

PH: Physics

GA - General Aptitude

Q1 - Q5 carry one mark each.

- Q.No. 1 He is known for his unscrupulous ways. He always sheds _____ tears to deceive people.
- (A) fox's
 - (B) crocodile's
 - (C) crocodile
 - (D) fox
- Q.No. 2 Jofra Archer, the England fast bowler, is _____ than accurate.
- (A) more fast
 - (B) faster
 - (C) less fast
 - (D) more faster
- Q.No. 3 Select the word that fits the analogy:
- Build : Building :: Grow : _____
- (A) Grown
 - (B) Grew
 - (C) Growth
 - (D) Growed
- Q.No. 4 I do not think you know the case well enough to have opinions. Having said that, I agree with your other point.
What does the phrase "having said that" mean in the given text?
- (A) as opposed to what I have said
 - (B) despite what I have said
 - (C) in addition to what I have said
 - (D) contrary to what I have said
- Q.No. 5 Define $[x]$ as the greatest integer less than or equal to x , for each $x \in (-\infty, \infty)$. If $y = [x]$, then area under y for $x \in [1,4]$ is _____.
- (A) 1
 - (B) 3
 - (C) 4
 - (D) 6

Q6 - Q10 carry two marks each.

Q.No. 6

Crowd funding deals with mobilisation of funds for a project from a large number of people, who would be willing to invest smaller amounts through web-based platforms in the project.

Based on the above paragraph, which of the following is correct about crowd funding?

- (A) Funds raised through unwilling contributions on web-based platforms.
- (B) Funds raised through large contributions on web-based platforms.
- (C) Funds raised through coerced contributions on web-based platforms.
- (D) Funds raised through voluntary contributions on web-based platforms.

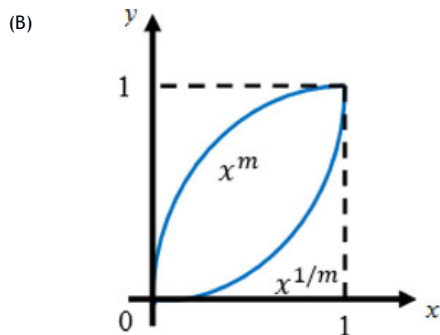
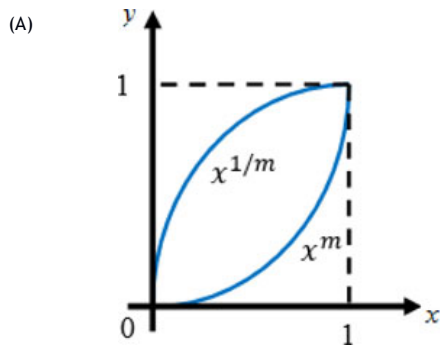
Q.No. 7 P, Q, R and S are to be uniquely coded using α and β . If P is coded as $\alpha\alpha$ and Q as $\alpha\beta$, then R and S, respectively, can be coded as _____.

- (A) $\beta\alpha$ and $\alpha\beta$
- (B) $\beta\beta$ and $\alpha\alpha$
- (C) $\alpha\beta$ and $\beta\beta$
- (D) $\beta\alpha$ and $\beta\beta$

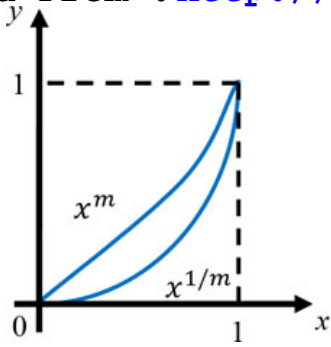
Q.No. 8 The sum of the first n terms in the sequence 8, 88, 888, 8888, ... is _____.

- (A) $\frac{81}{80}(10^n - 1) + \frac{9}{8}n$
- (B) $\frac{81}{80}(10^n - 1) - \frac{9}{8}n$
- (C) $\frac{80}{81}(10^n - 1) + \frac{8}{9}n$
- (D) $\frac{80}{81}(10^n - 1) - \frac{8}{9}n$

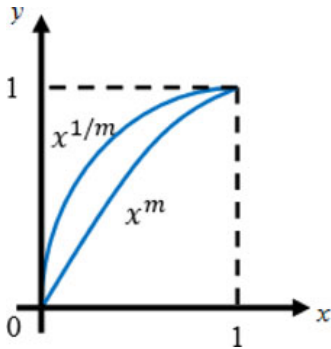
Q.No. 9 Select the graph that schematically represents BOTH $y = x^m$ and $y = x^{1/m}$ properly in the interval $0 \leq x \leq 1$, for integer values of m , where $m > 1$.



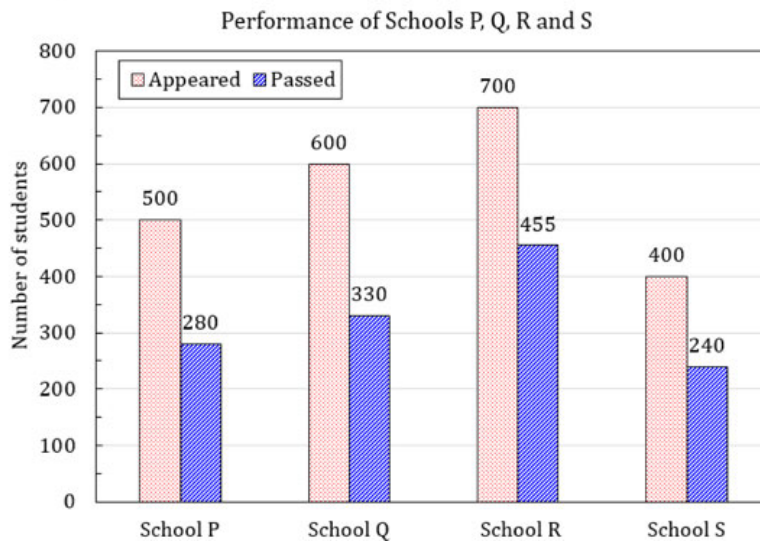
(C)



(D)



Q.No. 10 The bar graph shows the data of the students who appeared and passed in an examination for four schools P, Q, R and S. The average of success rates (in percentage) of these four schools is _____.



- (A) 58.5 %
- (B) 58.8 %
- (C) 59.0 %
- (D) 59.3 %

PH: Physics

Q1 - Q25 carry one mark each.

Q.No. 1 Which one of the following is a solution of $\frac{d^2u(x)}{dx^2} = k^2u(x)$, for k real?

- (A) e^{-kx}
- (B) $\sin kx$
- (C) $\cos kx$

(D) $\sinh x$

Q.No. 2 A real, invertible 3×3 matrix M has eigenvalues $\lambda_i, (i=1,2,3)$ and the corresponding eigenvectors are $|e_i\rangle, (i=1,2,3)$ respectively. Which one of the following is correct?

(A) $M|e_i\rangle = \frac{1}{\lambda_i}|e_i\rangle, \text{ for } i=1,2,3$

(B) $M^{-1}|e_i\rangle = \frac{1}{\lambda_i}|e_i\rangle, \text{ for } i=1,2,3$

(C) $M^{-1}|e_i\rangle = \lambda_i|e_i\rangle, \text{ for } i=1,2,3$

(D) The eigenvalues of M and M^{-1} are not related.

Q.No. 3 A quantum particle is subjected to the potential

$$V(x) = \begin{cases} \infty, & x \leq -\frac{a}{2} \\ 0, & -\frac{a}{2} < x < \frac{a}{2} \\ \infty, & x \geq \frac{a}{2}. \end{cases}$$

The ground state wave function of the particle is proportional to

(A) $\sin\left(\frac{\pi x}{2a}\right)$

(B) $\sin\left(\frac{\pi x}{a}\right)$

(C) $\cos\left(\frac{\pi x}{2a}\right)$

(D) $\cos\left(\frac{\pi x}{a}\right)$

Q.No. 4 Let \hat{a} and \hat{a}^\dagger , respectively denote the lowering and raising operators of a one-dimensional simple harmonic oscillator. Let $|n\rangle$ be the energy eigenstate of the simple harmonic oscillator. Given that $|n\rangle$ is also an eigenstate of $\hat{a}^\dagger \hat{a}^\dagger \hat{a} \hat{a}$, the corresponding eigenvalue is

(A) $n(n-1)$

(B) $n(n+1)$

(C) $(n+1)^2$

(D) n^2

Q.No. 5 Which one of the following is a universal logic gate?

(A) AND

(B) NOT

(C) OR

(D) NAND

Q.No. 6 Which one of the following is the correct binary equivalent of the hexadecimal

F6C?

- (A) 0110 1111 1100
- (B) 1111 0110 1100
- (C) 1100 0110 1111
- (D) 0110 1100 0111

Q.No. 7 The total angular momentum j of the ground state of the $^{17}_8\text{O}$ nucleus is

- (A) $\frac{1}{2}$
- (B) 1
- (C) $\frac{3}{2}$
- (D) $\frac{5}{2}$

Q.No. 8 A particle X is produced in the process $\pi^+ + p \rightarrow K^+ + X$ via the strong interaction. If the quark content of the K^+ is $u\bar{s}$, the quark content of X is

- (A) $c\bar{s}$
- (B) uud
- (C) uus
- (D) $u\bar{d}$

Q.No. 9 A medium ($\epsilon_r > 1, \mu_r = 1, \sigma > 0$) is semi-transparent to an electromagnetic wave when

- (A) Conduction current \gg Displacement current
- (B) Conduction current \ll Displacement current
- (C) Conduction current = Displacement current
- (D) Both Conduction current and Displacement current are zero

Q.No. 10 A particle is moving in a central force field given by $\vec{F} = -\frac{k}{r^3} \hat{r}$, where \hat{r} is the unit vector pointing away from the center of the field. The potential energy of the particle is given by

- (A) $\frac{k}{r^2}$
- (B) $\frac{k}{2r^2}$
- (C) $-\frac{k}{r^2}$
- (D) $-\frac{k}{2r^2}$

Q.No. 11

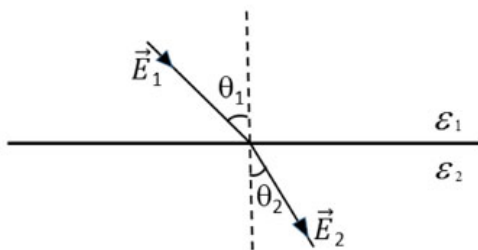
Choose the correct statement related to the Fermi energy (E_F) and the chemical potential (μ) of a metal.

- (A) $\mu = E_F$ only at 0 K
- (B) $\mu = E_F$ at finite temperature
- (C) $\mu < E_F$ at 0 K
- (D) $\mu > E_F$ at finite temperature

Q.No. 12 Consider a diatomic molecule formed by identical atoms. If E_V and E_e represent the energy of the vibrational nuclear motion and electronic motion respectively, then in terms of the electronic mass m and nuclear mass M , $\frac{E_V}{E_e}$ is proportional to

- (A) $\left(\frac{m}{M}\right)^{1/2}$
- (B) $\frac{m}{M}$
- (C) $\left(\frac{m}{M}\right)^{3/2}$
- (D) $\left(\frac{m}{M}\right)^2$

Q.No. 13 Which one of the following relations determines the manner in which the electric field lines are refracted across the interface between two dielectric media having dielectric constants ϵ_1 and ϵ_2 (see figure)?



- (A) $\epsilon_1 \sin \theta_1 = \epsilon_2 \sin \theta_2$
- (B) $\epsilon_1 \cos \theta_1 = \epsilon_2 \cos \theta_2$
- (C) $\epsilon_1 \tan \theta_1 = \epsilon_2 \tan \theta_2$
- (D) $\epsilon_1 \cot \theta_1 = \epsilon_2 \cot \theta_2$

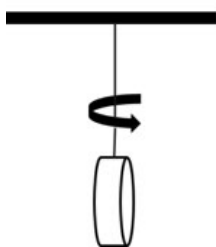
Q.No. 14 If \vec{E} and \vec{B} are the electric and magnetic fields respectively, then $\vec{E} \cdot \vec{B}$ is

- (A) odd under parity and even under time reversal
- (B) even under parity and odd under time reversal
- (C) odd under parity and odd under time reversal
- (D) even under parity and even under time reversal

Q.No. 15 A small disc is suspended by a fiber such that it is free to rotate about the fiber axis (see figure). For small angular deflections, the Hamiltonian for the disc is given by

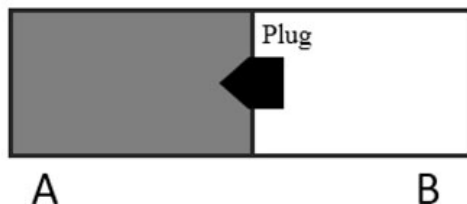
$$H = \frac{p_\theta^2}{2I} + \frac{1}{2}\alpha\theta^2,$$

where I is the moment of inertia and α is the restoring torque per unit deflection. The disc is subjected to angular deflections (θ) due to thermal collisions from the surrounding gas at temperature T and p_θ is the momentum conjugate to θ . The average and the root-mean-square angular deflection, θ_{avg} and θ_{rms} , respectively are



- (A) $\theta_{avg} = 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{3/2}$
- (B) $\theta_{avg} = 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{1/2}$
- (C) $\theta_{avg} \neq 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{1/2}$
- (D) $\theta_{avg} \neq 0$ and $\theta_{rms} = \left(\frac{k_B T}{\alpha}\right)^{3/2}$

Q.No. 16 As shown in the figure, an ideal gas is confined to chamber A of an insulated container, with vacuum in chamber B. When the plug in the wall separating the chambers A and B is removed, the gas fills both the chambers. Which one of the following statements is true?



- (A) The temperature of the gas remains unchanged
- (B) Internal energy of the gas decreases
- (C) Temperature of the gas decreases as it expands to fill the space in chamber B
- (D) Internal energy of the gas increases as its atoms have more space to move around

Q.No. 17

Particle A with angular momentum $j = \frac{3}{2}$ decays into two particles B and C with angular momenta j_1 and j_2 , respectively. If $|\frac{3}{2}, \frac{3}{2}\rangle_A = \alpha |1, 1\rangle_B \otimes |\frac{1}{2}, \frac{1}{2}\rangle_C$, the value of α is _____.

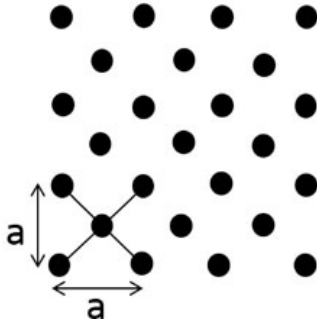
Q.No. 18

Far from the Earth, the Earth's magnetic field can be approximated as due to a bar magnet of magnetic pole strength 4×10^{14} Am. Assume this magnetic field is generated by a current carrying loop encircling the magnetic equator. The current required to do so is about 4×10^n A, where n is an integer. The value of n is _____.

(Earth's circumference: 4×10^7 m)

Q.No. 19

The number of distinct ways the primitive unit cell can be constructed for the two dimensional lattice as shown in the figure is _____.



Q.No. 20

A hydrogenic atom is subjected to a strong magnetic field. In the absence of spin-orbit coupling, the number of doubly degenerate states created out of the d -level is _____.

Q.No. 21

A particle Y undergoes strong decay $Y \rightarrow \pi^- + \pi^-$. The isospin of Y is _____.

Q.No. 22

For a complex variable z and the contour $c: |z|=1$ taken in the counter clockwise direction, $\frac{1}{2\pi i} \oint_c \left(z - \frac{2}{z} + \frac{3}{z^2} \right) dz =$ _____.

Q.No. 23

Let p be the momentum conjugate to the generalized coordinate q . If the transformation

$$Q = \sqrt{2} q^m \cos p$$

$$P = \sqrt{2} q^m \sin p$$

is canonical, then $m =$ _____.

Q.No. 24

A conducting sphere of radius 1 m is placed in air. The maximum number of electrons that can be put on the sphere to avoid electrical breakdown is about 7×10^n , where n is an integer. The value of n is _____.

Assume:

Breakdown electric field strength in air is $|\vec{E}| = 3 \times 10^6$ V/m

Permittivity of free space $\epsilon_0 = 8.85 \times 10^{-12}$ F/m

Electron charge $e = 1.60 \times 10^{-19}$ C

Q.No. 25 If a particle is moving along a sinusoidal curve, the number of degrees of freedom of the particle is ____.

Q26 - Q55 carry two marks each.

Q.No. 26

The product of eigenvalues of $\begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$ is

- (A) -1
- (B) 1
- (C) 0
- (D) 2

Q.No. 27

Let $|e_1\rangle \equiv \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$, $|e_2\rangle \equiv \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix}$ and $|e_3\rangle \equiv \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$. Let $S = \{|e_1\rangle, |e_2\rangle, |e_3\rangle\}$. Let \mathbb{R}^3 denote

the three-dimensional real vector space. Which one of the following is correct?

- (A) S is an orthonormal set
- (B) S is a linearly dependent set
- (C) S is a basis for \mathbb{R}^3
- (D)

$$\sum_{i=1}^3 |e_i\rangle \langle e_i| = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Q.No. 28

\hat{S}_x denotes the spin operator defined as $\hat{S}_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$. Which one of the

following is correct?

- (A) The eigenstates of spin operator \hat{S}_x are $|\uparrow\rangle_x \equiv \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and $|\downarrow\rangle_x \equiv \begin{pmatrix} 0 \\ 1 \end{pmatrix}$
- (B) The eigenstates of spin operator \hat{S}_x are $|\uparrow\rangle_x \equiv \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -1 \end{pmatrix}$ and $|\downarrow\rangle_x \equiv \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ 1 \end{pmatrix}$
- (C)

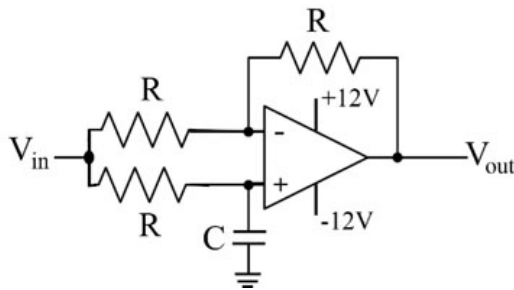
In the spin state $\frac{1}{2} \begin{pmatrix} 1 \\ \sqrt{3} \end{pmatrix}$, upon the measurement of \hat{S}_x , the probability for

obtaining $|\uparrow\rangle_x$ is $\frac{1}{4}$

(D) In the spin state $\frac{1}{2} \begin{pmatrix} 1 \\ \sqrt{3} \end{pmatrix}$, upon the measurement of \hat{S}_x , the probability for

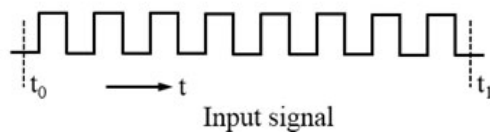
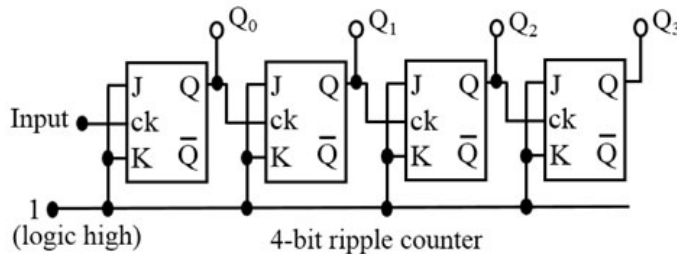
obtaining $|\uparrow\rangle_x$ is $\frac{2+\sqrt{3}}{4}$.

Q.No. 29 The input voltage (V_{in}) to the circuit shown in the figure is $2 \cos(100t)$ V. The output voltage (V_{out}) is $2 \cos(100t - \frac{\pi}{2})$ V. If $R = 1 \text{ k}\Omega$, the value of C (in μF) is



- (A) 0.1
- (B) 1
- (C) 10
- (D) 100

Q.No. 30 Consider a 4-bit counter constructed out of four flip-flops. It is formed by connecting the J and K inputs to logic high and feeding the Q output to the clock input of the following flip-flop (see the figure). The input signal to the counter is a series of square pulses and the change of state is triggered by the falling edge. At time $t = t_0$ the outputs are in logic low state ($Q_0 = Q_1 = Q_2 = Q_3 = 0$). Then at $t = t_1$, the logic state of the outputs is



- (A) $Q_0 = 1, Q_1 = 0, Q_2 = 0$ and $Q_3 = 0$
- (B)

$$Q_0 = 0, Q_1 = 0, Q_2 = 0 \text{ and } Q_3 = 1$$

- (C) $Q_0 = 1, Q_1 = 0, Q_2 = 1 \text{ and } Q_3 = 0$
 (D) $Q_0 = 0, Q_1 = 1, Q_2 = 1 \text{ and } Q_3 = 1$

Q.No. 31

Consider the Lagrangian $L = a\left(\frac{dx}{dt}\right)^2 + b\left(\frac{dy}{dt}\right)^2 + cxy$, where a , b and c are

constants. If p_x and p_y are the momenta conjugate to the coordinates x and y respectively, then the Hamiltonian is

- (A) $\frac{p_x^2}{4a} + \frac{p_y^2}{4b} - cxy$
 (B) $\frac{p_x^2}{2a} + \frac{p_y^2}{2b} - cxy$
 (C) $\frac{p_x^2}{2a} + \frac{p_y^2}{2b} + cxy$
 (D) $\frac{p_x^2}{a} + \frac{p_y^2}{b} + cxy$

Q.No. 32 Which one of the following matrices does NOT represent a proper rotation in a plane?

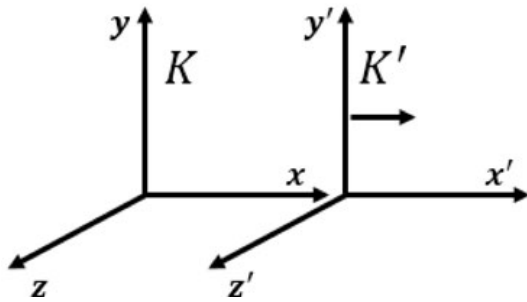
- (A) $\begin{pmatrix} -\sin \theta & \cos \theta \\ -\cos \theta & -\sin \theta \end{pmatrix}$
 (B) $\begin{pmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{pmatrix}$
 (C) $\begin{pmatrix} \sin \theta & \cos \theta \\ -\cos \theta & \sin \theta \end{pmatrix}$
 (D) $\begin{pmatrix} -\sin \theta & \cos \theta \\ -\cos \theta & \sin \theta \end{pmatrix}$

Q.No. 33

A uniform magnetic field $\vec{B} = B_0 \hat{y}$ exists in an inertial frame K . A perfect conducting sphere moves with a constant velocity $\vec{v} = v_0 \hat{x}$ with respect to this inertial frame. The rest frame of the sphere is K' (see figure). The electric and magnetic fields in K and K' are related as

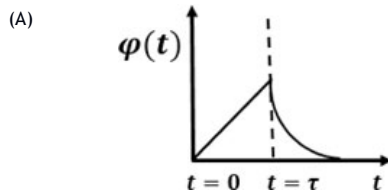
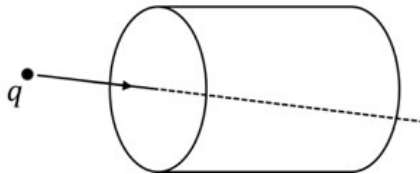
$$\left. \begin{aligned} \vec{E}'_{\parallel} &= \vec{E}_{\parallel} & \vec{E}'_{\perp} &= \gamma (\vec{E}_{\perp} + \vec{v} \times \vec{B}) \\ \vec{B}'_{\parallel} &= \vec{B}_{\parallel} & \vec{B}'_{\perp} &= \gamma \left(\vec{B}_{\perp} - \frac{\vec{v}}{c^2} \times \vec{E} \right) \end{aligned} \right\}, \quad \gamma = \frac{1}{\sqrt{1 - (v/c)^2}}$$

The induced surface charge density on the sphere (to the lowest order in v/c) in the frame K' is

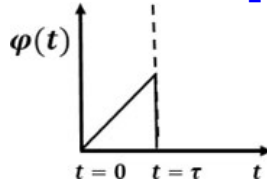


- (A) maximum along z'
 (B) maximum along y'
 (C) maximum along x'
 (D) uniform over the sphere

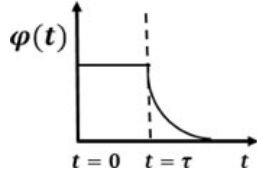
Q.No. 34 A charge q moving with uniform speed enters a cylindrical region in free space at $t = 0$ and exits the region at $t = \tau$ (see figure). Which one of the following options best describes the time dependence of the total electric flux $\varphi(t)$, through the entire surface of the cylinder?



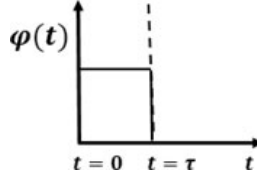
(B)



(C)



(D)



- Q.No. 35 Consider a one-dimensional non-magnetic crystal with one atom per unit cell. Assume that the valence electrons (i) do not interact with each other and (ii) interact weakly with the ions. If n is the number of valence electrons per unit cell, then at 0 K,
- (A) the crystal is metallic for any value of n
 - (B) the crystal is non-metallic for any value of n
 - (C) the crystal is metallic for even values of n
 - (D) the crystal is metallic for odd values of n

- Q.No. 36 According to the Fermi gas model of the nucleus, the nucleons move in a spherical volume of radius $R (= R_0 A^{1/3})$, where A is the mass number and R_0 is an empirical constant with the dimensions of length). The Fermi energy of the nucleus E_F is proportional to

- (A) R_0^2
- (B) $\frac{1}{R_0}$
- (C) $\frac{1}{R_0^2}$
- (D) $\frac{1}{R_0^3}$

- Q.No. 37 Consider a two dimensional crystal with 3 atoms in the basis. The number of allowed optical branches (n) and acoustic branches (m) due to the lattice vibrations are

- (A) $(n, m) = (2, 4)$
- (B) $(n, m) = (3, 3)$
- (C) $(n, m) = (4, 2)$
- (D) $(n, m) = (1, 5)$

Q.No. 38 The internal energy U of a system is given by $U(S, V) = \lambda V^{-2/3} S^2$, where λ is a constant of appropriate dimensions; V and S denote the volume and entropy, respectively. Which one of the following gives the correct equation of state of the system?

- (A) $\frac{PV^{1/3}}{T^2} = \text{constant}$
- (B) $\frac{PV}{T^{1/3}} = \text{constant}$
- (C) $\frac{P}{V^{1/3}T} = \text{constant}$
- (D) $\frac{PV^{2/3}}{T} = \text{constant}$

Q.No. 39 The potential energy of a particle of mass m is given by

$$U(x) = a \sin(k^2 x - \pi/2), \quad a > 0, \quad k^2 > 0.$$

The angular frequency of small oscillations of the particle about $x = 0$ is

- (A) $k^2 \sqrt{\frac{2a}{m}}$
- (B) $k^2 \sqrt{\frac{a}{m}}$
- (C) $k^2 \sqrt{\frac{a}{2m}}$
- (D) $2k^2 \sqrt{\frac{a}{m}}$

Q.No. 40 The radial wave function of a particle in a central potential is given by

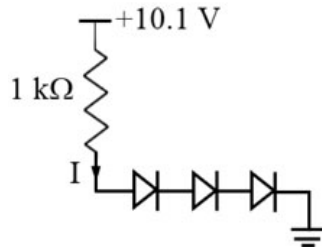
$$R(r) = A \frac{r}{a} \exp\left(-\frac{r}{2a}\right),$$
 where A is the normalization constant and a is positive

constant of suitable dimensions. If γa is the most probable distance of the particle from the force center, the value of γ is _____.

Q.No. 41 A free particle of mass M is located in a three-dimensional cubic potential well with impenetrable walls. The degeneracy of the fifth excited state of the particle is _____.

Q.No. 42

Consider the circuit given in the figure. Let the forward voltage drop across each diode be 0.7 V. The current I (in mA) through the resistor is ____.



- Q.No. 43 Let u^μ denote the 4-velocity of a relativistic particle whose square $u^\mu u_\mu = 1$. If $\epsilon_{\mu\nu\rho\sigma}$ is the Levi-Civita tensor then the value of $\epsilon_{\mu\nu\rho\sigma} u^\mu u^\nu u^\rho u^\sigma$ is ____.
- Q.No. 44 Consider a simple cubic monoatomic Bravais lattice which has a basis with vectors $\vec{r}_1 = 0, \vec{r}_2 = \frac{a}{4}(\hat{x} + \hat{y} + \hat{z})$, a is the lattice parameter. The Bragg reflection is observed due to the change in the wave vector between the incident and the scattered beam as given by $\vec{K} = n_1 \vec{G}_1 + n_2 \vec{G}_2 + n_3 \vec{G}_3$, where \vec{G}_1, \vec{G}_2 , and \vec{G}_3 are primitive reciprocal lattice vectors. For $n_1 = 3, n_2 = 3$ and $n_3 = 2$, the geometrical structure factor is ____.
- Q.No. 45 A plane electromagnetic wave of wavelength λ is incident on a circular loop of conducting wire. The loop radius is a ($a \ll \lambda$). The angle (in degrees), made by the Poynting vector with the normal to the plane of the loop to generate a maximum induced electrical signal, is ____.
- Q.No. 46 An electron in a hydrogen atom is in the state $n=3, l=2, m=-2$. Let \hat{L}_y denote the y -component of the orbital angular momentum operator. If $(\Delta \hat{L}_y)^2 = \alpha \hbar^2$, the value of α is ____.
- Q.No. 47 A sinusoidal voltage of the form $V(t) = V_0 \cos(\omega t)$ is applied across a parallel plate capacitor placed in vacuum. Ignoring the edge effects, the induced emf within the region between the capacitor plates can be expressed as a power series in ω . The lowest non-vanishing exponent in ω is ____.
- Q.No. 48 If $x = \sum_{k=1}^{\infty} a_k \sin kx$, for $-\pi \leq x \leq \pi$, the value of a_2 is ____.
- Q.No. 49

$$\text{Let } f_n(x) = \begin{cases} 0, & x < -\frac{1}{2n} \\ n, & -\frac{1}{2n} < x < \frac{1}{2n} \\ 0, & \frac{1}{2n} < x. \end{cases}$$

The value of $\lim_{n \rightarrow \infty} \int_{-\infty}^{\infty} f_n(x) \sin x dx$ is _____.

Q.No. 50 Consider the Hamiltonian $\hat{H} = \hat{H}_0 + \hat{H}'$ where

$$\hat{H}_0 = \begin{pmatrix} E & 0 & 0 \\ 0 & E & 0 \\ 0 & 0 & E \end{pmatrix} \text{ and } \hat{H}' \text{ is the time independent perturbation given by}$$

$$\hat{H}' = \begin{pmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{pmatrix}, \text{ where } k > 0. \text{ If, the maximum energy eigenvalue of } \hat{H} \text{ is } 3 \text{ eV}$$

corresponding to $E = 2 \text{ eV}$, the value of k (rounded off to three decimal places) in eV is _____.

Q.No. 51 A hydrogen atom is in an orbital angular momentum state $|l, m=l\rangle$. If \vec{L} lies on a cone which makes a half angle 30° with respect to the z -axis, the value of l is _____.

Q.No. 52 In the center of mass frame, two protons each having energy 7000 GeV , collide to produce protons and anti-protons. The maximum number of anti-protons produced is _____.

(Assume the proton mass to be $1 \text{ GeV}/c^2$)

Q.No. 53 Consider a gas of hydrogen atoms in the atmosphere of the Sun where the temperature is 5800 K . If a sample from this atmosphere contains 6.023×10^{23} of hydrogen atoms in the ground state, the number of hydrogen atoms in the first excited state is approximately 8×10^n , where n is an integer. The value of n is _____.

(Boltzmann constant: $8.617 \times 10^{-5} \text{ eV/K}$)

Q.No. 54

For a gas of non-interacting particles, the probability that a particle has a speed v in the interval v to $v+dv$ is given by

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

If E is the energy of a particle, then the maximum in the corresponding energy distribution in units of $E/k_B T$ occurs at _____ (rounded off to one decimal place).

Q.No. 55

The Planck's energy density distribution is given by $u(\omega) = \frac{\hbar \omega^3}{\pi^2 c^3 (e^{\hbar\omega/k_B T} - 1)}$.

At long wavelengths, the energy density of photons in thermal equilibrium with a cavity at temperature T varies as T^α , where α is _____.

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