



CSIR-NET, GATE, SET, JEST, IIT-JAM, BARC, TIFR

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GATE 2025

Question Paper With

Answer Key

PHYSICAL SCIENCE

1. For a two-dimensional hexagonal lattice with lattice constant a , the atomic density is

- (a) $\frac{1}{\sqrt{3}a^2}$ (b) $\frac{1}{\sqrt{6}a^2}$ (c) $\frac{4}{3\sqrt{3}a^2}$ (d) $\frac{1}{3\sqrt{3}a^2}$

2. Consider a crystal that has a basis of one atom. Its primitive vectors are $\vec{a}_1 = a\hat{i}$,

$$\vec{a}_2 = a\hat{j}, \vec{a}_3 = \frac{a}{2}(\hat{i} + \hat{j} + \hat{k})$$

where $\hat{i}, \hat{j}, \hat{k}$ are the unit vectors in the x, y and z directions of the Cartesian coordinate system and a is a positive constant. Which one of the following is the correct option regarding the type of the Bravais lattice?

(a) It is BCC and the volume of the primitive cell is $\frac{a^3}{2}$

(b) It is FCC and the volume of the primitive cell is $\frac{a^3}{4}$

(c) It is BCC and the volume of the primitive cell is $\frac{a^3}{8}$

(d) It is FCC and the volume of the primitive cell is a^3

3. A particle of mass m is in a potential $V(x) = \frac{1}{2}m\omega^2x^2$ for $x > 0$ and $V(x) = \infty$ for $x \leq 0$, where ω is the angular frequency. The ratio of the energies corresponding to the lowest energy level to the next higher level is

- (a) $\frac{3}{7}$ (b) $\frac{1}{2}$ (c) $\frac{1}{3}$ (d) $\frac{3}{5}$

4. A particle is scattered from a potential $V(\vec{r}) = g\delta^3(\vec{r})$, where g is a positive constant. Using the first Born approximation, the angular (θ, ϕ) dependence of differential scattering cross section $\frac{d\sigma}{d\Omega}$ is

(a) Independent of θ but dependent on ϕ (b) Dependent on θ but independent of ϕ

(c) Dependent on both θ and ϕ (d) Independent of both θ and ϕ

5. The Joule-Thomson expansion of a gas is

- (a) Isentropic (b) Isenthalpic (c) Isobaric (d) Isochoric

6. Which one of the following is correct for the phase velocity v_p and group velocity v_g ? (c is the speed of light in vacuum)

(a) For matter waves in the relativistic case, $v_p v_g > c^2$

(b) For electromagnetic waves in a medium, v_p represents the speed with which energy propagates

(c) For electromagnetic waves in a medium, both v_p and v_g can be more than c

(d) For matter waves in free space, $v_p \neq v_g$

7. As per the Drude model of metals, the electrical resistance of a metallic wire of length L and cross-section area A is (Consider τ as the relaxation time, m as electron mass, n as carrier concentration and e as electronic charge)

(a) $\frac{mL}{ne^2 A \tau}$

(b) $\frac{2mL}{ne^2 A \tau}$

(c) $\frac{mL}{2ne^2 A \tau}$

(d) $\frac{mL}{4ne^2 A \tau}$

8. Which one of the following baryons has strangeness quantum number $S = -1$?

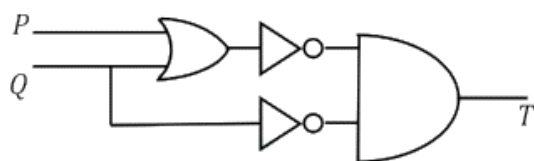
(a) Σ^{*0}

(b) n

(c) Ξ^{*0}

(d) Δ^0

9. A logic gate circuit is shown in the figure below. The correct combination for the input (P, Q) for which the output $T = 1$ is



(a) (0,0)

(b) (0,1)

(c) (1,1)

(d) (1,0)

10. The nuclear energy levels of mirror nuclei are similar. Using this empirical fact alone, the nuclear force can be said to be independent of which one of the following properties of the nucleons?

(a) Mass

(b) Spin

(c) Charge

(d) Parity

11. Consider the function $f(z) = \frac{1}{z^2(z-2)^3}$ of a complex variable z . The residues of the function at $z = 0$ and $z = 2$, respectively, are

(a) $-\frac{3}{8}$ and $\frac{3}{8}$

(b) $\frac{3}{8}$ and $-\frac{3}{16}$

(c) $-\frac{3}{16}$ and $\frac{3}{16}$

(d) $-\frac{3}{8}$ and $\frac{3}{16}$

12. Consider one mole of a monovalent metal at absolute zero temperature, obeying the free electron model. Its Fermi energy is E_F . The energy corresponding to the filling of $\frac{N_A}{2}$ electrons, where N_A is the Avogadro number, is $2^n E_F$. The value of n is

(a) $-\frac{2}{3}$

(b) $+\frac{2}{3}$

(c) $-\frac{1}{3}$

(d) -1

13. A paramagnetic material containing paramagnetic ions with total angular momentum $J = \frac{1}{2}$ is kept at absolute temperature T . The ratio of the magnetic field required for 80% of the ions to be in the lowest energy state to that required for having 60% of the ions to be in the lowest energy state at the same temperature is

(a) $\frac{2 \ln 2}{\ln \left(\frac{3}{2}\right)}$

(b) $\frac{\ln 2}{\ln \left(\frac{3}{2}\right)}$

(c) $\frac{3 \ln 2}{\ln \left(\frac{3}{2}\right)}$

(d) $\frac{\ln 3}{\ln \left(\frac{3}{2}\right)}$

14. Which of the following option(s) is/are correct for the ground state of a hydrogen atom?

(a) Linear Stark effect is zero

(b) It has definite parity

(c) Spin-orbit coupling is zero

(d) Hyperfine splitting is zero

15. Which of the following option(s) is/are correct for photons?

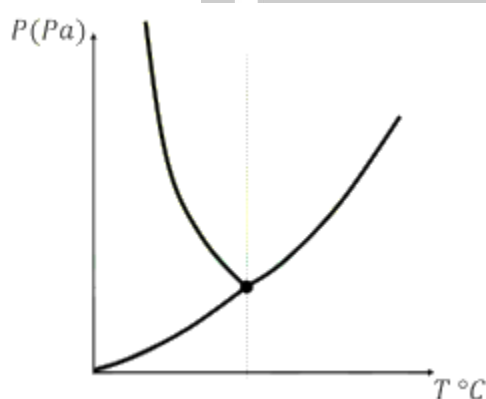
(a) Its rest mass is zero, but its energy is non-zero

(b) It carries non-zero linear momentum

(c) It carries zero spin angular momentum

(d) It has two linearly independent states of polarization

16. A schematic Pressure-Temperature diagram of water is shown in the figure. Which of the following option(s) is/are correct?



(a) Clausius-Clapeyron equation is valid across the melting curve and the vaporization Curve

(b) Melting curve has the highest slope

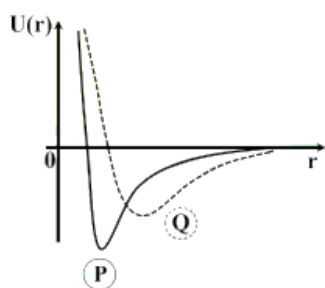
(c) The critical point exists only for the vaporization curve

(d) Clausius-Clapeyron equation is not valid across the melting curve and the vaporization curve

17. Which of the following consideration(s) is/are showing that nuclear beta decay, $n \rightarrow p + e^- + \bar{\nu}_e$, has to be a three-body decay?

- (a) Continuous distribution of the electron energy
- (b) Spin of the final state
- (c) Mass of the electron
- (d) Mass of the proton

18. Potential energy of two diatomic molecules P and Q of the same reduced mass is shown in the figure. According to this diagram, which of the following option(s) is/are correct?



- (a) The equilibrium inter-nuclear distance of Q is more than that of P
- (b) The total energy $E = 0$ separates bound and unbound states of the molecules
- (c) The lowest vibrational frequency of P is larger than that of Q
- (d) Dissociation energy of Q is more than that of P

19. Nuclear radiation emitted from a ^{60}Co radioactive source is detected by a photomultiplier tube (PMT) coupled to a scintillator crystal. Which of the following option(s) is/are correct?

- (a) γ radiation from ^{60}Co will directly hit the photocathode of the PMT without interacting with the scintillator crystal and produce a signal
- (b) β radiation from radiation, which will hit the photocathode of the PMT and produce a signal
- (c) A mu-metal shield is put all around the PMT to nullify the effect of external electric Fields
- (d) A mu-metal shield is put all around the PMT to nullify the effect of external magnetic fields

20. One mole of an ideal monatomic gas at absolute temperature T undergoes free expansion to double its original volume, so that the entropy change is ΔS_1 . An identical amount of the same gas at absolute temperature $2T$ undergoes isothermal expansion to double its original volume, so that the entropy change is ΔS_2 . The value of $\frac{\Delta S_1}{\Delta S_2}$ (in integer) is

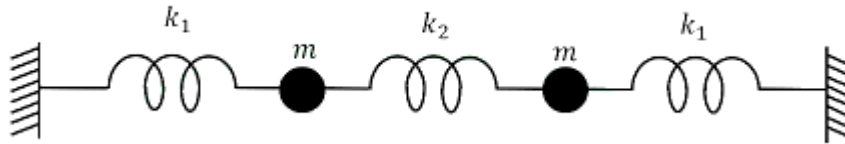
(a) $\sqrt{2}Id^2$

(b) $2Id^2$

(c) $\sqrt{3}Id^2$

(d) Id^2

28. The figure shows a system of two equal masses m and three massless horizontal springs with spring constants k_1, k_2, k_1 . Ignore gravity. The masses can move only in the horizontal direction and there is no dissipation. If $m = 1, k_1 = 2$ and $k_2 = 3$ (all in appropriate units), the frequencies of the normal modes of the system in the same system of units are



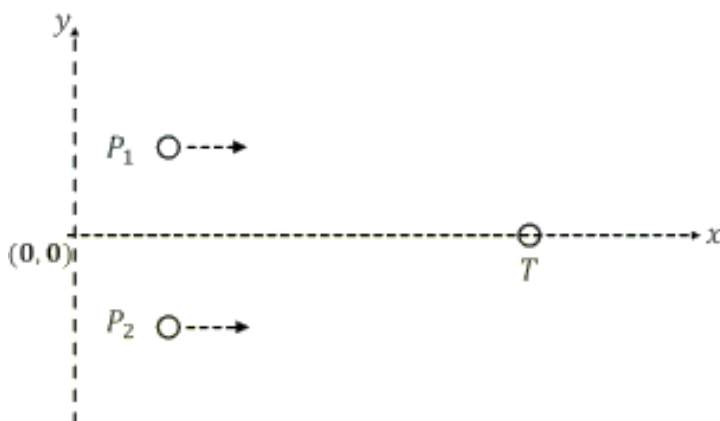
(a) $\sqrt{2}, \sqrt{8}$

(b) $\sqrt{2}, \sqrt{6}$

(c) $\sqrt{3}, \sqrt{10}$

(d) $\sqrt{3}, \sqrt{8}$

29. Two projectile protons P_1 and P_2 both with spin up (along the $+z$ direction) are scattered from another fixed target proton T with spin up at rest in the xy plane, as shown in the figure. They scatter one at a time. The nuclear interaction potential between both the projectiles and the target proton is $\lambda \vec{L} \cdot \vec{S}$, where $\vec{L}$ is the orbital angular momentum of the system with respect to the target, $\vec{S}$ is the spin angular momentum of the system and λ is a negative constant in appropriate units. Which one of the following is correct?



- (a) P_1 will be scattered in the $+y$ direction (upward) and P_2 will be scattered in the $-y$ direction (downward)
- (b) P_1 will be scattered in the $+y$ direction (upward) and P_2 will be scattered in the $+y$ direction (upward)
- (c) P_1 will be scattered in the $-y$ direction (downward) and P_2 will be scattered in the $+y$ direction (upward)
- (d) P_1 will be scattered in the $-y$ direction (downward) and P_2 will be scattered in the $-y$ direction (downward)

30. A thin circular ring of radius R lies in the xy plane with its centre coinciding with the origin. The ring carries a uniform line charge density λ . The quadrupole contribution to the electrostatic potential at the point $(0,0,d)$, where $d \gg R$, is

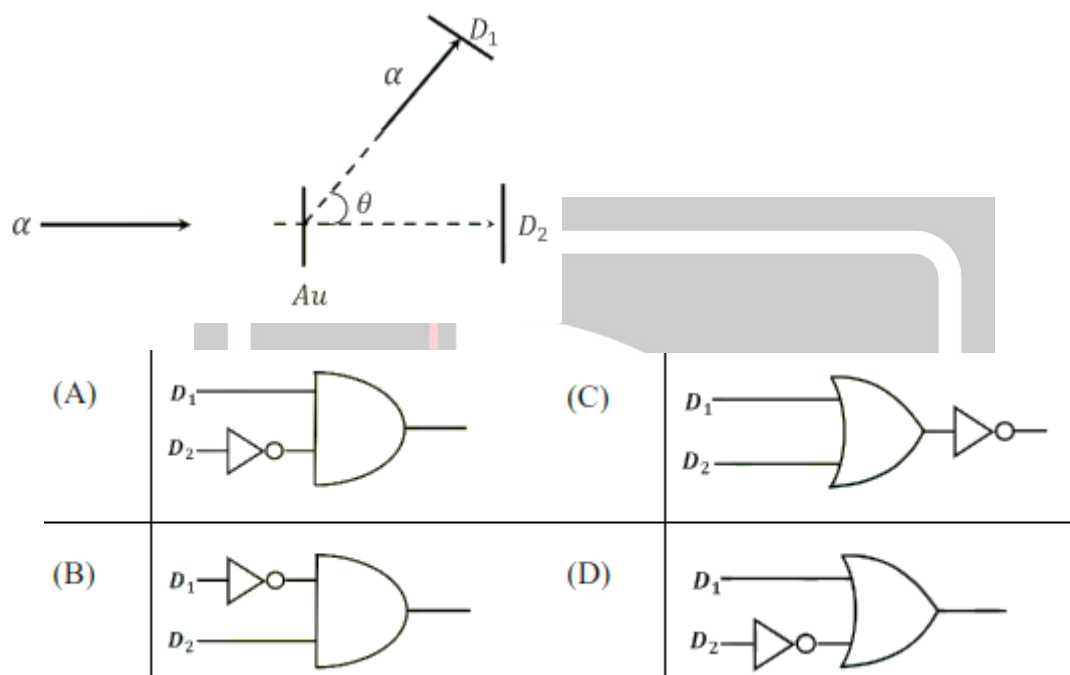
(a) $-\frac{\lambda R^3}{4\varepsilon_0 d^3}$

(b) 0

(c) $\frac{\lambda R^3}{4\varepsilon_0 d^3}$

(d) $-\frac{\lambda R^3}{2\varepsilon_0 d^3}$

31. An α particle is scattered from an Au target at rest as shown in the figure. D_1 and D_2 are the detectors to detect the scattered α particle at an angle θ and along the beam direction, respectively, as shown. The signals from D_1 and D_2 are converted to logic signals and fed to logic gates. When a particle is detected, the signal is 1 and is 0 otherwise. Which one of the following circuits detects the particle scattered at the angle θ only?



32. Consider a two-level system with energy states $+\varepsilon$ and $-\varepsilon$. The number of particles at $+\varepsilon$ level is N_+ and the number of particles at $-\varepsilon$ level is N_- . The total energy of the system is E and the total number of particles is $N = N_+ + N_-$. In the thermodynamic limit, the inverse of the absolute temperature of the system is (Given: $\ln N! \approx N \ln N - N$)

(a) $\frac{k_B}{2\varepsilon} \ln \left[\frac{N - \frac{E}{\varepsilon}}{N + \frac{E}{\varepsilon}} \right]$

(b) $\frac{k_B}{\varepsilon} \ln N$

(c) $\frac{k_B}{2\varepsilon} \ln N$

(d) $\frac{k_B}{\varepsilon} \ln \left[\frac{N - \frac{E}{\varepsilon}}{N + \frac{E}{\varepsilon}} \right]$

33. Let $|m\rangle$ and $|n\rangle$ denote the energy eigenstates of a one-dimensional simple harmonic oscillator. The position and momentum operators are $\hat{X}$ and $\hat{P}$, respectively. The matrix element $\langle m | \hat{P} \hat{X} | n \rangle$ is non-zero when

(a) $m = n \pm 2$ only

(b) $m = n$ or $m = n \pm 2$

(c) $m = n \pm 3$ only

(d) $m = n \pm 1$ only

34. A two-level quantum system has energy eigenvalues E_1 and E_2 . A perturbing potential $H' = \lambda \Delta \sigma_x$ is introduced, where Δ is a constant having dimensions of energy, λ is a small

dimensionless parameter, and $\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$. The magnitudes of the first and the second order corrections to E_1 due to H' , respectively, are

- (a) 0 and $\frac{\lambda^2 \Delta^2}{|E_1 - E_2|}$ (b) $\frac{|\lambda \Delta|}{2}$ and $\frac{\lambda^2 \Delta^2}{|E_1 - E_2|}$
- (c) $|\lambda \Delta|$ and $\frac{\lambda^2 \Delta^2}{|E_1 - E_2|}$ (d) 0 and $\frac{1}{2} \frac{\lambda^2 \Delta^2}{|E_1 - E_2|}$

35. An electron with mass m and charge q is in the spin up state $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ at time $t = 0$. A constant magnetic field is applied along the y -axis, $B = B_0 \hat{j}$, where B_0 is a constant. The Hamiltonian of the system is $H = -\hbar \omega \sigma_y$, where $\omega = \frac{qB_0}{2m} > 0$ and $\sigma_y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$. The minimum time after which the electron will be in the spin down state along the x -axis, i.e., $\frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -1 \end{pmatrix}$, is

- (a) $\frac{\pi}{8\omega}$ (b) $\frac{\pi}{4\omega}$ (c) $\frac{\pi}{2\omega}$ (d) $\frac{\pi}{\omega}$

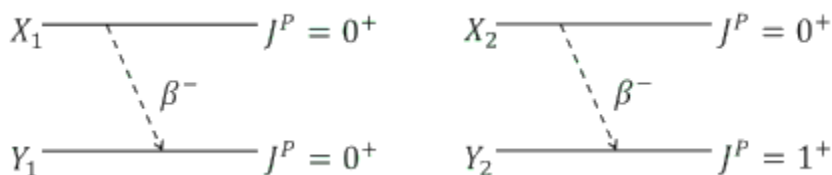
36. A system of three non-identical spin $\frac{1}{2}$ particles has the Hamiltonian $H = \frac{A}{\hbar^2} (\vec{S}_1 + \vec{S}_2) \cdot \vec{S}_3$, where $\vec{S}_1, \vec{S}_2$ and $\vec{S}_3$ are the spin operators of particles labelled 1, 2 and 3 respectively and A is a constant with appropriate dimensions. The set of possible energy eigenvalues of the system is

- (a) $0, \frac{A}{2}, -A$ (b) $0, \frac{A}{2}, -\frac{A}{2}$ (c) $0, \frac{3A}{2}, -\frac{A}{2}$ (d) $0, -\frac{3A}{2}, \frac{A}{2}$

37. Which of the following option(s) is/are correct for a Type I superconductor?

- (a) The phase transition to the normal state in the absence of a magnetic field is of second order
- (b) With increase in temperature, the critical magnetic field decreases linearly to zero
- (c) Below the critical temperature, the entropy in the superconducting state is less than that in the normal state
- (d) The phase transition to the normal state in the presence of a magnetic field is of first order

38. Consider two hypothetical nuclei X_1 and X_2 undergoing β decay, resulting in nuclei Y_1 and Y_2 , respectively. The decay scheme and the corresponding J^P values of the nuclei are given in the figure. Which of the following option(s) is/are correct? (J is the total angular momentum and P is parity)



- (a) $X_1 \rightarrow Y_1$ is Fermi transition and $X_2 \rightarrow Y_2$ is Fermi transition
- (b) $X_1 \rightarrow Y_1$ is Fermi transition and $X_2 \rightarrow Y_2$ is Gamow-Teller transition
- (c) $X_1 \rightarrow Y_1$ is Gamow-Teller transition and $X_2 \rightarrow Y_2$ is Fermi transition
- (d) $X_1 \rightarrow Y_1$ is Gamow-Teller transition and $X_2 \rightarrow Y_2$ is Gamow-Teller transition

39. A point charge q is placed at a distance d above an infinite, grounded conducting plate placed on the xy plane at $z = 0$. The electrostatic potential in $z > 0$ region is given by $\phi = \phi_1 + \phi_2$, where $\phi_1 = \frac{1}{4\pi\epsilon_0} \frac{q}{\sqrt{x^2 + y^2 + (z-d)^2}}$ $\phi_2 = -\frac{1}{4\pi\epsilon_0} \frac{q}{\sqrt{x^2 + y^2 + (z+d)^2}}$. Which of the following option(s) is/are correct?

- (a) The magnitude of the force experienced by the point charge q is $\frac{1}{16\pi\epsilon_0} \frac{q}{d^2}$
- (b) The electrostatic energy of the system is $\frac{1}{8\pi\epsilon_0} \frac{q^2}{d}$
- (c) The induced surface charge density on the plate is proportional to $\frac{1}{\sqrt{x^2 + y^2 + d^2}}$
- (d) The electrostatic potential ϕ_1 satisfies Poisson's equation for $z > 0$

40. In coordinates (t, x) , a contravariant second rank tensor A has non-zero diagonal components $A^{tt} = P$ and $A^{xx} = Q$, with all other components vanishing, and P, Q being real constants. Here, t is time and x is space coordinate. Consider a Lorentz transformation $(t, x) \rightarrow (t', x')$ to another frame that moves with relative speed v in the $+x$ direction, so that $A \rightarrow A'$. If A'^{tt} and A'^{xx} are the diagonal components of A' , then setting the speed of light $c = 1$, and with $\gamma = \frac{1}{\sqrt{1-v^2}}$, which of the following option(s) is/are correct?

- (a) $A'^{tt} = \gamma^2 P + \gamma^2 v^2 Q$ (b) $A'^{tt} = \gamma^2 v^2 P + v^2 Q$
- (c) $A'^{xx} = \gamma^2 v^2 P + \gamma^2 Q$ (d) $A'^{xx} = v^2 P + \gamma^2 Q$

41. The Lagrangian of a particle of mass m and charge q moving in a uniform magnetic field of magnitude $2B$ that points in the z direction, is given by $L = \frac{m}{2} v^2 + qB(xv_y - yv_x)$ where v_x, v_y, v_z are the components of its velocity $\vec{v}$. If p_x, p_y, p_z denote the conjugate momenta in the x, y, z directions and H is the Hamiltonian, which of the following option(s) is/are correct?

$$(a) \frac{dx}{dt} = \frac{1}{m}(p_x - qBy)$$

$$(b) \frac{dp_x}{dt} = \frac{qB}{m}(p_y - qBx)$$

$$(c) \frac{dp_y}{dt} = -\frac{qB}{m}(p_x + qBy)$$

$$(d) H = \frac{1}{2m} \left[(p_x + qBy)^2 + (p_y - qBx)^2 + p_z^2 \right]$$

42. A bead is constrained to move along a long, massless, frictionless horizontal rod parallel to the x axis. The rod itself is moving vertically upward along the z direction against gravity with a constant speed, starting from $z = 0$ at $t = 0$, and remains horizontal. The conjugate momenta are denoted by p_x, p_y, p_z and the Hamiltonian by H . Which of the following option(s) is/are correct?

(a) H is the total energy of the system and is conserved

(b) H is the total energy of the system and is not conserved

(c) H is not the total energy of the system, but it is conserved

(d) H is not the total energy of the system and is not conserved

43. In a one-dimensional Hamiltonian system with position q and momentum p , consider the canonical transformation $(q, p) \rightarrow (Q = \frac{1}{p}, P = qp^2)$, where Q and P are the new position and momentum, respectively. Which of the following option(s) regarding the generating function F is/are correct?

$$(a) F = F_1(q, Q) = \frac{q}{Q}$$

$$(b) F = F_2(q, P) = \sqrt{Pq}$$

$$(c) F = F_3(p, Q) = 2 \frac{p}{Q}$$

$$(d) F = F_4(p, P) = \frac{P}{p}$$

44. The energy of a free, relativistic particle of rest mass m moving along the x axis in one dimension, is denoted by T . When moving in a given potential $V(x)$, its Hamiltonian is $H = T + V(x)$. In the presence of this potential, its speed is v , conjugate momentum p , and the Lagrangian L . Then, which of the following option(s) is/are correct?

$$(a) H = c^2 \sqrt{m^2 + \frac{p^2}{c^2}} + V(x)$$

$$(b) v = \frac{pc}{\sqrt{p^2 + m^2 c^2}}$$

$$(c) L = mc^2 \sqrt{1 - \frac{v^2}{c^2}} - V(x)$$

$$(d) L = -mc^2 \sqrt{1 - \frac{v^2}{c^2}} - V(x)$$

45. Consider the integral $I = \frac{1}{2\pi i} \oint \frac{z^4 - 1}{\left(\frac{z-a}{b}\right)\left(\frac{z-b}{a}\right)} dz$ where z is a complex variable and a, b are positive real numbers. The integral is taken over a unit circle with center at the origin. Which of the following option(s) is/are correct?

(a) $I = \frac{5}{8}$ when $a = 1, b = 2$

(b) $I = \frac{10}{3}$ when $a = 1, b = 3$

(c) $I = \frac{5}{8}$ when $a = 2, b = 1$

(d) $I = \frac{5}{8}$ when $a = 3, b = 2$

46. A neutral conducting sphere of radius R is placed in a uniform electric field of magnitude E_0 , that points along the z axis. The electrostatic potential at any point $\vec{r}$ outside the sphere is given by $V(r, \theta) = V_0 - E_0 r \left(1 - \frac{R^3}{r^3}\right) \cos \theta$, where V_0 is the constant potential of the sphere. Which of the following option(s) is/are correct?

(a) The induced surface charge density on the sphere is proportional to $\sin \theta$

(b) As $r \rightarrow \infty, \vec{E} = E_0 \cos \theta \hat{r}$

(c) The electric field at any point is curl free for $r > R$

(d) The electric field at any point is divergence free for $r > R$

47. A point charge q is placed at the origin, inside a linear dielectric medium of infinite extent, having relative permittivity ϵ_r . Which of the following option(s) is/are correct?

(a) The magnitude of the polarization varies as $\frac{1}{r^2}$

(b) The magnitude of the polarization varies as $\frac{1}{r^3}$

(c) The magnitude of the screened charge due to the dielectric medium is less than the magnitude of the point charge q for $\epsilon_r > 1$

(d) The magnitude of the screened charge due to the dielectric medium is more than the magnitude of the point charge q for $\epsilon_r = 1$

48. A linear magnetic material in the form of a cylinder of radius R and length L is placed with its axis parallel to the z axis. The cylinder has uniform magnetization $M\hat{k}$. Which of the following option(s) is/are correct?

(a) The magnetic field at any point outside the cylinder can be expressed as the gradient of a scalar function

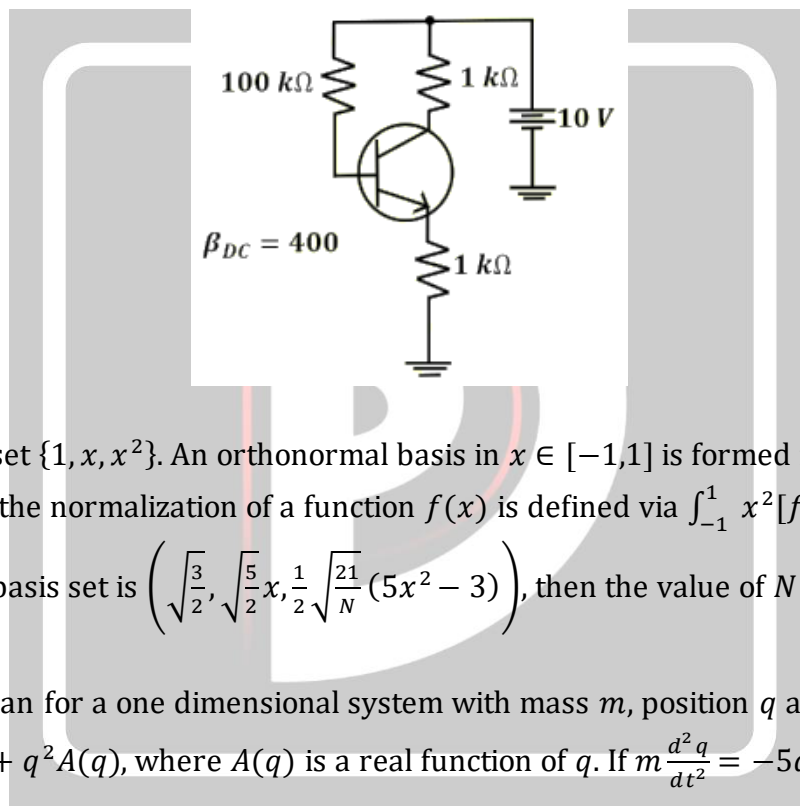
(b) The bound volume current density is zero

(c) The surface current density on the curved surface is non-zero

(d) The surface current densities on the flat surfaces (top and bottom) are non-zero

49. Cyclotrons are used to accelerate ions like deuterons (d) and α particles. Keeping the magnetic field same for both, d and α are extracted with energies 10 MeV and 20 MeV with extraction radii r_d and r_α , respectively. Taking the masses $M_d = 2000 \text{ MeV}/c^2$ and $M_\alpha = 4000 \text{ MeV}/c^2$, the value of $\frac{r_\alpha}{r_d}$ (in integer) is

50. In the transistor circuit shown in the figure, $V_{BE} = 0.7 \text{ V}$ and $\beta_{DC} = 400$. The value of the base current in μA (rounded off to one decimal place) is

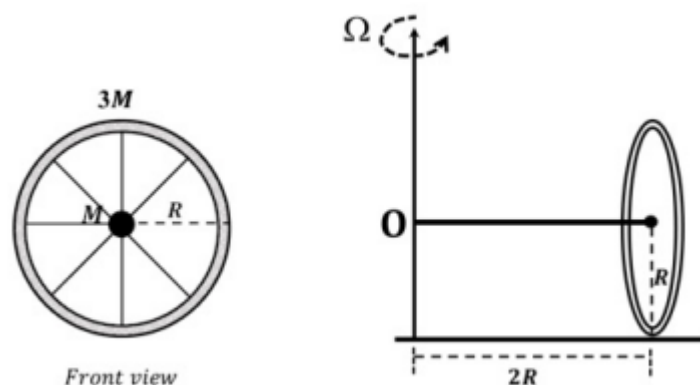


51. Consider the set $\{1, x, x^2\}$. An orthonormal basis in $x \in [-1, 1]$ is formed from these three terms, where the normalization of a function $f(x)$ is defined via $\int_{-1}^1 x^2 [f(x)]^2 dx = 1$. If the orthonormal basis set is $\left(\sqrt{\frac{3}{2}}, \sqrt{\frac{5}{2}}x, \frac{1}{2}\sqrt{\frac{21}{N}}(5x^2 - 3) \right)$, then the value of N (in integer) is

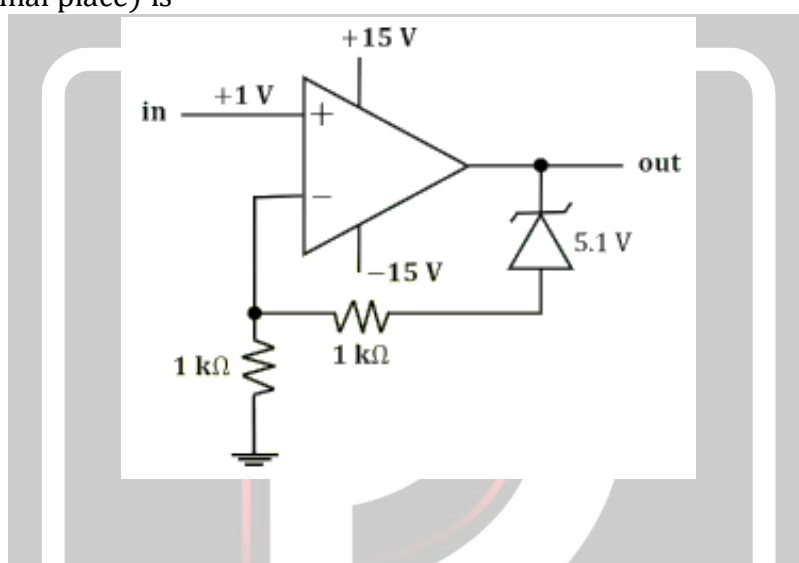
52. The Hamiltonian for a one dimensional system with mass m , position q and momentum p is $H(p, q) = \frac{p^2}{2m} + q^2 A(q)$, where $A(q)$ is a real function of q . If $m \frac{d^2 q}{dt^2} = -5qA(q)$, then $\frac{dA(q)}{dq} = n \frac{A(q)}{q}$. The value of n (in integer) is

53. A system of five identical, non-interacting particles with mass m and spin $\frac{3}{2}$ is confined to a one-dimensional potential well of length L . If the lowest energy of the system is $N \frac{\pi^2 \hbar^2}{2mL^2}$, the value of N (in integer) is

54. A wheel of mass $4M$ and radius R is made of a thin uniform distribution of mass $3M$ at the rim and a point mass M at the center. The spokes of the wheel are massless. The center of mass of the wheel is connected to a horizontal massless rod of length $2R$, with one end fixed at O , as shown in the figure. The wheel rolls without slipping on horizontal ground with angular speed Ω . If $\vec{L}$ is the total angular momentum of the wheel about O , then the magnitude $\left| \frac{d\vec{L}}{dt} \right| = N(MR^2\Omega^2)$. The value of N (in integer) is



55. The figure shows an opamp circuit with a 5.1 V Zener diode in the feedback loop. The opamp runs from ± 15 V supplies. If a +1 V signal is applied at the input, the output voltage (rounded off to one decimal place) is



Answer Key

1. c	2. a	3. a	4. d	5. b	6. d	7. a	8. a	9. a	10. c
11. c	12. a	13. a	14. a,b,c	15. a,b,d	16. a,b,c	17. a,b	18. a,b,c	19. b,d	20. 1 to 1
21. 1 to 1	22. 0 to 0	23. 2.5 to 2.5	24. 794.0 to 797.0	25. 1 to 1	26. a	27. d	28. a	29. b	30. a
31. a	32. a	33. b	34. a	35. b	36. a	37. a,c,d	38. b	39. d	40. a,c
41. b,c,d	42. d	43. a,d	44. a,b,d	45. a,c	46. c,d	47. a,c	48. a,b,c	49. 1 to 1	50. 18 to 19
51. 6 to 6	52. 3 to 3	53. 8 to 8	54. 6 to 6	55. 7.0 to 7.2					