CUET-UG Physics Sample Paper-19

Duration: 1 Hour **Maximum Marks: 250**

Instructions

- This paper contains a total of 50 Multiple Choice Questions.
- Each correct answer carries **+5 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Q1. An electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$. The torque τ acting on the dipole and its potential energy U are given by:

(A) $\tau = \vec{p} \cdot \vec{E}, U = -\vec{p} \times \vec{E}$

(B) $\tau = \vec{p} \times \vec{E}, U = \vec{p} \cdot \vec{E}$

(C) $\tau = \vec{p} \times \vec{E}, U = -\vec{p} \cdot \vec{E}$

(D) $\tau = \vec{p} \cdot \vec{E}, U = \vec{p} \cdot \vec{E}$

Q2. A spherical conductor of radius R has a charge Q. If a concentric spherical shell of radius $2R$ carrying a charge $-Q$ is placed around it, the potential difference between the two spheres will be:

(A) $\frac{1}{4\pi\epsilon_0}\frac{Q}{R}$

(B) $\frac{1}{4\pi\epsilon_0}\frac{Q}{2R}$

(C) $\frac{1}{4\pi\epsilon_0}\frac{2Q}{R}$

(D) $\frac{1}{4\pi\epsilon_0}\frac{Q}{4R}$

Q3. Three capacitors, $C_1 = 2\mu F$, $C_2 = 3\mu F$, and $C_3 = 6\mu F$, are connected such that C_1 and C_2 are in parallel, and this combination is in series with C_3. The equivalent capacitance of the arrangement is:

(A) $1\mu F$

(B) $2\mu F$

(C) $3\mu F$

(D) $11\mu F$

Q4. A parallel plate capacitor has capacitance C. If a dielectric slab of dielectric constant K and thickness $d/2$ (where d is the plate separation) is inserted between the plates, the new capacitance will be:

(A) $\frac{2KC}{K+1}$

(B) $\frac{KC}{2}$

(C) $\frac{K+1}{2K}C$

(D) $\frac{2K+1}{K+1}C$

Q5. A point charge q is placed at the center of a cube of side L. The electric flux emerging from the surface of the cube is:

(A) $\frac{q}{\epsilon_0}$

(B) $\frac{q}{6\epsilon_0}$

(C) $\frac{6q}{\epsilon_0}$

(D) Zero

Q6. An electric dipole consists of two opposite charges of magnitude $1\mu C$ separated by a distance of $2cm$. If this dipole is placed in an electric field of $10^5 N/C$ making an angle of $30°$ with the field, the magnitude of the torque experienced by the dipole is:

(A) $1 \times 10^{-3} Nm$

(B) $2 \times 10^{-3} Nm$

(C) $1 \times 10^{-4} Nm$

(D) $2 \times 10^{-4} Nm$

Q7. A metal sphere is connected to the ground. A charged rod is brought near it but does not touch it. Which of the following is true?

(A) The sphere acquires a charge opposite to that of the rod.

(B) The sphere acquires a charge same as that of the rod.

(C) The sphere remains neutral.

(D) The sphere becomes negatively charged regardless of the rod's charge.

Q8. The energy stored in a capacitor of capacitance C with charge Q is U. If the charge is doubled and the capacitance is halved, the new energy stored will be:

(A) U

(B) $2U$

(C) $4U$

(D) $8U$

Q9. If the drift velocity of electrons in a conductor is v_d when current I flows, what will be the drift velocity if the current is doubled and the cross-sectional area of the conductor is halved?

(A) v_d

(B) $2v_d$

(C) $4v_d$

(D) $v_d/2$

Q10. In a Wheatstone bridge, the resistances in the four arms are P, Q, R, S. If the bridge is balanced, then:

(A) $P/R = Q/S$

(B) $P/Q = R/S$

(C) $P + Q = R + S$

(D) $PQ = RS$

Q11. Two cells of EMFs E_1 and E_2 and internal resistances r_1 and r_2 respectively, are connected in parallel. The equivalent EMF of the combination is:

(A) $E_1 + E_2$

(B) $\frac{E_1 r_1 + E_2 r_2}{r_1 + r_2}$

(C) $\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

(D) $\frac{E_1 E_2}{E_1 + E_2}$

Q12. A $100W$, $200V$ bulb is connected across a $100V$ supply. The power consumed by the bulb will be:

(A) $100W$

(B) $50W$

(C) $25W$

(D) $12.5W$

Q13. Kirchhoff's first law (junction rule) is based on the conservation of:

(A) Energy

(B) Charge

(C) Momentum

(D) Both energy and charge

Q14. A wire of resistance R is cut into n equal parts, which are then connected in parallel. The equivalent resistance of the combination is:

(A) nR

(B) R/n

(C) R/n^2

(D) n^2R

Q15. A current I flows in a long straight conductor. A rectangular loop is placed near it such that one side of the loop is parallel to the conductor and at a distance a, and the other side is at a distance b ($b > a$). The magnetic force on the loop will be:

(A) Attractive

(B) Repulsive

(C) Zero

(D) Depends on the current direction in the loop

Q16. A moving coil galvanometer has a resistance G. To convert it into an ammeter of range I_A, a shunt resistance S is connected in parallel. If the galvanometer gives full scale deflection for a current I_g, then S is given by:

(A) $\frac{I_g G}{I_A - I_g}$

(B) $\frac{I_A G}{I_g - I_A}$

(C) $\frac{(I_A - I_g)G}{I_g}$

(D) $\frac{I_g G}{I_A}$

Q17. Which of the following statements is true for a diamagnetic material?

(A) It is strongly attracted by a magnetic field.

(B) Its magnetic susceptibility is large and positive.

(C) It moves from stronger to weaker parts of an external magnetic field.

(D) It retains magnetism after the external field is removed.

Q18. A long solenoid has 1000 turns/meter and carries a current of $2A$. The magnetic field inside the solenoid is (permeability of free space $\mu_0 = 4\pi \times 10^{-7} Tm/A$):

(A) $8\pi \times 10^{-4} T$

(B) $8\pi \times 10^{-5} T$

(C) $2\pi \times 10^{-4} T$

(D) $4\pi \times 10^{-4} T$

Q19. Ampere's circuital law is analogous to Gauss's law in electrostatics. It states that the line integral of magnetic field $\vec{B}$ around any closed loop is equal to:

(A) μ_0 times the total current passing through the loop.

(B) Zero.

(C) The magnetic flux through the loop.

(D) μ_0 times the displacement current.

Q20. A proton, a deuteron, and an alpha particle, all having the same kinetic energy, enter a region of uniform magnetic field perpendicularly. The ratio of their radii of circular paths is:

(A) $1 : \sqrt{2} : 1$

(B) $1 : 1 : 1$

(C) $1 : \sqrt{2} : \sqrt{2}$

(D) $1 : 1 : \sqrt{2}$

Q21. A transformer has 100 turns in the primary coil and 1000 turns in the secondary coil. If the input power is $100W$ at $2V$, assuming 100% efficiency, the output voltage and current are:

(A) $20V, 5A$

(B) $20V, 0.5A$

(C) $200V, 0.5A$

(D) $200V, 5A$

Q22. In an LCR series circuit, the voltage across the inductor (V_L), capacitor (V_C), and resistor (V_R) are $40V$, $20V$, and $30V$ respectively. The supply voltage is:

(A) $90V$

(B) $50V$

(C) $70V$

(D) $36.05V$

Q23. Lenz's Law is a consequence of the principle of conservation of:

(A) Charge

(B) Momentum

(C) Energy

(D) Magnetic flux

Q24. A conducting rod of length L is moved with a uniform velocity v perpendicular to a uniform magnetic field B. The induced EMF developed between the ends of the rod is:

(A) BLv

(B) B/Lv

(C) Bv/L

(D) BL/v

Q25. The quality factor (Q-factor) of a series LCR circuit is given by:

(A) $R\sqrt{L/C}$

(B) $\frac{1}{R}\sqrt{L/C}$

(C) $\frac{1}{R}\sqrt{C/L}$

(D) $R\sqrt{C/L}$

Q26. An AC generator produces a maximum EMF of $100V$. What is its RMS EMF?

(A) $100V$

(B) $70.7V$

(C) $141.4V$

(D) $50V$

Q27. The concept of displacement current was introduced by Maxwell to resolve the inconsistency in Ampere's circuital law when applied to a:

(A) Wire with steady current

(B) Solenoid

(C) Capacitor during charging or discharging

(D) Coaxial cable

Q28. Which of the following electromagnetic waves has the lowest frequency?

(A) X-rays

(B) Radio waves

(C) Ultraviolet rays

(D) Microwaves

Q29. A convex lens of focal length f is immersed in water (refractive index 1.33). If the refractive index of the lens material is 1.5, its focal length in water will be:

(A) f (unchanged)

(B) Greater than f

(C) Less than f

(D) Zero

Q30. In Young's Double Slit Experiment (YDSE), if the monochromatic light source is replaced by white light, what will be observed on the screen?

(A) A central white fringe surrounded by colored fringes.

(B) Only a central white fringe.

(C) Only colored fringes with no white fringe.

(D) All fringes appear white.

Q31. An astronomical telescope has an objective lens of focal length $100cm$ and an eyepiece of focal length $5cm$. When the telescope is in normal adjustment, its magnifying power is:

(A) 100

(B) 20

(C) 105

(D) 500

Q32. The phenomenon of diffraction of light is best explained by assuming light to be:

(A) Composed of particles

(B) A longitudinal wave

(C) A transverse wave

(D) Both particle and wave

Q33. A person suffering from hypermetropia (farsightedness) needs to use a lens of:

(A) Convex lens

(B) Concave lens

(C) Cylindrical lens

(D) Bifocal lens

Q34. For a single slit diffraction pattern, if the width of the slit is a and the wavelength of light is λ, the angular width of the central maximum is:

(A) λ/a

(B) $2\lambda/a$

(C) a/λ

(D) $2a/\lambda$

Q35. The least distance of distinct vision for a normal human eye is approximately:

(A) $2.5cm$

(B) $25cm$

(C) $2.5m$

(D) $25m$

Q36. Two thin lenses of focal lengths f_1 and f_2 are placed in contact. The effective power of the combination is:

(A) $P_1 + P_2$

(B) $P_1 - P_2$

(C) $P_1 P_2$

(D) $(P_1 + P_2)/(P_1 P_2)$

Q37. The phenomenon of total internal reflection occurs when light travels from:

(A) Denser to rarer medium

(B) Rarer to denser medium

(C) Air to vacuum

(D) Glass to water

Q38. In the photoelectric effect, if the intensity of the incident light is doubled, while keeping the frequency constant, what happens to the maximum kinetic energy of the emitted photoelectrons?

(A) It doubles.

(B) It becomes half.

(C) It remains unchanged.

(D) It quadruples.

Q39. The de-Broglie wavelength of an electron accelerated through a potential difference V is given by:

(A) $\frac{h}{\sqrt{2meV}}$

(B) $\frac{h}{\sqrt{2mV}}$

(C) $\frac{h}{\sqrt{eV}}$

(D) $\frac{\sqrt{2meV}}{h}$

Q40. If the threshold frequency for a photoelectric material is f_0, and light of frequency $2f_0$ is incident on it, the stopping potential will be:

(A) $\frac{hf_0}{e}$

(B) $\frac{2hf_0}{e}$

(C) $\frac{hf_0}{2e}$

(D) Zero

Q41. Which of the following graphs correctly represents the variation of particle momentum (p) with its de-Broglie wavelength (λ)?

(A) $p \propto \lambda$ (linear increase)

(B) $p \propto 1/\lambda$ (hyperbola)

(C) $p \propto \lambda^2$ (parabola)

(D) p is independent of λ

Q42. According to Bohr's model, the energy of an electron in the n^{th} orbit of a hydrogen atom is proportional to:

(A) n

(B) n^2

(C) $1/n$

(D) $1/n^2$

Q43. The binding energy per nucleon is maximum for nuclei with mass number approximately:

(A) 20

(B) 56

(C) 120

(D) 235

Q44. In nuclear fission, a heavy nucleus breaks into two or more smaller nuclei. This process releases energy because:

(A) The total mass of the products is greater than the initial nucleus.

(B) The total binding energy of the products is less than the initial nucleus.

(C) The total binding energy of the products is greater than the initial nucleus.

(D) The sum of the atomic numbers changes.

Q45. The half-life of a radioactive isotope is 4 hours. After 12 hours, the fraction of the initial number of undecayed atoms remaining is:

(A) $1/2$

(B) $1/4$

(C) $1/8$

(D) $1/16$

Q46. When an electron jumps from the $n = 4$ orbit to the $n = 2$ orbit in a hydrogen atom, the emitted radiation corresponds to:

(A) Lyman series

(B) Balmer series

(C) Paschen series

(D) Brackett series

Q47. In a p-n junction diode, the barrier potential primarily arises due to:

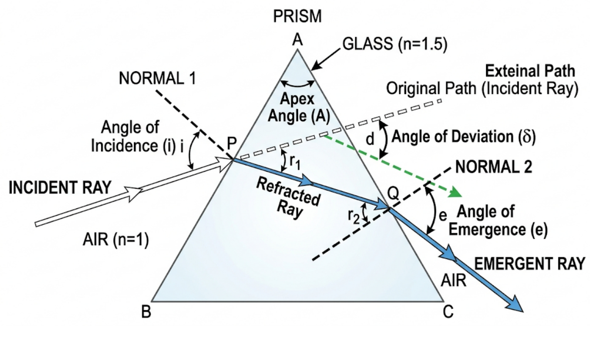
(A) Accumulation of charges near the junction due to doping.

(B) Diffusion of majority carriers across the junction, leaving behind immobile ions.

(C) Flow of minority carriers across the junction.

(D) External voltage applied across the junction.

Q48. A ray of light is incident on a prism as shown in an accompanying diagram.



Which of the following relations is always true for the angles of a prism (angle of prism A, angle of incidence i, angle of emergence e, and angle of deviation δ)?

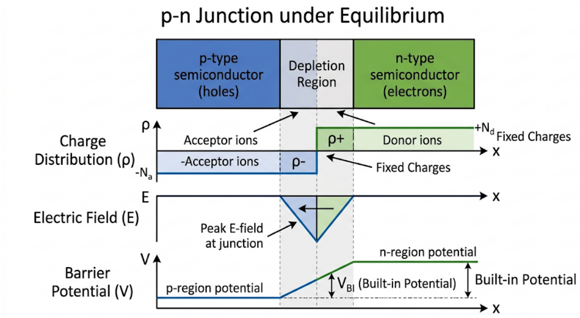
(A) $i + A = e + \delta$

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

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

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

Q49. An accompanying diagram illustrates the basic structure of a p-n junction diode.



When this p-n junction diode is subjected to reverse bias, which of the following phenomena occurs?

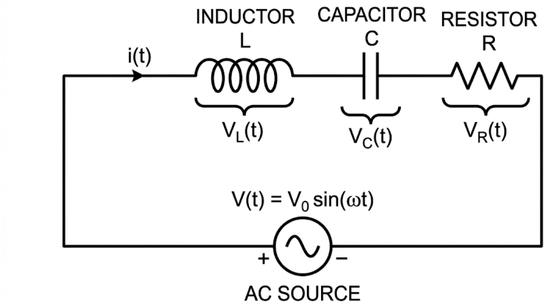
(A) The width of the depletion region increases, and the barrier potential increases.

(B) The width of the depletion region decreases, and the barrier potential decreases.

(C) The width of the depletion region increases, and the barrier potential decreases.

(D) The width of the depletion region decreases, and the barrier potential increases.

Q50. Observe the given circuit diagram which represents an LCR series AC circuit connected to a variable frequency AC source.



At resonance, what is the phase relationship between the applied voltage (V) and the current (I) flowing through this series LCR circuit?

(A) Voltage leads current by 90°.

(B) Current leads voltage by 90°.

(C) Voltage and current are in phase.

(D) Voltage lags current by 45°.

Detailed Solutions

Q1.

Solution

Concept: The torque on an electric dipole in a uniform electric field is given by the vector cross product of the dipole moment and the electric field. The potential energy of an electric dipole in a uniform electric field is given by the negative of the scalar dot product of the dipole moment and the electric field.

Solution: For an electric dipole of dipole moment $\vec{p}$ placed in a uniform electric field $\vec{E}$:

1. The torque $\vec{\tau}$ acting on the dipole is given by $\vec{\tau} = \vec{p} \times \vec{E}$. This formula correctly represents the rotational effect of the field on the dipole.

2. The potential energy U of the dipole in the field is given by $U = -\vec{p} \cdot \vec{E}$. This formula indicates that the potential energy is minimum when the dipole moment is aligned with the electric field ($\theta = 0°, U = -pE$) and maximum when anti-aligned ($\theta = 180°, U = pE$).

Comparing these standard formulas with the given options, option C matches both expressions.

Final Answer : "$\tau = \vec{p} \times \vec{E}, U = -\vec{p} \cdot \vec{E}$"

Answer: (C)

Q2.

Solution

Concept: The electric potential due to a charged spherical conductor or shell. For a point outside a charged sphere, it behaves as if all charge is at the center. For a point inside a charged spherical shell, the potential is constant and equal to the potential on the surface of the shell.

Solution: Let V_R be the potential on the inner spherical conductor (at radius R) and V_{2R} be the potential on the outer spherical shell (at radius $2R$).

The potential on the inner sphere (radius R, charge Q) is due to its own charge Q and the charge $-Q$ on the outer shell (radius $2R$).

$V_R = \frac{1}{4\pi\epsilon_0}\frac{Q}{R} + \frac{1}{4\pi\epsilon_0}\frac{(-Q)}{2R}$ (Potential due to inner sphere at its surface + Potential due to outer shell at R, where for points inside the outer shell, its potential is constant and equal to its surface potential).

The potential on the outer spherical shell (radius $2R$, charge $-Q$) is due to the inner charge Q and its own charge $-Q$.

$V_{2R} = \frac{1}{4\pi\epsilon_0}\frac{Q}{2R} + \frac{1}{4\pi\epsilon_0}\frac{(-Q)}{2R} = 0.$ (Potential due to inner sphere at $2R$ + Potential due to outer shell at its surface).

The potential difference between the two spheres is:

$\Delta V = V_R - V_{2R} = \left(\frac{1}{4\pi\epsilon_0}\frac{Q}{R} - \frac{1}{4\pi\epsilon_0}\frac{Q}{2R}\right) - 0$ $\Delta V = \frac{Q}{4\pi\epsilon_0}\left(\frac{1}{R} - \frac{1}{2R}\right)$ $\Delta V = \frac{Q}{4\pi\epsilon_0}\left(\frac{2-1}{2R}\right)$ $\Delta V = \frac{1}{4\pi\epsilon_0}\frac{Q}{2R}$.

Final Answer : "$\frac{1}{4\pi\epsilon_0}\frac{Q}{2R}$"

Answer: (B)

Q3.

Solution

Concept: For capacitors in parallel, the equivalent capacitance is the sum of individual capacitances ($C_p = C_1 + C_2 + ...$). For capacitors in series, the reciprocal of the equivalent capacitance is the sum of the reciprocals of individual capacitances ($1/C_s = 1/C_1 + 1/C_2 + ...$).

Solution: Given capacitances: $C_1 = 2\mu F$, $C_2 = 3\mu F$, and $C_3 = 6\mu F$.

1. C_1 and C_2 are in parallel.

The equivalent capacitance for this parallel combination (C_{12}) is:

$C_{12} = C_1 + C_2 = 2\mu F + 3\mu F = 5\mu F$.

2. This combination (C_{12}) is in series with C_3.

The equivalent capacitance of the arrangement (C_{eq}) is found using the series formula:

$\frac{1}{C_{eq}} = \frac{1}{C_{12}} + \frac{1}{C_3}$

$\frac{1}{C_{eq}} = \frac{1}{5\mu F} + \frac{1}{6\mu F}$

$\frac{1}{C_{eq}} = \frac{6+5}{30\mu F} = \frac{11}{30\mu F}$

$C_{eq} = \frac{30}{11}\mu F$.

Calculating the value: $C_{eq} \approx 2.727\mu F$.

Among the given options:

A) $1\mu F$
B) $2\mu F$
C) $3\mu F$
D) $11\mu F$

The calculated value $2.727\mu F$ is closest to $3\mu F$.

Final Answer : "$3\mu F$"

Answer: (C)

Q4.

Solution

Concept: The capacitance of a parallel plate capacitor is $C = \frac{\epsilon_0 A}{d}$. When a dielectric slab is inserted, it can be treated as a combination of capacitors. If the dielectric fills a portion of the gap, it can be modeled as two capacitors in series: one with air and one with the dielectric.

Solution: Let the original capacitance be $C = \frac{\epsilon_0 A}{d}$, where A is the area of the plates and d is the plate separation.

When a dielectric slab of dielectric constant K and thickness $d/2$ is inserted, the space between the plates can be considered as two capacitors in series:

1. An air capacitor of thickness $d/2$. Its capacitance $C_1 = \frac{\epsilon_0 A}{d/2} = \frac{2\epsilon_0 A}{d} = 2C$.

2. A dielectric capacitor of thickness $d/2$ and dielectric constant K. Its capacitance $C_2 = \frac{K\epsilon_0 A}{d/2} = \frac{2K\epsilon_0 A}{d} = 2KC$.

For capacitors in series, the equivalent capacitance C_{new} is given by:

$$\frac{1}{C_{new}} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C_{new}} = \frac{1}{2C} + \frac{1}{2KC}$$

To combine these fractions, find a common denominator:

$$\frac{1}{C_{new}} = \frac{K}{2KC} + \frac{1}{2KC} = \frac{K+1}{2KC}$$

Therefore, the new capacitance C_{new} is:

$$C_{new} = \frac{2KC}{K+1}.$$

Final Answer : "$\frac{2KC}{K+1}$"

Answer: (A)

Q5.

Solution

Concept: Gauss's Law states that the total electric flux (Φ_E) through any closed surface is equal to the net charge (Q_{enc}) enclosed by the surface divided by the permittivity of free space (ϵ_0). Mathematically, $\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\epsilon_0}$.

Solution: A point charge q is placed at the center of a cube. The cube acts as a closed surface. According to Gauss's Law, the total electric flux emerging from any closed surface is independent of the shape or size of the surface, as long as it encloses the same net charge. In this case, the charge $Q_{enc} = q$ is entirely enclosed by the cube.

Therefore, the total electric flux emerging from the surface of the cube is $\Phi_E = \frac{q}{\epsilon_0}$.

The side length L of the cube is irrelevant for the total flux, as long as the charge is enclosed.

Final Answer : "$\frac{q}{\epsilon_0}$"

Answer: (A)

Q6.

Solution

Concept: The magnitude of the torque (τ) experienced by an electric dipole of dipole moment p in a uniform electric field E at an angle θ with the field is given by $\tau = pE \sin\theta$. The electric dipole moment p is defined as the product of the magnitude of one charge q and the separation distance $2a$ between the charges, i.e., $p = q \times (2a)$.

Solution: Given: Magnitude of charges, $q = 1\mu C = 1 \times 10^{-6}C$.

Separation distance, $2a = 2cm = 2 \times 10^{-2}m$.

Electric field, $E = 10^5 N/C$.

Angle with the field, $\theta = 30°$.

First, calculate the electric dipole moment p:

$p = q \times (2a) = (1 \times 10^{-6}C) \times (2 \times 10^{-2}m) = 2 \times 10^{-8}C \cdot m$.

Now, calculate the magnitude of the torque τ:

$\tau = pE \sin\theta$

$\tau = (2 \times 10^{-8}C \cdot m) \times (10^5 N/C) \times \sin(30°)$

Since $\sin(30°) = \frac{1}{2}$:

$\tau = (2 \times 10^{-8}) \times (10^5) \times \frac{1}{2}$

$\tau = 1 \times 10^{-3}Nm$.

Final Answer : "$1 \times 10^{-3}Nm$"

Answer: (A)

Q7.

Solution

Concept: This describes charging by induction with grounding. When a charged object is brought near a conductor connected to the ground, free charges in the conductor redistribute. Charges of the opposite sign to the charged object are attracted to the conductor, while charges of the same sign are repelled and flow to/from the ground. When the ground connection is removed, the conductor is left with a net charge opposite to that of the inducing charged object.

Solution: 1. Bring charged rod near sphere: Let's assume the rod is positively charged. When it's brought near the metal sphere (without touching), it attracts free electrons within the sphere towards the side closer to the rod. The side of the sphere near the rod becomes negatively charged, and the side away from the rod becomes positively charged (due to a deficit of electrons).

2. Sphere connected to ground: Since the sphere is connected to the ground, it provides a path for charge flow. The positive charges repelled by the rod (which are actually the atomic nuclei of the sphere that remain after electrons are attracted away) cannot move, but the electrons from the ground (an infinite reservoir of charge) are attracted by the positive rod and flow onto the sphere.

3. Result: The sphere acquires a net negative charge. If the rod were negatively charged, it would repel electrons from the sphere into the ground, leaving the sphere with a net positive charge.

In both cases, the sphere acquires a charge opposite to that of the rod.

Final Answer : "The sphere acquires a charge opposite to that of the rod."

Answer: (A)

Q8.

Solution

Concept: The energy U stored in a capacitor can be expressed in terms of charge Q and capacitance C as $U = \frac{Q^2}{2C}$.

Solution: Initial energy stored in the capacitor is $U = \frac{Q^2}{2C}$.

According to the problem, the charge is doubled and the capacitance is halved.

New charge $Q' = 2Q$.

New capacitance $C' = C/2$.

Substitute these new values into the energy formula to find the new energy U':

$U' = \frac{(Q')^2}{2C'}$

$U' = \frac{(2Q)^2}{2(C/2)}$

$U' = \frac{4Q^2}{C}$

Now, express U' in terms of the original energy U:

We know $U = \frac{Q^2}{2C}$.

So, $\frac{Q^2}{C} = 2U$.

Substitute this into the expression for U':

$U' = 4 \times \left(\frac{Q^2}{C}\right) = 4 \times (2U) = 8U.$

The new energy stored will be $8U$.

Final Answer : "$8U$"

Answer: (D)

Q9.

Solution

Concept: The relationship between current (I) and drift velocity (v_d) of electrons in a conductor is given by $I = nAev_d$, where n is the number density of free electrons, A is the cross-sectional area of the conductor, and e is the elementary charge. From this, drift velocity $v_d = \frac{I}{nAe}$.

Solution: Let the initial current be $I_1 = I$ and the initial cross-sectional area be $A_1 = A$. The initial drift velocity is $v_d = \frac{I}{nAe}$.

Now, the current is doubled ($I_2 = 2I$) and the cross-sectional area is halved ($A_2 = A/2$). The new drift velocity v_{d2} will be:

$v_{d2} = \frac{I_2}{nA_2e}$

Substitute the new values for current and area:

$v_{d2} = \frac{2I}{n(A/2)e}$

$v_{d2} = \frac{2I \times 2}{nAe}$

$v_{d2} = \frac{4I}{nAe}$

Since $v_d = \frac{I}{nAe}$, we can substitute this into the expression for v_{d2}:

$v_{d2} = 4 \times \left(\frac{I}{nAe}\right)$

$v_{d2} = 4v_d$.

The new drift velocity will be $4v_d$.

Final Answer : "$4v_d$"

Answer: (C)

Q10.

Solution

Concept: A Wheatstone bridge is balanced when the galvanometer connected between the two midpoints shows no deflection (zero current). This occurs when the potential difference across the galvanometer is zero, which implies a specific ratio of resistances in the four arms.

Solution: Let the four resistances in the arms of the Wheatstone bridge be P, Q, R, S. When the bridge is balanced, the potential at the junction between P and R (say, point B) is equal to the potential at the junction between Q and S (say, point D). This means there is no current flowing through the galvanometer connected between B and D.

Under this condition, the ratio of resistances in adjacent arms is equal. Specifically:

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

This can also be written as $PS = QR$.

Another equivalent form is $\frac{P}{R} = \frac{Q}{S}$.

Among the given options, option B, $P/Q = R/S$, correctly states the balance condition for a Wheatstone bridge.

Final Answer : "$P/Q = R/S$"

Answer: (B)

Q11.

Solution

Concept: When two cells with EMFs E_1, E_2 and internal resistances r_1, r_2 are connected in parallel, the equivalent EMF (E_{eq}) and equivalent internal resistance (r_{eq}) can be found by considering the combined current output and voltage across the combination. A common method involves using the reciprocal of resistance for parallel components and applying Kirchhoff's laws or nodal analysis.

Solution: For two cells with EMFs E_1 and E_2 and internal resistances r_1 and r_2 connected in parallel, the formula for the equivalent EMF (E_{eq}) is:

$$E_{eq} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}$$

To simplify this expression, find a common denominator for the numerator and the denominator:

Numerator: $\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}$

Denominator: $\frac{r_2 + r_1}{r_1 r_2}$

Substitute these back into the formula for E_{eq}:

$$E_{eq} = \frac{\frac{E_1 r_2 + E_2 r_1}{r_1 r_2}}{\frac{r_1 + r_2}{r_1 r_2}}$$

Cancel out $r_1 r_2$ from the numerator and denominator:

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

This formula holds true when the positive terminals are connected together and the negative terminals are connected together.

Final Answer : "$\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$"

Answer: (C)

Q12.

Solution

Concept: The power consumed by an electrical appliance is given by $P = V^2/R$, where V is the voltage across the appliance and R is its resistance. The resistance of an appliance is typically constant, and can be calculated from its rated power and rated voltage using $R = V_{rated}^2/P_{rated}$.

Solution: Given:

Rated power $P_{rated} = 100W$.

Rated voltage $V_{rated} = 200V$.

First, calculate the resistance R of the bulb. The resistance of the bulb is a constant value: $R = \frac{V_{rated}^2}{P_{rated}} = \frac{(200V)^2}{100W} = \frac{40000}{100}\Omega = 400\Omega$.

Now, the bulb is connected across a supply voltage $V_{supply} = 100V$.

The power consumed by the bulb ($P_{consumed}$) at this new voltage is:

$$P_{consumed} = \frac{V_{supply}^2}{R}$$

$$P_{consumed} = \frac{(100V)^2}{400\Omega} = \frac{10000}{400}W = 25W.$$

Final Answer : "25W"

Answer: (C)

Q13.

Solution

Concept: Kirchhoff's First Law, also known as the junction rule or current law, states that the algebraic sum of currents entering any junction in an electrical circuit is equal to the algebraic sum of currents leaving that junction.

Solution: Kirchhoff's First Law can be expressed mathematically as $\sum I_{in} = \sum I_{out}$ or $\sum I = 0$ (where currents entering are positive and leaving are negative, or vice-versa). This law essentially means that charge cannot accumulate at any point in a circuit. If charge flows into a junction, an equal amount of charge must flow out in the same amount of time. Therefore, this law is a direct consequence of the principle of conservation of charge.

Final Answer : "Charge"

Answer: (B)

Q14.

Solution

Concept: The resistance of a wire is directly proportional to its length ($R = \rho L/A$). When resistors are connected in parallel, the equivalent resistance R_{eq} is given by $\frac{1}{R_{eq}} = \sum \frac{1}{R_i}$. For n identical resistors each of resistance R', connected in parallel, $R_{eq} = R'/n$.

Solution: 1. Resistance of each part: A wire of total resistance R is cut into n equal parts. Since resistance is directly proportional to length, the resistance of each individual part, let's call it R', will be $R' = R/n$.

2. Equivalent resistance in parallel: These n equal parts, each having a resistance R/n, are then connected in parallel. For n identical resistors connected in parallel, the equivalent resistance R_{eq} is the resistance of one part divided by the number of parts: $R_{eq} = \frac{R'}{n}$

3. Substitute R': $R_{eq} = \frac{R/n}{n} = \frac{R}{n^2}$.

Final Answer : "R/n^2"

Answer: (C)

Q15.

Solution

Concept: Two parallel current-carrying conductors exert a force on each other. If the currents are in the same direction, they attract; if in opposite directions, they repel. The magnitude of the magnetic field produced by a long straight current-carrying wire is inversely proportional to the distance from the wire ($B \propto 1/r$). Consequently, the force between current-carrying wires is stronger when they are closer.

Solution: Let the current in the long straight conductor be I_1 and the current in the rectangular loop be I_2.

The magnetic field produced by the long straight conductor is stronger closer to the wire.

Consider the two sides of the rectangular loop parallel to the straight conductor:

1. Inner side: This side is at distance a from the straight conductor.

2. Outer side: This side is at distance b from the straight conductor ($b > a$).

The current in the inner side of the loop will be in the same direction as I_1 (to complete the loop circulation). This means the inner side will experience an attractive force towards the straight conductor.

The current in the outer side of the loop will be in the opposite direction to I_1. This means the outer side will experience a repulsive force from the straight conductor.

Since $a < b$, the magnetic field at distance a is stronger than the magnetic field at distance b. Therefore, the attractive force on the inner side (F_a) will be greater in magnitude than the repulsive force on the outer side (F_b).

The forces on the other two sides of the loop (perpendicular to the straight conductor) will be equal and opposite, thus canceling each other out.

The net magnetic force on the loop will be the difference between the attractive and repulsive forces: $F_{net} = F_a - F_b$. Since $F_a > F_b$, the net force on the loop will be attractive.

Final Answer : “Attractive”

Answer: (A)

Q16.

Solution

Concept: To convert a galvanometer into an ammeter, capable of measuring larger currents, a low resistance (shunt resistance S) is connected in parallel with the galvanometer. The total current I_A entering the ammeter splits, with a part I_g going through the galvanometer for full-scale deflection, and the remaining part $(I_A - I_g)$ passing through the shunt. Since the galvanometer and shunt are connected in parallel, the potential difference across them must be the same.

Solution: Given:
Resistance of galvanometer = G
Current for full-scale deflection of galvanometer = I_g
Range of ammeter (maximum total current) = I_A
Shunt resistance = S (connected in parallel with G)

When the total current I_A flows through the ammeter, it divides:
Current through galvanometer = I_g
Current through shunt resistance = $I_S = I_A - I_g$

Since the galvanometer and the shunt resistance are connected in parallel, the voltage drop across them must be equal:
Voltage across galvanometer (V_g) = Voltage across shunt resistance (V_S)

Using Ohm's Law ($V = IR$):
$I_g G = I_S S$

Substitute the expression for I_S:
$I_g G = (I_A - I_g)S$

To find the shunt resistance S, rearrange the equation:
$S = \frac{I_g G}{I_A - I_g}$

Final Answer : "$\frac{I_g G}{I_A - I_g}$"

Answer: (A)

Q17.

Solution

Concept: Diamagnetic materials are those that are weakly repelled by an external magnetic field. This repulsion occurs because an external field induces an opposing magnetic dipole moment in the material. Their magnetic susceptibility (χ_m) is small and negative. They do not retain magnetism once the external field is removed.

Solution: Let's analyze each statement for a diamagnetic material:

A) **It is strongly attracted by a magnetic field.** This is false. Diamagnetic materials are weakly repelled by a magnetic field. Paramagnetic materials are weakly attracted, and ferromagnetic materials are strongly attracted.

B) **Its magnetic susceptibility is large and positive.** This is false. Diamagnetic materials have a small and *negative* magnetic susceptibility ($\chi_m < 0$).

C) **It moves from stronger to weaker parts of an external magnetic field.** This is true. Because diamagnetic materials are repelled by magnetic fields, they tend to move away from regions of higher magnetic field strength towards regions of weaker magnetic field strength.

D) **It retains magnetism after the external field is removed.** This is false. Diamagnetism is an induced phenomenon; it exists only in the presence of an external magnetic field. Once the external field is removed, the induced magnetic moment disappears, and the material loses its magnetism.

Final Answer : "It moves from stronger to weaker parts of an external magnetic field."

Answer: (C)

Q18.

Solution

Concept: The magnetic field inside a long solenoid is uniform and can be calculated using the formula $B = \mu_0 n I$, where μ_0 is the permeability of free space, n is the number of turns per unit length, and I is the current flowing through the solenoid.

Solution: Given:

Number of turns per meter, $n = 1000$ turns/meter.

Current, $I = 2A$.

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ Tm/A.

Using the formula for the magnetic field inside a long solenoid:

$$B = \mu_0 n I$$
$$B = (4\pi \times 10^{-7}\ \text{Tm/A}) \times (1000\ \text{m}^{-1}) \times (2A)$$
$$B = (4\pi \times 10^{-7}) \times (10^3) \times (2)$$
$$B = 8\pi \times 10^{(-7+3)} T$$
$$B = 8\pi \times 10^{-4} T.$$

Final Answer : "$8\pi \times 10^{-4} T$"

Answer: (A)

Q19.

Solution

Concept: Ampere's Circuital Law is a fundamental law in electromagnetism that relates the line integral of the magnetic field around a closed loop to the electric current passing through the surface enclosed by the loop. It is one of Maxwell's equations.

Solution: Ampere's Circuital Law states that the line integral of the magnetic field $\vec{B}$ around any closed loop is directly proportional to the total current (I_{enc}) passing through the area bounded by the loop. The constant of proportionality is μ_0, the permeability of free space. Mathematically, this is expressed as:
$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$

Here, I_{enc} refers to the net conduction current passing through the loop. While Maxwell later added a displacement current term (I_D) to make it consistent with the conservation of charge and applicable to time-varying fields, the question refers to the basic Ampere's Circuital Law.

Therefore, it is equal to μ_0 times the total current passing through the loop.

Final Answer : "μ_0 times the total current passing through the loop."

Answer: (A)

Q20.

Solution

Concept: When a charged particle with charge q and mass m moves with velocity v perpendicular to a uniform magnetic field B, it follows a circular path. The magnetic force (qvB) provides the centripetal force (mv^2/r). The kinetic energy of the particle is $KE = \frac{1}{2}mv^2$.

Solution: 1. Radius of circular path: Equating magnetic force to centripetal force: $qvB = \frac{mv^2}{r} \implies r = \frac{mv}{qB}$

2. Relating momentum to kinetic energy: We are given that all particles have the same kinetic energy (KE). $KE = \frac{1}{2}mv^2 \implies 2mKE = m^2v^2 \implies mv = \sqrt{2mKE}$

3. Expression for radius in terms of KE: Substitute $mv = \sqrt{2mKE}$ into the radius equation: $r = \frac{\sqrt{2mKE}}{qB}$

4. Proportionality for radius: Since KE and B are the same for all particles, the radius r is proportional to $\frac{\sqrt{m}}{q}$. $r \propto \frac{\sqrt{m}}{q}$

5. Characteristics of the particles: Proton (p): Mass = m_p, Charge = $+e$. Ratio $\propto \frac{\sqrt{m_p}}{e}$. Deuteron (d): A deuteron (isotope of hydrogen) has 1 proton and 1 neutron. Mass = $2m_p$, Charge = $+e$. Ratio $\propto \frac{\sqrt{2m_p}}{e} = \sqrt{2}\frac{\sqrt{m_p}}{e}$.
Alpha particle (α): An alpha particle (helium nucleus) has 2 protons and 2 neutrons.
Mass = $4m_p$, Charge = $+2e$. Ratio $\propto \frac{\sqrt{4m_p}}{2e} = \frac{2\sqrt{m_p}}{2e} = \frac{\sqrt{m_p}}{e}$.

6. Ratio of radii:
$r_p : r_d : r_\alpha :: \frac{\sqrt{m_p}}{e} : \sqrt{2}\frac{\sqrt{m_p}}{e} : \frac{\sqrt{m_p}}{e}$
Dividing by the common factor $\frac{\sqrt{m_p}}{e}$, we get the ratio: $r_p : r_d : r_\alpha :: 1 : \sqrt{2} : 1$.

Final Answer : "$1 : \sqrt{2} : 1$"

Answer: (A)

Q21.

Solution

Concept: For an ideal transformer (assuming 100% efficiency), the input power is equal to the output power ($P_{in} = P_{out}$). The voltage and current ratios in a transformer are related to the number of turns in the primary (N_p) and secondary (N_s) coils. Specifically, the ratio of secondary voltage (V_s) to primary voltage (V_p) is equal to the ratio of secondary turns to primary turns: $\frac{V_s}{V_p} = \frac{N_s}{N_p}$. Conversely, the ratio of secondary current (I_s) to primary current (I_p) is inversely proportional to the turns ratio: $\frac{I_s}{I_p} = \frac{N_p}{N_s}$. Power is also defined as the product of voltage and current: $P = VI$.

Solution: Given information:
Number of turns in primary coil, $N_p = 100$.
Number of turns in secondary coil, $N_s = 1000$.
Input power, $P_{in} = 100W$.
Input voltage, $V_p = 2V$.
Efficiency is assumed to be 100%.

Step 1: Calculate the output voltage (V_s).
We use the transformer voltage ratio formula:
$\frac{V_s}{V_p} = \frac{N_s}{N_p}$
Rearranging to solve for V_s:
$V_s = V_p \times \frac{N_s}{N_p}$
Substitute the given values:
$V_s = 2V \times \frac{1000}{100}$
$V_s = 2V \times 10$
$V_s = 20V$.

Step 2: Calculate the output current (I_s).
Since the transformer is 100% efficient, the output power is equal to the input power: $P_{out} = P_{in} = 100W$.
The output power is also given by the product of output voltage and output current: $P_{out} = V_s I_s$
Rearranging to solve for I_s:
$I_s = \frac{P_{out}}{V_s}$
Substitute the calculated V_s and given P_{out}:
$I_s = \frac{100W}{20V}$
$I_s = 5A$.

Therefore, the output voltage is $20V$ and the output current is $5A$.

Final Answer : "$20V, 5A$"

Answer: (A)

Q22.

Solution

Concept: In a series LCR (Inductor-Capacitor-Resistor) circuit driven by an alternating current (AC) source, the voltages across the individual components (V_R across the resistor, V_L across the inductor, and V_C across the capacitor) are generally not in phase with each other. The voltage across the resistor (V_R) is in phase with the current. The voltage across the inductor (V_L) leads the current by 90°, and the voltage across the capacitor (V_C) lags the current by 90°. This means V_L and V_C are 180° out of phase with each other and can be subtracted directly as phasors. The total supply voltage (V) is the phasor sum of these voltages and can be found using the formula derived from phasor diagrams: $V = \sqrt{V_R^2 + (V_L - V_C)^2}$.

Solution: Given voltage values for the components in a series LCR circuit:
Voltage across the inductor, $V_L = 40V$.
Voltage across the capacitor, $V_C = 20V$.
Voltage across the resistor, $V_R = 30V$.

We need to find the supply voltage (V). Using the formula for the supply voltage in a series LCR circuit:
$V = \sqrt{V_R^2 + (V_L - V_C)^2}$

First, calculate the difference between the inductive and capacitive voltages:
$V_L - V_C = 40V - 20V = 20V$.

Now, substitute this value and V_R into the formula:
$V = \sqrt{(30V)^2 + (20V)^2}$
$V = \sqrt{900 + 400}$
$V = \sqrt{1300}$

To find the numerical value:
$V \approx 36.055V$.

Rounding to two decimal places, the supply voltage is approximately $36.06V$. Among the given options, $36.05V$ is the closest.

Final Answer : "36.05V"

Answer: (D)

Q23.

Solution

Concept: Lenz's Law is a fundamental principle in electromagnetism that describes the direction of induced currents. It states that the direction of the induced electromotive force (EMF) or current in a conductor is always such that it opposes the change in magnetic flux that produced it. This opposition is crucial for maintaining a consistent physical framework.

Solution: Lenz's Law is a direct consequence and an application of the principle of conservation of energy.

To understand why, consider a scenario where Lenz's law was not true. If the induced current were to *assist* the change in magnetic flux (instead of opposing it), the following would happen:
1. A change in magnetic flux (e.g., moving a magnet towards a coil) would induce a current.
2. If this induced current generated a magnetic field that reinforced the original change, it would further increase the magnetic flux.
3. This increased flux would, in turn, induce an even stronger current, which would further increase the flux, and so on.
4. This would create a self-sustaining process where the current and magnetic field would grow indefinitely without any external work being done, generating an infinite amount of electrical energy from nothing.

This hypothetical scenario directly violates the law of conservation of energy, which states that energy cannot be created or destroyed, only transformed from one form to another. Therefore, the opposing nature described by Lenz's Law is necessary to ensure that energy is conserved. When work is done to move a magnet towards a coil (or vice-versa), this mechanical work is converted into the electrical energy of the induced current, overcoming the opposition described by Lenz's Law. Without this opposition, no work would be required to generate current, leading to a violation of energy conservation.

Final Answer : "Energy"

Answer: (C)

Q24.

Solution

Concept: Motional electromotive force (EMF) is an EMF induced across the ends of a conductor when it moves in a magnetic field such that the conductor cuts the magnetic field lines. This phenomenon occurs due to the Lorentz force acting on the charge carriers (electrons) within the moving conductor. When a conductor moves through a magnetic field, the free electrons within it experience a magnetic force, causing them to accumulate at one end of the conductor, while the other end becomes positively charged. This separation of charge creates an electric field and thus a potential difference (EMF) across the conductor.

Solution: Given: Length of the conducting rod = L. Uniform velocity of the rod = v. Uniform magnetic field = B.

The problem states that the velocity v is perpendicular to the magnetic field B, and implicitly, the length L of the rod is also perpendicular to both v and B. This is the configuration that produces the maximum induced motional EMF.

Consider a free electron of charge e inside the rod. As the rod moves with velocity $\vec{v}$ in a magnetic field $\vec{B}$, each electron experiences a magnetic Lorentz force $\vec{F_B} = e(\vec{v} \times \vec{B})$. Since $\vec{v}$ and $\vec{B}$ are perpendicular, the magnitude of the force is $F_B = evB$. This force pushes the electrons towards one end of the rod, causing a charge separation and setting up an electric field $\vec{E}$ inside the rod. The electrons move until the electric force $F_E = eE$ balances the magnetic force F_B. At equilibrium, $eE = evB$, so $E = vB$.

The induced EMF (ε) across the length L of the rod is the potential difference, which is given by $E \times L$: $\varepsilon = EL$ Substitute the value of E: $\varepsilon = (vB)L$ $\varepsilon = BLv$.

This formula represents the magnitude of the motional EMF induced across the ends of the conducting rod.

Final Answer : "BLv"

Answer: (A)

Q25.

Solution

Concept: The quality factor (Q-factor) of a series LCR (Inductor-Capacitor-Resistor) circuit is a dimensionless parameter that describes how underdamped an oscillator or resonator is. It is a measure of the sharpness or selectivity of the circuit's resonance. A higher Q-factor indicates a narrower bandwidth relative to its resonant frequency.

The Q-factor can be defined in several ways. One common definition is the ratio of the resonant angular frequency (ω_0) times the inductance (L) to the resistance (R), or inversely, the ratio of the reciprocal of the resonant angular frequency times capacitance (C) to resistance.

The resonant angular frequency (ω_0) for a series LCR circuit is given by $\omega_0 = \frac{1}{\sqrt{LC}}$.

Solution: We start with one of the standard definitions for the Q-factor in a series LCR circuit at resonance:

$Q = \frac{\text{Voltage across L or C}}{\text{Voltage across R}} = \frac{V_L}{V_R} = \frac{I\omega_0 L}{IR} = \frac{\omega_0 L}{R}$

Alternatively, $Q = \frac{V_C}{V_R} = \frac{I/(\omega_0 C)}{IR} = \frac{1}{\omega_0 CR}$.

Let's use the expression $Q = \frac{\omega_0 L}{R}$.

Now, we substitute the formula for the resonant angular frequency, $\omega_0 = \frac{1}{\sqrt{LC}}$, into the Q-factor equation:

$Q = \left(\frac{1}{\sqrt{LC}}\right) \times \frac{L}{R}$

To simplify this expression, we can write L as $\sqrt{L} \times \sqrt{L}$:

$Q = \frac{1}{\sqrt{L}\sqrt{C}} \times \frac{\sqrt{L}\sqrt{L}}{R}$

Cancel out one $\sqrt{L}$ term from the numerator and denominator:

$Q = \frac{\sqrt{L}}{R\sqrt{C}}$

This can be rewritten by factoring out $1/R$:

$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

This matches option B.

Final Answer : "$\frac{1}{R}\sqrt{L/C}$"

Answer: (B)

Q26.

Solution

Concept: For a sinusoidal alternating current (AC) waveform, the instantaneous value of EMF varies periodically between a maximum positive value (ε_{max}) and a maximum negative value. The Root Mean Square (RMS) value is a way to express the effective value of a varying voltage or current. It is equivalent to the DC voltage or current that would produce the same heating effect in a resistor. For a sinusoidal EMF, the RMS value (ε_{RMS}) is related to the maximum (peak) EMF (ε_{max}) by a specific factor.

Solution: Given: Maximum EMF (ε_{max}) = $100V$.

For a sinusoidal AC waveform, the RMS value is defined as the maximum value divided by the square root of 2.
The relationship is:
$\varepsilon_{RMS} = \frac{\varepsilon_{max}}{\sqrt{2}}$

Now, substitute the given maximum EMF:
$\varepsilon_{RMS} = \frac{100V}{\sqrt{2}}$

To calculate the numerical value, we use the approximation $\sqrt{2} \approx 1.41421$:
$\varepsilon_{RMS} = \frac{100}{1.41421}V$
$\varepsilon_{RMS} \approx 70.7106V$

Rounding to one decimal place, the RMS EMF is approximately $70.7V$.

Final Answer : "$70.7V$"

Answer: (B)

Q27.

Solution

Concept: Ampere's Circuital Law ($\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$) describes the magnetic field generated by steady conduction currents. However, Maxwell found it inconsistent for time-varying electric fields. To resolve this, he introduced the concept of displacement current, which accounts for changing electric flux as a source of magnetic fields.

Solution: Maxwell's inconsistency arose when applying Ampere's Law to a capacitor during charging or discharging (Option C).

Consider a capacitor being charged by current I:
1. An Amperian loop enclosing the wire leading to a capacitor plate, with a surface S1 passing through the wire, gives $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$.
2. Using the *same* loop but a different surface S2 passing *between* the capacitor plates (where no conduction current flows), the original Ampere's Law would yield $\oint \vec{B} \cdot d\vec{l} = 0$.

This contradiction implies that the magnetic field depends on the chosen surface, which is physically impossible and violates charge conservation for time-varying fields.

Maxwell resolved this by adding the displacement current ($I_D = \epsilon_0 \frac{d\Phi_E}{dt}$) to Ampere's Law. This current arises from the changing electric field between the capacitor plates.

The generalized Ampere-Maxwell Law becomes:
$\oint \vec{B} \cdot d\vec{l} = \mu_0 (I_{conduction} + I_{displacement}) = \mu_0 (I_{conduction} + \epsilon_0 \frac{d\Phi_E}{dt})$

With this modification, for surface S2 between the plates, $I_{conduction} = 0$, but $I_{displacement}$ is non-zero and equals the conduction current I in the wire. This makes the law consistent for all surfaces and resolves the issue of a capacitor during charging/discharging.

Final Answer : "Capacitor during charging or discharging"

Answer: (C)

Q28.

Solution

Concept: The electromagnetic spectrum is a continuum of all electromagnetic waves arranged according to frequency or wavelength. All electromagnetic waves travel at the speed of light (c) in a vacuum. The relationship between speed, frequency (f), and wavelength (λ) is $c = f\lambda$. This means that frequency and wavelength are inversely proportional: a lower frequency corresponds to a longer wavelength, and a higher frequency corresponds to a shorter wavelength.

Solution: To determine which of the given electromagnetic waves has the lowest frequency, we need to recall the order of the electromagnetic spectrum from lowest to highest frequency (or longest to shortest wavelength). The common order is:
1. Radio waves (longest wavelength, lowest frequency)
2. Microwaves
3. Infrared radiation
4. Visible light (Red, Orange, Yellow, Green, Blue, Indigo, Violet)
5. Ultraviolet radiation
6. X-rays
7. Gamma rays (shortest wavelength, highest frequency)

Comparing the options provided with this spectrum:
X-rays: Are very high frequency waves, used in medical imaging and security.
Radio waves: Are at the lowest frequency end of the spectrum, used in communication (radio, TV, Wi-Fi).
Ultraviolet rays: Are higher in frequency than visible light, known for causing sunburn.
Microwaves: Are higher in frequency than radio waves, used in microwave ovens and radar.

Based on this order, Radio waves have the lowest frequency among the given options.

Final Answer : "Radio waves"

Answer: (B)

Q29.

Solution

Concept: The focal length of a lens depends on its material's refractive index (n_{lens}) and the surrounding medium's refractive index (n_{medium}). This is given by the lens maker's formula: $\frac{1}{f} = \left(\frac{n_{lens}}{n_{medium}} - 1\right) C$, where $C = \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ is constant for a given lens geometry.

Solution: Given:
Focal length in air = f
$n_{lens} = 1.5$
$n_{water} = 1.33$
$n_{air} \approx 1.0$

Step 1: For the lens in air ($n_{medium} = 1.0$):
$\frac{1}{f} = \left(\frac{1.5}{1.0} - 1\right) C = (1.5 - 1)C = 0.5C$ (Eq 1)

Step 2: For the lens in water ($n_{medium} = 1.33$), let the focal length be f_{water}:
$\frac{1}{f_{water}} = \left(\frac{1.5}{1.33} - 1\right) C \approx (1.1278 - 1)C \approx 0.1278C$ (Eq 2)

Step 3: Divide Equation 2 by Equation 1:
$\frac{1/f_{water}}{1/f} = \frac{0.1278C}{0.5C}$
$\frac{f}{f_{water}} = \frac{0.1278}{0.5} \approx 0.2556$

Solve for f_{water}:
$f_{water} = \frac{f}{0.2556} \approx 3.91f$

The focal length in water is significantly greater than in air because the relative refractive index difference between the lens and the medium is reduced, making the lens less converging.

Final Answer : "Greater than f"

Answer: (B)

Q30.

Solution

Concept: Young's Double Slit Experiment (YDSE) demonstrates the wave nature of light through interference. The interference pattern consists of alternating bright and dark fringes. The position of a bright fringe (constructive interference) is given by $d \sin\theta = m\lambda$, and for a dark fringe (destructive interference) by $d \sin\theta = (m + \frac{1}{2})\lambda$, where d is the slit separation, θ is the angular position of the fringe, m is the order of the fringe (an integer), and λ is the wavelength of light. Monochromatic light produces distinct bright and dark fringes. White light is a combination of all visible colors, each with its own specific wavelength range.

Solution: When monochromatic light is used in YDSE, we observe a series of equally spaced bright and dark fringes. If the monochromatic light source is replaced by white light, the interference pattern will be affected because white light consists of multiple wavelengths.

1. Central Fringe (m=0):
The condition for the central maximum (or central bright fringe) is when the path difference between the waves from the two slits is zero ($d \sin\theta = 0$). This condition is independent of the wavelength (λ). Therefore, light of all wavelengths present in white light will undergo constructive interference at the exact center of the screen. As a result, the central fringe will be white because all colors recombine there.

2. Other Fringes (m=1, 2, ...):
For any other bright fringe (i.e., for $m \neq 0$), the condition for constructive interference is $d \sin\theta = m\lambda$. Since different colors have different wavelengths (e.g., violet light has a shorter wavelength than red light), their constructive interference maxima for a given order m will occur at different angular positions (θ) on the screen.
For a given order m, colors with shorter wavelengths (like violet) will form their bright fringes closer to the central maximum.
Colors with longer wavelengths (like red) will form their bright fringes farther from the central maximum.
This leads to a separation of colors. Consequently, the fringes on either side of the central white fringe will appear as colored fringes (spectral bands), typically with violet on the inner edge (closer to the center) and red on the outer edge (farther from the center). The higher the order of the fringe, the more spread out the colored band becomes, and the distinctness of the fringes decreases.

Therefore, the observation will be a central white fringe surrounded by colored fringes.

Final Answer : "A central white fringe surrounded by colored fringes."

Answer: (A)

Q31.

Solution

Concept: An astronomical telescope uses two main lenses: an objective lens (larger focal length) and an eyepiece (shorter focal length). When the telescope is in "normal adjustment" (also known as relaxed eye adjustment), the final image is formed at infinity. This configuration provides the maximum angular magnification that the eye can accommodate without strain. The magnifying power (M) of an astronomical telescope in normal adjustment is given by the ratio of the focal length of the objective lens (f_o) to the focal length of the eyepiece (f_e).

Solution: Given:
Focal length of the objective lens, $f_o = 100cm$.
Focal length of the eyepiece, $f_e = 5cm$.

The formula for the magnifying power (M) of an astronomical telescope in normal adjustment is:
$M = \frac{f_o}{f_e}$

Substitute the given focal lengths into the formula:
$M = \frac{100 \text{ cm}}{5 \text{ cm}}$
$M = 20$.

The magnifying power is a dimensionless quantity, representing how much larger the image appears angularly compared to the object viewed directly.

Final Answer : "20"

Answer: (B)

Q32.

Solution

Concept: Light exhibits both wave-like and particle-like properties, a concept known as wave-particle duality. However, specific phenomena are best explained by one nature over the other.
Diffraction is a wave phenomenon, characterized by the bending of waves around obstacles and the spreading out of waves as they pass through apertures.

Solution: The phenomenon of diffraction is a classic example that unequivocally demonstrates the wave nature of light.

Here's why:

1. Bending and Spreading: Diffraction involves light waves bending around edges or spreading out after passing through small openings. If light were purely composed of particles (as suggested by Newton's corpuscular theory), these particles would simply travel in straight lines, creating sharp shadows. They would not bend into the geometric shadow region.

2. Interference Patterns: The diffraction pattern observed (e.g., from a single slit or a circular aperture) consists of a central bright region flanked by alternating weaker bright and dark fringes. These patterns are a direct result of the constructive and destructive interference of the secondary wavelets generated from different parts of the wavefront passing through the aperture, as described by Huygens' principle. Interference is a property exclusive to waves.

3. Wavelength Dependence: The extent of diffraction (e.g., the width of the central maximum in a single-slit pattern) depends on the wavelength of light and the size of the aperture/obstacle. This dependency is inherent to wave mechanics.

While light does exhibit particle properties (like in the photoelectric effect), diffraction cannot be explained by assuming light to be composed of particles. The patterns observed are clearly characteristic of wave propagation. Furthermore, light is specifically a transverse electromagnetic wave, meaning its oscillating electric and magnetic fields are perpendicular to the direction of propagation. Longitudinal waves (like sound waves) have vibrations parallel to the direction of propagation, and while they also exhibit diffraction, light's specific nature is transverse.

Final Answer : "A transverse wave"

Answer: (C)

Q33.

Solution

Concept: Hypermetropia, commonly known as farsightedness, is a refractive defect of the eye where light rays from nearby objects are focused *behind* the retina instead of directly on it. This results in blurred vision for close-up objects, while distant objects can typically be seen clearly. This condition usually arises either because the eyeball is too short, or the cornea/lens system is not converging enough (i.e., has too long a focal length). To correct this, an additional converging power is needed to bring the focal point forward onto the retina.

Solution: To correct hypermetropia, a lens that converges light rays before they enter the eye is required. This effectively shortens the overall focal length of the eye's optical system, ensuring that light from nearby objects focuses precisely on the retina.

A convex lens (also known as a converging lens) has the property of converging parallel or diverging light rays. When a convex lens is placed in front of an eye with hypermetropia, it adds the necessary converging power. The convex lens causes the incoming light rays from a nearby object to converge slightly before they enter the eye. This pre-convergence allows the eye's own lens to form a clear image on the retina, enabling the person to see nearby objects distinctly.

A concave lens (diverging lens) would make light rays diverge even more, worsening hypermetropia. A cylindrical lens is used to correct astigmatism, which is a different refractive error. A bifocal lens contains two different focal lengths and is often used for presbyopia (age-related farsightedness) where both near and far vision correction might be needed, but the corrective power for near vision in a bifocal lens would be convex. However, the fundamental type of lens needed for hypermetropia itself is convex.

Therefore, a convex lens is used to correct hypermetropia.

Final Answer : "Convex lens"

Answer: (A)

Q34.

Solution

Concept: In single-slit diffraction, when monochromatic light passes through a narrow slit, it produces a diffraction pattern on a screen. This pattern consists of a wide, bright central maximum, flanked by narrower, less intense subsidiary maxima, separated by dark minima. The angular positions of these minima are crucial for determining the width of the central maximum. The condition for the minima in a single-slit diffraction pattern is given by $a \sin\theta = m\lambda$, where a is the width of the slit, λ is the wavelength of the light, and m is an integer representing the order of the minimum ($m = \pm 1, \pm 2, \ldots$).

Solution: Given:
Width of the slit = a.
Wavelength of light = λ.

The central maximum extends from the first minimum on one side to the first minimum on the other side.
Let's find the angular position of the first minima ($m = \pm 1$).
Using the condition for minima:
$a \sin\theta = m\lambda$

For the first minima, $m = \pm 1$:
$a \sin\theta = \pm\lambda$
$\sin\theta = \pm\frac{\lambda}{a}$

For small angles (which is typically the case for diffraction patterns when the screen is far away), $\sin\theta \approx \theta$ (in radians).
So, the angular positions of the first minima are $\theta_1 = +\frac{\lambda}{a}$ and $\theta_2 = -\frac{\lambda}{a}$.

The angular width of the central maximum is the total angular extent from one first minimum to the other.
Angular width = $\theta_1 - \theta_2 = \left(+\frac{\lambda}{a}\right) - \left(-\frac{\lambda}{a}\right)$
Angular width = $\frac{\lambda}{a} + \frac{\lambda}{a} = \frac{2\lambda}{a}$.

Therefore, the angular width of the central maximum is $2\lambda/a$.

Final Answer : "$2\lambda/a$"

Answer: (B)

Q35.

Solution

Concept: The human eye has the ability to adjust its focal length to focus on objects at various distances, a process known as accommodation. However, there are limits to this adjustment. The farthest distance at which the eye can see objects clearly without any strain is called the far point (for a normal eye, this is infinity). The closest distance at which an object can be seen clearly and distinctly without strain is called the near point or the least distance of distinct vision.

Solution: For a normal human eye, the ciliary muscles can adjust the curvature (and thus the focal length) of the eye lens to focus objects located anywhere from infinity down to a certain minimum distance. When an object is brought closer than this minimum distance, the eye muscles cannot contract sufficiently to increase the converging power of the lens enough to form a clear image on the retina. Beyond this point, the image becomes blurred, and the eye experiences strain.

This minimum distance for clear and comfortable vision is a standard value in optics and is approximately 25 cm for an average, healthy young adult. This value is often denoted by 'D' in optics problems. It's important to note that this value can vary with age, typically increasing as a person gets older (a condition known as presbyopia).

Final Answer : "$25cm$"

Answer: (B)

Q36.

Solution

Concept: The power of a lens (P) is a measure of its ability to converge or diverge light rays. It is defined as the reciprocal of its focal length (f) in meters: $P = 1/f$. The unit of power is dioptre (D). When multiple thin lenses are placed in contact with each other, their individual powers combine to form an effective power for the combination. This is a simple additive relationship.

Solution: Given:
Focal length of the first thin lens = f_1.
Focal length of the second thin lens = f_2.

The power of the first lens (P_1) is:
$P_1 = \frac{1}{f_1}$

The power of the second lens (P_2) is:
$P_2 = \frac{1}{f_2}$

When these two thin lenses are placed in contact, the equivalent focal length (F) of the combination is given by the formula:
$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

The effective power of the combination (P_{eff}) is defined as the reciprocal of the effective focal length F:
$P_{eff} = \frac{1}{F}$

Substituting the expression for $1/F$:
$P_{eff} = \frac{1}{f_1} + \frac{1}{f_2}$

From our definitions of P_1 and P_2, we can replace the terms:
$P_{eff} = P_1 + P_2$.

This formula implies that for thin lenses in contact, their powers simply add up algebraically. If one lens is converging (positive power) and another is diverging (negative power), their powers will add with their respective signs.

Final Answer : "$P_1 + P_2$"

Answer: (A)

Q37.

Solution

Concept: Total Internal Reflection (TIR) is an optical phenomenon where light is completely reflected back into its original medium. For TIR to occur, two conditions are essential:
1. Light must be traveling from an optically denser medium to an optically rarer medium.
2. The angle of incidence must be greater than the critical angle for that interface.

Solution: The two necessary conditions for total internal reflection are:
1. Light travels from a denser to a rarer medium.
2. The angle of incidence exceeds the critical angle.

Let's evaluate the options:
A) Denser to rarer medium: This is the primary and most general condition that must be met for TIR to be possible.
B) Rarer to denser medium: TIR cannot occur. Light will always refract towards the normal.
C) Air to vacuum: The refractive index difference is negligible, so significant TIR would not occur.
D) Glass to water: Glass (denser) to water (rarer) is a specific example that satisfies condition 1. However, option A provides the general principle.

Therefore, "Denser to rarer medium" is the most fundamental and general necessary condition for total internal reflection.

Final Answer : "Denser to rarer medium"

Answer: (A)

Q38.

Solution

Concept: The photoelectric effect is the phenomenon where electrons are emitted from a material (typically a metal) when light shines on it. This effect is best explained by the particle nature of light (photons). According to Einstein's photoelectric equation, the maximum kinetic energy (KE_{max}) of the emitted photoelectrons depends on the energy of the individual photons and the work function of the material.
The energy of a single photon is $E = h\nu$, where h is Planck's constant and ν is the frequency of the incident light.
The work function (ϕ) is the minimum energy required to eject an electron from the material.
Einstein's photoelectric equation is: $KE_{max} = h\nu - \phi$.
The intensity of light, on the other hand, is proportional to the number of photons incident per unit area per unit time.

Solution: Given:
The frequency of the incident light is kept constant.
The intensity of the incident light is doubled.

Let's analyze the effect on KE_{max} using Einstein's photoelectric equation:
$KE_{max} = h\nu - \phi$

1. Effect of constant frequency: Since the frequency (ν) of the incident light is kept constant, the energy of each individual photon ($h\nu$) remains unchanged.
2. Effect of work function: The work function (ϕ) is a characteristic property of the material and depends only on the type of metal used. It does not change with the intensity or frequency of the incident light.

Since both $h\nu$ and ϕ remain constant, the maximum kinetic energy of the emitted photoelectrons (KE_{max}) will also remain unchanged.

What does doubling the intensity do?
Doubling the intensity of the incident light, while keeping the frequency constant, means that twice as many photons are striking the metal surface per unit time. If the photon energy is greater than the work function ($h\nu > \phi$), then doubling the number of incident photons will lead to:
Doubling the number of photoelectrons emitted per unit time (i.e., doubling the photocurrent).
However, it does not change the energy of each individual photon, and thus it does not change the maximum kinetic energy of the individual electrons that are ejected.

Therefore, the maximum kinetic energy of the emitted photoelectrons remains unchanged.

Final Answer : "It remains unchanged."

Answer: (C)

Q39.

Solution

Concept: The de-Broglie hypothesis states that all matter exhibits wave-like properties, and the wavelength associated with a particle (its de-Broglie wavelength, λ) is inversely proportional to its momentum (p). The relationship is given by $\lambda = h/p$, where h is Planck's constant. When a charged particle, such as an electron, is accelerated through a potential difference, it gains kinetic energy, which can be related to its momentum.

Solution: Given: Electron (mass m, charge e).
Accelerated through a potential difference V.
Planck's constant h.

Step 1: Calculate the kinetic energy (KE) gained by the electron.
When an electron with charge e is accelerated from rest through a potential difference V, the work done on it by the electric field is converted into its kinetic energy.
$KE = eV$

Step 2: Relate kinetic energy to momentum (p).
The kinetic energy of a non-relativistic particle of mass m and momentum p is given by:
$KE = \frac{p^2}{2m}$
Equating the two expressions for kinetic energy:
$\frac{p^2}{2m} = eV$

Now, solve for the momentum p:
$p^2 = 2meV$
$p = \sqrt{2meV}$

Step 3: Substitute the momentum into the de-Broglie wavelength formula.
The de-Broglie wavelength is given by:
$\lambda = \frac{h}{p}$
Substitute the expression for p found in Step 2:
$\lambda = \frac{h}{\sqrt{2meV}}$

This formula shows how the de-Broglie wavelength of an electron is determined by the accelerating potential difference, its mass, its charge, and Planck's constant.

Final Answer : "$\frac{h}{\sqrt{2meV}}$"

Answer: (A)

Q40.

Solution

Concept: The photoelectric effect describes electron emission from a metal surface when illuminated by light. Einstein's photoelectric equation states $KE_{max} = h\nu - \phi$, where KE_{max} is the maximum kinetic energy of emitted electrons, h is Planck's constant, ν is light frequency, and ϕ is the work function. The work function is $\phi = hf_0$, where f_0 is the threshold frequency. The stopping potential V_s is related to KE_{max} by $KE_{max} = eV_s$.

Solution: Given:
Threshold frequency = f_0
Incident light frequency = $\nu = 2f_0$
Electron charge = e
Planck's constant = h

Step 1: Calculate the work function (ϕ).
$\phi = hf_0$

Step 2: Calculate the maximum kinetic energy (KE_{max}) using Einstein's photoelectric equation.
$KE_{max} = h\nu - \phi$
Substitute $\nu = 2f_0$ and $\phi = hf_0$:
$KE_{max} = h(2f_0) - hf_0$
$KE_{max} = hf_0$

Step 3: Relate KE_{max} to the stopping potential (V_s).
$KE_{max} = eV_s$
So, $eV_s = hf_0$

Step 4: Solve for V_s.
$V_s = \frac{hf_0}{e}$

Final Answer : "$\frac{hf_0}{e}$"

Answer: (A)

Q41.

Solution

Concept: The de-Broglie hypothesis establishes the wave-particle duality for matter. It states that a particle with momentum p has an associated wavelength λ, known as the de-Broglie wavelength. The relationship between them is given by the de-Broglie equation: $\lambda = h/p$, where h is Planck's constant.

Solution: The de-Broglie wavelength formula is $\lambda = \frac{h}{p}$.
To understand the relationship between momentum (p) and de-Broglie wavelength (λ), we can rearrange the formula to express p in terms of λ:
$p = \frac{h}{\lambda}$

Since Planck's constant (h) is a universal constant, this equation clearly shows that the momentum p is inversely proportional to the de-Broglie wavelength λ. Mathematically, $p \propto \frac{1}{\lambda}$.

When one quantity is inversely proportional to another, their graph is a hyperbola.

Let's check the options:

A) $p \propto \lambda$: This would be a linear graph passing through the origin.

B) $p \propto 1/\lambda$: This correctly represents an inverse relationship, which graphically is a hyperbola. As λ increases, p decreases, and vice-versa.

C) $p \propto \lambda^2$: This would be a parabolic graph.

D) p is independent of λ: This would be a horizontal line, meaning p is constant irrespective of λ, which is incorrect.

Thus, the graph correctly representing the variation of particle momentum with its de-Broglie wavelength is a hyperbola.

Final Answer : "$p \propto 1/\lambda$ (hyperbola)"

Answer: (B)

Q42.

Solution

Concept: Bohr's model for the hydrogen atom successfully explained the line spectrum of hydrogen. One of its key postulates led to the quantization of energy levels for the electron. The energy of an electron in a stationary orbit (principal quantum number n) is inversely proportional to the square of the principal quantum number.

Solution: According to Bohr's model, the energy of an electron in the n^{th} orbit of a hydrogen atom (or hydrogen-like atoms) is given by the formula:

$$E_n = -\frac{Z^2 R_H hc}{n^2}$$

For a hydrogen atom, the atomic number $Z = 1$. So, the formula simplifies to:

$$E_n = -\frac{R_H hc}{n^2}$$

where R_H is the Rydberg constant, h is Planck's constant, and c is the speed of light.
The product $R_H hc$ is a constant value, approximately 13.6 eV.

Thus, the formula becomes:

$$E_n = -\frac{13.6 \text{ eV}}{n^2}$$

From this equation, it is clear that the energy E_n is directly proportional to $1/n^2$. The negative sign indicates that the electron is bound to the nucleus, and its energy becomes less negative (i.e., increases) as n increases, approaching zero as $n \to \infty$ (ionization).

Therefore, the energy of an electron in the n^{th} orbit of a hydrogen atom is proportional to $1/n^2$.

Final Answer : "$1/n^2$"

Answer: (D)

Q43.

Solution

Concept: The binding energy per nucleon is a crucial quantity in nuclear physics, representing the average energy required to remove a single nucleon (proton or neutron) from a nucleus. It is a measure of the stability of a nucleus. A higher binding energy per nucleon indicates greater stability. The variation of binding energy per nucleon with mass number (A) follows a characteristic curve, which helps explain nuclear fission and fusion.

Solution: The binding energy per nucleon curve is obtained by plotting the binding energy per nucleon against the mass number (A) for various nuclei.

This curve shows the following general features:

1. It is relatively low for very light nuclei (e.g., hydrogen isotopes).

2. It increases rapidly for light nuclei, reaching a maximum value for intermediate mass numbers.

3. It then gradually decreases for very heavy nuclei.

The maximum value of binding energy per nucleon occurs for nuclei with mass numbers approximately between 50 and 80. Specifically, iron-56 (^{56}Fe) has the highest binding energy per nucleon (about 8.79 MeV/nucleon), making it one of the most stable nuclei. Cobalt-59 (^{59}Co) and Nickel-62 (^{62}Ni) also have very high binding energies per nucleon.

Among the given options:

A) 20: This is too low; binding energy per nucleon is increasing in this range.

B) 56: This is exactly the mass number for Iron-56, which has the maximum binding energy per nucleon.

C) 120: This is in the region where binding energy per nucleon is slowly decreasing from its maximum.

D) 235: This is a very heavy nucleus (like Uranium-235), where binding energy per nucleon is significantly lower than the maximum, making these nuclei unstable and susceptible to fission.

Therefore, the binding energy per nucleon is maximum for nuclei with a mass number approximately 56.

Final Answer : "56"

Answer: (B)

Q44.

Solution

Concept: Nuclear fission is the process where a heavy nucleus splits into lighter nuclei, releasing significant energy. This energy release is due to the change in nuclear binding energy. Nuclei with higher binding energy per nucleon are more stable. Energy is released when the products of a nuclear reaction are more stable (have higher total binding energy) than the reactants.

Solution: In nuclear fission, a heavy nucleus (e.g., Uranium-235) splits into two or more medium-sized nuclei. These fission products are generally located closer to the peak of the binding energy curve, meaning they have a *higher binding energy per nucleon* than the original heavy nucleus.

1. Binding Energy per Nucleon: Heavy nuclei have lower binding energy per nucleon compared to intermediate-mass nuclei.
2. Energy Release: When fission occurs, the resulting product nuclei have a *greater total binding energy* than the initial heavy nucleus. This increase in total binding energy means that the total mass of the products is slightly *less* than the mass of the initial nucleus (mass defect, Δm).
3. Mass-Energy Equivalence: According to Einstein's $E = \Delta mc^2$, this lost mass is converted into the large amount of energy released during fission.

Therefore, the energy is released because the total binding energy of the more stable fission products is greater than that of the initial heavy nucleus.

Let's evaluate the options:
A) The total mass of the products is greater than the initial nucleus. (Incorrect, mass is *less* due to mass defect).
B) The total binding energy of the products is less than the initial nucleus. (Incorrect, products are more stable with *greater* binding energy).
C) The total binding energy of the products is greater than the initial nucleus. (Correct, this accounts for the energy released).
D) The sum of the atomic numbers changes. (Incorrect, total atomic number is conserved).

Final Answer : "The total binding energy of the products is greater than the initial nucleus."

Answer: (C)

Q45.

Solution

Concept: Radioactive decay is a first-order process where the number of undecayed nuclei decreases exponentially over time. The half-life ($T_{1/2}$) of a radioactive isotope is the time it takes for half of the initial number of radioactive nuclei to decay. After n half-lives, the fraction of the initial number of undecayed atoms remaining is given by the formula $\left(\frac{1}{2}\right)^n$. The number of half-lives n can be calculated as $n = \frac{\text{total time elapsed}}{\text{half-life}}$.

Solution: Given:
Half-life of the radioactive isotope, $T_{1/2} = 4$ hours.
Total time elapsed, $t = 12$ hours.

Step 1: Calculate the number of half-lives (n) that have passed.
$n = \frac{t}{T_{1/2}} = \frac{12 \text{ hours}}{4 \text{ hours}} = 3.$
So, 3 half-lives have passed.

Step 2: Calculate the fraction of initial undecayed atoms remaining.
The fraction remaining (N/N_0) after n half-lives is given by:
$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$
Substitute $n = 3$:
$\frac{N}{N_0} = \left(\frac{1}{2}\right)^3 = \frac{1^3}{2^3} = \frac{1}{8}.$

Therefore, after 12 hours, 1/8 of the initial number of undecayed atoms remains.

Final Answer : "1/8"

Answer: (C)

Q46.

Solution

Concept: In a hydrogen atom, electrons can occupy discrete energy levels, labeled by the principal quantum number $n = 1, 2, 3, \ldots$. When an electron jumps from a higher energy level (n_i) to a lower energy level (n_f), it emits a photon whose energy corresponds to the energy difference between the two levels. These transitions result in specific spectral series, each defined by the final energy level n_f.

Solution: The spectral series for hydrogen atom transitions are named based on the final principal quantum number (n_f):

Lyman series: Transitions to the ground state, $n_f = 1$ (from $n_i = 2, 3, 4, \ldots$). These emissions are in the ultraviolet region.

Balmer series: Transitions to the first excited state, $n_f = 2$ (from $n_i = 3, 4, 5, \ldots$). These emissions include the visible light spectrum.

Paschen series: Transitions to the second excited state, $n_f = 3$ (from $n_i = 4, 5, 6, \ldots$). These emissions are in the infrared region.

Brackett series: Transitions to the third excited state, $n_f = 4$ (from $n_i = 5, 6, 7, \ldots$). These emissions are also in the infrared region.

Pfund series: Transitions to the fourth excited state, $n_f = 5$ (from $n_i = 6, 7, 8, \ldots$). These are in the far-infrared region.

In this question, an electron jumps from the $n = 4$ orbit (initial state, $n_i = 4$) to the $n = 2$ orbit (final state, $n_f = 2$).
Since the electron's final state is $n_f = 2$, the emitted radiation belongs to the Balmer series.

Final Answer : "Balmer series"

Answer: (B)

Q47.

Solution

Concept: A p-n junction is formed by joining a p-type semiconductor with an n-type semiconductor. In a p-type material, holes are the majority carriers, and in an n-type material, electrons are the majority carriers. At the moment of junction formation, a process of diffusion occurs across the interface, leading to the creation of a depletion region and an associated barrier potential.

Solution: The barrier potential in a p-n junction diode primarily arises due to the diffusion of majority carriers across the junction, leaving behind immobile ions.
Here's a more detailed breakdown of the process:

1. Diffusion: When the p-type and n-type materials are brought into contact, there is a concentration gradient of charge carriers. Majority electrons from the n-side diffuse into the p-side, and majority holes from the p-side diffuse into the n-side.

2. Recombination: As electrons diffuse into the p-side, they recombine with holes. Similarly, holes diffusing into the n-side recombine with electrons.

3. Formation of Immobile Ions: When an electron leaves the n-side to diffuse into the p-side, it leaves behind a positively charged, immobile donor ion (which has lost an electron). Conversely, when a hole leaves the p-side to diffuse into the n-side, it exposes a negatively charged, immobile acceptor ion (which has accepted an electron).

4. Depletion Region: This process of diffusion and recombination creates a region near the junction that is depleted of free charge carriers (electrons and holes). This region is called the depletion layer or depletion region.

5. Electric Field and Barrier Potential: The immobile positive ions on the n-side of the depletion region and the immobile negative ions on the p-side create an electric field across the depletion region. This electric field points from the n-side to the p-side. This electric field acts as a barrier, opposing further diffusion of majority carriers across the junction. The potential difference corresponding to this electric field is known as the barrier potential (or contact potential or built-in voltage). It effectively creates an energy hill that majority carriers must overcome to cross the junction.

Therefore, the core reason for the barrier potential is the diffusion of majority carriers and the subsequent exposure of immobile charged dopant ions.

Final Answer : "Diffusion of majority carriers across the junction, leaving behind immobile ions."

Answer: (B)

Q48.

Solution

Concept: The relationship between the angles of incidence (i), emergence (e), prism angle (A), and deviation (δ) in a prism is a fundamental geometric property derived from the path of light through the prism.

Solution: Consider a ray of light incident on the first face of a prism at an angle i and refracting into the prism with an angle r_1. This refracted ray then hits the second face of the prism at an angle r_2 and emerges into the air at an angle e.

From the geometry of the prism and the refraction process:

1. The sum of the angles inside the prism formed by the normal at the two surfaces and the refracting ray equals the prism angle: $A = r_1 + r_2$.

2. The deviation at the first surface is $\delta_1 = i - r_1$.

3. The deviation at the second surface is $\delta_2 = e - r_2$.

The total angle of deviation δ is the sum of these individual deviations:

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

Rearranging the terms:

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

Substituting $A = r_1 + r_2$ into the equation:

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

This equation can be rearranged to express the sum of the external angles in terms of the internal angles:

$$i + e = A + \delta$$

This relation is always true for any ray passing through a prism, provided that total internal reflection does not occur at the second surface.

Final Answer : "i + e = A + δ"

Answer: (B)

Q49.

Solution

Concept: Understanding the behavior of a p-n junction diode under reverse bias conditions, specifically its effect on the depletion region and barrier potential.

Solution: In a p-n junction diode, a depletion region forms at the interface due to the diffusion of majority carriers across the junction, creating an electric field and a barrier potential that opposes further diffusion.

When the p-n junction diode is subjected to reverse bias, the positive terminal of the external voltage source is connected to the n-type semiconductor, and the negative terminal is connected to the p-type semiconductor.

1. Effect on Majority Carriers: In the p-type region, the holes (majority carriers) are attracted towards the negative terminal of the external battery, moving away from the junction. Similarly, in the n-type region, the electrons (majority carriers) are attracted towards the positive terminal of the external battery, also moving away from the junction.

2. Width of Depletion Region: As majority carriers move away from the junction, the region around the junction that is devoid of mobile charge carriers (the depletion region) expands. This means the width of the depletion region increases.

3. Barrier Potential: The external reverse bias voltage is in the same direction as the built-in potential barrier. Therefore, the external voltage adds to the existing barrier potential, effectively increasing the potential difference that any remaining charge carriers would need to overcome to cross the junction. This increased barrier potential makes it more difficult for charge carriers to flow across the junction.

These two phenomena (increased depletion region width and increased barrier potential) lead to a very small reverse saturation current, primarily due to the flow of minority carriers.

Final Answer : "The width of the depletion region increases, and the barrier potential increases."

Answer: (A)

Q50.

Solution

Concept: The behavior of a series LCR (Inductor-Capacitor-Resistor) AC circuit at resonance, particularly the phase relationship between the applied voltage and the current.

Solution: In a series LCR AC circuit, the impedance (Z) is given by $Z = \sqrt{R^2 + (X_L - X_C)^2}$, where R is resistance, $X_L = \omega L$ is inductive reactance, and $X_C = 1/(\omega C)$ is capacitive reactance. The phase angle (ϕ) between the applied voltage (V) and the current (I) is given by $\tan\phi = \frac{X_L - X_C}{R}$.

Resonance in a series LCR circuit occurs when the inductive reactance equals the capacitive reactance:
$X_L = X_C$
$\omega L = \frac{1}{\omega C}$
At this condition:
1. Net Reactance: The term $(X_L - X_C)$ becomes zero.
2. Impedance: The total impedance of the circuit simplifies to $Z = \sqrt{R^2 + (0)^2} = R$.
This means that at resonance, the circuit behaves purely resistively, and the impedance is at its minimum value.
3. Phase Angle: Substituting $(X_L - X_C) = 0$ into the phase angle formula:
$\tan\phi = \frac{0}{R} = 0$
Therefore, $\phi = 0^\circ$.
A phase angle of 0° signifies that there is no phase difference between the applied voltage and the current flowing through the circuit. In other words, the voltage and current are in phase with each other. This leads to maximum current for a given applied voltage and maximum power transfer.

Final Answer : "Voltage and current are in phase."

Answer: (C)

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	B	3	C	4	A	5	A
6	A	7	A	8	D	9	C	10	B
11	C	12	C	13	B	14	C	15	A
16	A	17	C	18	A	19	A	20	A
21	A	22	D	23	C	24	A	25	B
26	B	27	C	28	B	29	B	30	A
31	B	32	C	33	A	34	B	35	B
36	A	37	A	38	C	39	A	40	A
41	B	42	D	43	B	44	C	45	C
46	B	47	B	48	B	49	A	50	C