

CBSE Class 12 Physics Question Paper with Solutions(Memory Based)

Time Allowed :3 Hours

Maximum Marks :70

Total questions :37

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Please check that this question paper contains 23 printed pages.
2. Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
3. Please check that this question paper contains 37 questions.
4. 15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the candidates will read the question paper only and will not write any answer on the answer-book during this period.

1. In a Young's double-slit experiment, the fringe width is found to be β . If the entire apparatus is immersed in a liquid of refractive index μ , the new fringe width will be:

- (A) β
(B) $\mu\beta$
(C) $\frac{\beta}{\mu}$
(D) $\frac{\beta}{\mu^2}$

Correct Answer: (C) $\frac{\beta}{\mu}$

Solution: Concept: In Young's double-slit experiment (YDSE), the fringe width is given by:

$$\beta = \frac{\lambda D}{d}$$

where:

- λ = wavelength of light

- D = distance between slits and screen
- d = slit separation

Effect of Medium: When the apparatus is immersed in a liquid of refractive index μ , the wavelength of light changes.

Wavelength in medium:

$$\lambda' = \frac{\lambda}{\mu}$$

However, D and d remain unchanged.

New Fringe Width:

$$\beta' = \frac{\lambda' D}{d} = \frac{(\lambda/\mu) D}{d}$$

$$\beta' = \frac{1}{\mu} \cdot \frac{\lambda D}{d}$$

$$\boxed{\beta' = \frac{\beta}{\mu}}$$

Final Answer:

$$\boxed{\frac{\beta}{\mu}}$$

Quick Tip

In YDSE, fringe width is directly proportional to wavelength. If refractive index increases, wavelength decreases, so fringe width decreases.

2. A light of frequency ν is incident on a metal surface whose work function is W_0 . The kinetic energy of emitted electron is K . If the frequency of the incident light is doubled, then the kinetic energy of emitted electron will be:

- (A) $2K$
- (B) more than $2K$
- (C) between K and $2K$
- (D) less than K

Correct Answer: (B) more than $2K$

Solution: Concept: From Einstein's photoelectric equation:

$$K = h\nu - W_0$$

where:

- $h\nu$ = energy of incident photon
- W_0 = work function of metal

Initial Condition:

$$K = h\nu - W_0 \quad \dots (1)$$

When Frequency is Doubled: New frequency = 2ν

New kinetic energy:

$$K' = h(2\nu) - W_0 = 2h\nu - W_0$$

Rewrite using equation (1):

$$2h\nu = 2(K + W_0)$$

$$K' = 2K + 2W_0 - W_0$$

$$K' = 2K + W_0$$

Comparison with $2K$: Since $W_0 > 0$,

$$K' = 2K + W_0 > 2K$$

Final Answer:

More than $2K$

Quick Tip

In photoelectric effect:

$$K = h\nu - W_0$$

Doubling frequency increases kinetic energy by more than double because work function is subtracted only once.

3. Which of the following statements is not true for nuclear forces?

- (A) They are stronger than Coulomb forces.
- (B) They have about the same magnitude for different pairs of nucleons.
- (C) They are always attractive.
- (D) They saturate as the separation between two nucleons increases.

Correct Answer: (C) They are always attractive.

Solution: Concept: Nuclear forces are the strong forces that act between nucleons (protons and neutrons) inside the nucleus. They have unique properties different from electromagnetic or gravitational forces.

Key Properties of Nuclear Forces:

- Very strong compared to Coulomb forces.
- Short range (effective up to about 1–2 fm).
- Charge independent (similar for p-p, n-n, and p-n interactions).
- Saturation property (each nucleon interacts only with nearby nucleons).
- Repulsive at very short distances and attractive at intermediate distances.

Checking Each Option:

(A) Stronger than Coulomb forces — True. Nuclear forces overcome proton-proton repulsion inside nucleus.

(B) Same magnitude for nucleon pairs — True. They are approximately charge independent.

(C) Always attractive — False. At extremely small separations, nuclear forces become strongly repulsive (hard core repulsion).

(D) Saturation property — True. Each nucleon interacts only with nearby neighbors.

Final Answer:

They are always attractive.

Quick Tip

Nuclear force behavior:

- Attractive at intermediate distances
- Repulsive at very short distances

This prevents nucleus from collapsing.

4. A particle of mass m and charge $-q$ is moving with a uniform speed v in a circle of radius r , with another charge q at the centre of the circle. The value of r is:

- (A) $\frac{1}{4\pi\epsilon_0 m} \left(\frac{q}{v}\right)$
(B) $\frac{1}{4\pi\epsilon_0 m} \left(\frac{q}{v}\right)^2$
(C) $\frac{m}{4\pi\epsilon_0} \left(\frac{q}{v}\right)$
(D) $\frac{m}{4\pi\epsilon_0} \left(\frac{q}{v}\right)^2$

Correct Answer: (D) $\frac{m}{4\pi\epsilon_0} \left(\frac{q}{v}\right)^2$

Solution: Concept: The particle moves in a circular path due to electrostatic attraction between opposite charges. The Coulomb force provides the necessary centripetal force.

Step 1: Coulomb Force

Electrostatic force between charges:

$$F = \frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2}$$

Step 2: Centripetal Force

For circular motion:

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

Step 3: Equating Forces

$$\frac{mv^2}{r} = \frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2}$$

Multiply both sides by r :

$$mv^2 = \frac{1}{4\pi\epsilon_0} \frac{q^2}{r}$$

Solve for r :

$$r = \frac{1}{4\pi\epsilon_0} \frac{q^2}{mv^2}$$

Rewriting:

$$r = \frac{m}{4\pi\epsilon_0} \left(\frac{q}{v}\right)^2$$

Final Answer:

$$\boxed{\frac{m}{4\pi\epsilon_0} \left(\frac{q}{v}\right)^2}$$

Quick Tip

Whenever a charged particle moves in a circular path due to electrostatic force:

$$\text{Coulomb force} = \text{Centripetal force}$$

A standard electrostatics + circular motion problem.

5. Photons of energy 3.2 eV are incident on a photosensitive surface. If the stopping potential for the emitted electrons is 1.5 V, the work function for the surface is:

- (A) 1.5 eV
- (B) 1.7 eV
- (C) 3.2 eV
- (D) 4.7 eV

Correct Answer: (B) 1.7 eV

Solution: Concept: From Einstein's photoelectric equation:

$$E_{\text{photon}} = \phi + K_{\text{max}}$$

Where:

- ϕ = work function
- $K_{\text{max}} = eV_0$ (stopping potential in eV equals kinetic energy)

Given:

$$E_{\text{photon}} = 3.2 \text{ eV}, \quad V_0 = 1.5 \text{ V}$$

Since $1 \text{ eV} = e \times 1 \text{ V}$,

$$K_{\text{max}} = 1.5 \text{ eV}$$

Using Photoelectric Equation:

$$\phi = E_{\text{photon}} - K_{\text{max}}$$

$$\phi = 3.2 - 1.5 = 1.7 \text{ eV}$$

Final Answer:

$$\boxed{1.7 \text{ eV}}$$

Quick Tip

In photoelectric problems:

$$\phi = E_{\text{photon}} - eV_0$$

If energy is in eV, you can subtract stopping potential directly.

6. Which one of the following has relative magnetic permeability between 0 and 1?

- (A) Aluminium
- (B) Alnico

- (C) Water
- (D) Sodium

Correct Answer: (C) Water

Solution: Concept: Relative magnetic permeability (μ_r) indicates how a material responds to a magnetic field.

Types of materials based on μ_r :

- Diamagnetic: $0 < \mu_r < 1$
- Paramagnetic: $\mu_r > 1$ (slightly)
- Ferromagnetic: $\mu_r \gg 1$

Checking Each Option:

(A) **Aluminium:** Paramagnetic material $\rightarrow \mu_r > 1$

(B) **Alnico:** Ferromagnetic alloy \rightarrow very high μ_r

(C) **Water:** Diamagnetic substance $\rightarrow \mu_r < 1$

(D) **Sodium:** Paramagnetic $\rightarrow \mu_r > 1$

Final Answer:

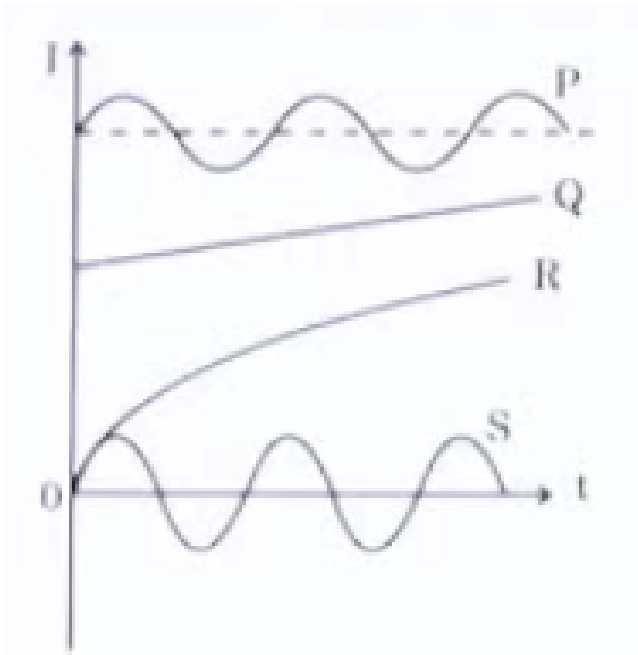
Water

Quick Tip

Remember:

- Diamagnetic $\rightarrow \mu_r < 1$ (e.g., water, bismuth)
- Paramagnetic \rightarrow slightly > 1
- Ferromagnetic $\rightarrow \gg 1$

7. The figure shows variation of current (I) with time (t) in four devices P, Q, R, and S. The device in which an alternating current flows is:



- (A) P
- (B) Q
- (C) R
- (D) S

Correct Answer: (D) S

Solution: Concept: An alternating current (AC) is defined as a current that:

- Changes magnitude with time
- Reverses direction periodically
- Alternates about the zero axis

A graph representing AC must cross the time axis repeatedly.

Analysis of Graphs:

P: Current varies with time but remains entirely above the axis → does not reverse direction (pulsating DC).

Q: Current increases linearly with time → direct current (DC).

R: Current rises and saturates → unidirectional current (not AC).

S: Sinusoidal wave alternating above and below zero → direction reverses periodically → true alternating current.

Final Answer:

S

Quick Tip

AC must cross the time axis. If the graph never goes below zero, it is not true alternating current.

8. Name the electromagnetic waves also known as ‘heat waves’.

- (A) Radio waves
- (B) Microwaves
- (C) X-rays
- (D) Infrared waves

Correct Answer: (D) Infrared waves

Solution: Concept: Electromagnetic waves cover a wide spectrum including radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.

Explanation: Infrared radiation is commonly referred to as *heat waves* because:

- They are emitted by hot bodies.
- They produce a heating effect when absorbed by matter.
- We feel warmth from sunlight mainly due to infrared radiation.

Why Other Options Are Incorrect:

- (A) Radio waves — Used in communication, not heat waves.
- (B) Microwaves — Used in cooking but not commonly called heat waves.
- (C) X-rays — High-energy radiation used in medical imaging.

Final Answer:

Infrared waves

Quick Tip

Infrared = heat radiation. All hot objects emit infrared waves, even at room temperature.

9. A plane wavefront is incident on a concave mirror of radius of curvature R . The radius of the reflected wavefront will be:

- (A) $2R$
- (B) R
- (C) $\frac{R}{2}$
- (D) $\frac{R}{4}$

Correct Answer: (C) $\frac{R}{2}$

Solution: Concept: A plane wavefront corresponds to parallel rays incident on a mirror. After reflection from a concave mirror, parallel rays converge at the principal focus.

Key Relation: For a concave mirror:

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

where:

- f = focal length
- R = radius of curvature

Wavefront Interpretation:

- Incident plane wavefront \rightarrow reflected spherical wavefront.
- The reflected wavefront converges toward the focus.
- Radius of curvature of reflected wavefront = focal length.

Thus,

$$\text{Radius of reflected wavefront} = f = \frac{R}{2}$$

Final Answer:

$$\boxed{\frac{R}{2}}$$

Quick Tip

Plane wavefront + concave mirror \rightarrow spherical wavefront with radius equal to focal length $f = R/2$.

10. A proton and an alpha particle have the same kinetic energy. The ratio of de Broglie wavelengths associated with the proton to that with the alpha particle is:

- (A) 1
- (B) 2
- (C) $2\sqrt{2}$
- (D) $\frac{1}{2}$

Correct Answer: (B) 2

Solution: Concept: The de Broglie wavelength is given by:

$$\lambda = \frac{h}{p}$$

Using kinetic energy relation:

$$K = \frac{p^2}{2m} \Rightarrow p = \sqrt{2mK}$$

Thus,

$$\lambda = \frac{h}{\sqrt{2mK}}$$

So,

$$\lambda \propto \frac{1}{\sqrt{m}} \quad (\text{for same } K)$$

Given:

- Same kinetic energy
- Mass of alpha particle = $4m_p$

Ratio of Wavelengths:

$$\frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}}$$

$$= \sqrt{\frac{4m_p}{m_p}} = \sqrt{4} = 2$$

Final Answer:

2

Quick Tip

For equal kinetic energy:

$$\lambda \propto \frac{1}{\sqrt{m}}$$

Heavier particle \rightarrow smaller wavelength.

11. State the law and derive the electric field due to an infinitely long straight charged wire.

Solution: Concept: To find the electric field due to an infinitely long straight charged wire, we use **Gauss's Law**, which is one of Maxwell's fundamental equations in electrostatics.

Gauss's Law: The total electric flux through any closed surface is equal to $\frac{1}{\epsilon_0}$ times the total charge enclosed within that surface.

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

This law is especially useful when the charge distribution has high symmetry (spherical, cylindrical, or planar).

Step 1: Charge Distribution and Symmetry

Consider an infinitely long straight wire carrying a uniform linear charge density λ (charge per unit length).

Due to symmetry:

- The electric field is radial and perpendicular to the wire.
- The magnitude of the electric field depends only on the radial distance r from the wire.

Step 2: Choosing Gaussian Surface

Choose a cylindrical Gaussian surface:

- Radius = r
- Length = L
- Axis coincides with the charged wire

This surface is chosen because the electric field is constant over the curved surface and perpendicular to it.

Step 3: Electric Flux Through Gaussian Surface

The cylindrical surface has three parts:

- Curved surface
- Two flat circular ends

Flux through circular ends: The electric field is parallel to these surfaces, so

$$\vec{E} \cdot d\vec{A} = 0$$

Flux through curved surface: Here, the electric field is perpendicular and uniform.

$$\Phi = E \times \text{Curved surface area} = E(2\pi rL)$$

Step 4: Charge Enclosed

If the linear charge density is λ , then charge enclosed by the Gaussian surface:

$$Q_{\text{enc}} = \lambda L$$

Step 5: Applying Gauss's Law

$$E(2\pi rL) = \frac{\lambda L}{\epsilon_0}$$

Cancel L from both sides:

$$E(2\pi r) = \frac{\lambda}{\epsilon_0}$$

$$\boxed{E = \frac{\lambda}{2\pi\epsilon_0 r}}$$

Final Result:

The magnitude of electric field at a distance r from an infinitely long straight charged wire is:

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

Direction: Radially outward if the wire is positively charged and radially inward if negatively charged.

Quick Tip

For infinite line charges, always use Gauss's Law with a cylindrical Gaussian surface.

Remember: Field varies as $\frac{1}{r}$, unlike point charges where it varies as $\frac{1}{r^2}$.

12. Derive the electric field at axial and equatorial points of an electric dipole.

Solution: Concept: An electric dipole consists of two equal and opposite charges $+q$ and $-q$ separated by a small distance $2a$. The dipole moment is defined as:

$$\vec{p} = q(2a) \hat{p}$$

where \hat{p} is directed from negative to positive charge.

We derive the electric field at:

- Axial point (along dipole axis)
- Equatorial point (perpendicular bisector of dipole)

Part 1: Electric Field at Axial Point

Step 1: Geometry

Consider a point P on the axis at a distance r from the center of the dipole.

Distances from charges:

$$r_+ = r - a, \quad r_- = r + a$$

Step 2: Fields due to individual charges

Electric field due to $+q$:

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

Electric field due to $-q$:

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

Both fields are along the same line, so net field:

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

Step 3: Simplification

$$E_{\text{axial}} = \frac{q}{4\pi\epsilon_0} \frac{(r+a)^2 - (r-a)^2}{(r^2 - a^2)^2}$$

$$(r+a)^2 - (r-a)^2 = 4ar$$

$$E_{\text{axial}} = \frac{1}{4\pi\epsilon_0} \frac{4qar}{(r^2 - a^2)^2}$$

Since $p = 2aq$:

$$E_{\text{axial}} = \frac{1}{4\pi\epsilon_0} \frac{2pr}{(r^2 - a^2)^2}$$

For large distance ($r \gg a$):

$$E_{\text{axial}} = \frac{1}{4\pi\epsilon_0} \frac{2p}{r^3}$$

Direction: Along dipole moment.

Part 2: Electric Field at Equatorial Point

Step 1: Geometry

Consider point P at distance r from center on perpendicular bisector.

Distance from each charge:

$$d = \sqrt{r^2 + a^2}$$

Step 2: Fields due to charges

Magnitude of each field:

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2 + a^2}$$

Resolve components:

- Perpendicular components cancel
- Axial components add

Component along axis:

$$E_{\text{component}} = E \cos \theta = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2 + a^2} \cdot \frac{a}{\sqrt{r^2 + a^2}}$$

Total field (two charges):

$$E_{\text{equatorial}} = 2 \times \frac{1}{4\pi\epsilon_0} \frac{qa}{(r^2 + a^2)^{3/2}}$$

Using $p = 2aq$:

$$E_{\text{equatorial}} = \frac{1}{4\pi\epsilon_0} \frac{p}{(r^2 + a^2)^{3/2}}$$

For large distance ($r \gg a$):

$$E_{\text{equatorial}} = \frac{1}{4\pi\epsilon_0} \frac{p}{r^3}$$

Direction: Opposite to dipole moment.

Final Results:

- Axial field: $E = \frac{1}{4\pi\epsilon_0} \frac{2p}{r^3}$
- Equatorial field: $E = \frac{1}{4\pi\epsilon_0} \frac{p}{r^3}$

Quick Tip

For dipoles at large distances:

- Axial field is twice the equatorial field.
- Both vary as $\frac{1}{r^3}$, unlike point charges which vary as $\frac{1}{r^2}$.

13. Derive the relation between current and drift velocity ($I = nAev_d$).

Solution: Concept: Electric current in a conductor is the rate of flow of charge. When an electric field is applied across a conductor, free electrons acquire a small average velocity called **drift velocity** v_d . The macroscopic current can be expressed in terms of microscopic charge motion.

Key quantities:

- n = number of charge carriers per unit volume

- e = charge of each carrier
- A = cross-sectional area of conductor
- v_d = drift velocity

Step 1: Definition of Current

Electric current is defined as the rate of flow of charge:

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

So we need to find the charge crossing a cross-section in time t .

Step 2: Volume of Charge Flowing

In time t , charge carriers move a distance:

$$\text{distance} = v_d t$$

The volume of conductor from which charges cross the cross-section:

$$\text{Volume} = A \cdot v_d t$$

Step 3: Total Number of Charge Carriers

If n is number of carriers per unit volume, then total carriers in this volume:

$$\text{Number of carriers} = n A v_d t$$

Step 4: Total Charge Passing

Each carrier has charge e , so total charge:

$$Q = n A v_d t \cdot e$$

Step 5: Substitute in Current Formula

$$I = \frac{Q}{t} = \frac{n A v_d t \cdot e}{t}$$

Cancel t :

$$\boxed{I = n A e v_d}$$

Final Result:

$$I = nAev_d$$

This equation relates macroscopic current with microscopic motion of charge carriers.

Physical Meaning:

- Current increases with more charge carriers.
- Larger area allows more charge flow.
- Higher drift velocity produces more current.

Quick Tip

Remember the microscopic form of current:

$$I = nAev_d$$

This is useful in problems involving mobility, relaxation time, and Ohm's law derivations.

14. State the principle of Wheatstone bridge and derive the balancing condition.

Solution: Concept: A Wheatstone bridge is an electrical circuit used to measure an unknown resistance accurately by balancing two arms of a bridge circuit.

It consists of four resistances arranged in a diamond shape with a galvanometer connected between two junctions.

Principle: When no current flows through the galvanometer, the bridge is said to be balanced. At this condition, the ratio of resistances in one pair of opposite arms equals the ratio in the other pair.

Step 1: Arrangement of Wheatstone Bridge

Let the four resistances be:

- P and Q in one branch
- R and S in the other branch

A battery is connected across points A and C , and a galvanometer between B and D .

Step 2: Balanced Condition

When the bridge is balanced:

- No current flows through the galvanometer
- Potential at points B and D becomes equal

So,

$$V_B = V_D$$

Step 3: Current Distribution

Let current I_1 flow through branch P and Q , and current I_2 through branch R and S .

Since no current flows through the galvanometer, currents in each branch remain separate.

Step 4: Applying Ohm's Law

Potential drop from A to B :

$$V_{AB} = I_1 P$$

Potential drop from A to D :

$$V_{AD} = I_2 R$$

Since $V_B = V_D$,

$$I_1 P = I_2 R \quad \dots (1)$$

Similarly, from B to C and D to C :

$$I_1 Q = I_2 S \quad \dots (2)$$

Step 5: Balancing Condition

Dividing equation (1) by (2):

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

Cancel currents:

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

Final Result:

The Wheatstone bridge is balanced when:

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

If three resistances are known, the fourth can be determined using this relation.

Applications:

- Measuring unknown resistance
- Meter bridge (practical form)
- Strain gauges and sensors

Quick Tip

In Wheatstone bridge problems, remember:

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

At balance point, galvanometer current is zero and potentials of junctions are equal.

15. Derive the expression for the force per unit length between two parallel current-carrying wires.

Solution: Concept: When two parallel conductors carry electric currents, they exert magnetic forces on each other due to the magnetic fields produced by the currents.

This phenomenon is based on:

- Magnetic field due to a straight current-carrying conductor
- Lorentz force on a current-carrying conductor

Step 1: Magnetic Field due to First Wire

Consider two long parallel wires separated by distance d . Let currents be:

- I_1 in wire 1

- I_2 in wire 2

Magnetic field at distance d from wire 1:

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

This field acts at the location of the second wire.

Step 2: Force on Second Wire

A current-carrying conductor in a magnetic field experiences a force:

$$F = ILB \sin \theta$$

Here:

- $\theta = 90^\circ$ (field is perpendicular to current)
- $\sin \theta = 1$

So force on length L of wire 2:

$$F = I_2 L B_1$$

Substitute B_1 :

$$F = I_2 L \cdot \frac{\mu_0 I_1}{2\pi d}$$

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

Step 3: Force per Unit Length

Divide both sides by L :

$$\boxed{\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}}$$

Final Result:

Force per unit length between two long parallel current-carrying wires separated by distance d :

$$\boxed{\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}}$$

Nature of Force:

- Same direction currents → Attractive force
- Opposite direction currents → Repulsive force

Special Note: This formula is used to define the SI unit of current (Ampere).

Quick Tip

Remember:

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

Parallel currents attract, antiparallel currents repel — a common conceptual question.

16. State the laws of electromagnetic induction.

Solution: Concept: Electromagnetic induction is the phenomenon in which an emf is induced in a conductor when the magnetic flux linked with it changes. This fundamental concept was discovered by Michael Faraday.

There are two main laws of electromagnetic induction known as **Faraday's Laws**.

First Law of Electromagnetic Induction:

Whenever the magnetic flux linked with a conductor or circuit changes, an emf is induced in the circuit.

The change in magnetic flux can occur due to:

- Relative motion between magnet and conductor
- Change in magnetic field strength
- Change in area of the loop
- Change in orientation of the loop

If the circuit is closed, an induced current also flows.

Second Law of Electromagnetic Induction:

The magnitude of the induced emf is directly proportional to the rate of change of magnetic flux linked with the circuit.

Mathematically:

$$e \propto \frac{d\Phi}{dt}$$

Including proportionality constant:

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

For a coil of N turns:

$$e = -N\frac{d\Phi}{dt}$$

Negative Sign (Lenz's Law):

The negative sign indicates the direction of induced emf and is explained by **Lenz's Law**:

The induced emf always opposes the change in magnetic flux that produces it.

This ensures conservation of energy.

Magnetic Flux:

$$\Phi = BA \cos \theta$$

where:

- B = magnetic field
- A = area of loop
- θ = angle between field and normal to the surface

Summary:

- Changing magnetic flux induces emf.
- Induced emf is proportional to rate of change of flux.
- Direction is given by Lenz's Law.

Quick Tip

Remember Faraday's law in compact form:

$$e = -N\frac{d\Phi}{dt}$$

The negative sign represents Lenz's Law — a common theory question in exams.

17. Explain the working of a step-up/step-down transformer and causes of energy loss.

Solution: Concept: A transformer is an electrical device used to increase or decrease alternating voltage using the principle of electromagnetic induction. It works only with alternating current (AC) and transfers electrical energy from one circuit to another without direct electrical contact.

It consists of:

- Primary coil (input)
- Secondary coil (output)
- Soft iron core (to enhance magnetic flux linkage)

Principle: A transformer works on the principle of **mutual induction**. When alternating current flows through the primary coil, it produces a changing magnetic flux in the core, which induces an emf in the secondary coil.

Working of Transformer:

Let:

- N_p = number of turns in primary coil
- N_s = number of turns in secondary coil
- V_p = primary voltage
- V_s = secondary voltage

From Faraday's law:

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

Step-Up Transformer:

A transformer that increases voltage.

Condition:

$$N_s > N_p \quad \Rightarrow \quad V_s > V_p$$

Features:

- Secondary coil has more turns
- Voltage increases
- Current decreases (since power is nearly conserved)

Used in:

- Power transmission lines
- Power stations

Step-Down Transformer:

A transformer that decreases voltage.

Condition:

$$N_s < N_p \quad \Rightarrow \quad V_s < V_p$$

Features:

- Secondary coil has fewer turns
- Voltage decreases
- Current increases

Used in:

- Domestic appliances
- Chargers and adapters

Ideal Transformer:

$$V_p I_p = V_s I_s$$

Power input equals power output (no losses).

Causes of Energy Loss in Transformer:

In practical transformers, some energy is lost due to the following reasons:

1. Copper Loss (Joule Heating):

- Due to resistance of windings
- Energy lost as heat ($I^2 R$ loss)

2. Eddy Current Loss:

- Circulating currents induced in the iron core
- Produce heat and waste energy
- Reduced using laminated cores

3. Hysteresis Loss:

- Due to repeated magnetization of the core
- Energy lost in magnetizing and demagnetizing
- Reduced using soft iron or silicon steel cores

4. Flux Leakage:

- Not all magnetic flux links both coils
- Some flux escapes into air

Final Summary:

- Transformer works on mutual induction.
- Step-up transformer increases voltage.
- Step-down transformer decreases voltage.
- Energy losses occur due to copper loss, eddy currents, hysteresis, and flux leakage.

Quick Tip

Key transformer relations:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}, \quad V_p I_p \approx V_s I_s$$

Remember the four losses: copper, eddy current, hysteresis, and flux leakage.

18. State Einstein's photoelectric equation and its significance.

Solution: Concept: The photoelectric effect is the phenomenon in which electrons are emitted from a metal surface when light of suitable frequency falls on it. Einstein explained this effect using the quantum theory of light, proposing that light consists of discrete packets of energy called photons.

Einstein's Photoelectric Equation:

According to Einstein, when a photon of energy $h\nu$ strikes a metal surface, its energy is used in two ways:

- Part of the energy is used to overcome the work function ϕ of the metal.
- The remaining energy appears as the kinetic energy of the emitted electron.

Mathematically:

$$h\nu = \phi + K_{\max}$$

Where:

- h = Planck's constant
- ν = frequency of incident radiation
- ϕ = work function of the metal
- K_{\max} = maximum kinetic energy of emitted electrons

Since $\phi = h\nu_0$ (threshold frequency),

$$\boxed{h\nu = h\nu_0 + K_{\max}}$$

Also,

$$K_{\max} = \frac{1}{2}mv_{\max}^2 = eV_0$$

So another form:

$$\boxed{h\nu = \phi + eV_0}$$

Significance of Einstein's Photoelectric Equation:

1. Explains Threshold Frequency: No photoelectric emission occurs if $\nu < \nu_0$, regardless of intensity.

2. Particle Nature of Light: It proved that light behaves as particles (photons), supporting quantum theory.

3. Linear Relation Between Frequency and Kinetic Energy:

$$K_{\max} \propto \nu$$

This explains experimental observations of a straight-line graph.

4. Independence from Intensity: Kinetic energy depends only on frequency, not intensity of light.

5. Determination of Planck's Constant: The equation allows experimental determination of h .

6. Basis of Quantum Physics: Einstein's explanation marked the beginning of modern quantum mechanics and earned him the Nobel Prize (1921).

Final Summary:

- Photon energy is shared between work function and kinetic energy.
- Validates quantum nature of light.
- Explains key features of photoelectric effect.

Quick Tip

Remember the core equation:

$$h\nu = \phi + K_{\max}$$

Frequency controls energy of emitted electrons, while intensity controls their number.