is diamagnetic

(a)Liquid oxygen (b)Air (c)Water (d) Copper Sulphate.

10. The major contribution of magnetizatim in substance due to

(a)orbital Motion of plections (b) spin motion of elections
(c)equally due to orbital and spin Motions (d) hidden magnets.

ANSWERS:

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

ASSERSTION REASONINIG:

1. Both A and R are true and R is correct explanation of A
2. Both A and R are true and R is not the correct explanation of A
3. A is true R is false
4. A is false R is true

Q1. Assertion : A magnet remains stable if it aligns itself with field
Reason : The potential energy of a bar magnet is minimum if it is parallel to magnetic field

Q2. Assertion : Basic difference between eclectic field lines and magnetic field in that former is discontinous or latter is continuous
Reason : No electric field lines exists inside the charged conductor but magnetic field lines do exists inside

Q3. Assertion : X-T graph for a diamagnetic material is a straight line parallel to Y-axis.
Reason : This is because susceptiblity of a diamagnetic material is not affected by temp.

Q4. Assertion : The ferromagnetic substances do not obey curice law
Reason : At curice print ferromagnetic substance start behaving as a paramagnetic sub.

Q5. Assertion : Steel is attracted by magnet. Reason : Steel is not a magnetic substance

ANSWERS:

1 – 1 2 – 1 3 – 1 4 – 2 5 - 3

CASE STUDY:

{1}Before nineteenth century, scientists believed that magnetic properties were confined to a few materials like iron, cobalt and nickel. But in 1846, Curie and Faraday discovered that all the materials in the universe are magnetic to some extent These magnetic substances are categorized into two groups. Weak magnetic materials are called diamagnetic and paramagnetic materials. Strong magnetic materials are called ferromagnetic materials According to the modern theory of magnetism, the magnetic response of any material is due to circulating electrons in the atoms. Each such electron has a magentic moment in a direction perpendicular to the plane of circulation In magnetic materials all these magnetic moments due to the orbital and spin motion of all the electrons in any atom, vectorially add upto a resultant magnetic moment. The magnitude and direction of these resultant magnetic moment is responsible for the behaviour of the materials. For diamagnetic materials x is small and negative and for paramagnetic materials x is small and positive. Ferromagnetic materials have large x and are characterised by non-linear relation between B and vec H

QUESTIONS (Answer any four of the following questions)

1. The universal (or inherent) property among a substances is

(a) diamagnetism (b) paramagnetism (c) ferromagnetism (d) both (a) & (b)

2. When a bar is placed near a strong magnetic field anc it is repelled, then the material of bar is

(a) diamagnetic (b) ferromagnetic (c) paramagnetic (d) anti-ferromagnetic.

3. Magnetic susceptibility of a diamagnetic substance

(a) decreases with temperature (b) is not affected by temperature

(c) increases with temperature (d) first increases then decreases with temperature.

4.For a paramagnetic material, the dependence of the magnetic susceptibility x on the absolute temperature is given as

(α) chi propto T (b) chi propto 1 / (T ^ 2) (c) chi propto 1 / T (d) independent.

5.The value of the magnetic susceptibility for a superconductor is

(a) zero (b) infinity (c) +1 (d)-1

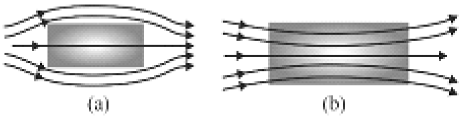
2 marks Questions:

Q1. If X− stands for the magnetic susceptibility of a given material, identify the class of material for which (a) $-1 \geq x < 0$ (b) $0 < x < \varepsilon$. Give an example for each class of magnetic material.

Ans.- (a) Diamagnetic substance, bismuth, copper, diamond, gold, lead, silver

(b) Paramagnetic substance, aluminium, calcium, chromium, lithium, magnesium etc.

Q2. A uniform magnetic field gets modifies as shown in Figure below, when two specimens A and B are placed in it.



- Identify the specimen A and B
- How is the magnetic susceptibility of A different from that of specimen B.

Ans.- 1. Specimen A is diamagnetic, Specimen B is paramagnetic

2. For diamagnetic $-1 \geq x < 0$ and for paramagnetic $0 < x < \varepsilon$

Q3. Name the point where magnetic field due to bar magnet is

1.Parallel to magnetic moment and

2. Opposite to the magnetic dipole moment

Ans.- 1. Axial point

- Perpendicular point or equitorial point

Q4. Why is a current loop considered as magnetic dipole?
Ans.- Like a bar magnet, current-loop experience at torque in magnetic field.
Q5. A magnet is held vertically along its length at the equator and then released. Will it strike the ground head on or fall flat on the ground?
Ans.- The magnet will fall flat on the ground because due to Earth magnetic field which is horizontal at equator will make it horizontal.
Q6. Suppose you are facing the north pole of the earth. An electron flying horizontally away from you in the meridian is deflected to the left. Are you in the Northern hemisphere or Southern hemisphere?
Ans.- From Fleming's left-hand rule shows that magnetic field B on the electron must have a component acting vertically upward. This can happen only in Southern hemisphere.
Q7. How can you decide whether the magnetic field at a point is due to some current carrying conductor or due to Earth?
Ans.- If compass needle at a given point stays in north-south direction then magnetic field is due to Earth otherwise it is due to current carrying conductor.
Q8. Suggest two methods to destroy the magnetism of a magnet.
Ans.- 1. By heating the magnet 2. By applying magnetic field in the reverse direction.
Q9. What do you mean by statement that susceptibility of iron is more than that of copper?
Ans.- This indicates that iron can be magnetized more easily than copper.
Q10. An iron bar is heated to 1000°C and then cooled in a magnetic field free space. Will it retain magnetism?
Ans.- The curie temperature of iron is 770°C so when it is heated above curie temperature it losses its magnetic properties but when it cool in a magnetic field free space it does not regains it's magnetism.

3 Marks Questions:

Q1. A proton has been and magnetic moment just like an electron. Why then its effect is neglected in magnetism of materials?
Ans.- The magnetic moment is given by

$\mu = eh/4 \pi m$ as mp >> me, so Me >> Mp

Q2. Two identical looking bars A and B are given. One of which is definitely known to be magnetised [we do not know which one]. How would one ascertain whether or not both are magnetized, if only one is magnetized. How does one ascertain which one [use nothing else but the bar A and B].
Ans.- Pick up one say A and lower one of its ends, first on one of the ends of the other say B and then on the middle of B. Then you notice that the middle of B, A experience no force then B is magnetized. If you do not notice any change from the end of the middle of B, then A is magnetized.
Q3. Magnetic field lines shows the direction (at every point) along which a small magnetised needle aligns. Do the magnetic field lines also represent the lines of force on a moving charged particle at every point?
Ans.- No, the magnetic force is always normal to the magnetic field B. It is misleading to call magnetic field lines as lines of force.
Q4. Does a bar magnet exerts a torque on itself due to its on field? Does one element of a current carrying wire exerts a force on another element of the same wire?
Ans.- No, there is no force or torque on an element due to the field produced by the element itself but there is a force on an element of the same wire.
Q5. Can a system have magnetic moment even though it's net charges zero?
Ans.- The average of the charge in the system maybe zero. Yet the mean of magnetic moment due to various current loops may not be zero. In paramagnetic material net charges zero but it pursues net dipole moment.

Numerical

Q1. A short bar magnet placed with an axis at 30° to a uniform magnetic field at 0.2 T experience a torque of 0.06 Nm. Calculate the 1. Magnetic moment of the magnet
2. Find out what orientation of the magnet corresponds to its stable equilibrium in the magnetic field. Hints: $m = \tau/B\sin\theta$ $U = -mB\cos\theta$
Ans. 1. 0.6 Am^2 2. $\theta=0°$

Q2. A current of 5A is flowing through 10 turn circular coil of radius 7 cm. The coil lies in X-Y plane. What is magnitude and direction of the magnetic dipole moment associated with it?
Hints: $m = NIA$ Ans. $m = 0.77\ Am^2$

Q3. A solenoid has a core of a material with relative permeability 400. The winding of solenoid are insulated from the core and carry a current of 2A. If the number of turn is 1000 per metre, calculate 1.H 2. M and 3. B

Ans. 1. $H = nI$ $= 2\times10^3$ A/m
2. $B = \mu H$ $=1.0T$
3. $M = XH$ $=8\times10$ J A/m

Q4. A bar magnet of magnetic moment 1.5 J/T lies aligned with direction of a uniform magnetic field of 0.22 T. (a) What is the amount of work required to turn the magnet show as to align its magnetic moment? 1. Normal to the field direction, 2. Opposite to the field direction (b) What is the torque on the magnet in case (1) and (2) ?

Ans.- 1. $W= -mB [\cos\theta2 - \cos\theta1]$, $\theta1= 0°$, $\theta2 =90°$
2. $\theta1= 0°$, , $\theta2 =180°$

Q5. The earth's field, it is claimed roughly approximates the field due to dipole of magnetic moment 8×10^{22} J/T located at centre. Check the order of magnitude of this number in some way.

Ans.- $B=\mu0/4\pi\ m/r^3$ $= 0.3/10^4$ T $=0.3$ G

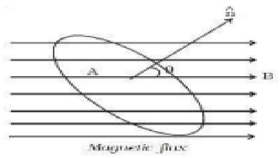
This value is same order of magnitude as that of the observed field of the earth

CHAPTER 6
ELECTROMAGNETIC INDUCTION

SUMMARY

Michael Faraday demonstrated the reverse effect of Oersted experiment. He explained the possibility of producing emf across the ends of a conductor when the magnetic flux linked with the conductor changes. This was termed as electromagnetic induction. The discovery of this phenomenon brought about a revolution in the field of power generation..

Magnetic flux The magnetic flux (φ) linked with a surface held in a magnetic field (B) is defined as the number of magnetic lines of force crossing a closed area (A) as shown in figure.



If θ is the angle between the direction of the field and normal to the area, then

$$\phi = \vec{B} \cdot \vec{A}$$

$$\phi = BA\cos\theta$$

Induced emf and current – Electromagnetic induction.

Whenever there is a change in the magnetic flux linked with a closed circuit an emf is produced. This emf is known as the induced emf and the current that flows in the closed circuit is called induced current. The phenomenon of producing an induced emf due to the change in the magnetic flux associated with a closed circuit is known as electromagnetic induction.

Faraday's laws of electromagnetic induction

Based on his studies on the phenomenon of electromagnetic induction, Faraday proposed the following two laws **First law**

Whenever the amount of magnetic flux linked with a closed circuit changes, an emf is induced in the circuit. The induced emf lasts so long as the change in magnetic flux continues.

Second law The magnitude of emf induced in a closed circuit is directly proportional to the rate of change of magnetic flux linked with the circuit. Let φ1 be the magnetic flux linked with the coil initially and φ2 be the magnetic flux linked with the coil after a time t. Then rate of change of magnetic flux = (φ2- φ1)/t

According to Faraday's second law, the magnitude of induced emf is, E α (φ2- φ1)/t

If dt→ 0, dφ is the change in magnetic flux in a time dt,

Then the above equation can be written as E α (dφ/dt)

Lenz's law

Lenz's law states that the induced current produced in a circuit always flows in such a direction that it opposes the change or cause that produces it.

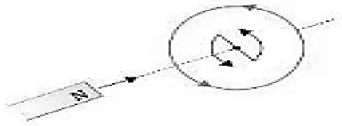
If the coil has N number of turns and φ is the magnetic flux linked with each turn of the coil, then the total flux linked with the coil is NØ

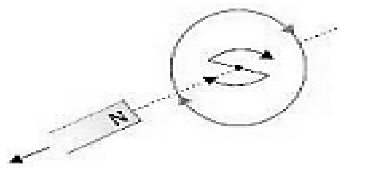
$$E = -\frac{d}{dt}(N\phi)$$

$$E = -N\frac{d\phi}{dt}$$

$$E = -\frac{N(\phi_2 - \phi_1)}{t}$$

Lenz's law - a consequence of conservation of energy





A magnet is moved towards the coil as shown in figure. The upper face of the coil acquires north polarity. Consequently work has to be done to move the magnet further against the force of repulsion. When we withdraw the magnet away from the coil, its upper face acquires south polarity. Now the work done is against the force of attraction. When the magnet is moved, the number of magnetic lines of force linking the coil changes, which causes an induced current to flow through the coil. The direction of the induced current, according to Lenz's law is always to oppose the motion of the magnet. The work done in moving the magnet is converted into electrical energy. This energy is dissipated as heat energy in the coil.
If on the contrary, the direction of the current were to help the motion of the magnet, that is, if when north pole approaches coil south pole is produced at the face of coil due to flow of current. And when North pole goes away from coil if North pole is produced at the face of coil, magnet would start moving faster increasing the change of magnetic flux linking the coil. This results in the increase of induced current. Hence kinetic energy and electrical energy would be produced without any external work being done, but this is impossible.
Therefore, the induced current always flows in such a direction to oppose the cause. Thus it is proved that Lenz's law is the consequence of conservation of energy.

Fleming's right hand rule

The forefinger, the middle finger and the thumb of the right hand are held in the three mutually perpendicular directions. If the forefinger points along the direction of the magnetic field and the thumb are along the direction of motion of the conductor, then the middle finger points in the direction of the induced current. This rule is also called generator rule.

Motional emf : The potential difference induced in a conductor of length l moving with velocity v, in a direction perpendicular to magnetic field B is given by
$\varepsilon = \int (v \times B)\, dl = vBl$

Self Induction

The property of a coil which enables to produce an opposing induced emf in it when the current in the coil changes is called self induction.

Coefficient of self induction

When a current I flows through a coil, the magnetic flux (φ) linked with the coil is proportional to the current.
$\Phi \propto I$ or $\varphi = LI$ Where L is a constant of proportionality and is called coefficient of self induction or self inductance.
If I = 1A, $\varphi = L \times 1$, then $L = \varphi$
Therefore, coefficient of self induction of a coil is numerically equal to the magnetic flux linked with a coil when unit current flows through it. According to laws of electromagnetic induction

$$E = -\frac{d\phi}{dt} = -\frac{d}{dt}(LI)$$

$$E = -L\frac{dI}{dt}$$

$$if \quad \frac{dI}{dt} = 1As^{-1}$$

$$L = -E$$

The coefficient of self induction of a coil is numerically equal to the opposing emf induced in the coil when the rate of change of current through the coil is unity. The unit of self inductance is henry (H). One henry is defined as the self-inductance of a coil in which a change in current of one ampere per second produces an opposing emf of one volt.

Self-inductance of a Solenoid

We will take a solenoid having N turns; let its length be '*l*', and the area of the cross-section be 'A', where current I is flowing through it. There will be a magnetic field 'B' at any given point in the solenoid. Therefore, the magnetic flux per turn will be equal to B × area of each turn.
However, $B = (\mu_0 NI)/l$
Therefore, magnetic flux per turn = $(\mu_0 NIA)/l$

Now, the total magnetic flux (φ) that is connected with the solenoid will be given by the product of flux present through every turn and the total number of turns.

$\Phi = (\mu_0 NIA) \times N / l$

That is, $\Phi = (\mu_0 N^2 IA) / l$ ….(eq 1)

If L is the self-inductance of the solenoid, then

$\Phi = LI$ …..(eq 2)

Combining the equations (1) and (2) from above, we get

$L = (\mu_0 N^2 A) / l$

If you have a core that is made up of a magnetic material of permeability μ, then

$L = (\mu N^2 A) / l$

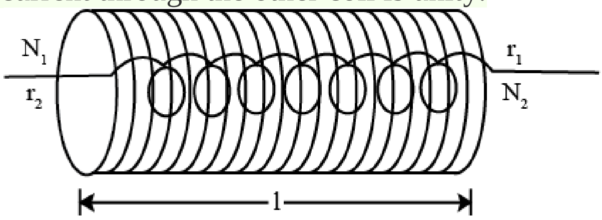
Mutual Inductance

When two coils are brought in proximity to each other, the magnetic field in one of the coils tends to link with the other. This further leads to the generation of voltage in the second coil. This property of a coil which affects or changes the current and voltage in a secondary coil is called mutual inductance.

$\phi_2 \propto I_1$ or $\phi_2 = MI_1$

The S.I unit of coefficient of mutual induction is henry (H)

Mutual inductance of two coils is equal to the e.m.f. induced in one coil when rate of change of current through the other coil is unity.



The Magnetic field produced at any point inside the solenoid

S1 due to the current l1 is $B1 = \mu 0 N_1 I_1 / l$

Flux linked with each turn of $S_2 = B_1 A$

Total Magnetic flux with linked with solenoid having N_2 turns is

$\phi_2 = B_1 A N_2 = (\mu_0 N_1 I_1)/l \, (AN_2)$

$\phi_2 = MI_1$

$M = \mu 0 N_1 N_2 A / l$

$M_{12} = M_{21}$

AC Generator:

AC generator is the one which produces a current that alternates or changes its direction regularly after a fixed interval of time, i.e., it is a device which converts mechanical energy into the alternating form of electrical energy.

The principle of AC Generator:

It is based on the phenomenon of **electromagnetic induction**–when the coil is rotated with a constant angular velocity W in a uniform magnetic field B, then the magnetic flux linked with the coil changes and an alternating current is induced in the coil.

$$e = \frac{-d\phi}{dt}$$

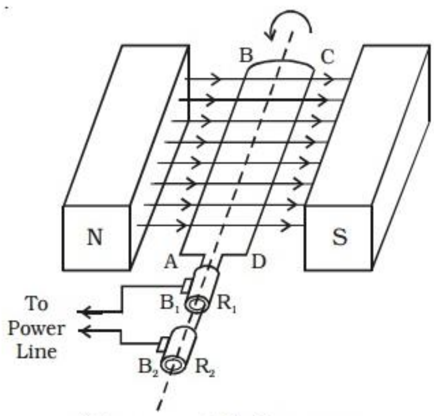


Fig AC dynamo

$$e = \frac{-d}{dt} \quad NBA \cos\theta$$

$$e = -NBA \frac{d}{dt} \cos\theta$$

$$e = -NBA(-\sin\theta)\frac{d\theta}{dt}$$

$$e = NBA\, w \sin\theta \qquad \left[\text{as } w = \frac{d\theta}{dt}\right]$$

$$e = e_0 \sin\theta \qquad (\text{where } e_0 \text{ is maximum emf})$$

$$e = e_0 \sin wt \qquad (\text{as } \theta = wt)$$

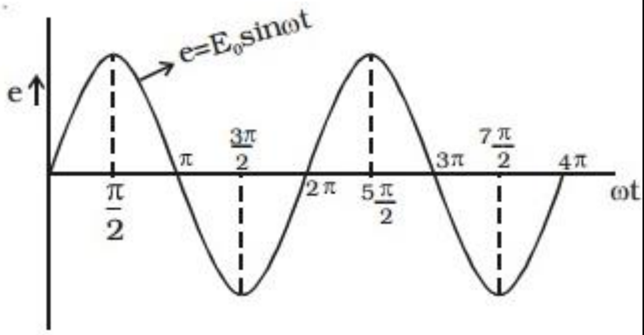


Fig emf varies sinusoidally

Maximum induced emf,

$e_0 = NBA\omega$

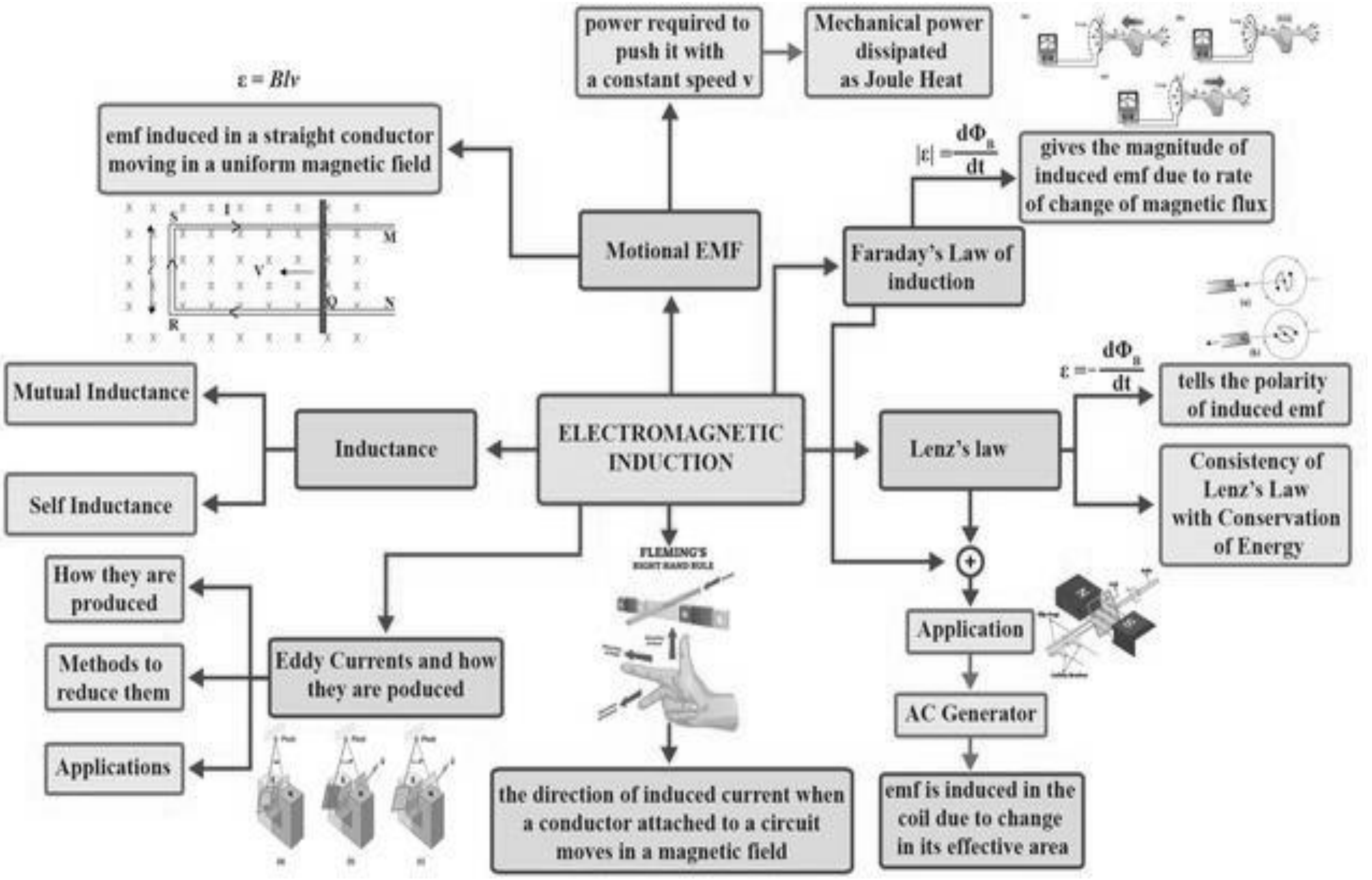
When a load of resistance R is connected across the terminals, a current I flows in the external circuit.

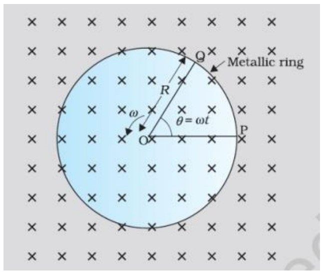
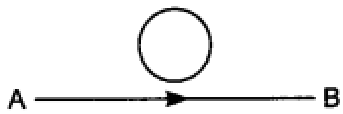
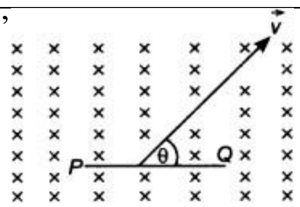
$$I = \frac{e}{R} = \frac{e_0 \sin\omega t}{R} = I_0 \sin\omega t$$

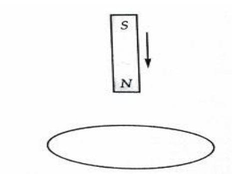
where $I_0 = e_0/R$, both current and voltage vary sinusoidally with time.

Maximum current,

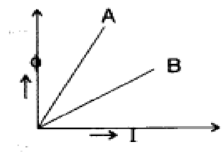
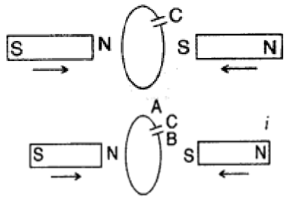
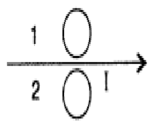
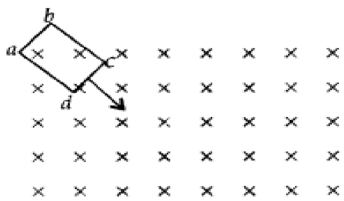
$$I_0 = \frac{e_0}{R} = \frac{NBA\omega}{R}$$

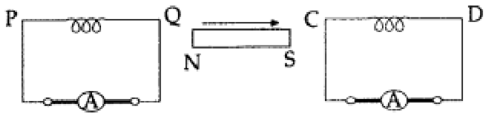
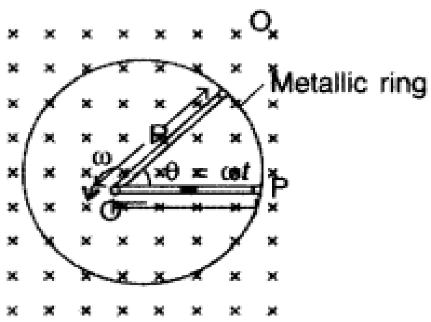


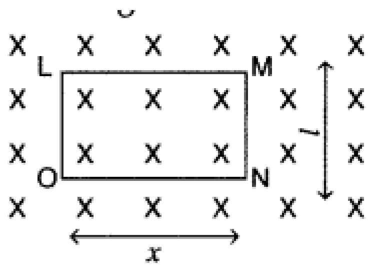
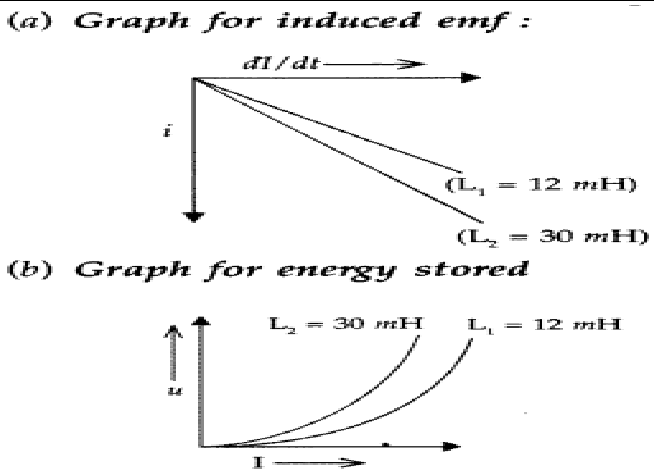
	MCQ	Ans
1	Lenz's law of electromagnetic induction is as per law of conservation of a) energy. b)angular momentum. c) charge. d) electromotive force.	a
2	Which of the following statements is not correct? a)Whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in circuit. b) The induced emf lasts so long as the change in magnetic flux continues. c)The direction of induced emf is given by Lenz's law d)Lenz's law is a consequence of the law of conservation of momentum	d
3	Which of the following statements is wrong for magnetic flux a)Magnetic flux can be negative b) Magnetic flux can be positive c)Magnetic flux can be zero d)Magnetic flux is always positive or negative.	d
4	A metallic rod of length ' L' is rotated with a angular frequency of ' ω ' , with oneend hinged at the centre and the other end at the circumference of circular metallic ring of radius 'R', about an axis passing through the centre and perpendicular to the plane of the ring as shown in the figure. A constant and uniform magnetic field 'B' parallel to the axis is present everywhere. What is theemf between the centre and the metallic ring?  a) (BωR)/2 b) ($B\omega^2R$)/2 c) ($B\omega R^2$)/2 d) ($B^2\omega R$)/2	c
5	In the given figure current from A to B in the straight wire is increasing. The directionof the induced current in the loop is  a) clockwise. b) anticlockwise. c) straight line. d) no induced e.m.f.produced.	b
6	When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50V is produced. The self inductance of the coil is V isproduced. The self-inductance of the coil will be. (a) 1.67 H (b) 6 H (c) 3 H (d) 0.67 H	a
7	If number of turns in primary and secondary coils is increased to two times each, the mutual induction a)becomes 4 times b)becomes 2 times c) becomes 8 times d)remains unchanged	a
8	The polarity of the induced emf is given by a) Ampere' circuital law b) Biot- Savart Law c) Lenz's law d) Fleming's right-hand rule	c
9	SI unit of magnetic flux a) weber b) tesla x meter c) tesla d) Gauss	a
10	A rod PQ of length 'L' is moved in uniform magnetic field '**B**' as shown. If the rod is moving with a velocity 'v' making an angle 'θ' with themagnetic field. What will be the emf induced in it?  a) BLvsinθ b) BLvcosθ c) BLv d) BLvtanθ	a

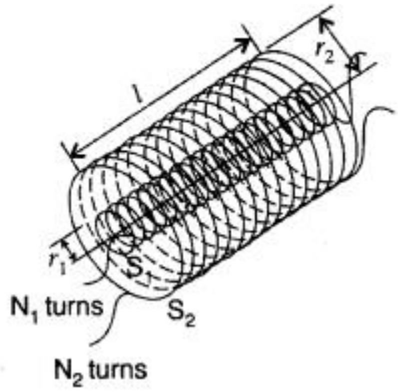
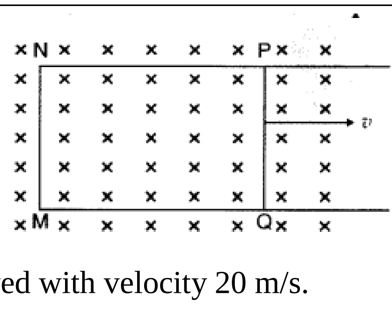
	Assertion Reason Questions	
	Directions: These questions consist of two statements, each printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses. (a) If both Assertion and Reason are correct and the Reason is a correct explanation 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:** When two coils are wound on each other, the mutual induction betweenthe coils is maximum. **Reason:** Mutual induction does not depend on the orientation of the coils.	c
2	**Assertion:** Magnetic flux linked to closed surface is zero. **Reason:** Direction of induced current due to change of magnetic flux is given by Faraday's Law.	c
3	**Assertion**: If a coil is rotated in uniform magnetic field about an axis perpendicular to the field, emf induced in coil is maximum for orientation of coil in which magnetic flux through the coil is zero. **Reason:** Work done to rotate the coil will get converted into electrical energy.	b
4	**Assertion**: The presence of large magnetic flux through a coil maintains a current in the coil, if the circuit is continuous. **Reason:** Only a change in magnetic flux will maintain an induced current in the coil.	d
5	**Assertion**: The bar magnet falling vertically along the axis of the horizontal coil will be having acceleration less than 'g' **Reason**: Clock wise current is induced in the coil 	c
	Case Study questions	
1	Definition: Mutual Inductance between the two coils is defined as the property of the coil due to which it opposes the change of current in the other coil, or you can say in the neighboring coil. When the current in the neighboring coil changes, the flux sets up in the coil and because of this, changing flux emf is induced in the coil called Mutually Induced emf and the phenomenon is known as Mutual Inductance. The value of Mutual Inductance (M) depends upon the following factors Number of turns in the secondary or neighboring coil, Cross-sectional area Closeness of the two coils, Mutual Coupling In the Magnetic Circuit When on a magnetic core, two or more than two coils are wound, the coils are said to be mutually coupled. The current, when passed in any of the coils wound around the magnetic core, produces flux which links all the coils together and also the one in which current is passed. Hence, there will be both self-induced emf and mutual induced emf in each of the coils. The best example of the mutual inductance is the transformer, which works on the principle of Faraday's Law of Electromagnetic Induction. Faraday's law of electromagnetic induction states that "the magnitude of voltage is directly proportional to the rate of change of flux." which is explained in the topic Faraday's Law of Electromagnetic Induction.	

a	The phenomenon due to which there is an induced current in one coil due to current in a neighboring coil is? A. Electromagnetism B.Susceptance C.Mutual inductance D.Steady current	C
b	. Mutual inductance between two magnetically coupled coils depends on A. Permeability of the core material B. Number of turns of the coils C. Cross sectional area of their common core D. All of the above	D
c	Which of the following is unit of inductance? A. Ohm B. Henry C. Ampere turns D. Weber/meter	B
d	. Which of the following circuit elements will oppose the change in circuit current? A. Capacitance B. Inductanc C. Resistance D. All of the above	B
e	If in an iron cored coil the iron core is removed so as to make the air cored coil, the inductance of the coil will be A. More B. Less C. The same D. None of these	B
2	Faraday’s law of electromagnetic induction, also known as Faraday’s law is the basic law of electromagnetism which helps us to predict how a magnetic field would interact with an electric circuit to produce an electromotive force (EMF). This phenomenon is known as electromagnetic induction. Faraday’s Experiment: Relationship Between Induced EMF and Flux In the first experiment, he proved that when the strength of the magnetic field is varied, only then-current is induced. An ammeter was connected to a loop of wire; the ammeter deflected when a magnet was moved towards the wire. In the second experiment, he proved that passing a current through an iron rod would make it electromagnetic. He observed that when a relative motion exists between the magnet and the coil, an electromotive force will be induced. When the magnet was rotated about its axis, no electromotive force was observed, but when the magnet was rotated about its own axis then the induced electromotive force was produced. Thus, there was no deflection in the ammeter when the magnet was held stationary. While conducting the third experiment, he recorded that the Galvanometer did not show any deflection and no induced current was produced in the coil when the coil was moved in a stationary magnetic field. The ammeter deflected in the opposite direction when the magnet was moved away from the loop.	
a	As per Faraday's laws of electromagnetic induction, an e.m.f. is induced in a conductor whenever it (A) Lies perpendicular to the magnetic flux (B) Lies in a magnetic field (C) Cuts magnetic flux (D) Moves parallel to the direction of the magnetic field	C
b	According to Faraday’s law, EMF stands for a) Electromagnetic field b) Electromagnetic force c) Electromagnetic friction d) Electromotive force	D
c	For time varying currents, the field or waves will be a) Electrostatic b) Magneto static c) Electromagnetic d) Electrical	C
d	Find the displacement current when the flux density is given by t^3 at 2 seconds. a) 3 b) 6 c) 12 d) 27	C

e	Which of the following statements is true? a) E is the cross product of v and B b) B is the cross product of v and E c) E is the dot product of v and B d) B is the dot product of v and E	A
	SA (2Marks)	
1	A plot of magnetic flux (ϕ) versus current (I) is shown in the figure for two inductors A and B. Which of the two has larger value of self inductance?  Answer: *Since $\phi = LI$* ***∴ $L = \phi I$ = slope*** ***Slope of A is greater than slope of B*** ***∴ Inductor A has larger value of self inductance than inductor B.***	
2	Two bar magnets are quickly moved towards a metallic loop connected across a capacitor 'C' as shown in the figure. Predict the polarity of the capacitor.  **Answer:*When both magnets move towards loop, the A side plate of capacitor will be positive while the lower plate B is negative, making the induced current in a clockwise direction.***	
3	Predict the directions of induced currents in metal rings 1 and 2 lying in the same plane where current I in the wire is increasing steadily.  ***Answer:*** ***In metal ring 1, the induced current flows in the clockwise direction.*** ***In metal ring 2, the induced current flows in the anticlockwise direction***.	
4	Predict the direction of induced current in a metal ring when the ring is moved towards a conductor is carrying current I in the direction shown in the figure.  ***Answer: Clockwise direction.***	
5	Predict the direction of the induced current in the rectangular loop abed as it is moved into the region of a uniform magnetic field $\vec{B}$ directed normal to the plane of the loop.  ***Answer: The direction of the induced current in the given rectangular loop is anti-clockwise, i.e., cbadc.***	
6	How does the mutual inductance of a pair of coils change when (i) distance between the coils is increased and (ii) number of turns in the coils is increased ***Answer: (i) Mutual inductance decreases', because flux linked with the secondary coil decreases. (ii) M=μ0n1n2Al, so when n_1 and n_2 increase, mutual inductance (M) increases***.	
7	A long straight current carrying wire passes normally through the centre of a circular loop. If the current through the wire increases, will there be an induced emf in the. loop? Justify. ***Answer:No, As the magnetic field due to current carrying wire will be in the plane of the circular loop, so magnetic flux will remain zero.***	
8	Define the term 'self-inductance' of a coil. Write its S.I. Unit. ***Answer: The self inductance of a coil numerically equals to the induced emf produced in the coil, when the rate of change of current in the coil is unity.*** $e = -L \frac{dI}{dt}$ (where L is the self inductance of the coil) S.I. Unit: Henry.	

9	State Faraday's law of electromagnetic induction.	
10	A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the direction of the induced current in each coil  Answer :Induced current flows from P to Q through ammeter while it flows from D to C through ammeter	
	LA(3 marks)	
1	Derive an expression for the self-inductance of a long air-cored solenoid of length l and number of turns N. Answer: Consider a long solenoid of length l and radius r with r << 1 and having n turns per unit length. If a current I flows through the coil, then the magnetic field inside the coil is almost constant and is given by $B = \mu_0 nI$ Magnetic flux linked with each turn = BA = $\mu_0 nIA$ ...where [$A = \pi r^2$ = cross-sectional area of the solenoid ∴ Magnetic flux linked with the entire solenoid is ϕ = Flux linked with each turn × Total number of turns $= \mu_0 nIA \times nl = \mu_0 n^2 IAl$ But $\phi = LI$ ∴ Self-inductance of the long solenoid is $L = \mu_0 n^2 lA$ If N is the total number of turns in the solenoid then $n = \frac{N}{l}$ ∴ $L = \frac{\mu_0 N^2 A}{l}$	
2	Two identical loops, one of copper and the other of aluminum, are rotated with the same angular speed in the same magnetic field. Compare (i) the induced emf and (ii) the current produced in the two coils. Justify your answer.(All India 2010) ***Answer: (i) Induced emf in a coil is ε = NBAω sin ωt*** ***As the angular speed is same, induced emf will also be same in both the loops.*** ***(ii) Current induced in a loop is I=e/R =eA/pl*** ***As the resistivity of copper is lesser, more amount of current is induced in it.***	
3	A metallic rod of 'L' length is rotated with angular frequency of 'ω' with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius L, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere. Deduce the expression for the emf between the centre and the metallic ring. Answer: The magnitude of the emf, generated across a length dr of the rod, as it moves at right angles to the magnetic field, is given by $d\varepsilon = Bvdr$ $\therefore \quad \varepsilon = \int d\varepsilon = \int_0^R Bv\,dr = \int_0^R B\omega r\,dr = \frac{B\omega R^2}{2}$  	

4	A rod of length l is moved horizontally with a uniform velocity ‘v’ in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod. (b) How does one understand this motional emf by invoking the Lorentz force acting on the free charge carriers of the conductor? Explain.  Answer: ...[∵ Max flux, $\phi = BA$] Induced emf, $E = -\frac{d\phi}{dt} = -\frac{d}{dt} Blx$ $= -Bl\frac{dx}{dt} = Blv$ where $\left[\frac{dx}{dt} = -v\right.$, that is the velocity of conductor MN. $\lvert F \rvert = \lvert qvB \rvert$ ...(ii) The work done in moving, the charge through a distance is : W = qvBl Since the emf is the work done per unit charge, $e = \frac{W}{q} = \frac{qvBl}{q} = Blv$ ...(iii) This expression is the same as given in (i)	
5	The current through two inductors of self-inductance 12 mH and 30 mH is increasing with time at the same rate. Draw graphs showing the variation of the (a) emf induced with the rate of change of current in each inductor (b) energy stored in each inductor with the current flowing through it. Answer:  	
	LA(5 marks)	
1	Deduce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns. Answer: When a current I_2 is set up through S_2, it in turn sets up a magnetic flux through S_1. Let us denote it by ϕ_1. The corresponding flux linkage with solenoid S_1 is	

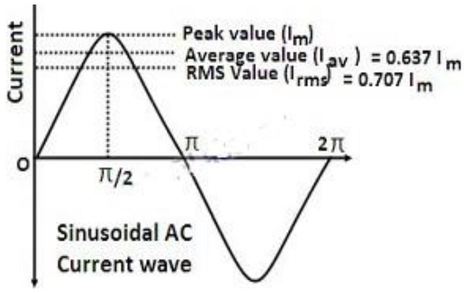
	$N_1\phi_1 = M_{12}I_2$ ...(i)  is $\mu_0 n_2 I_2$. The resulting flux linkage with coil S_1 is, $N_1\phi_1 = (n_1 l)(\pi r_1^2)(\mu_0 n_2 I_2)$ $= \mu_0 n_1 . n_2 \pi r_1^2 l I_2$ ...(ii) **where [$n_1 l$ is the total number of turns in solenoid S_1** Thus $M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$ ...(iii) $N_2\phi_2 = (n_2 l)(\pi r_1^2)(\mu_0 n_1 I_1)$ ...(v) **where [$n_2 l$ is the total number of turns of S_2** From equation (iv) $M_{21} = \mu_0 n_1 n_2 \pi r_1^2 l$ From equations (ii) and (iii), we get $M_{12} = M_{21} = M$ (say) $\therefore$ $\boxed{M = \mu_r \mu_0 n_1 n_2 \pi r_1^2 l}$ $N_2\phi_2 = M_{21}I_1$ ...(iv)	
2	Describe the construction, principle and working of an AC generator Answer: refer to summary	
	Numerical (3 marks)	
1	A rectangular loop PQMN with movable arm PQ of length 10 cm and resistance 2 Ω is placed in a uniform magnetic field of 0.1 T acting perpendicular to the plane of the loop as is shown in the figure. The resistances of the arms MN, NP and MQ are negligible. Calculate the  (i) emf induced in the arm PQ and (ii) current induced in the loop when arm PQ is moved with velocity 20 m/s. Answer: (i) emf induced $e = Blv = (0.1) \times (10 \times 10^{-2}) \times 20\ V = \mathbf{0.2\ V}$ (ii) Current in the loop, $i = \frac{e}{R} = \frac{0.2}{2} = \mathbf{0.1\ A}$	

2	A long solenoid with 15 turns per cm has a small loop of area 2.0 cm^2 placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0 A to 4.0 A in 0.1 s, what is the induced emf in the loop while the current is changing? Answer : $e = \frac{d}{dt}(BA)$ $= A\mu_0 n \times \left(\frac{di}{dt}\right)$ $= 2\times10^{-4}\times4\pi\times10^{-7}\times1500\times\frac{2}{0.1}$ $= 7.54\times10^{-6}$ V	
3	A 1.0 m long metallic rod is rotated with an angular frequency of 400 rad s^{-1} about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field of 0.5 T parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring. Answer $e = Blv = Bl\left(\frac{l\omega}{2}\right) = \frac{Bl^2\omega}{2}$ $= \frac{0.5\times(1)^2\times400}{2} = 100$ V	
4	When the current changes from +2A to – 2A in 0.05s, an e.m.f of 8V is induced in the coil. The coefficient of self induction of coil is? AnswerGiven – L = 8v E = | L dI/dT | E = (8 V × 0.05) /4 E = 0.1 H	
5	A 100 mH coil carries a current of 1 A. Energy stored in the form of magnetic field is Answer Given – L = 100 mH I = 1 A E = ½ LI^2 E = ½ 100 × 10^{-3} × 1 E = 50 × 10^{-3} J	

CHAPTER – 7
ALTERNATING CURRENT

GIST OF LESSON

1. Alternating Current (AC) :It is the current which varies in both magnitude as well as direction alternatively and periodically.
Instantaneous current is represented by $I = I0 \sin \omega t$ or $I = I0 \cos\omega t$,
where, I0 = peak value or maximum value of AC. Angular frequency $\omega=2\pi\nu$ [Where ν=frequency]



2. Effective Value or rms Value of AC It is defined as the value of AC over a complete cycle which would generate same amount of heat in a given resistors that is generated by steady current in the same resistor and in the same time during a complete cycle.
The 70.7% of peak value of current gives effective or rms value of AC. [Im or I0 is maximum or peak value of current]

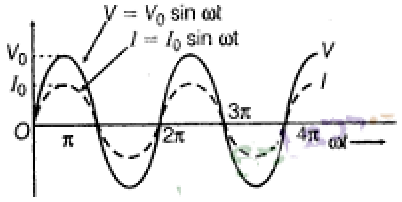
3. Average or Mean Value of AC It is defined as the value of AC which would send same amount of charge through a circuit in half-cycle that is sent by steady current in the same time.
Mean or average value of alternating current for first half cycle is $I_{av} = 2I_o / \pi = 0.637\ I_o$
Mean or average value of alternating current for next half cycle is $I'_{av} = -2I_o / \pi = -0.637\ I_o$
The 63.7% of peak value of AC gives average or mean value of AC.
NOTE: Mean or average value of alternating current for one complete cycle = O.

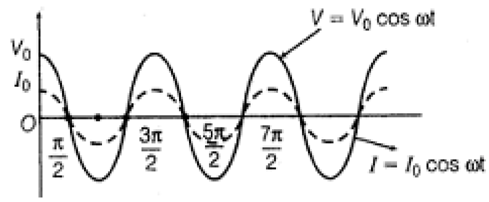
4. Alternating emf or Voltage It is the emf which varies in both magnitude as well as direction alternatively and periodically. The instantaneous alternating emf is given by

$$V = V_0 \sin \omega t \quad \text{or} \quad V = V_0 \cos\omega t$$

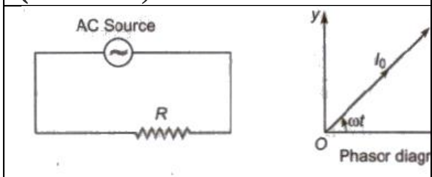
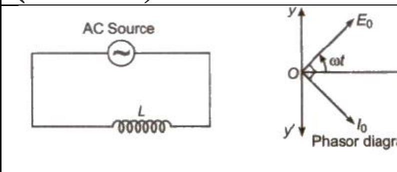
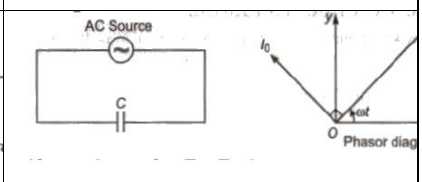
$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = 0.707 \quad \text{or} \quad V_{\text{rms}} = 70.7\% \text{ of } V_0$$

AC voltage and AC current are represented by diagrams as shown below:



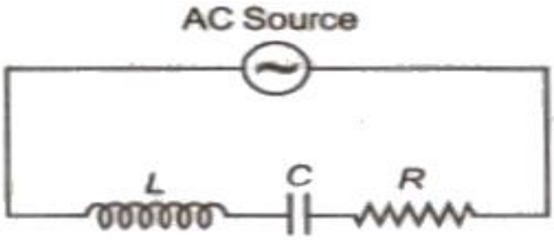


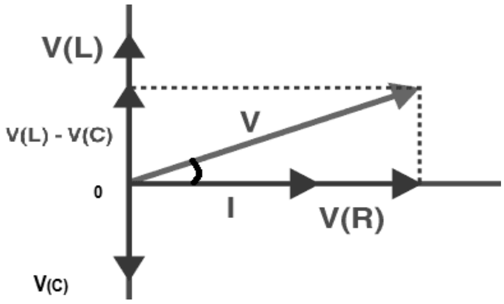
5.Current and Potential Relations

(i) **Pure Resistive Circuit** (**R** circuit)	**(ii) Pure Inductive Circuit** (**L** Circuit)	(iii) **Pure Capacitive Circuit**
		
(a) Alternating emf, $E = E_o \sin \omega t$	(a) Alternating emf, $E = E_o \sin \omega t$	(a) Alternating emf, $E = E_o \sin \omega t$
(b) Alternating current, $I = I_o \sin \omega t$	(b) Alternating current, $I = I_o \sin (\omega t - \pi / 2)$	(b) Alternating current, $I = I_o \sin (\omega t + \pi / 2)$

I Alternating emf and alternating current both are in the same phase.	I Alternating current lags behind alternating emf by π / 2.	I Alternating current leads alternating emf by π / 2.
(d) Average power decay, (P) = E_v . I_v	(d) Inductive reactance, $X_L = L\omega = L\ 2\pi f$	(d) Inductive reactance, $X_L = C\omega = C2\pi f$
(e) Power factor, cos θ = 1	(e) Average power decay, (P) = 0	(e) Average power decay, (P) = 0
	(f) Power factor, cos θ = cos 90° = 0	(f) Power factor, cos θ = cos 90° = 0

6. **L – C – R Series Circuit.**





(a) Alternating emf, $E = E_0 \sin \omega t$
(b) Alternating current, $I = I_0 \sin (\omega t \pm \theta)$
(c) Resultant voltage, $V = \sqrt{V^2_R + (V_L - V_C)^2}$
(d) Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$
(e) Power factor, $\cos \theta = R / Z = R / \sqrt{R^2 + (X_L - X_C)^2}$
(f) Average power decay, $(P) = E_V I_V \cos \theta$

Depending upon the values of X_L and X_C We have three possible conditions
If $X_L > X_c$, then tan θ > 0 and the voltage leads the current and the circuit is said to be inductive
If $X_L < X_c$, then tan θ < 0 and the voltage lags the current and the circuit is said to be capacitive
If $X_L = X_c$, then tan θ = 0 and the voltage is in phase with the current and is known as resonant circuit.

7. Difference between Reactance and Impedance

Reactance	Impedence
1) The reactance measures the opposition of capacitance and inductance to current. 2) There are two types of reactance: capacitive reactance and inductive reactance. 3) When in the circuit there will be either inductor or capacitor then there will be reactance. 4) The reactance represented by the letter X . 5) The reactance is measured in the unit of ohms (Ω).	1) The impedance measures the overall opposition of a circuit to current. 2)The impedance can be split into two parts Resistance R and Reactance X . 3) In the circuit when there will be both capacitor and inductor or capacitor, Inductor and resistor then there will be impedence. 4) The impedance is represented by the letter Z. 5) The impedence is measured in the unit of ohms (Ω) but in complex form.

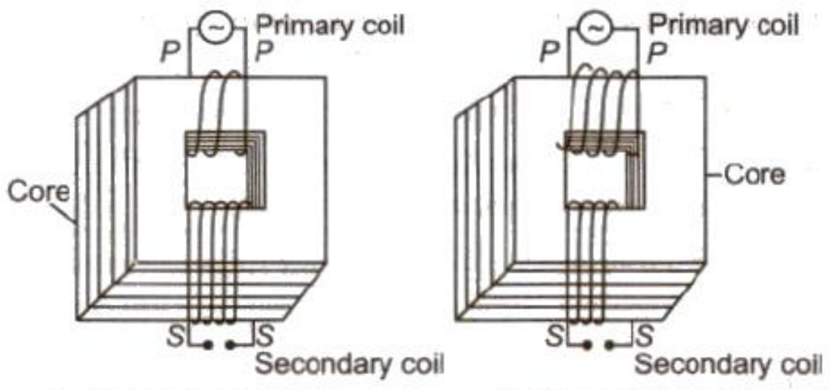
8. Power In an AC circuit, both emf and current change continuously w.r.t. time, so in circuit, we have to calculate average power in complete cycle (0 –> T). $P_{av} = E_{rms} I_{rms} \cos \varphi$, Where Cosφ is called power factor

9. Wattless Current The current in an AC circuit when average power consumption in AC circuit is zero, is referred as wattless current or idle current. In case of L or C ,φ is 90^0. So $Cos90^0=0$or $P_{av}=0$

11.Transformer

It is a device which can change **a low voltage of high current into a high voltage of low current and vice-versa.**

PRINCIPLE: Its working is based on mutual induction



(b) Step-up transformer (b) Step-down transformer

Types of transformers.

(i) **Step-up Transformers;** It converts a low voltage of high current into a high voltage of low current. In this transformer,

$N_s > N_P$, $E_s > E_P$ and $I_P > I_S$

(ii) Step-down Transformer It converts a high voltage of low current into a low voltage of high current.

In this transformer, $N_P > N_S$, $E_P > E_S$ and $I_P < I_S$

Transformation Ratio

$K = N_S / N_P = E_S / E_P = I_P / I_S$ [For step-up transformer, K > 1, For step-down transformer, K < 1]

Energy Losses in a Transformer

Iron loss , 2. Copper loss , 3 Flux loss , 4.Hysteresis loss , 5.Humming loss

Important Points

Transformer does not operate on direct current. It operates only on alternating voltages at input as well as at output.

Transformer does not amplify power as vacuum tube.

Efficiency, η = Output power / Input power

Generally efficiency ranges from 70% to 90%.

GRADED QUESTIONS OF THE CHAPTER
VSA (1Marks questions)

MCQ [Choose correct one]

1 In an LCR-series ac circuit, the voltage across each of the component L, C and R is 50 V. The voltage across the LC-combination will be

(a) 50 V (b) $50\sqrt{2}$ V (c) 100 V (d) zero

HINT: The voltage across L and C are out of phase.

2 An ac circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be

(a) 0.8 (b) 0.4 (c) 0.125 (d) 1.25

HINT: Power factor, $\cos \Phi = R/Z$

3. A transformer is used to light a 100 W lamp from a 220 V mains. If the main current is 0.5 A, the efficiency of the transformer is …

(a) 30% (b) 50% (c) 90% (d) 10%

HINT: efficiency=output power/input power =100/220x0.5

4 What is the value of inductance L for which the current is maximum in a series LCR- circuit with C = 10 μF and $\omega = 1000\ s^{-1}$?
(a) 100 mH (b) 1 mH (c) 10 mH (d) cannot be calculated unless R is known
HINT:For $X_L = X_C$, , $L = 1/\omega^2 C$
5. Average power dissipated in an inductor connected to an a.c. source is
(a) $1/2LI^2$ (b) LI^2 (c) zero (d) none of these
Hint : $P_{av} = V_0 I_0 \cos\varphi$
6. The power factor varies between
(a) 2 and 2.5 (b) 3.5 to 5 (c) 0 to 1 (d) 1 to 2
Hint: Power factor cos Φ in an ac circuit varies between 0 and 1.
7. Reciprocal of impedance is called
(a) Susceptance (b) Conductance (c) Admittance (d) Transconductance
HINTS: Admittance
7. What happens to the inductive reactance when the frequency of the AC supply is increased?
(a) Increases (b) Decreases (c)Remains the same (d) Decreases inversely
HINTS: increases
8.Why is the DC ammeter incapable of measuring alternating current?
(a) AC is incompatible with DC ammeters. (b) AC modifies its course.
(c) AC is virtual. (d) Zero is the average value of a whole cycle.
HINT: d) Zero is the average value of a whole cycle.
9. Energy is lost in the LCR circuit by:
(a) L only (b) C only © R only (d) All of the above
HINTS: R ONLY
10. A 50 mH inductor is connected to a 200 V, 50 Hz AC supply. Determine the rms value of the current in the circuit.
a)12.74 A b)13.57 A c) 11.5 A d) 9.53 A
HINTS: Inductive reactance, $X_L = 2\pi fL = 2 \times 3.14 \times 50 \times 50 \times 10^{-3} = 15.7$ ohm
Now, $I_{rms} = V_{rms} / X_L = 200/15.7 = 12.74$ A

ASSERTION /REASONING QUESTIONS

Directions: Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.
(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(c) Assertion is correct, reason is incorrect
(d) Assertion is incorrect, reason is correct.

1.Assertion : Average value of ac over a complete cycle is always zero.
Reason: Average value of ac is always defined over half cycle.
HINTS: (b)

2 Assertion : The alternating current lags behind the emf by a phase angle of, π/2 when AC flows through an inductor.
Reason : The inductive reactance increases as the frequency of AC source increases.
Hints: (b)

3 **Assertion :** In a purely inductive or capacitive circuit, the current is referred to as wattless current.
Reason: No power is dissipated in a purely inductive or capacitive circuit even though a current is flowing in the circuit.
Hints:(a)

4. **Assertion: The** power in an ac circuit is minimum if the circuit has only a resistor.
Reason: Power of a circuit is independent of the phase angle.
Hint: (d)

5. **Assertion :** The power is produced when a transformer steps up the voltage.
Reason : In an ideal transformer VI = constant.
Hint: Transformer cannot produce power, but it transfer from primary to secondary.

CASE STUDY BASED QUESTIONS

1. A transformer is essentially an a.c. device. It cannot work on d.c. It changes alternating voltages or currents. It does not affect the frequency of a.c. It is based on the phenomenon of mutual induction. A transformer essentially consists of two coils of insulated copper wire having different number of turns and wound on the same soft iron core.
The number of turns in the primary and secondary coils of an ideal transformer are 2000 and 50 respectively. The primary coil is connected to a main supply of 120 V and secondary coil is connected to a bulb of resistance 0.6Ω.

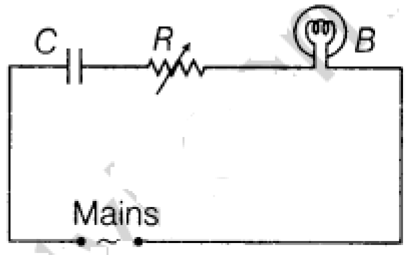
(i) The value of voltage across the secondary coil is
(a) 5V (b) 2V (c) 3 V (d) 10 V
(ii) The value of current in the bulb is
(a) 7 A (b) 15 A (c) 3 A (d) 5 A
(iii) The value of current in primary coil is
(a) 0.125 A (b) 2.52 A (c) 1.51 A (d) 3.52 A
(iv) Power in primary coil is
(a) 20W (b) 5W (c) 10 W (d) 15W
(v) Power in secondary coil is
(a) 15W (b) 20 W (c) 7W (d) 8 W

2. An LC circuit also called a resonant circuit, tank circuit or tuned circuit is an electric circuit consisting of an inductor represented by the letter L and a capacitor, represented by the letter C connected together. An LC circuit is an idealized model since it assumes there is no dissipation of energy due to resistance.
An LC circuit contains a 20 mH inductor and a **50μF** capacitor with an initial charge of 10 mC The resistance of the circuit is negligible. Let the instant the circuit is closed be t = 0.

(i) The total energy stored initially is
(a) 5 J (b) 3 J (c) 10 J (d) 1 J
(ii) The natural frequency of the circuit is
(a) 159.24 Hz (b) 200.12 Hz (c) 110.25 Hz (d) 95 Hz
(iii) At what time is the energy stored completely electrical?
(a) T,5T,9T (b) T/2,5T/2,9T/2 (c) 0, T, 2T, 3T (d) 0,T/2,T,3T/2
(iv) At what time is the energy stored completely magnetic?
(a) T/2,3T/2,T/4 (b) T/3,T/9,T/12 (c) 0, 2T, 3T (d) T/4,3T/4,5T/4
(v) The value of X_L is
(a) 20Ω (b) 40Ω (c) 60Ω (d) 50Ω

SHORT ANSWER TYPE 2 QUESTIONS:

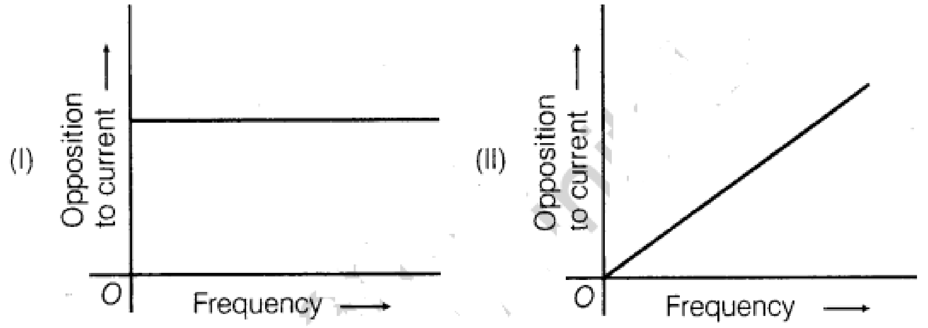
1 A capacitor C, a variable resistor R and a bulb B are connected in series to the AC mains in the circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor keeping resistance R to be the same (ii) the resistance R is increased keeping the same capacitance?



2. In a series L-C-R circuit, obtain the conditions under which
(i) the impedance of circuit is minimum and (ii) wattless current flows in the circuit.

3. (i) The graphs (I) and (II) represent the variation of the opposition offered by the circuit element to the flow of alternating current with frequency of the applied emf. Identify the circuit element corresponding to each graph.

(ii) Write the expression for the impedance offered by the series combination of the above two elements connected across the AC sources. Which will be ahead in phase in this circuit, voltage or current?



4. An AC source of voltage $V = V_m \sin wt$ is applied across a series L-C-R Draw the phasor diagram for this circuit when the
(a)capacitative impedance exceeds the inductive impedance.
(b) inductive impedance exceeds the capacitative impedance.

5. An AC source of voltage $V = V_m \sin \omega t$ is applied across a
(i)series R-C circuit in which the capacitative impedance is ‘a’ times the resistance in the circuit.
(ii)series R – L circuit in which the inductive impedance is ‘b’ times the resistance in the circuit.
Calculate the value of the power factor of the circuit in each case
6. A voltage $V = V_0 \sin wt$ is applied to a series L-C-R Derive the expression for the average power dissipated over a cycle.
Under what condition is (i) no power dissipated even though the current flows through the circuit (ii) maximum power dissipated in the circuit?
7. An AC voltage $V = V_0 \sin wt$ is applied across a pure inductor Obtain an expression for the current / in the circuit and hence obtain the
(a)inductive reactance of the circuit and
(b)the phase of the current flowing with respect to the applied voltage
8. An AC source of voltage, $V = V_m \sin \omega t$ is applied across a pure inductor of inductance L. Obtain an expression for the current I flowing in the circuit. Also draw the
(a)phasor diagram. (b) graphs of V and I versus ωt for this circuit.
9. It is required to construct a transformer which gives 12 V from a 240 V AC supply
The number of turns in the primary is 4800.
a) Calculate the number of turns in the secondary.
b) State weather, coil in the secondary has to be thick or thin. Justify your answer.
10. State the underlying principle of a transformer. How is the large scale transmission of electric energy over long distances done with the use of transformers?

LA1: 3 Marks Questions [NUMERICALS]

Q1 A 100 Ω resistor is connected to a 220 V, 50 Hz ac supply. (a) What is the rms value of current in the circuit? (b) What is the net power consumed over a full cycle?

2 A series LCR circuit with R = 20 Ω, L = 1.5 H and C = 35 μF is connected to a variable-frequency 200 V ac supply. When the frequency of the supply equals the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle?

3 An LCR circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be t = 0.

4 What is the total energy stored initially? Is it conserved during LCR oscillations?
(b) What is the natural frequency of the circuit?
(c) At what time is the energy stored (i) completely electrical (i.e., stored in the capacitor)? (ii) completely magnetic (i.e., stored in the inductor)?

5 A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.
Obtain the current amplitude and rms values. (b) Obtain the rms values of potential drops across each element. (c) What is the average power transferred to the inductor?

6. A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply. (a) What is the source frequency for which current amplitude is maximum? Obtain this maximum value (b) What is the source frequency for which average power absorbed by the circuit is maximum? Obtain the value of this maximum power. (c) For which frequencies of the source is the power transferred to the circuit half the power at resonant frequency? What is the current amplitude at these frequencies?

LA2: 5 Marks Questions

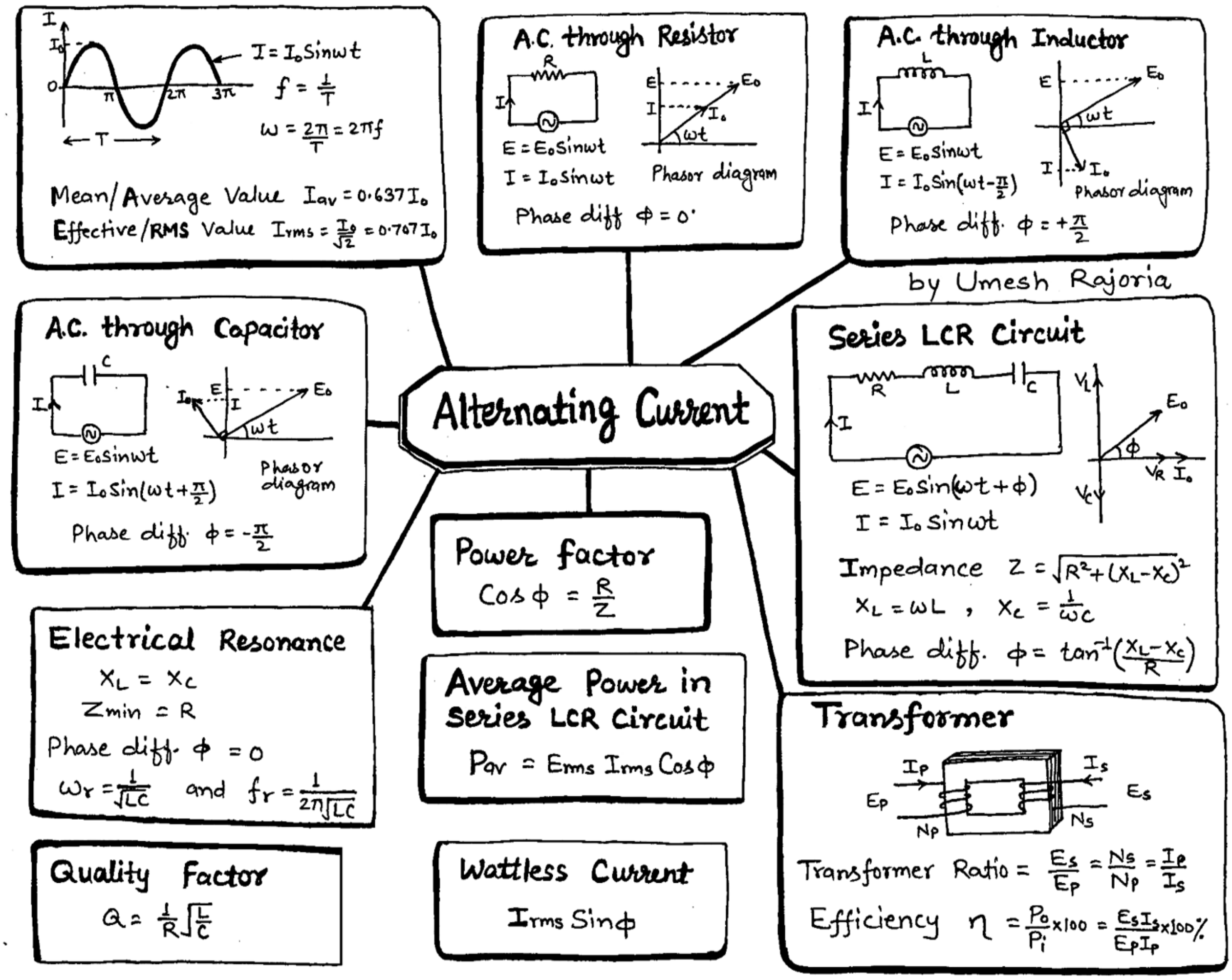
1. (i) A series L-C-R circuit is connected to an AC source of variable frequency. Draw a suitable phasor diagram to deduce the expressions for the amplitude of the current and phase angle.
(ii) Obtain the condition at resonance. Draw a plot showing the variation of current with the frequency of AC source for two resistances R_1 and R2 (R_1 > R2). Hence, define the quality factor Q and write its role in the tuning of the circuit.

Or

A series L-C-Rcircuit is connected to an AC source having voltage $V = V_m \sin wt$ Derive the expression for the instantaneous current I and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define power factor. State the conditions under which it is (a) maximum and (b)minimum.

2.(i) Draw a schematic arrangement for winding of primary and secondary coils in a transformer when the two coils are wound on top of each other.
(ii) State the underlying principle of a transformer and obtain the expression for the ratio of secondary to primary voltage in terms of the number of secondary and primary windings and primary & secondary currents.
(iii) Write the main assumption involved in deriving the above relations.
(iv) Write any two reasons due to which energy losses may occur in actual transformer

MIND MAP


Alternating Current
$I = I_0 \sin\omega t$
$f = \frac{1}{T}$
$\omega = \frac{2\pi}{T} = 2\pi f$
Mean/Average Value $I_{av} = 0.637 I_0$
Effective/RMS Value $I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707 I_0$
A.C. through Resistor
$E = E_0 \sin\omega t$
$I = I_0 \sin\omega t$
Phasor diagram
Phase diff $\phi = 0°$
A.C. through Inductor
$E = E_0 \sin\omega t$
$I = I_0 \sin(\omega t - \frac{\pi}{2})$
Phasor diagram
Phase diff. $\phi = +\frac{\pi}{2}$
by Umesh Rajoria
A.C. through Capacitor
$E = E_0 \sin\omega t$
$I = I_0 \sin(\omega t + \frac{\pi}{2})$
Phasor diagram
Phase diff. $\phi = -\frac{\pi}{2}$
Series LCR Circuit
$E = E_0 \sin(\omega t + \phi)$
$I = I_0 \sin\omega t$
Impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$
$X_L = \omega L$, $X_C = \frac{1}{\omega C}$
Phase diff. $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$
Power factor
$\cos\phi = \frac{R}{Z}$
Electrical Resonance
$X_L = X_C$
$Z_{min} = R$
Phase diff. $\phi = 0$
$\omega_r = \frac{1}{\sqrt{LC}}$ and $f_r = \frac{1}{2\pi\sqrt{LC}}$
Average Power in Series LCR Circuit
$P_{av} = E_{rms} I_{rms} \cos\phi$
Transformer
Transformer Ratio $= \frac{E_s}{E_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$
Efficiency $\eta = \frac{P_o}{P_i} \times 100 = \frac{E_s I_s}{E_p I_p} \times 100\%$
Quality Factor
$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$
Wattless Current
$I_{rms} \sin\phi$

CHAPTER-8
ELECTROMAGNETIC WAVES

DIFFERENT TYPES OF ELECTROMAGNETIC WAVES

SN	Part of the EM spectrum	Wavelength range	Production	Uses
1	Radio	>0.1	Rapid acceleration and decelerations of electrons in aerials	In radio and television communication, in radio astronomy
2	Microwaves	0.1 to1mm	Klystron valve or magnetron valve	Aircraft navigation, in microwave ovens
3	Infra-red	1 mm to 700 nm	Vibration of atoms and molecules	Heating effect
4	Light	700 nm to 40 nm	Electrons in atoms emit light when they move from one energy level to a lower energy level	Information of the world around us
5	Ultraviolet	400 nm to 1 nm	Inner shell electrons in atoms moving from one energy level to a lower level	In food preservation, in study of invisible writings, forged documents and finger prints, in study of molecular structure, kill germs in water purifiers
6	X-rays	1 nm to 10^{-3} nm	X-ray tubes or inner shell electrons	In radiotherapy, for detecting faults, cracks, flaws and hole in finished metal products
7	Gamma rays	<10^{-3} nm	Radioactive decay of the nucleus	Manufacture of polyethylene from ethylene, to preserve food stuff, to study of atomic nuclei

SUMMARY

1 Displacement current: The current arising due to the changing electric field is called displacement current (I_d) then $I_d = \varepsilon_\circ\ d\phi_{e/dt} = \varepsilon_\circ A \frac{dE}{dt}$.

2 Ampere's Maxwell circuit law is given as $\oint B\, dl = \mu_\circ I_c + \mu_\circ \varepsilon_\circ\ d\phi_{e/dt}$ where B is magnetic field, dl is small element of length l and I_c is conducting current and ϕ_E is electric flux.
Accelerated charged particles produce electromagnetic wave.
In free space, the velocity electromagnetic wave is $3x10^8$m/s.

3 Electromagnetic wave require no material medium for their propagation.
The energy in an electromagnetic waves is dividing equally between the electric and magnetic fields.

4 Transverse Nature of EM waves : Electromagnetic waves are the result of the superposition of mutually perpendicular time varying electric and magnetic fields. Time varying electric and magnetic fields are also perpendicular to the direction of the propagation of e.m. wave.

5 Electromagnetic waves are transverse in nature.

6 Electromagnetic spectrum: The whole range of frequency or wavelength of the e.m.waves is known as electromagnetic spectrum

7 Electromagnetic waves in the order of increasing frequency are: Radio waves, micro waves, infrared rays , visible light, ultra-violet waves , x-rays and gamma rays.

8 Electromagnetic waves in the increasing order of wavelength are : gamma rays, x-rays, ultraviolet waves , visible light , infra-red rays, microwaves and radio waves.

9 Visible light radiations are produced by filament lamps LED' s : hot objects etc. and are used in photography.

10 Infrared waves are produced by hot objects and are useful in producing green house effect. They are also useful in cooking, in remote switches and muscle relaxation.

MULTIPLE CHOICE OF QUESTIONS

1. Electromagnetic waves are transverse wave in nature is evident by
a. polarisation b. interference c. reflection d. diffraction

2. Which radiations are used in treatment of muscle ache?
a. infrared b. ultraviolet c. microwave d. X-rays

3.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. B c. B X E d. E X B

4. In electromagnetic waves the phase difference between electric and magnetic field vectors are
a. Zero b. $\pi/4$ c. $\pi/2$ d. π

5. The structure of solids is investigated by using
a. cosmic rays b. X-rays c. γ-rays d. infrared rays

6. From Maxwell's hypothesis, a charging electric field gives rise to
a. an electric field b. an induced emf c. a magnetic field d. a magnetic dipole.

7. The electromagnetic radiation used for water purification and eye surgery is
a. infrared b. microwave c. X-rays d. ultraviolet wave

8. Electromagnetic wave having frequency $6x10^{11}$Hz is
a. ultraviolet wave b. radio wave c. microwave d. X- rays

9. Which of the following is called heat radiation?
a X-rays b. γ-rays c. infrared radiation d. microwave

10. Which of the following has maximum penetrating power?
a. γ-rays b. ultraviolet radiation c. microwaves d radio waves

ANSWER: 1. - a 2. –b 3. – d 4. – a 5. –b 6. - c 7. D 8. c 9.C 10.a

Assertion (A) and 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 true.

Q1. Assertion (A) :Accelerated charged particle produces electromagnetic waves.
Reason(R): Electromagnetic waves are charged one.

Q2. Assertion (A):visible light are transverse in nature.
Reason(R):All electromagnetic waves are transverse in nature .

Q3. Assertion (A) : Force exerted by electromagnetic wave on a perfect reflector is more than a Perfect absorber.
Reason (R) The rate of change in momentum of electromagnetic wave is more in case of a perfect reflector than a perfect absorber .

Q4. Assertion(A): Radio waves can be polarized .
Reason: Sound waves in air are longitudinal in nature.

Q5. Assertion(A) :Microwaves are considered suitable for radar system.
Reason(R):Microwaves are of shorter wavelength.

Hints: 1 C, Explanation: Electromagnetic waves are the result of superposition of mutually perpendicular electric and magnetic field vectors.

2 a, Explanation: Visible light is electromagnetic wave.

3 a, Explanation: In case of a perfect reflector , change in momentum= p-(-p) = 2p and in case of a perfect absorber, no wave is reflected, so change in momentum = p-0= p.

4 b, Explanation: Radio waves are transverse in nature and hence can be polarized.

5 a, Explanation: due to shorter wavelength of microwaves (10^{-3} to 0.1m), it can be bounced from any small object. So it is suitable for radar system.

Case Based MCQS (01)

Read the below case and answer the questions that follow:

Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These wave have frequency and energy smaller than visible light and wavelength larger than it. When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45GHz. If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating the water. These molecules share this energy with neighbouring food molecules, heating the food. One should use porcelain vessels and nonmetal containers in a microwave oven because of danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, basic principle of a microwave oven is to generate microwave radiationof appropriate frequency in the working space of oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

Q1. The frequency of rotation of water molecules is about:
a 2.45MHz   b. 2.45KHz   c. 2.45GHz   d. 2.45THz

Q2. As compared to visible light microwave has frequency and energy:

More than visible light b. less than visible light
c. Equal to visible light d. frequency is less but energy is more

Q3. In the microwave oven,

a. Energy is directly delivered to water molecules which is shared by the entire food
b. The vessel gets heated first, and then the food grains inside
c. The vessel gets heated first and then the water molecules collect heat from the body of the vessel.
d. Energy is directly delivered to the food grains.

Q4. When temperature of a body rises:

a.The energy of random motion of atoms and molecules increases.
b.The energy of random motion of atoms and molecules decrease.
c.The energy of random motion of atoms and molecules remains same.
d. The random motion of atoms and molecules becomes streamlined.

Answer: (CB01) Q1. c Q2. b Q3. a Q4.a.

Case Based MCQS (02)

Read the below case and answer the questions that follow:LASER: Electromagnetic radiation is a natural phenomenon found in almost all area of daily life, from radio waves to sunlight to x-rays. Laser radiation – like aii light –is also a form of electromagnetic radiation. The wave length range between 380nm to 700nm is visible to human eye. Wavelength longer than780nm, optical radiation is termed infrared(IR) and is invisible to the eye. Wavelength shorter than 380nm, optical radiation is termed ultraviolet(UV) and is also invisible to eye. The term ˛laser light˒ refer to much broader range of the electromagnetic spectrum that just the visible spectrum, anything between 150nm up to 11000nm9ie. From the UV up to the far IR). The term laser is an acronym which stands for light amplification by stimulated emission of radiation. Einstein explained the stimulated emission. In an atom, electron may move to higher energy level by absorbing a photon. When the electron comes back to the lower energy level it releases the same photon. This is called spontaneous emission. This may also so happen that the excited electron absorbs another photon, releases two photons and returns to the lower energy state. This is known as stimulated emission. Laser emission is therefore a light emission whose energy is used, in lithotripsy, for targeting and ablating the stone inside human body organ. Apart from medical usage, laser is used for optical disk drive, printer, barcode reader etc.

Q1. What is full form of LASER?

a) Light amplified by stimulated emission of radiation
b) Light amplification by stimulated emission of radiation
c) Light amplification by simultaneous emission of radiation
d) Light amplified by synchronous emission of radiation

Q2. What is range of amplitude of LASER?

a) 150nm - 400nm b) 700nm- 11000nm c) Both the above d) 600nm- 700nm

Q3.LASER is used in:

a) Optical disk drive b) Transmitting satellite signal c) Radio communication d) Ionization

Q4. Lithotripsy is :

a) An industrial application b) A medical application
c) Laboratory application d) Process control application

Answer(CB02): 1. b 2. b 3.a 4.b

Short Answer Type Questions (2marks)

Q1. What does an electromagnetic wave consist of? On what factors does its velocity in vacuum depend?

Solution: e.m.wave consist of varying electric and magnetic fields which are mutually perpendicular to each other. Velocity of e,m.wave in vacuum is given by $c = 1/\sqrt{\mu_\circ \varepsilon_\circ}$ So its velocity depends on the permittivity and permeability of free space.

Q2. Find wavelength of electromagnetic wave of frequency 5×10^{19}Hz in free space. Give its two applications.

Solution: $\lambda = c/\nu = 6\times10^{-12}$m ,these are Gamma rays

These are used to get information regarding atomic structure and for detection purposes due to its properties of high penetrating power.

Q3.Name the main parts of electromagnetic spectrum in ascending order of their wavelength.

Solution: γ-rays, x-rays, UV, visible light, IR, microwaves, radio waves.

Q4.How are amplitudes of electric and magnetic fields related in e.m. waves? Name the electromagnetic radiation used for viewing object through haze or fog. What is their wavelength range?

Solution: i) $E_\circ = c\,B_\circ$ ii)Infrared rays iii) wavelength range of infrared rays is 1nm to 700nm

Q5. Give two characteristic of electromagnetic waves. Write the expression for the velocity of electromagnetic waves in terms permittivity and permeability of free space..

Solution: i) They are transverse in nature. ii)They do not require any material medium for their propagation. Velocity of e.m. wave is given by $c = 1/\sqrt{\mu_\circ \varepsilon_\circ} = 3\times10^{8}$m/s

Q6. I) How are infrared waves produced? Write their one important use.

ii) The thin ozone layer on top of the stratosphere is crucial for human survival.Why?

Solution: i) Infrared waves are produced by hot bodies and molecules.

Important use: (a) to treat muscular strains. (b) to reveal the secret writing on the ancient walls. (c) for producing dehydrated fruits (d) Solar heater (any one)

ii) Ozone layer protects us from harmful UVrays.

Q7. Explain briefly how electromagnetic waves are produced by an oscillating charge. How is the frequency of e.m. waves produced related to that of the oscillating charge?

Solution: An oscillating or accelerated charge is supposed to be source of an electromagnetic wave. An oscillating charge produces an oscillating electric field in space which further produces an oscillating magnetic field which in turn is a source of electric field. These oscillating electric and magnetic field, hence, keep on regenerating each other and an electromagnetic wave is produced.

The frequency of em wave = Frequency of oscillating charge.

Q8. Name the part of electromagnetic spectrum whose wavelength lies in the range 10^{-10}m. Give its one use.

Solution: The electromagnetic waves having wavelength 10^{-10}m are x-rays.

X-rays are used to study crystal structure.

Q9. Identify the electromagnetic waves whose wavelength vary as:

$10^{-12}\text{m} < \lambda < 10^{-8}\text{m}$ b) $10^{-3} < \lambda < 10^{-1}$. write one use for each.

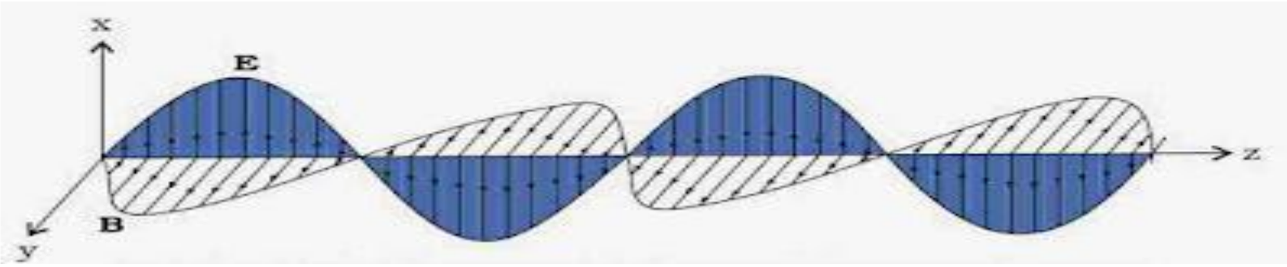
Solution : (a)x-rays : used as a diagnostic tool in medicine and as a treatment for certain forms of cancer. (b) Microwaves : used in radar systems for aircraft navigation.

Q10. a). How does oscillating charge produce electromagnetic waves?

b)Sketch a schematic diagram depicting oscillating electric and magnetic field of an em wave propagating along + z-direction.

Solution: a) An oscillating charge produces an oscillating electric field in space, which produces an oscillating magnetic field. The oscillating electric and magnetic fields regenerate each other, and this results in the production of em waves in space.

Electric field is along x-axis and magnetic field is along y-axis.



Long Answer type Questions (3marks)

Q1.(a) How are electromagnetic waves produced? What is the source of energy of these waves? Write mathematical expression for electric and magnetic fields of an electromagnetic wave propagating along the z-axis. Write any two important properties of electromagnetic waves.

Solution: EM waves are produced by oscillating charged particle.
Mathematical expression for electromagnetic waves travelling along z-axis.

$E_x = E_0\sin(kz - \omega t)$ for electric field

$B_y = B_0\sin(kz - \omega t)$ for magnetic field

Properties : (i) Electromagnetic waves have oscillating electric and magnetic fields along mutually perpendicular directions. (ii) They have transverse nature.

Q2. Arrange the following electromagnetic waves in order of their increasing wavelength: γ- rays b. microwaves c. x-rays d. Radio waves
How are infrared waves produced? What role does infrared radiation play in (i) maintaining the earth's warmth and (ii) physical therapy?

Solution: γ-rays < x-rays< microwaves < Radio waves.
Infrared rays are produced by the vibration of atoms and molecules.
Maintaining the earth's warmth : Infrared rays are absorbed by the earth's surface and reradiated as longer wave length infrared rays. These radiations are trapped by green house gases such as co_2 and maintain earth's warmth.
Physical Therapy: Infrared rays are easily absorbed by water molecules present in body. After absorption, their thermal motion increases causing heating which is used as physical therapy.

Q3. Give reason for following: Long distance radio broadcasts use short wave bands.
The small ozone layer on top of the stratosphere is crucial for human survival.
Satellites are used for a long distance TV transmission.

Solution: (i) As radio waves from short wave bands get reflected from an ionosphere, we use them for a long distance communication.
.(ii) It absorbs a large portion of ultraviolet radiations harmful for living organisms on the earth, emitted by the sun.
(iii)Television signals of the frequency range from 100 MHz to 200 MHz neither follow the curvature of the earth nor get reflected by ionosphere. Therefore, satellites are used for a long distance TV transmission.

Q4. Name the radiation of electromagnetic spectrum Which are used in:
(i)warfare to look through fog.
(ii)radar and geostationary satellites.
(iii)study the structure and properties of atoms and molecules.

Solution: i) infrared waves. ii) Microwaves iii) X-rays

Q5. Identify the following electromagnetic radiations as per the frequencies given below. Write one application of each. (a) 10^{20} Hz (b) 10^{9} Hz (c) 10^{11}Hz

Solutions: (a) x-rays. These are used as a diagnostic tool in medicine.
(b) Radio waves: These are used in radio and television communication
System.
(c)Microwaves . These are used in microwave ovens.

Long Answer type Questions (5Marks)

Q1. **Answer the following questions:**

(i) Name the em-waves which are produced during radioactive decay of a nucleus. Write their frequency range. (ii) Welders wear special glass goggles while working. Why? Explain.
(iii) Why are infrared waves often called as heat waves? Give their one application.
(iv) Optical and radiotelescopes are built on the ground but X-rays astronomy is possible only from a satellite orbiting the earth, why?
(v) What do you understand by the statement "Electromagnetic waves transport momentum"?
Solution: a). em-waves :γ-rays , Range : 10^{19} to 10^{23} Hz.
b). This is because the special glass goggles protect the eyes from large amount of UV radiations produced by welding arcs.
c). Infrared waves are called heat waves because water molecules present in materials readily absorb the infrared rays and get heated up.
d) The visible radiations and radio waves can penetrate the earth' atmosphere but x-rays are absorbed by the atmosphere.
e) Electromagnetic waves can set and sustain electric charges in motion by their electric and magnetic fields. The charges thus acquire energy and momentum from the waves. Since it carries momentum, an electro magnetic wave also exerts pressure, called radiation pressure. Hence they are said to transport momentum.

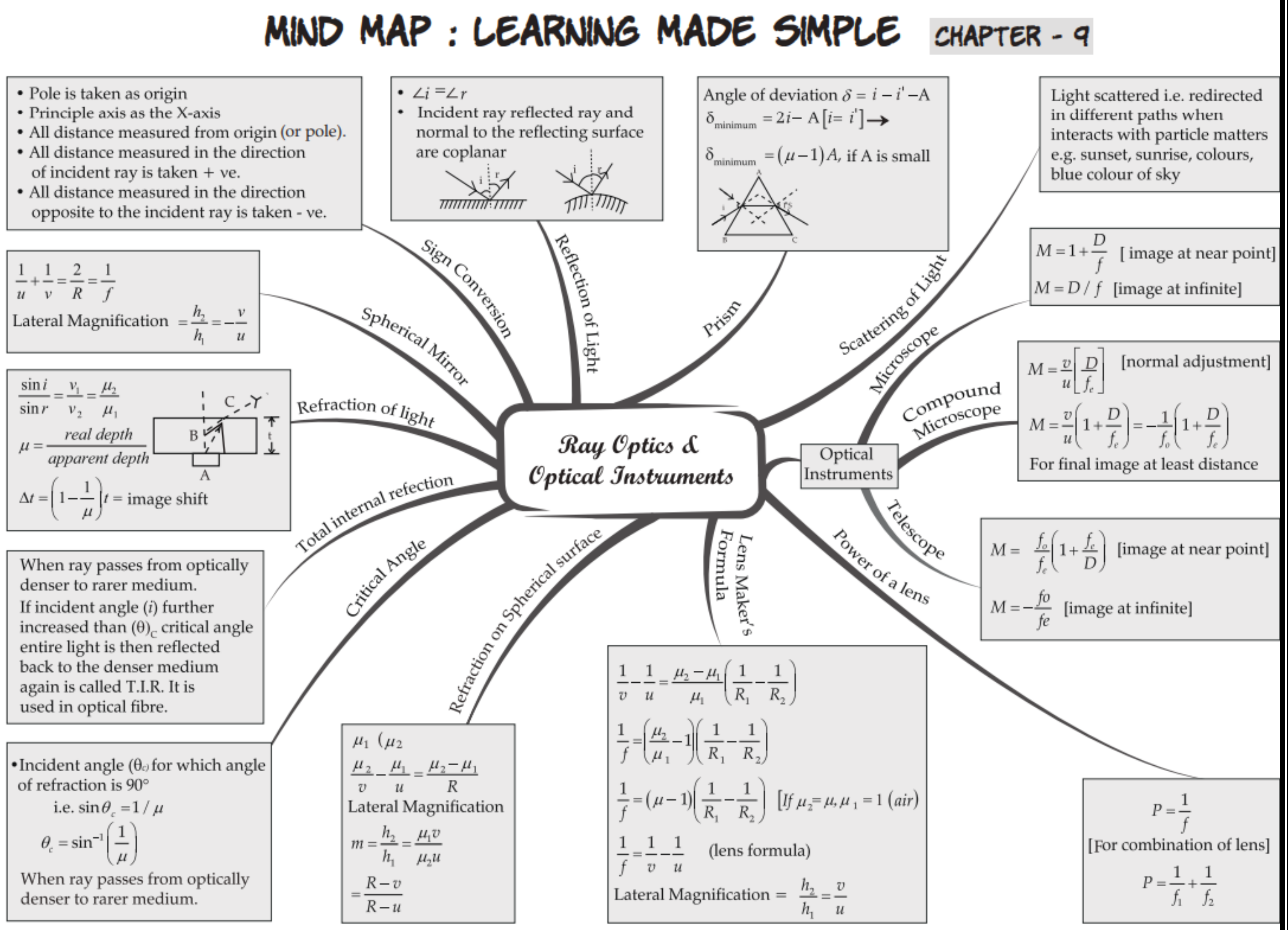
Q2. **(i)** Identify the part of the electromagnetic spectrum Which is:
absorbed from sunlight by ozone layers? produced by bombarding a metal target by high speed electrons (ii)Why does a galvanometer show a momentary deflection at the time of charging or discharging a capacitor? Write the necessary expression to explain this observation.
(iii)The charging current for a capacitor is o.25A. What is displacement current across its plates?
(iv)Name the physical quantity which remains same for microwaves of wavelength 1mm and UV **Solution:** (i) (a) Ultraviolet light (b) x-rays
(ii)Due to conduction current in the connecting wires and the production of displacement current between the plates of capacitor on account of changing electric field. Current inside the capacitor is given by
$I_d = \varepsilon_\circ \, d\phi_e / dt$ (iii)The displacement current is equal to the charging current. So, displacement current is also 0.25A. (iv)Velocity ($c = 3\times10^8$m/s) , This is because both are electromagnetic waves.

NUMERICAL (3marks)

Q1. The amplitude of oscillating magnetic field in an electromagnetic wave is 2×10^{-6}T. What will be the amplitude of the oscillating electric field?
Solution: $E_\circ = c\,B_\circ$ $E_\circ = 3\times10^8 \times 2 \times 10^{-6} = 600$V/m
Q2. A plane electromagnetic wave of frequency 25 MHz travels in free space along x-direction. At a particular point in space and time. E=6.3 V/m. What is B at that point?
Solution: B= E/C then, B 6.3/ (3×10^8) = 2.1×10^{-8}T since wave is travelling along x-direction and E is along y direction. So B must be along z-direction.
Q3. The frequency band of a radio station is 7.5MHz to 12MHz. What is the corresponding wavelength band?
Solution: When ν= 6MHz, Then, λ= c/ν = $(3\times10^8)/(7.5\times10^6)$ = 40m. When ν = 8 MHz, then, , λ= c/ν = $(3\times10^8)/(12\times10^6)$ = 25m Wavelength band is from 25m to 40m
Q4.Laser emits a beam of light of 2mmdiameter. If the power of beam is 10mW, find the intensity of the beam of light.
Solution: d=2mm= 2×10^{-3}m A = πr^2 =3.1×10^{-6} m^2 P = 10mW 10×10^{-3}W =10^{-2}W
Intensity , I = $\frac{p}{A}$ = 10^{-2}w/($3.142 \times 10^{-6}m^2$) = $3.183\times10^3$$Wm^{-2}$

Chapter-9
Ray optics and optical Instrument

Mind Map



Part 1 : Reflection , Refraction of light through lenses and prism

GIST OF THE LESSON

Light is an electromagnetic radiation

Speed of light in vacuum is highest speed attainable in nature ie . 3×10^8 m/s

Wavelength of light is very small compared to the size of the lenses and mirror , thus light wave is considered to travel from one point to another along straight line while observing phenomenon of refraction and reflection and dispersion of light

Reflection :

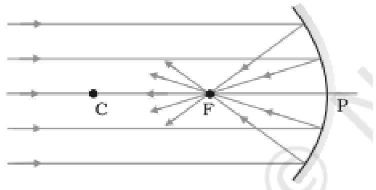
Laws of reflection

1st law- The angle of incidence (i) is equal to the angle of reflection (r)

2nd law- The incident ray, the reflected ray and the normal, at the point of incidence, all lie in the same plane.

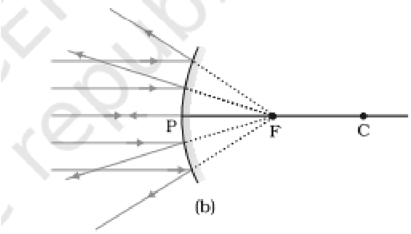
Reflection By spherical mirrors

<table>
<tr>
<td>



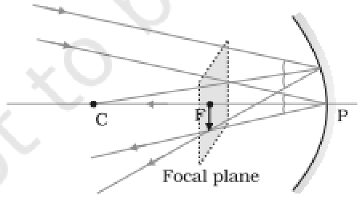
(a)

Focus Point of concave mirror



(b)

Focus point of concave mirror



(c)

Focal Plane

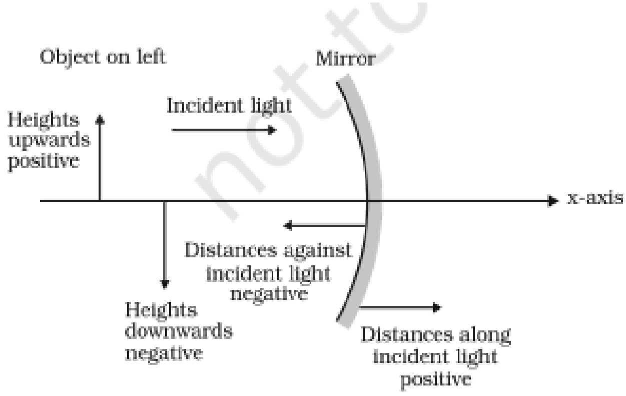
</td>
<td>

Focus Point : Point on principal axis where parallel Paraxial rays after reflection converge on a point(for concave mirror) or diverge from a point (for convex mirror).

Paraxial Rays: Rays incident close to Pole, making small angle with principal axis Focal length: Distance between Pole and Focus Point

Focal Plane : plane through F normal to the principal axis where parallel paraxial beam of light after reflection would converge (or appear to diverge)when incident, making some angle with the principal axis

Cartesian Sign Convention



</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>

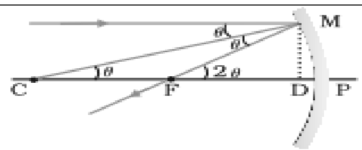
Relationship Between Focal Length and Radius of Curvature

f=R/2

where f = focal length

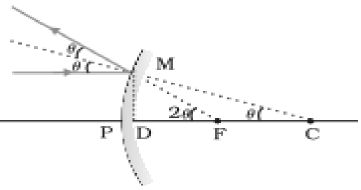
R= Radius of curvature of mirror

</td>
<td>



(a)

Ray diagram for concave mirror



(b)

Ray diagram for convex mirror

</td>
</tr>
<tr>
<td>

Mirror equation :

1/f=1/v+1/u

Where f = focal length, v= image distance from pole, u= object distance from pole

Magnification formula :

$m = \frac{h'}{h} = -\frac{v}{u}$

Where m = magnification of image

h' = height of image, h= height of object

</td>
<td>

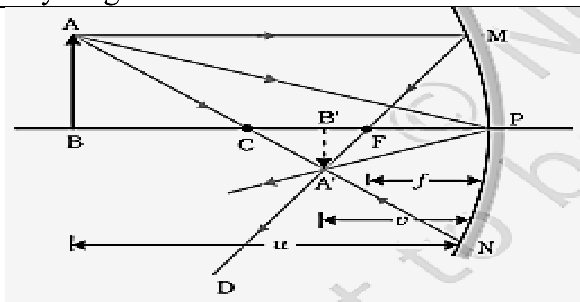
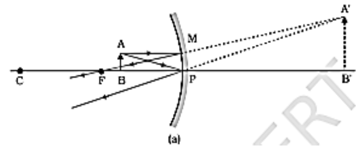


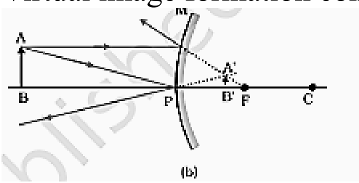
FIGURE 9.5 Ray diagram for image formation by a concave mirror.

</td>
</tr>
</table>

Real image: When two rays of light after reflection actual meet at point
Virtual Image : When two rays of light after reflection appear to meet at point



Virtual image formation concave mirror



Virtual image formation by convex mirror

- **Refraction**: The direction of propagation of an obliquely incident ray of light that enters the other medium, changes at the interface of the two media.This phenomenon is called refraction of light.

Laws of reflection

1.The incident ray, the refracted ray, the normal to the interface at the point of incidence, all lie in the same plane.

2. Snell's Law- The ratio of the sine of angle of incidence(i) to the sine of angle of refraction(r) is constant for a given color of light and a given pair of media.

Sin (i)/sin(r) =n_{21}

Where n_{21} = refractive index of the second medium with respect to the first medium

$n_{21}=n_2/n_1 =v_1/v_2 =1/n_{12}$

Where n_2 = Medium of refracted light

n_1= medium of incident light

where v_1= speed of light in medium 1

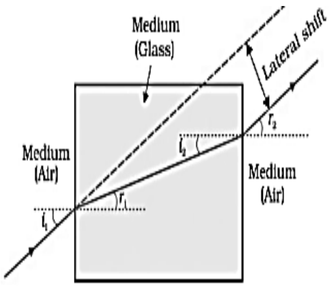
v_2= speed of light in medium 2

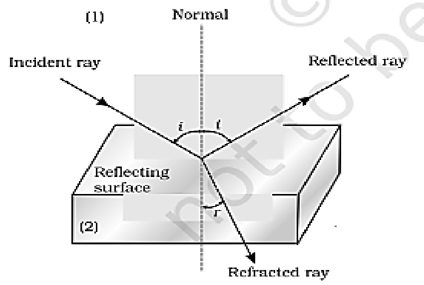
<u>Refraction through glass slab</u>

<u>1.</u> The emergent ray is parallel to the incident ray

<u>2.</u> The emergent ray is laterally shifted/displaced w.r.t. the incident ray

ie $i_1=r_2$

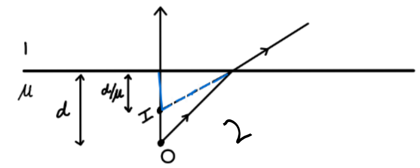




Refraction and reflection of incident light at boundary of two medium

Note:

- The refractive index of a medium depends on **the wavelength of light** in the medium but is independent of theangle of incidence. μ decreases with increase in wavelength i.e. $n_{red} < n_{violet}$
- If $n_{21}>1$, light travels slower in medium 2 and the refracted ray bends towards the normal. Such a medium iscalled an optically denser medium than medium 1.
- If $n_{21}<1$, light travels faster in medium 2 and the refracted ray bends away from the normal. Such a medium iscalled an optically rarer medium than medium 1.
- On refraction frequency of light wave does not change

Apparent Depth : When an object in a denser medium is viewed from a rarer medium, it appear to shifted up **apparent depth= real depth/n21**	

****(VVIMP) Total internal reflection: When a ray of light travels from an optically denser medium to an optically rarer medium, if angle of incidence (i) is greater than the critical angle, then the ray of light is completely reflected back into the same medium. This is called Total Internal Reflection (TIR).**

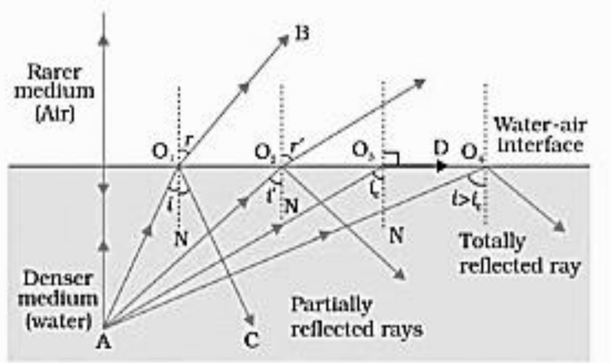
Essential condition

i) light must travels from an optically denser medium to an optically rarer medium
ii) angle of incidence (i) must be greater than the critical angle.

Critical angle (θc/ic) - It is the angle of incidence at which angle of refraction is 90°

Relation between critical and refractive index of medium

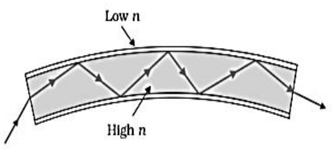
$$n_{12} = \frac{1}{\sin\theta_C}$$



Refraction and internal reflection at different incident angle.

Application of total internal reflection

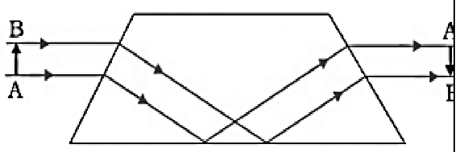
1. Optical fibre .: used for transmitting audio and video signals through long distances.



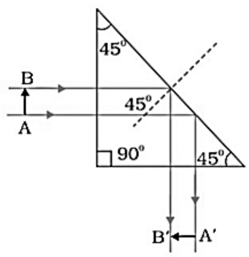
2. Brilliance of diamond is due to total internal reflection . reflection. The critical angle for the diamond air interface is very small and light is likely to undergo TIR when it enters a diamond.

3 . **Prism :** Prism- Prisms are used to bend light by 90° or 180° by making use of TIR. Such a prism is also used to invert images without changing their size.

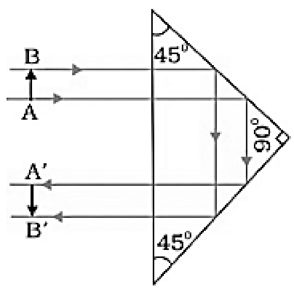
Ray diagram 1.



To invert image without deflection



2



3

Refraction through spherical surface

Relations to find position of image:

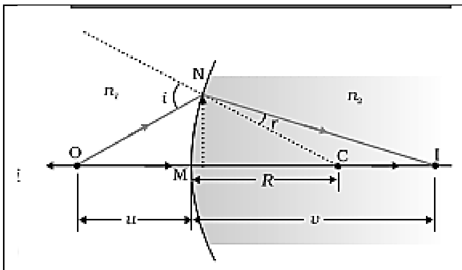


FIGURE 9.15 Refraction at a spherical surface separating two media.

When light enters from rare medium to denser medium

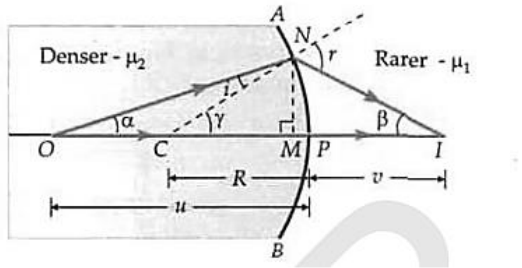
n2/v - n1/u = n2-n1/R

where n2 = refractive index of denser medium

n1 = refractive index of rarer medium

R = Radius of curvature of spherical surface

u = object distance , v= image distance



When light enters from denser medium to rarer medium

n1/v – n2/u = n1-n2/R

Note: These formulas are applicable for any curved spherical surface

Assumption : Rays are paraxial

Refraction of light through lens

Lens maker Formula (Relationship between focal length and radius of curvature)

$$\frac{1}{f}=\left(\frac{n_2}{n_1}-1\right)\times\left(\frac{1}{R_1}\ \ \frac{-1}{R_2}\right)$$

Where

R1, R2 is radius of curvature of two spherical surfaces

u , v distance of object and image from lens

f = focal length of lens

Thin Lens formula

1/f =1/v-1/u

Magnification produced by a lens (m)

$$m=\frac{h'}{h}=\frac{v}{u}$$

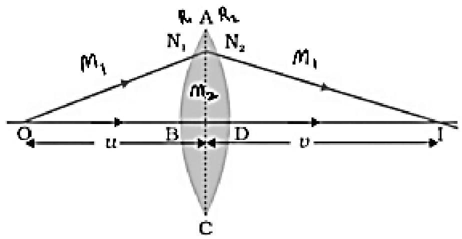
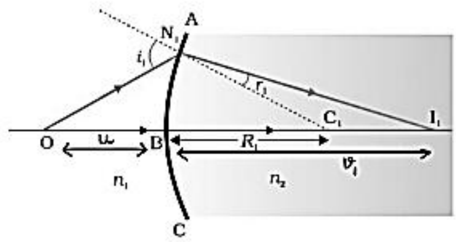
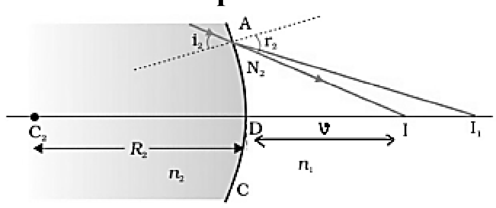


Image formation by lens



$n_2/v_1 - n_1/u = n_2-n_1/R_1$

Refraction at first spherical surface

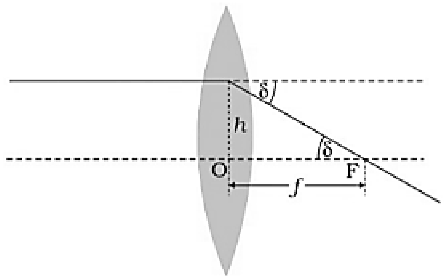


Refraction at 2nd spherical surface

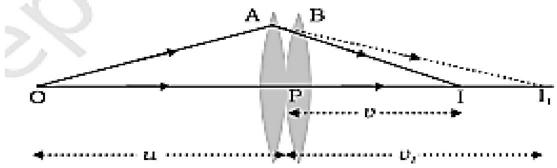
$n_1/v - n_2/v_1 = n_1\text{-}n_2/R_2$

Power of lens : Power of a lens is a measure of the convergence or divergence which a lens introduces in the light falling on it. It can
be defined as the tangent of the angle by which it converges or diverges a beam of light falling at unit distance from
the optical center. SI unit- m-1/ D (diopter)

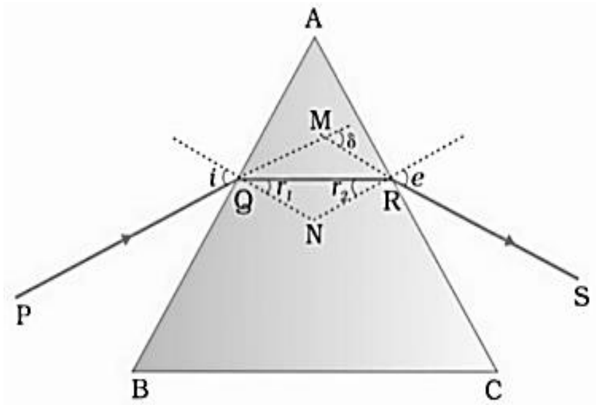
P= 1/f
Where f is focal length in meter



Combination of thin lens :
$1/f = 1/f_1+1/f_2$
f= focal length of combined lens
f_1 = focal length of lens 1
f_2 = focal length of lens 2
Magnification :
$m = m_1 * m_2$



Refraction Through a Prism A = Angle of prism ie angle between the incident and the emergent face.
δ = angle of deviation ie angle between the incident ray produced forward and the emergent ray produced backwards.
e = angle of emergence i= angle of incidence
Relation ships
r1+r2 =A
δ = i+e - A



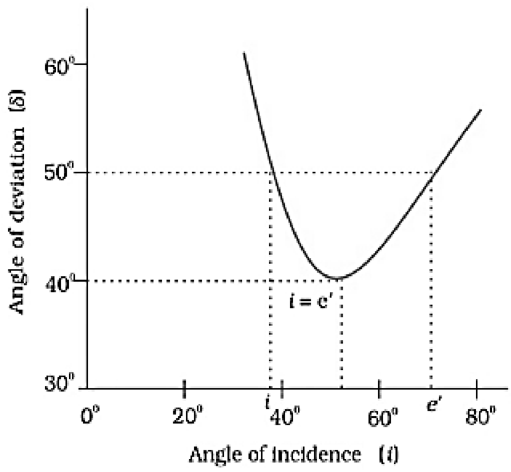
Conditions for Minimum deviation

- At minimum deviation, the refracted ray becomes parallel to the base
- i = e
- $r_1=r_2$
- r = A/2
- $\boldsymbol{\delta_m=2i-A}$

By calculation of $\boldsymbol{\delta_m}$ we can find refractive index of prism by :

$$\mu_{21} = \frac{\mu_2}{\mu_1} = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin(A/2)}$$

Where μ_{21} is refractive index of prism wrt surrounding



Variation of δ with i

For small angled (ie A is small) prism we can use $\delta_m = (\mu_{21} - 1)$ A.	

Practice Questions

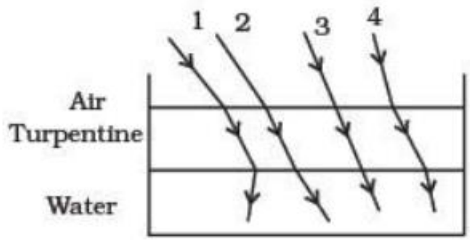
MCQ

1. How does the focal length of a convex lens changes if mono chromatic red light is used instead of violet light?

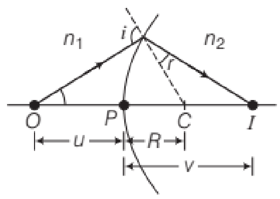
(a) Focal length is increased when red light is used (b) Focal length is decreased when red light is used (c) Focal length is remain same when red light is used (d) Not depends on color of light.

2. **The optical density of turpentine is higher than that of water while its mass density is lower shows a layer of turpentine floating over water in a container. For which one of the four rays incident on turpentine in the path shown is correct?**

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



3. For the refraction shown below the correct relation is,

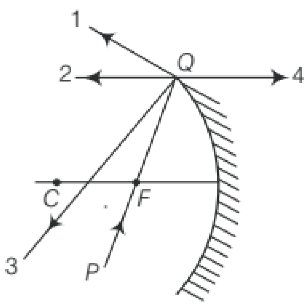


(a) $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ (b) $\frac{n_1}{v} - \frac{n_2}{u} = \frac{n_2 - n_1}{R}$

(c) $\frac{n_1}{v} - \frac{n_2}{u} = \frac{n_1 - n_2}{R}$ (d) $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_1 - n_2}{R}$

4. Two lenses are in contact having powers of 5D and - 3 D. The focal length of this combination will be (a) 50 cm (b) 75 cm (c) 25 cm (d) + 20 cm a

5. The direction of ray of light incident on a concave mirror is shown by PQ while directions in which the ray would travel after reflection is shown by four rays marked 1, 2, 3 and 4 (figure). Which of the four rays correctly shows the direction of reflected ray?



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

Answers

1(a) 2 (b) 3(a) 4(a) 5 (b)

Assertion reason Questions

a)If both Assertion and Reason are true and Reason is correct explanation of Assertion. b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion. c) If Assertion is true but Reason is false. d) If both Assertion and Reason are false

1. Assertion (A) : Propagation of light through an optical fibre is due to total internal reflection taking place at the core-cladding interface.

Reason (R): Refractive index of the material of the cladding of the optical fibre is greater than that of the core**.**

2. Assertion A convex mirror always make a virtual image.

Reason The rays always diverge after reflection from the convex mirror.

Answer **1(c)** **2(a)**

Short Answer Question 2 Marks

1. A ray of monochromatic light passes through an equilateral glass prism in such a way that the angle of incidence is equal to the angle of emergence and each of these angles is 3/4 times the angle of the prism. Determine the angle of deviation and the refractive index of the glass prism

Ans Here angle of prism A = 60°, angle of incidence i = angle of emergence e and under this condition angle of deviation is minimum

$i = e = 3/4\ A = 3/4 \times 60° = 45°$ and $i + e = A + D_m$,

hence $D_m = 2i - A = 2 \times 45° - 60° = 30°$

∴ Refractive index of glass prism

$$n = \frac{\sin\left(\frac{A+D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60°+30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)} = \frac{\sin 45°}{\sin 30°} = \frac{1/\sqrt{2}}{1/2} = \sqrt{2}.$$

2. Use the mirror equation to show that an object placed between f and 2f of a concave mirror forms an image beyond 2f.

Ans . The mirror formula is given by

$1/v + 1/u = 1/f$ (f is – ve) If, $u = -f \Rightarrow 1/v = 0 \Rightarrow v = \infty$

If, $u = -2f \Rightarrow 1/v = -1/2f \Rightarrow v = -2f$

Hence, if $-2f < u < -f$ then, $-2f < v < \infty$

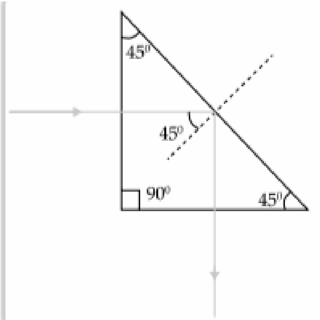
3. A biconvex lens made of a transparent material of refractive index 1.25 is immersed in water of refractive index 1.33. Will the lens behave as a converging or a diverging lens? Justify your answer.

Ans.

Formula $\frac{1}{f} = \left(\frac{\mu_m}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ **used** $\frac{\mu_m}{\mu_w} = \frac{1.25}{1.33}$ **where**

The value of (μ– 1) is negative. So, 'f ' will be negative. So, it will behave like diverging lens.

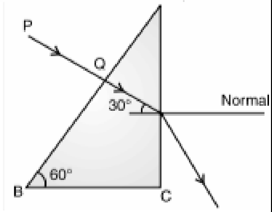
4. Under what conditions does the phenomenon of total internal reflection take place? Draw a ray diagram showing how a ray of light deviates by 90° after passing through a right-angled isosceles prism.



Ans Conditions: 1. Light travels from denser to rarer medium. 2. Angle of incidence in denser medium must be greater than the critical angle.

5. 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.

Ans . Face-AC ,here, $i_c = \sin^{-1}(2/3) = \sin^{-1}(0.6)$ < i on face AC is 30° which is less than < i_c. Hence the ray get retracted from face AC.

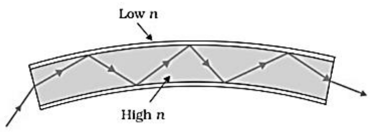


6**. Define refractive index of a transparent medium. If a ray of light propagates from a rarer to a denser medium, how does its frequency change?**

Ans Refractive index of a medium is defined as the ratio of velocity of light in vacuum to the velocity of light in that medium. On reflection frequency does not change

7. State with the help of a ray diagram, the working principle of optical fibres. Write one important use of optical fibre.

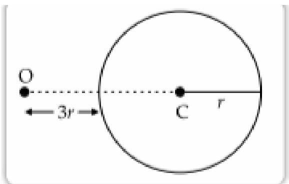
Ans Used in communication



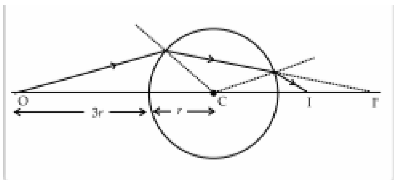
Short answer Question (3 marks)

Q1 (a) An object is placed in front of a converging lens. Obtain the conditions under which the magnification produced by the lens is (i) negative and (ii) positive.

(b) A point object is placed at O in front of a glass sphere as shown in figure.Show formation of image



Ans (a) (i) Magnification is negative for real image formed by convex lens. (ie when u> = to focal length) (ii) Magnification is positive for virtual image formed by convex lens. (ie when u < focal length of lens)



2. Draw a ray diagram for the formation of image of a point object by a thin double convex lens having radii of curvature R_1 and R_2. Hence derive lens maker's formula.

Assumptions used :
(i) lens used is very thin. (ii) Aperture of the lens is very small (iii) Object is a point object placed at the principal axis. (iv) All the rays are paraxial.
For the refraction at the interface ABC

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R_1} \quad \text{---------(1)}$$

For the refraction at ADC, image will act as an imaginary object and if the lens is very thin, then

$$\frac{\mu_1}{v} - \frac{\mu_2}{v'} = -\frac{(\mu_2 - \mu_1)}{R_2} \quad \text{---------(2)}$$

on adding (1) & (2) we get

$$\frac{\mu_1}{v} - \frac{\mu_1}{u} = (\mu_2 - \mu_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = \frac{(\mu_2 - \mu_1)}{\mu_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{v} - \frac{1}{u} = (\mu_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

But when $u = -\infty$ then $v = f$

$$\frac{1}{f} - \frac{1}{-\infty} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (n_{21} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

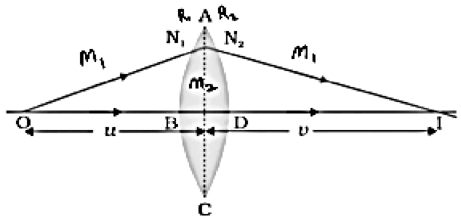
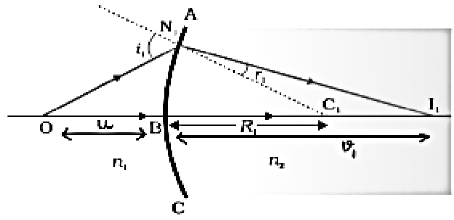
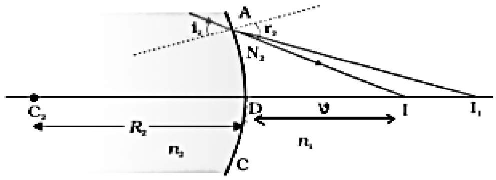


Image formation by lens



$n_2/v_1 - n_1/u = n_2 - n_1/R_1$

Refraction at first spherical surface



Refraction at 2nd spherical surface

3. Two thin convex lenses and of focal lengths and respectively, are placed coaxially in contact. An object is placed at a point beyond the focus of lens . Draw a ray diagram to show the image formation and hence derive the expression for the focal length of the combined system.

Consider two lenses A and B of focal lengths f_1 and f_2 placed in contact with each other. Let the object O be placed
beyond the focus of the first lens. The first lens produces image I_1 which acts as a virtual object for the second lens
which in turn produces image I. since the lenses are thin, we assume that the optical centers of the two lenses coincide at P. For the first lens-

$$\frac{1}{v_1} - \frac{1}{u} = \frac{1}{f_1}$$

For the second lens-

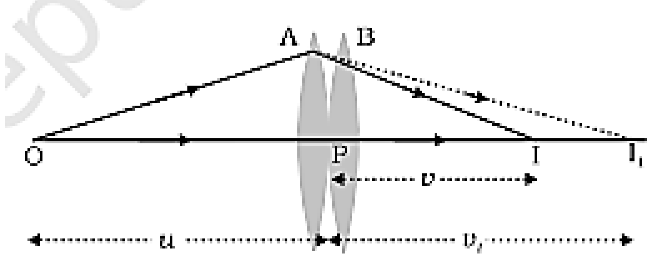


FIGURE 9.19 Image formation by a combination of two thin lenses in contact.

$$\frac{1}{v} - \frac{1}{v_1} = \frac{1}{f_2} \qquad \frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$$

Adding 1,2
If the two-lens system is regarded as equivalent to a single lens of focal length f we have,
1/f = 1/v-1/u
So, we get-$1/f = 1/f_1 + 1/f_2$

5. Draw the ray diagram showing refraction of ray of light through a glass prism. Derive the expression for the refractive index μ of the material of prism in terms of the angle of prism A and angle of minimum deviation δ_m.

Ans

Let a light ray is incident on the principal section ABC of a glass prism as shown

In quadrilateral AQNR,

$\angle A + 90^0 + \angle QNR + 90^0 = 360^0$

⇨ $\angle A + \angle QNR = 180^0$ ----------(1)

In triangle QNR,

$r_1 + r_2 + \angle QNR = 180^0$ ----------(2)

From (1) and (2)

$r_1 + r_2 = A$ --------(3)

Now, total deviation

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

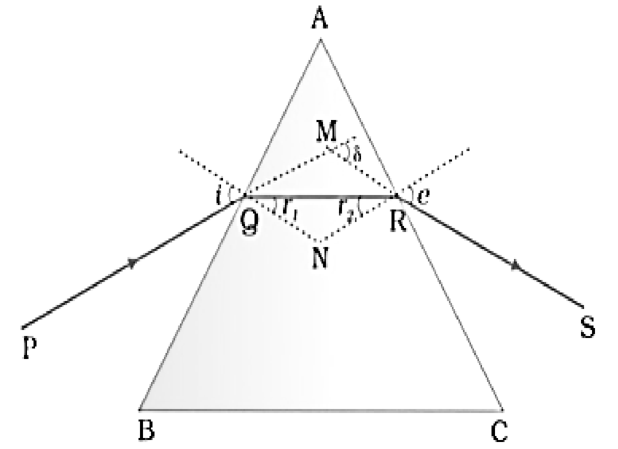
⇨ $\delta = i + e - A$ ---------(4)

But when $\delta = \delta_m$, $i = e$ hence $r_1 = r_2$

⇨ from (3), $2r = A$ ⇨ $r = A/2$

From (4), $\delta_m = 2i - A$ ⇨ $i = (A + \delta_m)/2$

⇨ $\mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin A/2}$



6. (i) Define SI unit of power of a lens. (ii) A plano- convex lens is made of glass of refractive index 1.5. The radius of curvature of the convex surface is 25 cm. (a) Calculate the focal length of the lens. (b) If an object is placed 50 cm in front of the lens, find the nature and position of the image formed.

Ans (i) SI unit of power of lens: Dioptre is the SI unit of power of a lens. The power of the lens is the reciprocal of its focal length measured in metre(m).

ii) (a) Refractive index = m = 1.5 Radius of curvature of convex side = 25 cm = 25 /100 m

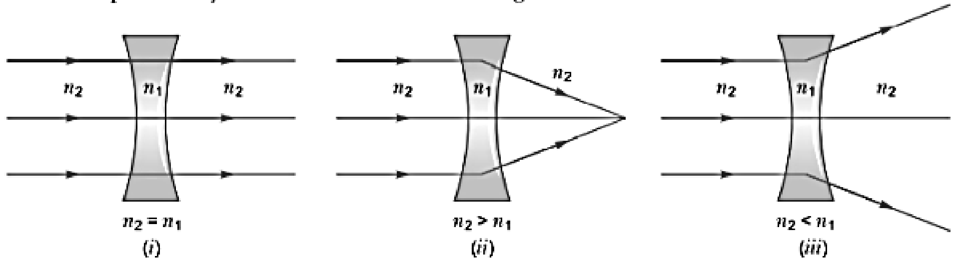
Radius of curvature of plane side = ∞

Applying lens maker's formula, f = 50 cm

(b) Focal length = f = 50 cm Object distance = u = – 50 cm When the object distance = focal length, then the image will be formed at infinity. Image will be highly magnified, real and inverted.

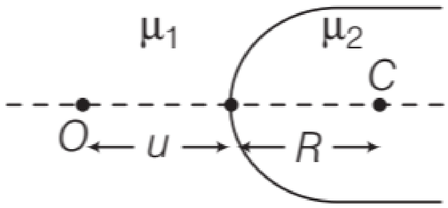
7 The refractive index of a material of a concave lens is n_1. It is immersed in a medium of refractive index n_2. A parallel beam of light is incident on the lens. Trace the path of emergent rays when (i) $n_2 = n_1$ (ii) $n_2 > n_1$ (iii) $n_2 < n_1$

Ans

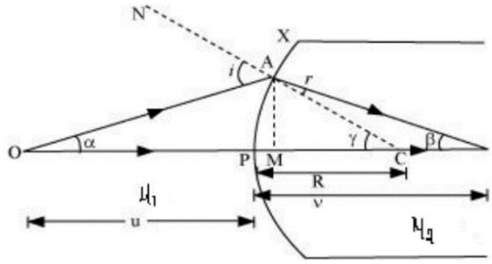


Long Answer Question (5 marks)

1 a)A point object O is kept in a medium of refractive index . μ1 in front of a convex spherical surface of radius of curvature R which separates the second medium of refractive index μ2 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 μ1 μ2 , and R.



Ans a)



[**Ans**. By Snell's law, $\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$

For small angles, $\frac{i}{r} = \frac{\mu_2}{\mu_1}$

⇨ $\mu_1 i = \mu_2 r$ -----------(1)

In Δ OAC and Δ IAC,

$i = \alpha + \gamma$ & $\gamma = r + \beta$

⇨ from (1),

$\mu_1 (\alpha + \gamma) = \mu_2 (\gamma - \beta)$

⇨ $\mu_1 \alpha + \mu_2 \beta = (\mu_2 - \mu_1) \gamma$ ----------(2)

let the aperture of the surface is also very small then we have

$\alpha \approx \tan\alpha = \frac{AM}{MO} \approx \frac{AM}{PO}$

$\beta \approx \tan\beta = \frac{AM}{MI} \approx \frac{AM}{PI}$ & $\gamma \approx \tan\gamma = \frac{AM}{MC} \approx \frac{AM}{PC}$

⇨ from equation (2)

$$\mu_1 \left(\frac{AM}{PO}\right) + \mu_2 \left(\frac{AM}{PI}\right) = (\mu_2 - \mu_1)\left(\frac{AM}{PC}\right)$$

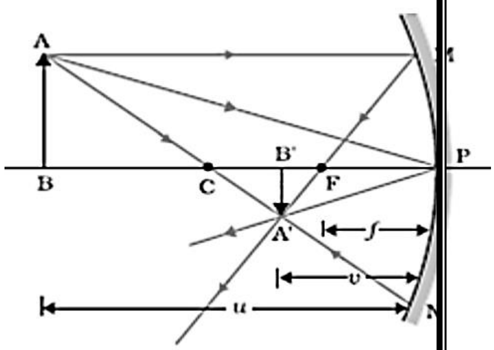
⇨ $\frac{\mu_1}{-u} + \frac{\mu_2}{+v} = \frac{(\mu_2 - \mu_1)}{+R}$

b) A magician during a show makes a glass lens with n = 1.47 disappear in a trough of liquid. What is the refractive index of the liquid? Could the liquid be water?

Ans The refractive index of the liquid must be equal to 1.47 in order to make the lens disappear. This means n1 = n2 . This gives 1/f =0 or f= ∞ . The lens in the liquid will act like a plane sheet of glass. No, the liquid is not water.

2. a) Draw a ray diagram to show image formation when the concave mirror produces a real, inverted and magnified image of the object. Derive the mirror formula

Ans



ΔABC and ΔA′B′C are similar

∴ $\frac{B'A'}{BA} = \frac{B'C}{CB} = \frac{PC - PB'}{PB - PC}$ ------------(1)

ΔABP and ΔA′B′P are also similar

∴ $\frac{B'A'}{BA} = \frac{PB'}{PB}$ -----------(2)

from equation (1) and (2)

⇨ $\frac{-2f-(-v)}{-u-(-2f)} = \frac{-v}{-u}$ ⇨ $\frac{v-2f}{2f-u} = \frac{v}{u}$ ⇨ $uv - 2uf = 2vf - uv$

⇨ $2uv = 2vf + 2uf$

Dividing by $2uvf$ on both sides we get, $\frac{2uv}{2uvf} = \frac{2vf}{2uvf} + \frac{2uf}{2uvf}$

⇨ $\boxed{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$

b) A tank is filled with water to a height of 12.5 cm. The apparent depth of a needle lying at the bottom of the tank is measured by a microscope to be 9.4 cm. What is the refractive index of water?
(Hint : Formula used apparent depth= real depth/n_{21}

Case Study

The criteria for image formation by a mirror or a lens is , minimum two reflected or refracted light rays actually meet at a point or appears to meet at a point. The image formed by actual meeting of light rays is called real image. When two light rays appears to meet at point , the image formed is called virtual image. Real image can be focussed on screen but virtual image cannot be focussed on screen. Real image always inverted while virtual image is erect.

1. A convex lens is of focal length 20 cm is cut in to two equal halves horizontally parallel to principal axis. Then the focal length of each halves
a) 10 cm, 10 cm b) 5 cm, 5 cm c) 20 cm , 20 cm d) 20 cm , 10 cm

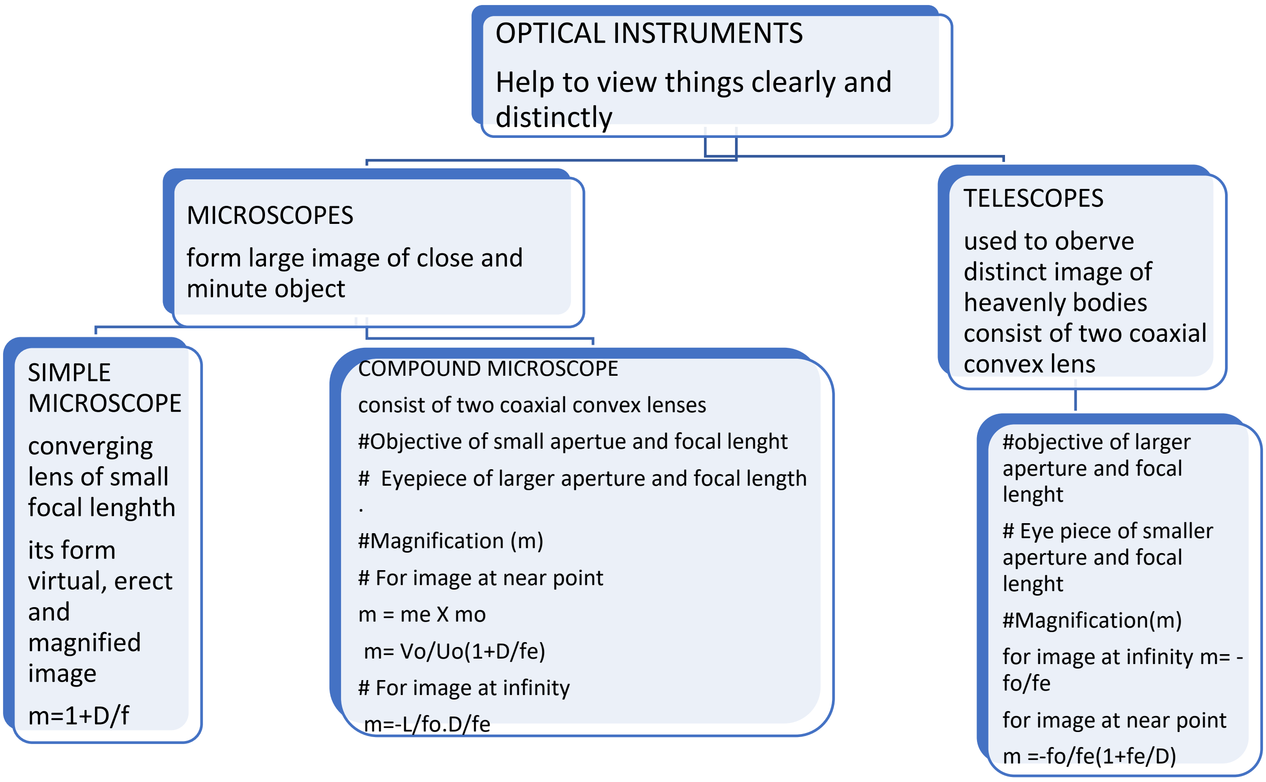
2. The half portion (both sides) of a convex lens is painted with black colour, the what happens to the image
a) the image will not be formed b) the size of the image will be half
c)image will be formed but its intensity will be half d) blurred image will be formed

3. A concave mirror and a convex lens are immersed in water, then what happens to focal length
a) focal length of both will not change b) focal length of both will change
c) mirror focal length will not change but lens focal length will increases d)) mirror focal length will not change but lens focal length will decreases

4. A convex lens of focal length 15 cm and concave lens of focal length 15 cm combined together then the combination will acts as
a) converging b) diverging c) neither converging nor diverging d)it will not pass light rays

Ans: (i) c (ii) c (iii) c (iv) c**Part 2 Optical Instrument**

OPTICAL INSTRUMENTS CHAPTER AT A GLANCE:



MCQ (Multiple choice questions):

1) For a telescope the larger the diameter of the objective lens.
A)Greater the resolving power B)Greater the magnifying power
C) Smaller the resolving power D)Smaller the magnifying power
ANS: A
2) The objective of a telescope must be of large diameter in order to
A) Remove chromatic aberration B) Remove spherical aberration and high magnification
C) Gather more light and form high resolution D) Increase range of observation
ANS: C
3) To increase the angular magnification of a simple microscope, one should increase
A) The focal length of the lens B) The power of the lens
C) The aperture of the of the lens D) The object size
ANS: B
4) the system of combination of lenses is commonly used in designing lenses for
A) microscope B) telescope C) cameras D) all of these
ANS: D
5) Athe image formed by an object of an compound microscope is
A) real and diminished B) real and enlarged C) Virtual +and enlarged D) virtual and diminished
ANS: B

ASSERTION REASON QUESTIONS:-

1 ASSERTION: If the objective and eye piece of a microscope are interchanged then it can work as telescope. **REASON:** The objective lens of telescope has small focal length
2 ASSERTION: The microscope magnifies the image **REASON:** Angular magnification for image is more than object in microscope
3 ASSERTION: The resolving power of a telescope is more than If the diameter of the objective lens is more. **REASON:** Objective lens of large diameter collects more light
ANS: 1 D 2 A 3 A

SHORT ANSWER TYPE QUESTIONS [2 MARKS]

1 **Define the magnifying power of a compound microscope when the final image is formed at infinity. Why must both the objective and eyepiece of a compound microscope has short focal lengths? Explain.**
ANS: Magnifying power: It is the ratio of the angle subtended by the image formed at infinity to the angle subtended on the eye by the object placed at least distance of distinct vision.

$$M = \frac{-D}{f_e} . \frac{L}{f_o}$$

Therefore, To increase angular magnification f_o and f_e should be small.

2 Using the data given below, state which two of the given lenses will be preferred to construct a Telescope, and Microscope. Also indicate which is to be used as objective and as eyepiece in each case.

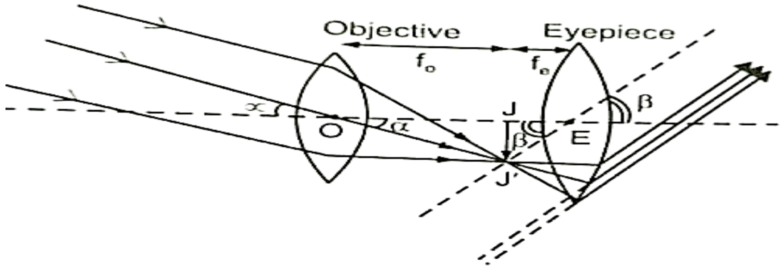
LENSES	POWER (P)	APERTURE (A)
L_1	6 D	1 cm
L_2	3 D	8 cm
L_3	10 D	1 cm

ANS. (i) For a telescope: L_2 and L_3

Lens $L_2$is chosen as an objective because its power is least (or focal length is maximum) and aperture is large. (ii) For a microscope: L_1 and L_3 Lens L_3 is chosen as objective because its focal length is small, and L_1as an eyepiece because its focal length is not large.

3 **Draw a neat labelled ray diagram of an astronomical telescope in normal adjustment.**

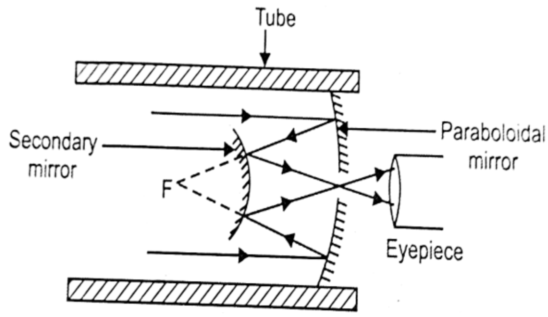
ANS.



SHORT ANSWER TYPE QUESTIONS [3 MARKS]

1 (i) Draw a schematic labelled ray diagram of a reflecting type telescope.
(ii) Writing two important advantages justifying why reflecting type telescopes are preferred over refracting telescopes. (iii) The objective of a telescope is of larger focal length and of larger aperture. Why? give reasons

ANS. (i)



(ii) advantages over refracting type telescope.

it produces a brighter image because the refraction through lenses causes absorption of light.

it is easier to fabricate a mirror of large aperture than a lens and hence has larger has larger light gathering power as well as resolving power.

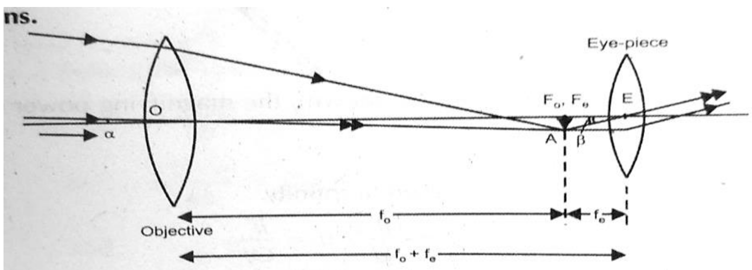
(iii) (a) Larger focal length ensures larger magnifying power of telescope because

$$m = \frac{f_o}{f_e}$$

(b) larger aperture ensures larger light gathering power and larger resolving power.

2. Draw a labelled ray diagram of a refracting telescope. Define its magnifying power and write the expression for it. Write two important limitations of a refracting telescope over a reflecting type telescope.

ANS. Magnifying power of a telescope is the ratio of the angle subtended by image on the eye seen through the telescope to angle subtended by object on the unaided eye.



$$M = \frac{\beta}{\alpha}$$

$$\cong \frac{tan\beta}{tan\alpha} = \frac{AF_0/F_e}{AF_0/OF_0} = \frac{OF_O}{F_OE}$$

$$= \frac{f_o}{f_e} = \frac{focal\ lenght\ of\ objective}{focal\ lenghth\ of\ eye\ piece}$$

Limitation of refracting telescope:

1) The image is less bright because the lenses absorb some light.

2) The lenses suffer from chromatic aberration because refraction effects depends on wavelength of light.

3 **A compound microscope uses an objective lens of focal length 4cm and eyepiece lens of focal length 10cm. An object is placed at 6cm from objective lens. Calculate the magnifying power of the compound microscope. Also calculate the length of microscope.**

ANS. for objective f = +4cm   u = -6cm

By lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ $\frac{1}{f} = \frac{1}{v_0} - \frac{1}{u_0}$ $= \frac{1}{4} - \frac{1}{6} = \frac{1}{12}$

$v_o = 12cm$ For eyepiece $f_e = +10cm$ $v_e = -25cm$

$\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{-25} - \frac{1}{10}$ $u_e = \frac{-50}{7}$cm

M = $M_O \times M_e = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = \frac{12}{6}\left(1 + \frac{25}{10}\right) = 7$

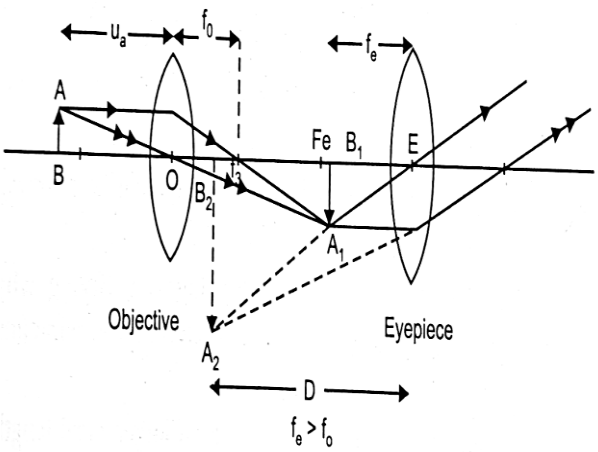
Length of microscope = 12+ $\frac{50}{7} = \frac{134}{7}$cm.

LONG ANSWER 5 MARKS :

1 (a) Draw a labeled ray diagram showing the formation of a final image by a compound microscope at least distance of distinct vision.

(b) The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. The distance between the objective and eye piece is observed to be 14cm. if least distance of distinct vision is 20cm, calculate the focal length of the objective and eyepiece.

ANS: (a)



(b) M=20; $M_e = 5$; also M=$M_0 \times M_e$

$|M_o| = \frac{M}{M_e} = 4$

For eyepiece; v_e= -20 cm ; $|u_e| = \frac{V_e}{m} = 4$

Or, u_e = -4cm

$\frac{1}{f_e} = \frac{1}{v_e} - \frac{1}{u_e} \Rightarrow f_e = 5cm$

Also, $|v_o| + |u_e|$=14cm

$$v_o = 14 - 4 = 10cm$$

$$|u_o| = \left|\frac{v_o}{m_o}\right| = \frac{10}{4} = -2.5cm$$

$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{10} + \frac{2}{5} \Rightarrow f_o = 2cm$

CASE STUDY BASED QUESTIONS

ASTRONOMICAL TELESCOPE An astronomical telescope is an optical instrument which is used for observing distinct images of heavenly bodies libe stars, planets etc. It consists of two lenses. In normal adjustment of telescope, the final image is formed at infinity. Magnifying power of an astronomical telescope in normal adjustment is defined as the ratio of the angle subtended at the eye by the angle subtended at the eye by the final image to the angle subtended at the eye, by the object directly, when the final image and the object both lie at infinite distance from the eye. It is given by, m = $f0/f$e increase magnifying power of an astronomical telescope in normal adjustment, focal length of objective lens should be large and focal length of eye lens should be small.

(i) An astronomical telescope of magnifying power 7 consists of the two thin lenses 40 cm apart, in normal adjustment. The focal lengths of the lenses are

(a) 5 cm, 35 cm   (b) 7 cm, 35 cm   (c) 17 cm, 35 cm   (d) 5 cm, 30 cm

(ii) An astronomical telescope has a magnifying power of 10. In normal adjustment, distance between the objective and eye piece is 22 cm. The focal length of objective lens is

(a) 25 cm (b) 10 cm (c) 15 cm (d) 20 cm

(iii) In astronomical telescope compare to eye piece, objective lens has

(a) negative focal length (b) zero focal length (c) small focal length (d) large focal length

(iv) To see stars, use

(a) simple microscope (b) compound microscope (c) endoscope (d) astronomical telescope

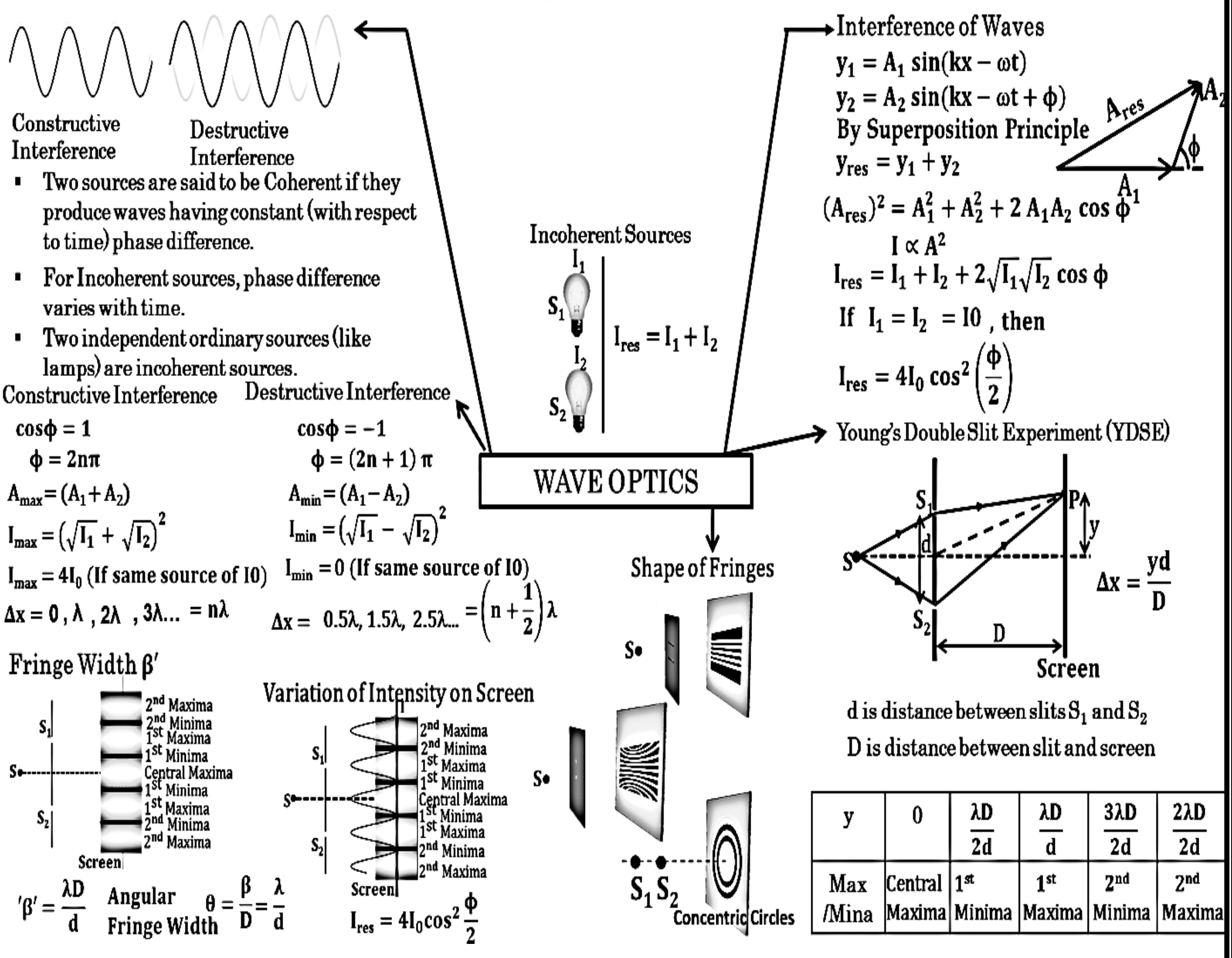
(v) For large magnifying power of astronomical telescope

a. ƒ0 << fe b. f_o - f_o c. $f_o >> f_e$ d. none of these

ANSWERS CASE STUDY

1 a 3.d 2 d 4.d

CHAPTER- 10
WAVE OPTICS



y	0	λD/2d	λD/d	3λD/2d	2λD/2d
Max /Mina	Central Maxima	1st Minima	1st Maxima	2nd Minima	2nd Maxima

VERY SHORT ANSWER QUESTIONS(1 MARK)

Assertion and Reason questions:

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 : According to Huygen's principle, no backward wave-front is possible.
Reason : Amplitude of secondary wavelet is proportional to (1 + cos θ) where θ is the angle between the ray at the point of consideration and the direction of secondary wavelet.
2 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.
3 Assertion :In Young's double slit experiment if the wavelength of incident monochromatic light is just doubled, the number of bright fringes on the screen will increase.
Reason : Maximum number of bright fringe on the screen is inversely proportional to the wavelength of light used
4 Assertion : Diffraction takes place for all types of waves mechanical or nonmechanical, transverse or longitudinal. **Reason** : Diffraction's effect are perceptible only if wavelength of wave is comparable to dimensions of diffracting device.
5 Assertion : In YDSE, if a thin film is introduced in front of the upper slit, then the fringe pattern shifts in the downward direction.
Reason : In YDSE if the slit widths are unequal, the minima will be completely dark.
6 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 slits.
7Assertion: In Young's double slit experiment, the fringes become indistinct if one of the slits is covered with cellophane paper. **Reason** :The cellophane paper decrease the wavelength of light.
8 Assertion: The unpolarised light and polarised light can be distinguished from each other by using polaroid. **Reason** : A polaroid is capable of producing plane polarised beams of light.
9 **Assertion**: Microwave communication is preferred over optical communication.
Reason: Microwaves provide large number of channels and band width compared to optical signals.
10 Assertion: Nicol prism is used to produce and analyse plane polarised light.
Reason: Nicol prism reduces the intensity of light to zero.
11 Assertion: When a light wave travels from rarer to denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave.
Reason: The energy of a wave is directly proportional to velocity of a wave.
12 Assertion: No interference pattern is detected when two coherent sources is extremely closed to each other. **Reason**: The fringe width is inversely proportional to the distance between two coherence sources.
13 Assertion: Coloured spectrum is seen when we look through a muslin cloth.
Reason: It is due to diffraction of white light on passing through fine slits.
14 Assertion: According to Huygens's principle, no backward wave-front is possible.
Reason: Amplitude of secondary wavelet is proportional to (1+cosθ) where θ is the angle between the ray at the point of consideration and the direction of secondary wavelet.
15 1Assertion: In YDSE number of bright fringe or dark fringe can not be limited.

Reason: In YDSE path difference between superposing waves cannot be more than the distance between slits.

16 Assertion : The speed of light in vacuum doesn't depend on nature of the source, direction of propagation, motion of the source or observer wavelength and intensity of the wave.

Reason: The speed of light in vacuum is a universal constant independent of all the factors listed and anything else.

17 Assertion: Interference pattern is made by using yellow light instead of red light, the fringes becomes narrower.

Reason:In YDSE, fringe width is given by $\beta=\lambda D/d$

18 Assertion: The phase difference between any two points on a wave front is zero.

Reason: Corresponding to a beam of parallel rays of light, the wave fronts are planes parallel to one another.

19 Assertion: When the apparatus of YDSE is brought in a liquid from air, the fringe width decreases. **Reason**:The wavelength of light decreases in the liquid.

20 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.

21 Assertion: Diffraction takes place for all types of waves mechanical or non-mechanical, transverse or longitudinal. **Reason**:Diffraction's effect are perceptible only if wavelength of wave is comparable to dimensions of diffracting device.

22 Assertion. To observe diffraction of light, the size of obstacle/aperture should be Of the order of 10-7 m . **Reason**.10-7 m is the order of wavelength of visible light .

23 Assertion. Corpuscular theory fails in explaining the velocities of light in air and water. **Reason**.According to corpuscular theory, light should travel faster in denser media than in rarer media .

24 Assertion. For identical coherent waves, the maximum intensity is four times the intensity due to each wave. **Reason**. Intensity is proportional to the square of amplitude.

25 Assertion. No interference pattern is detected when two coherent sources are infinitely close to each other. **Reason**. Fringe width is inversely proportional to separation between the slit.

Answers

1. B	**6. B**	**11. D**	**16. A**	**21. B**
2. A	**7. C**	**12. A**	**17. A**	**22. A**
3. A	**8. A**	**13. A**	**18. B**	**23. A**
4. B	**9. A**	**14. B**	**19. A**	**24. B**
5. D	**10. C**	**15. A**	**20. A**	**25. B**

MULTIPLE CHOICE QUESTIONS(10 questions)

1.What happens if one of the slits, say S1 in Young's double, slit experiment-is covered with a glass plate which absorbs half the intensity of light from it?

(a) The bright fringes become less-bright and the dark fringes have a finite light intensity

(b) The bright fringes become brighter and the dark fringes become darker

(c) The fringe width decreases (d) No fringes will be observed

2.What happens to the interference pattern the two slits S1 and S2 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

3.What is the reason for your answer to the above question?

(a) The two sources do not emit light of the same wavelength

(b) The two sources emit waves which travel with different speeds
(c) The two sources emit light waves of different amplitudes
(d) There is not constant phase difference between the waves emitted by the two sources

4. Two sources of light are said to be coherent when both give out light waves of the same:
(a) amplitude and phase (b) intensity and wavelength
(c) speed (d) wavelength and a constant phase difference

5. Which of the following is conserved when light waves interference?
(a) phase (b) intensity
(c) amplitude (d) none of these

6: An optically active compound
(a) rotates the plane of polarised light (b) changes the direction of polarised light
(c) does not allow plane polarised light to pass through (d) none of these

7: Which among the following isn't a suitable phenomenon to establish that light is wave motion?
a) Interference b) Diffraction c) Reflection d) Polarization

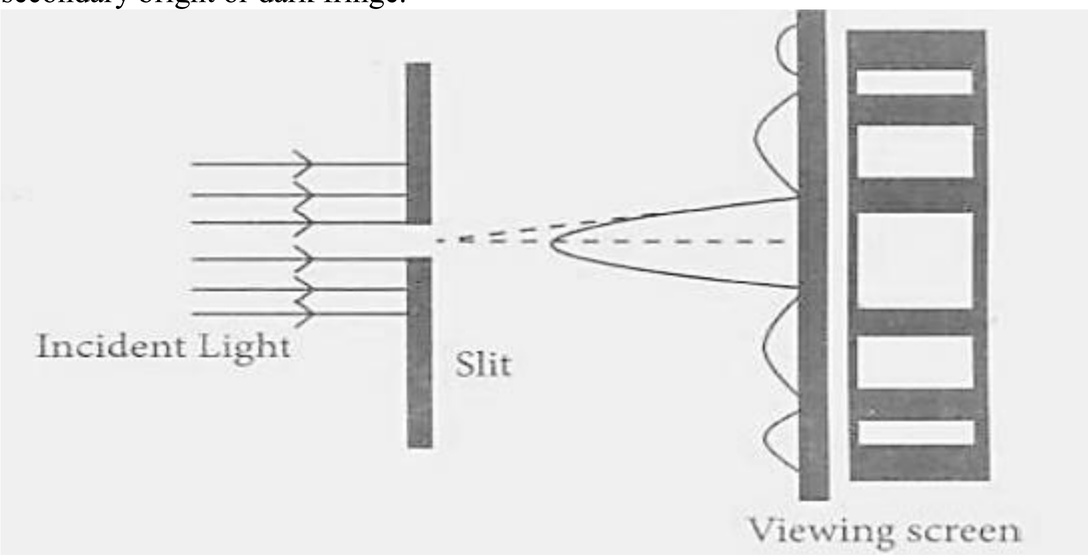
8: The locus of all particles in a medium, vibrating in the same phase is called
(a) wavelet (b) fringe (c) wave front (d) None of these

9: Wavefront is the locus of all points, where the particles of the medium vibrate with the same
(a) phase (b) amplitude (c) frequency (d) period

10: When light suffers reflection at the interface between water and glass, the change of phase in the reflected wave is
(a) zero (b) π (c) π/2 (d) 2π

<u>CASE BASED (2 Questions)</u>

1. When light from a monochromatic source is incident on a single narrow slit, it gets diffracted and a pattern of alternate bright and dark fringes is obtained on screen, called "Diffraction Pattern" of single slit. In diffraction pattern of single slit, it is found that
(I) Central bright fringe is of maximum intensity and the intensity of any secondary bright fringe decreases with increase in its order. (II) Central bright fringe is twice as wide as any other secondary bright or dark fringe.



Question (i) A single slit of width 0.1 mm is illuminated by a parallel beam of light of wavelength 6000 A and diffraction bands are observed on a screen 0.5 m from the slit. The distance of the third dark band from the central bright band is
(a) 3 mm (b) 1.5 mm (c) 9 mm (d) 4.5 mm

Question (ii) A diffraction pattern is obtained by using a beam of red light. What will happen, if the red light is replaced by the blue light?
(a) bands disappear (b) bands become broader and farther apart
(c) no change will take place (d) diffraction bands become narrower and crowded together

2. Huygens' Principle: Huygens' principle is the basis of wave theory of light. Each point on a wavefront acts as a fresh source of new disturbance, called secondary waves or wavelets. The secondary wavelets spread out in all directions with the speed of light in the given medium. An initially parallel cylindrical beam travels in a medium of refractive index $\mu(I) = \mu_0 + \mu_2 I$, where μ_0 and μ_2 are the positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.

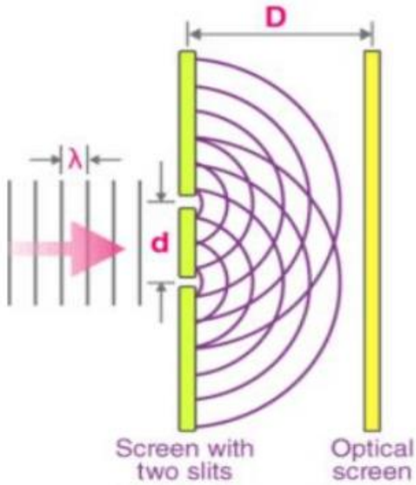
i. The initial shape of the wave front of the beam is ?
a. Planar (b)convex (c) concave (d) both (a) and (b)

ii. In Huygens theory , light waves are longitudinal and do not require a material medium for their propagation.
a. True (b) False

iii. As beam enters into the medium , it will
(a)travel as a cylindrical beam (b) diverge
(c) converge (d) diverge near the axis and converge near the periphery.

iv. According to Huygens' Principle the surface of constant phase is called
a. An optical ray (b) a wave (c) a wavefront (d) always linear in shape

3. Young's double-slit experiment uses two coherent sources of light placed at a small distance apart, usually, only a few orders of magnitude greater than the wavelength of light is used. Young's double-slit experiment helped in understanding the wave theory of light which is explained with the help of a diagram. A screen or photo detector is placed at a large distance 'D' away from the slits as shown. The original Young's double-slit experiment used diffracted light from a single source passed into two more slits to be used as coherent sources. Lasers are commonly used as coherent souce in the modern-day experiments.



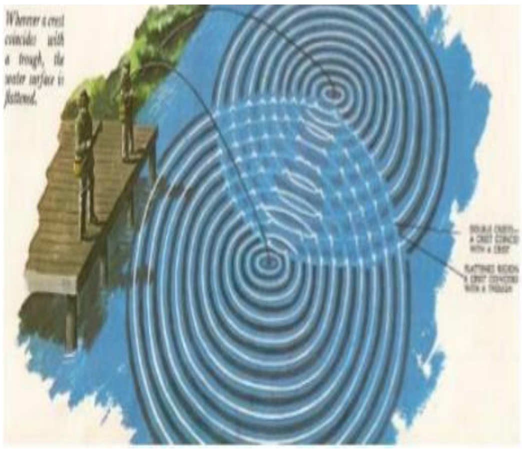
i. In Young's Double Slit Experiment, if instead of monochromatic light white light is used, what would be the observation?
(a) The pattern will not be visible
(b) The shape of the pattern will change from hyperbolic to circular
(c) Coloured fringes will be observed with a white bright fringe at the center
(d) The bright and dark fringes will change position

ii. What kind of sources is required for Young's Double Slit experiment?
(a) Coherent (b) Incoherent (c) Intense (d) Bright

iii. If the distance between the two slits is doubled, the fringe width _________
(a) Doubles (b) Halves (c) Four-times (d) Remains same

iv. There is no effect on the interference pattern when the width of the slit is increased.
(a) True (b) False

4. Jimmy and Johnny were both creating a series of circular waves by jiggling their legs in water. The waves form a pattern similar to the diagram as shown. Their friend, Anita, advised Jimmy and Johnny not to play with water for a long time. She then observed beautiful patterns of ripples which became very colourful. When her friend Latha poured an oil drop on it. Latha, a 12th standard girl, had explained the cause for colorful ripple patterns to Anita earlier.



(i)Name the phenomenon involved in the activity

(A) Reflection (B) Refraction

(C) Interference (D) Polarization

(ii) A surface over which an optical wave has a constant phase is called.

(A) Wave (B) Wave front

(C) Elasticity (D) None of these

(iii) Which of the following is correct for light diverging from a point source?

(A)The intensity decreases in proportion for the distance squared.

(B)The wave front is parabolic

(C)The intensity at the wavelength does depend of the distance.

(D)None of these.

(iv)The phenomena which is not explained by Huygens's construction of wave front

(A) reflection (B) diffraction (C) refraction (D) origin of spectra

(v)Huygens's concept of secondary wave

A. allows us to find the focal length of a thick lens

B. is a geometrical method to find a wave front

C. is used to determine the velocity of light

D. is used to explain polarization

5. CD reflecting rainbow colours:

Almost all of you have seen a rainbow formation on rainy days. Well, rainbow is formed because water droplets in the atmosphere separate white light into different colours of the rainbow Compact Disc (CD) also resembles the same kind of colours when viewed from different angles. Recorded data on CD is stored in microscopic pits of different lengths which carries information in the CD. These pits are placed in a row of the same width and at equal distance. This forms a diffraction grating on the CD mirror surface.

i. Formation of rainbow colours on the CD is due to

(A) Reflection (B) Refraction (C) Diffraction (D) None of these

ii)The recorded data on the discs behaves as

A. Diffraction grating B. Rainbow C. Drops D. Colours

iii)Bending of light at the corners of the door is an example of

(A) Reflection (B) Refraction (C) Interference (D) Diffraction

(iv) Which of the following is an example of diffraction?

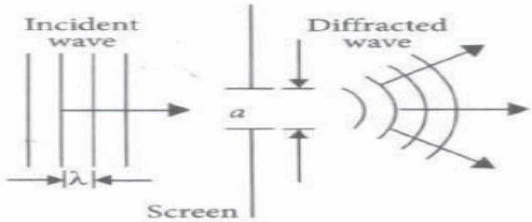
(A)Holograms (B) Sun appears red during sunset

C. From the shadow of an object D. All of these

(v)The intensity of light from the central maxima goes on ……in diffraction pattern.

(A) Increasing (B) Decreasing (C) Both a and b (D) Neither a nor b

6.The phenomenon of bending of light around the sharp corners and the spreading of light within the geometrical shadow of the opaque obstacles is called diffraction of light. The light thus deviates from its linear path. The deviation becomes much



more pronounced, when the dimensions of the aperture or the obstacle are comparable to the wavelength of light.

i. Light seems to propagate in rectilinear path because

(a) its spread is very large (b) its wavelength is very small
(c) reflected from the upper surface of atmosphere (d) it is not absorbed by atmosphere

ii. In diffraction from a single slit the angular width of the central maxima does not depend on

(a) λ of light used (b) width of slit
(c) distance of slits from the screen (d) ratio of λ and slit width

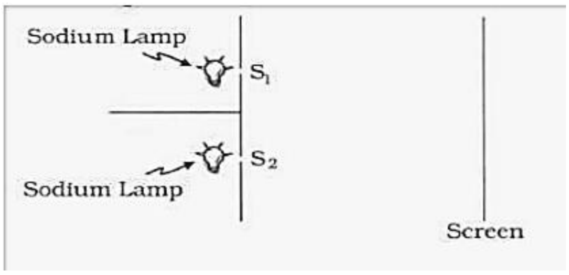
iii. For a diffraction from a single slit, the intensity of the central point is

(a) infinite
(b) finite and same magnitude as the surrounding maxima
(c) finite but much larger than the surrounding maxima
(d) finite and substantially smaller than the surrounding maxima

iv. In a single diffraction pattern observed on a screen placed at D metre distance from the slit of width d metre, the ratio of the width of the central maxima to the width of other secondary maxima is

(i)2:1 (ii)2:3 (iii) 1:1 (iv) 3:2

7.Interference is based on the superposition principle. According to this principle, at a particular point in the medium, the resultant displacement produced by a number of waves is the vector sum of the displacements produced by each of the waves. If two sodium lamps illuminate two pinholes S_1 and S_2. the intensities will add up and no interference fringes will be observed on the screen. Here the source undergoes abrupt phase change in times of the order of 10^{-10} seconds.



i. Two coherent sources of intensity 9 W/m^2 and 25 W/m^2 interfere to form fringes. Find the ratio of maximum intensity to minimum intensity

(i) 10:3 (ii) 16:1 (iii) 4:1 (iv) 2:1

ii. In a Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to

(i)2D (ii) 4D (iii) D/2 (iv) D/4

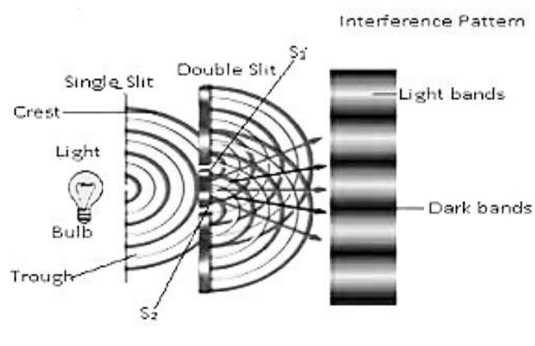
iii. The maximum number of possible interference maxima for slit separation equal to twice the wavelength in Young's double-slit experiment, is

(i)infinite (ii)five (iii)three (iv)zero

iv. The resultant amplitude of a vibrating particle by the superposition of the two waves, $y_1 = a \sin [\omega t+\pi/3]$ and $y_2 = a \sin \omega t$

(a) a (b)22 a (c)2 a (d)3 a

8.Interference is a pattern produced by the superposition of two waves. According to the superposition principle at a particular point in the medium, the resultant displacement produced by a number of waves is the vector sum of the displacement produced by each of the wave. When the crest of a wave overlaps the crest of another wave of the same frequency at the same point, then the resultant amplitude will be the sum of the amplitudes of individual waves. Then it is known as constructive interference. It will be a bright band.



When the crest of one wave meets the trough of another wave, then the resultant amplitude is given as difference of the two individual amplitudes. Then it is known as destructive interference. It will be a dark fringe.

(i). Choose the wrong statement

(A) superposition is the redistribution of light energy
(B) In constructive interference intensity of light will increase
(C) In destructive interference intensity of light will decrease
(D) interference can be generated by two identical sodium bulbs

(ii). Two beams of light of intensities I_1 and I_2, interfere to given an interference pattern. Here the ratio of the maximum intensity to minimum intensity is 25/9 then I_1/I_2 is –

(A) 5/3 (B) 4 /3 (C) 81/625 (D) 16/25

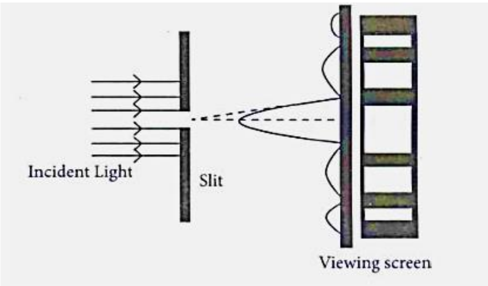
(iii). If young's double slit experiment is performed in water instead of air, then

(A) no fringe would be seen (B) fringe width would decrease
(C) fringe width would increase (D) fringe width will remain same

(iv) in young's double slit experiment, the slit width and distance of slits from the screen both are halved. Then the fringe width will

(A) increase (B) decrease
(C) remain unchanged (D) none of these

9. When light from a monochromatic source is incident on a single narrow slit, it gets diffracted and a pattern of alternate bright and dark fringes is obtained on screen, called "Diffraction Pattern" of single slit. In diffraction pattern of single slit, it is found that



(I) Central bright fringe is ·of maximum intensity and the intensity of any secondary bright fringe decreases with increase in its order. (II) Central bright fringe is twice as wide as any other secondary bright or dark fringe .

Answer the questions based on the above study:

i. A single slit of width 0.1 mm is illuminated by a parallel beam of light of wavelength 6000 A and diffraction bands are observed on a screen 0.5 m away from the slit. The distance of the third dark band from the central bright band is

(a) 3 mm (b) 1.5 mm (c) 9 mm (d) 4.5 mm

ii. In Fraunhofer diffraction pattern, slit width is 0.2 mm and screen is at 2 m away from the lens. If wavelength of light used is 5000 λ then the distance between the first minimum on either side the central maximum is

(a) 10^{-1} m (b) 10^{-2} m (c) 2 x 10^{-2} m (d) 2 x 10^{-1} m

iii. Light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. The angular width of central maxima in the diffraction pattern is (measured from minimum to minimum)

(a) 6 x 10_{-3} rad (b) 4 x 10_{-3} rad (c) 2.4 x 10_{-3} rad (d) 4.5 x 10_{-3} rad

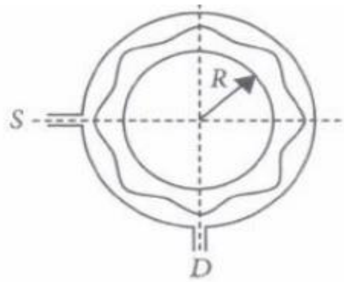
iv. A diffraction pattern is obtained by using a beam of red light. What will happen, if the red light is replaced by the blue light?

(a). bands disappear (b). bands become broader and farther apart
(c). no change will take place (d). diffraction bands become narrower and crowded together.

v. To observe diffraction, the size of the obstacle

(a) should be A/2, where A is the wavelength. (b) should be of the order of wavelength.
(c) has no relation to wavelength. (d) should be much larger than the wavelength.

10. A narrow tube is bent in the form of a circle of radius R, as shown in figure. Two small holes Sand D are made in the tube at the positions at right angle to each other. A source placed at S generates a wave of intensity Io which is equally divided into two parts: one-part travels along the longer path, while the other travels along the shorter path. Both the waves meet at point D where a detector is placed.



Answer the following question on the basis of the above case:

i. If a maxima is formed at a detector, then the magnitude of wavelength λ of the wave produced is given by

(a)πR (b)πR/2 (c)πR/4 (d) all of these

ii. If the intensity ratio of two coherent sources used in Young's double slit experiment is 49 : 1, then the ratio between the maximum and minimum intensities in the interference pattern is

(a) 1: 9 (b) 9: 16 (c) 25: 16 (d) 16: 9

iii. The maximum intensity produced at D is given by

(a) $4I_0$ (b) $2I_0$ (c) I_0 (d) $3I_0$

iv. In a Young's double slit experiment, the intensity at a point where the path difference is λ/6 (λ - wavelength of the light) is I. If I_0 denotes the maximum intensity, then I/I_0 is equal to

(a)1/2 (b)√3/2 (c)1/√2 (d)3/4

v. Two identical light waves, propagating in the same direction, have a phase difference d. After they superpose the intensity of the resulting wave will be proportional to

(a)cosδ (b)cos(δ/2) (c)$\cos^2(\delta/2)$ (d)$\cos^2\delta$

Answers

	i.	ii	iii	iv	v
1	C	D			
2	a	b	c	c	
3	c	a	b	b	
4	c	b	a	d	b
5	c	a	d	d	b
6	b	c	c	d	
7	b	a	a	d	
8	d	c	b	c	
9	c	b	a	d	b
10	d	d	b	d	c

SHORT ANSWER TYPE(2 MARKS) QUESTION(10 questions)

1 Can white light produce interference? What is the nature?

Ans. 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.

2. (a) Write the conditions under which light sources can be said to be coherent.

(b) Why is it necessary to have coherent sources in order to produce an interference pattern?

Answer: a)**Coherent sources of light**: The sources of light, which emit continuously light waves of the same wavelength, same frequency and in same phase are called Coherent sources of light. Two independent sources cannot act as coherent sources and interference pattern is not obtained. This is because phase difference between the light waves emitted from two different sodium lamps will change continuously. (**b)Conditions for interference.**

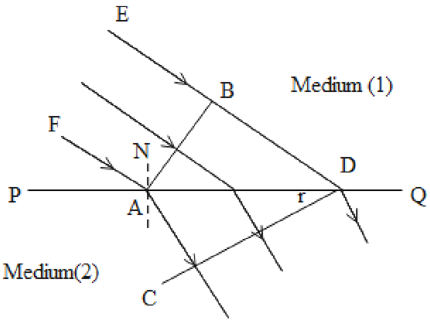
i) The two sources of light must be coherent. i.e. they should exist continuous waves of same wavelength or frequency. Ii) The two sources should be monochromatic. Iii)The phase difference of waves from two sources should be constant. The amplitude of waves from two sources should be equal. The coherent sources must be very close to each other.

3. Two slits are made 1mm apart and the screen is placed away. What should be the width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern.

Answer: As per question, width of central maxima of single slit pattern = width of 10 maxima of double slit pattern 2λD/a=10(λD/d)

a=0.2d , 0.2×10−3=0.2×10−3m=0.2mm

4. Using Huygen's wave theory, derive Snell's law of refraction.



Answer:

Consider the triangles BAD ACD figure above.

Sini = sin∠BAD= AD/BD=AD/C_1r

Sinr = sin∠ADC=AD/AC=AD/C_2r

sinr/sini= C2t/C1t=C2/C1= constant

This constant is called the refractive index of the second medium (2) with respect to the first medium (1).

C2/C1=n1/n2=1n2

This equation proves the Snell's law.

5. Obtain an expression for the ratio of intensities at maxima and minima in an interference pattern.

Ans: Suppose $a_1 and\ a_2$ be the amplitudes and $I_1 and\ I_2$ the intensities of light waves which interfere each other

Intensity α (Amplitude)^2

$$\frac{I_1}{I_2} = \frac{a_1}{a_2}$$

After interference (applying superposition principle)

Amplitude at maxima = $a_1 + a_2$

Amplitude at minima = $a_1 - a_2$

$$\frac{\text{Imax}}{\text{Imin}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} \qquad \frac{\text{Imax}}{\text{Imin}} = \frac{\left(\frac{a_1}{a_2}+1\right)^2}{\left(\frac{a_1}{a_2}-1\right)^2} = \left(\frac{r+1}{r-1}\right)^2$$

$$where\ r = \frac{a_1}{a_2} = \sqrt{\frac{I_1}{I_2}} =$$

amplitude ratio of two waves.

6. 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?

Ans: $\beta = \frac{D\lambda}{d}$

If light of smaller frequency is of higher wavelength is used the fringe width will increase.

(b) If distance between the slits is decreased

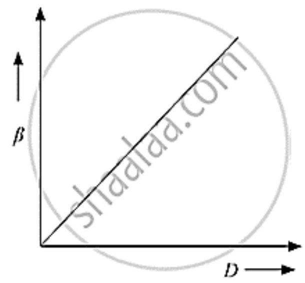
i.e $\beta \alpha \frac{1}{d}$. Fringe width will increase.

7.What type of wavefront will emerge from a(i) point source, and (ii) distant light source?

Answer:

(i) Point source – Spherical wavefront (ii) Distant light source – Plane wavefront.

8. Sketch a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits (keeping other parameters same) in young's double slit experiment. What information can one obtain from the slope of this graph?



Ans: Information from graph: Wavelength λ = Slope x d

9. (i)State one feature by which the phenomenon of interference can be distinguished from that of diffraction.

(ii)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.

Ans: (i) In interference all the maxima are of equal intensity. In diffraction pattern central fringe is of maximum intensity while intensity of secondary maxima falls rapidly.

(ii) Position of nth maximum,

$y=(2n+1)\lambda D/2d$,here n=2 $y=5\lambda D/2d$

Substituting and solving, we get, d=80µm 78 4.

10. Yellow light (λ = 6000Å) illuminates a single slit of width 1 x 10-4 m. Calculate (i)the distance between the two dark lines on either side of the central maximum, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit; (ii)the angular spread of the first diffraction minimum.

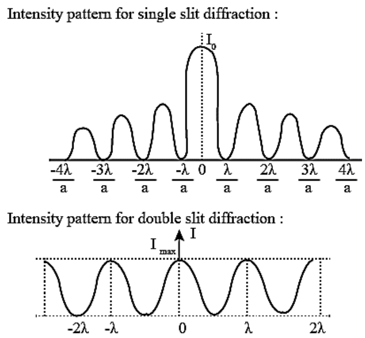
Ans: (i) Distance between two dark lines, on either side of central maximum is $=2\lambda D/a$, Substituitng and solving we get,18mm

(ii)Angular spread of the first diffraction minimum (on either side) $\Theta=\lambda/a$

Substituting and solving we get $\Theta=6*10^{-3}$ rad .

LONG ANSWER TYPE-1 QUESTIONS (3 MARKS)

1) Draw the intensity pattern for single slit diffraction and double slit interference. Hence, state two differences between interference and diffraction patterns.



Ans: Basic features of distinction between interference and diffraction patterns :

(i)The interference pattern has a number of equally spaced bright and dark bands while diffraction pattern has a central bright maximum which is twice as wide as the other maxima.

(ii)Interference pattern is the superimposition of two waves slits originating from two narrow slits. The diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.

(iii)For a single slit of width 'a' the first null of diffraction pattern occurs at an angle of λ/a. At the same angle of λ/a, we get a maxima for two narrow slits separated by a distance 'a

2) Two monochromatic waves emanating from two coherent sources have the displacements represented by y1 = a cos ωt and y2 = a cos (ωt + ϕ), where ϕ is the phase difference between the two displacements (a)Show that the resultant intensity at a point due to their superposition is given by

$I = 4I_0 \cos^2 \phi/2$, where $I_0 = a2$.

(b) Hence obtain the conditions for constructive and destructive interference.

Answer: (a) Let the two waves be represented by equations $y_1=a\cos\omega t$, $y_2=a\cos(\omega t+\varphi)$

From the Principle of superposition of waves we get, $Y = y_1+y_2=2a\cos(\varphi/2)\cos(\omega t+\varphi/2)$

Resultant Amplitude is $A=2a\cos(\varphi/2)$

Hence, Resultant Intensity α (amplitude)2 $=4a^2 \cos2 (\varphi/2)$

(b) (i)Condition for constructive interference

$Cos\left(\frac{\phi}{2}\right) = \pm 1 \qquad \frac{\phi}{2} = n\prod$

$\phi = 2\,n\prod$

(ii)For destructive interference:

Cos (Φ/2) = 0 or Φ/2 = (2n-1) π/2 Φ = (2n-1) π

3 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 light beam, λ = 500 nm = 500 × 10 -9 m

Distance of the screen from the slit, D = 1 m

For first minima, n = 1

Distance between the slits = d

Distance of the first minimum from the centre of the screen can be obtained as:

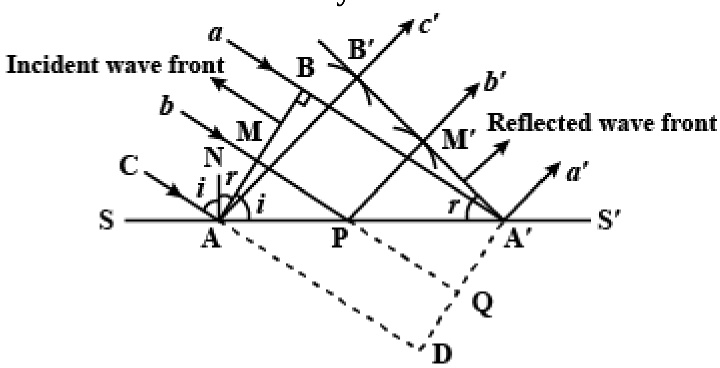
x = 2.5 mm = 2.5 × 10 -3 m

It is related to the order of minima as: d = nλD/ = 1x500x10-9x1 / 2.5x10-3 = 2x10-4 = 0.2 mm

Therefore, the width of the slit is 0.2 mm

4 A plane wavefront is incident at an angle of incidence i on a reflecting surface. Draw a diagram showing incident wavefront, reflected wavefront and verify the laws of reflection.

Ans: AB′ =BA′ =AD = vt,



By the time incident wave front strike A', the reflected ray has already covered a distance AB' in the medium.

AB′ =A′B = vt

From triangle ABA' and A'B'A

∠B=∠B′=90°

A'A common AB′ =A′B =vt

Therefore, the two triangles are congruent

∴ ∠BAA′=∠B′A′A′

or ∠i=∠r

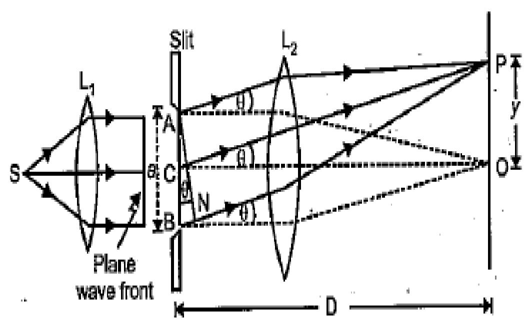
that is, the angle of incidence is equal to the angle of reflection. This is the second law of reflection. Since AB, A'S' and SS' are in the plane of the paper, they will also be in the same plane. Therefore, the incidence ray, the reflected ray and the normal at the point of incidence are all in the same plane. This is the first law of reflection.

LONG ANSWER TYPE-2 QUESTIONS (5 MARKS)

1 (a)Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence obtain the conditions for the angular width of secondary maxima and secondary minima.

b) Two wavelengths of sodium light 590nm and 596nm are used in turn to study the diffraction taking place at a single slit of aperture 2×10^{-6} m . The distance between the slit and the screen is 1.5m . Calculate the separation between the positions of the first maxima and the diffraction pattern obtained in the two cases.

Ans: A) The phenomenon of diffraction of light around the sharp corners of an obstacle and spreading into the regions of geometrical shadow is called diffraction.



From the diagram, approximate path difference is given by:

BN=AB sin(θ)=a sin(θ)

For BN=n λ, constructive interference occurs

Hence, nλ/a =sin(θn)

This is the nth bright fringe.

$\tan\theta n = y_n /D$,

For small θn,

Sinθn ≈ tanθn $Y_n = n\lambda D/a$
Width of the secondary maximum,
$\beta = Y_n - Y_{n-1} = \lambda D/a$ Following same lines, width of secondary minimum comes out to be the same.
(b)For first maximum, $y_1 = \lambda D/a$ For 590 nm,
$y_{1,590} = 590\times10^{-9}\times1.5/2\times10^{-6}$ $y_{1,590} = 0.4425m$
For 596 nm, $y_{1,596} = 596\times10^{-9}\times1.5/2\times10^{-6}$ $y_{1,596} = 0.447m$
Separation is $y_{1,596} - y_{1,590} = 0.0045m$

IMPORTANT NUMERICALS

1 Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (a) reflected, and (b) refracted light? Refractive index of water is 1.33.

Ans: (a) In the process of reflection wavelength, frequency and speed of incident light remain unchanged. So, speed of reflected light = speed of incident light

$c = 3 \times 10^8 \text{ m s}^{-1}$

Wavelength of reflected light = wavelength of incident light

$\lambda = 589 \times 10^{-9}$ m

frequency of reflected light = frequency of incident light

$$f = \frac{c}{\lambda} = \frac{3\times10^8}{589\times10^{-9}} = 5.09\times10^{14} \text{ Hz}$$

(b) In the process of refraction wavelength and speed changes but the frequency remain the same. Speed of light in water

$$v = \frac{c}{{}^a\mu_w} = \frac{3\times10^8}{1.33} = 2.26\times10^8 \text{ m s}^{-1}$$

Wavelength of light in water

$$\lambda = \frac{v}{f} = \frac{2.26\times10^8}{5.09\times10^{14}} = 444\times10^{-9} \text{ m}$$

or $\lambda = 444$ nm.

2 In Young's double-slit experiment using monochromatic light of wavelength X, the intensity of light at a point on the screen where path difference is X, is K units. What is the intensity of light at a point where path difference is λ/3?

Ans: In Young's double-slit experiment net intensity of light at a point on screen is

$$I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

For $I_1 = I_2 = I$, $I_{net} = 2I + 2I\cos\phi$

Relation between path difference and phase difference is $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

For path difference λ, phase difference,

$$\Delta\phi = \frac{2\pi}{\lambda}\lambda = 2\pi$$

$$I_{net} = K = 2I + 2I\cos 2\pi \quad \text{or} \quad K = 4I \quad ...(i)$$

For a path difference λ/3, phase difference

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$

$$\Delta\phi = \frac{2\pi}{\lambda}\left(\frac{\lambda}{3}\right) = \frac{2\pi}{3}$$

Now the intensity, $I_{net} = 2I + 2I\cos\frac{2\pi}{3}$

$$I_{net} = 2I - 2I\sin 30°$$

$$I_{net} = I = \frac{K}{4}$$

CHAPTER 11
DUAL NATURE OF MATTER AND RADIATION

1. Photoelectric Effect The phenomenon of emission of photoelectron from the surface of metal, when a light beam of suitable frequency is incident on it, is called photoelectric effect. The emitted electrons are called photoelectrons and the current so produced is called photoelectric current.

Hertz' Observation The phenomenon of photo electric emission was discovered in 1887 by Heinrich Hertz during his electromagnetic wave experiment. In his experimental investigation on the production of electromagnetic waves by means of spark across the detector loop were enhanced when the emitter plate was illuminated by ultraviolet light from an arc lamp.

Lenard's Observation Lenard observed that when ultraviolet radiation were allowed to fall on emitter plate of an evacuated glass tube enclosing two electrodes, current flows. As soon as, the ultraviolet radiations were stopped, the current flows also stopped. These observations indicate that when ultraviolet radiations fall on the emitter plate, electrons are ejected from it which are attracted towards the positive plate by the electric field.

2. Terms Related to Photoelectric Effects:

There are many terms related to photoelectric effects which are of follow:

(i) Free Electrons In metals, the electrons in the outer shells (valence electrons) are loosely bound to the atoms, hence they are free to move easily within the metal surface but cannot leave the metal surface. Such electrons are called free electrons.

(ii) Electron Emission The phenomenon of emission of electrons from the surface of a metal is called electron emission.

(iii) Photoelectric Emission It is the phenomenon of emission of electrons from the surface of metal when light radiations of suitable frequency fall on it.

(iv) Work Function The minimum amount of energy required to just eject an electron from the outer most surface of metal is known as work function of the metal.

Also, work function $W = h\nu_0 = \frac{hc}{\lambda_0}$

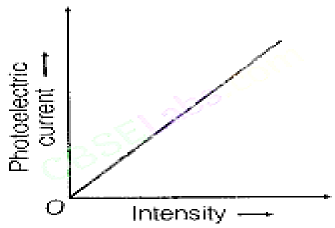
where, ν_0 and λ_0 are the threshold frequency and threshold wavelength, respectively.

(v) Cut-off Potential For a particular frequency of incident radiation, the minimum negative (retarding) potential V_0 given to plate for which the photoelectric current becomes zero, is called cut-off or stopping potential.

$$KE_{max} = eV_0 \Rightarrow \frac{1}{2} mv_{max}^2 = eV_0$$

(vi) Cut-off Frequency The minimum frequency of light which can emit photoelectrons from a material is called threshold frequency or cut-off frequency of that material.

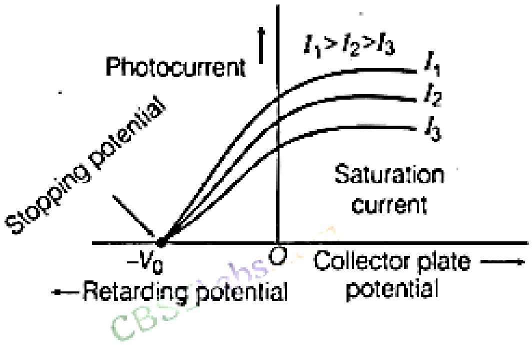
(vii) Cut-off Wavelength The maximum wavelength of light which can emit photoelectrons from a material is called threshold wavelength or cut-off wavelength of that material.



3. Effect of Intensity of Light on Photo current For a fixed frequency of incident radiation, the photoelectric current increases linearly with increase in intensity of incident light.

4. Effect of Potential on Photoelectric Current For a fixed frequency and intensity of incident light, the photoelectric current increases with increase in the potential applied to the collector.

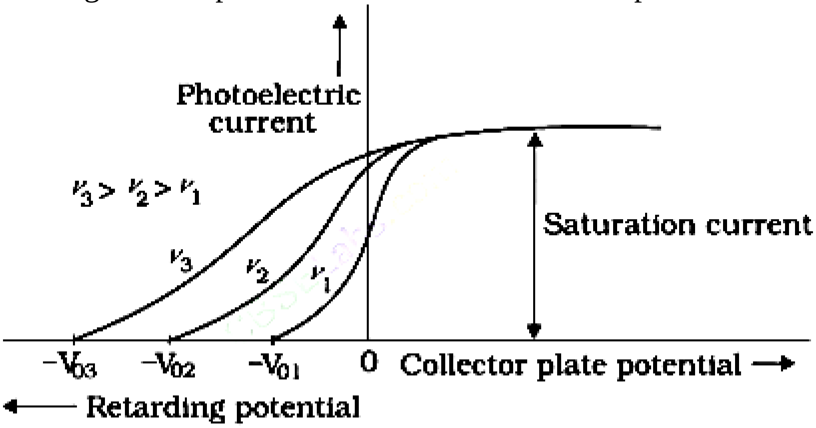
When all the photoelectrons reach the plate A, current becomes maximum it is known as saturation current.



NOTE Photoelectric current is zero whenever no electron even the fastest photoelectrons cannot reach the plate *A*. Hence, Maximum kinetic energy is given as $K_{max} = eV_0 = \frac{1}{2} mv^2_{max}$

where, m is the mass of photoelectron and v_{max} is the maximum velocity of emitted photoelectron.

5. Effect of Frequency of Incident Radiation on Stopping Potential We take radiations of different frequencies but of same intensity. For each radiation, we study the variation of photoelectric current against the potential difference between the plates.



6. Laws of Photoelectric Emission

(i) For a given material and a given frequency of incident radiation, the photoelectric current number of photoelectrons ejected per second is directly proportional to the intensity of the incident light.

(ii) 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.

(iii) For a given material, there exists a certain minimum frequency of the incident radiation below which no emissions of photoelectrons takes place. This frequency is called threshold frequency.

Above the threshold frequency, the maximum kinetic energy of the emitted photoelectron or equivalent stopping potential is independent of intensity of incident light but depends only upon the frequency (or wavelength) of the incident light.

(iv) The photoelectric emission is an instantaneous process. The time lag between the incidence of radiations and emission of photoelectron is very small, less than even 10^{-9} s.

7. Einstein Photoelectric Equation Energy Quantum of Radiation, Kmax = hv – Φ_0 where, hv = energy of photon and Φ = work-function **NOTE:** According to Planck's quantum theory, light radiations consist of tiny packets of energy called quanta. One quantum of light radiation is called a photon which travels with the speed of light.

8. Relation between Stopping Potential (V_0) and Threshold Frequency (ν_0)

We know that $h\nu = KE_{max} + W_0$

where, W_0 = work function

$$KE_{max} = h\nu - W_0 \quad \text{also,} \quad W_0 = h\nu_0$$

$$KE_{max} = h\nu - h\nu_0 \quad \Rightarrow KE_{max} = h(\nu - \nu_0)$$

$$eV_0 = h(\nu - \nu_0) \quad \Rightarrow V_0 = \frac{h}{e}(\nu - \nu_0) \qquad [\because KE_{max} = eV_0]$$

$$\nu = \frac{c}{\lambda} \text{ and } \nu_0 = \frac{c}{\lambda_0}$$

$$V_0 = \frac{h}{e}\left[\frac{c}{\lambda} - \frac{c}{\lambda_0}\right] \Rightarrow V_0 = \left(\frac{hc}{e}\right)\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$$

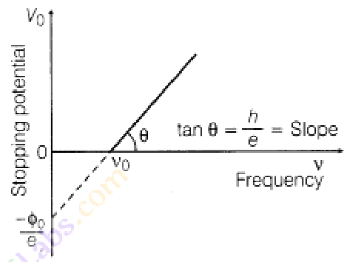
For photoelectric emission $\lambda < \lambda_0$ and $\nu > \nu_0$.

9. Important Graphs related to Photoelectric Effect

(*i*) Graph between frequency (ν) and stopping potential V_0, we know that

$$eV_0 = h\nu - \phi_0 \Rightarrow V_0 = \frac{h}{e}\nu - \frac{\phi_0}{e}$$

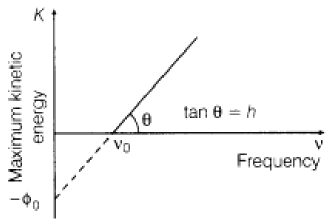
So, $V_0 \propto \nu$



(*ii*) Frequency (ν) and maximum kinetic energy graph

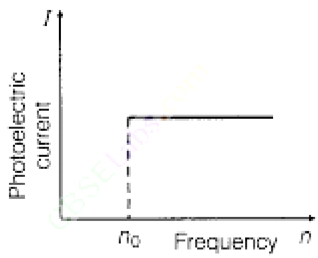
$$KE_{max} = h\nu - \phi_0$$

So, $KE_{max} \propto \nu$

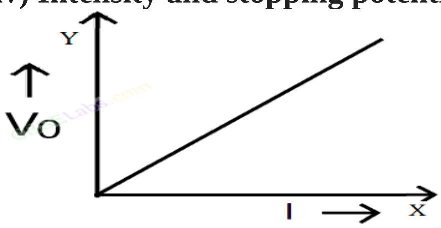


(iii) Frequency (ν) and photoelectric current (I) graph.

This graph shows that the photoelectric current (I) is independent of frequency of the incident light till intensity remains constant**.**



(iv) Intensity and stopping potential (V_0) graph



MULIPLE CHOICE QUESTIONS (1marks)

Q1. The slope of frequency of incident light and stopping potential for a given photosensitive surface will be

(a) h (b) h/e (c) eh (d) e

Q2.Photoelectric emission occurs only when the incident light has more than a certain minimum:

(a) frequency (b) power (c)wave length (d) intensity

Q3. When UV rays are incident on a metal plate, photo-electric effect does not occur. It occurs by incidence of :

(a) infrared (b) X-rays (c) radio wave (d) microwave

Q4. The energy that should be added to an electron to reduce its de Broglie wavelength from 1 nm to 0.5 nm is :

(a) four times the initial energy (b) equal to its initial energy

(c) twice the initial energy (d) thrice the initial energy

Q5. The emission of electron from a surface is possible due to

(a) Photoelectric effect (b) Thermo ionic effect (c) Both (a) and (b) (d) None of the above

Q6. The magnitude of photoelectric current depends upon:

(a) frequency (b) Intensity (c) Work function (d) Stopping potential

Q7. A photon of energy 4 eV incident on a metal surface having work function 2 eV , the minimum reverse potential to be applied to stop the emission of electron will be

(a) 8 V (b) 6 V (c) 4 V (d) 2 V

Q8. The De-Broglie wavelength associated with a tennis ball of mass 60 gram moving with a velocity 10 m/sec will be (h= 6.6 x 10^{-34} Js

(a) 10^{-16} m (b) 10^{-25} m (c) 10^{-33} m (d) 10^{-34} m

Q9. (De-Broglie wavelength λ associated with neutron is related with absolute temperature T is :

(A) $\lambda \propto T$ (B) $\lambda \propto 1/T$ (C) $\lambda \propto 1/\sqrt{T}$ (D) $\lambda \propto \sqrt{T}$

Q10. If the kinetic energy of a free electron doubles its de-Broglie wavelength changes by the factor:

(A) ½ (B) 2 (C) $1/\sqrt{2}$ (D) $\sqrt{2}$

Ans: 1-b 2-a 3- b 4-d 5-c 6-b 7-d 8-c 9-c 10-c

ASSERTION- REASON QUESTION (1 mark questions)

Choose the correct options as:

(A) Both Assertion and reason are true and reason is correct explanation of assertion.

(B) Assertion and reason both are true but reason is not correct explanation of assertion.

(C) Assertion is true, reason is false.

(D) Assertion is false, reason is true.

Q1. **Assertion:** The de Broglie wavelength of a molecule varies inversely as the square root of temperature. **Reason**. The root mean square velocity of the molecule depends on the temperature.

Q2. Assertion (A): A very intense beam of light having frequency less than the threshold frequency does not cause photoelectric emission

Reason (R) : Photoelectric emission is only possible with if the frequency of incident radiation is greater than the threshold frequency.

Q3 Assertion (A): Work function is the part of energy required by an electron to cross the surface barrier so that it may come out of the surface

Reason (R): The work function depends on the intensity of incident radiation of the source.

Q4 Assertion: If the maximum kinetic energy of electrons emitted by a photo cell is 5 eV, then the stopping potential is 5 V. **Reason**: Stopping potential for fastest photoelectrons is numerically equal to their kinetic energy.

Q5 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 : 1- B 2- A 3 -B 4 – A 5-C

CASE STUDY BASED QUESTIONS

Q1 Lenard observed that when ultraviolet radiations were allowed to fall on the emitter plate of an evacuated glass tube, enclosing two electrodes (metal plates), current started flowing in the circuit connecting the plates. As soon as the ultraviolet radiations were stopped, the current flow also stopped. These observations proved that it was ultraviolet radiations, falling on the emitter plate, that ejected some charged particles from the emitter and the positive plate attracted them.

i) Alkali metals like Li, Na, K and Cs show photo electric effect with visible light but metals like Zn, Cd and Mg respond to ultraviolet light. Why?

Ans :. Frequency of visible light is less than that for ultraviolet light

ii) Why do we not observe the phenomenon of photoelectric effect with non-metals?

Ans : For non-metals the work function is high

iii) What is the effect of increase in intensity on photoelectric current?

Ans: Photoelectric current increases

iv) Name one factor on which the stopping potential depends

Ans:. Frequency

v) How does the maximum K.E of the electrons emitted vary with the work function of metal?

Ans : It decreases as the work function increases

Q2. According to de-Broglie a moving material particle sometimes acts as a wave and sometimes as a particle or a wave is associated with moving material particle which controls the particle in every respect. The wave associated with moving material particle is called matter wave or de-Broglie wave whose wavelength called de-Broglie wavelength, is given by $\lambda = h/mv$

(i) The dual nature of light is exhibited by

Ans: diffraction and photo electric effect

ii) If the momentum of a particle is doubled, then its de-Broglie wavelength will

Ans: become half

iii) If an electron and proton are propagating in the form of waves having the same λ , it implies that they have the same

Ans : Momentum

iv) Velocity of a body of mass m, having de-Broglie wavelength λ , is given by relation

Ans : $v = h/ \lambda m$

v) Moving with the same velocity, which of the following has the longest de Broglie wavelength?

Ans : β -particle

SA- I (2 marks question)

1. It is difficult to remove a free electron from copper than from sodium? Why?

Ans. Since work function = $\frac{hc}{\lambda}$ Where λ is the threshold wavelength

Since,work function for copper is greater and it becomes difficult to remove a free electron from copper

2. Is photoelectric emission possible at all frequencies? Give reason for your answer?

Ans .No, photoelectric emission is not possible at all frequencies because it is possible only if radiation energy is greater than work function of the emitter.

3. An □-particle and a proton are accelerated from rest by the same potential. Find the ratio of their de-Broglie wavelengths

Ans.

4. Assume that the frequency of the radiation incident on a metal plate is greater than its threshold frequency. How will the following change, if the incident radiation is doubled? (1) Kinetic energy of electrons (2) Photoelectric current

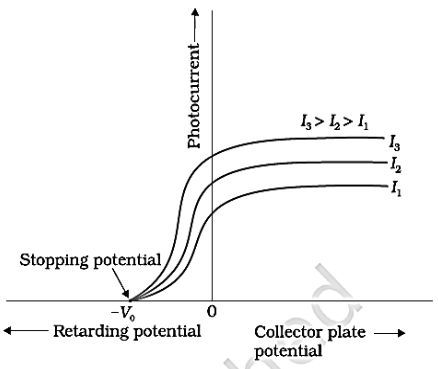
Ans.(1) If the frequency of the incident radiation is doubled is increased, hence kinetic energy is increased. (2) If the frequency of the incident radiation is doubled there will be no change in the number of photoectrons i.e. photoelectronic current.

5. Why are de – broglie waves associated with a moving football is not visible?

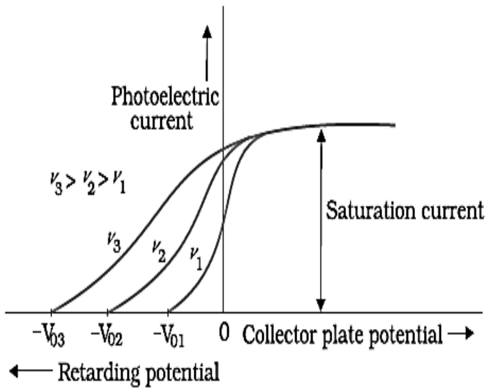
Ans. de – Broglie wave length $\lambda = h / mv$ As momentum of mass is much more. The wavelength of a wave associated with a moving football will be extremely small, which cannot be detected.

6.Draw suitable graphs to show the variation of photoelectric current with collector plate potential for (i) a fixed frequency but different intensities I1>I2>I3. (ii) a fixed intensity but different frequencies ν1>ν2> ν3.

Ans :



(ii)



7. State three important properties of photons which describe the particle picture of electromagnetic radiation.

Ans : Photons : According to Planck's quantum theory of radiation, an electromagnetic wave travels in the form of discrete packets of energy called quanta.

The main features of photons are as given(i) In the interaction of photons with free electrons, the entire energy of photon is absorbed. (ii) Energy of photon is directly proportional to frequency. Intensity of incident radiation depends on the number of photons falling per unit area per unit time for a given frequency. (iii) In photon electron collision, the total energy and momentum remain constant.

Einstein's photoelectric equation is $K\text{max} = h\,u - \phi o$

8. A metallic surface is irradiated with monochromatic light of variable wavelength. Above a wavelength of 5000 Å, no photoelectrons are emitted from the surface. With an unknown wavelength, stopping potential is 3 V. Find the unknown wavelength.

Ans : According to question, λth = 5000 Å and Vs = 3V.

Using equation of photoelectric equation,

$K\text{max} = E - W$ ($K\text{max} = eVs$) 3eV = 12400/λ - 12400/5000

= 12400/λ - 2.8 eV λ = 2262 Å

9.In case of photoelectric effect experiment, explainthe following facts, giving reasons.

(a) The wave theory of light could not explain the existence of the threshold frequency.

(b) The photo electric current increases with increase in the intensity of incident light.

Ans. (a) Since energy of the wave is dependent on the square of its amplitude, the classical wave theory predicts that if sufficiently intense light is incident, the electrons would absorb that energy to escape. There should not be any threshold frequency for
the emission of electrons from metal's surface due to incident light.
(b) According to classical wave theory, if intensity of light increases, the kinetic energy of an ejected electron will increase. This is because the greater the intensity of light, the larger the energy of the light wave striking the metal surface, so electrons are ejected with greater kinetic energy. However, it cannot explain the increase of number of ejected electrons *i.e*. the increase of photoelectric current, with the increase in intensity of incident light.

10.Assume that the frequency of the radiation incident on a metal plate is greater than its threshold frequency. How will the following change, if the incident radiation is doubled? (1) Kinetic energy of electrons (2) Photoelectric current

Ans.(1) If the frequency of the incident radiation is doubled is increased, hence
kinetic energy is increased. (2) If the frequency of the incident radiation is doubled there will be no change in the number of photoectrons i.e. photoelectronic current.

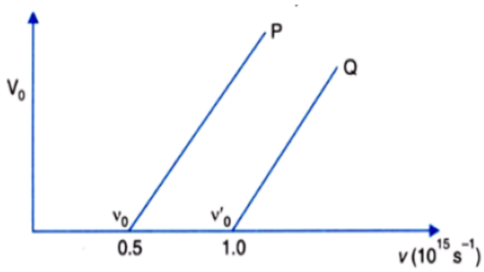
Short Answer -II (3 marks)

Q1. State the main implications of observations obtained from various photoelectric experiments. Can these implications be explained by wave nature of light? Justify your answer.

Ans. Main implications:
Kinetic energy of emitted electrons depends upon frequency, but not on intensity of radiation. There exist a frequency of radiation below which no photoemission takes place, how high intensity of radiation may be.
Explanation: wave nature of radiation fails to explain photoelectric effect.

Q2. A beam of monochromatic radiation is incident on a photosensitive Surface. Answer the following questions giving reasons.
a. Do the emitted photoelectrons have the same kinetic energy? b. Does the kinetic energy of the emitted electrons depend on the intensity of incident radiation? c. On what factors does the number of emitted photoelectrons depend?

Q3. .The following graph shows the variation of stopping potential V_0 with the frequency v of the incident ıdiation for two photosensitive metals X and Y



Which of the metals has larger threshold wavelength? Give reason.

. Explain, giving reason, which metal gives out electrons, having larger kinetic energy, for the same ıavelength of the incident radiation.

i. If the distance between the light source and metal X is halved, how will the kinetic energy of electrons ımitted from it change? Give reason.

Long Answer Questions (5 marks)

Q1. Draw properly labelled graphs to show the following concerning photo electric emission:
(i) Variation of photo electric current with the intensity of incident radiation.
(ii) Variation of photo electric current with accelerating and stopping potential.
(iii) Variation of stopping potential with frequency of incident radiation.

From the graph how the following can be determined.
1) Plank's constant. 2) The work function of the material.
Q2. Obtain Einstein s photo- electric equation. Explain how it enables us to understand the (i) Independence of maximum energy of the emitted photo electrons from the intensity of incident light (ii) Linear dependence of the maximum energy of the emitted electrons on the frequency of the incident radiation . (iii) The existence of threshold frequency for a given photo emitter.
Q3. Derive the expression for the de Broglie wavelength of an electron moving under a potential difference of V volts . A deuteron and an alpha particle are accelerated through the same accelerating potential .Which one of the two has; (i) greater value of de Broglie wavelength (ii) Less kinetic energy? Explain.

Numerical (3marks)

Q1. The work function of Caesium metal is 2.14eV. When light of frequency 6 x 10^{14} Hz is incident on the metal surface photoemission of electrons occurs.
a. What is the maximum kinetic energy of the emitted b. stopping potential cmaximum speed of the emitted photoelectrons

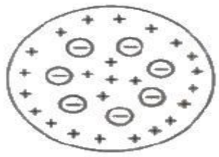
Ans: 1. Kmax = hv – ϕ_0 = (6.63×10^{-34} x 6 $\times10^{14}$ / 1.6×10^{-19}) – 2.14eV = 0.314 eV
ii) eV_o = Kmax = 0.314eV V_0 = 0.314V
iii) V_{max} = 345.8 X 10^3 m/s
Q2. Monochromatic radiation of wavelength 640.2nmfrom a neon lamp irradiates a photosensitive metal made of tungsten. The stopping potential is measured to be 0.54 V. The source is replaced by an iron source which emits radiation of wavelength 427.2nm which irradiates at the same potential. Calculate the stopping potential.
Ans: Use Einstein equation
eVo = hc/λ – Φo
For neon lamp eVo1= hc/λ1– Φo
for iron source eVo2=hc/λ2–Φo
then, V02 – V01 =hc/e [1/ λ1- 1/ λ2}
Place values and solve = 0.97 V
V02=V01+ 0.97 = 0.54V + 0.97V
=1.51V
Q3. Light of wavelength 2000 A0 falls on an aluminum surface. In aluminum 4.2 eV are required to remove an electron. What is the kinetic energy of (a) fastest (b) the slowest photoelectron?
Ans: Given wavelength is λ = 2000A0 = 2×10-7 m Φ0= 4.2eV.
The kinetic energy is K.E max = 1/2mv2 max
= hv−½ mV2 max= hc/λ−ϕ0
= (6.6×10−34×3×108 /2×10−7)−4.2 ½ mV2 max = 2eV
This is the K.E of the fastest electron is 2eV The velocity of the slowest electron would be zero, hence the kinetic energy it possesses is also zero.
Q4. An electron and a photon each have a wavelength 10^{-9} m. Find (i) Their momenta (ii) The energy of the photon and (iii) The kinetic energy of electron.
Ans ; p= h/λ = 6.63x10-25 m (ii) E= hc/λ= 1243 eV (iii) E= p2/2m= 1.52 eV.
Q5. The work function for a certain metal is 4.2 eV. Will this metal give photoelectric emission for incident radiation of wavelength 330 nm?
Ans : E = hc/λ =6.6×10--34×3×108/ 330 x10-9
= 3.767eV
But ϕ0 = 4.2eV since E < W0 , no photoelectric emission.

CHAPTER 12

ATOMS

SUMMARY POINTS

Thomson's Atomic Model

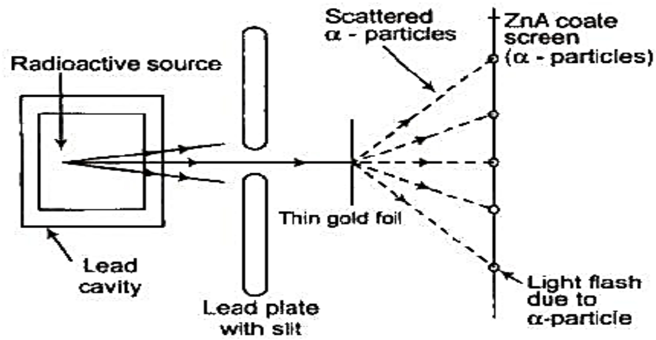


Every atom is uniformly positive charged sphere of radius of the order of 10^{-10} m, in which entire mass is uniformly distributed and negative charged electrons are embedded randomly. The atom as a whole is neutral.

Limitations of Thomson's Atomic Model

1. It could not explain the origin of spectral series of hydrogen and other atoms.
2. It could not explain large angle scattering of α – particles.

Rutherford's Atomic Model



On the basis of this experiment, Rutherford made following observations

(i) The entire positive charge and almost entire mass of the atom is concentrated at its centre in a very tiny region of the order of 10^{-15} m, called nucleus.

(ii) The negatively charged electrons revolve around the nucleus in different orbits.

(iii) The total positive charge 011 nucleus is equal to the total negative charge on electron. Therefore atom as a overall is neutral.

(iv) The centripetal force required by electron for revolution is provided by the electrostatic force of attraction between the electrons and the nucleus.

Distance of Closest Approach

$r_o = 1 / 4\pi \varepsilon_o \cdot 2Ze^2 / E_k$ where, E_k = kinetic energy of the cc-particle.

Impact Parameter

The perpendicular distance of the velocity vector of a-particle from the central line of the nucleus, when the particle is far away from the nucleus is called impact parameter.

$$b = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze^2 \cot\left(\frac{\theta}{2}\right)}{E_k}$$

Impact parameter where, Z = atomic number of the nucleus, E_k = kinetic energy of the c-particle and θ = angle of scattering.

Rutherford's Scattering Formula

$$N(\theta) = \frac{N_i n t Z^2 e^4}{(8\pi\varepsilon_0)^2 r^2 E^2 \sin^4\left(\frac{\theta}{2}\right)}$$

where, N(θ) =number of c-particles, N_i = total number of α-particles reach the screen. n = number of atoms per unit volume in the foil, Z = atoms number, E = kinetic energy of the alpha particles and t = foil thickness

Limitations of Rutherford Atomic Model

$$N \propto \frac{1}{\sin^4\left(\frac{\theta}{2}\right)}$$

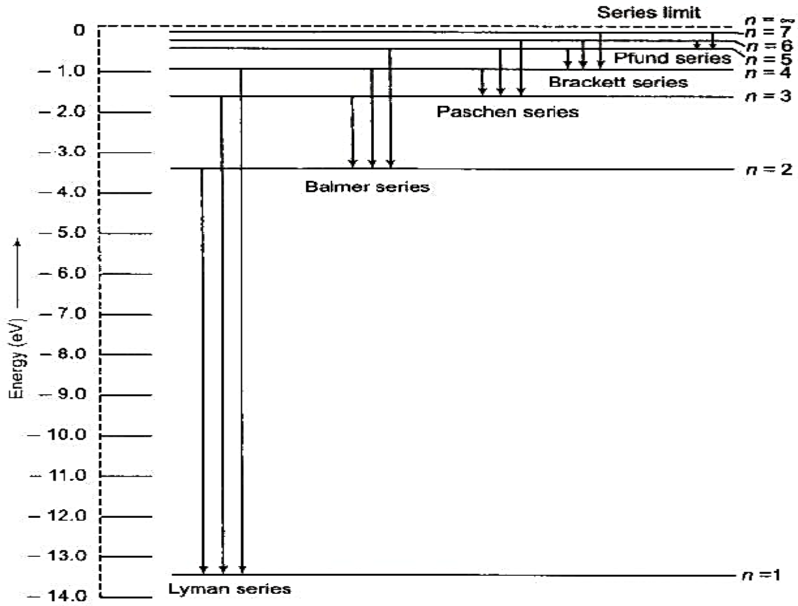
(i) **About the Stability of Atom** According to Maxwell's electromagnetic wave theory electron should emit energy in the form of electromagnetic wave during its orbital motion. Therefore. radius of orbit of electron will decrease gradually and ultimately it will fall in the nucleus. (ii) **About the Line Spectrum** Rutherford atomic model cannot explain atomic line spectrum.

Bohr's Atomic Model

Electron can revolve in certain non-radiating orbits called stationary or bits for which the angular momentum of electron is an integer multiple of (h / 2π)

$mvr = nh / 2\pi$

where n = I, 2. 3,… called principle quantum number.The radiation of energy occurs only when any electron jumps from one permitted orbit to another permitted orbit. Energy of emitted photon $hv = E_2 – E_1$ where E_1 and $E_2$are energies of electron in orbits.
Radius of orbit of electron is given by $r = n^2h^2 / 4\pi^2 mK Ze^2 \Rightarrow r \propto n^2 / Z$
where, n = principle quantum number, h = Planck's constant, m = mass of an electron, K = 1 / 4 π ε, Z = atomic number and e = electronic charge.
Velocity of electron in any orbit is given by $v = 2\pi KZe^2 / nh \Rightarrow v \propto Z / n$
Frequency of electron in any orbit is given by $v = KZe^2 / nhr = 4\pi^2Z^2e^4mK^2 / n^3 h^3$
$\Rightarrow$ v prop; Z^3 / n^3
Kinetic energy of electron in any orbit is given by $E_k = 2\pi^2me^4Z^2K^2 / n^2 h^2 = 13.6 Z^2 / n^2$ eV
Potential energy of electron in any orbit is given by $E_p = – 4\pi^2me^4Z^2K^2 / n^2 h^2 = 27.2 Z^2 / n^2$ eV $\Rightarrow E_p = \propto Z^2 / n^2$
Total energy of electron in any orbit is given by $E = – 2\pi^2me^4Z^2K^2 / n^2 h^2 = – 13.6 Z^2 / n^2$ eV $\Rightarrow E_p = \propto Z^2 / n^2$ In quantum mechanics, the energies of a system are discrete or quantized. The energy of a particle of mass m is confined to a box of length L can have discrete values of energy given by the relation $E_n = n^2 h^2 / 8mL^2$; n < 1, 2, 3,…
Hydrogen Spectrum Series
Each element emits a spectrum of radiation, which is characteristic of the element itself. The spectrum consists of a set of isolated parallel lines and is called the **line spectrum.**



Hydrogen spectrum contains five series **(i) Lyman Series When electron jumps from n = 2, 3,4, …orbit to n = 1 orbit,** then a line of Lyman series is obtained. This series lies in ultra violet region.
(**ii) Balmer Series When electron jumps from n = 3, 4, 5,… orbit to n = 2 orbit,** then a line of Balmer series is obtained. This series lies in visual region.
(iii) Paschen Series When electron jumps from n = 4, 5, 6,… orbit to n = 3 orbit, then a line of Paschen series is obtained. This series lies in infrared region
(iv) Brackett Series When electron jumps from n = 5,6, 7…. orbit to n = 4 orbit, then a line of Brackett series is obtained. This series lies in infrared region.
(v) Pfund Series When electron jumps from n = 6,7,8, … orbit to n = 5 orbit, then a line of Pfund series is obtained. This series lies in infrared region.

MULTIPLE CHOICE QUESTIONS

Q.1. Electrons in the atom are held to the nucleus by
(a) coulomb's force (b) nuclear force (c) vander waal's force (d) gravitational force
Q.2. In Rutherford's α -particle scattering experiment, what will be correct angle for α scattering for an impact parameter b = 0 ?
(a) 90º (b) 270º (c) 0º (d) 180º
Q.3. When hydrogen atom is in its first excited level, it's radius is
(a) four times, it ground state radius (b) twice times, it ground state radius
(c) same times, it ground state radius (d) half times, it ground state radius.

Q.4.The first spectral series was discovered by
(a) Balmer (b) Lyman (c) Paschen (d) Pfund
Q.5. The angular momentum of the electron in hydrogen atom in the ground state is
(a) 2h (b) h/2 (c) h/2π (d) h/4π
Q.6. In a hydrogen atom, which of the following electronic transitions would involve the maximum energy change
(a) n = 2 to n = 1 (b) n = 3 to n = 1 (c) n = 4 to n = 2 (d) n = 3 to n = 2
Q.7.A spectral line is emitted when an electron
(a) jumps from lover orbit to higher orbit. (b) jumps from higher orbit to lower orbit.
(c) rotates in a circular orbit. (d) rotates in an elliptical orbit.
Q.8.The ratio of the energies of the hydrogen atom in its first to second excited state is :
(a) ¼ (b) 4/9 (c) 9/4 (d) 4
Q.9.To explain fine structure of spectrum of hydrogen atom, we must consider.
(a) a finite size of nucleus. (b) the presence of neutrons in the nucleus.
(c) spin angular momentum. (d) orbital angular momentum..
Q.10.When an electron jumps from some outer orb it to the innermost orbit in the hydrogen atom, the spectral line belongs to
(a) Lyman series (b) Balmer series (c) Paschen series (d) Pfund series

ASSERTION REASON QUESTIONS

Two statements are given – one labelled Assertion (A) and other labelled as Reason (R). Select the correct answer to these questions from the codes (A),(B),(C),(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

Q.11.Assertion : The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law. **Reason :** Rutherford did α-particle scattering experiment.
Q.12.**Assertion :** In Lyman series, the ratio of minimum and maximum wavelength is 3/4
Reason : Lyman series constitute spectral lines corresponding to transition from higher energy to ground state of hydrogen atom.
Q.13. **Assertion**: Electron is revolving around the nucleus **Reason :** If the electrons were stationary they would fall into the Nucleus due to electrostatic
attraction and the atom would be unstable.
Q.14.Assertion: Most of the space in an atom is empty space **Reason :** From Rutherford's experiment , size of nucleus is 10^{-10} m and from kinetic theory, the size of atom is 10^{-15} m.
Q.15. **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.

ANSWERS :-

Q.1 (a) Q.2 (d) Q.3 (a) Q.4 (a) Q.5 (c) Q.6 (b) Q.7 (b) Q.8 (c) Q.9 (b) Q.10 (a) Q.11 (B) Q.12 (B) Q.13(A) Q.14 (A) Q.15 (A)

CASE BASED QUESTIOS(4 MARKS)

Q.1.The spectral series of hydrogen atom were accounted for by Bohr using the relation

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where, R=Rydberg constant = 1.097×10^{7} m^{-1}
Lyman series is obtained when an electron jumps to first orbit from any subsequent orbit. Similarly,
Balmer series is obtained when an electron jumps to 2^{nd} orbit from any subsequent orbit.
Paschen series is obtained when an electron jumps to 3^{rd} orbit from any subsequent orbit.

Whereas Lyman series in U.V. region, Balmer series is in visible region and Paschen series lies in infrared region. Series limit is obtained when $n_2=\infty$.

Q.1:- What is the ratio of minimum to maximum wavelength in Balmer series?

Q.2:- Which series of hydrogen spectrum can we see through naked eye?

Q.3:-What is the wavelength of first spectral line of Lyman series?

OR

What is the frequency of first spectral line of Balmer series?

Answer:-Q.1 :- 5:9 Q.2 :- Balmer Series Q.3:- By putting n_1 =1 and n_2 =2 we get wavelength = 1215.4 A^0

OR

By putting n_1=2 and n_2 =3 and using c = Frequency x wavelength , we get frequency = 4.57 x 10^{14} Hz

S.A QUESTIONS(2 MARKS EACH)

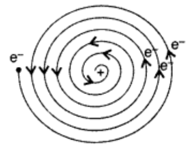
Q1:-The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of electron in this state?

Answer: Kinetic energy, K_E = + T.E. = 13.6 eV

Potential energy, P_E = 2 T.E. = 2 (-13.6) = – 27.2 Ev

Q.2.:-Why is the classical (Rutherford) model for an atom—of electron orbitting around the nucleus—not able to explain the atomic structure?

Answer:-



As the revolving electron loses energy continuously, it must spiral inwards and eventually fall into the nucleus. So it was not able to explain the atomic structure.

Q.3:- What is the maximum number of spectral lines emitted by a hydrogen atom when it is in the third excited state?

Answer: For third excited state, n_2 = 4, and n_1 = 3, 2, 1 Hence there are 3 spectral lines.

Q.4:-Define ionisation energy. What is its value for a hydrogen atom?

Answer :-Ionisation energy : The energy required to knock out an electron from an atom is called ionisation energy of the atom. For hydrogen atom it is 13.6 eV.

Q,5:-Write the expression for Bohr's radius in hydrogen atom.

Answer:-Bohr's radius in hydrogen atom,

$$r_1 = \frac{\varepsilon_0 h^2}{\pi m e^2} = \mathbf{0.5.29 \times 10^{-10}\ m}$$

Q.6.:-What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom?

Answer:

Radius of Bohr's stationary orbits, $r = \frac{n^2 h}{4\pi^2 m K e^2}$

Clearly, $r \propto n^2$ and in ground state, $n = 1$

For 1st excited state, $n = 2$

$\therefore$ Ratio of radii of the orbits $= \frac{2^2}{1^2} = \frac{4}{1} = \mathbf{4 : 1}$

Q.7.:-The radius of innermost electron orbit of a hydrogen atom is 5.3 × 10^{-11} m. What is the radius of orbit in the second excited state?

Answer:

$r = n^2 \times 5.3 \times 10^{-11}$ m

$\therefore$ Radius of second excited state ($n = 3$) is :

$r = (3)^2 \times 5.3 \times 10^{-11}$ m $= 9 \times 5.3 \times 10^{-11}$ m

$= \mathbf{4.77 \times 10^{-10}\ m}$

Q.8:-When is Ha line of the Balmer series in the emission spectrum of hydrogen atom obtained?

Answer: Balmer series is obtained when an electron jumps to the second orbit ($n_1 = 2$) from any orbit $n_2 = n > 2$

Q.9:-Find the ratio of energies of photons produced due to transition of an electron of hydrogen atom from its (i) second permitted energy level to the first level, and (ii) the highest permitted energy level to the first permitted level. (All India 2010)

Answer:

We have,

$$E_{2-1} = \text{const.} \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \text{const.}\ \frac{3}{4}$$

and $$E_{\infty \to 2} = \text{const.} \left(\frac{2}{2^2} - \frac{1}{\infty^2}\right) = \text{const.}\ \frac{1}{4}$$

$\therefore$ Ratio = **3 : 1**

Q.10:-What are the two limitations of the Rutherford model?

(i) : As the revolving e− loses energy continuously, it must spiral inwards and eventually fall into the nucleus. (ii) Rutherford could not explain why atoms emit light of only discrete wave length.

Long answer type questions (3 Marks)

Q.1:-State the basic assumptions of Rutherford model of atom. Explain in brief why this model cannot account for stability of an atom? [ANS: RF TO SUMMARY]

Q2 :- Calculate the shortest wavelength in the Balmer series of hydrogen atom. In which region (infra-red, visible, ultraviolet) of hydrogen spectrum does this wavelength lie?

Answer: In Balmer series, an electron jumps from higher orbits to the second stationary orbit ($n_f = 2$). Thus for this series :

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \text{ and in this case}$$

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_i^2}\right)$$

R (Rydberg's constant) = $1.097 \times 10^7\ m^{-1}$

For the shortest wavelength, $n_i = \infty$;

Hence, $\frac{1}{\lambda} = \frac{R}{4}$

or $\lambda = \frac{4}{R} = \frac{4}{1.097 \times 10^7}$ m

$= 3.646 \times 10^{-7}$ m = **3646 Å**

It will lie in ultra-violet region.

Q.3:- Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

Answer: When an electron moves around hydrogen nucleus, the electrostatic force between electron and hydrogen nucleus provides necessary centripetal force.

$$\frac{mv^2}{r} = \frac{1}{4\pi \epsilon_0}\frac{e^2}{r^2} \quad \text{or } mv^2r = \frac{e^2}{4\pi\epsilon_0} \quad \ldots(i)$$

Also we know from Bohr's postulate,

$$mvr = \frac{nh}{2\pi} \quad \text{or } m^2v^2r^2 = \frac{n^2h^2}{4\pi^2} \quad \ldots(ii)$$

Dividing (*ii*) by (*i*), we have

$$mr = \frac{n^2h^2}{4\pi^2} \times \frac{4\pi\epsilon_0}{e^2}$$

$$\therefore \quad r = \frac{n^2h^2}{4\pi^2 me^2}.4\pi\epsilon_0 \quad \therefore\ r \propto n^2$$

Q.4:-An α-particle moving with initial kinetic energy K towards a nucleus of atomic number z approaches a distance'd' at which it reverses its direction. Obtain the expression for the distance of closest approach'd' in terms of the kinetic energy of α-particle K.

Answer:

At the distance d, the K.E. (K) gets converted into P.E. (P) of the system.

$$\therefore \quad \text{P.E. at distance } (d) = \frac{1}{4\pi\varepsilon_0}\frac{2e \times Ze}{d}$$

$$\therefore \quad \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{d} = \text{K}$$

$$\therefore \quad d = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{\text{K}}$$

Q.5:- Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?

Answer: Expression for total energy of electron in H-atom using Rutherford model : As per Rutherford model of atom, centripetal force (F_c) required to keep electron revolving in orbit is provided by the electrostatic force (Fe) of attraction between the revolving electron and nucleus.

The negative sign indicates that the revolving electron is bound to the positive nucleus.

$$F_c = F_e$$

$$\frac{mv^2}{r} = \frac{ee}{4\pi\varepsilon_0 r^2} \quad \ldots(i)$$

$$r = \frac{e^2}{4\pi\varepsilon_0 mv^2} \quad \ldots(ii)$$

$$\text{From equation } (i), \text{ KE} = \frac{1}{2}mv^2 = \frac{e^2}{8\pi\varepsilon_0 r} \quad \ldots(iii)$$

$$\text{PE} = \frac{e(-e)}{4\pi\varepsilon_0 r} = \frac{-e^2}{4\pi\varepsilon_0 r}$$

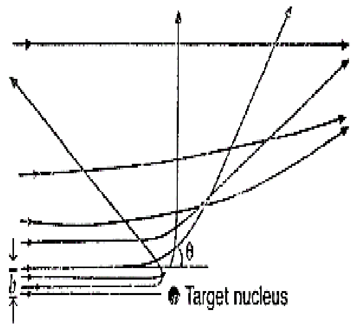
$$\therefore \quad \text{TE} = \text{KE} + \text{PE} = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r} = \frac{-e^2}{8\pi\varepsilon_0 r}$$

LONG ANSWER TYPE QUESTIONS II (5 Marks)

Q.1:-(a) Draw the trajectory of the a-particle in the coulomb field of a nucleus. What is the significance of impact parameter and what information can be obtained regarding the size of the nucleus? (b) Estimate the distance of closest approach to the nucleus (Z = 80) if a 7.7 MeV a-particle before it comes momentarily to rest and reverses its direction.

Answer:-

Trajectory of α-particles It gives an estimate of the size of nucleus, that it relatively very very small as compared to the size of atom (b) K.E. of the a-particle = Potential energy possessed by beam at distance of closest approach.



$$\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{(2e)(Ze)}{r_0}$$

$$7.7 \times (1.6 \times 10^{-13}) = \frac{(9 \times 10^9) \times 2 \times (1.6 \times 10^{-19})^2 \times 80}{r_0}$$

$$r_0 = \frac{9 \times 10^9 \times 2 \times 2.56 \times 10^{-38} \times 80}{7.7 \times 1.6 \times 10^{-13}} \text{ m}$$

$$= 299 \times 10^{-16} \text{ m}$$

$$= 29.9 \times 10^{-15} \text{ m} \approx 30 \times 10^{-15} \text{ m}$$

Q.2:- (a) Write two important limitations of Rutherford model which could not explain the observed features of atomic spectra. How were these explained in Bohr's model of hydrogen atom? Use the Rydberg formula to calculate the wavelength of the H_α line. (Take R = 1.1 × 10^7 m^{-1}). (b) Using Bohr's postulates, obtain the expression for the radius of the n^{th} orbit in hydrogen atom.

Answer: (a) Limitations of Rutherford Model : (i) Electrons moving in a circular orbit around the nucleus would get, accelerated, therefore it would spiral into the nucleus, as it looses its energy. (ii) It must emit a continuous spectrum.

Explanation according to Bohr's model of hydrogen atom :

(i) Electron in an atom can revolve in certain stable orbits without the emission of radiant energy. (ii) Energy is released/absorbed only, when an electron jumps from one stable orbit to another stable orbit. This results in a discrete spectrum. Wavelength of H_α line :

H_α line is formed when an electron jumps from n_f = 3 to n_i = 2 orbit. It is the Balmer series

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\frac{1}{\lambda} = 1.1 \times 10^7 \left(\frac{1}{4} - \frac{1}{9}\right) \text{ or } \lambda = 656.3 \text{ nm}$$

(b) Radius of n^{th} orbit

We have, $\frac{mv^2}{r_n} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{e^2}{{r_n}^2}$

$$\Rightarrow \quad r_n = \frac{e^2}{4\pi\varepsilon_0 {v_n}^2} \quad \ldots(i)$$

From Bohr's Postulates:

$$mv_n r_n = \frac{nh}{2\pi}, \quad v_n = \frac{nh}{2\pi m r_n}$$

Substituting for v_n, in equation (*i*), we get

$$r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2}$$

NUMERICAL(3 Marks)

Q.1:- (i) A hydrogen atom initially in the ground state absorbs a photon which excites it to the n- 4 level. Determine the wavelength of the photon.

(ii) The radius of innermost electron orbit of a hydrogen atom is 5.3 × 10^{-11}m. Determine its radius in n = 4 orbit.

Answer:

(*i*) Energy of the ground state = −13.6 eV

Energy of (n = 4) state = $\frac{E_0}{n^2} = \frac{E_0}{(4)^2} = \frac{-13.6}{16}$ eV

∴ Energy of the photon absorbed

$= \left(\frac{-13.6}{16} - (-13.6)\right) = \left(\frac{-13.6}{16} + 13.6\right)$ eV

$= \frac{15}{16} \times 13.6$ eV = 12.75 eV

= 12.75 × (1.6 × 10^{-19}) J

∴ $E = \frac{hc}{\lambda} = 12.75 \times 1.6 \times 10^{-19}$

$\Rightarrow \lambda = \frac{hc}{12.75 \times 1.6 \times 10^{-19}}$

∴ $\lambda = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{12.75 \times (1.6 \times 10^{-19})}$

$= \frac{19.89}{20.400} \times 10^{-7}$ m

= 0.97 × 10^{-7} m = **970 Å** or **97 nm**

(*ii*) Radius of (n = 4) orbit = $(4)^2 \times (5.3 \times 10^{-11})$ m

= **8.48 Å**

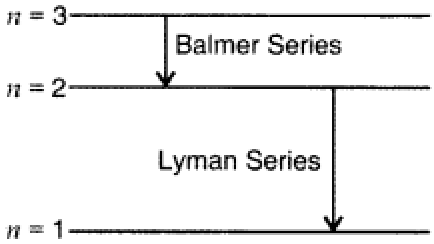
Q.2:- (i) In hydrogen atom, an electron undergoes transition from 2nd excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong.(ii) Find out the ratio of the

wavelengths of the emitted radiations in the two cases.

Answer:

(*i*) $n_f = 2, \quad n_i = 3 \quad$ *Balmer series*

$n_i = 2, \quad n_f = 1 \quad$ *Lyman series*



(*ii*) $\frac{1}{\lambda_B} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5}{36}R$

...where λ_B **is the wavelength for Balmer series.**
λ_L **is the wavelength for Lyman series.**

Q.3:- (i) In hydrogen atom, an electron undergoes transition from third excited state to the second excited state and then to the first excited state. Identify the spectral series to which these transitions belong.(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

Answer:

(*i*) These transitions belong to :

1. *Paschen series,* 2. *Balmer series*

(*ii*) $$\frac{1}{\lambda_P} = R\left[\frac{1}{9} - \frac{1}{16}\right] = R\left[\frac{16-9}{144}\right] = \frac{7}{144}R$$

$$\frac{1}{\lambda_B} = R\left[\frac{1}{4} - \frac{1}{9}\right] = R\left[\frac{9-4}{36}\right] = \frac{5}{36}R$$

$$\therefore \quad \frac{\lambda_P}{\lambda_B} = \frac{144}{7} \times \frac{5}{36} = \frac{20}{7}$$

$\therefore$ ***Ratio = 20 : 7***

Q.4:-.The ground state energy of hydrogen atom is – 13.6 eV. What are the kinetic and potential energies of electron in this state?

Ans. Given, total ground state energy (TE) = (-13.6eV) . Kinetic energy = – TE = -(-13.6 eV) =13.6 eV Potential energy = 2 (TE) = 2 x(-13.6) = -27.2 eV

Q.5:-..Find the ratio of energies of photons produced due to transition of an electron of hydrogen atom from its second permitted energy level to the first permitted level and the highest permitted energy level to the first permitted level.

Ans.

(*i*) Since, the second permitted energy level to the first level $= E_2 - E_1 =$ energy of photon released $= (-3.4 \text{ eV}) - (-13.6 \text{ eV}) = 10.2 \text{ eV}$

(*ii*) The highest permitted energy level to the first permitted level

$= E_\infty - E_1 = 0 - (-13.6) = 13.6 \text{ eV}$

$\therefore$ Ratio of energies of photon

$$= \frac{10.2}{13.6} = \frac{3}{4} = 3 : 4 \qquad \textbf{(1)}$$

CHAPTER:13
NUCLEI

SUMMARY:

Nucleus: The small, dense region consisting of protons and neutrons at the center of an atom is the atomic 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.

Nucleons: The nucleus of an atom consists of protons and neutrons. They are collectively called nucleons.

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 (126C) atom.

1 amu or 1 u=1.660539 x10-27 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.

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)

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

$\frac{4}{3\pi R^3} \propto A$ $\quad R \propto A^{1/3}$ $\quad R=R_0 A^{1/3}$

Where, R0= $1.2\text{x}10^{-15}$ 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.

$\rho=m/(4/3\pi R0^3)$ => $\rho = 2.38\text{x}10^{17}\text{kg/m}^3$ where, m = average mass of one nucleon and R_0=1.2 fm = $1.2\text{x}10^{-15}$**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 actualmass 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 oneneutron and M= mass of nucleus.

Mass-Energy Relation Einstein's mass-energy equivalence equation is given by $E = mc^2$, (where E is the energy and c is the speed of light =$3\text{x}10^8$ m/s and m = mass of nucleus)

Nuclear Forces Short ranged (2-3 fm) strong attractive forces which hold protons and neutrons together inagainst of coulombian repulsive forces between positively charged particle is called nuclearforce. 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 individualmasses 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 nearlyequal masses is known as nuclear fission, e.g.

$${}_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\ {}_{0}n^{1} + Q$$

Nuclear Fusion

The phenomenon of fusing or combining of two lighter nuclei into a single heavy nucleus is called nuclear fusion, e.g.

$${}_{1}H^{1} + {}_{1}H^{1} \rightarrow {}_{1}H^{2} + e^{1} + v + 0.42\ MeV$$

[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 $\Delta E = [Zm_p + (A-Z)m_n - M]c^2$

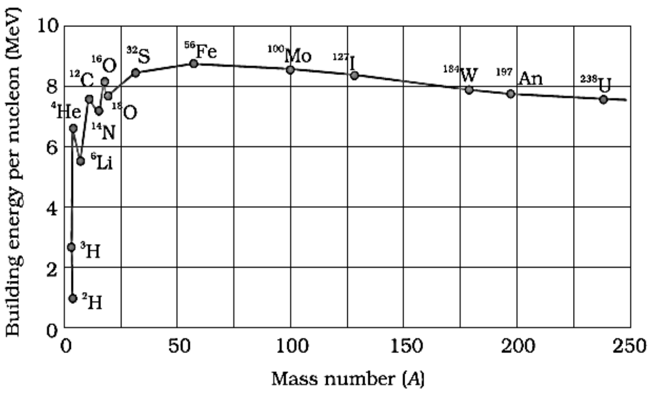
Average Binding Energy Per Nucleon of a Nucleus

It is the average energy required to extract a nucleon from the nucleus to infinite distance. Itis given by total binding energy divided by the mass number of the nucleus.

Binding energy per nucleon = $\frac{Total\ binding\ energy}{mass\ number}$

Binding energy curve:

It is a plot of the binding energy per nucleon versus the mass number A for a large numberof nuclei as shown below:



The binding energy per nucleon as a function of mass number.

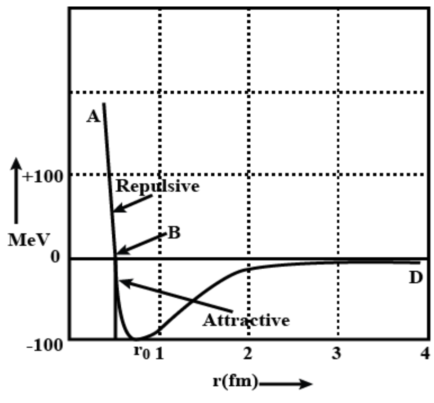
Binding energy per nucleon as a function of mass number :It is used to explain phenomena of nuclear fission and fusion.

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.

LONG ANSWER TYPE I (3 MARKS)

1.Draw a graph showing the variations of potential energy between a pair of nucleons as a function of their separation. Indicate the regions in which the nuclear force is (i)attractive (ii) repulsive. Writes two important conclusions which you can draw regarding the nature of the Nuclear Forces.



Conclusion:

The potential energy is minimum at a distance r_0 of about 0.8fm Nuclear force is attractive for distance larger than r_0. Nuclear force is repulsive if two are separated by distance less than r_0

2. How does the size of a nucleus depend on its mass number? Hence Explain why the density of nuclear matter should be independent of the size of the nucleus.

Answer: The radius of a nucleus having mass number A is $R = R_0 (A)^{1/3}$

R_0 is constant.

Volume of the nucleus $\frac{4}{3}\pi R^3 = \frac{4}{3}\pi(R_0\ A^{1/3})^3$

$= \frac{4}{3}\pi(R_0)^3A$

If m be the average mass of a nucleon then mass of the nucleus =mA

Nuclear density $= \frac{Mass}{Volume} = \frac{mA}{\frac{4}{3}\pi(R0)3A} = \frac{3m}{4\pi R_0^3}$

i.e., nuclear density is independent of the size of the nucleus.

3. (i)The density of the nuclear matter is tremendously larger than the physical density of the material. Explain.

(ii) The nuclear radius of $^{27}_{13}Al$ is 3.6 fermi. Find the nuclear radius of $^{64}_{29}Cu$.

Ans: (i)The nuclear density of nuclear matter is tremendously larger than the physical density of material because more than 99.9% mass of atom is concentrated in the nucleus and it is of the order of 10^{17} Kg/m^3 which is very large as compared to the density of matter, eg., the density of water is $\rho = 10^3$ Kg/m^3.

(ii) As $R = R_0 (A)^{1/3}$ $\quad \therefore \frac{R_2}{R_1} = (\frac{A_2}{A_1})^{1/3}$ $\quad$ or, $\frac{R_2}{3.6} = \left(\frac{64}{27}\right)^{1/3}$

Or, $R_2 = 3.6 \left(\frac{64}{27}\right)^{1/3} = 3.6 \text{ X } \frac{4}{3} = 4.8$ fermi.

4. Nuclear forces are not Coulomb forces between nucleons. Explaine.

OR

Write two characteristic features Of nuclear force which distinguish it from Coulomb's force.

Answer: Characteristic features of nuclear Force Nuclear forces are short range attractive forces (range 2 to 3 fm), while Coulomb's forces have range up to Infinity and may be attractive or repulsive. Nuclear forces are charge independent forces, while Coulomb's force acts only between charged particles.

5. Define Nuclear forces and gives their important characteristics/properties.

Answer: 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.

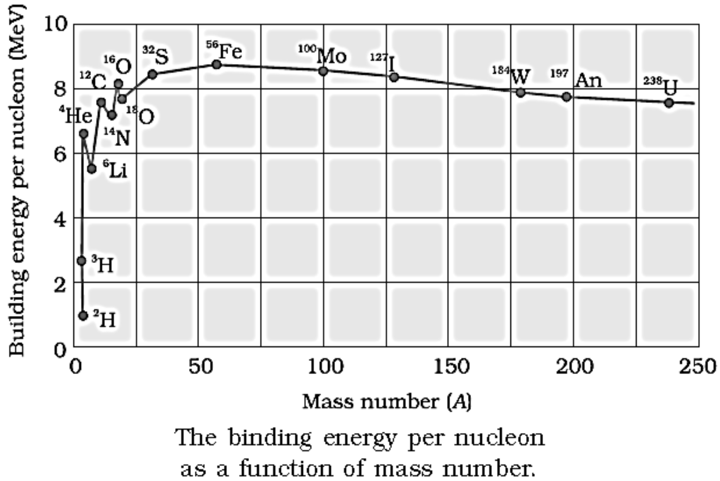
Characteristics/Properties of nuclear forces:

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

LONG ANSWER TYPE II (5 MARKS)

1. Draw the graph showing the variation of binding energy per nucleon with the mass number for a large number of nuclei 2< A < 240. What are the main interfaces from the graph? How do you explain the constancy of binding energy in the range 30 < A < 170 using the property that the nuclear force is short – ranged? Explain with the help of this plot the release of energy in the processes of nuclear fission and fusion.

Answer: The variation of binding energy per nucleon versus mass number is shown in figure:



The binding energy per nucleon as a function of mass number.

Inferences from Graph

1. The nuclei having mass number below 20 and above 180 have relatively small binding energy and hence they are unstable.
2. The nuclei having mass number 56 and about 56 have maximum binding energy - 8.8 MeV and so they are most stable.
3. Some nuclei have peaks, e.g., ${}_{2}^{4}He$, ${}_{6}^{12}C$, ${}_{8}^{16}O$; this indicates that these nuclei are relatively more stable than their neighbours.

(i) Explanation of constancy of binding energy: Nuclear force is short ranged, so every nucleon interacts with its neighbours only, therefore binding energy per nucleon remains constant

(ii) **Explanation of nuclear fission**: When a heavy nucleus ($A \geq 235\ say$) breaks into two lighter nuclei, the binding energy per nucleon increases, that is nucleons get more tightly bound. This implies that energy would be released in nuclear fission.

(iii)Explanation of nuclear fusion: When two very light nuclei ($A \leq 10$) join to form heavy nucleus, the binding energy per nucleon of fused heavier nucleus more than the binding energy per nucleon of lighter nuclei, so again energy would be released in near fusion.

2.(i) What is nuclear fission? Give one representative equation.
(ii) (a) What is nuclear fusion? Give one representative equation.
(b) State the necessary conditions for nuclear fusion to occure.

Answer:(i) The phenomenon in which a heavy nucleus(A > 230) when excited splits into two smaller nuclei of nearly comparable masses is called nuclear fission. For example, when a uranium target is bombarded by slow moving neutrons, a ${}_{92}^{235}U$ nucleus gets excited by capturing a slow moving neutron and splits into two nearly equal fragments like ${}_{56}^{141}Ba$ and ${}_{36}^{92}Kr$ along with the emission of 3 neutrons. The nuclear reaction involved can be written as

${}_{92}^{235}U + {}_{0}^{1}n \rightarrow {}_{92}^{236}U \rightarrow {}_{56}^{141}Ba + {}_{36}^{92}Kr + 3\ {}_{0}^{1}n + Q$

Fission does not always produce barium and Krypton. A number of other pairs are formed.

${}_{92}^{235}U + {}_{0}^{1}n \rightarrow {}_{92}^{236}U \rightarrow {}_{51}^{133}Sb \rightarrow {}_{41}^{99}Nb + 3\ {}_{0}^{1}n + Q$

${}_{92}^{235}U + {}_{0}^{1}n \rightarrow {}_{92}^{236}U \rightarrow {}_{54}^{140}Xe + {}_{38}^{94}Sr + 2\ {}_{0}^{1}n + Q$

(ii)(a)The phenomenon of combination of two or more light nuclei to form a heavy nucleus with release of enormous amount of energy is called the nuclear fusion.

For example, the fusion of two neutrons into a Triton takes place as follows.

${}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{1}^{3}H$ + 4.0 MeV energy

Alternatively fusion of three deuterons into an $\propto$ - particle can take place as follows

${}_{1}^{2}H + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{0}^{1}n$ + 3.3MeV energy

${}_{2}^{2}He + {}_{1}^{2}H \rightarrow {}_{2}^{3}He + {}_{1}^{1}H$ + 18.3MeV energy

(b) The necessary conditions for nuclear fusion are:

High temperature: The high temperature is necessary for the light nuclei to have sufficient kinetic energy so that they can overcome the repulsion force between them.

High density: Hight density or pressure increases the frequency of collision of light nuclei and hence increases the rate of fusion.

Numericals (3 Marks)

1.When four hydrogen nuclei combine to form a helium nucleus estimate the amount of energy in MeV released in this process of fusion. (Neglect the masses of electrons and neutrons). Given i) Mass of ${}_{1}^{1}H$ = 1.007825 u ii) Mass of helium nucleus = 4.002603 u, 1u = 931MeV / c^2

Answer: Energy released = $\Delta m\ X\ 931MeV$

Δm = 4m $({}_{1}^{1}H) - m({}_{2}^{4}He)$

Energy released (Q) = [4m $({}_{1}^{1}H) - m({}_{2}^{4}He)$] X 931MeV = [4 X 1.007825 – 4.002603] X 931MeV = 26.72MeV

2. A heavy nucleus X of mass number 240 and binding energy per nucleon 7.6 MeV is split into two fragments Y and Z of mass numbers 110 and 130. The binding energy per nucleon in Y and Z is 8.5MeV per nucleon. Calculate the energy Q released per fission in MeV.

Answer: Energy released Q = $(M_Y + M_Z) c^2 - M_X c^2$ = 8.5 (110 + 130) MeV – 7.6 X 240 MeV
= (8.5 – 7.6) X 240 MeV = 0.9 X 240 MeV = 216 MeV

3. The neutron separation energy is defined as the energy required to remove a neutron from the nucleus. Obtain the neutron separation energy of the nuclei $^{41}_{20}Ca$ and $^{27}_{13}Al$ from the following data:

m ($^{40}_{20}Ca$) = 39.962591 u m ($^{41}_{20}Ca$) = 40.962278 u m ($^{26}_{13}Al$) = 25.986895 u
m ($^{27}_{13}Al$) = 26.981541 u

Answer: When neutron is separated from $^{41}_{20}Ca$, the new formed isotope is $^{40}_{20}Ca$. The process may be expressed as $^{41}_{20}Ca \rightarrow {}^{40}_{20}Ca + {}^{1}_{0}n + Q$

Energy, Q = [m ($^{41}_{20}Ca$) – {m ($^{40}_{20}Ca$) + m_n }] X c^2
= [40.962278 u –{39.962591 u + 1.008665}] u
= [40.962278 u – 40.971256] u = -0.008978 u
= -0.008978 X 931.5 MeV = -8.363 MeV

As Q is negative, this means energy has to be supplied externally. Thus, neutron separation energy of nucleus $^{41}_{20}Ca$ = 8.363 MeV

Q = [($^{27}_{13}Al$) – { m ($^{26}_{13}Al$) + m_n }] c^2 = [26.981541 – (25.986895 + 1.008665)]
= - 0.014019 u X (931.5 MeV/ u) = -13.06 MeV

4. **Calculate the energy in fusion reaction:**
$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He$ + n, where BE of $^{2}_{1}H$ = 2.23 MeV and $^{3}_{2}He$ = 7.73 MeV

Answer: Initial binding energy
BE_1 = (2.23 + 2.23) = 4.46 MeV Final binding energy BE_2 = 7.73 MeV
∴ energy released = (7.73 – 4.46) MeV = 3.27 MeV

5. Calculate for how many years will the fusion of 2.0kg deuterium keep 800 W electric lamp glowing. Take the fusion reaction as
$^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$ + 3.27 MeV

Answer: Energy released per deuterium atom
= $\frac{3.27}{2}$ X 1.6 X 10^{-13} J

Number of atoms in 2kg of deuterium
= $\frac{6.023 \, X 10^{23} \, X \, 2000}{2}$ = 6.023 X 10^{26}

Total energy released = 6.023 X 10^{26} X $\frac{3.27}{2}$ X 1.6 X 10^{-13} J
= 15.75 X 10^{13} J

Time required = $\frac{Total\ energy}{Power\ of\ lamp} = \frac{15.75 \text{ X } 1013 \text{ J}}{800}$ = 1.97 X 10^{11} s
= $\frac{1.97 \text{ X } 1011 \text{ s}}{365 \, X \, 24 \, X \, 60 \, X \, 60}$ years = 2.28 X 10^6 years

Case Based Questions: (4 Marks)

1. 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 = Δm c^2, where c is the velocity of light in vacuum =3 x 10^8 m/s. The reverse is also true i.e. whenever energy E disappears an equivalent mass Δm = 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 x10^{-10} J b) 1.49 x10^{-7} J c) 1.49 x10^{10} J d) 1.49 x10^{-10} MJ

ii)Which of the following process releases energy?
a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None

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
iv)Which process releases energy in Atom Bomb?
a)Nuclear Fission b)Nuclear Fusion c)Both (a) and (b) d)None
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: 1(a) 2(c) 3(a) 4(a) 5(a)
2. In nuclear holocaust, nuclear Apocalypse or atomic holocaust is a theoretical scenario where the mass detonation of nuclear weapons causes globally widespread destruction and radioactive fallout. Under such scenario, large parts of the Earth are made uninhabitable by nuclear warfare, potentially causing the collapse of civilization. In a single uranium fission above 0.9 X 235 MeV (≈200 MeV) of energy is liberated. If each nucleus of about 50 Kg of ${}^{235}_{92}U$ undergoes fission, the amount of energy involved is about 4 X 10^{15} J. This energy is equivalent to about 20000 tons of TNT, enough for a super explosion. Uncontrolled release of large nuclear energy is called an atomic explosion.
i) In a nuclear reactor, moderators slow down the neutrons which comes out in a fission process. The moderator used have light nuclei. Heavy nuclei will not serve the purpose because
a) Substance with heavy nuclei do not occur in liquid or gaseous state at room temperature.
b) The net weight of the reaction would be unbearably high.
c) Elastic collision of neutrons with heavy nuclei will not slow down the neutrons.
d) They will break up.
ii) In an atomic bomb, the energy is released due to
(a) chain reaction of neutron and ${}^{240}_{92}U$ (b) Chain reaction of neutron and ${}^{238}_{92}U$
(c) Chain reaction of neutron and ${}^{236}_{92}U$ (d) Chain reaction of neutron and ${}^{235}_{92}U$
iii) Energy released in nuclear fission is due to
a) Total binding energy of fragment is more than the binding energy of parental element.
b) Total binding energy of fragment is less than the binding energy of parental element.
c)Total binding energy of fragment is equal to the binding energy of parental element
d) Some mass is converted into energy.
iv) Solar energy is mainly caused due to
(a) Gravitational contraction
(b) Fusion of proton during synthesis of heavier elements
(c)Fission of uranium parent in the sun
(d) Burning of hydrogen in the oxygen.
v) Heavy stable nuclei have more neutrons than proton. This is because of the fact that
a) Electrostatic force between protons are repulsive.
b) Neutrons decay into protons through beta decay
c) Nuclear forces between neutrons are weaker than that between protons
d) Neutrons are heavier than protons
(i) c (ii) d (iii) a (iv) b (v) a

MCQ

Q6.In nuclear reaction control rods are made of
a.cadmium b.graphyte c.kripton d. plutonium
Q7.Particles which can be added to nucleus without changing its chemical properties are called
a.neutron b.electron c.alpha particle d.proton
Q8.The neutron was discovered by
a.Marrie curie b.Piere curie c.Rutherford d.James chadwick

Q9.In nuclear reaction there is conservation of
a.Mass only b.Energy only c.Momentum only d.Mass,energy and momentum
Q10.For a nuclear fusion process ,suitable nucei are
a.Any nuclei b.Heavy nuclei c.Light nuclei d.Nclei lying in middle of periodic table

ASSERTION –REASON QUESTION DIRECTIONS:Read the following questions and choose any one of the following four responses. EACH Q OF 1 MARK
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 a correct explanation of assertion.
C.If assertion is true but reason is false.
D.If both assertion and reason is false.
Q11.ASSERTION:If a heavy nucleus is split into two medium size parts , each of new nucleus will have more binding energy per nucleon than original nucleus.
REASON: Joining two light nuclie together to give a single nucleus of medium size means more binding energy per nucleon in new nucleus.
Q12.ASSERTION: In the process of nuclear fisson,the fragment emit two or three neutron as soon as they are formed and as soon as they are formed and subsequently emit particle
REASON: As the fragments contains an excess of neutrons over protons,emission of neutrons and particles bring their neutron/proton ratio to stable values.
Q13.ASSERTION: Fragments produced in the fission of U^{235} are active.
REASON: The fragments have abnormally high proton to neutron ratio.
Q14.ASSERTION:Density of nuclear matter is same for all nuclei.
REASON:Density has nothing to do with mass and size of the nucleus.
Q15.ASSERTION:1amu=933MeV. **REASON**: It follows from $E= mc^2$

S.A. Q OF 2 MARKS

1.Draw the plot of binding energy per nucleon curve as a function of mass number.
2.write two charecteristics of nuclear forces.
3.The mass of H atom is less than masses of proton and electron.give reason.
4.Name three nuclei which lie on maxima in binding energy curve.
5.Which one is unstable among neutron,proton,electron?
6.What is mass defect?
7.How does binding energy calculated for nucleons in a nucleus
8.What is nuclear reaction?Write its various types.
9.How can we obtain electrical energy from nuclear energy?
10.What are effect of nuclear radiation emitted by nuclar fission on our daily life?
ANSWER KEY
A. Short Answer
1. Binding energy graph 2.Two charecteristics 3.Reason
4.Name of nuclei 5.Neutron 6.Difference in mass of nucleus and mass of nucleons
7.Mass defect 8.Definition and types 9.Nuclear reaction
10.Emmits radioactive rays which damages human cells
MCQ
1.a 2.a 3.d 4.b 5.c

ASSERTION REASON
6.B 7.A 8.D 9. 10.B

CHAPTER - 14
SEMICONDUCTOR ELECTRONICS: MATERIALS, DEVICES AND SIMPLE CIRCUITS

SUMMARY

INTRODUCTION: Electronic devices work on the controlled flow of electrons through them. These devices are the building blocks of all the electronic circuits. Examples: vacuum tubes, diodes, triodes, transistors etc. These devices are small in size, consume low power, need low operational voltages and have long life and high reliability.

ENERGY BANDS IN CONDUCTORS, SEMICONDUCTORS AND INSULATORS

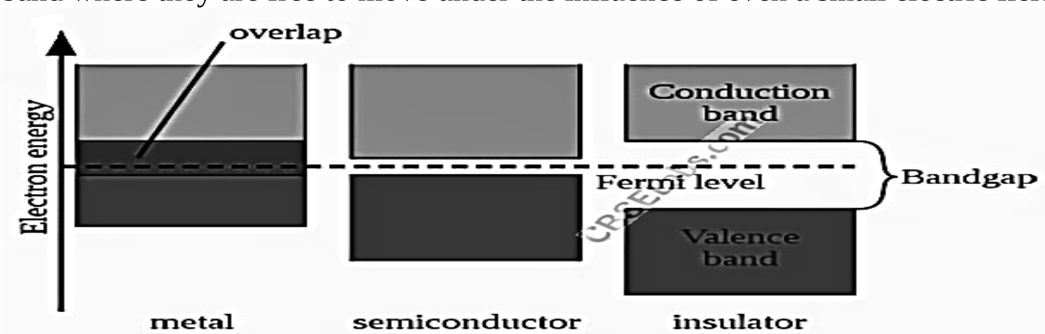
According to Bohr's atomic model, there are well-defined energy levels of electrons in an isolated atom. But when the atoms come together to form a solid crystal valence electrons are shared by more than one atom. So splitting of energy level takes place with continuous energy variations. The collection of these closely spaced energy levels is called an energy band. **The energy band which include the energy levels of the valence electrons is called the valence band** and **the energy band above the valence band is called the conduction band.**

At room temperature this valence band is either empty or partially filled with electrons. Electrons may gain energy from some external sources such as electric field, radiation etc to jump from valence band to conduction band and thus contribute to the electric current. **The minimum energy required to send electron from top of the valence band to the bottom of the conduction band is called energy band gap (E_g)**.

In metals, the conduction band and valence band partly overlap each other and there is no **forbidden energy gap ($E_g \approx 0$).**

In insulators, the conduction band is empty and valence band is completely filled and forbidden **gap is quite large ≈ 6 eV (> 3 eV).** No electron from valence band can cross over to conduction band at room temperature, even if electric field is applied. Hence there is no conductivity of the insulators.

In semiconductors, the conduction band is empty and valence band is totally filled. But the forbidden gap between conduction band and valence band is quite small, **which is about 1 eV (< 3 eV).** No electron from valence band can cross over to conduction band. Therefore, the semiconductor behaves as insulator. At room temperature, some electrons in the valence band acquire thermal energy, greater than energy gap of 1 eV and jump over to the conduction band where they are free to move under the influence of even a small electric field to conduct**.**



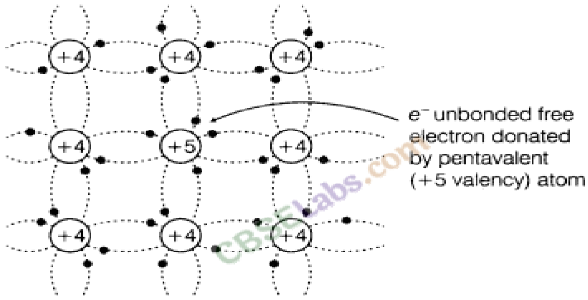
EXTRINSIC AND INTRINSIC SEMICONDUCTORS

Pure semiconductors (intrinsic semiconductors) such as tetravalent elements Si, Ge have very low conductivity wherein the number of thermally excited electrons (n_e) is equal to the number of holes (n_h) created due to vacancy created by shifted electrons. **That is $n_e = n_h = n_i$**, where n_i is the no. of intrinsic charge carrier concentration.

Extrinsic semiconductor The conductivity of intrinsic semiconductors can be increased manyfold by doping i.e adding suitable impurity (such as trivalent or pentavalent atoms in say parts per million) to the pure semiconductor. Such doped semiconductors are called extrinsic semiconductors.

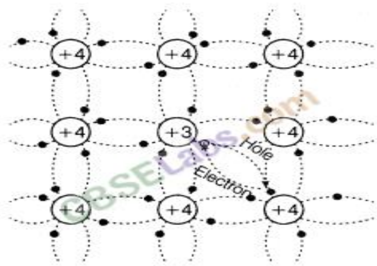
The necessary condition is that size of the dopant and the semiconductor atoms should be nearly the same to avoid distortion of original pure semiconductor atom sites in the crystal. **Types of extrinsic semiconductors: (i) n-type semiconductor (ii) p-type semiconductor n-type semiconductor is obtained when pentavalent impurity (such as As, Sb, P) is added to pure Si or Ge crystal.**

During doping, four electrons of pentavalent element bond with the four Si neighbours while the fifth electron remains very weakly bound to its parent atom. So the ionization energy required to set this electron free is very small. Here the electrons are majority **In n-type semiconductors, $n_e >> n_h$**



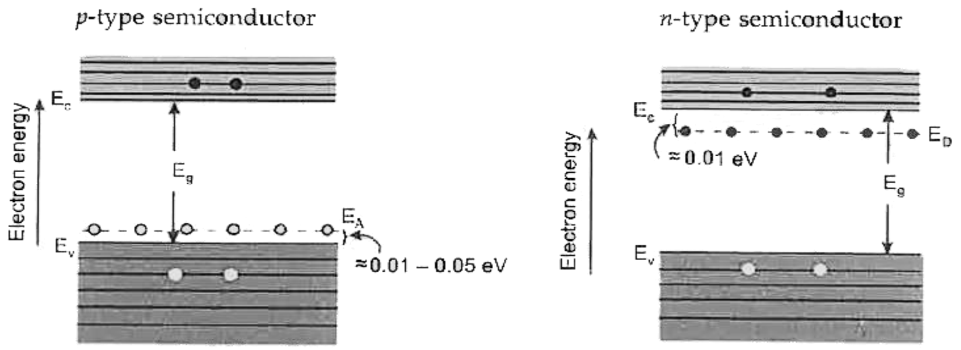
Pentavalent donar atom (As, Sb, P, etc.) doped for tetravalent Si or Ge giving -type

p-type semiconductor is obtained when Si or Ge is doped with a trivalent impurity (such as Al, B, In). The three valence electrons of the dopant atom form covalent bonds with neighbouring three Si or Ge atom but one covalent bond will be improper and give out a vacancy or a hole. These holes are available for conduction. In p-type semiconductors holes become the majority charge carriers i.e. $n_h >> n_e$



Trivalent acceptor atom (In, Al, B, etc) doped in tetravalent Si or Ge lattice giving *p*-type semiconductor

Energy Band in Extrinsic Semiconductors

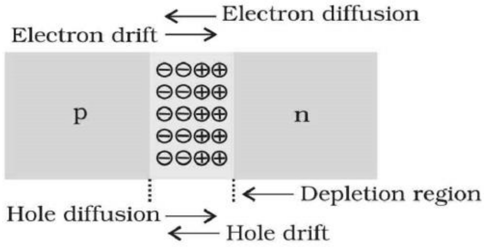


p-type semiconductor	*n-type semiconductor*
1. It is formed by doping with a trivalent impurity. 2. Here $n_h >> n_e$	1. It is formed by doping with a pentavalent impurity. 2. Here $n_e >> n_h$

p-n Junction:

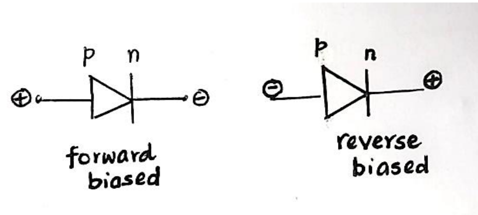
It is an arrangement made by a close contact of n-type semiconductor and p-type semiconductor. Two important processes occur during the formation of p-n junction. They are:

***Diffusion* and *drift*. During the formation of p-n junction and due to difference in the concentration of charge carriers holes diffuse from p-side to n-side(p→n) and electrons diffuse from n-side to p-side9 (n→p). This motion of charge carriers gives rise to diffusion current across the junction. Drift is the process of movement of charge carriers due to the net electric field.** Thus when a hole diffuses from p side to n side, it leaves behind an acceptor (negative charge) which is immobile. As the holes continue to diffuse, a layer of negatively charged immobile ions is developed on the p side of the junction. The diffused charge carriers combine with their counterparts in the immediate vicinity of the junction and neutralize each other. The region on either side of the junction which becomes depleted from the mobile charge carriers is called the depletion region or depletion layer whose width is of the order of 10^{-6}m. This sets up a potential difference across the junction and an internal electric field E directed from n side to p side. This electric field set up stops further diffusion of majority charge carriers**.**



Forward and reverse biasing of p-n junction diode

When an external voltage V is applied across the diode such that p-side is connected to the positive terminal of the battery and n-side to the negative terminal, it is said to be forward biased. Similarly when n-side is positive and p-side is negative, it is said to be **reverse biased.**



Forward Bias: When the diode is forward biased, an external electric field E is set up from p-side to n-side to oppose the internal electric field. The holes move along the field E and electrons move opposite to it eliminating the depletion layer. A current is thus set up in the junction diode. As the applied voltage is low, the current through the diode is almost zero because of the potential barrier or knee voltage. The current increases sharply once the applied voltage exceeds the barrier voltage..

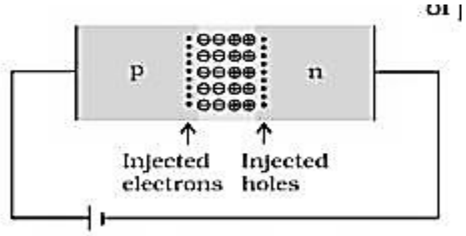
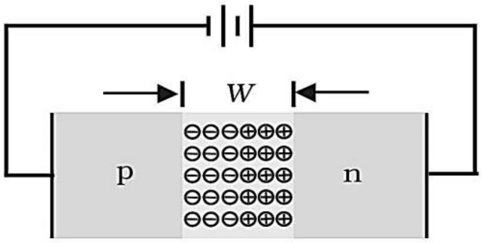
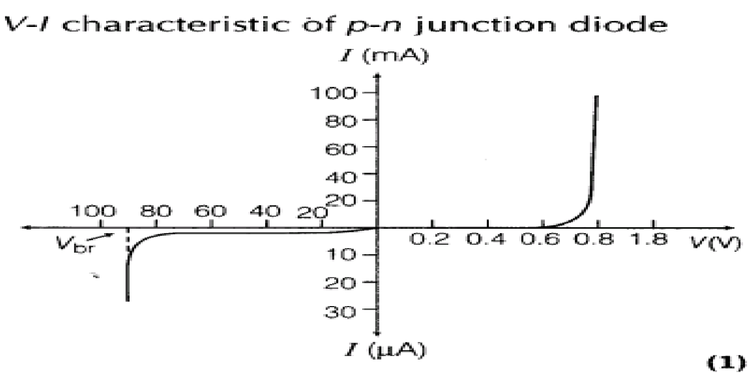


FIGURE 14.14 Forward bias minority carrier injection.

Reverse Bias:

Due to reverse biasing an external field E is established to support the internal field E_i. Under this biasing the holes in p-region and the electrons in n-region are pushed away from the junction to widen the depletion layer and hence increases the size of the potential barrier, therefore the junction does not conduct. When the reverse bias is made sufficiently high, the covalent bonds near the junction break down releasing large number of free electrons and holes and the current increases abruptly to high value. This is called avalanche breakdown and may damage the junction.

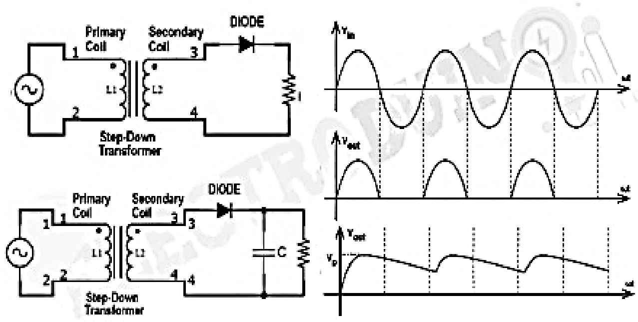




APPLICATION OF A DIODE AS A RECTIFIER

Rectifier: The conversion of ac into dc is called rectification and the device/arrangement is called a rectifier. There are two types of rectifiers: Half wave rectifier and full wave **rectifier.**

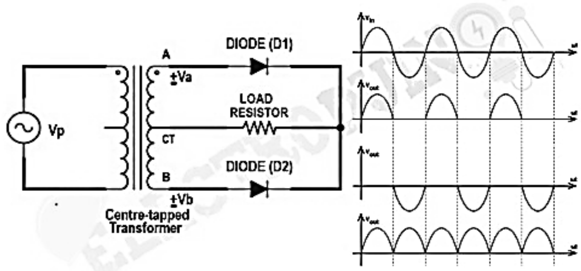
HALF WAVE RECTIFIER:



In the above diagram, during positive half cycle of the input AC, the p-n junction is forward biased. Thus the resistance in 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 the 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. The output voltage is unidirectional but pulsating. This process is called half wave rectification and the arrangement is called half wave rectifier.

FULL WAVE RECTIFIER: During the first half of input cycle, the upper end of the coil is at positive potential and lower end at negative potential. The function diode D_1 is forward biased and D_2 is reverse biased. Current flows in output load resistance in the direction shown in the figure. During the second half of input cycle, D_2 is forward biased. In this way, current flows in the load in in the single direction.



MULTIPLE CHOICE QUESTIONS.

1. In semiconductors at a room temperature

(a) the valance band is partially empty and the conduction band is partially filled.
(b) the valance band is completely filled and the conduction band is partially filled.
(c) the valance band is completely filled.
(d) the conduction band is completely empty.

2. If no external voltage is applied across p-n junction, then there would be

(a) no electric field across the junction
(b) an electric field pointing from n-type to p-type side across the junction
(c) an electric field pointing from p-type to n-type side across the junction
(d) a temporary electric field during formation of p-n junction that would subsequently disappear.

3. Choose the only false statement from the following.

(a) substances with energy gap of the order of 10 eV are insulators.
(b) the conductivity of a semiconductor increases with increase in temperature.
(c) in conductors the valance and conduction bands may overlap.
(d) the resistivity of a semiconductor increases with increase in temperature.

4. A semiconducting device is connected in series circuit with a battery and a resistance. A current is found to pass through the circuit. If the polarity of the battery is reversed, the current drops to almost zero. The device may be

(a) a p-type semiconductor (b) a n-type semiconductor
(c) a p-n junction (d) an intrinsic semiconductor.

5. A p-n photodiode is fabricated from a semiconductor with a band gap of 2.5 eV. It can detect a signal of wavelength
(a) 4000 nm (b) 6000 nm (c) 6000 A° (d) 4000 A°

6. The dominant mechanism for the motion of charge carriers in forward and reverse biased silicon p-n junction are
(a) drift in forward bias, diffuse in reversed bias
(b) diffuse in forward bias, drift in reversed bias
(c) diffusion in both forward and reverse bias
(d) drift in both forward and reverse bias

7. The impurity atoms, with which pure silicon should be doped to make a p-type semiconductor, are those of
(a) antimony (b) arsenic (c) phosphorous (d) boron

8. In the middle of the depletion layer of reverse biased p-n junction, the
(a) electric field is nearly zero (b) potential is zero
(c) potential is maximum (d) electric field is maximum.

9. In a full wave rectifier circuit operating from 50 Hz main frequency, the fundamental frequency in the ripple would be
(a) 50 Hz (b) 25 Hz (c) 100 Hz (d) 70 Hz

10. If the ratio of the concentration of electrons to that of holes in a semiconductor is 7/5 and the ratio of current is 7/4, then what is the ratio of their drift velocities?
(a) 5 : 8 (b) 4 : 5 (c) 5 : 4 (d) 4 : 7

Ans :

Q.NO	**Ans**	**Q.NO**	**Ans**	**Q.NO**	**Ans**	**Q.NO**	**Ans**
1	**a**	**4**	**C**	**7**	**d**	**10**	**c**
2	**b**	**5**	**D**	**8**	**a**		
3	**b**	**6**	**B**	**9**	**c**		

ASSERTION - REASONING:

(A)Assertion and reason both are correct statements and Reason is correct explanation for Assertion
(B)Assertion and Reason both are correct statement but Reason is not correct explanation for assertion.
(C) Assertion is correct statement but reason is wrong statement.
(D) Assertion is Wrong statement but Reason is correct statement.

1. Assertion: The electrical conductivity of a semiconductor increases with increase in temperature. **Reason:** With increase in temperature, large number of electrons from the valence band can jump to the conduction band.

2. Assertion: When two semiconductors 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 convert alternating current into direct current.
Answer- B

3. Assertion- The diffusion current in a p-n junction is from the p side to n side.
Reason- The diffusion current in a p-n junction is greater than the drift current when the junction is in forward biased.

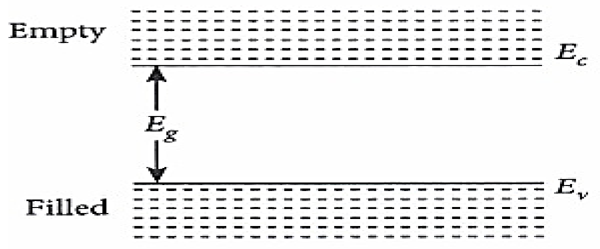
4. Assertion- The drift current in a p-n junction is from the n side to the p side.
Reason- It is due to free electrons only.

5. Assertion- A p-n junction with revers bias can be used as a photo diode to measure light intensity. **Reason-** In a reverse bias condition the current is small but it is more sensitive to changes in incident light intensity.

ANS 1A 2B 3B 4A 5A

CASE STUDY BASED QUESTION

From Bohr's atomic model, we know that the electrons have well defined energy levels in an isolated atom. But due to inter atomic interactions in a crystal, the 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) In an insulator energy band gap is

(a) $E_g = 0$ (b) $E_g < 3eV$ (c) $E_g > 3eV$ (d) None of the above

(ii) In a semiconductor, separation between conduction and valence band is of the order of

(a) 0 eV (b) 1eV (c) 10 eV (d) 50 eV

(iii) Based on the band theory of conductors, insulators and semiconductors, the forbidden gap is smallest in

(a) conductor (b) insulator (c) semiconductors (d) All of these

ANSWER

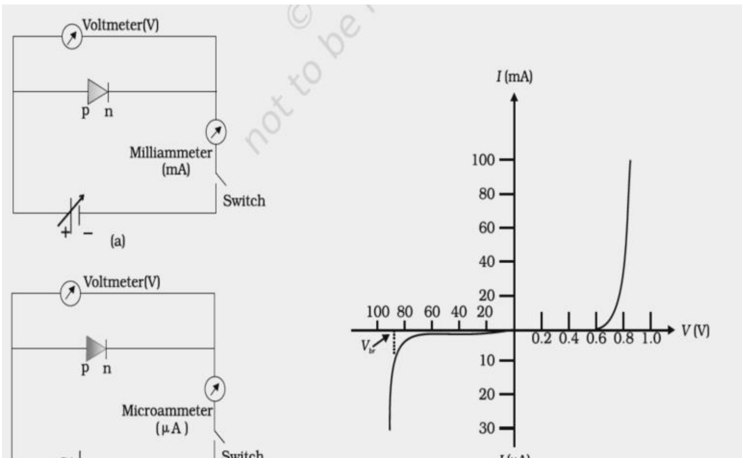
(i) (c) :In insulator, energy band gap is > 3 eV

(ii) (b) : In conductor, separation between conduction and valence bands is zero and in insulator, it is greater than 1 eV. Hence in semiconductor the separation between conduction and valence band is 1 eV.

(iii) (a): According to band theory the forbidden gap in conductors $E_g = 0$, in insulators $E_g > 3$ eV and in semiconductors $E_g < 3$ eV.

2. V – I CHARACTERISTICS OF A p – n JUNCTION DIODE

The circuit arrangement for studying the V – I characteristics of a diode, (i.e. the variation of current as a function of applied voltage) are shown in figures. The battery is connected to the diode through a potentiometer (or Rheostat) so that applied voltage to the diode can be changed. For different values of voltages, the value of the current is noted. A graph between V and I is obtained as shown in figure. Note that in forward bias measurement, we use a mill ammeter since the expected current is large while a micrometer is used in reverse bias to measure the current.



Answer the following questions.

(i) when the p-n junction (diode) is said to be forward bias and when it is said to be reverse bias? (ii) what happens to the width of depletion layer of a p-n junction in forward and reverse bias? (iii) Why there is large current in forward bias and small current in reverse bias through a circuit having p-n junction?

Ans : (i) Refer to summary (ii) Refer to summary (iii) Large current (in milli ampere) in forward bias is due to diffusion of majority charge carriers through the junction and hence offers very small resistance. Small current (in micro ampere) is due to leakage of minority charge carriers through the junction and hence offers very large resistance.

SHORT ANSWERS (SA) QUESTIONS

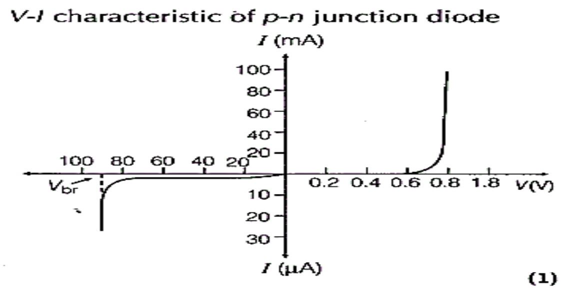
1. Explain with the help of a suitable diagram, the two processes which occur during the formations of a p-n junction diode.

Ans: refer to summary

2. Define the terms (i) depletion region and (ii) potential barrier.

3. Draw V-I characteristics of a p-n junction diode.

Ans :



4. Why is the current under reverse bias almost independent of the applied potential up to a critical voltage?

Ans :Under the reverse bias condition, the holes of p-side are attracted towards the negative terminal of the battery and the electrons of the n-side are attracted towards the positive terminal of the battery. This increases the depletion layer and the potential barrier. However, the minority charge carriers are drifted across the junction producing a small current. At any temperature, the number of minority carriers is constant, so there is the small current at any applied potential. This is the reason for the current under reverse bias to be almost independent of applied potential.

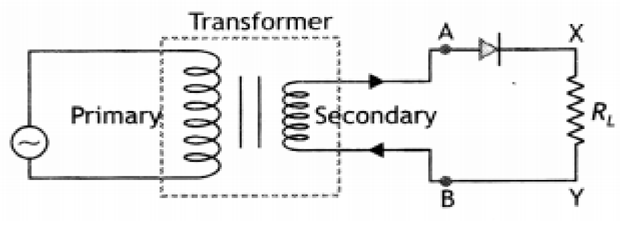
5. Why does the reverse current show a sudden increase at the critical voltage?

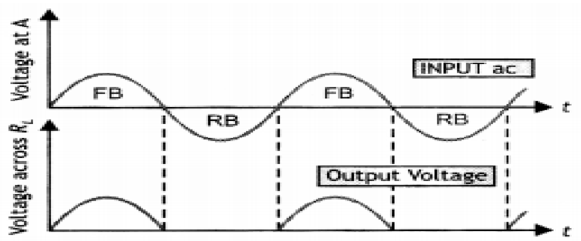
Name any semiconductor device which operates under the reverse bias in the breakdown region.

Ans :) At the critical voltage, the holes in the n-side and conduction electrons in the p-side are accelerated due to the reverse bias voltage. These minority carriers acquire sufficient kinetic energy from the electric field and collide with a valence electron. Thus, the bond is finally broken and the valence electrons move into the conduction band resulting in enormous flow of electrons and thus, formation of hole-electron pairs. Thus, there is a sudden increase in the current at the critical voltage.

7. Draw the circuit diagram to show the use of a p-n junction diode as a half-wave rectifier. Also show the input and the output voltages, graphically.

Ans : The diagram is as shown. The input and output waveforms are as shown.

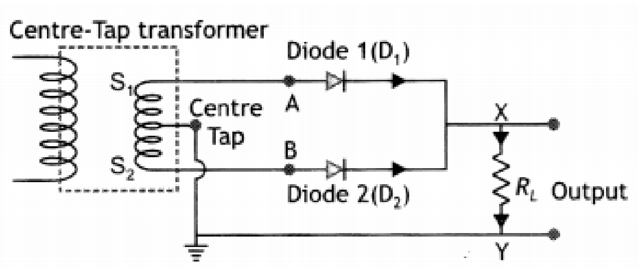


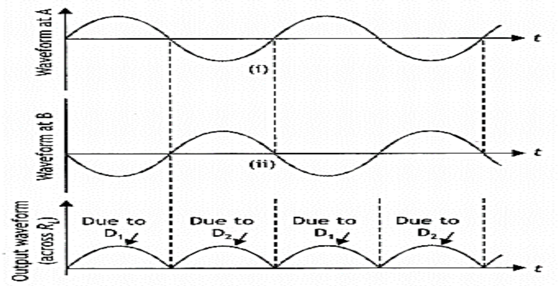


8 Draw the circuit diagram of a full-wave rectifier. Also, give the input and output waveforms.

Ans :

9





Write two differences between n-type and p-type semiconductors.

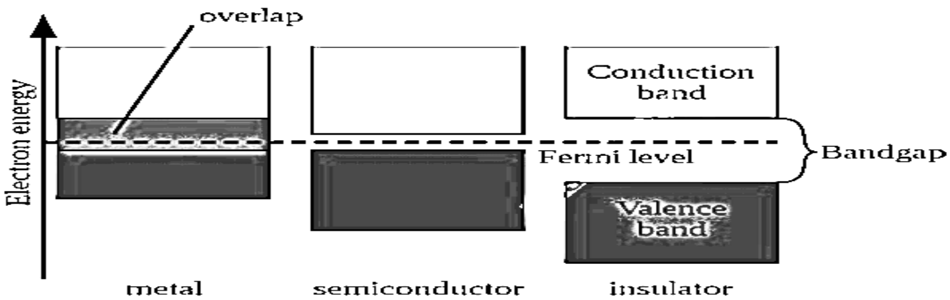
LONG ANSWER TYPE QUESTIONS (LA – I)

1. Distinguish between Intrinsic and Extrinsic semiconductors

Ans **:Intrinsic semiconductor** (i) It is a semicond
(ii) Charge carriers are electrons and holes with eq
(iii) Current due to charge carriers are feeble (of t
Extrinsic semiconductor (i) It is a semiconducto
impurities. (ii) Charge carriers are electrons in maj
majority in p-type semiconductor. (iii) Current du er
of milli ampere.

2. What are energy bands? Write any two distinguishing features between conductors, semiconductors and insulators on the basis of energy band diagrams.

Ans : An isolated atom has well defined energy levels. However, when large number of such atoms get together to form a solid, these individual energy levels overlap and get completely modified. Instead of discrete value of energy of electrons, the energy values lie in a certain range. The collection of these closely packed energy levels are said to form an energy band.



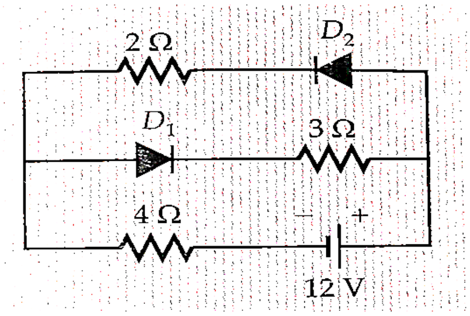
Difference :In metals, the conduction band and valence band partly overlap each other and there is no forbidden energy gap (E_g≈0).

In insulators, the conduction band is empty and valence band is completely filled and forbidden gap is quite large ≈6 eV(>3eV).

In semiconductors, the conduction band is empty and valence band is totally filled. But the forbidden gap between conduction band and valence band is quite small, which is about 1eV (<3eV).

NUMERICALS

1. The circuit has two oppositely connected ideal diodes in parallel. Calculate the current flowing in the circuit.



Ans :- 2 A

2. A semiconductor has equal electron and hole concentration of 2×10^8 m^{-3}. On doping with a certain impurity, the hole concentration increases to 4×10^{10} m^{-3}.

(i) What type of semiconductor is obtained on doping? (ii) Calculate the new electron concentration of the semiconductor. (iii) How does the Energy gap vary with doping?

Ans : (i) p-type semiconductor. (ii) As $n_e . n_h = n_i^2$ $n_e = 10^6$ m^{-3}. (iii) Energy gap decreases with doping.

3. In half wave rectification, what is the output frequency if the input frequency is 50 Hz. What is the output frequency of a full wave rectifier for the same input frequency?

Ans : 50 Hz for half wave rectifier. 100 Hz for full wave rectifier.

4. Suppose a pure Si crystal has 5×10^{28} atoms m^{-3}. It is doped by 1 ppm concentration of pentavalent As. Calculate the number of electrons and holes. Given that $n_i = 1.5 \times 10^{16}$ m^{-3}.

Ans : Note that thermally generated electrons ($n_i = 1.5 \times 10^{16}$ m^{-3}) are negligibly small as compared to those produced by doping ($n_e = 5 \times 10^{28} / 10^6 = 5 \times 10^{22}$)

We know that, $n_e . n_h = n_i^2$. $n_h = n_i^2 / n_i$ $n_h = 4.5 \times 10^9$ m^{-3}.

5. A semi conductor is known to have an electron concentration of 8×10^{13} Cm^{-3} and a hole concentration of 5×10^{12} Cm^{-3}. (a) Is the semiconductor n-type or p-type? (b) What is the resistivity of the sample if the electron mobility is 23000 Cm^2/Vs and hole mobility is 100 Cm^2/Vs.

Ans : (a) As number of electrons is more than numbers of holes, the semiconductors must be n-type.

(b) Hint : Resistivity

$$\rho = \frac{1}{e(n_e \mu_e + n_h \mu_h)}$$

Resistivity = 3.395 Ω Cm.