PHYSICS

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

Choose the correct answer:

1. A message signal of frequency 5 kHz is used to modulate a carrier signal of frequency 2 MHz. The bandwidth for amplitude modulation is:

(1) 5 kHz (2) 2.5 kHz

(3) 10 kHz (4) 20 kHz

Answer (3)

Sol. Frequency of modulating wave = 5 kHz

Bandwidth = Twice the frequency of modulating signal

= 2 × 5 kHz

= 10 kHz

2. Electron beam used in an electron microscope, when accelerated by a voltage of 20 kV, has a de-Broglie wavelength of λ_0. If the voltage is increased to 40 kV, then the de-Broglie wavelength associated with the electron beam would be:

(1) $9\lambda_0$ (2) $\frac{\lambda_0}{2}$

(3) $\frac{\lambda_0}{\sqrt{2}}$ (4) $3\lambda_0$

Answer (3)

Sol. $\lambda_0 = \frac{h}{\sqrt{2m[e(20\times10^3)]}}$

$$\lambda_{new} = \frac{h}{\sqrt{2m[e(40\times10^{-3})]}} = \frac{\lambda_0}{\sqrt{2}}$$

3. The root mean square velocity of molecules of gas is

(1) Proportional to square root of temperature $(\sqrt{T})$

(2) Inversely proportional to square root of temperature $\left(\sqrt{\frac{1}{T}}\right)$

(3) Proportional to temperature (T)

(4) Proportional to square of temperature (T^2)

Answer (1)

Sol. $\because \quad v_{rms} = \sqrt{\frac{3RT}{M}}$

$\therefore \quad v_{rms} \propto \sqrt{T}$

4. In Young's double slits experiment, the position of 5th bright fringe from the central maximum is 5 cm. The distance between slits and screen is 1 m and wavelength of used monochromatic light is 600 nm. The separation between the slits is:

(1) 12 μm

(2) 60 μm

(3) 48 μm

(4) 36 μm

Answer (2)

Sol. y_5 = 5 cm, D = 1 m, λ = 600 nm

$$\because \quad \frac{5\lambda D}{d} = \frac{5}{100}$$

$$\therefore \quad d = \frac{5\times600\times10^{-9}\times1\times100}{5}$$

$= 6 \times 10^{-5}$ m

= 60 μm

5. Match **List I** with **List II**

	List I		**List II**
A.	Surface tension	I.	kg $m^{-1}s^{-1}$
B.	Pressure	II.	kg ms^{-1}
C.	Viscosity	III.	kg $m^{-1}s^{-2}$
D.	Impulse	IV.	kg s^{-2}

Choose the correct answer from the options given below:

(1) A-III, B-IV, C-I, D-II

(2) A-II, B-I, C-III, D-IV

(3) A-IV, B-III, C-I, D-II

(4) A-IV, B-III, C-II, D-I

Answer (3)

Sol. (A) Surface tension : kg s^{-2} (IV)

(B) Pressure : kg $m^{-1}s^{-2}$ (III)

(C) Viscosity : kg $m^{-1}s^{-1}$ (I)

(D) Impulse : kg ms^{-1} (II)

6. A bowl filled with very hot soup cools from 98°C to 86°C in 2 minutes when the room temperature is 22°C. How long it will take to cool from 75°C to 69°C?

(1) 2 minutes (2) 1.4 minutes

(3) 0.5 minute (4) 1 minute

Answer (2)

Sol. From Newton's law of cooling.

$$\frac{dT}{dt} = -k(T - T_s)$$

Case I : dT = 12°C, dt = 2 min

$$\frac{12}{2} = -k[92 - 22°] = -k\ 70 \quad ...(1)$$

Case II : dT = 6°C

$$\frac{6}{dt} = -k[72 - 22] = -k50 \quad ...(2)$$

From (1) and (2)

dt = 1.4 min

7. T is the time period of simple pendulum on the earth's surface. Its time period becomes xT when taken to a height R (equal to earth's radius) above the earth's surface. Then, the value of x will be:

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

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

Answer (3)

Sol. $T = 2x\sqrt{\frac{l}{g}}$

g = acceleration due to gravity

On earth's surface $g = \frac{Gm}{R^2}$

On height R, $g_R = \frac{Gm}{4R^2}$

$$g_R = \frac{g}{4}$$

Time period at height R = $2\pi\sqrt{\frac{l}{g_R}}$

= 2T

8. A Camot engine with efficiency 50% takes heat from a source at 600 K. In order to increase the efficiency to 70%, keeping the temperature of sink same, the new temperature of the source will be :

(1) 360 K (2) 300 K

(3) 900 K (4) 1000 K

Answer (4)

Sol. $\eta = 1 - \frac{T_{sink}}{T_{source}}$

50% efficiency $\Rightarrow \frac{1}{2} = 1 - \frac{T_{sink}}{T_{source}}$

$$\frac{1}{2} = 1 - \frac{T_{sink}}{600} \Rightarrow T_{sink} = 300$$

Now, 70% efficiency $\Rightarrow \frac{7}{10} = 1 - \frac{T_{sink}}{T_{source}}$

$$\frac{300}{T_{source}} = \frac{3}{10}$$

T_{source} = 1000 K

9. The ratio of the density of oxygen nucleus $({}^{16}_{8}O)$ and helium nucleus $({}^{4}_{2}He)$ is

(1) 2 : 1 (2) 8 : 1

(3) 1 : 1 (4) 4 : 1

Answer (3)

Sol. Nuclear density is constant.

$$\frac{\rho_{oxygen}}{\rho_{Helium}} = 1$$

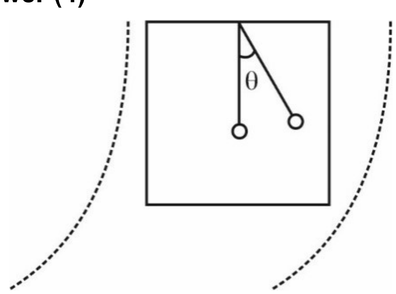
10. A car is moving with a constant speed of 20 m/s in a circular horizontal track of radius 40 m. A bob is suspended from the roof of the car by a massless string. The angle made by the string with the vertical will be : (Take g = 10 m/s^2)

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

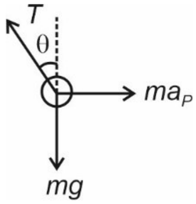
(3) $\frac{\pi}{6}$ (4) $\frac{\pi}{4}$

Answer (4)

Sol.



In car's frame, FBD of bob

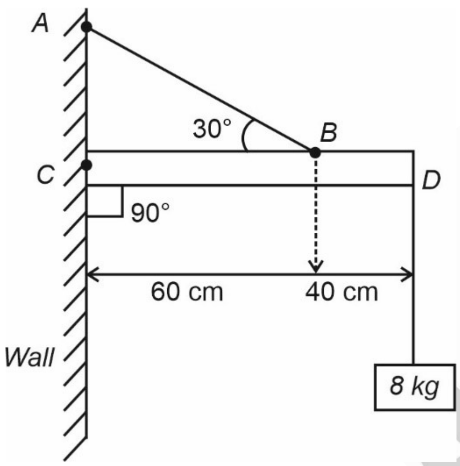


where a_P = Pseudoforce or centrifugal force

$$\theta = \tan^{-1}\left(\frac{a_P}{g}\right) = \tan^{-1}\left(\frac{v^2}{Rg}\right) = \tan^{-1}\left(\frac{400}{40\times 10}\right)$$

$$= 45°$$

11. An object of mass 8 kg is hanging from one end of a uniform rod CD of mass 2 kg and length 1 m pivoted at its end C on a vertical wall as shown in figure. It is supported by a cable AB such that the system is in equilibrium. The tension in the cable is : (Take g = 10 m/s²)

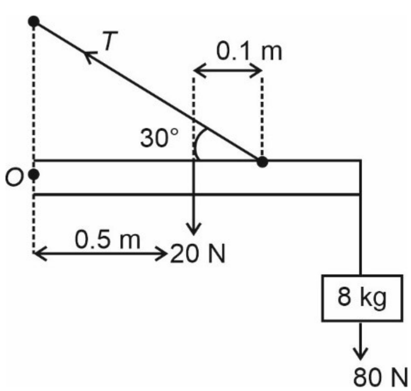


(1) 240 N (2) 90 N

(3) 300 N (4) 30 N

Answer (3)

Sol.



Torque balance about '*O*'

$$\frac{T}{2}\times 0.6 = 20\times 0.5 + 80\times 1$$

$$T \times 0.3 = 10 + 80 = 90$$

$$T = \frac{900}{3} = 300 \text{ N}$$

12. A car travels a distance of '*x*' with speed v_1 and then same distance '*x*' with speed v_2 in the same direction. The average speed of the car is

(1) $\frac{v_1+v_2}{2}$

(2) $\frac{v_1 v_2}{2(v_1+v_2)}$

(3) $\frac{2\,v_1 v_2}{v_1+v_2}$

(4) $\frac{2x}{v_1+v_2}$

Answer (3)

Sol. $v_{avg} = \dfrac{2x}{\left(\dfrac{x}{v_1}+\dfrac{x}{v_2}\right)} = \left(\dfrac{2v_1v_2}{v_1+v_2}\right)$

13. An electromagnetic wave is transporting energy in the negative *z* direction. At a certain point and certain time the direction of electric field of the wave is along positive *y* direction. What will be the direction of the magnetic field of the wave at that point and instant?

(1) Negative direction of *x*

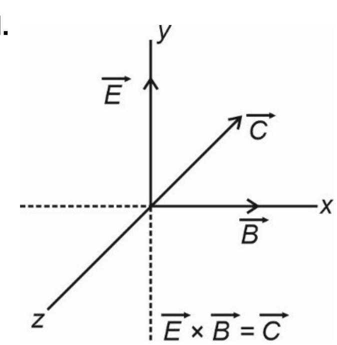
(2) Negative direction of *y*

(3) Positive direction of *z*

(4) Positive direction of *x*

Answer 4)

Sol.



So, $\vec{B}$ should be in *x* direction

14. A uniform metallic wire carries a current 2 A. When 3.4 V battery is connected across it. The mass of uniform metallic wire is 8.92×10^{-3} kg, density is 8.92×10^3 kg/m^3 and resistivity is $1.7 \times 10^{-8}\ \Omega$–m. The length of wire is:

(1) $l = 100$ m

(2) $l = 6.8$ m

(3) $l = 10$ m

(4) $l = 5$ m

Answer (3)

Sol. $m = 8.92 \times 10^{-3}$ kg

Density = 8.92×10^3 kg/m^3

Volume $= \frac{8.92\times10^{-3}}{8.92\times10^{3}} = (10^{-6})\text{m}^3$

Resistance $= \frac{3.4}{2} = 1.7\ \Omega = \left(\frac{\rho l}{A}\right)$

$1.7 = \frac{\rho l^2}{(Al)}$

$\Rightarrow\ 1.7 = \frac{1.7\times10^{-8}\times l^2}{10^{-6}}$

$l^2 = 100$

$\boxed{l = 10\text{ m}}$

15. In an LC oscillator, if values of inductance and capacitance become twice and eight times, respectively, then the resonant frequency of oscillator becomes x times its initial resonant frequency ω_0. The value of x is:

(1) $\frac{1}{16}$

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

(3) 4

(4) 16

Answer (2)

Sol. $\omega_0 = \frac{1}{\sqrt{LC}}$

If inductance becomes $2L$ and capacitance becomes $8C$

$\omega = \frac{1}{\sqrt{2L\times8C}} = \frac{1}{4\sqrt{LC}}$

$\boxed{\omega = \left(\frac{\omega_0}{4}\right)}$

16. A solenoid of 1200 turns is wound uniformly in a single layer on a glass tube 2 m long and 0.2 m in diameter. The magnetic intensity at the center of the solenoid when a current of 2 A flows through it is:

(1) A m^{-1}

(2) 2.4×10^{-3} A m^{-1}

(3) 1.2×10^3 A m^{-1}

(4) 2.4×10^3 A m^{-1}

Answer (3)

Sol. Number of turns per unit length = $\frac{1200}{2} = 600$

So, Magnetic Intensity $H = nI$

$= 600 \times 2$ Am^{-1}

$= 1200$ Am^{-1}

17. Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R

Assertion A: Photodiodes are used in forward bias usually for measuring the light intensity.

Reason R: For a p-n junction diode, at applied voltage V the current in the forward bias is more than the current in the reverse bias for $|V_z| > \pm V \geq |V_0|$ where V_O is the threshold voltage and V_z is the breakdown voltage.

In the light of the above statements, choose the ***correct*** answer from the options given below

(1) A is false but R is true

(2) Both A and R are true and R is correct explanation A

(3) Both A and R are true but R is NOT the correct explanation A

(4) A is true but R is false

Answer (1)

Sol. Photodiodes are used in reverse bias therefore the assertion is incorrect.

18. Assume that the earth is a solid sphere of uniform density and a tunnel is dug along its diameter throughout the earth. It is found that when a particle is released in this tunnel, it executes a simple harmonic motion. The mass of the particle is 100 g. The time period of the motion of the particle will be (approximately)

(Take g = 10 m s^{-2}, radius of earth = 6400 km)

(1) 1 hour 40 minutes

(2) 12 hours

(3) 24 hours

(4) 1 hour 24 minutes

Answer (4)

Sol. Gravitational acceleration at a distance of r from centre of earth is given by

$$g' = \frac{g}{R}r$$

Where R is the radius of earth

So, $\frac{d^2r}{dt^2} = -\frac{g}{R}r$

$$\Rightarrow \quad T = 2\pi\sqrt{\frac{R}{g}} = 2\pi\sqrt{\frac{6400000}{10}}$$

$= 2\pi \times 800$ sec

$= 5024$ sec

= 1 hour 24 minutes (approx.)

19. A parallel plate capacitor has plate area 40 cm^2 and plates separation 2 mm. The space between the plates is filled with a dielectric medium of a thickness 1 mm and dielectric constant 5. The capacitance of the system is :

(1) $\frac{3}{10}\varepsilon_0$ F (2) $\frac{10}{3}\varepsilon_0$ F

(3) $10\varepsilon_0$ F (4) $24\varepsilon_0$ F

Answer (2)

Sol. $c = \frac{\varepsilon_0 A}{(d-t)+\frac{t}{K}}$

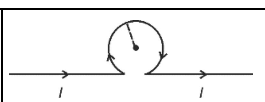
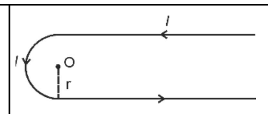
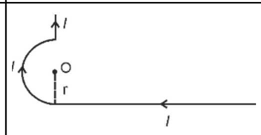
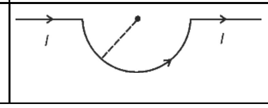
$$= \frac{K\,\varepsilon_0 A}{Kd - t + (K-1)}$$

$$= \frac{5\,\varepsilon_0 \times 40 \times 10^{-4}}{5 \times 2 \times 10^{-3} - 1 \times 10^{-3}(5-1)}$$

$$= \frac{20\,\varepsilon_0}{6}$$

$$= \frac{10\,\varepsilon_0}{3}$$

20. Match List I with List II

List I (Current configuration)		List II (Magnitude of Magnetic Field at point O)	
A.		I.	$B_0 = \frac{\mu_0 I}{4\pi r}[\pi + 2]$
B.		II.	$B_0 = \frac{\mu_0}{4}\frac{I}{r}$
C.		III.	$B_0 = \frac{\mu_0 I}{2\pi r}[\pi - 1]$
D.		IV.	$B_0 = \frac{\mu_0 I}{4\pi r}[\pi + 1]$

Choose the correct answer from the options given below :

(1) A–III, B–IV, C–I, D–II (2) A–I, B–III, C–IV, D–II

(3) A–III, B–I, C–IV, D–II (4) A–II, B–I, C–IV, D–III

Answer (3)

Sol. A $\rightarrow$ $B_0 = \frac{-\mu_0 I}{4\pi r} + \frac{\mu_0 I}{2r} - \frac{\mu_0 I}{4\pi r}$

$B_0 = \frac{\mu_0 I}{2\pi r}(\pi - 1)$ A $\rightarrow$ III

B $\rightarrow$ $B_0 = \frac{\mu_0 I}{4\pi r} + \frac{\mu_0 I}{4r} + \frac{\mu_0 I}{4\pi r}$

$B_0 = \frac{\mu_0 I}{4\pi r}(\pi + 2)$ B $\rightarrow$ I

C $\rightarrow$ $B_0 = \frac{\mu_0 I}{4\pi r} + \frac{\mu_0 I}{4r} + 0$

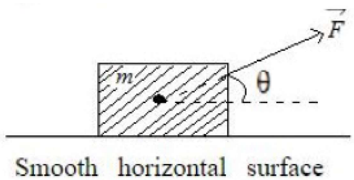
$B_0 = \frac{\mu_0 I}{4\pi r}(\pi + 1)$ C $\rightarrow$ IV

D. $\rightarrow$ $B_0 = \frac{\mu_0 I}{4r}$ D $\rightarrow$ II

SECTION - B

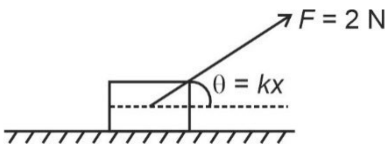
Numerical Value Type Questions: This section contains 10 questions. In Section B, attempt any five questions out of 10. The answer to each question is a **NUMERICAL VALUE.** For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the second decimal place; e.g. 06.25, 07.00, –00.33, –00.30, 30.27, –27.30) using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.

21. An object of mass 'm' initially at rest on a smooth horizontal plane starts moving under the action of force F = 2N. In the process of its linear motion, the angle θ (as shown in figure) between the direction of force and horizontal varies as $\theta = kx$, where k is a constant and x is the distance covered by the object from its initial position. The expression of kinetic energy of the object will be $E = \frac{n}{k}\sin\theta$, the value of n is ______.



Answer (2)

Sol.



Work done = ΔK.E

$$\therefore \int F \cdot dx = \frac{1}{2}mv^2 = E$$

$$\therefore E = \int_0^x 2\cos(kx)dx$$

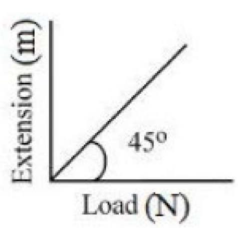
$$E = \frac{2}{k}[\sin kx]_0^x$$

$$= \frac{2}{k}\sin kx$$

$$= \frac{2\sin\theta}{k}$$

22. As shown in the figure, in an experiment to determine Young's modulus of a wire, the extension-load curve is plotted. The curve is a straight line passing through the origin and makes an angle of 45° with the load axis. The length of wire is 62.8 cm and its diameter is 4 mm. The Young's modulus is found to be x × 10^4 Nm^{-2}.

The value of x is _____.



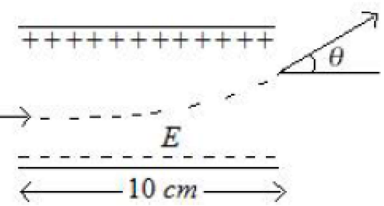
Answer (5)

Sol. $Y = \frac{F}{\Delta l} \times \left(\frac{l(4)}{\pi d^2}\right)$

$$= (\text{slope})\frac{(62.8 \times 10^{-2})}{\pi(4 \times 10^{-3})^2}$$

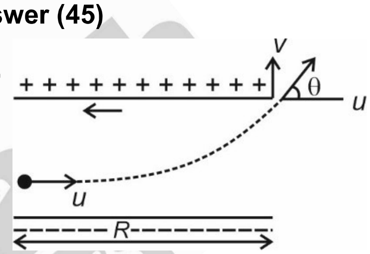
= (1) × 5 × 10^4 N/m^2

23. A uniform electric field of 10 N/C is created between two parallel charged plates (as shown in figure). An electron enters the field symmetrically between the plates with a kinetic energy 0.5 eV. The length of each plate is 10 cm. The angle (θ) of deviation of the path of electron as it comes out of the field is ____ (in degree).



Answer (45)

Sol.



Let R is the range and T be the time of motion inside the plate.

$\therefore$ $R = vT$

and, $\tan\theta = \frac{v}{u}$

$$= \frac{\left(\frac{eE}{m}\right)T}{u}$$

$$= \frac{\frac{eE}{m}\left(\frac{R}{u}\right)}{u}$$

$$= \frac{eER}{mu^2}$$

$$= \frac{eER}{2(\text{K.E.})}$$

$$= \frac{(e)\times(10)\times(10\times10^{-2})}{2\times(0.5\text{ eV})}$$

= 1

$\therefore$ $\tan\theta = 1$

$\theta = 45°$

24. An LCR series circuit of capacitance 62.5 nF and resistance of 50 Ω, is connected to an A.C. source of frequency 2.0 kHz. For maximum value of amplitude of current in circuit, the value of inductance is _____mH.

(Take $\pi^2 = 10$)

Answer (100)

Sol. ∵ For maximum amplitude of current, circuit should be at resonance.

$\therefore \quad X_L = X_C$

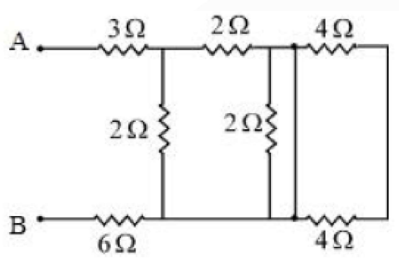
$$\omega L = \frac{1}{\omega C}$$

$$L = \frac{1}{\omega^2 C}$$

$$= \frac{1}{(2\pi \times 2 \times 10^3)^2 \times 62.5 \times 10^{-9}}$$

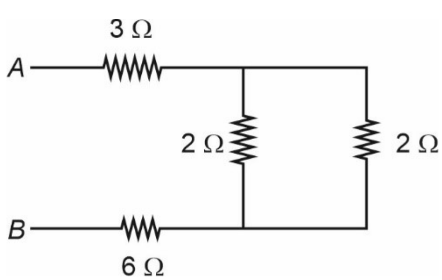
= 100 mH

25. In the given circuit, the equivalent resistance between the terminal A and B is _______ Ω.



Answer (10)

Sol. Equivalent circuit can be redrawn as

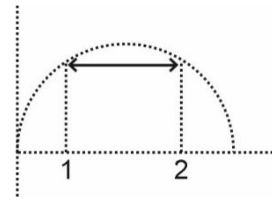


$\therefore R_{AB} = 10\ \Omega$

26. The distance between two consecutive points with phase difference of 60° in a wave of frequency 500 Hz is 6.0 m. The velocity with which wave is traveling is _____ km/s

Answer (18)

Sol.



$$\Delta x = \frac{\lambda}{2\pi} \times \left(\frac{\pi}{3}\right) = \left(\frac{\lambda}{6}\right)$$

$$\Rightarrow \frac{\lambda}{6} = 6\text{m}$$

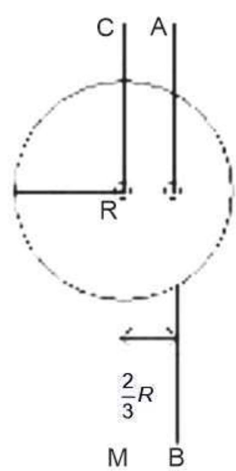
$\lambda = 36$ m

$U = f\lambda = 500 \text{ Hz} \times 36$

= 18000 m/s

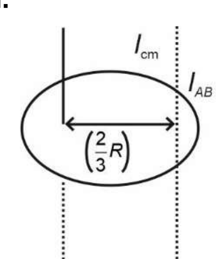
= 18 km/s

27. I_{CM} is the moment of inertia of a circular disc about an axis (CM) passing through its center and perpendicular to the plane of disc. I_{AB} is it's moment of inertia about an axis AB perpendicular to plane and parallel to axis CM at a distance $\frac{2}{3}$R from center. Where R is the radius of the disc. The ratio of I_{AB} and I_{CM} is x : 9. The value of x is______.



Answer (17)

Sol.



$$I_{cm} = \frac{1}{2}MR^2$$

$$I_{AB} = I_{cm} + M \times \left(\frac{2}{3}R\right)^2$$

$$= \frac{1}{2}MR^2 + \frac{4}{9}MR^2$$

$$= \frac{(9+8)MR^2}{18} = \left(\frac{17}{18}\right)MR^2$$

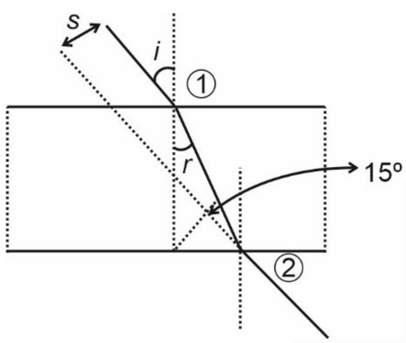
$$\frac{I_{AB}}{I_{cm}} = \frac{17/18}{1/2} = \left(\frac{17}{9}\right)$$

Value of $x = 17$

28. A ray of light is incident from air on a glass plate having thickness $\sqrt{3}$ cm and refractive index $\sqrt{2}$. The angle of incidence of a ray is equal to the critical angle for glass-air interface. The lateral displacement of the ray when it passes through the plate is _______ × 10^{-2} cm. (given sin 15° = 0.26)

Answer (52)

Sol.



$$\sin i = \frac{1}{\sqrt{2}} = 45^\circ$$

$\Rightarrow$ at point (1)

$$\mu \sin r = \sin i = \frac{1}{\sqrt{2}}$$

$$\sin r = \frac{1}{2} \qquad \Rightarrow \qquad \boxed{r = 30^\circ}$$

Lateral displacement

$$= \frac{t}{\cos r}\sin(15^\circ) = \frac{\sqrt{3}}{\left(\frac{\sqrt{3}}{2}\right)} \times 0.26$$

= 2 × 0.26

= 0.52 cm

= 52 × 10^{-2} cm

29. If $\vec{P} = 3\hat{i} + \sqrt{3}\hat{j} + 2\hat{k}$ and $\vec{Q} = 4\hat{i} + \sqrt{3}\hat{j} + 2.5\hat{k}$ then, the unit vector in the direction of $\vec{P} \times \vec{Q}$ is $\frac{1}{x}(\sqrt{3}\hat{i} + \hat{j} - 2\sqrt{3}\hat{k})$. The value of x is

Answer (4)

Sol. $\vec{P} = 3\hat{i} + \sqrt{3}\hat{j} + 2\hat{k}$

$\vec{Q} = 4\hat{i} + \sqrt{3}\hat{j} + 2.5\hat{k}$

$$\vec{P} \times \vec{Q} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & \sqrt{3} & 2 \\ 4 & \sqrt{3} & 2.5 \end{vmatrix}$$

$$= \hat{i}\left(\frac{\sqrt{3}}{2}\right) - \hat{j}\left(-\frac{1}{2}\right) + \hat{k}(-\sqrt{3})$$

$$= \frac{\sqrt{3}}{2}\hat{i} + \frac{\hat{j}}{2} - \sqrt{3}\hat{k}$$

$$|\vec{P} \times \vec{Q}| = \sqrt{\frac{3}{4} + \frac{1}{4} + 3} = 2$$

Unit vector along $\vec{P} \times \vec{Q} = \frac{1}{4}(\sqrt{3}\hat{i} + \hat{j} - 2\sqrt{3}\hat{k})$

$x = 4$

30. The wavelength of the radiation emitted is λ_0 when an electron jumps from the second excited state to the first excited state of hydrogen atom. If the electron jumps from the third excited state to the second orbit of the hydrogen atom, the wavelength of the radiation emitted will be $\frac{20}{x}\lambda_0$. The value of x is ________.

Answer (27)

Sol. Transition, $n = 3$ to $n = 2$

$$\frac{1}{\lambda_0} = R\left(\frac{1}{4} - \frac{1}{9}\right) = \left(\frac{5R}{36}\right) \qquad \ldots(1)$$

For transition from, $n = 4$ to $n = 2$

$$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{16}\right) = \left(\frac{3}{16}R\right) \qquad \ldots(2)$$

Taking ratio of (1) and (2)

$$\frac{\lambda}{\lambda_0} = \frac{5}{36} \times \frac{16}{3} = \left(\frac{20}{27}\right)$$

$$\boxed{\lambda = \frac{20}{27}\lambda_0}$$

$x = 27$