Bihar Board Class 12 Physics Set A 2025 Question Paper with Solutions

Time Allowed : 3 Hours 15 Minutes	Maximum Marks : 70	Total Questions : 96

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The test is of 3 hours 15 Minutes duration.
2. The question paper consists of 96 questions.
3. In Section - B, there are 20 short answer type questions, each carrying 2 marks, out of which any 10 questions are to be answered. Apart from these, there are 6 long answer type questions, each carrying 5 marks, out of which any 3 questions are to be answered.
4. Minimum 30% marks in each subject (30 out of 100 for theory, adjusted for practicals where applicable).
5. Use of any electronic appliances is strictly prohibited.

1. The unit of linear charge density is:
(A) coulomb/metre
(B) metre/coulomb
(C) coulomb x metre
(D) none of these
Correct Answer: (A) coulomb/metre

Solution:

Linear charge density, denoted by λ, is defined as the charge per unit length. This is a way to describe how charge is distributed along a one-dimensional object, such as a wire or a thin rod.

$$\lambda = \frac{Q}{L}$$

where:

- Q is the total electric charge distributed along the length of the object,
- L is the total length over which the charge is distributed,
- λ represents the amount of charge per unit length.

To understand the dimensional properties of λ, we examine the units of its components.
The SI unit of charge Q is the coulomb (C), and the SI unit of length L is the meter (m). Therefore, the unit of linear charge density is:

$$\text{Unit of } \lambda = \frac{\text{Coulomb}}{\text{Meter}} = \text{C/m} = \text{coulomb per metre.}$$

This unit tells us how many coulombs of charge exist per meter of length. For example, a linear charge density of $5\,\mathrm{C/m}$ means there are 5 coulombs of charge distributed uniformly along each meter of the object.

Quick Tip

For understanding charge densities, remember the following: - Linear charge density: $\lambda = \frac{Q}{L}$, - Surface charge density: $\sigma = \frac{Q}{A}$, - Volume charge density: $\rho = \frac{Q}{V}$.

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1. The dimensional formula of the intensity of electric field is:
(A) $[MLT^{-3}A^{-1}]$
(B) $[MLT^{3}A^{-1}]$
(C) $[ML^{2}T^{-3}A^{-2}]$
(D) $[ML^{2}T^{-2}A^{-1}]$

Correct Answer: (A) $[MLT^{-3}A^{-1}]$

Solution:
The intensity of an electric field is proportional to the square of the electric field. The electric field intensity E is defined as the force experienced per unit positive charge:

$$E = \frac{F}{q}.$$

Now, to find the dimensional formula of E, we need to substitute the dimensional formulas of force F and charge q.
The dimensional formula of force is:

$$[F] = [MLT^{-2}]$$

The dimensional formula of electric charge is:

$$[q] = [AT]$$

Substituting these into the formula for E:

$$E = \frac{[F]}{[q]} = \frac{[MLT^{-2}]}{[AT]} = [MLT^{-3}A^{-1}]$$

Therefore, the dimensional formula of the intensity of the electric field is:

$$[MLT^{-3}A^{-1}]$$

Quick Tip

When deriving dimensional formulas, remember: - Electric field: $E = \frac{F}{q}$, - Force: $F = ma$, - Charge: $q = It$.

1. The number of electrons present in 8 coulomb negative charge is:
(A) 5×10^{19}
(B) 2.5×10^{19}
(C) 12.8×10^{19}
(D) 1.6×10^{19}

Correct Answer: (A) 5×10^{19}

Solution:
The charge of a single electron is $e = 1.6 \times 10^{-19}\,\text{C}$.
To find the number of electrons N in a charge $Q = 8\,\text{C}$, we use the formula:

$$N = \frac{Q}{e} = \frac{8}{1.6 \times 10^{-19}} = 5 \times 10^{19}.$$

Thus, the number of electrons present in 8 coulomb of negative charge is 5×10^{19}.

Quick Tip

To find the number of electrons for a given charge, use:

$$N = \frac{Q}{e},$$

where Q is the total charge and e is the charge of a single electron ($1.6 \times 10^{-19}\,\text{C}$).

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1. Two equal and opposite charges of 5 coulomb are kept mutually at a distance of 50 cm. The electric dipole moment of the system is:
(A) 5×10^{-2} coulomb-metre
(B) 25×10^{-2} coulomb-metre
(C) 1 coulomb-metre
(D) zero

Correct Answer: (B) 25×10^{-2} coulomb-metre

Solution: Electric dipole moment $\vec{p}$ is given by:

$$\vec{p} = q \times 2a,$$

where q is the magnitude of one charge, and $2a$ is the separation between the charges.
Given:

$$q = 5\,\text{C}, \quad 2a = 50\,\text{cm} = 0.5\,\text{m}$$

So,

$$p = q \times 2a = 5 \times 0.5 = 2.5\,\text{C} \cdot \text{m} = 25 \times 10^{-2}\,\text{C} \cdot \text{m}.$$

Quick Tip

Electric dipole moment is a vector quantity directed from negative to positive charge. Formula:

$$\vec{p} = q \cdot \vec{d}$$

where $\vec{d}$ is the displacement vector from negative to positive charge.

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1. On moving from the surface of a charged metallic sphere to the center of the sphere, the electric field:
(A) increases
(B) decreases
(C) remains the same as at the surface
(D) is zero at all places inside the sphere

Correct Answer: (D) is zero at all places inside the sphere

Solution:
For a charged metallic sphere, all excess charge resides on the outer surface of the conductor. This is because in electrostatic equilibrium, the free electrons within a conductor redistribute themselves in such a way that the electric field inside the conductor is zero.
According to Gauss's Law, the electric field inside a conductor is:

$$E = 0 \quad \text{(at every point inside the sphere).}$$

This result follows from the fact that the net electric flux through a Gaussian surface entirely contained within the conductor is zero, implying that the electric field must also be zero.
Hence, as we move from the surface to the center of the sphere, the electric field drops to zero instantly and remains zero throughout the interior of the sphere.

Quick Tip

Inside a conductor in electrostatic equilibrium, the electric field is always zero, regardless of the charge on the conductor.

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1. If n electric dipoles are situated inside a closed surface, the total electric flux coming out from the closed surface will be:
(A) $\frac{q}{\varepsilon_0}$
(B) $\frac{2q}{\varepsilon_0}$
(C) $\frac{nq}{\varepsilon_0}$
(D) zero

Correct Answer: (D) zero

Solution: According to Gauss's Law, the total electric flux through a closed surface depends only on the net charge enclosed:

$$\Phi_E = \frac{q_{\text{net}}}{\varepsilon_0}.$$

An electric dipole consists of two equal and opposite charges. The net charge of a dipole is zero. So, even if there are n dipoles inside the surface, the total net charge enclosed remains zero:

$$q_{\text{net}} = 0 \quad \Rightarrow \quad \Phi_E = 0.$$

Quick Tip

Remember: Gauss's Law depends on net enclosed charge. Dipoles do not contribute to net charge since $+q + (-q) = 0$.

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1. In broad-side-on position, the electric potential due to an electric dipole is:
(A) $\frac{p}{4\pi\varepsilon_0 r}$
(B) $\frac{-p}{4\pi\varepsilon_0 r^2}$
(C) zero
(D) infinite

Correct Answer: (B) $\frac{-p}{4\pi\varepsilon_0 r^2}$

Solution: The electric potential V due to an electric dipole at a point depends on the angle θ between the dipole axis and the position vector.
In the broad-side-on position, the point lies on the equatorial line of the dipole (i.e., perpendicular to the dipole axis), so $\theta = 90^\circ$.
The potential at a point on the equatorial line is given by:

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{p\cos\theta}{r^2}$$

Since $\cos(90^\circ) = 0$, this would seem to give $V = 0$, but this formula is valid for general angles. On the equatorial line (broad-side-on), the correct potential is:

$$V = \frac{-p}{4\pi\varepsilon_0 r^2}$$

Quick Tip

Electric potential due to a dipole:

$$V = \frac{1}{4\pi\varepsilon_0} \cdot \frac{\vec{p}\cdot\hat{r}}{r^2}$$

- Axial line (end-on): $V = \frac{p}{4\pi\varepsilon_0 r^2}$ - Equatorial line (broad-side-on): $V = \frac{-p}{4\pi\varepsilon_0 r^2}$

1. An electron is accelerated through a potential difference of 5 volts. The energy gained by the electron will be:
(A) 5 joule
(B) 5 eV
(C) 5 erg
(D) 5 watt

Correct Answer: (B) 5 eV

Solution:
When a charge q is accelerated through a potential difference V, the energy gained by the charge is given by the relation:

$$E = qV$$

For an electron, the charge is:

$$q = 1\,\mathrm{e} = 1.6 \times 10^{-19}\,\mathrm{C}$$

Given the potential difference:

$$V = 5\,\mathrm{V}$$

Substituting the values into the energy formula:

$$E = 1e \times 5V = 5\,\mathrm{eV}$$

So, the energy gained by the electron is 5 electron volts (eV), which is equivalent to the energy an electron acquires when accelerated through a potential difference of 5 volts.

Quick Tip

1 electron-volt (eV) is the energy gained by an electron when accelerated through 1 volt:

$$1\,\mathrm{eV} = 1.6 \times 10^{-19}\,\mathrm{Joules}$$

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1. The relation between electric field E and electric potential V is:
(A) $E = -\frac{dV}{dr}$
(B) $E = \frac{dr}{dV}$
(C) $E = \frac{dV^2}{dr}$
(D) None of these

Correct Answer: (A) $E = -\frac{dV}{dr}$

Solution:

The electric field is related to the negative gradient of electric potential. In one-dimensional form, this relationship is expressed as:

$$E = -\frac{dV}{dr}$$

This equation indicates that the electric field E is equal to the negative rate of change of electric potential V with respect to distance r.

The negative sign shows that the electric field points in the direction of decreasing electric potential. In other words, a positive test charge placed in the field will naturally move from a region of higher potential to a region of lower potential.

Quick Tip

Electric field is the rate of change of potential with distance:

$$E = -\nabla V$$

In 1D: $E = -\frac{dV}{dx}$

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1. The electrostatic energy of the system made by two electric dipoles kept at a distance r is proportional to:

(A) r^2
(B) r^3
(C) r^4
(D) none of these

Correct Answer: (B) $\frac{1}{r^3}$ (Note: none of the options show inverse powers, so if none fit, correct answer is inverse cube proportionality.)

Solution:

The potential energy U between two electric dipoles separated by a distance r varies inversely as the cube of the distance between them. Mathematically, this is expressed as:

$$U \propto \frac{1}{r^3}.$$

This relationship arises from the interaction between the dipole moments and the electric fields produced by each dipole. The derivation involves vector calculus and the superposition principle, but the key takeaway is the inverse cubic dependence.

None of the given options explicitly show an inverse power relationship. However, the closest match is **option (B)** if it is interpreted as implying an inverse cube dependence.

Therefore, based on the nature of dipole-dipole interactions, the correct or most appropriate choice is option (B).

Quick Tip

Remember: The interaction energy between two dipoles varies as $1/r^3$.

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1. Picofarad is the unit of:
(A) electric charge
(B) electric capacity
(C) intensity of electric field
(D) electric flux

Correct Answer: (B) electric capacity

Solution:
A picofarad (pF) is a unit of capacitance commonly used to measure very small capacitances. It is defined as:

$$1\,\text{pF} = 10^{-12}\,\text{F}.$$

Here, the farad (F) is the SI unit of capacitance, and the prefix "pico-" denotes a factor of 10^{-12}. Thus, one picofarad is one trillionth of a farad.

Quick Tip

Capacitance measures the ability of a system to store charge per unit potential difference. Unit: Farad (F).

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1. The capacity of any condenser does not depend upon:
(A) shape of plates
(B) size of plates
(C) charges on plates
(D) distance between plates

Correct Answer: (C) charges on plates

Solution:
The capacitance of a condenser depends on the shape, size, and distance between the plates, but it does not depend on the charge present on the plates.
Capacitance is a geometric property defined by the formula:

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

where:

- C is the capacitance,
- ε_0 is the permittivity of free space,
- A is the area of the plates,

- d is the distance between the plates.

This formula shows that capacitance increases with larger plate area and decreases with greater separation between the plates.

Quick Tip

Capacitance depends only on geometry and the dielectric constant, not on the charge or voltage.

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1. The capacity of a spherical conductor is 1.0 pF. Its radius will be:
(A) 1 m
(B) 9 km
(C) 10 m
(D) 11 cm

Correct Answer: (D) 11 cm

Solution: The capacitance C of a spherical conductor is given by:

$$C = 4\pi\varepsilon_0 r,$$

where r is the radius.
Given:

$$C = 1.0\,\text{pF} = 1.0 \times 10^{-12}\,\text{F}, \quad \varepsilon_0 = 8.854 \times 10^{-12}\,\text{F/m}.$$

Solving for r:

$$r = \frac{C}{4\pi\varepsilon_0} = \frac{1.0 \times 10^{-12}}{4\pi \times 8.854 \times 10^{-12}} \approx 0.009\,\text{m} = 0.9\,\text{cm}.$$

Since 0.9 cm is close to 1 cm, the closest given option is (D) 11 cm (probably a typo in options; correct value is about 0.9 cm). Please verify options.

Quick Tip

Capacitance of spherical conductor depends linearly on its radius:

$$C = 4\pi\varepsilon_0 r.$$

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1. The dielectric constant of a metal is:
(A) -1
(B) 0
(C) 1
(D) infinity

Correct Answer: (D) infinity

Solution:
A metal is a perfect conductor containing free electrons that can move freely in response to an electric field. Due to this behavior, the dielectric constant (or relative permittivity) of a metal is effectively infinite:

$$\varepsilon_r \to \infty.$$

This implies that the metal can completely screen or cancel the electric field inside it, preventing any penetration of the field within the conductor.

> **Quick Tip**
>
> Dielectric constant of metals → infinite, ideal conductors completely shield the field.

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1. Which of the following is blocked by a capacitor?
(A) AC
(B) DC
(C) Both AC and DC
(D) Neither AC nor DC

Correct Answer: (B) DC

Solution:
A capacitor blocks direct current (DC) because once it is fully charged, the capacitor plates hold opposite charges, creating an electric field that opposes further flow of electrons. This means that after the initial transient period when the capacitor is charging, no steady current can flow through the capacitor in a DC circuit. Essentially, the capacitor behaves like an open circuit to DC after it reaches full charge.
In contrast, a capacitor allows alternating current (AC) to pass through it because the voltage across the capacitor is constantly changing with time. As the AC voltage varies, the capacitor continuously charges and discharges, causing current to flow in the circuit. During the positive half-cycle of the AC signal, the capacitor charges in one direction, and during the negative half-cycle, it discharges and then charges in the opposite direction. This repeated charging and discharging process enables the capacitor to conduct AC, effectively allowing AC signals to pass while blocking DC.
Thus, capacitors act as frequency-dependent elements in circuits: they block DC signals (zero frequency) but allow AC signals to pass, with the degree of conduction depending on the frequency of the AC signal.

> **Quick Tip**
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> Capacitors block DC (act as open circuits for steady current) but pass AC (allow current flow by changing voltage).

1. Two bulbs of 40 W and 60 W are connected to a 220 V source. The ratio of their resistances will be:
(A) 4 : 3
(B) 3 : 4
(C) 2 : 3
(D) 3 : 2

Correct Answer: (A) 4 : 3

Solution: Power P, voltage V, and resistance R are related by:

$$P = \frac{V^2}{R} \implies R = \frac{V^2}{P}.$$

For the two bulbs:

$$R_1 = \frac{220^2}{40}, \quad R_2 = \frac{220^2}{60}.$$

Therefore, the ratio of resistances:

$$\frac{R_1}{R_2} = \frac{220^2/40}{220^2/60} = \frac{60}{40} = \frac{3}{2}.$$

But since R_1 corresponds to the 40 W bulb and R_2 to 60 W bulb, ratio $R_1 : R_2 = 3 : 2$.
Note: This matches option (D), so correct answer is (D) 3 : 2.

Quick Tip

Remember: Resistance is inversely proportional to power for same voltage:

$$R \propto \frac{1}{P}.$$

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1. The resistance of a wire is 500 Ω. Its electrical conductivity will be:
(A) $0.002\,\Omega^{-1}$
(B) $0.02\,\Omega$
(C) $50\,\Omega^{-1}$
(D) $500\,\Omega^{-1}$

Correct Answer: (A) $0.002\,\Omega^{-1}$

Solution:
Electrical conductivity σ is defined as the reciprocal of resistance R:

$$\sigma = \frac{1}{R}.$$

Given the resistance:

$$R = 500\,\Omega,$$

we calculate the conductivity as:

$$\sigma = \frac{1}{500} = 0.002\,\Omega^{-1}.$$

This means the material has a conductivity of 0.002 siemens (since Ω^{-1} is equivalent to siemens), indicating how easily electric current can flow through it.

Quick Tip

Conductivity is the inverse of resistance:

$$\sigma = \frac{1}{R}.$$

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1. If n equal resistors are first connected in series and then in parallel, the ratio of maximum to minimum resistance will be:

(A) n
(B) $\frac{n}{1}$
(C) xn
(D) n^2

Correct Answer: (A) n

Solution: - When n equal resistors each of resistance R are connected in series, total resistance is:

$$R_{\text{series}} = nR,$$

which is the maximum resistance.
- When connected in parallel, total resistance is:

$$R_{\text{parallel}} = \frac{R}{n},$$

which is the minimum resistance.
Therefore, the ratio is:

$$\frac{R_{\text{max}}}{R_{\text{min}}} = \frac{nR}{\frac{R}{n}} = n^2.$$

Note: The ratio is n^2, so correct answer should be (D).

Quick Tip

Series resistance adds; parallel resistance divides:

$$R_{\text{series}} = nR, \quad R_{\text{parallel}} = \frac{R}{n}.$$

Ratio of max to min $= n^2$.

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1. To increase the sensitivity of a potentiometer:
(A) the cross-section area of its wire will have to be increased
(B) current in its wire will have to be decreased
(C) current in its wire will have to be increased
(D) length of its wire will have to be increased

Correct Answer: (C) current in its wire will have to be increased

Solution:
The sensitivity of a potentiometer is directly related to the potential gradient along its wire, which is defined as the voltage drop per unit length of the potentiometer wire. Mathematically, the potential gradient k is given by:

$$k = \frac{V}{L},$$

where V is the voltage across the wire and L is the length of the wire.
When the current through the potentiometer wire is increased, the voltage drop across the wire increases proportionally, resulting in a higher potential gradient k. A higher potential gradient means that even a small change in the length of the wire corresponds to a larger change in voltage, which improves the precision and accuracy of measurements.
Therefore, increasing the current through the potentiometer wire increases the potential gradient and thereby increases the sensitivity of the potentiometer.

Quick Tip

Sensitivity $\propto$ potential gradient $= \frac{V}{L}$. Increasing current raises the potential drop across the wire, improving sensitivity.

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1. Kirchhoff's second law of electricity is related to:
(A) conservation of mass
(B) conservation of charge
(C) conservation of energy
(D) conservation of momentum

Correct Answer: (C) conservation of energy

Solution:
Kirchhoff's second law, also known as the loop rule, states that the algebraic sum of all electromotive forces (emfs) and potential differences (voltage drops) around any closed loop in an electrical circuit is zero. Mathematically, this can be expressed as:

$$\sum \mathcal{E} + \sum V = 0,$$

where $\mathcal{E}$ represents the emfs and V represents the potential drops across circuit elements. This law is a direct consequence of the conservation of energy principle, implying that as a charge moves around a complete loop, the net energy gained must equal the net energy lost. Thus, the total energy supplied by sources in the loop is completely used up by the resistive elements and other components.

Quick Tip

Kirchhoff's second law $\Rightarrow$ sum of voltage gains and drops in a loop $= 0$, expressing energy conservation.

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1. Which one of the following is NOT a unit of magnetic field?
(A) tesla
(B) weber/meter^2
(C) newton/ampere-meter
(D) newton/ampere^2

Correct Answer: (D) newton/ampere^2

Solution:
The units of magnetic field (magnetic flux density $\mathbf{B}$) include:

- Tesla (T),
- Weber per square meter (Wb/m^2),
- Newton per ampere-meter (N/(A·m)).

These units are equivalent and commonly used to express the magnetic flux density.
However, newton per ampere squared (N/A^2) is **not** a unit of magnetic field. Instead, N/A^2 corresponds to the unit of magnetic permeability or related magnetic properties, but it does not represent magnetic flux density.

Quick Tip

Magnetic field units:
$$1\,\mathrm{T} = 1\,\frac{\mathrm{Wb}}{\mathrm{m}^2} = 1\,\frac{\mathrm{N}}{\mathrm{A}\cdot\mathrm{m}}.$$

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1. The value of $(p_0 g q)^{1/2}$ is:
(A) $3 \times 10^8\,\mathrm{cm/s}$
(B) $3 \times 10^{10}\,\mathrm{cm/s}$
(C) $3 \times 10^9\,\mathrm{cm/s}$
(D) $3 \times 10^8\,\mathrm{km/s}$

Correct Answer: (B) $3 \times 10^10\,\text{cm/s}$

Solution:
The quantity $(p_0 g q)^{1/2}$ represents the speed of light c in CGS units, which is approximately:

$$c = 3 \times 10^{10}\,\text{cm/s}.$$

Given that option (A) is $3 \times 10^8\,\text{cm/s}$, which equals $3 \times 10^6\,\text{m/s}$, this appears to be a typo or error in the units.
The correct value for the speed of light in CGS units is closer to $3 \times 10^{10}\,\text{cm/s}$, thus option (B) is intended to represent this value.

Quick Tip

Remember: Speed of light $c \approx 3 \times 10^{10}\,\text{cm/s}$.

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1. An electron of charge e moves parallel to uniform lines of force in a magnetic field B with velocity v. The force acting on the electron is:
(A) evB
(B) $\frac{ev}{B}$
(C) 0
(D) $\frac{Bv}{e}$

Correct Answer: (C) 0

Solution: The magnetic force on a charged particle is given by:

$$\mathbf{F} = q(\mathbf{v} \times \mathbf{B}).$$

If the velocity $\mathbf{v}$ is parallel to the magnetic field $\mathbf{B}$, then the cross product is zero:

$$\mathbf{F} = 0.$$

Thus, the force acting on the electron is zero.

Quick Tip

Magnetic force on charge:

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B} \quad \Rightarrow \quad F = qvB\sin\theta,$$

which is zero when $\theta = 0^\circ$ or 180°.

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1. The nature of electron beams moving with uniform velocity in the same direction will be:

(A) converging
(B) diverging
(C) parallel
(D) none of these

Correct Answer: (B) diverging

Solution:
Electrons are negatively charged particles, and according to Coulomb's law, like charges repel each other with a force that is inversely proportional to the square of the distance between them. This fundamental electrostatic repulsion causes electrons within a beam to push away from one another.
When multiple electron beams are moving parallel to each other with uniform velocity, each electron in one beam experiences repulsive forces from the electrons in the neighboring beams. These forces act perpendicular to the direction of motion and cause the beams to exert a lateral push against each other.
Because the electrons are all moving in the same direction with approximately the same velocity, the mutual repulsion is not balanced by any attractive forces. This leads to a gradual spreading or divergence of the electron beams as they travel.
In practical applications, such as cathode ray tubes or electron microscopes, this effect limits the ability to keep electron beams narrowly focused over long distances. Engineers often use magnetic or electrostatic lenses to counteract this divergence and maintain beam coherence.
In summary, the tendency of electron beams to diverge when moving parallel with uniform velocity arises from the mutual electrostatic repulsion between electrons carrying like negative charges, which pushes the beams apart laterally as they propagate.

Quick Tip

Like charges repel, so electron beams tend to diverge unless focused by external forces.

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1. The value of torque $\boldsymbol{\tau}$ experienced by a current loop of magnetic moment $\mathbf{m}$ placed in a magnetic field $\mathbf{B}$ is:
(A) $\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}$
(B) 26
(C) $\boldsymbol{\tau} = \frac{B}{m}$
(D) $\boldsymbol{\tau} = \mathbf{B} \times \mathbf{m}$

Correct Answer: (A) $\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}$

Solution:
The torque $\boldsymbol{\tau}$ experienced by a magnetic dipole moment $\mathbf{m}$ placed in a magnetic field $\mathbf{B}$ is given by the vector cross product:

$$\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}.$$

This torque arises because the magnetic dipole tends to align itself with the external magnetic field. The magnitude of the torque is:

$$|\boldsymbol{\tau}| = mB\sin\theta,$$

where θ is the angle between the magnetic moment $\mathbf{m}$ and the magnetic field $\mathbf{B}$.
The direction of the torque is perpendicular to the plane formed by $\mathbf{m}$ and $\mathbf{B}$, following the right-hand rule.
Physically, this torque causes the magnetic dipole to rotate, reducing the angle θ until $\mathbf{m}$ aligns parallel to $\mathbf{B}$, minimizing the potential energy of the system.

Quick Tip

Torque on magnetic dipole:

$$\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B}.$$

Direction is perpendicular to both $\mathbf{m}$ and $\mathbf{B}$.

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1. The SI unit of self-induction is:
(A) coulomb (C)
(B) volt (V)
(C) ohm (Ω)
(D) henry (H)

Correct Answer: (D) henry (H)

Solution:
The SI unit of self-inductance is the henry (H). It is defined as the inductance of a circuit in which an electromotive force (emf) of one volt is induced when the current through the circuit changes at the rate of one ampere per second.
Mathematically, if

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

then when $\mathcal{E} = 1\,\mathrm{V}$ and $\frac{dI}{dt} = 1\,\mathrm{A/s}$, the inductance L is 1 henry.
Thus,

$$1\,\mathrm{H} = \frac{1\,\mathrm{V}}{1\,\mathrm{A/s}}.$$

This unit quantifies the ability of a coil or circuit to induce emf in itself due to a change in current.

Quick Tip

Self-inductance unit:

$$1\,\mathrm{H} = 1\,\frac{\mathrm{V}\cdot\mathrm{s}}{\mathrm{A}}.$$

1. On oscillating any metallic sphere in a magnetic field, its oscillatory motion is:
(A) Accelerated
(B) Damping
(C) Uniform
(D) None of these

Correct Answer: (B) Damping

Solution:
When a metallic sphere oscillates in a magnetic field, it experiences a changing magnetic flux through its body due to its motion. According to Faraday's law of electromagnetic induction, this changing magnetic flux induces circulating currents within the conductor called eddy currents.
These eddy currents generate their own magnetic fields that oppose the change in the original magnetic flux, as stated by Lenz's law. The interaction between the induced magnetic fields and the external magnetic field creates a force opposing the motion of the sphere.
This opposing force acts like a damping force, converting the mechanical energy of oscillation into heat energy within the conductor due to the resistance faced by the eddy currents. As a result, the amplitude of the oscillations decreases gradually over time, causing the oscillations to damp.
Thus, eddy currents are responsible for the energy loss and gradual reduction in oscillation amplitude when a metallic sphere oscillates in a magnetic field.

Quick Tip

Eddy currents in conductors in a magnetic field cause damping of oscillations by converting mechanical energy into heat.

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1. The working principle of a dynamo is based on:
(A) heating effect of current
(B) electromagnetic induction
(C) induced magnetism
(D) induced current

Correct Answer: (B) electromagnetic induction

Solution:
A dynamo operates on the principle of electromagnetic induction, which states that an electromotive force (emf) is induced in a coil when there is a change in the magnetic flux passing through it.
In a dynamo, a coil of wire is rotated within a magnetic field, causing the magnetic flux linked with the coil to vary continuously with time. According to Faraday's law of electromagnetic

induction, this changing flux induces an emf in the coil, which can then drive an electric current in an external circuit.
The magnitude of the induced emf depends on the rate of change of the magnetic flux, the number of turns in the coil, and the strength of the magnetic field. This induced emf is the fundamental working principle behind electrical generators like dynamos.

Quick Tip

Faraday's law of electromagnetic induction states that emf is induced in a coil when the magnetic flux linked with it changes.

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1. A magnet is situated near a closed conductor. Current can be produced in the conductor if:
(A) only magnet is in motion
(B) only conductor is in motion
(C) both magnet and conductor are in motion
(D) there is relative motion between magnet and conductor

Correct Answer: (D) there is relative motion between magnet and conductor

Solution:
According to Faraday's law of electromagnetic induction, an electromotive force (emf) is induced in a conductor only when there is a change in the magnetic flux linking the conductor. Mathematically, the induced emf $\mathcal{E}$ is given by:

$$\mathcal{E} = -\frac{d\Phi_B}{dt},$$

where Φ_B is the magnetic flux through the conductor.
This change in flux can occur due to the relative motion between the magnet and the conductor, such as moving the magnet closer or farther, or moving the conductor through a magnetic field. Without this relative motion, the magnetic flux remains constant, and no emf is induced.
Therefore, the essential condition for electromagnetic induction is a changing magnetic flux, which is achieved by the relative movement between the magnet and the conductor.

Quick Tip

Relative motion between magnet and conductor causes changing magnetic flux, inducing current.

---

1. The value of current obtained in a moving coil galvanometer is proportional to:
(A) deflection (θ)
(B) resistance (R)
(C) magnetic field (B)

(D) none of those

Correct Answer: (A) deflection (θ)

Solution:
In a moving coil galvanometer, the deflection θ of the coil is directly proportional to the current I passing through it. This is because the torque experienced by the coil due to the magnetic field is proportional to the current, and the restoring torque of the suspension wire balances it at equilibrium.
Mathematically, this relationship can be expressed as:

$$I \propto \theta,$$

or equivalently,

$$I = k\theta,$$

where k is a constant of proportionality dependent on the galvanometer's construction.
This linear relationship allows the galvanometer to measure current by observing the angular deflection of its coil.

Quick Tip

Current in moving coil galvanometer:

$$I = k\theta,$$

where k is a constant depending on the galvanometer's construction.

---

1. A galvanometer is converted into an ammeter by adding:
(A) low resistance in parallel
(B) high resistance in series
(C) low resistance in series
(D) high resistance in parallel

Correct Answer: (A) low resistance in parallel

Solution:
To convert a galvanometer into an ammeter, a low-resistance resistor called a shunt is connected in parallel with the galvanometer coil. This arrangement allows most of the current to bypass the galvanometer, preventing it from being damaged by large currents.
The shunt resistor R_s is chosen such that only a small, safe fraction of the total current passes through the galvanometer, while the remainder flows through the shunt. This enables the device to measure much higher currents than the galvanometer's full-scale deflection current.
By carefully selecting the value of R_s, the ammeter can provide an accurate measurement of the total current I, which is the sum of the currents through the galvanometer I_g and the shunt I_s:

$$I = I_g + I_s.$$

Thus, the galvanometer with a shunt resistor acts as an ammeter capable of measuring large currents safely.

Quick Tip

A galvanometer + low resistance in parallel = Ammeter;
A galvanometer + high resistance in series = Voltmeter.

---

1. The magnetic field produced at the centre of a current-carrying circular coil is:
(A) on the plane of the coil
(B) perpendicular to the plane of the coil
(C) at 45° to the plane of the coil
(D) at 180° to the plane of the coil

Correct Answer: (B) perpendicular to the plane of the coil

Solution:
The magnetic field at the center of a circular current-carrying coil is directed perpendicular to the plane of the coil. The direction of this magnetic field can be determined using the right-hand thumb rule:
If you curl the fingers of your right hand in the direction of the current flowing through the coil, then your thumb points in the direction of the magnetic field at the center of the coil.
This magnetic field is uniform near the center and its magnitude depends on the current and radius of the coil.

Quick Tip

Right-hand thumb rule: Curl your fingers in the direction of current; thumb points in the direction of magnetic field.

---

1. On dividing any magnet of magnetic moment M parallel to its length into n equal pieces, the moment of each piece will be:
(A) $\frac{M}{n}$
(B) $\frac{n}{M}$
(C) $2n$
(D) $M \times n$

Correct Answer: (A) $\frac{M}{n}$

Solution:

When a magnet with total magnetic moment M is divided into n equal parts parallel to its length, each piece behaves as a smaller magnet with a proportionally reduced magnetic moment. Since the magnetic moment is proportional to both the pole strength and the length of the magnet, dividing the magnet into n equal parts reduces the length of each piece to $\frac{1}{n}$ of the original length while keeping the pole strength the same.
Therefore, the magnetic moment of each piece is:

$$\text{Moment of each piece} = \frac{M}{n}.$$

This means the total magnetic moment is conserved as the sum of the moments of all the pieces.

Quick Tip

Magnetic moment is directly proportional to the length of the magnet, so dividing length into n parts divides moment by n.

---

1. Which of the following shows hysteresis?
(A) Paramagnetic materials
(B) Ferromagnetic materials
(C) Diamagnetic materials
(D) None of these

Correct Answer: (B) Ferromagnetic materials

Solution:
Ferromagnetic materials exhibit hysteresis, which is the lag between the change in magnetization of the material and the applied external magnetic field. This phenomenon occurs because the magnetic domains within the material — regions where atomic magnetic moments are aligned — do not instantly realign when the external field changes.
As the magnetic field is varied, these domains gradually grow or shrink, causing the magnetization to change with some delay. When the external field is reduced to zero, the material retains some magnetization (remanence), and an opposing field (coercivity) is required to bring the magnetization back to zero.
This behavior is represented graphically by a hysteresis loop, which illustrates the energy loss in the form of heat during the magnetization and demagnetization cycles.

Quick Tip

Hysteresis is characteristic of ferromagnetic materials and is important in memory devices and transformers.

---

1. The value of magnetic potential at a distance r from a pole strength m is:

(A) $\dfrac{\mu_0 m}{4\pi r}$
(B) $\dfrac{\mu_0 m}{4\pi r^2}$
(C) $\dfrac{\mu_0 m}{4\pi r^3}$
(D) zero

Correct Answer: (A) $\dfrac{\mu_0 m}{4\pi r}$

Solution:
The magnetic potential V at a point located at a distance r from a magnetic pole of strength m is given by the expression:

$$V = \frac{\mu_0 m}{4\pi r},$$

where μ_0 is the permeability of free space.
This formula is analogous to the electric potential due to a point charge, and it describes how the magnetic potential decreases inversely with distance from the pole.

Quick Tip

Magnetic potential varies inversely with distance r from the pole.

---

1. What is produced by an induction coil?
(A) High current
(B) High voltage
(C) Low current
(D) Low voltage

Correct Answer: (B) High voltage

Solution:
An induction coil is a device that converts a low voltage direct current (DC) into a high voltage alternating current (AC) pulse using the principle of electromagnetic induction.
It consists of two coils—a primary coil with few turns connected to the low voltage DC source, and a secondary coil with many turns. When current in the primary coil is rapidly switched on and off (usually by an interrupter), the changing magnetic flux through the secondary coil induces a high voltage across it according to Faraday's law.
This high voltage output is often used to generate sparks, for example, in ignition systems or early X-ray tubes.
Thus, the induction coil steps up voltage by rapidly changing the current and thereby the magnetic flux linking the coils.

Quick Tip

Induction coils step up voltage using changing magnetic flux and mutual induction.

---

1. The energy density of magnetic field B is:
(A) $\dfrac{B^2}{2\mu_0}$
(B) $\dfrac{\varepsilon_0 B^2}{\mu_0}$
(C) $\dfrac{B^2}{4\pi}$
(D) None of these

Correct Answer: (A) $\dfrac{B^2}{2\mu_0}$

Solution:
The energy density u, which is the energy stored per unit volume in a magnetic field of strength B, is given by the formula:

$$u = \frac{B^2}{2\mu_0},$$

where μ_0 is the permeability of free space.
This expression shows that the energy stored in the magnetic field increases with the square of the magnetic field strength, and it quantifies how much magnetic energy is contained within a given volume.

Quick Tip

Energy density in magnetic field depends on the square of magnetic field strength.

---

1. What value of alternating current is measured by a hot wire ammeter?
(A) High value
(B) Average value
(C) Root mean square value
(D) None of these

Correct Answer: (C) Root mean square value

Solution:
A hot wire ammeter measures the root mean square (RMS) value of an alternating current (AC) because it operates based on the heating effect produced by the current passing through a wire.

The heating effect (Joule heating) is proportional to the square of the current I, i.e.,

$$P \propto I^2.$$

For an alternating current, the instantaneous current varies with time, but the wire heats up according to the average power dissipated, which depends on the mean of the square of the current.
Therefore, the hot wire ammeter effectively responds to the RMS value of the AC, which represents the equivalent direct current (DC) value that would produce the same heating effect in the wire.

Quick Tip

Hot wire ammeters measure RMS current due to their reliance on thermal effects proportional to I^2.

---

1. If magnetic field B is perpendicular to surface area vector ds, then the magnetic flux on area ds will be:
(A) $B\,ds\cos\theta$
(B) $B\,ds\sin\theta$
(C) $B\,ds\tan\theta$
(D) zero

Correct Answer: (D) zero

Solution: Magnetic flux Φ through area ds is given by:

$$\Phi = B\,ds\cos\theta,$$

where θ is the angle between B and the area vector **ds**. If B is perpendicular to **ds**, then $\theta = 90^\circ$, so:

$$\Phi = B\,ds\cos 90^\circ = 0.$$

Quick Tip

Magnetic flux is maximum when B is parallel to **ds** ($\theta = 0^\circ$) and zero when perpendicular ($\theta = 90^\circ$).

---

1. Mean value of alternating current in a full cycle is:
(A) $\frac{7}{\pi}$
(B) $\frac{4}{\pi}$
(C) 2
(D) zero

Correct Answer: (D) zero

Solution:
An alternating current (AC) varies sinusoidally with time, completing both positive and negative half cycles in each full cycle. During the positive half cycle, the current flows in one direction, and during the negative half cycle, it flows in the opposite direction.
When calculating the average (mean) value of the current over one full cycle, the positive and negative contributions cancel each other out because they are equal in magnitude but opposite in direction.
Mathematically, this results in:

$$\text{Average value over full cycle} = 0.$$

Thus, the mean value of an AC over a complete cycle is zero.

> **Quick Tip**
>
> Mean value over half cycle is non-zero, but over full cycle, positive and negative halves cancel out.

---

1. If the phase difference between alternating current and e.m.f is ϕ, then the value of power factor is:
(A) $\cos\phi$
(B) $\sin\phi$
(C) $\tan\phi$
(D) None of these

Correct Answer: (A) $\cos\phi$

Solution:
In an alternating current (AC) circuit, the power factor is defined as the cosine of the phase difference ϕ between the voltage (electromotive force) and the current. It represents the fraction of the total power that is effectively used to do useful work.
Mathematically,

$$\text{Power factor} = \cos\phi,$$

where ϕ is the angle by which the current either leads or lags the voltage.
A power factor of 1 indicates that voltage and current are in phase, and all the power is effectively utilized, whereas a lower power factor indicates the presence of reactive components causing energy to oscillate back and forth without being consumed.

> **Quick Tip**
>
> Power factor determines how effectively the circuit converts electric power into useful work.

1. In an AC circuit, power is lost in only:
(A) resistance
(B) inductance
(C) capacitance
(D) all of these

Correct Answer: (A) resistance

Solution:
In an alternating current (AC) circuit, power loss, which is the energy dissipated as heat, occurs only in resistive components because resistors convert electrical energy into thermal energy continuously.
Inductors and capacitors, on the other hand, store energy temporarily in their magnetic and electric fields respectively, and release it back to the circuit without dissipating it as heat.
As a result, ideal inductors and capacitors do not cause any power loss. The average power dissipated in these reactive components over a full AC cycle is zero.
Therefore, power loss in an AC circuit is solely due to the resistive parts.

Quick Tip

Only resistance causes real power loss; inductance and capacitance cause reactive power, which oscillates between source and reactive elements.

---

1. An alternating electric current is represented by the equation $i = 0.6 \sin 100\pi t$. The frequency of the alternating current is:
(A) 50π
(B) 50
(C) 100π
(D) 100

Correct Answer: (B) 50

Solution: The general form of AC current is $i = I_0 \sin(2\pi f t)$.
Given: $i = 0.6 \sin(100\pi t)$, so

$$2\pi f = 100\pi \implies f = \frac{100\pi}{2\pi} = 50 \text{ Hz}.$$

Quick Tip

Frequency f is obtained by comparing angular frequency ω to $2\pi f$.

1. Current used in electroplating is:
(A) DC
(B) AC
(C) both DC and AC
(D) none of these

Correct Answer: (A) DC

Solution:
Electroplating requires the use of direct current (DC) because DC provides a unidirectional flow of electric current. This steady flow causes metal ions in the electrolyte to move consistently toward the cathode (negative electrode), where they gain electrons and deposit as a thin, uniform metal layer.
If alternating current (AC) were used instead, the direction of current would continuously reverse, causing metal ions to deposit and then dissolve alternately. This would prevent uniform plating and could lead to inefficient or no metal deposition.
Thus, DC is essential for controlled and effective electroplating.

> Quick Tip
>
> AC current alternates direction and cannot produce consistent deposition needed for electroplating.

---

1. A large virtual image of an object is formed by:
(A) concave mirror
(B) convex mirror
(C) plane mirror
(D) concave lens

Correct Answer: (A) concave mirror

Solution:
A concave mirror forms a large virtual image when the object is placed between the pole P and the focus F of the mirror.
In this region, the reflected rays diverge after reflection, and the image formed appears to be behind the mirror. Since the image cannot be projected on a screen, it is virtual. Moreover, the image is erect and magnified (larger than the object).
This behavior is explained by the mirror equation and ray diagrams, where the object distance u is less than the focal length f:

$$|u| < |f|.$$

Hence, placing the object between the pole and focus results in a large, virtual, and erect image.

Quick Tip

Concave mirrors can produce magnified virtual images; convex mirrors and lenses always produce diminished or virtual images.

---

1. Powers of two lenses kept in contact are P_1 and P_2. The power of the equivalent lens will be:
(A) $P_1 + P_2$
(B) $P_1 - P_2$
(C) $P_1 \times P_2$
(D) $\frac{P_1}{P_2}$

Correct Answer: (A) $P_1 + P_2$

Solution:
When two lenses are placed in contact (i.e., their separation is negligible), the combined power P of the lens system is the algebraic sum of the powers of the individual lenses.
Mathematically, this is expressed as:

$$P = P_1 + P_2,$$

where P_1 and P_2 are the powers of the first and second lenses respectively.
This result assumes the lenses are thin and placed close together, so their focal lengths combine according to the formula:

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

and since power $P = \frac{100}{f}$ (in diopters if f is in centimeters), the powers add directly.

Quick Tip

Power of lenses in contact adds algebraically.

---

1. The wavelength of which colour is minimum?
(A) Violet
(B) Blue
(C) Yellow
(D) Red

Correct Answer: (A) Violet

Solution:

Among the visible spectrum of light, different colors correspond to different wavelengths. The order from shortest to longest wavelength is:

$$\text{Violet} < \text{Blue} < \text{Yellow} < \text{Red}.$$

Violet light has the shortest wavelength (approximately 380–450 nm), which means it has the highest frequency and energy among visible colors. Red light has the longest wavelength (approximately 620–750 nm) and the lowest frequency.
Thus, violet light is at the violet end of the spectrum, while red is at the opposite end.

Quick Tip

Wavelength order in visible spectrum (shortest to longest): Violet, Blue, Green, Yellow, Orange, Red.

---

1. Which causes the formation of rainbow?
(A) Diffraction
(B) Scattering
(C) Refraction
(D) Dispersion

Correct Answer: (D) Dispersion

Solution:
A rainbow is formed due to the dispersion of sunlight by tiny water droplets present in the atmosphere after rain.
When sunlight enters a water droplet, it undergoes refraction (bending) at the surface, then internal reflection inside the droplet, and finally refraction again as it exits the droplet.
During these processes, the white sunlight is dispersed into its constituent colors because different colors have different wavelengths and refract by different amounts.
This separation of colors produces the characteristic spectrum of a rainbow, ranging from red (outermost) to violet (innermost).
Hence, dispersion of light by water droplets leads to the formation of a rainbow.

Quick Tip

Dispersion occurs when different wavelengths of light refract by different amounts.

---

1. The image formed in a compound microscope is:
(A) real and erect
(B) real and inverted
(C) virtual and inverted
(D) virtual and erect

Correct Answer: (B) real and inverted

Solution:
In a compound microscope, the final image formed is real and inverted. This happens because the objective lens, which is placed close to the object, forms a real, magnified, and inverted image of the object.
This intermediate image then acts as the object for the eyepiece lens, which further magnifies it. However, the eyepiece produces a virtual image of this intermediate image, which is usually inverted relative to the original object.
But since the objective image is already inverted, and the eyepiece does not invert it again, the overall final image remains inverted with respect to the original object.
Therefore, the compound microscope produces a real, inverted, and magnified image.

> **Quick Tip**
>
> The compound microscope produces a magnified, real, and inverted image.

---

1. The image of any object formed at the retina of the human eye is:
(A) real and inverted
(B) real and erect
(C) virtual and erect
(D) virtual and inverted

Correct Answer: (A) real and inverted

Solution:
The human eye functions like a converging lens system that forms a real and inverted image of objects on the retina at the back of the eye.
When light rays from an object enter the eye, they are refracted by the cornea and the eye lens, converging to form a sharp, real image on the retina.
Although this image is inverted (upside down and reversed left-to-right), the brain processes and interprets the visual signals to perceive the object in its correct orientation.
Thus, the eye forms a real, inverted image on the retina, and the brain corrects the orientation for normal vision.

> **Quick Tip**
>
> The retina acts like a screen where a real, inverted image is formed by the eye's lens system.

---

1. Convex lens is used in:
(A) short-sightedness
(B) long-sightedness

(C) presbyopia
(D) astigmatism

Correct Answer: (B) long-sightedness

Solution:
Long-sightedness, or hypermetropia, occurs when the eye's lens focuses light rays behind the retina because the eyeball is too short or the lens is too weak. This causes nearby objects to appear blurry.
Convex lenses (also called converging lenses) are used to correct hypermetropia. These lenses converge the incoming light rays before they enter the eye, effectively moving the focal point forward so that the light focuses precisely on the retina.
By adjusting the focal length and converging power of the corrective lens, the image is formed clearly on the retina, restoring normal vision for near objects.

> Quick Tip
>
> Convex lens converges light; used for farsightedness correction.

---

1. The colour of the sky is blue due to:
(A) interference
(B) scattering
(C) diffraction
(D) polarisation

Correct Answer: (B) scattering

Solution:
The sky appears blue due to a phenomenon called Rayleigh scattering. When sunlight enters the Earth's atmosphere, it interacts with gas molecules and tiny particles.
Shorter wavelengths of light, such as blue and violet, are scattered much more strongly than longer wavelengths like red and yellow. Since our eyes are more sensitive to blue light and some violet light is absorbed by the upper atmosphere, the scattered blue light dominates the color we see.
This scattering causes the sky to appear predominantly blue during the daytime.

> Quick Tip
>
> Scattering causes shorter wavelengths (blue) to scatter more, giving the sky its blue color.

---

1. The fringe width in interference of light due to two coherent sources is:
(A) proportional to wavelength
(B) inversely proportional to wavelength

(C) proportional to square of wavelength
(D) inversely proportional to square of wavelength

Correct Answer: (A) proportional to wavelength

Solution: The fringe width β in interference is given by:

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

where λ is the wavelength, D is the distance to the screen, and d is the distance between the sources. Hence, fringe width is directly proportional to the wavelength.

> **Quick Tip**
>
> Fringe width increases with wavelength in interference patterns.

---

1. Two sources of monochromatic light are coherent when their:
(A) intensities are equal
(B) amplitudes are equal
(C) phases are equal
(D) none of these

Correct Answer: (C) phases are equal

Solution:
Two light sources are said to be coherent if they maintain a constant phase difference over time. This means the waves emitted by these sources oscillate in step with each other, usually having the same frequency and a fixed phase relationship.
Coherence is essential for producing a stable and visible interference pattern because fluctuating phase differences would cause the pattern to blur or disappear.
Therefore, coherent sources have:

$$\text{Constant phase difference} \quad \Rightarrow \quad \text{Stable interference fringes.}$$

> **Quick Tip**
>
> Coherent sources must maintain a constant phase relationship.

---

1. The de Broglie wavelength is:
(A) $\lambda = hmv$
(B) $\lambda = \frac{h}{mv}$
(C) $\lambda = hv$

(D) $\lambda = \frac{hv}{m}$

Correct Answer: (B) $\lambda = \frac{h}{mv}$

Solution:
According to de Broglie's hypothesis, every moving particle exhibits wave-like properties, with an associated wavelength known as the de Broglie wavelength.
For a particle having momentum $p = mv$, where m is its mass and v its velocity, the de Broglie wavelength λ is given by:

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

where h is Planck's constant (6.626×10^{-34} J·s).
This relationship shows that the wavelength is inversely proportional to the momentum of the particle, linking particle and wave nature.

Quick Tip

de Broglie wavelength relates particle momentum and wavelength via Planck's constant.

---

1. Photocell is based on:
(A) chemical effect of current
(B) photo-electric effect
(C) magnetic effect of current
(D) electro-magnetic induction

Correct Answer: (B) photo-electric effect

Solution:
A photocell operates based on the photoelectric effect, which occurs when light of sufficient frequency (or energy) shines on the surface of a material, typically a metal.
The energy from the incident photons is absorbed by the electrons in the material. If this energy exceeds the material's work function (the minimum energy required to free an electron), electrons are emitted from the surface.
These emitted electrons produce a current when collected, and this current varies with the intensity and frequency of the incident light.
Thus, a photocell converts light energy into electrical energy using the photoelectric effect.

Quick Tip

Photocells convert light energy into electrical energy via the photo-electric effect.

---

1. Cathode rays are group of:
(A) electrons
(B) protons
(C) neutrons
(D) atoms

Correct Answer: (A) electrons

Solution:
Cathode rays are streams of electrons emitted from the negative electrode (cathode) in a vacuum tube.
When a high voltage is applied across the electrodes in the vacuum tube, electrons are emitted from the cathode due to thermionic emission and accelerated towards the anode.
These electrons travel in straight lines and can be deflected by electric and magnetic fields, confirming their charged particle nature.
Cathode rays were fundamental in discovering the electron and understanding its properties.

Quick Tip

Cathode rays helped in discovery of electron.

---

1. The half-life of a radioactive substance is:
(A) $0.6931 \times X$
(B) $\frac{0.6931}{X}$
(C) $\frac{0.6931}{\log 102}$
(D) Average age 0.6931

Correct Answer: (B) $\frac{0.6931}{X}$

Solution:
The half-life $T_{1/2}$ of a radioactive substance is the time required for half of the radioactive nuclei to decay. It is related to the decay constant λ (here given as $\lambda = X$) by the formula:

$$T_{1/2} = \frac{0.6931}{\lambda}.$$

This relationship comes from the exponential decay law, where the number of undecayed nuclei decreases as:

$$N = N_0 e^{-\lambda t}.$$

At $t = T_{1/2}$, $N = \frac{N_0}{2}$, leading to the above formula.

Quick Tip

Half-life is the time taken for half the radioactive nuclei to decay.

1. The S.I. unit of decay constant is:
(A) metre
(B) hertz
(C) per metre
(D) metre (repeated)

Correct Answer: (B) hertz

Solution:
The decay constant λ represents the probability per unit time that a nucleus will decay. Therefore, its unit is the reciprocal of time.
In the SI system, this is expressed as:

$$[\lambda] = \mathrm{s}^{-1},$$

which is also equivalent to hertz (Hz), the unit of frequency. This reflects the fact that decay is a stochastic process characterized by a rate of events per second.

Quick Tip

Decay constant indicates the probability of decay per unit time.

---

1. Number of neutrons in an atom of $^{230}_{90}\mathrm{Th}$ is:
(A) 320
(B) 230
(C) 140
(D) 90

Correct Answer: (C) 140

Solution:
The number of neutrons in a nucleus is given by the difference between the mass number A and the atomic number Z:

$$\text{Number of neutrons} = A - Z.$$

Given the mass number $A = 230$ and atomic number $Z = 90$, the number of neutrons is:

$$230 - 90 = 140.$$

Hence, the nucleus contains 140 neutrons.

Quick Tip

Number of neutrons = Mass number - Atomic number.

1. P-N junction diode is used as:
(A) an amplifier
(B) an oscillator
(C) a modulator
(D) a rectifier

Correct Answer: (D) a rectifier

Solution:
A P-N junction diode is a semiconductor device formed by joining P-type and N-type materials. It allows current to flow easily when forward biased (P-side connected to positive terminal and N-side to negative), but blocks current when reverse biased.
This unidirectional conduction property makes the diode useful as a rectifier, which converts alternating current (AC) into direct current (DC) by allowing only one half of the AC waveform to pass through.
Thus, a P-N junction diode acts as an electrical one-way valve.

Quick Tip

Rectifiers are fundamental components in power supply circuits.

---

1. Instrument used to increase input voltage/current is called:
(A) oscillator
(B) amplifier
(C) diode
(D) rectifier

Correct Answer: (B) amplifier

Solution:
An amplifier is an electronic device that increases the amplitude of an input signal, which can be either voltage, current, or power.
It boosts the strength of the signal while preserving its original waveform, frequency, and other characteristics such as phase.
Amplifiers are widely used in communication systems, audio devices, and instrumentation to enhance weak signals for further processing or transmission.

Quick Tip

Amplifiers are widely used in audio and communication systems.

1. If in a logic gate output Y is obtained by the product of its both inputs $A \cdot B$, then the gate is:
(A) AND
(B) OR
(C) NOR
(D) NOT

Correct Answer: (A) AND

Solution:
An AND gate is a digital logic gate that outputs a high signal (1) only when all its inputs are high.
For two inputs A and B, the output Y is given by the logical product (AND) of the inputs:

$$Y = A \cdot B,$$

which means $Y = 1$ only if both $A = 1$ and $B = 1$; otherwise, $Y = 0$.
This behavior is fundamental in digital circuits for decision-making operations.

Quick Tip

AND gate performs logical multiplication of inputs.

---

1. Width of forbidden energy gap in the semiconductor is approximately:
(A) 1 eV
(B) 10 eV
(C) 100 eV
(D) 0.01 eV

Correct Answer: (A) 1 eV

Solution:
The forbidden energy gap, also known as the band gap, is the energy difference between the valence band and the conduction band in a semiconductor.
For common semiconductors such as silicon and germanium, this energy gap is approximately:

$$E_g \approx 1\,\text{eV}.$$

Specifically, silicon has a band gap of about 1.1 eV, while germanium's band gap is about 0.7 eV.
This small energy gap allows these materials to conduct electricity under certain conditions, making them suitable for electronic devices.

Quick Tip

Semiconductors have energy gaps between conductors and insulators, typically near 1 eV.

---

1. The equivalent of decimal number 27 in binary number system will be:
(A) $(10011)_2$
(B) $(10111)_2$
(C) $(11001)_2$
(D) $(11011)_2$

Correct Answer: (B) $(11011)_2$

Solution:
To convert the decimal number 27 to binary, we express it as a sum of powers of 2:

$$27 = 16 + 8 + 2 + 1 = 2^4 + 2^3 + 2^1 + 2^0.$$

Writing these powers as binary digits, where each power present corresponds to 1 and absent corresponds to 0, we get:

$$27_{10} = (11011)_2.$$

Quick Tip

Convert decimal to binary by dividing by 2 and recording remainders.

---

1. In a full wave rectifier, if input frequency is 50 Hz, then output frequency will be:
(A) 25 Hz
(B) 50 Hz
(C) 100 Hz
(D) 200 Hz

Correct Answer: (C) 100 Hz

Solution:
A full-wave rectifier converts both the positive and negative half cycles of an alternating current (AC) input into positive half cycles at the output.
This process effectively inverts every negative half cycle, resulting in an output signal whose frequency is twice that of the input AC signal.
Given the input frequency is 50 Hz, the output frequency after full-wave rectification is:

$$\text{Output frequency} = 2 \times 50 = 100 \text{ Hz}.$$

Quick Tip

Full-wave rectifiers double the input AC frequency in their output.

---

1. The device which works for both modulation and demodulation is called:
(A) Laser
(B) Radar
(C) Modem
(D) Fax

Correct Answer: (C) Modem

Solution:
A modem, short for modulator-demodulator, is an essential device in communication systems that enables the transmission of digital data over analog communication channels, such as telephone lines.
The process involves two main functions:

- **Modulation:** The modem converts digital signals generated by a computer or other digital device into analog signals suitable for transmission over analog media. This is necessary because traditional telephone lines and many communication channels are designed to carry analog signals, not digital pulses. The modulation process typically involves varying a carrier wave's properties—such as amplitude, frequency, or phase—according to the digital data.
- **Demodulation:** Upon receiving the analog signals, the modem performs the reverse operation, converting the analog signals back into digital data that the computer or receiving device can interpret. This ensures that the transmitted information can be correctly recovered and processed.

By performing these dual roles, the modem acts as a bridge between digital devices and analog communication infrastructure, allowing seamless digital communication over channels that would otherwise be incompatible with digital signals.
This capability is crucial for internet access via telephone lines, fax machines, and other data communication applications.

Quick Tip

Modem = Modulator + Demodulator.

---

1. Distance of communication satellite from the surface of the Earth is:

(A) 36000 km
(B) 3600 km
(C) 36000 mile
(D) 36000 metre

Correct Answer: (A) 36000 km

Solution:
Geostationary communication satellites are placed in a specific type of orbit known as the geostationary orbit (GEO). This orbit is located approximately 36,000 kilometers (about 35,786 km to be precise) above the Earth's equatorial plane.
The key characteristics and reasons for this orbital placement are:

- **Orbital Period Matching Earth's Rotation:** At this altitude, the satellite completes one full orbit around the Earth in exactly 24 hours, which matches the Earth's rotation period about its axis. This synchronization means that the satellite remains fixed over a particular point on the Earth's surface.
- **Fixed Position Relative to Earth:** Because the satellite appears stationary from any fixed position on Earth, ground antennas can be permanently aimed at the satellite without the need for tracking systems. This greatly simplifies the design and operation of communication systems.
- **Wide Coverage Area:** From this high vantage point, a single geostationary satellite can cover roughly one-third of the Earth's surface. This allows for efficient communication coverage of large geographical areas, including entire continents and oceans.
- **Applications:** Geostationary satellites are widely used for television broadcasting, weather monitoring, satellite radio, and telecommunications including telephone and internet services. Their fixed position ensures uninterrupted communication links.
- **Orbital Constraints:** To maintain a geostationary orbit, the satellite must orbit in the Earth's equatorial plane (zero inclination) and at the precise altitude of approximately 35,786 km above mean sea level. Any deviation results in the satellite appearing to move relative to the Earth's surface, which can disrupt communication.

In summary, placing communication satellites at approximately 36,000 km altitude in a geostationary orbit allows for continuous, reliable communication with fixed ground stations, making them essential components of global communication networks.

Quick Tip

Geostationary orbit altitude ¡ 36,000 km from Earth's surface.

---

1. Attenuation is measured in:
(A) ohm
(B) decibel

(C) mho
(D) siemen

Correct Answer: (B) decibel

Solution:
Attenuation is the gradual loss or reduction in the strength (amplitude) of a signal as it travels through a transmission medium such as a cable, optical fiber, or the atmosphere.
This reduction occurs due to factors like resistance, scattering, absorption, and other dissipative effects within the medium.
Attenuation is quantitatively expressed in **decibels (dB)**, a logarithmic unit that compares the input power to the output power of the signal.
Mathematically, attenuation A in decibels is given by:

$$A = 10 \log_{10} \left(\frac{P_{\text{input}}}{P_{\text{output}}} \right) \text{ dB},$$

where P_{input} and P_{output} are the powers of the signal at the input and output ends of the transmission path, respectively.
Using decibels allows easier handling and comparison of large variations in signal power, as the logarithmic scale compresses wide-ranging values into a manageable scale.
In summary, attenuation measured in decibels indicates how much the signal weakens as it propagates through the medium.

Quick Tip

Decibel (dB) is a logarithmic unit to express ratios of power or intensity.

---

1. Define intensity of electric field at any point. Write down its S.I. unit.

Solution:
The intensity of the electric field at any point is defined as the force experienced by a unit positive test charge placed at that point. It is a vector quantity that indicates both the magnitude and direction of the force exerted on the charge.
Mathematically, the electric field intensity $\vec{E}$ is given by:

$$\vec{E} = \frac{\vec{F}}{q},$$

where

- $\vec{E}$ is the electric field intensity,
- $\vec{F}$ is the force experienced by the test charge,
- q is the magnitude of the positive test charge placed in the field.

This definition implies that the electric field at a point is independent of the test charge used, provided the charge is small enough not to disturb the existing field.

S.I. Unit:
The S.I. unit of electric field intensity is derived from the units of force and charge. Since force is measured in newtons (N) and charge in coulombs (C), the unit of electric field intensity is:

$$\text{Newton per coulomb (N/C).}$$

Alternatively, electric field can also be expressed in terms of potential difference and distance, giving the unit:

$$\text{Volt per meter (V/m).}$$

Both units are equivalent, as $1\,\text{N/C} = 1\,\text{V/m}$.
Thus, the electric field quantifies how strongly and in which direction an electric force would act on a positive unit charge placed at any point in space.

> **Quick Tip**
>
> Electric field intensity relates force and charge; think of it as force per unit charge.

---

1. An electric dipole of dipole moment 2×10^{-6} cm is kept inside a closed surface. What will be the net electric flux coming out from the surface?

Solution:
According to Gauss's law, the net electric flux Φ_E through any closed surface is directly proportional to the net charge Q_{enc} enclosed within that surface. Mathematically, it is expressed as:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\varepsilon_0},$$

where $\vec{E}$ is the electric field, $d\vec{A}$ is the differential area vector on the closed surface, and ε_0 is the permittivity of free space.
An electric dipole consists of two equal and opposite charges, $+q$ and $-q$, separated by a small distance. Since these charges are equal in magnitude but opposite in sign, the total net charge enclosed by any closed surface that contains the dipole is:

$$Q_{\text{enc}} = +q + (-q) = 0.$$

Therefore, by Gauss's law, the net electric flux through any closed surface enclosing an electric dipole is:

$$\Phi_E = \frac{0}{\varepsilon_0} = 0.$$

This means that despite the presence of strong electric fields around the dipole, the total outward electric flux through a closed surface around it is zero because the positive and negative charges contribute equal and opposite fluxes that cancel each other out.
Hence, the net electric flux through a closed surface enclosing an electric dipole is always zero.

Quick Tip

Electric flux depends on enclosed net charge; dipoles have zero net charge so zero net flux.

---

1. Find the increase in energy of a condenser of capacity $6\,\text{pF}$ on changing the potential difference from 10 V to 20 V.

Solution:
The energy stored in a condenser (capacitor) is given by

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

where C is the capacitance and V is the potential difference.
Initial energy:

$$U_1 = \frac{1}{2} \times 6 \times 10^{-12} \times (10)^2 = 3 \times 10^{-10} \text{ J}.$$

Final energy:

$$U_2 = \frac{1}{2} \times 6 \times 10^{-12} \times (20)^2 = 1.2 \times 10^{-9} \text{ J}.$$

Increase in energy:

$$\Delta U = U_2 - U_1 = 1.2 \times 10^{-9} - 3 \times 10^{-10} = 9 \times 10^{-10} \text{ J} = 6 \times 10^{-7} \text{ J}.$$

Quick Tip

Energy stored in capacitor is proportional to the square of the voltage.

---

1. What are ohmic and non-ohmic resistances? Write down one example of each.

Solution:
Ohmic Resistance:
A resistance is called ohmic if it obeys Ohm's law, which states that the current I flowing through a conductor is directly proportional to the applied voltage V across it, provided the temperature remains constant. Mathematically, this can be expressed as:

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

where R is the resistance and remains constant for ohmic materials.
The graphical representation of voltage versus current (the $V - I$ characteristic) for an ohmic resistor is a straight line passing through the origin, indicating a constant resistance.
Example: Common conductors such as copper wires and metallic resistors exhibit ohmic behavior under normal conditions.

Non-Ohmic Resistance:

A resistance is termed non-ohmic if it does not obey Ohm's law, meaning the current flowing through the device is not directly proportional to the applied voltage. In such cases, the resistance changes with voltage or current, often due to changes in temperature or other physical properties.
The $V-I$ characteristic curve for a non-ohmic device is nonlinear, indicating that the resistance varies with applied voltage or current.
Example: Devices like diodes and filament bulbs are non-ohmic. For instance, in a filament bulb, the filament heats up as current passes through it, increasing its resistance and causing a nonlinear $V - I$ curve.

> **Quick Tip**
>
> Ohm's law: $V \propto I$. Ohmic resistors follow this; non-ohmic resistors don't.

---

1. What is an electromagnetic wave? On which factors does its velocity in vacuum depend?

Solution:
Step 1: Electromagnetic waves are produced by the acceleration of electric charges. When charges accelerate, they create time-varying electric and magnetic fields that are mutually perpendicular and propagate through space.
Step 2: These varying electric and magnetic fields sustain each other as they move through space. The changing electric field generates a magnetic field, and the changing magnetic field induces an electric field, allowing the wave to propagate even in vacuum without the need for any medium.
Step 3: The speed of electromagnetic waves (speed of light) in vacuum is derived from Maxwell's equations and is given by:

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \,\text{m/s},$$

where μ_0 is the permeability of free space, and ε_0 is the permittivity of free space.
Hence, the velocity of electromagnetic waves depends solely on these two fundamental constants μ_0 and ε_0, highlighting the intrinsic properties of free space.

> **Quick Tip**
>
> In vacuum, all electromagnetic waves (radio, light, X-rays, etc.) travel with the same velocity $c = 3 \times 10^8 \,\text{m/s}$.

---

2. What is a cyclotron? State its two limitations.

Solution:

Step 1: In a cyclotron, charged particles (such as protons or ions) are injected at the center between two hollow semi-circular electrodes called *dees*. These particles are accelerated each time they cross the gap between the dees by an alternating electric field.
Step 2: A strong magnetic field $\mathbf{B}$, applied perpendicular to the plane of the dees, forces the charged particles to move in a circular path due to the Lorentz force. As the particles gain energy and speed with each acceleration, the radius of their circular trajectory increases.
Step 3: The frequency f of revolution of the charged particles in the magnetic field is given by:

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

where q is the charge of the particle, B is the magnetic field strength, and m is the mass of the particle. This frequency, known as the cyclotron frequency, remains constant for non-relativistic speeds.
Step 4: However, for very light particles like electrons, when their speeds approach a significant fraction of the speed of light, relativistic effects become important. The effective mass of the particle increases, which reduces the frequency of revolution. This causes the particle to fall out of sync with the alternating electric field, leading to synchronization failure and limiting the cyclotron's ability to accelerate electrons efficiently.

Quick Tip

A cyclotron accelerates charged particles using perpendicular electric and magnetic fields. It is mainly used in nuclear physics and medical applications (like particle therapy).

---

3. Define two magnetic elements of the Earth.

Solution:
Step 1: The Earth's magnetic field at any location can be represented as a vector quantity, which has both horizontal and vertical components relative to the Earth's surface.
Step 2: To fully describe the magnetic field, we use magnetic elements such as:

- **Declination** (D): The angle between the geographic north (true north) and the horizontal component of the Earth's magnetic field. It indicates the direction of the magnetic north relative to true north.
- **Inclination** or **Dip** (I): The angle made by the total magnetic field vector with the horizontal plane. It measures how much the magnetic field dips below or rises above the horizontal.

Step 3: These magnetic elements are essential for compass navigation, geophysical surveys, and for understanding the Earth's magnetosphere. They allow navigators and scientists to accurately map the Earth's magnetic field and correct compass readings accordingly.

Quick Tip

The three magnetic elements are: 1. Magnetic Declination (D), 2. Magnetic Inclination (I), and 3. Horizontal Component (H). Often, only two are asked to be defined in short-answer questions.

---

4. What is an eddy current? Write down its utilities.

Solution:
Step 1: According to Faraday's law of electromagnetic induction, any change in the magnetic flux through a conductor induces an electromotive force (emf) in it:

$$\mathcal{E} = -\frac{d\Phi_B}{dt},$$

where Φ_B is the magnetic flux.
Step 2: In a bulky or solid conductor (not just a wire loop), this induced emf generates currents that flow in closed loops within the body of the conductor. These circulating currents are called *eddy currents*.
Step 3: Eddy currents produce resistive heating and oppose the change in magnetic flux (Lenz's law), leading to energy loss in the form of heat. Despite this, eddy currents have practical applications, such as:

- **Damping:** They provide electromagnetic damping in galvanometers and meters.
- **Braking:** Used in eddy current brakes in trains and roller coasters for smooth deceleration.
- **Heating:** Employed in induction heating for metal melting and cooking.

Quick Tip

Eddy currents are minimized (to reduce energy loss) by using **laminated cores** in electrical machines such as transformers and motors.

---

5. Write down the energy losses in a transformer.

Solution:
Step 1: In a practical transformer, when electrical power is transferred from the primary coil to the secondary coil, some energy is inevitably lost due to non-ideal conditions.
Step 2: The main causes of energy loss in a transformer are:

- **Copper losses:** These arise due to the resistance of the copper wire windings, causing heat dissipation when current flows through them.
- **Core losses:** Also called iron losses, these include hysteresis loss (due to continuous magnetization and demagnetization of the core) and eddy current loss (circulating currents induced in the core).

- **Leakage flux:** Not all magnetic flux produced by the primary coil links with the secondary coil, leading to energy loss.

Step 3: To improve transformer efficiency and reduce these losses, several methods are employed:

- Using **laminated cores** to reduce eddy current losses by increasing electrical resistance in the core.
- Utilizing **soft iron** or silicon steel cores with low hysteresis loss.
- Employing **thick copper wires** with low resistance to minimize copper losses.
- Designing the transformer to maximize magnetic coupling, thus reducing leakage flux.

Step 4: Despite these losses, modern transformers achieve efficiencies above 95%, making them highly effective for power transmission and distribution.

> Quick Tip
>
> A well-designed transformer can achieve an efficiency of about 95–99%. Use laminated silicon steel cores to reduce eddy current losses.

---

6. Explain the polarization of light.

Solution:
Step 1: Light is a transverse electromagnetic wave, meaning its electric and magnetic field vectors oscillate perpendicular to the direction of wave propagation.
Step 2: In unpolarized light, the electric field vectors vibrate randomly in all directions perpendicular to the direction of propagation.
Step 3: When unpolarized light undergoes reflection, refraction, or passes through certain materials such as polarizing filters or anisotropic crystals (e.g., calcite or tourmaline), only the components of the electric field vibrating in a specific direction are allowed to pass or are enhanced, resulting in polarized light.
Step 4: The direction of the electric field vector in polarized light is called the **plane of vibration**, while the plane perpendicular to this direction is called the **plane of polarization**. The latter is significant because many polarization phenomena, such as reflection and transmission, depend on the orientation of this plane.
Step 5: Polarization is important in various applications including glare reduction (polarized sunglasses), liquid crystal displays (LCDs), and optical communication.

> Quick Tip
>
> Only **transverse waves** (like light waves) can be polarized. **Longitudinal waves** (like sound waves) cannot be polarized.

---

7. What is the critical angle? Write down its necessary conditions.

Solution:
Step 1: According to Snell's law, when light travels from one medium to another, the relationship between the angle of incidence i and the angle of refraction r, as well as the refractive indices μ_1 (of the first medium) and μ_2 (of the second medium), is given by:

$$\mu_1 \sin i = \mu_2 \sin r.$$

This law governs how the direction of a light ray changes as it passes from one optical medium into another. Here, μ_1 and μ_2 are the absolute refractive indices of the first and second medium respectively.
Step 2: From Snell's law, it can be observed that as the angle of incidence i increases (with $\mu_1 > \mu_2$), the angle of refraction r also increases. This is because the sine function increases with the angle in the range $0°$ to $90°$, and to maintain the equality in Snell's law, $\sin r$ must increase when $\sin i$ increases. Therefore, the refracted ray bends further away from the normal as i increases.
Step 3: There exists a particular angle of incidence for which the angle of refraction becomes $90°$. At this condition, the refracted ray travels along the interface between the two media. This specific angle of incidence is known as the **critical angle**, denoted by C. Setting $r = 90°$ in Snell's law, we get:

$$\mu_1 \sin C = \mu_2 \sin 90^\circ = \mu_2.$$
$$\Rightarrow \sin C = \frac{\mu_2}{\mu_1}.$$

This equation is valid only when $\mu_1 > \mu_2$, i.e., when light is travelling from a denser medium to a rarer medium.
Step 4: If the angle of incidence i is increased beyond the critical angle C (i.e., $i > C$), Snell's law can no longer be satisfied for any real angle of refraction r, because $\sin r$ would have to be greater than 1, which is not possible. In this case, the light does not pass into the second medium at all. Instead, it is completely reflected back into the denser medium. This phenomenon is known as **total internal reflection**. It is characterized by the following two conditions:

- The light must travel from a denser medium to a rarer medium (i.e., $\mu_1 > \mu_2$).
- The angle of incidence must be greater than the critical angle ($i > C$).

Total internal reflection is the principle behind many optical devices such as fiber optics and prisms used in binoculars and periscopes.

Quick Tip

Total internal reflection is used in optical fibers and diamond brilliance. For water–air, $C \approx 48.6°$; for glass–air, $C \approx 42°$.

---

8. 10^{19} electrons are placed on an uncharged body. Calculate the charge produced on the body.

Solution:
Step 1: The charge on one electron is -1.6×10^{-19} C. This is a fundamental physical constant representing the elementary charge carried by a single electron, and the negative sign indicates that the electron is negatively charged.
Step 2: When 10^{19} electrons are added to an initially uncharged body, each carrying a charge of -1.6×10^{-19} C, the total charge acquired by the body is calculated as:

$$Q = n \times (-e) = 10^{19} \times (-1.6 \times 10^{-19}) = -1.6\,\text{C}.$$

Here, $n = 10^{19}$ is the number of electrons added, and $e = 1.6 \times 10^{-19}$ C is the magnitude of the charge on one electron. The product gives the total charge Q, and the negative sign indicates that the charge is negative.
Step 3: Therefore, the body gains a **negative charge of 1.6 C**. This means that the body is now negatively charged due to the excess of electrons.

Quick Tip

Always remember:

$$1\,\text{electron} = -1.6 \times 10^{-19}\,\text{C}$$

Adding electrons gives a **negative charge**, while removing electrons gives a **positive charge**.

---

9. Mention the difference between p-type and n-type semiconductors.

Solution:
Step 1: When a pure semiconductor like silicon is doped with a **trivalent impurity** (such as boron, aluminium, or gallium), each impurity atom forms covalent bonds with the surrounding silicon atoms but lacks one electron to complete the bonding structure. This creates a deficiency of electrons, known as **holes**, which act as positive charge carriers. The resulting material is called a **p-type semiconductor**, where holes are the majority charge carriers.
Step 2: When the same pure semiconductor is doped with a **pentavalent impurity** (such as phosphorus, arsenic, or antimony), each impurity atom forms covalent bonds with the silicon atoms and contributes an extra electron that is free to move within the crystal lattice. These free electrons act as negative charge carriers. The resulting material is called an **n-type semiconductor**, where electrons are the majority charge carriers.
Step 3: In both types of doping — p-type and n-type — the number of majority charge carriers (holes in p-type and electrons in n-type) increases significantly compared to the intrinsic (pure) semiconductor. As a result, the electrical **conductivity of the semiconductor increases**, making it more efficient for use in electronic components such as diodes, transistors, and integrated circuits.

Quick Tip

Remember: - p-type $\rightarrow$ **Positive (holes)** are majority carriers. - n-type $\rightarrow$ **Negative (electrons)** are majority carriers.

---

10. Write down two uses of a shunt.

Solution:
Step 1: When the current to be measured is very large, a low-resistance device called a **shunt** is connected in **parallel** with the ammeter. The shunt provides an alternative path for the current, thereby protecting the sensitive coil of the ammeter from excessive current.
Step 2: Since the shunt has a very low resistance compared to the internal resistance of the ammeter, **most of the current flows through the shunt**, and only a small, known fraction of the total current flows through the meter. This small current is within the safe operating limits of the ammeter.
Step 3: This arrangement **prevents damage to the ammeter** by avoiding overload and allows the device to **measure high currents accurately**. The total current can be calculated using the known resistance of the shunt and the reading on the ammeter, making it a practical method for extending the current range of an ammeter.

Quick Tip

Shunts are commonly used in electrical measurement devices to increase current measurement capacity safely.

---

11. What is wattless current?

Solution:
Step 1: In an alternating current (AC) circuit, the total current can be resolved into two distinct components based on its phase relationship with the applied voltage: - The **active current** (or real component) which is **in phase with the voltage**. This component is responsible for performing **real work**, such as producing heat, light, or mechanical energy. - The **wattless current** (or reactive component), which is **out of phase with the voltage by** 90°. This component does not perform any net work over a full cycle; instead, it simply transfers energy back and forth between the source and the reactive components (inductors and capacitors) of the circuit.
Step 2: The **wattless current** primarily arises in circuits with **purely inductive or purely capacitive loads**, where the phase difference between voltage and current is exactly 90°. In such cases, the current either leads or lags the voltage by a quarter cycle, resulting in zero average power consumption.
Step 3: The power consumed in an AC circuit is given by the expression:

$$P = VI\cos\phi,$$

where V is the RMS voltage, I is the RMS current, and ϕ is the phase angle between voltage and current. For **wattless current**, $\phi = 90°$, hence:

$$P = VI\cos 90^\circ = VI \times 0 = 0.$$

Therefore, the power associated with wattless current is **zero**, confirming that it does not contribute to any real energy transfer in the circuit.

Quick Tip

Wattless current is also called **reactive current** and contributes to the **reactive power** in the circuit.

---

12. What is a light-emitting diode (LED)? Write down one application of it.

Solution:
Step 1: When a Light Emitting Diode (LED) is **forward biased**, the applied voltage reduces the potential barrier at the p-n junction, allowing **electrons** from the n-region and **holes** from the p-region to move toward the junction. At the junction, electrons and holes recombine. During this recombination process, the electrons drop from a higher energy level to a lower energy level, and the **excess energy is released in the form of photons (light)**. This phenomenon is known as **electroluminescence**.
Step 2: The **color of the emitted light** depends on the **bandgap energy** of the semiconductor material used in the LED. Different materials emit different wavelengths (colors) of light. For example:

- Gallium arsenide (GaAs) emits infrared light,
- Gallium phosphide (GaP) emits green or red light,
- Gallium nitride (GaN) emits blue or white light.

By choosing appropriate semiconductor materials and doping levels, LEDs can be designed to emit a wide range of colors.
Step 3: LEDs are **highly energy-efficient**, converting most of the electrical energy into light with minimal heat loss. They also have a **long operational life**, are compact in size, and offer fast switching capabilities. Due to these advantages, LEDs are widely used in various applications such as **display systems, indicator lights, lighting solutions, remote controls, and digital signage**.

Quick Tip

LEDs consume less power and produce less heat compared to traditional incandescent bulbs.

---

13. Convert the binary number 1101 into the decimal system.

Solution:
Step 1: Write down the **place values** for each binary digit, starting from the rightmost digit (least significant bit). The place values are the powers of 2, increasing from right to left:

$$2^0, 2^1, 2^2, 2^3, 2^4, \dots$$

For example, for a 5-bit binary number like 10101, the place values would be:

$$2^4, 2^3, 2^2, 2^1, 2^0$$

Step 2: Multiply each binary digit (bit) by its corresponding power of 2. Consider the binary number 10101:

$$1 \times 2^4 = 160 \times 2^3 = 01 \times 2^2 = 40 \times 2^1 = 01 \times 2^0 = 1$$

Step 3: Add all the products obtained in Step 2 to get the **decimal equivalent**:

$$16 + 0 + 4 + 0 + 1 = 21$$

Therefore, the binary number 10101 is equal to 21 in decimal.

Quick Tip

Binary to decimal conversion uses powers of 2 corresponding to each bit's position.

---

14. Explain UNIVAC and Fax.

Solution:
Step 1: UNIVAC (Universal Automatic Computer) was one of the earliest commercial computers developed in the United States in the early 1950s. It was a pioneering machine in the history of computing, known for its remarkable **speed**, **accuracy**, and **reliability** in processing large volumes of data. UNIVAC played a significant role in applications such as the U.S. Census and business data processing, marking the beginning of the computer age in commercial environments.
Step 2: Fax machines (short for facsimile machines) are devices that allow documents to be transmitted electronically over telephone lines. The machine **scans** a physical document and **converts it into electronic signals**, which are then sent to a receiving fax machine. The receiving machine **reconstructs** the electronic data into a printed copy of the original document. This process enables **rapid sharing of printed documents** across long distances, making fax machines an essential tool for communication, especially before the widespread adoption of email and digital document transfer.

Quick Tip

UNIVAC represents early digital computing history, while Fax represents analog communication technology.

---

15. Explain the difference between nuclear fission and nuclear fusion.

Solution:
Step 1: Nuclear fission is a process in which a **heavy atomic nucleus** (such as uranium-235 or plutonium-239) splits into two or more **lighter nuclei**, along with the release of a large amount of **energy** and **free neutrons**. The energy released comes from the conversion of a small amount of mass into energy, as described by Einstein's equation $E = mc^2$. The emitted neutrons can initiate further fission reactions, leading to a **chain reaction** which is the basis of nuclear reactors and atomic bombs.

Step 2: **Nuclear fusion** is a process where two **light atomic nuclei** (typically isotopes of hydrogen such as deuterium and tritium) **combine to form a heavier nucleus** (such as helium), releasing an enormous amount of energy in the process. Fusion is the energy source of the sun and other stars. The energy yield from fusion is significantly **greater** than that from fission. However, achieving the extremely high temperatures and pressures required to initiate and sustain fusion reactions makes it technologically challenging.
Step 3: Both fission and fusion are **sources of nuclear energy**, but they differ in their mechanisms and practical applications:

- **Nuclear fission** is currently used in nuclear power plants for electricity generation.
- **Nuclear fusion** is still under experimental development but holds promise as a cleaner and more abundant energy source for the future.

While fission produces radioactive waste, fusion produces minimal long-lived radioactive byproducts, making it more environmentally friendly if harnessed successfully.

Quick Tip

Fusion is the source of energy in stars; fission is widely used in nuclear power plants.

---

16. What is the Rydberg constant? Write down its unit.

Solution:
Step 1: The **Rydberg constant** R is a fundamental physical constant that represents the limiting value of the highest wavenumber (inverse wavelength) of any photon that can be emitted from the hydrogen atom. It corresponds to the inverse of the wavelength associated with the transition of an electron from the ionization limit (infinite energy level) to the ground state (lowest energy level). The Rydberg constant is crucial in the formulation of the **Rydberg formula** for predicting the wavelengths of spectral lines in hydrogen.
Step 2: The approximate value of the Rydberg constant is:

$$R = 1.097 \times 10^7 \, \mathrm{m}^{-1}.$$

This value is experimentally determined and is used extensively in atomic physics and spectroscopy for calculating the wavelengths of emitted or absorbed light in hydrogen and hydrogen-like atoms.

Quick Tip

The Rydberg constant is fundamental in spectroscopy and quantum mechanics for predicting spectral lines.

---

17. What is an electric dipole? Find an expression for electric potential at any point due to an electric dipole.

Solution:
Step 1: Let the two charges be at points A and B, separated by distance $2a$. The point P is at distance r from the center O.
Step 2: The distances from P to the charges are:

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

assuming $r \gg a$.
Step 3: The potential at P is:

$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{q}{r_+} - \frac{q}{r_-}\right).$$

Step 4: Using binomial approximation for $r \gg a$:

$$\frac{1}{r_\pm} \approx \frac{1}{r} \mp \frac{a\cos\theta}{r^2}.$$

Step 5: Substitute to get:

$$V = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{r} - \frac{a\cos\theta}{r^2} - \frac{1}{r} - \frac{a\cos\theta}{r^2}\right) = \frac{1}{4\pi\epsilon_0}\frac{2qa\cos\theta}{r^2}.$$

Step 6: Since $p = 2qa$, the expression becomes:

$$\boxed{V = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2}}.$$

Quick Tip

The electric potential of a dipole decreases as $\frac{1}{r^2}$, faster than that of a single charge $(\frac{1}{r})$.

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18. What is interference of light? Find an expression for fringe width in Young's double slit experiment.

Solution:
Step 1: When light from two slits separated by distance d falls on a screen at distance D, the path difference between the two waves at point P is:

$$\Delta = d\sin\theta.$$

Step 2: For constructive interference (bright fringes), the path difference must be an integer multiple of wavelength:

$$\Delta = n\lambda, \quad n = 0, 1, 2, \ldots$$

Step 3: For small angles, $\sin\theta \approx \tan\theta = \frac{y}{D}$, where y is the fringe position on the screen.
Step 4: Substituting, we get:

$$d\frac{y}{D} = n\lambda \implies y = \frac{n\lambda D}{d}.$$

Step 5: The fringe width β is the distance between two consecutive bright fringes:

$$\beta = y_{n+1} - y_n = \frac{\lambda D}{d}.$$

Quick Tip

To get clearer fringes, increase D or decrease d. Also, shorter wavelengths produce narrower fringes.

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19. Mention the defects of human vision and describe the methods to remove them.

Solution:
Step 1: To diagnose a vision defect, first identify the type based on where the image is formed relative to the retina:

- In **myopia** (nearsightedness), the image is formed **in front of the retina**, causing distant objects to appear blurry.
- In **hypermetropia** (farsightedness), the image is formed **behind the retina**, making nearby objects appear blurry.

Step 2: Correct the defect by using appropriate lenses that adjust the focal length so that the image forms precisely on the retina, ensuring clear vision:

- For **myopia**, use **concave lenses** to diverge the incoming light rays, effectively moving the focal point backward onto the retina.
- For **hypermetropia**, use **convex lenses** to converge the incoming light rays sooner, moving the focal point forward onto the retina.

This optical correction restores sharp vision by compensating for the eye's improper focusing.

Quick Tip

Regular eye checkups help in early detection and correction of vision defects.

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20. Write the properties of diamagnetic, paramagnetic, and ferromagnetic materials.

Solution:
Step 1: Diamagnetic materials are characterized by having all their electrons paired, resulting in no permanent magnetic moment. When an external magnetic field is applied, these materials **induce a magnetic field in the opposite direction** due to changes in the orbital motion of electrons. This causes a very weak **repulsion** from the applied magnetic field.
Step 2: Paramagnetic materials possess **one or more unpaired electrons**, giving rise to permanent but randomly oriented magnetic moments. When subjected to an external magnetic

field, these magnetic moments **tend to align weakly in the direction of the field**, resulting in a slight **attraction** towards the magnetic source. However, this alignment is usually lost once the external field is removed.
Step 3: Ferromagnetic materials contain **magnetic domains**, which are regions where groups of atomic magnetic moments are strongly aligned in the same direction even without an external field. Upon applying a magnetic field, these domains **align more uniformly**, causing a **strong attraction**. Ferromagnetic materials can retain this alignment, exhibiting **permanent magnetism**, and are widely used in the fabrication of permanent magnets and magnetic storage devices.

> **Quick Tip**
>
> Ferromagnetism is responsible for most permanent magnets used in everyday life.

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21. Define self-inductance and write its S.I. unit. Find the self-inductance for a solenoid of N turns, length l, and radius r.

Solution:
Step 1: Self-inductance is defined as the property of a coil (or an electrical circuit) by which a **changing current** in the coil induces an electromotive force (emf) in the same coil itself. This induced emf opposes the change in current according to Lenz's law. The self-inductance L quantifies the ratio of the induced emf to the rate of change of current:

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

Step 2: Consider a solenoid of length l, cross-sectional area A, and N turns:

- The magnetic field inside a long solenoid carrying current I is uniform and given by:

  $$B = \mu_0 \frac{N}{l} I,$$

  where μ_0 is the permeability of free space.

- The magnetic flux ϕ through one turn of the solenoid is:

  $$\phi = B \times A = \mu_0 \frac{N}{l} I \times A.$$

- Since the solenoid has N turns, the total magnetic flux linked with the coil is:

  $$\Phi = N\phi = N \times \left(\mu_0 \frac{N}{l} IA\right) = \mu_0 \frac{N^2 A}{l} I.$$

Step 3: By definition, the self-inductance L is the ratio of the total magnetic flux linked to the current:

$$L = \frac{\Phi}{I} = \mu_0 \frac{N^2 A}{l}.$$

This expression shows that the self-inductance of a solenoid depends on the number of turns squared, the cross-sectional area, and inversely on its length.

Quick Tip

Self-inductance depends on geometry of the coil and the magnetic permeability of the medium.

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22. Describe with diagram the working method of p-n-p and n-p-n transistors.

Solution:
Step 1: In a Bipolar Junction Transistor (BJT), the **emitter-base junction** is **forward biased** to allow the majority charge carriers (electrons in an NPN transistor or holes in a PNP transistor) to flow from the emitter into the base region. This forward bias reduces the barrier potential, enabling carrier injection.
Step 2: The **base-collector junction** is **reverse biased**, creating a strong electric field that sweeps the injected carriers from the base into the collector region. Because the base is thin and lightly doped, most carriers pass through it without recombining.
Step 3: The **small base current** controls the **large collector current**, resulting in the **amplification** property of the transistor. This allows the transistor to act as a current amplifier, where a small input current at the base controls a much larger current flowing from emitter to collector.

Quick Tip

The transistor acts as a current amplifier: small base current controls larger collector current.
