



Learn Physics in Right Way

IIT-JAM Physics-2026
Solution-Mathematical Methods

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Section A: Q.1-Q.10 Carry ONE mark each.

Q8. Consider the following linear second order differential equation $\frac{d^2 y}{dt^2} + \omega^2 y = 0$, where ω is positive constant. The boundary conditions are $\left. \frac{dy}{dt} \right|_{t=0} = 1$, and $y(t=0) = \frac{1}{2}$.

Which of the following options gives the value of $y\left(t = \frac{\pi}{2\omega}\right)$?

- (a) $\frac{1}{\omega}$ (b) $\frac{2\pi}{\omega}$
(c) 0 (d) 1

Ans.: (a)

Solution.: $\because \frac{d^2 y}{dt^2} + \omega^2 y = 0 \Rightarrow \lambda^2 + \omega^2 = 0 \Rightarrow \lambda = \pm i\omega \Rightarrow y = A \cos \omega t + B \sin \omega t$

$\because y(t=0) = \frac{1}{2} \Rightarrow \frac{1}{2} = A$ and $\left. \frac{dy}{dt} \right|_{t=0} = 1 \Rightarrow 1 = B\omega \Rightarrow B = \frac{1}{\omega}$

Thus $y\left(t = \frac{\pi}{2\omega}\right) = \frac{1}{2} \cos \frac{\pi}{2} + \frac{1}{\omega} \sin \frac{\pi}{2} = \frac{1}{\omega}$

Q10. Consider the matrix $A = \begin{pmatrix} 0 & 1 & 1 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix}$. The value of $\det(A^{-1})$ is:

- (a) 4 (b) 1
(c) $\frac{1}{4}$ (d) 0

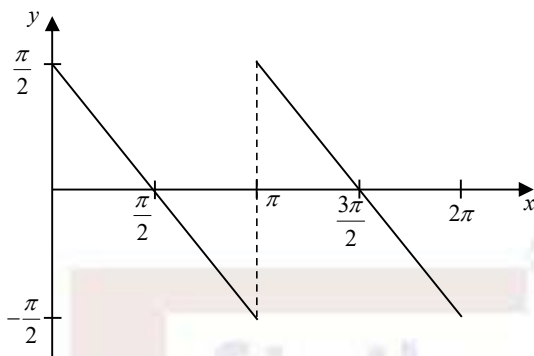
Ans.: (b)

Solution.: $\det(A) = \begin{vmatrix} 0 & 1 & 1 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{vmatrix} = 0 - 1(0 - 1) + 1(0 - 0) = 1$

$\because \det(A^{-1}) = \frac{1}{\det(A)} = 1$

Section A: Q.11-Q.30 Carry TWO marks each.

Q24. A piecewise regular function $f(x)$ is shown in the figure. It is expanded in Fourier series given by $f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos(nx) + \sum_{n=1}^{\infty} b_n \sin(nx)$ where a_0, a_n, b_n 's are the Fourier coefficients.

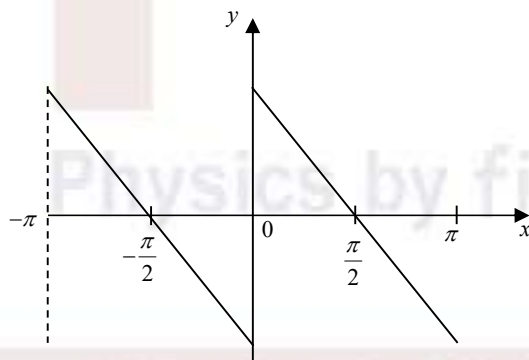


Which of the following options is correct?

- (a) $a_0 = 3\pi$ (b) All a_n are zero
(c) All b_n are zero (d) $a_0 = \frac{3\pi}{2}$

Ans.: (b)

Solution.:



It is anti-symmetrical about y-axis so it's a odd function so all a_n are zero.

Q25. Using Taylor series, expand $f(x) = x^3 - \frac{1}{8}$ around $x_0 = 1$ up to second order in x . The coefficient of x is:

- (a) -2 (b) 3
(c) 2 (d) -3

Ans.: (d)

Solution.: $f(x) = f(1) + f'(1)(x-1) + \frac{f''(1)}{2}(x-1)^2$

$$\because f(x) = x^3 - \frac{1}{8} \Rightarrow f'(x) = 3x^2, f''(x) = 6x$$

$$\therefore f(1) = 1 - \frac{1}{8} = \frac{7}{8}, f'(1) = 3, f''(1) = 6$$

$$\Rightarrow f(x) = \frac{7}{8} + 3(x-1) + 3(x-1)^2 = \frac{7}{8} + 3x - 3 + 3(x^2 - 2x + 1) = 3x^2 - 3x + \frac{7}{8}$$

The coefficient of x is: -3

Q26. Consider a 2×2 matrix A . The determinant of A is -1 and the trace(A) = 1 . Which of the following options gives the eigenvalues of A ?

- (a) 1, 0 (b) $\frac{1+\sqrt{5}}{2}, \frac{1-\sqrt{5}}{2}$
 (c) $\frac{1+\sqrt{5}}{4}, \frac{1-\sqrt{5}}{4}$ (d) $\frac{\sqrt{5}}{2}, 1 - \frac{\sqrt{5}}{2}$

Ans.: (b)

Solution.: $\det(A) = -1 = \lambda_1 \lambda_2$, $\text{trace}(A) = 1 = \lambda_1 + \lambda_2$

$$\lambda_1 \lambda_2 = \left(\frac{1+\sqrt{5}}{2} \right) \left(\frac{1-\sqrt{5}}{2} \right) = \frac{1}{4} - \frac{5}{4} = -1, \lambda_1 + \lambda_2 = \left(\frac{1+\sqrt{5}}{2} \right) + \left(\frac{1-\sqrt{5}}{2} \right) = \frac{1}{2} + \frac{1}{2} = 1$$

Q27. Consider the following vector $\vec{V} = xyz\hat{k}$. Which of the following statements is correct for the resultant vector $\vec{\nabla} \times \vec{\nabla} \times \vec{V}$?

- (a) It lies in xy -plane (b) It lies in yz -plane
 (c) It lies in xz -plane (d) It is along the x direction

Ans.: (a)

$$\text{Solution.} \because \vec{V} = xyz\hat{k} \Rightarrow \vec{\nabla} \times \vec{V} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & 0 & xyz \end{vmatrix} = xz\hat{i} - yz\hat{j}$$

$$\Rightarrow \vec{\nabla} \times \vec{\nabla} \times \vec{V} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ xz & -yz & 0 \end{vmatrix} = y\hat{i} + x\hat{j}$$

Section B: Q.31 - Q.40 Carry TWO marks each.

Section C: Q.41 - Q.50 Carry ONE mark each.

Q46. The value of $(1-i\sqrt{3})^3$ is _____. (Answer in integer)

Ans.: -8

Solution.: $1-i\sqrt{3} = 2e^{-i\pi/3} \Rightarrow (1-i\sqrt{3})^3 = (2e^{-i\pi/3})^3 = 8e^{-i\pi} = -8$

Section C: Q.51-Q60 Carry TWO marks each.

Q59. Consider a simple pendulum of length l and time period T . In a laboratory experiment, the time for 100 oscillations is measured to be $80s$ using a stop-watch with least count $1s$. The gravitational constant is known with a percentage error of 2.5% .

The percentage error in the measured length of the pendulum, in %, is _____.

(Answer in integer)

Ans.: 5

Solution.: $\because T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T^2 = 4\pi^2 \frac{l}{g} \Rightarrow l = \frac{gT^2}{4\pi^2} \Rightarrow \frac{\Delta l}{l} = \frac{\Delta g}{g} + 2\left(\frac{\Delta T}{T}\right)$

$$\Rightarrow \frac{\Delta l}{l} \times 100\% = \frac{\Delta g}{g} \times 100\% + 2\left(\frac{\Delta T}{T}\right) \times 100\%$$

The time for $n = 100$ oscillations is measured to be $t = 80s$. The least count of the stop-watch represents the absolute error in the total time measurement, so $\Delta t = 1s$.

Since $T = \frac{t}{n}$ and $\Delta T = \frac{\Delta t}{n}$, the relative error in a single period T is identical to the relative error

in the total measured time t :

$$\frac{\Delta T}{T} = \frac{\Delta t}{t} = \frac{1s}{80s} = \frac{1}{80} \Rightarrow \frac{\Delta T}{T} \times 100\% = \frac{1}{80} \times 100\% = 1.25\% \quad \text{and} \quad \frac{\Delta g}{g} \times 100\% = 2.5\%$$

$$\Rightarrow \frac{\Delta l}{l} \times 100\% = 2.5\% + 2(1.25\%) = 5\%$$



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Solution- Mechanics and General Properties of Matter

Solution-Mechanics and General Properties of Matter
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Section A: Q.1-Q.10 Carry ONE mark each.

Section A: Q.11-Q.30 Carry TWO marks each.

Q12. A particle of mass m moves in a potential given by

$$V(x, y, z) = -k \frac{y}{(x^2 + y^2 + z^2)},$$

where k is a constant.

Which of the following statements is correct?

- (a) The force corresponding to the potential is central
- (b) Angular momentum of the system is not conserved
- (c) Linear momentum along the y -direction is conserved
- (d) Energy of the system is not conserved

Ans.: (b)

Solution.: A central force must have the form $\vec{F} = f(r)\hat{r}$ where the potential depends only on

$$r = \sqrt{x^2 + y^2 + z^2}.$$

(a) Here, $V = -k \frac{y}{r^2}$. It explicitly depends on the direction through y , not just on r . Therefore, the force is not central.

So, (a) is false.

(b) Angular momentum is conserved if torque is zero: $\vec{\tau} = \vec{r} \times \vec{F} = 0$

Since the force is not central, in general $\vec{r} \times \vec{F} \neq 0$.

Hence angular momentum is not conserved. Therefore, **(b) is true.**

(c) For p_y to be conserved, $\frac{dp_y}{dt} = F_y = 0$.

But the potential depends explicitly on y : $V(x, y, z)$. Thus $F_y = -\frac{\partial V}{\partial y} \neq 0$ in general.

Hence p_y is not conserved. So (c) is false.

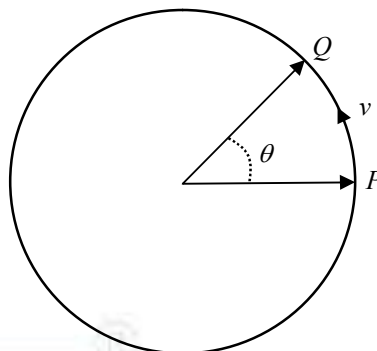
(d) The potential has no explicit time dependence: $V(x, y, z)$

Therefore, the total mechanical energy $E = \frac{p^2}{2m} + V$ is conserved.

So (d) is false

Q22. A particle is rotating along a circular path with uniform speed v , as shown in the figure. While moving from the point P to Q subtending an angle θ , the magnitude of the change in its velocity is:

- (a) zero
- (b) $v \cos \theta$
- (c) $2v \sin \frac{\theta}{2}$
- (d) $v \cos \frac{\theta}{2}$



Ans.: (c)

Solution.:

The initial and final velocity vectors have the same magnitude: $|\vec{v}_f| = |\vec{v}_i| = v$ but their directions differ by θ .

We need, $|\Delta \vec{v}| = |\vec{v}_f - \vec{v}_i|$.

From the triangle formed by $\vec{v}_f$, $\vec{v}_i$, and $\Delta \vec{v}$:

$$|\Delta \vec{v}|^2 = v^2 + v^2 - 2v^2 \cos \theta = 2v^2 (1 - \cos \theta) = 2v^2 \left(2 \sin^2 \frac{\theta}{2} \right)$$

$$\Rightarrow |\Delta \vec{v}| = 2v \sin \frac{\theta}{2}$$

Q30. The speed of an object of mass 20 kg increases from 2 m/s to 6 m/s in 10 s . The power required, in Watts, is:

- (a) 64
- (b) 54
- (c) 32
- (d) 72

Ans.: (c)

Solution.: Change in kinetic energy

$$\Delta K = \frac{1}{2} m (v^2 - u^2) = \frac{1}{2} (20) (6^2 - 2^2) = 320 \text{ J}$$

The average power required is

$$P_{av} = \frac{\Delta K}{t} = \frac{320}{10} \text{ W} = 32 \text{ W}$$

Section B: Q.31 - Q.40 Carry TWO marks each.

Q33. Consider a particle of mass m in a rotating frame. The force acting on the particle is expressed as $\vec{F} = (F_1 + F_2)\hat{e}_r + (F_3 + F_4)\hat{e}_\theta$, where $\hat{e}_r$ and $\hat{e}_\theta$ are the radial and angular unit vectors, respectively, and $F_1 = m\ddot{r}$, $F_2 = -mr\dot{\theta}^2$, $F_3 = mr\ddot{\theta}$, $F_4 = 2m\dot{r}\dot{\theta}$.

Which of the following statements is/are correct?

- (a) $\hat{e}_r$ and $\hat{e}_\theta$ are not constant unit vectors
- (b) F_1 and F_3 are fictitious forces
- (c) F_2 and F_4 are fictitious forces
- (d) F_1 and F_2 are zero in uniform circular motion

Ans.: (a), (c)

Solution.:

(a) In polar coordinates, the unit vectors depend on the angular position θ i.e.

$$\hat{e}_r = \cos \theta \hat{i} + \sin \theta \hat{j}, \quad \hat{e}_\theta = -\sin \theta \hat{i} + \cos \theta \hat{j}$$

Therefore, as the particle moves and θ changes, these unit vectors change direction.

Hence, $\hat{e}_r$ and $\hat{e}_\theta$ are not constant unit vectors. So **(a) is correct**.

(b) The acceleration in polar coordinates is $\vec{a} = (\ddot{r} - r\dot{\theta}^2)\hat{e}_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})\hat{e}_\theta$

Multiplying by m , $\vec{F} = (m\ddot{r} - mr\dot{\theta}^2)\hat{e}_r + (mr\ddot{\theta} + 2m\dot{r}\dot{\theta})\hat{e}_\theta$

Thus, the terms $F_1 = m\ddot{r}$, $F_3 = mr\ddot{\theta}$ are not fictitious forces. Therefore, (b) is false.

(c) In polar coordinates, $F_2 = -mr\dot{\theta}^2$ represents the centrifugal force (a fictitious force) and $F_4 = 2m\dot{r}\dot{\theta}$ represents the Coriolis force component (a fictitious force) arising due to the rotating frame.

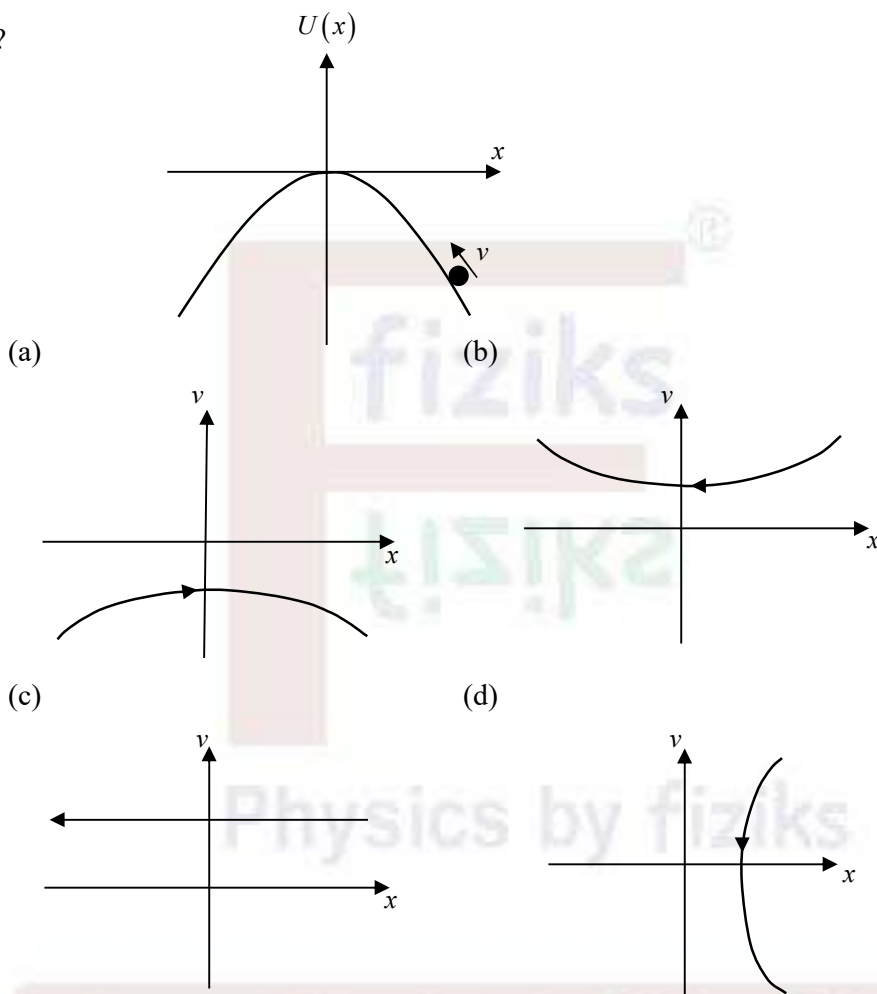
So, **(c) is correct**.

(d) For uniform circular motion: $r = \text{constant}$, $\dot{\theta} = \text{constant} \Rightarrow \dot{r} = 0$, $\ddot{r} = 0$ and $\ddot{\theta} = 0$.

$$F_1 = m\ddot{r} = 0, \quad F_2 = -mr\dot{\theta}^2 \neq 0.$$

So (d) is false.

Q35. A ball of mass m climbs the potential $U(x) = -\frac{1}{2}kx^2$, as shown in the figure. Assuming that the total energy of the system $E = \frac{1}{2}mv^2 + U(x)$ is conserved, which of the following correctly describe(s) the plot of velocity (v) as a function of position (x) of the system for $E < 0$?



Ans.: (d)

Solution.: $E = \frac{1}{2}mv^2 + U(x) = \frac{1}{2}mv^2 - \frac{1}{2}kx^2 \Rightarrow \frac{1}{2}mv^2 = E + \frac{1}{2}kx^2 \Rightarrow v^2 = \frac{k}{m}x^2 + \frac{2E}{m}$

$\therefore E < 0 \Rightarrow v^2 = \frac{k}{m}x^2 - \frac{2|E|}{m}$. Hence real velocity requires $\Rightarrow \frac{k}{m}x^2 \geq \frac{2|E|}{m}$

$\Rightarrow x^2 \geq \frac{2|E|}{k}$ or $\Rightarrow |x| \geq x_0$ where $x_0 = \frac{2|E|}{k}$

This means the particle cannot exist in the central region around the origin. The potential barrier has turning points at $x = \pm x_0$ where $v = 0$.

Section C: Q.41 - Q.50 Carry ONE mark each.

Section C: Q.51-Q60 Carry TWO marks each.

Q52. A spacecraft is placed 200 km above Earth in a circular orbit. The minimum change in the speed required to place the spacecraft in a parabolic orbit, in km/s , is _____.

(Rounded off to one decimal place)

[Use $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$, mass of Earth = $6 \times 10^{24} \text{ kg}$, radius of Earth = 6400 km]

Ans.: 3.0 to 3.5

Solution.: The spacecraft is at an altitude of $h = 200 \text{ km}$. Earth's radius is $R = 6400 \text{ km}$.

Therefore, orbital radius is $r = R + h = (6400 + 200) \text{ km} = 6600 \text{ km}$.

For a circular orbit, $v_c = \sqrt{\frac{GM}{r}} = \sqrt{\frac{(6.67 \times 10^{-11})(6 \times 10^{24})}{6600 \times 10^3}} = 7786.9 \text{ m/sec} \Rightarrow v_c = 7.787 \text{ km/sec}$

For a parabolic orbit, total mechanical energy is zero: $\frac{1}{2}mv_p^2 - \frac{GMm}{r} = 0 \Rightarrow v_p = \sqrt{\frac{2GM}{r}}$

$\Rightarrow v_p = \sqrt{2}v_c = (1.414)(7.787) = 11.012 \text{ km/sec}$

Required change in speed $\Delta v = v_p - v_c = 11.012 - 7.787 = 3.225 \text{ km/sec} \Rightarrow \Delta v \approx 3.2 \text{ km/sec}$



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Solution- Oscillations, Waves and Optics

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Section A: Q.1-Q.10 Carry ONE mark each.

Q1. Light of wavelength 632 nm is passing through an optically active medium of thickness 20 cm . The optical rotation exhibited by the medium is 18° . Which of the following options correctly states the magnitude of the difference in refractive indices corresponding to the left and the right circularly polarized light?

- (a) 1.81×10^{-5} (b) 3.16×10^{-7}
(c) 3.62×10^{-5} (d) 6.32×10^{-7}

Ans.: (b)

Solution.: Wavelength, $\lambda = 632\text{ nm} = 632 \times 10^{-9}\text{ m}$; Thickness, $l = 20\text{ cm} = 20 \times 10^{-2}\text{ m}$

Optical rotation, $\theta = 18^\circ = 18 \frac{\pi}{180} = \frac{\pi}{10}\text{ rad}$.

For an optically active medium, the phase difference between the two circular components is

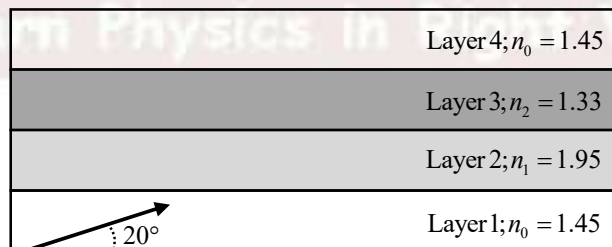
$$\Delta\phi = \frac{2\pi l}{\lambda}(n_L - n_R).$$

The optical rotation is half the phase difference: $\theta = \frac{\Delta\phi}{2} = \frac{\pi l}{\lambda}(n_L - n_R) \Rightarrow \Delta n = n_L - n_R = \frac{\lambda\theta}{\pi l}$

$$\Rightarrow \Delta n = n_L - n_R = \frac{(632 \times 10^{-9})(\pi/10)}{\pi(20 \times 10^{-2})} = 3.16 \times 10^{-7}$$

Section A: Q.11-Q.30 Carry TWO marks each.

Q16. Consider a multilayered structure composed of thin films of refractive indices n_0, n_1 , and n_2 as shown in the figure. A ray traveling in the first layer hits the interface at an angle of 20° with the horizontal. Which of the following options is correct?



- (a) The ray emerges at an angle of 20° with the horizontal in the 4th layer
(b) The ray emerges at an angle of 56° with the horizontal in the 4th layer
(c) The ray would not enter the 3rd layer
(d) The ray emerges at an angle of 44° with the horizontal in the 4th layer

Ans.: (c)

Solution.: First interface: $n_0 \rightarrow n_1$: By Snell's law, $n_0 \sin 70^\circ = n_1 \sin r_1$

$$\Rightarrow \sin r_1 = \frac{n_0}{n_1} \sin 70^\circ = \frac{1.45}{1.95} \sin 70^\circ = 0.698 \Rightarrow \sin r_1 \approx 0.698 \Rightarrow r_1 \approx 44.3^\circ$$

Second interface: $n_1 \rightarrow n_2$: By Snell's law, $n_1 \sin r_1 = n_2 \sin r_2 \Rightarrow n_0 \sin 70^\circ = n_2 \sin r_2$

$$\Rightarrow \sin r_2 = \frac{n_0}{n_2} \sin 70^\circ = \frac{1.45}{1.33} \sin 70^\circ \approx 1.027 \Rightarrow \sin r_2 > 1 \quad \text{which is impossible.}$$

Therefore, total internal reflection occurs at the interface between layers 2 and 3.

So, the ray does not enter the third layer.

Q21. A mass attached to the bottom end of a vertical massless spring stretches the spring by Δx . The system executes oscillation with a time period $T = 0.2\text{ s}$. The value of Δx , in cm , rounded off to the nearest integer is: [Assume the acceleration due to gravity $g = 9.8\text{ m/s}^2$]

- (a) 2 (b) 3
(c) 4 (d) 1

Ans.: (d)

Solution.: For a vertical spring, $T = 2\pi\sqrt{\frac{m}{k}}$

The equilibrium extension is $\Delta x = \frac{mg}{k}$, hence $\frac{m}{k} = \frac{\Delta x}{g} \Rightarrow T = 2\pi\sqrt{\frac{\Delta x}{g}}$

$$\Rightarrow \Delta x = \frac{gT^2}{4\pi^2} = \frac{(9.8)(0.2)^2}{4 \times 10} = \frac{(9.8)(0.04)}{40} = 0.0098\text{ m} \approx 1\text{ cm}$$

Q28. Two coherent plane waves having wavelength λ and wavevectors

$$\vec{k}_1 = \frac{2\pi}{\lambda} \left(\frac{1}{2} \hat{i} - \frac{\sqrt{3}}{2} \hat{j} \right) \text{ and } \vec{k}_2 = \frac{2\pi}{\lambda} \left(-\frac{1}{2} \hat{i} - \frac{\sqrt{3}}{2} \hat{j} \right),$$

are incident on a screen placed on the xz -plane. The overlap of the waves on the plane of the screen produces interference fringes.

The fringe width (center-to-center spacing of bright fringes) will be:

- (a) $\frac{\lambda}{2}$ (b) 2λ
(c) $\frac{\sqrt{3}\lambda}{2}$ (d) λ

Ans.: (d)

Solution.: The wave vectors are $\vec{k}_1 = \frac{2\pi}{\lambda} \left(\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j} \right)$ and $\vec{k}_2 = \frac{2\pi}{\lambda} \left(-\frac{1}{2}\hat{i} - \frac{\sqrt{3}}{2}\hat{j} \right)$

The screen is placed in the **xz -plane**, so points on the screen have $\vec{r} = x\hat{i} + y\hat{j}$.

The phase difference is $\Delta\phi = (\vec{k}_1 - \vec{k}_2) \cdot \vec{r} = \left(\frac{2\pi}{\lambda} \hat{i} \right) \cdot (x\hat{i} + y\hat{j}) = \frac{2\pi}{\lambda} x$

For successive bright fringes, $\Delta\phi = 2\pi m = \frac{2\pi}{\lambda} x \Rightarrow x = m\lambda$

Therefore, the separation between successive bright fringes is $\beta = \lambda$.

Section B: Q.31 - Q.40 Carry TWO marks each.

Q31. The displacement of a vibrating string of finite length stretched along the x -axis is given by $y(x, t) = 2A \cos(kx) \sin(\omega t)$ where, A is the amplitude, $k = 2\pi/\lambda$ is the wavenumber and ω is the angular frequency. Which of the following statements is/are correct for the standing wave?

- (a) The nodes are at $x = n \frac{\lambda}{2}$, where n is an integer
- (b) The antinodes are at $x = \left(n + \frac{1}{2} \right) \frac{\lambda}{2}$, where n is an integer
- (c) The nodes are at $x = \left(n + \frac{1}{2} \right) \frac{\lambda}{2}$, where n is an integer
- (d) The antinodes are at $x = n \frac{\lambda}{2}$, where n is an integer

Ans.: (c), (d)

Solution.: Given $y(x, t) = 2A \cos(kx) \sin(\omega t)$ where $k = 2\pi/\lambda$.

The amplitude at position x is $A_x = 2A |\cos(kx)|$

At a node, amplitude is zero: $\cos(kx) = 0$

$$\Rightarrow kx = \left(n + \frac{1}{2} \right) \pi \Rightarrow \frac{2\pi}{\lambda} x = \left(n + \frac{1}{2} \right) \pi \Rightarrow x = \left(n + \frac{1}{2} \right) \frac{\lambda}{2} \text{ where } n \text{ is an integer.}$$

So, statement (c) is correct.

At a anti-node: $|\cos(kx)| = 1$

$$\Rightarrow kx = n\pi \Rightarrow \frac{2\pi}{\lambda} x = n\pi \Rightarrow x = n \frac{\lambda}{2} \text{ where } n \text{ is an integer.}$$

So, statement (d) is correct.

Section C: Q.41 - Q.50 Carry ONE mark each.

Q41. Considering the diameter of the pupil of a human eye to be 2 mm , the angular resolution of the eye at a wavelength of 500 nm , in minute of arc, is _____.

(Rounded off to two decimal places)

Ans.: 1.01 to 1.11

Solution.: $D = 2\text{ mm} = 2 \times 10^{-3}\text{ m}$, $\lambda = 500\text{ nm} = 500 \times 10^{-9}\text{ m}$

For a circular aperture, Rayleigh's criterion gives

$$\theta_{\min} = 1.22 \frac{\lambda}{D} = 1.22 \times \frac{500 \times 10^{-9}}{2 \times 10^{-3}} = 3.05 \times 10^{-4}\text{ rad}$$

$$\therefore 1\text{ rad} = \frac{180}{\pi} \times 60 \text{ arc min so } \theta_{\min} = (3.05 \times 10^{-4}) \frac{180}{\pi} \times 60 \text{ arc min} \approx 1.0485 \text{ arc min}$$

$$\Rightarrow \theta_{\min} \approx 1.05 \text{ arc min}$$

Q42. Consider a 10 mW laser beam focused using a biconvex lens to a circular spot of area 10^{-10} m^2 . The magnitude of the electric field in the focal plane of the lens, in kV/m , is _____. (Rounded off to one decimal place)

[Use permittivity of free space $\epsilon_0 = 8.854 \times 10^{-12}\text{ C}^2/(\text{Nm}^2)$, and speed of light $c = 3 \times 10^8\text{ m/s}$]

Ans.: 273.0 to 276.0

Solution.: For an electromagnetic wave, the average intensity is $I = \frac{P}{A} = \frac{1}{2} c \epsilon_0 E_0^2$

$$\Rightarrow E_0 = \sqrt{\frac{2P}{Ac \epsilon_0}} = \sqrt{\frac{2(10^{-2})}{(10^{-10})(3 \times 10^8)(8.854 \times 10^{-12})}} \approx 2.744 \times 10^5\text{ V/m}$$

$$\Rightarrow E_0 \approx 274.4\text{ kV/m}$$

Section C: Q.51-Q60 Carry TWO marks each.

Q51. A particle of mass m undergoes periodic motion in one-dimension with its total energy given as $E = \frac{1}{2}m\dot{x}^2 + \frac{1}{4}kx^4$, where k is a positive constant and $\dot{x} = \frac{dx}{dt}$. Assuming that E is conserved, the time period T has the relation $T \propto E^{-1/n}$. The value of n is _____.

(Answer in integer)

Ans.: 4

Solution.: For a potential $V(x) = \alpha x^\beta$ the time period depends on total energy E via dimensional

scaling: $T \propto E^{\frac{1}{\beta} - \frac{1}{2}}$

$$\therefore V(x) = \frac{1}{4} kx^4 \Rightarrow \beta = 4. \text{ Thus } T \propto E^{\frac{1}{4} - \frac{1}{2}} \propto E^{-\frac{1}{4}} \propto E^{-1/n} \Rightarrow n = 4$$

Q55. On the surface of a thin water film of refractive index 1.33, two light beams of wavelength $\lambda_1 = 0.64 \mu\text{m}$ and $\lambda_2 = 0.40 \mu\text{m}$ are incident at an angle of 30° . The light of wavelength λ_1 exhibits maximum reflection, but that of wavelength λ_2 is not reflected at all. The minimum thickness of the water film, in μm , is _____. (Rounded off to two decimal places)

[Assume refractive index is independent of wavelength]

Ans.: 0.61 to 0.71

Solution.: For thin film interference at angle of refraction r and angle of incidence i :

$$\frac{\sin i}{\sin r} = \mu \Rightarrow \sin r = \frac{\sin i}{\mu} = \frac{\sin 30^\circ}{1.33} = \frac{0.5}{1.33} \approx 0.3759 \Rightarrow \sin r \approx 0.3759$$

$$\Rightarrow \cos r = \sqrt{1 - \sin^2 r} = \sqrt{1 - (0.3759)^2} \approx 0.9266$$

For $\lambda_1 = 0.64 \mu\text{m}$ (Maximum reflection - Constructive Interference):

$$2\mu t \cos r = \left(m_1 + \frac{1}{2}\right)\lambda_1, \quad m_1 = 0, 1, 2, \dots$$

For $\lambda_2 = 0.40 \mu\text{m}$ (No reflection - Destructive Interference):

$$2\mu t \cos r = m_2 \lambda_2, \quad m_2 = 0, 1, 2, \dots$$

$$\text{Equating the optical path differences: } \left(m_1 + \frac{1}{2}\right)\lambda_1 = m_2 \lambda_2 \Rightarrow \left(m_1 + \frac{1}{2}\right)(0.64) = m_2 (0.40)$$

$$\Rightarrow \left(\frac{2m_1 + 1}{2}\right)(0.64) = m_2 (0.40) \Rightarrow (2m_1 + 1)(0.8) = m_2$$

For minimum thickness t , take the smallest integers:

For $m_1 = 0$, $m_2 = 0.8$ (not an integer); For $m_1 = 1$, $m_2 = 2.4$ (not an integer);

For $m_1 = 2$, $m_2 = 4$ (an integer);

$$\text{So, } 2\mu t_{\min} \cos r = 4\lambda_2 \Rightarrow t_{\min} = \frac{2\lambda_2}{\mu \cos r} = \frac{2(0.40 \mu\text{m})}{1.33 \times (0.9266)} \approx 0.65 \mu\text{m}$$



Learn Physics in Right Way

IIT-JAM Physics-2026
Solution- Electricity and Magnetism

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Section A: Q.1-Q.10 Carry ONE mark each.

Q3. Consider the superposition of two electromagnetic waves with their electric field vectors given by $\vec{E}_1(z, t) = \hat{i}A_1 \cos(kz - \omega t)$ and $\vec{E}_2(z, t) = \hat{j}A_2 \sin(kz - \omega t + \phi)$, where A_1 and A_2 are the amplitudes, k is the wavenumber, ω is the angular frequency, and ϕ is the relative phase. Which of the following options represents a resultant elliptically polarized wave with its semi-major axis either along $\hat{i}$ or $\hat{j}$?

- (a) $\phi = 0$ and $A_1 \neq A_2$ (b) $\phi = \frac{\pi}{2}$ and $A_1 = A_2$
 (c) $\phi = \frac{\pi}{2}$ and $A_1 \neq A_2$ (d) $\phi = 0$ and $A_1 = A_2$

Ans.: (a)**Solution.:**(a) $\phi = 0$ and $A_1 \neq A_2$:

$$\vec{E}_1(z, t) = \hat{i}A_1 \cos(kz - \omega t) \text{ and } \vec{E}_2(z, t) = \hat{j}A_2 \sin(kz - \omega t + 0) \Rightarrow \frac{E_1^2}{A_1^2} + \frac{E_2^2}{A_2^2} = 1$$

(b) $\phi = \frac{\pi}{2}$ and $A_1 = A_2$

$$\vec{E}_1(z, t) = \hat{i}A_1 \cos(kz - \omega t) \text{ and } \vec{E}_2(z, t) = \hat{j}A_2 \sin\left(kz - \omega t + \frac{\pi}{2}\right) = \hat{j}A_2 \cos(kz - \omega t) \Rightarrow E_1 = E_2$$

(c) $\phi = \frac{\pi}{2}$ and $A_1 \neq A_2$

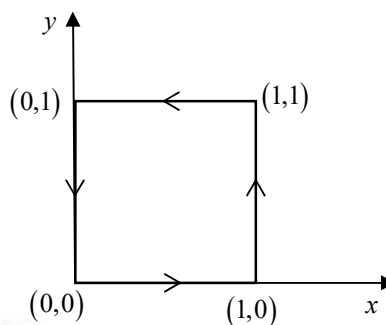
$$\vec{E}_1(z, t) = \hat{i}A_1 \cos(kz - \omega t) \text{ and } \vec{E}_2(z, t) = \hat{j}A_2 \sin\left(kz - \omega t + \frac{\pi}{2}\right) = \hat{j}A_2 \cos(kz - \omega t) \Rightarrow E_1 = \frac{A_1}{A_2} E_2$$

(d) $\phi = 0$ and $A_1 = A_2$

$$\vec{E}_1(z, t) = \hat{i}A_1 \cos(kz - \omega t) \text{ and } \vec{E}_2(z, t) = \hat{j}A_2 \sin(kz - \omega t + 0) \Rightarrow E_1^2 + E_2^2 = A_1^2$$

Q9. Consider the electrostatic potential in two dimensions $V(x, y) = x^8 y^9$. What is the line integral of the corresponding electric field along the path shown in the figure?

- (a) 0
(b) 1
(c) 2
(d) $\frac{1}{2}$



Ans.: (a)

Solution.: For electrostatic field line integral of the electric field along the closed path is zero.

Section A: Q.11-Q.30 Carry TWO marks each.

Q13. $(\vec{E}, \vec{B})$ are the electric and magnetic fields in a rest frame. $(\vec{E}', \vec{B}')$ represent the corresponding quantities in a reference frame moving with a constant velocity $\vec{v}_0$. Using the invariance of Lorentz force $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$ under Galilean transformations, identify the correct relation.

- (a) $\vec{E}' = \vec{E}$ and $\vec{B}' = \vec{B}$ (b) $\vec{E}' = \vec{E} + \vec{v}_0 \times \vec{B}$ and $\vec{B}' = \vec{B}$
(c) $\vec{E}' = \vec{E}$ and $\vec{v} \times \vec{B}' = (\vec{v} + \vec{v}_0) \times \vec{B}$ (d) $\vec{E}' = \vec{v}_0 \times \vec{B}$ and $\vec{v} \times \vec{B}' = \vec{E} + \vec{v} \times \vec{B}$

Ans.: (b)

Solution.:

Let S be the rest frame and S' be the reference frame moving with a constant velocity v_0 relative S . If a charge q moves with a velocity v in the rest frame S , its velocity v' in the moving frame S' is given by standard Galilean velocity transformation:

$$v' = v - v_0 \Rightarrow v = v' + v_0$$

Lorentz force $\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$ must remain invariant under Galilean transformations.

$$q\vec{E} + q\vec{v} \times \vec{B} = q\vec{E}' + q\vec{v}' \times \vec{B}' \Rightarrow \vec{E} + (\vec{v}' + \vec{v}_0) \times \vec{B} = \vec{E}' + \vec{v}' \times \vec{B}'$$

$$\Rightarrow \vec{E}' + \vec{v}' \times \vec{B}' = \vec{E} + \vec{v}' \times \vec{B} + \vec{v}_0 \times \vec{B} \Rightarrow \vec{E}' + \vec{v}' \times \vec{B}' = (\vec{E} + \vec{v}_0 \times \vec{B}) + (\vec{v}' \times \vec{B})$$

For this equality to hold true for any arbitrary velocity $\vec{v}'$ of the test charge, the velocity independent vectors must equal each other, and the coefficients of the velocity $\vec{v}'$ must match:

$$\Rightarrow \vec{E}' = \vec{E} + \vec{v}_0 \times \vec{B}, \quad \vec{B}' = \vec{B}$$

Q20. A thin ring of mass m and radius R has a total charge Q distributed uniformly. The ring is rotating with a constant angular velocity ω about an axis passing through its center and perpendicular to its plane. Which of the following options is correct?

- (a) The magnetic moment of the ring is $\frac{Q\omega R^2}{4}$
- (b) The ratio of the magnetic moment to angular momentum is $\frac{Q}{2m}$
- (c) The magnetic moment of the ring is $\frac{Q\omega R^2}{6}$
- (d) The ratio of the magnetic moment to angular momentum is $\frac{Q}{m}$

Ans.: (b)

Solution.: Magnetic moment of the ring $\mu = I' \times \pi R^2 = \lambda v \times \pi R^2 = \frac{Q}{2\pi R} R\omega \times \pi R^2 = \frac{Q\omega R^2}{2}$

Angular momentum of the ring which rotating with a constant angular velocity ω about an axis passing through its center and perpendicular to its plane is $L = I\omega = mR^2\omega$.

Thus $\frac{\mu}{L} = \frac{Q\omega R^2 / 2}{mR^2\omega} = \frac{Q}{2m}$.

Q23. A series LCR circuit contains $L = 175\text{ mH}$, $C = 62.5\mu\text{F}$, and $R = 40\Omega$ and is connected to a source of voltage amplitude $E_0 = 50\text{ V}$ and angular frequency $\omega = 400\text{ rad/s}$.

Which of the following statements is correct?

- (a) The magnitude of the maximum voltage across the inductor is less than 50 V
- (b) The magnitude of the maximum voltage across the capacitor is more than 60 V
- (c) The magnitude of the maximum voltage across the resistor is 50 V
- (d) The magnitude of the maximum voltage across the capacitor equals the maximum voltage across the resistor

Ans.: (d)

Solution.: Inductive reactance $X_L = \omega L = 400 \times 0.175 = 70\Omega$

Capacitive reactance $X_C = \frac{1}{\omega C} = \frac{1}{400(62.5 \times 10^{-6})} = 40\Omega$

Impedance $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{40^2 + 30^2} = 50\Omega$, Current amplitude $I_0 = \frac{E_0}{Z} = \frac{50}{50} = 1\text{ A}$

$V_R = I_0 R = 1 \times 40 = 40\text{ V}$, $V_L = I_0 X_L = 1 \times 70 = 70\text{ V}$, $V_C = I_0 X_C = 1 \times 40 = 40\text{ V}$

Section B: Q.31 - Q.40 Carry TWO marks each.

Q36. An LC oscillator circuit contains a capacitor of $4.0 \mu F$. The maximum potential difference across the capacitor is $2V$ and the maximum current through the inductor is $80 mA$.

Which of the following statements is/are correct?

- (a) The value of inductance is $2.5 mH$
- (b) The frequency of oscillator is $3.2 kHz$
- (c) The time for the charge in the capacitor to rise from zero to the maximum is nearly $0.157 ms$
- (d) The maximum potential difference across the inductor is $2.0V$

Ans.: (a), (c), (d)

Solution.:

$$C = 4.0 \mu F = 4 \times 10^{-6} F, V_{C, \max} = 2V, I_{L, \max} = 80 mA = 0.08 A.$$

(a) In an ideal LC oscillator, energy oscillates between the capacitor and inductor.

At maximum capacitor voltage:

$$\frac{1}{2} C V_{C, \max}^2 = \frac{1}{2} L I_{\max}^2 \Rightarrow L = \frac{C V_{C, \max}^2}{I_{\max}^2} = \frac{(4 \times 10^{-6})(2)^2}{(0.08)^2} = 2.5 mH$$

(b) Frequency

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14 \sqrt{(2.5 \times 10^{-3})(4 \times 10^{-6})}} = \frac{1}{2 \times 3.14 \times 10^{-4}} \approx 1.59 kHz$$

(c) For SHM, $q = q_{\max} \sin(\omega t)$,

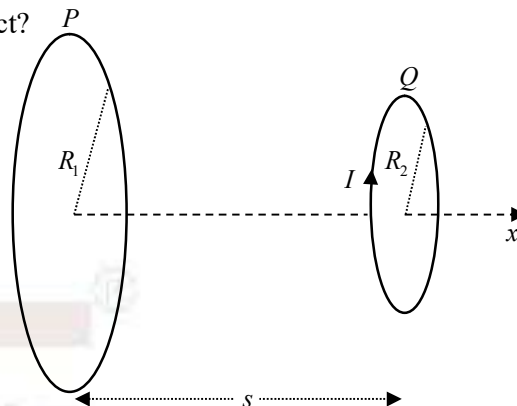
So going from 0 to $q_{\max}$ takes one-quarter period: $t = \frac{T}{4}$.

$$\text{Since } T = \frac{1}{f} = \frac{1}{1591.5} = 0.628 ms \Rightarrow t = \frac{0.628}{4} = 0.157 ms$$

$$(d) V_{L, \max} = X_L I_{L, \max} = \omega L I_{L, \max} = \frac{1}{\sqrt{LC}} L I_{L, \max} = \frac{1}{10^{-4}} (2.5 \times 10^{-3})(0.08) = 2.0V$$

Q38. Two small circular copper loops P and Q of radii R_1 and R_2 , respectively, are coaxially placed along the x -axis as shown in the figure. The loops are at a distance s apart, where $s \gg R_1, R_2$. The loop Q carrying a steady current I is moving away along x -axis with a speed v . Which of the following statements is/are correct?

- (a) The magnetic field at the center of P is $\propto \frac{1}{s^2}$
- (b) The magnetic flux through the loop P is $\propto \frac{1}{s^2}$
- (c) The emf induced in the loop P is $\propto \frac{1}{s^4}$
- (d) The emf induced in the loop P is $\propto v^2$



Ans.: (c)

Solution.: $\because s \gg R_1, R_2$, loop Q behaves like a magnetic dipole with magnetic moment

$$m = I\pi R_2^2.$$

The magnetic field on the axis of a dipole at distance s is $B \approx \frac{\mu_0}{4\pi} \frac{2m}{s^3} \propto \frac{1}{s^3}$

- (a) The magnetic field at the center of P is $\propto \frac{1}{s^3}$
- (b) The magnetic field at the center of P is $\phi = B_p \pi R_1^2 \propto \frac{1}{s^3}$
- (c) The emf induced in the loop P is $\varepsilon = \left| \frac{d\phi}{dt} \right|$.

$$\because \phi \propto \frac{1}{s^3} \Rightarrow \varepsilon = \left| \frac{d\phi}{dt} \right| \propto \frac{1}{s^4} \frac{ds}{dt} \propto \frac{1}{s^4} v \Rightarrow \varepsilon \propto \frac{1}{s^4}$$

- (d) The emf induced in the loop P is $\propto v$

Q39. A charge Q is distributed uniformly on the surface of a sphere of radius R . It is placed inside a concentric conducting hollow sphere of radius $2R$. The outer sphere is earthed.

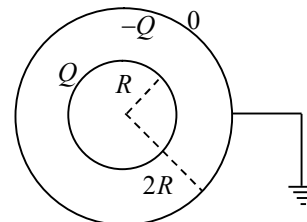
Which of the following statements is/are correct?

- (a) The charge on the inner surface of the outer sphere is $-Q$
- (b) The flux through a closed surface through the material of the outer sphere is $\frac{Q}{\epsilon_0}$
- (c) The charge on the outer surface of the outer sphere is zero
- (d) The potential at a radial distance r between the two spheres, $R < r < 2R$, is $\frac{1}{4\pi\epsilon_0} \frac{Q}{r}$

Ans.: (a), (c)

Solution.:

- (a) The charge on the inner surface of the outer sphere is $-Q$
 (b) The flux through a closed surface through the material of the outer sphere is 0
 (c) The charge on the outer surface of the outer sphere is zero
 (d) The potential at a radial distance r between the two spheres, $R < r < 2R$, is

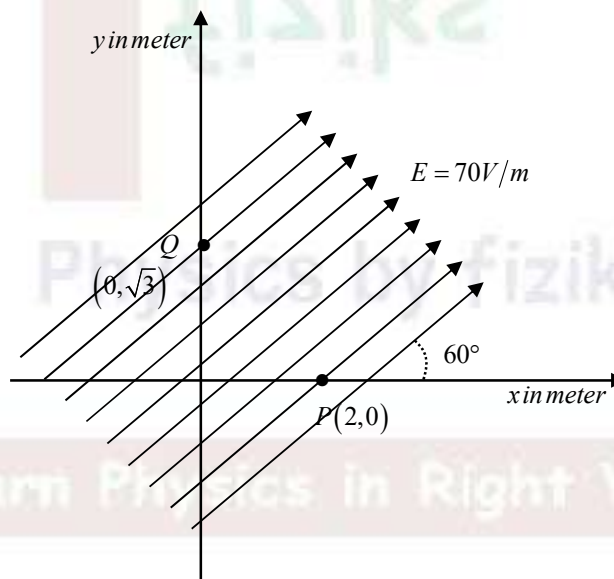


$$\frac{1}{4\pi\epsilon_0} \left(\frac{Q}{r} - \frac{Q}{2R} \right)$$

Section C: Q.41 - Q.50 Carry ONE mark each.

Section C: Q.51-Q60 Carry TWO marks each.

Q58. A uniform electric field of 70 V/m makes an angle of 60° with the positive x -axis, as shown in the figure. The potential difference between the points P and Q which are 2 m and $\sqrt{3} \text{ m}$ away from the origin, in Volts, is _____. (Rounded off to one decimal place)



Ans.: 34.5 to 35.5

Solution.: $E_x = 70 \cos 60^\circ = 35 \text{ V/m}$, $E_y = 70 \sin 60^\circ = 35\sqrt{3} \text{ V/m} \Rightarrow \vec{E} = 35\hat{i} + 35\sqrt{3}\hat{j}$

Position vectors: $\vec{r}_P = 2\hat{i}$, $\vec{r}_Q = \sqrt{3}\hat{j}$

So $V_P - V_Q = -\vec{E} \cdot (\vec{r}_P - \vec{r}_Q) = -(35\hat{i} + 35\sqrt{3}\hat{j}) \cdot (2\hat{i} - \sqrt{3}\hat{j}) = -(70 - 105) = 35.0 \text{ V}$



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IIT-JAM Physics-2026

Solution- Kinetic Theory, Thermodynamics

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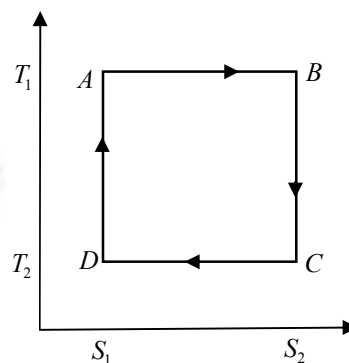
Section A: Q.1-Q.10 Carry ONE mark each.

Section A: Q.11-Q.30 Carry TWO marks each.

Q29. Consider a Carnot cycle as shown in the figure. The ideal gas expanded from volume V_1 to V_2 along the path AB . During this process, the temperature T_1 is constant and the entropy changes from S_1 to S_2 . T_2 is the temperature of the cold bath.

Which of the following statements is correct?

- (a) Work done along the path AB is $W_{AB} = -NRT_1 \ln \frac{V_2}{V_1}$
- (b) Work done along the path BC is $W_{BC} = 0$
- (c) Work done along the path CD is $W_{CD} = -NRT_1 \ln \frac{V_2}{V_1}$
- (d) Work done along the path DA is $W_{DA} = 0$



Ans.: (a)

Solution.:

(a) Work done by the gas in isothermal expansion is $W_{by} = NRT_1 \ln \frac{V_2}{V_1}$

Work done on the gas along the path AB is $W_{AB} = -W_{by} = -NRT_1 \ln \frac{V_2}{V_1}$

Option (a) is correct.

(b) For an adiabatic process (BC), $Q = 0$

$$\Delta U = Q - W_{by} = -W_{by} = nC_V(T_2 - T_1) \Rightarrow W_{BC} \neq 0$$

Option (b) is incorrect.

(c) Work done by the gas in isothermal compression is $W_{by} = NRT_2 \ln \frac{V_1}{V_2}$

Work done on the gas along the path CD is $W_{CD} = -W_{by} = -NRT_2 \ln \frac{V_1}{V_2}$

Option (c) is incorrect.

(d) For an adiabatic process (DA), $Q = 0$

$$\Delta U = Q - W_{by} = -W_{by} = nC_V(T_2 - T_1) \Rightarrow W_{DA} \neq 0$$

Option (b) is incorrect.

Section B: Q.31 - Q.40 Carry TWO marks each.

Q37. Consider an ideal gas of entropy S , molar specific heat C_v , pressure P and volume V .

Which of the following options is/are true?

- (a) Internal energy of the gas depends only on the temperature
- (b) $S \propto \ln V$, assuming C_v is constant
- (c) $S = 0$
- (d) Internal energy of the gas depends both on temperature and pressure

Ans.: (a), (b)

Solution.: The internal energy of an ideal gas is a function of **temperature only**, not independently of p or V .

$$dQ = dU + pdV = nC_v dT + \frac{nRT}{V} dV \quad \text{and} \quad dS = \frac{dQ_{rev}}{T} = nC_v \frac{dT}{T} + \frac{nR}{V} dV$$

$$\Rightarrow S = nC_v \ln T + nR \ln V + \text{constant}$$

There is no general reason for the entropy of an ideal gas to be zero.

Q40. Which of the following statements is/are true for a first order phase transition?

[C_p is the molar heat capacity, T_c is the critical temperature and S is the entropy]

- (a) At the transition point $C_p \rightarrow \infty$
- (b) The derivative of the Gibbs function with respect to pressure changes continuously across the phase transition
- (c) The two thermodynamic states between which the transition takes place are distinct
- (d) Entropy changes discontinuously with temperature at T_c

Ans.: (a), (c), (d)

Solution.:

First-order phase transitions involve a latent heat, meaning the order parameters (first-order derivatives of the Gibbs free energy) change discontinuously, while the specific heat diverges at the transition point.

(a) The molar heat capacity at constant pressure is given by $C_p = T \left(\frac{\partial S}{\partial T} \right)_p$. Because there is a

absorption or release of latent heat L at constant transition temperature T_c , the derivative

$\frac{\partial S}{\partial T}$ diverges to infinity at $T = T_c$. Thus, (a) is true.

(b) The derivative of the Gibbs free energy G with respect to pressure is volume: $\left(\frac{\partial G}{\partial p}\right)_T = V$.

In a first-order phase transition, volume changes abruptly (discontinuously), such as the sudden expansion from liquid to vapor. Thus, this derivative changes **discontinuously**, making (b) **false**.

(c) In a first-order phase transition, the two phases (e.g., solid and liquid, or liquid and vapor) exist with distinct densities, structures, and thermodynamic properties at the transition point. Thus, (c) is **true**.

(d) Entropy is given by $S = -\left(\frac{\partial G}{\partial T}\right)_p$. Due to latent heat $L = T_c \Delta S$, there is a sudden jump/discontinuity in entropy at $T = T_c$. Thus, (d) is **true**.

Statements (a), (c), and (d) are true.

Section C: Q.41 - Q.50 Carry ONE mark each.

Q45. One mole of an ideal gas undergoes a reversible isothermal expansion from $V_i = 1.5 \times 10^{-5} \text{ m}^3$ to $V_f = 1.6 \times 10^{-5} \text{ m}^3$ at a temperature 273 K . The amount of heat transfer during the process is αR , where R is the gas constant. The value of α is _____.

(Rounded off to one decimal place)

Ans.: 16.5 to 18.5

Solution.:

For a reversible isothermal expansion of an ideal gas, the change in internal energy is zero ($\Delta U = 0$). According to the first law of thermodynamics, the heat transferred is equal to the work done by the gas:

$$Q = W = nRT \ln \frac{V_f}{V_i} = 1 \times R \times 273 \ln \frac{1.6 \times 10^{-5}}{1.5 \times 10^{-5}} = 273R \ln \frac{16}{15} = 273R \times 0.0645385$$

$$\Rightarrow Q = 17.62R \Rightarrow \alpha = 17.6$$

Q47. Two thermodynamic systems separated by diathermic wall have the equations of state $U_1 = \frac{3}{2}RN_1T_1$ and $U_2 = \frac{5}{2}RN_2T_2$, where R is the gas constant. N_1, N_2 and T_1, T_2 are the mole numbers and the temperature of the two systems, respectively. The composite system in equilibrium has the total energy $1.5 \times 10^3 \text{ Joule}$. If $N_1 = 3$ and $N_2 = 2$, then the internal energy U_1 of the system one is _____. (Answer in integer)

Ans.: 709 to 712

Solution.: When two systems reach thermodynamic equilibrium across a diathermic wall, their final temperatures become equal ($T_1 = T_2 = T$).

The total energy of the composite system is the sum of their internal energies:

$$U_T = U_1 + U_2 = \frac{3}{2}RN_1T_1 + \frac{5}{2}RN_2T_2 = 1.5 \times 10^3 J$$

$$\Rightarrow \frac{9}{2}RT + \frac{10}{2}RT = 1.5 \times 10^3 J \Rightarrow \frac{19}{2}RT = 1500 J \quad \because N_1 = 3 \text{ and } N_2 = 2,$$

$$\Rightarrow RT = 1500 \times \frac{2}{19} J$$

$$\text{Thus } U_1 = \frac{3}{2}RN_1T_1 = \frac{3}{2}R(3)T = \frac{9}{2}RT = \frac{9}{2} \times 1500 \times \frac{2}{19} J = \frac{13500}{19} J = 710.56 J \approx 711 J$$

Q50. Consider an ensemble of hydrogen gas. The temperature, in K, at which the *rms* speed of the hydrogen molecule is twice the *rms* speed of the molecule at 300 K is _____.

(Answer in integer)

Ans.: 1200

Solution.: The root-mean-square (rms) speed of a gas molecule is given by: $v_{rms} = \sqrt{\frac{3k_B T}{m}}$

$$\Rightarrow \frac{v_{rms}(T_2)}{v_{rms}(T_1)} = \frac{\sqrt{T_2}}{\sqrt{T_1}} = 2 \Rightarrow T_2 = 4T_1 = 4 \times 300 K = 1200 K$$

Section C: Q.51-Q60 Carry TWO marks each.

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IIT-JAM Physics-2026

Solution- Modern Physics

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Section A: Q.1-Q.10 Carry ONE mark each.

Q5. A quantum particle is confined in a one-dimensional space of $0 \leq x \leq 2$. Consider a normalized wavefunction of the particle as

$$\psi(x) = \sqrt{p/5} [1 + \cos(\pi x/2)] \sin(\pi x/2)$$

Which of the following options gives the correct value of p ?

- (a) 2 (b) 3
(c) 4 (d) 1

Ans.: (c)

Solution.:

To find the value of p , we normalize the given wavefunction over the space $0 \leq x \leq 2$

Normalization Condition $\int_0^2 |\psi(x)|^2 dx = 1$

Given: $\psi(x) = \sqrt{p/5} [1 + \cos(\pi x/2)] \sin(\pi x/2)$

then $\int_0^2 \frac{p}{5} [1 + \cos(\pi x/2)]^2 \sin^2(\pi x/2) dx = 1$

$$\Rightarrow \int_0^2 \frac{p}{5} [1 + 2\cos(\pi x/2) + \cos^2(\pi x/2)] \sin^2(\pi x/2) dx = 1$$

Let $u = \frac{\pi x}{2} \Rightarrow dx = \frac{2}{\pi} du \Rightarrow \int_0^\pi \frac{p}{5} [1 + 2\cos(u) + \cos^2 u] \sin^2 u \left(\frac{2}{\pi} du\right) = 1$

$$\Rightarrow \frac{2p}{5\pi} \int_0^\pi [\sin^2 u + 2\cos u \sin^2 u + \cos^2 u \sin^2 u] du = 1$$

$$\Rightarrow \frac{2p}{5\pi} \left[\frac{\pi}{2} + 0 + \frac{\pi}{8} \right] = 1 \Rightarrow \frac{2p}{5\pi} \times \frac{5\pi}{8} = 1 \Rightarrow p = 4$$

Q6. Consider the normalized superposed state $\psi = c_0\phi_0 + c_1\phi_1$, where ϕ_0 and ϕ_1 are the ground and first excited states of a simple harmonic oscillator, respectively. c_0 and c_1 are imaginary superposition coefficients. Which of the following options is correct for the expectation value of $(\langle x \rangle + i\langle p \rangle)$?

- (a) Imaginary (b) Real
(c) Zero (d) Complex with non-zero real and imaginary parts

Ans.: (b)

Solution.: $\psi = c_0\phi_0 + c_1\phi_1$ where ϕ_0 and ϕ_1 are the ground and first excited states of a simple harmonic oscillator, respectively. c_0 and c_1 are imaginary superposition coefficients.

So $c_0 = ia$, $c_1 = ib$ $\psi = i(a\phi_0 + b\phi_1) \Rightarrow$

The i is a **common overall phase**, which has no effect on expectation values.

So the state effectively has **real coefficients**.

For a real harmonic-oscillator superposition, $\langle p \rangle = 0$

while $\langle x \rangle$ can be nonzero and is **real**. So $(\langle x \rangle + i\langle p \rangle) = \text{real}$

Q7. The potential of a quantum harmonic oscillator is modified from $\frac{1}{2}kx^2$ to $\frac{1}{2}kx^2 + 3ax$,

where k and a are constants and x is the position variable. When, the values of $a = 2$ and $k = 1$, which of the following options gives the change in the ground state energy?

(a and k are in appropriate units)

- (a) -3 (b) -6
(c) -12 (d) -18

Ans.: (d)

Solution.: $\frac{1}{2}kx^2 + 3ax = \frac{1}{2}k\left(x + \frac{3a}{k}\right)^2 - \frac{9a^2}{k^2}$

This shifts the harmonic oscillator potential horizontally by $-\frac{3a}{k}$ and lowers the minimum by

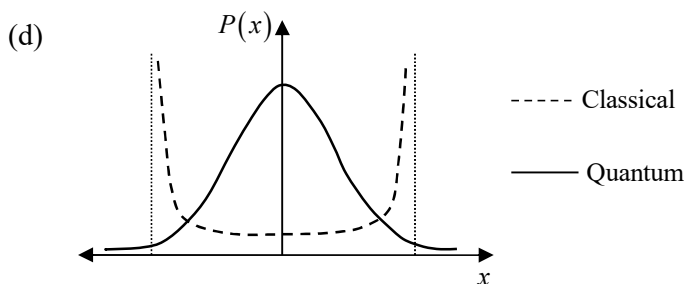
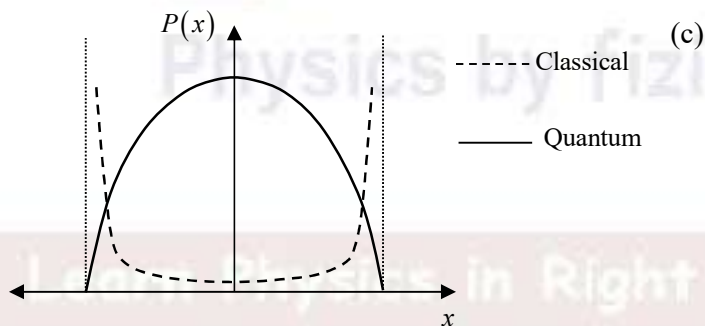
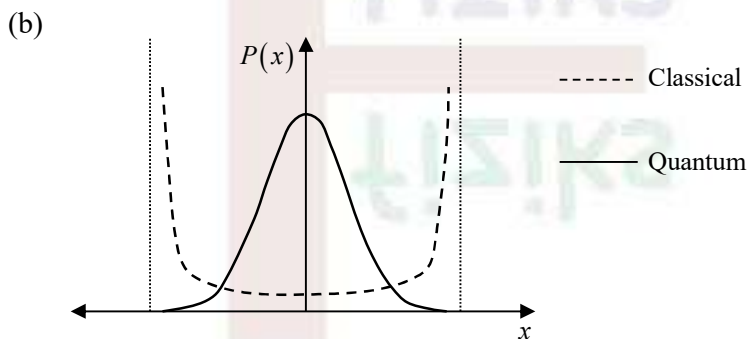
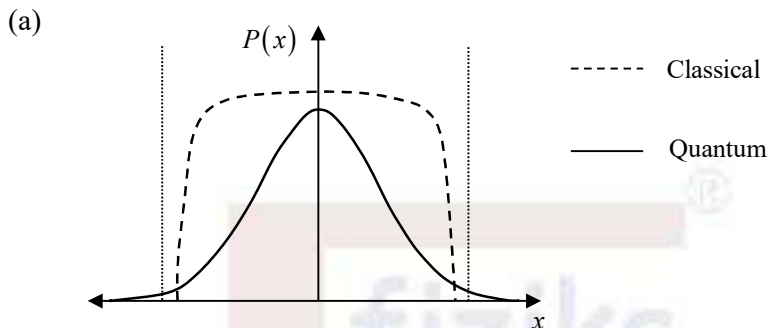
$$\Delta E = -\frac{9a^2}{k^2}.$$

For $a = 2$ and $k = 1$; $\Delta E = -\frac{9a^2}{k^2} = -\frac{9(2)^2}{(1)^2} = -18.$

Section A: Q.11-Q.30 Carry TWO marks each.

Q14. Which ONE of the following figures correctly represents the probability density, $P(x)$, of a particle undergoing simple harmonic oscillation as a function of position x ?

The dashed line is for the classical case. The solid line is for the quantum case, where the system is in its ground state. The vertical lines on the x axis denote the classical turning points.



Ans.: (d)

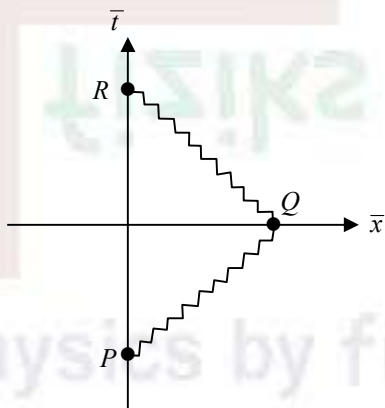
Solution.:

Quantum ground state: $\psi_0(x) \propto e^{-\alpha x^2/2}$, so $P(x) = |\psi_0(x)|^2$ is maximum at $x = 0$ and decays smoothly without diverging at the classical turning points.

Classical oscillator: $P(x) \propto \frac{1}{v(x)} \propto \frac{1}{\sqrt{x_0^2 - x^2}}$ which is minimum at $x = 0$ and diverges at the turning points ($x = \pm x_0$).

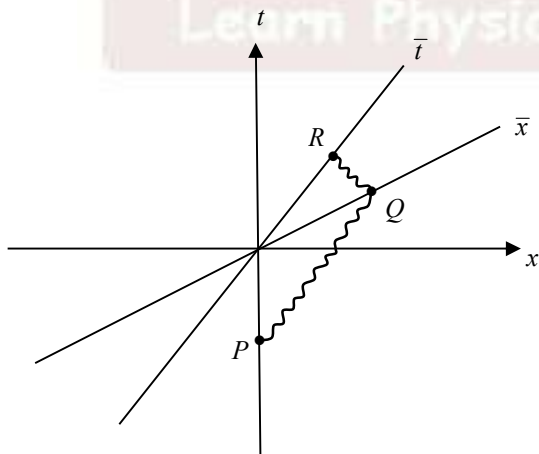
Option (d) correctly matches both probability density behaviors.

Q15. An observer $\bar{O}(\bar{t}, \bar{x})$ moves with a constant velocity in the positive x -direction relative to an observer $O(t, x)$ at rest. In the frame of reference of $\bar{O}(\bar{t}, \bar{x})$, a light-ray emitted at a point P at some time reaches the $\bar{x}$ -axis at the point Q . Then, on reflection it arrives at point R , as shown in the figure.

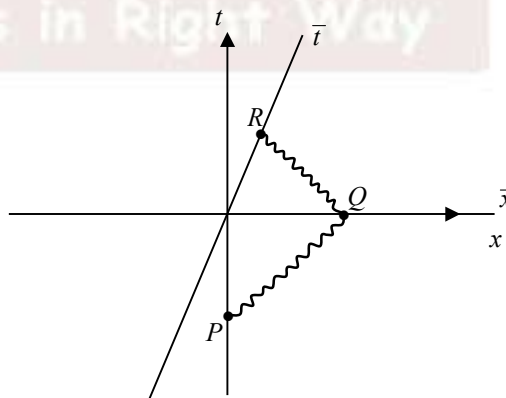


Which of the following options represents these events as observed by $O(t, x)$?

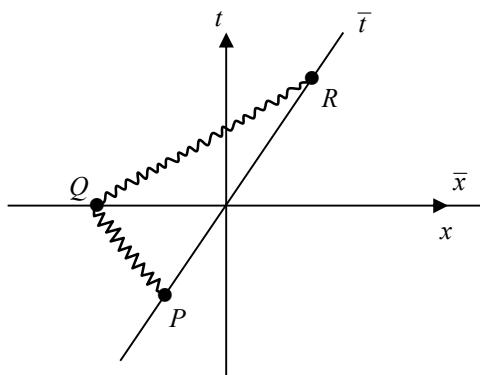
(a)



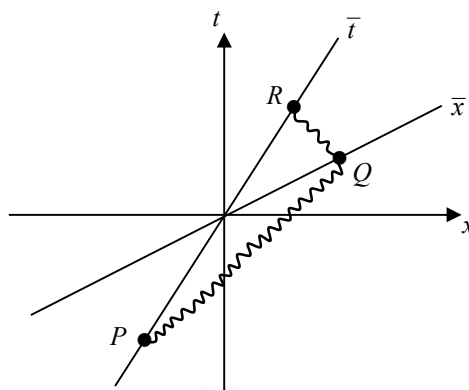
(b)



(c)



(d)



Ans.: (d)

Solution.: The Lorentz transformation is $x = \gamma(\bar{x} + v\bar{t})$, $t = \gamma\left(\bar{t} + \frac{v\bar{x}}{c^2}\right)$.

Event Q: In the barred frame, Q lies on the $\bar{x}$ -axis: $\bar{t}_Q = 0$, $\bar{x}_Q > 0$

Thus $x_Q = \gamma\bar{x}_Q > 0$, $t_Q = \gamma\frac{v\bar{x}_Q}{c^2} > 0$

Thus, Q moves to the **upper-right** of the origin in the t - x diagram

Event P: In the barred frame, P lies below the $\bar{x}$ -axis on the $\bar{t}$ -axis: $\bar{x}_P = 0$, $\bar{t}_P < 0$

Thus $x_P = \gamma v\bar{t}_P < 0$, $t_P = \gamma\bar{t}_P < 0$

Thus, P lies in the **lower-left** quadrant.

Event R: Similarly, $\bar{x}_R = 0$, $\bar{t}_R > 0$

Thus $x_R = \gamma v\bar{x}_R > 0$, $t_R = \gamma\bar{t}_R > 0$

So, R lies in the **upper-right** quadrant.

Hence option (d) is correct.

Q19. A quantum particle of mass 10^{-20} kg is confined within a length of 1 nm in one-dimension.

The minimum uncertainty in the measurement of velocity of the particle, in units of $\mu\text{m/s}$, rounded off to the nearest integer is:

[Assume the minimum uncertainty product $\Delta x \Delta p_x \approx \frac{\hbar}{2}$, use Planck's constant $h = 6.64 \times 10^{-34} \text{ Js}$]

(a) 2

(b) 5

(c) 10

(d) 1

Ans.: (b)

Solution.: Given $\Delta x = 1 \text{ nm} = 10^{-9} \text{ m}$, $m = 10^{-20} \text{ kg}$, $h = 6.64 \times 10^{-34} \text{ Js}$

$$\Delta p_x = m \Delta v_x \approx \frac{h}{2\Delta x} \Rightarrow \Delta v_x \approx \frac{h}{2m\Delta x} \approx \frac{h}{4\pi m\Delta x}$$

$$\Delta v_x \approx \frac{6.64 \times 10^{-34}}{4 \times 3.1416 \times 10^{-20} \times 10^{-9}} \approx \frac{6.64 \times 10^{-34}}{1.2566 \times 10^{-28}} \approx 5.28 \times 10^{-6} \text{ m/sec} \approx 5 \mu\text{m/s}$$

Section B: Q.31 - Q.40 Carry TWO marks each.

Q34. The events are represented by coordinates (ct, x, y, z) in some frame of reference. Which of the following statements is/are correct?

[c is the speed of light]

- (a) Events $(1, 0, -10, 1)$ and $(-1, 1, -9, 1)$ are space-like separated
- (b) Events $(-1, 0, -9, 1)$ and $(1, 1, -10, 1)$ are space-like separated
- (c) Events $(-10, 0, 1, -1)$ and $(-9, 1, -1, -1)$ are light-like separated
- (d) Events $(9, -1, 1, -1)$ and $(-10, 1, 0, -1)$ are time-like separated

Ans.: (d)

Solution.:

The spacetime interval between events 1 and 2 is

$$\Delta s^2 = -c^2 (\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2$$

- (a) Events $(1, 0, -10, 1)$ and $(-1, 1, -9, 1)$

$$\Delta ct = -2, \Delta x = 1, \Delta y = 1, \Delta z = 0 \Rightarrow \Delta s^2 = -(-2)^2 + (1)^2 + (1)^2 + (0)^2 = -2 < 0 \text{ (time-like separated)}$$

- (b) Events $(-1, 0, -9, 1)$ and $(1, 1, -10, 1)$

$$\Delta ct = 2, \Delta x = 1, \Delta y = -1, \Delta z = 0 \Rightarrow \Delta s^2 = -(2)^2 + (1)^2 + (-1)^2 + (0)^2 = -2 < 0 \text{ (time-like separated)}$$

- (c) Events $(-10, 0, 1, -1)$ and $(-9, 1, -1, -1)$

$$\Delta ct = 1, \Delta x = 1, \Delta y = -2, \Delta z = 0 \Rightarrow \Delta s^2 = -(1)^2 + (1)^2 + (-2)^2 + (0)^2 = +4 > 0 \text{ (space-like separated)}$$

- (d) Events $(9, -1, 1, -1)$ and $(-10, 1, 0, -1)$

$$\Delta ct = -19, \Delta x = 2, \Delta y = -1, \Delta z = 0 \Rightarrow \Delta s^2 = -(1)^2 + (1)^2 + (-2)^2 + (0)^2 = +4 > 0$$

(time-like separated)

Correct Option: (d)

Section C: Q.41 - Q.50 Carry ONE mark each.

Q44. A particle of mass 10^{-20} kg is moving along a circular orbit of radius 1 nm . The speed of the particle corresponds to the average thermal energy at temperature 10^{-6} K . Assuming the Bohr's angular momentum quantization condition, the quantum number of the circular path of the particle is _____. (Answer in integer)

[Use $h = 6.64 \times 10^{-34} \text{ J s}$ and $k_B = 1.38 \times 10^{-23} \text{ J/K}$]

Ans.: 6

Solution.: The average thermal kinetic energy is $K = \frac{3}{2} k_B T = \frac{1}{2} m v^2 \Rightarrow v = \sqrt{\frac{3 k_B T}{m}}$

$$\Rightarrow v = \sqrt{\frac{3(1.38 \times 10^{-23}) \times 10^{-6} \text{ K}}{10^{-20}}} = \sqrt{4.14 \times 10^{-9}} \approx 6.43 \times 10^{-5} \text{ m/sec}$$

Bohr's angular momentum condition is

$$mvr = n \frac{h}{2\pi} \Rightarrow n = \frac{2\pi mvr}{h} = \frac{2(3.14)(10^{-20})(6.43 \times 10^{-5})(10^{-9})}{6.64 \times 10^{-34}} \Rightarrow n = 6.09 \approx 6$$

Q48. Light of wavelength 500 nm is incident on the surface of Na metal for photoelectric emission. The corresponding threshold wavelength is 600 nm . The maximum kinetic energy of the emitted electron, in eV , is _____.

(Rounded off to two decimal places)

[Use Planck's constant $h = 6.625 \times 10^{-34} \text{ J s}$, speed of light $c = 3 \times 10^8 \text{ m/s}$, charge of electron $e = 1.6 \times 10^{-19} \text{ C}$]

Ans.: 0.38 to 0.44

Solution.: Einstein's photoelectric equation is $K_{\max} = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$,

where threshold wavelength is λ_0 .

$$\Rightarrow K_{\max} = (6.625 \times 10^{-34})(3 \times 10^8) \left[\frac{1}{500 \times 10^{-9}} - \frac{1}{600 \times 10^{-9}} \right]$$

$$\Rightarrow K_{\max} = 1.9875 \times 10^{-25} (3.3333 \times 10^5) = 6.625 \times 10^{-20} \text{ J}$$

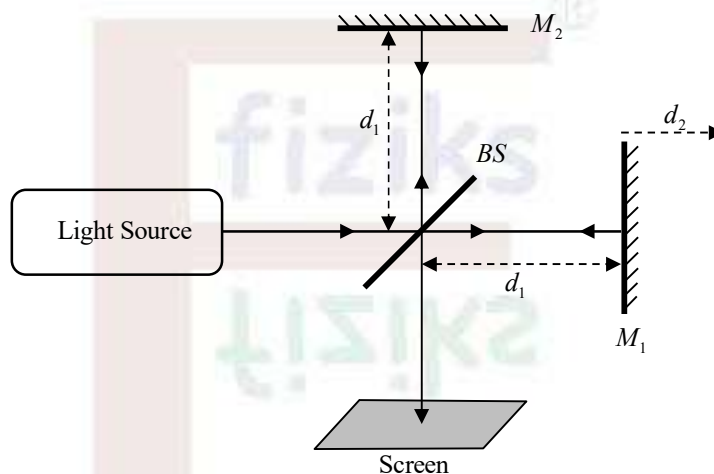
$$\Rightarrow K_{\max} = \frac{6.625 \times 10^{-20}}{1.6 \times 10^{-19}} \text{ eV} = 0.41 \text{ eV}$$

Section C: Q.51-Q60 Carry TWO marks each.

Q53. Consider a light source having a spectral linewidth of 10^{10} Hz , used in a Michelson interferometer. The mirrors M_1 and M_2 are equidistant from the beam-splitter of negligible thickness as shown in the figure. The minimum distance d_2 that the mirror M_1 is to be moved for the interference pattern to completely disappear, in cm , is _____.

(Rounded off to one decimal place)

[Use speed of light to be $3 \times 10^8 \text{ m/s}$]



Ans.: 1.5

Solution.: Given spectral linewidth: $\Delta\nu = 10^{10} \text{ Hz}$

The coherence time is approximately $\tau_c = \frac{1}{\Delta\nu} = \frac{1}{10^{10}} = 10^{-10} \text{ sec}$

The coherence length is $L_c = c\tau_c = 3 \times 10^8 \times 10^{-10} \text{ m} = 3 \times 10^{-2} \text{ m} \Rightarrow L_c = 3 \text{ cm}$

In a Michelson interferometer, if one mirror is moved through distance d , the optical path difference changes by $2d$.

For the interference pattern to disappear, $2d = L_c = 3 \text{ cm} \Rightarrow d = 1.5 \text{ cm}$

Q54. Muons are unstable relativistic particles created at high altitudes above the Earth, having a lifetime of $2.2 \times 10^{-6} s$ in their rest frame. As measured by an observer on the ground, the minimum velocity the muon requires to travel a distance of $6000 m$ is v . The value of v/c is _____. (Rounded off to three decimal places)

[Speed of light $c = 3 \times 10^8 m/s$]

Ans.: 0.992 to 0.997

Solution.: Given proper lifetime: $\tau_0 = 2.2 \times 10^{-6} s$, Distance to be travelled: $L = 6000 m$

The lifetime measured on Earth is time-dilated: $\tau = \gamma \tau_0$

The distance travelled is $L = v\tau = v\gamma\tau_0 = \beta c\gamma\tau_0$ where $\beta = \frac{v}{c}$.

$$\Rightarrow \beta\gamma = \frac{L}{c\tau_0} = \frac{6000}{(3 \times 10^8)(2.2 \times 10^{-6})} = \frac{6000}{660} = 9.0909 \Rightarrow \beta\gamma = 9.0909 \Rightarrow \frac{\beta}{\sqrt{1-\beta^2}} = 9.0909$$

$$\Rightarrow \frac{\beta^2}{1-\beta^2} = 82.6446 \Rightarrow \beta^2 \approx 0.9880 \Rightarrow \beta = \frac{v}{c} \approx 0.994$$

Q56. An electron is confined in a one-dimensional box of width $L = 10 \text{ \AA}$. The electron in the first excited state de-excites to the ground state. The wavelength of the emitted radiation, in μm , is _____. (Rounded off to one decimal place)

[Use the mass of the electron $m_e = 9.1 \times 10^{-31} kg$, Planck's constant $h = 6.625 \times 10^{-34} Js$, $c = 3 \times 10^8 m/s$]

Ans.: 0.9 to 1.3

Solution.: Given $L = 10 \text{ \AA} = 10 \times 10^{-10} m = 10^{-9} m$

For a particle in a one-dimensional infinite box, $E_n = \frac{n^2 h^2}{8mL^2}$

The first excited state corresponds to $n = 2$, and the ground state corresponds to $n = 1$.

$$\text{Therefore, } \Delta E = E_2 - E_1 = (4-1) \frac{h^2}{8mL^2} = \frac{3h^2}{8mL^2} = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{8mcL^2}{3h}$$

$$\Rightarrow \lambda = \frac{8(9.1 \times 10^{-31})(3 \times 10^8)(10^{-18})}{3(6.625 \times 10^{-34})} \approx 1.099 \times 10^{-6} m \approx 1.1 \mu m$$

Q57. An electron is accelerated through a potential of 200 V and then it passes through a slit of width 1.0 nm held normal to the path of the electron. Assuming the uncertainty relation $\Delta x \Delta p_x \approx \hbar/2$, maximum scattering angle of the electron after the slit is $\alpha \times 10^{-3}$ radian.

The value of α is _____. (Rounded off to nearest integer)

Given $\hbar = 1.054 \times 10^{-34} \text{ J s}$

Ans.: 7

Solution.: The electron is accelerated through $V = 200 \text{ volts}$

and passes through a slit of width $\Delta x = 1.0\text{ nm} = 10^{-9} \text{ m}$

The uncertainty relation is $\Delta x \Delta p_x \approx \frac{\hbar}{2}$

$$\Rightarrow \Delta p_x \approx \frac{\hbar}{2\Delta x} = \frac{1.054 \times 10^{-34}}{2 \times 10^{-9}} = 5.27 \times 10^{-26} \text{ kg-m/sec}$$

An electron accelerated through potential V gains kinetic energy $K = \frac{p^2}{2m} = eV \Rightarrow p = \sqrt{2meV}$

$$\Rightarrow p = \sqrt{2(9.1 \times 10^{-31})(1.6 \times 10^{-19})(200)} \Rightarrow p = 7.63 \times 10^{-24} \text{ kgm/s}$$

For a small scattering angle, $\alpha_{\text{scattering}} \approx \frac{\Delta p_x}{p} = \frac{5.27 \times 10^{-26}}{7.63 \times 10^{-24}} = 6.91 \times 10^{-3} \text{ rad} = \alpha \times 10^{-3} \text{ radian}$

$$\Rightarrow \alpha = 6.91 \approx 7$$

Q60. A particle of mass m in a potential $V(x) = \frac{1}{2}kx^2$ is described by normalized wavefunction $\sum_{n=0}^{\infty} (\sqrt{2})^{-(n+1)} \phi_n(x)$, where $\{\phi_n\}$ are the eigenstates of the particle. The energy

corresponding to the wavefunction, in units of $\frac{\hbar}{\pi} \sqrt{\frac{k}{m}}$, is _____.

(Rounded off to two decimal places)

[Given: $\sum_{n=0}^{\infty} (a)^{-n} = \frac{a}{a-1}, a > 1$]

Ans.: 0.75

Solution.: The potential is $V(x) = \frac{1}{2}kx^2$ and normalized wavefunction is $\sum_{n=0}^{\infty} (\sqrt{2})^{-(n+1)} \phi_n(x)$

where $\{\phi_n\}$ are the eigenstates of the particle.

Thus, the coefficient of $\phi_n(x)$ is $c_n = (\sqrt{2})^{-(n+1)} |c_n|^2 = (\sqrt{2})^{-2(n+1)} = 2^{-(n+1)}$

Notice that $\sum_{n=0}^{\infty} |c_n|^2 = \sum_{n=0}^{\infty} 2^{-(n+1)} = 2^{-1} + 2^{-2} + 2^{-3} + \dots = \frac{2^{-1}}{1-2^{-1}} = 1$

So the state is correctly normalized.

For a harmonic oscillator, Energy eigenvalues $E_n = \left(n + \frac{1}{2}\right) \hbar \omega$ where $\omega = \sqrt{\frac{k}{m}}$

The expectation value is $\langle E \rangle = \sum_{n=0}^{\infty} |c_n|^2 E_n = \hbar \omega \sum_{n=0}^{\infty} 2^{-(n+1)} \left(n + \frac{1}{2}\right)$

$$\Rightarrow \langle E \rangle = \hbar \omega \left[\sum_{n=0}^{\infty} n 2^{-(n+1)} + \frac{1}{2} \sum_{n=0}^{\infty} 2^{-(n+1)} \right] = \hbar \omega \left[\frac{1}{2} \sum_{n=0}^{\infty} n \left(\frac{1}{2}\right)^n + \frac{1}{2} \right]$$

$$\Rightarrow \langle E \rangle = \hbar \omega \left[\frac{1}{2} \times 2 + \frac{1}{2} \right] = \frac{3}{2} \hbar \omega = \frac{3}{2} \frac{h}{2\pi} \sqrt{\frac{k}{m}} = \frac{3}{4} \frac{h}{\pi} \sqrt{\frac{k}{m}} = 0.75 \left(\frac{h}{\pi} \sqrt{\frac{k}{m}} \right)$$



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Solution- Solid State Physics, Devices and Electronics

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Section A: Q.1-Q.10 Carry ONE mark each.

Q2. Consider an n -type silicon in which the fully ionized dopant concentration is 10^{17} cm^{-3} . The intrinsic electron density is $1.5 \times 10^{10} \text{ cm}^{-3}$. Which of the following options correctly states the equilibrium hole concentration in cm^{-3} ?

- (a) 2.25×10^3 (b) 1.55×10^3
(c) 3.01×10^3 (d) 4.52×10^3

Ans.: (a)

Solution.: Using the mass-action law: $n_0 p_0 = n_i^2$

For fully ionized n -type semiconductor, $n_0 \approx N_D = 10^{17} \text{ cm}^{-3}$

$$\Rightarrow p_0 = \frac{n_i^2}{N_D} = \frac{(1.5 \times 10^{10})^2}{10^{17}} = 2.25 \times 10^3 \text{ cm}^{-3}$$

Q4. Which of the following options represents the simplified form of the Boolean equation

$$Y = \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$$

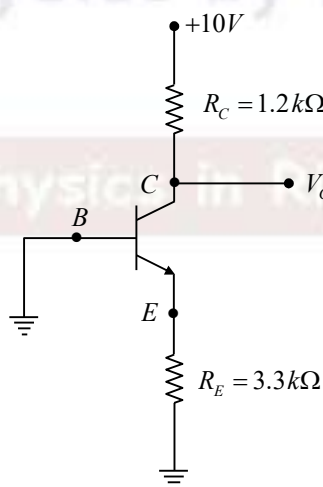
- (a) $\bar{A}\bar{B}$ (b) $\bar{A}\bar{B}\bar{C}$
(c) $\bar{B}\bar{C}$ (d) $\bar{C}$

Ans.: (d)

Solution.: $Y = \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC = (\bar{A} + A)\bar{B}\bar{C} + (\bar{A} + A)B\bar{C} = \bar{B}\bar{C} + B\bar{C} = (\bar{B} + B)\bar{C} = \bar{C}$

Section A: Q.11-Q.30 Carry TWO marks each.

Q11. Consider the circuit of the figure, the voltage V_C , in Volts, is:



- (a) 0 (b) 1.25
(c) 9.8 (d) 10

Ans.: (d)

Solution.: For *npn* transistor to conduct, $V_{BE} \approx 0.7V$.

Since $V_B = 0$, conduction would require, $V_E = V_B - 0.7 = -0.7V$

But the emitter is connected through R_E to ground. With no source capable of making V_E negative, the transistor cannot turn ON. Therefore, the transistor is in cutoff, so $I_C = 0$.

Thus $V_{R_C} = I_C R_C = 0$ and $V_C = V_{CC} = 10V$.

Q17. Consider a BCC lattice with one atom per lattice point. The maximum packing fraction is close to:

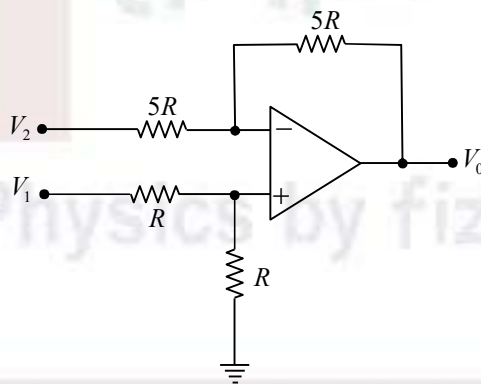
- (a) 53% (b) 68%
(c) 74% (d) 81%

Ans.: (b)

Solution.: For a Body-Centered Cubic (BCC) lattice, the atomic packing factor (APF) is:

$$APF = \frac{\pi\sqrt{3}}{8} \approx 0.6801 \text{ or } 68\%$$

Q18. The output voltage V_0 for the circuit shown in the figure is:



- (a) $(V_1 - V_2)$ (b) $(V_1 - 2V_2)$
(c) $(V_2 - V_1)$ (d) $2(V_1 - V_2)$

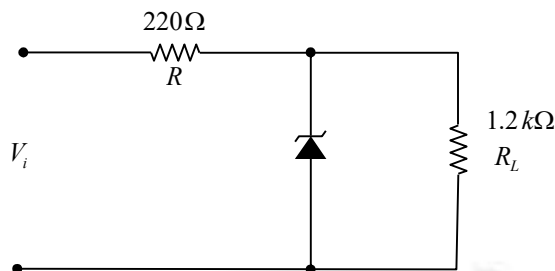
Ans.: (a)

Solution.: From superposition principle:

$$V_0 = V_{01} + V_{02} = \left(1 + \frac{5R}{5R}\right) \frac{R}{R+R} V_1 + \left(-\frac{5R}{5R} V_2\right) \Rightarrow V_0 = V_1 - V_2$$

Section B: Q.31 - Q.40 Carry TWO marks each.

Q32. In the circuit shown in the figure, the Zener voltage V_z is $20V$ and the maximum Zener current I_{ZM} is $60mA$. For what value(s) of the input voltage V_i , the Zener diode is in ON state?



- (a) $20V$ (b) $25V$
(c) $35V$ (d) $40V$

Ans.: (b), (c)

Solution.: For $V_{i,min}$, open circuit voltage $V_{OC} = V_z = V_{i,min} \frac{R_L}{R_L + R}$

$$\Rightarrow 20V = V_{i,min} \frac{1200}{220 + 1200} \Rightarrow V_{i,min} = \frac{1420}{1200} \times 20V = 23.67V$$

$$V_{i,max} = I_{R,max} R + V_z \text{ where } I_{R,max} = I_{ZM} + I_L = 60mA + \frac{20V}{1.2k} = 76.67mA$$

$$\Rightarrow V_{i,max} = (76.67mA)(0.22k\Omega) + 20V = 36.9V$$

Section C: Q.41 - Q.50 Carry ONE mark each.

Q43. An OP-AMP has differential gain of $A_d = 4000$, two input voltages $V_{i1} = 120\mu V$ and $V_{i2} = 80\mu V$, and CMRR = 100. The output voltage, in mV , is _____. (Answer in integer)

Ans.: 160 to 170

Solution.: Differential input voltage: $V_d = V_{i1} - V_{i2} = 120\mu V - 80\mu V = 40\mu V$

$$\text{Common-mode input voltage: } V_c = \frac{V_{i1} + V_{i2}}{2} = \frac{120\mu V + 80\mu V}{2} = 100\mu V$$

$$\text{Common-mode gain: } A_c = \frac{A_d}{CMRR} = \frac{4000}{100} = 40$$

Output voltage:

$$V_0 = A_d V_d + A_c V_c = (4000)(40 \times 10^{-6}) + (40)(100 \times 10^{-6}) \text{ volts} = (160 \times 10^{-3} + 4 \times 10^{-3}) \text{ volts}$$

$$\Rightarrow V_0 = 164mV$$

Q49. The first order Bragg peak for (100) plane of a material with simple cubic structure is measured using an X-ray of wavelength $1\text{\AA}$. If the lattice constant is $5\text{\AA}$ then the Bragg peak is observed at an angle, in degrees, _____. (Rounded off to two decimal places)

Ans.: 5.55 to 5.95

Solution.: The angle θ for the first-order Bragg reflection, use Bragg's Law: $2d \sin \theta = n\lambda$

$$\text{Where } n = 1, \lambda = 1\text{\AA}, d_{100} = \frac{a}{\sqrt{h^2 + k^2 + l^2}} = \frac{5\text{\AA}}{\sqrt{1^2 + 0^2 + 0^2}} = 5\text{\AA}$$

$$\text{Thus } 2(5\text{\AA}) \sin \theta = 1 \times 1\text{\AA} \Rightarrow \sin \theta = 0.1 \Rightarrow \theta = 5.74^\circ$$

Section C: Q.51-Q60 Carry TWO marks each.

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