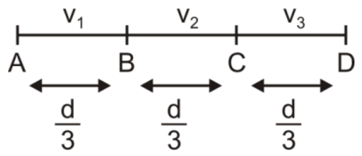
JEE Mains Paper-2022

PHYSICS

1. A particle moves such that it moves $\frac{1}{3}$rd distance with speed v_1 the next $\frac{1}{3}$rd distance with speed v_2 and remaining $\frac{1}{3}$rd distance with speed v_3. Then its average speed throughout motion is



(1) $\frac{2(v_1v_2+v_2v_3+v_3v_1)}{v_1+v_2+v_3}$

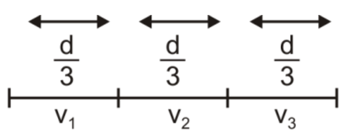
(2) $\frac{(v_1+v_2+v_3)}{3}$

(3) $\frac{v_1+v_2}{2}+\frac{v_2+v_3}{2}+\frac{v_3+v_1}{2}$

(4) $\frac{3v_1v_2v_3}{v_1v_2+v_2v_3+v_3v_1}$

Sol. Answer (4)

Avg speed = $\frac{\text{Total distance}}{\text{total time}}$



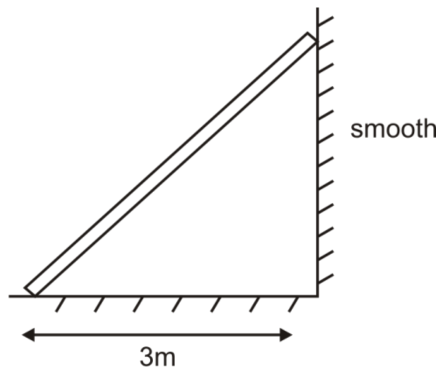
$t_1=\frac{d}{3v_1}$ $t_2=\frac{d}{3v_2}$ $t_3=\frac{d}{3v_3}$

$V_{avg}=\frac{d}{t_1+t_2+t_3}$

$=\frac{d}{\frac{d}{3v_1}+\frac{d}{3v_2}+\frac{d}{3v_3}}$

$V_{avg}=\frac{3v_1v_2v_3}{v_2v_3+v_1v_3+v_1v_2}$

2. A uniform rod of length $\sqrt{34}$ m is inclined against the wall as shown. Floor is sufficiently rough to prevent sliding. Then the ratio of magnitude of normal force on floor to normal force on wall is



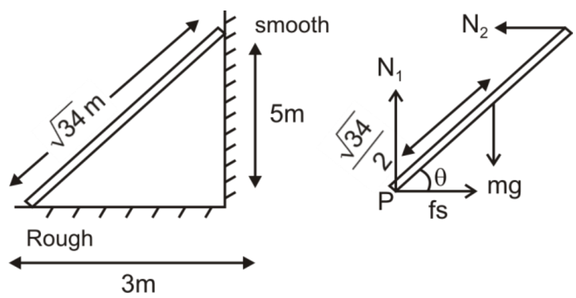
(1) $\frac{10}{3}$

(2) $\frac{5}{2}$

(3) $\frac{3}{5}$

(4) $\frac{10}{7}$

Sol. Answer (1)



For equilibrium,

$N_1 = mg$ ....(1)

$N_2 = fs$ ....(2)

Balancing torque about 'P',

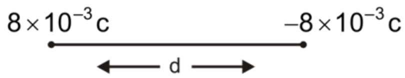
$$mg\left(\frac{\sqrt{34}}{2}\cos\theta\right) = N_2(5)$$

$$\Rightarrow mg\frac{\sqrt{34}}{2} \times \frac{3}{\sqrt{34}} = N_2(5)$$

$$\Rightarrow N_2 = \frac{3mg}{10}$$

So, $\frac{N_1}{N_2} = \frac{mg}{3mg/10} = \frac{10}{3}$

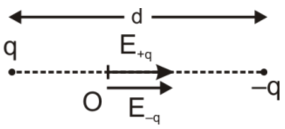
3. Two opposite changes are placed at a distance d as shown. Electric field strength at mid point is 6.4×10^4N/C. Then the value of d is



(1) 42.1 m (2) 94.86 m

(3) 72.2 m (4) 62.8 m

Sol. Answer (2)



$\vec{E}_0 = \vec{E}_{+q} + \vec{E}_{-q}$

Both are in same direction

$$E_0 = E_{+q} + E_{-q}$$

$$E_0 = 6.4 \times 10^4 \text{ N/C}$$

$$E_{+q} = \frac{kq}{(d/2)^2}$$

$$E_{-q} = \frac{kq}{(d/2)^2}$$

$$E_0 = \frac{4kq}{d^2} + \frac{4kq}{d^2}$$

$$6.4 \times 10^4 = \frac{8kq}{d^2}$$

$$6.4 \times 10^4 = \frac{8 \times 9 \times 10^9 \times 8 \times 10^{-3}}{d^2}$$

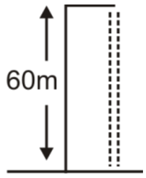
$$d^2 = \frac{64}{6.4} \times 9 \times 10^2$$

$$d^2 = 10^3 \times 9$$

$$d = 3 \times 10\sqrt{10}$$

$$d = 30\sqrt{10}\,m$$

4. Water falls at a rate of 600 kg / s from a height of 60m as shown. How many bulbs of capacity 100 W each will glow from the energy produced at the bottom of the fall. Assume full conversion of energy of falling water and all bulbs glowing at 100 W each.



(1) 25 (2) 50

(3) 100 (4) None

Sol. Answer (4)

Power produced at the bottom is,

$$P = \frac{mgh}{t}$$

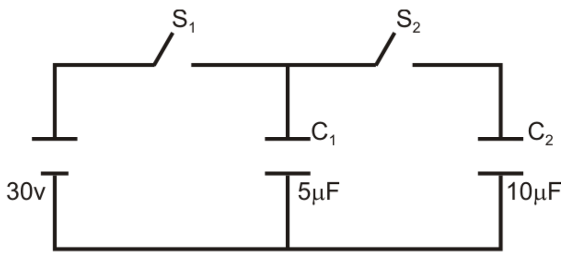
= (600) (10) (60)

= 36 × 10^4 watt.

No. of bulbs can glow = $\frac{36 \times 10^4}{100}$

= 3600

5. The switch S_1 is kept closed for long time. Now at t = 0 switch S_1 is opened and S_2 is closed. The charge on capacitor C_2 finally is

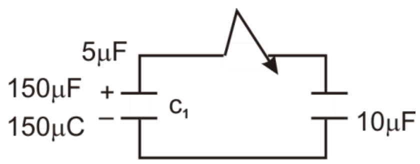


(1) 100 μc (2) 120 μc

(3) 50 μc (4) 80 μc

Sol. Answer (1)

Situation just before S_1 is opened and S_2 is closed



Situation long time after S_2 is closed

$q_1 + q_2 = 150\mu$ C

$v_{c_1} = v_{c_2}$

$\frac{q_1}{5} = \frac{q_2}{10}$

$q_1 = \frac{q_2}{2}$

$q_2 + q_2 = 150\mu c$

$\frac{3q_2}{2} = 150$

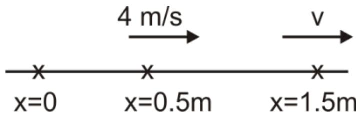
$q_2 = 100\mu c$

6. A mass of 2 kg crosses x = 0.5m with velocity 4m/s. The force acting on the mass is F = –kx where k is 12 N/m. with what velocity it will cross x = 1.5m

(1) 1 m/s (2) 3 m/s

(3) 2 m/s (4) 4 m/s

Sol. Answer (3)



Force acting on the particle (F) = –kx

using work - energy theorem,

$$\frac{1}{2}mv^2 - \frac{1}{2}m(4)^2 = W$$

$$\Rightarrow \frac{1}{2}m(v^2 - 16) = \int_{0.5}^{1.5} -kx\,dx$$

$$\Rightarrow \frac{1}{2} \times 2(v^2 - 16) = \frac{-k}{2}\left[(1.5)^2 - (0.5)^2\right]$$

$$\Rightarrow v^2 - 16 = -\frac{12}{2}(2)$$

$$\Rightarrow v = 2\,m/s$$

7. A resistor has a resistance of 2Ω at temperature 10^0C and a resistance of 3Ω at temperature 30^0C. Find the temperature co-efficient of resistance.

(1) 0.050 /^{0}C (2) 0.025 /^{0}C

(3) 0.0025 /^{0}C (4) 0.006 /^{0}C

Sol. Answer (2)

$R = R_0[1 + \alpha\Delta T]$

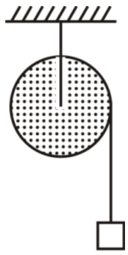
$3 = 2[1 + \alpha(30 - 10)]$

$20\alpha = \frac{1}{2}$

$\alpha = \frac{1}{40} /^0 C$

$\alpha = 0.025 /^0 C$

8. A block of mass m and a pulley of mass m are arranged as shown



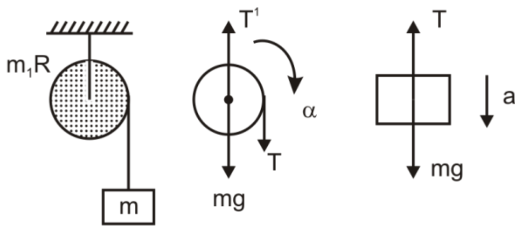
The string connecting the block and the string does not slip on the pulley as the block comes down. Find the tension in the string.

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

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

Sol. Answer (3)

Drawing FBD of pulley & mass $I_{pully} = \frac{mR^2}{2}$



For block, mg – T = ma ....(1)

For pulley; T • R = Iα

$\Rightarrow T = \frac{I\alpha}{R}$ ....(2)

Using constraint relation,

$a = R\alpha$ ....(3)

So from (2)

$T = \frac{Ia}{R^2}$

$\Rightarrow T = \frac{mR^2}{2} . \frac{a}{R^2} = \frac{ma}{2} - 2(a)$

Dividing (1) & 2(a)

$\frac{mg - T}{T} = 2$

$\Rightarrow mg - T = 2T \Rightarrow T = \frac{mg}{3}$

9. De-Broglie wavelength of two particle are relate as $\lambda_1 = 3\lambda_2$ then the kinetic energy k_1 and k_2 of particle respectively are related as

(1) $k_2 = 3k_1$ (2) $k_2 = 9k_1$

(3) $k_1 = 3k_2$ (4) $k_1 = 2k_2$

Sol. Answer (2)

$$\lambda = \frac{h}{\sqrt{2mk}}$$

$$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{k_2}{k_1}}$$

$$\frac{3\lambda_2}{\lambda_2} = \sqrt{\frac{k_2}{k_1}}$$

$$\frac{k_2}{k_1} = \frac{9}{1}$$

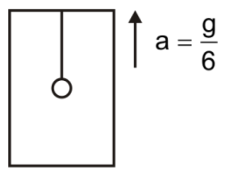
$k_2 = 9k_1$

10. Time period of simple pendulum of length l when placed in a lift which is accelerating upwards with the acceleration $\frac{g}{6}$ is

(1) $2\pi\sqrt{\frac{6l}{7g}}$ (2) $2\pi\sqrt{\frac{7l}{6g}}$

(3) $2\pi\sqrt{\frac{3l}{2g}}$ (4) $2\pi\sqrt{\frac{5l}{6g}}$

Sol. Answer (1)



$$g_{eff.} = g + a$$

$$= g + \frac{g}{6}$$

$$= \frac{7g}{6}$$

$$T = 2\pi\sqrt{\frac{l}{g_{eff}}} = 2\pi\sqrt{\frac{l \times 6}{7g}} = 2\pi\sqrt{\frac{6l}{7g}}$$

11. In a resonance column experiment, water level is decreased. First resonance is observed with a tuning fork of frequency 340 Hz when air column is of length 125 cm. Find how much further the water level should go down to observe the next resonance. (v_{sound} = 340 m/s)

(1) 25 cm (2) 50 cm

(3) 100 cm (4) 75 cm

Sol. Answer (2)

$$\lambda = \frac{v}{\nu} = \frac{340}{340} = 1\,\text{m}$$

$$L = (2n+1)\frac{\lambda}{4}$$

$$L_1 = \frac{1}{4}\text{m}$$

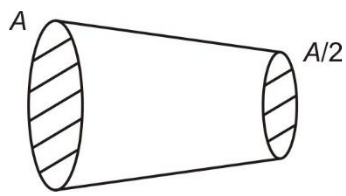
$$L_2 = \frac{3}{4}\text{m}$$

$$L_3 = \frac{5}{4}\text{m}$$

$$L_4 = \frac{7}{4}\text{m}$$

$$L_4 - L_3 = \frac{1}{2}\text{m} = 50\text{ cm}$$

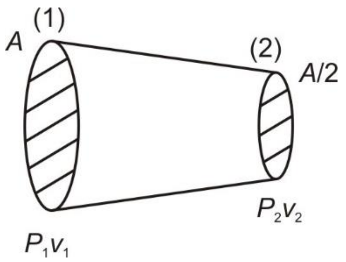
12. Water is flowing through a frustum like section of pipe as shown in the diagram. Pressure difference across the ends is 4000 N/m^2. Area of cross-section $A = \sqrt{6}\ \text{m}^2$. Find the value of flow rate through the pipe



(1) 4 m^3/s (2) 2 m^3/s

(3) 1 m^3/s (4) 8 m^3/s

Sol. Answer (1)



Using continuity equation between section 1 & 2

$$Av_1 = \frac{A}{2}v_2 \Rightarrow v_2 = 2v_1 \quad ......(1)$$

Using Bernoulli's equation between section 1 & 2

$$P_1+\frac{1}{2}\rho v_1^2+\rho gh=P_2+\frac{1}{2}\rho v_2^2+\rho gh$$

$$\Rightarrow P_1-P_2=\frac{1}{2}\rho(v_2^2-v_1^2)$$

$$\Rightarrow 4000=\frac{1}{2}\times(1000)[(2v_1)^2-(v_1)^2]$$

$$\Rightarrow 8=3v_1^2\Rightarrow v_1=\sqrt{\frac{8}{3}}\text{ m/s}$$

Volume flow rate (Q) = Av_1

$$\sqrt{6}\sqrt{\frac{8}{3}}=4\frac{\text{m}^3}{\text{s}}$$

13. In a YDSE if a slab of thickness $x\lambda$ and refractive index ($\mu=1.5$) is inserted in front of slit then intensity of previous central maxima remains unchanged, then the minimum value of x is

(1) 2 (2) 1

(3) 0.5 (4) 1.5

Sol. Answer (1)

Fringe shift due to insertion

$$\Delta y=\frac{(\mu-1)tD}{d}$$

$$\Delta y=w$$

$$\frac{(\mu-1)tD}{d}=\frac{\lambda D}{d}$$

$$t=\frac{\lambda}{\mu-1}$$

$$t=\frac{\lambda}{1.5-1}$$

$$x\lambda=2\lambda$$

$$x=2$$

14. Choose the **correct** statement

(1) In radioactive decay, λ depends on physical and chemical environment

(2) ln$N$ vs t graph slope is proportional to inverse of mean life

(3) Number of nuclei remaining is linearly related with time

(4) ln$N$ vs ln$t$ graph slope is proportional to inverse of mean life

Sol. Answer (2)

$$N=N_0e^{-\lambda t}$$

$\lambda=$ decay constant

*λ depends upon type of radioactive material

*No. of parent nuclei decreases exponentially with time.

$$N=N_0e^{-\lambda t}$$

$$\Rightarrow \ln(N)=\ln(N_0)-\lambda t$$

Slope of '$\ln(N)$' vs 't' graph is λ which is $\frac{1}{T_{mean}}$

15. A drop of water of radius 1 mm is falling through air. Find the terminal speed of the drop knowing that density of air is negligible as compared to density of water.

$(\eta_{air}=2\times10^{-3}\text{ Ns/m}^2, g=10\text{ m/s}^2)$.

(1) 2.2 m/s

(2) 1.1 m/s

(3) 1.6 m/s

(4) 2.8 m/s

Sol. Answer (2)

$$Mg=F_b+F_v$$

In air $F_b\sim0$

$$Mg=F_v$$

$$\frac{4}{3}\pi r^3\rho g=6\pi\eta rv_T$$

$$v_T=\frac{2}{9}\frac{r^2}{\eta}\rho g$$

$$v_T=\frac{2}{9}\frac{10^{-6}}{2\times10^{-3}}\times1000\times10$$

$$v_T=\frac{10}{9}\text{ m/s}$$

$$v_T=1.1\text{ m/s}$$

16. For an amplitude modulated wave given by $y(t)=10[1+0.4\cos(2\pi\times10^4t)]\sin(2\pi\times10^7t)$, find the band width.

(1) 10 kHz

(2) 20 MHz

(3) 20 kHz

(4) 10 MHz

Sol. Answer (3)

Amplitude modulate wave is,

$y(t) = 10[1 + 0.4\cos(2\pi \times 10^4 t)]\sin(2\pi \times 10^7 t)$

$w_m = 2\pi \times 10^4$

$\Rightarrow f_m = 10^4$

Bandwidth = $2f_m = 2 \times 10^4$ Hz

$= 20$ kHz

17. The temperature of a sample of gaseous O_2 is doubled such that O_2 dissociates into O. Find the ratio of new v_{rms} to old v_{rms}.

(1) 2

(2) $\sqrt{2}$

(3) 4

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

Sol. Answer (1)

$$v_{rms} = \sqrt{\frac{3RT}{M_0}}$$

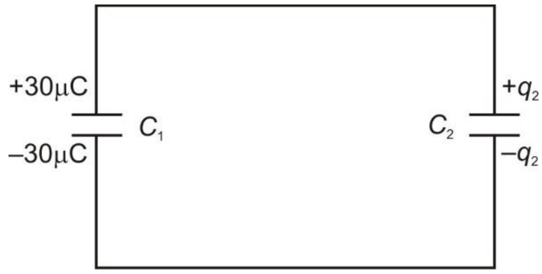
$$\frac{v_{rms_1}}{v_{rms_2}} = \sqrt{\frac{T_1}{T_2}}\sqrt{\frac{M_0}{M_{0_2}}}$$

$$\frac{v_{rms_1}}{v_{rms_2}} = \sqrt{\frac{T}{2T}}\sqrt{\frac{\frac{M}{2}}{M}}$$

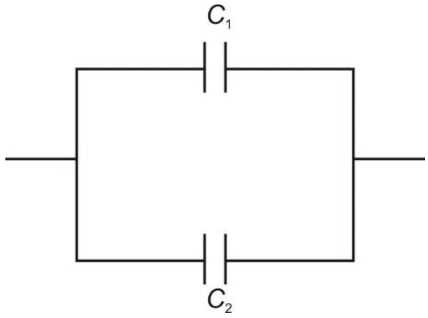
$$\frac{v_{rms_1}}{v_{rms_2}} = \frac{1}{2}$$

$$\frac{v_{rms_2}}{v_{rms_1}} = \frac{2}{1}$$

18. A capacitor (C_1) of capacity $3\mu F$ and another capacitor (C_2) of capacity $5\mu F$ are connected as shown. Find the value of q_2 (in μC)

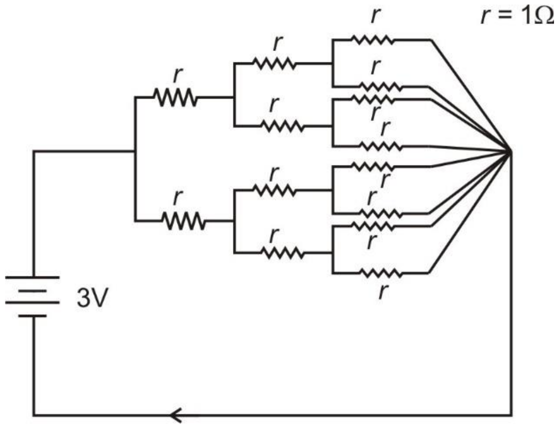


Sol. Answer (50.00)



$v_{c_1} = v_{c_2}$

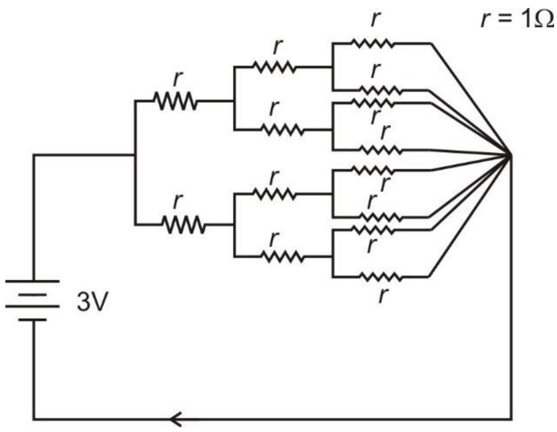
$$\frac{30\mu C}{3\mu F} = \frac{q_2}{5\mu F} \Rightarrow q_2 = 50\mu C$$

19. 

$I = \frac{a}{7}$ Amp

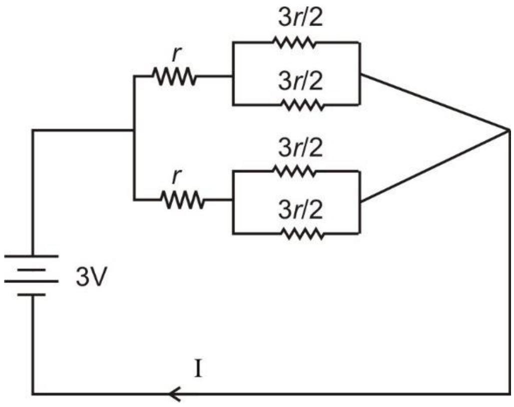
In the circuit shown above, find the value of a.

Sol. Answer (24.00)



$I = \frac{a}{7}$ Amp

⇓



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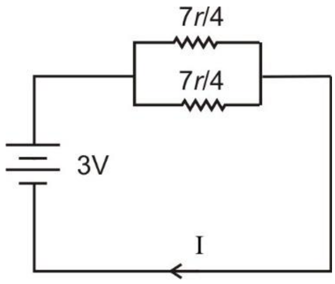

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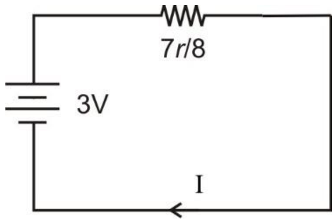
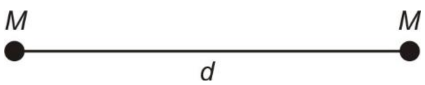


So, $\mathrm{I} = \dfrac{3}{\frac{7}{8}(1)} = \dfrac{24}{7}\,\text{A}$

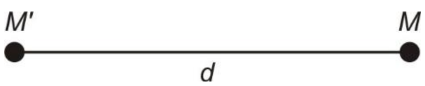
20. Consider two particles of equal mass and at separation r. How many times the force between them increases when mass of one of the particles becomes 3 times maintaining same separation?

Sol. Answer (03.00)



$$F = \frac{GM^2}{d^2}$$

Now,



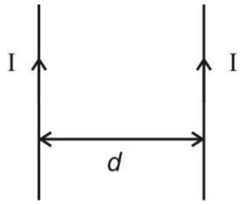
$$M' = 3M$$

$$F' = \frac{3GM^2}{d^2}$$

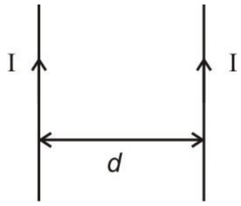
$$F' = 3F$$

21. Two parallel wires carry same magnitude current that is a. Distance between two wires is given as d. The force per unit length experienced by the wires (in 10^{-7} N) is equal to ____.

(a = 1 A, d = 4 cm)



Sol. Answer (50.00)



Force per unit length between two parallel conductors is

$$\frac{F}{\ell} = \frac{\mu_0 \mathrm{I}_1 \mathrm{I}_2}{2\pi d} = \frac{4\pi \times 10^{-7} \times 1 \times 1}{2\pi \times 4 \times 10^{-2}}$$

$$= \frac{200}{4} \times 10^{-7}\,\text{N}$$

$$= 50 \times 10^{-7}\,\text{N}$$

22. Half-life of radio-active substance is 200 days then the percentage of substance remaining after 83 days is

$$\left(\frac{1}{2^{0.415}} = 0.75\right)$$

Sol. Answer (75.00)

$$N = N_0 e^{-\lambda t} = N_0 e^{-\frac{\ln 2}{t_{1/2}} t}$$

$$N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

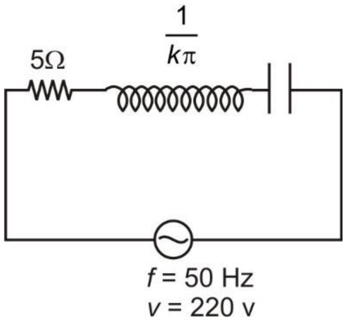
$$N = N_0 \left(\frac{1}{2}\right)^{\frac{83}{200}} = 0.75\, N_0$$

$$\%N = 75\%$$

23. In series RLC circuit voltage across capacitance and inductance is twice that of resistance. If

R = 5 ohm, v = 220 v, f = 50 Hz. If $L = \frac{1}{k\pi}$ then, the value of k is (in mH^{-1})

Sol. Answer (10.00)



$\because v_L = 2v_R \quad \therefore v_L = v_c$

$v_c = 2v_R$ that means circuit is in resonance.

$\therefore v_R = v$

$v_L = 2(220)$

$\Rightarrow iX_L = 2\times 220$

$\Rightarrow \left(\frac{220}{5}\right)\omega L = 2\times 220$

$\Rightarrow \omega L = 10 \Rightarrow 2\pi(50).\frac{1}{k\pi} = 10$

$\Rightarrow k = 10$

24. A coil is placed in a constant time varying magnetic field. If the no. of turns are halved and the radius of the coil is doubled. Then the ratio of power dissipated is:

Sol. Answer (04.00)

$\because \phi = N(\vec{B}.\vec{A})$

$or\ \phi = NB\pi R^2$

$\because \text{Power} = \frac{v^2}{R} \Rightarrow \text{Power} \propto \left(\frac{d\phi}{dt}\right)^2$

$\text{Power} \propto (NR^2)^2$

$\frac{P_1}{P_2} = \frac{(NR^2)^2}{\left[\frac{N}{2}.(2R)^2\right]^2} = \left(\frac{1}{2}\right)^2$

$P_2 = 4P_1$

25. A plane polarised electromagnetic wave moving along x-axis with speed c, if the frequency of wave is 10^6 Hz and amplitude of electric field $E_0 = 60\text{ N/C}\ \hat{j}$. Which of the following option correctly describes B as a function x and t

(1) $-\frac{60}{C}\hat{k}\sin\left(2\times 10^6\pi\left(t-\frac{x}{C}\right)\right)$

(2) $\frac{60}{C}\hat{k}\sin\left(2\times 10^6\pi\left(t-\frac{x}{C}\right)\right)$

(3) $-60C\hat{k}\sin\left(2\times 10^6\pi\left(t-\frac{x}{C}\right)\right)$

(4) $60C\hat{k}\sin\left(2\times 10^6\pi\left(t-\frac{x}{C}\right)\right)$

Sol. Answer (2)

$|B_0| = \frac{E_0}{C}$

$\hat{E} = -(\hat{V}\times\hat{B})$

$\hat{E} = -\hat{V}\times\hat{B}$

26. Angular acceleration of a body is given by $\alpha = 6t^2 + 2t$.

If $\omega(t=0) = 10$ rad/s, $\theta(t=0) = 4$ rad . Find $\theta(t) =$

(1) $4 + 10t + \frac{t^4}{2} + \frac{t^3}{3}$

(2) $14 + 10t + \frac{t^4}{2} + \frac{t^3}{3}$

(3) $16 + 10t + \frac{t^4}{2} + \frac{t^3}{3}$

(4) $4 - 10t + \frac{t^4}{2} + \frac{t^3}{3}$

Sol. Answer (1)

$\frac{d\omega}{dt} = 6t^2 + 2t$

$\int_{10}^{w} d\omega = \int_0^t (6t^2 + 2t)dt$

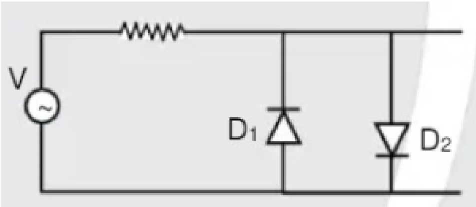
$\omega - 10 = 2t^3 + t^2$

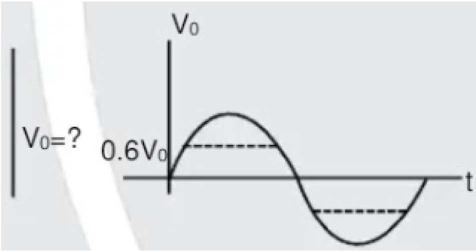
$\omega = 10 + 2t^3 + t^2$

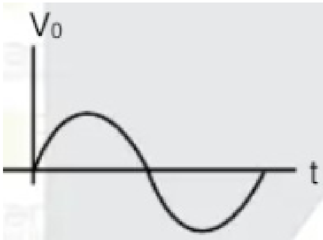
$\int_4^{\theta} d\theta = \int_0^t (10 + 2t^3 + t^2)dt$

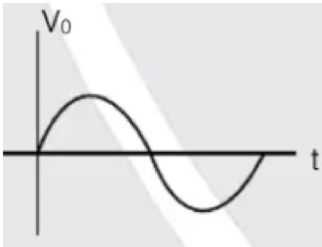
$\theta = 4 + 10t + \frac{t^4}{2} + \frac{t^3}{3}$

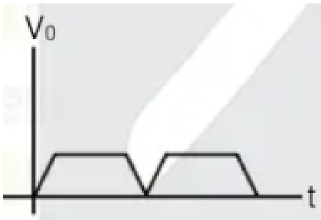
27. Depict the output of the following clipper circuit for the sinusoidal input. (Given cut-off voltage of diode = 0.6 V)

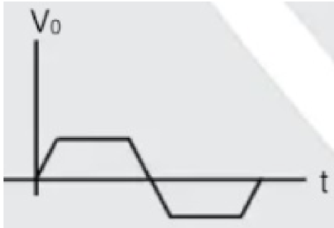




(1) 

(2) 

(3) 

(4) 

Sol. Answer (4)

Between $0 \le t \le \frac{T}{2}$

$D_2 \rightarrow$ Forward biased [for V > 0.6]

$D_1 \rightarrow$ Reverse biased

So, for 0 < V < 0.6 [Both diodes won't let current to pass/i.e. both diodes behave as open circuit element]

For $V > 0.6$ [D_2 becomes short circuited]

For $\frac{T}{2} < t < T$

$D_2 \rightarrow$ Reverse biased

$D_1 \rightarrow$ Forward biased [for $|v| > 0.6$]