IIT JAM 2023 PH Question Paper PDF

Time Allowed :1 Hour	Maximum Marks :100	Total Questions :60

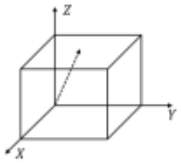
General Instructions

Read the following instructions very carefully and strictly follow them:

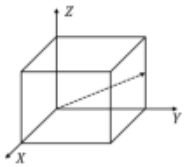
1. Please check that this question paper contains 60 questions.
2. Please write down the Serial Number of the question in the answer- book at the given place before attempting it.
3. This Question Paper has 60 questions. All questions are compulsory.
4. Adhere to the prescribed word limit while answering the questions.

1. For a cubic unit cell, the dashed arrow in which of the following figures represents the direction [220]?

(A)



(B)



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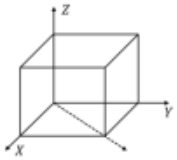

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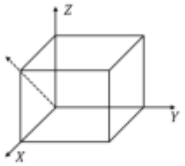

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2. Which of the following fields has non-zero curl?

(1) $\vec{F} = x\hat{i} + y\hat{j} + z\hat{k}$

(2) $\vec{F} = (y+z)\hat{i} + (x+z)\hat{j} + (x+y)\hat{k}$

(3) $\vec{F} = y^2\hat{i} + (2xy + z^2)\hat{j} + 2yz\hat{k}$
(4) $\vec{F} = xy\hat{i} + 2yz\hat{j} + 3xz\hat{k}$

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3. Which of the following statements about the viscosity of a dilute ideal gas is correct?
(1) It is independent of pressure at fixed temperature
(2) It increases with increasing pressure at fixed temperature
(3) It is independent of temperature
(4) It decreases with increasing temperature

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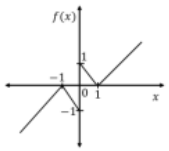
4. The plot of the function $f(x) = ||x| - 1|$ is:

(A)



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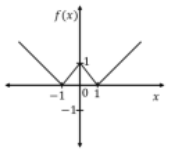

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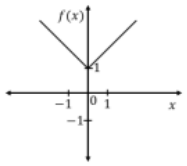

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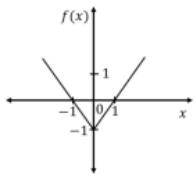

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5. A system has N spins, where each spin is capable of existing in 4 possible states. The difference in entropy of disordered states (where all possible spin configurations are equally probable) and ordered states is:
(1) $2(N-1)k_B \ln 2$
(2) $(N-1)k_B \ln 2$
(3) $4k_B \ln N$
(4) $Nk_B \ln 2$

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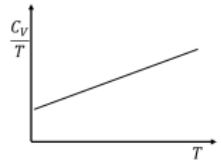
6. Temperature (T) dependence of the total specific heat (C_v) for a two-dimensional metallic solid at low temperatures is:

(A)



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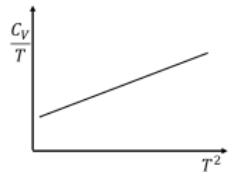
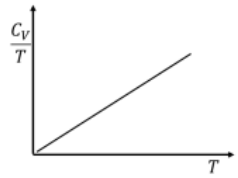


(C)



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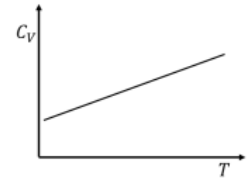

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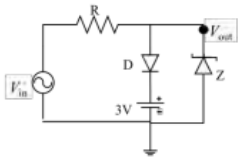
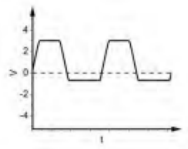
7. For the following circuit, choose the correct waveform corresponding to the output signal (V_{out}). Given $V_{in} = 5\sin(200\pi t)\,\mathrm{V}$, forward bias voltage of the diodes (D and Z) = 0.7 V and reverse Zener voltage = 3 V.



(A)



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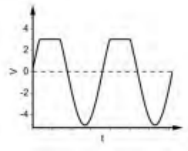

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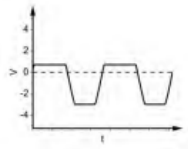

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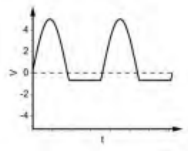

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8. If the ground state energy of a particle in an infinite potential well of width L_1 is equal to the energy of the second excited state in another infinite potential well of width L_2, then the ratio $\frac{L_1}{L_2}$ is equal to:

(1) 1
(2) $\frac{1}{3}$
(3) $\frac{1}{\sqrt{3}}$
(4) $\frac{1}{9}$

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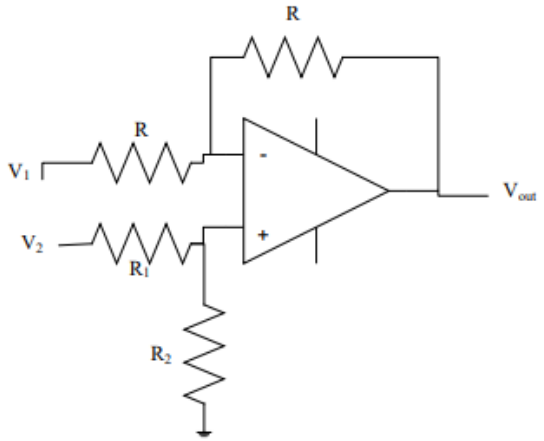
9. In the given circuit, with an ideal op-amp, for what value of $\frac{R_1}{R_2}$ the output of the amplifier $V_{out} = V_2 - V_1$?



(1) 1
(2) $\frac{1}{2}$
(3) 2
(4) $\frac{3}{2}$

---

10. A projectile of mass m is moving in the vertical xy-plane with the origin on the ground and the y-axis pointing vertically up. Taking the gravitational potential energy to be zero on the ground, the total energy of the particle written in planar polar coordinates (r, θ) is (where g is acceleration due to gravity):
(1) $\frac{m}{2}\dot{r}^2 + mgr\sin\theta$
(2) $\frac{m}{2}(\dot{r}^2 + r^2\dot{\theta}^2) + mgr\cos\theta$
(3) $\frac{m}{2}(\dot{r}^2 + r^2\dot{\theta}^2) + mgr\sin\theta$
(4) $\frac{m}{2}(\dot{r}^2 + r^2\dot{\theta}^2) - mgr\cos\theta$

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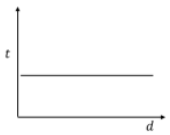
11. A small bar magnet is dropped through different hollow copper tubes with the same length and inner diameter but with different outer diameters. The variation in the time (t) taken for the magnet to reach the bottom of the tube depends on its wall thickness (d) as:

(A)



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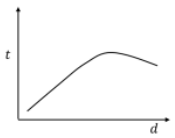

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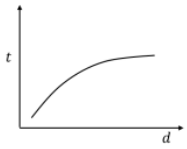

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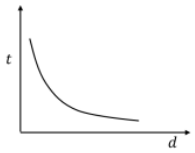

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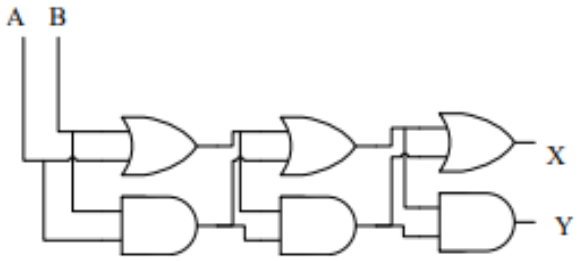
12. Two digital inputs A and B are given to the following circuit. For $A = 1, B = 0$, the values of X and Y are:



(1) $X = 0, Y = 0$
(2) $X = 1, Y = 0$
(3) $X = 0, Y = 1$
(4) $X = 1, Y = 1$

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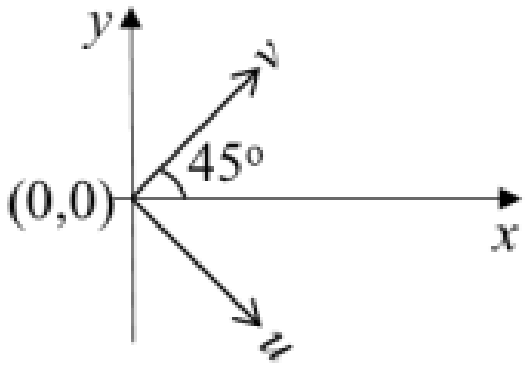
13. The Jacobian matrix for transforming from (x, y) to another orthogonal coordinate system (u, v) as shown in the figure is:



(1) $\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

(2) $\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ -1 & 1 \end{bmatrix}$

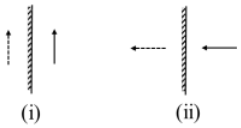
(3) $\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$

(4) $\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & -1 \\ 1 & -1 \end{bmatrix}$

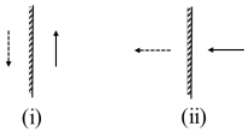
---

14. A rotating disc is held in front of a plane mirror in two different orientations: (i) angular momentum parallel to the mirror, (ii) angular momentum perpendicular to the mirror. Which schematic figure correctly describes the angular momentum (solid arrow) and its mirror image (dashed arrow) in both orientations?

(A)



(B)



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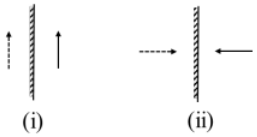
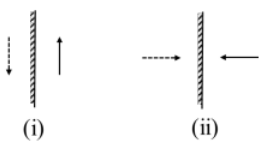


(D)



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15. Inverse of the matrix $\begin{bmatrix} 1 & 1 & 0 \\ 2 & 3 & 0 \\ 1 & 0 & 1 \end{bmatrix}$ **is:**

(1) $\begin{bmatrix} 1 & -2 & 1 \\ -1 & 3 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

(2) $\begin{bmatrix} 3 & -1 & 0 \\ -2 & 1 & 0 \\ -3 & 1 & 1 \end{bmatrix}$

(3) $\begin{bmatrix} -1 & -1 & 0 \\ 2 & 3 & 0 \\ 1 & 0 & 1 \end{bmatrix}$

(4) $\begin{bmatrix} 3 & -2 & -3 \\ -2 & 1 & 1 \\ 0 & 0 & 1 \end{bmatrix}$

---

16. Suppose the divergence of the magnetic field $\vec{B}$ is nonzero and is given as $\nabla \cdot \vec{B} = \mu_0 \rho_m$, where μ_0 is the permeability of vacuum and ρ_m is the magnetic charge density. If the corresponding magnetic current density is $\vec{j}_m$, then the curl $\nabla \times \vec{E}$ of the electric field $\vec{E}$ is:

(1) $\vec{j}_m - \frac{\partial \vec{B}}{\partial t}$

(2) $\mu_0 \vec{j}_m - \frac{\partial \vec{B}}{\partial t}$

(3) $-\vec{j}_m - \frac{\partial \vec{B}}{\partial t}$

(4) $-\mu_0 \vec{j}_m - \frac{\partial \vec{B}}{\partial t}$

---

17. For a thermodynamic system, the coefficient of volume expansion $\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$ and compressibility $\kappa = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T$. Considering that $\frac{dV}{V}$ is a perfect differential, we get:

(1) $\left(\frac{\partial \beta}{\partial P}\right)_T = \left(\frac{\partial \kappa}{\partial T}\right)_P$

(2) $\left(\frac{\partial \beta}{\partial T}\right)_P = -\left(\frac{\partial \kappa}{\partial P}\right)_T$

(3) $\left(\frac{\partial \beta}{\partial P}\right)_T = -\left(\frac{\partial \kappa}{\partial T}\right)_P$

(4) $\left(\frac{\partial \beta}{\partial T}\right)_P = \left(\frac{\partial \kappa}{\partial P}\right)_T$

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18. A linearly polarized light of wavelength 590 nm is incident normally on the surface of a 20 μm thick quartz film. The plane of polarization makes an angle 30° with the optic axis. Refractive indices of ordinary and extraordinary waves differ by 0.0091, resulting in a phase difference of $f\pi$ between them after transmission.

The value of f (rounded off to two decimal places) and the state of polarization of transmitted light is:

(1) 0.62 and linear
(2) 0.62 and elliptical
(3) -0.38 and elliptical
(4) 0.5 and circular

---

19. The phase velocity v_p of transverse waves on a one-dimensional crystal of atomic separation d is given as $v_p = C\frac{\sin(kd/2)}{(kd/2)}$. The group velocity of these waves is:

(1) $C\left[\cos(kd/2) - \frac{\sin(kd/2)}{(kd/2)}\right]$
(2) $C\cos(kd/2)$
(3) $C\left[\cos(kd/2) + \frac{\sin(kd/2)}{(kd/2)}\right]$
(4) $C\frac{\sin(kd/2)}{(kd/2)}$

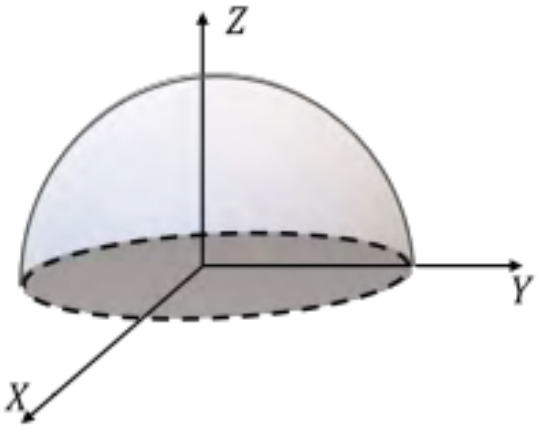
---

20. In a dielectric medium of relative permittivity 5, the amplitudes of displacement current and conduction current are equal for an applied sinusoidal voltage of frequency $f = 1$ MHz. The value of conductivity (in $\Omega^{-1}\mathrm{m}^{-1}$) of the medium is:

(1) 2.78×10^{-4}
(2) 2.44×10^{-4}
(3) 2.78×10^{-3}
(4) 2.44×10^{-3}

---

21. For a given vector $\vec{F} = -y\hat{i} + z\hat{j} + x^2\hat{k}$, the surface integral $\iint_S (\nabla \times \vec{F}) \cdot \hat{n}\, dS$ over the surface S of a hemisphere of radius R with the centre of the base at the origin is:

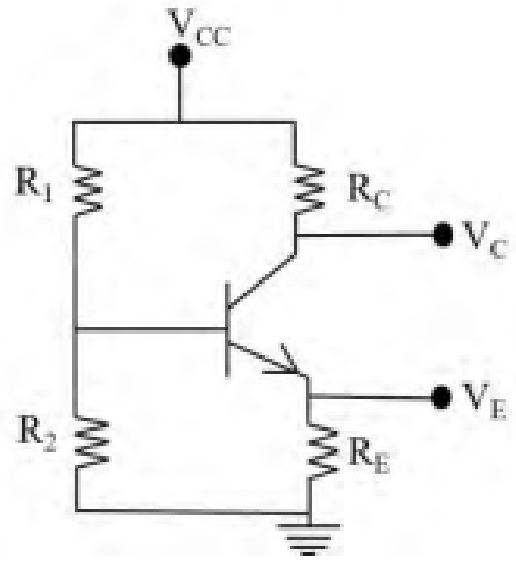


(1) πR^2
(2) $\frac{2\pi R^2}{3}$
(3) $-\pi R^2$
(4) $-\frac{2\pi R^2}{3}$

---

22. In the circuit shown, assuming the current gain $\beta = 100$ and $V_{BE} = 0.7$ V, what will be the collector voltage V_C in volts?

Given: $V_{CC} = 15$ V, $R_1 = 100$ kΩ, $R_2 = 50$ kΩ, $R_C = 4.7$ kΩ, and $R_E = 3.3$ kΩ.



(1) 8.9
(2) 5.1
(3) 4.3
(4) 3.2

---

23. A uniform stick of length l and mass m pivoted at its top end oscillates with an angular frequency ω_r. Assuming small oscillations, the ratio ω_r/ω_s, where ω_s is the angular frequency of a simple pendulum of the same length, is:

(1) $\sqrt{3}$
(2) $\sqrt{\frac{3}{2}}$
(3) $\sqrt{2}$
(4) $\frac{1}{\sqrt{3}}$

---

24. An oil film in air of thickness 255 nm is illuminated by white light at normal incidence. As a consequence of interference, which colour will be predominantly visible in the reflected light? Given refractive index of oil $n = 1.47$.

(1) Red (650 nm)
(2) Blue (450 nm)
(3) Green (500 nm)
(4) Yellow (560 nm)

---

25. Water from a tank flows down through a hole at its bottom with velocity $5\ \mathrm{m/s}$. If this water falls on a flat surface kept below the hole at a distance of $0.1\ \mathrm{m}$ and spreads horizontally, the pressure (in $\mathrm{kN/m^2}$) exerted on the flat surface is closest to:

(1) 13.5
(2) 27.0
(3) 17.6
(4) 6.8

---

26. At the planar interface of two dielectrics, which of the following statements related to the electric field ($\vec{E}$), electric displacement ($\vec{D}$) and polarization ($\vec{P}$) is true?

(1) Normal component of both $\vec{D}$ and $\vec{P}$ are continuous
(2) Normal component of both $\vec{D}$ and $\vec{E}$ are discontinuous
(3) Normal component of $\vec{D}$ is continuous and that of $\vec{P}$ is discontinuous
(4) Normal component of both $\vec{E}$ and $\vec{P}$ are continuous

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27. A system of a large number of particles can be in three energy states with energies 0 meV, 1 meV, and 2 meV. At temperature $T = 300\,\mathrm{K}$, the mean energy (in meV) is closest to:

Given: Boltzmann constant $k_B = 0.086\,\mathrm{meV/K}$
(1) 0.12
(2) 0.97
(3) 1.32
(4) 1.82

---

28. For the Maxwell-Boltzmann speed distribution, the ratio of the root-mean-square speed ($v_{\mathbf{rms}}$) to the most probable speed ($v_{\mathbf{max}}$) is:

$$f(v) = \left(\frac{m}{2\pi k_B T}\right)^{3/2} 4\pi v^2 \exp\left(-\frac{mv^2}{2k_B T}\right)$$

(1) $\sqrt{\frac{3}{2}}$

(2) $\sqrt{\frac{2}{3}}$
(3) $\frac{3}{2}$
(4) $\frac{2}{3}$

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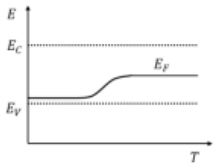
29. In an extrinsic p-type semiconductor, which schematic diagram correctly shows the variation of the Fermi energy level (E_F) with temperature (T)?

(A)



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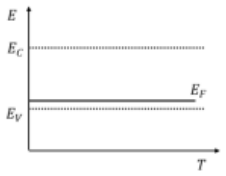
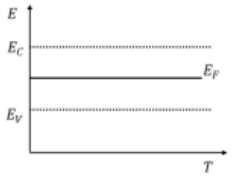
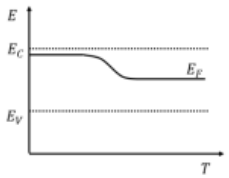


(C)



(D)



(1) (A)
(2) (B)
(3) (C)
(4) (D)

---

30. A container is occupied by a fixed number of non-interacting particles. If they obey Fermi-Dirac, Bose-Einstein, and Maxwell-Boltzmann statistics, the pressures in the container are P_{FD}, P_{BE}, and P_{MB}, respectively. Then:

(1) $P_{FD} > P_{MB} > P_{BE}$
(2) $P_{FD} > P_{MB} = P_{BE}$
(3) $P_{FD} > P_{BE} > P_{MB}$
(4) $P_{FD} = P_{MB} = P_{BE}$

31. The spectral energy density $u_T(\lambda)$ vs wavelength (λ) curve of a black body shows a peak at $\lambda = \lambda_{\max}$. If the temperature of the black body is doubled, then:

(1) the maximum of $u_T(\lambda)$ shifts to $\lambda_{\max}/2$
(2) the maximum of $u_T(\lambda)$ shifts to $2\lambda_{\max}$
(3) the area under the curve becomes 16 times the original area
(4) the area under the curve becomes 8 times the original area

---

32. A periodic function $f(x) = x^2$ for $-\pi < x < \pi$ is expanded in a Fourier series. Which of the following statements are correct?

(1) Coefficients of all the sine terms are zero
(2) The first term in the series is $\frac{\pi^2}{3}$
(3) The second term in the series is $-4\cos x$
(4) Coefficients of all the cosine terms are zero

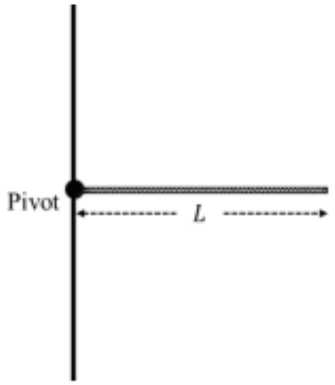
---

33. The state of a harmonic oscillator is given as $\Psi = \frac{1}{\sqrt{3}}\psi_0 - \frac{1}{\sqrt{6}}\psi_1 + \frac{1}{\sqrt{2}}\psi_2$, where ψ_0, ψ_1, ψ_2 are normalized eigenfunctions for the ground, first, and second excited states, respectively. Which of the following statements are true?

(1) A measurement of the energy yields $E = \frac{1}{2}\hbar\omega$ with nonzero probability
(2) A measurement of the energy yields $E = \frac{5}{2}\hbar\omega$ with nonzero probability
(3) Expectation value of the energy is $\frac{5}{3}\hbar\omega$
(4) Expectation value of the energy is $\frac{7}{6}\hbar\omega$

---

34. A rod of mass M, length L, and non-uniform linear mass density $\lambda(x) = \frac{3Mx^2}{L^3}$, is pivoted at one end and held horizontally. Which of the following statements are true?



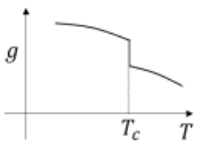
(1) Moment of inertia about the pivot is $\frac{3}{5}ML^2$

(2) Moment of inertia about the pivot is $\frac{1}{3}ML^2$
(3) Torque about pivot is $\frac{3}{4}MgL$
(4) The point at distance $\frac{2L}{3}$ from pivot falls with acceleration g when released

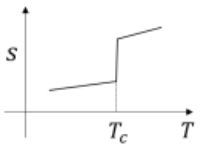
---

35. Which of the following schematic plots correctly represent a first-order phase transition at temperature $T = T_c$? Here, g, s, v are specific Gibbs free energy, entropy, and volume, respectively.

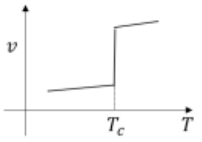
(A)



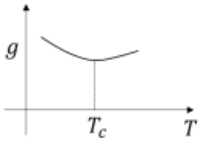
(B)



(C)



(D)



(1) (A)
(2) (B)
(3) (C)
(4) (D)

---

36. A particle p_1 of mass m moving with speed v collides elastically with a stationary identical particle p_2. After the collision, p_1 is deflected by an angle $\theta = 30^\circ$ from its original direction. Which of the following statements are true after the collision?

(1) Speed of p_1 is $\frac{\sqrt{3}}{2}v$
(2) Kinetic energy of p_2 is 25% of the total energy
(3) Angle between the directions of motion of the two particles is 90°
(4) The kinetic energy of the centre of mass of p_1 and p_2 decreases

---

37. A wave travelling along the x-axis with displacement y is described by which of the following equations (v = wave speed)?

(1) $\frac{\partial y}{\partial x} + \frac{1}{v}\frac{\partial y}{\partial t} = 0$
(2) $\frac{\partial y}{\partial x} - \frac{1}{v}\frac{\partial y}{\partial t} = 0$
(3) $\frac{\partial^2 y}{\partial x^2} + \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2} = 0$
(4) $\frac{\partial^2 y}{\partial x^2} - \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2} = 0$

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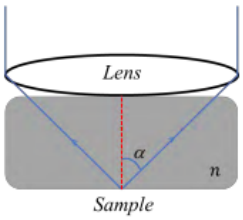
38. An objective lens of half angular aperture α is illuminated with light of wavelength λ. The refractive index of the medium between the sample and the objective is n. The lateral resolving power of the optical system can be increased by



(1) decreasing both λ and α
(2) decreasing λ and increasing α
(3) increasing both α and n
(4) decreasing λ and increasing n

---

39. Which of the following statements are true for an LC circuit with $L = 25\,\text{mH}$ and $C = 4\,\mu\text{F}$?

(1) Resonance frequency ≈ 503 Hz
(2) The impedance at 1 kHz is 15 Ω
(3) At 200 Hz, the voltage lags the current
(4) At 700 Hz, the voltage lags the current

---

40. For a particle moving in a general central force field, which of the following statements are true?

(1) Angular momentum is constant
(2) Kepler's second law is valid
(3) Motion is confined to a plane
(4) Kepler's third law is valid

---

41. The lattice constant (in Å) of copper, which has an FCC structure, is _____ (rounded off to two decimal places).
Given: density of Cu = $8.91\,\mathrm{g/cm^3}$, atomic mass = $63.55\,\mathrm{g/mol}$, Avogadro's number $N_A = 6.023 \times 10^{23}\,\mathrm{mol^{-1}}$.

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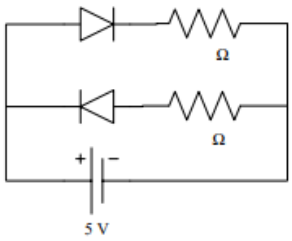
42. Two silicon diodes are connected to a battery and two resistors as shown. The current through the battery is _____ A (rounded off to two decimal places).



Given: each diode drop = $0.7\,\mathrm{V}$, battery = $5\,\mathrm{V}$, resistors = $1\,\mathrm{k\Omega}$.

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43. The absolute error in the value of $\sin\theta$ if approximated up to two terms in Taylor's series for $\theta = 60^\circ$ is _____ (rounded to three decimal places).

---

44. A simple pendulum in an elevator has period T_0 when stationary. If the elevator accelerates upward at $a = 0.2g$, find the ratio T_0/T_1.

---

45. A spacecraft moving with speed $v_s = fc$ observes the Earth's rotation period (24 h) as 48 h. Find f.

---

46. The sum of the x-components of unit vectors $\hat{r}$ and $\hat{\theta}$ for a particle moving with angular speed $2\,\mathrm{rad/s}$ at angle $\theta = 215^\circ$ is _____ (rounded off to two decimal places).

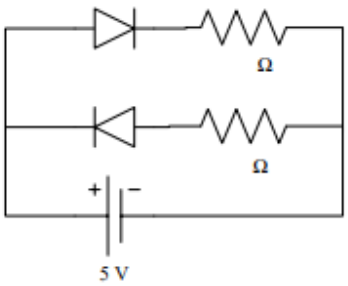
---

47. A spring–mass system with $m = 0.5\,\mathrm{kg}$, $k = 2\,\mathrm{N/m}$, and damping coefficient $b = 3\,\mathrm{kg/s}$ is in a viscous medium. Find the additional mass required for critical damping.

---

48. For potential $V(x, y, z) = 4x^2 + y^2 + z$, find the unit normal to the equipotential surface at (1,2,1). The value of $|b|$ in the unit vector $a\hat{i} + b\hat{j} + c\hat{k}$ is _____ (to two decimal places).

49. A rectangular pulse of width $0.5\,\text{cm}$ travels on a taut string (mass/length $= \mu_1$) and enters another string (μ_2). The transmitted pulse has width $0.7\,\text{cm}$. Find μ_1/μ_2.



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50. An α-particle ($E = 3\,\text{MeV}$) moves toward a nucleus of ^{50}Sn. Its minimum approach distance is $f \times 10^{-14}\,\text{m}$. Find f.

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51. In an X-ray tube operating at 20 kV, the ratio of the de Broglie wavelength of incident electrons to the shortest wavelength of the generated X-rays is _____ (rounded to two decimal places).
Given: $\frac{e}{m} = 1.76 \times 10^{11}\,\text{C/kg},\ c = 3 \times 10^{8}\,\text{m/s}$.

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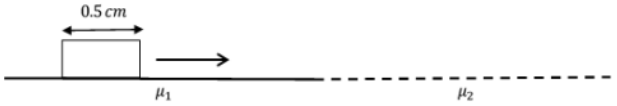
52. A 1 W source emits photons of 2 eV each isotropically. A photoelectric plate of area $10^{-4}\,\text{m}^2$ is placed 1 m away. If efficiency = 10%, find number of photoelectrons generated $f \times 10^{12}\,\text{s}^{-1}$.



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53. For the decay $^{90}\text{Th}^{232} \rightarrow^{88}\text{Ra}^{228}$, one gram of $^{90}\text{Th}^{232}$ gives 3000 counts/s. If $T_{1/2} = 4.4 \times 10^{17}\,\text{s}$, find detector efficiency (rounded to two decimal places).

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54. In the Thomson model of hydrogen, find minimum atomic radius $R = f \times 10^{-11}\,\text{m}$ such that the electron remains confined.
Given: $\hbar = 1 \times 10^{-34}\,\text{Js}, e = 1.6 \times 10^{-19}\,\text{C}, \frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}\,\text{Nm}^2\text{C}^{-2}$.

---

55. If $B = I + A + A^2$, with $A = \begin{bmatrix} 2 & 1 \\ -0.5 & 0.5 \end{bmatrix}$, find sum of eigenvalues $\lambda_1 + \lambda_2$ of B.

---

56. A container of volume V has He gas (N atoms). Another container of Ar gas has the same number of atoms in volume $2V$. If $r_{Ar} = 1.5 r_{He}$, find $\lambda_{Ar}/\lambda_{He}$ (mean free path ratio).

---

57. Three inertial frames F_0, F_1, F_2 move with $v_1 = v_2 = v_3 = c/2$. A particle moves with v_3 relative to F_2. Find its speed relative to F_0 as $f\,c$.

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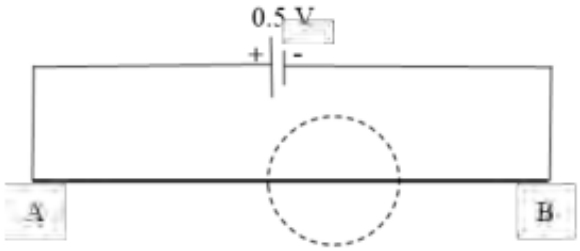
58. A fission device splits into pieces of rest masses m and $0.5m$, moving with $v_1 = c/\sqrt{13}$ and $v_2 = c/2$. If rest mass of device $= fm$, find f.

---

59. A conducting wire AB of length m has resistance of 6 Ω. It is connected to a voltage source of 0.5 V with negligible resistance as shown in the figure. The corresponding electric and magnetic fields give Poynting vectors $\vec{S}(\vec{r})$ all around the wire. Surface integral $\int \vec{S}(\vec{r})$ is calculated over a virtual sphere of diameter 0.2 m with its centre on the wire, as shown. The value of the integral is _____ W. (rounded off to three decimal places).



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60. A metallic sphere of radius R at potential V is inside a concentric shell of radius $2R$ at $2V$. Find potential at $r = \frac{3R}{2}$ as fV.
