JEE MAIN 2024
Paper with Solution

PHYSICS | 31st January 2024 _ Shift-2

SECTION – A

31. The speed of sound in oxygen at S.T.P. will be approximately :

(given, $R = 8.3\ JK^{-1}, \gamma = 1.4$)

(1) 325 m/s (2) 310 m/s (3) 341 m/s (4) 333 m/s

Sol. **2**

Molecular weight in terms of kg/mol = 32×10^{-3} kg/mol

$$V = \sqrt{\frac{\gamma RT}{M}}$$

$$V = \sqrt{\frac{1.4 \times 8.3 \times 273}{32 \times 10^{-3}}}$$

V = 314.85 m/s

32. Consider two physical quantities A and B related to each other as $E = \frac{B - x^2}{At}$ where E, x and t have dimensions of energy, length and time respectively. The dimension of AB is:

(1) $L^{-2}M^{-1}T^{1}$ (2) $L^{-2}M^{1}T^{0}$ (3) $L^{0}M^{-1}T^{1}$ (4) $L^{2}M^{-1}T^{1}$

Sol. **4**

$$E = \frac{B - x^2}{At}$$

Dimension of B = dimension of $x^2 = [L]^2$

Then $E = \frac{B - x^2}{At}$

$$A = \frac{x^2}{Et} = \frac{m^2}{kg \cdot m^2 \cdot sec^{-2} \cdot sec}$$

$$= \frac{[L]^2}{[ML^2T^{-1}]} = [M^{-1}T^{1}]$$

Dimension of AB = $[M^{-1}T^{1}][L^{2}] = [M^{-1}L^{2}T^{1}]$

33. A small spherical ball of radius r, falling through a viscous medium of negligible density has terminal velocity 'v'. Another ball of the same mass but of radius 2r, falling through the same viscous medium will have terminal velocity:

(1) $\frac{v}{2}$ (2) 4v (3) $\frac{v}{4}$ (4) 2v

Sol. **1**

$V_T = \frac{2r^2}{9\eta}(\rho_0 - \rho)g$ [$\rho_0 \to$ density of material and $\rho \to$ density of fluid]

$V_T = \frac{2}{9\eta}r^2(\rho_0)g$

Mass is same given $m = \frac{4}{3}\pi r^3 \rho_0$

$V_T = \frac{2}{9\eta}m\frac{3}{4\pi r^3}\cdot r^2 g$

$V_T = \left(\frac{2}{9\eta}m \times \frac{3}{4\pi}\cdot g\right)\cdot\frac{1}{r}$

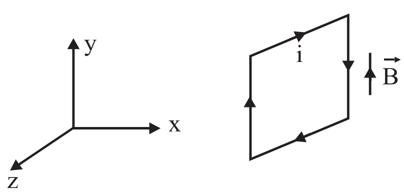
From here $V_T \propto \frac{1}{r}$

It radius is double then velocity becomes half = V/2

34. A uniform magnetic field of 2×10^{-3} T acts along positive Y-direction. A rectangular loop of sides 20 cm and 10 cm with current of 5A is in Y-Z plane. The current is in anticlockwise sense with reference to negative X axis. Magnitude and direction of the torque is:

(1) 2×10^{-4} N – m along positive Y-direction
(2) 2×10^{-4} N – m along positive Z-direction
(3) 2×10^{-4} N – m along positive X-direction
(4) 2×10^{-4} N – m along negative Z-direction

Sol. **4**



$\vec{M} = i\vec{A}$

$= 5 \times 0.2 \times 0.1\,(-\hat{i})$

$= 0.1(-\hat{i})$

$\vec{\tau} = \vec{M}\times\vec{B}$

$= 0.1(-\hat{i})\times 2\times10^{-3}(\hat{j})$

$= 2\times10^{-4}(-\hat{k})$N-m

35. Force between two point charges q_1 and q_2 placed in vacuum at 'r' cm apart is F. Force between them when placed in a medium having dielectric constant K = 5 at 'r/5' cm apart will be:

(1) F/5 (2) 25F (3) F/25 (4) 5F

Sol. **4**

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

In medium $F' = \frac{1}{4\pi(k\varepsilon_0)}\frac{q_1q_2}{r'^2}$

$$F' = \frac{1}{4\pi\varepsilon_0 \cdot k}\frac{q_1q_2}{r^2/25}$$

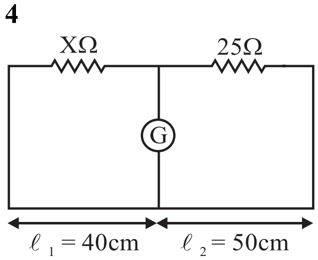
$$F' = \frac{25q_1q_2}{4\pi\varepsilon_0 r^2 \times 5}$$

F' = 5F

36. The resistance per centimeter of a meter bridge wire is r, with $X\,\Omega$ resistance in left gap. Balancing length from left end is at 40 cm with $25\,\Omega$ resistance in right gap. Now the wire is replaced by another wire of 2r resistance per centimeter. The new balancing length for same settings will be at

(1) 10 cm (2) 80 cm (3) 20 cm (4) 40 cm

Sol. **4**



$$\frac{25}{r\ell_1} = \frac{x}{r\ell_2} \quad \ldots (1)$$

$$\frac{25}{2r\ell_1'} = \frac{x}{2r\ell_2'} \quad \ldots (2)$$

using (1) & (2) $\ell_1' = \ell_2 = 40\text{cm}$

37. The mass number of nucleus having radius equal to half of the radius of nucleus with mass number 192 is:

(1) 24 (2) 20 (3) 40 (4) 32

Sol. **1**

$$R_1 = \frac{R_2}{2}$$

$$R_0(A_1)^{1/3} = \frac{R_0}{2}(A_2)^{1/3}$$

$$A_1 = \frac{1}{8}A_2$$

$$A_1 = \frac{192}{8}$$

$A_1 = 24$

38. In a photoelectric effect experiment a light of frequency 1.5 times the threshold frequency is made to fall on the surface of photosensitive material. Now if the frequency is halved and intensity is doubled, the number of photo electrons emitted will be:

(1) Zero (2) halved (3) doubled (4) quadrupled

Sol. **4**

Since $f/2 < f_0$

So current = 0

When the frequency of incident light is halved of its original value i.e. 1.5 v_0 then it becomes less than the threshold value. In that case no photo electric effect takes place. No Photo electrons would be emitted.

39. If two vectors $\vec{A}$ and $\vec{B}$ having equal magnitude R inclined at an angle θ, then

(1) $|\vec{A}-\vec{B}| = 2R\cos\left(\frac{\theta}{2}\right)$ (2) $|\vec{A}+\vec{B}| = 2R\cos\left(\frac{\theta}{2}\right)$

(3) $|\vec{A}-\vec{B}| = \sqrt{2}R\sin\left(\frac{\theta}{2}\right)$ (4) $|\vec{A}+\vec{B}| = 2R\sin\left(\frac{\theta}{2}\right)$

Sol. **2**

$R' = |\vec{A}+\vec{B}| = \sqrt{R^2+R^2+2R^2\cos\theta}$

a = b = R

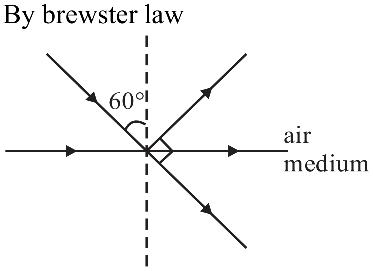
$R' = |\vec{A}+\vec{B}| = R\sqrt{2}\sqrt{1+\cos\theta} = \sqrt{2}R\sqrt{2\cos^2\theta/2}$ = 2R cosθ/2

40. When unpolarized light is incident at an angle of 60° on a transparent medium from air, the reflected ray is completely polarized. The angle of refraction in the medium is:

(1) 45° (2) 90° (3) 30° (4) 60°

Sol. **3**

By brewster law



at complete reflection refracted ray and reflected ray are perpendicular

so r = 30°

41. A gas mixture consists of 8 moles of argon and 6 moles of oxygen at temperature T. Neglecting all vibrational modes, the total internal energy of the system is:

(1) 27 RT (2) 20 RT (3) 29 RT (4) 21 RT

Sol. **1**

$u = nC_vT$

$u = n_1Cv_1T + n_2Cv_2T$

$u = 8 \times \frac{3}{2}RT + 6 \times \frac{5}{2}RT$

$u = 12RT + 15RT$

$u = 27RT$

42. Given below are two statements:

Statement I: Electromagnetic waves carry energy as they travel through space and this energy is equally shared by the electric and magnetic fields.

Statement II: When electromagnetic waves strike a surface, a pressure is exerted on the surface.

In the light of the above statements, choose the most appropriate answer from the options give below:

(1) Statement I is incorrect but Statement II is correct

(2) Both statement I and Statement II are correct

(3) Statement I is correct but statement II is incorrect

(4) Both statement I and Statement II are incorrect.

Sol. **2**

$$\frac{1}{2}\varepsilon_0 E^2 = \frac{B^2}{2\mu_0}$$

$$\because E = CB \text{ and } C = \frac{1}{\mu_0 E_0}$$

43. An AC voltage $V = 20\sin 200\pi t$ is applied to a series LCR circuit which drives a current $I = 10\sin\left(200\pi t + \frac{\pi}{3}\right)$.

The average power dissipated is:

(1) 200 W (2) 50 W

(3) 173.2 W (4) 21.6 W

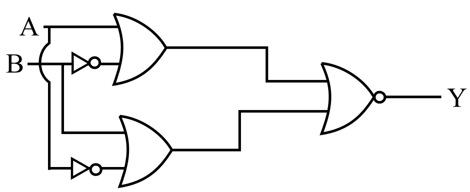
Sol. **2**

$\langle P\rangle = V_{rms} I_{rms} \cos\phi$

$$= \frac{10}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \cos 60°$$

$$= \frac{20 \times 10}{2 \times 2} = 50\text{w}$$

44.



The output of the given circuit diagram is:

(1)

A	B	Y
0	0	0
1	0	1
0	1	1
1	1	0

(2)

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	0

(3)

A	B	Y
0	0	0
1	0	0
0	1	1
1	1	0

(4)

A	B	Y
0	0	0
1	0	0
0	1	0
1	1	1

Sol. **2**

$= \overline{\left(A+\bar{B}\right)+\left(B+\bar{A}\right)}$

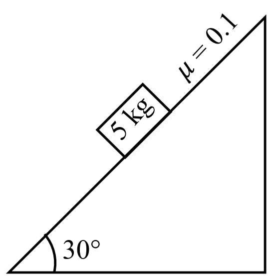
$= \overline{\left(A+\bar{B}\right)}\;\overline{\left(B+\bar{A}\right)}$

$= \left(\bar{A}\cdot\bar{\bar{B}}\right)\cdot\left(\bar{B}\cdot\bar{\bar{A}}\right)$

$= \left(\bar{A}\cdot B\right)\cdot\left(\bar{B}\cdot A\right)$

$= 0$

45.

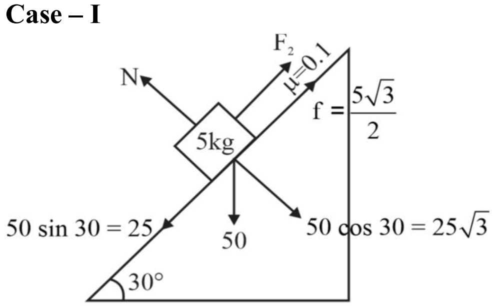


A block of mass 5 kg is placed on a rough inclined surface as shown in the figure. If $\vec{F}_1$ is the force required to just move the block up the inclined plane and $\vec{F}_2$ is the force required to just prevent the block from sliding down, then the value of $\left|\vec{F}_1\right| - \left|\vec{F}_2\right|$ is ; [Use g= 10m/s^2]

(1) $25\sqrt{3}$N (2) $\frac{5\sqrt{3}}{2}$N (3) $50\sqrt{3}$N (4) 10N

Sol. **Bonus**

Case – I



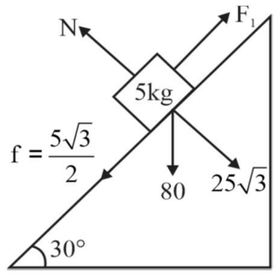
$f_{max} = \mu N$

$f_{max} = 2.5\sqrt{3}$

$f_{max} = \frac{5\sqrt{3}}{2}$

$F_2 = 25 - \frac{5\sqrt{3}}{2}$

Case - II



$F_1 = 25 + \frac{5\sqrt{3}}{2}$

$|F_1| - |F_2| = \frac{10\sqrt{3}}{2}$

$= 5\sqrt{3}$

46. A body of mass 2kg begins to move under the action of a time dependent force given by $\vec{F} = \left(6t\hat{i} + 6t^2\hat{j}\right)N$. The power developed by the force at time t is given by -

(1) $\left(9t^5 + 6t^3\right)W$ (2) $\left(6t^4 + 9t^5\right)W$ (3) $\left(9t^3 + 6t^5\right)W$ (4) $\left(3t^3 + 6t^5\right)W$

Sol. **3**

$F = 6t\hat{i} + 6t^2\hat{j}$

$F = ma$

$F = m\frac{dv}{dt}$

$(6t + 6t^2)dt = 2dv$

$\frac{6t^2}{2} + \frac{6t^3}{3} = 2V$

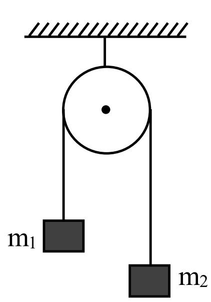
$3t^2 + 2t^3 = 2V$

$V = \frac{3}{2}t^2\hat{i} + t^3\hat{j}$

$P = f.V$

$P = (9t^3 + 6t^5)W$

47. A light string passing over a smooth light fixed pulley connects two blocks of masses m_1 and m_2. If the acceleration of the system is g/8, then the ratio of masses is:



(1) $\frac{9}{7}$ (2) $\frac{5}{3}$ (3) $\frac{8}{1}$ (4) $\frac{4}{3}$

Sol. **1**

$$a = \frac{(m_1 - m_2)g}{m_1 + m_2} = \frac{g}{8}$$

$8m_1 - 8m_2 = m_1 + m_2$

$7m_1 = 9m_2$

$$\frac{m_1}{m_2} = \frac{9}{7}$$

48. By what percentage will the illumination of the lamp decrease if the current drops by 20%?

(1) 56% (2) 36% (3) 46% (4) 26%

Sol. **2**

$P_1 = i^2R$

$P_2 = (0.8\ I)^2R$

$P_2 = 0.64\ I^2R$

$P_2 = 0.64\ P_1$

$$\%\text{ drop of power} = \frac{P_2 - P_1}{P_1} \times 100$$

$$= \frac{(0.64 - 1)P_1}{P_1} \times 100$$

$= -.36 \times 100 = 36\%$ drop

49. The measured value of the length of a simple pendulum is 20 cm with 2 mm accuracy. The time for 50 oscillations was measured to be 40 seconds with 1 second resolution. From these measurements, the accuracy in the measurement of acceleration due to gravity is N%. The value of N is

(1) 8 (2) 6 (3) 5 (4) 4

Sol. **2**

$$T = 2\pi\sqrt{\frac{\ell}{g}} \qquad [T = \frac{40}{50} = \frac{4}{5}\text{sec.}]$$

$$g = \frac{4\pi^2\ell}{T^2}$$

$$\frac{\Delta g}{g} \times 100\% = \frac{\Delta\ell}{\ell} \times 100\% + 2\frac{\Delta T}{T} \times 100\%$$

$$\frac{\Delta g}{g} \times 100\% = \frac{0.2}{20} \times 100 + 2 \times \frac{1}{40} \times 100$$

$$\frac{\Delta g}{g} \times 100\% = 6\%$$

50. The mass of the moon is $\frac{1}{144}$ times the mass of a planet and its diameter is $\frac{1}{16}$ times the diameter of a planet. If the escape velocity on the planet is v, the escape velocity on the moon will be:

(1) $\frac{v}{6}$ (2) $\frac{v}{12}$ (3) $\frac{v}{4}$ (4) $\frac{v}{3}$

Sol. **4**

$$V_{escape} = \sqrt{\frac{2GM}{R}} \quad \frac{V_{moon}}{V_{planet}} = \frac{\sqrt{\frac{2GM_m}{R_m}}}{\sqrt{\frac{2GM_p}{R_p}}} = \sqrt{\frac{M_m}{M_p}}\sqrt{\frac{R_p}{R_m}}$$

$$\frac{V_{moon}}{V} = \sqrt{\frac{1}{144}}\sqrt{\frac{16}{1}}$$

$$V_{moon} = \frac{4V}{12} \Rightarrow V_{moon} = \frac{V}{3}$$

SECTION – B

51. Two circular coils P and Q of 100 turns each have same radius of π cm. The currents in P and R are 1A and 2A respectively. P and Q are placed with their planes mutually perpendicular with their centers coincide. The resultant magnetic field induction at the centre of the coils is $\sqrt{x}$ mT, where x =________.

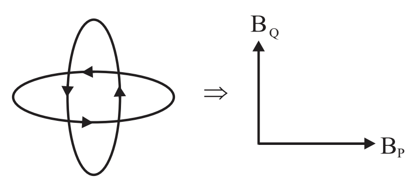
[Use $\mu_0 = 4\pi \times 10^{-7} TmA^{-1}$]

Sol. **20**

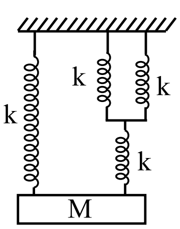
$$B_P = \frac{\mu_0 N i_1}{2r} = \frac{\mu_0 \times 1 \times 100}{2\pi} = 2 \times 10^{-3} T$$

$$B_Q = \frac{\mu_0 N i_2}{2r} = \frac{\mu_0 \times 2 \times 100}{2\pi} = 4 \times 10^{-3} T$$

$$B_{net} = \sqrt{B_P^2 + B_Q^2} = \sqrt{20} MT \Rightarrow x = 20$$



52. The time period of simple harmonic motion of mass M in the given figure is $\pi\sqrt{\frac{\alpha M}{5k}}$, where the value of α is____.



Sol. **12**

$$K_{eq} = \frac{2K}{3} + K = \frac{5K}{3}$$

$$T \text{ (Time period)} = 2\pi\sqrt{\frac{M}{K_{eq}}} = \pi\sqrt{\frac{12m}{5K}}$$

a = 12

53. Light from a point source in air falls on a convex curved surface of radius 20 cm and refractive index 1.5. If the source is located at 100 cm from the convex surface, the image will be formed at ________ cm from the object.

Sol. **200**

$$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$$

$$\frac{1.5}{V}-\left(\frac{1}{-100}\right)=\frac{1.5-1}{20}$$

$$\frac{1.5}{V}+\frac{1}{100}=\frac{1}{40}$$

$$\frac{1.5}{V}=\frac{1}{40}-\frac{1}{100}$$

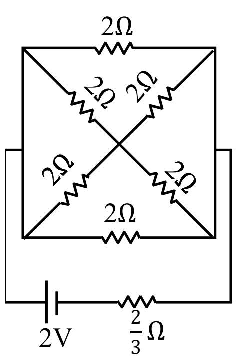
$$\frac{1.5}{V}=\frac{5-2}{200}$$

$$V=\frac{200\times1.5}{3}$$

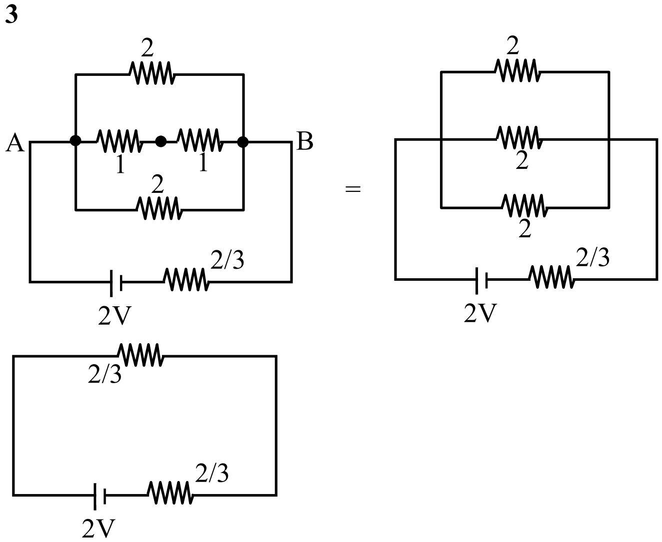
V = 100 cm

so distance from object = 200 cm

54. In the following circuit, the battery has an emf of 2V and an internal resistance of $\frac{2}{3}\Omega$. The power consumption in the entire circuit is _______ W.



Sol. **3**



$\Rightarrow R_{eq} = \frac{4}{3}$

$P = \frac{V^2}{R} = \frac{(2)^2}{4/3} = \frac{4}{4/3}$

P = 3 W

55. The magnetic flux ϕ (in weber) linked with a closed circuit of resistance $8\,\Omega$ varies with time (in seconds) as $\phi = 5t^2 - 36t + 1$. The induced current in the circuit at $t = 2$ s is ________A.

Sol. **2**

$\varepsilon = -\frac{d\phi}{dt}$

$= \frac{-d\phi}{dt}(5t^2 - 36t + 1)$

$\varepsilon = -[10t-36]$

Now at t = 2 sec

$\varepsilon = -[10\times2-36]$

$q = -[20 - 36]$

$\varepsilon = 16$

Now $i = \frac{\varepsilon}{R}$

$i = \frac{16}{8}$

$\Rightarrow i = 2$ A

56. A nucleus has mass number A_1 and volume V_1. Another nucleus has mass number A_2 and volume V_2. If relation between mass number is $A_2 = 4A_1$. Then $\frac{V_2}{V_1}$ =_________.

Sol. **4**

$V = \frac{4}{3}\pi R^3$

$R = R_0(A)^{\frac{1}{3}}$

$V = \frac{4}{3}\pi R_0^3 A$

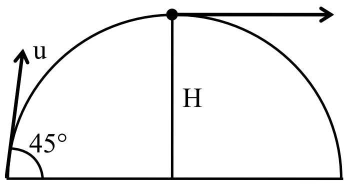
$\frac{V_2}{V_1} = \frac{A_2}{A_1} = 4$

57. A body of mass 'm' is projected with a speed 'u' making an angle of 45° with the ground. The angular momentum of the body about the point of projection at the highest point it expressed as $\frac{\sqrt{2}mu^3}{Xg}$. The value of 'X' is _______.

Sol. **8**

$$H = \frac{u^2 \sin^2\theta}{2g} = \frac{u^2}{4g}$$

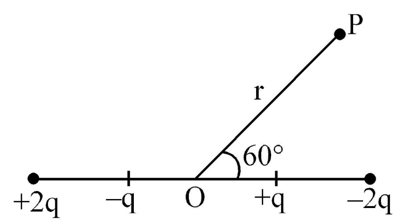
Angular momentum = mvH



$$= m.\frac{u}{\sqrt{2}}.\frac{u^2}{4g} = \frac{mu^3}{4\sqrt{2}g} \times \frac{\sqrt{2}}{\sqrt{2}} = \frac{\sqrt{2}mu^3}{8g}$$

x = 8

58. The distance between charges +q and –q is 2*l* and between +2q and –2q is 4*l*. The electrostatic potential at point P at a distance r from center O is $-\alpha\left[\frac{ql}{r^2}\right]\times 10^9\,V$, where the value of α is ______. $\left(\text{Use} \frac{1}{4\pi\varepsilon_0} = 9\times10^9\,Nm^2C^{-2}\right)$

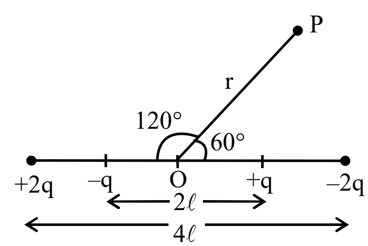


Sol. **27**

due to q

$$V_q = \frac{kP\cos\theta}{r^2} = \frac{K(q.2\ell)\times\frac{1}{2}}{r^2}$$

$$V_q = \frac{Kq\ell}{r^2} \quad \dots (i)$$



Due to 2q

$$V_{2q} = \frac{K[2q(4\ell)]\cos120^\circ}{r^2} = \frac{8Kq\ell}{r^2}.\left(-\frac{1}{2}\right)$$

$$V_{2q} = \frac{-4Kq\ell}{r^2} \quad \dots.(ii)$$

Using (i) and (ii)

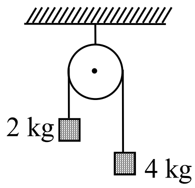
$$V_{net} = \frac{Kq\ell}{r^2} - \frac{4Kq\ell}{r^2} = \frac{-3Kq\ell}{r^2}$$

$$V_{net} = -3\left[\frac{q\ell}{r^2}\right]\times 9\times10^9$$

$$= -27\left[\frac{q\ell}{r^2}\right]\times10^9\,r$$

$$\boxed{\alpha = 27}$$

59. Two blocks of mass 2 kg and 4 kg are connected by a metal wire going over a smooth pulley as shown in figure. The radius of wire is 4.0×10^{-5} m and Young's modulus of the metal is $2.0 \times 10^{11}\ \mathrm{N/m^2}$. The longitudinal strain developed in the wire is $\frac{1}{\alpha\pi}$. The value of α is___________. [Use = $10\ \mathrm{m/s^2}$]



Sol. **12**

$r = 4\times10^{-5}$

$Y = 2\times10^{11}$

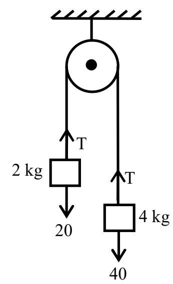
$g = 10$

$40 - T = 4a$

$T - 20 = 2a$

$20 \;=\; 6a$

$a = \frac{10}{3}\ \mathrm{m/sec^2}$



and

$40 - T = 4a$

$40 - 4a = T$

$T = 40 - 4\times\frac{10}{3}$

$T = 40 - \frac{40}{3}$

$T = \frac{120-40}{3}$

$T = \frac{80}{3}\mathrm{N}$

$Y = \frac{F/A}{\frac{\Delta\ell}{\ell}}$

$\frac{\Delta\ell}{\ell} = \frac{F}{AY}$

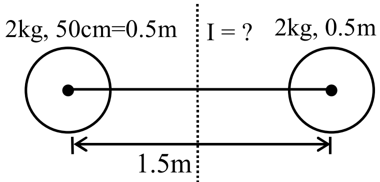
$\frac{\Delta\ell}{\ell} = \frac{80/3}{2\times10^{11}\pi r^2}$

$\frac{\Delta\ell}{\ell} = \frac{80}{3\times2\times10^{11}\times\pi\times(4\times10^{-5})^2}$

$\frac{\Delta\ell}{\ell} = \frac{1}{12\pi} = 12$

60. Two identical spheres each of mass 2 kg and radius 50 cm are fixed at the ends of a light rod so that the separation between the centers is 150 cm. Then, moment of inertia of the system about an axis perpendicular to the rod and passing through its middle point is $\frac{x}{20}$ kg m^2, where the value of x is

Sol. **53**



Sphere $= \frac{2}{5} mR^2$

$I = I_1 + I_2$

$$I = \left(\frac{2}{5} mR^2 + md^2\right) \times 2$$

$$I = \left[\frac{2}{5} \times 2 \times (0.5)^2 + 2 \times (0.75)^2\right] \times 2$$

$$I = \left[\frac{2}{5} \times 2 \times 0.25 + 2 \times 0.5625\right] \times 2$$

$$I = \left[\frac{1}{5} + 1.125\right] \times 2$$

$$I = [0.2 + 1.125] \times 2$$

$I = 2.65$

$$\Rightarrow I = \frac{265}{100}$$

$$I = \frac{53}{20} \Rightarrow x = 53$$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(2022)
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