JEE Advanced (2025)

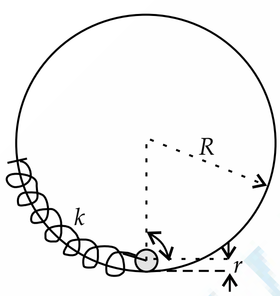
PAPER 1

***General Instructions*:**

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:
  - *Full Marks* : +3 **ONLY** if the option corresponding to the correct combination is chosen.
  - *Zero Marks* : 0 If none of the options is chosen (i.e., the question is unanswered);
  - *Negative Marks* : –1 In all other cases.

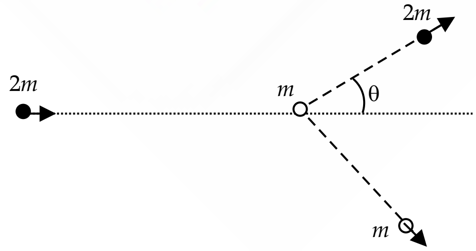
1. The centre of a disk of radius r and mass m is attached to a spring of spring constant K, inside a ring of radius $R > r$ as shown in the figure. The other end of the spring is attached on the periphery of the ring. Both the ring and the disk are in the same vertical plane. The disk can only roll 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 centre of mass of the disk is written as $T = \frac{2\pi}{\omega}$ 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)** $\sqrt{\frac{2g}{3(R-r)}+\frac{K}{m}}$

(C) $\sqrt{\frac{1}{6}\left(\frac{g}{R-r}+\frac{K}{m}\right)}$ **(D)** $\sqrt{\frac{1}{4}\left(\frac{g}{R-r}+\frac{K}{m}\right)}$

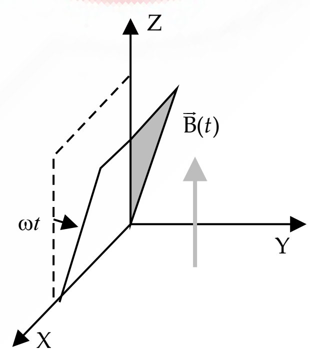
2. In a scattering experiment, a particle of mass $2m$ collides with another particle of mass m, which is initially at rest. Assuming the collision to be perfectly elastic, the maximum angular deviation θ of the heavier particle, as shown in the figure, in radians is:



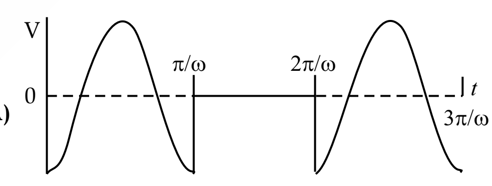
(A) π **(B)** $\tan^{-1}\left(\frac{1}{2}\right)$

(C) $\frac{\pi}{3}$ **(D)** $\frac{\pi}{6}$

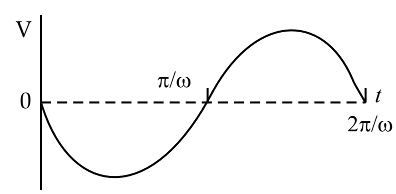
3. A conducting square loop initially lies in the XZ plane with its lower edge hinged along the X-axis. Only in the region $y \geq 0$, there is a time dependent magnetic field pointing along the Z-direction, $\vec{B}(t) = B_0(\cos \omega t)\hat{k}$, where B_0 is a constant. The magnetic field is zero 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 emf (V) in the loop as a function of time:

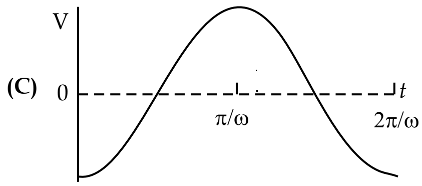


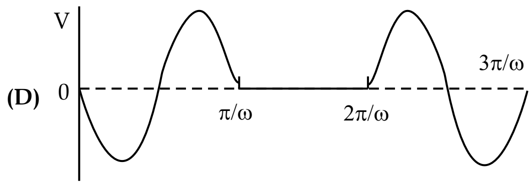
(A)



(B)







4. Fig.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:

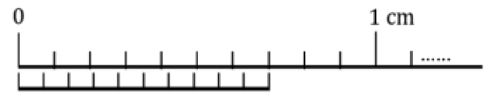


Fig. 1

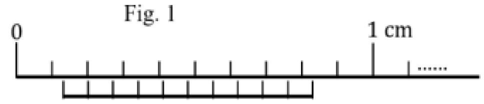


Fig. 2

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

General Instructions:

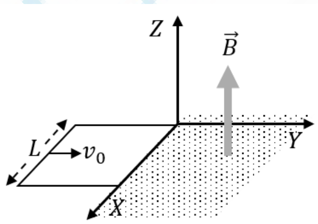
SECTION 2 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks	:	+4	ONLY if (all) the correct option(s) is(are) chosen;
Partial Marks	:	+3	If all the four options are correct but ONLY three options are chosen;
Partial Marks	:	+2	If three or more options are correct but ONLY two options are chosen, both of which are correct;
Partial Marks	:	+1	If two or more options are correct but ONLY one option is chosen and it is a correct option;
Zero Marks	:	0	If none of the options is chosen (i.e. the question is unanswered);
Negative Marks	:	−2	In all other cases.

- For example, in a question, if (A), (B) and (D) are the ONLY three options corresponding to the correct answers, then
choosing ONLY (A), (B) and (D) will get +4 marks;
choosing ONLY (A) and (B) will get +2 marks;
choosing ONLY (A) and (D) will get +2 marks;
choosing ONLY (B) and (D) will get +2 marks;
choosing ONLY (A) will get +1 mark;
choosing ONLY (B) will get +1 mark;
choosing ONLY (D) will get +1 mark;
choosing no option(s) (i.e., the question is unanswered) will get 0 marks and
choosing any other option(s) will get −2 marks.

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, $\vec{B} = B_0\hat{k}$. The magnetic field is zero everywhere else. At time $t = 0$, the loop starts to enter the magnetic field with an initial velocity $v_0\hat{j}$ m/s, as shown in the figure. Considering the quantity $K = \dfrac{B_0^2 L^2}{RM}$ 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 the magnetic field.

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

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

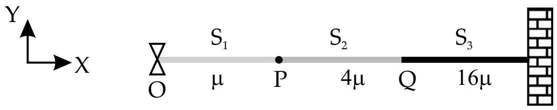
(D) If $v_0 = 3KL$, the complete loop enters inside the region of the magnetic field at time $t = \left(\dfrac{1}{K}\right)\ln\left(\dfrac{3}{2}\right)$.

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}

7. Consider a system of three connected strings, S_1, S_2 and S_3 with uniform linear mass densities μ kg/m, 4μ kg/m and 16μ 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 $y = a_1 y_0 \cos(\omega t + kx + \pi)$ cm, where a_1 is a positive constant.

(B) When the wave transmits through P for the first time, the transmitted wave is represented by $y = a_2 y_0 \cos(\omega t - kx)$ cm, where a^2 is a positive constant.

(C) When the wave reflects from Q for the first time, the reflected wave is represented by $y = a_3 y_0 \cos(\omega t - kx + \pi)$ cm, where a_3 is a positive constant.

(D) When the wave transmits through Q for the first time, the transmitted wave is represented by $y = a_4 y_0 \cos(\omega t - 4kx)$ cm, where a_4 is a positive constant.

***General Instructions*:**

SECTION 3 (Maximum Marks: 24)

- This section contains **SIX (06)** questions.
- The answer to each question is a **NUMERICAL VALUE.**
- For each question, enter the correct numerical value of the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.
- If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 **ONLY** if he correct numerical value is entered in the designated place;

Zero Marks : 0 In all other cases.

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 = 40π s. Taking an 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 _________.

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 the permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ Tm/A, Planck's constant $h = 6 \times 10^{-34}$ and $\pi = \frac{22}{7}$, the value of α is __________.

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 the 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 $\frac{W_0}{W_S}$ is _____.

Fig. 1

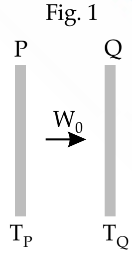
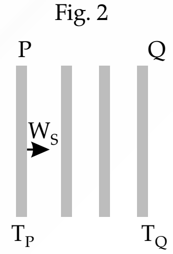
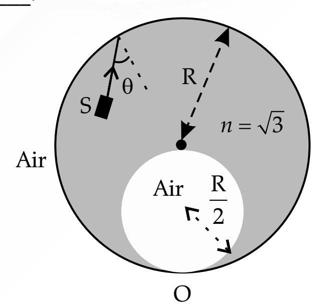


Fig. 2



11. A solid glass sphere of refractive index $n = \sqrt{3}$ and radius R contains a spherical air cavity of radius $\frac{R}{2}$ 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 unpolarised, 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 polarised, then the angle of incidence at the inner surface of the glass sphere is θ. The value of sin θ is ___________.



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 mth 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 _________.

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_BT 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 ________________.

General Instructions:

SECTION 4 (Maximum Marks: 12)

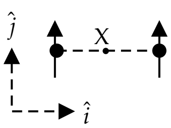
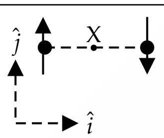
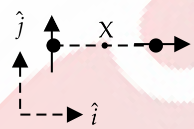
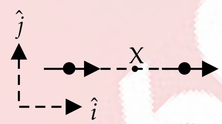
- This section contains **THREE (03)** Matching List Sets.
- Each set has **ONE** Multiple Choice Question.
- Each set has **TWO** lists: **List I** and **List II.**
- **List I** has **Four** entries (P), (Q), (R) and (S) and **List II** has **FIVE** entries (1), (2), (3), (4) and (5).
- **FOUR** options are given in each Multiple Choice Question based on **List I** and **List II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks	:	+4	**ONLY** if the option corresponding to the correct combination is chosen;
Zero Marks	:	0	If none of the options is chosen (i.e. the question is unanswered);
Negative Marks	:	–1	In all other cases.

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.

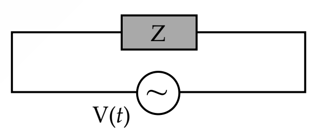
The midpoint of the line joining the two dipoles is X. The possible resultant electric fields $\vec{E}$ at X are given in List II.

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

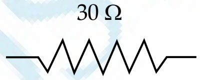
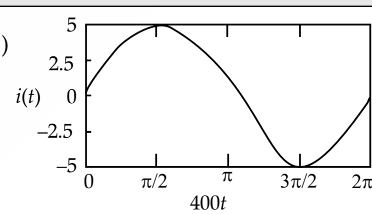
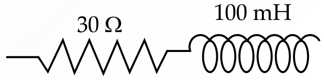
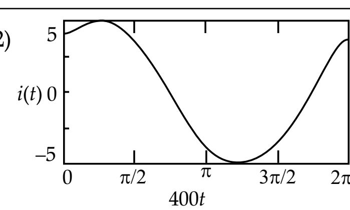
List I	List II
(P) 	(1) $\vec{E} = \vec{0}$
(Q) 	(2) $\vec{E} = \frac{p}{2\pi\varepsilon_0 r^3}\hat{j}$
(R) 	(3) $\vec{E} = -\frac{p}{4\pi\varepsilon_0 r^3}(\hat{i} - \hat{j})$
(S) 	(4) $\vec{E} = \frac{p}{4\pi\varepsilon_0 r^3}(2\hat{i} - \hat{j})$
	(5) $\vec{E} = \frac{p}{\pi\varepsilon_0 r^3}\hat{i}$

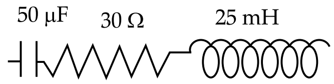
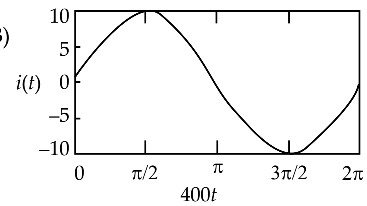
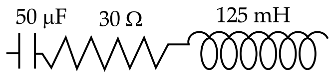
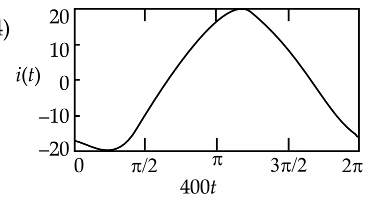
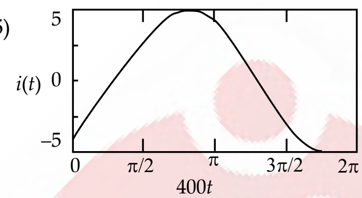
(A) P → 3; Q → 1; R → 2; S → 4
(B) P → 4; Q → 5; R → 3; S → 1
(C) P → 2; Q → 1; R → 4; S → 5
(D) P → 2; Q → 1; R → 3; S → 5

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 $V(t) = 300 \sin(400t)$ 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.



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

List I	List II
(P) 30 Ω 	(1) 
(Q) 30 Ω 100 mH 	(2) 

(R) 	(3) 
(S) 	(4) 
	(5) 

(A) $P \to 3$; $Q \to 5$; $R \to 2$; $S \to 1$

(B) $P \to 1$; $Q \to 5$; $R \to 2$; $S \to 3$

(C) $P \to 3$; $Q \to 4$; $R \to 2$; $S \to 1$

(D) $P \to 1$; $Q \to 4$; $R \to 2$; $S \to 5$

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	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) $E \propto (Z-1)$	(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) $P \to 4$; $Q \to 3$; $R \to 1$; $S \to 2$

(B) $P \to 5$; $Q \to 2$; $R \to 1$; $S \to 4$

(C) $P \to 5$; $Q \to 1$; $R \to 2$; $S \to 4$

(D) $P \to 3$; $Q \to 2$; $R \to 1$; $S \to 5$

Answer Key

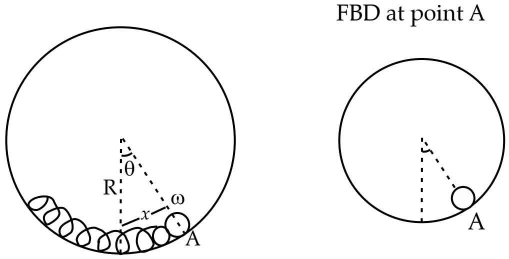
Q.No.	Answer key	Topic's name	Chapter's name
1	(A)	Torque, Centre of Mass	System of Particle and Rotational Motion
2	(D)	Conservation of Linear Momentum	Work, Energy and Power
3	(A)	Induced EMF, Magnetic Flux	Electromagnetic Induction
4	(C)	Vernier Calliper	Practical Physics
5	(B, D)	Motional EMF	Electromagnetic Induction
6	(D)	Significant Figures	Units and Measurements
7	(A, D)	Motion of Waves in a String	Waves
8	[2]	SHM	Oscillations
9	[21 to 25]	Energy in EMW	Electromagnetic Waves
10	[3]	Black Body Radiations	Thermal Properties of Matter
11	[0.5 or 0.75]	Polarisation	Wave Optics
12	[75 to 79]	Errors in Measurements	Units and Measurements
13	[72]	de Broglie Wavelength	Atoms and Nuclei
14	(C)	Electric Field Due to an Electric Dipole	Electrostatics
15	(A)	LCR Circuit	Alternating Current
16	(C)	Energy of Radiations, Binding Energy	Atoms and Nuclei

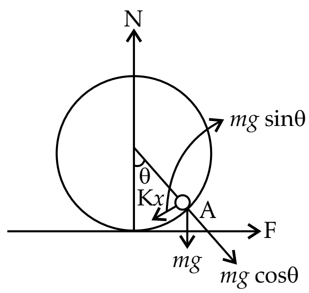
Answers With Explanations

1. Correct option is (A).

Let the spring coil is displaced slightly towards right

FBD at point A





Writing torque about point A

$$(mg\sin\theta)r + Kx\cdot r = \frac{3}{2}mr^2\alpha$$

$$mg\sin\theta + Kx = \frac{3}{2}m(r\alpha)$$

$$mg\sin\theta + Kx = \frac{3}{2}m\,a_{cm}$$

$$a_{cm} = \frac{2}{3}\left(g\sin\theta + \frac{Kx}{m}\right)$$

As θ is very very small $\sin\theta \approx \theta$

Also $\qquad x = (R - r)\theta$

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

Substituting the above value, we get,

$$a_{cm} = \frac{2}{3}\left(g\theta + \frac{Kx}{m}\right)$$

$$= \frac{2}{3}\left(\frac{gx}{R-r} + \frac{Kx}{m}\right)$$

$$a_{cm} = \frac{2}{3}\left(\frac{g}{R-r} + \frac{K}{m}\right)x$$

Comparing with standard SHM equation,

$$a_{cm} = -\omega^2$$

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

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

2. Correct option is (D).

Applying the law of conservation of linear momentum,

$$P_i = P_f$$

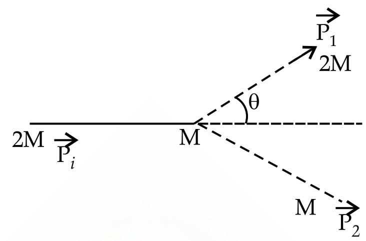
$$\vec{P_i} = \vec{P_1} + \vec{P_2}$$

$$\vec{P_i} - \vec{P_1} = \vec{P_2}$$

By squaring both sides, we get,

$$P_i^2 - 2P_iP_1\cos\theta + P_1^2 = P_2^2 \qquad \text{....(i)}$$

Also, we know $P^2 = 2\text{ K.E.} \times m$ or $KE = \dfrac{P^2}{2M}$



Applying COE (as collision is elastic)

$$KE_i = KE_F$$

$$\frac{P_i^2}{2\times 2\,m} = \frac{P_1^2}{2\times 2\,m} + \frac{P_2^2}{2\,m}$$

$$\Rightarrow \qquad \frac{P_i^2}{2} = \frac{P_1^2}{2} + P_2^2$$

$$\Rightarrow \qquad P_i^2 = P_1^2 + 2P_2^2 \qquad \text{...(ii)}$$

Substituting value of Eq. (ii) in Eq. (i),

$$P_i^2 - 2P_iP_1\cos\theta + P_1^2 = \frac{P_i^2}{2} - \frac{P_1^2}{2}$$

$$\Rightarrow P_i^2 - 4P_iP_1\cos\theta + 3P_1^2 = 0$$

To solve for (above quad) P_1,

$$b^2 - 4ac > 0. \qquad \text{(For real value)}$$

$$(4P_i\cos\theta)^2 - 4(3)(P_i^2) \geq 0$$

$$16P_i^2\cos^2\theta - 12P_i^2 \geq 0$$

$$4P_i^2(4\cos^2\theta - 3) \geq 0$$

$$4\cos^2\theta - 3 \geq 0$$

$$4\cos^2\theta \geq 3$$

$$\cos\theta \geq \frac{\sqrt{3}}{2}$$

i.e., $\qquad \theta \leq 30^\circ$ or $\dfrac{\pi}{6}$

As only for $0 \leq \theta < \dfrac{\pi}{6}$, $\cos\theta$ is between 1 and $\dfrac{\sqrt{3}}{2}$.

3. Correct option is (A).

As loop will pass from $-y$ region too, but as there is no magnetic field there, the time flux will be zero. Hence, graph (A) and (C) are the only possibilities.

Also at the starting, the flux will be changing and so emf will have non-zero value, hence graph (A), depicts induced emf vs time correctly.

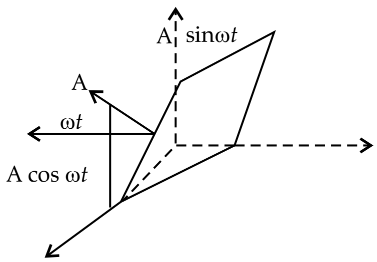
The magnetic flux $\phi = \vec{B}\cdot\vec{A}$

$$\Rightarrow \qquad \phi = B_0\cos\omega t\cdot A\sin\omega t$$

$$\phi = B_0A\cos\omega t\cdot\sin\omega t$$

(area vector in z-direction)

$$= \sin 2\omega t\cdot\frac{B_0A}{2}$$



$$\varepsilon = \frac{-d\phi}{dt} = -\frac{B_0 A}{2}\frac{d(\sin 2\omega t)}{dt}$$

$$= -\frac{B_0 A}{2} 2\omega \cos 2\omega t$$

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

$$\text{Time period } t = \frac{2\pi}{\omega} = \frac{2\pi}{2\omega} = \frac{\pi}{\omega}$$

At $t = \frac{\pi}{\omega}$, flux will become zero, and will be non-zero at $t = \frac{2\pi}{\omega}$.

4. Correct option is (C).

Here, $10 \text{ VSD} = 7 \text{ MSD}$

$$1 \text{ VSD} = \frac{7}{10} \text{ MSD} = 0.7 \text{ MSD}$$

$$\text{LC} = \text{MSD} - \text{VSD}$$

$$= 1 \text{ MSD} - 0.7 \text{ MSD} = 0.3 \text{ MSD}$$

$$\text{LC} = 0.3 \times 0.1 = 0.03 \text{ cm}$$

$$\text{D} = \text{Measured value} + \text{LC}$$

$$= 0.1 + 0.03 = 0.13 \text{ cm}$$

5. Correct options are (B, D).

Force, $F = I(\vec{l} \times \vec{B})$

$$F = ILB_0 \sin 90$$

$$Ma = -B_0 IL$$

$$Mv\frac{dv}{dx} = -B_0 IL$$

$$Mv\frac{dv}{dx} = -B_0 L \cdot \frac{B_0 vL}{R}$$

$$\int_{v_0}^{v} dv = -\int_0^x \frac{B_0^2 L^2}{MR} dx \quad \text{...(i)}$$

$$[v]_{v_0}^{v} = -\int_0^x K\, dx \qquad \left[K = \frac{B_0^2 L^2}{MR}\right]$$

$$(v - v_0) = -(Kx)_0^x$$

$$v - v_0 = -Kx$$

$$v = v_0 - Kx$$

To stop loop $v = 0$, i.e., $v_0 = Kx$

or, $0 = KL$

Option (A) is incorrect.

$\Rightarrow$ When the loop is completely inside the magnetic field, $\phi = 0$, so $F = 0$.

Option (B) is correct.

Also $$M\frac{dv}{dt} = -\frac{B_0^2 L^2}{R} v$$

$$\frac{dv}{v} = -\frac{B_0^2 L^2}{MR} dt = -K dt$$

Integrating both sides,

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

$$(\ln v - \ln v_0) = -Kt$$

or, $v = v_0 e^{-Kt}$

So at $t = \infty$, $v = 0$.

Option (C) is incorrect.

Also, $v = v_0 - Kx$

$$\frac{dx}{dt} = v_0 - Kx$$

$$\int_0^x \frac{dx}{v_0 - Kx} = \int_0^t dt$$

Integrating both sides

$$\left[-\ln\frac{(v_0 - Kx)}{K}\right]_0^x = (t)_0^t$$

$$t = -\frac{1}{K}(\ln(v_0 - Kx) - \ln(v_0))$$

Given $x = L$, $v_0 = 3KL$.

$$t = -\frac{1}{K}[\ln(3KL - KL) - \ln 3KL]$$

$$= -\frac{1}{K}(\ln 2KL - \ln 3KL)$$

$$t = \frac{1}{K}\ln\left(\frac{3KL}{2KL}\right)$$

$$t = \frac{1}{K}\ln\frac{3}{2}$$

Option (D) is correct.

6. Correct option is (D).

Volume, $V = l \times b \times t$

$$V = \underbrace{(10.5 \text{ cm})}_{3} \times \underbrace{(0.05 \text{ mm})}_{1} \times \underbrace{(6.0\ \mu\text{m})}_{2}$$

Answers will have only 1 (least of above) significant number. So,

$V = 10.5 \times 0.05 \times 10^{-1} \times 6.0 \times 10^{-4} \text{ cm}^3 = 3.15 \times 10^{-5} \text{ cm}^3$
$= 3 \times 10^{-5} \text{ cm}^3$ (only 1 significant number).

7. Correct option are (A, D).

(A) Due to reflection, inversion will take place.

So, $y' = y_0 \cos(\omega t + Kx + \pi)$. So, option A is correct.

(B) When wave passes through P, due to change in medium, the speed will change.

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

$$v' = \sqrt{\frac{T}{\mu_1}} = \sqrt{\frac{T}{4M}} = \frac{1}{2}\sqrt{\frac{T}{\mu}} = \frac{v}{2}$$

Wave no. $$K = \frac{\omega}{v}$$

$$K' = \frac{\omega}{v'} = \frac{2\omega}{v} = 2K$$

Hence, $y' = y\cos(\omega t - 2Kx)$

Option (B) is incorrect.

(C) Again due to reflection at θ_1, inversion will happens.

So,

$$y' = y\cos(\omega t + 2Kx + \pi)$$

Option (C) is incorrect.

(D) Again when wave passes through Q,

$$v'' = \sqrt{\frac{T}{\mu''}} = \sqrt{\frac{T}{16\mu}} = \frac{v}{4}$$

also $\qquad K'' = \frac{w}{v''} = \frac{4w}{v} = 4K$

Hence, $y'' = y\cos(\omega t - 4Kx)$

Option (D) is correct.

8. Correct answer is [2].

Given, $\qquad y = 8\left(1+\sin\frac{2\pi t}{T}\right)$

$$\text{Mass} = 50 \text{ kg}$$

$$T = 40\pi \text{ s}$$

$\Rightarrow \qquad y = 8 + 8\sin\frac{2\pi}{40\pi}t$

$$y = 8 + 8\sin\left(\frac{t}{20}\right)$$

Comparing with standard equation, $\omega = \frac{1}{20}$, $A = 8$

In SHM, $\qquad a = \omega^2 A$

$$\frac{d^2y}{dt^2} = a = \left(\frac{1}{20}\right)^2 \cdot 8 = \frac{8}{400} = \frac{1}{50} \text{ m/s}^2$$

$$\begin{aligned}\text{Diff. in weight} &= \omega_{max} - \omega_{min}\\ &= m(g+a) - m(g-a)\\ &= mg + ma - mg + ma\\ &= 2\,ma\\ &= 2 \times 50 \times \frac{1}{50} = 2 \text{ N}\end{aligned}$$

9. Correct answer is [22.97].

Total energy, $\qquad E = Nh\upsilon$

$$E_T = 35 \times 10^7 \times 6 \times 10^{-34} \times 10^{15}$$

$$= 21 \times 10^{-11} \text{ J}$$

Average energy, $\quad U = \frac{1}{2}\frac{B_0^2}{\mu_0}$

Given, $\qquad E_T = U,$

Hence, $\quad 21 \times 10^{-11} = \frac{B_0^2}{2\times 4\pi \times 10^{-7}}$

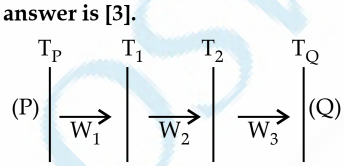
$$B_0^2 = 528 \times 10^{-18}$$

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

Comparing with $\alpha \times 10^{-9}$

We get, $\qquad \alpha = 22.97$

10. Correct answer is [3].



As per Stefan's law

$$E_1 = W_1 = \sigma Ae\,(T_P^4 - T_1^4)$$

$$E_2 = W_2 = \sigma Ae\,(T_1^4 - (T_2^4)$$

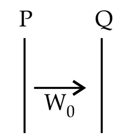
$$E_3 = W_3 = \sigma Ae\,(T_2^4 - T_Q^4)$$

On adding all three equations

$$W_S = W_1 + W_2 + W_3$$

$$= 3\sigma Ae\,(T_P^4 - T_Q^4) \qquad \text{...(i)}$$

In case II when there are no plates



$$W_0 = \sigma Ae\,(T_P^4 - T_Q^4) \qquad \text{...(ii)}$$

From Eqs (i) and (ii),

$$W_S = 3W_0$$

$\Rightarrow \qquad \frac{W_0}{W_S} = 3$

11. Correct answer is [0.75].

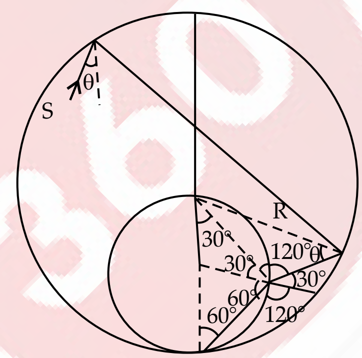
$$\frac{\sin r}{\sin 60} = \frac{1}{\sqrt{3}}$$

$$\sin r = \frac{\sqrt{3}/2}{\sqrt{3}} = \frac{1}{2}$$

$\Rightarrow \qquad r = 30^o$

Now, $\qquad \frac{R}{\sin 120} = \frac{R\sqrt{3}}{2\sin\theta}$

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



12. Correct answer is [75.6].

Given $\qquad \lambda = 600 \text{ nm} = 6 \times 10^{-7}$ m

$m = 3$

$d = 5 \times 10^{-3}$ m, $\Delta d = 1$ mm $= 10^{-3}$ m

$D = 1$ m, $\Delta D = 1$ cm $= 10^{-2}$ m

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

$\Rightarrow \qquad b = (m\lambda)\frac{D}{d}$

$$= 3 \times 6 \times 10^{-7} \times \frac{1}{5\times 10^{-3}}$$

$$= 3.6 \times 10^{-4} \text{ m}$$

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

$$\frac{\Delta b}{b} = \frac{10^{-2}}{1} + \frac{10^{-3}}{5\times 10^{-3}}$$

$$\begin{aligned}\Delta b &= 0.21 \times b\\ &= 0.21 \times 3.6 \times 10^{-4}\\ &= 0.756 \times 10^{-4}\\ &= 75.6\ \mu\text{m}\end{aligned}$$

13. Correct answer is [72].

$$\lambda_{neutron} = \frac{h}{\sqrt{2\,m_N k_B T}} \qquad \text{...(1)}$$

As per de Broglie $\lambda = \frac{2\pi r_n}{n}$

$$\lambda = \frac{2\pi r_3}{3} \quad \text{(Here } n = 3) \qquad \text{...(ii)}$$

From Eqs. (i) and (ii),

$$\frac{h}{\sqrt{2\, m_N k_B T}} = \frac{2\pi r_n}{n}$$

$$\frac{h}{\sqrt{2\, m_N k_B T}} = \frac{2\pi}{3}\left(a_0 \frac{3^2}{Z}\right) \qquad \text{...(iii)}$$

Given, $$T = \frac{Z^2 h^2}{\alpha \pi^2 a_0^2 m_N k_B} \qquad \text{...(iv)}$$

Substituting Eq. (iv) in Eq. (iii), we get,

$$\frac{h}{\sqrt{2}\,\frac{Zh}{\pi a_0 \sqrt{\alpha}}} = \frac{2\pi}{3}\left(a_0 \frac{9}{Z}\right)$$

$$\frac{\pi a_0 \sqrt{\alpha}}{\sqrt{2}} = \frac{2\pi}{3} a_0 \times 9$$

$$\sqrt{\alpha} = \sqrt{2} \times 2 \times 3$$

$$\sqrt{\alpha} = 6\sqrt{2}$$

$$\alpha = 36 \times 2 = 72$$

14. Correct option is (C).

$$\left.\begin{aligned} E_{axial} &= \frac{2PK}{r^3} \text{ or } \frac{2P}{4\pi\varepsilon_0 r^3} \\ E_{equ.} &= \frac{-P}{4\pi\varepsilon_0 r^3} \end{aligned}\right] \text{Due to an electric dipole}$$

Case 1: Both vectors are in same direction.

Hence, $\vec{E} = 2\left(-\frac{P}{4\pi\varepsilon_0 r^3}\right)\hat{j} = \frac{-P}{2\pi\varepsilon_0 r^3}\hat{j}$ (P) – (2)

Case 2: $\vec{E} = \vec{0}$ as both vectors are opposite to each other. Hence, Q $\rightarrow$ 1.

Case 3: $$\vec{E} = \frac{2P}{4\pi\varepsilon_0 r^3}\hat{i} + \frac{-P}{4\pi\varepsilon_0 r^3}\hat{j}$$

$$= \frac{P}{4\pi\varepsilon_0 r^3}(2\hat{i} - \hat{j})$$

(R) $\rightarrow$ (4)

Case 4: $$\vec{E} = \frac{2\times 2P}{4\pi\varepsilon_0 r^3}\hat{i} = \frac{P}{\pi\varepsilon_0 r^3}\hat{i}$$

(S) $\rightarrow$ (5)

15. Correct option is (A).

(P): $Z = R = 30\,\Omega$

$$i = \frac{V}{Z} = \frac{300}{30}\sin 400t > 10 \sin 400t$$

Matches with third graph of A = 10 and a sin curve (P) $\rightarrow$ (3).

(Q): $X_L = \omega L = 400 \times 100 \times 10^{-3} = 40\,\Omega$

$$Z = \sqrt{X_L^2 + R^2}$$

$$= \sqrt{40^2 + 30^2} = 50\,\Omega$$

$$I_0 = \frac{V_0}{Z} = \frac{300}{50} = 6$$

Also in LR, circuit I lags voltage (Q) $\rightarrow$ 5

(R): $$X_C = \frac{1}{\omega C} = \frac{1}{400 \times 50 \times 10^{-6}} = 50\,\Omega$$

$$X_L = \omega L = 400 \times 0.025 = 10\,\Omega$$

$$Z = \sqrt{(X_L - X_C)^2 + R^2}$$

$$= \sqrt{(50-10)^2 + 30^2} = 50$$

$$I_0 = \frac{V_0}{Z} = \frac{300}{50} = 6\text{A}$$

Also, Net X $= X_C - X_L = 40$ (capacitive)

I will lead V, so (2) graph is a perfect match.

(S): $X_C = 50\,\Omega$

$$X_L = 400 \times 125 \times 10^{-3} = 50\,\Omega$$

Net X $= X_L - X_C = 0.$

Hence, it will behave as pure resistive circuit.

$$I_0 = \frac{V_0}{R} = \frac{300}{60} = 5$$

$i = 5 \sin (400t)$, sin graph with A = 5

(S) $\rightarrow$ 1

16. Correct option is (C).

$E \propto Z^2$, energy level higher Z means higher E.

$E \propto (Z-1)^2$ Mosley's law depicts energy of X-rays

E is practically independent of Z especially between 30~170 BE is approx. constant.