JEE – Advanced 17th May 2026

Paper 01

Question paper and Solution

PHYSICS

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 If **ONLY** the correct option 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.

SECTION 2 (Maximum Marks: 16)

- This section contains **FOUR (04)** 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: —1 In all other cases.
- For example, in a question, if (A), (B) and (D) are the ONLY three options corresponding to 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 (i.e. the question is unanswered) will get 0 marks; and choosing any other combination of options will get –1 marks.

SECTION 3 (Maximum Marks: 16)

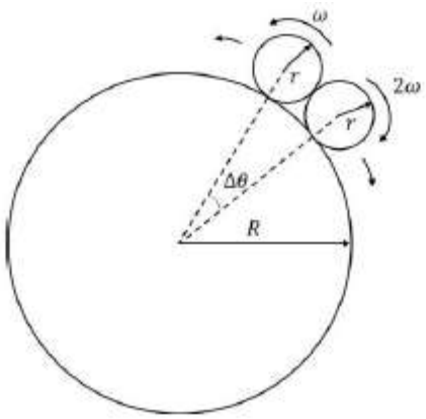
- This section contains **FOUR (04)** questions.
- The answer to each question is a **NUMERICAL VALUE.**
- For each question, enter the correct numerical value corresponding to the answer in the designated place using the mouse and the on-screen virtual numeric keypad.
- If the numerical value has more 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 If ONLY the correct numerical value is entered in the designated place;
  Zero Marks : 0 In all other cases.

SECTION 4 (Maximum Marks: 16)

- This section contains **FOUR (04)** 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.

Section 1
Multiple choice questions with one correct alternative

1. Consider a large disk of radius R and two smaller disks, each of radius $r = \frac{R}{50}$ lying on its circumference, as shown in the figure. The smaller disks are initially in contact with each other, with an angular separation $\Delta\theta$ between their centers. They are made to roll without slipping in opposite directions, with constant angular velocities ω and 2ω while the large disk is held stationary. The time τ at which the smaller disks are again in contact is
[Use sin $(\Delta\theta) = \Delta\theta$ and ignore gravity.



(A) $r = 51 \times \frac{\left(2\pi - \frac{4}{51}\right)}{\omega}$ (B) $r = 51 \times \frac{\left(2\pi - \frac{2}{51}\right)}{3\omega}$ (C) $r = 51 \times \frac{\left(2\pi - \frac{4}{51}\right)}{3\omega}$ (D) $r = 51 \times \frac{\left(2\pi - \frac{2}{51}\right)}{\omega}$

Ans (C)

The smaller disks roll without slipping on the circumference of the large disk. The center of each small disk moves along a circular path of radius.

$$R_c = R + r = \frac{51R}{50}$$

Initially, the two small disks are in contact. The angle subtended by each disk's radius r at the center of the large disk is $\Delta\theta$. Using the approximation provided

$$\sin(\Delta\theta) \approx \Delta\theta = \frac{2r}{R+r} = \frac{2}{51}$$

Thus, the initial angular separation between their centers is $2\Delta\theta = \frac{4}{51}$

For disk 1: $v_1 = \omega r$ and for disk 2: $v_2 = 2\omega r$

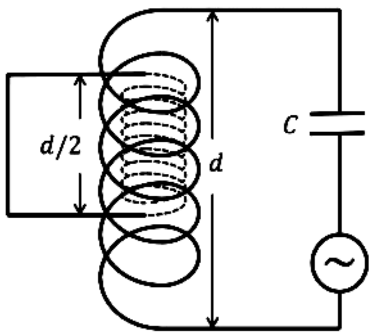
The effective rate of change of angle between the position vectors of the small disk's are

$$\left(\frac{d(\Delta\theta)}{dt}\right)_{eff} = \frac{\omega}{51} + \frac{2\omega}{51}$$

$$\tau = \frac{\theta_{total}}{\frac{d(\Delta\theta)}{dt}} = \frac{2\pi - \frac{4}{51}}{\frac{3\omega}{51}}$$

$$r = 51 \times \frac{\left(2\pi - \frac{4}{51}\right)}{3\omega}$$

2. Consider a circuit consisting of a capacitor of capacitance C and a coil with N turns per unit length, cross sectional area S and length d, where $d^2 >> S$. There is another coil of length $\frac{d}{2}$, cross sectional area $S/2$ and $2N$ turns per unit length completely inside the larger coil, as shown in the figure. The ends of this smaller coil are connected with each other by an insulated conducting wire. The self-inductance of the larger coil is L. Neglecting edge effects and all the Ohmic resistances, the resonant frequency of the circuit is:



(A) $\frac{4}{\sqrt{15LC}}$ (B) $\frac{6}{\sqrt{5LC}}$ (C) $\frac{2}{\sqrt{3LC}}$ (D) $\frac{2}{\sqrt{3LC}}$

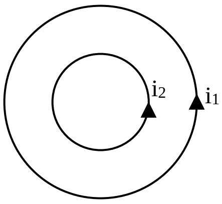
Ans (C)

$L_1 = \mu_0 n^2 A l$

$L_1 = \mu_0 N^2 S d = L$

$l_2 = \mu_0 (2N)^2 \frac{S}{2} \cdot \frac{d}{2} = L$

$M = \frac{(\mu N i_1)\frac{s}{2}\left(2N \times \frac{d}{2}\right)}{i_1} = \frac{L}{2}$



$L\frac{di_2}{dt} - M\frac{di_1}{dt} = 0$

$L\frac{di_2}{dt} - \frac{L}{2}\frac{di_1}{dt} = 0$

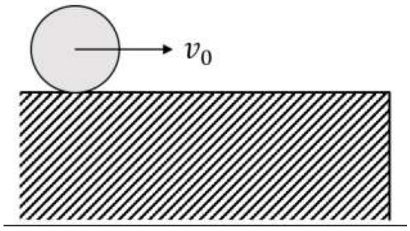
$i_2 = \frac{i_1}{2}$

$L_{eq}\frac{di_1}{dt} = L\frac{di_1}{dt} - M\frac{di_2}{dt} = L\frac{di_1}{dt} - \frac{L}{2}\frac{d}{dt}\left(\frac{i_1}{2}\right)$

$L_{eq} = \frac{3L}{4}$

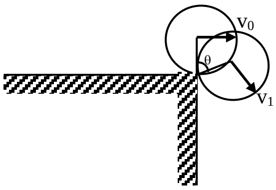
$\omega = \frac{1}{\sqrt{L_{eq}C}} = \frac{2}{\sqrt{3LC}}$

3. A solid cylinder of radius R rolls without slipping with a center of mass speed $v_0 = \sqrt{\frac{gR}{3}}$ on a horizontal surface with a vertical edge, as shown in the figure. Here, g is the acceleration due to the gravity. At the moment when the cylinder loses contact with the surface due to rotation around the corner, the speed of its center of mass is



(A) 0 (B) $\sqrt{\frac{5gR}{7}}$ (C) $\sqrt{\frac{gR}{15}}$ (D) $\sqrt{\frac{3gR}{7}}$

Ans (B)



$mgR(1-\cos\theta) = \frac{3}{4}m(v^2 - v_0^2)$

$mg\cos\theta = \frac{mv^2}{R}$ (N = 0, to loose contact)

$$1-\cos\theta=\frac{3}{4}\left(\cos\theta-\frac{1}{3}\right)$$

$$4-4\cos\theta=3\cos\theta-1$$

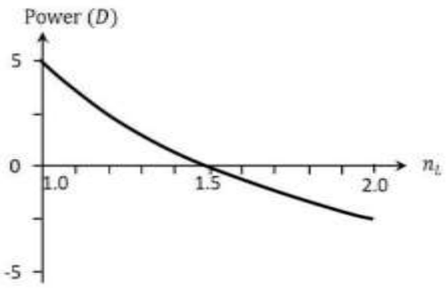
$$7\cos\theta=5$$

$$\cos\theta=\frac{5}{7}$$

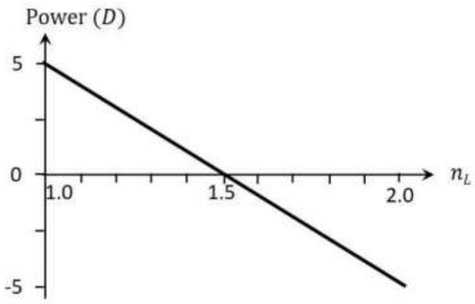
$$v=\sqrt{\frac{5}{7}gR}$$

4. A double convex lens made of glass of refractive index 1.5 and radii of curvature of the curved surfaces 20 cm each is immersed in a liquid of refractive index n_L. The correct plot showing the variation of the power, in the units of diopter (D), as a function of n_L is

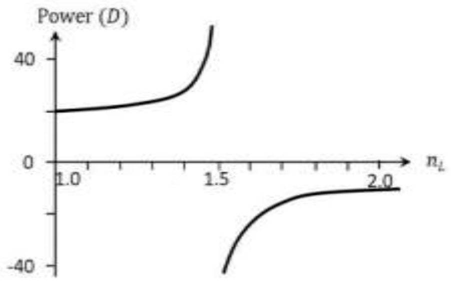
(A)



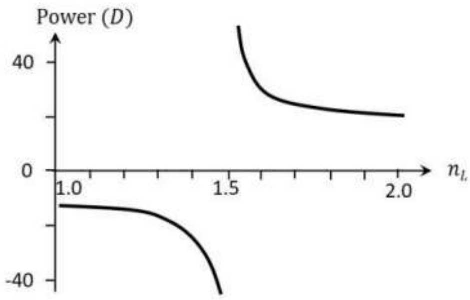
(B)



(C)



(D)



Ans (A) or (B)

$$P=\frac{1}{f}=\left(\frac{n_g}{n_L}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=\left(\frac{1}{0.2}-\frac{1}{-0.2}\right)=5+5=10\,m^{-1}$$

$$P=\left(\frac{1.5}{n_L}-1\right)\times 10=\frac{15}{n_L}-10$$

If n_L = 1.0 (air): $P=\frac{15}{1}-10=+5D$

If n_L = 1.5 (same as glass): $P=\frac{15}{1.5}-10=0D$

If n_L = 2.0; $P=\frac{15}{2}-10=7.5-10=-2.5D$

(A) represents a hyperbolic curve passing through these points.

(B) is a straight line, which is incorrect

(C) and (D) shown asymptotic behavior at n_L = 1.5, which is incorrect.

In deeper concepts of optics (not covered in NCERT) optical power is not always just 1/f. The more fundamental quantity is often:

$$\phi = \frac{n'}{v} - \frac{n}{u}$$

For a refracting system, power is connected to the change in vergence of light, where vergence is:

$$V = \frac{n}{x}$$

So in a medium of refractive index n, focal power can be written as:

$$P = \frac{n}{f}$$

not merely $\frac{1}{f}$

In elementary lens optics, when the image-side medium is air (n=1), we simply write:

$$P = \frac{1}{f}$$

because n=1. So n/f and 1/f become numerically identical.

For a lens inside a liquid, the image-side medium is liquid, so the more complete definition is:

$$P = \frac{n_L}{f}$$

Now for a thin lens immersed in a medium:

$$P = \frac{1}{f} = \left(\frac{n_g}{n_L} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

So, $P = \frac{n_L}{f}$

$$P = \frac{1}{f} = n_L\left(\frac{n_g}{n_L} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = = \left(n_g - n_L\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

This gives a linear relation with n_L.

For this question:

$R_1 = 0.2$ $R_2 = -0.2$

So: $\frac{1}{R_1} - \frac{1}{R_2} = 10$

$P = (1.5 - n_L) \times 10$

* At $n_L = 1$, P = 5D
* At $n_L = 1.5$, P = 0
* At $n_L = 2$, P = –5D

Therefore, if the exam is using the true vergence power P = n/f, the correct graph is B

So, in a medium, especially when power is defined via vergence, P = n/f is the more physically fundamental definition. For this JEE question more accurate answer is B as well.

Section 2

Multiple choice questions with one or more than one correct alternative/s

5. Consider a hydrogen atom with v_k, r_k, and K_k denoting the velocity, orbital radius and kinetic energy of the electron in the k^{th} orbit, respectively. The electron undergoes a transition from the n^{th} orbit, emitting radiation corresponding to the Lyman series. Considering h to be the Planck's constant and ε_0 the permittivity of the free space. the correct statement(s) is/are

(A) Magnitude of change in kinetic energy of electron can be expressed as $\frac{h}{4\pi}\left[\frac{nv_n}{r_n}-\frac{v_1}{r_1}\right]$

(B) Magnitude of change in de Broglie wavelength of the electron can be expressed as $\frac{e^2}{4\varepsilon_0}\left[\frac{1}{K_n}-\frac{1}{K_1}\right]$

(C) Frequency of the radiation emitted can be expressed as $\frac{e^2}{8\pi\varepsilon_0 h}\left(\frac{1}{r_1}-\frac{1}{r_n}\right)$

(D) Magnitude of change in total energy of the electron can be expressed as $\frac{h}{2\pi}\left[\frac{v_1}{r_1}-\frac{nv_n}{r_n}\right]$

Ans (A) and (C)

$$|\Delta K| = |K_n - K_1|$$

$$K = \frac{1}{2}mv^2 \text{ and } mv = \frac{kh}{2\pi r}$$

$$K = \frac{v}{2}\cdot\frac{kh}{2\pi r} = \frac{h}{4\pi}\cdot\frac{kv_k}{r_k}$$

$$|\Delta K| = \frac{h}{4\pi}\left|\frac{mv_n}{r_n}-\frac{1v_1}{r_1}\right|$$

So, (A) is correct.

$$\lambda_k = \frac{h}{p_k} = \frac{h}{\sqrt{2mK_k}}$$

$$K_k = \frac{e^2}{8\pi\varepsilon_0 r_k}$$

Hence, (B) is incorrect

$$hf = E_n - E_1 = K_1 - K_n$$

$$K_k = \frac{e^2}{8\pi\varepsilon_0 r_k}$$

$$hf = \frac{e^2}{8\pi\varepsilon_0}\left(\frac{1}{r_1}-\frac{1}{r_n}\right) \Rightarrow f = \frac{e^2}{8\pi\varepsilon_0 h}\left(\frac{1}{r_1}-\frac{1}{r_n}\right)$$

So, Statement (C) is correct

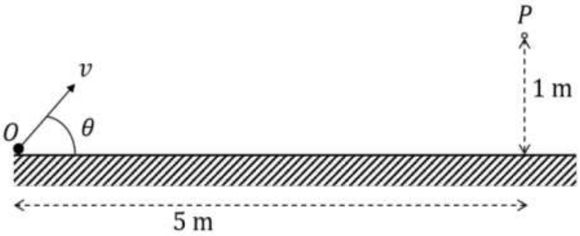
E = –K

$$|\Delta E| = \frac{h}{4\pi}\left|\frac{nv_n}{r_n}-\frac{v_1}{r_1}\right|$$

The expression in (D) uses $\frac{h}{2\pi}$ instead of $\frac{h}{4\pi}$

Statement (D) in incorrect.

6. A particle is thrown with a speed v from a point O at an angle θ with the horizontal plane such that it passes through the point P at a height of 1 m and horizontal distance of 5 m from O, as shown in the figure. If acceleration due to gravity is $g\ \text{ms}^{-2}$, then the correct statement(s) is/are



(A) If $\theta = 45°$, then $v = \frac{5\sqrt{g}}{2}\text{ms}^{-1}$

(B) If $\theta = 45°$, the particle reaches its maximum height before it reaches P

(C) If $\theta = 30°$, the particle reaches its maximum height after reaching P

(D) If $\theta = \tan^{-1}\left(\frac{1}{5}\right)$, then $v = 125\sqrt{g}\ \text{ms}^{-1}$

Ans (A) and (B)

$x = v\cos\theta\, t$ and $y = v\sin\theta - \frac{1}{2}gt^2$

$x\tan\theta = y + \frac{1}{2}gt^2$

$gt^2 = 2(x\tan\theta - y)$

$v = \frac{x}{\cos\theta t}$

$v_y = u\sin\theta - gt = \frac{x\tan\theta - gt^2}{t}$

$\theta = 45°$

$gt^2 = 8$

$t = 2\sqrt{\frac{2}{g}}$

$v = \frac{5}{\frac{1}{\sqrt{2}} \times 2\sqrt{\frac{2}{g}}} = \frac{5}{2}\sqrt{g}$

$v_y < 0$

Particle reaches (5, 1) after reaching maximum height

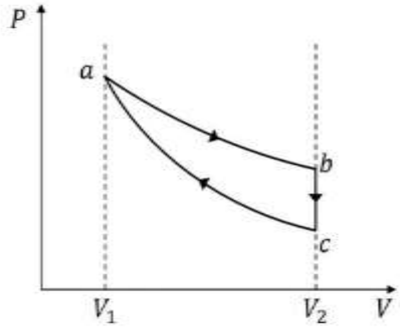
$\theta = 30°$

$gt^2 = 2\left(\frac{5-1}{\sqrt{3}}\right)$

$v_y = \frac{\frac{5}{\sqrt{3}} - 2\left(\frac{5}{\sqrt{3}} - 1\right)}{t} = \frac{2 - \frac{5}{\sqrt{3}}}{t} < 0$

Also reaches (5, 1) after reaching maximum height

7. A quasi-static cycle of a monoatomic ideal gas contains an isothermal process (ab), followed by an isochoric process (bc) and an adiabatic process (ca) as shown in the figure. The volumes of the gas are V_1 and V_2 at a and b, respectively. If the cycle has heat input Q_{in} and output Q_{out}, then the efficiency of the cycle is defined as $\eta = \frac{Q_{in} - Q_{out}}{Q_{in}}$. The correct statement(s) is/are: (Given: $l n 2 \approx 0.7$)



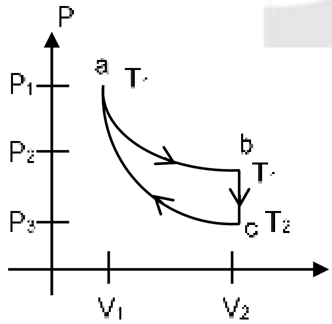
(A) If $\frac{V_2}{V_1} = 8$, the heat released in the process bc is smaller than the heat absorbed in the process ab.

(B) For a given value of $\frac{V_2}{V_1}$, η does not depend on the temperature of the isothermal process.

(C) If $\frac{V_2}{V_1} =$ 8, then the temperature of the gas at a is 4 times the temperature of the gas at c.

(D) If $\frac{V_2}{V_1} =$ 8, then the pressure of the gas at a is 4 times the pressure of the gas at b.

Ans (A), (B) and (C)



$$T_2V_2^{2/3} = T_1V_1^{2/3}$$

$$T_1 = T_2 \times \left(\frac{V_2}{V_1}\right)^{2/3}$$

$$\eta = \frac{Q_{in} - Q_{out}}{Q_{in}} = 1 - \frac{|Q_{bc}|}{Q_{ab}}$$

$$Q_{abc} = n\frac{3R}{2}(T_2 - T_1) = \frac{3}{2}nR\left[T_1\left(\frac{V_1}{V_2}\right)^{2/3} - T_1\right]$$

$$Q_{bc} = \frac{3}{2}nRT_1\left(1 - \left(\frac{V_1}{V_2}\right)^{2/3}\right)$$

$|Q_{bc}| = \frac{3}{2}nRT, \left(1 - \left(\frac{V_1}{V_2}\right)^{2/3}\right)$

$$\eta = 1 - \frac{\frac{3}{2}\left(1 - \left(\frac{V_1}{V_2}\right)^{\frac{2}{3}}\right)}{ln\left(\frac{V_2}{V_1}\right)}$$

As seen, η does not depend on T_1.

8. The electric field associated with an electromagnetic wave travelling in vacuum is given by $E_0 \sin(3y + 4z + \omega t)\hat{i}$, where ω is the angular frequency. All quantities are in S.I units. The correct statement(s) about this wave is/are: [Given: speed of Light in vacuum $c = 3 \times 10^8\ ms^{-1}$]

(A) The wave is travelling in $-\frac{1}{5}\left(3\hat{j} + 4\hat{k}\right)$ direction

(B) The magnitude of the wave vector is $0.5\,m^{-1}$

(C) The value of ω is 1.5×10^9 rad s^{-1}

(D) The magnetic field associated with this wave is given by $\frac{E_0}{c}\sin(3y + 4z + \omega t)\left(4\hat{j} - 3\hat{k}\right)$

Ans (A) and (C)

Given electric field, $E_0 \sin(3y + 4z + \omega t)\hat{i}$

$k_x = 0$, $k_y = 3$ and $k_z = 4$

So, $\vec{K} = 3\hat{j} + 4\hat{k}$

$|\vec{K}| = 5\,m^{-1}$. So, option (B) is incorrect.

Wave travels opposite to $\vec{K}$

So, direction is $-\left(\frac{3\hat{i} + 4\hat{k}}{5}\right)$. So option (A) is correct.

Now, $\omega = ck$

K = 5 m^{-1}

c = 3 × 10^8

$\omega = (3 \times 10^8)5\ = 1.5 \times 10^9$ rad s^{-1}

We know: $\vec{E} \perp \vec{B} \perp$ direction of propagation

Electric field is along: $\hat{i}$

Propagation direction: $-\frac{3\hat{i} + 4\hat{k}}{5}$

Using, $\vec{E} \times \vec{B}$

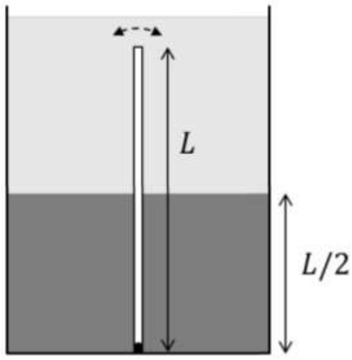
Now, check $\hat{i} \times \left(4\hat{j} - 3\hat{k}\right) = 4\hat{k} + 3\hat{j} = 3\hat{j} + 4\hat{k}$

This gives $+\vec{K}$ direction, but actual propagation is opposite $-\left(3\hat{i} + 4\hat{k}\right)$

Hence, option (D) is wrong

Section 3
Numerical problems (truncate/round-off the value to TWO decimal places)

9. A tank contains two immiscible liquids of densities 6ρ and 2ρ. The higher density liquid is filled up to a height $\frac{L}{2}$ from the bottom. A thin rod of density ρ and length L is fully immersed and hinged at the bottom so that it can oscillate freely, as shown in the figure. If the rod is slightly disturbed from its equilibrium, the time period of small oscillations is $\frac{2\pi}{n}\sqrt{\frac{L}{g}}$, where g is the acceleration due to gravity. The value of n is:



Ans 1.73

Net force acting on point $A = \frac{6\rho V}{2}g - \frac{\rho V}{2}g = \frac{5\rho vg}{2}$

Net force acting on point $B = \frac{2\rho vg}{2} - \frac{\rho V}{2}g = \frac{\rho Vg}{2}$

Total restoring torque $= -\left(\frac{5\rho Vg}{2}\frac{L}{4}x\sin\theta + \frac{\rho Vg}{2}\sin\theta\frac{3L}{a}\right) = -\rho VgL\sin\theta$

$\tau = -\rho VgL\theta$

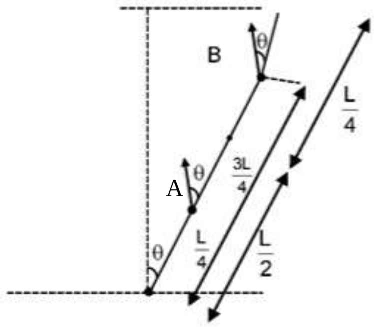
$\tau > I\alpha$

$I = \frac{ML^2}{3} = \frac{\rho VL^2}{3}$

$\alpha + \frac{\rho VgL}{\frac{\rho VL^2}{3}}\theta = 0$

$\alpha + \frac{3g}{L}\theta = 0$

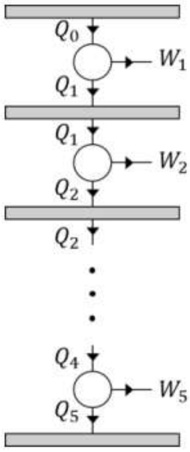
$\omega = \sqrt{\frac{3g}{L}}$



$T = 2\pi\sqrt{\frac{L}{3g}}$

$n = \sqrt{3} = 1.73$

10. As shown in the figure, five Carnot engines, each with efficiency η and same number of cycles per unit time, are operating between six heat reservoirs. The amount of heat released per cycle by one engine is completely absorbed by the next engine. Consider Q_0 to be the amount of heat absorbed per cycle by the first engine and W as the amount of total work done by all the engines per cycle, then the net efficiency of the system is found to be $\eta_{net} = \frac{W}{Q_0} = \frac{211}{243}$. The value of η is



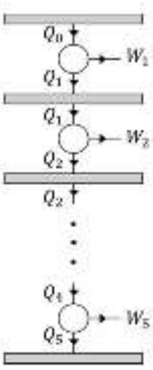
Ans 0.33

$$\eta = 1 - \frac{Q_1}{Q_0} = 1 - \frac{Q_2}{Q_1} = ...$$

$$\eta_{net} = \frac{W_1 + W_2 + ...W_s}{Q_0}$$

$$= \frac{Q_0 - Q_1 + Q_1 - Q_2 + ... - Q_5}{Q_0}$$

$$= 1 - \frac{Q_5}{Q_0}$$



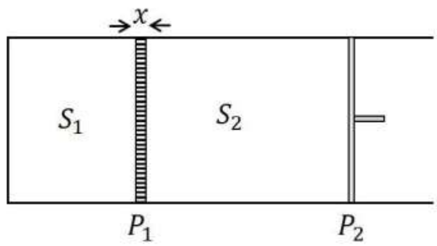
$$\frac{Q_1}{Q_0} = \frac{Q_2}{Q_1} = ...\frac{Q_5}{Q_4} = 1 - \eta$$

$$\frac{Q_s}{Q_0} = \frac{Q_1}{Q_0}.\frac{Q_2}{Q_1} \times \frac{Q_3}{Q_2} \times \frac{Q_4}{Q_3} \times \frac{Q_5}{Q_4} = (1-\eta)^s$$

$$\frac{211}{243} = 1 - (1-\eta)^5$$

$$(1-\eta)^5 = \frac{32}{243} \Rightarrow 1 - \eta = \frac{2}{3} \Rightarrow \eta = \frac{1}{3}$$

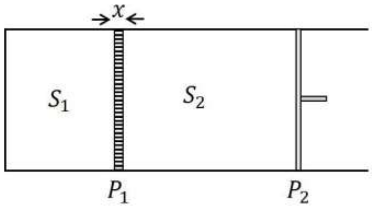
11. As shown in the figure, an insulated container is fitted with a thermally conducting but immovable partition (P_1) and a freely movable but thermally insulated piston (P_2). The partition P_1 with thermal conductivity K, cross sectional area A and width x divides the container into two sections, S_1 and S_2, each containing one mole of a monoatomic gas. The piston P_2 moves freely such that the gas in S_2 is always at the atmospheric pressure. Initially, the difference between the temperatures of S_2 and S_2 is ΔT_0 The time it takes for the temperature difference to become $\frac{\Delta T_0}{2}$ is $\frac{nxR}{KA}$, where R is the universal gas constant. The value of n is: [Given: $l n 2 \approx 0.7$]



Ans 0.66

Initial temperature : $T_{10} - T_{20} = \Delta T_0 = \theta_0$

Temperature at time t: $T_1 - T_2 = \theta$



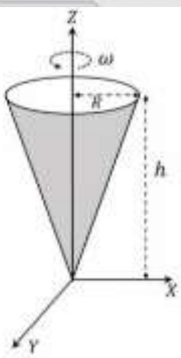
$$dQ = -\frac{3}{2}RdT_1 = +\frac{5}{2}RdT_2$$

$$\frac{dQ}{dt} = \frac{kA}{x}\theta = -\frac{3}{2}\frac{RdT_1}{dt} = -\frac{3}{2}R \times \frac{5}{8}\frac{d\theta}{dt}$$

$$\frac{kA}{x}\theta = -\frac{15R}{16}\frac{d\theta}{dt}$$

$$\int_0^t dt = -\frac{15}{16}\frac{Rx}{kA}\int_{\theta_0}^{\frac{\theta_0}{2}}\frac{d\theta}{\theta} = \frac{15}{16}\frac{Rx}{kA}\ln 2$$

12. A hollow, right circular cone of base radius R and height h, with its tip at the origin is rotating about the Z-axis with an angular velocity ω, as shown in the figure. The cone carries a total charge Q uniformly distributed on its curved surface. The magnitude of magnetic field at a point (0, 0, z), where $z >> R$ and $z >> h$ is $\frac{n\mu_0}{4\pi}\frac{QR^2\omega}{z^3}$. The value of n is

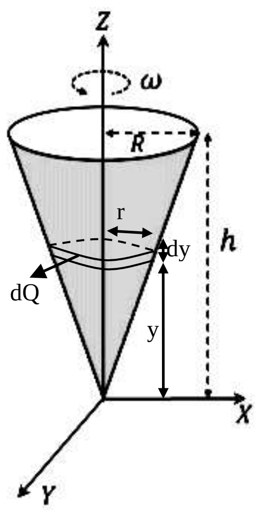


Ans 0.50

Consider an elementary ring of width dy

Charge on Ring = dQ = $\sigma \times dA$

dA = $2\pi r(dy)$



$$\frac{r}{y} = \frac{R}{h} \Rightarrow y = \frac{R \times r}{h}$$

$$dy = \frac{R}{h}(dr)$$

$$\Rightarrow \quad dQ = \sigma \times 2\pi r\left(\frac{R}{h}\right)dr, \qquad \sigma = \frac{Q}{\pi Rh}$$

Current due to rotation of $dQ = di = \frac{dQ \times \omega}{2\pi}$

$$di = \sigma \times 2\pi r(dr) \times \frac{R}{h} \times \frac{\omega}{\pi Rh},\ \sigma = \frac{Q}{\pi Rh}$$

Field at 'P' due to $di = dB = \frac{\mu_0 (di) r^2}{2\left[r^2 + x^2\right]^{\frac{3}{2}}} = \frac{r_0 (di) r^2}{2\left[r^2 + z^2\right]^{\frac{3}{2}}}$

$x = (z - y) \approx z$

Since z is large $z^2 + r^2 \approx z^2$

$$\Rightarrow dB = \frac{\mu_0 (di) r^2}{2z^3}$$

$$\Rightarrow B_P = \int_0^R dB = \frac{\mu_0}{2z^3} \int_0^R di\left(r^2\right) = \frac{\mu_0 Q R^2 \omega}{8\pi z^3} = \frac{n \mu_0 Q R^2 \omega}{4\pi z^3}$$

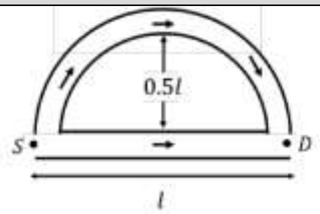
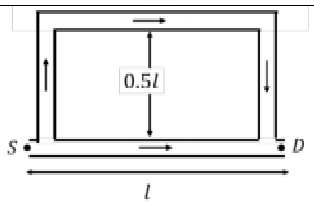
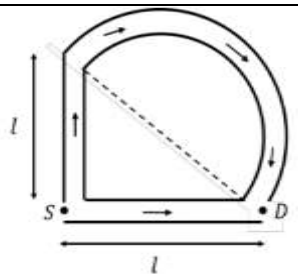
$$\Rightarrow n = \frac{1}{2}$$

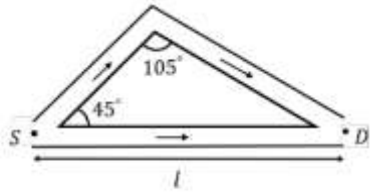
Section 4

Choose the appropriate entry/entries from List II to match each of the entries of the List I. It is possible that an option(s) in List II may be valid more than once, for a given entry in List I

13. List-I shows four configurations made of straight and semi-circular narrow tubes containing air. A sound wave of wavelength λ = 0.29 m enters these structures at the point S and a sound detector is placed at D. Between the points S and D, the sound travels only through the tubes. List-II contains the possible smallest values of *l* (refer to the figures) for which the detector D records maximum amplitude. Ignore effects of sharp corners. [Given cos(15°) = 0.97]

Choose the option that best describes the match between the entries in List-I to those in List-Il.

List - I		List - II	
(P)		(1)	1.32 m
(Q)		(2)	1.19 m
(R)		(3)	0.51 m

List - I		List - II	
(S)		(4)	0.29 m
		(5)	0.13 m

(A) (P) → (4); (Q) → (3); (R) → (5); (S) → (1)

(B) (P) → (4); (Q) → (3); (R) → (1); (S) → (5)

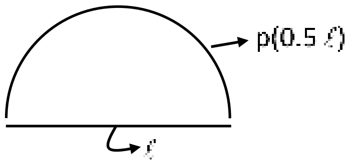
(C) (P) → (3); (Q) → (4); (R) → (1); (S) → (2)

(D) (P) → (3); (Q) → (4); (R) → (5); (S) → (2)

Ans (D)

$\lambda = 0.29$ m

For maxima ; $\Delta x = n\lambda$



(P)

$$\Delta x = \pi(0.5)\,\ell - \ell = \ell\left(\frac{\pi}{2}-1\right) = \frac{\ell}{2}(\pi-2) = n\lambda \Rightarrow \ell = \frac{2n\lambda}{\pi-2}$$

n = 1

$$\ell = \frac{0.58}{1.14} = 0.508 \simeq 0.51$$

(Q) $\Delta x = 0.5\ell + \ell + 0.5\ell - \ell \Rightarrow l = n\lambda \Rightarrow \ell = n \times 0.29 \Rightarrow \ell = 0.29$ m

(R) $\ell + \pi\frac{\ell}{\sqrt{2}} - \ell = n \times 0.29$ (n = 1)

$$\ell = \frac{0.29 \times 1.414}{3.14} = 0.13 \text{ m}$$

14. In the List-I, four optical effects are mentioned. The physical phenomena of light which are essential to describe these optical effects are given in List-II. Choose the option which describes the correct match between the entries in List-I to those in List-II.

List - I		List - II	
(P)	Colorful sky in north polar region (Aurora Borealis)	(1)	Dispersion and reflection
(Q)	Partially polarized sun light	(2)	Total internal reflection
(R)	Rainbow	(3)	Diffraction
(S)	Dark and bright fringes	(4)	Scattering of light by molecules in the atmosphere
		(5)	Emission of radiation from oxygen and nitrogen atoms excited by charged particles

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

Ans (A)

Rainbow → Dispersion and reflection
Dark bright fringer → Diffraction
Partially polarized sunlight → Scattering of light by molecular in atmosphere
Colourful sky in north polar region → Emission of radiation from oxygen and nitrogen.

(P) Colourful sky in north polar region (Aurora Borealis) → (5)
Aurora Borealis occurs because charged particles from the Sun enter Earth's atmosphere and excite oxygen and nitrogen atoms. These atoms emit coloured radiation when they return to lower energy states.

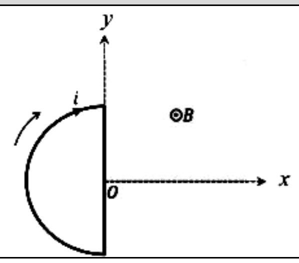
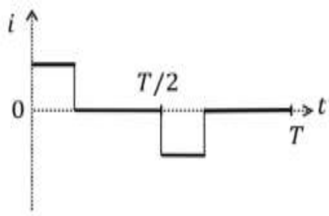
(Q) Partially polarized sunlight → (4)
Sunlight becomes partially polarized due to scattering by molecules in the atmosphere. The scattered light has preferred vibration directions, especially at 90° scattering.

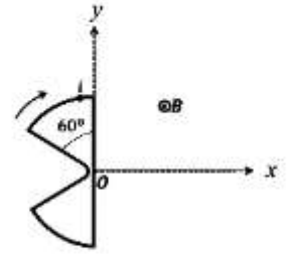
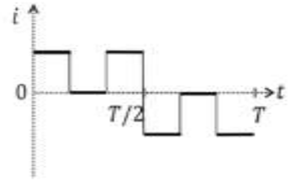
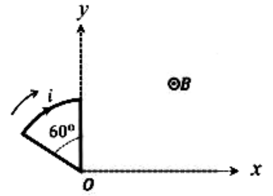
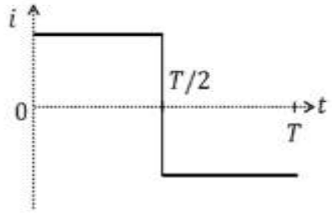
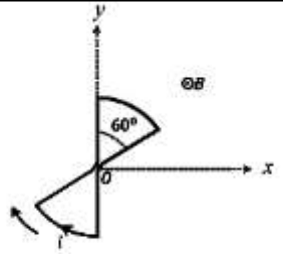
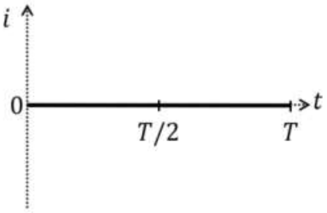
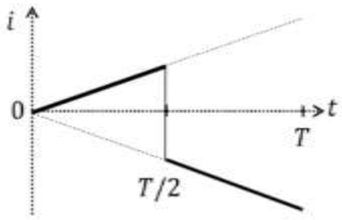
(R) Rainbow → (1)
A rainbow forms because sunlight undergoes dispersion inside water droplets along with partial internal reflection. Different colours emerge at different angles due to wavelength dependence.

(S) Dark and bright fringes → (3)
Bright and dark fringes are produced due to diffraction/interference of light waves. Superposition causes constructive and destructive intensity patterns.

Therefore the correct matching is:
(P) → (5), (Q) → (4), (R) → (1), (S) → (3)
Hence the correct option is: (A).

15. List-I contains four conducting loops lying in the XY plane, as shown in the figures. The loops are rotating about Z axis passing through the point 0 with time period T in clockwise direction. The region $x > 0$ contains a uniform magnetic field B in the +z direction. List-II contains the qualitative variation of the induced current i(t) for each of these loops. Choose the option which describes the correct match between the entries in List-I to those in List-II.

List - I		**List - II**	
(P)		(1)	

List - I		List - II	
(Q)		(2)	
(R)		(3)	
(S)		(4)	
		(5)	

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

Ans (C)

(P) Current will be positive for first half and negative for other half

(Q) $\frac{60}{360} = \frac{1}{6}$

For $\frac{T}{6}$ part current will be recorded.

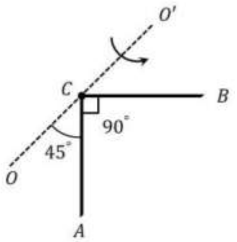
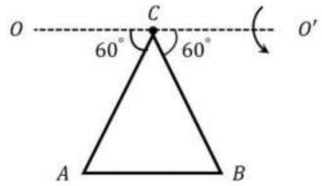
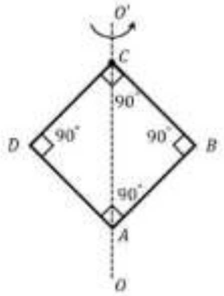
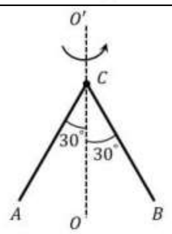
For next $\frac{T}{6}$ part current will be zero as there is no loop

For last $\frac{T}{6}$ part current will recorded once again

(R) Here for $\frac{T}{6}^{th}$ part only current will be there, for rest of the time, current will be zero

(S) Here, current for one loop will cancel out the other, so net current is zero.

16. List-I shows four planar structures made of uniform solid rods each of mass in and length l. In the List-II the possible moment of inertia of these structures about an axis OCO′, which lies in the plane of the structures, are given. 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)	$\frac{5}{4}ml^2$
(Q)		(2)	$\frac{1}{6}ml^2$
(R)		(3)	$\frac{1}{12}ml^2$
(S)		(4)	$\frac{2}{3}ml^2$
		(5)	$\frac{1}{3}ml^2$

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

Ans (A)

(P) Moment of inertia of rod about an axis at an angle θ

$$I_1 = \frac{1}{3}mL^2 \sin^2 45 = \frac{1}{6}mL^2$$

$$I_T = 2I_1 = 2\times\frac{1}{6}mL^2 = \frac{1}{3}mL^2$$

(Q) $I_1 = I_2 = \frac{1}{3}mL^2 \sin^2 60 = \frac{1}{3}mL^2\,\frac{3}{4} = \frac{mL^2}{4}$

$$I_T = 2I_1 + I_3 = 2\left(\frac{mL^2}{4}\right) + m\left(\frac{\sqrt{3}L}{2}\right)^2 \Rightarrow I_T = \frac{5}{4}mL^2$$

(R) $I_1 = \frac{1}{3}mL^2 \sin^2 45 = \frac{1}{3}mL^2\left(\frac{1}{2}\right) \Rightarrow I_1 = \frac{1}{6}mL^2$

$$I_T = I_1 + I_2 + I_3 + I_4 = 4\left(\frac{1}{6}\right)mL^2$$

$$I_T = \frac{2}{3}mL^2$$

(S) $I_1 = \frac{1}{3}mL^2 \sin^2 30 = \frac{1}{3}mL^2 \frac{1}{4}$

$$I_1 = \frac{1}{12}mL^2$$

$$I_T = 2I_1 = 2\times\frac{1}{12}mL^2 \Rightarrow I_T = \frac{1}{6}mL^2$$

* * *