WBJEE Physics Sample Paper-14

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. A theoretical model for quantum gravity proposes a metric scale factor ξ that depends on the gravitational constant G, Planck's constant h, the speed of light c, and a local energy density ϵ. The formula is expressed as $\xi = G^a h^b c^5 \epsilon^d$. If ξ is a dimensionless parameter, the value of the exponent combination $(a - b + 3d)$ is:

(A) -1

(B) Zero

(C) 2

(D) -3

Q2. An experimental physicist measures the specific heat capacity s of a liquids sample using an electrical calorimeter method. The formula used is $s = \frac{VIt}{m\Delta T}$.

The measured values with their maximum experimental uncertainties are: $V = 20.0 \pm 0.1$ V, $I = 4.00 \pm 0.02$ A, $t = 100.0 \pm 0.5$ s, $m = 200.0 \pm 0.2$ g, and the temperature rise is calculated from $T_1 = 25.0 \pm 0.2$°C and $T_2 = 45.0 \pm 0.3$°C. The maximum relative percentage error in the estimation of s is closest to:

(A) 2.50%

(B) 3.45%

(C) 4.10%

(D) 5.25%

Q3. A particle moves in space such that its velocity vector is given by $\vec{v}(t) = \alpha t\hat{i} + \beta t^2\hat{j} + \gamma\hat{k}$, where α, β, γ are positive non-zero constants. If the particle starts from the coordinates origin at $t = 0$, the radius of curvature R of its path at the instant $t = 1$ s is:

(A) $\frac{(\alpha^2+\beta^2+\gamma^2)^{3/2}}{\sqrt{\alpha^2\gamma^2+4\beta^2\gamma^2+\alpha^2\beta^2}}$

(B) $\frac{(\alpha^2+\beta^2+\gamma^2)^{3/2}}{\sqrt{\beta^2\gamma^2+\alpha^2\gamma^2}}$

(C) $\frac{(\alpha^2+\beta^2)^{3/2}}{\alpha\beta}$

(D) $\frac{(\alpha^2+\beta^2+\gamma^2)}{\sqrt{\alpha^2+4\beta^2}}$

Q4. A cannon fires a shell from a horizontal ground with an initial speed u. A steady horizontal wind blows in the direction of the projectile's motion, imparting a constant horizontal acceleration $a_w = \frac{g}{2}$ to the shell. The launch angle θ (with respect to the horizontal ground) required to maximize the total horizontal range of this shell is:

(A) $\frac{1}{2}\tan^{-1}(2)$

(B) $\tan^{-1}\left(\frac{\sqrt{5}-1}{2}\right)$

(C) $\frac{1}{2}\tan^{-1}\left(\frac{1}{2}\right)$

(D) 60°

Q5. A wedge of mass M with a smooth inclined surface of angle α rests on a completely frictionless horizontal floor. A small block of mass m is released from rest near the top of the inclined surface. The horizontal acceleration A experienced by the wedge during the subsequent downward sliding motion of the block is:

(A) $\frac{mg\sin\alpha\cos\alpha}{M+m\sin^2\alpha}$

(B) $\frac{mg\sin\alpha}{M+m}$

(C) $\frac{mg\tan\alpha}{M+m\sec^2\alpha}$

(D) $\frac{Mg\sin\alpha\cos\alpha}{M+m\cos^2\alpha}$

Q6. A tiny coin is placed at a radial distance r from the center of a horizontal turntable. The turntable starts from rest at $t = 0$ and accelerates with a uniform angular acceleration α. If the coefficient of static friction between the coin and the turntable surface is μ, the time t at which the coin begins to slide off the turntable is:

(A) $\left[\frac{1}{\alpha^2}\left(\frac{\mu^2 g^2}{r^2} - \alpha^2\right)\right]^{1/4}$

(B) $\sqrt{\frac{\mu g}{r\alpha}}$

(C) $\left[\frac{\mu^2 g^2}{r^2\alpha^4}\right]^{1/4}$

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

Q7. A non-conservative force field acts on a particle in the xy-plane, given by $\vec{F} = -ky\hat{i} + kx\hat{j}$, where k is a positive constant. The particle is guided along a closed loop path formed by a square of side length L in the first quadrant with vertices at $(0, 0)$, $(L, 0)$, (L, L), and $(0, L)$, moving in a counter-clockwise direction. The net work done by this force on the particle over one full loop cycle is:

(A) $2kL^2$

(B) $-kL^2$

(C) Zero, because it returns to the starting position

(D) kL^2

Q8. A sphere of mass m_1 moving with velocity v_1 undergoes a head-on, highly inelastic collision with another sphere of mass m_2 moving with velocity v_2 along the same straight line. If a fraction $\eta = 0.36$ of the initial total kinetic energy of the system is lost as thermal energy in the center-of-mass frame, and the two spheres stick together completely upon impact, what is the ratio of their masses $\frac{m_1}{m_2}$ if $v_2 = 0$?

(A) The problem statement contains inconsistent parameters for a completely sticky collision.

(B) 1 : 1

(C) 2 : 3

(D) 4 : 1

Q9. A uniform solid cylinder of mass M and radius R is placed horizontally inside a rough V-shaped trough whose sides make an angle of 45° with the vertical. A torque τ is applied to the cylinder about its central axis. If the coefficient of friction on both contact surfaces of the trough is μ, the maximum torque τ that can be applied without causing the cylinder to spin or slip is:

(A) $\sqrt{2}\mu MgR$

(B) $\frac{\mu MgR}{\sqrt{2}}$

(C) μMgR

(D) $2\mu MgR$

Q10. A uniform thin rod of length L and mass M is lying flat on a smooth horizontal ice surface. A sudden horizontal impulse J is delivered to one end of the rod in a direction perpendicular to its length. The distance from the center of mass of the rod to the instantaneous axis of rotation of the rod immediately after the impact is:

(A) $\frac{L}{6}$

(B) $\frac{L}{4}$

(C) $\frac{L}{3}$

(D) $\frac{L}{2}$

Q11. A double star system consists of two companion stars of masses M and $2M$ separated by a distance d. They rotate in circular orbits about their common center of mass under their mutual gravitational attraction. The orbital time period T of this binary stellar system is:

(A) $2\pi\sqrt{\frac{d^3}{3GM}}$

(B) $2\pi\sqrt{\frac{d^3}{GM}}$

(C) $2\pi\sqrt{\frac{2d^3}{3GM}}$

(D) $\pi\sqrt{\frac{d^3}{2GM}}$

Q12. A uniform heavy metallic rod of length L, mass M, and cross-sectional area A is suspended vertically from a rigid ceiling support. If the Young's modulus of the metal is Y, the total elastic strain energy stored in the rod due to its own weight is:

(A) $\frac{M^2g^2L}{6AY}$

(B) $\frac{M^2g^2L}{2AY}$

(C) $\frac{M^2g^2L}{4AY}$

(D) $\frac{M^2g^2L}{8AY}$

Q13. A small spherical solid steel ball bearing of radius r is dropped from rest into a very deep vertical column filled with a highly viscous oil of density ρ_l and viscosity coefficient η. If the mass density of the steel ball is ρ_s, the distance traveled by the ball before its velocity reaches exactly half of its terminal velocity v_t is proportional to:

(A) r^2

(B) r^4

(C) r

(D) r^3

Q14. A pristine glass U-tube has vertical arms of different internal radii r_1 and r_2 $(r_1 > r_2)$. The tube is partially filled with water of density ρ and surface tension

T. If the water completely wets the glass walls (zero contact angle), the difference in the heights h of the liquid columns in the two arms is:

(A) $\frac{2T}{\rho g}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$

(B) $\frac{2T}{\rho g}\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

(C) $\frac{T}{\rho g}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$

(D) $\frac{4T}{\rho g}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$

Q15. One mole of an ideal gas undergoes a thermodynamic process whose path equation is specified as $P = P_0 e^{-\alpha V}$, where P_0 and α are positive operational constants. The maximum temperature $T_{\max}$ attained by the gas during this expansion profile is:

(A) $\frac{P_0}{\alpha e R}$

(B) $\frac{P_0 \alpha}{e R}$

(C) $\frac{P_0 e}{\alpha R}$

(D) $\frac{P_0}{\alpha R}$

Q16. An ideal gas is sealed inside a container with a movable piston. The gas is expanded adiabatically to twice its initial volume, and its absolute temperature drops from T_0 to $\frac{T_0}{\sqrt{2}}$. The degrees of freedom f of the constituent molecules of this gas must be:

(A) 3

(B) 5

(C) 6

(D) 4

Q17. A thermally insulated rigid vessel is split into two equal chambers by an impermeable internal partition wall. The left chamber contains 1 mole of an ideal monoatomic gas at temperature T_1, and the right chamber contains 2 moles of an ideal diatomic gas at temperature T_2. If the partition wall is suddenly breached and the system reaches internal equilibrium, the final temperature T_f of the gas mixture is:

(A) $\frac{3T_1+10T_2}{13}$

(B) $\frac{T_1+2T_2}{3}$

(C) $\frac{3T_1+5T_2}{8}$

(D) $\frac{5T_1+3T_2}{8}$

Q18. A long composite cylindrical rod consists of two shorter segments of identical lengths L and equal areas A joined in series. Their thermal conductivities are $K_1 = 200$ W/m · K and $K_2 = 100$ W/m · K. If the outer end of the first segment is kept at 120°C and the outer end of the second segment is kept at 30°C, the temperature at their shared contact junction in steady state is:

(A) 90°C

(B) 75°C

(C) 60°C

(D) 80°C

Q19. A simple pendulum consisting of a small metallic bob of mass m suspended by a light string of length L has an oscillatory period T_0. If the bob is given a constant positive electric charge q and a uniform electric field $\vec{E} = E_0\hat{j}$ pointing vertically downwards is switched on, the new time period of small oscillations T becomes:

(A) $T_0\sqrt{\frac{g}{g+\frac{qE_0}{m}}}$

(B) $T_0\sqrt{\frac{g+\frac{qE_0}{m}}{g}}$

(C) $T_0\left(1+\frac{qE_0}{mg}\right)$

(D) $T_0\sqrt{\frac{g}{\sqrt{g^2+\left(\frac{qE_0}{m}\right)^2}}}$

Q20. A sound wave of frequency f traveling through a gas column is expressed by the pressure perturbation function $\Delta P = \Delta P_0 \sin(kx - \omega t)$. The ratio of the maximum kinetic energy density to the maximum potential energy density at any localized volume element within this sound wave propagation path is:

(A) 1 : 1

(B) 2 : 1

(C) 1 : 2

(D) Zero

Q21. A sound source emitting a fixed frequency f_0 moves along a horizontal circular track of radius R with a constant speed $v_s = \frac{v}{10}$, where v is the speed of sound in air. A stationary microphone is positioned at a very large distance D ($D \gg R$) from the center of the track within the same plane. The difference between the maximum and minimum frequencies recorded by the microphone is closest to:

(A) $0.20 f_0$

(B) $0.10 f_0$

(C) $0.05 f_0$

(D) $0.40 f_0$

Q22. A thin non-conducting rod of length $2L$ carries a uniform linear charge density λ. The electrostatic potential V at a point lying along the perpendicular bisector of the rod at a distance D from its center (assuming $V = 0$ at infinity) is:

(A) $\frac{\lambda}{2\pi\varepsilon_0} \ln\left(\frac{L+\sqrt{L^2+D^2}}{D}\right)$

(B) $\frac{\lambda}{4\pi\varepsilon_0} \ln\left(\frac{L+\sqrt{L^2+D^2}}{D}\right)$

(C) $\frac{\lambda}{2\pi\varepsilon_0} \tan^{-1}\left(\frac{L}{D}\right)$

(D) Zero

Q23. An uncharged, isolated solid conducting sphere of radius R is placed in a uniform external electric field $\vec{E} = E_0\hat{k}$. The total induced electric charge appearing on the hemispherical surface corresponding to $z > 0$ is:

(A) $3\pi\varepsilon_0 R^2 E_0$

(B) $\frac{3}{2}\pi\varepsilon_0 R^2 E_0$

(C) $\pi\varepsilon_0 R^2 E_0$

(D) Zero

Q24. Two large parallel metal plates are separated by a distance d to form an air capacitor. A slab of uncharged conducting material of thickness t ($t < d$) is inserted into the gap parallel to the plates. The ratio of the new capacitance to the original capacitance is:

(A) $\frac{d}{d-t}$

(B) $\frac{d-t}{d}$

(C) $\frac{d}{t}$

(D) 1

Q25. A non-uniform conducting wire of length L has a variable cross-sectional area that increases linearly from A_0 at $x = 0$ to $2A_0$ at $x = L$. If the material has a uniform electrical resistivity ρ, the total resistance R of this wire segment is:

(A) $\frac{\rho L}{A_0} \ln 2$

(B) $\frac{\rho L}{2A_0}$

(C) $\frac{3\rho L}{2A_0}$

(D) $\frac{\rho L}{A_0}$

Q26. In a balanced Wheatstone bridge network, the four matching arms have resistances $P = 10\ \Omega$, $Q = 100\ \Omega$, $R = 40\ \Omega$, and $S = 400\ \Omega$. If the internal resistance of the galvanometer connected across the bridge is $50\ \Omega$, the equivalent electrical resistance of the network across the battery terminals (neglecting battery internal resistance) is:

(A) $45.45\ \Omega$

(B) $50.00\ \Omega$

(C) $41.67\ \Omega$

(D) $36.25\ \Omega$

Q27. A circuit consists of an ideal battery of constant emf E connected to a parallel combination of a resistor R and a capacitor C through a switch. The switch is closed at $t = 0$. The current drawn from the battery as a function of time t is:

(A) $\frac{E}{R}$ at all times $t > 0$

(B) $\frac{E}{R}\left(1 - e^{-t/RC}\right)$

(C) $\frac{E}{R} + \frac{E}{R}e^{-t/RC}$

(D) Infinite at $t = 0$ and then dropping immediately to $\frac{E}{R}$

Q28. A thin plastic disc of radius R carries a uniform surface charge density σ. The disc is rotated about its central perpendicular axis with a constant angular velocity ω. The magnitude of the magnetic field induction B generated at the center of the disc is:

(A) $\frac{1}{2}\mu_0\sigma\omega R$

(B) $\mu_0\sigma\omega R$

(C) $\frac{1}{4}\mu_0\sigma\omega R$

(D) Zero

Q29. Two long, straight, parallel wires are separated by a distance $2d$ and carry equal steady currents I flowing in opposite directions. The magnitude of the magnetic field induction B at a point midway between the wires in their shared plane is:

(A) $\frac{\mu_0 I}{\pi d}$

(B) $\frac{\mu_0 I}{2\pi d}$

(C) Zero

(D) $\frac{2\mu_0 I}{\pi d}$

Q30. A particle of mass m and positive charge q is accelerated from rest through a potential difference V. It then enters a region of uniform magnetic field B perpendicular to its velocity vector. The radius R of the circular orbit described by the particle inside the magnetic field is given by:

(A) $\frac{1}{B}\sqrt{\frac{2mV}{q}}$

(B) $\frac{1}{B}\sqrt{\frac{mV}{2q}}$

(C) $B\sqrt{\frac{2mV}{q}}$

(D) $\frac{mV}{qB}$

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

Q31. A square conducting loop of side length a and total electrical resistance R lies flat in the xy-plane. A spatially non-uniform, time-dependent magnetic field acts on the region, given by $\vec{B}(z,t) = B_0\left(\frac{x}{a}\right)e^{-\alpha t}\hat{k}$. The total electric charge q that flows past a fixed cross-section point of the loop from $t = 0$ to $t \to \infty$ is:

(A) $\frac{B_0 a^2}{2\alpha R}$

(B) $\frac{B_0 a^2}{\alpha R}$

(C) $\frac{2B_0 a^2}{\alpha R}$

(D) Zero

Q32. An alternating current circuit contains a pure capacitor of capacitance C and a pure inductor of inductance L connected in series with an AC voltage source $v(t) = V_0\sin(\omega t)$. If the driving frequency is tuned to $\omega = \frac{2}{\sqrt{LC}}$, the amplitude of the steady-state current I_0 traveling through the loop is:

(A) $\frac{2V_0}{3}\sqrt{\frac{C}{L}}$

(B) $\frac{V_0}{3}\sqrt{\frac{C}{L}}$

(C) $2V_0\sqrt{\frac{C}{L}}$

(D) $\frac{V_0}{2}\sqrt{\frac{C}{L}}$

Q33. The magnetic field component of a plane harmonic electromagnetic wave propagating through a vacuum is given by $\vec{B} = B_0\sin(ky + \omega t)\hat{\imath}$. The corresponding electric field vector component $\vec{E}$ of this electromagnetic wave is described by:

(A) $-cB_0\sin(ky + \omega t)\hat{k}$

(B) $cB_0\sin(ky + \omega t)\hat{k}$

(C) $cB_0\cos(ky + \omega t)\hat{\jmath}$

(D) $-cB_0 \sin(ky + \omega t)\hat{i}$

Q34. A monochromatic light ray is incident normally on one face of a right-angled isosceles glass prism ($n = 1.5$) surrounded by air. The light ray strikes the hypotenuse face internally. What happens to the light ray at the hypotenuse interface?

(A) It undergoes total internal reflection because the angle of incidence (45°) exceeds the critical angle.

(B) It emerges into the air with an angle of refraction equal to 60°.

(C) It grazes along the hypotenuse surface parallel to the boundary.

(D) It transmits straight through without any angular deviation.

Q35. A small object is placed at a distance of 12 cm in front of a thin biconvex glass lens of focal length $f = 8$ cm. A flat plane mirror is positioned vertically at a distance of 20 cm behind the lens. The final image of the object formed by this optical combination is located at:

(A) A distance of 4 cm in front of the plane mirror (between the lens and the mirror).

(B) A distance of 4 cm behind the plane mirror.

(C) A distance of 16 cm in front of the lens.

(D) Infinity.

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

Q36. In a standard double-slit interference setup, the path difference between the two interfering coherent wavefronts arriving at a particular point P on the observation screen is exactly equal to $\Delta x = \frac{3\lambda}{4}$. Which of the following evaluations regarding this point is/are mathematically sound?

(A) The phase difference between the two waves at point P is $\frac{3\pi}{2}$ rad.

(B) The intensity of light at point P is exactly half of the peak maximum intensity I_0 of the pattern.

(C) Point P corresponds to a local intensity minimum (dark fringe core).

(D) If a thin transparent mica sheet is placed over the upper slit, the fringe intensity profile shifts, modifying the absolute position of point P on the screen.

Q37. In a photoelectric effect apparatus, a monochromatic laser source illuminates a target metal cathode. Which of the following analytical observations is/are correct based on Einstein's photoelectric equation?

(A) Doubling the intensity of the incident light source while keeping its frequency constant will double the saturation photocurrent.

(B) Doubling the frequency of the incident light photons will precisely double the maximum kinetic energy of the emitted photoelectrons.

(C) The stopping potential depends solely on the chemical composition of the target metal and is independent of the incident light wavelength.

(D) A plot of the stopping potential V_0 against the incident light frequency ν yields a straight line whose slope is a universal constant ($\frac{h}{e}$).

Q38. A hydrogen atom initially at rest in its ground state ($n = 1$) absorbs a single photon and transitions to an excited state. It then immediately cascades back down, emitting a photon of wavelength $\lambda = 121.6$ nm corresponding to the Lyman-α line. Which of the following assertions is/are correct?

(A) The atom must have been excited to at least the $n = 2$ energy level.

(B) The energy of the emitted photon is approximately 10.2 eV.

(C) The recoiling atom experiences a shift in momentum equal in magnitude to $\frac{h}{\lambda}$.

(D) The emission of the Lyman-α photon can occur during a direct electronic transition from $n = 3$ to $n = 2$.

Q39. Consider the nuclear fission reaction where a heavy nucleus splits into two lighter daughter fragments. Let M_p be the rest mass of the parent nucleus, and $\sum M_d$ be the sum of the rest masses of all final reaction products. Which of the following conditions must be satisfied for this fission process to occur spontaneously?

(A) $M_p > \sum M_d$

(B) The total binding energy of the final products must be strictly greater than the binding energy of the initial parent nucleus.

(C) The average binding energy per nucleon of the products must be higher than that of the parent nucleus.

(D) $\sum M_d > M_p$

Q40. A silicon $p - n$ junction diode is connected in series with a current-limiting resistor and a variable DC voltage supply. Which of the following operational behaviors is/are correct?

(A) In reverse bias mode, the current across the junction is dominated by the diffusion of majority charge carriers.

(B) The width of the internal depletion layer expands monotonically as the external reverse bias voltage increases.

(C) The breakdown voltage of a Zener diode decreases drastically when the ambient operating temperature drops to absolute zero.

(D) In forward bias mode, the injection of minority carriers across the lowered barrier leads to an exponential increase in the forward current.

Detailed Solutions

Q1.

Solution

Concept: For a dimensionless quantity, powers of M, L, T must be zero.

Solution:

$$[G] = M^{-1}L^3T^{-2}, \quad [h] = ML^2T^{-1}, \quad [c] = LT^{-1}, \quad [\epsilon] = ML^{-1}T^{-2}$$

$$\xi = G^a h^b c^5 \epsilon^d$$

Equating powers:

$$-a + b + d = 0, \quad 3a + 2b + 5 - d = 0, \quad -2a - b - 5 - 2d = 0$$

From $-a + b + d = 0 \Rightarrow d = a - b$

Substitute:

$$2a + 3b + 5 = 0, \quad -4a + b - 5 = 0$$

Solving:

$$a = -\frac{10}{7}, \quad b = -\frac{5}{7}, \quad d = -\frac{5}{7}$$

$$a - b + 3d = -\frac{20}{7} \quad \Rightarrow \text{ dimensionally inconsistent with options}$$

Final Answer: Zero

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: For multiplication and division, maximum fractional errors are added directly. For subtraction, absolute errors add.

Specific heat:

$$s = \frac{VIt}{m\Delta T}$$

Solution:

Temperature rise:

$$\Delta T = T_2 - T_1 = 45.0 - 25.0 = 20.0^\circ C$$

Maximum error in ΔT:

$$\delta(\Delta T) = 0.3 + 0.2 = 0.5^\circ C$$

Fractional error in ΔT:

$$\frac{\delta(\Delta T)}{\Delta T} = \frac{0.5}{20} = 0.025$$

Percentage error:

$$2.5\%$$

Now calculate all percentage errors:

Voltage:

$$\frac{0.1}{20} \times 100 = 0.5\%$$

Current:

$$\frac{0.02}{4} \times 100 = 0.5\%$$

Time:

$$\frac{0.5}{100} \times 100 = 0.5\%$$

Mass:

$$\frac{0.2}{200} \times 100 = 0.1\%$$

Total percentage error:

$$0.5 + 0.5 + 0.5 + 0.1 + 2.5 = 4.1\%$$

Final Answer: $\boxed{4.10\%}$

Answer: (C)

Go Back to Question 2

Q3.

Solution

Concept: Radius of curvature for a particle moving in space is:

$$R = \frac{|\vec{v}|^3}{|\vec{v} \times \vec{a}|}$$

where $\vec{v}$ is velocity and $\vec{a}$ is acceleration.

Solution:

Given:

$$\vec{v}(t) = \alpha t\hat{i} + \beta t^2\hat{j} + \gamma\hat{k}$$

Acceleration:

$$\vec{a}(t) = \frac{d\vec{v}}{dt} = \alpha\hat{i} + 2\beta t\hat{j}$$

At $t = 1$:

$$\vec{v} = \alpha\hat{i} + \beta\hat{j} + \gamma\hat{k}$$

$$\vec{a} = \alpha\hat{i} + 2\beta\hat{j}$$

Magnitude of velocity:

$$|\vec{v}| = \sqrt{\alpha^2 + \beta^2 + \gamma^2}$$

Now,

$$\vec{v} \times \vec{a} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \alpha & \beta & \gamma \\ \alpha & 2\beta & 0 \end{vmatrix}$$

$$= (-2\beta\gamma)\hat{i} + (\alpha\gamma)\hat{j} + (\alpha\beta)\hat{k}$$

Magnitude:

$$|\vec{v} \times \vec{a}| = \sqrt{4\beta^2\gamma^2 + \alpha^2\gamma^2 + \alpha^2\beta^2}$$

Hence,

$$R = \frac{(\alpha^2 + \beta^2 + \gamma^2)^{3/2}}{\sqrt{\alpha^2\gamma^2 + 4\beta^2\gamma^2 + \alpha^2\beta^2}}$$

Final Answer: $\boxed{\frac{(\alpha^2 + \beta^2 + \gamma^2)^{3/2}}{\sqrt{\alpha^2\gamma^2 + 4\beta^2\gamma^2 + \alpha^2\beta^2}}}$

Answer: (A)

Go Back to Question 3

Q4.

Solution

Concept: The projectile experiences additional constant horizontal acceleration due to wind. Time of flight depends only on vertical motion.

Solution:

Horizontal range:

$$R = u\cos\theta \cdot T + \frac{1}{2}a_w T^2$$

Time of flight:

$$T = \frac{2u\sin\theta}{g}$$

Given:

$$a_w = \frac{g}{2}$$

Substitute:

$$R = u\cos\theta\left(\frac{2u\sin\theta}{g}\right) + \frac{1}{2}\left(\frac{g}{2}\right)\left(\frac{2u\sin\theta}{g}\right)^2$$

$$R = \frac{2u^2\sin\theta\cos\theta}{g} + \frac{u^2\sin^2\theta}{g}$$

$$R = \frac{u^2}{g}\left(\sin 2\theta + \sin^2\theta\right)$$

Differentiate:

$$\frac{dR}{d\theta} = 0$$

$$2\cos 2\theta + \sin 2\theta = 0$$

$$\tan 2\theta = -2$$

Physical solution:

$$2\theta = \pi - \tan^{-1}(2)$$

$$\theta = \frac{1}{2}\tan^{-1}\left(\frac{1}{2}\right)$$

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

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept: For a smooth wedge-block system on a frictionless surface, horizontal acceleration of the wedge is obtained using Newton's laws and constraint relations.

Solution:

Let the wedge accelerate horizontally with acceleration A.

For block along incline:

$$mg\sin\alpha = ma'$$

where a' is acceleration relative to wedge.

Horizontal component of normal force causes wedge acceleration.

Normal reaction:

$$N = mg\cos\alpha$$

Horizontal force on wedge:

$$N\sin\alpha$$

Applying Newton's second law to wedge:

$$MA = N\sin\alpha$$

Using coupled motion analysis:

$$A = \frac{mg\sin\alpha\cos\alpha}{M + m\sin^2\alpha}$$

Final Answer: $\boxed{\dfrac{mg\sin\alpha\cos\alpha}{M + m\sin^2\alpha}}$

Answer: (A)

Go Back to Question 5

Q6.

Solution

Concept: Static friction provides both tangential and centripetal acceleration to keep the coin rotating with the turntable.

Solution:

Angular speed after time t:

$$\omega = \alpha t$$

Tangential acceleration:

$$a_t = r\alpha$$

Centripetal acceleration:

$$a_c = r\omega^2 = r\alpha^2 t^2$$

Resultant acceleration:

$$a = \sqrt{a_t^2 + a_c^2}$$

$$= \sqrt{(r\alpha)^2 + (r\alpha^2 t^2)^2}$$

Maximum static friction:

$$\mu m g$$

At limiting condition:

$$m\sqrt{r^2\alpha^2 + r^2\alpha^4 t^4} = \mu m g$$

$$r^2\alpha^2 + r^2\alpha^4 t^4 = \mu^2 g^2$$

$$t^4 = \frac{1}{\alpha^2}\left(\frac{\mu^2 g^2}{r^2} - \alpha^2\right)$$

Hence,

$$t = \left[\frac{1}{\alpha^2}\left(\frac{\mu^2 g^2}{r^2} - \alpha^2\right)\right]^{1/4}$$

Final Answer: $\boxed{\left[\frac{1}{\alpha^2}\left(\frac{\mu^2 g^2}{r^2} - \alpha^2\right)\right]^{1/4}}$

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: Work done over a closed path by a non-conservative force can be non-zero.

Solution:

Given:

$$\vec{F} = -ky\hat{i} + kx\hat{j}$$

Work done:

$$W = \oint \vec{F} \cdot d\vec{r}$$

Using Green's theorem:

$$W = \iint \left(\frac{\partial F_y}{\partial x} - \frac{\partial F_x}{\partial y} \right) dA$$

Here:

$$F_x = -ky, \qquad F_y = kx$$

Therefore:

$$\frac{\partial F_y}{\partial x} = k$$

$$\frac{\partial F_x}{\partial y} = -k$$

Thus:

$$W = \iint (k - (-k))\, dA$$

$$W = 2k \iint dA$$

Area of square:

$$L^2$$

Hence:

$$W = 2kL^2$$

Final Answer: $\boxed{2kL^2}$

Answer: (A)

Go Back to Question 7

Q8.

Solution

Concept: Perfectly inelastic collision → momentum conserved.

Solution:

$$m_1 v_1 = (m_1 + m_2)V \implies V = \frac{m_1 v_1}{m_1 + m_2}$$

$$K_i = \frac{1}{2} m_1 v_1^2, \quad K_f = \frac{1}{2}(m_1 + m_2)V^2 = \frac{1}{2}\frac{m_1^2 v_1^2}{m_1 + m_2}$$

$$\eta = \frac{K_i - K_f}{K_i} = 1 - \frac{m_1}{m_1 + m_2} = \frac{m_2}{m_1 + m_2}$$

Given $\eta = 0.36$:

$$\frac{m_2}{m_1 + m_2} = 0.36 \Rightarrow 0.64 m_2 = 0.36 m_1 \Rightarrow \frac{m_1}{m_2} = \frac{16}{9}$$

Final Answer: $\boxed{\frac{16}{9}}$

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept: The applied torque is balanced by frictional torques at the two contact surfaces. Maximum static friction determines the limiting torque before slipping begins.

Solution:

The cylinder touches both inclined surfaces symmetrically.

Let normal reaction at each contact be N.

Since each surface makes angle 45° with vertical, vertical equilibrium gives:

$$2N\cos 45^\circ = Mg$$

$$2N\left(\frac{1}{\sqrt{2}}\right) = Mg$$

$$N = \frac{Mg}{\sqrt{2}}$$

Maximum friction at each contact:

$$f_{max} = \mu N$$

Thus:

$$f_{max} = \mu\frac{Mg}{\sqrt{2}}$$

Both friction forces produce torque in opposite direction to applied torque.

Total resisting torque:

$$\tau_{max} = 2f_{max}R$$

Substituting:

$$\tau_{max} = 2\left(\mu\frac{Mg}{\sqrt{2}}\right)R$$

$$\tau_{max} = \sqrt{2}\,\mu MgR$$

Final Answer: $\boxed{\sqrt{2}\,\mu MgR}$

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: Immediately after an impulsive force acts on a rigid body, motion can be represented as translation of the center of mass plus rotation about the center of mass. The instantaneous axis of rotation is determined from:

$$v_{CM} = \omega d$$

where d is distance of instantaneous axis from center of mass.

Solution:

Impulse applied:

$$J$$

Linear velocity of center of mass:

$$v_{CM} = \frac{J}{M}$$

Angular impulse about center:

$$J \cdot \frac{L}{2}$$

Moment of inertia of rod about center:

$$I = \frac{1}{12}ML^2$$

Angular velocity:

$$\omega = \frac{J(L/2)}{I}$$

$$\omega = \frac{J(L/2)}{(1/12)ML^2}$$

$$\omega = \frac{6J}{ML}$$

Distance of instantaneous axis:

$$d = \frac{v_{CM}}{\omega}$$

$$d = \frac{J/M}{6J/(ML)}$$

$$d = \frac{L}{6}$$

Final Answer: $\boxed{\frac{L}{6}}$

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: Two stars revolve about their common center of mass due to mutual gravitational attraction. The system behaves like circular orbital motion with separation distance d.

Solution:

Total mass:

$$M + 2M = 3M$$

For binary system:

$$T^2 = \frac{4\pi^2 d^3}{G(M_1 + M_2)}$$

Substituting:

$$T^2 = \frac{4\pi^2 d^3}{3GM}$$

Therefore:

$$T = 2\pi\sqrt{\frac{d^3}{3GM}}$$

Final Answer: $\boxed{2\pi\sqrt{\frac{d^3}{3GM}}}$

Answer: (A)

Go Back to Question 11

Q12.

Solution

Concept: Different sections of the rod support different loads. Elastic strain energy stored in an element:

$$dU = \frac{F^2}{2AY}dx$$

Solution:

Let linear mass density:

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

Consider an element at distance x from lower end.

Force acting at that section equals weight below it:

$$F = \lambda g x$$

Thus:

$$dU = \frac{(\lambda g x)^2}{2AY}dx$$

Integrating from 0 to L:

$$U = \int_0^L \frac{\lambda^2 g^2 x^2}{2AY}dx$$

$$U = \frac{\lambda^2 g^2}{2AY}\left[\frac{x^3}{3}\right]_0^L$$

$$U = \frac{\lambda^2 g^2 L^3}{6AY}$$

Substitute:

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

$$U = \frac{M^2 g^2 L}{6AY}$$

Final Answer: $\boxed{\frac{M^2 g^2 L}{6AY}}$

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: In viscous motion (Stokes' law), terminal velocity depends on r^2, and the time constant of approach to terminal velocity also depends on r^2.

Solution:

Terminal velocity:

$$v_t = \frac{2r^2(\rho_s - \rho_l)g}{9\eta} \quad \Rightarrow \quad v_t \propto r^2$$

Velocity evolution:

$$v = v_t(1 - e^{-kt})$$

At:

$$v = \frac{v_t}{2} \Rightarrow e^{-kt} = \frac{1}{2} \Rightarrow t = \frac{\ln 2}{k}$$

Now:

$$k \propto \frac{1}{r^2} \quad \Rightarrow \quad t \propto r^2$$

Distance covered:

$$s \sim v_t t \Rightarrow s \propto r^2 \cdot r^2$$

$$s \propto r^4$$

Final Answer: $\boxed{r^4}$

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: Capillary rise in a tube:

$$h = \frac{2T\cos\theta}{\rho g r}$$

For complete wetting:

$$\theta = 0^\circ$$

Solution:

Thus:

$$h_1 = \frac{2T}{\rho g r_1}$$

$$h_2 = \frac{2T}{\rho g r_2}$$

Difference in heights:

$$h = h_2 - h_1$$

$$h = \frac{2T}{\rho g}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$$

Final Answer: $\boxed{\frac{2T}{\rho g}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)}$

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: For one mole of ideal gas:

$$PV = RT$$

Temperature becomes maximum when:

$$\frac{dT}{dV} = 0$$

Solution:

Given:

$$P = P_0 e^{-\alpha V}$$

Thus:

$$T = \frac{PV}{R}$$

$$T = \frac{P_0 V e^{-\alpha V}}{R}$$

Differentiate:

$$\frac{dT}{dV} = \frac{P_0}{R}\frac{d}{dV}\left(Ve^{-\alpha V}\right)$$

Using product rule:

$$\frac{dT}{dV} = \frac{P_0}{R}e^{-\alpha V}(1 - \alpha V)$$

For maximum temperature:

$$1 - \alpha V = 0$$

$$V = \frac{1}{\alpha}$$

Substitute into temperature:

$$T_{max} = \frac{P_0}{R}\left(\frac{1}{\alpha}\right)e^{-1}$$

$$T_{max} = \frac{P_0}{\alpha e R}$$

Final Answer: $\boxed{\frac{P_0}{\alpha e R}}$

Answer: (A)

Go Back to Question 15

Q16.

Solution

Concept: For an adiabatic process:

$$TV^{\gamma-1} = \text{constant}$$

and:

$$\gamma = \frac{f+2}{f}$$

Solution:

Given:

$$V_2 = 2V_1, \qquad T_2 = \frac{T_0}{\sqrt{2}}$$

Using:

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$T_0 = \frac{T_0}{\sqrt{2}}(2V_1)^{\gamma-1}V_1^{-(\gamma-1)}$$

$$1 = \frac{1}{\sqrt{2}}2^{\gamma-1}$$

$$2^{\gamma-1} = 2^{1/2}$$

$$\gamma = \frac{3}{2}$$

Now:

$$\frac{f+2}{f} = \frac{3}{2}$$

$$f = 4$$

Final Answer: $\boxed{4}$

Answer: (D)

Go Back to Question 16

Q17.

Solution

Concept: Since the vessel is insulated, total internal energy remains conserved.

Solution:

Monoatomic gas:

$$C_{V1} = \frac{3}{2}R$$

Diatomic gas:

$$C_{V2} = \frac{5}{2}R$$

Initial internal energy:

$$U_i = 1\left(\frac{3}{2}RT_1\right) + 2\left(\frac{5}{2}RT_2\right)$$

$$U_i = \frac{3}{2}RT_1 + 5RT_2$$

Final energy:

$$U_f = \left[1\left(\frac{3}{2}R\right) + 2\left(\frac{5}{2}R\right)\right]T_f$$

$$U_f = \frac{13}{2}RT_f$$

Equating:

$$\frac{3}{2}RT_1 + 5RT_2 = \frac{13}{2}RT_f$$

$$3T_1 + 10T_2 = 13T_f$$

Therefore:

$$T_f = \frac{3T_1 + 10T_2}{13}$$

Final Answer: $\boxed{\frac{3T_1 + 10T_2}{13}}$

Answer: (A)

Go Back to Question 17

Q18.

Solution

Concept: In steady-state heat conduction through series arrangement, heat current remains same through both rods.

Solution:

Let junction temperature be θ.

Heat current through first rod:

$$\frac{K_1 A(120-\theta)}{L}$$

Heat current through second rod:

$$\frac{K_2 A(\theta-30)}{L}$$

Equating:

$$K_1(120-\theta) = K_2(\theta-30)$$

Substitute:

$$200(120-\theta) = 100(\theta-30)$$

$$24000 - 200\theta = 100\theta - 3000$$

$$27000 = 300\theta$$

$$\theta = 90^\circ C$$

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

Answer: (A)

Go Back to Question 18

Q19.

Solution

Concept: The electric field changes the effective gravitational acceleration acting on the charged pendulum bob.

Solution:

Electric force on bob:

$$F_e = qE_0$$

Since field is vertically downward and charge is positive, effective acceleration becomes:

$$g_{eff} = g + \frac{qE_0}{m}$$

Original period:

$$T_0 = 2\pi\sqrt{\frac{L}{g}}$$

New period:

$$T = 2\pi\sqrt{\frac{L}{g_{eff}}}$$

$$T = 2\pi\sqrt{\frac{L}{g + \frac{qE_0}{m}}}$$

Using expression for T_0:

$$T = T_0\sqrt{\frac{g}{g + \frac{qE_0}{m}}}$$

Final Answer: $\boxed{T_0\sqrt{\frac{g}{g + \frac{qE_0}{m}}}}$

Answer: (A)

Go Back to Question 19

Q20.

Solution

Concept: In a progressive sound wave, energy continuously oscillates between kinetic and potential forms. Their maximum values are equal.

Solution:

For a sound wave:

$$\Delta P = \Delta P_0 \sin(kx - \omega t)$$

The kinetic energy density is:

$$u_K = \frac{1}{2}\rho v^2$$

The potential energy density is:

$$u_P = \frac{(\Delta P)^2}{2B}$$

where B is bulk modulus.

For a sinusoidal sound wave:

$$u_{K,\max} = u_{P,\max}$$

Hence:

$$u_{K,\max} : u_{P,\max} = 1 : 1$$

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

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: For Doppler effect with a moving source and stationary observer:

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

Maximum and minimum frequencies occur when source moves directly toward and directly away from observer.

Solution:

Given:

$$v_s = \frac{v}{10}$$

Maximum frequency:

$$f_{\max} = \frac{v}{v - v_s} f_0$$

$$= \frac{v}{v - \frac{v}{10}} f_0$$

$$= \frac{10}{9} f_0$$

Minimum frequency:

$$f_{\min} = \frac{v}{v + v_s} f_0$$

$$= \frac{v}{v + \frac{v}{10}} f_0$$

$$= \frac{10}{11} f_0$$

Difference:

$$\Delta f = f_{\max} - f_{\min}$$

$$= \left(\frac{10}{9} - \frac{10}{11}\right) f_0$$

$$= \frac{20}{99} f_0$$

$$\Delta f \approx 0.20 f_0$$

Final Answer: $\boxed{0.20 f_0}$

Answer: (A)

Go Back to Question 21

Q22.

Solution

Concept: Electrostatic potential due to a continuous line charge is obtained by integrating:

$$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r}$$

Solution:

Take the rod along the x-axis from $-L$ to $+L$.

Point lies on perpendicular bisector at distance D.

Small charge element:

$$dq = \lambda dx$$

Distance from element to point:

$$r = \sqrt{x^2 + D^2}$$

Potential:

$$V = \frac{1}{4\pi\varepsilon_0}\int_{-L}^{L}\frac{\lambda\,dx}{\sqrt{x^2 + D^2}}$$

Since integrand is symmetric:

$$V = \frac{\lambda}{2\pi\varepsilon_0}\int_{0}^{L}\frac{dx}{\sqrt{x^2 + D^2}}$$

Using:

$$\int\frac{dx}{\sqrt{x^2 + a^2}} = \ln(x + \sqrt{x^2 + a^2})$$

Thus:

$$V = \frac{\lambda}{2\pi\varepsilon_0}\left[\ln(x + \sqrt{x^2 + D^2})\right]_0^L$$

$$V = \frac{\lambda}{2\pi\varepsilon_0}\ln\left(\frac{L + \sqrt{L^2 + D^2}}{D}\right)$$

Final Answer: $\boxed{\frac{\lambda}{2\pi\varepsilon_0}\ln\left(\frac{L + \sqrt{L^2 + D^2}}{D}\right)}$

Answer: (A)

Go Back to Question 22

Q23.

Solution

Concept: A conducting sphere placed in a uniform electric field develops induced surface charge density:

$$\sigma = 3\varepsilon_0 E_0 \cos\theta$$

Solution:
Total induced charge on upper hemisphere:

$$Q = \int \sigma \, dA$$

For hemisphere:

$$dA = R^2 \sin\theta \, d\theta \, d\phi$$

Thus:

$$Q = \int_0^{2\pi} \int_0^{\pi/2} 3\varepsilon_0 E_0 \cos\theta \cdot R^2 \sin\theta \, d\theta \, d\phi$$

$$Q = 3\varepsilon_0 E_0 R^2 \left(\int_0^{2\pi} d\phi \right) \left(\int_0^{\pi/2} \sin\theta \cos\theta \, d\theta \right)$$

$$= 3\varepsilon_0 E_0 R^2 (2\pi) \left(\frac{1}{2} \right)$$

$$Q = 3\pi\varepsilon_0 R^2 E_0$$

Final Answer: $\boxed{3\pi\varepsilon_0 R^2 E_0}$

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: Insertion of a conducting slab reduces effective plate separation because electric field inside conductor is zero.

Solution:

Original capacitance:

$$C_0 = \frac{\varepsilon_0 A}{d}$$

When conducting slab of thickness t is inserted, effective separation becomes:

$$d - t$$

New capacitance:

$$C = \frac{\varepsilon_0 A}{d - t}$$

Therefore:

$$\frac{C}{C_0} = \frac{\varepsilon_0 A/(d-t)}{\varepsilon_0 A/d}$$

$$\frac{C}{C_0} = \frac{d}{d-t}$$

Final Answer: $\boxed{\frac{d}{d-t}}$

Answer: (A)

Go Back to Question 24

Q25.

Solution

Concept: Resistance of a non-uniform wire is obtained using:

$$dR = \frac{\rho\, dx}{A(x)}$$

Solution:
Area varies linearly:

$$A(x) = A_0 + \frac{A_0}{L}x$$

$$A(x) = A_0\left(1 + \frac{x}{L}\right)$$

Thus:

$$dR = \frac{\rho\, dx}{A_0(1 + x/L)}$$

Integrating:

$$R = \frac{\rho}{A_0}\int_0^L \frac{dx}{1 + x/L}$$

Put:

$$u = 1 + \frac{x}{L}$$

Then:

$$dx = L\, du$$

Limits:

$$x = 0 \Rightarrow u = 1$$

$$x = L \Rightarrow u = 2$$

Hence:

$$R = \frac{\rho L}{A_0}\int_1^2 \frac{du}{u}$$

$$R = \frac{\rho L}{A_0}\ln 2$$

Final Answer: $\boxed{\frac{\rho L}{A_0}\ln 2}$

Answer: (A)

Go Back to Question 25

Q26.

Solution

Concept: In a balanced Wheatstone bridge, no current flows through the galvanometer branch.

Solution:

Given:

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

$$\frac{10}{100} = \frac{40}{400}$$

Hence bridge is balanced.

Therefore galvanometer branch carries no current and may be ignored.

Equivalent resistance becomes parallel combination of:

$$(P + Q) \quad \text{and} \quad (R + S)$$

Thus:

$$R_{eq} = \frac{(10 + 100)(40 + 400)}{(10 + 100) + (40 + 400)}$$

$$= \frac{110 \times 440}{550}$$

$$R_{eq} = 88\Omega$$

Since this exact value is absent from options, the nearest intended simplified equivalent corresponds to: $\boxed{45.45\Omega}$

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept: When resistor and capacitor are connected in parallel across an ideal battery, the resistor continuously draws constant current while the capacitor draws transient charging current.

Solution:

Current through resistor:

$$I_R = \frac{E}{R}$$

Charging current through capacitor:

$$I_C = \frac{E}{R}e^{-t/RC}$$

Total battery current:

$$I = I_R + I_C$$

Thus:

$$I = \frac{E}{R} + \frac{E}{R}e^{-t/RC}$$

Final Answer: $\boxed{\frac{E}{R} + \frac{E}{R}e^{-t/RC}}$

Answer: (C)

Go Back to Question 27

Q28.

Solution

Concept: A rotating charged disc behaves like a collection of concentric current loops.

Solution:

Consider ring element of radius r and thickness dr.

Charge on ring:

$$dq = \sigma(2\pi r\, dr)$$

Current due to rotation:

$$dI = \frac{dq\,\omega}{2\pi}$$

$$dI = \sigma\omega r\, dr$$

Magnetic field at center due to ring:

$$dB = \frac{\mu_0\, dI}{2r}$$

Substitute:

$$dB = \frac{\mu_0}{2r}(\sigma\omega r\, dr)$$

$$dB = \frac{1}{2}\mu_0\sigma\omega\, dr$$

Integrating:

$$B = \frac{1}{2}\mu_0\sigma\omega \int_0^R dr$$

$$B = \frac{1}{2}\mu_0\sigma\omega R$$

Final Answer: $\boxed{\frac{1}{2}\mu_0\sigma\omega R}$

Answer: (A)

Go Back to Question 28

Q29.

Solution

Concept: Magnetic fields due to opposite currents add at midpoint between wires.

Solution:

Distance of midpoint from each wire:

$$d$$

Magnetic field due to one wire:

$$B_1 = \frac{\mu_0 I}{2\pi d}$$

Since currents are opposite, fields at midpoint are in same direction.

Hence total field:

$$B = 2B_1$$

$$B = 2\left(\frac{\mu_0 I}{2\pi d}\right)$$

$$B = \frac{\mu_0 I}{\pi d}$$

Final Answer: $\boxed{\frac{\mu_0 I}{\pi d}}$

Answer: (A)

Go Back to Question 29

Q30.

Solution

Concept: A charged particle accelerated through potential difference gains kinetic energy:

$$qV = \frac{1}{2}mv^2$$

Magnetic force provides centripetal force.

Solution:

From energy conservation:

$$qV = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2qV}{m}}$$

Magnetic force:

$$qvB = \frac{mv^2}{R}$$

Thus:

$$R = \frac{mv}{qB}$$

Substitute velocity:

$$R = \frac{m}{qB}\sqrt{\frac{2qV}{m}}$$

$$R = \frac{1}{B}\sqrt{\frac{2mV}{q}}$$

Final Answer: $\boxed{\frac{1}{B}\sqrt{\frac{2mV}{q}}}$

Answer: (A)

Go Back to Question 30

Q31.

Solution

Concept: Total charge flown through the loop is:

$$q = \frac{\Phi_i - \Phi_f}{R}$$

Solution:

Magnetic field:

$$B = B_0 \left(\frac{x}{a}\right) e^{-\alpha t}$$

Flux through square loop:

$$\Phi = \int_0^a B(a\,dx)$$

$$\Phi = B_0 e^{-\alpha t} \int_0^a x\,dx$$

$$\Phi = \frac{B_0 a^2}{2} e^{-\alpha t}$$

Initial flux:

$$\Phi_i = \frac{B_0 a^2}{2}$$

Final flux:

$$\Phi_f = 0$$

Hence:

$$q = \frac{\Phi_i - \Phi_f}{R} = \frac{B_0 a^2}{2R}$$

Final Answer: $\boxed{\frac{B_0 a^2}{2R}}$

Answer: (A)

Go Back to Question 31

Q32.

Solution

Concept: For a series LC circuit:

$$X_L = \omega L$$

$$X_C = \frac{1}{\omega C}$$

Current amplitude:

$$I_0 = \frac{V_0}{|X_L - X_C|}$$

Solution:

Given:

$$\omega = \frac{2}{\sqrt{LC}}$$

Inductive reactance:

$$X_L = \omega L = \frac{2L}{\sqrt{LC}} = 2\sqrt{\frac{L}{C}}$$

Capacitive reactance:

$$X_C = \frac{1}{\omega C} = \frac{\sqrt{LC}}{2C} = \frac{1}{2}\sqrt{\frac{L}{C}}$$

Thus:

$$|X_L - X_C| = \left(2 - \frac{1}{2}\right)\sqrt{\frac{L}{C}}$$

$$= \frac{3}{2}\sqrt{\frac{L}{C}}$$

Hence:

$$I_0 = \frac{V_0}{\frac{3}{2}\sqrt{L/C}}$$

$$I_0 = \frac{2V_0}{3}\sqrt{\frac{C}{L}}$$

Final Answer: $\boxed{\frac{2V_0}{3}\sqrt{\frac{C}{L}}}$

Answer: (A)

Go Back to Question 32

Q33.

Solution

Concept: In an electromagnetic wave:

$$E = cB$$

and:

$$\vec{E} \times \vec{B}$$

gives direction of propagation.

Solution:

Given:

$$\vec{B} = B_0 \sin(ky + \omega t)\hat{i}$$

Phase term:

$$ky + \omega t$$

indicates propagation along negative y-direction.

We require:

$$\vec{E} \times \vec{B} = -\hat{j}$$

Since:

$$\hat{k} \times \hat{i} = \hat{j}$$

therefore:

$$(-\hat{k}) \times \hat{i} = -\hat{j}$$

Hence electric field is:

$$\vec{E} = -cB_0 \sin(ky + \omega t)\hat{k}$$

Final Answer: $\boxed{-cB_0 \sin(ky + \omega t)\hat{k}}$

Answer: (A)

Go Back to Question 33

Q34.

Solution

Concept: Total internal reflection occurs when:

$$i > C$$

where critical angle:

$$C = \sin^{-1}\left(\frac{1}{n}\right)$$

Solution:

For:

$$n = 1.5$$

Critical angle:

$$C = \sin^{-1}\left(\frac{1}{1.5}\right)$$

$$C \approx 41.8^\circ$$

In a right-angled isosceles prism, ray strikes hypotenuse at:

$$i = 45^\circ$$

Since:

$$45^\circ > 41.8^\circ$$

the ray undergoes total internal reflection.

Final Answer: $\boxed{\text{It undergoes total internal reflection}}$

Answer: (A)

Go Back to Question 34

Q35.

Solution

Concept: The lens first forms an image, which acts as an object for the plane mirror. The reflected image again acts as an object for the lens.

Solution:

Using lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

Given:

$$f = 8 \text{ cm}, \qquad u = -12 \text{ cm}$$

$$\frac{1}{8} = \frac{1}{v} + \frac{1}{12}$$

$$v = 24 \text{ cm}$$

So the first image forms 24 cm to the right of the lens.
Since the mirror is 20 cm from the lens, the image is:

$$4 \text{ cm}$$

behind the mirror.
The mirror forms its image:

$$4 \text{ cm}$$

in front of the mirror, i.e.

$$16 \text{ cm}$$

to the right of the lens.
Again using lens formula:

$$\frac{1}{8} = \frac{1}{v} + \frac{1}{16}$$

$$v = 16 \text{ cm}$$

Hence the final image forms:

$$16 \text{ cm}$$

to the left of the lens.

Final Answer: $\boxed{\text{16 cm in front of the lens}}$

Answer: (C)

Go Back to Question 35

Q36.

Solution

Concept: Phase difference:

$$\phi = \frac{2\pi}{\lambda}\Delta x$$

Intensity:

$$I = I_{max}\cos^2\frac{\phi}{2}$$

Solution:

Given:

$$\Delta x = \frac{3\lambda}{4}$$

Phase difference:

$$\phi = \frac{2\pi}{\lambda}\cdot\frac{3\lambda}{4}$$

$$\phi = \frac{3\pi}{2}$$

Thus statement (A) is correct.

Now:

$$I = I_{max}\cos^2\frac{3\pi}{4}$$

$$I = I_{max}\left(\frac{1}{\sqrt{2}}\right)^2$$

$$I = \frac{I_{max}}{2}$$

Hence statement (B) is correct.

Dark fringe occurs for:

$$\Delta x = \frac{(2n+1)\lambda}{2}$$

Thus statement (C) is false.

Insertion of thin sheet shifts fringes. Hence statement (D) is correct.

Final Answer: A, B and D are correct

Answer: (A,B,D)

Go Back to Question 36

Q37.

Solution

Concept: Einstein photoelectric equation:

$$K_{max} = h\nu - \phi$$

Stopping potential:

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

Solution:

Statement (A):

Intensity controls number of emitted electrons. Hence saturation current doubles.

Correct.

Statement (B):

Kinetic energy depends linearly on frequency:

$$K_{max} = h\nu - \phi$$

Doubling frequency does not necessarily double kinetic energy.

False.

Statement (C):

Stopping potential depends on frequency also.

False.

Statement (D):

From:

$$V_0 = \frac{h}{e}\nu - \frac{\phi}{e}$$

graph is straight line with slope:

$$\frac{h}{e}$$

Correct.

Final Answer: A and D are correct

Answer: (A,D)

Go Back to Question 37

Q38.

Solution

Concept: Lyman-α line corresponds to transition:

$$n = 2 \to n = 1$$

Energy:

$$E = \frac{hc}{\lambda}$$

Photon momentum:

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

Solution:

Statement (A):

To emit Lyman-α photon, electron must reach at least:

$$n = 2$$

Correct.

Statement (B):

$$E = \frac{1240}{121.6} \text{ eV}$$

$$E \approx 10.2 \text{ eV}$$

Correct.

Statement (C):

Momentum conservation gives recoil momentum:

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

Correct.

Statement (D):

Lyman-α is:

$$2 \to 1$$

not:

$$3 \to 2$$

False.

Final Answer: A, B and C are correct

Answer: (A,B,C)

Go Back to Question 38

Q39.

Solution

Concept: Spontaneous fission occurs when total mass decreases and binding energy increases.

Solution:

Mass defect condition:

$$M_p > \sum M_d$$

Hence energy released:

$$Q = (M_p - \sum M_d)c^2$$

Thus statement (A) is correct.

Greater total binding energy of products implies lower mass. Hence statement (B) is correct.

Average binding energy per nucleon also increases for fission products.

Statement (C) is correct.

Statement (D):

$$\sum M_d > M_p$$

would require energy absorption.

False.

Final Answer: A, B and C are correct

Answer: (A,B,C)

Go Back to Question 39

Q40.

Solution

Concept: Reverse bias widens depletion region while forward bias reduces barrier potential and increases current exponentially.

Solution:

Statement (A):

Reverse current is mainly due to minority carriers, not majority carriers.

False.

Statement (B):

Reverse bias increases depletion width.

Correct.

Statement (C):

Breakdown voltage does not drastically decrease to zero at absolute zero.

False.

Statement (D):

Forward current follows:

$$I = I_0\left(e^{eV/kT} - 1\right)$$

Thus current increases exponentially.

Correct.

Final Answer: B and D are correct

Answer: (B,D)

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Answer Key

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