JEE ADVANCED

ANSWER KEY

2021

PHYSICS

Paper-2

QUESTION WITH SOLUTION

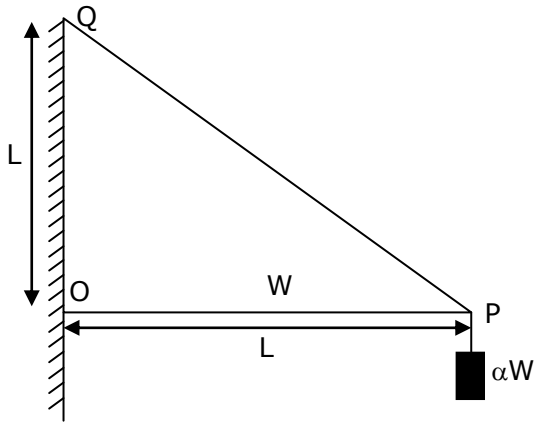
SECTION – A

- This section contains SIX (06) 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 If only (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 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 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 +2marks;
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.

Q.1 One end of a horizontal uniform beam of weight W and length L is hinged on a vertical wall at point O and its other end is supported by a light inextensible rope. The other end of the rope is fixed at point Q, at a height L above the hinge at point O. A block of weight αW is attached at the point P of the beam, as shown in the figure (not to scale). The rope can sustain a maximum tension of $\left(2\sqrt{2}\right)$W. Which of the following statement(s) is(are) correct?

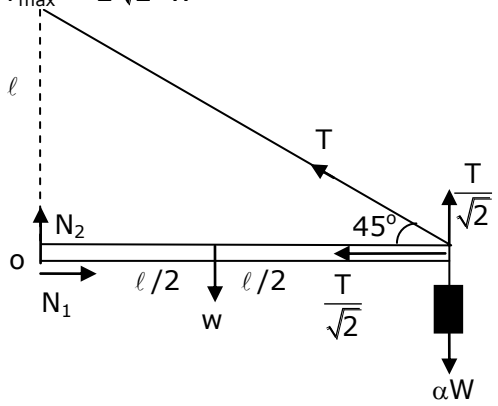


(A) The vertical component of reaction force at O does not depend on α
(B) The horizontal component of reaction force at O is equal to W for α = 0.5
(C) The tension in the rope is 2W for α = 0.5
(D) The rope breaks if α > 1.5

Sol. **A,B,D**

Given

$T_{max} = 2\sqrt{2}$ W



$\tau_0 = 0$

From figure

In equilibrium

$W\frac{\ell}{2} + \alpha W\ell = \frac{T\ell}{\sqrt{2}}$ .....(i)

$\frac{W}{2} + \alpha W = \frac{2\sqrt{2}W}{2}$

$\alpha = \frac{3}{2}$ condition where rope will just break.

So, Option D is correct

Again from the figure

Now, $N_1 = \frac{T}{\sqrt{2}} = \frac{W}{2} + \frac{W}{2} = W$

$\rightarrow$ Option A is correct

$\rightarrow N_2 + \frac{T}{\sqrt{2}} = W + \alpha W$

or, $N_2 + \frac{W}{2} + \alpha W = W + \alpha W$

or, $N_2 = \frac{W}{2}$ (Independent of α)

$\rightarrow$ Option B is correct

$\Rightarrow \frac{T}{\sqrt{2}} = \frac{W}{2} + \alpha W$

$= \frac{W}{2} + \frac{W}{2}$ (If $\alpha = 0.5$)

$= W$

Or, $T = \sqrt{2}W$

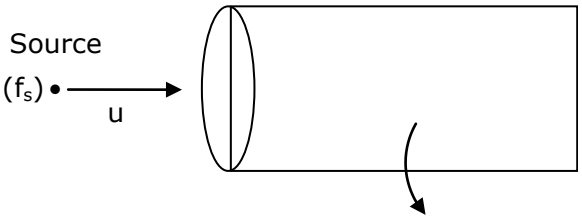
$\rightarrow$ Option C is Incorrect

Q.2 A source, approaching with speed u towards the open end of a stationary pipe of length L, is emitting a sound of frequency f_s. The farther end of the pipe is closed. The speed of sound in air is v and f_0 is the fundamental frequency of the pipe. For which of the following combination(s) of u and f_s, will the sound reaching the pipe lead to a resonance ?

(A) u = 0.8v and $f_s = f_0$ (B) u = 0.8v and $f_s = 2f_0$

(C) u = 0.8v and $f_s = 0.5f_0$ (D) u = 0.5v and $f_s = 1.5f_0$

Sol. **A,D**



$$f = (2n-1)f_0$$

Using Doppler's effect

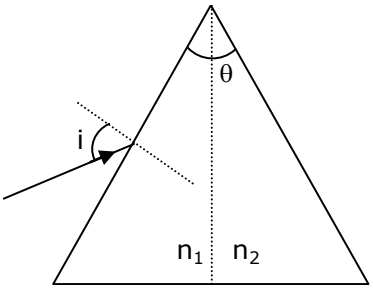
$$f = \left(\frac{v \pm V_0}{v \pm V_s}\right) f_s$$

$$f = \left(\frac{v}{v-u}\right) f_s$$

Now, $\left(\frac{v}{v-u}\right) f_s = (2n-1) f_0$

Now check options using values keeping mind (2n–1) must be any possible integer.

Q.3 For a prism of prism angle $\theta = 60°$, the refractive indices of the left half and the right half are, respectively, n_1 and n_2 ($n_2 \geq n_1$) as shown in the figure. The angle of incidence i is chosen such that the incident light rays will have minimum deviation if $n_1 = n_2 = n = 1.5$. For the case of unequal refractive indices, $n_1 = n$ and $n_2 = n + \Delta n$ (where $\Delta n << n$), the angle of emergence $e = i + \Delta e$. Which of the following statement(s) is (are) correct ?



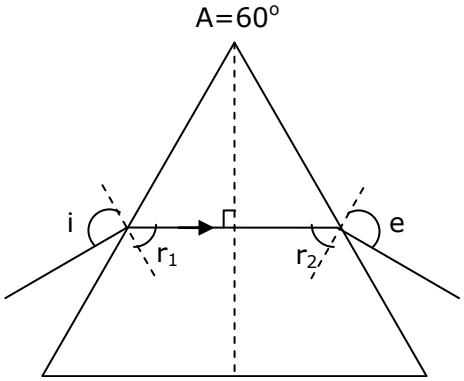
(A) The value of Δe (in radians) is greater than that of Δn

(B) Δe is proportional to Δn

(C) Δe lies between 2.0 and 3.0 milliradians, if $\Delta n = 2.8 \times 10^{-3}$

(D) Δe lies between 1.0 and 1.6 milliradians, if $\Delta n = 2.8 \times 10^{-3}$

Sol. **B,C**



Given

$n_1 = n_2 = 1.5$

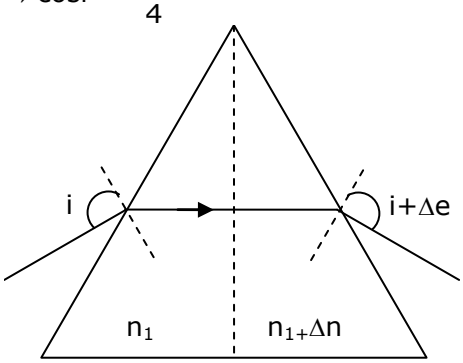
For δ_{min}

$i = e$ and $r_1 = r_2 = \frac{A}{2} = 30^o$

$1\sin i = 1.5 \sin 30^o$

$\sin i = \frac{3}{4}$ .....(i)

$\rightarrow \cos i = \frac{\sqrt{7}}{4}$



Now, $n_2 \rightarrow 1.5 + \Delta n$

$e \rightarrow i + \Delta e$

Hence, light from n_1 to n_2 goes perpendicularly; so, no deviation

$(1.5 + \Delta n)\sin 30^o = 1 \times \sin(i+\Delta e)$

$\frac{3}{4} + \frac{\Delta n}{2} = \sin i \times \cos \Delta e + \cos i \times \sin \Delta e$

$\Rightarrow \frac{3}{4} + \frac{\Delta n}{2} = \frac{3}{4} \times 1 + \frac{\sqrt{7}}{4} \Delta e$

$\frac{\Delta n}{2} = \frac{\sqrt{7}}{4} \Delta e$

$\Delta n = \frac{\sqrt{7}}{2} \Delta e$

$\because \Delta n > \Delta e$

$\therefore$ Option A is Incorrect

Check option using values given in options.

Q.4 A physical quantity $\vec{S}$ is defined as $\vec{S} = \left(\vec{E} \times \vec{B}\right) / \mu_0$, where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantity (ies) ?

(A) $\dfrac{\text{Energy}}{\text{Charge} \times \text{current}}$ (B) $\dfrac{\text{Force}}{\text{Length} \times \text{Time}}$

(C) $\dfrac{\text{Energy}}{\text{Volume}}$ (D) $\dfrac{\text{Power}}{\text{Area}}$

Sol. **B,D**

Given

$$\vec{s} = \frac{\left(\vec{E} \times \vec{B}\right)}{\mu_0}$$

This is pointing vector. This gives rate of flow of energy per unit area.

i.e s $\rightarrow \dfrac{J}{sm^2} = \dfrac{\text{Power}}{\text{Area}}$

Also, $\dfrac{\text{Power}}{\text{Area}}$ can be written in form : - $\dfrac{F\ell}{t \cdot \ell^2} = \dfrac{F}{\ell \times t}$

Q.5 A heavy nucleus N, at rest, undergoes fission N $\rightarrow$ P + Q, where P and Q are two lighter nuclei. Let $\delta = M_N - M_P - M_Q$, where M_P, M_Q and M_N are the masses of P, Q and N, respectively. E_P and E_Q are the kinetic energies of P and Q, respectively. The speeds of P and Q are v_P and v_Q, respectively. If c is the speed of light, which of the following statement(s) is (are) correct ?

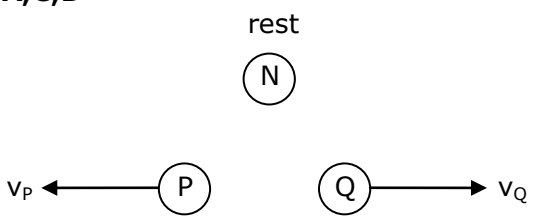
(A) $E_P + E_Q = c^2\delta$

(B) $E_P = \left(\dfrac{M_P}{M_P + M_Q}\right)c^2\delta$

(C) $\dfrac{v_P}{v_Q} = \dfrac{M_Q}{M_P}$

(D) The magnitude of momentum for P as well as Q is $c\sqrt{2\mu\delta}$, where $\mu = \dfrac{M_P M_Q}{(M_P + M_Q)}$

Sol. **A,C,D**



Given

$m_p v_p = m_Q m_Q$

$$\frac{v_p}{v_Q} = \frac{m_Q}{m_p}$$

$\rightarrow$ option C is correct.

Now, $E_p + E_Q = \Delta mc^2 = \delta c^2$

$\rightarrow$ option A is correct.

$\Rightarrow E_p = \frac{P^2}{2m_p}; E_Q = \frac{P^2}{2m_Q}$

or, $\frac{E_p}{E_Q} = \frac{m_Q}{m_p}$

$\Rightarrow \frac{E_p}{E_p + E_Q} = \frac{m_Q}{m_p + m_Q}$

$\Rightarrow E_p = \left(\frac{m_Q}{m_p + m_Q}\right)\delta c^2$

$\rightarrow$ option B is Incorrect.

Now, $E_p + E_Q = \delta c^2$

$\frac{p^2}{2m_p} + \frac{p^2}{2m_Q} = \delta c^2$

$\frac{p^2}{2}\left(\frac{1}{m_p} + \frac{1}{m_Q}\right) = \delta c^2$

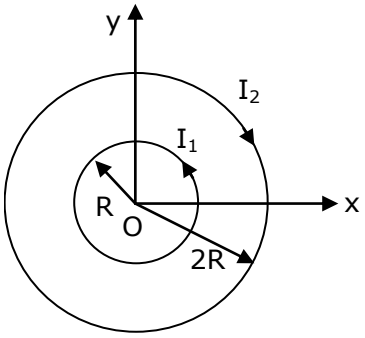
$\frac{p^2}{2} = \delta c^2 \times \frac{m_p m_Q}{m_p + m_Q} = \delta c^2 \mu$

$P^2 = 2\mu\delta c^2$

$P = c\sqrt{2\mu\delta}$

$\rightarrow$ option D is correct.

Q.6 Two concentric circular loops, one of radius R and the other of radius 2R, lie in the xy-plane with the origin as their common center, as shown in the figure. The smaller loop carries current I_1 in the anti-clockwise direction and the larger loop carries current I_2 in the clockwise direction, with $I_2 > 2I_1$. $\vec{B}(x,y)$ denotes the magnetic field at a point (x,y) in the xy-plane. Which of the following statement(s) is (are) correct ?



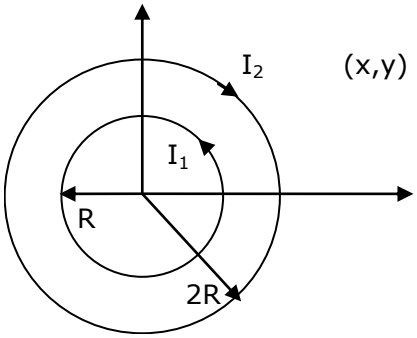
(A) $\vec{B}(x,y)$ is perpendicular to the x-y plane at any point in the plane

(B) $|\vec{B}(x,y)|$ depends on x and y only through the radial distance r = $\sqrt{x^2+y^2}$

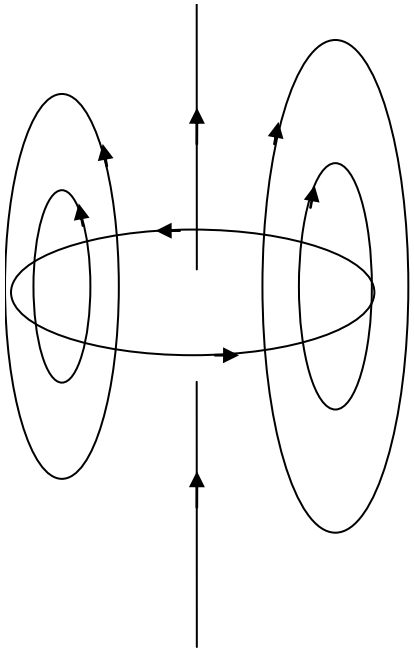
(C) $|\vec{B}(x,y)|$ is non-zero at all points for r < R

(D) $\vec{B}(x,y)$ points normally outward from the x-y plane for all the points between the two loops

Sol. A,B



Given
$I_2 > 2I_1$
Option A is correct
Because M.F. will always be along z-axis due to both loops at point (x,y)
Now, if any point (x,y);
$r = \sqrt{x^2 + y^2}$

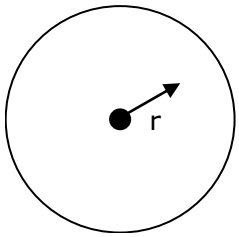


for any point in space; we have disting M.F.
So, M.F. will depend on r.
Option B is not asking exact relation of M.F. with 'r'
So option is B is correct.

Now, at 'O' $B_{net} = \frac{\mu_0 I_1}{R} - \frac{\mu_0 I_2}{2R}$ B_{net} at 'O' is inward

If $B_{net} = 0$; $\frac{\mu_0 I_1}{R} = \frac{\mu_0 I_2}{2R}$

$I_2 = 2I_1$ But in Question its given that $I_2 > 2I_1$



If $r \to 0$; $B_1 \to \infty$
So there may be possibility that $B_1 = B_2$
So be may become zero somewhere.

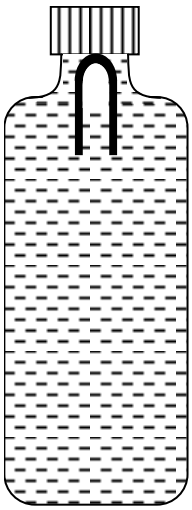
Section – 2

- This section contains THREE (03) question stems.
- There are TWO (02) questions corresponding to each question stem.
- 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 : +2 If ONLY the correct numerical value is entered at the designated place;
  Zero Marks : 0 In all other cases.

Questions stem for questions nos. 7 and 8

Question Stem

A soft plastic bottle, filled with water of density 1 gm/cc, carries an inverted glass test-tube with some air (ideal gas) trapped as shown in the figure. The test-tube has a mass of 5 gm, and it is made of a thick glass of density 2.5 gm/cc. Initially the bottle is sealed at atmospheric pressure $p_0 = 10^5$ Pa so that the volume of the trapped air is $v_0 = 3.3$ cc. When the bottle is squeezed from outside at constant temperature, the pressure inside rises and the volume of the trapped air reduces. It is found that the test tube begins to sink at pressure $p_0 + \Delta p$ without changing its orientation. At this pressure, the volume of the trapped air is $v_0 - \Delta v$. Let $\Delta v = X$ cc and $\Delta p = Y \times 10^3$ Pa.



Q.7 The value of X is _____.

Sol. **0.3**

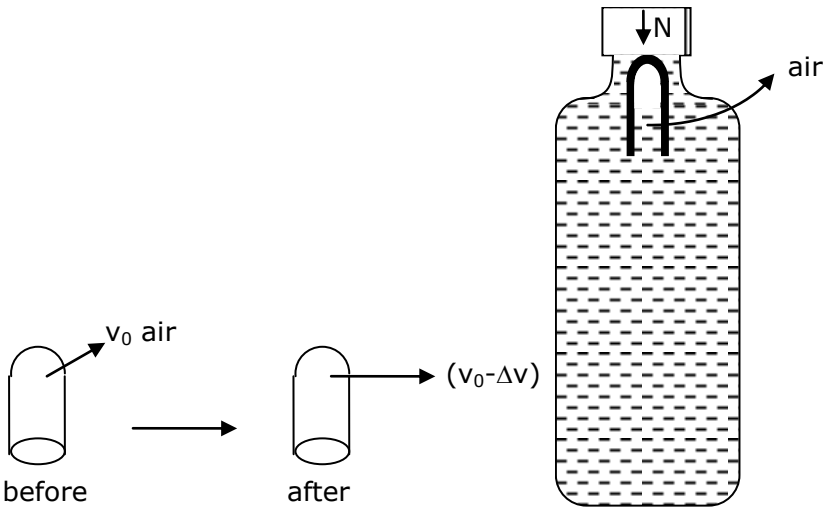
Q.8 The value of Y is _____.

Sol. **10**

Given

m_{tube} = 5g

ρ_{tube} = 2.5 gm/cc.



$V_{tube} = \frac{5}{2.5}$

Check when 'N' becomes Zero.

$mg = \rho_w(v_{air} + v_{tube})g$

$5g = 1\ (v_{air} + \frac{5}{2.5})g$

v_{air} = 3cc $\rightarrow$ when N is just zero.

Δv = 3.3 cc – 3cc = 0.3cc

Sol. (7) = 0.3cc

Now, **Sol.8**

PV = constant

$P_1V_1 = P_2V_2$

$10^5\ (3.3) = P_2(3)$

$P_2 = 1.1 \times 10^5$

$\Delta P = P_2 - P_1 = 1.1 \times 10^5 - 10^5$

$= 0.1 \times 10^5$

$= 10 \times 10^3$ pascal

$= Y \times 10^3$ pascal

So, Y = 10

Questions stem for Qusetions nos. 9 and 10

Question Stem

A pendulum consists of a bob of mass m = 0.1 kg and a massless inextensible string of length L = 1.0 m. It is suspended from a fixed point at height H = 0.9 m above a frictionless horizontal floor. Initially, the bob of the pendulum is lying on the floor at rest vertically below the point of suspension. A horizontal impulse P = 0.2 kg-m/s is imparted to the bob at some instant. After the bob slides for some distance, the string become taut and the bob lifts off the floor. The magnitude of the angular momentum of the pendulum about the point of suspension just before the bob lifts off is J kg-m^2/s. The kinetic energy of the pendulum just after the lift off is K joules.

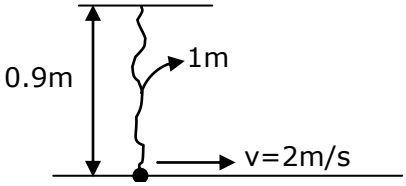
Q.9 The value of J is _____.

Sol. **0.18**

Angular momentum = $L = mvr_{\perp}$

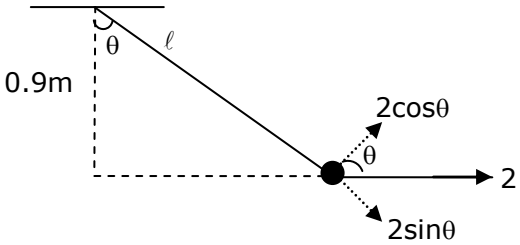
$= 0.2 \times 0.9$

$= 0.18$



Q.10 The value of K is _____.

Sol. **0.16**



$2\sin\theta$ will become zero

because of impulse from string

K.E. = $\frac{1}{2} \times 0.1 \times (2 \times 0.9)^2$ = 0.16J

Questions Stem for Questions nos. 11 and 12

Question Stem

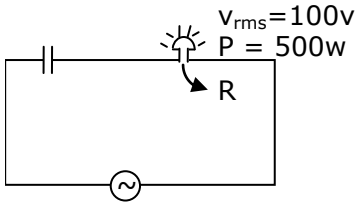
In a circuit, a metal filmanet lamp is connected in series with a capacitor of capacitance CμF across a 200 V, 50 Hz supply. The power consumed by the lamp is 500 W while the voltage drop across it is 100 V. Assume that there is no inductive load in the circuit. Take rms values of the voltages. The magnitude of the phase angle (in degrees) between the current and the supply voltage is ϕ. Assume, $\pi\sqrt{3} \approx 5$.

Q.11 The value of C is _____.

Sol. **100**

Q.12 The value of ϕ is _____.

Sol. **60**



v_{rms} = 1200 volt

f = 50 Hz

$P = \frac{V_{rms}^2}{R} = \frac{100 \times 100}{R}$

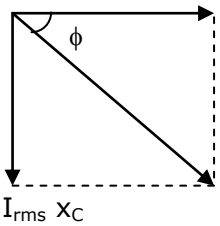
$R = \frac{10^4}{500} = 20\Omega$

Also, $\Rightarrow$ For resistance

$P = V_{rms} \cdot I_{rms}$

$P = 100 \times I_{rms}$

$\Rightarrow I_{rms} = 5A$



$\cos\theta = \frac{100}{200} = \frac{1}{2}$

$\phi = 60°$

From above phaser ; $200 \sin 60° = I_{rms}\, x_c$

$200 \times \frac{\sqrt{3}}{2} = 5 \times x_c$

$x_c = 20\sqrt{3}$

$\frac{1}{\omega C} = 20\sqrt{3}$

We get c = 100 μF

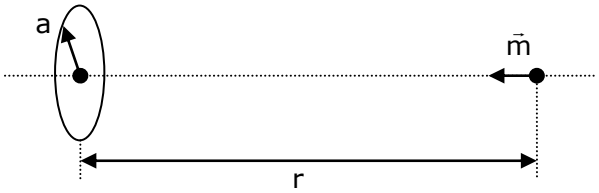
Section – 3

- This section contains TWO (02) paragraphs. Based on each paragraph, there are TWO (02) 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.

Paragraph

A special metal S conducts electricity without any resistance. A closed wire loop, made of S, does not allow any change in flux through itself by inducing a suitable current to generate a compensating flux. The induced current in the loop cannot decay due to its zero resistance. This current gives rise to a magnetic moment which in turn repels the source of magnetic field or flux. Consider such a loop, of radius a, with its center at the origin. A magnetic dipole of moment m is brought along the axis of this loop from infinity to a point at distance r (>> a) from the center of the loop with its north pole always faing the loop, as shown in the figure below. The magnitude of magnetic field of a dipole m, at a point on its axis at distance r, is $\frac{\mu_0}{2\pi}\frac{m}{r^3}$, where μ_0 is the permeability of free space. The magnitude of the force between two magnetic dipoles with moments, m_1 and m_2, separated by a distance r on the common axis, with their north poles facing each other, is $\frac{km_1m_2}{r^4}$, where k is a constant of appropriate dimensions. The direction of this force is along the line joining the two dipoles.



Q.13 When the dipole m is placed at a distance r from the center of the loop (as shown in the figure), the current induced in the loop will be proportional to

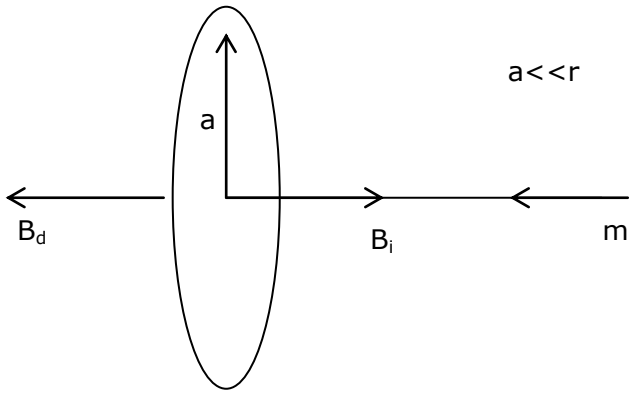
(A) m/r^3 (B) m^2/r^2 (C) m/r^2 (D) m^2/r

Sol. **A**

Q.14 The work done in bringing the dipole from infinity to a distance r from the center of the loop by the given proces is proportional to

(A) m/r^5 (B) m^2/r^5 (C) m^2/r^6 (D) m^2/r^7

Sol. **C**



$\rightarrow$ flux of super condutor remains same.

$B_d = B_i$

(B_d due to dipole, B_i due to induce)

$$\frac{\mu_0 2m}{4\pi r^3} = \frac{\mu_0 i}{2a}$$

$$\Rightarrow i \propto \frac{m}{r^3} \quad .....(1)$$

$W = U_f - U_i$ and $U = -\vec{M}.\vec{B}$

$U_i = 0$ $= MB$ $(\theta = 180^\circ)$

$\therefore W = mB$

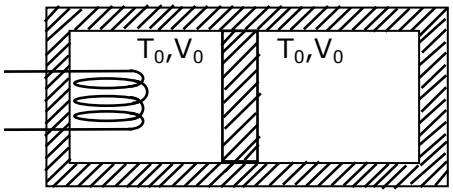
$$W = m\frac{\mu_0 i a^2}{2(a^2 + r^2)^{3/2}}$$

Put i from equation (1)

$$W \propto \frac{m^2}{r^6}$$

Paragraph

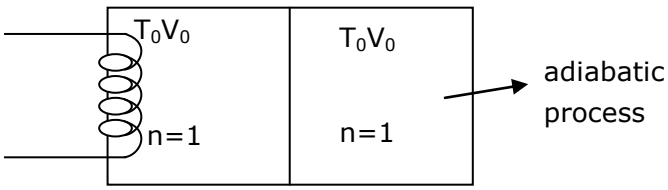
A thermally insulating cylinder has a thermally insulating and frictionless movable partition in the middle, as shown in the figure below. On each side of the partition, there is one mole of an ideal gas, with specific heat at constant volume, $C_V = 2R$. Here, R is the gas constant. Initially, each side has a volume V_0 and temperature T_0. The left side has an electric heater, which is turned on at very low power to transfer heat Q to the gas on the left side. As a result the partition moves slowly towards the right reducing the right side volume to $V_0/2$. Consequently, the gas temperatures on the left and the right sides become T_L and T_R, respectively. Ignore the changes in the temperatures of the cylinder, heater and the partition.



Q.15 The value of $\frac{T_R}{T_0}$

(A) $\sqrt{2}$ (B) $\sqrt{3}$ (C) 2 (D) 3

Sol. **A**



process in right chamber is adiabatic

PV^γ = constant

$\because \gamma = \frac{3}{2}$

$$\therefore T_0 V_0^{\gamma-1} = T_f\left(\frac{V_0}{2}\right)^{\gamma-1}$$

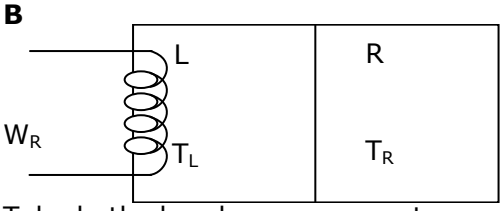
$T_R = T_0\, 2^{1/2}$

$$\frac{T_R}{T_0} = \sqrt{2}$$

Q.16 The value of $\frac{Q}{RT_0}$

(A) $4(2\sqrt{2}+1)$ (B) $4(2\sqrt{2}-1)$ (C) $(5\sqrt{2}+1)$ (D) $(5\sqrt{2}-1)$

Sol. **B**



Take both chamber as one system
net work done = 0
i.e. $\Delta W_L + \Delta W_R = 0$ ....(i)
Apply 1st law of thermodynamics
$\Delta Q_{L+R} = \Delta U_L + \Delta U_R + \Delta W_L + \Delta W_R$
$\Delta Q_{L+R} = \Delta U_L + \Delta U_R$
$\because \Delta U = nC_V dT$

$$\Delta Q_{L+R} = 1 \times 2R (T_L - T_0) + 1 \times 2R \left(\sqrt{2}T_0 - T_0\right) \quad \text{....(i)}$$

Calculation of T_L
(Final temperature in left chamber)
From ideal gas equation

$\frac{3v_0}{2}$	$\frac{v_0}{2}$

$PV = nRT$

$$nR = \frac{PV}{T}$$

$$\frac{P_0V_0}{T_0} = \frac{P\left(\frac{3V_0}{2}\right)}{T_L} \rightarrow \text{For left chamber}$$

$$\frac{P_0V_0}{T_0} = \frac{P\left(\frac{V_0}{2}\right)}{\sqrt{2}T_0} \rightarrow \text{for right chamber}$$

$T_L = 3\sqrt{2}T_0$
Put the value of T_L in equation (i)

$$\Delta Q_{L+R} = 2R\left[3\sqrt{2}T_0 - T_0\right] + 2R\left[\sqrt{2}T_0 - T_0\right]$$

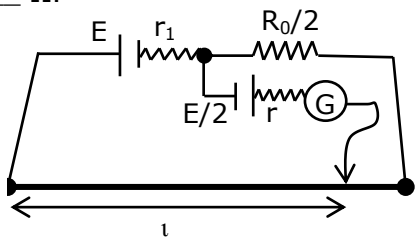
$$\Delta Q_{L+R} = 2R\left[4\sqrt{2}T_0 - 2T_0\right]$$

$$\text{or } \frac{\Delta Q_{L+R}}{RT_0} = 4\left[2\sqrt{2} - 1\right]$$

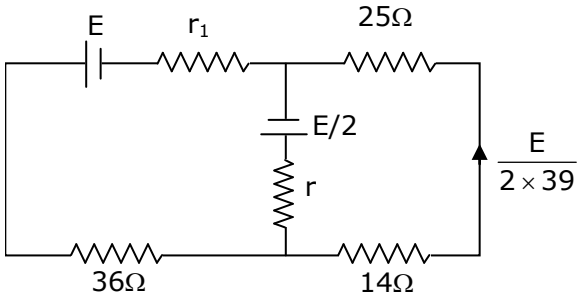
SECTION 4

- This section contains THREE (03) questions.
- The answer to each question is a NON-NEGATIVE INTEGER.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:
  Full Marks : +4 If ONLY the correct integer is entered;
  Zero Marks : 0 In all other cases.

Q.17 In order to measure the internal resistance r_1 of a cell of emf E, a meter bridge of wire resistance R_0 = 50Ω, a resistance $R_0/2$, another cell of emf $E/2$ (internal resistance r) and a galvanometer G are used in a circuit, as shown in the figure. If the null point is found at l=72 cm, then the value of r_1=___ Ω.



Sol. **3**



From the circuit

$$\frac{E}{2\times 39} = \frac{E}{75+r_1}$$

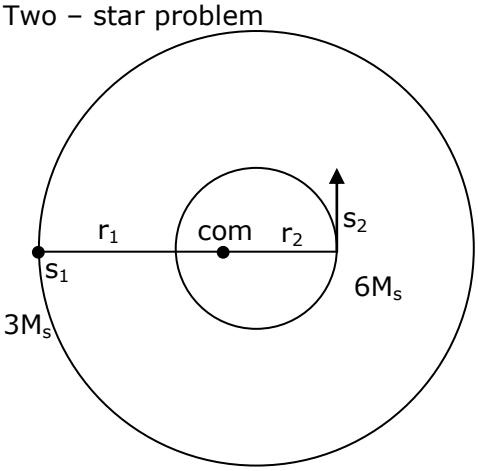
$75 + r_1 = 2 \times 39$

$r_1 = 3\ \Omega$

Q.18 The distance between two stars of masses $3M_S$ and $6M_S$ is $9R$. Here R is the mean distance between the centers of the Earth and the Sun, and M_S is the mass of the Sun. The two stars orbit around their common center of mass in circular orbits with period nT, where T is the period of Earth's revolution around the Sun. The value of n is ___.

Sol. **9**

Two – star problem



$r_1 = \frac{6\times 9}{9} R = 6R$

$r_2 = 3R$

on $6M_s$

$$\frac{G3M_S6M_s}{(9R)^2} = 6M_S\left(\frac{2\pi}{nT}\right)^2 3R \qquad ....(i)$$

for S-E system

$$\frac{GM_sM_E}{R^2} = M_E\left(\frac{2\pi}{T}\right)^2 R \qquad ....(ii)$$

Solve equation (i) and (ii)

n = 9

Q.19 In a photoemission experiment, the maximum kinetic energies of photoelectrons from metals P, Q and R are E_P, E_Q and E_R, respectively, and they are related by E_P=2E_Q=2E_R. In this experiment, the same source of monochromatic light is used for metals P and Q while a different source of monochromatic light is used for the metal R. The work functions for metals P, Q and R are 4.0 eV, 4.5 eV and 5.5 eV, respectively. The energy of the incident photon used for metal R, in eV, is ___.

Sol. **6**

Photo-electric effect

$E = h\upsilon - W_0$

Here, W_0 = work function

Given : $E_P = 2E_Q = 2E_R$

Now,

$E_P = h\upsilon_P - 4$ ...(i)

$E_Q = h\upsilon_Q - 4.5$ ....(ii)

$E_R = h\upsilon_R - 5.5$ ....(iii)

we have to calculate $h\upsilon_R$

$\upsilon_Q = \upsilon_Q \rightarrow$ Given

Equation (i) – equation (ii)

E = 0.5

$h\upsilon_R = 6$