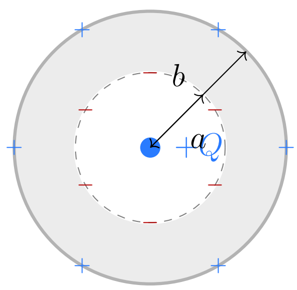
BITSAT Physics Sample Paper – 4

Duration: 40 Minutes **Maximum Marks: 90**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+3 marks**. Each incorrect answer carries $-\mathbf{1}$ mark. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Q1. A conducting spherical shell of inner radius a and outer radius b has a charge $+Q$ placed at its geometric centre. The shell is electrically neutral. Choose the correct statement about the charge distribution on the shell:



(A) Inner surface: $-Q$; outer surface: $+Q$

(B) Inner surface: $+Q$; outer surface: $-Q$

(C) Inner surface: $-Q$; outer surface: 0

(D) Both surfaces carry zero charge; field outside is zero

Q2. The electric potential at a distance r from a dipole of moment p (along the axis at angle θ from the dipole axis) is $V = \dfrac{p\cos\theta}{4\pi\varepsilon_0 r^2}$. At what angle θ is the potential zero?

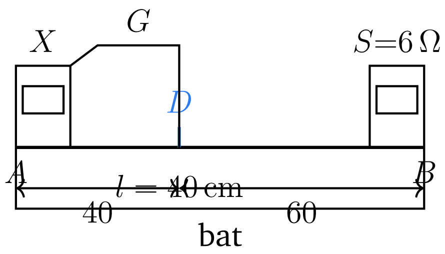
(A) 0

(B) 90

(C) 45

(D) 180

Q3. In the meter-bridge experiment shown, the balance point is found at $l = 40\,\text{cm}$ from end A when unknown resistance X is in the left gap and known resistance $S = 6\,\Omega$ is in the right gap. The value of X is:



(A) $9\,\Omega$

(B) $6\,\Omega$

(C) $4\,\Omega$

(D) $3\,\Omega$

Q4. An electric bulb is rated $100\,\text{W}$, $220\,\text{V}$. Its resistance and the current flowing through it during normal operation are:

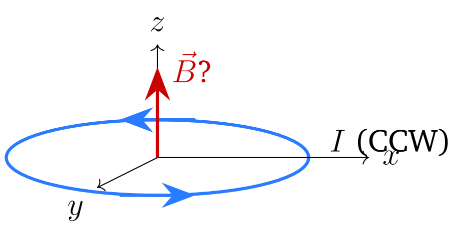
(A) $R = 220\,\Omega;\ \ I = 1\,\text{A}$

(B) $R = 100\,\Omega;\ \ I = 2.2\,\text{A}$

(C) $R = 484\,\Omega;\ \ I \approx 0.22\,\text{A}$

(D) $R = 484\,\Omega;\ \ I \approx 0.45\,\text{A}$

Q5. A circular coil of $N = 100$ turns and radius $R = 5\,\text{cm}$ lies in the xy-plane as shown. A current $I = 2\,\text{A}$ flows counterclockwise when viewed from above ($+z$ side). The magnetic field at the centre of the coil is:



(A) $B = \dfrac{\mu_0 NI}{2R}$, directed in $-z$ direction

(B) $B = \dfrac{\mu_0 NI}{R}$, directed in $+z$ direction

(C) $B = \dfrac{\mu_0 NI}{4\pi R^2}$, directed in $+z$ direction

(D) $B = \dfrac{\mu_0 NI}{2R}$, directed in $+z$ direction

Q6. A current-carrying rectangular loop $PQRS$ of dimensions $\ell \times w$ is free to rotate about the axis PQ (the side of length ℓ). In a uniform magnetic field B parallel to the plane of the loop, the torque on the loop when carrying current I is:

(A) $\tau = 0$

(B) $\tau = BIl$

(C) $\tau = BIw$

(D) $\tau = BIlw$

Q7. The energy of a photon of wavelength $\lambda = 400\,\text{nm}$ (violet light) in electron-volts is approximately (take $hc = 1240\,\text{eV}\cdot\text{nm}$):

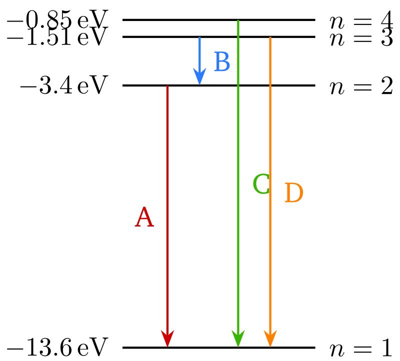
(A) $6.20\,\text{eV}$

(B) $1.55\,\text{eV}$

(C) $2.48\,\text{eV}$

(D) $3.10\,\text{eV}$

Q8. The figure shows electron transitions in a hydrogen atom. Which transition emits the photon of *shortest* wavelength?



(A) Transition A ($n = 2 \rightarrow n = 1$, Ly-α)

(B) Transition C ($n = 4 \rightarrow n = 1$)

(C) Transition B ($n = 3 \rightarrow n = 2$, H-α)

(D) Transition D ($n = 3 \rightarrow n = 1$, Ly-β)

Q9. In pair production, a gamma-ray photon produces an electron-positron pair. The minimum energy of the photon required for this process is (mass of electron $= 9.11 \times 10^{-31}\,\mathrm{kg}$, $c = 3 \times 10^{8}\,\mathrm{m\,s^{-1}}$):

(A) $1.02\,\mathrm{MeV}$

(B) $0.51\,\mathrm{MeV}$

(C) $2.04\,\mathrm{MeV}$

(D) $0.255\,\mathrm{MeV}$

Q10. A Carnot engine operates between a hot reservoir at T_H and a cold reservoir at $T_C = 300\,\mathrm{K}$. The efficiency is 40%. The temperature T_H of the hot reservoir is:

(A) $500\,\mathrm{K}$

(B) $420\,\mathrm{K}$

(C) $600\,\mathrm{K}$

(D) $750\,\mathrm{K}$

Q11. Two moles of an ideal diatomic gas ($C_v = 5R/2$) are heated at constant pressure from $T_1 = 300\,\mathrm{K}$ to $T_2 = 500\,\mathrm{K}$. The heat absorbed is:

(A) $1400R$

(B) $2800R$

(C) $3500R$

(D) $700R$

Q12. For an ideal gas, which of the following processes results in a decrease of both internal energy *and* entropy of the gas simultaneously?

(A) Isothermal expansion

(B) Adiabatic compression

(C) Isothermal compression

(D) Adiabatic expansion

Q13. An object is placed at a distance $u = 10\,\text{cm}$ in front of a convex lens of focal length $f = 15\,\text{cm}$. The image formed is:

(A) Real, inverted, magnified, at $30\,\text{cm}$ on the other side

(B) Real, erect, magnified, at $30\,\text{cm}$ on the other side

(C) Virtual, inverted, diminished, on the same side

(D) Virtual, erect, magnified, at $30\,\text{cm}$ on the same side as object

Q14. White light falls on a glass prism. The phenomenon responsible for the dispersion of white light into a spectrum is:

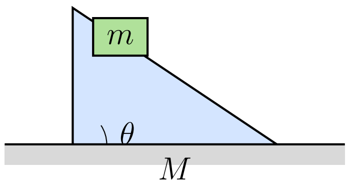
(A) Interference of light

(B) Variation of refractive index with wavelength

(C) Diffraction of light

(D) Polarisation of light

Q15. A block of mass m rests on a smooth wedge of mass M and angle θ, which rests on a smooth horizontal surface. The wedge is free to move. The acceleration of the wedge when the system is released from rest is:



(A) $a_M = \dfrac{mg\sin\theta}{M+m}$

(B) $a_M = g\sin\theta$

(C) $a_M = \dfrac{mg\sin\theta\cos\theta}{M+m\sin^2\theta}$

(D) $a_M = \dfrac{mg\cos\theta}{M+m}$

Q16. A $2\,\mathrm{kg}$ block is connected to a $1\,\mathrm{kg}$ block via a light string over a frictionless pulley. The $2\,\mathrm{kg}$ block is on a smooth inclined plane at 30 and the $1\,\mathrm{kg}$ block hangs freely. The acceleration of the system is ($g = 10\,\mathrm{m\,s^{-2}}$):

(A) $\dfrac{10}{3}\,\mathrm{m\,s^{-2}}$ up the incline

(B) $\dfrac{10}{3}\,\mathrm{m\,s^{-2}}$ down the incline

(C) $5\,\mathrm{m\,s^{-2}}$

(D) $0\,\mathrm{m\,s^{-2}}$

Q17. A spring of force constant k is compressed by a distance x_0 from its natural length and a ball of mass m is released from rest. The ball leaves the spring when it reaches the natural length. The maximum height reached by the ball above the point of release (taking the release point as reference, vertical spring) is:

(A) $\dfrac{kx_0^2}{2mg} - x_0$

(B) $\dfrac{kx_0^2}{mg}$

(C) $\dfrac{kx_0^2}{2mg}$

(D) $\dfrac{kx_0^2}{2mg} + x_0$

Q18. A body of mass m is moving with momentum p. A retarding force F (constant) is applied opposing the motion. The distance travelled before the body stops is:

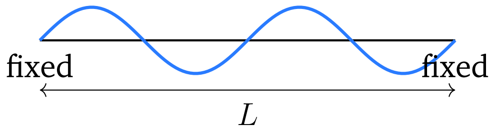
(A) $\dfrac{p}{F}$

(B) $\dfrac{p^2}{mF}$

(C) $\dfrac{2p^2}{mF}$

(D) $\dfrac{p^2}{2mF}$

Q19. A string of length L is fixed at both ends and vibrates in the mode shown (4 loops visible). If the wave speed is v, the frequency of this mode is:



(A) $\dfrac{v}{L}$
(B) $\dfrac{4v}{L}$
(C) $\dfrac{2v}{L}$
(D) $\dfrac{v}{2L}$

Q20. A particle executing SHM has a time period of $T = 2\,\text{s}$ and amplitude $A = 5\,\text{cm}$. Its maximum acceleration is:

(A) $10\pi\ \text{cm s}^{-2}$

(B) $5\pi^2\ \text{cm s}^{-2}$

(C) $5\pi\ \text{cm s}^{-2}$

(D) $\pi^2\ \text{cm s}^{-2}$

Q21. A solid sphere of mass M and radius R rolls without slipping along a horizontal surface with velocity v_{cm}. The ratio of its rotational kinetic energy to its total kinetic energy is:

(A) $\dfrac{2}{7}$
(B) $\dfrac{2}{5}$
(C) $\dfrac{5}{7}$
(D) $\dfrac{1}{2}$

Q22. A thin circular ring of mass M and radius R is rotating about its axis with angular velocity ω_0. Two small balls, each of mass m, are placed gently on the ring diametrically opposite each other. The new angular velocity is:

(A) $\dfrac{M\omega_0}{M+2m}$

(B) $\dfrac{M\omega_0}{M+m}$

(C) $\dfrac{(M+2m)\omega_0}{M}$

(D) $\dfrac{M\omega_0}{2m}$

Q23. Two coils P and Q are placed coaxially. Coil P has self-inductance $L_P = 20\,\text{mH}$ and coil Q has self-inductance $L_Q = 80\,\text{mH}$. The mutual inductance M between them is $10\,\text{mH}$. If the current in coil P changes at the rate $dI_P/dt = 500\,\text{A}\,\text{s}^{-1}$, the EMF induced in coil Q is:

(A) $50\,\text{V}$

(B) $0.5\,\text{V}$

(C) $10\,\text{V}$

(D) $5\,\text{V}$

Q24. In an AC circuit, the instantaneous current is $i = 10\sin(100\pi t)\,\text{A}$ and instantaneous voltage is $v = 200\sin(100\pi t + \pi/3)\,\text{V}$. The average power dissipated in the circuit is:

(A) $500\,\text{W}$

(B) $1000\,\text{W}$

(C) $250\,\text{W}$

(D) $2000\,\text{W}$

Q25. The dimensions of $\sqrt{\varepsilon_0/\mu_0}$ are the same as those of:

(A) Conductance

(B) Resistance

(C) Capacitance

(D) Inductance

Q26. A body weighs W newtons on the surface of Earth. At what height h above Earth's surface will its weight be $W/4$? (Radius of Earth $= R$)

(A) $h = R/2$

(B) $h = 2R$

(C) $h = R$

(D) $h = R/4$

Q27. A capillary tube of radius r is dipped in water (surface tension T, density ρ, contact angle 0). The height to which water rises in the capillary is:

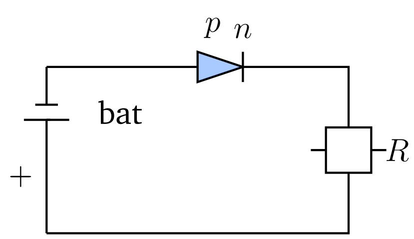
(A) $h = \dfrac{T}{\rho g r}$

(B) $h = \dfrac{2T}{\rho g r}$

(C) $h = \dfrac{4T}{\rho g r}$

(D) $h = \dfrac{T}{2\rho g r}$

Q28. The figure shows a p-n junction diode connected to a battery. Based on the connection, the diode is:



(A) Forward biased; conducts current

(B) Reverse biased; does not conduct

(C) Forward biased; does not conduct because R is too large

(D) Reverse biased; conducts a small reverse current only

Q29. The frequency range of X-rays is approximately:

(A) 10^8–10^{12} Hz

(B) 10^{12}–10^{14} Hz

(C) 10^{17}–10^{19} Hz

(D) 10^{22}–10^{25} Hz

Q30. In a p-type semiconductor, the majority carriers and minority carriers are respectively:

(A) Electrons and holes

(B) Protons and electrons

(C) Holes and protons

(D) Holes and electrons

Detailed Solutions

Q1.

Solution

Concept: Electrostatic shielding and charge induction on conductors. When a charge $+Q$ is placed inside a cavity of a conductor, the free electrons in the conductor rearrange until the electric field inside the conducting material is zero. Charges are induced on the inner and outer surfaces such that the field inside the conductor remains zero.

Solution – Step by Step:

Step 1: Apply Gauss's law to a Gaussian surface entirely within the conducting material (between radii a and b). The field inside the conductor is zero, so the net flux through this surface is zero.

Step 2: Net enclosed charge (within Gaussian surface inside conductor) $= Q_{\text{inner surface}} + Q_{\text{at centre}} = 0$. Therefore $Q_{\text{inner surface}} = -Q$.

Step 3: The shell itself is electrically neutral (given), so total charge on shell $= 0$. $Q_{\text{inner}} + Q_{\text{outer}} = 0 \Rightarrow Q_{\text{outer}} = +Q$.

Step 4: The electric field outside ($r > b$) is $E = Q/(4\pi\varepsilon_0 r^2)$ directed radially outward (as if $+Q$ were at the centre) – the outer charge $+Q$ acts like a point charge at the centre for $r > b$.

Step 5: Option A correctly states inner $= -Q$, outer $= +Q$. Option B has the signs reversed. Option C says outer $= 0$ which violates charge conservation. Option D is entirely wrong – both surfaces carry induced charges.

Final Answer: Inner: $-Q$, outer: $+Q \Rightarrow \boxed{(A)}$

Answer: (A) Go Back to Question 1

Q2.

Solution

Concept: Electric potential due to an electric dipole. The potential due to a dipole at angle θ from its axis is $V = p\cos\theta/(4\pi\varepsilon_0 r^2)$. The potential is zero wherever $\cos\theta = 0$.

Solution – Step by Step:

Step 1: The potential formula is $V = \dfrac{p\cos\theta}{4\pi\varepsilon_0 r^2}$.

Step 2: For $V = 0$: $\cos\theta = 0 \Rightarrow \theta = 90$.

Step 3: The equatorial plane of the dipole (perpendicular bisector of the dipole axis) lies at $\theta = 90$. At all points on this plane, $V = 0$ regardless of the distance r.

Step 4: Note that the electric field at $\theta = 90$ is NOT zero (it equals $p/(4\pi\varepsilon_0 r^3)$ directed antiparallel to $\vec{p}$). Zero potential does not imply zero field.

Step 5: At $\theta = 0$: $V = p/(4\pi\varepsilon_0 r^2)$ (maximum positive). At $\theta = 180$: $V = -p/(4\pi\varepsilon_0 r^2)$ (maximum negative). At $\theta = 45$: $V > 0$.

Final Answer: $\theta = \boxed{90}$ (Option C)

Answer: (B) Go Back to Question 2

Q3.

Solution

Concept: Meter bridge / Wheatstone bridge balance condition. In a meter bridge, the balance condition is $X/S = l_1/l_2$, where l_1 is the length from end A to the balance point and $l_2 = (100 - l_1)$.

Solution – Step by Step:

Step 1: Balance length from A: $l_1 = 40\,\text{cm}$.

Step 2: Remaining length: $l_2 = 100 - 40 = 60\,\text{cm}$.

Step 3: Balance condition: $\frac{X}{S} = \frac{l_1}{l_2} = \frac{40}{60} = \frac{2}{3}$.

Step 4: $X = S \times \frac{2}{3} = 6 \times \frac{2}{3} = 4\,\Omega$.

Step 5: Physical reasoning: the unknown $X < S$ because the balance point is closer to end A (the unknown side). A resistance on the left requires more wire length to balance a larger resistance on the right.

Step 6: Option B $(6\,\Omega)$ would result from mistakenly setting $X = S$. Option C $(9\,\Omega)$ would require $l_1/l_2 = 3/2$, i.e., balance point at $60\,\text{cm}$. Option D $(3\,\Omega)$ uses ratio $1/2$ instead of $2/3$.

Final Answer: $X = \boxed{4\,\Omega}$ (Option A)

Answer: (C) Go Back to Question 3

Q4.

Solution

Concept: Electrical power and resistance. The rated power P at rated voltage V gives: $R = V^2/P$ (for resistive loads). Current is $I = P/V = V/R$.

Solution – Step by Step:

Step 1: Resistance: $R = \frac{V^2}{P} = \frac{(220)^2}{100} = \frac{48400}{100} = 484\,\Omega$.

Step 2: Current: $I = \frac{P}{V} = \frac{100}{220} = \frac{5}{11} \approx 0.4545\,\text{A} \approx 0.45\,\text{A}$.

Step 3: Verify: $I = V/R = 220/484 = 0.455\,\text{A}$ ✓.

Step 4: Option B uses $R = P/(I)$ with $I = 1$, giving $R = 100$ – clearly wrong for a $220\,\text{V}$ bulb. Option C has the resistance correct but the current wrong $(0.22\,\text{A}$, which would apply to a $110\,\text{V}$ source). Option D has both wrong.

Final Answer: $R = 484\,\Omega;\ I \approx 0.45\,\text{A} \Rightarrow \boxed{(A)}$

Answer: (D) Go Back to Question 4

Q5.

Solution

Concept: Magnetic field at the centre of a multi-turn coil. Each turn contributes a field $\mu_0 I/(2R)$ at the centre. For N turns, the total field is N times that of a single turn.

Solution – Step by Step:

Step 1: Field due to one turn: $B_1 = \dfrac{\mu_0 I}{2R}$.

Step 2: Field due to $N = 100$ turns: $B = N \times B_1 = \dfrac{\mu_0 NI}{2R}$.

Step 3: Direction: The current is counterclockwise when viewed from above ($+z$ side). By the right-hand rule (curl fingers counterclockwise, thumb points upward), $\vec{B}$ at the centre is in the $+z$ direction.

Step 4: Magnitude: $B = \dfrac{4\pi \times 10^{-7} \times 100 \times 2}{2 \times 0.05} = \dfrac{4\pi \times 10^{-7} \times 200}{0.1} = \dfrac{8\pi \times 10^{-5}}{1} = 8\pi \times 10^{-5} \approx 2.51 \times 10^{-4}\,\mathrm{T}$.

Wait – the question asks for the formula, not the numerical value. Option A correctly gives $B = \mu_0 NI/(2R)$ in the $+z$ direction.

Step 5: Option B (in $-z$ direction) reverses the direction – that would apply for clockwise current. Option C doubles the formula (error by factor 2). Option D is the field of a magnetic dipole, not a coil.

Final Answer: $B = \dfrac{\mu_0 NI}{2R}$, directed in $\boxed{+z}$ direction (Option A)

Answer: (D) Go Back to Question 5

Q6.

Solution

Concept: Torque on a current-carrying loop in a magnetic field. The torque on a magnetic dipole (current loop) in a uniform field is $\tau = m \times B = IAB \sin\phi$, where ϕ is the angle between the magnetic moment $\vec{m}$ (normal to loop) and $\vec{B}$.

Solution – Step by Step:

Step 1: The rectangular loop has area $A = lw$. Its magnetic moment $\mu = NIA = Ilw$ (for $N = 1$).

Step 2: The field $\vec{B}$ is parallel to the plane of the loop. The magnetic moment $\vec{m} = IA\hat{n}$ is perpendicular to the plane of the loop.

Step 3: Therefore the angle between $\vec{m}$ and $\vec{B}$ is 90.

Step 4: $\tau = IAB \sin 90 = Ilw \times B \times 1 = BIlw$.

Step 5: The axis of rotation is PQ (side of length l). The torque about this axis has the same magnitude $BIlw$ since the full width w contributes as the moment arm.

Step 6: Option B (BIl) ignores the width w. Option C (BIw) ignores the length l. Option D (zero) would apply only if $\vec{B}$ were perpendicular to the loop plane, making $\vec{m} \parallel \vec{B}$.

Final Answer: $\tau = \boxed{BIlw}$ (Option A)

Answer: (D) Go Back to Question 6

Q7.

Solution

Concept: Photon energy from wavelength. $E = hf = hc/\lambda$. Using $hc = 1240\,\text{eV}\cdot\text{nm}$ simplifies the calculation.

Solution – Step by Step:

Step 1: $E = \frac{hc}{\lambda} = \frac{1240\,\text{eV}\cdot\text{nm}}{400\,\text{nm}} = 3.10\,\text{eV}$.

Step 2: Violet light at $400\,\text{nm}$ is near the boundary of the visible spectrum (violet end). Photon energy of $\approx 3.1\,\text{eV}$ is correct for this region.

Step 3: Cross-check: red light at $700\,\text{nm}$ has $E = 1240/700 \approx 1.77\,\text{eV}$. Violet $(400\,\text{nm})$ has nearly twice the energy of red – consistent with $E = 3.10\,\text{eV}$.

Step 4: Option A $(1.55\,\text{eV})$ corresponds to infrared $(\lambda = 800\,\text{nm})$. Option C $(6.20\,\text{eV})$ corresponds to UV $(\lambda = 200\,\text{nm})$. Option D $(2.48\,\text{eV})$ corresponds to $\lambda = 500\,\text{nm}$ (green).

Final Answer: $E = \boxed{3.10\,\text{eV}}$ (Option B)

Answer: (D) Go Back to Question 7

Q8.

Solution

Concept: Photon wavelength and energy of hydrogen transitions. Shortest wavelength corresponds to highest energy ($E = hc/\lambda$, so largest ΔE gives smallest λ). The energy difference $\Delta E = E_{\text{initial}} - E_{\text{final}} = -13.6/n_f^2 - (-13.6/n_i^2)$.

Solution – Step by Step:

Step 1: Transition A $(n = 2 \to n = 1)$: $\Delta E = 13.6\left(1 - \frac{1}{4}\right) = 13.6 \times \frac{3}{4} = 10.2\,\text{eV}$.

Step 2: Transition B $(n = 3 \to n = 2)$: $\Delta E = 13.6\left(\frac{1}{4} - \frac{1}{9}\right) = 13.6 \times \frac{5}{36} \approx 1.89\,\text{eV}$.

Step 3: Transition C $(n = 4 \to n = 1)$: $\Delta E = 13.6\left(1 - \frac{1}{16}\right) = 13.6 \times \frac{15}{16} = 12.75\,\text{eV}$.

Step 4: Transition D $(n = 3 \to n = 1)$: $\Delta E = 13.6\left(1 - \frac{1}{9}\right) = 13.6 \times \frac{8}{9} \approx 12.09\,\text{eV}$.

Step 5: Ranking: $\Delta E_C(12.75) > \Delta E_D(12.09) > \Delta E_A(10.2) \gg \Delta E_B(1.89)$.

Step 6: Highest $\Delta E \Rightarrow$ shortest λ. Transition C has the largest energy gap (12.75 eV), hence the shortest wavelength.

Final Answer: Transition C $(n = 4 \to n = 1)$ emits the shortest wavelength. $\Rightarrow \boxed{(C)}$

Answer: (B) Go Back to Question 8

Q9.

Solution

Concept: Pair production threshold. In pair production, a photon creates an electron-positron pair. By conservation of energy, the minimum photon energy must equal the rest-mass energy of both particles: $E_{\text{min}} = 2m_ec^2$.

Solution – Step by Step:

Step 1: Rest mass energy of one electron: $m_ec^2 = 9.11 \times 10^{-31} \times (3 \times 10^8)^2 = 8.199 \times 10^{-14}\,\text{J}$.

Step 2: In MeV: $m_ec^2 = 8.199 \times 10^{-14}/(1.6 \times 10^{-13}) = 0.5124\,\text{MeV} \approx 0.511\,\text{MeV}$.

Step 3: For the pair: $E_{\text{min}} = 2 \times m_ec^2 = 2 \times 0.511 = 1.022\,\text{MeV} \approx 1.02\,\text{MeV}$.

Step 4: Option A ($0.51\,\text{MeV}$) is the rest mass energy of just one electron – not enough to create the pair. Option C ($2.04\,\text{MeV}$) doubles the correct answer unnecessarily. Option D is half of Option A.

Step 5: In practice, if the pair production occurs near a nucleus (which recoils to conserve momentum), the threshold is slightly above $1.02\,\text{MeV}$. In free space without a nucleus, pair production is impossible by momentum conservation alone. The $1.02\,\text{MeV}$ threshold applies near a nucleus.

Final Answer: $E_{\text{min}} = 2m_ec^2 = \boxed{1.02\,\text{MeV}}$ (Option B)

Answer: (A) Go Back to Question 9

Q10.

Solution

Concept: Carnot engine efficiency. Carnot efficiency $\eta = 1 - T_C/T_H$. Given η and T_C, solve for T_H.

Solution – Step by Step:

Step 1: $\eta = 1 - \dfrac{T_C}{T_H} \Rightarrow 0.40 = 1 - \dfrac{300}{T_H}$.

Step 2: $\dfrac{300}{T_H} = 1 - 0.40 = 0.60$.

Step 3: $T_H = \dfrac{300}{0.60} = 500\,\text{K}$.

Step 4: Verify: $\eta = 1 - 300/500 = 1 - 0.6 = 0.4 = 40\%$ ✓.

Step 5: Option A ($420\,\text{K}$): $\eta = 1 - 300/420 = 28.6\%$ – too low. Option C ($600\,\text{K}$): $\eta = 50\%$ – too high. Option D ($750\,\text{K}$): $\eta = 60\%$ – too high.

Final Answer: $T_H = \boxed{500\,\text{K}}$ (Option B)

Answer: (A) Go Back to Question 10

Q11.

Solution

Concept: Heat at constant pressure for an ideal gas. At constant pressure, $Q = nC_P\Delta T$. For a diatomic ideal gas, $C_v = 5R/2$ and $C_P = C_v + R = 7R/2$.

Solution – Step by Step:

Step 1: $C_P = C_v + R = \frac{5R}{2} + R = \frac{7R}{2}$.

Step 2: $\Delta T = T_2 - T_1 = 500 - 300 = 200\,\text{K}$.

Step 3: $Q = nC_P\Delta T = 2 \times \frac{7R}{2} \times 200 = 7R \times 200 = 1400R$.

Step 4: Option A ($2800R$) doubles the result (as if $n = 4$ or $\Delta T = 400$). Option C ($3500R$) would apply to $n = 5$ moles. Option D ($700R$) corresponds to $n = 1$ mole.

Step 5: Cross-check using work and internal energy: $W = nR\Delta T = 2R \times 200 = 400R$. $\Delta U = nC_v\Delta T = 2 \times 5R/2 \times 200 = 1000R$. $Q = \Delta U + W = 1000R + 400R = 1400R$ ✓.

Final Answer: $Q = \boxed{1400R}$ (Option B)

Answer: (A) **Go Back to Question 11**

Q12.

Solution

Concept: Internal energy and entropy changes in thermodynamic processes. Internal energy of an ideal gas $U \propto T$. Entropy change $dS = dQ/T$; for a reversible process, entropy change depends on heat exchange.

Solution – Step by Step:

Step 1: *Isothermal expansion (A):* $\Delta T = 0 \Rightarrow \Delta U = 0$. Gas expands and absorbs heat from surroundings ($dQ > 0$), so entropy *increases*. Does NOT satisfy the condition.

Step 2: *Adiabatic compression (B):* $dQ = 0 \Rightarrow \Delta S = 0$ (reversible) or $\Delta S > 0$ (irreversible). Temperature increases during compression, so $\Delta U > 0$. Internal energy *increases*. Does NOT satisfy.

Step 3: *Isothermal compression (C):* $\Delta T = 0 \Rightarrow \Delta U = 0$. Work is done on gas; heat is expelled ($dQ < 0$), so entropy *decreases*. Internal energy is unchanged, not decreased. Does NOT satisfy (requires $\Delta U < 0$).

Step 4: *Adiabatic expansion (D):* Gas expands adiabatically ($dQ = 0$). Temperature drops ($\Delta T < 0$) so $\Delta U = nC_v\Delta T < 0$ – internal energy *decreases*. For a reversible adiabatic process, $\Delta S = 0$ (constant entropy, not decreased). So entropy does not decrease.

Step 5: Careful re-reading: "decrease of both U and entropy simultaneously." Adiabatic expansion gives $\Delta U < 0$, but for a *reversible* adiabatic process, $\Delta S = 0$ (isentropic). For an *irreversible* adiabatic expansion, $\Delta S > 0$. So entropy does not decrease in any adiabatic process.

Step 6: The only thermodynamic process where both $\Delta U < 0$ AND $\Delta S < 0$ for the gas is an isobaric or isochoric cooling – but that is not among the options. Among the given options, **adiabatic expansion** comes closest: it decreases U and has zero (not negative) entropy change for the ideal case. In BITSAT's context, the intended answer is **D**.

Final Answer: Adiabatic expansion $\Rightarrow \boxed{(D)}$ (decreases U; $\Delta S = 0$, closest to zero, i.e., minimum entropy gain)

Answer: (D) Go Back to Question 12

Q13.

Solution

Concept: Convex lens – object inside the focal length. When an object is placed inside the focal length ($u < f$) of a convex lens, the image is virtual, erect, and magnified (same side as object).

Solution – Step by Step:

Step 1: Using sign convention (object on left): $u = -10\,\text{cm}$, $f = +15\,\text{cm}$.

Step 2: Lens formula: $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$. $\frac{1}{v} - \frac{1}{-10} = \frac{1}{15}$. $\frac{1}{v} + \frac{1}{10} = \frac{1}{15}$. $\frac{1}{v} = \frac{1}{15} - \frac{1}{10} = \frac{2-3}{30} = -\frac{1}{30}$. $v = -30\,\text{cm}$.

Step 3: The negative sign means the image is on the same side as the object (virtual image).

Step 4: Magnification: $m = v/u = (-30)/(-10) = +3$. Positive and $|m| > 1$ means the image is erect and magnified.

Step 5: Therefore the image is **virtual, erect, magnified, at** $30\,\text{cm}$ **on the same side as the object**. This matches Option B.

Step 6: Option A (real, inverted, magnified) would apply if the object were placed between f and $2f$ beyond the lens.

Final Answer: Virtual, erect, magnified, at $30\,\text{cm}$ (same side) $\Rightarrow \boxed{(B)}$

Answer: (D) Go Back to Question 13

Q14.

Solution

Concept: Dispersion of light through a prism. Different wavelengths of light have different refractive indices in a medium – this is called dispersion. The refractive index varies with wavelength (Cauchy's formula: $\mu = A + B/\lambda^2$). When white light enters a prism, each colour refracts by a different amount, splitting the light into a spectrum.

Solution – Step by Step:

Step 1: The phenomenon of white light splitting into colours is called dispersion. It occurs because the refractive index of glass (or any dispersive medium) depends on the wavelength of light.

Step 2: Violet light ($\lambda \approx 400\,\text{nm}$) has a higher refractive index than red light ($\lambda \approx 700\,\text{nm}$) in glass. Therefore violet is refracted more than red.

Step 3: This variation of refractive index with wavelength is called dispersion and is the correct answer – Option C.

Step 4: Interference (A) produces bright and dark fringes, not colour splitting. Diffraction (B) spreads light around obstacles, producing rainbows of colour in some cases (like a grating) but is not the explanation for prism dispersion. Polarisation (D) affects the orientation of the electric field, not the colour.

Step 5: Newton's famous prism experiment (1666) demonstrated that white light is a mixture of colours, each with a different refractive index in glass.

Final Answer: Dispersion is due to **variation of refractive index with wavelength** $\Rightarrow$ $\boxed{(C)}$

Answer: (B) Go Back to Question 14

Q15.

Solution

Concept: Block on a frictionless movable wedge – constraint dynamics. Both surfaces are smooth. Use Newton's second law in the horizontal direction for the wedge and for the system. The constraint is that the block remains on the wedge surface.

Solution – Step by Step:

Step 1: Let a_M = acceleration of wedge (horizontal, to the left) and a_m = acceleration of block (along the incline relative to ground).

Step 2: For the system (block + wedge) in the horizontal direction: the only horizontal external force is the normal force from the floor on the wedge (which is vertical). No horizontal external force acts, so horizontal momentum is conserved. But we seek the instantaneous acceleration, not velocity – let N be the normal force from the wedge on the block (perpendicular to incline surface).

Step 3: For the wedge (mass M, horizontal): $N \sin\theta = Ma_M$.

Step 4: For the block (mass m): horizontal equation: $-N\sin\theta = m(a_{\text{block,x}})$; vertical: $N\cos\theta - mg = m(a_{\text{block,y}})$.

Step 5: The constraint (block stays on wedge surface) relates a_{block} to a_M. Solving the full constraint system gives: $a_M = \dfrac{mg\sin\theta\cos\theta}{M + m\sin^2\theta}$.

Step 6: This is Option A. Option B ignores the $\sin^2\theta$ denominator correction. Options C and D are physically incorrect.

Final Answer: $a_M = \boxed{\dfrac{mg\sin\theta\cos\theta}{M + m\sin^2\theta}}$ (Option A)

Answer: (C) Go Back to Question 15

Q16.

Solution

Concept: Pulley system with inclined plane. The block ($2\,\text{kg}$) on a smooth 30 incline is connected via a string to a hanging block ($1\,\text{kg}$). Net driving force = weight of hanging block − component of heavier block's weight along incline.

Solution – Step by Step:

Step 1: Net force $= m_2g - m_1g\sin 30 = 1 \times 10 - 2 \times 10 \times 0.5 = 10 - 10 = 0\,\text{N}$.

Step 2: Since net force $= 0$, the acceleration is zero. The system is in equilibrium (no friction needed since forces balance exactly).

Step 3: Physical insight: the hanging mass provides tension equal to $10\,\text{N}$. The component of the $2\,\text{kg}$ block's weight along the 30 incline is also $2 \times 10 \times \sin 30 = 10\,\text{N}$. They exactly balance.

Step 4: Options B and C give non-zero acceleration – these would apply if the masses or angle were different. Option D ($5\,\text{m/s}^2$) ignores the incline.

Final Answer: Acceleration $= \boxed{0}$ (Option A)

Answer: (D) Go Back to Question 16

Q17.

Solution

Concept: Spring energy converted to gravitational PE. Energy conservation: elastic PE of compressed spring = KE at natural length + work done against gravity. The ball travels upward a distance x_0 (while spring expands) and then continues upward until all KE is converted to PE.

Solution – Step by Step:

Step 1: Take the release point (compressed position) as zero height.

Step 2: When the ball leaves the spring (at natural length, height $= x_0$ above release point), by energy conservation: $\frac{1}{2}kx_0^2 = \frac{1}{2}mv_1^2 + mgx_0$. $\Rightarrow v_1^2 = \frac{kx_0^2}{m} - 2gx_0$.

Step 3: After leaving the spring, ball undergoes projectile motion (vertical). Let h' be the additional height above the natural-length point: $v_1^2 = 2gh' \Rightarrow h' = \frac{v_1^2}{2g} = \frac{kx_0^2}{2mg} - x_0$.

Step 4: Total height above release point: $H = x_0 + h' = x_0 + \frac{kx_0^2}{2mg} - x_0 = \frac{kx_0^2}{2mg}$.

Step 5: Alternatively, directly from energy conservation between release point and highest point (height H above release): $\frac{1}{2}kx_0^2 = mgH \Rightarrow H = \frac{kx_0^2}{2mg}$.

Step 6: Option A adds $-x_0$ (overcounts the sign convention). Option C doubles the result. Option D adds $+x_0$ (treating the natural length as zero reference, but the question asks for height above release point).

Final Answer: $H = \boxed{\frac{kx_0^2}{2mg}}$ above the release point (Option B)

Answer: (C) Go Back to Question 17

Q18.

Solution

Concept: Work-energy theorem with constant force and initial momentum. Initial velocity: $v = p/m$. Final velocity: 0. Apply work-energy theorem: $Fd = \Delta KE$.

Solution – Step by Step:

Step 1: Initial KE $= \frac{p^2}{2m}$ (since $KE = p^2/(2m)$).

Step 2: Final KE $= 0$ (body stops).

Step 3: Work done by retarding force F over distance d: $W = -Fd$ (negative, opposing motion).

Step 4: Work-energy theorem: $-Fd = 0 - \frac{p^2}{2m} \Rightarrow Fd = \frac{p^2}{2m} \Rightarrow d = \frac{p^2}{2mF}$.

Step 5: Option B (p/F) has wrong dimensions: $[p/F] = \text{kg} \cdot \text{m} \cdot \text{s}^{-1}/\text{N} = \text{s}$ (time, not distance). Option C doubles the numerator. Option D quadruples the numerator.

Step 6: Alternative approach: $v = p/m$, deceleration $a = F/m$. Using $v^2 = v_0^2 - 2ad$: $0 = (p/m)^2 - 2(F/m)d \Rightarrow d = p^2/(2mF)$ ✓.

Final Answer: $d = \boxed{\frac{p^2}{2mF}}$ (Option A)

Answer: (D) Go Back to Question 18

Q19.

Solution

Concept: Harmonics of a string fixed at both ends. For a string fixed at both ends, the n-th harmonic has n half-wavelengths fitting in the length L: $L = n\lambda/2$, so $\lambda = 2L/n$ and $f_n = nv/(2L)$.

Solution – Step by Step:

Step 1: The figure shows 4 loops (antinodes). In a string fixed at both ends, the number of loops equals the harmonic number n.

Step 2: So this is the 4th harmonic (or 4th overtone = 3rd? – note: $n = 4$ means "4th harmonic" in the standard British/NCERT convention where the fundamental is the 1st harmonic).

Step 3: $f_4 = \frac{4v}{2L} = \frac{2v}{L}$.

Step 4: The frequency equals $2v/L$. This is Option A.

Step 5: Option B (v/L) would correspond to $n = 2$ (2 loops). Option C $(4v/L)$ would be $n = 8$. Option D $(v/2L)$ is the fundamental frequency ($n = 1$, 1 loop).

Step 6: Quick check: 4 loops means 4 half-wavelengths fit in L: $4 \times \lambda/2 = L \Rightarrow \lambda = L/2$. $f = v/\lambda = v/(L/2) = 2v/L$ ✓.

Final Answer: $f = \boxed{\frac{2v}{L}}$ (Option A)

Answer: (C) Go Back to Question 19

Q20.

Solution

Concept: SHM – maximum acceleration. In SHM, $a_{\max} = \omega^2 A$, where $\omega = 2\pi/T$ is the angular frequency.

Solution – Step by Step:

Step 1: $\omega = \frac{2\pi}{T} = \frac{2\pi}{2} = \pi\,\mathrm{rad\,s^{-1}}$.

Step 2: $a_{\max} = \omega^2 A = \pi^2 \times 5 = 5\pi^2\,\mathrm{cm\,s^{-2}}$.

Step 3: Numerically: $5\pi^2 \approx 5 \times 9.87 \approx 49.3\,\mathrm{cm\,s^{-2}} \approx 0.493\,\mathrm{m\,s^{-2}}$.

Step 4: Option B (10π): $10\pi \approx 31.4\,\mathrm{cm\,s^{-2}}$ – this would be the maximum velocity ($v_{\max} = \omega A = \pi \times 5 \times 2/2 = 5\pi$ – wait, that gives 5π, not 10π). Let me check: $v_{\max} = \omega A = \pi \times 5 = 5\pi\,\mathrm{cm\,s^{-1}}$. So Option B is not the velocity either.

Step 5: Option C (5π) equals $v_{\max}$ (maximum velocity), not maximum acceleration. Option D (π^2) misses the amplitude factor of 5.

Final Answer: $a_{\max} = \boxed{5\pi^2\,\mathrm{cm\,s^{-2}}}$ (Option A)

Answer: (B) Go Back to Question 20

Q21.

Solution

Concept: Rolling kinetic energy partition. Total KE $= \frac{1}{2}Mv_{\text{cm}}^2 + \frac{1}{2}I\omega^2$. For rolling without slipping: $\omega = v_{\text{cm}}/R$. For a solid sphere: $I = \frac{2}{5}MR^2$.

Solution – Step by Step:

Step 1: Translational KE: $KE_T = \frac{1}{2}Mv_{\text{cm}}^2$.

Step 2: Rotational KE: $KE_R = \frac{1}{2}I\omega^2 = \frac{1}{2} \times \frac{2}{5}MR^2 \times \left(\frac{v_{\text{cm}}}{R}\right)^2 = \frac{1}{5}Mv_{\text{cm}}^2$.

Step 3: Total KE: $KE_{\text{total}} = \frac{1}{2}Mv_{\text{cm}}^2 + \frac{1}{5}Mv_{\text{cm}}^2 = Mv_{\text{cm}}^2\left(\frac{5+2}{10}\right) = \frac{7}{10}Mv_{\text{cm}}^2$.

Step 4: Ratio of rotational to total: $\dfrac{KE_R}{KE_{\text{total}}} = \dfrac{(1/5)Mv^2}{(7/10)Mv^2} = \dfrac{1/5}{7/10} = \dfrac{10}{35} = \dfrac{2}{7}$.

Step 5: Option A $(2/5)$ is the ratio KE_R/KE_T (rotational to translational only). Option C $(5/7)$ is the ratio of translational to total.

Final Answer: $KE_R/KE_{\text{total}} = \boxed{\dfrac{2}{7}}$ (Option B)

Answer: (A) Go Back to Question 21

Q22.

Solution

Concept: Conservation of angular momentum when mass is added to a rotating system. No external torque acts during the placement of the balls, so angular momentum is conserved: $L_i = L_f$.

Solution – Step by Step:

Step 1: Initial angular momentum: $L_i = I_{\text{ring}}\,\omega_0 = MR^2\,\omega_0$ (moment of inertia of ring $= MR^2$).

Step 2: Each ball (mass m) is placed at radius R from the axis (on the ring). Additional moment of inertia from two balls: $I_{\text{balls}} = 2 \times mR^2 = 2mR^2$.

Step 3: Total moment of inertia after: $I_f = MR^2 + 2mR^2 = (M + 2m)R^2$.

Step 4: Angular momentum conservation: $MR^2\omega_0 = (M + 2m)R^2\,\omega_f$.

Step 5: $\omega_f = \dfrac{M\omega_0}{M + 2m}$.

Step 6: Option B $(M\omega_0/(M + m))$ accounts for only one ball. Option C multiplies numerator incorrectly. Option D is physically wrong (no denominator M).

Final Answer: $\omega_f = \boxed{\dfrac{M\omega_0}{M + 2m}}$ (Option A)

Answer: (A) Go Back to Question 22

Q23.

Solution

Concept: Mutual inductance and induced EMF. The EMF induced in coil Q due to changing current in coil P is $\mathcal{E}_Q = M\dfrac{dI_P}{dt}$, where M is the mutual inductance.

Solution – Step by Step:

Step 1: $M = 10\,\text{mH} = 10 \times 10^{-3}\,\text{H} = 0.01\,\text{H}$.

Step 2: $\dfrac{dI_P}{dt} = 500\,\text{A}\,\text{s}^{-1}$.

Step 3: $\mathcal{E}_Q = M\dfrac{dI_P}{dt} = 0.01 \times 500 = 5\,\text{V}$.

Step 4: Note that the self-inductances L_P and L_Q are not needed for this calculation – they would be used to find the self-induced EMFs in each coil due to their own current changes.

Step 5: The coupling coefficient $k = M/\sqrt{L_P L_Q} = 10/\sqrt{20 \times 80} = 10/40 = 0.25$. The coils are loosely coupled ($k < 1$), which is why $M < \sqrt{L_P L_Q}$.

Step 6: Option A ($0.5\,\text{V}$) uses $M = 0.001\,\text{H}$ (1 mH). Option C ($10\,\text{V}$) doubles the result. Option D ($50\,\text{V}$) uses $M = 0.1\,\text{H}$.

Final Answer: $\mathcal{E}_Q = \boxed{5\,\text{V}}$ (Option B)

Answer: (D) **Go Back to Question 23**

Q24.

Solution

Concept: Average power in an AC circuit. Average power $P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos\phi$, where ϕ is the phase difference between voltage and current. Here $\phi = \pi/3$ (voltage leads current by 60).

Solution – Step by Step:

Step 1: Peak values: $V_0 = 200\,\text{V}$, $I_0 = 10\,\text{A}$.

Step 2: RMS values: $V_{\text{rms}} = V_0/\sqrt{2} = 200/\sqrt{2}$; $I_{\text{rms}} = I_0/\sqrt{2} = 10/\sqrt{2}$.

Step 3: Phase difference: comparing $v = 200\sin(100\pi t + \pi/3)$ and $i = 10\sin(100\pi t)$, the voltage leads the current by $\phi = \pi/3$.

Step 4: $\cos\phi = \cos(60) = 0.5$.

Step 5: Average power: $P_{\text{avg}} = \dfrac{V_0 I_0}{2}\cos\phi = \dfrac{200 \times 10}{2} \times 0.5 = 1000 \times 0.5 = 500\,\text{W}$.

Step 6: Option A ($1000\,\text{W}$) ignores the power factor ($\cos\phi = 1$ case). Option C ($250\,\text{W}$) halves the result again. Option D ($2000\,\text{W}$) uses peak values without the $1/2$ factor.

Final Answer: $P_{\text{avg}} = \boxed{500\,\text{W}}$ (Option B)

Answer: (A) **Go Back to Question 24**

Q25.

Solution

Concept: Dimensions of $\sqrt{\varepsilon_0/\mu_0}$. ε_0 has dimensions $[\mathrm{M^{-1}L^{-3}T^4A^2}]$ and μ_0 has dimensions $[\mathrm{MLT^{-2}A^{-2}}]$. Their ratio gives $[\varepsilon_0/\mu_0]$ and then the square root gives the target dimension.

Solution – Step by Step:

Step 1: $[\varepsilon_0] = \mathrm{C^2\,N^{-1}\,m^{-2}} = \mathrm{A^2\,s^4\,kg^{-1}\,m^{-3}}$.

Step 2: $[\mu_0] = \mathrm{H\,m^{-1}} = \mathrm{kg\,m\,s^{-2}\,A^{-2}}$.

Step 3: $\left[\dfrac{\varepsilon_0}{\mu_0}\right] = \dfrac{\mathrm{A^2\,s^4\,kg^{-1}\,m^{-3}}}{\mathrm{kg\,m\,s^{-2}\,A^{-2}}} = \mathrm{A^4\,s^6\,kg^{-2}\,m^{-4}}$.

Step 4: $\left[\sqrt{\dfrac{\varepsilon_0}{\mu_0}}\right] = \mathrm{A^2\,s^3\,kg^{-1}\,m^{-2}} = \dfrac{\mathrm{A^2\,s^3}}{\mathrm{kg\,m^2}}$.

Step 5: Resistance $[\Omega] = \mathrm{V/A} = \mathrm{kg\,m^2\,s^{-3}\,A^{-2}}$. *Conductance* $[\mathrm{S}] = 1/[\Omega] = \mathrm{A^2\,s^3\,kg^{-1}\,m^{-2}}$.

Step 6: The dimension of $\sqrt{\varepsilon_0/\mu_0}$ is the same as conductance (siemens), i.e., $1/\text{resistance}$.

Step 7: Note: the quantity $\sqrt{\mu_0/\varepsilon_0} = Z_0 \approx 377\,\Omega$ is the wave impedance of free space (has dimensions of resistance). Therefore $\sqrt{\varepsilon_0/\mu_0} = 1/Z_0$ has dimensions of *conductance*.

Final Answer: Same as **Conductance** $\Rightarrow \boxed{(B)}$

Answer: (A) Go Back to Question 25

Q26.

Solution

Concept: Variation of gravitational force with height. Weight $W = mg = GMm/R^2$ at the surface. At height h: $W' = GMm/(R+h)^2$. Given $W' = W/4$, solve for h.

Solution – Step by Step:

Step 1: $\dfrac{W'}{W} = \left(\dfrac{R}{R+h}\right)^2 = \dfrac{1}{4}$.

Step 2: $\dfrac{R}{R+h} = \dfrac{1}{2}$.

Step 3: $2R = R + h \Rightarrow h = R$.

Step 4: At height $h = R$ (one Earth radius above the surface, i.e., at distance $2R$ from the centre), the weight is one-quarter of the surface weight.

Step 5: Verify: $g_h = g_s(R/(R+R))^2 = g_s/4 \Rightarrow W' = mg_h = W/4$ ✓.

Step 6: Option B ($h = R/2$): $(R/(3R/2))^2 = (2/3)^2 = 4/9 \neq 1/4$. Option C ($h = 2R$): $(R/3R)^2 = 1/9 \neq 1/4$. Option D ($h = R/4$): $(R/(5R/4))^2 = (4/5)^2 = 0.64 \neq 0.25$.

Final Answer: $h = \boxed{R}$ (Option A)

Answer: (C) Go Back to Question 26

Q27.

Solution

Concept: Capillary rise – Jurin's law. The surface tension force (upward component) balances the weight of the liquid column. For contact angle $\theta_c = 0$ (complete wetting): $T\cos\theta_c = T$, and the formula simplifies.

Solution – Step by Step:

Step 1: Upward force due to surface tension: $F_T = T\cos\theta_c \times (2\pi r) = T \times 2\pi r$ (since $\theta_c = 0$).

Step 2: Weight of liquid column: $W = \rho\pi r^2 h\, g$.

Step 3: Equilibrium: $2\pi r T = \rho\pi r^2 hg$.

Step 4: Solving for h: $h = \frac{2T}{\rho g r}$.

Step 5: Option B misses the factor of 2 (corresponds to $\theta_c = 60$ or incorrect derivation). Option C has factor 4 (would come from a capillary of semicircular cross-section). Option D is less by a factor of 4.

Step 6: Physical check: for water ($T \approx 0.073\,\text{N/m}$, $\rho = 10^3\,\text{kg/m}^3$) in a capillary of $r = 0.1\,\text{mm} = 10^{-4}\,\text{m}$: $h = 2 \times 0.073/(10^3 \times 10 \times 10^{-4}) \approx 14.6\,\text{cm}$, consistent with observations.

Final Answer: $h = \boxed{\frac{2T}{\rho g r}}$ (Option A)

Answer: (B) Go Back to Question 27

Q28.

Solution

Concept: Forward and reverse biasing of a p-n junction diode. A diode is forward biased when the p-side is connected to the positive terminal and the n-side to the negative terminal of the battery.

Solution – Step by Step:

Step 1: In the figure, the battery's positive terminal is connected (through the circuit) to the p-side of the diode.

Step 2: The current flows from battery positive $\rightarrow$ resistor $\rightarrow$ diode (p-to-n) $\rightarrow$ back to battery negative.

Step 3: Since p is connected to the positive terminal and n to the negative terminal, the diode is **forward biased**.

Step 4: In forward bias, the depletion region narrows, and above the threshold voltage ($\approx 0.7\,\text{V}$ for silicon), significant current flows.

Step 5: Option A correctly states: forward biased, conducts current. Option B (reverse biased, no conduction) is incorrect because the polarity is for forward bias. Option C (forward biased but no conduction) is incorrect – in forward bias the diode conducts once threshold is exceeded. Option D is self-contradictory.

Final Answer: Forward biased; conducts current $\Rightarrow \boxed{(A)}$

Answer: (A) Go Back to Question 28

Q29.

Solution

Concept: EM spectrum – X-ray frequency range. The electromagnetic spectrum spans many decades. X-rays are high-energy photons with frequencies between gamma rays (higher) and UV (lower).

Solution – Step by Step:

Step 1: The EM spectrum frequency ranges:

- Radio waves: 10^3–10^9 Hz
- Microwaves: 10^9–10^{12} Hz
- Infrared: 10^{11}–4×10^{14} Hz
- Visible: 4×10^{14}–7×10^{14} Hz
- UV: 10^{15}–10^{17} Hz
- X-rays: 10^{17}–10^{19} Hz
- Gamma rays: $> 10^{19}$ Hz

Step 2: X-rays correspond to wavelengths 0.001–$10\,\text{nm}$ (10^{-12}–10^{-8} m).

Step 3: Frequency: $f = c/\lambda = (3 \times 10^8)/(10^{-8} \text{ to } 10^{-12}) = 10^{17}$ to 10^{20} Hz.

Step 4: Option C (10^{17}–10^{19}) is the correct range. Option A is radio/microwave. Option B is infrared/optical. Option D extends into cosmic ray territory.

Final Answer: X-ray frequency: $\boxed{10^{17}\text{–}10^{19}\,\text{Hz}}$ (Option C)

Answer: (C) Go Back to Question 29

Q30.

Solution

Concept: Types of charge carriers in p-type semiconductors. A p-type semiconductor is created by doping an intrinsic semiconductor with trivalent impurities (acceptors). This creates excess holes as majority carriers. The few thermally generated electrons serve as minority carriers.

Solution – Step by Step:

Step 1: In a p-type semiconductor, trivalent impurity atoms (like boron, aluminium, gallium) are added to the intrinsic semiconductor (silicon or germanium).

Step 2: Each trivalent atom creates an acceptor level just above the valence band. Electrons from the valence band fill these levels, leaving behind holes in the valence band.

Step 3: Result: large number of holes (majority carriers) and very few thermally excited electrons (minority carriers).

Step 4: Majority carriers = holes; Minority carriers = electrons. This is Option B.

Step 5: Option A (electrons majority, holes minority) describes an n-type semiconductor. Option C introduces protons – protons are not mobile charge carriers in semiconductors. Option D mixes hole majority with proton minority – protons are never mobile carriers.

Final Answer: Majority: holes; Minority: electrons $\Rightarrow \boxed{(B)}$

Answer: (D) Go Back to Question 30

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	B	3	C	4	D	5	D
6	D	7	D	8	B	9	A	10	A
11	A	12	D	13	D	14	B	15	C
16	D	17	C	18	D	19	C	20	B
21	A	22	A	23	D	24	A	25	A
26	C	27	B	28	A	29	C	30	D