JEE Main - 2023

Physics

Answers

Section A

1. Correct Answer: C

$$\lambda = \frac{h}{mv}, \qquad m = \frac{m_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}, v \to c, m \to \infty$$

Hence, $\lambda \to 0$

2. Correct Answer: C

$$r_n = r_1 n^2$$

$$\therefore n^2 = \frac{r_n}{r_1} = \frac{21.2\times10^{-11}}{5.3\times10^{-11}} = 4$$

$$\therefore n = 2$$

3. Correct Answer: D

Voltage gain $\Delta_v = \beta\frac{R_{\text{out}}}{R_{\text{in}}}$

$\Rightarrow G = 25\frac{R_{\text{out}}}{R_{\text{in}}}$ ....(i)

Trans conductance $g_m = \frac{\beta}{R_{\text{in}}}$

$$\Rightarrow R_{\text{in}} = \frac{\beta}{g_m} = \frac{25}{0.03}$$

Putting this value of R_{in} in eqn. (i)

$G = 25\frac{R_{\text{out}}}{25} \times 0.03$ ....(ii)

$\therefore G' = 20\frac{R_{\text{out}}}{20} \times 0.02$ ...(iii)

From eqs. (ii) and (iii)

Voltages gain of new transistor $G' = \frac{2}{3}G$

4. Correct Answer: B

100% Modulation $\Rightarrow m_a = 1$

$$\frac{\text{useful power}}{\text{total power radiated}} = \frac{m_a^{\,2}}{2 + m_{a^2}} = \frac{1}{2+1} = \frac{1}{3}$$

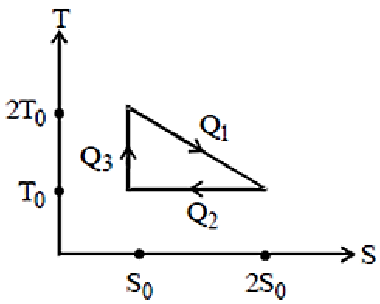
$$\Rightarrow \text{Useful power} = \frac{1}{3}(\text{total power radiated})$$

5. Correct Answer: A

Heat produced $= ms\Delta T = \frac{1}{2}\left(\frac{1}{2}mv^2\right)$

$$\Rightarrow \Delta T = \frac{v^2}{4s} = \frac{(200)^2}{4 \times 125} = \frac{4 \times 10^4}{4 \times 125} = 80°\text{C}$$

6. Correct Answer: D



$$Q_1 = T_0S_0 + \frac{1}{2}T_0S_0 = \frac{3}{2}T_0S_0$$

$Q_2 = T_0(2S_0 - S_0) = T_0S_0$ and $Q_3 = 0$

$$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_0S_0}{\frac{3}{2}T_0S_0} = \frac{1}{3}$$

7. Correct Answer: B

By Lens maker's formula for convex lens

$$\frac{1}{f} = \left(\frac{\mu}{\mu_L} - 1\right)\left(\frac{2}{R}\right)$$

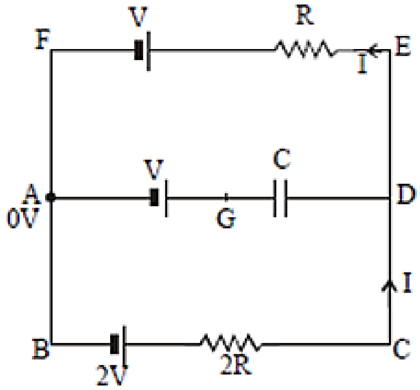
For, $\mu_{L_1} = \frac{4}{3}, f_1 = 4R$

For $\mu_{L_2} = \frac{5}{3}, f_2 = -5R \Rightarrow f_2 = (-)\text{ve}$

8. Correct Answer: B

Diffraction is defined as the bending of light around the corners of the obstacle or aperture into the region of geometrical shadow if the obstacle. Diffraction occurs with all waves, including sound waves, water waves and electromagnetic waves.

9. Correct Answer: C



Applying Kirchhoff's law in $BCDEFAB$ we get, $I = \frac{V}{3R}$

Let A be at $0V$. Then potential at G is V.

Applying Kirchhoff's law for $AFED$, we get

$$0 + V + IR = V_D \Rightarrow 0 + V + \frac{V}{3R} \times R = V_D \Rightarrow V_D = \frac{4V}{3}$$

$\therefore$ Potential different across capacitor $= \frac{4V}{3} - V = \frac{V}{3}$

10. Correct Answer: A

As the ring has no resistance, the three resistance of $3R$ each are in parallel.

$$\Rightarrow \frac{1}{R'} = \frac{1}{3R} + \frac{1}{3R} + \frac{1}{3R} = \frac{1}{R} \Rightarrow R' = R$$

$\therefore$ Between point A and B equivalent resistance

$$= R + R = 2R$$

11. Correct Answer: C

Drift speed is the average speed between two successive collisions.

12. Correct Answer: C

Electrostatic potential energy of charge $+q$ placed at the centre of cube is

$$U = 8 \times \frac{1}{4\pi\varepsilon_0} \times \frac{q-(q)}{\text{half} - \text{diagonal distance}}\Bigg|$$

$$= 8 \times \frac{1}{4\pi\varepsilon_0} \frac{-q^2}{b\frac{\sqrt{3}}{2}}\Bigg|$$

$$= \frac{-4q^2}{\sqrt{3}\pi\varepsilon_0 b}$$

13. Correct Answer: A

When S is closed, there will be no shifting of negative charge from plate A to B as the charge $-q$ is held by the charge $+q$. Neither there will be any shifting of charge from B to A

14. Correct Answer: A

Given:

Electric field at P is zero. Therefore electric field due to Sphere 1 and sphere 2 is equal and opposite.

$\therefore E_1 = E_2$

For Q_1, point P is inside the sphere and for Q_2 it is outside of sphere.

$$\Rightarrow \frac{KQ_1 \frac{R}{2}}{R^3} = \frac{KQ_2}{\left(\frac{3R}{2}\right)^2}$$

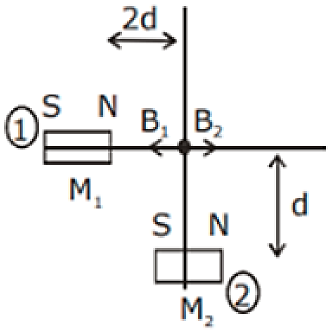
$$\Rightarrow Q_1 = \frac{8}{9} \times Q_2$$

$$\Rightarrow 64 = \frac{8}{9} \times Q_2$$

$\Rightarrow Q_2 = 72\mu C$

15. Correct Answer: B

$B_1 = B_2$



$$\frac{2\mu_0}{4\pi}\cdot\frac{M_1}{(2d)^3} = \frac{\mu_0}{4\pi}\cdot\frac{M_2}{d^3}$$

$$\frac{M_1}{M_2} = \frac{4}{1}$$

16. Correct Answer: A

In case of the electric field of an electric dipole, the electric lines of force originate from positive charge and end at negative charge. Since isolated magnetic lines are closed continuous loops extending throughout the body of the magnet.

17. Correct Answer: C

The term $\frac{Q^2}{2C}$ is the formula of energy stored in a capacitor so it has the dimension of energy $= \left[ML^2T^{-2}\right]$

18. Correct Answer: B

$v = \sqrt{\mu r g}$

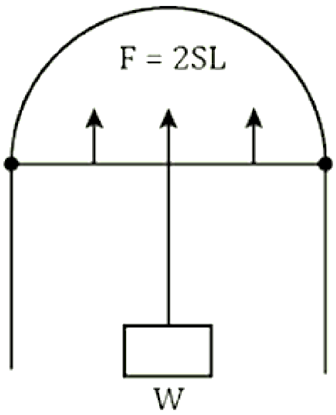
$v = \sqrt{0.6 \times 150\,\text{m} \times 10}$

$v = 30$

19. Correct Answer: D

Here, $W = 1.5 \times 10^{-2}\,\text{N}$

$L = 30\,\text{cm} = 30 \times 10^{-2}\,\text{m}$



As film has two surface.

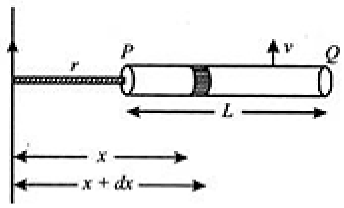
$\therefore$ Force due surface tension $= 2 \times L \times S$

At equilibrium, weight of the give block is balanced by force due to surface tension, i.e.,

$2L \times S = W$

$\Rightarrow S = \dfrac{W}{2L} = \dfrac{1.5 \times 10^{-2}\,\text{N}}{2 \times 0.3\,\text{m}} = 0.025\,\text{N/m}$

20. Correct Answer: C



Consider a small element of length dx of the rod at a distance x and $(x+dx)$ from the wire. The emf induced across the element $de = B\upsilon dx$

(i). We know that magnetic field B at a distance x from a wire carrying a current; is given by $B = \frac{\mu_0}{2\pi} \cdot \frac{i}{x}$

(ii). From eqs. (i) and (ii) $de = \frac{\mu_0 i}{2\pi x} v dx$

(iii). The emf induced in the entire length of the rod PQ is given by

$$e = \int de = \int_P^Q \frac{\mu_0}{2\pi} \frac{i}{x} v\,dx = \int_r^{r+L} \frac{\mu_0}{2\pi} \frac{i}{x} v\,dx = \frac{\mu_0}{2\pi} iv \int_r^{r+L} \frac{dx}{x} = \frac{\mu_0 iv}{2\pi} \log_e\left(\frac{r+L}{R}\right)$$

Section-B

21. Answer: 1

Here,

$y = \frac{1}{(1+x^2)}$ at $t = 0\text{sec}$

$y = \frac{1}{\left[1+(x-1)^2\right]}$ at $t = 1\text{sec}$

According to mathematics, [play with graph], if $f(x) = f(x-1)$, it means shape of graph is same just change the position. Graph shift right direction by 1 unit. Here it is clear that the shape of wave doesn't change. also wave move in $1\text{sec}, 1\text{m}$ in positive x direction

So, wave moves 1m in 1sec.

So, velocity of wave $= \frac{\text{displacement of wave}}{\text{time taken}}$

$= 1\text{m}/1\text{sec} = 1\text{m}/\text{sec}$

So, velocity of wave $= 1\text{m/s}$

22. Answer: 2

Time taken by particle to move from $x=0$ (mean position) to $x=4$ (extreme position)

$$=\frac{T}{4}=\frac{12}{4}=3\text{s}$$

Let t be the time taken by the particle top move from $x=0$ to $x=2\text{cm}$

$$y=a=\sin\omega t$$

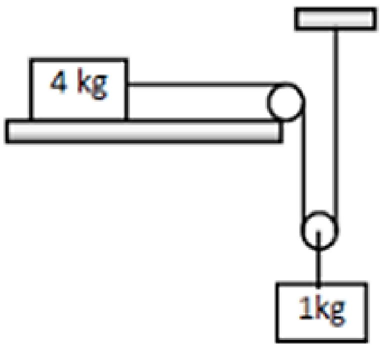
$$\Rightarrow 2=4\sin\frac{2\pi}{T}t$$

$$\Rightarrow \frac{1}{2}=\sin\frac{2\pi}{12}t$$

$$\Rightarrow \frac{\pi}{6}=\frac{2\pi}{12}t \Longrightarrow t=1\text{s}$$

Hence time to move from $x=2$ to $x=4$ will be equal to $3-1=2\text{s}$

23. Answer: 12



$m_1=4\text{kg}, m_2=1\text{kg},\quad V_2=0.3\text{m/sec}\ \ V_1=2\times(0.3)=0.6\text{m/sec}$

$(v_1=2x_2\text{m this system})$

$h=1\text{m}=$ height descent by 1kg block

$s=2\times1=2\text{m}$ distance travelled by 4kg block

$u=0$

Applying change in K.E. $=$ work done (for the system)

$$\left[\left(\frac{1}{2}\right)m_1v_1^{\,2}+\left(\frac{1}{2}\right)m_2v_m^{\,2}\right]-0=(-\mu R)S+m_2g \qquad [R=4\,g=40\,N]$$

$$\Rightarrow \frac{1}{2}\times 4\times(0.36)\times\frac{1}{2}\times 1\times(0.09)=-\mu\times 40\times 2+1\times 10$$

$$\Rightarrow 0.72+0.045=-80\mu+10$$

$$\Rightarrow \mu=\frac{9.235}{80}=0.12=12\times 10^{-2}$$

$$\therefore x=12$$

24. Answer: 10

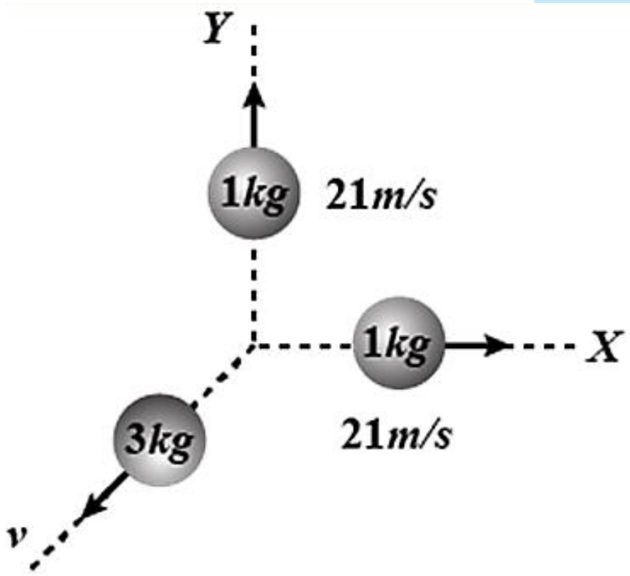
$$P_x=m\times V_x=1\times 21=21\,\text{kgm/s}$$

$$P_y=m\times V_y=1\times 21=21\,\text{kgm/s}$$

$\therefore$ Resultant $=\sqrt{P_x^2+P_y^2}=21\sqrt{2}\,\text{kgm/s}$

The momentum of heavier fragment should be numerically equal to resultant of $\overrightarrow{P_x}$ and $\overrightarrow{P_y}$

$$3\times v=\sqrt{P_x^2+P_Y^2}=21\sqrt{2}\therefore v=7\sqrt{2}=9.89\,\text{m/s}\approx 10\,\text{m/s}$$



25. Answer: 15

Given that,

Velocity of $A = 20\,\text{m/s}$

Velocity of $B = V_B\,\text{m/s}$

According to diagram

Velocity of A along X axis towards B is

$V_{AX} = V_A \cos 53°$

$V_{AX} = 20 \cos 53°$

$V_{AX} = 20 \times \frac{3}{5}$

$V_{AX} = 12\,\text{m/s}.......(\text{I})$

Now, velocity of B along X axis towards A is

$V_{BX} = V_B \cos 37°$

$V_{BX} = V_B \times \frac{3.95}{5}$

$V_{BX} = V_B \times \frac{4}{5}.....(\text{II})$

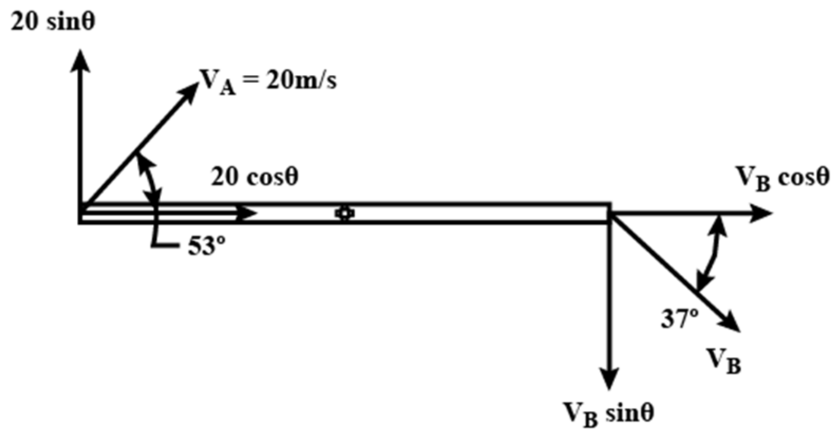
Now, from equation (I) and (II)

$12 = V_B \times \frac{4}{5}$

$V_B = \frac{60}{4}$

$V_B = 15\,\text{m/s}$

Hence, the velocity V_B is $15\,\text{m/s}$



26. Answer: 1

Elastic energy $=\frac{1}{2}\times F\times x$

$F=200\,\text{N}, x=1\,\text{mm}=10^{-3}\,\text{m}$

$\therefore E=\frac{1}{2}\times 200\times 1\times 10^{-3}=0.1=1\times 10^{-1}\,J$

The value of m is 1.

27. Answer: 3

N_0 is initial amount of uranium.

N is present amount of uranium after 1.5×10^{9} years.

The amount of lead present is N_0-N

$\therefore$ The required ratio is $\frac{N_0-N}{N}=\frac{1-e^{-\lambda t}}{e^{-\lambda t}}$

Now, $T_{\frac{1}{2}}=\frac{\ln 2}{\lambda}\Rightarrow \lambda=\frac{\ln 2}{T_{\frac{1}{2}}}$

$$\therefore \frac{N_0 - N}{N} = \frac{1-e^{-\ln 2 \frac{t}{T_{\frac{1}{2}}}}}{e^{-\ln 2 \frac{t}{T_{\frac{1}{2}}}}} = \frac{1-2^{-\frac{t}{T_{\frac{1}{2}}}}}{2^{-\frac{t}{T_{\frac{1}{2}}}}} = \frac{1-2^{-\frac{1}{3}}}{2^{-\frac{1}{3}}} = 2^{\frac{1}{3}} - 1 = 0.259$$

Ratio $= 259 \times 10^{-k} = 0.259$

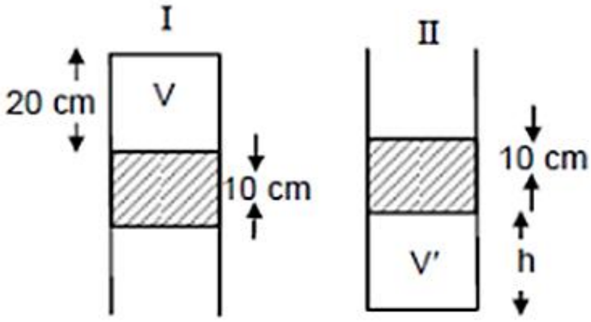
$$\frac{259}{0.259} = 10^k$$

$$10^3 = 10^k$$

$$k = 3 \rightarrow$$

28. Answer: 15

Case I $\rightarrow$ Net pressure on air in volume V



$= P_{\text{atm}} - h\rho g$

$= 75\times \rho gH \times g - 10\rho gH \times g = 65\times \rho gH \times g$

Case II $\rightarrow$ Net pressure on air in volume $'V' = P_{\text{atm}} + \rho gH \times g \times h$

$P_1V_1 = P_2V_2$

$\Rightarrow \rho Hg \times 9\times 65\times A\times 20 = \rho Hg \times g \times 75 + \rho Hg \times 9\times 10\times A\times h$

$\Rightarrow 62\times 20 = 85h \Rightarrow h = \dfrac{65\times 20}{85} = 15.2\,\text{cm} \approx 15\,\text{cm}$

29. Answer: 641

$d\sin\theta = n\lambda$

$\sin\theta \times 32\times 10^{-5} = \dfrac{n\times 500\times 10^{-9}}{}$

$\sin\theta = \dfrac{n5}{3200}$

At $\theta = 30°$

$\dfrac{1}{2} = \dfrac{n5}{3200}$

$\Rightarrow n = \dfrac{1600}{5}$

$= 320$

So there will be $320+\text{ve}, 320-\text{ve}, 1$ central

Total $=641$

30. Answer: 28

$\vec{s}=\left(5\hat{i}+4\hat{j}\right)2+\frac{1}{2}\left(4\hat{i}+4\hat{j}\right)4$

$=10\hat{i}+8\hat{j}+8\hat{i}+8\hat{j}$

$\overrightarrow{r_f}-\vec{r_i}=18\hat{i}+16\hat{j}$

$\overrightarrow{r_f}=20\hat{i}+20\hat{j}$

$\left|\overrightarrow{r_f}\right|=20\sqrt{2}=28.2\approx 28\text{m}$.