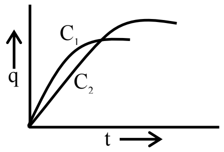
JEE–MAIN EXAMINATION – JANUARY 2025

(HELD ON TUESDAY 28th JANUARY 2025) **TIME : 9 : 00 AM TO 12 : 00 NOON**

PHYSICS | **TEST PAPER WITH SOLUTION**

SECTION-A

26. Two capacitors C_1 and C_2 are connected in parallel to a battery. Charge-time graph is shown below for the two capacitors. The energy stored with them are U_1 and U_2, respectively. Which of the given statements is true ?



(1) $C_1 > C_2, U_1 > U_2$ (2) $C_2 > C_1, U_2 < U_1$

(3) $C_1 > C_2, U_1 < U_2$ (4) $C_2 > C_1, U_2 > U_1$

Ans. (4)

Sol. potential difference,

$v \rightarrow$ same

$$U = \frac{1}{2}cv^2$$

as $q_1 < q_2$

$\therefore c_1 < c_2$

& $U_1 < U_2$

27. In the experiment for measurement of viscosity 'η' of given liquid with a ball having radius R, consider following statements.

A. Graph between terminal velocity V and R will be a parabola

B. The terminal velocities of different diameter balls are constant for a given liquid.

C. Measurement of terminal velocity is dependent on the temperature.

D. This experiment can be utilized to assess the density of a given liquid.

E. If balls are dropped with some initial speed, the value of η will change.

Choose the correct answer from the options given below:

(1) B, D and E only

(2) A, C and D only

(3) C, D and E only

(4) A, B and E only

Ans. (2)

Sol. $$V_T = \frac{2}{9}R^2\frac{g}{\eta}(d-\rho)$$

28. Consider following statements:

A. Surface tension arises due to extra energy of the molecules at the interior as compared to the molecules at the surface, of a liquid.

B. As the temperature of liquid rises, the coefficient of viscosity increases.

C. As the temperature of gas increases, the coefficient of viscosity increases.

D. The onset of turbulence is determined by Reynold's number.

E. In a steady flow two stream lines never intersect.

Choose the correct answer from the options given below :

(1) A, D, E only (2) C, D, E only

(3) B, C, D only (4) A, B, C only

Ans. (2)

29. Three infinitely long wires with linear charge density λ are placed along the x-axis, y-axis and z-axis respectively. Which of the following denotes an equipotential surface ?

(1) $xy + yz + zx = \text{constant}$

(2) $(x + y)(y + z)(z + x) = \text{constant}$

(3) $(x^2 + y^2)(y^2 + z^2)(z^2 + x^2) = \text{constant}$

(4) $xyz = \text{constant}$

Ans. (3)

Sol. $v = -\int \vec{E}.d\vec{r} = \int \frac{2k\lambda}{r} dr = 2k\lambda \ln r + c$

Net potential due to all wire

$$v = 2k\lambda \ln\sqrt{x^2+y^2} + 2k\lambda \ln\sqrt{y^2+z^2} + 2k\lambda \ln\sqrt{z^2+x^2} + c$$

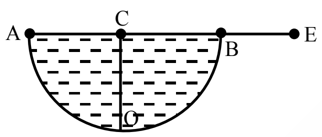
for v = c

$$\sqrt{(x^2+y^2)(y^2+z^2)(z^2+x^2)} = c$$

$$\therefore\ (x^2+y^2)(y^2+z^2)(z^2+x^2) = c$$

where c = constant

30. A hemispherical vessel is completely filled with a liquid of refractive index μ. A small coin is kept at the lowest point (O) of the vessel as shown in figure. The minimum value of the refractive index of the liquid so that a person can see the coin from point E (at the level of the vessel) is______.

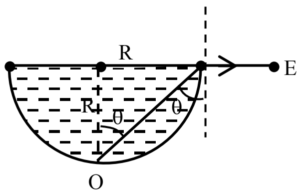


(1) $\sqrt{3}$ (2) $\frac{3}{2}$

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

Ans. (3)

Sol.



$$\sin c = \frac{1}{\mu}$$

for $\mu \to$ least, $c \to$ maximum

$\theta = c = 45$

$$\mu = \frac{1}{\sin 45} = \sqrt{2}$$

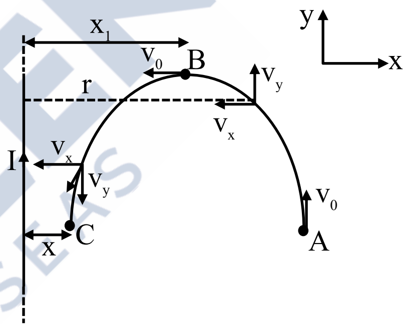
31. Consider a long thin conducting wire carrying a uniform current I. A particle having mass "M" and charge "q" is released at a distance "a" from the wire with a speed v_o along the direction of current in the wire. The particle gets attracted to the wire due to magnetic force. The particle turns round when it is at distance x from the wire. The value of x is [μ_0 is vacuum permeability]

(1) $a\left[1 - \frac{mv_o}{2q\mu_o I}\right]$ (2) $\frac{a}{2}$

(3) $a\left[1 - \frac{mv_o}{q\mu_o I}\right]$ (4) $ae^{\frac{-4\pi m v_o}{q\mu_o I}}$

Ans. (4)

Sol.



$A \to B$

$$\vec{V} = -v_x\hat{i} + v_y\hat{j}$$

$$\vec{B} = \frac{\mu_0 I}{2\pi r}(-\hat{k})$$

$$\vec{F} = q(\vec{v}\times\vec{B}) = \frac{\mu_0 Iq}{2\pi r}[-v_x\hat{j} - v_y\hat{i}]$$

$$a_x = -\frac{\mu_0 Iq}{2\pi m}.\frac{v_y}{r}$$

$$a_y = -\frac{\mu_0 Iq}{2\pi m}.\frac{v_x}{r}$$

$$\frac{v_x dv_x}{dr} = -\frac{\mu_0 Iq}{2\pi m}\frac{v_y}{r}$$

$$\frac{v_x dv_x}{v_y} = -\frac{\mu_0 Iq}{2\pi m}\frac{dr}{r}$$

$$\int_0^{v_0}\frac{v_x dv_x}{\sqrt{v_0^2 - v_x^2}} = -\frac{\mu_0 Iq}{2\pi m}\int_a^{x_1}\frac{dr}{r}$$

Let, $z^2 = v_0^2 - v_x^2$

$2zdz = -2v_x dv_x$

$zdz = -v_x dv_x$

$$\frac{v_x dv_x}{\sqrt{v_0^2 - v_x^2}} = \frac{-zdz}{z} = -dz$$

then integral becomes

$$-\int_{v_0}^{0} dz = -\frac{\mu_0 Iq}{2\pi m}\ln\frac{x_1}{a}$$

$$v_0 = -\frac{\mu_0 Iq}{2\pi m}\ln\frac{x_1}{a}$$

$$x_1 = a\ e^{-\frac{2\pi m v_0}{\mu_0 Iq}} \quad ......(1)$$

For $B \to C$

$$\vec{v} = -v_x\hat{i} - v_y\hat{j}$$

$$\vec{B} = \frac{\mu_0 I}{2\pi r}(-\hat{k})$$

$$\vec{F} = q(\vec{v}\times\vec{B}) = \frac{\mu_0 Iq}{2\pi r}(-v_x\hat{j} + v_y\hat{i})$$

$$a_x = +\frac{\mu_0 Iq}{2\pi m}\frac{v_y}{r} \qquad a_y = -\frac{\mu_0 Iq}{2\pi m}.\frac{v_x}{r}$$

$$\frac{v_x dv_x}{dr} = \frac{\mu_0 Iq}{2\pi m}\frac{v_y}{r}$$

$$\int_{v_0}^{0}\frac{v_x dv_x}{\sqrt{v_0^2 - v_x^2}} = \frac{\mu_0 Iq}{2\pi m}\int_{x_1}^{x}\frac{dr}{r}$$

$$\frac{\mu_0 Iq}{2\pi m}\ln\frac{x}{x_1} = -\int_{0}^{v_0} dz = -v_0$$

$$x = x_1\ e^{-\frac{2\pi m v_0}{\mu_0 Iq}} \quad ..... (2)$$

From equation 1 and 2

$$X = a\ e^{-\frac{4\pi m v_0}{\mu_0 Iq}}$$

32. A Carnot engine (E) is working between two temperatures 473K and 273K. In a new system two engines – engine E_1 works between 473K to 373K and engine E_2 works between 373K to 273K. If η_{12}, η_1 and η_2 are the efficiencies of the engines E, E_1 and E_2, respectively, then

(1) $\eta_{12} < \eta_1 + \eta_2$ (2) $\eta_{12} = \eta_1\,\eta_2$

(3) $\eta_{12} = \eta_1 + \eta_2$ (4) $\eta_{12} \geq \eta_1 + \eta_2$

Ans. (1)

Sol. $\eta_{12} = 1 - \frac{273}{473} = \frac{200}{473} = 0.423$

$$\eta_1 = 1 - \frac{373}{473} = \frac{100}{473} = 0.211$$

$$\eta_2 = 1 - \frac{273}{373} = \frac{100}{373} = 0.268$$

33. Given below are two statements: one is labelled as **Assertion A** and the other is labelled as **Reason R**

Assertion A: A sound wave has higher speed in solids than gases.

Reason R: Gases have higher value of Bulk modulus than solids.

In the light of the above statements, choose the **correct** answer from the options given below

(1) Both **A** and **R** are true and **R** is the correct explanation of **A**

(2) **A** is false but **R** is true

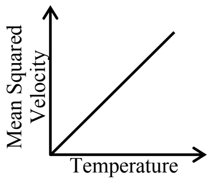
(3) Both **A** and **R** are true but **R** is **NOT** the correct explanation of **A**

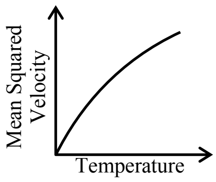
(4) **A** is true but **R** is false.

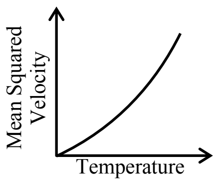
Ans. (4)

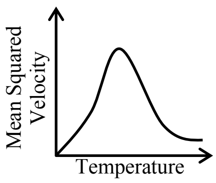
Sol. Solids have higher value of bulk modulus than gases.

34. For a particular ideal gas which of the following graphs represents the variation of mean squared velocity of the gas molecules with temperature ?

(1) 

(2) 

(3) 

(4) 

Ans. (1)

Sol. $V_{rms} = \sqrt{\frac{3RT}{M}}$

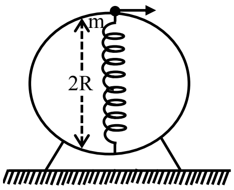
$$V_{rms}^2 = 3RT/M$$

Hence we can conclude that V_{rms}^2 is directly proportional to temperature

$y = m\,x$

$\Rightarrow$ Graph will be straight line

35. A bead of mass 'm' slides without friction on the wall of a vertical circular hoop of radius 'R' as shown in figure. The bead moves under the combined action of gravity and a massless spring (k) attached to the bottom of the hoop. The equilibrium length of the spring is 'R'. If the bead is released from top of the hoop with (negligible) zero initial speed, velocity of bead, when the length of spring becomes 'R', would be (spring constant is 'k', g is acceleration due to gravity)

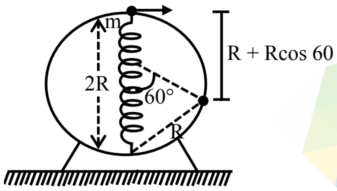


(1) $2\sqrt{gR + \frac{kR^2}{m}}$ (2) $\sqrt{2Rg + \frac{4kR^2}{m}}$

(3) $\sqrt{2Rg + \frac{kR^2}{m}}$ (4) $\sqrt{3Rg + \frac{kR^2}{m}}$

Ans. (4)

Sol.



Work energy theorem

$$Mg\,(R + R\cos 60) + \frac{1}{2}k\left(R^2 - 0^2\right) = \frac{1}{2}mv^2$$

$$Mg\,\frac{3R}{2} + \frac{KR^2}{2} = \frac{1}{2}mv^2$$

$$V = \sqrt{3gR + \frac{KR^2}{m}}$$

36. Given below are two statements: one is labelled as **Assertion A** and the other is labelled as **Reason R**

Assertion A: In a central force field, the work done is independent of the path chosen

Reason R: Every force encountered in mechanics does not have an associated potential energy.

In the light of the above statements, choose the ***most appropriate*** answer from the options given below

(1) **A** is true but **R** is false

(2) Both **A** and **R** are true but **R** is **NOT** the correct explanation of **A**

(3) Both **A** and **R** are true and **R** is the correct explanation of **A**

(4) **A** is false but **R** is true

Ans. (2)

Sol. Both statement are correct but Reason is not the correct explanation of Assertion.

37. Choose the correct nuclear process from the below options

[p: proton, n: neutron, e^- : electron, e^+ : positron, ν : neutrino, $\bar{\nu}$: antineutrino]

(1) $n \rightarrow p + e^- + \bar{\nu}$ (2) $n \rightarrow p + e^- + \nu$

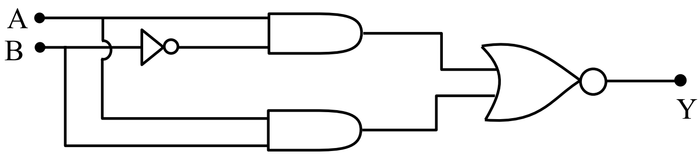
(3) $n \rightarrow p + e^+ + \bar{\nu}$ (4) $n \rightarrow p + e^+ + \nu$

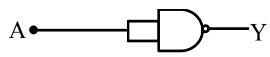
Ans. (1)

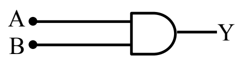
Sol. Theoretical equation for β^{-1} decay

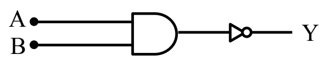
$$n_0^1 \rightarrow p_1^1 + e_{-1}^{-0} + \bar{\nu}$$

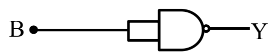
38. Which of the following circuits has the same output as that of the given circuit?



(1)


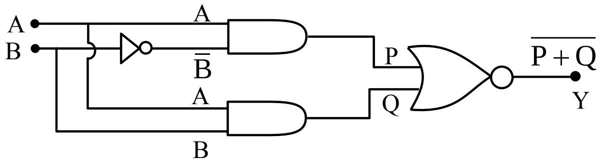
(2)


(3)


(4)


Ans. (1)

Sol.



$P = A\cdot\overline{B}$

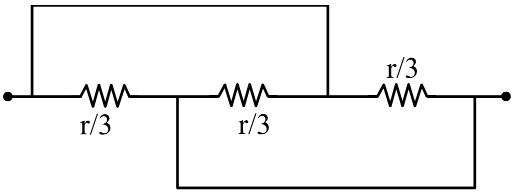
$Q = A\cdot B$

$Y = \overline{P+Q} = \overline{A\cdot\overline{B}+A\cdot B}$

$= \overline{A\cdot(B+\overline{B})} = \overline{A\cdot I}$

$Y = \overline{A}$

39. Find the equivalent resistance between two ends of the following circuit.

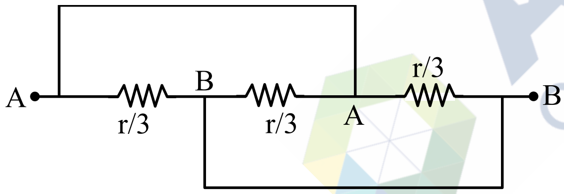


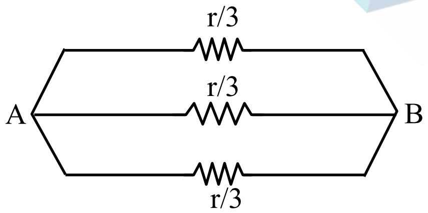
(1) r (2) $\frac{r}{6}$

(3) $\frac{r}{9}$ (4) $\frac{r}{3}$

Ans. (3)

Sol.





All are in parallel

$R_{eq} = \frac{r/3}{3} = r/9$

40. A wire of resistance R is bent into an equilateral triangle and an identical wire is bent into a square. The ratio of resistance between the two end points of an edge of the triangle to that of the square is

(1) 9/8 (2) 8/9

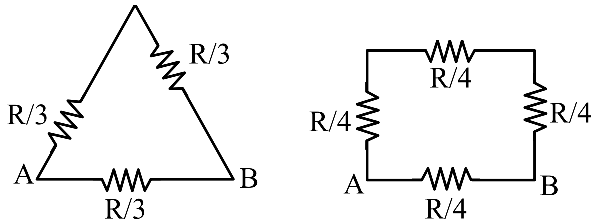
(3) 27/32 (4) 32/27

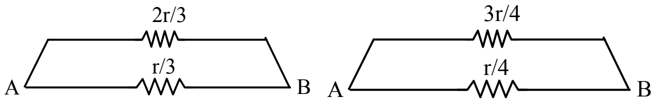
Ans. (4)

Sol. $R = \frac{\rho\ell}{A}$

So, $R \propto \ell$

Side length of triangle is 1/3 of total length.





$(R_{eq})_1 = \frac{2r/3\times r/3}{2r/3+r/3}$ $(R_{eq})_2 = \frac{3r/4\times r/4}{3r/4+r/4}$

$(R_{eq})_1 = 2r/9$ $(R_{eq})_2 = 3r/16$

$\frac{(R_{eq})_1}{(R_{eq})_2} = \frac{2r/9}{3r/16} = \frac{32}{27}$

41. Due to presence of an em-wave whose electric component is given by $E = 100\sin(\omega t - kx)\ NC^{-1}$, a cylinder of length 200 cm holds certain amount of em-energy inside it. If another cylinder of same length but half diameter than previous one holds same amount of em-energy, the magnitude of the electric field of the corresponding em-wave should be modified as

(1) $25\sin(\omega t - kx)\ NC^{-1}$

(2) $200\sin(\omega t - kx)\ NC^{-1}$

(3) $400\sin(\omega t - kx)\ NC^{-1}$

(4) $50\sin(\omega t - kx)\ NC^{-1}$

Ans. (2)

Sol. Energy density $= \frac{1}{2}\epsilon_0 E^2 \times c$

Energy $= \frac{1}{2}\epsilon_0 E^2 \times c \times \text{volume}$

$(\text{Energy})_1 = (\text{Energy})_2$ (Given)

$\frac{1}{2}\epsilon_0 E_1^2 c\pi R_1^2 \times L_1 = \frac{1}{2}\epsilon_0 E_2^2 c\pi R_2^2 \times L_2$

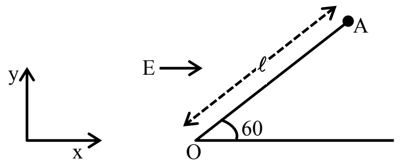
$E_1^2 R_1^2 = E_2^2 R_2^2$

$E_1 R_1 = E_2 R_2$

$100 \times R_1 = E_2 \times \frac{R_1}{2}$

$E_2 = 200$ N/C

42. A particle of mass 'm' and charge 'q' is fastened to one end 'A' of a massless string having equilibrium length ℓ, whose other end is fixed at point 'O'. The whole system is placed on a frictionless horizontal plane and is initially at rest. If uniform electric field is switched on along the direction as shown in figure, then the speed of the particle when it crosses the x-axis is

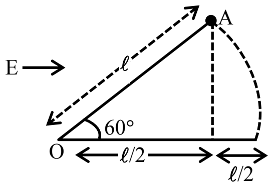


(1) $\sqrt{\frac{2qE\ell}{m}}$ (2) $\sqrt{\frac{qE\ell}{4m}}$

(3) $\sqrt{\frac{qE\ell}{m}}$ (4) $\sqrt{\frac{qE\ell}{2m}}$

Ans. (3)

Sol.



$W_{all} = \Delta k$

$W_e = k_f - k_i$

$qE\frac{\ell}{2} = \frac{1}{2}mv^2 - 0$

$v = \sqrt{\frac{qE\ell}{m}}$

43. A proton of mass 'm_p' has same energy as that of a photon of wavelength 'λ'. If the proton is moving at non-relativistic speed, then ratio of its de Broglie wavelength to the wavelength of photon is.

(1) $\frac{1}{c}\sqrt{\frac{2E}{m_p}}$ (2) $\frac{1}{c}\sqrt{\frac{E}{m_p}}$

(3) $\frac{1}{c}\sqrt{\frac{E}{2m_p}}$ (4) $\frac{1}{2c}\sqrt{\frac{E}{m_p}}$

Ans. (3)

Sol. E is missing in the question but considering E as energy, the solution will be

$E_{photon} = \frac{hc}{\lambda} = E$; $E_{proton} = \frac{1}{2}m_p v^2 = E$

$\frac{\lambda_{proton}}{\lambda_{photon}} = \frac{h/p}{hc/E} = \frac{h/\sqrt{2m_pE}}{hc/E}$

$= \frac{E}{c\sqrt{2m_pE}}$

$\frac{\lambda_{proton}}{\lambda_{photon}} = \frac{1}{c}\sqrt{\frac{E}{2m_p}}$

44. The centre of mass of a thin rectangular plate (fig - x) with sides of length a and b, whose mass per unit area (σ) varies as $\sigma = \frac{\sigma_0 x}{ab}$ (where σ_0 is a constant), would be______

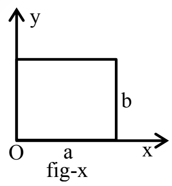


fig-x

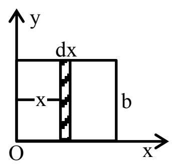
(1) $\left(\frac{2}{3}a, \frac{b}{2}\right)$ (2) $\left(\frac{2}{3}a, \frac{2}{3}b\right)$

(3) $\left(\frac{a}{2}, \frac{b}{2}\right)$ (4) $\left(\frac{1}{3}a, \frac{b}{2}\right)$

Ans. (1)

Sol. σ is constant in y-direction

So, $y_{cm} = b/2$



$$x_{cm} = \frac{\int_0^a x\,dm}{\int_0^a dm}$$

$$= \frac{\int_0^a x\sigma_x dA}{\int_0^a \sigma_x dA}$$

$$= \frac{\int_0^a x\frac{\sigma_\circ x}{ab} bdx}{\int_0^a \frac{\sigma_\circ x}{ab} bdx}$$

$$x_{cm} = \frac{\int_0^a x^2 dx}{\int_0^a x dx}$$

$$= \frac{\left(\frac{x^3}{3}\right)_0^a}{\left(\frac{x^2}{2}\right)_0^a} = \frac{a^3/3}{a^2/2}$$

$$= \frac{2a}{3}$$

45. A thin prism P_1 with angle 4° made of glass having refractive index 1.54, is combined with another thin prism P_2 made of glass having refractive index 1.72 to get dispersion without deviation. The angle of the prism P_2 in degrees is

(1) 4 (2) 3

(3) 16/3 (4) 1.5

Ans. **(2)**

Sol. $\delta_{net} = 0$

$$(\mu_1 - 1)A_1 - (\mu_2 - 1)A_2 = 0$$

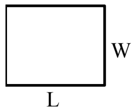
$$(1.54 - 1)4 - (1.72 - 1)A_2 = 0$$

$A_2 = 3°$

46. A tiny metallic rectangular sheet has length and breadth of 5 mm and 2.5mm, respectively. Using a specially designed screw gauge which has pitch of 0.75 mm and 15 divisions in the circular scale, you are asked to find the area of the sheet. In this measurement, the maximum fractional error will be $\frac{x}{100}$ where x is______

Ans. **(3)**

Sol.



Since least count of the instrument can be calculated as

$$\text{Least count} = \frac{\text{pitch length}}{\text{No. of division on circular scale}}$$

$$= \frac{0.75}{15} = 0.05\text{mm.}$$

Here we are provided L = 5 mm & W = 2.5 mm

L = 5 mm & W = 2.5 mm

∵ We know that

A = L.W

For calculating fractional error, we can write

$$\frac{dA}{A} = \frac{dL}{L} + \frac{dW}{W}$$

Here dL = dW = 0.05 mm

$$\frac{dA}{A} = \frac{0.05}{5} + \frac{0.05}{2.5}$$

$$\Rightarrow \frac{dA}{A} = \frac{1}{100} + \frac{2}{100} = \frac{3}{100},$$

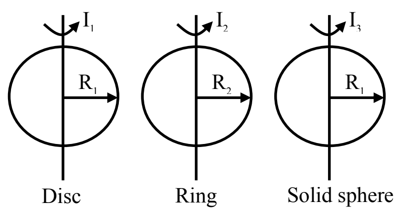
So, x = 3

47. The moment of inertia of a solid disc rotating along its diameter is 2.5 times higher than the moment of inertia of a ring rotating in similar way. The moment of inertia of a solid sphere which has same radius as the disc and rotating in similar way, is n times higher than the moment of inertia of the given ring. Here, n =_______.

Consider all the bodies have equal masses.

Ans. **(4)**

Sol.



$$I_1 = \frac{MR_1^2}{4}, I_2 = \frac{MR_2^2}{2}, I_3 = \frac{2MR_1^2}{5}$$

According to problem

$$\frac{I_1}{I_2} = 2.5 \Rightarrow \frac{\frac{MR_1^2}{4}}{\frac{MR_2^2}{2}} = \frac{5}{2} \Rightarrow \frac{R_1^2}{R_2^2} = 5 \ldots(1)$$

Now we are provided with information that

$$\frac{I_3}{I_2} = n$$

$$\Rightarrow \frac{\frac{2MR_1^2}{5}}{\frac{MR_2^2}{2}} = n \Rightarrow \frac{4R_1^2}{5R_2^2} = n \quad \ldots..(2)$$

From Eq', (1) and (2)

$\Rightarrow n = 4$

48. In a measurement, it is asked to find modulus of elasticity per unit torque applied on the system. The measured quantity has dimension of $[M^a\ L^b\ T^c]$. If b = 3, the value of c is_____

NTA Ans. (4)

ALLEN Ans. (0)

Sol. $$\frac{\text{modulus of elasticity}}{\text{Torque}} = \frac{\text{Stress}}{\text{strain} \times \text{torque}}$$

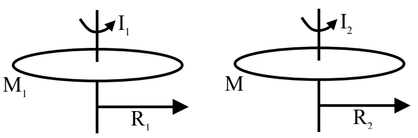
$$= \frac{[\text{Force}]}{[\text{Area}] \times [\text{Force} \times \text{length}]}$$

$$= \frac{1}{[\text{Area} \times \text{length}]} = [L^{-3}]$$

49. Two iron solid discs of negligible thickness have radii R_1 and R_2 and moment of intertia I_1 and I_2, respectively. For $R_2 = 2R_1$, the ratio of I_1 and I_2 would be 1/x, where x = _______

Ans. (16)

Sol.



Given $R_2 = 2R_1$

$M_1 = \sigma \times \pi R_1^2 = M_o$

$M_2 = \sigma \times \pi R_2^2 = M_o$

$M_2 = \sigma \times \pi R_2^2 = \sigma \times \pi [2R_1]^2 = \sigma \times 4\pi R_1^2 = 4M_o$

$$\frac{I_1}{I_2} = \frac{\frac{M_1R_1^2}{2}}{\frac{M_2R_2^2}{2}} = \frac{M_1R_1^2}{M_2R_2^2} = \frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$$

50. A double slit interference experiment performed with a light of wavelength 600 nm forms an interference fringe pattern on a screen with 10^{th} bright fringe having its centre at a distance of 10 mm from the central maximum. Distance of the centre of the same 10^{th} bright fringe from the central maximum when the source of light is replaced by another source of wavelength 660 nm would be_____mm.

Ans. (11)

Sol. In case of YDSE the distance of n^{th} maxima from central maxima is given by

$$Y = \frac{n\lambda D}{d}$$

Here n , D & d are same

So, $y \times \lambda$

$$\Rightarrow \frac{y_2}{y_1} = \frac{\lambda_2}{\lambda_1} \Rightarrow \frac{y_2}{10\text{ mm}} = \frac{660\text{ nm}}{600\text{ nm}}$$

$\Rightarrow y_2 = 11$ mm