II PUC PHYSICS

EXCLUSIVELY FOR 2023 KARNATAKA PU BOARD EXAM

CHAPTERWISE SOLVED KARNATAKA PU BOARD EXAM PAPERS AND MOST IMPORTANT QUESTIONS WITH ANSWERS

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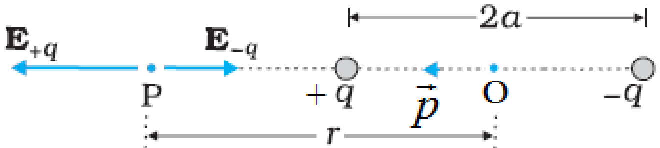
FIVE MARK QUESTIONS

1. Derive an expression for the electric field due to an electric dipole at a point on the axial line. **(March 2016, July 2017)**



Consider an electric dipole consisting of charges +q and –q separated by a small distance 2a. Let the point P be at distance r from the center of the dipole on the side of +q as shown in fig.

The electric field at p due to charge +q is

$$\vec{E}_{+q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$$

Where $\hat{p}$ is the unit vector along dipole axis.

The electric field at p due to charge –q is

$$\vec{E}_{-q} = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

The resultant electric field at p is

$$\vec{E} = \vec{E}_{+q} + \vec{E}_{-q}$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

$$\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$$

$$\vec{E} = \frac{q}{4\pi\varepsilon_0}\frac{4ar}{(r^2-a^2)^2}\hat{p}$$

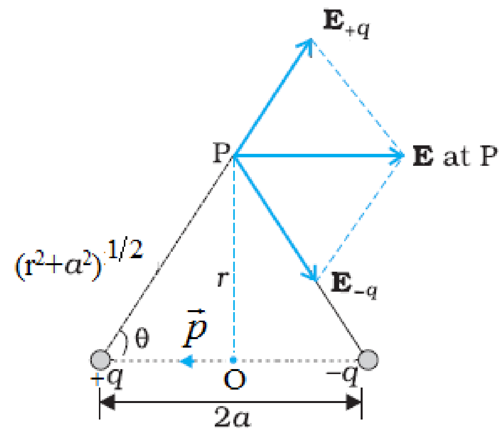
$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2r.\vec{p}}{(r^2-a^2)^2} \qquad (\because \vec{p} = q(2a)\hat{p})$$

For short dipole (r >> a), $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3}$

2. Derive the expression for electric field at a point on the equatorial plane of an electric dipole. **(March 2015, Sept 2020)**

Obtain an expression for electric field on the equatorial plane of an electric dipole. **(June 2019)**

Consider an electric dipole consisting of charges +q and –q separated by a small distance 2a as shown in fig. Let the point P be a point on the equatorial line of the dipole at distance r from it.



The electric field at p due to charge +q is

$$E_{+q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}$$

The electric field at p due to charge -q is

$$E_{-q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}$$

Thus $E_{+q} = E_{-q}$

Clearly, the components perpendicular to the dipole axis cancel out.

The components parallel to the dipole axis add up.

The total electric field $\vec{E}$ is

$$\vec{E} = \left(E_{+q}\cos\theta + E_{-q}\cos\theta\right)(-\hat{p})$$

Where $\hat{p}$ is the unit vector along dipole axis and it is negative because $\vec{E}$ is opposite to $\vec{P}$.

$$\vec{E} = -2E_{+q}\cos\theta\ \hat{p} \qquad \left(\because E_{+q} = E_{-q}\right)$$

$$\vec{E} = -2\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}\frac{a}{\left(r^2+a^2\right)^{1/2}}\hat{p} \qquad \left(\because \cos\theta = \frac{a}{\left(r^2+a^2\right)^{\frac{1}{2}}}\right)$$

$$\vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{\left(r^2+a^2\right)^{3/2}} \qquad (\because \vec{p} = q(2a)\hat{p})$$

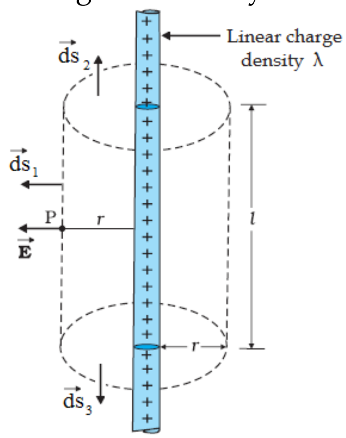
For short dipole (r >> a), $\vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$

3. Derive the expression for the electric field due to an infinitely long charged straight conductor using Gauss law. **(July 2015)**

Derive the expression for the electric field due to an infinitely long thin charged straight wire using Gauss law. **(July 2016)**

State Gauss's law in electrostatics. Derive the expression for electric field at a point due to an infinitely long straight uniformly charged wire using Gauss's law. (Aug 2022)

Statement: Gauss's law states that total electric flux passing through a closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the closed surface.



Consider an infinitely long thin straight wire having a uniform linear charge density λ.

To determine the field at a distance r from the line charge, we choose a cylindrical Gaussian surface of radius r.

Here $\vec{ds}_1 \| \vec{E}(\theta = 0^0)$, $\vec{ds}_2 \perp \vec{E}(\theta = 90^0)$, $\vec{ds}_3 \perp \vec{E}(\theta = 90^0)$.

The total electric flux is

$$\phi = \phi_1 + \phi_2 + \phi_3$$

$$\phi = \sum \vec{E}\cdot\vec{ds}_1 + \sum \vec{E}\cdot\vec{ds}_2 + \sum \vec{E}\cdot\vec{ds}_3$$

$$\phi = \sum Eds_1 \cos 0^0 + \sum Eds_2 \cos 90^0 + \sum Eds_3 \cos 90^0$$

$$\phi = E\sum ds_1 + 0 + 0$$

$$\phi = E \times 2\pi rl \text{ ---------- (1)} \qquad \left(\because \sum ds_1 = 2\pi rl\right)$$

By using gauss's law,

$$\phi = \frac{q}{\varepsilon_0} = \frac{\lambda l}{\varepsilon_0} \text{ ---------- (2)} \qquad \left(\because q = \lambda l\right)$$

Equating equn (1) and (2), we get

$$E \times 2\pi rl = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Vectorially, $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{n}$

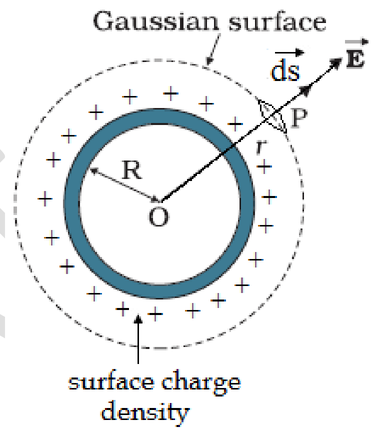
4. State Gauss law in electrostatics. Using the law, derive an expression for the electric field due to a uniformly charged thin spherical shell at a point outside the shell. (March 2014, March 2019)

Derive an expression for electric field at a point outside uniformly charged spherical shell placed in vacuum using Gauss law. (July 2014)

Using Gauss law in electrostatics, obtain the expression for electric field due to a uniformly charged thin spherical shell at a point (i) outside the shell and (ii) inside the shell (July 2018)

Statement: Gauss's law states that total electric flux passing through a closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the closed surface.

Electric field outside the shell:



Consider a point p outside the shell at a distance r from the center O as shown in fig. To calculate the electric field $\vec{E}$ at p, the Gaussian surface chosen is a sphere of radius r with center O.

The angle between $\vec{E}$ and $\vec{ds}$ is zero.

The electric flux passing through the Gaussian surface is

$$\phi = \sum \vec{E}\cdot\vec{ds}$$

$$\phi = \sum Eds \cos 0^0 = E\sum ds$$

$$\phi = E \times 4\pi r^2 \text{ ---------- (1)} \qquad \left(\because \sum ds = 4\pi r^2\right)$$

By using Gauss's law,

$$\phi = \frac{q}{\varepsilon_0} \text{ ---------- (2)}$$

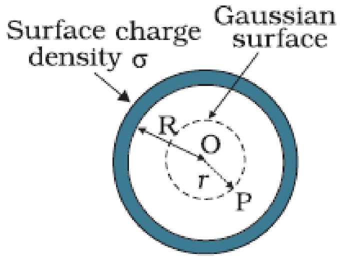
Equating equn (1) and (2), we get

$$E \times 4\pi r^2 = \frac{q}{\varepsilon_0}$$

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

Vectorially, $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$

Electric field inside the shell:



Consider a point p inside the shell as shown in fig. The electric flux passing through the Gaussian surface is

$$\phi = E \times 4\pi r^2$$

By using Gauss's law,

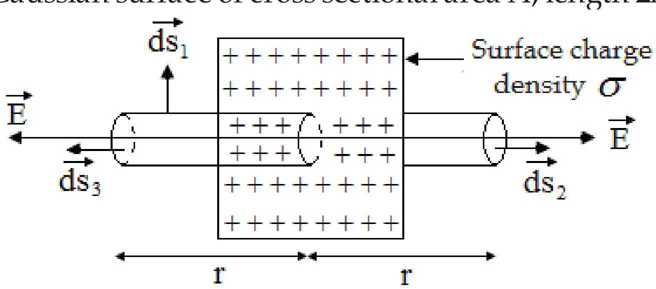
$$\phi = \frac{q}{\varepsilon_0} = 0 \quad (\because q = 0)$$

$$E \times 4\pi r^2 = 0$$

$$E = 0$$

5. Obtain the expression for electric field due to a uniformly charged infinite plane sheet using Gauss law.

Consider a thin infinite plane sheet of charge with uniform surface charge density σ as shown in fig. To determine the field, we choose a cylindrical Gaussian surface of cross sectional area A, length 2r.



Here $\vec{ds}_1 \perp \vec{E}(\theta = 90^0)$, $\vec{ds}_2 \parallel \vec{E}(\theta = 0^0)$, $\vec{ds}_3 \parallel \vec{E}(\theta = 0^0)$.

The total electric flux is

$$\phi = \phi_1 + \phi_2 + \phi_3$$

$$\phi = \sum \vec{E} \cdot \vec{ds}_1 + \sum \vec{E} \cdot \vec{ds}_2 + \sum \vec{E} \cdot \vec{ds}_3$$

$$\phi = \sum E ds_1 \cos 90^0 + \sum E ds_2 \cos 0^0 + \sum E ds_3 \cos 0^0$$

$$\phi = 0 + E\sum ds_2 + E\sum ds_3$$

$$\phi = EA + EA = 2EA \text{ ---------(1)} \quad \left(\because \sum ds_2 = \sum ds_3 = A\right)$$

By using Gauss's law,

$$\phi = \frac{q}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0} \quad \text{---------- (2)} \quad (\because q = \sigma A)$$

Equating equn (1) and (2), we get

$$2EA = \frac{\sigma A}{\varepsilon_0}$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

6. What is an electric field line? Write the four general properties of electric field lines. **(May2022)**
Write three properties of electric field lines. **(July 2018, June 2019)**
Write two properties of electric field lines.
(2Mark)(March2016,July2015,March2017, Sept2020)

An electric field line is a curve drawn in an electric field in such a way that the tangent to it at any point is in the direction of the net field at that point.

Properties of electric field lines:

1. Electric field lines always start from positive charges and end at negative charges. If there is single charge, they start or end at infinity.
2. In a charge-free region, electric field lines are continuous curves without any breaks.
3. Two field lines never cross each other.
4. Electrostatic field lines never form closed loops.

THREE MARK QUESTIONS:

1. Mention any three properties of electric charges. **(March 2018, July 2014)**
Write any two basic properties of charge. **(2 mark) (March 2019)**

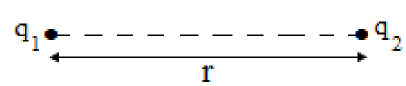
1. Additivity of charges.
2. Quantization of charges.
3. Conservation of charges.

TWO MARK QUESTIONS:

1. State and explain coulomb's law in electrostatics. **(March 2014, March 2020)**
State coulomb's law. **(1 Mark)(March 2017, July 2015, March 2019)**

Statement: Coulomb's law states that the electrostatic force between two point charges is directly proportional to product of magnitude of the two charges and inversely proportional to square of the distance between them.

Explanation: Consider two point charges q_1 and q_2 are separated by a distance r in vacuum.



Force between them is $F \propto \frac{q_1 q_2}{r^2}$

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

Where k is a constant of proportionality.

2. Write coulomb's law in vector form. Explain the terms. **(March 2015)**

Coulomb's law in vector form is $\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$

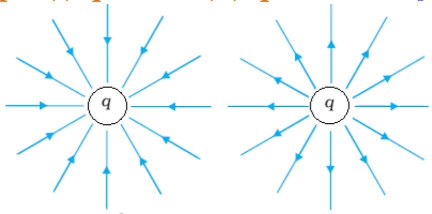
Where, q_1 & q_2 –point charges

ε_0 - permittivity of free space

r – distance between q_1 & q_2

$\hat{r}$ - the unit vector

3. Sketch the electric lines of force due to a point charge q if (i) q<0 and (ii) q>0. **(July 2016)**

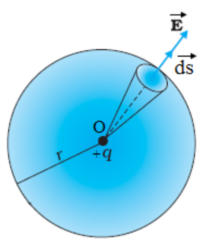


$q < 0$ (q is negative) $q > 0$ (q is positive)

4. State and explain Gauss law in electrostatics. **(July 2017)**

Statement: Gauss's law states that the total electric flux passing through a closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the closed surface.

Proof: The electric field on any point on the spherical surface is



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

The electric flux through surface is $\phi = \sum \vec{E}\cdot\vec{ds} = \sum Eds\cos 0^0$

$$\phi = E\sum ds = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\times 4\pi r^2 \quad \left(\because \sum ds = 4\pi r^2\right)$$

$$\therefore \phi = \frac{q}{\varepsilon_0}$$

ONE MARK QUESTIONS:

1. Write the SI unit of charge. **(March 2014)**

coulomb.

2. Define SI unit of charge. (or) Define coulomb. **(March 2015)**

One coulomb of charge is that charge which when placed at a distance of 1m from another charge of same magnitude in vacuum experiences an electric force of repulsion of magnitude 9×10^9 N.

3. What is an electric dipole? **(March 2016)**

A pair of equal and opposite point charges separated by a small distance is called an electric dipole.

4. Write the SI unit of electric field. **(July 2016)**

NC^{-1} or Vm^{-1}

5. How does the electrostatic force between two point charges change when a dielectric medium is introduced between them? **(July 2017, Aug 2022)**

Decreases. $\left(\because F_{medium} = \frac{F_{air}}{\varepsilon_r}\right)$

6. Write the SI unit of electric flux. **(March 2020)**

Nm^2C^{-1} or Vm.

7. What is the electric field inside a thin charged spherical shell? **(Sept 2020)**

Zero.

8. Name the apparatus used to detect electric charge on a body. **(May 2022)**

Gold leaf electroscope.

9. Define 'electric dipole moment'. **(May 2022)**

It is defined as the product of the magnitude of either charge and the separation between the charges (or dipole length).

10. Mention one method of charging a body. **(Aug22)**

Charging by induction.

11. Write the SI unit of dipole moment.

Coulomb meter (C-m).

12. Define linear charge density.

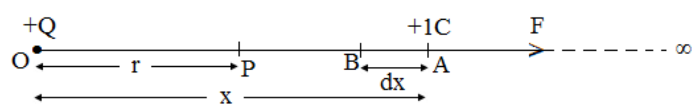
It is defined as charge per unit length at any point on linear charge distribution.

2 ELECTROSTATIC POTENTIAL AND CAPACITANCE

FIVE MARK QUESTIONS:

1. Define electrostatic potential due to a point charge and arrive at the expression for electric potential at a point due to a point source charge. **(March 2018)**

Definition: The electrostatic potential at any point in an electric field is defined as the amount of work done in bringing a unit positive charge from infinity to the point against electric field.



Consider a point charge +Q placed at point O. Let r be the distance of point p from O. Imagine an unit positive charge at A with a distance x from O.

Force on the unit positive charge at A is

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Q.1}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{x^2}$$

The small amount of work done in moving unit positive charge from A to B is

$$dw = -\frac{1}{4\pi\varepsilon_0}\frac{Q}{x^2}dx$$

The negative sign because for $dx < 0$, dw is positive.

The total amount of work done in bringing unit positive charge from ∞ to r is

$$W = \int_{\infty}^{r} dw$$

$$W = \int_{\infty}^{r} -\frac{1}{4\pi\varepsilon_0}\frac{Q}{x^2}dx = -\frac{Q}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{1}{x^2}dx$$

$$W = -\frac{Q}{4\pi\varepsilon_0}\left[\frac{-1}{x}\right]_{\infty}^{r} = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{x}\right]_{\infty}^{r}$$

$$W = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

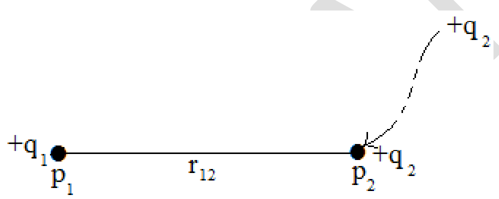
$$W = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

By definition, this work done is the electric potential at point p.

$\therefore$ The electric potential $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

THREE MARK QUESTIONS:

1.Derive the expression for potential energy of a system of two charges in the absence of the external electric field. (March 2014, July 2016)



Consider a charges q_1 and q_2 initially at infinity. When we bring the first charge $+q_1$ from infinity to point p_1, no work is done. $\therefore W_1 = 0$

Electric potential due to charge q_1 at a point p_2 is

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{12}}$$

If charge q_2 is moved from infinity to point p_2, the work required is

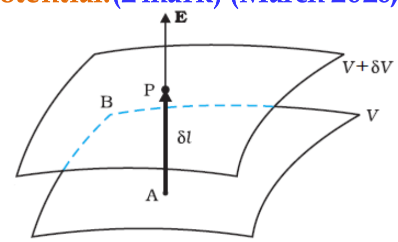
$$W_2 = V_1 \times q_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

This total work done is stored as Potential energy.

$$\therefore U = W_1 + W_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$$

2. Derive the relation between electric field and electric potential due to a point charge. (March 2017, July 2017, Sept 2020, Aug 2022)

Establish the relation between electric field and electric potential.(2 mark) (March 2020, July 2014)



Consider two equipotential surfaces A and B with potential V and V+δ V respectively. When a unit positive charge is moved along perpendicular distance δl from the surface B to A against the electric field.

The work done is $dW = E\delta l$

This work done is equal to the potential difference between A and B.

$$dW = V_A - V_B$$

$$E\delta l = V - (V + \delta V) = -\delta V$$

$$E = -\frac{\delta V}{\delta l}$$

3. Mention the three factors on which the capacitance of a dielectric parallel plate capacitor depends. (May 2022)

On what factors does the capacitance of a parallel plate capacitor depends. (March 2017,March 2018)

1.Area of the plates. $(C \alpha A)$

2.Distance between plates. $\left(C\alpha\frac{1}{d}\right)$

3.Dielectric constant of the medium between plates. $(C \alpha K)$

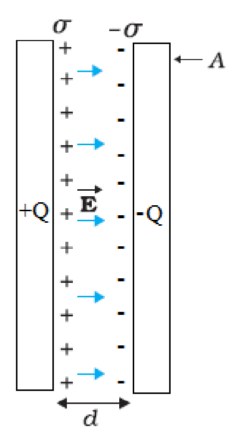
4. Derive the expression for capacitance of a parallel plate capacitor. (March 2015)

A - area of each plate

d - distance between the plates

V - potential difference across the plates

Q - charge on each plate



$\sigma = \frac{Q}{A}$ - surface charge density

The electric field in the outer regions of the two plates,

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

The electric field in between the plates,

$$E = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0} \quad \left(\because \sigma = \frac{Q}{A}\right)$$

Potential difference between the plates = E × distance between the plates

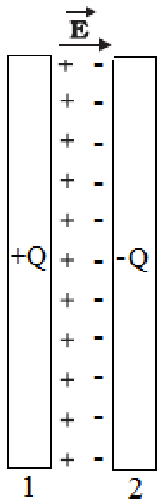
$$V = Ed = \frac{Qd}{A\varepsilon_0}$$

Capacitance of parallel plate capacitor is

$$C = \frac{Q}{V} = \frac{Q}{Qd/A\varepsilon_0}$$

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

5. Derive the expression for the energy stored in a charged capacitor. (March2016,March17,March20)



Consider a capacitor of capacitance C. Suppose the +q charge is transferred from the plate 2 to plate 1, plate 2 acquires charge –q.

The potential difference across the capacitor is $V = \frac{q}{C}$

Suppose now a small additional charge dq be transferred from plate 2 to plate 1. The work done will be

$$dW = Vdq = \frac{q}{C}dq$$

The total work done in transferring a charge Q from plate 2 to plate 1 will be

$$W = \int_0^Q dW = \int_0^Q \frac{q}{C}dq$$

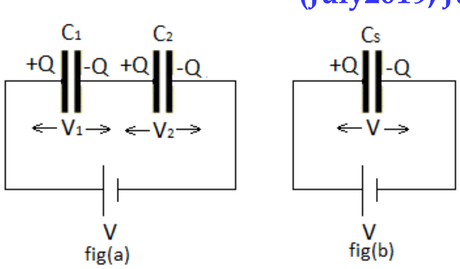
$$W = \frac{1}{C}\int_0^Q q\,dq = \frac{1}{C}\left[\frac{q^2}{2}\right]_0^Q$$

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

This work done is stored as electric potential energy U of the capacitor.

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

6. Obtain the expression for effective capacitance of two capacitors connected in series. (July2019, June 2019)



In series combination, the charge on each capacitor is same and potential difference across capacitor depends upon capacitance value.

If V_1 and V_2 are the potential differences across the capacitors C_1 and C_2 respectively, then

$V = V_1 + V_2$ ----------(1)

If Q is the charge on each capacitor, then

$V_1 = \frac{Q}{C_1}$ $\quad V_2 = \frac{Q}{C_2}$

$(1) \Rightarrow V = \frac{Q}{C_1} + \frac{Q}{C_2}$

$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$ -------(2)

Consider C_S is the effective capacitance of the series combination of capacitors. The charge on capacitor C_S is Q and potential difference is V. So

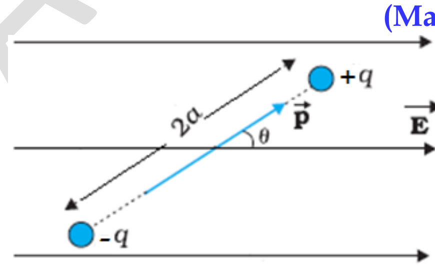
$V = \frac{Q}{C_S}$ -------(3)

Equating equations (2) and (3), we have

$$\frac{Q}{C_S} = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$$

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}$$

7. Derive the expression for potential energy of electric dipole placed in uniform electric field. (March 2019)



In a uniform electric field, the net force experienced by the dipole is zero. But it experiences a torque given by

$$\tau = \vec{p} \times \vec{E} = pE\sin\theta$$

If the dipole is rotated through a small angle $d\theta$ against the torque acting on it, then the small work done is

$$dw = \tau\, d\theta = pE\sin\theta\, d\theta$$

Therefore, the total work done in rotating the dipole from angle θ_1 to θ_2 is

$$W = \int_{\theta_1}^{\theta_2} dw = \int_{\theta_1}^{\theta_2} pE\sin\theta\, d\theta$$

$$W = pE[-\cos\theta]_{\theta_1}^{\theta_2} = pE(\cos\theta_1 - \cos\theta_2)$$

This work done is stored as the potential energy U of the dipole

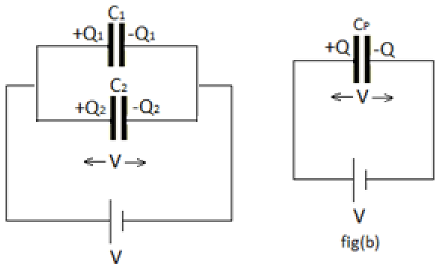
$$U = pE(\cos\theta_1 - \cos\theta_2)$$

If initially the dipole is oriented at $\theta_1 = 90^0$ and brought to some orientation $\theta_2 = \theta$, then

$$U = pE(\cos 90^0 - \cos\theta)$$

$$U = -pE\cos\theta = -\vec{p}\cdot\vec{E}$$

8. Obtain the expression for effective capacitance of two capacitors connected in parallel.



fig(a) fig(b)

In parallel combination the potential difference across each capacitor is same and the charge stored in capacitors depends upon capacitance value.

If Q_1 and Q_2 are the charges on capacitors C_1 and C_2 respectively, then

$Q = Q_1 + Q_2$ ----------(1)

If V is the voltage across each capacitor, then

$Q_1 = C_1V, \ Q_2 = C_2V$

(1) $\Rightarrow Q = C_1V + C_2V$

$Q = V(C_1 + C_2)$ -------(2)

Consider C_P is the effective capacitance of the parallel combination of capacitors.

The charge on C_p is Q and potential difference is V.

$Q = C_PV$ -------(3)

Equating equations (2) and (3), we have

$C_PV = V(C_1 + C_2)$

$C_P = C_1 + C_2$

TWO MARK QUESTIONS:

1. A parallel plate capacitor with air between the plates has capacitance C. What will be the capacitance if

a) the distance between the plates is doubled?

b) the space between the plates is filled with a substance of dielectric constant 5? (March 2020)

a) $C = \dfrac{\varepsilon_0 A}{d}$

$$C' = \frac{\varepsilon_0 A}{d'} = \frac{\varepsilon_0 A}{2d} = \frac{C}{2}$$

New capacitance is half of the initial capacitance.

b) $C' = \dfrac{k\varepsilon_0 A}{d} = kC = 5C$

New capacitance is 5 times of the initial capacitance.

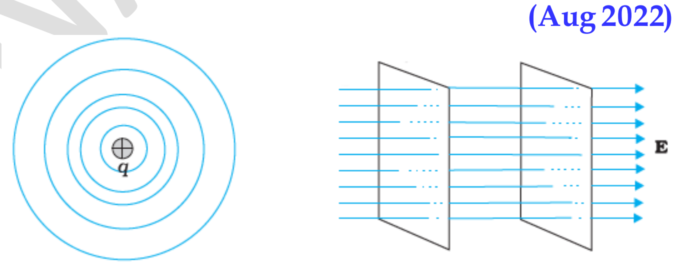
2. Write two properties of equipotential surface.

1. No work is done in moving a test charge over an equipotential surface.
2. Electric field is always normal to the equipotential surface at every point.
3. No potential differene between any two points on the surface.

3. What are polar and non-polar molecules? (May22) Distinguish between polar and non-polar dielectrics.

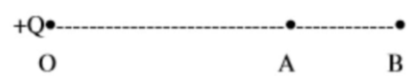
Polar molecules (Polar dielectrics)	Non-polar molecules (Non-Polar dielectrics)
Polar molecules are the molecules in which the centre of positive charges and the centre of negative charges donot coincide (A dielectric which is made of polar molecules is called polar dielectrics.)	Non-polar molecules are the molecules in which the centre of positive charges and the centre of negative charges coincide. (A dielectric which is made of non-polar molecules is called non-polar dielectrics)
They have permanent electric dipole moment.	They do not have permanent electric dipole moment.
Ex : Water (H_2O), HCL	Ex : Oxygen(O_2), Hydrogen(H_2)

4. Draw equipotential surface for (a) a positive point charge (b) a uniform electric field. (Aug 2022)



A positive point charge A uniform electric field

5. Write the relation between electric field and potential. A point charge +Q is placed at point O as shown in the figure. Is the potential difference $V_A - V_B$ positive, negative or zero?



Relation between electric field and potential is

$E = -\dfrac{\delta V}{\delta l}$

$V_A - V_B$ is positive because $V_A > V_B$

ONE MARK QUESTIONS:

1. What is an equipotential surface? (March 2018)

Any surface which has the same electric potential at every point is called an equipotential surface.

2. What is a capacitor? (July 2014)

Capacitor is a system of two conductors separated by a dielectric medium. Capacitor is a device used to store electric charge and electric energy.

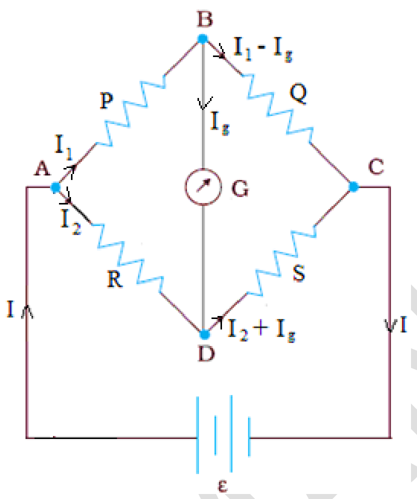
3. **Define dielectric constant in terms of capacity of a parallel plate capacitor. (Sept 2020)**
Dielectric constant is the ratio of the capacitance of the capacitor with dielectric material to the capacitance of an identical capacitor with vacuum as dielectric.

4. **What is electrostatic shielding?**
Electrostatic shielding is the phenomenon in which the cavity of a conductor is shielded from outside electric field.

3 CURRENT ELECTRICITY

FIVE MARK QUESTIONS:

1. **Derive the condition for balance of Wheatstone's bridge using Kirchhoff's rules. (March 2016, July 2014, March 2017, July 2016, June 2019)**
Using Kirchhoff's rules, obtain the expression for the balancing condition of Wheatstone bridge. (May 2022, Aug 2022)
Draw Wheatstone's bridge circuit and write the condition for its balance. (2 mark) (March 2014)



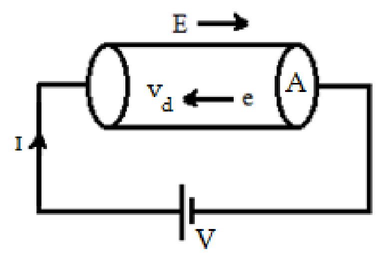
I_1 - current through P
I_2 - current through R
I_g - current through galvanometer
(I_1-I_g) - Current through Q
(I_2+I_g) - Current through S
Applying kirchhoff's second rule to loop ABDA,
$-I_1 P - I_g G + I_2 R=0$ ---------- (1)
Applying kirchhoff's second rule to loop BCDB,
$-(I_1-I_g) Q +(I_2+I_g) S + I_g G=0$ --------- (2)
When the Wheatstone network is balanced, $I_g=0$.
Equ (1) reduces to $-I_1 P + I_2 R=0$
$\Rightarrow$ $I_1 P = I_2 R$ ----------(3)
Equ (2) reduces to $-I_1 Q + I_2 S=0$
$\Rightarrow$ $I_1 Q = I_2 S$ ----------(4)
Dividing equ (3) by equ (4),

$$\frac{I_1 P}{I_1 Q} = \frac{I_2 R}{I_2 S}$$

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

This is the balanced condition of the Wheatstone bridge (Wheatstone network).

2. **Assuming the expression for drift velocity, derive the expression for conductivity of a material $\sigma = \frac{ne^2\tau}{m}$ where symbols have usual meaning.**
Define the term mobility. (July 2015, March 2019)
Derive $\sigma = \frac{ne^2\tau}{m}$, where the symbols have their usual meaning. (July 2018)



V - potential difference applied across the wire
E - electric field set up in the wire
v_d - drift velocity of the electrons
A - area of cross section of the wire
n - number of electrons per unit volume
e - charge of an electron
Current through a conductor is

$$I = neAv_d$$

$$I = neA\left(\frac{eE\tau}{m}\right) \qquad \left(\because v_d = \frac{eE\tau}{m}\right)$$

$$I = \frac{ne^2 A\tau}{m} E$$

The current density, $j = \frac{I}{A} = \frac{ne^2\tau}{m} E$ ------------(1)

From ohm's law, $j = \sigma E$ ------------(2)

Comparing equ (1) and (2), we get

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

Mobility: It is defined as the magnitude of drift velocity acquired per unit electric field applied.

3. **Obtain the expression for the effective emf and the effective internal resistance of two cells connected in parallel such that the current flowing in the same direction. (March 2018)**
Two cells of emf E_1 and E_2 and internal resistance r_1 and r_2 are connected in parallel such that they send current in same direction. Derive an expression for equivalent resistance and equivalent emf of the combination. (March 2019)

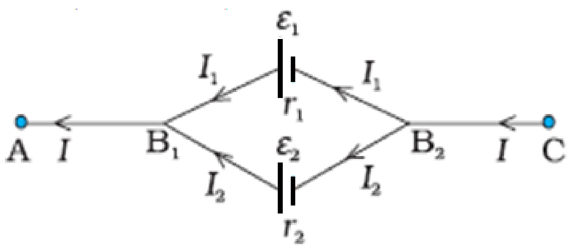


fig (a)

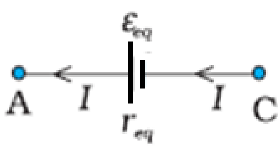


fig (b)

Let ε_1, ε_2 be the emfs of two cells and r_1, r_2 be their internal resistances respectively.
At the point B_1, $I = I_1 + I_2$ --------(1)
Potential difference across first cell is

$$V = \varepsilon_1 - I_1 r_1 \Rightarrow I_1 = \frac{\varepsilon_1 - V}{r_1} \text{ --------(2)}$$

Potential difference across second cell is

$$V = \varepsilon_2 - I_2 r_2 \Rightarrow I_2 = \frac{\varepsilon_2 - V}{r_2} \text{ --------(3)}$$

Substituting equ (2) and (3) in (1), we get

$$I = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2}$$

$$I = \frac{\varepsilon_1}{r_1} - \frac{V}{r_1} + \frac{\varepsilon_2}{r_2} - \frac{V}{r_2}$$

$$I = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$V\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - I$$

$$V\frac{r_2 + r_1}{r_1 r_2} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 r_2} - I$$

$$V = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} - I\frac{r_1 r_2}{r_1 + r_2} \text{ --------(4)}$$

If the parallel combination of cell is replaced by a single cell of ε_{eq} and r_{eq} as shown in fig(b), then

$$V = \varepsilon_{eq} - Ir_{eq} \text{ --------(5)}$$

Comparing equs (4) and (5), we get

$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

4. **Derive an expression for equivalent emf and equivalent resistance of two cells connected in series. (Sept 2020)**

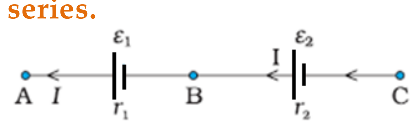


fig (a)

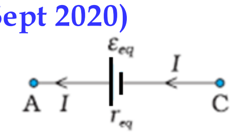


fig (b)

Let ε_1, ε_2 be the emfs of two cells and r_1, r_2 be their internal resistances respectively.
Potential difference between A and B is

$$V_{AB} = V_A - V_B = \varepsilon_1 - Ir_1$$

Potential difference between B and C is

$$V_{BC} = V_B - V_C = \varepsilon_2 - Ir_2$$

Potential difference between A and C is

$$V_{AC} = V_A - V_C = (V_A - V_B) + (V_B - V_C)$$

$$V_{AC} = (\varepsilon_1 - Ir_1) + (\varepsilon_2 - Ir_2)$$

$$V_{AC} = (\varepsilon_1 + \varepsilon_2) - I(r_1 + r_2) \text{ --------(1)}$$

If the series combination of cell is replaced by a single cell of ε_{eq} and r_{eq} as shown in fig(b), then

$$V_{AC} = \varepsilon_{eq} - Ir_{eq} \text{ --------(2)}$$

Comparing equs (1) and (2), we get

$$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$$

$$r_{eq} = r_1 + r_2$$

5. **What is equivalent resistance? With the help of circuit diagram, obtain the expression for equivalent resistance of two resistors connected in parallel. (March 2015)**
With the help of circuit diagram, obtain the expression for equivalent resistance of two resistors connected in parallel. (March 2014)

Equivalent resistance : The resistance that produces the same effect as that of the combination of resistances is called equivalent resistance.

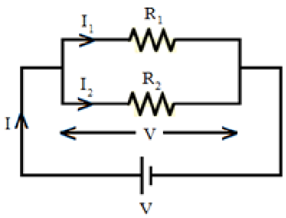
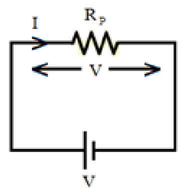


fig (a)



fig(b)

In parallel combination, the potential difference (V) across each resistor is same. The current divides in resistors and depends on its resistance.

If I_1 and I_2 are the current through resistors R_1 and R_2 respectively, then the total current

$I = I_1 + I_2$ -------(1)

From ohm's law, $I_1 = \dfrac{V}{R_1}$ and $I_2 = \dfrac{V}{R_2}$

$$(1) \Rightarrow I = \frac{V}{R_1} + \frac{V}{R_2}$$

$$I = V\left[\frac{1}{R_1} + \frac{1}{R_2}\right] \text{-------(2)}$$

Consider R_P is the equivalent resistance of the parallel combination of resistors.

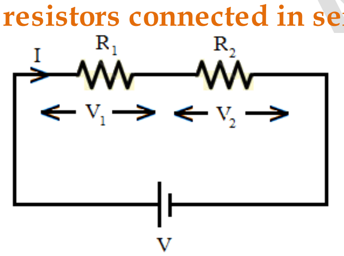
From ohm's law, $I = \dfrac{V}{R_p}$ -------(3)

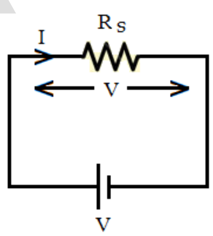
Equating equ (2) & (3), we have

$$\frac{V}{R_p} = V\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

6. With the help of circuit diagram, obtain the expression for equivalent resistance of two resistors connected in series.





In series combination, the current through each resistor is same. The potential difference divides and depends on its resistance.

If V_1 and V_2 are the voltage across resistors R_1 and R_2 respectively, then the total potential difference

$V = V_1 + V_2$ -------(1)

From ohm's law, $V_1 = IR_1$ and $V_2 = IR_2$

$$(1) \Rightarrow V = IR_1 + IR_2$$

$$V = I(R_1 + R_2) \text{-------(2)}$$

Consider R_S is the equivalent resistance of the series combination of resistors.

From ohm's law, $V = IR_s$ -------(3)

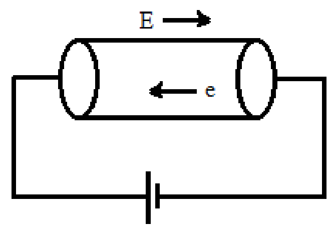
Equating equ (2) & (3), we have

$$IR_s = I(R_1 + R_2)$$

$$R_s = R_1 + R_2$$

THREE MARK QUESTIONS:

1. Derive an expression for drift velocity of free electrons in a conductor. (March 2016, July 2016)
Derive the expression for the drift velocity of electrons in a conductor in terms of their relaxation time. (May 2022)



When an electric field is present, each free electrons experiences a force of – eE.

The acceleration of the electrons is

$$a = -\frac{eE}{m}$$

Velocity of electrons at any time is

$$V_i = v_i - \frac{eE}{m}t_i$$

Where, v_i – velocity immediately after collision,

t_i – time elapse after its last collision.

Drift velocity v_d is the average velocity of the electrons under the influence of electric field.

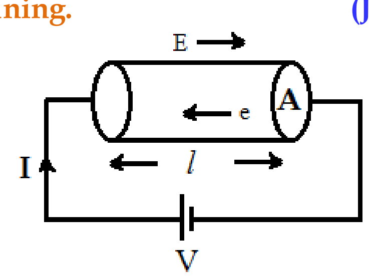
Relaxation time τ is the average time interval between two successive collisions.

$$v_d = (V_i)_{ave} = (v_i)_{ave} - \frac{eE}{m}(t_i)_{ave}$$

$$v_d = 0 - \frac{eE}{m}\tau \qquad (\because (v_i)_{ave} = 0 \ \& \ (t_i)_{ave} = \tau)$$

$$v_d = -\frac{eE}{m}\tau$$

2. Derive the relation $\vec{J} = \sigma\vec{E}$ with the terms having usual meaning. (July 2017)



If E is the magnitude of electric field in a conductor of length l, then the potential difference across its ends is

$$V = El \quad \text{--------(1)}$$

According to ohm's law, $V = IR$

$$V = I\frac{\rho l}{A} \quad \text{--------(2)} \qquad \left(\because R = \frac{\rho l}{A}\right)$$

Equating equ (1) & (2), we get

$$El = I\frac{\rho l}{A}$$

$$E = \frac{I}{A}\rho$$

$$E = j\rho \qquad \left(\because j = \frac{I}{A}\right)$$

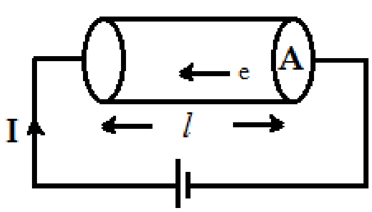
$$\vec{E} = \vec{j}\rho \quad (\because \text{direction of E and j are same})$$

$$\vec{j} = \frac{1}{\rho}\vec{E}$$

$$\vec{j} = \sigma\vec{E}$$

Where, $\sigma = \frac{1}{\rho}$ is called conductivity. The above equation is the vector form of ohm's law.

3. **Derive the expression for current in terms of drift velocity. (Aug 2022)**



n - number of electrons per unit volume

Volume of the conducting wire, V=Al

Total number of electrons in conducting wire = nAl

Total charge in conducting wire, q=nAle

Where, e - charge of an electron

If v_d is the drift velocity of the electrons then time taken by the electrons to cross a wire of length l is

$$t = \frac{l}{v_d}$$

Current through a conductor wire is

$$I = \frac{q}{t}$$

$$I = \frac{nAle}{\frac{l}{v_d}}$$

$$I = nAev_d$$

TWO MARK QUESTIONS:

1. **State and explain ohm's law. (March17, Aug2022)**
State ohm's law. (1mark)(July 2018, May 2022)

Statement: The current flowing through a conductor is directly proportional to potential difference across its ends, provided the temperature and other physical conditions remains same.

Explanation: If I is the current flowing through a conductor and V is the potential difference across its ends, then

$$I \propto V$$

$$I = \frac{1}{R}V$$

$$V = IR$$

Where R is a constant of proportionality called resistance of the conductor.

2. **Give any two limitations of ohm's law. (July 2014, March 2015, July 2015, June 2019, March 2020)**

1. Ohm's law fails, if the current varies non-linearly with voltage.

2. Ohm's law fails, if the relation between voltage and current is not unique (In GaAs).

3. Ohm's law is not applicable to non-ohmic devices (In diode, triode, etc.)

4. Ohm's law is not applicable at very low temperature and very high temperature.

3. **Define mobility. Mention its SI unit. (July 2017)**
Define mobility of electron. (or) Define electron mobility. (1 mark) (March 2014, July 2014, March 2017, March 2018, Aug2022)

The mobility of free electron is defined as the drift velocity acquired by an electron per unit electric field applied.

The SI unit of electron mobility is

$m^2s^{-1}V^{-1}$ or $ms^{-1}N^{-1}C$.

4. **What is ohmic device? Give one example.(July2017)**

The devices which obey ohm's law are called ohmic devices.

Ex: Metallic conductor, Resistor.

5. **State Kirchhoff's laws of electrical network. (March 2018)**
State Kirchhoff's junction rule.(1 mark)(July2017)

Kirchhoff's junction rule or first rule : At any junction, the sum of the currents entering the junction is equal to the sum of the currents leaving the junction.

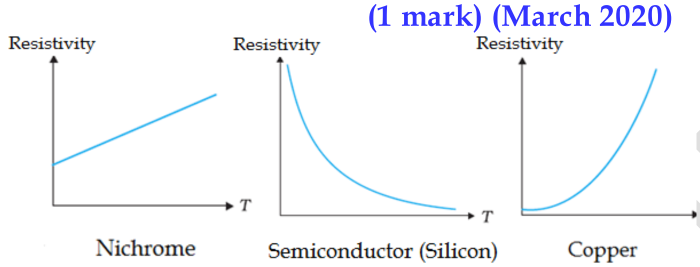
Kirchhoff's loop rule or second rule : The algebraic sum of emf's and voltage drops in resistors around any closed circuit (loop) is zero.

6. **Write the expression for drift velocity interms of current, explain the terms used.** **(March 2019)**

Drift velocity $v_d = \dfrac{I}{neA}$

Where I- current through conductor,
n – number of electrons per unit volume
A – cross sectional area of conductor,
e - charge on electron.

7. **Represent graphically the variation of resistivity with absolute temperature for Copper and Nichrome metals.** **(July 2018)**
Show with schematic graphs, variation of resistivity with absolute temperature for (a) Nichrome and (b) Silicon. **(May 2022)**
Draw the curve to show the variation of resistivity as a function of temperature for copper. **(1 mark)(Sept 2020)**
Graphically represent the variation of resistivity of a semiconductor with absolute temperature. **(1 mark) (March 2020)**



8. **Define the terms 'Drift Velocity' and 'mobility' of free electrons.** **(Sept2020)**
The average velocity with which the free electrons drift under the influence of an electric field is called drift velocity.
The mobility of free electron is defined as the drift velocity acquired by an electron electron per unit electric field applied.

9. **What is a meter bridge? What is the principle behind the working of meter bridge?**
A meter bridge is a device used to find unknown resistance.
It works on the principle of Wheatstone bridge.

10. **What is a potentiometer? Mention two applications of potentiometer.**
A potentiometer is a device used to measure the emf of a cell or potential difference between two points in a circuit.
They are used (i) To compare emf of two cells (ii) To determine the internal resistance of the cell.

ONE MARK QUESTIONS:

1. **Define electrical resistivity of material of a conductor.** **(March 2019)**
Resistivity of a conductor is the resistance offered by 1m length of a conductor having a cross sectional area of $1m^2$.

2. **How does the resistance of a conductor vary with its length?** **(June 2019)**
The resistance of a conductor is directly proportional to its length. $(R \alpha l)$

4. **A resistor is marked with colours red, red, orange and gold. Write the value of its resistance.** **(March 2015)**
$22 \times 10^3 \pm 5\%\ \Omega$

5. **The resistance of a carbon resistor with four coloured rings is $(500 \pm 50)\Omega$. Identify the colour of fourth ring.** **(May 2022)**
Silver.

6. **Write the colour code for a resistor of resistance $45 \pm 10\%\Omega$.** **(Aug 2022)**
Yellow, green, black, silver.

7. **A wire of resistivity ρ is stretched to three times its length. What will be its new resistivity?**
Resistivity is same (because resistivity does not depend on length).

5. **Name the Kirchhoff's law which is a consequence of principle of conservation of energy.**
Kirchhoff's second law or loop rule.

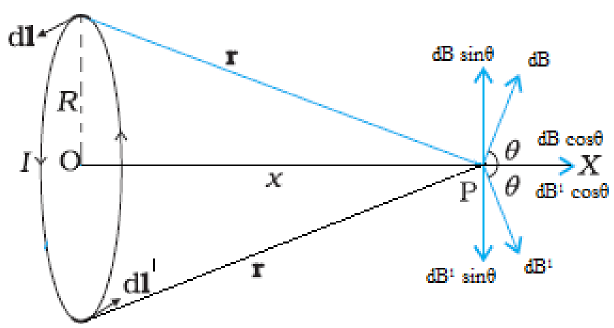
6. **Name the Kirchhoff's law which is a consequence of principle of conservation of charge.**
Kirchhoff's first law or junction rule.

7. **How does resistivity of the nichrome vary with absolute temperature?**
Very weak dependence of resistivity with temperature

8. **The coloured rings marked on a carbon resistor are Red, Red, Red and Silver. What is the tolerance of this resistor?**
Tolerance is 10%. (R = 22 x 10^2 ± 10%)

FIVE MARK QUESTIONS:

1. **Derive the expression for magnetic field at a point on the axis of a circular current loop using Biot-Savart's law.** **(March 2014, March 2015, March 2017, March 2018, March 2019)**



Consider a circular loop of radius R, center O and carrying a current I. Consider two conducting elements d*l* and d*l′* are located diametrically opposite to each other. The distance of d*l* and d*l′* from P is r. the distance between p and centre of loop is x.

Angle between d*l* and r is 90°.

According to Biot-Savart law, the magnetic field at the point P due to d*l* is

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin 90^0}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2} \quad ------(1)$$

Similarly, the magnetic field at the point p due to d*l′* is

$$dB' = \frac{\mu_0}{4\pi}\frac{Idl}{r^2} \quad -----(2)$$

From equ (1) & (2), dB = dB′

The vertical components of $\vec{dB}$ and $\vec{dB'}$ cancel each other and horizontal components of $\vec{dB}$ and $\vec{dB'}$ are added.

The resultant magnetic field at P due to the loop is

$$B = \sum dB\cos\theta$$

From fig, $\cos\theta = \frac{R}{r}$

$$B = \sum\left(\frac{\mu_0}{4\pi}\frac{Idl}{r^2}\right)\frac{R}{r}$$

$$B = \frac{\mu_0}{4\pi}\frac{IR}{r^3}\sum dl$$

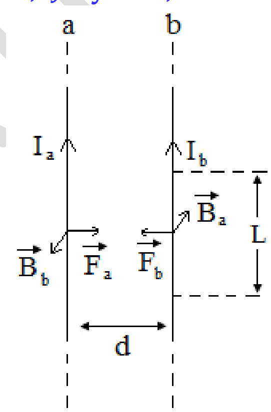
$$B = \frac{\mu_0}{4\pi}\frac{IR}{r^3}2\pi R \qquad \left(\because \sum dl = 2\pi R\right)$$

From fig, $r = \sqrt{R^2 + x^2}$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi IR^2}{\left(\sqrt{R^2+x^2}\right)^3}$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi IR^2}{\left(R^2+x^2\right)^{3/2}}$$

2. **Derive the expression for the force between two straight parallel conductors carrying currents and hence define ampere.** **(July 2015, March 2016, July2016, July17, July2018, March2020, Aug 2022)**



Consider two long parallel conductors a and b carrying currents I_a and I_b respectively. d is the separation between conductors a and b.

The magnetic field produced by current I_a on the conductor b is

$$B_a = \frac{\mu_0 I_a}{2\pi d}$$

The force on a segment L of conductor b due to a is

$$F_b = I_b \times L \times B_a \sin 90^0 = B_a I_b L$$

$$F_b = \frac{\mu_0 I_a I_b}{2\pi d}L \quad ---------(1)$$

The magnetic field produced by current I_b on the conductor a is

$$B_b = \frac{\mu_0 I_b}{2\pi d}$$

The force on a segment L of conductor a due to b is

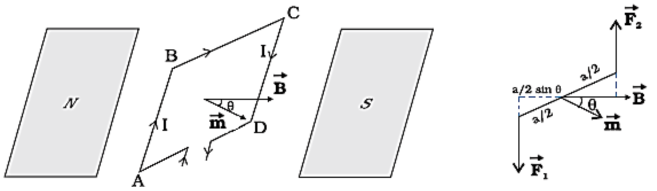
$$F_a = I_a \times L \times B_b \sin 90^0 = B_b I_a L$$

$$F_a = \frac{\mu_0 I_a I_b}{2\pi d}L \quad ---------(2)$$

From equations (1) and (2), magnitude of F_a and F_b are equal. $F_a = F_b = \dfrac{\mu_0 I_a I_b}{2\pi d}$

Ampere: Ampere is defined as that current flowing in each of the two very long straight parallel conductors placed 1m apart in vacuum, would produce force of 2×10^{-7} newton per meter of length.

3. **With the help of a diagram, derive the expression for the torque on a rectangular loop placed in a uniform magnetic field.** **(May 2022)**



Consider a rectangular loop ABCD carrying current I placed in uniform magnetic field as shown in the fig. The magnetic field makes an angle θ with the normal to the plane of coil.

The forces on the arms BC and DA are equal, opposite and acts along the axis of the coil (collinear). They cancel each other, resulting no net force or torque.

The forces on arms AB and CD are equal and opposite with a magnitude

$F_1 = F_2 = IbB$ ----------(i)

These two forces form a couple which exerts a toque.

The magnitude of the torque on the loop is,

$$\tau = F_1 \frac{a}{2}\sin\theta + F_2 \frac{a}{2}\sin\theta$$

$$\tau = IbB\frac{a}{2}\sin\theta + IbB\frac{a}{2}\sin\theta$$

$$\tau = IabB\sin\theta$$

$$\tau = IAB\sin\theta \qquad (\because A = ab)$$

The magnetic moment of the loop is m = IA,

$$\tau = mB\sin\theta$$

In vector form, $\vec{\tau} = \vec{m}\times\vec{B}$

THREE MARK QUESTIONS:

1. **Give an expression for force acting on a charge moving in a magnetic field and explain the symbols. When does the force become maximum?** **(July 2014)**

When does the force acting on a charged particle moving in a uniform magnetic field is maximum. **(1 mark) (July 2016, June 2019)**

Write the expression for force acting on a moving charge in a magnetic field. (1 mark) (March 2019)

The force on a moving charge due to a magnetic field is $\vec{F_m} = q(\vec{v}\times\vec{B}) = qvB\sin\theta\,\hat{n}$

Where, q – charge of the particle

$\vec{v}$ - velocity of charged particle

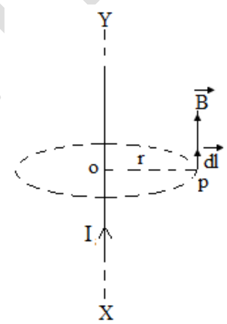
$\vec{B}$ - magnetic field

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

The magnetic force become maximum when the angle between the velocity of charge and magnetic field is 90⁰. $(\theta = 90^0)$

2. **State Ampere's circuital law. Using it, derive the expression for magnetic field at a point due to a long current carrying conductor.** **(March 2018, July 2015)**

Statement: The line integral of magnetic field $\vec{B}$ around a closed path is equal to μ_0 times the total current enclosed by that path.



Consider an infinite straight conductor carrying current I from X to Y. The magnetic lines of force are concentric circles. The magnetic field $\vec{B}$ is same in this circular path.

Applying Ampere's circuital law to this closed path,

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

$$\oint Bdl\cos 0^0 = \mu_0 I \quad (\because \text{angle between } \vec{B} \text{ and } \vec{dl} \text{ is } 0^0)$$

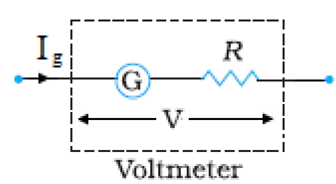
$$B\oint dl = \mu_0 I$$

$$B(2\pi r) = \mu_0 I \qquad (\because \oint dl = 2\pi r)$$

$$B = \frac{\mu_0 I}{2\pi r}$$

3. **How can a galvanometer converted into a voltmeter? Explain with diagram.** **(March 2017, July 2017, Aug 2022)**

A galvanometer is converted into a voltmeter by connecting a suitable high resistance in series with it.



From the fig, $V = I_g(G+R)$

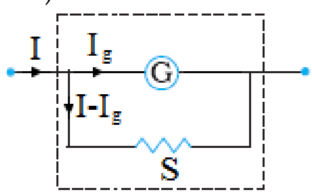
$$\frac{V}{I_g} = G + R$$

$$R = \frac{V}{I_g} - G$$

4. Explain with circuit diagram, how to convert galvanometer into an ammeter. **(March 2015, June 2019)**

How would you convert galvanometer into an ammeter? Explain. **(Sept 2020)**

A galvanometer is converted into an ammeter by connecting a suitable low resistance S in parallel (called shunt) with it.



Ammeter

From the fig, $(I - I_g)S = I_g G$

$$S = \frac{I_g}{I - I_g} G$$

5. Give the principle of cyclotron and draw the neat labeled schematic diagram of cyclotron. **(March 2020)**

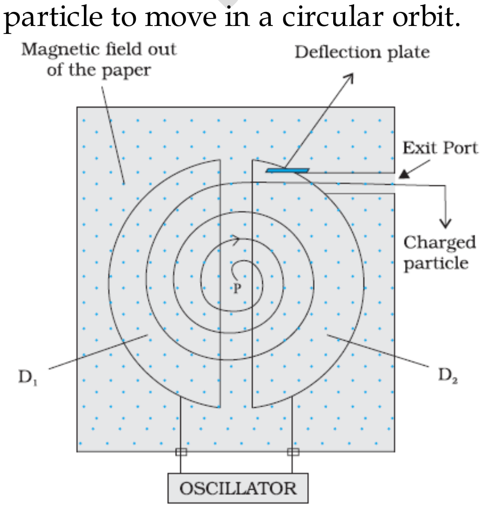
What is a cyclotron? Draw its neat diagram and label the parts. **(Sept 2020)**

Draw a neat labeled diagram of Cyclotron. **(2 mark)(June 2019)**

What is a cyclotron? **(March 2006)**

The cyclotron is a machine to accelerate positively charged particles or ions to high energies.

Principle: The frequency of charged particle does not depend on the speed of the charged particle. In the crossed fields, the electric field accelerates the charged particle and the magnetic field makes the charged particle to move in a circular orbit.



6. Write the expression for force per unit length between two straight parallel current carrying conductors of infinite length. Hence define SI unit of current 'ampere'. **(March 2019)**

The force per unit length between two straight parallel current carrying conductors is

$$F = \frac{\mu_0 I_a I_b}{2\pi d}$$

Where, μ_0 - permeability of free space

I_a and I_b are currents through conductors a and b.

d – separation between conductors a and b.

Definition of SI unit of current 'ampere':

Ampere is defined as that current flowing in each of the two very long straight parallel conductors placed 1m apart in vacuum, would produce force of 2×10^{-7} newton per meter of length.

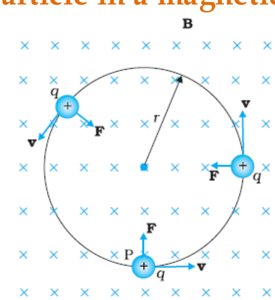
7. Write the two reasons to show that, 'the galvanometer as such can not be used as an ammeter'. Give the method of converting the galvanometer into an ammeter. **(May 2022)**

1. It is a sensitive device

2. It is connected in series and it has high resistance

Method: By connecting low resistance in parallel with galvanometer.

8. Obtain the expression for radius of circular path of charged particle in a magnetic field.



Consider a particle of mass m and charge q moving with velocity v in a uniform magnetic field B. When a charged particle moves perpendicular to the uniform magnetic field, it moves in a circular path of radius r due to the magnetic force.

centripetal force = magnetic force

$$\frac{mv^2}{r} = Bqv$$

$$r = \frac{mv}{qB}$$

9. State and explain Biot-Savart law.

Statement: The magnitude of magnetic field dB at point P due to the current element depends upon the following factors:

1. Directly proportional to the current flowing through the current element ($dB \propto I$)

2. Directly proportional to the length of the current element ($dB \propto dl$)

3. Directly proportional to $\sin\theta$ ($dB \propto \sin\theta$)

4. Inversely proportional to the square of the distance between P and the current element (dB α $1/r^2$)

Explanation: According to Biot-Savart law,

$$dB \alpha \frac{I\, dl \sin\theta}{r^2}$$

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

Where $\frac{\mu_0}{4\pi}$ is a constant of proportionality.

In vector form, $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\left(d\vec{l} \times \vec{r}\right)}{r^3}$

TWO MARK QUESTIONS:

1. **State Ampere's circuital law and represent mathematically.** **(July 2014)**
   State Ampere's circuital law.
   (1 mark) (March 2015, June 2019, Sept 2020)

   Statement: The line integral of magnetic field $\vec{B}$ around a closed path is equal to μ_0 times the total current enclosed by that path.

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

   Where, $\oint \vec{B}.\vec{dl}$ - line integral of magnetic field $\vec{B}$ around a closed path,
   I - current enclosed by the path,
   μ_0 - permeability of free space.

2. **Write any two uses of cyclotron.** **(March 2014, July 2014)**
   Give an application of cyclotron. (1mark)(March18)
   1. To study the resulting nuclear reactions.
   2. To synthesize new materials.
   3. To produce radioactive substances.

3. **Write the expression for cyclotron frequency and explain the terms.**

   Cyclotron frequency, $f = \frac{qB}{2\pi m}$

   Where, q - charge of the particle
   B - magnetic field
   m - the mass of the charged particle.

4. **What is toroid? Mention an expression for magnetic field at a point inside a toroid.** **(March 2016)**

   The toroid is a hollow circular ring on which a large number of turns of a wire are closely wound. The expression for magnetic field at a point inside a toroid is $B = \mu_0 nI$

5. **Mention an expression for the magnetic field produced at the center on the axis of a current carrying solenoid and explain the terms.** **(June 2019)**

   $B = \mu_0 nI$

   Where, μ_0 - permeability of free space,
   I - current through the solenoid
   n – number of turns per unit length

6. **What is a moving coil galvanometer? What is the principle of moving coil galvanometer?**

   A moving coil galvanometer is an instrument used for detection of small current.
   It works based on the principle that when a current carrying coil is placed in a uniform magnetic field, the coil experiences a torque.

7. **When does the force experienced by a straight current carrying conductor placed in a uniform magnetic field become (a) maximum and (b) minimum?**

   $F = IlB \sin\theta$
   θ - angle between the direction of length vector and magnetic field.
   The force is maximum when $\theta = 90°$
   The force is minimum when $\theta = 0°$

8. **A proton and an electron enter a uniform magnetic field at the same angle with the field and with the same speed. Do they experience force of same magnitude? Justify your answer.**

   They experience force of same magnitude and opposite direction. This is because magnetic force ($F = qvB \sin\theta$) depends on q, v, B, and θ. These (q, v, B, and θ) are same to proton and electron.

ONE MARK QUESTIONS:

1. **What is the nature of force between two parallel conductors carrying currents in same direction?** **(March 2014, July 2014)**

   Attractive force

2. **What is Lorentz force?** **(July 2017)**

   The total force experienced by a charge moving with velocity in the presence of magnetic field and electric field is called Lorenz force.

3. **A charged particle enters an electric field in the direction of electric field. What is the nature of path traced by it?** **(July 2015)**

   Straight line path. (positive charge - in the direction of electric field and negative charge – opposite to the direction of electric field)

4. **What is the magnitude of the magnetic force on a charged particle moving anti-parallel to a uniform magnetic field?** **(May 2022)**

   Zero.

5. **A charged particle enters a magnetic field in the direction of it. What is the nature of the path traced by it? (Aug 2022)**
Straight line path. ($F_m=0$)

6. **Write the expression for force experienced by a straight conductor of length $\vec{l}$ carrying a steady current I, moving in a uniform externalmagnetic field $\vec{B}$.**
$\vec{F} = I(\vec{l} \times \vec{B}) = IlB \sin\theta\, \hat{n}$

7. **Define current sensitivity of a galvanometer.**
It is the deflection produced in the galvanometer per unit current.

7. **What is the nature of the force between two infinitely long straight parallel current carrying conducting wires if the currents are flowing in opposite directions?**
Repulsive force.

8. **Write the value of Bohr magneton.**
Bohr magneton, $\mu_b = 9.27 \times 10^{-24}$ Am^2.

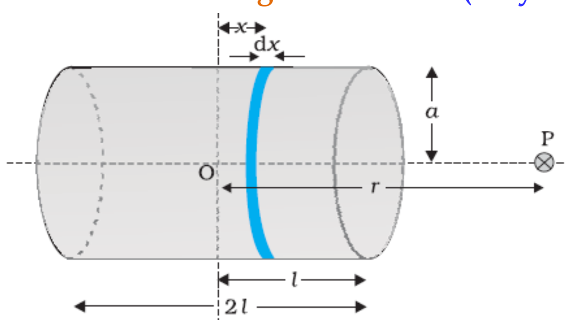
9. **Mention the SI unit of magnetic moment.**
Am^2 or NmT^{-1}.

5 MAGNETISM AND MATTER

FIVE MARK QUESTIONS:

1. **Write any five properties of ferromagnetic materials. (March 2017)**
Write any four properties of ferromagnetic materials and give an example for it. (July 2014)
Write three properties of ferromagnetic materials. (3 mark) (March 2016)
List any three properties of ferromagnetic substances. (May 2022)
1. Ferromagnetic substances are strongly magnetized when placed in an external magnetic field.
2. They are strongly attracted by a magnet.
3. The relative permeability of a ferromagnetic substance is very high (in the order of 10^3).
4. The magnetic susceptibility of a ferromagnetic substance has a large positive value.
5. As temperature increases, magnetization or susceptibility decreases.

2. **Show that a current carrying solenoid is equivalent to a bar magnet. (July 2017)**
Derive the expression for the magnitude of the magnetic field at a point on the axis of a current carrying solenoid. Hence show that it is equivalent to a bar magnet. (May 2022)



a - radius of the solenoid
2l - length of the solenoid
n - number of turns per unit length of the solenoid
r – distance between p and centre of the solenoid
I - the current in the solenoid
Consider a current element of thickness dx of the solenoid at a distance x from its centre.
The number of turns in the element = ndx
The magnitude of magnetic field at P is

$$dB = \frac{\mu_0}{4\pi}\frac{2\pi(ndx)Ia^2}{\left[(r-x)^2 + a^2\right]^{3/2}}$$

If r >> a and r >> x, then $\left[(r-x)^2 + a^2\right]^{3/2} \approx r^3$

$$dB = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}dx$$

The total magnetic field at P on the axial line is

$$B = \int_{-l}^{l} dB = \int_{-l}^{l}\frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}dx$$

$$B = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}\int_{-l}^{l} dx$$

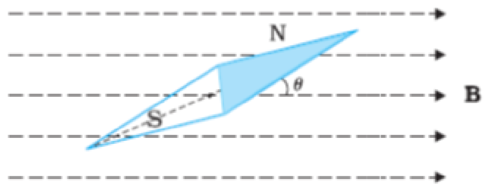
$$B = \frac{\mu_0}{4\pi}\frac{2\pi nIa^2}{r^3}2l \qquad \left(\because \int_{-l}^{l} dx = 2l\right)$$

The magnetic moment of the solenoid is
m = $(n2l) \times I \times \pi a^2$

$$\therefore B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$$

This expression is similar to the magnetic field on the axial line of the short bar magnet. Therefore a current carrying solenoid is equivalent to a bar magnet.

3. **Obtain an expression for period of a magnetic dipole kept in a uniform magnetic field and hence obtain an expression for magnetic field.** **(Sept 2020)**



Consider a magnetic dipole (compass needle) of magnetic dipole moment m and moment of inertia I is allowed to oscillate in the uniform magnetic field B.

The deflecting torque acting on the dipole is

$\tau = mB\sin\theta$

Where, θ is the angle between $\vec{m}$ and $\vec{B}$.

Restoring torque is equal and opposite to deflecting torque.

$\therefore\ \tau = -mB\sin\theta$

In equilibrium, $I\dfrac{d^2\theta}{dt^2} = -mB\sin\theta \quad \left(\because \tau = I\dfrac{d^2\theta}{dt^2}\right)$

For small values of θ, sin θ ≈ θ.

$$I\frac{d^2\theta}{dt^2} = -mB\theta$$

$$\frac{d^2\theta}{dt^2} = -\frac{mB}{I}\theta \quad \text{-------(1)}$$

This equation is similar to simple harmonic motion.

$$\frac{d^2\theta}{dt^2} = -\omega^2\theta \quad \text{-------(2)}$$

Comparing (1) and (2), we get

$$\omega^2 = \frac{mB}{I}$$

$$\omega = \sqrt{\frac{mB}{I}}$$

$$\frac{2\pi}{T} = \sqrt{\frac{mB}{I}}$$

Time period, $T = \dfrac{1}{2\pi}\sqrt{\dfrac{I}{mB}}$

Magnetic field, $B = \dfrac{4\pi^2 I}{mT^2}$

THREE MARK QUESTIONS:

1. **What are (i) magnetic declination (ii) magnetic dip (iii) horizontal component of earth's magnetic field at the given place?** **(March 2014, Aug 2022)**
Define (i) magnetic declination (ii) magnetic dip. Mention the SI unit of magnetization. **(July 2015)**
Define the terms:(i) declination (ii) inclination or dip. **(2 mark)(March 2018, March 2017)**
What is magnetic declination? **(1 mark)(March 2015)**
Define magnetic dip and declination at a place. **(2 mark)(March 2019)**
Define declination. **(1 mark) (June 2019)**
Define the magnetic declination at a place on the Earth. **(May 2022)**

1. **Magnetic declination:** The angle between the true geographic north and north shown by a compass needle is called the magnetic declination.
2. **Magnetic dip:** The magnetic dip at a place is the angle made by the total magnetic field B_E of the earth with the horizontal surface of the earth.
3. **Horizontal component of earth's magnetic field at a place:** It is the component of earth total magnetic field along horizontal direction in the magnetic meridian.

The SI unit of magnetization is Am^{-1}

2. **Write three differences between diamagnetic and paramagnetic substances.** **(March 2015, July 2018)**
Write any two differences between diamagnetic and paramagnetic substances. **(2 mark)(July 2017)**

Diamagnetic substance	Paramagnetic substance
The relative permeability (μ_r) is always less than 1.	The relative permeability (μ_r) is slightly greater than 1.
The magnetic susceptibility (χ) is small negative value.	The magnetic susceptibility (χ) is small positive value.
They are feebly repelled by a strong magnet.	They are weakly attracted by a magnet.

3. **What is hysteresis? Define the terms retentivity and coercivity of a ferromagnetic material.** **(March 2018)**
Define "retentivity" and "coercivity". **(March2020)**
What is retentivity in magnetism?
What is retentivity? **(1 mark)(July 2018, June 2019)**

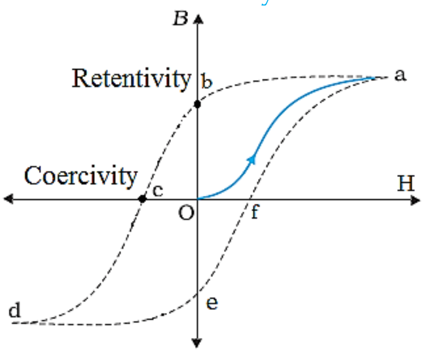
The phenomenon of lagging of magnetic field in the material (B) behind the magnetic intensity (H) in a ferromagnetic material subjected to a cycle of magnetisation is known as hysteresis.

The value of magnetic field B left in the material when the magnetic intensity H is reduced to zero is called retentivity or remanence.

The value of magnetic intensity H at which the magnetic field B inside the sample becomes zero is called coercivity.

4. **What is hysteresis? Draw hysteresis curve for a ferromagnetic material.** **(Aug 2022)**
Draw the variation of magnetic field (B) with magnetic intensity (H) when a ferromagnetic material is subjected to a cycle of magnetisation. **(2 Mark) (March 2016)**

The phenomenon of lagging of magnetic field in the material (B) behind the magnetic intensity (H) in a ferromagnetic material subjected to a cycle of magnetisation is known as hysteresis.



5. **Distinguish between dia and ferro magnetic materials.** **(March 2019)**
Write any three distinguishing properties between diamagnetic and ferromagnetic materials. **(June2019)**
Distinguish between diamagnetism and ferromagnetism on the basis of relative permeability and susceptibility. **(2-mark)(July 2015)**

Diamagnetic substance	Ferromagnetism substance
The relative permeability (μ_r) is always less than 1.	The relative permeability (μ_r) is very high.
The magnetic susceptibility (χ) is small negative value.	The magnetic susceptibility (χ) is large positive value.
They are feebly repelled by a strong magnet.	They are strongly attracted by a magnet.

6. **State and explain Gauss law in magnetism.** **(2 mark)(July 2016, June 2019)**

Statement: The net magnetic flux through a closed surface is zero.
Explanation: Magnetic poles exist in pairs of equal and opposite strengths (magnetic dipole). This means a surface encloses a pair of equal and opposite magnetic poles so that net pole strength enclosed by the surface is zero. Hence Gauss law in magnetism is $\phi_B = \sum \vec{B}\cdot\vec{ds} = 0$

TWO MARK QUESTIONS:

1. **What is magnetic susceptibility? For which material is it low and positive.** **(March 2014)**
What is magnetic susceptibility? **(1 mark)(March 2019)**

The magnetic susceptibility of a material is defined as the ratio of magnetisation (M) developed in the material to the applied magnetizing force (H). **(or)** it is a measure of how a magnetic material responds to an external field.
It is low and positive for paramagnetic substance.

2. **Write any two properties of magnetic field lines.** **(March 2015, July 2014)**
1. The magnetic field lines of a magnet form a continuous closed loop.
2. The tangent to the field line at a given point represents the direction of the net magnetic field at that point.
3. The magnetic field lines does not intersect.

3. **Distinguish between paramagnetic and ferromagnetic substances.** **(July 2016)**

Paramagnetic substance	Ferromagnetism substance
The relative permeability is slightly greater than 1.	The relative permeability is very high.
The magnetic susceptibility is small positive value.	The magnetic susceptibility is large positive value.

4. **Write the expression for magnetic potential energy of a magnetic dipole kept in a uniform magnetic field and explain the terms.** **(March2018)**

$U = -mB\cos\theta = -\vec{m}\cdot\vec{B}$

Where, m – magnetic dipole moment,
B - uniform magnetic field
θ - angle between $\vec{m}$ and $\vec{B}$.

7. **State and explain Curie's law in magnetism.** **(July 2018)**
State Curie's law. **(1 mark)(July15, July16, Aug22)**

The magnetic susceptibility of a paramagnetic substance is inversely proportional to its absolute temperature.
That is, $\chi \propto \frac{1}{T} \quad \Rightarrow \quad \chi = \frac{\mu_0 C}{T}$
Where, μ_0 is the permeability of free space
C is the Curie constant.

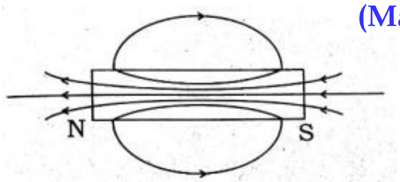
8. **What is hysteresis? Mention the significance of hysteresis curve.** **(Sept2020)**

The phenomenon of lagging of magnetic field in the material (B) behind the magnetic intensity (H) in a ferromagnetic material subjected to a cycle of magnetisation is known as hysteresis.
Significance: The size and shape of hysteresis loop gives information like retentivity, coercivity and hysteresis loss.

9. **What is an magnetic dipole moment? Write its SI unit.**
The magnetic dipole moment (m) of a magnetic dipole is the product of the strength of its either pole and magnetic length.
The SI unit of magnetic dipole moment is Am^2 or JT^{-1}.

ONE MARK QUESTIONS:

1. **Draw the pattern of magnetic field lines for a bar magnet.** **(March 2014)**

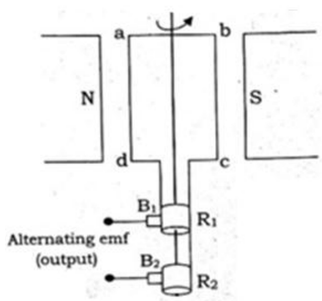


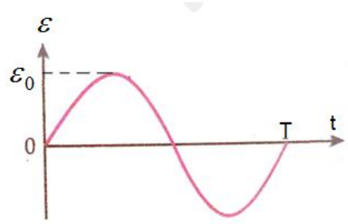
2. **Define magnetization of a sample. (March 2016)**
It is defined as the magnetic moment developed per unit volume of the sample.
3. **Where on the earth's surface is the magnetic dip is zero? (July 2016, July 2018)**
Magnetic equator.
4. **Give (Mention) any one use of electromagnet. (March 2020, Aug 2022)**
Electric bells, loudspeakers, telephone diaphragms.

6 ELECTROMAGNETIC INDUCTION

FIVE MARK QUESTIONS:

1. **Derive an expression for instantaneous induced emf in an AC generator. (June 2019)**
With the help of labelled diagram, derive the expression for instantaneous emf induced in an AC generator. (March 2020)
Derive an expression for the alternating emf when a coil is rotating in a uniform magnetic field. (Aug 2022)





Consider a rectangular coil of N turns and cross sectional area A.
When the coil rotates with a constant angular speed ω in uniform magnetic field $\vec{B}$.
The angle between $\vec{B}$ and $\vec{A}$ of the coil at any instant t is θ = ωt (Assuming θ=0⁰ at t=0s)
The magnetic flux linked with the coil at the instant t is

$\phi_B = BA\cos\theta = BA\cos\omega t$

As the coil rotates the magnetic flux linked with it changes and hence an emf is induced in it.
According to Faraday's law,

$$\varepsilon = -N\frac{d\phi_B}{dt}$$

$$\varepsilon = -N\frac{d(BA\cos\omega t)}{dt}$$

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

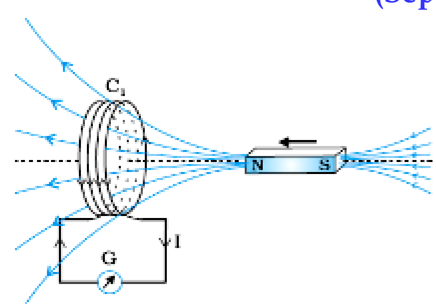
$$\varepsilon = NBA\omega\sin\omega t \qquad \left(\because \frac{d(\cos\omega t)}{dt} = \omega\sin\omega t\right)$$

$$\varepsilon = \varepsilon_0 \sin\omega t$$

Where ε_0 = NBAω is the maximum value of induced emf .

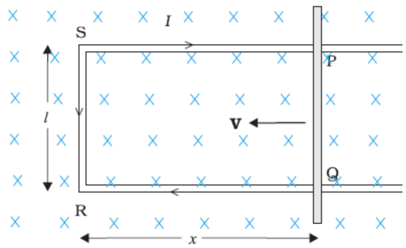
THREE MARK QUESTIONS:

1. **Explain briefly the coil and magnet experiment to demonstrate electromagnetic induction. (March 2016, July 2018)**
Describe Faraday and Henry coil and magnet experiment to demonstrate the electro-magnetic induction. (Sept 2020)



The coil C_1 is connected to a galvanometer G. When the North-pole of a bar magnet is pushed towards the coil, the galvanometer shows a deflection, indicating the electric current induced in the coil. The galvanometer does not show any deflection when the magnet is held stationary. When the magnet is pulled away from the coil, the galvanometer shows deflection in the opposite direction. South-pole of the bar magnet is moved towards or away from the coil, the deflections in the galvanometer are opposite to that observed with the North-pole. When the bar magnet is held stationary and the coil C_1 is moved towards or away from the magnet, the same effects are observed. It shows that the relative motion between the magnet and the coil is responsible for induction of current in the coil.

2. Derive an expression for electromotive force (motional emf) induced in a rod moving perpendicular to the uniform magnetic field.
(March 2015, July 2014, March 2017, July 2016)



When a conductor of length 'l' is free to move on the rectangular conductor PQRS in a uniform magnetic field B through a distance x at any instant of time t, the change in magnetic flux linked with the loop PQRS is

$\phi_B = BA = Bl\,x \qquad (\because A = l\,x \rightarrow \text{Area of PQRS})$

According to Faraday's law of electromagnetic induction,

$$\varepsilon = -\frac{d\phi_B}{dt}$$

$$\varepsilon = -\frac{d(Blx)}{dt} = -Bl\frac{d(x)}{dt}$$

$$\varepsilon = Blv \qquad \left(\because v = -\frac{dx}{dt}\right)$$

3. Mention any three application of eddy currents. **(July 2017)**

Write any three applications in which advantage of eddy currents are used. **(May 2022)**

(1) Magnetic braking in trains
(2) Electromagnetic damping
(3) Induction furnace
(4) Electric power meters

4. Mention any two advantages of eddy currents in practical applications. **(2 mark) (March 2014)**

Write any one advantages of eddy currents.
(1 mark) (June 2019, Sept 2020)

(1) Electromagnetic breaks - eddy currents induced in the rails oppose the motion of the train. Braking effect is smooth because no mechanical linkages.

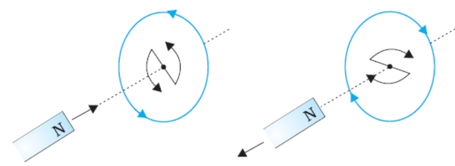
(2) Electromagnetic damping – when the coil oscillates in the certain galvanometers, eddy currents generated in the core oppose the motion and bring the coil to rest quickly.

5. State and explain Lenz's law for induced emf.
(March 2014)

State Lenz's law in electromagnetic induction.
(1 mark)(July 2018)

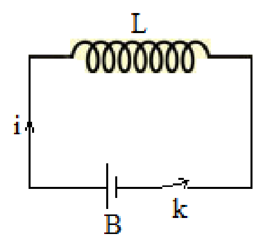
Statement: The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

Explanation:



When north pole of a bar magnet moved towards the closed coil, the magnetic flux through the coil increases. Current is induced in the coil in such a direction that it opposes the increase in the flux. This is possible only when the current induced in the coil is in anticlockwise direction. This induces north polarity. Similarly, when north pole of the magnet is moved away from the coil, the magnetic flux linked with the coil decreases. To counter this decrease in magnetic flux, current induced in the coil is clockwise direction so that its south pole face receding the north pole of the magnet.

6. Derive the expression for energy stored in a current carrying coil. **(July 2015)**



The source neend to do work against the back emf to establish current I through an inductor.
The small amount of work done for a small time dt is

$$dW = -\varepsilon I\,dt$$

$$dW = L\frac{dI}{dt}Idt \qquad \left(\because \varepsilon = -L\frac{dI}{dt}\right)$$

$$dW = LIdI$$

The total work done in establishing current I is

$$W = \int dW = \int_0^I LIdI = L\left[\frac{I^2}{2}\right]_0^I$$

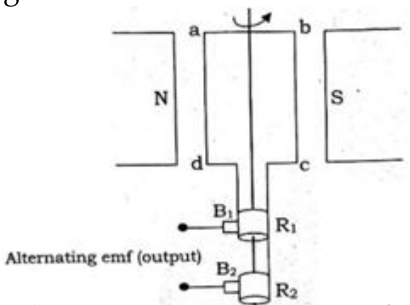
$$W = \frac{1}{2}LI^2$$

This work done is stored as magneti potential energy U in inductor.

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

7. Give the principle on which AC generator works. With the schematic diagram explain the basic parts of the AC generator.

AC generator work on the principle of electromagnetic induction.



As the coil rotates in a magnetic field **B**, the effective area of the loop ($A\cos\theta$) changes and flux linked with coil changes. It produces emf in a coil. This is the principle of operation of a simple ac generator.

AC generator consists of a coil mounted on a rotor shaft. The axis of rotation of the coil is perpendicular to the direction of the magnetic field. The coil (called armature) is mechanically rotated in the uniform magnetic field by some external means. The rotation of the coil causes the magnetic flux through it to change, so an emf is induced in the coil. The ends of the coil are connected to an external circuit by means of slip rings (R_1 and R_2) and brushes(B_1 and B_2).

TWO MARK QUESTIONS:

1. State and explain Faraday's law of electromagnetic induction. (March 2017)

State Faraday's law of electromagnetic induction. (1 mark) (July 2014, March 2016, March 2018)

Statement: The magnitude of the emf induced in a coil is equal to the time rate of change of magnetic flux linked with the coil.

Explanation: In Faraday's experiment, when magnet is moved faster, the magnetic flux linked with the coil changes at a faster rate. In this case, galvanometer deflection is more (i.e. induced emf is more). When the magnet is moved slower, the rate of change of magnetic flux is smaller. In this case, galvanometer deflection is smaller (i.e. induced emf is smaller). Hence induced emf in a coil is directly proportional to the rate of change of magnetic flux linked with the coil. i.e. $\varepsilon \propto \frac{d\phi}{dt}$

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

The negative sign indicates the direction of emf and current in a closed loop.

2. What is eddy currents? Give one use of it. (March 2014, July 2015)

The currents induced in a bulk piece of conductors when they are subjected to changing magnetic flux are called eddy currents.

Uses: Magnetic braking in trains.

3. What is meant by self inductance and mutual inductance? (July 2016)

What is self induction. (1 Mark) (July 2015)

The self inductance of a coil is defined as the emf induced in the coil due to rate of change of flux produced by the same coil.

The mutual inductance between two coils is defined as the current induced in one coil when the rate of change of flux produced by the another coil.

The self induction is the phenomenon of emf induced in the coil due to rate of change of flux produced by the same coil.

4. Mention any two factors on which the self-inductance of a coil depends.(July2018, Aug 2022)

1) The number turns per unit length ($L\propto n^2$)

2) The area of cross – section of the solenoid($L\propto A$)

3) The length of the solenoid ($L\propto l$)

4)The permeability of medium($L\propto \mu$) $\left(\because L=\mu n^2 Al\right)$

5. Give the working principle of AC generator. 'Why the current generated by it is called alternating current? (May 2022)

Principle: Electromagnetic induction

Alternating current: The direction of current changes periodically and reverses periodically.

ONE MARK QUESTIONS:

1. Give the expression of energy stored in an inductance coil carrying current. (March 2014)

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

2. Mention the significance of Lenz's law.(March 2015, July 2016, March 2017, March2020, May2022)

Law of conservation of energy.

3. What is motional electromotive force (motional emf)? (July 2017, Aug 2022)

The emf induced in a conductor due to its motion in a magnetic field is called motional emf.

4. How the self inductance of a coil depends on number of turns in the coil? (March 2019)

Directly proportional to square of number of turns $\left(L\alpha\, n^2\right)$.

5. Name the law used to find the polarity of induced emf in a coil.

Lenz's law.

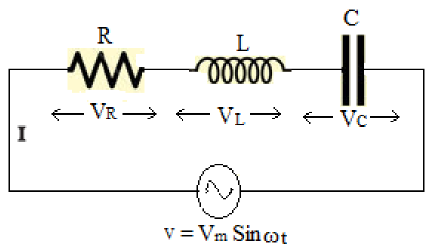
6. **How does self-inductance of an ideal coil vary with the current passing through it?**
Self-inductance does not depend on current passing through it.

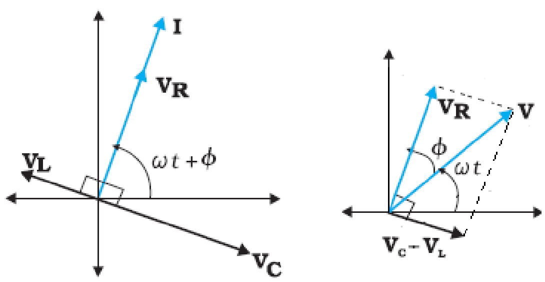
7. **What is AC generator?**
AC generator is a device used to convert mechanical energy into electrical energy (Alternating current).

7 ALTERNATING CURRENT

FIVE MARK QUESTIONS:

1. **Arrive at the expression for the impedance of a series LCR circuit using phasor diagram method and hence write the expression for the current through the circuit.** **(March 2018)**
Derive an expression for the impedance of a series LCR circuit, when an AC voltage is applied to it. **(March 2019)**





Let V_R, V_L, V_C and V represent the voltage across the resistor, inductor, capacitor and the source respectively and I be the current in the circuit.
$V_R = IR$ - V_R and I are in phase
$V_L = IX_L$ - V_L leads I by $\pi/2$
$V_C = IX_C$ - I leads V_C by $\pi/2$
The phasor diagram for series LCR when $V_C > V_L$ is shown in fig.
Using Pythagorean theorem, we get
$V^2 = V_R^2 + (V_C - V_L)^2$
$V^2 = (I R)^2 + (I X_C - I X_L)^2$
$V^2 = I^2 [R^2 + (X_C - X_L)^2]$

$$I^2 = \frac{V^2}{R^2 + (X_C - X_L)^2}$$

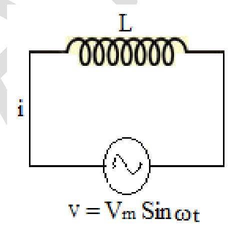
$$I = \frac{V}{\sqrt{R^2 + (X_C - X_L)^2}} = \frac{V}{Z}$$

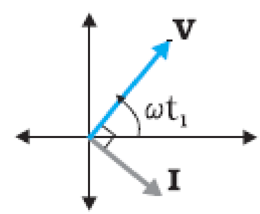
Clearly, $\sqrt{R^2 + (X_C - X_L)^2}$ is the effective opposition of the series LCR is called its impedance (Z).

$$\therefore Z = \sqrt{R^2 + (X_C - X_L)^2}$$

Current through the circuit, $I = \frac{V}{Z}$

2. **Show that the current lags the voltage by $\frac{\pi}{2}$ in an AC circuit containing a pure inductor. Draw the phasor diagram for it.** **(May 2022)**
Show that the voltage leads current by $\frac{\pi}{2}$ in an AC circuit containing pure inductor. **(Aug 2022)**
Show that voltage leads current by $\pi/2$ when ac voltage is applied to pure inductor.
(3 mark) (March 2015)





The instantaneous value of alternating voltage is
$v = V_m \sin\omega t$ ----- (1)
An emf induced in inductor is $-L\frac{di}{dt}$

Using kirchhoff's loop rule,

$$v - L\frac{di}{dt} = 0$$

$$V_m \sin\omega t = L\frac{di}{dt} \qquad \text{(From equ(1))}$$

$$di = \frac{V_m}{L}\sin\omega t\, dt$$

Integrating,

$$\int di = \int \frac{V_m}{L}\sin\omega t\, dt = \frac{V_m}{L}\left(\frac{-\cos\omega t}{\omega}\right)$$

$$i = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right) \quad \left(\because -\cos\omega t = \sin\left(\omega t - \frac{\pi}{2}\right)\right)$$

$$i = I_m \sin\left(\omega t - \frac{\pi}{2}\right) ------(2)$$

Where, $I_m = \frac{V_m}{\omega L} = \frac{V_m}{X_L}$ - maximum value of ac

$X_L = \omega L$ - inductive reactance
From equ (1) and (2) it is clear that voltage leads the current by $\frac{\pi}{2}$.

THREE MARK QUESTIONS:

1. **What is a transformer? Mention any two sources of energy loss in transformer. (March 2016, March 2017)**
   What is the principle behind the working of a transformer? Mention any two sources of energy loss in transformer. (July 2015)
   Mention one power loss in transformer. (1 mark) (March 2018)
   What is a transformer? Mention any one sources of energy loss. (2 mark) (June 2019)
   Mention the three type's energy loss in an actual transformer. (3 mark)(March 2019, May 2022)
   Mention two sources of energy loss in transformer. (2 mark) (March 2020)
   What is transformer? On which principle it works? (Aug 2022)

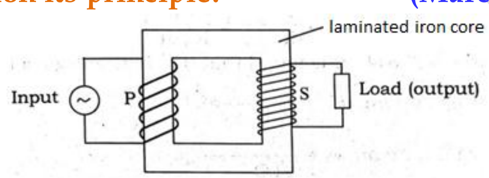
   A transformer is an electrical device which converts low alternating voltage into high alternating voltage or vice versa.

   Principle: The transformer works on the principle of mutual induction.

   Energy (Power) loss in a transformer are

   (i) Flux Leakage
   (ii) heating due to resistance of the windings
   (iii) Eddy currents
   (iv) Hysteresis loss.

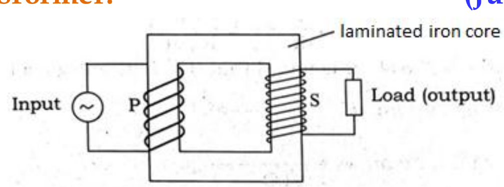
2. **Explain the construction of a transformer. Mention its principle. (March 2014)**



   Construction: A transformer consisting of two coils wound on an insulated iron core as shown in fig. One of the coils connected to an ac source is called primary coil (input coil). The other coil is connected to load is called secondary coil(output coil).

   Principle: The transformer works on the principle of mutual induction.

3. **With diagram, explain the working of a transformer. (July 2016)**



   The ac source connected to primary coil produces a varying current in the primary winding creates a varying magnetic flux in the core of transformer. This varying magnetic flux ϕ gets linked with the secondary coil and produces an emf (voltage) in it.

   Let N_P and N_S be the number of turns in the primary and secondary respectively. Then according to Faraday's law,

   Induced emf in the primary coil

   $$\varepsilon_p = -N_p \frac{d\phi}{dt} \quad ----(1)$$

   Induced emf in the secondary coil

   $$\varepsilon_s = -N_s \frac{d\phi}{dt} \quad -----(2)$$

   $$\frac{(2)}{(1)} \Rightarrow \frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}$$

   To a good approximation, $\varepsilon_s = V_s$ and $\varepsilon_p = V_p$

   $$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

4. **Derive an expression for resonant frequency of series circuit containing inductor, capacitor and resistor. (July 2014)**

   The force at which $X_L = X_C$ is called resonant frequency.

   $X_L = X_C$

   $$\omega_0 L = \frac{1}{\omega_0 C}$$

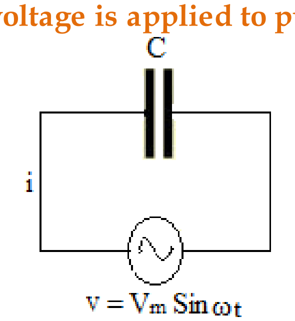
   $$\omega_0^2 = \frac{1}{LC}$$

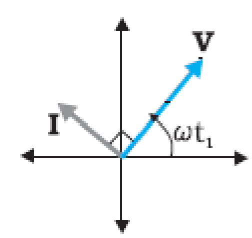
   $$\omega_0 = \frac{1}{\sqrt{LC}}$$

   $$2\pi f_0 = \frac{1}{\sqrt{LC}}$$

   $$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

5. **Show that current leads voltage by $\pi/2$ when ac voltage is applied to pure capacitor.**





   The instantaneous value of alternating voltage is

   $v = V_m \sin \omega t$ ----- (1)

   If the capacitor is connected to an instantaneous voltage v, instantaneous current i flows through it, then q is the charge on the capacitor.

   $q = Cv = CV_m \sin \omega t$

   Current at any instant is

   $$i = \frac{dq}{dt} = \frac{d(CV_m \sin \omega t)}{dt}$$

   $i = CV_m \omega \cos \omega t$

$$i = \frac{V_m}{\frac{1}{\omega C}} \sin\left(\omega t + \frac{\pi}{2}\right) \qquad \left[\because \cos(\omega t) = \sin\left(\omega t + \frac{\pi}{2}\right)\right]$$

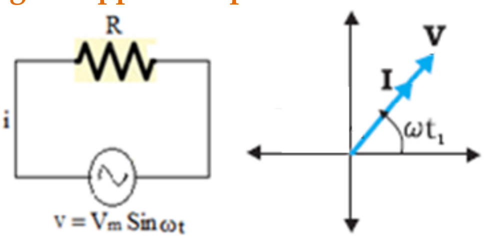
$$i = I_m \sin\left(\omega t + \frac{\pi}{2}\right) ----- (2)$$

Where $I_m = \frac{V_m}{\frac{1}{\omega C}} = \frac{V_m}{X_C}$ - maximum value of ac.

$X_C = \frac{1}{\omega C}$ - capacitive reactance

From equ (1) and (2) it is clear that current leads the voltage by $\frac{\pi}{2}$.

6. **Show that voltage and current are in phase when ac voltage is applied to pure resistor.**



The instantaneous value of alternating voltage is

$v = V_m \sin \omega t$ -----(1)

Using ohm's law, the instantaneous value of current is

$$i = \frac{v}{R} = \frac{V_m \sin \omega t}{R}$$

$i = I_m \sin \omega t$ ------ (2)

Where, $I_m = \frac{V_m}{R}$ - maximum value of ac

From equ(1) and (2) it is clear that the voltage and current are in phase.

TWO MARK QUESTIONS:

1. **What is resonant frequency? Write the expression for resonant frequency.** **(Sept 2020)**

The frequency at which inductive reactance is equal to capacitive reactance is called resonant frequency.

$\omega_o = \frac{1}{\sqrt{LC}} \Rightarrow f_o = \frac{1}{2\pi\sqrt{LC}}$

2. **Write the expression for the natural frequency of oscillations in an LC circuit.** **(1 Mark) (May 2022)**
What is LC oscillation? Mention the expression for frequency of LC oscillations.

LC oscillations are the electrical oscillations produced in a parallel combination of inductor and capacitor.

The natural frequency of oscillations in an LC oscillations is $\omega_o = \frac{1}{\sqrt{LC}} \Rightarrow f_o = \frac{1}{2\pi\sqrt{LC}}$

ONE MARK QUESTIONS:

1. **How is rms voltage of ac related to peak value of ac voltage?** **(March 2014)**

$V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707\ V_m$

2. **Write the relation connecting rms value and peak value of alternating current.** **(July 2017)**

$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707\ I_m$

3. **Write the condition for 'resonance' of series LCR circuit.**

Inductive reactance=Capacitive reactance(i.e, X_L=X_C)

4. **How does capacitive reactance vary with frequency?**

Capacitive reactance is inversely proportional to frequency. ($X_C = \frac{1}{2\pi f C}$)

5. **Mention the value of power factor on a pure capacitor.** **(July 2017)**

Zero.

6. **What are wattless current?**

Wattless current is the current flowing in the circuit for which the power dissipation is zero.

8 ELECTROMAGNETIC WAVES

THREE MARK QUESTIONS:

1. **What is displacement current? Write the expression for displacement current and explain the terms.** **(Aug 2022)**
What is displacement current? Write the expression for displacement current. **(July 2015, March 2020, May 2022)**
Define displacement current. **(1 mark)(March17)**
Write an expression for the displacement current. **(1 mark) (March 2016)**

Displacement current is that current which appears in the region in which the electric flux is changing with time.

The expression for displacement current is

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

Where, ε_0 - permeability of free space

$\frac{d\phi_E}{dt}$ - rate of change of electric flux with time

TWO MARK QUESTIONS:

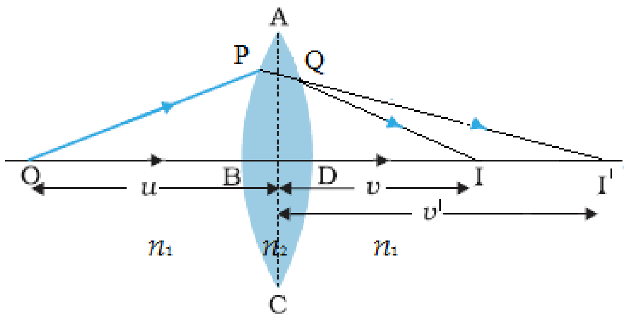
1. **Give two uses of microwaves.** **(July 2014)**
   Write one application of microwave. **(1 mark) (March 2017)**
   (1) Microwave ovens
   (2) Radar systems used in aircraft navigation
   (3) tennis-serves
   (4) automobiles
2. **Mention two applications of infrared radiation.** **(March 2015, Sept 2020)**
   (1) Remote switches of household electronic systems (TV remote)
   (2) Infrared lamps are used in physical therapy
   (3) Infrared detectors are used earths satellite.
3. **Give any two applications of X-rays.** **(March 2018)**
   (1) To produce images of internal organs of the body
   (2) Treatment for certain forms of cancer
4. **Write any two uses of ultraviolet rays.** **(July 2018, June 2019)**
   (1) To kill germs in water purifiers
   (2) LASIK eye surgery
5. **Who predicted the existence of electromagnetic waves? Give the wave length range of electromagnetic spectrum.** **(March 2014, Aug 2022)**
   Give the wavelength range of electromagnetic spectrum. **(1 Mark) (Sept 2020)**
   James clerk Maxwell predicted the existence of electromagnetic waves.
   The wavelength range of electromagnetic spectrum is 10^{-14}m to 10^{7}m.
6. **What are electromagnetic waves? Write the expression for the velocity of electromagnetic waves in terms of permittivity and magnetic permeability of free space.** **(July 2016)**
   Electromagnetic waves are sinusoidal oscillations with time varying electric and magnetic fields perpendicular to each other and perpendicular to the direction of propagation.
   The velocity of electromagnetic waves in free space is $c = \dfrac{1}{\sqrt{\mu_0 \varepsilon_0}}$
7. **Write Maxwell's equation for the speed of electromagnetic waves and explain the terms.** **(July 2017)**
   Write the expression for speed of light interms of "μ_0" and "ϵ_0", explain the terms used. **(March 2019)**
   The speed of electromagnetic waves in free space is
   $$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$
   Where, μ_0 and ε_0 are permeability and permittivity of free space.
8. **Write two properties of Electromagnetic waves.**
   1. These waves do not require any material medium for their propagation.
   2. Electromagnetic waves are transverse in nature.
   3. The oscillations of electric and magnetic fields are in the same phase.
9. **Write any two uses of gamma rays.**
   (1) To destroy cancer cells
   (2) To produce nuclear reactions

ONE MARK QUESTIONS:

1. **Give the wavelength range of X-rays.** **(March 2016)**
   10^{-8} m to 10^{-13} m.
2. **Arrange the following electromagnetic waves in ascending order of their wavelength: Radio waves, Gamma rays, Infrared waves, X-rays.** **(March 2020)**
   Gamma rays, X-rays, Infrared waves, Radio waves.
3. **Name the type of electromagnetic rays lying between ultraviolet and gamma rays.** **(May 2022)**
   X-ray
4. **Write the relation between the magnitude of the electric and the magnetic fields in an electromagnetic wave.** **(May 2022)**
   $$B_o = \frac{E_o}{c}$$
5. **Name the physical quantity which remains same for microwaves of wavelength 1 mm and UV radiations of 160 nm in vacuum.**
   Speed remains same.
6. **Which kind of electromagnetic radiations are used in LASIK eye surgery?**
   Ultraviolet radiations.
7. **Mention the angle between electric field and magnetic field in an electromagnetic wave.**
   90^{o}
8. **Name the electromagnetic wave which keeps the Earth warm by greenhouse effect.**
   Infrared radiation.

FIVE MARK QUESTIONS:

1. Derive lens maker's formula.
(March2019,March2017,July2015,July2016, July2017)
Derive lens maker's formula for a convex lens.
(May 2022)



Let R_1 and R_2 be the radii of curvature of two spherical surfaces ABC and ADC respectively.
The formation of image can be considered in two steps.

(i) Refraction at the surface ABC: In the absence of ADC, surface ABC form the image I′ of the object O(v = v′)

$$\frac{n_2}{v'}-\frac{n_1}{u}=\frac{n_2-n_1}{R_1} \quad \text{------ (1)}$$

(ii) Refraction at the surface ADC: The image at I′ acts as an virtual object (u=v′). I is the final image of object O.

$$\frac{n_1}{v}-\frac{n_2}{v'}=\frac{n_1-n_2}{R_2}=-\frac{n_2-n_1}{R_2} \quad \text{------ (2)}$$

Adding equs (1) and (2), we get

$$\frac{n_2}{v'}-\frac{n_1}{u}+\frac{n_1}{v}-\frac{n_2}{v'}=\frac{n_2-n_1}{R_1}-\frac{n_2-n_1}{R_2}$$

$$\frac{n_1}{v}-\frac{n_1}{u}=(n_2-n_1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$n_1\left(\frac{1}{v}-\frac{1}{u}\right)=(n_2-n_1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

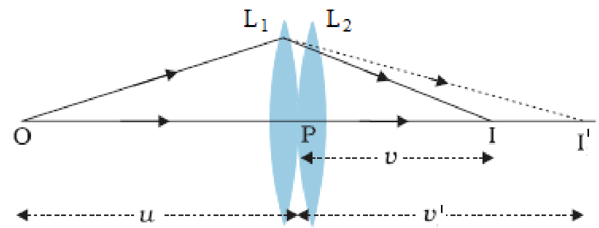
$$\frac{1}{v}-\frac{1}{u}=\left(\frac{n_2}{n_1}-1\right)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

$$\frac{1}{v}-\frac{1}{u}=(n_{21}-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

When u=∞, the image is formed at the principal focus v = f.

$$\frac{1}{f}=(n_{21}-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]$$

2. Derive an expression for the equivalent focal length of two thin lenses kept in contact.
(March 2016, Aug 2022)
Derive the expression for effective focal length of two thin lenses kept in contact.(3mark)(July 2018)



Consider two thin convex lenses L_1 and L_2 of focal lengths f_1 and f_2 placed in contact with each other.
The first lens L_1 alone form the image at I′ of an object O at a distance v′.

Using lens formula, $\frac{1}{v'}-\frac{1}{u}=\frac{1}{f_1}$ ------- (1)

The image I′ acts as a virtual object for second lens L_2 (u=v′), which forms the final image I at a distance v.

Using lens formula, $\frac{1}{v}-\frac{1}{v'}=\frac{1}{f_2}$ ------- (2)

Adding equs (1) and (2), we get

$$\frac{1}{v'}-\frac{1}{u}+\frac{1}{v}-\frac{1}{v'}=\frac{1}{f_1}+\frac{1}{f_2}$$

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f_1}+\frac{1}{f_2} \quad \text{------- (3)}$$

If two thin lenses in contact is equivalent to a single lens of focal length *f*, then

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \text{------- (4)}$$

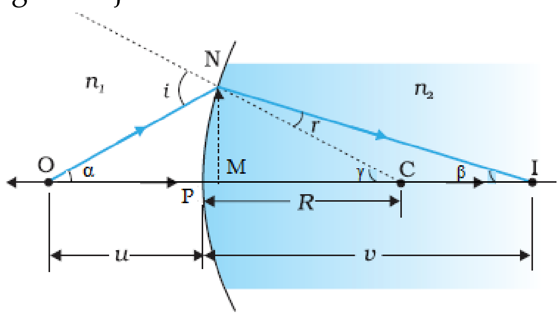
From equs (3) and (4),

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}$$

3. Deduce the relation between n, u, v and R for refraction at a spherical surface where the symbols have their usual meaning.
(March 2018, July 2014, March 2018)

Consider a spherical surface with centre of curvature C and radius of curvature R.
A ray ON from a medium of refractive index n_1 is incident on the surface of another medium of refractive index n_2. A ray ON incident at an angle i

is refracted along NI at an angle r. I is the real image of object O.



Draw NM perpendicular to the principal axis. α, β and γ are angles shown in fig.

For small angles, $\alpha \approx \tan\alpha = \frac{MN}{OM}$

$$\beta \approx \tan\beta = \frac{MN}{MI}$$

$$\gamma \approx \tan\gamma = \frac{MN}{MC}$$

In triangle NOC, $i = \alpha + \gamma$ (i is an exterior angle)

$$i = \frac{MN}{OM} + \frac{MN}{MC} \quad \text{----------(1)}$$

In triangle INC, $\gamma = r + \beta \Rightarrow r = \gamma - \beta$

$$r = \frac{MN}{MC} - \frac{MN}{MI} \quad \text{----------(2)}$$

Using snell's law $n_1 \sin i = n_2 \sin r$

For small angles $n_1 i = n_2 r$

$$n_1\left[\frac{MN}{OM} + \frac{MN}{MC}\right] = n_2\left[\frac{MN}{MC} - \frac{MN}{MI}\right]$$

$$n_1\left[\frac{1}{OM} + \frac{1}{MC}\right] = n_2\left[\frac{1}{MC} - \frac{1}{MI}\right]$$

$$\frac{n_1}{OM} + \frac{n_1}{MC} = \frac{n_2}{MC} - \frac{n_2}{MI}$$

$$\frac{n_2}{MI} + \frac{n_1}{OM} = \frac{n_2 - n_1}{MC} \quad \text{----------(3)}$$

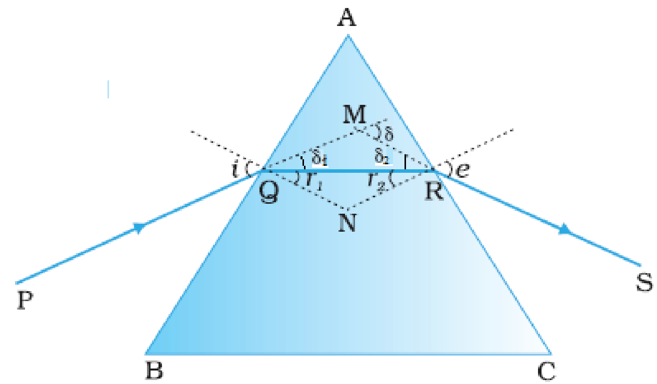
Using Cartesian sign conventions, OM $\cong$ OP = -u, MI $\cong$ PI = v and MC $\cong$ PC = R.

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

4. Derive an expression for refractive index of the material of the prism in terms of angle of the prism and angle of minimum deviation.

(March 2015)

Let ABC represent the principal section of prism and A be the angle of the prism as shown in fig.



At the surface AB, the angle of incidence is i and angle of refraction is r_1. So the deviation at the surface is $\delta_1 = i - r_1$

At the surface AC, the angle of incidence is r_2 and angle of refraction (or emergence) is e. So the deviation at the surface is $\delta_2 = e - r_2$

$\therefore$ Total deviation produced by the ray is

$$\delta = \delta_1 + \delta_2 = (i - r_1) + (e - r_2)$$

$$\delta = (i + e) - (r_1 + r_2) \quad \text{------(1)}$$

From triangle AQR,

$A + (90^0 - r_1) + (90^0 - r_2) = 180^0$

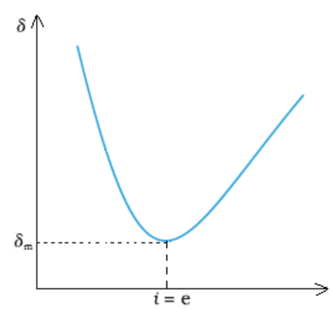
$A = r_1 + r_2$ ------(2)

Substituting equ (2) in (1),

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

$$A + \delta = (i + e) \quad \text{------(3)}$$

As i increases, δ first decreases and reaches a minimum value D_m and then increases. When the prism is in the position of minimum deviation, i = e, $r_1 = r_2$, $\delta = D_m$.



From equ (3), $A + D_m = i + i = 2i$

$$i = \frac{A + D_m}{2}$$

From equ (2), A= r+ r=2r

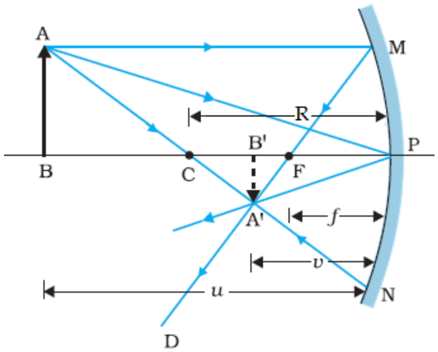
$$r = \frac{A}{2}$$

From Snell's law, the refractive index of the material of the prism is

$$n = \frac{\sin i}{\sin r}$$

$$n = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

5. **Derive the mirror formula in the case of concave mirror producing a real image.**



Consider an object AB is placed in front of the concave mirror perpendicular to the principal axis beyond centre of curvature C of the mirror. A real and inverted image $A'B'$ of the object is formed as shown in the fig.

From similar triangles ABC and $A'B'C$, we have

$$\frac{AB}{A'B'}=\frac{CB}{CB'} \text{ ---- (1)}$$

From similar triangles ABP and $A'B'P$, we have

$$\frac{AB}{A'B'}=\frac{PB}{PB'} \text{ --- (2)}$$

Comparing equns (1) and (2),

$$\frac{CB}{CB'}=\frac{PB}{PB'}$$

$$\frac{PB-PC}{PC-PB'}=\frac{PB}{PB'}$$

Using Cartesian sign convention,

PB = - u, PC = - R, $PB'=-v$

$$\frac{-u+R}{-R+v}=\frac{-u}{-v}$$

$$\Rightarrow uR+vR=2uv$$

Dividing throughout by uvR, we have,

$$\frac{1}{v}+\frac{1}{u}=\frac{2}{R}$$

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \qquad (\because R = 2f)$$

This relation is known as mirror equation.

THREE MARK QUESTIONS:

1. **What is total internal reflection? Mention the conditions for total internal reflection.** **(Sept 2020)**

The phenomenon of reflection of total light when it travels from a denser medium to the rarer medium at an angle greater than the critical angle is called total internal reflection.

Condition for total internal reflection:

1. Light should travel from a denser medium to a rarer medium.

2. The angle of incidence in denser medium should be greater than the critical angle for the given pair of media.

2. **Mention three applications of total internal reflection of light.** **(March 2014)**

1. Mirage.

2. Optical fibers.

3. Brilliance of diamond.

4. Total reflecting glass prism.

3. **What is total internal reflection? Mention two applications of optical fibers.** **(July 2016)**
Mention any three uses of optical fibres. **(Aug 2022)**

The phenomenon of reflection of total light when it travels from a denser medium to the rarer medium at an angle greater than the critical angle is called total internal reflection.

Applications of optical fibers:

1. Used for transmission of optical signals.

2. Used as a light pipe to facilitate visual examination of interal organs (like stomac, intestine)

3. Used in decorative lamp.

4. **Define critical angle. Write two conditions of total internal reflection.** **(July 2017)**
Write the two conditions of total internal reflection. **(2 mark) (July 2015)**

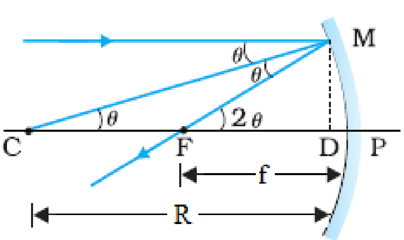
The angle of incidence in the denser medium for which the angle of refraction in the rarer medium becomes 90^0 is called critical angle (C).

Condition for total internal reflection:

1. Light should travel from a denser medium to a rarer medium.

2. The angle of incidence in denser medium should be greater than the critical angle for the given pair of media.

5. **Derive the relation between focal length and radius of curvature of concave mirror.** **(July 2019)**
Arrive at the relation between focal length and radius of curvature of a spherical concave mirror. **(Mar 2020)**



Consider a ray parallel to the principal axis incident at M of a concave mirror. After reflection, it passes through its principal focus F. Let θ be the angle of incidence and draw MD perpendicular to the principal axis. Then,

$\angle MCP = \theta$ and $\angle MFP = 2\theta$

From fig, $\tan\theta = \dfrac{MD}{CD}$ and $\tan 2\theta = \dfrac{MD}{FD}$

For small θ, $\tan\theta \approx \theta = \dfrac{MD}{CD}$ and $\tan 2\theta \approx 2\theta = \dfrac{MD}{FD}$

$$\therefore \frac{MD}{FD} = 2\frac{MD}{CD}$$

$$FD = \frac{CD}{2}$$

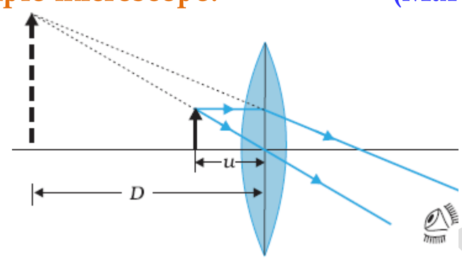
For small θ, the point D is very close to the point P. Therefore FD=f and CD=R.

$$f = \frac{R}{2}$$

Focal length (f) is equal to half of the radius of curvatures (R).

TWO MARK QUESTIONS:

1. **Write the ray diagram for formation of image in the simple microscope.** **(March 2019)**

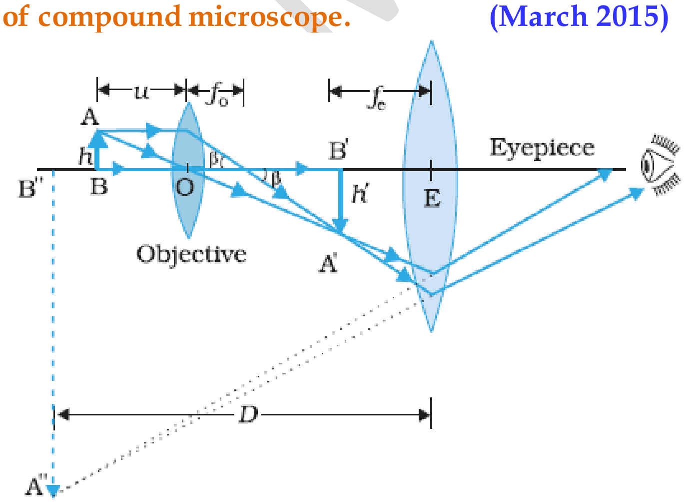


2. **State law's of refraction.** **(July 2014)**

   1. The incident ray, the refracted ray and the normal at the point of incidence, all lies in the same plane.

   2. The ratio of the sine of the angle of incidence to the sine of angle of refraction is constant for given pair of media. i.e., $\dfrac{\sin i}{\sin r} = \text{constant} = n_{21}$

3. **Draw the ray diagram of image formation in case of compound microscope.** **(March 2015)**



4. **Give the reasons for the following statements :**
   a) The sun is visible a little before the actual sunrise and until a little after the actual sunset.
   b) The sky appears blue. **(May 2022)**

   (a) Refraction of light through the atmosphere
   (b) Scattering of light by the atmospheric particles

5. **Define power of a lens. How does the power of a lens vary with its focal length?** **(Aug 2022)**
   How does the power of a lens vary with its focal length? (March2015, March2016, March17, Sept 2020)

   The power P of a lens is defined as the tangent of the angle by which it converges or diverges a beam of light falling at unit distant from the optical centre.
   Power of a lens is the reciprocal of focal length of the lens. $P = \dfrac{1}{f}$

6. **State law's of reflection.**

   1. The angle of incidence is equal to the angle of reflection.

   2. The incident ray, normal at the point of incidence and the reflected ray all lie's in the same plane.

ONE MARK QUESTIONS:

1. **For which position of the object magnification of convex lens is -1 (minus one)?** **(March 2019)**
   Object position at 2F (twice the focal length) from the lens.

2. **Why does sky appear blue? (March2020, Aug2022)**
   It is due to the scattering of sunlight by the particles of atmosphere.

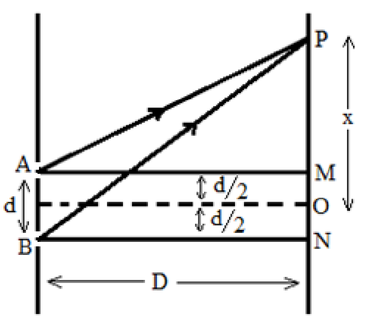
3. **Give the relation between focal length and radius of curvature of a spherical concave mirror.** **(Aug 2022)**

$$f = \frac{R}{2}$$

4. **A concave lens of refractive index 1.5 is immersed in a medium of refractive index 1.65. What is the nature of the lens?**
   convex lens.

FIVE MARK QUESTIONS:

1. **Obtain the expression for the fringe width in the case of interference of the light wave.**
(March 2014, July 2014, March 2020, Sept 2020)
Derive an expression for the fringe width of interference fringes in the double slit experiment.
(June 2019)



Consider A and B are two narrow slits separated by a small distance d. Screen placed at a distance D from slits A and B. A point P on the screen at distance x from the center O.

The path difference, $\Delta x = BP - AP$ -------(1)

From triangle BNP,

$$BP^2 = BN^2 + NP^2 = D^2 + \left(x + \frac{d}{2}\right)^2 \text{ --------(2)}$$

From triangle AMP,

$$AP^2 = AM^2 + MP^2 = D^2 + \left(x - \frac{d}{2}\right)^2 \text{ -----(3)}$$

$(2)-(3) \Rightarrow$

$$BP^2 - AP^2 = \left[D^2 + \left(x + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(x - \frac{d}{2}\right)^2\right]$$

$$(BP + AP)(BP - AP) = 2xd$$

$$(BP - AP) = \frac{2xd}{(BP + AP)}$$

$$\Delta x = \frac{2xd}{(BP + AP)} \quad \text{[From equ(1)]}$$

If x << D and d << D, then BP+AP = 2D

$$\Delta x = \frac{2xd}{2D}$$

$$\Delta x = \frac{xd}{D}$$

For bright fringes, $\Delta x = n\lambda$

$$\frac{xd}{D} = n\lambda$$

$$x = \frac{n\lambda D}{d} \quad \text{Where n=0,1,2,3,------}$$

The positions of two successive bright fringes are

For n=1, $x_1 = \frac{\lambda D}{d}$

For n=2, $x_2 = \frac{2\lambda D}{d}$

Fringe width (β) is the separation between two successive bright or dark fringes.

$$\beta = x_2 - x_1$$

$$\beta = \frac{2\lambda D}{d} - \frac{\lambda D}{d}$$

$$\beta = \frac{\lambda D}{d}$$

THREE MARK QUESTIONS:

1. **What is interference? Write the condition for path difference in case of constructive and destructive interference.** **(March 2015)**
Write the relation between the path difference and wavelength of light waves used for constructive and destructive interference of light.
(2 mark) (July 2016)

The modification in the distribution of light energy due to the superposition of two or more waves of light from two coherent sources is called interference of light.

For constructive interference, path difference is
$\Delta x = n\lambda$ where $n = 0,1,2---$

For destructive interference, path difference is

$$\Delta x = (2n+1)\frac{\lambda}{2} \quad \text{where } n = 0,1,2---$$

2. **Write the expression for limit of resolution of (a) microscope and (b) telescope. Write one method of increasing the resolving power of microscope.**
(July 2014)

The limit of resolution of microscope is

$$d = \frac{1.22\lambda}{2n\sin\beta}$$

The limit of resolution of telescope is

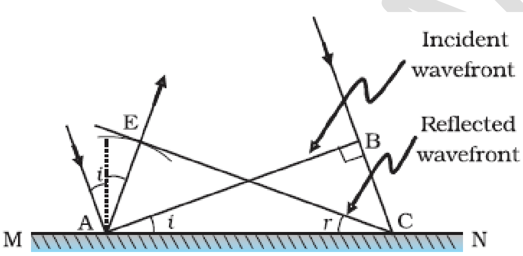
$$d\theta = \frac{1.22\lambda}{2a} = \frac{0.61\lambda}{a}$$

The resolving power of microscope can be increased decreasing the wavelength.

3. **Mention any three application of polaroids.**
(March 2017)
Mention two application of polaroids.
(2 mark)(March 2016)
Write any two uses of polaroids (2 mark)(May 2022)
1. Used in sun glasses.
2. Used in wind screens of automobiles.
3. Used in 3D movie cameras.
4. Used in photographic cameras.

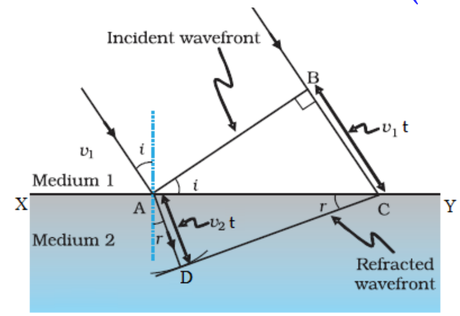
4. **What is polarization of light? Mention two methods of producing plane polarized light.**
(Sept 2020)
What is polarization of light? Name any one method of producing plane polarized light.
(2 mark) (July 2018)
It is the phenomenon in which the vibrations of light wave are restricted to one plane perpendicular to the direction of propagation.
Plane polarized light produced by
(1) scattering of light
(2) reflection of light

5. **Using Huygens principle, show that the angle of incidence is equal to angle of reflection during a plane wave front reflected by a plane surface.**
(June 2019, March 2020)
Using Huygen's principle, show that the angle of incidence is equal to the angle of reflection, when a plane wavefront is reflected by a plane surface.
(May 2022, Aug 2022)



Consider a plane wave AB incident at an angle i on a reflecting surface MN. Let 'v' be the speed of the wave and 't' be the time taken by the wavefront to reach from the point B to C. Then the distance
BC = v t.
During the same time t, secondary wavelet from point A will travel a distance
AE = v t.
In triangles EAC and BAC, AE = BC = v t and
$\angle AEC = \angle ABC = 90^0$. Therefore triangles are congruent.
Hence $\angle BAC = \angle ACE$
$i = r$

6. **Arrive at Snell's law of refraction, using Huygen's principle for refraction of a plane wave.**
(March2018)



Consider a plane wavefront AB incident on a plane XY. If v_1 and v_2 are the velocity of plane wave in medium 1 and medium 2, then

$$n_{21} = \frac{v_1}{v_2}$$

Let t be the time taken by the wavefront AB to travel the distance BC strikes the surface XY at C, then the distance
BC= v_1t
During the same time t, refracted wavefront travel a distance
AD = v_2t
Let i and r be the angles of incidence and refraction respectively.

From triangle ABC, $\sin i = \frac{BC}{AC}$ ------- (1)

From triangle ADC, $\sin r = \frac{AD}{AC}$ ------- (2)

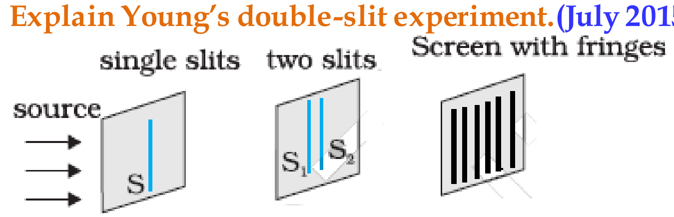
$$\frac{(1)}{(2)} \Rightarrow \frac{\sin i}{\sin r} = \frac{BC/AC}{AD/AC} = \frac{BC}{AD}$$

$$\frac{\sin i}{\sin r} = \frac{v_1 t}{v_2 t}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = n_{21} = \text{constant}$$

This proves Snell's law of refraction.

7. **Explain Young's double-slit experiment.(July 2015)**

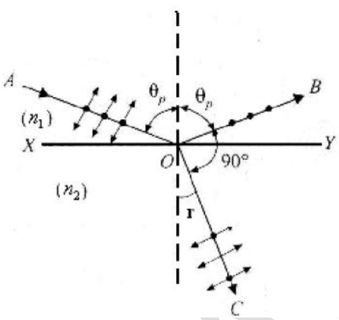


Light from a monochromatic source is incident on a narrow slit S. S_1 and S_2 are two narrow slits at equal distance from S. Wavefront from S incident on two narrow slits S_1 and S_2. S_1 and S_2 then behaves like two coherent sources. Wavefronts emerging from S_1 and S_2 interfere with each other and produces the alternative bright and dark fringes on a screen. Constructive interference produces bright fringe and destructive interference produces dark fringe.

8. **Write any three differences between interference and diffraction.** **(July 2017)**

Interference	Diffraction
Interference is the result of superposition of two waves coming from two coherent sources.	Diffraction is the result of superposition of secondary waves coming from different parts of the same wavefront.
All bright and dark fringes are of equal width.	Diffraction fringes have unequal width.
All bright fringes are of same intensity.	Intensity of bright fringes decreases as we move away from central bright fringe.
The dark fringes are perfectly dark.	The dark fringes are not perfectly dark.

9. **Derive the expression for Brewster's law of polarisation of light.**



In the fig, the ray light AO is incident on interface XY at the angle of incidence θ_p, so that reflected ray OB is completely plane polarised. The reflected ray and the refracted ray are perpendicular to each other.

Using Snell's law, $n_1 \sin\theta_p = n_2 \sin r$ -----(1)

From Fig, r + θ_p = 90^0 or r = 90^0 - θ_p

$$(1) \Rightarrow n_1 \sin\theta_p = n_2 \sin(90^0 - \theta_p)$$

$$\frac{n_2}{n_1} = \frac{\sin\theta_P}{\sin(90^0 - \theta_P)} = \frac{\sin\theta_P}{\cos\theta_P}$$

$$\therefore n_{21} = \tan\theta_p$$

This is known as Brewster's law.

TWO MARK QUESTIONS:

1. **What is diffraction of light?** **(March 2019)**
What is diffraction of light? **(1mark) (Sept 2020)**
The phenomenon of bending of light around the edges of small obstacles and entering into a geometrical shadow of the obstacle. Diffraction is the result of superposition of secondary waves coming from different parts of the same wavefront.

2. **Explain Malus law for polaroids.** **(March 2014)**
When completely polarized light is incident on the analyser, the intensity I of the light transmitted by the analyser is directly proportional to the square of the cosine of angle between the pass axes of the analyser and the polarizer
i.e., $I \propto \cos^2\theta$
$I = I_0 \cos^2\theta$
Where I_0 – intensity of the polarized light incident on the analyser.

3. **Mention the expression for limit of resolution of a telescope and explain the terms.** **(Aug 2022)**
The limit of resolution of telescope is
$$d\theta = \frac{1.22\lambda}{2a} = \frac{0.61\lambda}{a}$$
Where, 2a – diameter of the lens.
λ - wavelength of light.

4. **What is the shape of the emergent wavefront when a plane wavefront is incident on: (a) a prism and (b) a convex lens?**
(a) The tilting of the plane wavefront
(b) A spherical wavefront and converges to the principal focus F.

ONE MARK QUESTIONS:

1. **What is wavefront of light wave?** **(March 2014)**
The locus of all points which oscillate in the same phase is called a wavefront.

2. **How can the resolving power of a telescope be increased?** **(March 2016)**
By increasing the diameter(2a) of the objective lens.

3. **How does the resolving power of a telescope change on increasing the diameter of the objective lens?** **(May 2022)**
Increases.

4. **Write the formula for Malus law.** **(July16, Aug22)**
$I = I_0 \cos^2\theta$

5. **A blue ray of light enters an optically denser medium from air. What happens to its frequency in denser medium?** **(July 2018)**
Frequency remains same.

6. **For which angle of incidence reflected ray is completely polarized? (March 2019, Aug 2022)**
Brewster's angle (polarizing angle)
7. **Mention a method to increase the resolving power of a microscope. (March 2020)**
Resolving power can be increased by choosing a medium of higher refractive index.
8. **What are coherent sources of light? (May 2022)**
Two sources of light which emit light waves of same wavelength (or frequency) and constant phase difference
9. **Name the type of wave front observed from a distant point source.**
Plane wavefront.
10. **Write the condition for diffraction maxima in terms of wavelength of light and slit width.**
Secondary maxima,
$$\theta = \left(n + \frac{1}{2}\right)\frac{\lambda}{a} \qquad \text{where } n = 1,2,---$$
11. **How does the resolving power of a telescope change on decreasing the aperture of its objective lens?**
Resolving power of a telescope decreases.

11 DUAL NATURE OF RADIATION AND MATTER

FIVE MARK QUESTIONS:

1. **Write the experimental observations of photoelectric effect. (March 2016, Sept 2020)**
Write any three experimental observations of photoelectric effect.
(3 mark) (March 2017, July 2018, March 2019)
Define photoelectric work function. Write the four experimental observations of photoelectric effect. (May 2022)
(i) Photoelectric work function: The minimum photo energy required by an electron to escape from the metal surface is called work function.
Experimental observations of photoelectric effect:
1. For a given photosensitive material and above threshold frequency, the photoelectric current is directly proportional to the intensity of incident light.
2. For a given photosensitive material and above threshold frequency, saturation current is proportional to the intensity of incident radiation and stopping potential is independent of its intensity.
3. For a given photosensitive material, there exists a certain minimum cut-off frequency (threshold frequency), below which no emission of photoelectrons takes place. Above the threshold frequency, the stopping potential (or maximum kinetic energy) increases linearly with the frequency of the incident radiation.
4. The photoelectric emission is an instantaneous process.
2. **Write Einstein's equation of photoelectric effect. Give Einstein's explanation of photoelectric effect. (March 2015)**
Einstein's equation of photoelectric effect is
$K_{max} = h\nu - \phi_0 = h\nu - h\nu_0$
Einstein's explanation of photoelectric effect:
1. The intensity of radiation increases means the number of photons striking the metal surface per unit time increases. As each photon eject one electron, so that the number of ejected photoelectrons increases with the increase in intensity of incident radiation.
2. If $\nu < \nu_0$, the kinetic energy of photoelectrons become negative. This has no physical meaning. So photoelectric emission does not occur below the threshold frequency (ν_0).
3. If $\nu > \nu_0$, then K_{max} depends linearly on ν $[\because K_{max} = h(\nu - \nu_0)]$. The kinetic energy of photoelectrons increases with the frequency ν.
4. Photoelectric effect is instantaneous process because the collision between a photon and an electron can be considered as the elastic collision between two micro particles, which results in instantaneous transfer of energy.
3. **Explain Hallwach's and Lenard's observations on photoelectric effect. Define (a) work function (b) threshold frequency (c) stopping potential. (July 2015)**
Define the terms (a) work function (b) threshold frequency (c) stopping potential.(3mark)(July 2017)
Hallwach's observation: zinc plate lost its charge when it was illuminated by uv light. The uncharged zinc plates becomes positively charged when uv light incident on it. Hallwach concluded

that negatively charged particles emitted from zinc plate.

Lenard's observation: when uv radiations were allowed to fall on the emitter plate of an evacuated glass tube enclosing two electrodes, a current flows in the circuit. When uv radiation stopped, the current flow stopped.

(a) Work function: The minimum energy required by an electron to escape from metal surface is called work function.

(b) Threshold frequency: The minimum frequency of incident light below which no emission of electrons from metal surface is called threshold frequency.

(c) Stopping potential: The minimum negative potential of the anode at which photocurrent becomes zero is called stopping potential.

THREE MARK QUESTIONS:

1. Name the three types of electron emission. **(June 2019)**

Write any two types of electron emission. **(2 mark) (March 2014)**

Mention any one type of electron emission. **(1 mark) (March 2019)**

1. Thermionic emission
2. Photoelectric emission
3. Field emission

2. What are matter waves? Write the expression for de-broglie wavelength of a particle and explain the terms. **(July 2016)**

Write the expression for de-Broglie wavelength of a particle. **(1 mark)(March 2017)**

The wave associated with moving particles of matter is called matter wave or di-broglie wave.

The expression for de-broglie wavelength of a particle is $\lambda = \frac{h}{p}$

Where, λ - wave length of a moving particle,
p = mv – momentum of the particle,
h – planck's constant.

3. Define work function. Write Einstein's photoelectric equation and explain the terms. **(March 2020)**

The minimum energy required to eject an electron from the metal surface is called work function.

Einstein's equation of photoelectric effect is

$K_{\max} = h\nu - \phi_0$

Where, K_{max} - maximum kinetic energy of emitted photoelectron
$h\nu$ - energy of incident light
h - Plank's constant
ν - frequency of incident light
ϕ_0 - work function.

4. Give three characteristics of photons. **(March 2014)**

1. Photons are electrically neutral.
2. Photons travel with a speed of light.
3. The energy of photon depends only on the frequency of the radiation and not on its intensity.
4. The rest mass of a photon is zero.

TWO MARK QUESTIONS:

1. Define (i) Photoelectric work function (ii) electron volt (eV). **(July 2016)**

(i) Photoelectric work function: The minimum photo energy required by an electron to escape from the metal surface is called work function.

(ii) Electron volt (eV): Electron volt is the energy gained by an electron when it is accelerated through a potential difference.

2. What are de-broglie waves? How does the de-broglie wavelength vary with momentum of moving particle. **(July 2017)**

The wave associated with moving particles of matter is called de-broglie wave or matter wave. de-broglie wavelength increases with decrease in momentum of the moving particle.

3. Write the expression for de-Broglie wavelength of electrons in terms of electric potential and explain the terms used. **(March 2019)**

de-Broglie wavelength of electron, $\lambda = \frac{h}{\sqrt{2meV}}$

Where, h - Planck's constant
m - mass of electron
V - accelerating potential
e - charge of electron.

4. Write the expression for de-Broglie wavelength of a charged particle and explain the terms. **(Aug 2022)**

de-Broglie wavelength of charged particle,

$\lambda = \frac{h}{\sqrt{2mqV}}$

Where, h - Planck's constant
m - mass of charged particle
V - accelerating potential
q - charge of charged particle.

5. An alpha particle, a proton and an electron are moving with equal kinetic energy. Which one of these particles has the longest de Broglie wavelength? Give reason. **(March 2020)**

An electron has the longest de Broglie wavelength. de Broglie wavelength of moving particle,

$\lambda = \frac{h}{\sqrt{2mK}}$

It is because mass of an electron is less than mass of a proton and an alpha particle.

6. **What are de Broglie waves? Name an experiment which verified the wave nature of electrons.** (May 2022)

The wave associated with moving particles of matter is called matter wave or di-broglie wave.
Davisson and Germer experiment verifies the wave nature of electrons.

ONE MARK QUESTIONS:

1. **What is the rest mass of photon ?** (June 2019)

Zero

2. **What is the conclusion of Davisson and Germer experiment on the nature of electron?** (March 2014, March 2017)

Wave nature of moving electron.

3. **How does the stopping potential of a photosensitive material vary with intensity of incident radiation?**

Stopping potential does not change with intensity of incident radiation.

12 ATOMS

FIVE MARK QUESTIONS:

1. **Write three postulates of Bohr. Mention two limitations of Bohr atom model.** (March 2014)
State Bohr's postulates of the hydrogen atom model. (3 mark)(March 2018, July 2015)
Write the three postulates of Bohr's atomic model. (3 mark)(March 2019)
Write the three postulates of Bohr model of the hydrogen atom. (May 2022)
Write the Limitations of Bohr's atomic model. (2 mark)(Sept2020)

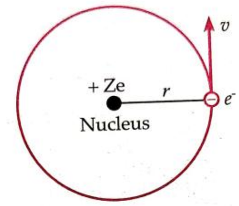
Bohr's postulates:

1. An electron can revolve around nucleus in certain stable circular orbits without the emission of energy. These are called the states of the atom.
2. An electron can revolve only in those orbits in which its angular momentum is an integral multiple of $\frac{h}{2\pi}$ i.e. $L = n\frac{h}{2\pi}$. h-planck's constant.
3. An electron can jump from higher energy (E_2) orbit to lower energy (E_1) orbit. In this process a photon is emitted having energy equal to the energy difference between the initial and final states. i.e. $h\gamma = E_2 - E_1$.

Limitations:

1. It is applicable to hydrogen atom. It cant be extend to two or more electron atoms.
2. It does not explain the relative intensities of the frequencies in the spectrum.

2. **Derive an expression for total energy of an electron in stationary state of hydrogen atom assuming the expression for the radius.** (July 2014, July 2016, July 2017)
Assuming the expression for radius of the orbit, derive an expression for the total energy of an electron in stationary state of the hydrogen atom. (July 2018)
Derive an expression for the energy of an electron in n^{th} stationary orbit of hydrogen atom by assuming the expression for the radius. (June2019)



Consider an electron of mass m, charge –e revolving round the nucleus of charge +Ze in a circular orbit of radius r with an orbital velocity v.
According to Bohr's postulates,
centripetal force = electrostatic force of attraction

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(e)}{r^2}$$

$$mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$$

The kinetic energy of electron in the n^{th} orbit is

$$K_n = \frac{1}{2}mv^2 = \frac{Ze^2}{8\pi\varepsilon_0 r}$$

The potential energy of electron in the n^{th} orbit is

$$U_n = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(-e)}{r} = -\frac{Ze^2}{4\pi\varepsilon_0 r}$$

The total energy of the electron in the n^{th} orbit is

$$E_n = K_n + U_n$$

$$E_n = \frac{Ze^2}{8\pi\varepsilon_0 r} - \frac{Ze^2}{4\pi\varepsilon_0 r}$$

$$E_n = -\frac{Ze^2}{8\pi\varepsilon_0 r}$$

The radius of n^{th} orbit is

$$r = \frac{n^2h^2\varepsilon_0}{Ze^2\pi m}$$

$$E_n = -\frac{Ze^2}{8\pi\varepsilon_0\left(\frac{n^2h^2\varepsilon_0}{Ze^2\pi m}\right)}$$

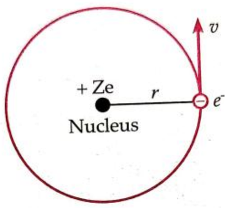
$$E_n = -\frac{Z^2e^4m}{8\varepsilon_0^2h^2n^2}$$

For hydrogen atom Z=1,

$$E_n = -\frac{e^4m}{8\varepsilon_0^2h^2n^2}$$

3. Using Bohr's postulates derive the expression for the radius of n^{th} stationary orbit of electron in hydrogen atom. Hence write the expression for Bohr radius. (March 2020)

By assuming Bohr's postulates, derive an expression for radius of n^{th} orbit of electron revolving round the nucleus of hydrogen atom. (3 mark)(March 2015, Sept 2020)



Consider an electron of mass m, charge –e revolving round the nucleus of charge +Ze in a circular orbit of radius r with an orbital velocity v.

According to Bohr's postulates,

centripetal force = electrostatic force of attraction

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$$

$$r = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{mv^2} \text{ ---------(1)}$$

Using Bohr's quantized condition

$$mvr = \frac{nh}{2\pi}$$

$$v = \frac{nh}{2\pi m r} \text{ ---------(2)}$$

Substituting equ (2) in (1), we get

$$r = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{m\left(\frac{nh}{2\pi m r}\right)^2} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2 4\pi^2m^2r^2}{mn^2h^2}$$

$$r = \frac{Ze^2\pi m}{\varepsilon_0 n^2h^2}r^2$$

$$r = \frac{n^2h^2\varepsilon_0}{Ze^2\pi m}$$

Radius of n^{th} orbit is $r_n = \frac{n^2h^2\varepsilon_0}{Ze^2\pi m}$

For hydrogen atom Z=1,

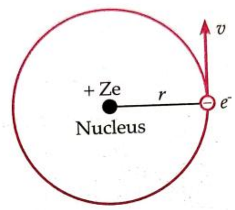
$$r_n = \frac{n^2h^2\varepsilon_0}{e^2\pi m}$$

Bohr Radius is the radius of first orbit of hydrogen atom i.e., $n = 1$

Bohr Radius, $a_o = \frac{h^2\varepsilon_0}{e^2\pi m}$

THREE MARK QUESTIONS:

1. Derive an expression for velocity of electron revolving round the nucleus of hydrogen atom.



Consider an electron of mass m, charge –e revolving round the nucleus of charge +Ze in a circular orbit of radius r with an orbital velocity v.

According Bohr's quantized condition,

$$mvr = \frac{nh}{2\pi}$$

Velocity of electron in n^{th} orbit is

$$v_n = \frac{nh}{2\pi m r_n} \text{ -------(1)}$$

The radius of n^{th} orbit is

$$r_n = \frac{n^2h^2\varepsilon_0}{Ze^2\pi m} \text{ -------(2)}$$

Substituting equ (2) in (1), we get

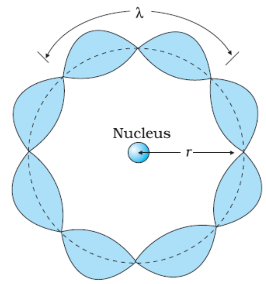
$$v_n = \frac{nh}{2\pi m\left(\frac{n^2h^2\varepsilon_0}{Ze^2\pi m}\right)}$$

$$v_n = \frac{Ze^2}{2\varepsilon_0 n h}$$

For hydrogen atom Z=1,

$$v_n = \frac{e^2}{2\varepsilon_0 n h}$$

2. **Give de Broglie's explanation of Bohr's second postulate.**



According to de Broglie hypothesis, orbiting electron around the nucleus of an atom is associated with a standing wave. Waves with other wavelengths interfere with themselves upon reflection and their amplitudes quickly drop to zero. For an electron moving in n^{th} circular orbit of radius r_n, the total distance is the circumference of the orbit = $2\pi r_n$.

Thus $2\pi r_n = n\lambda$

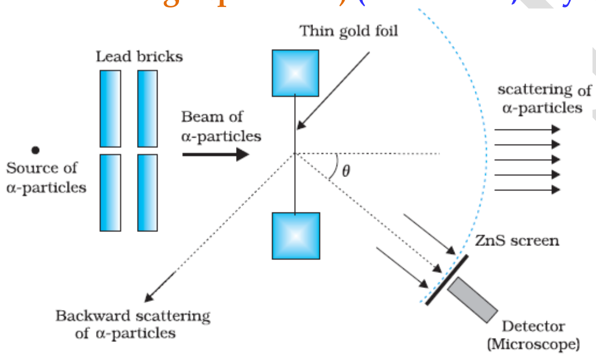
de Broglie wavelength, $\lambda = \frac{h}{mv}$

$$2\pi r_n = n\frac{h}{mv}$$

$$mvr_n = n\frac{h}{2\pi}$$

TWO MARK QUESTIONS:

1. **Draw the diagram representing the schematic arrangement of Geiger-Marsden experimental setup for the alpha particle scattering (Rutherford alpha scattering experiment).(March2018,May2022)**



ONE MARK QUESTIONS:

1. **Name the spectral series of hydrogen which lies in the ultraviolet region of electromagnetic spectrum. (March 2015)**
Lyman series.
2. **Name the spectral series of hydrogen atom in the visible region of electromagnetic spectrum.(July15)**
Name the spectral series of hydrogen atom which lies in the visible region of electromagnetic spectrum. (June 2019)
Balmer series.
3. **Write the expression for energy of an electron in electron orbit of hydrogen atom. (March 2019)**

$$E_n = -\frac{e^4 m}{8\varepsilon_0^2 h^2 n^2}$$

4. **What is meant by the ionisation energy of an atom? (May 2022)**
The minimum energy required to remove an electron from the atom.
5. **Define Impact parameter. (Aug 2022)**
The impact parameter is the perpendicular distance of the initial velocity vector of the α -particle from the centre of the nucleus.
6. **Name the spectral series of hydrogen atom in the infrared region of electromagnetic spectrum.**
Paschen series, Brackett series and Pfund series.

13 NUCLEI

FIVE MARK QUESTIONS:

1. **State radioactive decay law. Derive $N = N_0 e^{-\lambda t}$ for radioactive element. (March 2017)**
Using radioactive decay law, derive $N = N_0 e^{-\lambda t}$ for a radioactive element where the symbols have their usual meaning. (Aug 2022)
State radioactive decay law. (1 mark)(March 2014)

Statement: The number of nuclei undergoing the decay per unit time at any instant is directly proportional to the number of undecayed nuclei present in the sample at that instant.

N_0 - number of radioactive nuclei present at $t_0 = 0$,
N - number of radioactive nuclei present at t.
dN - the number of nuclei undergoing decay in the small interval dt.

According to radioactive law,

$$\frac{dN}{dt} \propto N$$

$$\therefore \frac{dN}{dt} = -\lambda N$$

Where λ is decay constant or disintegration constant and negative sign shows that the number of undecayed nuclei decreases with time.

$$\frac{dN}{N} = -\lambda dt$$

Integrating, $\int_{N_0}^{N} \frac{dN}{N} = \int_0^t -\lambda dt$

$$\ln N \Big|_{N_0}^{N} = -\lambda t\Big|_0^t$$

$$\ln N - \ln N_0 = -\lambda(t-0)$$

$$\ln \frac{N}{N_0} = -\lambda t$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$N = N_0 e^{-\lambda t}$$

THREE MARK QUESTIONS:

1. **State any three characteristics of nuclear force. (March 2016, July 2014)**
   Write any two characteristics of nuclear forces. (2 mark)(March 2018)

   1. Nuclear forces are strong attractive forces.
   2. Nuclear forces are charge independent.
   3. Nuclear forces are short range forces.

2. **Define half life period of a radioactive sample. Arrive at the relation between half life and decay constant. (July 2014)**
   Derive the expression for the half life of a radioactive nuclide. (March 2018)
   Define half life of a radioactive sample.(July2017)

   Definition: The time interval in which one-half of the radioactive nuclei originally present in the sample to disintegrate is called the half life of a radioactive sample.

   From radioactive decay law, $N = N_0 e^{-\lambda t}$ --------(1)

   When t = $T_{1/2}$ (Half life of a radioactive substance),

   then $N = \frac{N_0}{2}$

   $$\frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}}$$

   $$e^{\lambda T_{1/2}} = 2$$

   Taking natural logarithm, we get

   $$\lambda T_{1/2} = \ln 2$$

   $$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

3. **Define 'mass defect' and 'binding energy' of a nucleus. Write the relation between them. (May 2022)**

   Mass defect: It is the difference between the sum of masses of nucleons and the actual mass of the nucleus.

   Binding energy: It is the minimum energy required to separate all the nucleons from the nucleus.

   Relation: $E_b = (\Delta m)\, c^2$ or $E_b = (\Delta m)$ 931.5 MeV

4. **Give the differences between nuclear fission and fusion.**
   What are nuclear fission and fusion?

Fission	Fusion
Definition: It is the process of splitting of a heavy nucleus into two light nuclei with a release of large amount of energy.	Definition: It is the process of combining the two lighter nuclei to form a heavier nucleus with a release of large amount of energy.
Energy released per nucleon is less	Energy released per nucleon is more
It takes place at all temperatures	It takes place at high temperatures only

TWO MARK QUESTIONS:

1. **What are isotopes and isobars? (March 2016)**
   What are isotopes? (1 mark)(July 2014, June 2019)
   What are isobars? Give example. (Aug 2022)
   What are isotopes and isobars? Give one example.

   Isotopes: The atoms having the same atomic number but different mass number are called isotopes.

   Ex: Isotopes of hydrogen are ${}_1H^1, {}_1H^2$ and ${}_1H^3$.

   Isobars: The atoms having the same mass number but different atomic number are called isobars.

   Ex: ${}_1H^3$ and ${}_2He^3$

2. **What are isotones? Give one example?**

   These are the nuclei having same neutron number but different atomic number.

   Ex: ${}_1H^3$ and ${}_2He^4$

3. **Define atomic mass unit. Write the value of 1 atomic mass unit in kilogram.**

   Atomic mass unit (u) is defined as 1/12th of the mass of the carbon (^{12}C) atom.

   1u =1.660539 × 10^{-27}kg

4. **Define mass defect. Give the equation of mass defect.**
Mass defect is the difference between the sum of masses of nucleons and the actual mass of the nucleus.
Mass defect, $\Delta m = Zm_p + (A - Z)m_n - M$
Where, M – Rest mass of the nucleus
Number of Protons Z each of mass m_p,
Number of neutrons (A – Z) each of mass m_n

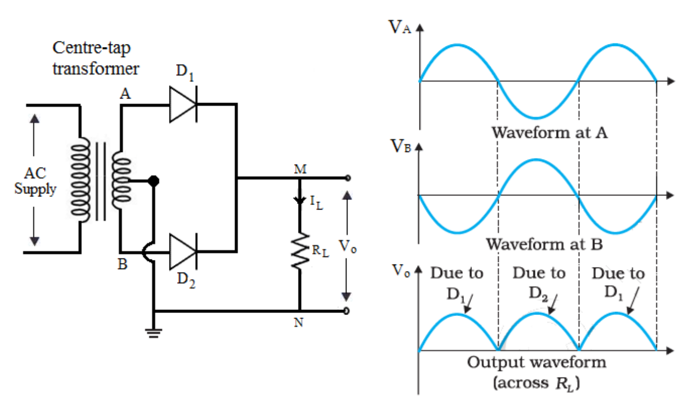
ONE MARK QUESTIONS:

1. **What is the ratio of the nuclear densities of two nuclei having mass numbers in the ratio 1:3? (July 2016)**
One (because nuclear density is constant and it is independent of A)
2. **Define specific binding energy. (March 2015)**
The binding energy per nucleon (or specific binding energy) is the average energy per nucleon needed separate nuclons from the nucleus. **(or)**
It is the ratio of binding energy of the nucleus to the number of nucleons in that nucleus.
3. **Write the SI unit of radio activity.(March17, July15)**
Name the SI unit of activity.(Sept 2020, Aug 2022)
becquerel (Bq).
4. **In the following nuclear reaction, identify the particle X.** $n \rightarrow p + e^{-} + X$ **(March 2016)**
X is antinutrino ($\bar{\nu}$)
5. **The decay of proton to neutron is possible only inside the nucleus. Why? (March 2018)**
The decay of proton to neutron is possible only inside the nucleus because proton is smaller than neutron.
6. **Write the relation between Half-Life and Mean-Life of radioactive element. (March 2019)**
$T_{1/2} = \tau \ln 2 = 0.693\,\tau$
7. **$_{92}U^{238}$ undergoes alpha decay giving rise to thorium. What is the mass number of daughter nuclide? (July 2018)**
Mass number of daughter nuclide (thorium) is 234.
8. **Write the nuclear reaction equation for alpha decay of $_{92}U^{238}$. (March 2020)**
$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$
9. **Give an example for conversion of mass to energy.**
Nuclear fusion, Nuclear fission.
10. **Who discovered neutrons?**
James Chadwick.
11. **How is the radius of the nucleus of an atom related to its mass number?**
$R = R_o A^{1/3}$
12. **How does the nuclear density depend on the size of the nucleus?**
Nuclear density is independent of the size of the nucleus.
13. **What is nuclear force?**
It is the strongest attractive force that holds the nucleons together with in the nucleus.

14 SEMICONDUCTOR ELECTRONICS

FIVE MARK QUESTIONS:

2. **What is rectification? With a relevant circuit diagram and wave forms, explain the working of p-n junction diode as a full wave rectifier. (July 2015, March 2016, March 2017)**
Explain the working of p-n junction diode as a full wave rectifier with circuit diagram. Give input and output waveform.(March2018,July2014)
What is rectifier? With the suitable circuit diagram, explain the working of p-n junction diode as a full-wave rectifier. Draw the input and the output waveforms. (May 2022)
Rectification: The process of converting ac into dc is called rectification.
Rectifier: The circuit which ac into dc (pulsating voltage) is called rectifier.



It consists of a centre-tap transformer, two diodes (D_1 and D_2) and load resistor R_L.
During positive half cycle of the input ac, A is positive potential with respect to centre-tap and B is negative potential with respect to centre-tap. The diode D_1 is forward biased and D_2 is reverse biased. As a result D_1 conduct current and D_2 does

not conduct current. Therefore the output voltage is developed across R_L.

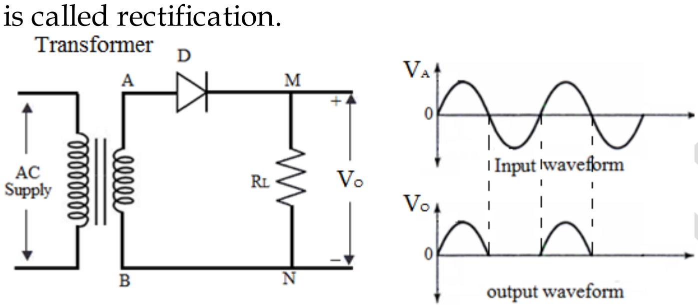
During negative half cycle of the input ac, A is negative potential with respect to centre-tap and B is positive potential with respect to centre-tap. The diode D_2 is forward biased and D_1 is reverse biased. As a result D_2 conduct current and D_1 does not conduct current. Therefore the output voltage is developed across R_L.

The input and output waveforms are shown in fig.

3. What is rectification? Describe the circuit diagram the working of a p-n junction diode as half wave rectifier with input and output waveform. (June 2019, March 2020)

What is rectification? With relevant circuit diagram and waveforms, explain the working of p-n junction diode as a half wave rectifier? (Aug 2022)

Rectification: The process of converting ac into dc is called rectification.



It consists of a transformer, diode and load resistor R_L.

During positive half cycle of the input ac, voltage at A is positive with respect to B. The diode D is forward biased and conducts current through R_L. Therefore output voltage is developed across R_L.

During negative half cycle of the input ac, voltage at A is negative with respect to B. The diode is reverse biased and does not conduct current (The reverse saturation current of diode is negligible and can be considered equal to zero). Therefore there is no ouput voltage across R_L.

The input and output waveforms are shown in fig above.

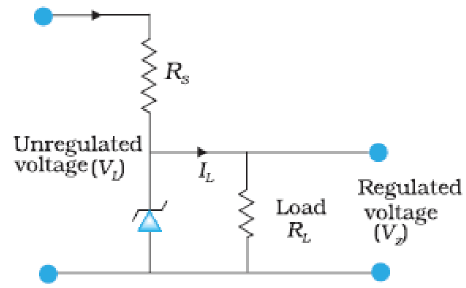
3. What is a Zener diode? Explain the action of Zener diode as a voltage regulator with relevant circuit diagram. (Sept 2020)

Explain the use of zener diode as a voltage regulator? (3 mark) (March 2014, July 2017)

How is Zener diode used as voltage regulator? (3 mark) (July2018)

Zener diode is a heavily doped diode designed to operate under reverse bias in the breakdown region.

Zener diode as voltage regulator:



The unregulated dc voltage is connected to the Zener diode through a series resistance *Rs* such that the Zener diode is reverse biased. If the input voltage increases, the current through *Rs* and Zener diode also increases. This increases the voltage drop across *Rs* without any change in the voltage across the Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes.

Similarly, if the input voltage decreases, the current through *Rs* and Zener diode also decreases. The voltage drop across *Rs* decreases without any change in the voltage across the Zener diode. Thus the Zener diode acts as a voltage regulator

4. On the basis of energy bands, distinguish between a metal, a semiconductor and an insulator. Explain the formation of energy bands in solids. (March14)

Distinguish between conductor and semiconductor on the basis of band theory of solids. (3 mark)(M2015)

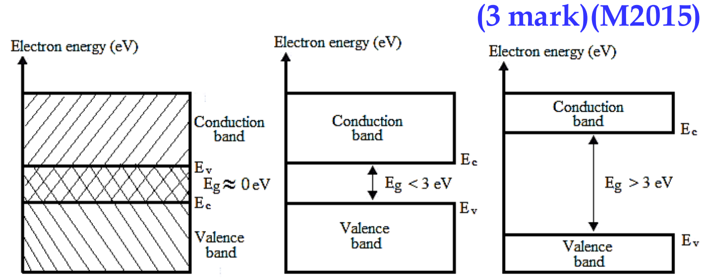


Fig (a) : Metal (Conductor) Fig(b) : Semiconductor Fig(c) : Insulator

Metals (Conductors): The energy gap between valence band and the conduction band is very less or overlap with each other. Ex: Copper, Aluminium, iron, salt solutions etc.

Semiconductors: The energy gap between valence band and the conduction band is less(<3eV). The energy gap is 0.72 eV for germanium and 1.1 eV for silicon. Ex: Germanium, Silicon.

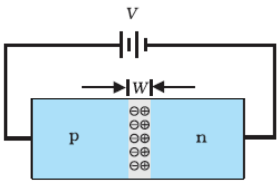
Insulators: The energy gap between valence band and the conduction band is very large(>3eV). Ex: Rubber, Paper, Mica, Glass, Wood etc.

Formation of energy bands in solids:

When atoms combine together to form a solid, the energy of the electrons may increase or decrease due to the interaction between the electrons of different atoms. The energies of electrons spreads out and forms an energy band. Energy band formed from the valence electrons is called valence band. The upper energy band in solids is called conduction band.

4. **Describe with suitable block diagram action of p-n junction diode under forward and reverse bias conditions. Also draw I –V characteristics. (July18)**
Explain the working of p-n junction diode in forward bias. (3 Mark) (Aug 2022)

p-n junction diode under forward bias:

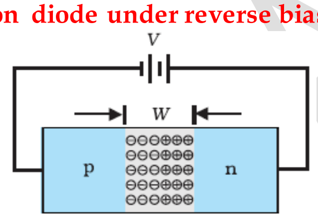


Forward bias

If the forward voltage is small, the barrier potential will be reduced only slightly and only a small number of carriers (carriers which have uppermost energy levels) cross the junction. So the current will be small. If the forward voltage increased, the barrier height will be reduced and more number of carriers will cross the junction. Thus the current increases.

Due to the forward voltage, electrons from n-side cross the depletion region and reach p-side, and holes from p-side cross the junction and reach the n-side. The total diode forward current is sum of hole diffusion current and conventional current due toelectron diffusion.

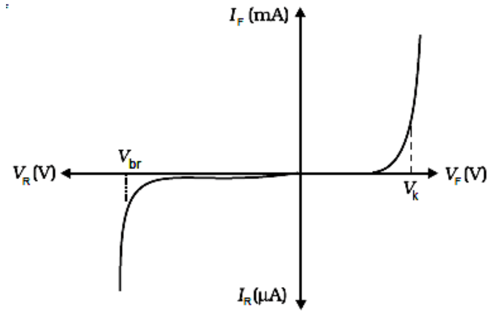
p-n junction diode under reverse bias:



Reverse bias

If the reverse voltage is applied, the barrier height increases and the depletion region widen. This suppresses the flow of electrons from n to p side and holes from p to n side. But the electric field direction of the junction is such that the electrons from p-side or holes from n-side cross the junction. This drift of carriers gives rise to very small current.

I –V characteristics of p-n junction diode:



THREE MARK QUESTIONS:

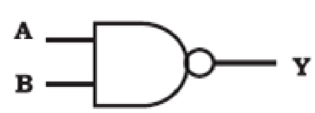
1. **Give any three difference between n-type and p-type semiconductors. (July 2014, July 2016, March 2017, March 2018, Aug 2022)**
Distinguish between n-type and p-type semiconductors. (2 mark)(March 2019)

n-type semiconductor	p-type semiconductor
n-type semiconductor is formed by doping pentavalent impurity to the pure semiconductor.	p-type semiconductor is formed by doping trivalent impurity to the pure semiconductor.
Electrons are majority carriers.	Holes are majority carriers.
Holes are minority carriers.	Electrons are minority carriers.
Free electron density is much greater than hole density i.e $n_e >> n_h$	Hole density is much greater than free electron density i.e $n_h >> n_e$

2. **What is NAND gate? Write its logic symbol and truth table. (June 2019)**
What is a NAND gate? Give its logic symbol. (2 mark) (March 2017)
What is the logic symbol and truth table of NAND gate? (2 mark) (March 2016)
Write the truth table of NAND gate. (1 mark)(July 2016)

NAND gate is an AND gate followed by a NOT gate. If the inputs A and B both are 1, then output Y is 0.

Logic symbol:



Truth table:

Input		Output
A	B	$Y = \overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

3. **Distinguish between intrinsic and extrinsic semiconductors.** **(March 2020)**
Give any three differences between intrinsic and extrinsic semiconductors. **(May 2022)**

Intrinsic semiconductor	Extrinsic semiconductor
It is a pure form of semiconductor.	It is a doped semiconductor.
The number of free electrons(n_e) is equal to the number of holes (n_h) i.e. $n_e = n_h$	The number of free electrons (n_e) is not equal to the number of hole (n_h) $i.e. n_e \neq n_h$
Electrical conductivity is low	Electrical conductivity is high
Electrical conductivity depends on temperature.	Electrical conductivity depends on temperature and dopants.

4. **What are optoelectronic devices? Name any two optoelectronic devices.** **(Sept 2020)**
These are the p-n junctions in which the charge carriers are generated by photons.
Optoelectronic devices are Photo diode, LED, Solar cell.

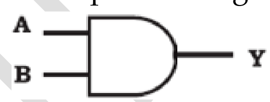
5. **Explain Conduction band, Valance band and Energy gap in semiconductors.** **(March 2019)**
In semiconductors, energy gap is finite but small. It is less than 3eV. Because of small energy gap, at room temperature some electrons from valance band can acquire enough energy to cross the energy gap and enter the conduction band. These electrons (small in number) can move in the conduction band.

TWO MARK QUESTIONS:

1. **What are intrinsic semiconductors? Name the element used as a dopant to obtain p-type semiconductor.** **(July 2015)**
Semiconductor in its purest form is called as an intrinsic semiconductor.
The element used to obtain p-type semiconductor are Boron, Aluminium, indium, Gallium

2. **Write any two advantages of light emitting diode (LED) over conventional incandescent low power lamps.** **(July 2018)**
Give any two advantages of LEDs over conventional incandescent low power lamps. **(May 2022)**
Write any one advantage of LED **(1 mark) (July 2017)**
LED's are operate at low voltage, consumes less power, have long life, operate at very speed.

3. **What is photo diode? Mention its one use.** **(March 2015)**
Photo diode is a reverse biased p-n junction diode which converts incident light energy into photo current.
The photodiodes are used as photodetector to detect optical signal (alarm systems, counting systems, cd players).

4. **Write the logic symbol of AND gate and write its truth table.** **(Aug 2022)**
Write the circuit symbol of AND gate. **(1 mark) (July 2014, July 2017)**
What is AND gate?
AND gate is a basi gate which produces a high (1) output when all the inputs are high(1).
Logic symbol :


Truth table :

Inputs		Output
A	B	Y= AB
0	0	0
0	1	0
1	0	0
1	1	1

5. **What are the majority and minority charge carriers in n-type semiconductor and p-type semiconductor?**
n-type semiconductor: majority charge carriers are free electrons and minority charge carriers are holes
p-type semiconductor: majority charge carriers are holes and minority charge carriers are free electrons

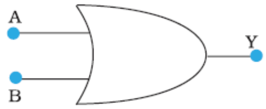
6. **What is forward and reverse bias of diode?**
The diode is said to be forward biased when positive terminal of the battery is connected to p-type and negative terminal of the battery is connected to n- type semiconductor of the diode.
The diode is said to be reverse biased when positive terminal of the battery is connected to n-type and negative terminal of the battery is connected to p- type semiconductor of the diode.

7. **What is solar cell? Mention its one use.**
A solar cell is a p-n junction which generates emf when radiation falls on the p-n junction.
Uses:
(1) They are used to supply power to satellites and space vehicles.
(2) They are used in calculators.

ONE MARK QUESTIONS:

1. **Write the truth table of logic OR gate.** **(March2014)**
   What is a OR gate? Give its logic symbol.
   OR gate is a basic gate which produces a high(1) output if at least any one of the input is high(1).

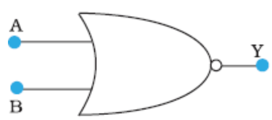
   Logic symbol :



   Truth table :

Inputs		Output
A	B	Y= A+B
0	0	0
0	1	1
1	0	1
1	1	1

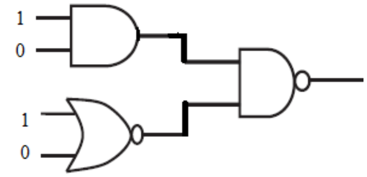
2. **Mention any one application of Light Emitting Diode (LED).** **(July 2014)**
   What is LED?
   LED's are used in remote controls, burglar alarm systems, optical communication.
   LED is a heavily doped p-n junction which emits radiation when forward biased.
3. **Input of NAND gate are A=1, B=0. What is the output?** **(July 2015)**
   $Y=\overline{A\cdot B}=\overline{1\cdot 0}=1$
4. **What is a depletion region in a semiconductor diode?** **(March 2018)**
   The region near the junction consists of ionised donors on n-side and ionised acceptors on p-side is called the depletion region or space charge region.
5. **Which logic gate is used as inverter?** **(Sept 2020)**
   NOT gate
6. **Draw the logic symbol of NOR gate.**
   (1 mark)(March 2020)
   What is NOR gate? Write its logic symbol and truth table.
   NOR gate is an OR gate followed by a NOT gate. If the inputs A and B both are 0, then output Y is 1.
   Logic symbol :



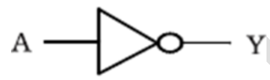
   Truth table :

Inputs		Output
A	B	Y= $\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

7. **What is the output of this combination?**



   (March 2018)
   Ans: 1
8. **Draw the logic symbol of NOT-gate.** **(May 2022)**
   What is NOT gate? Write its logic symbol and truth tale.
   NOT gate is a gate which produces a '1' output if the input is '0' and vice-versa.
   Logic symbol :

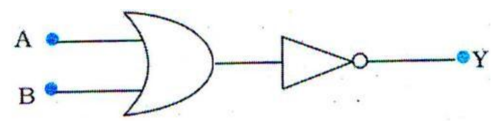


   Truth table :

Input	Output
A	Y= $\overline{A}$
0	1
1	0

9. **Give an example for elemental semiconductor.** **(May 2022)**
   Silicon or Germanium (Si or Ge).
10. **Draw the circuit symbol for p-n junction diode.**

11. **In the following circuit, if A = 1 and B = 1, what is the value of Y? Name the equivalent logic gate that this circuit represents.**



   If A = 1 and B = 1, then y=0
   Equivalentlogic gate is NOR gate

1 ELECTRIC CHARGES AND FIELDS

1. Two point charges q_A = 3μC and q_B =–3μC are located 20cm apart in vacuum.
   (a) What is the electric field at the mid-point O of the line AB joining the two charges?
   (b) If a negative test charge of magnitude 1.5 x 10^{-9}C is placed at this point, then what is the force experienced by the test charge? **(March 2017, Aug 2022)**
2. Three charges each equal to +4nC are placed at the three corners of a square of side 2cm. Find the electric field at the fourth corner. **(March 2018)**
3. Two point charges q_A=5μC and q_B=-5μC are located at A and B separated by 0.2m in vacuum.
   (a) What is the electric field at the midpoint O of the line joining the two charges?
   (b) If a negative test charge of magnitude 2nC is placed at O, what is the force experienced by the test charge? **(March 2020)**
4. Two small charged spheres having charges of 2x10^{-7}C and 3x10^{-7}C are placed 3 cm apart in vacuum. Find the electrostatic force between them. Find the new force, when the distance between them is doubled. Given: $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\,\text{Nm}^2\text{C}^{-2}$. **(May 2022)**

2 ELECTROSTATIC POTENTIAL AND CAPACITANCE

1. In a parallel plate capacitor with air between the plates, each plate has an area of 6 x 10^{-3} m^2 and the distance between the plates is 3mm. Calculate the capacitance of the capacitor. If this capacitor is connected to a 100V supply, what is the charge on each plate of the capacitor?
   Absolute permittivity of free space = 8.85 x 10^{-12} F/m. **(March 2014)**
2. Two charges 3 x 10^{-8}C and –2 x 10^{-8}C are located 15cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero. **(July 2014)**
3. Two point charges +1nC and –4nC are 1m apart in air. Find the positions along the line joining the two charges at which resultant potential is zero. **(March 2015)**
4. ABCD is a square of side 2m. Charges of 5nC, +10nC and –5nC are placed at corners A, B and C respectively. What is the work done in transferring a charge of 5μC from D to the point of intersection of the diagonals? **(July 2015)**
5. When two capacitors are connected in series and connected across 4kV line, the energy stored in the system is 8J. The same capacitors, if connected in parallel across the same line, the energy stored is 36J. Find the individual capacitances. **(March 2016)**
6. Charges 2μC, 4μC and 6μC are placed at the three corners A, B and C respectively of a square ABCD of side x metre. Find what charge must be placed at the fourth corner so that the total potential at the centre of the square is zero? **(July 2016)**
7. In a parallel plate capacitor with air between the plates, each plate has an area of 8 x 10^{-3} m^2 and the distance between the plates is 2mm. Calculate the capacitance of the capacitor. If this capacitor is connected to a 50V supply, what is the charge on each plate of the capacitor?
   Absolute permittivity of free space = 8.85 x 10^{-12} F/m. **(July 2017)**
8. The plates of a parallel plate capacitor have an area of 100cm^2 each and are separated by 3mm.The capacitor is charged by connecting it to a 400V supply. Calculate (a) the electrostatic energy stored in the capacitor, (b) if a dielectric of constant 2.5 is introduced between the plates of the capacitor, then find electrostatic energy stored and also change in the energy stored. **(July 2018)**
9. In a circular parallel plate capacitor radius of each plate is 5 cm and they are separated by a distance of 2 mm. Calculate the capacitance and the energy stored, when it is charged by connecting the battery of 200 V (given $\in_0$ = 8.854 × 10-12 Fm^{-1}) **(March 2019)**
10. A B C D is a square of side 1m. Charges of +3nc, -5nc and +3nc are placed at the corners A,B and C respectively. Calculate the work done in transferring a charge of 12μc from D to the point of intersection of the diagonals? **(June 2019)**

11. In a parallel plate capacitor with air between the plates, each plate has an area of 6 x 10^{-3} m^2 and the distance between the plates is 3 mm. Calculate the capacitance of the capacitor. If this capacitor is connected to a 100V supply, what is the charge on each plate of the capacitor?
(ε_0 = 8.854 x 10^{-12} Fm^{-1}) **(Sept 2020)**

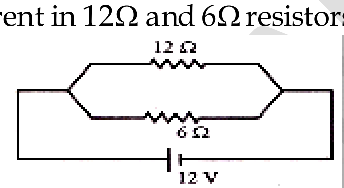
12. A charge of 8mC is located at the origin. Calculate the work done in taking a small charge of -2×10^{-8}C from a point A(3cm, 0, 0) to a point B (0, 4cm, 0) via a point C(3cm, 4cm, 0).
Given : $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\,Nm^2C^{-2}$. **(May 2022)**

13. In a parallel plate capacitor, the area of each plate is 6 x $10^{-3}m^2$ and the distance between the plates is 3mm. Calculate the capacitance of the capacitor. If this capacitor is connected to 100 V supply, what is the charge on each plate of the capacitor?
Given: ε_0 = 8.854 x 10 $^{-12}$? Fm^{-1}. **(Aug 2022)**

3 CURRENT ELECTRICITY

1. A battery of internal resistance 3Ω is connected to a 20Ω resistor and potential difference across the resistor is 10V. If another resistor of 30Ω is connected in series with the first resistor and battery is again connected to the combination, calculate the emf and terminal potential difference across the combination. **(March 2014)**

2. A network of resistors is connected to a 12V battery as shown in the figure.
(a) Calculate the equivalent resistance of the network.
(b) Obtain current in 12Ω and 6Ω resistors. **(July2014)**



3. Two cells of emf 2V and 4V and internal resistance 1Ω and 2Ω respectively are connected in parallel so as to send the current in the same direction through an external resistance of 10Ω. Find the potential difference across 10Ω resistor. **(March 2015)**

4. Two identical cells either in series or in parallel combination, gives the same current of 0.5A through external resistance of 4Ω. Find emf and internal resistance of each cell. **(July 2015)**

5. Three resistors of resistances 2Ω, 3Ω and 4Ω are combined in series. (a) What is the total resistance of the combination? (b) If this combination is connected to a battery of emf 10V and negligible internal resistance, obtain the potential drop across each resistor. **(March 2016)**

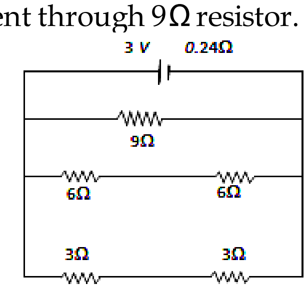
6. A wire having length 2m, diameter 1mm and resistivity 1.963 x 10^{-8}Ωm is connected in series with a battery of emf 3V and internal resistance 1Ω. Calculate the resistance of the wire and current in the circuit. **(July 2016)**

7. When two resistors are connected in series with a cell of emf 2V and negligible internal resistance, a current of $\frac{2}{5}$ A flows in the circuit. When the resistors are connected in parallel, the main current is $\frac{5}{3}$ A. Calculate the resistances. **(March 2017)**

8. (a) Three resistors 4Ω, 6Ω and 8Ω are combined in parallel. What is the total resistance of the combination?
(b) If this combination is connected to a battery of emf 25V and negligible internal resistance, then determine the current through each resistor and the total current drawn from the battery. **(July2017)**

9. 100mg mass of nichrome metal is drawn into a wire of area of cross section 0.05mm^2. Calculate the resistance of this wire. Given density of nichrome as 8.4 x $10^3kg/m^3$ and the resistivity of the material as 1.2 x 10^{-6} Ωm. **(March 2018)**

10. In the given diagram, calculate
(i) the main current through the circuit and
(ii) also current through 9Ω resistor. **(July 2018)**



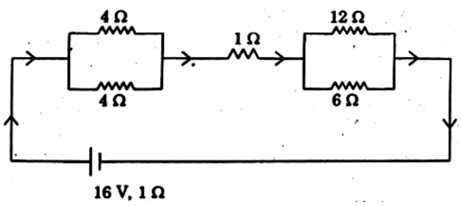
11. Two resistors are connected in series with 5V battery of negligible internal resistance. A current of 2A flows through each resistor. If they are

connected in parallel with the same battery a current of $\frac{25}{3}$ A flows through combination. Calculate the value of each resistance. **(March 2019)**

12. A network of Resistors is Connected to a $16\,V$ battery with internal resistance $1\,\Omega$ as shown in figure.

(a)Compute the equivalent resistance of the network

(b)Calculate the total current in the circuit. **(June2019)**

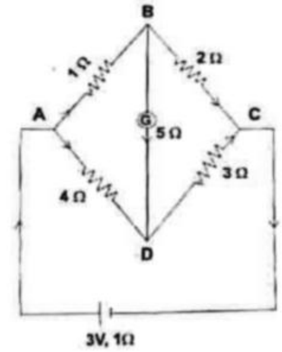


13. (a) Three resistors 3Ω, 4Ω and 12Ω are connected in parallel. What is the effective resistance of the combination?

(b) If the combination is connected to a battery of emf 6Vand internal resistance 0.5Ω, find the current drawn from the battery and terminal potential difference across the battery.

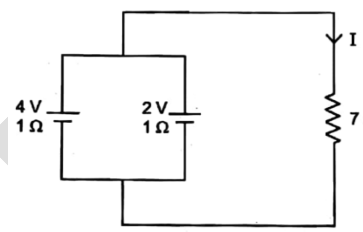
(March 2020)

14. In the given circuit, calculate the current through the galvanometer (I_g): **(Sept2020)**



15. In the following circuit, find the current I.

(May 2022)



16. Two cells of emf 2V and 4V and internal resistance $1\,\Omega$ and $2\,\Omega$ respectively are connected in parallel so as to send the current in the same direction through an external resistance of $10\,\Omega$. Find the potential difference across $10\,\Omega$ resistor.

(Aug 2022)

4 MOVING CHARGES AND MAGNETISM

1. A galvanometer having coil of resistance 12Ω gives full scale deflection for a current of 4mA. How can it be converted into a voltmeter of range 0 to 24V?

(2 mark)(July 2016)

2. In a region, an electric field $\vec{E}=5\times10^3\,\hat{j}NC^{-1}$ and a magnetic field of $\vec{B}=0.1\hat{k}T$ are applied. A beam of charged particles are projected along X-direction. Find the velocity of charged particles which move undeflected in this crossed fields.

(2 mark)(March 2020)

3. A circular copper coil of mean radius 6.284 cm has 20 tums. If a current of 2A is passed through this coil, find the magnitude of the magnetic field at its centre. Also find the magnetic dipole moment of this current coil. Given: $\mu_0 = 4\pi\times10^{-7}\,Hm^{-1}$.

(May 2022)

4. A 100turn closely wound circular coil of radius 10 cm carries a current of 3.2A. (a) What is the magnetic field at the centre of the coil? (b) What is the magnetic moment of this coil?

(Aug 2022)

6 ELECTROMAGNETIC INDUCTION

1. Current in a coil falls from 2.5A to 0A in 0.1s inducing an emf of 200V. Calculate the value of self inductance. **(2 mark) (March 2015)**

2. The current in a coil of self inductance 5mH changes from 2.5A to 2A in 0.01s. Calculate the value of self induced emf. **(2 mark) (March 2016)**

3. The magnetic flux linked with a coil varies as $\phi = 3t^2 + 4t + 9$. Find the magnitude of the emf induced at t = 2s. **(2 mark) (July 2017)**
4. A circular coil of radius 10cm and 25 turns is rotated about its vertical diameter with an angular speed of 40 rad s^{-1} in a uniform horizontal magnetic field of magnitude 5 x 10^{-2} T. Calculate the emf induced in the coil. Also find the current in the coil if the resistance of the coil is 15Ω. **(March 2018)**
5. A conductor of length 3m moving in a uniform magnetic field of strength 100 T . It covers a distance of 70 m in 5 sec. Its plane of motion makes an angle of 30° with direction of magnetic field. Calculate the emf induced in it. **(March 2019)**
6. The current through a coil of 2mH changes from zero ampere to 5 mA in 0.1 second. What is the emf induced in the coil? **(Sept 2020)**
7. The current in a coil falls from 25 mA to 0 mA in 1 ms and induces an emf of 10 V in it. Find the self-inductance of the coil. **(May 2022)**

7 ALTERNATING CURRENT

1. If the peak value of ac current is 4.24 A, what is its root mean square value? **(2 mark)(March18, Aug22)**
2. Calculate resonant frequency and Q-factor of a series LCR circuit containing a pure inductor of inductance 3H, capacitor of capacitance 27μF and resistor of resistance 7.4Ω. **(March 2014)**
3. A pure inductor of 25mH is connected to a source of 220V and 50Hz. Find the inductive reactance, rms value of current and peak current in the circuit. **(July 2014)**
4. A sinusoidal voltage of peak value 283V and frequency 50Hz is applied to a series LCR circuit in which R = 3Ω, L = 25.48mH and C = 786μF. Find (a) Impedance of the circuit (b) The phase difference between the voltage across the source and the current (c) The power factor. **(March 2015)**
5. A resistor of 100Ω, a pure inductance coil of L = 0.5H and capacitor are in series in a circuit containing an a.c. source of 200V, 50Hz. In the circuit, current is ahead of the voltage by 30^0. Find the value of the capacitance. **(July 2015)**
6. Calculate the resonant frequency and Q-factor of a series LCR circuit containing a pure inductor of inductance 4H, capacitor of capacitance 27μF and resistor of resistance 8.4Ω. **(March 2016)**
7. An inductor and a bulb are connected in series to an AC source of 220V, 50Hz. A current of 11A flows in the circuit and phase angle between voltage and current is $\pi/4$ radians. Calculate the impedance and inductance of the circuit. **(July 2016)**
8. A source of alternating emf of 220V – 50Hz is connected in series with a resistance of 200Ω, an inductance of 100mH and a capacitance of 30μF. Does the current lead or lag the voltage and by what angle? **(March 2017)**
9. A sinusoidal voltage of peak value 285V is applied to a series LCR circuit in which resistor of resistance 5Ω, pure inductor of inductance 28.5mH and capacitor of capacitance 800μF are connected. (a) Find the resonant frequency. (b) Calculate the impedance, current and power dissipated at the resonance. **(July 2017)**
10. A 20 Ω resistor, 1.5 H inductor, and 35 μF capacitors are connected in series with a 220 V, 50 Hz ac supply. Calculate the impedance of the circuit and also find the current through the circuit. **(July 2018)**
11. A sinusoidal voltage of peak value 283 V and frequency 50Hz is applied to a series LCR circuit in which R=3 Ω, L=25.48mH and C=796μF. Find (a) Impedance of the circuit. (b) The phase difference between the Voltage across the source and the current. **(June 2019)**
12. A series LCR circuit contains a pure inductor of inductance 5.0H, a capacitorof capacitance 20μF and a resistor of resistance 40Ω.
    a) Find the resonant frequency of the circuit.
    b) Calculate the Quality factor (Q - factor) of the circuit.
    c) What is the impedance at resonant condition? **(March 2020)**
13. An AC source of 200 volt, 50 Hz is applied to a series LCR circuit in which R=3 Ω , L= 25mH and C = 790 μ F. Find (a) the impedance of the circuit and (b) current in the circuit. **(Sept 2020)**

9 RAY OPTICS AND OPTICAL INSTRUMENTS

1. Two lenses of power +1.5D and –0.5D are kept in contact on their principal axis. What is the effective power of the combination? **(1 mark) (March 2018)**
2. Two lenses of focal lengths 0.2m and 0.3m are kept in contact. Find the focal length of the combination. Calculate powers of two lenses and combination. **(March 2014)**
3. A prism of angle 60^0 produces angle of minimum deviation of 40^0. What is its refractive index? Calculate the angle of incidence. **(July 2014)**
4. The radii of curvature of two surfaces of a convex lens are 0.2m and 0.22m. Find the focal length of the lens if refractive index of the material of lens is 1.5. Also find the change in focal length, if it is immersed in water of refractive index 1.33. **(July 2018)**
5. An object of 3cm is placed 14*cm* in front of a concave lens of focal length 21*cm*. Find the position, Nature and Size of the Image formed. **(June 2019)**
6. At what angle should a ray of light be incident on the face of an equilateral prism, so that it just suffers total internal reflection at the other face? The refractive index of the material of the prism is 1.5. **(March 2020)**
7. The refractive index of an equilateral prism is 1.532. Calculate the angle of minimum deviation when it is immersed in water of refractive index 1.33. **(Sept 2020)**
8. A ray of light passes through an equilateral glass prism such that the refracted ray inside the prism is parallel to its base. Calculate the a) angle of deviation of the ray and b) speed of light ray inside the prism. Given : the refractive index of glass = $\frac{3}{2}$ and the speed of light in vacuum = 3×10^8 ms^{-1}. **(May 2022)**

10 WAVE OPTICS

1. In a Young's double slit experiment, the distance between the slits is 1mm. The fringe width is found to be 0.6mm. When the screen is moved through a distance of 0.25m away from the plane of the slit, the fringe width becomes 0.75mm. Find the wavelength of light used. **(March 2015)**
2. A beam of light consisting of two wavelengths 4200 Å and 5600 Å is used to obtain interference fringes in Young's double slit experiment. The distance between the slits is 0.3mm and the distance between the slits and the screen is 1.5m. Compute the least distance of the point from the central maximum, where the bright fringes due to both the wavelengths coincide. **(July 2015)**
3. In Young's double slit experiment, fringes of certain width are produced on the screen kept at a certain distance from the slits. When the screen is moved away from the slits by 0.1m, the fringe width increases by 6×10^{-5}m. The separation between the slits is 1mm. Calculate the wavelength of the light used. **(March 2016)**
4. In Young's double slit experiment while using a source of light of wavelength 4500 Å, the fringe width is 5mm. If the distance between the screen and the plane of the slits is reduced to half, what should be the wavelength of light to get fringe width of 4mm? **(July 2016)**
5. Light of wavelength 6000 Å is used to obtain interference fringes of width 6mm in a Young's double slit experiment. Calculate the wavelength of the light required to obtain fringe of width 4mm when the distance between the screen and slits is reduced to half of its initial value? **(March 2017)**
6. In a Young's double slit experiment, the distance between the slits is 0.5mm. When the screen is kept at a distance of 100cm from the slits, the distance of 9^{th} bright fringe from the centre of the fringe system is 8.835mm. Find the wavelength of light used. **(July 2017)**
7. In Young's double slit experiment, the slits are separated by 0.28mm and the screen is placed at a distance of 1.4m away from the slits. The distance between the central bright fringe and the fifth dark fringe is measured to be 1.35cm. Calculate the wavelength of the light used. Also find the fringe width if the screen is moved 0.4m towards the slits for the same experimental setup. **(March 2018)**

8. In a Young's double slit experiment wave length of light used is 5000 Å and distance between the slits is 2 mm, distance of screen from the slits is 1m. Find fringe width and also calculate the distance of 7^{th} dark fringe from central bright fringe. **(March 2019)**

9. Two slits separated by 1 mm in Young's double slit experiment are illuminated by the violet light of the wavelength 400 nm. The interference fringes are obtained on the screen placed at 1 m from the slits. Find the fringe width. If the violet light is replaced by the red light of the wavelength 700 nm, find the percentage change in fringe width. **(May 2022)**

10. In Young's double slit experiment, fringes of certain width are produced on the screen kept at a certain distance from the slits. When the screen is moved away from the slits by 0.1m, fringe width increases by 6×10^{-5}m. The separation between the slits is 1mm, calculate the wavelength of light used. **(Aug 2022)**

11 DUAL NATURE OF RADIATION AND MATTER

1. The work function of caesium metal is 2.14eV. When light of frequency 6×10^{14} Hz is incident on the metal surface, photoemission of electrons occurs. Find : (a) energy of incident photons (b) maximum kinetic energy of photoelectrons. Given: Planck's constant, $h = 6.63 \times 10^{-34}$ Js, $1eV = 1.6 \times 10^{-19}$ J. **(July 2014)**

2. Light of frequency 8.41×10^{14}Hz is incident on a metal surface. Electrons with their maximum speed of 7.5×10^5m/s are ejected from the surface. Calculate the threshold frequency for photoemission of electrons. Also find the work function of the metal in electron volt(eV). Given: Planck's constant $h = 6.625 \times 10^{-34}$Js and mass of the electron 9.1×10^{-31}kg. **(March 2018)**

3. Calculate de-Broglie wavelength associated with an electron moving with a speed of $2X10^6 ms^{-1}$. Given: $h= 6.625x10^{-34}$Js, $m_e = 9.11x10^{-31}$kg. **(2 mark)(July 2018)**

4. Light of frequency 7.21×10^{14} Hz is incident on a metal surface. Electrons with a maximum speed of 6×10^5 ms^{-1} are ejected from the surface. What is the threshold frequency for photo emission of electrons? Also find the work function of the metal in electron volt (ev). Given: Planck's constant $h = 6.625 \times 10^{-34}$ Js. Mass of electron $m_e = 9.1 \times 10^{-31}$ Kg. **(Aug 2022)**

12 ATOMS

1. Calculate the shortest and longest wavelengths of Balmer series of hydrogen atom. Given: $R = 1.097 \times 10^7$/m. **(March 2016)**

2. The first member of the Balmer series of hydrogen atom has a wavelength of 6563 Å. Calculate the wavelength and frequency of the second member of the same series. Given $c = 3 \times 10^8$m/s. **(March 2017, Aug 2022)**

13 NUCLEI

1. Calculate the binding energy and binding energy per nucleon (in MeV) of a nitrogen nucleus ($_7N^{14}$) from the following data :
Mass of proton = 1.00783u
Mass of neutron = 1.00867u
Mass of nitrogen nucleus = 14.00307u. **(March 2014)**

2. Calculate the binding energy and binding energy per nucleon (in MeV) of an oxygen nucleus ($_8O^{16}$) from the following data:
Mass of proton = 1.007825u
Mass of neutron = 1.008665u
Mass of oxygen nucleus = 15.995u. **(July 2017)**

3. Calculate the binding Energy of an alpha particle in MeV from the following data.
Mass of Helium Nucleus= 4.00260u,
Mass of Neutron = 1.008662u
Mass of Proton=1.007825u. **(June 2019)**

4. A copper coin has a mass of 63.0 g. Calculate the nuclear energy that would be required to separate all the neutrons and protons form each other. The coin is entirely made of $^{63}_{29}Cu$ atoms.
Mass of $^{63}_{29}Cu$ atom = 62.92960 u
Mass of proton = 1.00727 u
Mass of neutron = 1.00866 u
Avogadro's number = 6.022×10^{23}. **(March 2020)**

5. Calculate the binding energy and binding energy per nucleon of an Alpha (α) particle in MeV from the following data:
Mass of α -particle nucleus = 4.00260 u.
Mass of neutron = 1.008662 u
Mass of proton = 1.007825 u. **(Sept2020)**

6. Determine the mass of Na^{22} which has an activity of 5mCi. Half life of Na^{22} is 2.6 years. Avogadro number = 6.023×10^{23} atoms. **(March 2015)**

7. Calculate the half life and mean life of Radium–226 of activity 1Ci. Given the mass of Radium–226 is 1 gram and 226 gram of radium consists of 6.023×10^{23} atoms. **(July 2015)**

8. The activity of a radioactive substance is 4700 per minute. Five minutes later, the activity is 2700 per minute. Find (a) decay constant and (b) half life of the radioactive substance. **(July 2016)**

9. The half life of a radioactive sample $_{38}Sr^{90}$ is 28 years. Calculate the rate of disintegration of 15 mg of this isotope. Given Avogadro's number = $6.023X10^{23}$. **(July2018)**

10. Half life of U-238 undergoing α - decay is 4.5×10^9 years. What is the activity of one gram of U-238 sample? **(March 2019)**

11. A copper coin has a mass of 63.0 g. Calculate the nuclear energy that would be required to separate all the neutrons and protons form each other. The coin is entirely made of $^{63}_{29}Cu$ atoms.
Mass of $^{63}_{29}Cu$ atom = 62.92960 u
Mass of proton = 1.00727 u
Mass of neutron = 1.00866 u
Avogadro's number = 6.022×10^{23}. **(March 2020)**

12. The normal activity of living carbon (C-14) containing matter is found to be about 15 decays per minute per gram of carbon. A specimen found in an archaeological excavation has an activity of 1.5 decays per minute per gram of carbon matter. Estimate the age of the specimen. Given: the half-life of carbon (C-14) is 5730 years. **(May 2022)**

KARNATAKA BOARD MODEL QUESTION PAPER (2022)

23. Find the potential difference through which an electron be accelerated so that its de Broglie wavelength becomes 0.1227 nm. **(2 mark)**

44. Two charges of 2 μC and 8 μC are separated by 4 cm. Calculate the electrostatic force between them. If the distance between the charges is halved and a medium of dielectric constant 2 is placed between them, find the new electrostatic force. Also find the change in force (Given: $\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ Nm^2C^{-2}$)

45. A parallel plate capacitor consists of two circular metal plates, each of radius 1.38 cm. A coating of Teflon 40 μm thick is applied to the inner surface of one plate to provide a dielectric layer, and then the plates are pressed together. Find the voltage to be applied between the plates of this capacitor to establish a charge of 0.5 nC on each plate. (Given: $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m and dielectric constant of Teflon = 2).

46. Two cells of emf 3 V and 4 V and internal resistance 1 Ω and 2 Ω respectively are connected in parallel so as to send the current in the same direction through an external resistance of 5 Ω. Find the potential difference across 5 Ω resistor.

47. Two circular loops of radii 6.28 cm and 3.14 cm are arranged concentric to one another with their planes at right angles to each other. If a current of 2 A is passed through each of them, calculate the magnitude of the net magnetic field at their common centre
(Given: $\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$).

48. An object is placed at 10 cm in front of a concave mirror of radius of curvature 15 cm. Find the position and the magnification of the image. Write the nature of the image.

49. Two narrow parallel slits separated by 0.850 mm are illuminated by a light of wavelength 600 nm and the viewing screen is placed at 2.80 m

from the slits. Find (a) the phase difference between the two interfering waves on the screen at a point 2.50 mm from the central bright fringe and (b) the ratio of the intensity at this point to the intensity at the centre of a bright fringe.

50. The half-life of radon is 3.8 days. Find its decay constant. Calculate, after how many days will 5% of the sample be left over.

KARNATAKA BOARD MODEL QUESTION PAPER – I (2021)

33. A 4 μF capacitor is charged by a 200 V supply. It is then disconnected from the supply, and is connected to another uncharged 2 μF capacitor. How much electrostatic energy of the first capacitor is lost in the form of heat and electromagnetic radiation?

34. Six lead-acid type of secondary cells each of emf 2.0 V and internal resistance 0.015 Ω are joined in series to provide a supply to a resistance of 8.5 Ω. What are the current drawn from the supply and its terminal voltage?

35. A sinusoidal voltage of peak value 283 V and frequency 50 Hz is applied to a series LCR circuit in which R = 3 Ω, L = 25.48 mH, and C = 796 μF. Find (a) the impedance of the circuit, (b) the phase difference between the voltage across the source and the current and (c) the power dissipated in the circuit.

36. In a Young's double slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and the fourth bright fringe is measured to be 1.2 cm. Determine the fringe width and the wavelength of light used in the experiment.

37. The work function of caesium is 2.14 eV. Find (a) the threshold frequency for cesium and (b) the wavelength of the incident light if the photocurrent is brought to zero by a stopping potential of 0.60V.

KARNATAKA BOARD MODEL QUESTION PAPER – II (2021)

33. Two charges 5×10^{-8} C and -3×10^{-8} C are located 16 cm apart. At what points on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.

34. A wire of length 2 m, area of cross-section 0.5 mm^2 and resistivity 1.5×10^{-6} Ω m is connected in series with a cell of emf 4 V. If the current through the wire is 0.5 A, calculate: (a) the internal resistance of the cell and (b) the rate of energy dissipated by the wire.

35. Calculate the resonant frequency of a series LCR circuit with L = 2.0 H, C = 32 μF and R= 10 Ω. What is the Q-value of this circuit?

36. In a Young's double slit experiment setup with monochromatic light, fringes are obtained on a screen placed at a certain distance from the slits. If the screen is moved by 5 cm towards the slits, the change in fringe width is 20 μm. Given the distance between two slits to be 1.2 mm, calculate the wavelength of the light used.

37. Light of frequency 7.21×10^{14} Hz is incident on a metal surface. The cut-off wavelength for photoelectric emission from the metal surface is 540 nm. Determine the maximum speed of the photoelectrons emitted from the surface. (Given: h = 6.63×10^{-34} Js, mass of an electron = 9.1×10^{-31} kg).

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