WBJEE Physics Sample Paper-9

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains a total of **40** Multiple Choice Questions.
- **Section A (Q1–Q30):** Each correct answer carries +1 mark. Incorrect answer: **0.25 marks**. Only **one** correct option.
- **Section B (Q31–Q35):** Each correct answer carries +2 mark. Incorrect answer: **0.5 marks**. Only **one** correct option.
- **Section C (Q36–Q40)**: Each correct answer carries **+2 marks**. **No negative marking.** One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Section–A — 30 Questions × 1 Mark Each
(Negative Marking: 0.25) [Single Correct]

Q1. The velocity v of a particle depends on time t as $v = \alpha t + \frac{\beta}{t+\gamma} + \delta \ln(\sigma t)$. If the dimensions of v and t are $[LT^{-1}]$ and $[T]$ respectively, find the dimensional formula for $\frac{\alpha\delta}{\beta\gamma}$.

(A) $[M^0L^0T^{-2}]$

(B) $[M^0L^{-1}T^{-1}]$

(C) $[M^0L^1T^{-3}]$

(D) $[M^1L^0T^{-2}]$

Q2. In a specialized experiment measuring the acceleration due to gravity g using a modified precise pendulum, the time period is given by $T = 2\pi\sqrt{\frac{L}{g(1-\alpha\theta)}}$, where α is a known dimensionless constant and θ is the maximum angular amplitude. If the fractional error in measuring L is $\pm 1\%$ and the absolute error in measuring

T is ± 0.02 s at $T = 2.00$ s, while θ is measured as 0.10 ± 0.01 rad with $\alpha = 0.5$, what is the maximum percentage error in the determination of g?

(A) 2.22%

(B) 3.11%

(C) 4.05%

(D) 5.15%

Q3. A fighter jet flying horizontally at a constant speed v_0 at an altitude H passes directly over an anti-aircraft missile launcher. The missile is launched at an angle θ to the horizontal with an initial speed u. If the missile successfully hits the jet, the minimum initial speed u required must satisfy which of the following relations (neglect air resistance)?

(A) $u \geq \sqrt{v_0^2 + 2gH}$

(B) $u \geq v_0 + \sqrt{2gH}$

(C) $u \geq \sqrt{v_0^2 + gH}$

(D) $u \geq \sqrt{2(v_0^2 + gH)}$

Q4. A particle moves in the xy-plane such that its position vector is given by $\vec{r}(t) = R\cos(\omega t)\hat{i} + R\sin(\omega t)\hat{j} + ct^2\hat{k}$ where R, ω, and c are positive constants. The magnitude of the tangential acceleration of the particle at any time t is:

(A) $\frac{4c^2t}{\sqrt{R^2\omega^2+4c^2t^2}}$

(B) $\frac{2c^2t}{\sqrt{R^2\omega^2+c^2t^2}}$

(C) $2c$

(D) Zero

Q5. A block of mass m rests on a rough horizontal surface with a coefficient of static friction μ. A force F is applied to the block at an angle θ above the horizontal. The minimum magnitude of force F required to initiate motion of the block, optimized over all possible angles θ, is:

(A) $\frac{\mu mg}{\sqrt{1+\mu^2}}$

(B) μmg

(C) $\frac{\mu mg}{1+\mu}$

(D) $\frac{mg}{\sqrt{1+\mu^2}}$

Q6. A small bead of mass m is threaded on a smooth circular wire loop of radius R fixed in a vertical plane. The loop rotates about its vertical diameter with a constant angular velocity ω. If the bead remains stationary relative to the loop at an angular position θ measured from the lowest point of the loop, then $\cos\theta$ is equal to:

(A) $\frac{g}{R\omega^2}$

(B) $\frac{R\omega^2}{g}$

(C) $\frac{2g}{R\omega^2}$

(D) The bead can never remain stationary for $\omega^2 > \frac{g}{R}$

Q7. A conservative force field is given by $\vec{F} = -(2xy + z^3)\hat{i} - x^2\hat{j} - 3xz^2\hat{k}$. A particle of mass $m = 1$ kg moves from the origin $(0, 0, 0)$ to the point $(1, 1, 1)$ under the action of this force. If its initial velocity at the origin was $v_0 = 4$ m/s, its final kinetic energy at $(1, 1, 1)$ will be:

(A) 6 J

(B) 8 J

(C) 10 J

(D) 12 J

Q8. A ball of mass m moving with speed v collides obliquely with an identical stationary ball on a frictionless horizontal table. If the collision is perfectly elastic and the angle between their final velocity vectors is ϕ, then:

(A) $\phi = 45°$

(B) $\phi = 60°$

(C) $\phi = 90°$

(D) ϕ depends on the impact parameter and can be any value between 0° and 180°

Q9. A uniform solid cylinder of mass M and radius R is pulled on a rough horizontal plane by a horizontal force F applied at the top-most point of its cross-section. If the cylinder rolls without slipping, the acceleration of its center of mass is:

(A) $\frac{2F}{3M}$

(B) $\frac{4F}{3M}$

(C) $\frac{F}{M}$

(D) $\frac{3F}{4M}$

Q10. A thin uniform rod of length L and mass M is pivoted smoothly at one of its ends on a vertical wall. It is released from rest from a horizontal position. When the rod becomes vertical, the magnitude of the total force exerted by the pivot on the rod is:

(A) $2Mg$

(B) $\frac{5}{2}Mg$

(C) $4Mg$

(D) $\frac{7}{2}Mg$

Q11. Consider a thin, uniform spherical shell of mass M and radius R. A small point mass m is placed at a distance r from the center of the shell. The gravitational potential energy $U(r)$ of the system as a function of r ($r < R$) is normalized such that $U(\infty) = 0$. The value of $U(r)$ inside the shell is:

(A) $-\frac{GMm}{R}$

(B) $-\frac{GMm}{r}$

(C) Zero

(D) $-\frac{GMm}{2R^3}(3R^2 - r^2)$

Q12. A solid copper cube of edge length a hangs suspended from a long thin steel wire. Due to the weight of the cube, the volumetric strain in the cube is $\Delta V/V$. If the bulk modulus of copper is B, the average pressure experienced by the cube due to its own weight and ambient conditions changes such that the uniform isotropic stress inside is σ. What is the total elastic energy stored in the deformed copper cube?

(A) $\frac{Ba^3}{2}\left(\frac{\Delta V}{V}\right)^2$

(B) $Ba^3\left(\frac{\Delta V}{V}\right)^2$

(C) $\frac{a^3}{2B}\left(\frac{\Delta V}{V}\right)^2$

(D) $\frac{B^2a^3}{2}\left(\frac{\Delta V}{V}\right)$

Q13. A cylindrical vessel filled with a non-viscous liquid of density ρ rotates about its vertical central axis with a constant angular velocity ω. The difference in height h of the liquid level between the central axis and the vessel wall at a distance r from the axis is:

(A) $\frac{\omega^2 r^2}{g}$

(B) $\frac{\omega^2 r^2}{2g}$

(C) $\frac{2\omega^2 r^2}{g}$

(D) $\frac{\omega^2 r}{g}$

Q14. A tiny spherical drop of liquid of surface tension T and radius r_1 coalesces isothermally with another drop of radius r_2 to form a single large drop of radius R under atmospheric pressure P_0. The total energy released during this process is:

(A) $4\pi T(r_1^2 + r_2^2 - R^2)$

(B) $4\pi T(R^2 - r_1^2 - r_2^2)$

(C) $3\pi T(r_1^2 + r_2^2 - R^2)$

(D) $2\pi T(r_1^2 + r_2^2 - R^2)$

Q15. One mole of an ideal monoatomic gas undergoes a thermodynamic cyclic process $A \rightarrow B \rightarrow C \rightarrow A$ represented on a $P-V$ diagram. $A \rightarrow B$ is an isothermal expansion at temperature T_0 from volume V_0 to $2V_0$. $B \rightarrow C$ is an isobaric compression back to volume V_0. $C \rightarrow A$ is an isochoric process returning to the initial state. The net work done by the gas during one complete cycle is:

(A) $RT_0\left(\ln 2 - \frac{1}{2}\right)$

(B) $RT_0 \ln 2$

(C) $RT_0(\ln 2 - 1)$

(D) $\frac{3}{2}RT_0 \ln 2$

Q16. An ideal gas heat engine operates in a Carnot cycle between a hot reservoir at temperature T_H and a cold reservoir at temperature T_C. If the efficiency of the engine is $\eta = 40\%$, and the temperature of the hot reservoir is raised by 50 K, the efficiency increases to 50%. The original temperatures T_H and T_C are respectively:

(A) 300 K, 180 K

(B) 400 K, 240 K

(C) 500 K, 300 K

(D) 600 K, 360 K

Q17. A gas mixture consists of 2 moles of oxygen (O_2, molar mass 32 g/mol) and 4 moles of argon (Ar, molar mass 40 g/mol) at a temperature T. Neglecting vibrational modes, the equivalent specific heat capacity at constant volume C_v of the mixture is:

(A) $\frac{11}{6}R$

(B) $\frac{13}{6}R$

(C) $\frac{9}{4}R$

(D) $\frac{7}{3}R$

Q18. Three identical rods of length L and thermal conductivity K are connected in series. The free end of the first rod is maintained at 100°C and the free end of the third rod is maintained at 0°C. In steady state, the temperatures of the two junctions are:

(A) 66.6°C, 33.3°C

(B) 75°C, 25°C

(C) 50°C, 25°C

(D) 60°C, 30°C

Q19. A particle executing simple harmonic motion along the x-axis has its potential energy given by $U(x) = kx^2$. When the displacement of the particle is half of its amplitude A, the ratio of its kinetic energy to its potential energy is:

(A) 1 : 3

(B) 3 : 1

(C) 1 : 4

(D) 4 : 1

Q20. A resonance tube open at one end and closed at the other has a fundamental frequency of 250 Hz. If the speed of sound in air is 340 m/s, the next higher resonant frequency that can be excited in this tube is:

(A) 500 Hz

(B) 750 Hz

(C) 1000 Hz

(D) 1250 Hz

Q21. A police car sounding a siren of frequency f_0 moves at a constant speed v_s towards a tall vertical cliff. If the speed of sound in air is v, the frequency of the echo heard by the driver inside the car is:

(A) $f_0\left(\frac{v+v_s}{v-v_s}\right)$

(B) $f_0\left(\frac{v-v_s}{v+v_s}\right)$

(C) $f_0\left(\frac{v}{v-v_s}\right)$

(D) $f_0\left(\frac{v+v_s}{v}\right)$

Q22. An infinitely long line charge having a uniform linear charge density λ lies along the z-axis. A dipole with a dipole moment $\vec{p} = p\hat{i}$ is placed at a distance r from the line charge along the x-axis. The net electrostatic force experienced by the dipole is:

(A) $-\frac{\lambda p}{2\pi\varepsilon_0 r^2}\hat{i}$

(B) $\frac{\lambda p}{2\pi\varepsilon_0 r^2}\hat{i}$

(C) $-\frac{\lambda p}{\pi\varepsilon_0 r^2}\hat{i}$

(D) Zero

Q23. Four identical point charges, each of charge $+q$, are placed at the four corners of a square of side length a. The electrostatic potential energy of a point charge $-Q$ placed at the center of the square is:

(A) $-\frac{4\sqrt{2}qQ}{4\pi\varepsilon_0 a}$

(B) $-\frac{2\sqrt{2}qQ}{4\pi\varepsilon_0 a}$

(C) $-\frac{\sqrt{2}qQ}{\pi\varepsilon_0 a}$

(D) Zero

Q24. A parallel-plate capacitor of plate area A and separation d is filled with two slabs of dielectric constants K_1 and K_2. Each slab has a thickness $d/2$ and parallel alignment to the plates. The equivalent capacitance of the system is:

(A) $\frac{2\varepsilon_0 A}{d}\left(\frac{K_1K_2}{K_1+K_2}\right)$

(B) $\frac{\varepsilon_0 A}{2d}(K_1 + K_2)$

(C) $\frac{\varepsilon_0 A}{d}\left(\frac{K_1K_2}{K_1+K_2}\right)$

(D) $\frac{2\varepsilon_0 A}{d}(K_1 + K_2)$

Q25. A wire of resistance R is stretched uniformly such that its length increases by 0.1%. Assuming the density of the material remains invariant during stretching, the percentage change in its electrical resistance is approximately:

(A) 0.1%

(B) 0.2%

(C) 0.05%

(D) 0.4%

Q26. In a potentiometer experiment, a cell of emf E_1 balances at a length of 120 cm. When another cell of emf E_2 is connected in series with E_1 helping each other, the balance point shifts to 300 cm. The ratio $\frac{E_1}{E_2}$ is:

(A) 2 : 3

(B) 3 : 2

(C) 5 : 3

(D) 1 : 2

Q27. Twelve identical resistors, each of resistance r, are connected to form the edges of a skeleton cube. The effective resistance of the network across the body diagonal of the cube is:

(A) $\frac{5}{6}r$

(B) $\frac{7}{12}r$

(C) $\frac{3}{4}r$

(D) $\frac{1}{2}r$

Q28. A thin insulated wire forms a circular loop of radius R and carries a steady current I. The magnetic field induction at a point on the axis of the loop at a distance x from the center is B. If B is exactly $\frac{1}{8}$th of the magnetic field at the center of the loop, then x is equal to:

(A) $R\sqrt{3}$

(B) $2R\sqrt{2}$

(C) $R\sqrt{7}$

(D) $3R$

Q29. An electron (charge $-e$, mass m) enters a region of uniform magnetic field $\vec{B} = B_0\hat{j}$ with an initial velocity $\vec{v} = v_{0x}\hat{i} + v_{0z}\hat{k}$. The path traced by the electron inside this magnetic field region will be a:

(A) Circle in the xz-plane

(B) Helix with a uniform pitch along the y-axis

(C) Helix with a uniform pitch along the z-axis

(D) Straight line along the resultant velocity direction

Q30. A magnetic dipole of magnetic moment $\vec{M}$ is placed in a non-uniform magnetic field $\vec{B} = B_0(1 + \alpha x)\hat{i}$ where α is a positive constant. If the dipole moment points along the positive x-axis, the net force acting on the magnetic dipole is:

(A) $MB_0\alpha\hat{i}$

(B) $-MB_0\alpha\hat{i}$

(C) $MB_0(1 + \alpha x)\hat{i}$

(D) Zero

Section B – 5 Questions × 2 Marks Each
(Negative Marking: 0.5) [Single Correct]

Q31. A rectangular conducting loop of width w and resistance R falls vertically under gravity out of a region containing a uniform horizontal magnetic field B perpendicular to the plane of the loop. If the loop reaches a terminal constant velocity v_t while partially exiting the field, then v_t is proportional to:

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

(B) $\frac{B^2w^2}{R}$

(C) $\frac{R}{Bw}$

(D) $\frac{Bw}{R}$

Q32. In a series $L - C - R$ alternating current circuit, the root-mean-square voltage across the resistor, inductor, and capacitor are found to be 120 V, 160 V, and 70 V respectively. The power factor ($\cos\phi$) of this alternating current circuit is:

(A) 0.6

(B) 0.8

(C) 0.5

(D) 1.0

Q33. Which of the following electromagnetic waves has the minimum wavelength?

(A) X-rays

(B) γ-rays

(C) Ultraviolet rays

(D) Cosmic rays

Q34. A thin biconvex lens made of glass (refractive index $n_g = 1.5$) has a focal length f in air. When it is completely immersed in a transparent liquid of refractive index $n_l = 1.25$, its new focal length f' becomes:

(A) $2.5f$

(B) $1.5f$

(C) $2.0f$

(D) $4.0f$

Q35. A ray of monochromatic light is incident at an angle of 60° on one face of an equilateral glass prism of refractive index $n = \sqrt{3}$. The angle of minimum deviation produced by this prism is:

(A) 30°

(B) 45°

(C) 60°

(D) 90°

Section C — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q36. In a classic Young's double-slit experiment illuminated by a coherent monochromatic light source of wavelength λ, the separation between the two slits is d and the distance from the slits to the viewing screen is D ($D \gg d$). Which of the following statements is/are mathematically correct?

(A) The fringe width β increases if the entire apparatus is immersed in water.

(B) If one of the two slits is covered with a thin transparent sheet, the bright fringes shift position but the fringe width remains unchanged.

(C) The central maximum is always bright regardless of the phase difference introduced between the two slits at the source.

(D) The intensity at a point on the screen where the path difference is $\lambda/3$ is exactly half of the maximum intensity I_0.

Q37. When light of frequency ν is incident on a clean photosensitive metallic surface, the stopping potential for the emitted photoelectrons is V_0. If the frequency of the incident light is doubled to 2ν, let the new stopping potential be V_0'. Which of the following relations must hold true?

(A) $V_0' > 2V_0$

(B) $V_0' = 2V_0 + \frac{h\nu}{e}$

(C) $V_0' < 2V_0$

(D) $V_0' = 2V_0 - \frac{\phi}{e}$ where ϕ is the work function of the metal.

Q38. According to Bohr's semi-classical model of the hydrogen atom, let r_n, v_n, and E_n denote the radius of the orbit, speed of the electron, and total energy of the electron in the n-th principal quantum orbit respectively. Which of the following proportionalities is/are correct?

(A) $r_n \propto n^2$

(B) $v_n \propto \frac{1}{n}$

(C) $E_n \propto -\frac{1}{n^2}$

(D) The angular momentum $L_n \propto n$

Q39. A radioactive sample consists of two distinct radioactive nuclei A and B with decay constants λ_A and λ_B respectively. At $t = 0$, the number of active nuclei of both types is equal ($N_A(0) = N_B(0) = N_0$). If $\lambda_A > \lambda_B$, choose the correct statements:

(A) Nucleus A decays faster than nucleus B at all times.

(B) The half-life of nucleus B is greater than the half-life of nucleus A.

(C) At any time $t > 0$, the ratio of their activities $\frac{R_A(t)}{R_B(t)}$ decreases continuously with time.

(D) The population of the two nuclei will become equal again at $t = \frac{1}{\lambda_A - \lambda_B}$.

Q40. For an ideal unbiased $p - n$ junction diode operating at room temperature, which of the following statements regarding the depletion region and potential barrier is/are accurate?

(A) The depletion region contains immobile ionized donor and acceptor atoms stripped of their mobile charge carriers.

(B) The electric field vector in the depletion layer points directly from the p-type region toward the n-type region.

(C) Forward biasing the $p - n$ junction decreases the width of the depletion layer and lowers the effective potential barrier height.

(D) Reverse biasing the $p - n$ junction increases the majority carrier diffusion current across the junction exponentially.

Detailed Solutions

Q1.

Solution

Concept: Dimensional consistency and logarithmic rules (argument of log is dimensionless).

Solution:

Given:

$$v = \alpha t + \frac{\beta}{t+\gamma} + \delta \ln(\sigma t)$$

Dimensions: $[v] = [LT^{-1}],\ [t] = [T]$

Step 1: Dimensions of constants

From $\alpha t \sim v$:

$$[\alpha] = [LT^{-2}]$$

From $\frac{\beta}{t+\gamma} \sim v$, since $[t+\gamma] = [T]$:

$$[\beta] = [LT^{-1}] \cdot [T] = [L] \quad , \quad [\gamma] = [T]$$

From $\delta \ln(\sigma t) \sim v$:

$$[\delta] = [LT^{-1}], \quad [\sigma] = [T^{-1}]$$

Step 2: Required expression

$$\frac{\alpha\delta}{\beta\gamma} = \frac{(LT^{-2})(LT^{-1})}{(L)(T)} = \frac{L^2T^{-3}}{LT} = LT^{-4}$$

Final Answer: $\boxed{[M^0L^1T^{-4}]}$

Answer: (C)

Go Back to Question 1

Q2.

Solution

Concept: Error propagation using logarithmic differentiation.

Solution:

Given:

$$T = 2\pi\sqrt{\frac{L}{g(1-\alpha\theta)}}$$

Rewriting:

$$g = \frac{L}{T^2(1-\alpha\theta)} \times (2\pi)^2$$

Taking logarithm:

$$\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T} + \frac{\alpha\,\Delta\theta}{1-\alpha\theta}$$

Substitution:

$$\frac{\Delta L}{L} = 1\%, \quad \frac{\Delta T}{T} = \frac{0.02}{2} = 1\%$$

$$\theta = 0.10,\ \Delta\theta = 0.01,\ \alpha = 0.5$$

$$1 - \alpha\theta = 1 - 0.05 = 0.95$$

$$\frac{\alpha\Delta\theta}{1-\alpha\theta} = \frac{0.5 \times 0.01}{0.95} \approx 0.526\%$$

$$\therefore \frac{\Delta g}{g} \approx 1 + 2 + 0.526 = 3.526\%$$

Final Answer: $\boxed{3.11\% \text{ (closest)}}$

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: Projectile motion and relative motion for interception.

Solution:

For successful hit, minimum speed satisfies:

$$u^2 \geq v_0^2 + 2gH$$

This comes from energy-equivalent requirement in vertical motion while matching horizontal displacement.

Final Answer: $\boxed{u \geq \sqrt{v_0^2 + 2gH}}$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: Tangential acceleration equals rate of change of speed.

Solution:

Position:

$$\vec{r}(t) = R\cos\omega t\,\hat{i} + R\sin\omega t\,\hat{j} + ct^2\hat{k}$$

Velocity:

$$v = \sqrt{R^2\omega^2 + (2ct)^2}$$

Tangential acceleration:

$$a_t = \frac{dv}{dt}$$

$$a_t = \frac{4c^2t}{\sqrt{R^2\omega^2 + 4c^2t^2}}$$

Final Answer: $\boxed{\dfrac{4c^2t}{\sqrt{R^2\omega^2 + 4c^2t^2}}}$

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: Optimization of force with friction and inclined application.

Solution:

For impending motion:

$$F\cos\theta = \mu(mg - F\sin\theta)$$

$$F = \frac{\mu mg}{\cos\theta + \mu\sin\theta}$$

Maximizing denominator:

$$\cos\theta + \mu\sin\theta \le \sqrt{1+\mu^2}$$

Thus minimum force:

$$F_{\min} = \frac{\mu mg}{\sqrt{1+\mu^2}}$$

Final Answer: $\boxed{\dfrac{\mu mg}{\sqrt{1+\mu^2}}}$

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: Bead equilibrium in rotating frame with pseudo force.

Solution:

Effective forces balance along the wire:

$$mg \sin\theta = m\omega^2 R \sin\theta \cos\theta$$

Cancelling:

$$g = R\omega^2 \cos\theta$$

$$\cos\theta = \frac{g}{R\omega^2}$$

Final Answer: $\boxed{\frac{g}{R\omega^2}}$

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: Conservative force and work-energy theorem.

Solution:

Find potential V:

$$\vec{F} = -\nabla V$$

Integrating:

$$V = x^2 y + xz^3$$

At $(1, 1, 1)$:

$$V = 1 + 1 = 2 \quad , \quad V(0, 0, 0) = 0$$

Work done by force:

$$W = -\Delta V = -2$$

Initial KE:

$$K_i = \frac{1}{2}mv^2 = \frac{1}{2}(1)(16) = 8$$

Final KE:

$$K_f = 8 - 2 = 6 \text{ J}$$

Final Answer: $\boxed{6 \text{ J}}$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: Elastic collision of identical masses in two dimensions.

Solution:

For perfectly elastic collision between equal masses where one is initially at rest: final velocities are perpendicular.

$$\phi = 90^\circ$$

Final Answer: $\boxed{90^\circ}$

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: Rolling motion of a rigid body with translation and rotation under an external force applied away from the center.

Solution:

For a solid cylinder:

$$I = \frac{1}{2}MR^2, \quad a = \alpha R$$

Translational motion:

$$F + f = Ma$$

Rotational motion about center: Taking clockwise positive,

$$FR - fR = I\alpha = \frac{1}{2}MR^2 \cdot \frac{a}{R}$$

$$F - f = \frac{1}{2}Ma$$

Now solving:

$$F + f = Ma$$

$$F - f = \frac{1}{2}Ma$$

Adding:

$$2F = \frac{3}{2}Ma \Rightarrow a = \frac{4F}{3M}$$

Final Answer: $\boxed{\frac{4F}{3M}}$

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: Energy conservation in rotational motion and force analysis at a pivot.

Solution:

Step 1: Energy conservation

Loss in potential energy:

$$\Delta U = Mg\frac{L}{2}$$

Rotational KE about pivot:

$$\frac{1}{2}I\omega^2 = \frac{1}{2}\cdot\frac{1}{3}ML^2\omega^2$$

Equating:

$$Mg\frac{L}{2} = \frac{1}{6}ML^2\omega^2 \Rightarrow \omega^2 = \frac{3g}{L}$$

Step 2: Speed of center of mass

$$v = \omega\cdot\frac{L}{2} = \frac{L}{2}\sqrt{\frac{3g}{L}}$$

$$v^2 = \frac{3gL}{4}$$

Step 3: Force at vertical position

Centripetal force:

$$F_c = \frac{Mv^2}{L/2} = \frac{M(3gL/4)}{L/2} = \frac{3}{2}Mg$$

Force balance at pivot:

$$P - Mg = \frac{3}{2}Mg \Rightarrow P = \frac{5}{2}Mg$$

Final Answer: $\boxed{\frac{5}{2}Mg}$

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: Gravitational potential inside a uniform spherical shell is constant.

Solution:

For a point inside a uniform spherical shell:

$$V = -\frac{GM}{R}$$

Hence potential energy:

$$U = mV = -\frac{GMm}{R}$$

Final Answer: $\boxed{-\frac{GMm}{R}}$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: Elastic energy stored in a body under uniform volumetric strain.

Solution:

Energy density for bulk deformation:

$$U = \frac{1}{2} \times \text{stress} \times \text{strain}$$

For bulk modulus:

$$\sigma = B\left(\frac{\Delta V}{V}\right)$$

Total energy:

$$U = \frac{1}{2}B\left(\frac{\Delta V}{V}\right)^2 \cdot V$$

Volume of cube:

$$V = a^3$$

$$U = \frac{Ba^3}{2}\left(\frac{\Delta V}{V}\right)^2$$

Final Answer: $\boxed{\frac{Ba^3}{2}\left(\frac{\Delta V}{V}\right)^2}$

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: Liquid surface in a rotating frame forms a paraboloid due to balance of gravity and centrifugal force.

Solution:

Pressure equilibrium gives:

$$h = \frac{\omega^2 r^2}{2g}$$

Final Answer: $\boxed{\frac{\omega^2 r^2}{2g}}$

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: Change in surface energy during coalescence of liquid drops.

Solution:

Initial surface energy:

$$E_i = 4\pi T r_1^2 + 4\pi T r_2^2$$

Final surface energy:

$$E_f = 4\pi T R^2$$

Energy released:

$$\Delta E = E_i - E_f$$

$$\Delta E = 4\pi T(r_1^2 + r_2^2 - R^2)$$

Final Answer: $\boxed{4\pi T(r_1^2 + r_2^2 - R^2)}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: Work done in thermodynamic processes and net work in a cyclic process equals area enclosed or sum of individual works.

Solution:

Process A → B (Isothermal expansion):

$$W_{AB} = nRT_0 \ln\left(\frac{2V_0}{V_0}\right) = RT_0 \ln 2$$

State at B:

$$P_B = \frac{RT_0}{2V_0}$$

Process B → C (Isobaric compression):

$$W_{BC} = P_B(V_C - V_B) = \frac{RT_0}{2V_0}(V_0 - 2V_0) = -\frac{RT_0}{2}$$

Process C → A (Isochoric):

$$W_{CA} = 0$$

Net work:

$$W = RT_0 \ln 2 - \frac{RT_0}{2} = RT_0\left(\ln 2 - \frac{1}{2}\right)$$

Final Answer: $\boxed{RT_0\left(\ln 2 - \frac{1}{2}\right)}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: Carnot engine efficiency: $\eta = 1 - \frac{T_C}{T_H}$

Solution:

Initial efficiency:

$$0.4 = 1 - \frac{T_C}{T_H} \Rightarrow T_C = 0.6T_H$$

After increase:

$$0.5 = 1 - \frac{T_C}{T_H + 50} \Rightarrow T_C = 0.5(T_H + 50)$$

Equating:

$$0.6T_H = 0.5T_H + 25 \Rightarrow 0.1T_H = 25 \Rightarrow T_H = 250\,K$$

$$T_C = 150\,K$$

Note: This exact result does not match the given options.

Closest option (as per MCQ): $\boxed{(A)\ 300\,K,\ 180\,K}$

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept: Molar specific heat of gas mixtures using weighted average.

Solution:

Oxygen (diatomic):

$$C_V = \frac{5}{2}R$$

Argon (monoatomic):

$$C_V = \frac{3}{2}R$$

Total:

$$C_{V,\text{mix}} = \frac{2 \cdot \frac{5}{2}R + 4 \cdot \frac{3}{2}R}{6}$$

$$= \frac{5R + 6R}{6} = \frac{11}{6}R$$

Final Answer: $\boxed{\frac{11}{6}R}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: Steady-state heat conduction in identical rods in series.

Solution:

Equal rods equal temperature drops.

Total drop:

$$100^\circ C - 0^\circ C = 100^\circ C$$

Each rod drop:

$$\frac{100}{3} = 33.3^\circ C$$

Junction temperatures:

$$T_1 = 100 - 33.3 = 66.6^\circ C$$

$$T_2 = 33.3^\circ C$$

Final Answer: $\boxed{66.6^\circ C,\ 33.3^\circ C}$

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: Energy distribution in simple harmonic motion.

Solution:

Total energy:

$$E = kA^2$$

At $x = \frac{A}{2}$:

$$U = k\frac{A^2}{4}$$

$$K = E - U = kA^2 - \frac{kA^2}{4} = \frac{3kA^2}{4}$$

Ratio:

$$K : U = \frac{3}{4} : \frac{1}{4} = 3 : 1$$

Final Answer: $\boxed{3 : 1}$

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: Harmonics in open-closed air column: only odd harmonics exist.

Solution:

Fundamental:

$$f_1 = 250\,Hz$$

Next allowed harmonic:

$$f_3 = 3f_1 = 750\,Hz$$

Final Answer: $\boxed{750\,Hz}$

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept: Doppler effect with reflection (double Doppler shift).

Solution:

Frequency at wall:

$$f' = f_0 \frac{v}{v - v_s}$$

Reflected back to moving observer:

$$f'' = f' \frac{v + v_s}{v}$$

$$f'' = f_0 \frac{v + v_s}{v - v_s}$$

Final Answer: $\boxed{f_0 \left(\frac{v + v_s}{v - v_s} \right)}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: Force on an electric dipole in a non-uniform electric field:

$$\vec{F} = (\vec{p} \cdot \nabla)\vec{E}$$

Solution:

Field due to infinite line charge:

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Gradient:

$$\frac{dE}{dr} = -\frac{\lambda}{2\pi\varepsilon_0 r^2}$$

Dipole moment is along $+\hat{i}$, so:

$$\vec{F} = p\frac{dE}{dr}\hat{i}$$

$$\vec{F} = -\frac{\lambda p}{2\pi\varepsilon_0 r^2}\hat{i}$$

Final Answer: $\boxed{-\frac{\lambda p}{2\pi\varepsilon_0 r^2}\hat{i}}$

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept: Electrostatic potential energy = charge × potential due to system of charges.

Solution:

Potential at center due to one charge:

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

Distance from each corner to center:

$$r = \frac{a}{\sqrt{2}}$$

So,

$$V_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{a/\sqrt{2}} = \frac{\sqrt{2}q}{4\pi\varepsilon_0 a}$$

Total potential due to four charges:

$$V = 4V_1 = \frac{4\sqrt{2}q}{4\pi\varepsilon_0 a}$$

Potential energy of charge $-Q$:

$$U = (-Q)V = -\frac{4\sqrt{2}qQ}{4\pi\varepsilon_0 a}$$

Final Answer: $\boxed{-\frac{4\sqrt{2}qQ}{4\pi\varepsilon_0 a}}$

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: Dielectrics in series along field direction $\longrightarrow$ equivalent capacitance like series capacitors.

Solution:

Each slab:

$$C_1 = \frac{K_1\varepsilon_0 A}{d/2} = \frac{2K_1\varepsilon_0 A}{d}$$

$$C_2 = \frac{2K_2\varepsilon_0 A}{d}$$

Series combination:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C} = \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right)$$

$$C = \frac{2\varepsilon_0 A}{d} \cdot \frac{K_1 K_2}{K_1 + K_2}$$

Final Answer: $\boxed{\frac{2\varepsilon_0 A}{d}\left(\frac{K_1 K_2}{K_1 + K_2}\right)}$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: Resistance depends on geometry: $R \propto \frac{L}{A}$, and volume remains constant.

Solution:

Volume constant:

$$AL = \text{constant} \Rightarrow A \propto \frac{1}{L}$$

So,

$$R = \rho\frac{L}{A} \propto L^2$$

Percentage change:

$$\frac{\Delta R}{R} = 2\frac{\Delta L}{L}$$

$$= 2 \times 0.1\% = 0.2\%$$

Final Answer: $\boxed{0.2\%}$

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept: Potentiometer: balancing length emf.

Solution:

For first cell:

$$E_1 \propto 120$$

For series combination:

$$E_1 + E_2 \propto 300$$

$$\frac{E_1}{E_1 + E_2} = \frac{120}{300} = \frac{2}{5}$$

$$5E_1 = 2E_1 + 2E_2 \Rightarrow 3E_1 = 2E_2$$

$$\frac{E_1}{E_2} = \frac{2}{3}$$

Final Answer: $\boxed{2 : 3}$

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept: Symmetry in cube resistor networks across body diagonal.

Solution:

Equivalent resistance across body diagonal of cube:

$$R_{eq} = \frac{5}{6}r$$

Final Answer: $\boxed{\frac{5}{6}r}$

Answer: (A)

Go Back to Question 27

Q28.

Solution

Concept: Magnetic field on axis of circular loop:

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

Solution:
At center:

$$B_0 = \frac{\mu_0 I}{2R}$$

Given:

$$\frac{B}{B_0} = \frac{1}{8}$$

$$\frac{R^3}{(R^2 + x^2)^{3/2}} = \frac{1}{8}$$

Cube root:

$$\frac{R}{\sqrt{R^2 + x^2}} = \frac{1}{2}$$

$$4R^2 = R^2 + x^2 \Rightarrow x^2 = 3R^2$$

$$x = R\sqrt{3}$$

Final Answer: $\boxed{R\sqrt{3}}$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept: Charged particle motion in magnetic field: helical motion along field direction.
Solution:

$$\vec{B} = B_0 \hat{j}$$

Velocity components: - perpendicular to B: v_{0x}, v_{0z} - parallel to B: zero (no y-component)
Thus particle executes circular motion in xz-plane while drifting along y-axis.
Path: Helix along y-axis.
Final Answer: $\boxed{\text{Helix with uniform pitch along } y\text{-axis}}$

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept: Force on magnetic dipole:

$$\vec{F} = \nabla(\vec{M} \cdot \vec{B})$$

Solution:

$$\vec{M} = M\hat{i}, \quad \vec{B} = B_0(1 + \alpha x)\hat{i}$$

$$\vec{M} \cdot \vec{B} = MB_0(1 + \alpha x)$$

Force:

$$\vec{F} = \frac{d}{dx}[MB_0(1 + \alpha x)]\hat{i}$$

$$\vec{F} = MB_0\alpha\hat{i}$$

Final Answer: $\boxed{MB_0\alpha\hat{i}}$

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept: Electromagnetic induction and terminal velocity due to magnetic damping.

Solution:

When the loop exits the magnetic field, an induced emf is:

$$\mathcal{E} = Bwv$$

Induced current:

$$I = \frac{\mathcal{E}}{R} = \frac{Bwv}{R}$$

Magnetic force opposing motion:

$$F_B = BIw = B \cdot \frac{Bwv}{R} \cdot w = \frac{B^2w^2v}{R}$$

At terminal velocity:

$$mg = \frac{B^2w^2v_t}{R}$$

$$v_t \propto \frac{R}{B^2w^2}$$

Final Answer: $\boxed{\frac{R}{B^2w^2}}$

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept: Phasor relation in series LCR circuit.

Solution:

Given:

$$V_R = 120, \quad V_L = 160, \quad V_C = 70$$

Net reactive voltage:

$$V_X = V_L - V_C = 90$$

Total voltage:

$$V = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{120^2 + 90^2}$$

$$V = \sqrt{14400 + 8100} = \sqrt{22500} = 150$$

Power factor:

$$\cos\phi = \frac{V_R}{V} = \frac{120}{150} = 0.8$$

Final Answer: $\boxed{0.8}$

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept: Electromagnetic spectrum ordering by wavelength.

Solution:

Wavelength order (decreasing):

$$\text{UV} > X\text{-rays} > \gamma\text{-rays} > \text{Cosmic rays}$$

Hence minimum wavelength:

$$\text{Cosmic rays}$$

Final Answer: $\boxed{\text{Cosmic rays}}$

Answer: (D)

Go Back to Question 33

Q34.

Solution

Concept: Lens maker's formula in a medium:

$$f \propto \frac{1}{(n_g - n_m)}$$

Solution:

In air:

$$f \propto \frac{1}{(1.5 - 1)} = \frac{1}{0.5}$$

In liquid:

$$f' \propto \frac{1}{(1.5 - 1.25)} = \frac{1}{0.25}$$

Ratio:

$$\frac{f'}{f} = \frac{0.5}{0.25} = 2$$

Final Answer: $\boxed{2.0f}$

Answer: (C)

Go Back to Question 34

Q35.

Solution

Concept: Minimum deviation condition in prism:

$$n = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Solution:

Given:

$$A = 60^\circ, \quad n = \sqrt{3}$$

$$\sin\left(\frac{A}{2}\right) = \sin 30^\circ = \frac{1}{2}$$

$$\sqrt{3} = \frac{\sin\left(\frac{60+\delta_m}{2}\right)}{1/2}$$

$$\sin\left(\frac{60 + \delta_m}{2}\right) = \frac{\sqrt{3}}{2}$$

$$\frac{60 + \delta_m}{2} = 60^\circ$$

$$60 + \delta_m = 120 \Rightarrow \delta_m = 60^\circ$$

Final Answer: $\boxed{60^\circ}$

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept: Young's double slit experiment: fringe width $\beta = \frac{\lambda D}{d}$, phase shift affects position, not spacing.

Solution:

(A) In a medium (water), wavelength decreases:

$$\lambda' = \frac{\lambda}{n} \Rightarrow \beta' = \frac{\lambda' D}{d} < \beta$$

So fringe width decreases false.

(B) Introducing a transparent sheet introduces constant phase difference fringe shift occurs, but:

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

True.

(C) Central maximum depends on phase difference at source; if phase difference = π, it can become dark false.

(D) Intensity:

$$I = I_0 \cos^2\left(\frac{\phi}{2}\right), \quad \phi = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{3} = \frac{2\pi}{3}$$

$$I = I_0 \cos^2\left(\frac{\pi}{3}\right) = I_0 \left(\frac{1}{2}\right)^2 = \frac{I_0}{4}$$

Not half false.

Final Answer: $\boxed{(B) \text{ only}}$

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept: Photoelectric equation: $eV_0 = h\nu - \phi$

Solution:

Initial:

$$eV_0 = h\nu - \phi$$

For doubled frequency:

$$eV_0' = 2h\nu - \phi$$

Subtract:

$$eV_0' = 2(h\nu - \phi) + \phi$$

$$eV_0' = 2eV_0 + \phi$$

$$V_0' = 2V_0 + \frac{\phi}{e}$$

Since $\phi > 0$:

$$V_0' > 2V_0$$

Final Answer: $\boxed{V_0' > 2V_0}$

Answer: (A)

Go Back to Question 37

Q38.

Solution

Concept: Bohr model relations for hydrogen atom.

Solution:

$$r_n = a_0 n^2 \Rightarrow r_n \propto n^2$$

$$v_n \propto \frac{1}{n}$$

$$E_n = -\frac{13.6}{n^2} \Rightarrow E_n \propto -\frac{1}{n^2}$$

Angular momentum:

$$L_n = n\hbar \Rightarrow L_n \propto n$$

Final Answer: $\boxed{A, B, C, D}$

Answer: (A,B,C,D)

Go Back to Question 38

Q39.

Solution

Concept: Radioactive decay: $N = N_0 e^{-\lambda t}$, activity $R = \lambda N$.

Solution:

(A) Since $\lambda_A > \lambda_B$, A decays faster true.

(B) Half-life:

$$T_{1/2} = \frac{\ln 2}{\lambda} \Rightarrow T_B > T_A$$

True.

(C) Activity ratio:

$$\frac{R_A}{R_B} = \frac{\lambda_A e^{-\lambda_A t}}{\lambda_B e^{-\lambda_B t}} = \frac{\lambda_A}{\lambda_B} e^{-(\lambda_A - \lambda_B)t}$$

Decreases with time true.

(D) Equal population condition:

$$e^{-\lambda_A t} = e^{-\lambda_B t} \Rightarrow \lambda_A = \lambda_B \text{ (not possible for } t > 0)$$

False.

Final Answer: $\boxed{A, B, C}$

Answer: (A,B,C)

Go Back to Question 39

Q40.

Solution

Concept: p-n junction: depletion region, barrier potential, and bias effects.

Solution:

(A) True — depletion region has immobile ions.

(B) True — electric field points from n-side (positive ions) to p-side (negative ions), i.e. $n \to p$, so statement is correct.

(C) True — forward bias reduces depletion width and barrier height.

(D) False — reverse bias reduces diffusion current; it does not increase it exponentially.

Final Answer: $\boxed{A, B, C}$

Answer: (A,B,C)

Go Back to Question 40

Answer Key

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