Solutions to FE Exam "Dynamics" Review Problems;
Problems are Online at McGraw-Hill Website

Prepared by
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Start the web page for the book: Beer and Johnston, *Vector Mechanics for Engineers, Statics and Dynamics*, Ninth Edition, 2010, at: http://highered.mcgraw-hill.com/sites/0073529400/information_center_view0/ .

Look for the "Online Learning Center" box on the left. Click on the "Student Edition" link. Select a chapter from the pull-down menu. My solutions, which you will find below, are for the online problems that are associated with the following chapters and topics:

Chpt. 11: Kinematics of Particles
Chpt. 12: Kinetics of Particles: Newton's Second Law
Chpt. 13: Kinetics of Particles: Energy and Momentum Methods
Chpt. 14: Systems of Particles
Chpt. 15: Kinematics of Rigid Bodies
Chpt. 16: Plane Motion of Rigid Bodies: Forces and Accelerations
Chpt. 17: Plane Motion of Rigid Bodies: Energy and Momentum Methods
Chpt. 19: Mechanical Vibrations

Click on "FE Exam Review."

Solve the problem, and select the answer from the multiple choices at the bottom. Click on the right-arrow to continue to the next problem. This process ends when you click on the right-arrow for the third time. To try to solve other problems from the same chapter, you will need to exit by clicking on, say, >Chapter XX> at the top, and restart "FE Exam Review." Now you will be presented with all new, or a mixture of old and new, problems. After repeated trials, no new problems will appear.

As I mentioned in class, some of the online problem statements have errors in them, and some solutions and answers are wrong. For this reason, I have prepared a separate document that lists the errors and corrections. You can access this document at:
http://www.calstatela.edu/sites/default/files/users/u28426/felszeghy/fe_exam_review_rev3.pdf .
Although I shared the errors and corrections with McGraw-Hill, the company has not made any corrections on its Website.

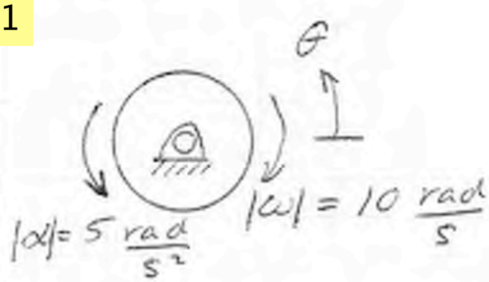
The online problems are not numbered, except for being associated with chapter numbers. For this reason, I downloaded the online problems in no particular order, and numbered them consecutively in a decimal format, XX.X, where XX refers to the chapter number, and X stands for the sequence number. All the online problems numbered this way are included in the above "FE_Exam_Review_rev3.pdf" document under the heading: "Part 1, FE Exam Review, Online Problems and Solutions."

My own solutions, which you will find below, follow the problem numbering scheme I established above. I include sketches in my solutions to allow you to identify the problems to which my solutions apply without necessarily having to refer to Part 1 of the above "FE_Exam_Review_rev3.pdf" document.

I wish you all the best on your computer-based FE exam!

Chpt. 11

11.1



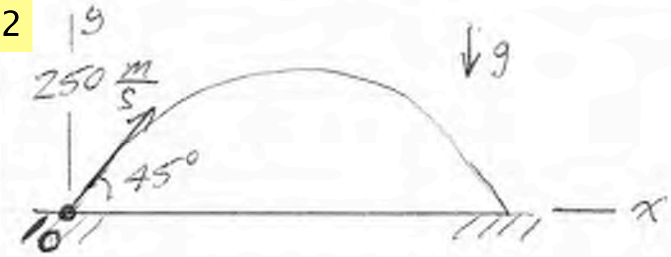
$$\omega_0 = -10 \, \frac{rad}{s}$$

$$\alpha = 5 \, \frac{rad}{s^2}$$

$$\omega = \omega_0 + \alpha t = -10 + 5t$$

$$\omega = 0 \quad at \quad t = 2\,s \quad \leftarrow \text{Ans.}$$

11.2



$$v_y = v_0 \sin\theta - gt$$

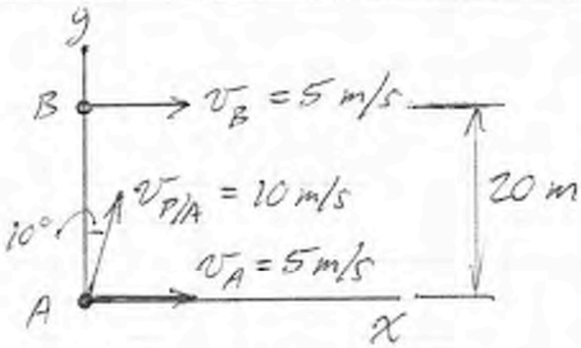
$$v_y = 0 \quad at \quad t_1 = \frac{v_0 \sin\theta}{g} = \frac{250 \sin 45^\circ}{9.81} = 18.02\,s$$

$y = 0$ at $t_2 = 36.04\,s$

x @ $t_2 = 36.04\,s$:

$$x = v_0 (\cos\theta) t_2 = 250(\cos 45^\circ) 36.04 = 6371\,m \quad \leftarrow \text{Ans.}$$

11.3



A and B remain fixed in moving x-y axes attached to A.

Puck motion in y-direction

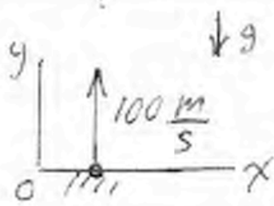
$$y = v_{P/A} (\cos 10^\circ) t$$

Puck reaches line of $\underline{v}_B$ at $t = \frac{20}{10 \cos 10^\circ} = 2.031\,s$

x @ $t = 2.031\,s$: $x = v_{P/A} (\sin 10^\circ) t = 10(\sin 10^\circ) 2.031$

$$= 3.53\,m \quad \leftarrow \text{Ans.}$$

11.4

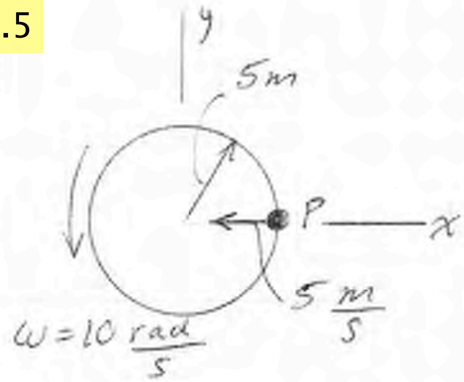


$$v = v_0 + a_0 t \qquad a_0 = -g$$

$$v = 0 \quad at \quad t = \frac{v_0}{g} = \frac{100}{9.81} = 10.19\,s \quad \leftarrow \text{Ans.}$$

Note: $y = y_{max}$ when $v = 0$: $y_{max} = v_0 t - a_0 \frac{t^2}{2} = 509.7\,m$

11.5



Use polar coordinates

$$a_r = \ddot{r} - r\dot{\theta}^2$$

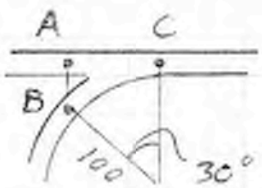
$$= 0 - (5)(10)^2 = -500 \ \frac{m}{s^2}$$

$$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta}$$

$$= 0 + (2)(-5)(10) = -100 \ \frac{m}{s^2}$$

$$\underline{a} = -500\,\underline{e}_r - 100\,\underline{e}_\theta = -500\,\underline{i} - 100\,\underline{j}, \ \frac{m}{s^2} \longleftarrow \text{Ans.}$$

11.6



Time for B to arrive at C:

$$t = \frac{s_B}{v_B} = \frac{(\pi/6)100}{\left(\frac{90 \times 1000}{3600}\right)} = 2.094 \text{ s}$$

Time for A to arrive at C:

$$t = \frac{s_A}{v_A} = \frac{100 \sin 30°}{\left(\frac{100 \times 1000}{3600}\right)} = 1.800 \text{ s}$$

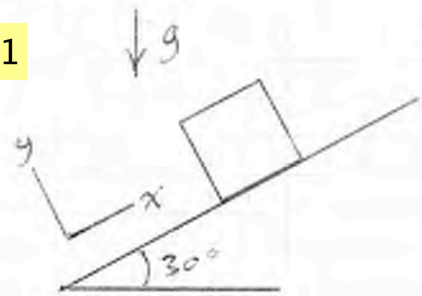
So A gets to C first and B gets to C by distance <u>B is behind A</u> when

$$d = (2.094 - 1.8)\left(\frac{100 \times 1000}{3600}\right)$$

$$= 8.17 \text{ m} \longleftarrow \text{Ans}$$

<u>Chpt. 12</u>

12.1



$$\Sigma F_x = ma \Rightarrow -mg \sin 30° = ma$$

$$a = -9.81 \sin 30° = -4.905 \ \frac{m}{s^2}$$

$$v = v_0 + at = 5 - 4.905\,t$$

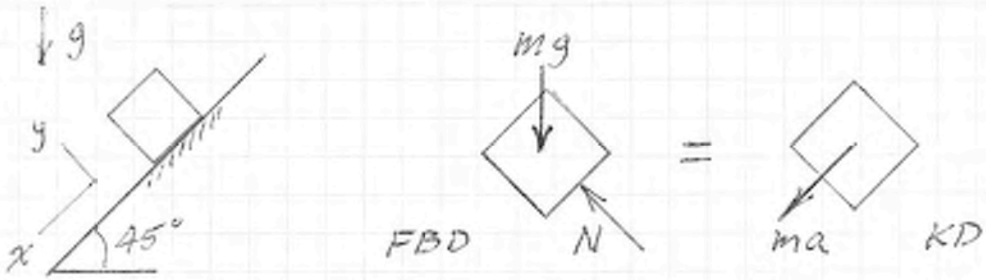
$v = 0$ when $t = \frac{5}{4.905} = 1.019 \text{ s}$

x @ $t = 1.019\text{ s}$: $x = v_0 t + \frac{at^2}{2} = (5)(1.019) - 4.905\frac{(1.019)^2}{2} = 2.55\text{ m}$

Ans.

INSERT AFTER 2

12.2



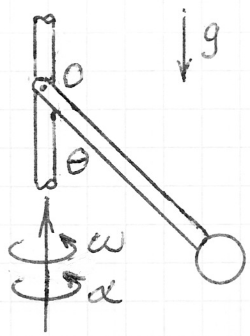
$$\Sigma F_x = ma$$

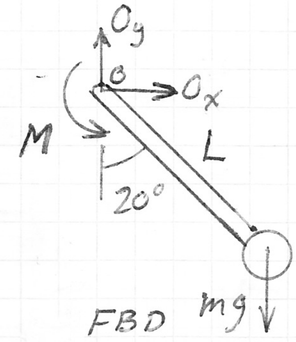
$$\cancel{m}g\cos 45^\circ = \cancel{m}a$$

$$a = (9.81)\cos 45^\circ = 6.94\ \frac{m}{s^2}$$ ← Ans.

③

12.3





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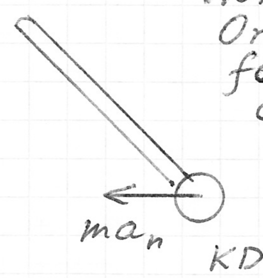


Note: Only <u>in-plane</u> forces and couple are shown.

$$\circlearrowleft \Sigma M_o = -ma_n L\cos 20^\circ$$

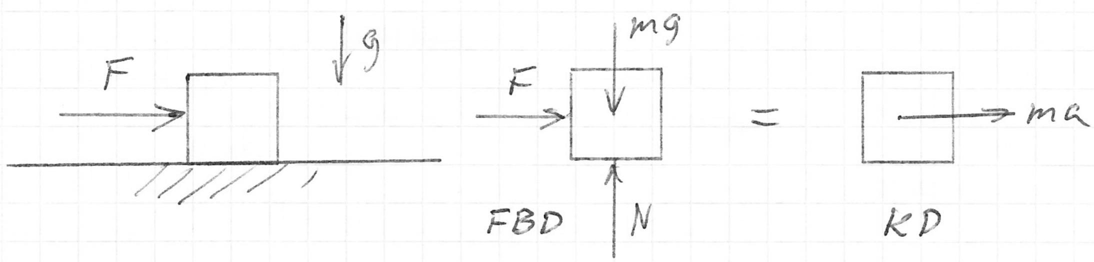
$$M - mgL\sin 20^\circ = -m(\omega^2 L\sin 20^\circ)L\cos 20^\circ$$

$$M = (5)(9.81)(2\sin 20^\circ) - (5)\left(\frac{50\times 2\pi}{60}\right)^2(2\sin 20^\circ)(2\cos 20^\circ)$$

$$M = -142.7\ \text{N}\cdot\text{m}$$

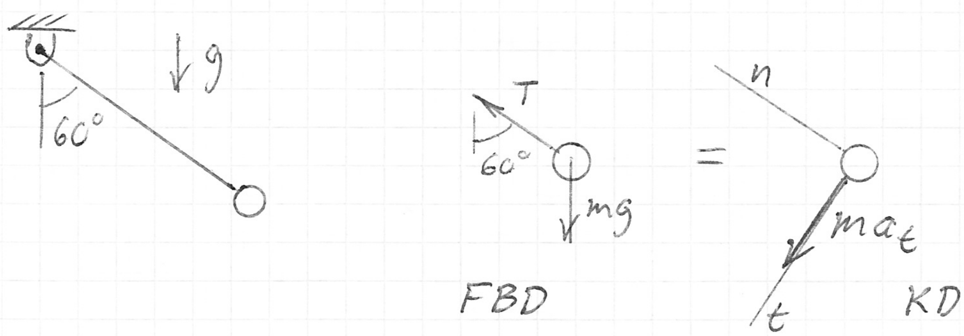
$$\underline{M} = 142.7\ \text{N}\cdot\text{m}\ \circlearrowright \quad \longleftarrow \text{Ans.}$$

12.4



$$F = ma = (4)(15) = 60\ \text{N} \quad \longleftarrow \text{Ans.}$$

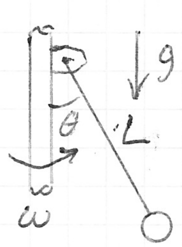
12.5

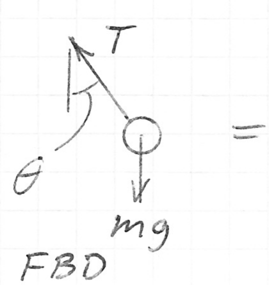


$$\Sigma F_n = 0 \Rightarrow T - mg\cos 60^\circ = 0$$

$$T = mg\cos 60^\circ = (3)(9.81)\cos 60^\circ = 14.72\ \text{N} \quad \longleftarrow \text{Ans.}$$

12.6





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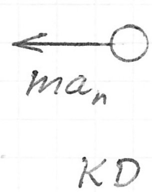
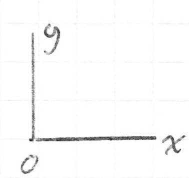




(Cont'd next page.)

$$\Sigma F_x = -ma_n \Rightarrow -T\sin\theta = -ma_n \quad (1)$$

$$\Sigma F_y = 0 \Rightarrow T\cos\theta - mg = 0 \quad (2)$$

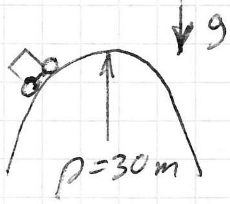
Eliminate T between (1) & (2):

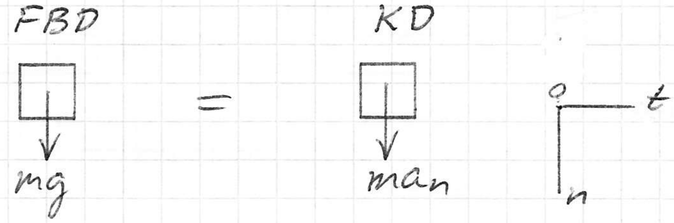
$$\tan\theta = \frac{\cancel{m}a_n}{\cancel{m}g} = \frac{\omega^2 L\sin\theta}{g}$$

$$\cos\theta = \frac{g}{\omega^2 L} = \frac{9.81}{\left(\frac{20\times 2\pi}{60}\right)^2 4} = 0.559$$

$$\theta = 56.0^\circ \quad \longleftarrow \text{Ans.}$$

12.7





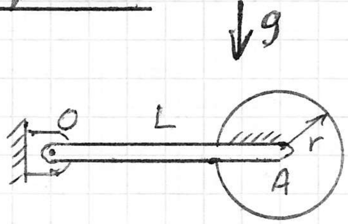
$$\Sigma F_n = ma_n$$

$$\cancel{m}g = \cancel{m}\frac{v^2}{\rho}$$

$$v^2 = \rho g = (30)(9.81)$$

$$v = 17.1 \text{ m/s} \quad \longleftarrow \text{Ans.}$$

13.1 Chpt. 13



$$0 = \Delta T + \Delta V_g$$

$$\Delta T = \frac{1}{2} I_o \omega_2^2$$

$$= \frac{1}{2}\left[\frac{1}{3}m_r L^2 + \frac{1}{2}m_d r^2 + m_d L^2\right]\omega_2^2$$

$$= \frac{1}{2}\left[\frac{1}{3}\frac{10}{9.81}1^2 + \frac{1}{2}10(0.3)^2 + 10(1)^2\right]\omega_2^2$$

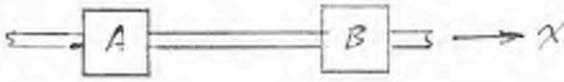
$$= 5.39\,\omega_2^2$$

$$\Delta V_g = -m_r g\frac{L}{2} - m_d g L = -10(0.5) - 10(9.81)(1) = -103.1$$

$$\Delta T = -\Delta V_g \Rightarrow \omega_2^2 = 19.11, \quad \omega_2 = 4.37, \quad v_A = \omega_2 1 = 4.37\,\frac{m}{s} \quad \longleftarrow \text{Ans.}$$

5

13.2



Conservation of total linear momentum:

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$$

$$(10)(10) + (20)(-15) = 10 v_A' + 20 v_B'$$

$$-200 = 10 v_A' + 20 v_B' \quad (1)$$

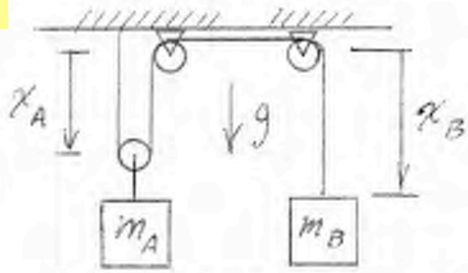
$$e = \frac{v_B' - v_A'}{v_A - v_B} \Rightarrow 0.6 = \frac{v_B' - v_A'}{10 - (-15)} \Rightarrow 15 = -v_A' + v_B' \quad (2)$$

$$(1) - 20 \times (2) \Rightarrow -200 - 300 = 10 v_A' + 20 v_A'$$

$$30 v_A' = -500$$

$$v_A' = -16.67 \frac{m}{s} \quad \longleftarrow \text{Ans.}$$

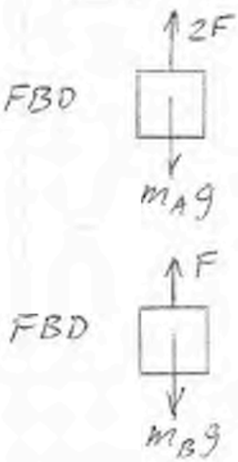
13.3



Cable length is const. Therefore,
$2x_A + x_B + \text{const.} = \text{const.}$

$$2\Delta x_A = -\Delta x_B \quad (1)$$

$$2\dot{x}_A = -\dot{x}_B \quad (2)$$



Work-energy:

$$m_A g \Delta x_A - 2F\Delta x_A = \frac{1}{2} m_A \dot{x}_A^2 \quad (3)$$

$$m_B g \Delta x_B - F\Delta x_B = \frac{1}{2} m_B \dot{x}_B^2 \quad (4)$$

Substitute (1) into (3), and (2) into (4), and add resulting equations

$$(-m_A g/2 + m_B g)\Delta x_B = \frac{1}{2}(m_A \dot{x}_A^2 + m_B 4\dot{x}_A^2)$$

$$9.81(-15 + 40)(10) = (15 + 80)\dot{x}_A^2$$

$$\dot{x}_A^2 = 25.82, \quad \dot{x}_A = 5.08 \frac{m}{s} \quad \longleftarrow \text{Ans.}$$

13.4

Conservation of total linear momentum:

$$m_A v_A + \cancel{m_B v_B}^{\,0} = (m_A + m_B)v'$$

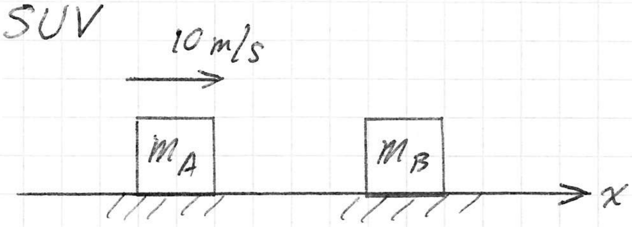
$$v' = \frac{m_A v_A}{m_A + m_B} = \frac{(0.015)(750)}{10.015}$$

$$v' = 1.123 \frac{m}{s} \quad \longleftarrow \text{Ans}$$

⑥

13.5

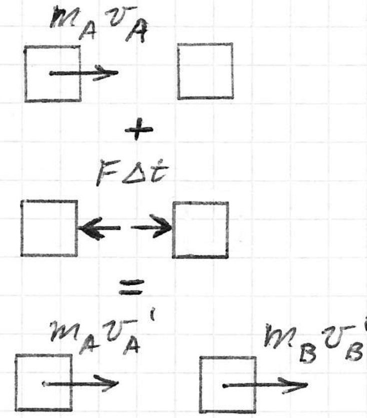
SUV



Initial momentum

Collision Impulses

Final momenta



$$e = \frac{v_B' - v_A'}{v_A - \cancel{v_B}^{\,0}}$$

$$0.7 = \frac{v_B' - v_A'}{10} \qquad (1)$$

Conservation of total linear momentum:

$$m_A v_A + m_B \cancel{v_B}^{\,0} = m_A v_A' + m_B v_B'$$

$$(6000)(10) = 6000 v_A' + 4000 v_B'$$

or $\quad 10 = v_A' + \frac{2}{3} v_B' \qquad (2)$

Add (1) & (2): $\quad 17 = \frac{5}{3} v_B'$

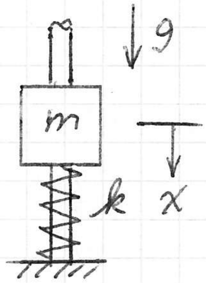
$$v_B' = 10.2 \text{ m/s}$$

Apply impulse-momentum eq. for B:

$$F\Delta t = m_B v_B'$$

$$F = \frac{m_B v_B'}{\Delta t} = \frac{(4000)(10.2)}{0.3} = 136 \text{ kN} \longleftarrow \text{Ans.}$$

13.6



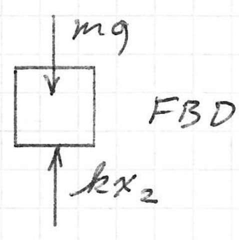
$k = 0.1$ kN/mm (NEW)

$x_1 = 0.02$ m, $v_1 = 0$ m/s.
$v_2 = v_{max}$ when $a_2 = 0$.

$$k x_2 = mg$$

$$x_2 = \frac{(10)(9.81)}{10^5}$$

$$= 98.1 \times 10^{-5} \text{ m}$$



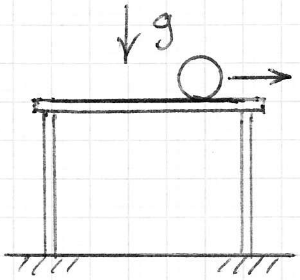
$$0 = \Delta T + \Delta V_g + \Delta V_e$$

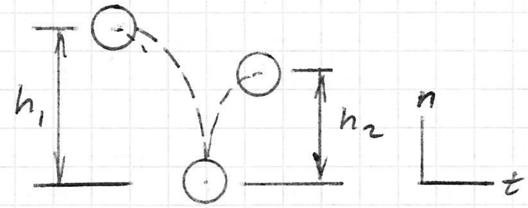
$$0 = \frac{1}{2} m v_{max}^2 - mg(x_2 - x_1) + \frac{1}{2} k (x_2^2 - x_1^2)$$

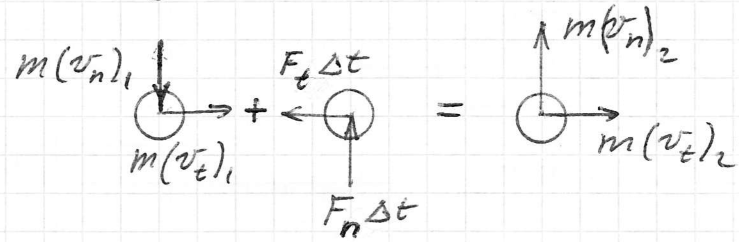
$$v_{max}^2 = \frac{2}{10}\left[-(10)(9.81)(0.02 - 98.1\times 10^{-5}) + \frac{1}{2} 10^5 (0.02^2 - 98.1^2 \times 10^{-10})\right]$$

$$v_{max}^2 = 3.617 \Longrightarrow v_{max} = 1.902 \ \frac{\text{m}}{\text{s}} \longleftarrow \text{Ans.}$$

13.7







$$0 = \Delta T + \Delta V_g \Rightarrow \quad \frac{1}{2} m [(v_n)_1]^2 = mgh_1 \quad ①$$

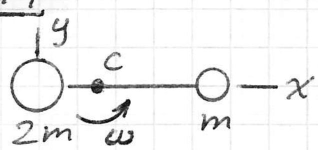
$$\frac{1}{2} m [(v_n)_2]^2 = mgh_2 \quad ②$$

Solve ① and ② for $(v_n)_1$ and $(v_n)_2$, and substitute in eq. below:

$$e = \frac{(v_n)_2}{(v_n)_1} = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{0.8}{1}} = 0.894 \longleftarrow \text{Ans.}$$

14.1

Chpt. 14



Center of mass: $x_c = \frac{3m}{3m}$

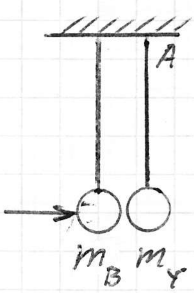
$= 1\ m$

$$H_c = 2 \times m(2\omega) + 1 \times 2m(1\omega)$$

$$= 6m\omega = 6(1)(5) = 30\ \frac{kg \cdot m^2}{s} \longleftarrow \text{Ans.}$$

14.2

See middle p. ⑧



Conserv. of total linear momentum:

$$m_B v_B + \cancel{m_Y v_Y}^{\,0} = m_B v_B' + m_Y v_Y'$$

$$(0.5)(6) = 0.5 v_B' + (1) v_Y' \quad ①$$

$$e = \frac{v_Y' - v_B'}{v_B}$$

$$1 = \frac{v_Y' - v_B'}{6} \Rightarrow 6 = -v_B' + v_Y' \quad ②$$

$$① + 0.5 \times ② \Rightarrow \quad 6 = 1.5 v_Y' \Rightarrow v_Y' = 4\ \frac{m}{s}$$

$$H_A = 3 \times m_Y v_Y' = 3 \times (1)(4) = 12\ \frac{kg \cdot m^2}{s} \longleftarrow \text{Ans.}$$

14.3

$m = 5\ kg \qquad \underline{r} = 10\underline{i} - 2\underline{j} + 5\underline{k}$, m

$\underline{v} = 3\underline{i} + 2\underline{j} - 5\underline{k}$, m/s

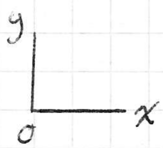
$$\underline{H}_o = \underline{r} \times m\underline{v} = 5\begin{vmatrix} \underline{i} & \underline{j} & \underline{k} \\ 10 & -2 & 5 \\ 3 & 2 & -5 \end{vmatrix}$$

$$= 5\left[\underline{i}(10-10) - \underline{j}(-50-15) + \underline{k}(20+6)\right]$$

$$= 325\,\underline{j} + 130\,\underline{k},\ \frac{kg\cdot m^2}{s} \longleftarrow \text{Ans.}$$

14.4

See 7 bottom $\Longrightarrow v_Y' = 4\,\frac{m}{s}$

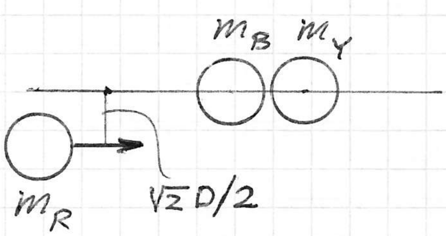


$m_Y: \ 0 = \Delta T + \Delta V_g$

$$0 = \left[0 - \tfrac{1}{2}m_Y(v_Y')^2\right] + m_Y g\left[y_2 - 0\right]$$

$$y_2 = \frac{\frac{1}{2}\cancel{m_Y}(4)^2}{\cancel{m_Y}\,g} = 0.815\ m \longleftarrow \text{Ans.}$$

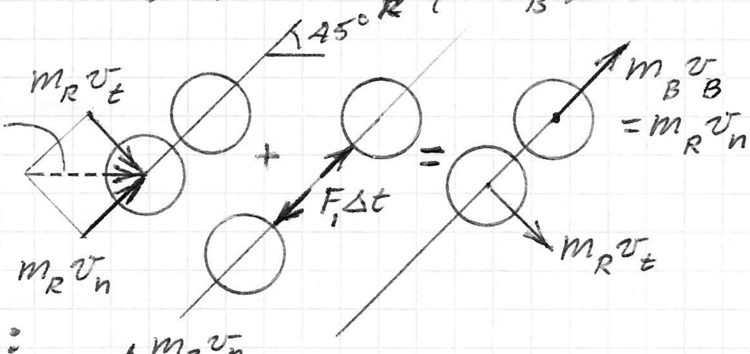
14.5



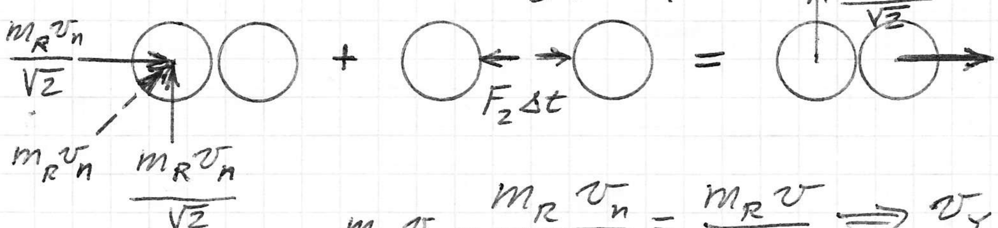
$v = 5\,\frac{m}{s}$

Collision between m_R & m_B:

$$\boxed{m_R v_n = \frac{m_R v}{\sqrt{2}}}$$



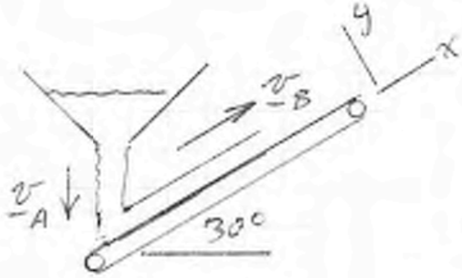
Collision between m_B & m_Y:



$$m_Y v_Y = \frac{m_R v_n}{\sqrt{2}}$$

$$m_Y v_Y = \frac{m_R v_n}{\sqrt{2}} = \frac{m_R v}{2} \Longrightarrow v_Y = \frac{v}{2} = 2.5\,\frac{m}{s} \longleftarrow \text{Ans.}$$

14.6



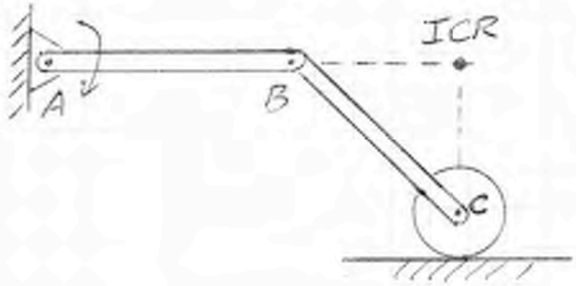
$$\Sigma \underline{F} = \frac{dm}{dt}\left(\underline{v}_B - \underline{v}_A\right)$$

$$\Sigma F_x = \frac{20000}{9.81 \times 3600}\left(0.5 - (-0.5 \sin 30°)\right)$$

$$= 0.425\ N \quad \longleftarrow \text{Ans.}$$

Chpt. 15

15.1



$$\underline{\omega}_{AB} = 10\ \frac{rad}{s}$$

$$\underline{\alpha}_{AB} = \underline{0}\ \frac{rad}{s^2}$$

$$\underline{a}_c = \underline{a}_B + \underline{a}_{c/B} \quad ①$$

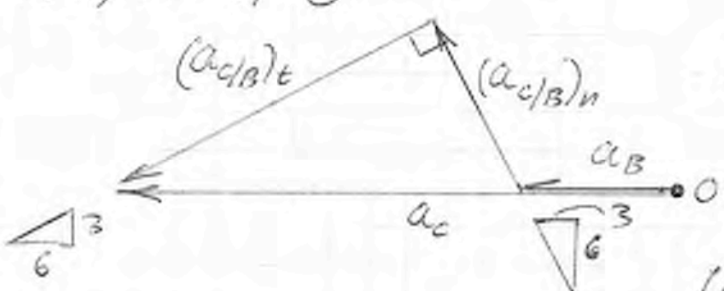
$$= \underline{a}_B + (\underline{a}_{c/B})_t + (\underline{a}_{c/B})_n$$

$$a_B = \omega_{AB}^2\, \overline{AB} = (10)^2(0.6) = 60\ m/s^2$$

Using ICR of BC: $\omega_{BC} = \frac{v_B}{0.3} = \frac{\omega_{AB}\,\overline{AB}}{0.3} = \frac{(10)(0.6)}{0.3} = 20$

$$(a_{c/B})_n = \omega_{BC}^2\, \overline{BC} = (20)^2\sqrt{0.3^2 + 0.6^2} = 268.3\ \frac{m}{s^2}$$

Vector diagram of ①:



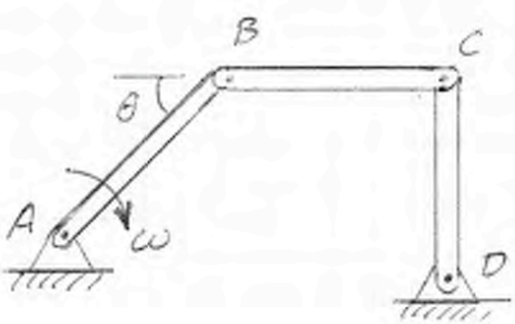
$$(a_{c/B})_t = (a_{c/B})_n\,\frac{6}{3}$$

$$= 536.7\ \frac{m}{s^2}$$

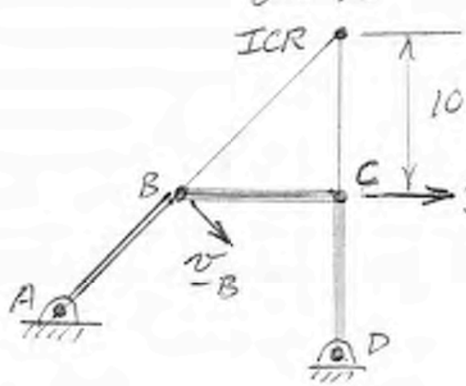
$$(a_{c/B})_t = \alpha_{BC}\,\overline{BC}$$

$$\alpha_{BC} = \frac{536.7}{\sqrt{0.45}} = 800\ \frac{rad}{s^2} \quad \longleftarrow \text{Ans.}$$

15.2



$\theta = 45°$



$\longleftarrow$ Ans.

15.3

See bottom of 9 $\qquad \underline{\omega}_{AB} = 5 \text{ rad/s}$ ↻

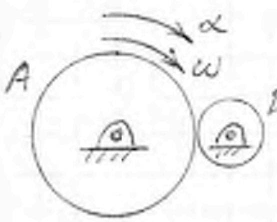
Using ICR of BC: $\omega_{BC} = \dfrac{v_B}{\sqrt{2}\,0.1}$ ↺

$$\omega_{BC} = \frac{\omega_{AB}\,\overline{AB}}{\sqrt{2}\,0.1}$$

$$v_C = \frac{\omega_{AB}\,\overline{AB}}{\sqrt{2}\,\cancel{0.1}}\,\cancel{0.1}$$

$$\omega_{CD} = \frac{\omega_{AB}}{\sqrt{2}}\,\frac{\overline{AB}}{\overline{CD}} = \frac{(5)(0.14)}{\sqrt{2}\,(0.20)} = 2.47 \circlearrowright \leftarrow \text{Ans.}$$

15.4



Gear A: $d_A = 20\text{ cm}$

Gear B: $d_B = 5\text{ cm}$

$\omega_A = 20 \text{ rad/s}$

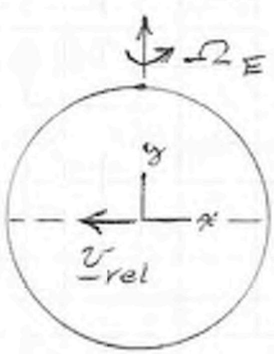
$\alpha_A = 4 \text{ rad/s}^2$

At point of engagement: $\alpha_A r_A = \alpha_B r_B$

$$\alpha_B = \alpha_A \frac{r_A}{r_B} = 4\left(\frac{10}{2.5}\right)$$

$$\alpha_B = 16 \frac{\text{rad}}{s^2} \circlearrowleft \leftarrow \text{Ans.}$$

15.5

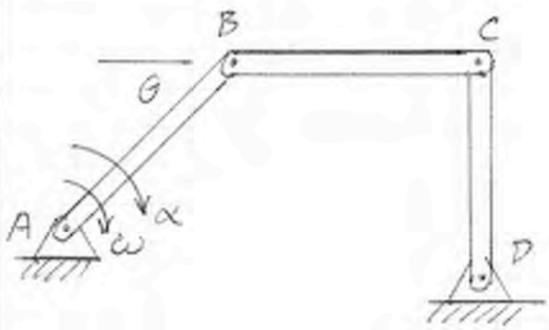


$$2\underline{\Omega}_E \times \underline{v}_{rel} = 2\Omega_E \underline{j} \times (-v_{rel}\,\underline{i})$$

$$= 2\Omega_E v_{rel} \underbrace{(\underline{j} \times -\underline{i})}_{\underline{k}}$$

$$= 2\Omega_E v_{rel}\,\underline{k} \leftarrow \text{Ans.}$$

15.6

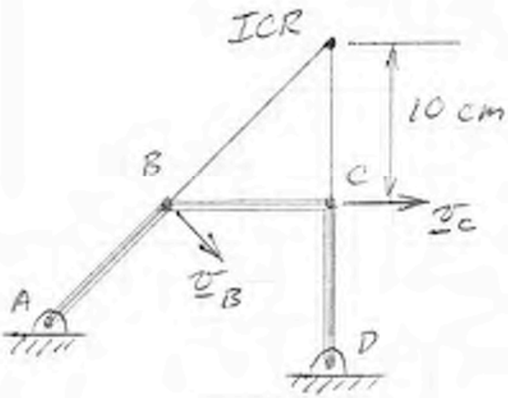


$\theta = 45°$

$\underline{\omega}_{AB} = 5 \ \frac{rad}{s}$ ↻

$\underline{\alpha}_{AB} = 10 \ \frac{rad}{s^2}$ ↻

Using the ICR of BC:



$$\omega_{BC} = \frac{v_B}{\sqrt{2}\, 0.1}$$

$$\omega_{BC} = \frac{\omega_{AB}\,\overline{AB}}{\sqrt{2}\, 0.1} = \frac{(5)(.1414)}{\sqrt{2}\ 0.1}$$

$$= 5 \ \frac{rad}{s} \ ↺$$

$$v_c = \omega_{BC}\, 0.1 = 0.5$$

$$v_c = \omega_{CD}\, \overline{CD}$$

$$\omega_{CD} = \frac{0.5}{0.2} = 2.5 \ \frac{rad}{s} \ ↻$$

$$\underline{a}_c = \underline{a}_B + \underline{a}_{c/B}$$

$$(\underline{a}_c)_t + (\underline{a}_c)_n = (\underline{a}_B)_t + (\underline{a}_B)_n + (\underline{a}_{c/B})_t + (\underline{a}_{c/B})_n \quad (1)$$

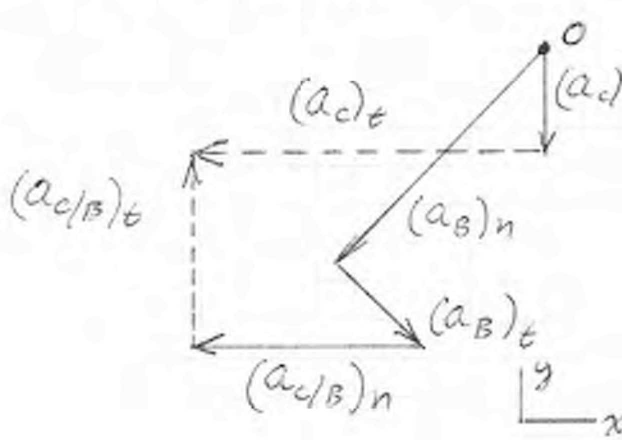
$$(a_c)_n = \omega_{CD}^2\, \overline{CD} = (2.5)^2(0.20) = 1.25 \ m/s^2$$

$$(a_B)_t = \alpha_{AB}\, \overline{AB} = (10)(0.1414) = 1.414 \ m/s^2$$

$$(a_B)_n = \omega_{AB}^2\, \overline{AB} = (5)^2(0.1414) = 3.535 \ m/s^2$$

$$(a_{c/B})_n = \omega_{BC}^2\, \overline{BC} = (5)^2(0.1) = 2.5 \ m/s^2$$

Vector diagram of (1):



$$(a_c)_t = \frac{(a_B)_n}{\sqrt{2}} - \frac{(a_B)_t}{\sqrt{2}} + (a_{c/B})_n$$

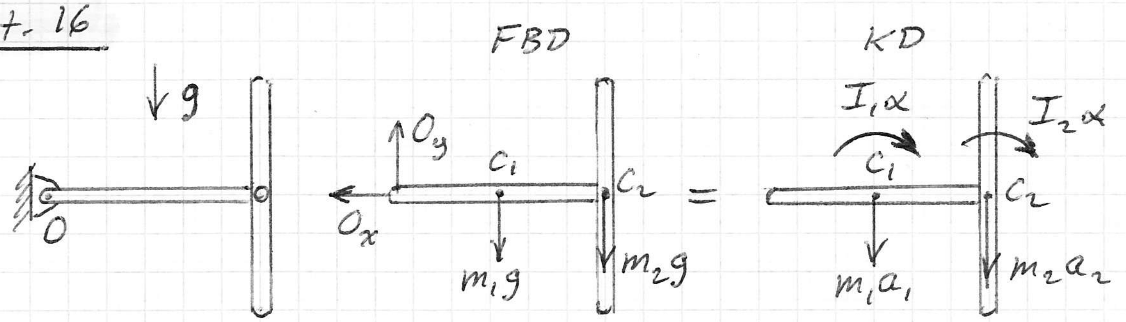
$$= \frac{3.535}{\sqrt{2}} - \frac{1.414}{\sqrt{2}} + 2.5$$

$$= 4 \ m/s^2$$

$$\underline{a}_c = -4\underline{i} - 1.25\underline{j} \ , \ \frac{m}{s^2}$$

Ans.

16.1



$$\curvearrowright\!+\ \sum M_o = m_1 a_1 \overline{OC_1} + I_1\alpha + m_2 a_2 \overline{OC_2} + I_2\alpha$$

$$a_1 = \overline{OC_1}\,\alpha, \quad a_2 = \overline{OC_2}\,\alpha$$

$$m_1 g \overline{OC_1} + m_2 g \overline{OC_2} = I_o\,\alpha$$

$$(20)(0.5) + (20)(1) = \left[\frac{1}{3}\left(\frac{20}{9.81}\right)1^2 + \frac{1}{12}\left(\frac{20}{9.81}\right)1^2 + \frac{20\times 1^2}{9.81}\right]\alpha$$

$$30 = 2.89\,\alpha$$

$$\alpha = 10.39 \text{ rad/s}^2 \curvearrowright$$

$$\sum F_y = -ma_1 - ma_2$$

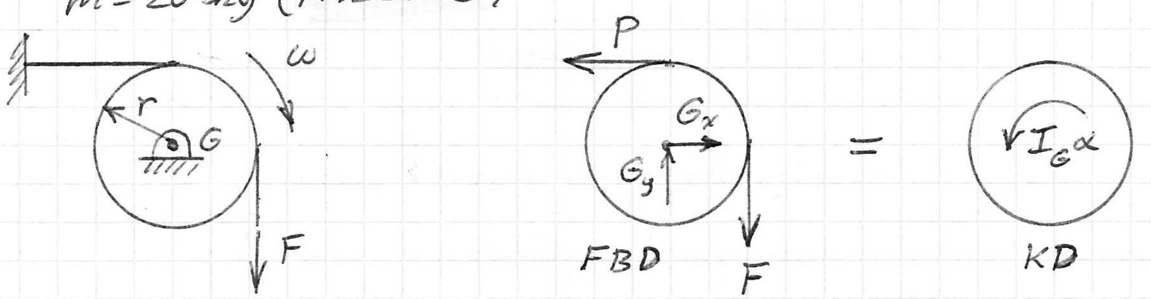
$$O_y - m_1 g - m_2 g = -ma_1 - ma_2$$

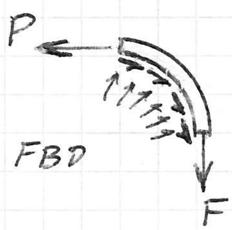
$$O_y = 20 + 20 - \frac{20}{9.81}(0.5\times 10.39 + 1\times 10.39)$$

$$= 8.24 \text{ N} \longleftarrow \text{Ans.}$$

16.2

$m = 20$ kg (MISSING)





$$+\circlearrowleft \sum M_G = I_G\,\alpha$$

$$(P - F)r = \frac{1}{2} m r^2 \alpha$$

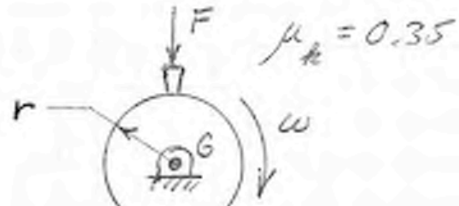
$$P = F e^{\mu_k \pi/2} \quad \text{(p. 67 68, Handbook)}$$

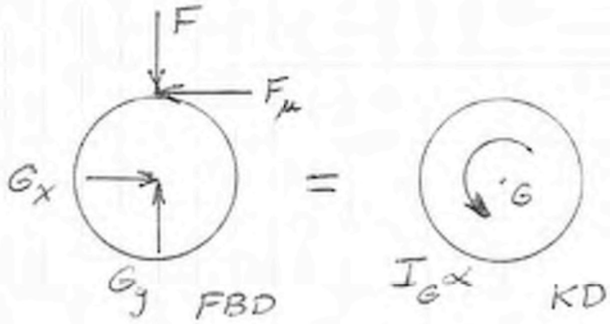
$$\alpha = \frac{2F(e^{\mu_k \pi/2} - 1)}{mr} = \frac{2(350)(e^{0.35\pi/2} - 1)}{(20)(0.25)}$$

$$= 102.6 \text{ rad/s}^2$$

$$\omega = \omega_o - \alpha t, \quad \omega = 0 \text{ at } t = \frac{\omega_o}{\alpha} = \frac{500\times 2\pi}{60}\,\frac{1}{102.6} = 0.510 \text{ s} \longleftarrow \text{Ans.}$$

16.3





$$+\circlearrowleft \ \Sigma M_G = I_G \alpha$$

$$F_\mu r = I_G \alpha \quad (1)$$

$$F_\mu = \mu_k F \quad (2)$$

(2) → (1) :

$$\alpha = \frac{\mu_k F r}{I_G} \quad (3)$$

$\omega d\omega = \alpha d\theta \Rightarrow \omega^2 = \omega_0^2 - 2\alpha\theta$, $\omega = 0$ when $\theta = \frac{\pi}{2}$:

$$\alpha = \frac{\omega_0^2}{2\theta} = \left(\frac{60 \times 2\pi}{60}\right)^2 \frac{1}{\pi}$$

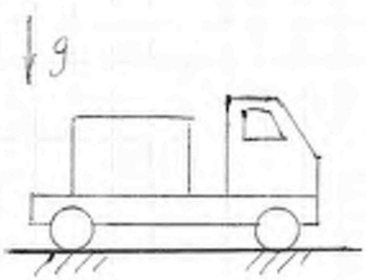
$$= 4\pi \quad (4)$$

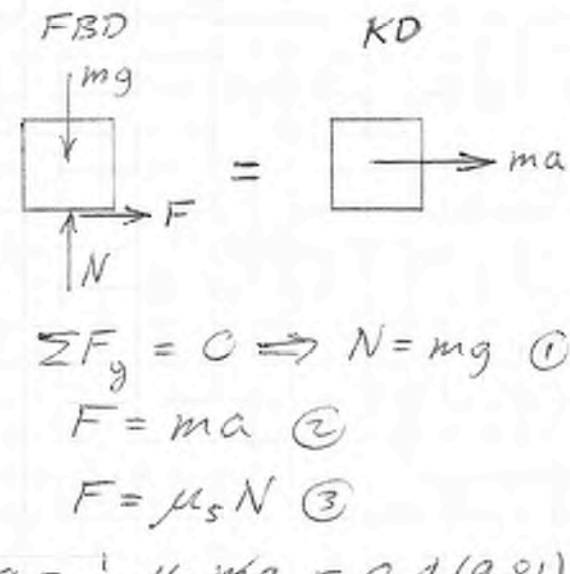
(4) → (3)

$$F = \frac{I_G \alpha}{\mu_k r} = \frac{\frac{1}{2}(5)(0.35)^2 4\pi}{(0.35)(0.35)}$$

$$= 31.4 N \quad \longleftarrow \text{Ans.}$$

16.4





$$\Sigma F_y = 0 \Rightarrow N = mg \quad (1)$$

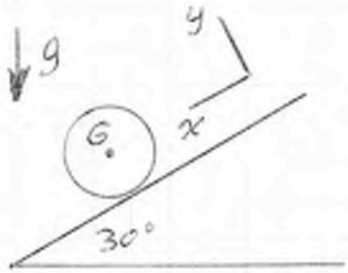
$$F = ma \quad (2)$$

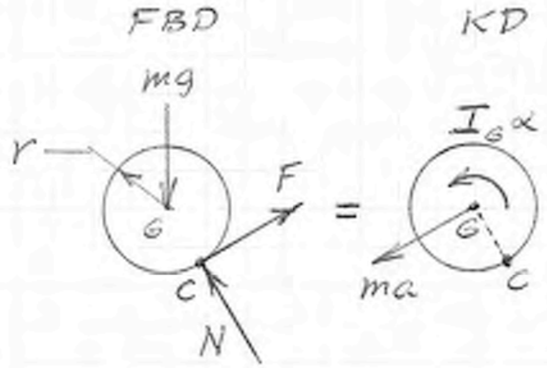
$$F = \mu_s N \quad (3)$$

From (1), (2) & (3) : $\quad a = \frac{1}{m}\mu_s m g = 0.4(9.81)$

$$= 3.92 \frac{m}{s^2} \quad \longleftarrow \text{Ans.}$$

16.5





$$a = r\alpha$$

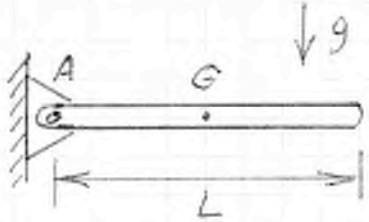
$$+\circlearrowleft\ \Sigma M_C = mar + I_G\alpha$$

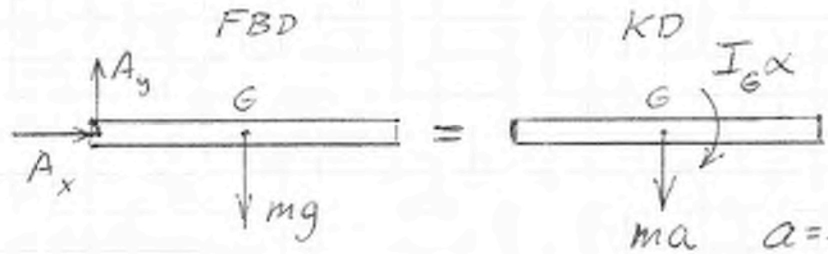
$$mgr\sin 30° = mar + \frac{1}{2}mr^2\frac{a}{r}$$

$$a = \frac{2g\sin 30°}{3} = \frac{2(9.81)\sin 30°}{3}$$

$$a = 3.27\ m/s^2 \longleftarrow \text{Ans.}$$

16.6





$$a = \frac{L}{2}\alpha$$

$$\Sigma F_y = -ma \Rightarrow A_y - mg = -ma \quad (1)$$

$$\circlearrowright + \ \Sigma M_A = ma\frac{L}{2} + I_G\alpha$$

$$mg\frac{L}{2} = ma\frac{L}{2} + \frac{1}{12}mL^2\frac{2a}{L}$$

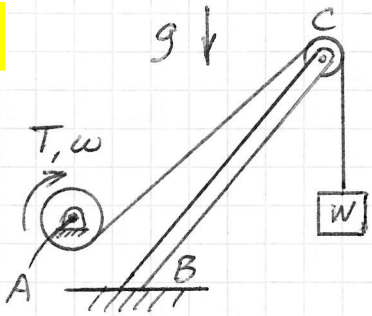
$$mg\frac{L}{2} = \frac{2}{3}maL \Rightarrow a = \frac{3}{4}g \quad (2)$$

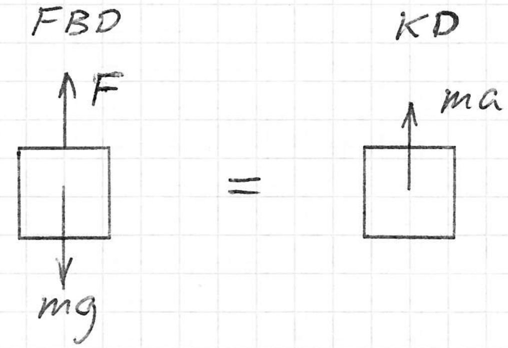
$$(2) \rightarrow (1):\ A_y = mg - ma = mg - \frac{3}{4}mg = \frac{mg}{4}$$

$$= 10/4 = 2.5\ N \longleftarrow \text{Ans.}$$

Chpt. 17

17.1



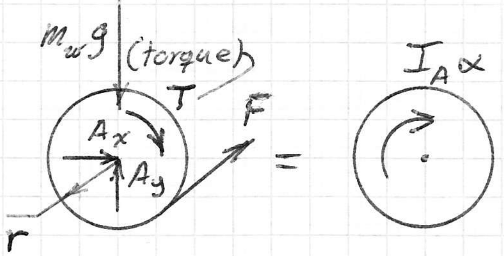


$\Sigma F_y = ma$

$F - mg = ma$

$F = ma + mg$

$= \frac{10{,}000}{9.81}(1) + 10{,}000 = 11{,}019\ N$



$\circlearrowleft + \ \Sigma M_A = I_A \alpha$

$r\alpha = a$

$T - Fr = I_A \alpha$

$T = Fr + I_A a/r$ radius of gyration $= \sqrt{\frac{I_A}{m_w}}$

$= (11{,}019)(0.5) + (0.4)^2(600)(1)/0.5$

$= 5702\ N \cdot m$

$P = \text{Power} = T\omega = T\frac{v}{r} = 5702\,\frac{10/60}{0.5}$

$P = 1.90\ kW$ ← Ans.

17.2 Above figure $\quad P = Fv \quad F = mg$

$= mgv = (10{,}000)\left(\frac{10}{60}\right) = 1.67\ kW$ ← Ans

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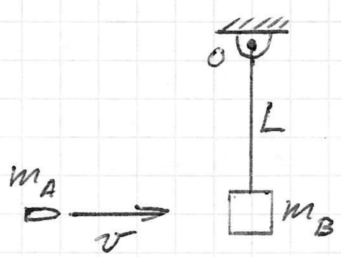
17.3



Conservation of angular momentum about O:

$m_A v \cancel{L} = (m_A + m_B)(\omega L)\cancel{L}$

$(0.035)(300) = (500.035)(0.5\omega)$

$\omega = 0.0420\ rad/s$ ← Ans

17.4 Above figure.

Conservation of energy after impact:

$0 = \Delta T + \Delta V_g \Rightarrow \frac{1}{2}(m_A + m_B)(\omega L)^2 = (m_A + m_B) g L \times (1 - \cos 30°)$

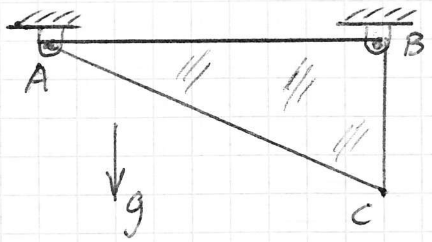
$\omega^2 = \frac{(2)(9.81)(1 - \cos 30°)}{0.5}$

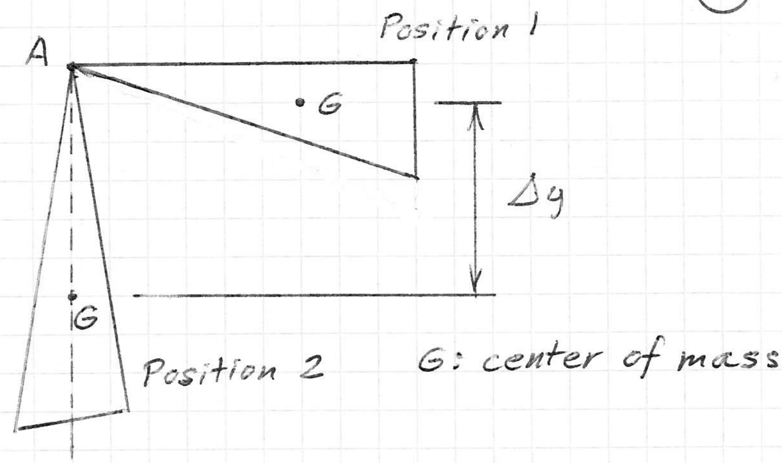
$\omega = 2.29\ rad/s$

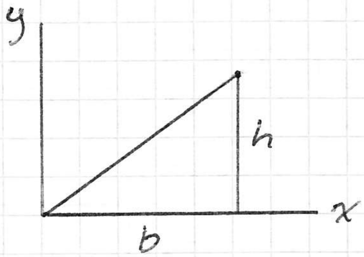
Conser. of momentum during impact

$(0.035)v = (500.035)(0.5\omega) \Rightarrow v = 16{,}379\ m/s$ ← Ans.

17.5







Page ~~68~~ 69, Handbook:

$$I_x = bh^3/12, \quad I_y = \frac{b^3 h}{4}$$

Therefore, $I_A = (I_x + I_y)\rho t$; ρ = density, t = thickness

$$= \frac{bh\rho t}{2}\left(\frac{h^2}{6} + \frac{b^2}{2}\right)$$

$$m = bh\rho t/2$$

$$I_A = m\left(\frac{h^2}{6} + \frac{b^2}{2}\right)$$

$$0 = \Delta T + \Delta V_g \implies \frac{1}{2} I_A \omega^2 = mg\,\Delta y$$

$$\frac{1}{2}\cancel{m}\left(\frac{h^2}{6} + \frac{b^2}{2}\right)\omega^2 = \cancel{m}g\left\{\left[\left(\frac{2}{3}b\right)^2 + \left(\frac{h}{3}\right)^2\right]^{1/2} - \frac{h}{3}\right\}$$

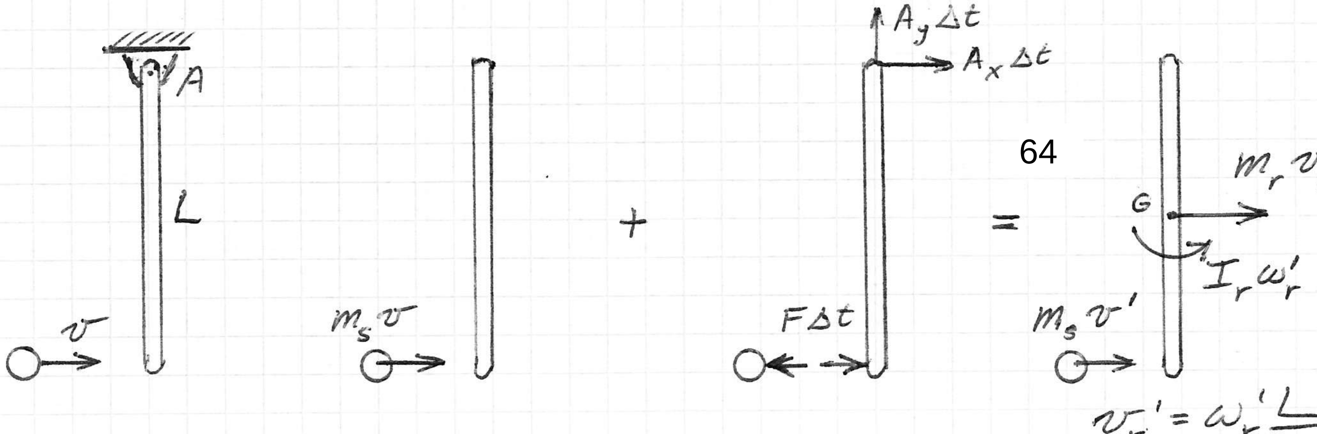
$$\frac{1}{2}\left(\frac{0.3^2}{6} + \frac{0.9^2}{2}\right)\omega^2 = 9.81\left\{\left[\left(\frac{2}{3}0.9\right)^2 + \left(\frac{0.3}{3}\right)^2\right]^{1/2} - \frac{0.3}{3}\right\}$$

$$0.21\,\omega^2 = 4.99$$

$$\omega^2 = 23.7$$

$$\omega = 4.87 \text{ rad/s} \longleftarrow \text{Ans.}$$

17.6



Conservation of angular momentum about A.

$$m_s v L = m_s v' L + I_r \omega_r' + m_r v_r' \frac{L}{2}$$

$$m_s v L = m_s v' L + \frac{1}{12} m_r L^2 \frac{2 v_r'}{L} + m_r v_r' \frac{L}{2}$$

$$m_s v \cancel{L} = m_s v' \cancel{L} + \frac{2}{3} m_r v_r' \cancel{L} \quad ①$$

$$e = \frac{2 v_r' - v'}{v} \quad ②$$

$$① \Longrightarrow (1)(10) = (1) v' + \frac{2}{3}(10) v_r' \quad ③$$

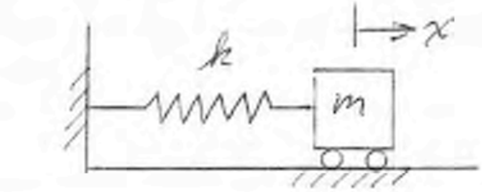
$$② \Longrightarrow (0.7)(10) = -v' + 2 v_r' \quad ④$$

$$③ - \frac{10}{3} \times ④ \qquad 10 - (7)\left(\frac{10}{3}\right) = \left(1 + \frac{10}{3}\right) v'$$

$$v' = -3.08 \ \frac{m}{s} \longleftarrow \text{Ans.}$$

Chpt. 19

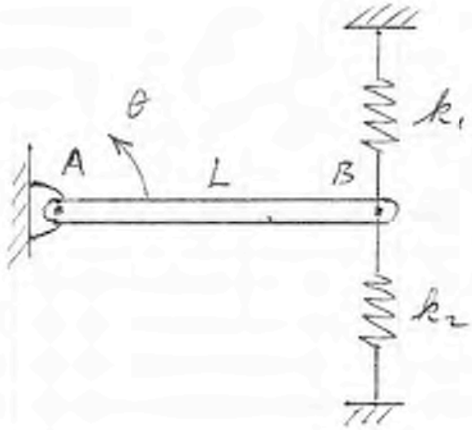
19.1

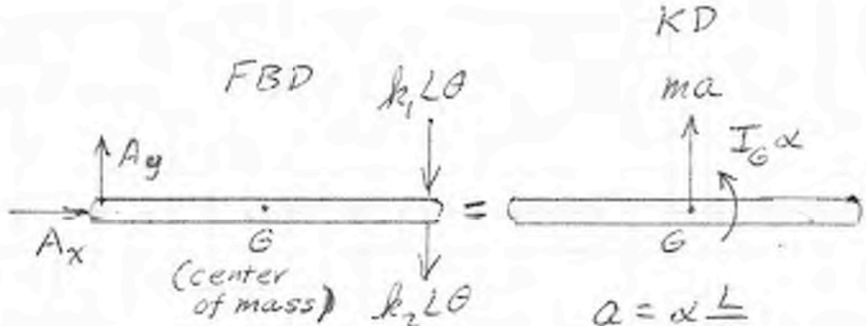


$k = 800\ N/m$
$m = 6\ kg$

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{800}{6}} = 11.55\ \frac{rad}{s} \longleftarrow \text{Ans.}$$

19.2





$$a = \alpha \frac{L}{2}$$

$$\circlearrowleft \Sigma M_A = ma\frac{L}{2} + I_G\alpha$$

$$-(k_1+k_2)L^2\theta = m\alpha\left(\frac{L}{2}\right)^2 + I_G\alpha$$

$$= I_A\alpha$$

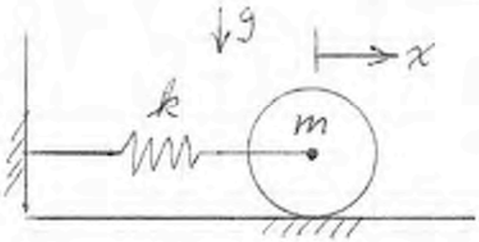
$$I_A\ddot{\theta} + (k_1+k_2)L^2\theta = 0$$

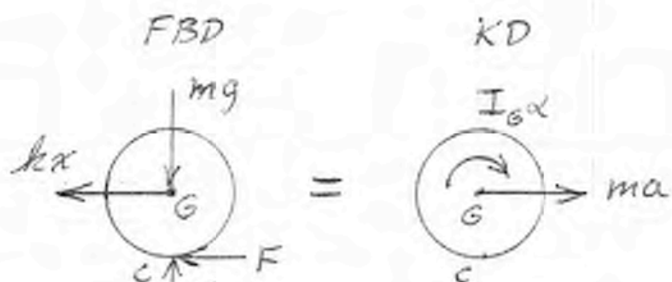
$$\omega_n = \sqrt{\frac{(k_1+k_2)L^2}{I_A}} = \sqrt{\frac{(k_1+k_2)L^2}{\frac{1}{3}mL^2}} = \sqrt{\frac{1600\times 3}{10}}$$

$$= 21.9\ rad/s$$

$$\omega_n = \frac{2\pi}{\tau} \implies \tau = 0.287\,s \longleftarrow \text{Ans.}$$

19.3





$$a = \alpha r$$

$$\circlearrowleft \Sigma M_c = mar + I_G\alpha$$

$$-kxr = m\ddot{x}r + \frac{1}{2}mr^2\frac{\ddot{x}}{r}$$

(Cont'd next page)

$$\frac{3}{2} m\ddot{x} + kx = 0$$

$$\omega_n = \sqrt{\frac{k}{\frac{3}{2}m}} = \sqrt{\frac{850}{\frac{3}{2}10}} = 7.53 \ \frac{rad}{s}$$

$$x = 0.02 \cos(\omega_n t)$$

$$\dot{x} = 0.02\, \omega_n (-\sin(\omega_n t))$$

$$|\dot{x}|_{max} = 0.02\, \omega_n = 0.151 \ \frac{m}{s} \leftarrow \text{Ans.}$$

19.4 Above figure $\omega_n = \frac{2\pi}{\tau} \Rightarrow \tau = 0.835\,s \leftarrow$ Ans.

19.5 Figure on top of page 18

$$x = 0.030 \cos(\omega_n t)$$

$$\dot{x} = -0.03\, \omega_n \sin(\omega_n t)$$

$$|\dot{x}|_{max} = 0.03\, \omega_n = 0.346 \ m/s \leftarrow \text{Ans.}$$

19.6

$$\ddot{x} = -0.03\, \omega_n^2 \cos(\omega_n t)$$

$$|\ddot{x}|_{max} = 0.03\, \omega_n^2 = 4 \ m/s^2 \leftarrow \text{Ans.}$$
