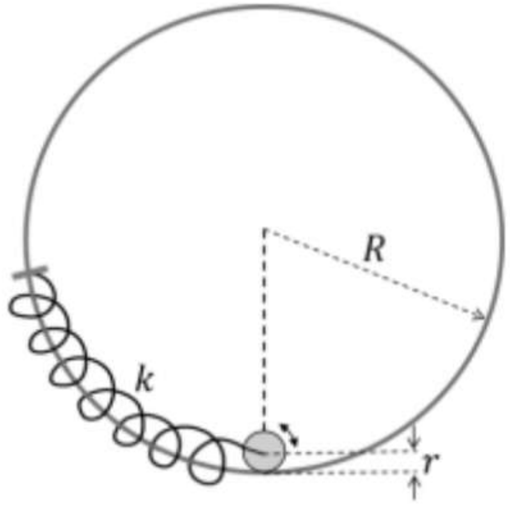
1. The center of a disk of radius r and mass m is attached to a spring of spring constant k, inside a ring of radius $R > r$ as shown in the figure. The other end of the spring is attached on the periphery of the ring. Both the ring and the disk are in the same vertical plane. The disk can only roll along the inside periphery of the ring, without slipping. The spring can only be stretched or compressed along the periphery of the ring, following the Hooke's law. In equilibrium, the disk is at the bottom of the ring. Assuming small displacement of the disc, the time period of oscillation of center of mass of the disk is written as $T = 2\pi / \omega$. The correct expression for ω is (g is the acceleration due to gravity)



(A)	$\sqrt{\frac{2}{3}\left(\frac{g}{R-r}+\frac{k}{m}\right)}$	(B)	$\sqrt{\frac{2g}{3(R-r)}+\frac{k}{m}}$
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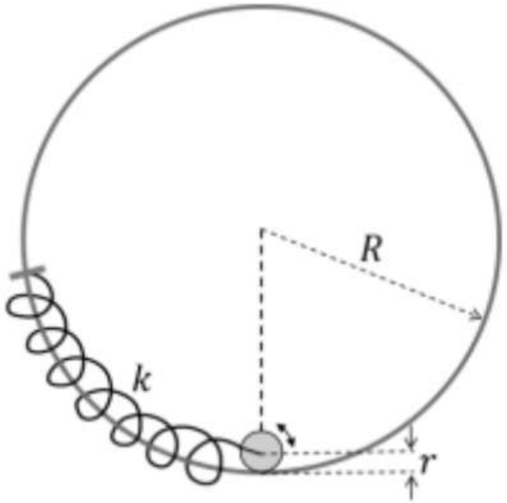

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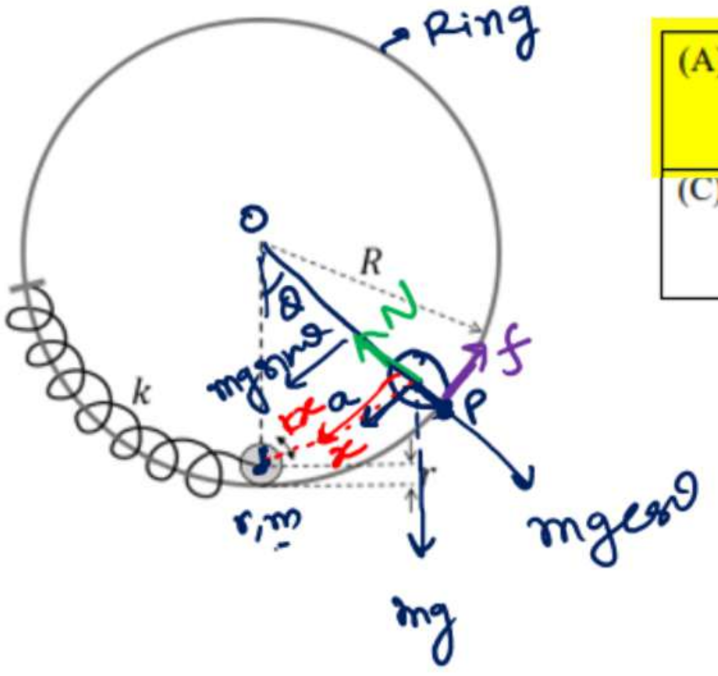

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without slipping → pure rolling

↓

$a = r\alpha$

τ about IAOR

f, N → No torque

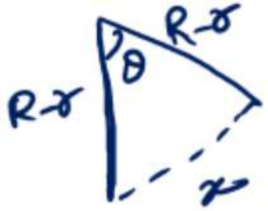
$\tau = I\alpha$

$I_p = I_{cm} + Mh^2$

$= \frac{1}{2}mr^2 + mr^2$

$= \frac{3}{2}mr^2$

$kx\,r + mg\sin\theta\, r = \frac{3}{2}mr^2 \frac{a}{r}$



$\theta = \frac{x}{R-r}$

$x = (R-r)\theta$

$k(R-r)\theta\, r + mg\,\theta\, r = \frac{3}{2}m r a$

$a = \frac{2}{3}\left[\frac{k(R-r)\theta + mg\theta}{m}\right]$

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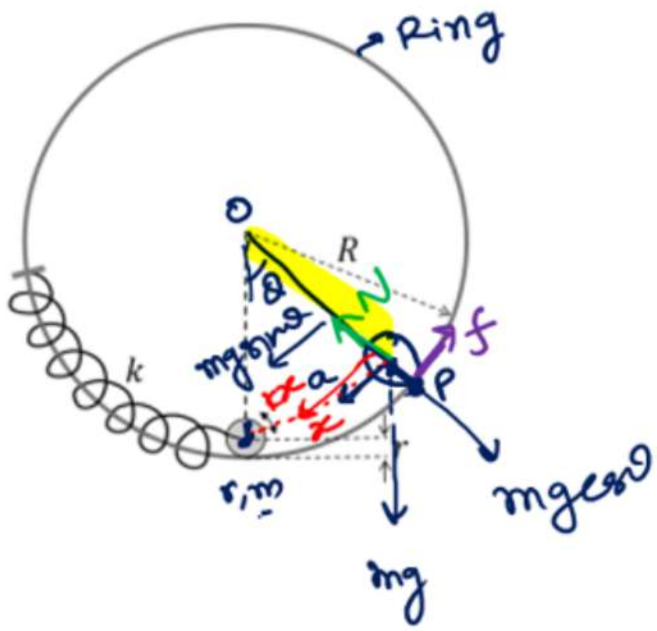

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$$a = \frac{2}{3}\left[\frac{k(R-r)\theta + mg\theta}{m}\right]$$

$$a = (R-r)\alpha$$

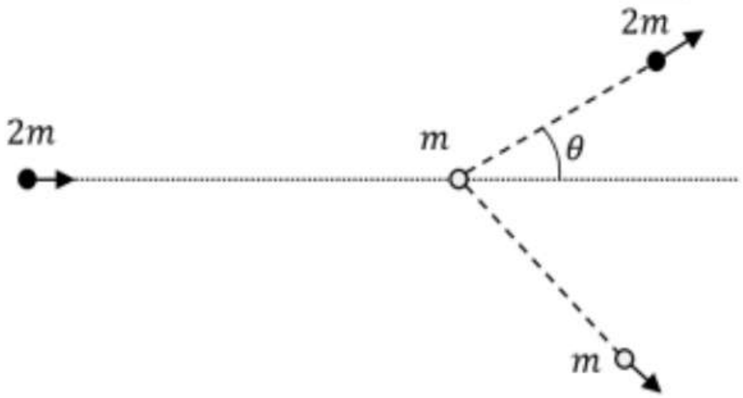
$$\alpha = \omega^2\theta$$

$$(R-r)\alpha = \frac{2}{3}\left[\frac{k(R-r)\theta}{m} + g\theta\right]$$

$$\alpha = \frac{2}{3}\left[\frac{k}{m} + \frac{g}{R-r}\right)\theta$$

$$\omega = \sqrt{\frac{2}{3}\left(\frac{k}{m}+\frac{g}{R-r}\right)}$$

2. In a scattering experiment, a particle of mass $2m$ collides with another particle of mass m, which is initially at rest. Assuming the collision to be perfectly elastic, the maximum angular deviation θ of the heavier particle, as shown in the figure, in radians is:



(A)	π	(B)	$\tan^{-1}\left(\frac{1}{2}\right)$	(C)	$\frac{\pi}{3}$	(D)	$\frac{\pi}{6}$

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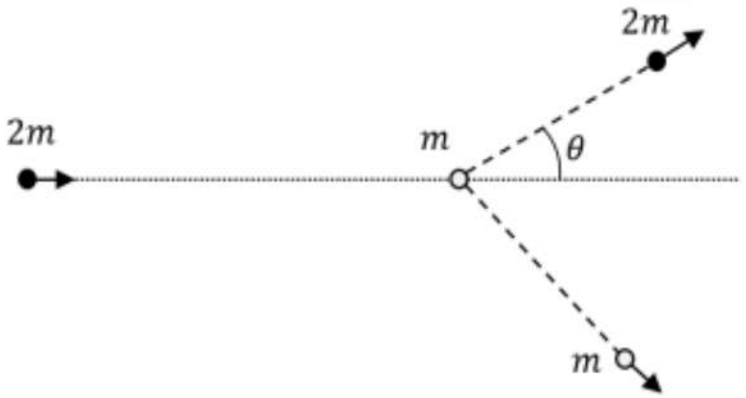

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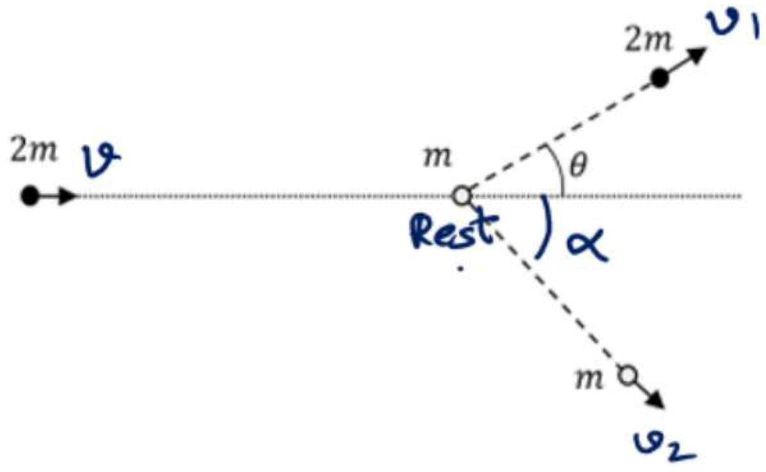

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$2v^2 = 2v_1^2 + v_2^2$ --- ①

$2v = 2v_1\cos\theta + v_2\cos\alpha$ --- ②

$0 = 2v_1\sin\theta - v_2\sin\alpha$ --- ③

$4v^2 + 4v_1^2 - v_2^2 - 8vv_1\cos\theta = 0$ --- ④

1 + 4

$6v_1^2 + 4v^2 - 8vv_1\cos\theta = 2v^2$

$6v_1^2 + 2v^2 - 8vv_1\cos\theta = 0$

$3v_1^2 + v^2 - 4vv_1\cos\theta = 0$ ---- ⑤

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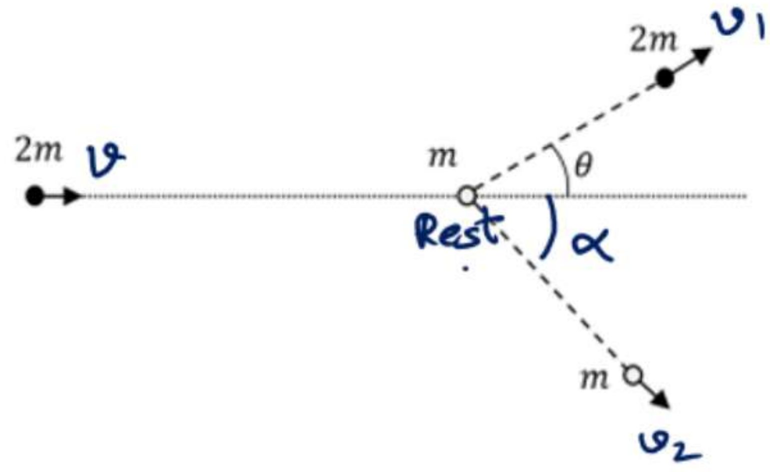

(A)	π	(B)	$\tan^{-1}\left(\frac{1}{2}\right)$	(C)	$\frac{\pi}{3}$	(D)	$\frac{\pi}{6}$

elastic → P & K.E. conserved, $\theta = ?$

$\frac{1}{2} \cdot 2m v^2 = \frac{1}{2} 2m v_1^2 + \frac{1}{2} m v_2^2$

$2v^2 = 2v_1^2 + v_2^2$ -- ①

$2mv = 2m v_1 \cos\theta + m v_2 \cos\alpha$

$2v = 2v_1 \cos\theta + v_2 \cos\alpha$ -- ②

$0 = 2m v_1 \sin\theta - m v_2 \sin\alpha$

$0 = 2v_1 \sin\theta - v_2 \sin\alpha$ -- ③

eq³ square $4v_1^2 \sin^2\theta = v_2^2 \sin^2\alpha$

eqⁿ 2 → $2v = 2v_1 \cos\theta + v_2 \sqrt{1 - \sin^2\alpha}$

$2v = 2v_1 \cos\theta + v_2 \sqrt{1 - \frac{4v_1^2 \sin^2\theta}{v_2^2}}$

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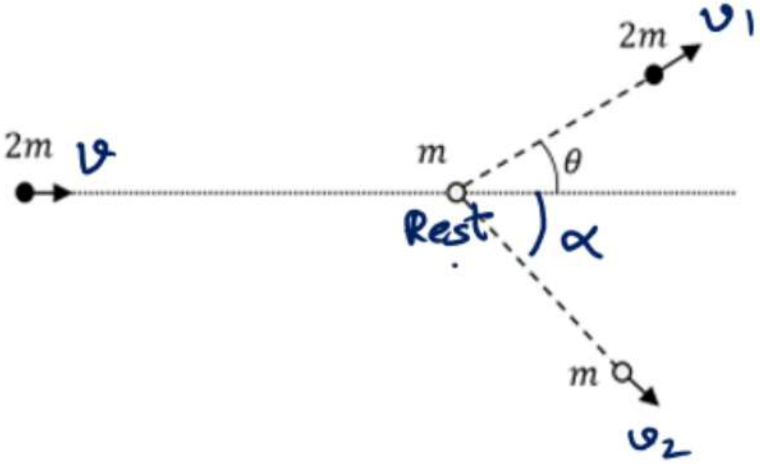

(A)	π	(B)	$\tan^{-1}\left(\frac{1}{2}\right)$	(C)	$\frac{\pi}{3}$	(D)	$\frac{\pi}{6}$

$$2v = 2v_1\cos\theta + \sqrt{v_2^2 - 4v_1^2\sin^2\theta}$$

$$2v - 2v_1\cos\theta = \sqrt{v_2^2 - 4v_1^2\sin^2\theta}$$

$$4v^2 + 4v_1^2\cos^2\theta - 8vv_1\cos\theta = v_2^2 - 4v_1^2\sin^2\theta$$

$$4v^2 + 4v_1^2 - v_2^2 - 8vv_1\cos\theta = 0 \quad \text{---} \quad (4)$$

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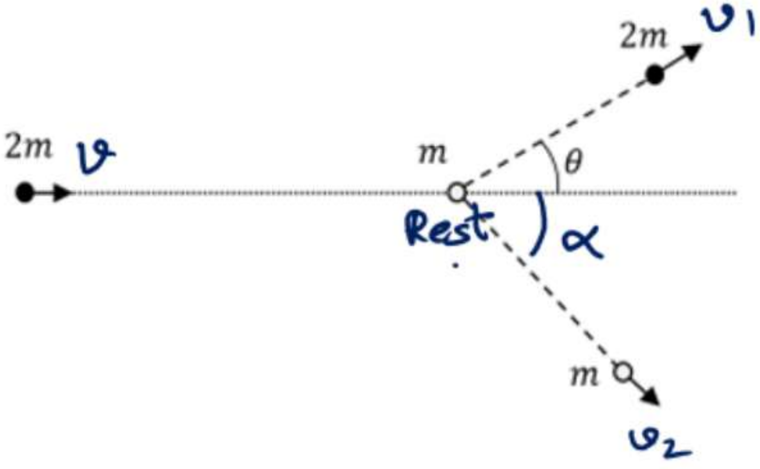


(A)	π	(B)	$\tan^{-1}\left(\frac{1}{2}\right)$	(C)	$\frac{\pi}{3}$	(D)	$\frac{\pi}{6}$

for the m^n of 2m, its speed v_1 Real no.

discrimant ≥ 0

$b^2 - 4ac \geq 0$

$(4v\cos\theta)^2 - 4.3.v^2 \geq 0$

$16 v^2 \cos^2\theta \geq 12 v^2$

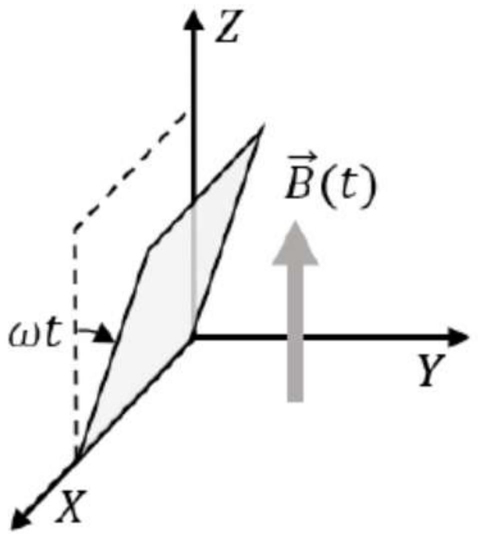
$\cos^2\theta \geq \frac{\cancel{12}\,3}{\cancel{16}\,4}$

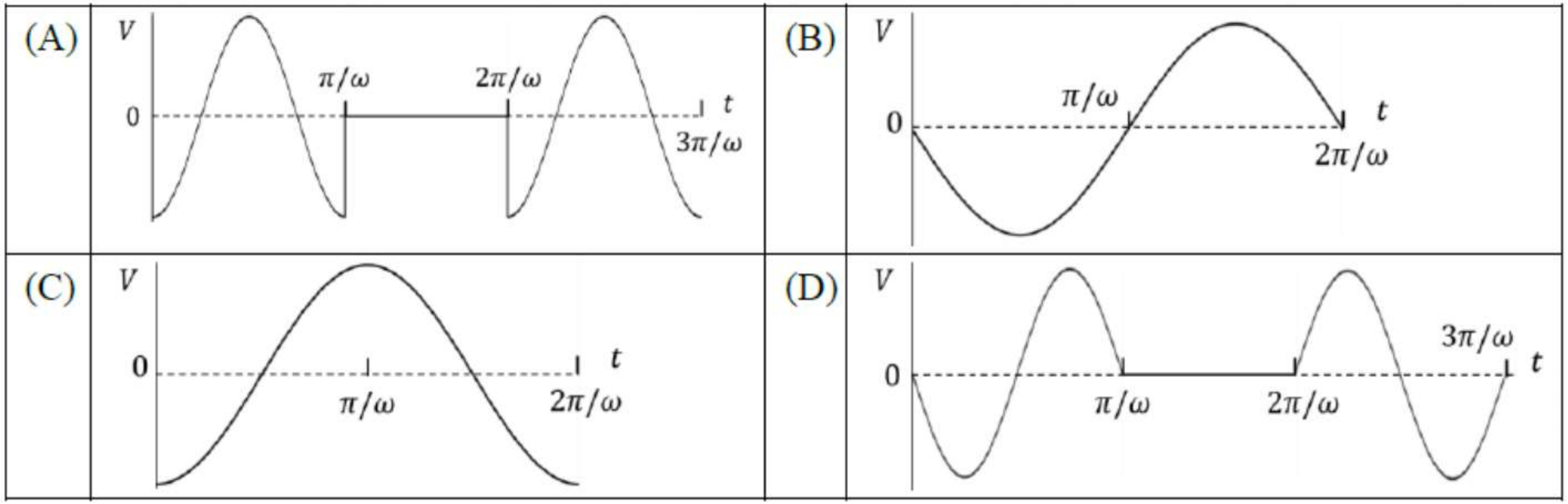
$\cos\theta \geq \frac{\sqrt{3}}{2} \Rightarrow \theta \leq \pi/6$

$3v_1^2 + v^2 - 4 v v_1 \cos\theta = 0$ ---- (5)

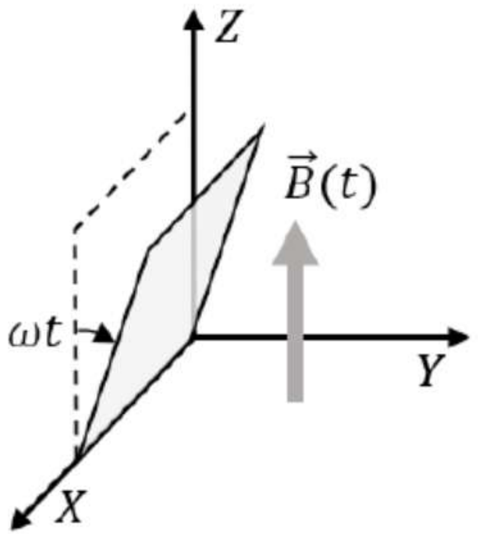
$ax^2 + c + bx = 0$

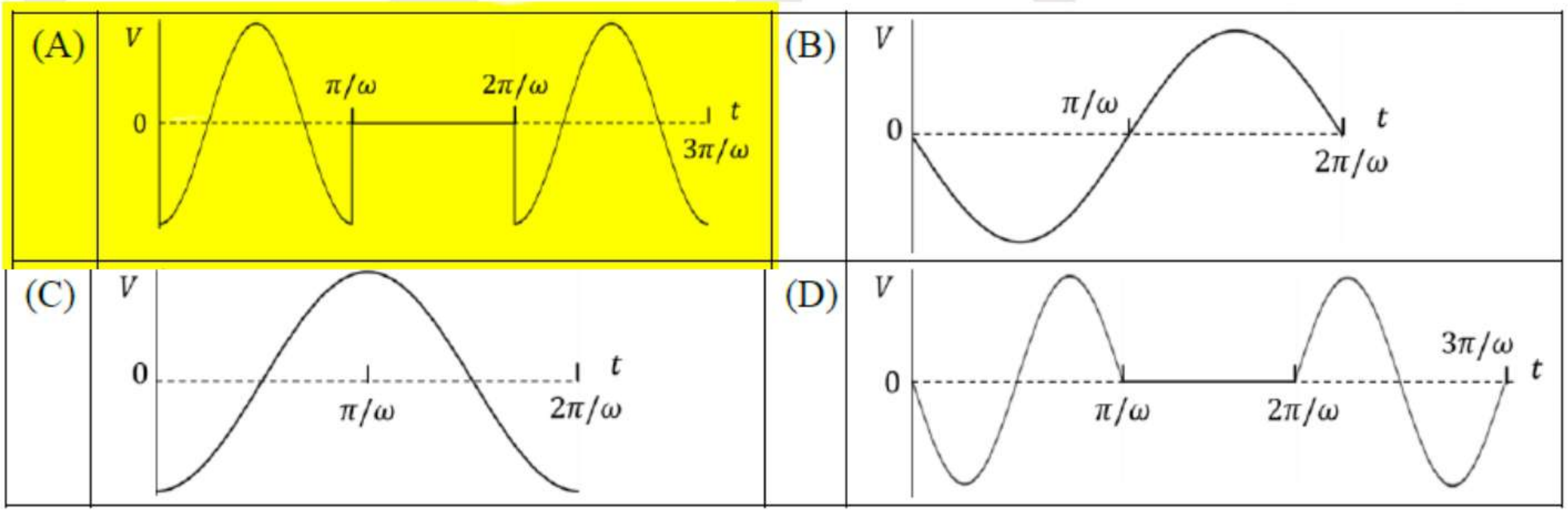
3. A conducting square loop initially lies in the XZ plane with its lower edge hinged along the X-axis. Only in the region $y \geq 0$, there is a time dependent magnetic field pointing along the Z-direction, $B(t) = B_0(\cos \omega t)\,k$, where B_0 is a constant. The magnetic field is zero everywhere else. At time $t = 0$, the loop starts rotating with constant angular speed ω about the X axis in the clockwise direction as viewed from the $+X$ axis (as shown in the figure). Ignoring self-inductance of the loop and gravity, which of the following plots correctly represents the induced e.m.f. (V) in the loop as a function of time:





3. A conducting square loop initially lies in the XZ plane with its lower edge hinged along the X-axis. Only in the region y ≥ 0, there is a time dependent magnetic field pointing along the Z-direction, $B(t) = B_0 (\cos \omega t)\, k$, where B_0 is a constant. The magnetic field is zero everywhere else. At time t = 0, the loop starts rotating with constant angular speed ω about the X axis in the clockwise direction as viewed from the $+X$ axis (as shown in the figure). Ignoring self-inductance of the loop and gravity, which of the following plots correctly represents the induced e.m.f. (V) in the loop as a function of time:





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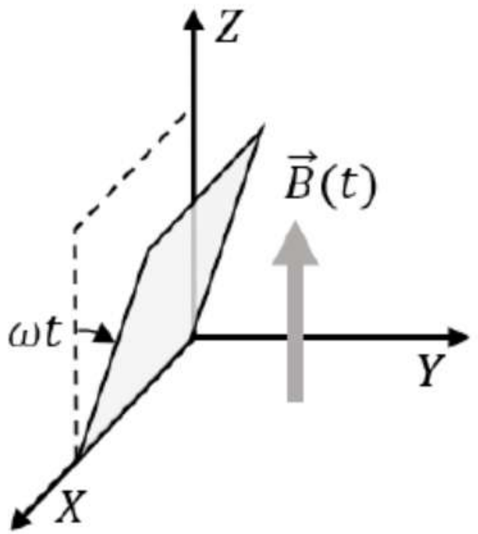
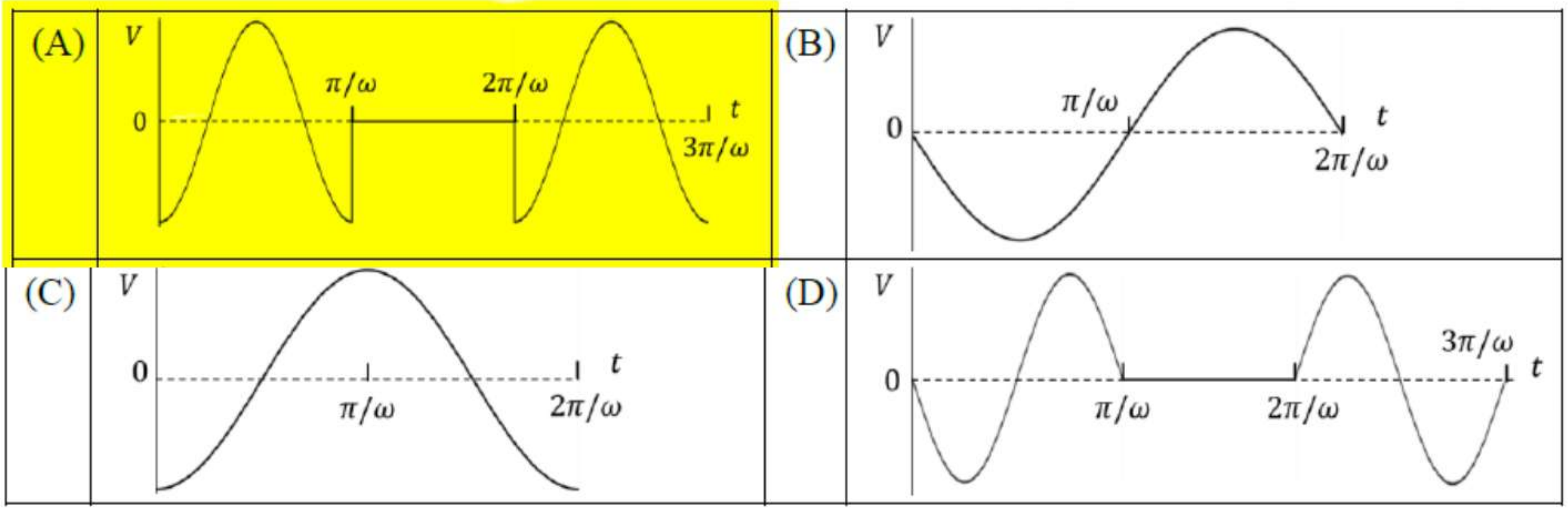
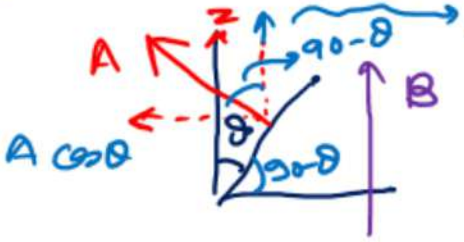




$B = B_0 \cos\omega \hat{k}$

$\phi = \vec{B} \cdot \vec{A}$

Let Area of square loop is A , $\theta = \omega t$



Time to rotate loop in 1 turn = $\frac{2\pi}{\omega}$

induced emf will remain for half turn up to time = π/ω

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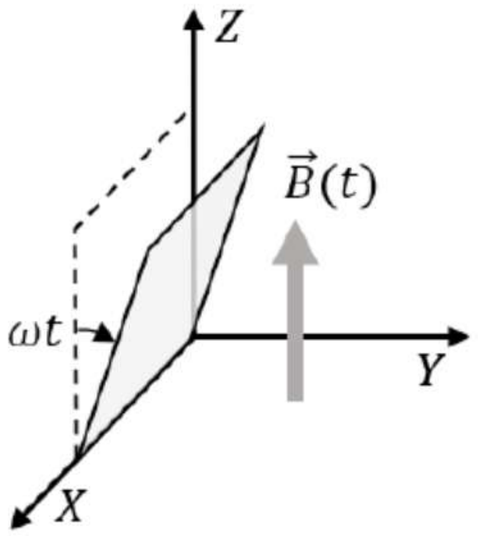

$\phi = B_0 \cos\omega t \; A \sin\omega t = A B_0 \cos\omega t \sin\omega t \times \frac{2}{2}$

$\phi = \frac{B_0 A}{2} \sin 2\omega t$

$e = -\frac{d\phi}{dt} = -2\omega \frac{B_0 A}{2} \cos 2\omega t$

$e = -B_0 A \omega \cos 2\omega t$

$e = -B_0 A \omega \cos 2\omega t$, $\rightarrow$ time pd. of this function $= \frac{2\pi}{2\omega} = \pi/\omega$

4. Figure 1 shows the configuration of main scale and Vernier scale before measurement. Fig. 2 shows the configuration corresponding to the measurement of diameter D of a tube. The measured value of D is:

(A) 0.12 cm
(B) 0.11 cm
(C) 0.13 cm
(D) 0.14 cm

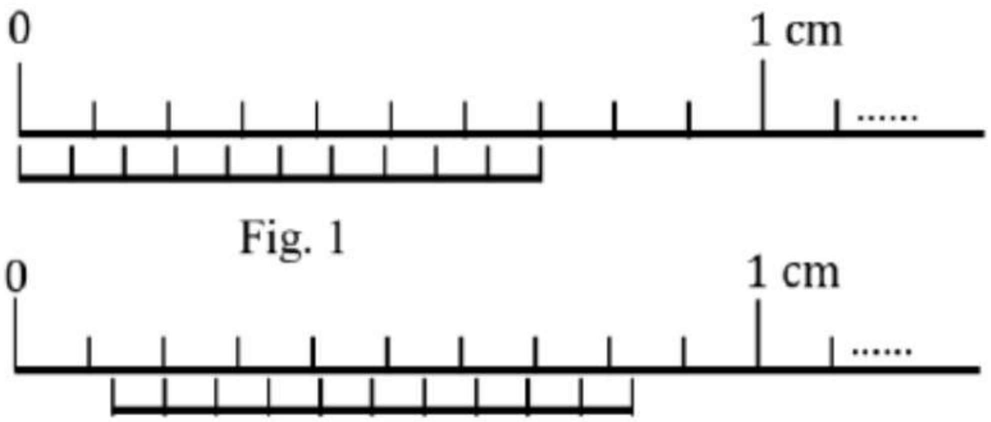

Fig. 1

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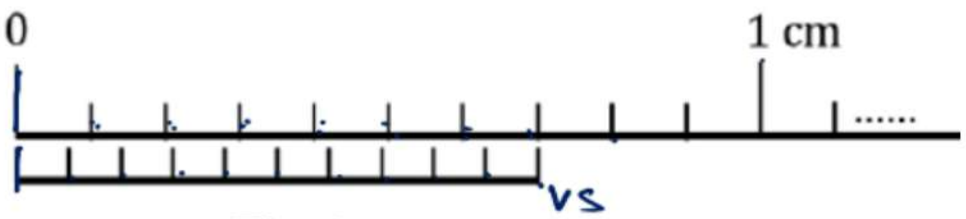


Fig. 1

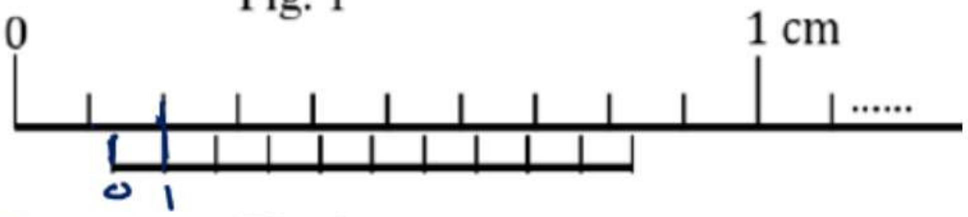


Fig. 2

No zero error

$1 MSD = \frac{1}{10} cm = 0.1 cm$

$10 VSD = 7 MSD$

$1 VSD = \frac{7}{10} MSD = \frac{7}{10} \times \frac{1}{10} = 0.07 cm$

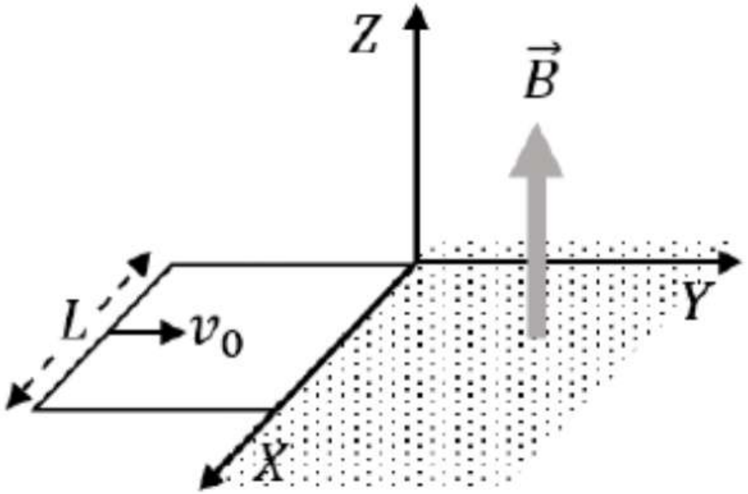
$LC = 1 MSD - 1 VSD = 0.1 - 0.07 = 0.03 cm$

$TR.\Omega\ D = M.S. + (VR \times LC)$

$= 0.1 cm + (1 \times 0.03) cm$

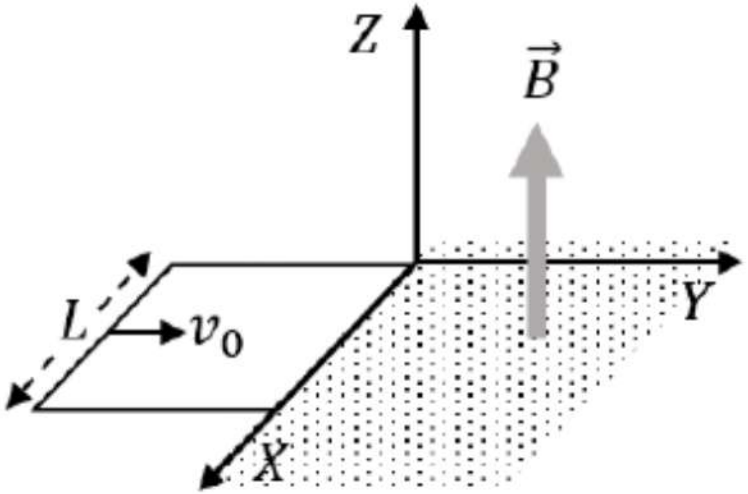
$= 0.1 + 0.03 = 0.13 cm$

5. A conducting square loop of side L, mass M and resistance R is moving in the XY plane with its edges parallel to the X and Y axes. The region $y \geq 0$ has a uniform magnetic field $B = B_0\, k$. The magnetic field is zero everywhere else. At time $t = 0$, the loop starts to enter the magnetic field with an initial velocity $v_0\, j$ m/s, as shown in the figure. Considering the quantity $K = (B_0^2 L^2) / (RM)$ in appropriate units, ignoring self-inductance of the loop and gravity, which of the following statements is/are correct:



(A)	If $v_0 = 1.5KL$, the loop will stop before it enters completely inside the region of magnetic field.
(B)	When the complete loop is inside the region of magnetic field, the net force acting on the loop is zero.
(C)	If $v_0 = \frac{KL}{10}$, the loop comes to rest at $t = \left(\frac{1}{K}\right)\ln\left(\frac{5}{2}\right)$.
(D)	If $v_0 = 3KL$, the complete loop enters inside the region of magnetic field at time $t = \left(\frac{1}{K}\right)\ln\left(\frac{3}{2}\right)$.

5. A conducting square loop of side L, mass M and resistance R is moving in the XY plane with its edges parallel to the X and Y axes. The region $y \geq 0$ has a uniform magnetic field $B = B_0\, k$. The magnetic field is zero everywhere else. At time $t = 0$, the loop starts to enter the magnetic field with an initial velocity $v_0\, j$ m/s, as shown in the figure. Considering the quantity $K = (B_0^2 L^2) / (RM)$ in appropriate units, ignoring self-inductance of the loop and gravity, which of the following statements is/are correct:



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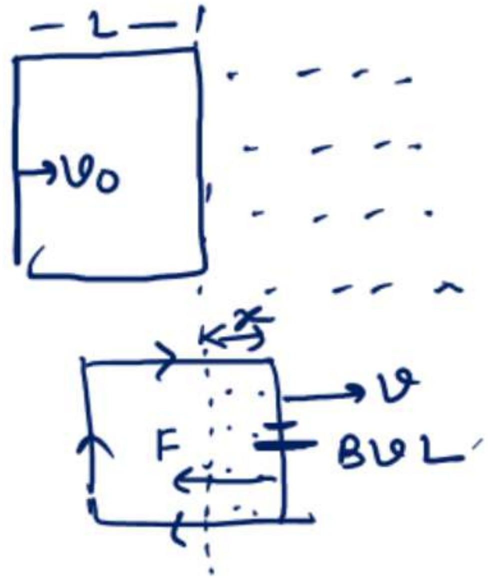
Answer : B,D



$$a = -\frac{B^2 v L^2}{mR}$$

$$a = -kv$$

$$v\frac{dv}{dx} = -kv$$

$$\int_{v_0}^{v} dv = -k\int_0^x dx$$

$$v - v_0 = -kx$$

$$v = v_0 - kx$$

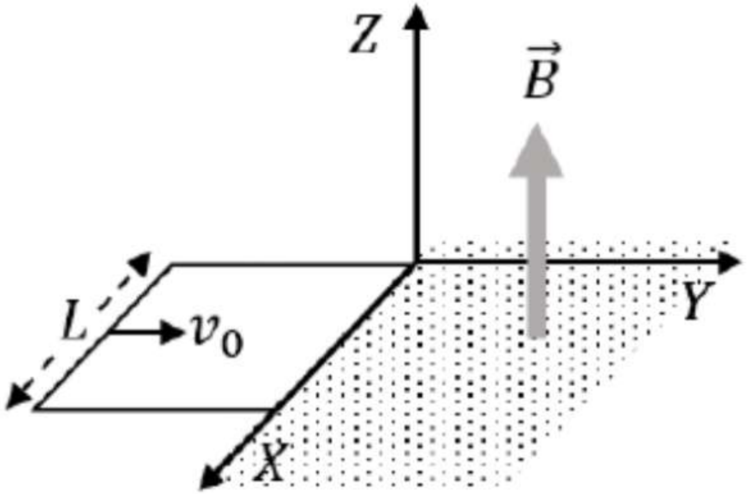
$$\frac{dv}{dt} = -kv$$

$$\int_{v_0}^{v} \frac{dv}{v} = -k\int_0^t dt$$

$$\ln\frac{v}{v_0} = -kt$$

$$v = v_0 e^{-kt}$$

5. A conducting square loop of side L, mass M and resistance R is moving in the XY plane with its edges parallel to the X and Y axes. The region y ≥ 0 has a uniform magnetic field B = B_0 k . The magnetic field is zero everywhere else. At time t = 0, the loop starts to enter the magnetic field with an initial velocity v_0 j m/s, as shown in the figure. Considering the quantity K = ($B_0^2 L^2$) / (RM) in appropriate units, ignoring self-inductance of the loop and gravity, which of the following statements is/are correct:



(A)	If $v_0 = 1.5KL$, the loop will stop before it enters completely inside the region of magnetic field.

$v = v_0 - Kx$ ✓

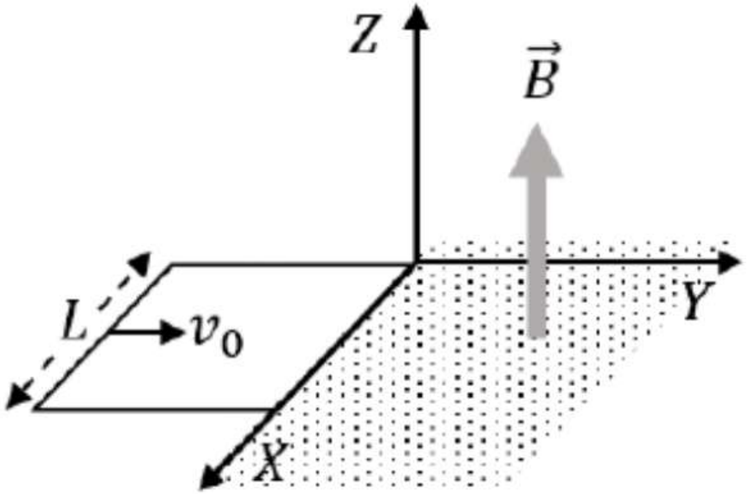
$v = v_0 e^{-Kt}$

$0 = 1.5KL - Kx$

$x = 1.5L$

$1.5L > L \rightarrow$ it means loop completely enter in mag. Field, but when it completely enter, then, mag. Field constant, no change in ϕ, no induced current, no force $F = i\ell B$, it means after enter completey speed is constant. after completely enter $v = v_0 - Kx$ & $v = v_0 e^{-Kt}$ not effective

5. A conducting square loop of side L, mass M and resistance R is moving in the XY plane with its edges parallel to the X and Y axes. The region y ≥ 0 has a uniform magnetic field B = B_0 k . The magnetic field is zero everywhere else. At time t = 0, the loop starts to enter the magnetic field with an initial velocity v_0 j m/s, as shown in the figure. Considering the quantity K = ($B_0^2L^2$) / (RM) in appropriate units, ignoring self-inductance of the loop and gravity, which of the following statements is/are correct:



(B)	When the complete loop is inside the region of magnetic field, the net force acting on the loop is zero.

$v = v_0 - Kx$

$v = v_0 e^{-Kt}$

B = K

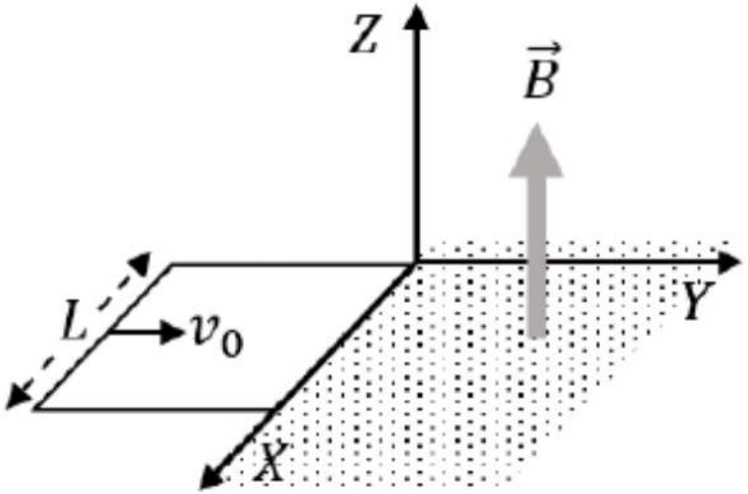
ϕ = No change

$e = 0$

$i_{induced} = 0$

$F = i l B = 0$

5. A conducting square loop of side L, mass M and resistance R is moving in the XY plane with its edges parallel to the X and Y axes. The region $y \geq 0$ has a uniform magnetic field $B = B_0\, k$. The magnetic field is zero everywhere else. At time $t = 0$, the loop starts to enter the magnetic field with an initial velocity $v_0\, j$ m/s, as shown in the figure. Considering the quantity $K = (B_0^2 L^2) / (RM)$ in appropriate units, ignoring self-inductance of the loop and gravity, which of the following statements is/are correct:



(C)	If $v_0 = \frac{KL}{10}$, the loop comes to rest at $t = \left(\frac{1}{K}\right) \ln\left(\frac{5}{2}\right)$.

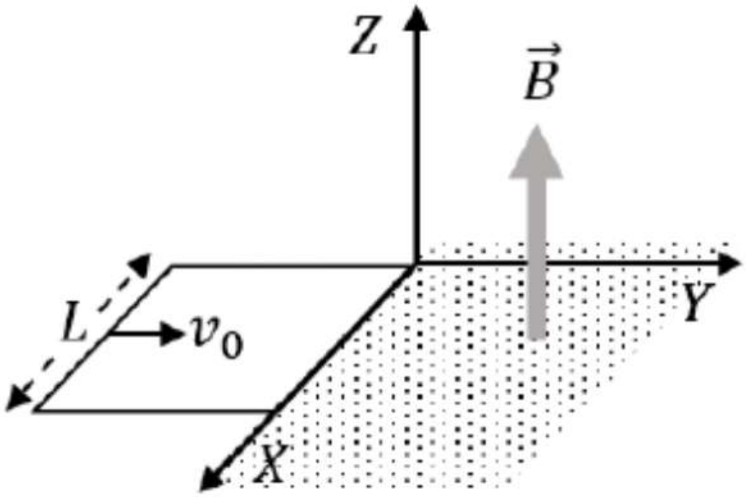
$v = v_0 - Kx$

$v = v_0 e^{-Kt}$

$y = e^{-x}$

$x \to +\infty$

$y \to 0$



(D)	If $v_0 = 3KL$, the complete loop enters inside the region of magnetic field at time $t = \left(\frac{1}{K}\right)\ln\left(\frac{3}{2}\right)$.

$v = v_0 - kx$

$v = v_0 e^{-kt}$

$v = 3kL - kL \quad (x = L)$

$v = 2kL$

$v = v_0 e^{-kt}$

$2kL = 3kL\, e^{-kt}$

$\frac{2}{3} = e^{-kt}$

$e^{kt} = \frac{3}{2}$

$kt = \ln\frac{3}{2}$

$t = \frac{1}{k}\ln 3/2$

6. Length, breadth and thickness of a strip having a uniform cross section are measured to be 10.5 cm, 0.05 mm, and 6.0 μm, respectively. Which of the following option(s) give(s) the volume of the strip in cm^3 with correct significant figures :

(A) 3.2×10^{-5}
(B) 32.0×10^{-6}
(C) 3.0×10^{-5}
(D) 3×10^{-5}

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(C) 3.0×10^{-5}
(D) 3×10^{-5}

$L = 10.5$ cm → sig. fig. → 3

$B = 0.05$ mm → sig. fig → 1

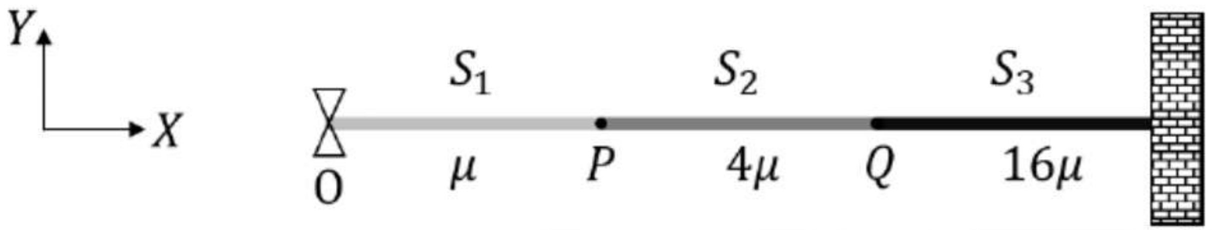
$H = 6.0$ μm → sig fig → 2

Volume = $L \times B \times H$

in multiplication, we req. answer in least sig. figure 1

(A) 3.2×10^{-5} → 2
(B) 32.0×10^{-6} → 3
(C) 3.0×10^{-5} → 2
(D) 3×10^{-5} → 1

7. Consider a system of three connected strings, S_1 , S_2 and S_3 with uniform linear mass densities μ kg/m, 4 μ kg/m and 16 μ kg/m, respectively, as shown in the figure. S_1 and S_2 are connected at the point P, whereas S_2 and S_3 are connected at the point Q, and the other end of S_3 is connected to a wall. A wave generator O is connected to the free end of S_1 . The wave from the generator is represented by $y = y_0 \cos(\omega t - kx)$ cm, where y_0,ω and k are constants of appropriate dimensions. Which of the following statements is/are correct :



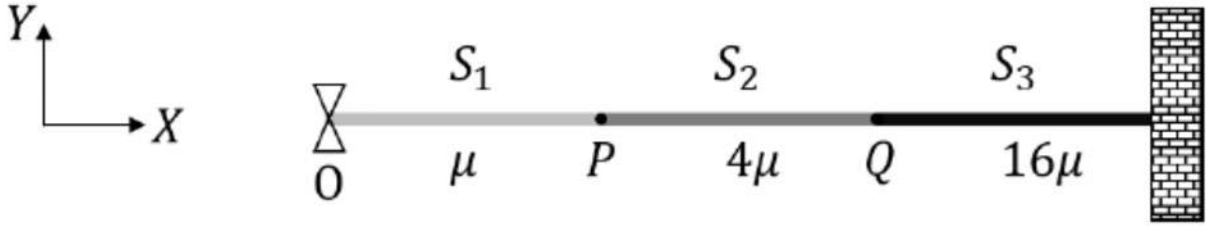
(A) When the wave reflects from P for the first time, the reflected wave is represented by $y = \alpha_1 y_0 \cos(\omega t + kx + \pi)$ cm, where α_1 is a positive constant.

(B) When the wave transmits through P for the first time, the transmitted wave is represented by $y = \alpha_2 y_0 \cos(\omega t - kx)$ cm, where α_2 is a positive constant.

(C) When the wave reflects from Q for the first time, the reflected wave is represented by $y = \alpha_3 y_0 \cos(\omega t - kx + \pi)$ cm, where α_3 is a positive constant.

(D) When the wave transmits through Q for the first time, the transmitted wave is represented by $y = \alpha_4 y_0 \cos(\omega t - 4kx)$ cm, where α_4 is a positive constant.

7. Consider a system of three connected strings, S_1 , S_2 and S_3 with uniform linear mass densities μ kg/m, 4 μ kg/m and 16 μ kg/m, respectively, as shown in the figure. S_1 and S_2 are connected at the point P, whereas S_2 and S_3 are connected at the point Q, and the other end of S_3 is connected to a wall. A wave generator O is connected to the free end of S_1 . The wave from the generator is represented by $y = y_0 \cos(\omega t - kx)$ cm, where y_0,ω and k are constants of appropriate dimensions. Which of the following statements is/are correct :



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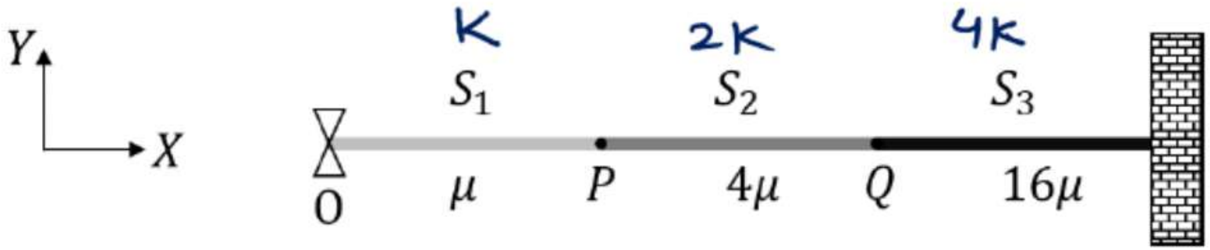
$v = \frac{\omega}{k} = \sqrt{\frac{T}{\mu}}$



if med. change, ω not change

$k \propto \sqrt{\mu}$

(A) When the wave reflects from P for the first time, the reflected wave is represented by $y = \alpha_1 y_0 \cos(\omega t + kx + \pi)$ cm, where α_1 is a positive constant.

1. $S_1 < S_2 < S_3$
   Rare → Dense medium
2. Tension in each string same bec. connected in series
3. free end O will be A.N
4. wave is travelling +x axis

$Y_i = y_0 \cos(\omega t - kx)$

reflected from dense med., so phase change of π

$Y_r = a_r y_0 \cos(\omega t + kx + \pi)$

7. Consider a system of three connected strings, S_1 , S_2 and S_3 with uniform linear mass densities μ kg/m, 4 μ kg/m and 16 μ kg/m, respectively, as shown in the figure. S_1 and S_2 are connected at the point P, whereas S_2 and S_3 are connected at the point Q, and the other end of S_3 is connected to a wall. A wave generator O is connected to the free end of S_1 . The wave from the generator is represented by $y = y_0 \cos(\omega t - kx)$ cm, where y_0,ω and k are constants of appropriate dimensions. Which of the following statements is/are correct :

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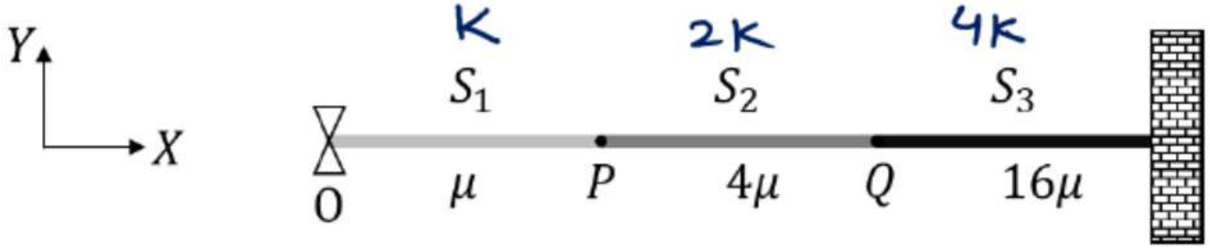

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$y = \alpha_2 y_0 \cos(\omega t - kx)$ cm, where α_2 is a positive constant.

1. $S_1 < S_2 < S_3$
Rare → Dense medium

$k \to 2k$

2. Tension in each string same
bec. connected in series

3. free end O will be A.N

4. wave is travelling +x axis

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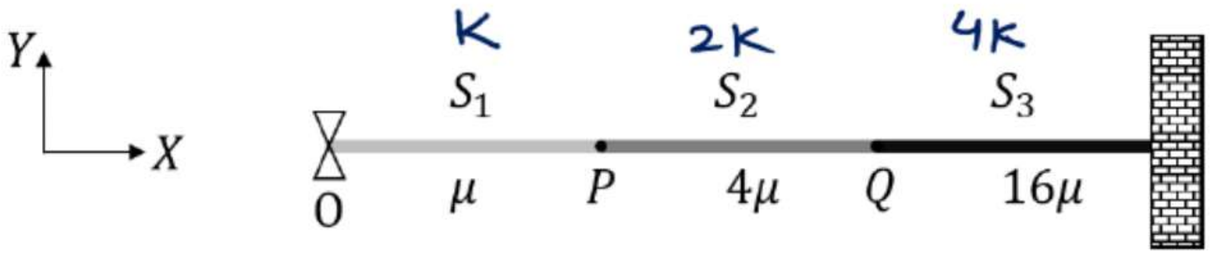

if med. change, ω not change

$K \propto \sqrt{\mu}$

(C) When the wave reflects from Q for the first time, the reflected wave is represented by
$y = \alpha_3\, y_0 \cos(\omega t - kx + \pi)$ cm, where α_3 is a positive constant.

1. $S_1 < S_2 < S_3$
   Rare → Dense medium

$k \rightarrow 2k$

2. Tension in each string same
   bec. connected in series
3. free end O will be A.N
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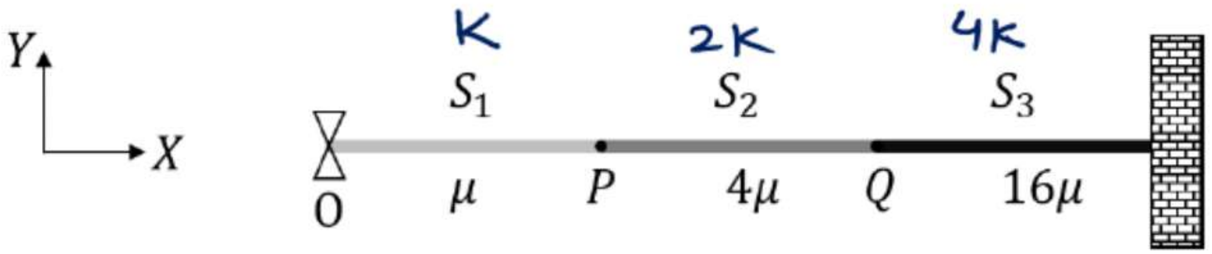

(D) When the wave transmits through Q for the first time, the transmitted wave is represented by $y = \alpha_4 y_0 \cos(\omega t - 4kx)$ cm, where α_4 is a positive constant.

1. $S_1 < S_2 < S_3$
   Rare → Dense medium
2. Tension in each string same
   bec. connected in series
3. Free end O will be A.N
4. wave is travelling +x axis

8. A person sitting inside an elevator performs a weighing experiment with an object of mass 50 kg. Suppose that the variation of the height y (in m) of the elevator, from the ground, with time t (in s) is given by ,

$$y = 8\left[1 + \sin\left(\frac{2\pi t}{T}\right)\right]$$

where T = 40 π s. Taking acceleration due to gravity, g = 10 m/s^2 , the maximum variation of the object's weight (in N) as observed in the experiment is ________

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(2)

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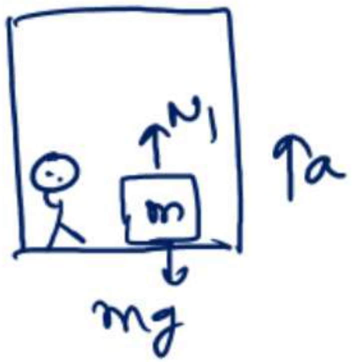


$N_1 - mg = ma$

$N_1 = mg + ma$

$g = 10\, m/s^2$

$m = 50\, kg$

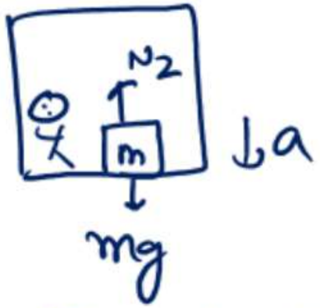
$y = 8 + 8 \sin \frac{2\pi t}{T}$

$y = y_0 + A \sin \omega t$

$y_0 =$ mean position

$A = 8\, m$

$\omega = \frac{2\pi}{T} = \frac{2\pi}{4\pi} = \frac{1}{2}$



$mg - N_2 = ma$

$N_2 = mg - ma$

$N_1 - N_2 = 2ma$

$a_{max} = \omega^2 A = \frac{1}{4} \times 8 = 2$

$N_1 - N_2 = 2$

9. A cube of unit volume contains 35×10^7 photons of frequency 10^{15} Hz. If the energy of all the photons is viewed as the average energy being contained in the electromagnetic waves within the same volume, then the amplitude of the magnetic field is $\alpha \times 10^{-9}$ T. Taking permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ Tm/A, Planck's constant $h = 6 \times 10^{-34}$ Js and $\pi = 22 / 7$, the value of α is ---------

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Answer : 21 to 25

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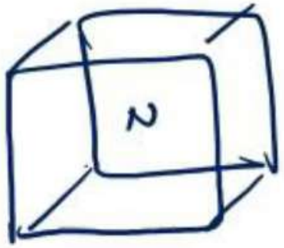


$V = 1\,m^3$

$N = 35 \times 10^7$

$\nu = 10^{15}\,Hz$

$\langle B \rangle = \frac{B^2}{4\mu_0}$

T.E. density $= \frac{1}{2}\frac{B^2}{\mu_0}$

$Nh\nu = \frac{B_0^2}{2\mu_0}$

$B_0^2 = 2Nh\nu\mu_0 = 2 \times \overset{5}{\cancel{35}} \times 10^7 \times 6 \times 10^{-34} \times 10^{15} \times 4 \times \frac{22}{\cancel{7}} \times 10^{-7}$

$B_0^2 = 528 \times 10^{-18}$

$B_0 = 22.97 \times 10^{-9}$

$\alpha = 22.97 \simeq 23$

10. Two identical plates P and Q, radiating as perfect black bodies, are kept in vacuum at constant absolute temperatures T_P and T_Q, respectively, with $T_Q < T_P$, as shown in Fig. 1. The radiated power transferred per unit area from P to Q is W_0. Subsequently, two more plates, identical to P and Q, are introduced between P and Q, as shown in Fig. 2. Assume that heat transfer takes place only between adjacent plates. If the power transferred per unit area in the direction from P to Q (Fig. 2) in the steady state is W_S, then the ratio w_0 / w_s is --------

Fig. 1

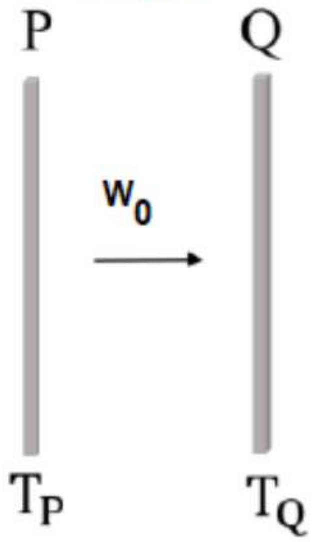
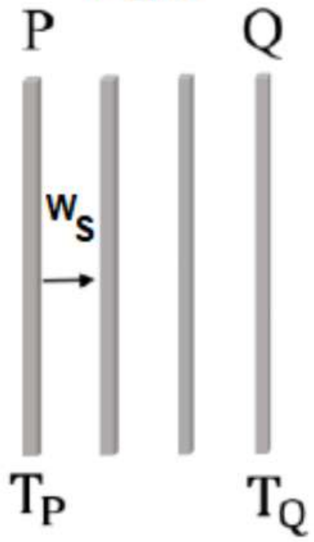
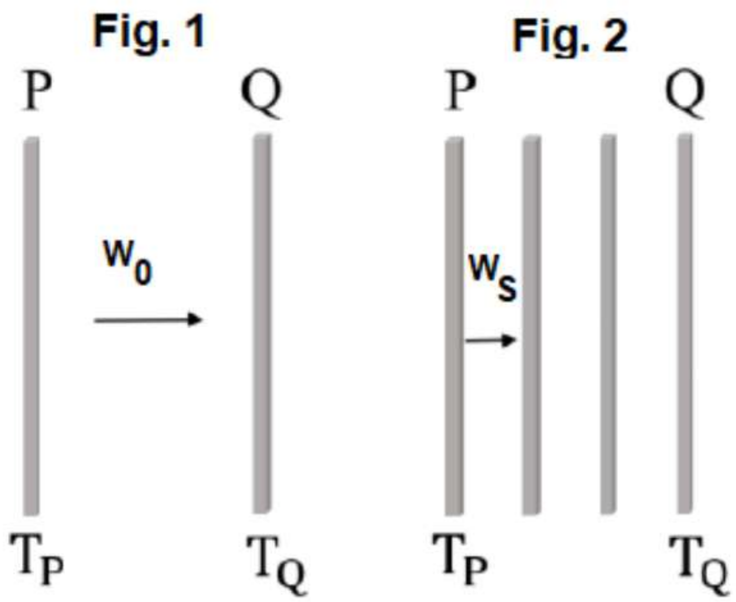


Fig. 2



10. Two identical plates P and Q, radiating as perfect black bodies, are kept in vacuum at constant absolute temperatures T_P and T_Q, respectively, with $T_Q < T_P$, as shown in Fig. 1. The radiated power transferred per unit area from P to Q is W_0. Subsequently, two more plates, identical to P and Q, are introduced between P and Q, as shown in Fig. 2. Assume that heat transfer takes place only between adjacent plates. If the power transferred per unit area in the direction from P to Q (Fig. 2) in the steady state is W_S, then the ratio w_0 / w_s is --------



(3)

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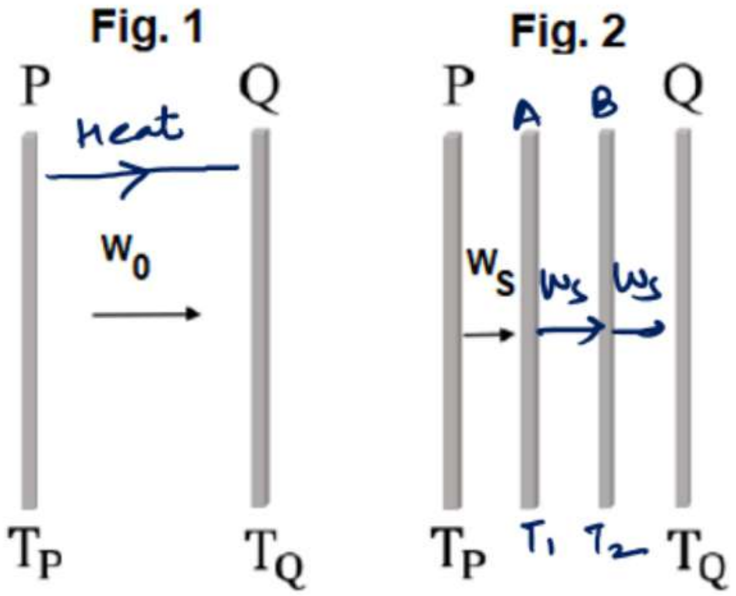

BB ⇒ $a=1$, $e=1$

Stefan- Boltzmann's law

$$I = e\sigma T^4$$

$$\frac{E}{A\,t} = \sigma T^4$$

$$P = \sigma A T^4 \Rightarrow \frac{P}{A} = \sigma T^4$$

$$w_0 = \sigma T_P^4 - \sigma T_Q^4 \quad \text{---(1)}$$

$$w_s = \sigma T_P^4 - \sigma T_1^4 = \sigma T_1^4 - \sigma T_2^4 = \sigma T_2^4 - \sigma T_Q^4 \quad \text{---(2)}$$

Steady state

Heat is not taken by any Plate

$P \xrightarrow[w_s]{} A$

$A \xrightarrow[w_s]{} B$

$B \xrightarrow[w_s]{} Q$

10. Two identical plates P and Q, radiating as perfect black bodies, are kept in vacuum at constant absolute temperatures T_P and T_Q, respectively, with $T_Q < T_P$, as shown in Fig. 1. The radiated power transferred per unit area from P to Q is W_0. Subsequently, two more plates, identical to P and Q, are introduced between P and Q, as shown in Fig. 2. Assume that heat transfer takes place only between adjacent plates. If the power transferred per unit area in the direction from P to Q (Fig. 2) in the steady state is W_S, then the ratio w_0 / w_s is --------

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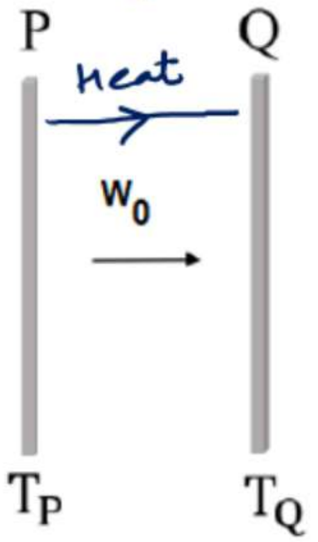


Fig. 2

$$w_0 = \sigma T_P^4 - \sigma T_Q^4 \quad \text{---}(1)$$

$$w_s = \sigma T_P^4 - \sigma T_1^4 = \sigma T_1^4 - \sigma T_2^4 = \sigma T_2^4 - \sigma T_Q^4 \quad \text{--}(2)$$

$$w_s = \sigma T_P^4 - \sigma T_1^4$$

$$w_s = \sigma T_1^4 - \sigma T_2^4$$

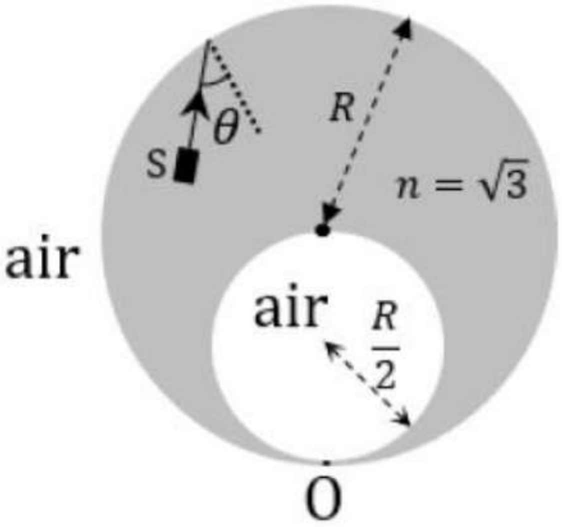
$$w_s = \sigma T_2^4 - \sigma T_Q^4$$

$$3w_s = \sigma T_P^4 - \sigma T_Q^4$$

$$3w_s = w_0$$

$$\frac{w_0}{w_s} = \frac{3}{1} = 3$$

11. A solid glass sphere of refractive index $n = \sqrt{3}$ and radius *R* contains a spherical air cavity of radius R/2,as shown in the figure. A very thin glass layer is present at the point O so that the air cavity (refractive index *n* = 1) remains inside the glass sphere. An unpolarized, unidirectional and monochromatic light source *S* emits a light ray from a point inside the glass sphere towards the periphery of the glass sphere. If the light is reflected from the point O and is fully polarized, then the angle of incidence at the inner surface of the glass sphere is θ. The value of sin θ is ________



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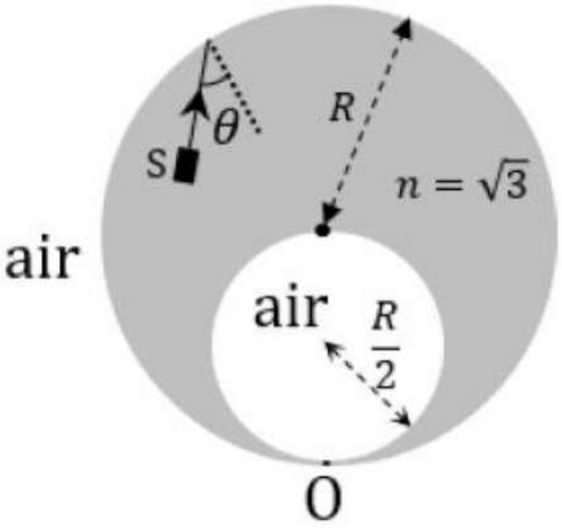
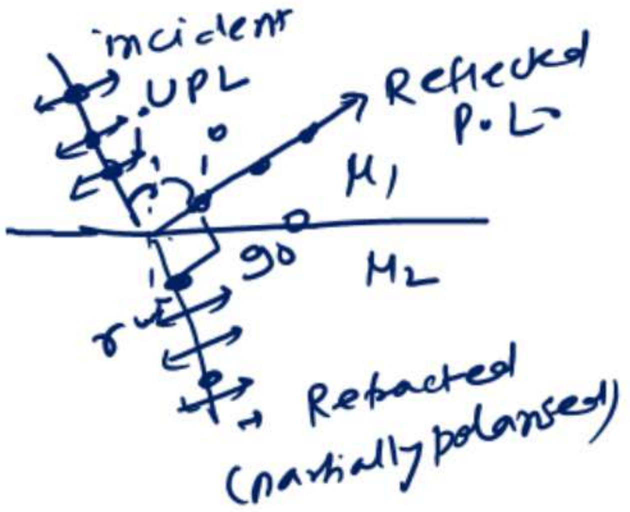


Answer: 0.5 OR 0.75

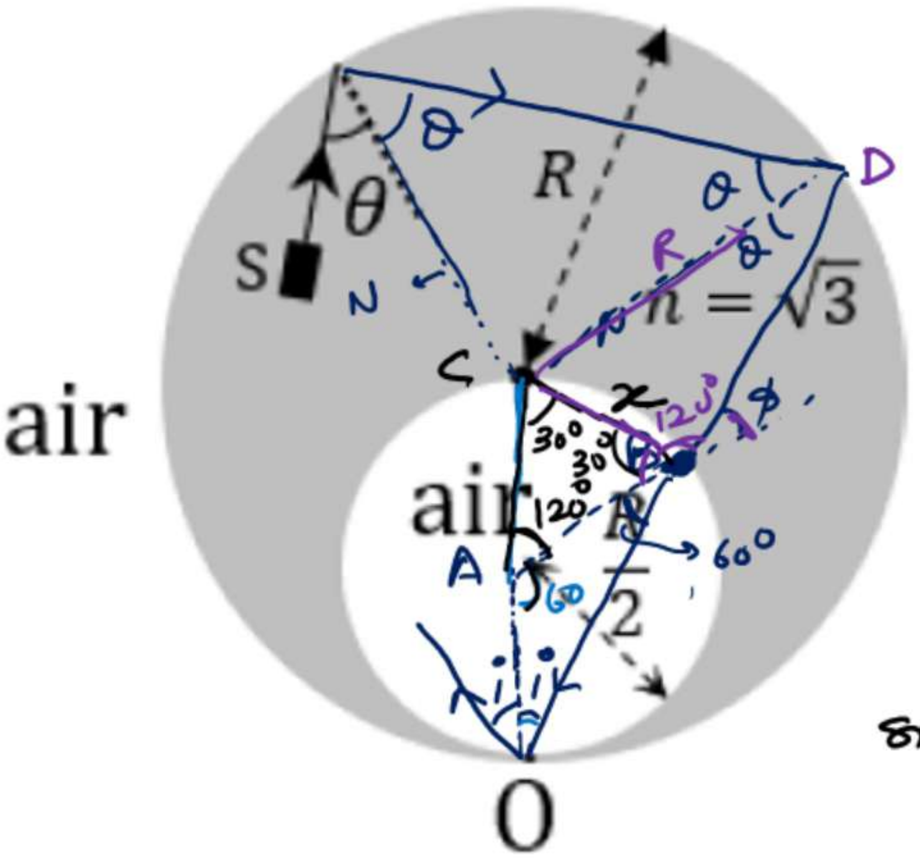


$\mu_1 \sin i = \mu_2 \sin r$

$i + r = 90^\circ$

$\mu_1 \sin i = \mu_2 \cos i$

$\tan i = \frac{\mu_2}{\mu_1}$



From Brewster law

$\tan i = \frac{\sqrt{3}}{1} \Rightarrow i = 60^\circ$

$OA = AB$

$\angle AOB = \angle ABO = 60^\circ$

From snell's law

$\sqrt{3} \sin\phi = \sin 60^\circ = \frac{\sqrt{3}}{2}$

$\sin\phi = \frac{1}{2} \Rightarrow \phi = 30^\circ$

$AC = AB = R$

Sine rule, ABC

$\frac{x}{\sin 120^\circ} = \frac{R/2}{\sin 30^\circ} \Rightarrow x = \frac{R}{2} \frac{\sqrt{3}}{\cancel{2}} \frac{\cancel{2}}{1} = \frac{R\sqrt{3}}{2}$

Sine rule $\triangle$ BCD

$\frac{R}{\sin 120^\circ} = \frac{R\sqrt{3}}{2 \sin\theta} \Rightarrow \sin\theta = \frac{\sqrt{3}}{2} \sin 120^\circ$

$\sin\theta = \frac{\sqrt{3}}{2} \frac{\sqrt{3}}{2} = \frac{3}{4} = 0.75$

12. A single slit diffraction experiment is performed to determine the slit width using the equation,

$$\frac{bd}{D} = m\lambda,$$

where b is the slit width, D the shortest distance between the slit and the screen, d the distance between the m^{th} diffraction maximum and the central maximum, and λ is the wavelength. D and d are measured with scales of least count of 1 cm and 1 mm, respectively. The values of λ and m are known precisely to be 600 nm and 3, respectively. The absolute error (in μm) in the value of b estimated using the diffraction maximum that occurs for m = 3 with d = 5 mm and D = 1 m is -----------

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Answer : (75 to 79) OR (94 to 95)

12. A single slit diffraction experiment is performed to determine the slit width using the equation,

$$\frac{bd}{D} = m\lambda,$$

where b is the slit width, D the shortest distance between the slit and the screen, d the distance between the m^{th} diffraction maximum and the central maximum, and λ is the wavelength. D and d are measured with scales of least count of 1 cm and 1 mm, respectively. The values of λ and m are known precisely to be 600 nm and 3, respectively. The absolute error (in μm) in the value of b estimated using the diffraction maximum that occurs for m = 3 with d = 5 mm and D = 1 m is ----------

$D = 1m$, $\Delta D = 1cm$

$d = 5mm$, $\Delta d = 1mm$

$\lambda = 600\,nm$ (no error)

$m = 3$ (no error)

$\Delta b = ---$ (μm)

$$\frac{bd}{D} = m\lambda$$

$$b \propto \frac{D}{d}$$

$$\frac{\Delta b}{b} = \frac{\Delta D}{D} + \frac{\Delta d}{d}$$

$$\frac{\Delta b}{360} = \frac{1}{5} + \frac{1}{100}$$

$$\frac{\Delta b}{360} = \frac{21}{100}$$

$$\Delta b = \frac{21}{100} \times 360 = \frac{7560}{100}$$

$$= 75.6$$

$$b = \frac{Dm\lambda}{d}$$

$$= \frac{1 \times 3 \times \overset{120}{600} \times 10^{-9}}{5 \times 10^{-3}}$$

$$= 36 \times 10^{-5}\,m$$

$$= 36 \times 10^{-5} \times 10^{6}\,\mu m$$

$$= 360\,\mu m$$

13. Consider an electron in the n = 3 orbit of a hydrogen-like atom with atomic number Z. At absolute temperature T, a neutron having thermal energy $k_B T$ has the same de Broglie wavelength as that of this electron. If this temperature is given by

$$T = \frac{Z^2 h^2}{\alpha \pi^2 a_0^2 m_N k_B},$$

(where h is the Planck's constant, k_B is the Boltzmann constant, m_N is the mass of the neutron and a_0 is the first Bohr radius of hydrogen atom) then the value of α is ______

13. Consider an electron in the n = 3 orbit of a hydrogen-like atom with atomic number Z. At absolute temperature T, a neutron having thermal energy $k_B T$ has the same de Broglie wavelength as that of this electron. If this temperature is given by

$$T = \frac{Z^2 h^2}{\alpha \pi^2 a_0^2 m_N k_B},$$

(where h is the Planck's constant, k_B is the Boltzmann constant, m_N is the mass of the neutron and a_0 is the first Bohr radius of hydrogen atom) then the value of α is ______

Answer : 72

13. Consider an electron in the n = 3 orbit of a hydrogen-like atom with atomic number Z. At absolute temperature T, a neutron having thermal energy $k_B T$ has the same de Broglie wavelength as that of this electron. If this temperature is given by

$$T = \frac{Z^2 h^2}{\alpha \pi^2 a_0^2 m_N k_B},$$

(where h is the Planck's constant, k_B is the Boltzmann constant, m_N is the mass of the neutron and a_0 is the first Bohr radius of hydrogen atom) then the value of α is ______

neutron →

$K.E. = k_B T$

T = ✓ given

$\lambda_{neutron} = \lambda_{e^-}$

$\frac{h}{p} = \frac{h}{p}$

$\frac{h}{\sqrt{2 m_N k_B T}} = \frac{h}{mv}$

$mvr = \frac{nh}{2\pi}$

$mv = \frac{nh}{2\pi r}$

$r = a_0 \frac{n^2}{Z}$

$\frac{1}{\sqrt{2mKT}} = \frac{2\pi r}{nh}$

$\sqrt{2mKT} = \frac{nh}{2\pi a_0 n^2} Z = \frac{hZ}{2\pi a_0 3}$

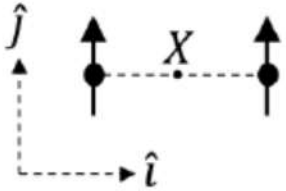
$T = \frac{h^2 Z^2}{2 \times 4 \times 9\, \pi^2 a_0^2 mK} = \frac{h^2 Z^2}{72 \pi^2 a_0^2 mK}$

$\alpha = 72$

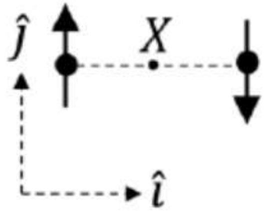
14. List-I shows four configurations, each consisting of a pair of ideal electric dipoles. Each dipole has a dipole moment of magnitude p, oriented as marked by arrows in the figures. In all the configurations the dipoles are fixed such that they are at a distance 2r apart along the x direction. The midpoint of the line joining the two dipoles is X. The possible resultant electric fields E at X are given in List-II. Choose the option that describes the correct match between the entries in **List-I** to those in **List-II.**

List-I

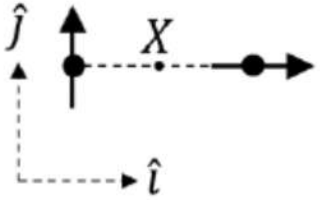
(P)



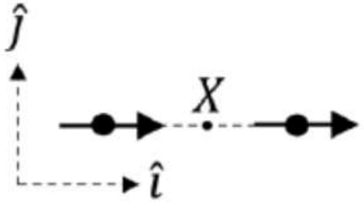
(Q)



(R)



(S)



List-II

(1) $\vec{E} = 0$

(2) $\vec{E} = -\frac{p}{2\pi\epsilon_0 r^3}\hat{j}$

(3) $\vec{E} = -\frac{p}{4\pi\epsilon_0 r^3}(\hat{\imath} - \hat{j})$

(4) $\vec{E} = \frac{p}{4\pi\epsilon_0 r^3}(2\hat{\imath} - \hat{j})$

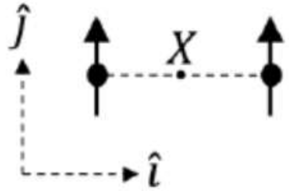
(5) $\vec{E} = \frac{p}{\pi\epsilon_0 r^3}\hat{\imath}$

(A)	P→3, Q→1, R→2, S→4
(B)	P→4, Q→5, R→3, S→1
(C)	P→2, Q→1, R→4, S→5
(D)	P→2, Q→1, R→3, S→5

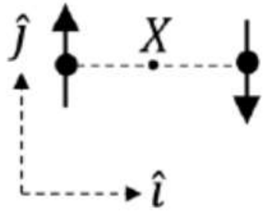
14. List-I shows four configurations, each consisting of a pair of ideal electric dipoles. Each dipole has a dipole moment of magnitude p, oriented as marked by arrows in the figures. In all the configurations the dipoles are fixed such that they are at a distance 2r apart along the x direction. The midpoint of the line joining the two dipoles is X. The possible resultant electric fields E at X are given in List-II. Choose the option that describes the correct match between the entries in **List-I** to those in **List-II.**

List-I

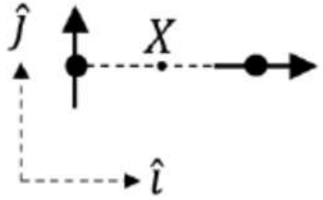
(P)



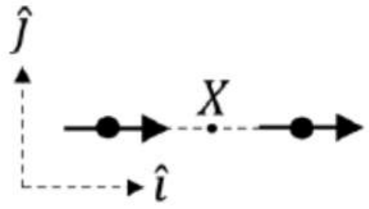
(Q)



(R)



(S)



List-II

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(A)	P→3, Q→1, R→2, S→4
(B)	P→4, Q→5, R→3, S→1
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(D)	P→2, Q→1, R→3, S→5

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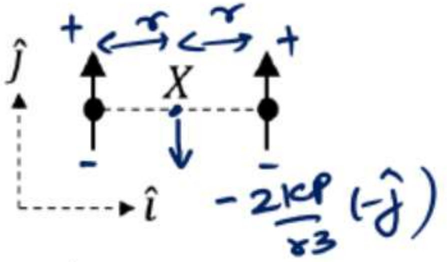
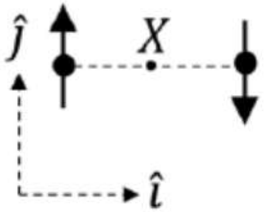
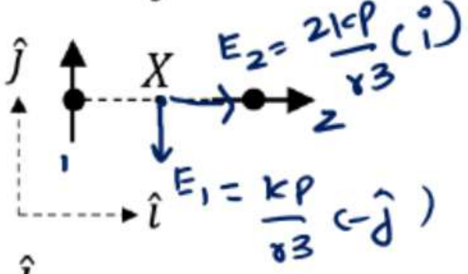
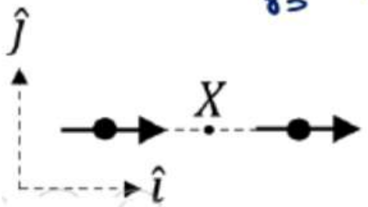
List-I

(P) 

(Q) 

(R) 

(S) 

List-II

(1) $\vec{E} = 0$

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(3) $\vec{E} = -\frac{p}{4\pi\epsilon_0 r^3}(\hat{\imath} - \hat{j})$

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(5) $\vec{E} = \frac{p}{\pi\epsilon_0 r^3}\hat{\imath}$

(A)	P→3, Q→1, R→2, S→4
(B)	P→4, Q→5, R→3, S→1
(C)	P→2, Q→1, R→4, S→5
(D)	P→2, Q→1, R→3, S→5

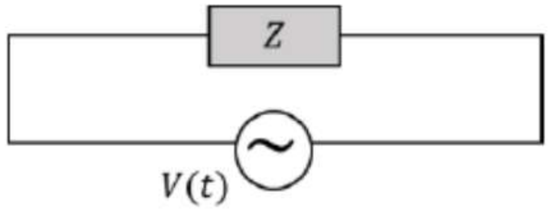
$E_{eq} = \frac{kp}{r^3}$

$E_{axial} = \frac{2kp}{r^3}$

$E_R = \frac{2kp}{r^3}\hat{\imath} - \frac{kp}{r^3}\hat{j}$

$= \frac{kp}{r^3}(2\hat{\imath} - \hat{j}) = \frac{p}{4\pi\epsilon_0 r^3}(2\hat{\imath} - \hat{j})$

15. A circuit with an electrical load having impedance Z is connected with an AC source as shown in the diagram. The source voltage varies in time as $V(t) = 300 \sin(400\,t)$ V, where t is time in s. List-I shows various options for the load. The possible currents i(t) in the circuit as a function of time are given in List-II.



(A)	P→3, Q→5, R→2, S→1
(B)	P→1, Q→5, R→2, S→3
(C)	P→3, Q→4, R→2, S→1
(D)	P→1, Q→4, R→2, S→5

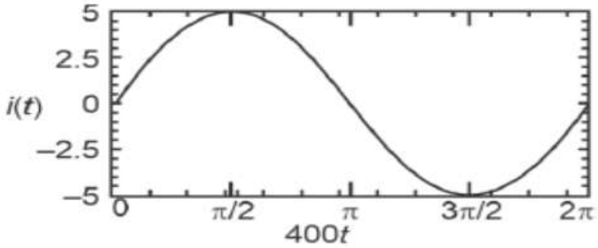
Choose the option that describes the correct match between the entries in List-I to those in List-II.

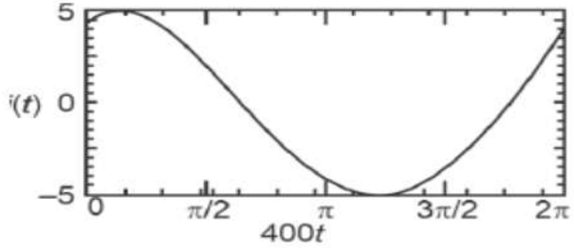
(P) 

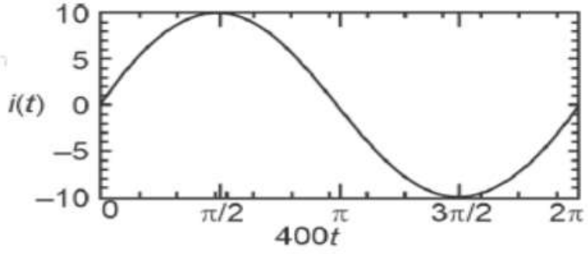
(Q) 

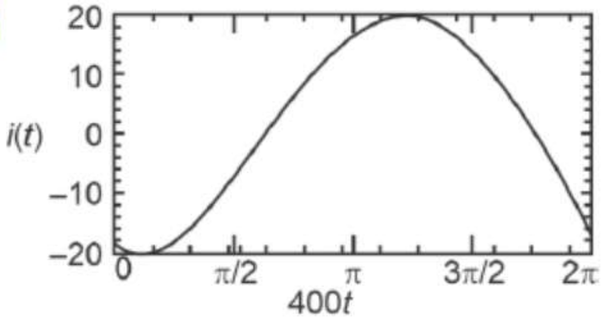
(R) 

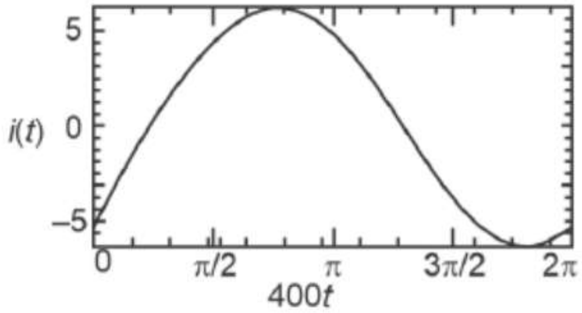
(S) 

(1) 

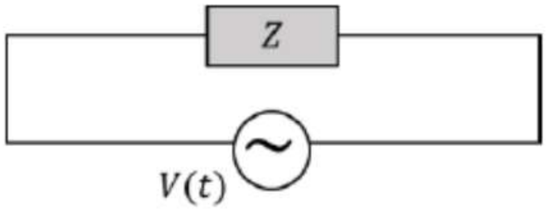
(2) 

(3) 

(4) 

(5) 

15. A circuit with an electrical load having impedance Z is connected with an AC source as shown in the diagram. The source voltage varies in time as V(t) = 300 sin (400 t) V, where t is time in s. List-I shows various options for the load. The possible currents i(t) in the circuit as a function of time are given in List-II.



(A)	P→3, Q→5, R→2, S→1
(B)	P→1, Q→5, R→2, S→3
(C)	P→3, Q→4, R→2, S→1
(D)	P→1, Q→4, R→2, S→5

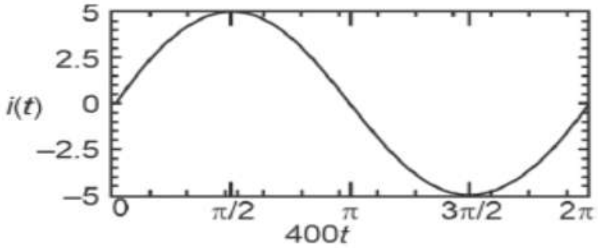
Choose the option that describes the correct match between the entries in List-I to those in List-II.

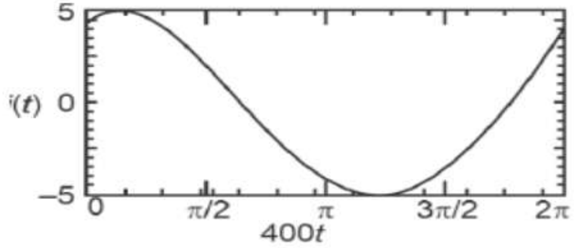
(P) 

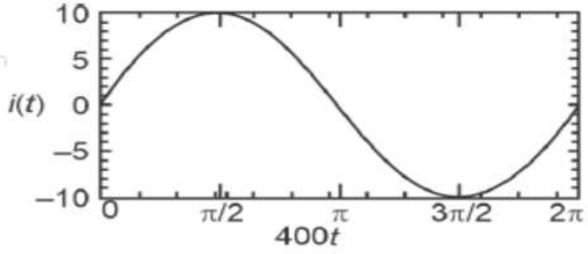
(Q) 

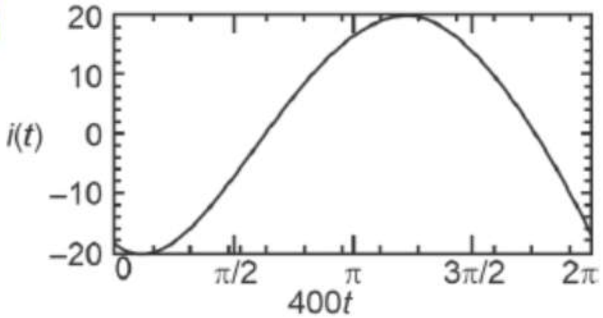
(R) 

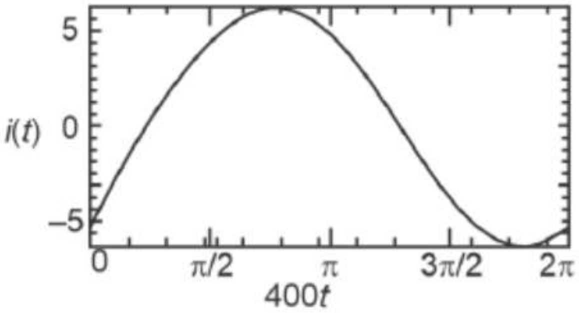
(S) 

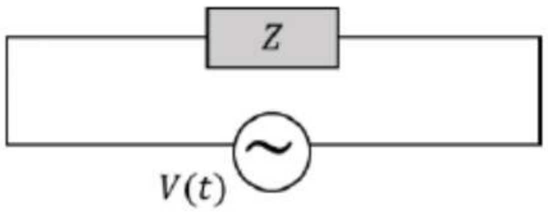
(1) 

(2) 

(3) 

(4) 

(5) 



V(t) = 300 sin (400 t) V

P → pure resistive ckt

$$i = \frac{300}{30} \sin 400t$$

$$i = 10 \sin 400t$$

$$i = i_0 \sin \omega t$$

(A)	P→3, Q→5, R→2, S→1
(B)	P→1, Q→5, R→2, S→3
(C)	P→3, Q→4, R→2, S→1
(D)	P→1, Q→4, R→2, S→5

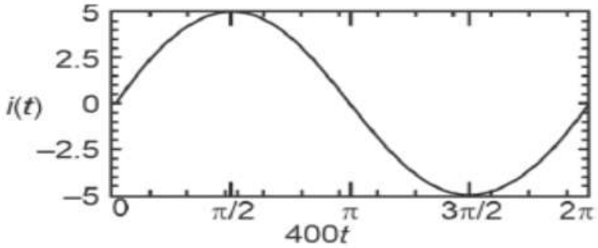
Choose the option that describes the correct match between the entries in List-I to those in List-II.

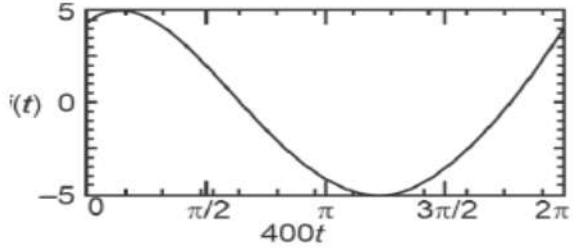
(P) 

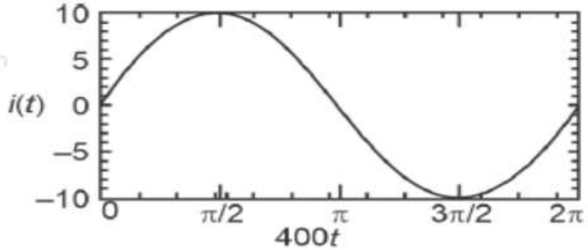
(Q) 

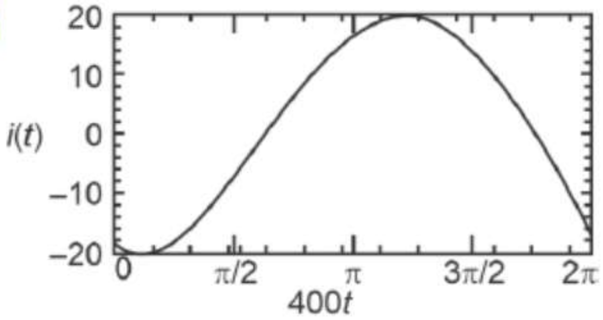
(R) 

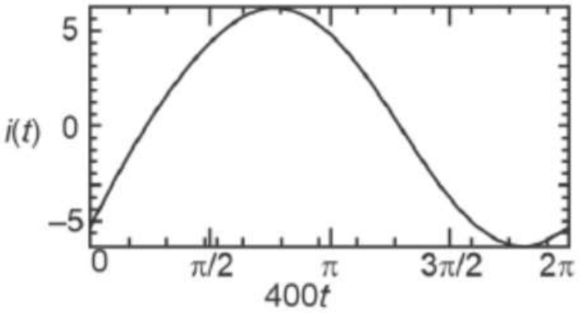
(S) 

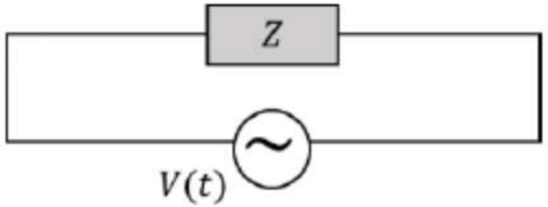
(1) 

(2) 

(3) 

(4) 

(5) 



V(t) = 300 sin (400 t) V

$R = 30\Omega, L = 100 mH$

$X_L = \omega L = 400 \times 100 \times 10^{-3} = 40\Omega$

$Z = 50\Omega$ $\quad i_0 = \frac{V_0}{Z} = \frac{300}{50} = 6$

$\tan\theta = \frac{40}{30} = \frac{4}{3} \Rightarrow \theta = 53^\circ$

$i = i_0 \sin(\omega t - \theta) = 6 \sin(400t - 53^\circ)$

(A)	P→3, Q→5, R→2, S→1
(B)	P→1, Q→5, R→2, S→3
(C)	P→3, Q→4, R→2, S→1
(D)	P→1, Q→4, R→2, S→5

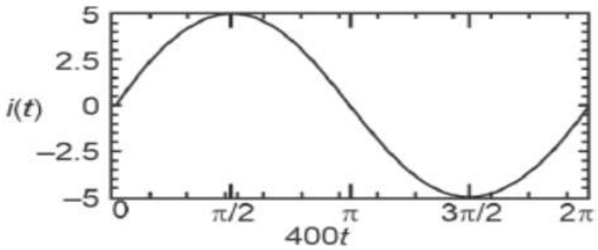
Choose the option that describes the correct match between the entries in List-I to those in List-II.

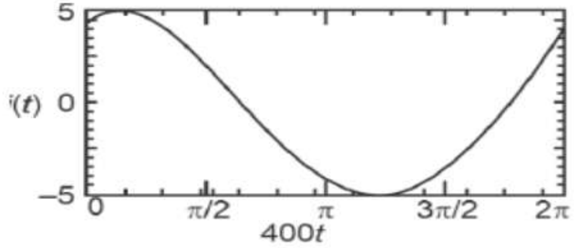
(P)


(Q)


(R)


(S)


(1)


(2)


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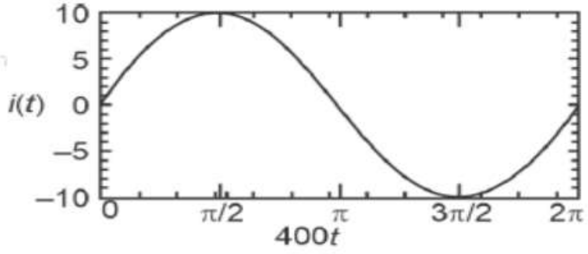

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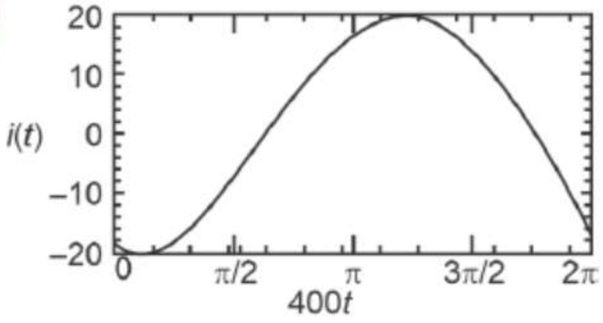
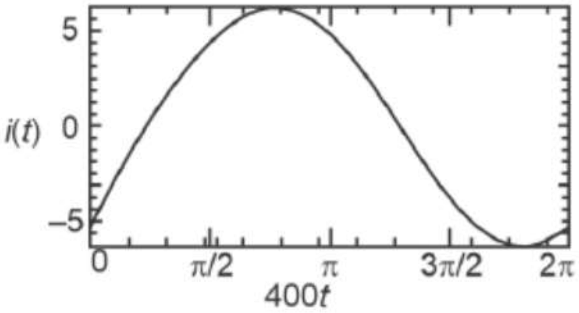


(5)


16. List-I shows various functional dependencies of energy (E) on the atomic number (Z). Energies associated with certain phenomena are given in List-II.
Choose the option that describes the correct match between the entries in **List-I** to those in **List-II.**

List-I

(P) $E \propto Z^2$

(Q) $E \propto (Z-1)^2$

(R) $E \propto Z(Z-1)$

(S) E is practically independent of Z

List-II

(1) energy of characteristic x-rays

(2) electrostatic part of the nuclear binding energy for stable nuclei with mass numbers in the range 30 to 170

(3) energy of continuous x-rays

(4) average nuclear binding energy per nucleon for stable nuclei with mass number in the range 30 to 170

(5) energy of radiation due to electronic transitions from hydrogen-like atoms

(A)	P→4, Q→3, R→1, S→2
(B)	P→5, Q→2, R→1, S→4
(C)	P→5, Q→1, R→2, S→4
(D)	P→3, Q→2, R→1, S→5

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List-I	List-II
(P) $E \propto Z^2$	(1) energy of characteristic x-rays
(Q) $E \propto (Z-1)^2$	(2) electrostatic part of the nuclear binding energy for stable nuclei with mass numbers in the range 30 to 170
(R) $E \propto Z(Z-1)$	(3) energy of continuous x-rays
(S) E is practically independent of Z	(4) average nuclear binding energy per nucleon for stable nuclei with mass number in the range 30 to 170
	(5) energy of radiation due to electronic transitions from hydrogen-like atoms

(A)	P→4, Q→3, R→1, S→2
(B)	P→5, Q→2, R→1, S→4
(C)	P→5, Q→1, R→2, S→4
(D)	P→3, Q→2, R→1, S→5

16. List-I shows various functional dependencies of energy (E) on the atomic number (Z). Energies associated with certain phenomena are given in List-II.
Choose the option that describes the correct match between the entries in **List-I** to those in **List-II.**

List-I

(P) $E \propto Z^2$

(Q) $E \propto (Z-1)^2$

(R) $E \propto Z(Z-1)$

(S) E is practically independent of Z

List-II

(1) energy of characteristic x-rays

(2) electrostatic part of the nuclear binding energy for stable nuclei with mass numbers in the range 30 to 170

(3) energy of continuous x-rays

(4) average nuclear binding energy per nucleon for stable nuclei with mass number in the range 30 to 170

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S. $E = -13.6 \frac{z^2}{n^2} \Rightarrow E \propto z^2$

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1. Energy of characteristic of x ray

moseley's law $\sqrt{\nu} = a(Z-b)$

$\nu = a^2(z-b)^2$

k-shell, $b=1$

$\nu = a^2(z-1)^2$

Energy of x ray

$E = h\nu$

$E = h a^2 (z-1)^2$

$E \propto (z-1)^2$

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R. The electrostatic energy of Z protons uniformly distributed throughout a spherical nucleus of radius R is given by

$$E = \frac{3}{5}\frac{Z(Z-1)e^2}{4\pi\varepsilon_0 R} \qquad E \propto Z(Z-1)$$

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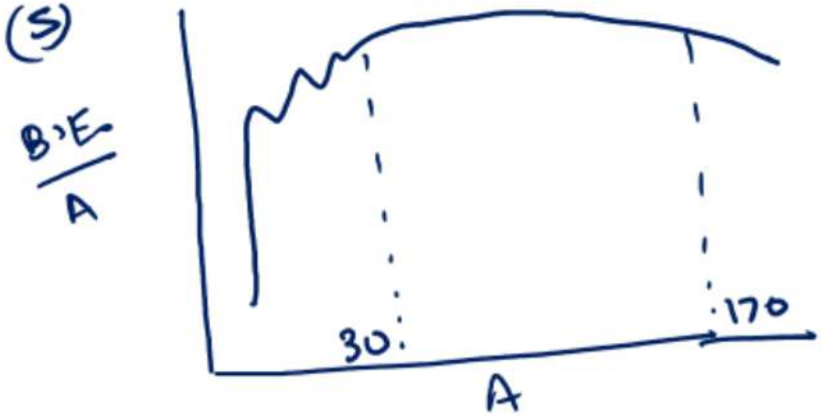
(S)



B.E. per nucleon E_{bn} is practically constant for mass no (30 < A < 170)

E_{bn} is max for Fe = 8.75 MeV