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Unsolved problems :

12) Given :-

$d = 1\,m$

$\therefore r = 0.5\,m$

$n = 2$ rps → after 10 seconds

$t = 10$ sec

To find :

① No. of revolutions completed by ant in 10 sec

② Time taken for 1st revolution i.e. t_1.

③ Time taken for last revolution i.e. t_{last}.

Formula : $\omega = 2\pi n$

$\omega = \omega_0 + \alpha t$ → 1st kinematical eqⁿ

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ → 3rd —"— eqⁿ

Solution :

$\omega = 2\pi n$, $n = 2$ rps

$= 2\pi \times 2$

$\boxed{\omega = 4\pi \text{ rad/s}}$

Initially when wheel is at rest

$\omega_0 = 0$

$\therefore \omega = \omega_0 + \alpha t$ — (1st kinematical eqⁿ)

$4\pi = 0 + \alpha(10)$

$4\pi = 10\alpha$

$\therefore \boxed{\alpha = \frac{4\pi}{10} = 0.4\pi \text{ rad/s}^2}$

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ — (3rd Kinematical eqⁿ)

$= 0 + \frac{1}{2} \times 0.4\pi \times (10)^2$ $(\because \omega_0 = 0)$

$= \frac{1}{2} 0.4\pi \times 100\ 50$

$\boxed{\theta = 20\pi \text{ rad}}$

$\therefore$ No. of revolutions $= \frac{\theta}{2\pi} = \frac{20\pi}{2\pi} = 10$ rev

$\therefore$ No. of revolutions in 10sec = 10 revolutions

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let Time taken for 1st revolution t_1

$$\theta_1 = \omega_0 t + \frac{1}{2}\alpha t_1^2$$

$$2\pi = 0 \times t + \frac{1}{2} \overset{0.2}{0.4\pi} \times t_1^2$$

$$2\pi = 0 + 0.2\pi\, t_1^2$$

$$2 = 0.2\, t_1^2$$

$$\therefore t_1^2 = \frac{2}{0.2}$$

$$t_1^2 = 10 \qquad \therefore \boxed{t_1 = \sqrt{10} = 3.16 \text{ sec}}$$

let Time taken for last revolution t_{last}

$$\therefore t_{last} = t_{10} - t_9 \qquad t_{10} = 10 \text{ sec (given)}$$

$$\therefore \theta_9 = \omega_0 t + \frac{1}{2}\alpha t_9^2$$

$$9 \times 2\pi = 0 + \frac{1}{2} \overset{0.2}{0.4\pi}\, t_9^2 \qquad (\because \theta_9 = 9 \times \theta_1 = 9 \times 2\pi)$$

$$18\pi = 0.2\pi\, t_9^2$$

$$t_9^2 = \frac{18}{0.2} = 90 \qquad \therefore \boxed{t_9 = \sqrt{90} = 9.486 \text{ sec}}$$

$$\therefore t_{last} = t_{10} - t_9$$

$$= 10 - 9.486$$

$$\boxed{t_{last} = 0.5131}$$

14) Given

Radius of racing track = 72 m

V_{max} = 216 kmph → Km per hour

$$= 216 \times \frac{1000}{60 \times 60} \text{ kmps}$$

$$= \frac{2160}{36}$$

$$V_{max} = 60 \text{ kmps}$$

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width of road = 10 m , $g = 9.8\ m/s^2$

To find :

① Angle of banking (θ)

② Height of its outer edge (h)

Formula :

$$\theta = \tan^{-1} \frac{v^2}{rg}$$

$$\sin\theta = \frac{h}{\text{Hypothenuse}}$$

Solution $\theta = \tan^{-1} \frac{v^2}{rg}$

$$= \tan^{-1}\left(\frac{(60)^2}{72 \times 9.8}\right)$$

$$= \tan^{-1}\left(\frac{3600}{705.6}\right)$$

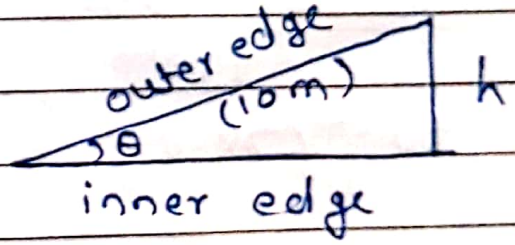
$$= \tan^{-1}(5.1020)$$

$$\boxed{\theta \approx \tan^{-1}(5) = 78.69^\circ}$$

To find h

From figure

$$\sin\theta = \frac{\text{opp. side}}{\text{hypo}}$$



$$\sin\theta = \frac{h}{10}$$

$$h = 10 \times \sin\theta$$

$$= 10 \times \sin(78.69)$$

$$= 10 \times 0.9805$$

$$\boxed{h = 9.805\ m}$$

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15) Given :

$r = 72\,m$, $\theta = 78.69°$, $\mu_s = 0.8$, $g = 9.8$

To find

v_{min} (lower speed limit)

v_{max} (upper speed limit)

Formula :

$$v_{min} = \sqrt{rg\left(\frac{\tan\theta - \mu_s}{1 + \mu_s \tan\theta}\right)}$$

$$v_{max} = \sqrt{rg\left(\frac{\tan\theta + \mu_s}{1 - \mu_s \tan\theta}\right)}$$

Solution :

To find v_{min}

$$v_{min} = \sqrt{rg\left(\frac{\tan\theta - \mu_s}{1 + \mu_s \tan\theta}\right)}$$

$$= \sqrt{(72 \times 9.8)\left[\frac{\tan(78.69) - 0.8}{1 + 0.8 \times \tan(78.69)}\right]}$$

$$= \sqrt{705.6\left[\frac{5 - 0.8}{1 + 0.8 \times 5}\right]}$$

$\tan(78.69) = 4.999 \approx 5$

$$= \sqrt{705.6\left(\frac{5 - 0.8}{1 + 4}\right)}$$

$$= \sqrt{705.6\left(\frac{4.2}{5}\right)}$$

$$= \sqrt{705.6 \times 0.84}$$

$v_{min} = \sqrt{592.70}$ ~~= 24.34~~

$v_{min} = 24.34$ m/s

Convert $v_{min} = 24.34$ m/s in km/h

$\therefore v_{min} = \frac{24.34 \times 3600}{1000} = 24.34 \times 3.6$

$= 87.64 \approx 88$

$\therefore$ **$v_{min} = 88$ kmph**

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To find Vmax (upper speed limit)

As, $\theta = 78.69° > 45°$

For such case $V_{max} = \infty$

∴ **no upper speed limit as $\theta > 45°$**

16) Given :

$r = 6.05\ m$

$\mu_s = 0.5$

$m = 50\ kg$, $g = 10\ m/s^2$

To Find :-

① Minimum speed V_{min}

② Force of friction if speed in increase by 20%

formula

$$V_{min} = \sqrt{\frac{rg}{\mu_s}}$$

Force of friction $F_s = mg$

Solution :

① $$V_{min} = \sqrt{\frac{rg}{\mu_s}}$$

$$= \sqrt{\frac{6.05 \times 10}{0.5}}$$

$$= \sqrt{\frac{60.5}{0.5}}$$

$$V_{min} = \sqrt{121}$$

$V_{min} = \sqrt{121} = 11$

$V_{min} = 11\ m/s$

② $F_s = mg$

$= 50 \times 10$

$F_s = 500\ N$

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17) Given:

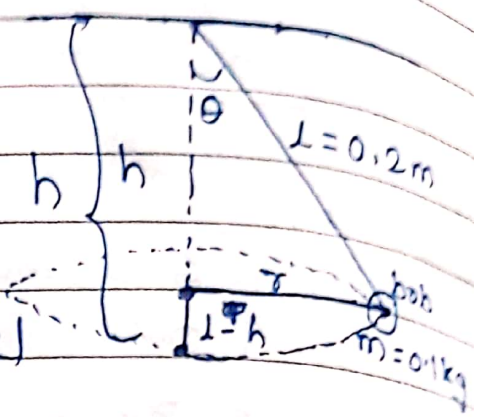
length of pendulum $l = 20cm = 20 \times 10^{-2}$ m $= 0.2$ m

$m = 100g = 0.1$ kg

$n = 75$ rpm

$= \frac{75}{60}$ rps

$\pi^2 = 10$, $g = 10 m/s^2$



To find

① Kinetic energy

② Increase in gravitational Potential energy

Formula

$$t = 2\pi\sqrt{\frac{l\cos\theta}{g}}$$

$$v^2 = \sqrt{rg\tan\theta}$$

$$K.E = \frac{1}{2}mv^2$$

$$\Delta(P.E) = mgh = mg(l-h)$$

Solution

$$t = 2\pi\sqrt{\frac{l\cos\theta}{g}}$$

$$\frac{1}{n} = 2\pi\sqrt{\frac{l\cos\theta}{g}}$$

~~60/75~~ squaring

$$\frac{1}{n^2} = 4\pi^2\left(\frac{l\cos\theta}{g}\right)$$

$$\left(\frac{60}{75}\right)^2 = \frac{4 \times 10 \times 0.2 \times \cos\theta}{10}$$

$$\left(\frac{4}{5}\right)^2 = 0.8\cos\theta$$

$$\frac{16}{25} = 0.8\cos\theta$$

$$\frac{16}{25 \times 0.8} = \cos\theta = \frac{16}{20} = 0.8$$

$\therefore \boxed{\cos\theta = 0.8}$

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$\therefore \theta = \cos^{-1} 0.8$

$\boxed{\theta = 37^\circ}$

$v = \sqrt{rg \tan\theta}$

$v^2 = rg \tan\theta$

$= l \sin\theta \times g \tan\theta$

{ From fig
$\sin\theta = \frac{r}{l}$
$\therefore r = l \sin\theta$

$= 0.2 \times \sin 37^\circ \times 10 \times \tan 37^\circ$

$= 0.2 \times 0.6018 \times 10 \times 0.7535$

$\boxed{v^2 = 0.9069}$

$\therefore$ Kinetic energy $= \frac{1}{2} mv^2$

$= \frac{1}{2} \times 0.1 \times 0.9069$ (0.05)

$\boxed{K.E = 0.045 \text{ J}}$

To find increase in P.E.

$P.E = mgh$ { but increase in height $h = l - h$ from fig)

$\Delta(P.E) = mg(l-h)$

$= 0.1 \times 10 \times (0.2 - l\cos\theta)$

$= 1 \times (0.2 - l\cos 37^\circ)$

$= 0.2 - l(0.8)$

$= (0.2 - 0.2 \times 0.8)$

$= 0.2 - 0.16$

$\boxed{\Delta(PE) = 0.04 \text{ J}}$

{ From fig
$\cos\theta = \frac{h}{l}$
$\therefore h = l\cos\theta$

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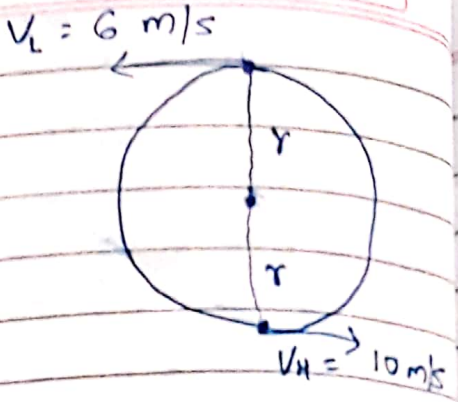
18 Given :

$V_H = 6$ m/s , $V_L = 10$ m/s



To find :

① Diameter d

② $V_{L(min)}$

③ $V_{H(min)}$

Formula

$(T.E)_L = (T.E)_H$

$V_{H(min)} = \sqrt{rg}$

$V_{L(min)} = \sqrt{5rg}$

Solution :

$(TE)_L = (TE)_H$

$(KE + PE)_L = (KE + PE)_H$

$\frac{1}{2}mV_L^2 + 0 = \frac{1}{2}mV_H^2 + mg(2r)$

$(PE)_L = 0$

$(PE)_H = mgh$

$h = r + r = 2r$

$\therefore PE = 2mgr$

$\frac{1}{2}mV_L^2 = \frac{1}{2}mV_H^2 + 2mgr$

$\frac{1}{2}(10)^2 = \frac{1}{2}(6)^2 + 2 \times 10 \times r$

$\frac{1}{2} \times 100^{50} = \frac{1}{2}\,36^{18} + 20r$

$50 = 18 + 20r$

$\therefore 20r = 50 - 18$

$20r = 32$

$r = \frac{32}{20} = 1.6$

$\therefore$ **$d = 2r = 2 \times 1.6 = 3.2$ m**

$V_{H(min)} = \sqrt{rg}$

$= \sqrt{1.6 \times 10}$

$= \sqrt{16}$

$V_{H(min)} = 4$ m/s

$V_{L(min)} = \sqrt{5rg}$

$= \sqrt{5 \times 1.6 \times 10}$

$= \sqrt{5 \times 16}$

$= \sqrt{80}$

$= \sqrt{16 \times 5}$

$V_{L(min)} = 4\sqrt{5}$

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19) Given :

$m = 1\ kg$

$I_r = 1\ kg\ m^2$ (M.I. of ring)

Radius of ring = Radius of disc

$R_r = R_d$

To Find :-

Moment of inertia of disc (I_d)

Formula :

$$I_r = \frac{mR^2}{2}, \quad I_d = \frac{mR^2}{2}$$

Solution :

$$I_r = \frac{mR^2}{2}$$

$$1 = \frac{1 R^2}{2}$$

$$\therefore R^2 = 2 \quad \therefore \boxed{R = \sqrt{2}}$$

∴ Moment of Inertia of disc is

$$I_d = \frac{mR^2}{2}$$

$$= \frac{1(\sqrt{2})^2}{2}$$

$$I_d = \frac{2}{2}$$

$$\boxed{I_d = 1\ kg\ m^2}$$

20) Given :

Mass of rod $m_R = 60g = 60 \times 10^{-3}\ kg$

length of rod $l_R = 20cm = 20 \times 10^{-2}\ m$

Mass of solid sphere $m_S = 50\ kg = 50 \times 10^{-3}\ kg$

Radius of solid sphere $R = 10cm = 10 \times 10^{-2}\ m$

To Find :

M.I. of dumb-bell when rotate about an axis passing through its centre & 1er to the length (I)

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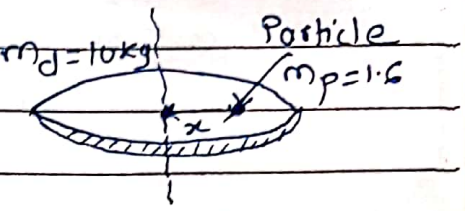
21) Given :-

$n_1 = 100$ rpm $= \frac{100}{60}$ rps $= \frac{5}{3}$ rps

$n_2 = 80$ rpm $= \frac{80}{60}$ rps $= \frac{4}{3}$ rps



$m_d = 10$ kg , $m_p = 1.6$ kg

$r = 0.4$ m , $x = h$ (distance of particle)

To Find :- x

Formula :- ① $I_1\omega_1 = I_2\omega_2$

② $\omega = 2\pi n$

③ $I_1 = \frac{1}{2} m_d r^2$

④ $I_2 = \frac{1}{2} m_d r^2 + m_p h^2$

Solution :-

$I_1\omega_1 = I_2\omega_2$

$\left(\frac{1}{2} m_d r^2\right)(2\pi n_1) = \left(\frac{1}{2} m_d r^2 + m_p h^2\right)(2\pi n_2)$

$\frac{1}{2} \times 10^5 \times (0.4)^2 \times 2\pi \times \frac{5}{3} = \left[\frac{1}{2} \times 10 \times (0.4)^2 + 1.6x^2\right] 2\pi \times \frac{4}{3}$

$5 \times 0.16 \times 5 = (5 \times 0.16 + 1.6x^2)\, 4$

$4 = (0.8 + 1.6x^2) \times 4$

$4 = 3.2 + 6.4x^2$

$\therefore 6.4x^2 = 4 - 3.2$

$6.4x^2 = 0.8$

$\therefore x^2 = \frac{0.8}{6.4}$

$x^2 = \frac{1}{8}$

$\therefore \boxed{x = \frac{1}{\sqrt{8}} = 0.35 \text{ m}}$

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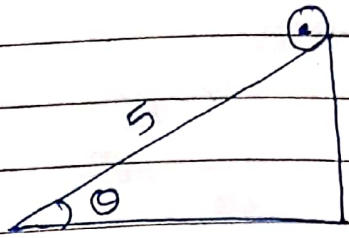
22) Given :

initial velocity $u = 0$

Final velocity $v = \sqrt{10}$

$g = 10 \text{ m/s}^2$

displacement $s = \frac{5}{3}$



$\sin\theta = \frac{3}{5}$

To Find :

The possible shape/s of objects

Formula

$$v^2 = u^2 + 2as$$

$$a = \frac{g\sin\theta}{1 + \frac{k^2}{R^2}}$$

Solution :-

$$v^2 = u^2 + 2as$$

$$(\sqrt{10})^2 = 0 + 2 \times \frac{g\sin\theta}{1 + \frac{k^2}{R^2}} \times \frac{5}{3}$$

$$10 = 0 + 2 \times \frac{10 \times 3/5}{1 + \frac{k^2}{R^2}} \times \frac{5}{3}$$

$$10 = \frac{2 \times 10 \times \frac{3}{5} \times \frac{5}{3}}{1 + \frac{k^2}{R^2}}$$

$$1 = \frac{2}{1 + \frac{k^2}{R^2}}$$

$$1 + \frac{k^2}{R^2} = 2$$

$$\frac{k^2}{R^2} = 2 - 1 = 1$$

$$\boxed{\frac{k^2}{R^2} = 1}$$ → For ring or hollow cylinder

$\therefore k^2 = R^2$

Thus the shape of object can be ring or hollow cylinder

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