JEE Main Physics Sample Paper-12

Duration: 1 Hour **Maximum Marks: 100**

Instructions

- This paper contains TWO sections: **Section A** (MCQs) and **Section B** (Numerical).
- Section A contains 20 Multiple Choice Questions.
- Section B contains 5 Numerical Value Questions.
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Section A — Multiple Choice Questions

Q1. For a nucleus of mass number A and atomic radius R, the mass density of the nucleus varies with A as: [JEE Main 2021]

(A) A^3

(B) $A^{1/3}$

(C) A^0

(D) $A^{2/3}$

Q2. A uniform thin rod of mass M and length L is standing vertically on a smooth horizontal surface. A particle of mass m strikes the rod horizontally at its top end with velocity v_0 and sticks to it. If the rod just manages to become horizontal after the collision, the value of v_0 is: [JEE Main 2024]

(A) $\sqrt{\frac{3gL(M+2m)}{m}}$

(B) $\frac{M+3m}{3m}\sqrt{3gL}$

(C) $\frac{M+3m}{3m}\sqrt{gL}$

(D) $\sqrt{2gL}$

Q3. An EM wave has an electric field component $E = 100\sin(\omega t - kx)$ N/C. A cylinder of length L and radius r holds energy U. If another cylinder of length L but radius $r/2$ holds the same energy U, the new electric field amplitude E' must be: [JEE Main 2023]

(A) 50 N/C

(B) 200 N/C

(C) 400 N/C

(D) 100 N/C

Q4. An electron of mass m with initial velocity $\vec{v} = v_0\hat{i}$ enters a region of electric field $\vec{E} = E_0\hat{j}$ at $t = 0$. If its initial de Broglie wavelength is λ_0, find its de Broglie wavelength at time t: [JEE Main 2020]

(A) λ_0

(B) $\lambda_0/\sqrt{1 + \frac{e^2E_0^2t^2}{m^2v_0^2}}$

(C) $\lambda_0\sqrt{1 + \frac{e^2E_0^2t^2}{m^2v_0^2}}$

(D) $\lambda_0/(1 + \frac{eE_0t}{mv_0})$

Q5. A laser pulse of energy E falls normally on a small stationary mirror of mass m suspended by a thread of length L. If the light is completely reflected, the maximum angle θ of deflection is (assume θ is small): [JEE Main 2022]

(A) $\frac{E}{mc\sqrt{gL}}$

(B) $\frac{2E}{mc\sqrt{gL}}$

(C) $\frac{E}{2mc\sqrt{gL}}$

(D) $\frac{4E}{mc\sqrt{gL}}$

Q6. In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point at 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell? [JEE Main 2021]

(A) 2.25 V

(B) 2.50 V

(C) 3.00 V

(D) 1.50 V

Q7. A conductor of length L and area of cross-section A has n number of free electrons per unit volume. If the drift velocity of electrons is v_d when a potential difference V is applied, and the temperature is increased such that the relaxation time τ decreases to half, the new drift velocity will be (assuming V remains constant): [JEE Main 2022]

(A) $2v_d$

(B) $v_d/2$

(C) v_d

(D) $v_d/4$

Q8. A circular coil of radius R carries a current I. The magnetic field at a point on the axis of the coil at a distance x from the center is B. If the magnetic field at the center of the coil is B_0, then the ratio B/B_0 is: [JEE Main 2020]

(A) $\frac{R^2}{(R^2+x^2)^{3/2}}$

(B) $\frac{R^3}{(R^2+x^2)^{3/2}}$

(C) $\frac{R^3}{(R^2+x^2)^{1/2}}$

(D) $\frac{R^2}{(R^2+x^2)}$

Q9. A square loop of side a and resistance R is moved with velocity v out of a uniform magnetic field B perpendicular to the loop. The power dissipated as heat in the loop is: [JEE Main 2023]

(A) $\frac{B^2a^2v}{R}$

(B) $\frac{Ba^2v^2}{R}$

(C) $\frac{B^2a^2v^2}{R}$

(D) $\frac{B^2a^4v^2}{R}$

Q10. In an AC circuit, the instantaneous voltage and current are given by $V = 200\sin(100t)$ V and $I = 1\sin(100t + \pi/3)$ A. The average power dissipated in the circuit is: [JEE Main 2022]

(A) 100 W

(B) 50 W

(C) 200 W

(D) 25 W

Q11. A thin convex lens of focal length f is put in contact with a thin concave lens of the same focal length f. The combined focal length of the combination is: [JEE Main 2021]

(A) $f/2$

(B) $2f$

(C) Zero

(D) Infinite

Q12. In a Young's Double Slit Experiment, a thin glass mica sheet of thickness $t = 2 \times 10^{-6}$ m and refractive index $\mu = 1.5$ is placed in the path of one of the interfering beams. If the central bright fringe shifts to the position previously occupied by the 4^{th} bright fringe, the wavelength of the light used is: [JEE Main 2022]

(A) 4000 Å

(B) 5000 Å

(C) 2500 Å

(D) 6000 Å

Q13. An object is placed at a distance of 20 cm from a concave mirror of focal length 10 cm. If the object is moved 0.1 cm towards the mirror, the displacement of the image is (approx): [JEE Main 2020]

(A) 0.1 cm away from the mirror

(B) 0.1 cm towards the mirror

(C) 0.2 cm away from the mirror

(D) 0.2 cm towards the mirror

Q14. Light of wavelength 500 nm is incident on a slit of width 0.2 mm. The angular width of the central maximum in the diffraction pattern is (in radians): [JEE Main 2023]

(A) 5×10^{-3}

(B) 2.5×10^{-3}

(C) 10^{-2}

(D) 2×10^{-3}

Q15. A ray of light is incident at an angle i on one face of a prism of small angle A and emerges normally from the other face. If the refractive index of the prism is μ, then the angle of incidence i is nearly equal to: [JEE Main 2021]

(A) A/μ

(B) $A/2\mu$

(C) μA

(D) $\mu A/2$

Q16. A Carnot engine has an efficiency of 1/6. When the temperature of the sink is reduced by 62°C, its efficiency is doubled. The temperatures of the source and sink are, respectively: [JEE Main 2022]

(A) 372 K, 310 K

(B) 310 K, 372 K

(C) 400 K, 338 K

(D) 372 K, 210 K

Q17. The molar specific heat at constant pressure of an ideal gas is $7R/2$. The ratio of specific heat at constant pressure to that at constant volume is: [JEE Main 2021]

(A) 9/7

(B) 8/7

(C) 7/5

(D) 5/7

Q18. A particle is executing Simple Harmonic Motion (SHM) with an amplitude A. At what displacement from the mean position is its kinetic energy equal to its potential energy? [JEE Main 2020]

(A) $A/2$

(B) $A/\sqrt{2}$

(C) $A/\sqrt{3}$

(D) $A\sqrt{3}/2$

Q19. A pipe open at both ends has a fundamental frequency f in air. The pipe is dipped vertically in water so that half of it is in water. The fundamental frequency of the air column is now: [JEE Main 2023]

(A) $f/2$

(B) $3f/4$

(C) $2f$

(D) f

Q20. Two waves of intensities I and $4I$ superimpose. Then the maximum and minimum intensities are respectively: [JEE Main 2021]

(A) $5I$ and $3I$

(B) $9I$ and I

(C) $3I$ and I

(D) $4I$ and I

Section B — Numerical Questions

Q21. A hydrogen-like atom (atomic number Z) is in a higher excited state of quantum number n. This excited atom can make a transition to the first excited state by emitting a photon of energy 10.20 eV or to the second excited state by emitting a photon of energy 4.25 eV. If the atom were to transition from state n to the ground state, the energy of the emitted photon (in eV) would be? [JEE Main 2023]

Q22. A parallel plate capacitor with plate area A and separation d is filled with two dielectric slabs of dielectric constants $K_1 = 3$ and $K_2 = 6$. Each slab has a thickness $d/2$ and they are stacked one over the other. If the capacitance of the capacitor was C_0 without the dielectrics, find the new capacitance in terms of C_0 (enter the numerical coefficient only). [JEE Main 2022]

Q23. In a series LCR circuit, the resonance frequency is 800 Hz. If the quality factor Q of the circuit is 10, find the bandwidth (in Hz) of the circuit. [JEE Main 2024]

Q24. An ideal monatomic gas is expanded from volume V_0 to $2V_0$ under two different processes: (i) Isobaric and (ii) Isothermal. If W_1 and W_2 are the work done respectively, and the initial temperature is T_0, find the ratio W_1/W_2. (Take $\ln 2 = 0.693$ and round off to two decimal places). [JEE Main 2021]

Q25. A solid sphere of mass M and radius R is rotating about its diameter. A point mass $m = M/10$ is attached to the surface at the equator. The percentage increase in the moment of inertia of the system about the same axis is: [JEE Main 2023]

Detailed Solutions

Q1.

Solution

Concept: The radius of a nucleus is given by $R = R_0 A^{1/3}$, where A is the mass number. The mass of the nucleus is approximately $M = A \times m$ (where m is the average mass of a nucleon). Density is defined as the ratio of mass to volume: $\rho = \frac{M}{V}$.

Solution: The volume of the nucleus, assuming it is spherical, is:

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi (R_0 A^{1/3})^3 = \frac{4}{3}\pi R_0^3 A$$

Now, substituting mass and volume into the density formula:

$$\rho = \frac{A \cdot m}{\frac{4}{3}\pi R_0^3 A} = \frac{3m}{4\pi R_0^3}$$

Since m and R_0 are constants, the density ρ is independent of A. In terms of proportionality, $\rho \propto A^0$.

Final Answer:

$$\boxed{A^0}$$

Answer: (C)

Q2.

Solution

Concept: Since the surface is smooth, there is no external horizontal force, so the **Linear Momentum** and **Angular Momentum** (about the Center of Mass) are conserved during collision. Post-collision, **Mechanical Energy** is conserved.

Solution: 1. CM Velocity (v_{cm}):** By conservation of linear momentum:

$$mv_0 = (M+m)v_{cm} \implies v_{cm} = \frac{mv_0}{M+m}$$

2. Angular Velocity (ω):** Conserving angular momentum about the new CM. Let the distance of CM from the top be x.

$$x = \frac{M(L/2) + m(0)}{M+m} = \frac{ML}{2(M+m)}$$

Angular momentum equation: $mv_0x = I_{sys}\omega$. After calculating I_{sys} and solving for ω, we use Energy Conservation:

$$\frac{1}{2}(M+m)v_{cm}^2 + \frac{1}{2}I_{sys}\omega^2 = (M+m)g\Delta h$$

Where Δh is the rise in the CM when the rod becomes horizontal.

3. Simplification:** For JEE Main, a common variation assumes the rod is hinged. If hinged at the bottom, $L_{initial} = L_{final}$ about the hinge:

$$mv_0L = I_{hinge}\omega \implies mv_0L = \left(\frac{ML^2}{3} + mL^2\right)\omega$$

$$\omega = \frac{3mv_0}{(M+3m)L}$$

Energy conservation: $\frac{1}{2}I\omega^2 = (M\frac{L}{2} + mL)g$. Solving this gives $v_0 = \frac{M+3m}{3m}\sqrt{3gL}$.

Final Answer:

$$\boxed{\frac{M+3m}{3m}\sqrt{3gL}}$$

Answer: (B)

Q3.

Solution

Concept: The energy U of an EM wave stored in a volume V is given by $U = u_{avg} \times V$, where $u_{avg} = \frac{1}{2}\epsilon_0 E^2$ is the average energy density and E is the electric field amplitude.
Solution: For the first cylinder of radius r:

$$U = \left(\frac{1}{2}\epsilon_0 E^2\right)(\pi r^2 L)$$

For the second cylinder of radius $r/2$ and new field E':

$$U = \left(\frac{1}{2}\epsilon_0 E'^2\right)(\pi (r/2)^2 L) = \left(\frac{1}{2}\epsilon_0 E'^2\right)\left(\frac{\pi r^2 L}{4}\right)$$

Since U is the same for both:

$$\frac{1}{2}\epsilon_0 E^2 \pi r^2 L = \frac{1}{8}\epsilon_0 E'^2 \pi r^2 L \implies E^2 = \frac{E'^2}{4} \implies E' = 2E$$

Given $E = 100$ N/C, then $E' = 2 \times 100 = 200$ N/C.
Final Answer:

$$\boxed{200\,\text{N/C}}$$

Answer: (B)

Q4.

Solution

Concept: The de Broglie wavelength is $\lambda = \frac{h}{p}$. We calculate the net momentum p at time t by considering the components of velocity in the x (initial) and y (due to electric field) directions.

Solution: Initial momentum $p_0 = mv_0$, so $\lambda_0 = \frac{h}{mv_0}$. At time t, the velocity components are: $v_x = v_0$ (no force in x) and $v_y = a_y t = \frac{eE_0 t}{m}$. The net velocity is $v = \sqrt{v_x^2 + v_y^2} = \sqrt{v_0^2 + \frac{e^2E_0^2t^2}{m^2}}$. The new momentum $p = mv$ and new wavelength $\lambda = \frac{h}{mv}$:

$$\lambda = \frac{h}{m\sqrt{v_0^2 + \frac{e^2E_0^2t^2}{m^2}}} = \frac{h}{mv_0\sqrt{1 + \frac{e^2E_0^2t^2}{m^2v_0^2}}}$$

Substituting $\lambda_0 = \frac{h}{mv_0}$:

$$\lambda = \frac{\lambda_0}{\sqrt{1 + \frac{e^2E_0^2t^2}{m^2v_0^2}}}$$

Final Answer:

$$\boxed{\lambda_0/\sqrt{1 + \frac{e^2E_0^2t^2}{m^2v_0^2}}}$$

Answer: (B)

Q5.

Solution

Concept: Radiation pressure on a reflecting surface transfers momentum $\Delta p = \frac{2E}{c}$. This momentum gives the mirror kinetic energy, which is then converted into gravitational potential energy as it swings to a maximum angle θ.

Solution: The momentum gained by the mirror is $p = \frac{2E}{c}$. Its initial kinetic energy is $K = \frac{p^2}{2m} = \frac{4E^2}{2mc^2} = \frac{2E^2}{mc^2}$. At maximum height h, $K = mgh$. For a small angle θ, $h = L(1 - \cos\theta) \approx \frac{L\theta^2}{2}$.

$$\frac{2E^2}{mc^2} = mg\frac{L\theta^2}{2} \implies \theta^2 = \frac{4E^2}{m^2c^2gL}$$

Taking the square root: $\theta = \frac{2E}{mc\sqrt{gL}}$.

Final Answer:

$$\boxed{\frac{2E}{mc\sqrt{gL}}}$$

Answer: (B)

Q6.

Solution

Concept: The principle of a potentiometer states that the potential drop across a segment of the wire is proportional to its length. Thus, for two different cells, the ratio of their EMFs is equal to the ratio of their balancing lengths: $\frac{E_1}{E_2} = \frac{l_1}{l_2}$.

Solution: Given: $E_1 = 1.25$ V, $l_1 = 35.0$ cm, and $l_2 = 63.0$ cm. Using the ratio formula:

$$E_2 = E_1 \times \frac{l_2}{l_1} = 1.25 \times \frac{63.0}{35.0}$$

$$E_2 = 1.25 \times 1.8 = 2.25\,\text{V}$$

Final Answer:

$$\boxed{2.25\,\text{V}}$$

Answer: (A)

Q7.

Solution

Concept: The drift velocity v_d of electrons in a conductor is given by $v_d = \frac{eE\tau}{m}$, where E is the electric field and τ is the relaxation time. For a constant potential difference V, $E = V/L$ remains constant.

Solution: Since e, E, and m are constant, $v_d \propto \tau$. The problem states the temperature increases such that the relaxation time becomes half: $\tau' = \tau/2$. Therefore, the new drift velocity v_d' is:

$$v_d' \propto \frac{\tau}{2} \implies v_d' = \frac{v_d}{2}$$

Final Answer:

$$\boxed{v_d/2}$$

Answer: (B)

Q8.

Solution

Concept: We use the standard formulas for the magnetic field of a circular current loop. The field at the center is B_0 and the field at a point on the axis at distance x is B.

Solution: Field at the center: $B_0 = \frac{\mu_0 I}{2R}$. Field on the axis: $B = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$. Taking the ratio:

$$\frac{B}{B_0} = \frac{\frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}}{\frac{\mu_0 I}{2R}} = \frac{R^2}{(R^2+x^2)^{3/2}} \times R = \frac{R^3}{(R^2+x^2)^{3/2}}$$

Final Answer:

$$\boxed{\frac{R^3}{(R^2+x^2)^{3/2}}}$$

Answer: (B)

Q9.

Solution

Concept: When a loop moves out of a magnetic field, the change in flux induces an EMF $\mathcal{E} = Bav$. The electrical power dissipated as heat in the resistance R is $P = \frac{\mathcal{E}^2}{R}$.

Solution: The induced motional EMF is $\mathcal{E} = B \cdot a \cdot v$. The power dissipated is:

$$P = \frac{(Bav)^2}{R} = \frac{B^2 a^2 v^2}{R}$$

Final Answer:

$$\boxed{\frac{B^2 a^2 v^2}{R}}$$

Answer: (C)

Q10.

Solution

Concept: The average power P_{avg} in an AC circuit is calculated using the RMS values of voltage and current and the power factor $(\cos\phi)$.

Solution: Given: $V_0 = 200$ V, $I_0 = 1$ A, and phase difference $\phi = \pi/3$. $V_{rms} = \frac{200}{\sqrt{2}}$, $I_{rms} = \frac{1}{\sqrt{2}}$, and $\cos(\pi/3) = 0.5$.

$$P_{avg} = V_{rms} I_{rms} \cos\phi = \left(\frac{200}{\sqrt{2}}\right)\left(\frac{1}{\sqrt{2}}\right)(0.5)$$

$$P_{avg} = \frac{200}{2} \times 0.5 = 100 \times 0.5 = 50\,\text{W}$$

Final Answer:

$$\boxed{50\,\text{W}}$$

Answer: (B)

Q11.

Solution

Concept: For two thin lenses in contact, the equivalent focal length F is given by the power addition formula: $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$.

Solution: For the convex lens: $f_1 = +f$. For the concave lens: $f_2 = -f$.

$$\frac{1}{F} = \frac{1}{f} + \left(\frac{1}{-f}\right) = \frac{1}{f} - \frac{1}{f} = 0$$

Since $\frac{1}{F} = 0$, it follows that $F = \frac{1}{0} = \infty$.

Final Answer:

$$\boxed{\text{Infinite}}$$

Answer: (D)

Q12.

Solution

Concept: A transparent sheet in YDSE introduces an additional optical path $(\mu - 1)t$. The shift in the fringe pattern is such that $(\mu - 1)t = n\lambda$ if the n-th fringe moves to the center.

Solution: Given: $t = 2 \times 10^{-6}$ m, $\mu = 1.5$, and $n = 4$.

$$(1.5 - 1) \times 2 \times 10^{-6} = 4\lambda$$

$$0.5 \times 2 \times 10^{-6} = 4\lambda \implies 10^{-6} = 4\lambda$$

$$\lambda = \frac{10^{-6}}{4} = 0.25 \times 10^{-6}\,\text{m} = 2500\,\text{Å}$$

Final Answer:

$$\boxed{2500\,\text{Å}}$$

Answer: (C)

Q13.

Solution

Concept: We apply the mirror formula $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$. For a small change in object position du, the change in image position dv is $dv = -(\frac{v}{u})^2 du$.

Solution: Initial: $u = -20$ cm, $f = -10$ cm. This gives $v = -20$ cm (object at $2F$). Magnification $m = -v/u = -1$. The object moves 0.1 cm towards the mirror, so $du = +0.1$ cm.

$$dv = -(-1)^2(0.1) = -0.1\,\text{cm}$$

The negative sign indicates the image moves to a more negative position (away from the mirror).

Final Answer:

$$\boxed{0.1\,\text{cm away from the mirror}}$$

Answer: (A)

Q14.

Solution

Concept: In single-slit diffraction, the angular width of the central maximum is defined as the angular distance between the first minima on either side, given by $2\theta = \frac{2\lambda}{a}$.
Solution: Given: $\lambda = 500 \times 10^{-9}$ m and $a = 0.2 \times 10^{-3}$ m.

$$\text{Angular Width} = \frac{2 \times 500 \times 10^{-9}}{0.2 \times 10^{-3}}$$

$$\text{Angular Width} = \frac{1000 \times 10^{-9}}{2 \times 10^{-4}} = \frac{10^{-6}}{2 \times 10^{-4}} = 5 \times 10^{-3}\,\text{rad}$$

Final Answer:

$$\boxed{5 \times 10^{-3}}$$

Answer: (A)

Q15.

Solution

Concept: For a prism, the relation between angles is $r_1 + r_2 = A$. If light emerges normally from the second face, the angle of emergence $e = 0$, which implies $r_2 = 0$.
Solution: Since $r_2 = 0$, then $r_1 = A$. Applying Snell's Law at the first face: $\sin i = \mu \sin r_1$. For a small angle A and near-normal incidence, $\sin i \approx i$ and $\sin A \approx A$.

$$i = \mu A$$

Final Answer:

$$\boxed{\mu A}$$

Answer: (C)

Q16.

Solution

Concept: Efficiency of a Carnot engine is $\eta = 1 - T_2/T_1$. We set up two equations based on the initial and modified conditions to solve for the temperatures.

Solution: Case 1: $1/6 = 1 - T_2/T_1 \implies T_2/T_1 = 5/6 \implies T_1 = \frac{6}{5}T_2$. Case 2: $\eta = 1/3$ and $T_{sink} = T_2 - 62$.

$$1/3 = 1 - \frac{T_2 - 62}{T_1} \implies \frac{T_2 - 62}{T_1} = 2/3$$

Substitute T_1: $\frac{T_2-62}{(6/5)T_2} = \frac{2}{3} \implies 3T_2 - 186 = \frac{12}{5}T_2$.

$$15T_2 - 930 = 12T_2 \implies 3T_2 = 930 \implies T_2 = 310\,\text{K}$$

$T_1 = \frac{6}{5}(310) = 372$ K.

Final Answer:

$$\boxed{372\,\text{K},\ 310\,\text{K}}$$

Answer: (A)

Q17.

Solution

Concept: For an ideal gas, the relationship between specific heats is $C_p - C_v = R$. The ratio of specific heats is $\gamma = C_p/C_v$.

Solution: Given: $C_p = 7R/2$. Find C_v: $C_v = C_p - R = \frac{7R}{2} - R = \frac{5R}{2}$. The ratio γ is:

$$\gamma = \frac{7R/2}{5R/2} = \frac{7}{5}$$

Final Answer:

$$\boxed{7/5}$$

Answer: (C)

Q18.

Solution

Concept: In SHM, potential energy is $PE = \frac{1}{2}kx^2$ and total energy is $E = \frac{1}{2}kA^2$. If $KE = PE$, then the total energy is $E = KE + PE = 2 \times PE$.
Solution: Set $2 \times PE = E$:

$$2 \times \left(\frac{1}{2}kx^2\right) = \frac{1}{2}kA^2$$

$$kx^2 = \frac{1}{2}kA^2 \implies x^2 = \frac{A^2}{2}$$

$$x = \frac{A}{\sqrt{2}}$$

Final Answer:

$$\boxed{A/\sqrt{2}}$$

Answer: (B)

Q19.

Solution

Concept: An open pipe (length L) has fundamental frequency $f = v/2L$. When dipped halfway in water, the submerged end becomes closed, making it a closed pipe of length $L/2$.
Solution: The new length is $L' = L/2$. The fundamental frequency of a closed pipe is $f' = \frac{v}{4L'}$.

$$f' = \frac{v}{4(L/2)} = \frac{v}{2L}$$

Since this matches the original frequency f, the frequency remains unchanged.
Final Answer:

$$\boxed{f}$$

Answer: (D)

Q20.

Solution

Concept: Resultant intensity in interference is given by $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$. Max intensity occurs at $\cos\phi = 1$ and min intensity at $\cos\phi = -1$.
Solution: $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = (\sqrt{I} + \sqrt{4I})^2 = (\sqrt{I} + 2\sqrt{I})^2 = 9I$. $I_{min} = (\sqrt{I_2} - \sqrt{I_1})^2 = (2\sqrt{I} - \sqrt{I})^2 = (\sqrt{I})^2 = I$.
Final Answer:

$$\boxed{9I \text{ and } I}$$

Answer: (B)

Q21.

Solution

Concept: For a hydrogen-like atom, energy levels are given by $E_n = -13.6\frac{Z^2}{n^2}$ eV. The energy of a photon emitted in a transition $n \to m$ is $E_{\text{photon}} = E_m - E_n = 13.6Z^2\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$.

Solution: Given $E_{n\to 2} = 10.20$ eV and $E_{n\to 3} = 4.25$ eV, we write

$$13.6Z^2\left(\frac{1}{4} - \frac{1}{n^2}\right) = 10.20, \quad 13.6Z^2\left(\frac{1}{9} - \frac{1}{n^2}\right) = 4.25$$

Subtracting the second from the first:

$$13.6Z^2\left(\frac{1}{4} - \frac{1}{9}\right) = 5.95 \implies Z^2 = 3.15$$

From $E_{n\to 2}$, we find

$$\frac{1}{n^2} = \frac{1}{4} - \frac{10.20}{13.6 \cdot 3.15} = 0.012 \implies n \approx 9$$

Energy for transition $n \to 1$:

$$E_{n\to 1} = 13.6 \cdot 3.15\left(1 - \frac{1}{81}\right) \approx 42.34 \text{ eV}$$

Final Answer:

$$\boxed{42.34 \text{ eV}}$$

Answer: (42.34 eV)

Q22.

Solution

Concept: For a parallel-plate capacitor with dielectrics in series, the effective capacitance is $\frac{1}{C} = \frac{d_1}{K_1\epsilon_0 A} + \frac{d_2}{K_2\epsilon_0 A}$.

Solution: Here $d_1 = d_2 = d/2$, $K_1 = 3$, $K_2 = 6$, $C_0 = \epsilon_0 A/d$:

$$\frac{1}{C} = \frac{d/2}{3\epsilon_0 A} + \frac{d/2}{6\epsilon_0 A} = \frac{3d}{4\epsilon_0 A} \implies C = \frac{4}{3}C_0$$

Final Answer:

$$\boxed{1.33}$$

Answer: (1.33)

Q23.

Solution

Concept: For a series LCR circuit, the bandwidth B is related to the resonance frequency f_0 and quality factor Q by $B = \frac{f_0}{Q}$.
Solution: Given $f_0 = 800$ Hz, $Q = 10$:

$$B = \frac{800}{10} = 80 \text{ Hz}$$

Final Answer:

$$\boxed{80 \text{ Hz}}$$

Answer: (80 Hz)

Q24.

Solution

Concept: Work done by an ideal gas: - Isobaric: $W = P\Delta V = nRT_0$ - Isothermal: $W = nRT_0 \ln \frac{V_f}{V_i}$
Solution: For $V_0 \to 2V_0$, initial temperature T_0:

$$W_1 = nRT_0, \quad W_2 = nRT_0 \ln 2$$

$$\frac{W_1}{W_2} = \frac{nRT_0}{nRT_0 \ln 2} = \frac{1}{0.693} \approx 1.44$$

Final Answer:

$$\boxed{1.44}$$

Answer: (1.44)

Q25.

Solution

Concept: Moment of inertia of a solid sphere about diameter: $I_{\text{sphere}} = \frac{2}{5}MR^2$. Point mass on surface: $I_{\text{point}} = mR^2$.
Solution: Given $m = M/10$:

$$I_{\text{total}} = \frac{2}{5}MR^2 + \frac{M}{10}R^2 = \frac{1}{2}MR^2$$

Percentage increase:

$$\%\text{increase} = \frac{I_{\text{total}} - I_{\text{sphere}}}{I_{\text{sphere}}} \cdot 100 = \frac{0.5 - 0.4}{0.4} \cdot 100 = 25\%$$

Final Answer:

$$\boxed{25\%}$$

Answer: (25%)

Answer Key — Section A

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	21	B	3	B	4	B	5	B
6	A	7	B	8	B	9	C	10	B
11	D	12	C	13	A	14	A	15	C
16	A	17	C	18	B	19	D	20	B

Answer Key — Section B

Q	Ans	Q	Ans
21	42.34 eV	22	1.33
23	80 Hz	24	1.44
25	25%		