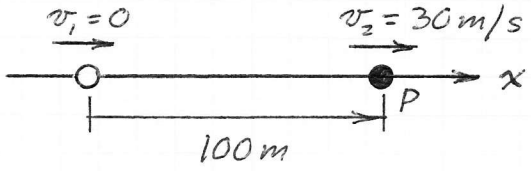
# Solutions to Problems

The following pages contain my solutions to selected problems from *Engineering Mechanics, Dynamics*, 10th Edition, R. C. Hibbeler, Pearson Prentice Hall, 2004, pp. 655-670.

Chpt. 12

D-2.




$$v\,dv = a\,dx$$

$$v_2^2 = 2a\,\Delta x$$

$$900 = 2a\,100$$

$$a = 4.5\ m/s^2 \longleftarrow \text{Ans.}$$

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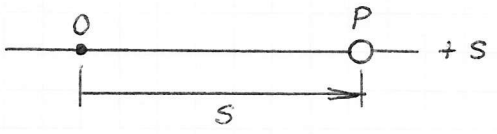
D-3.




$$s = (12t^3 + 2t^2 + 3t)\ m$$

$$\dot{s} = 36t^2 + 4t + 3$$

$$\ddot{s} = 72t + 4 \qquad \text{Ans.}$$

At $t = 2s$: $\dot{s} = (36)(4) + (4)(2) + 3 = 155\ \frac{m}{s}$

$\ddot{s} = (72)(2) + 4 = 148\ \frac{m}{s^2}$

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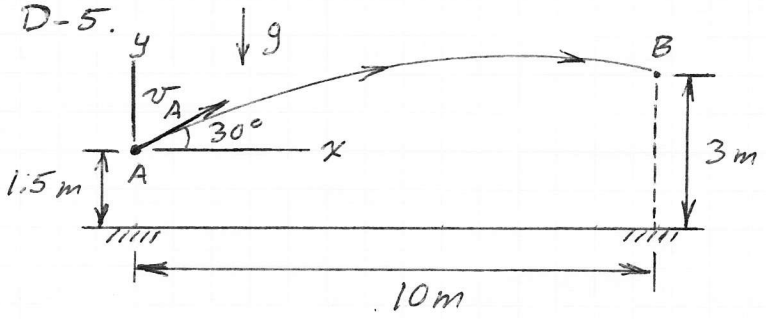
D-5.




$$x = v_A(\cos 30°)\,t$$

$$y = v_A(\sin 30°)\,t - \frac{9.81}{2}t^2$$

At B: $10 = v_A(\cos 30°)\,t$ (1)

$$1.5 = v_A(\sin 30°)\,t - \frac{9.81}{2}t^2 \quad (2)$$

$$(1) \rightarrow (2) \Rightarrow 1.5 = 10\tan 30° - \frac{9.81}{2}\left(\frac{100}{v_A^2\cos^2 30°}\right)$$

$$v_A^2 = 153.0$$

$$v_A = 12.37\ m/s \longleftarrow \text{Ans.}$$

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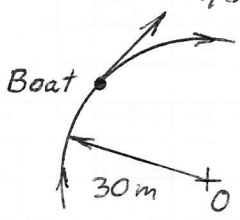
D-9. $v = 6\ m/s$, $a_t = 2\ m/s^2$



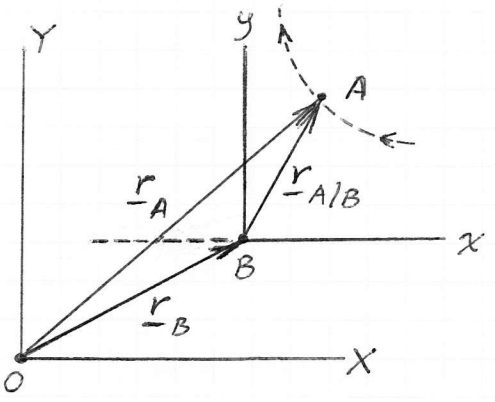

$a = ?$

$$a_n = \frac{v^2}{\rho} = \frac{36}{30} = 1.2\ m/s^2$$

$$a = \sqrt{a_t^2 + a_n^2} = \sqrt{4 + 1.2^2}$$

$$a = 2.33\ m/s^2 \longleftarrow \text{Ans.}$$

D-12.




$$\underline{r}_A = \underline{r}_B + \underline{r}_{A/B}$$

$$\underline{r}_{A/B} = \underline{r}_A - \underline{r}_B$$

$$\underline{v}_{A/B} = \underline{v}_A - \underline{v}_B$$

$$= 20\left(-\frac{1}{\sqrt{2}}\underline{i} + \frac{1}{\sqrt{2}}\underline{j}\right) - 65\,\underline{i}\ ,\ km/h$$

$$= -79.1\,\underline{i} + 14.14\,\underline{j}\ ,\ km/h$$

$$\underline{v}_{A/B} = 80.4\ \frac{km}{h} \ \angle 10.13^\circ \quad \text{Ans.}$$

$$\underline{a}_{A/B} = \underline{a}_A - \underline{a}_B\ , \qquad \underline{a}_A = \frac{v_A^2}{\rho}\left(\frac{1}{\sqrt{2}}\underline{i} + \frac{1}{\sqrt{2}}\underline{j}\right)$$

$$= \frac{20^2}{0.1}\left(\frac{1}{\sqrt{2}}\underline{i} + \frac{1}{\sqrt{2}}\underline{j}\right),\ km/h^2$$

$$\underline{a}_B = 1200\,\underline{i}\ \ km/h^2$$

$$\underline{a}_{A/B} = (2828 - 1200)\,\underline{i} + 2828\,\underline{j} = 1628\,\underline{i} + 2828\,\underline{j}\ ,\ km/h^2$$

$$\underline{a}_{A/B} = 3263\ \frac{km}{h^2} \ \angle 60.1^\circ \quad \text{Ans.}$$

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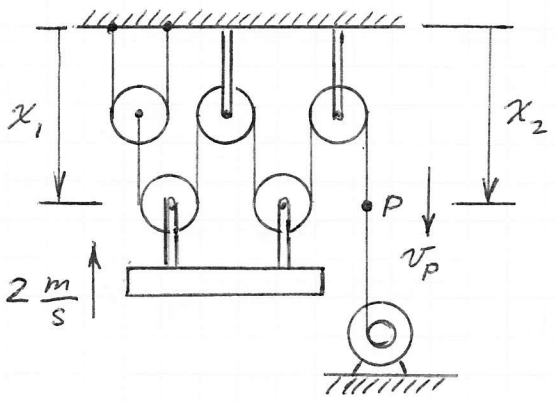
D-13.




$$\dot{x}_1 = -2\ m/s$$

$$\dot{x}_2 = v_P$$

$$4x_1 + x_2 = const$$

$$4\dot{x}_1 + \dot{x}_2 = 0$$

$$v_P = \dot{x}_2 = -4\dot{x}_1$$

$$v_P = 8\ m/s \quad \text{Ans.}$$

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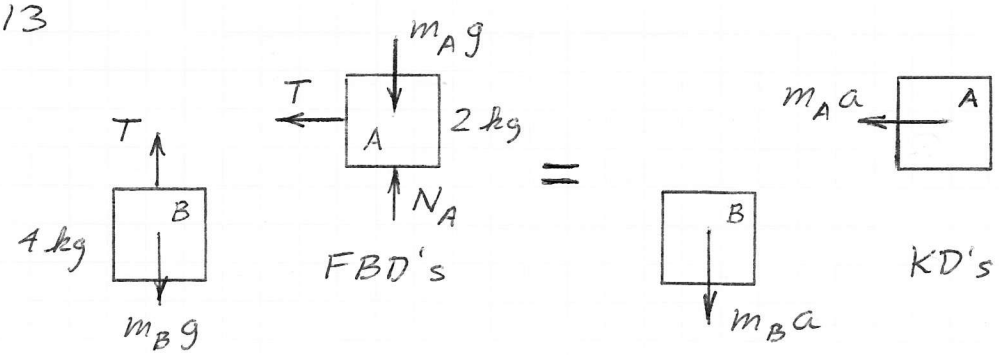
Chpt. 13

D-15.



D-15. Cont'd

$$m_A: \leftarrow \Sigma F = m_A a \Rightarrow T = m_A a \quad (1)$$

$$m_B: \downarrow \Sigma F = m_B a \Rightarrow m_B g - T = m_B a \quad (2)$$

$$(1)+(2) \quad m_B g = (m_A + m_B) a$$

$$a = \frac{m_B}{m_A + m_B} g = \frac{4}{6} 9.81 = 6.54$$

$$\underline{a}_B = 6.54 \frac{m}{s^2} \downarrow \quad \text{Ans}$$

$$(1) \Rightarrow T = m_A a = (2)(6.54) = 13.08 \text{ N} \quad \text{Ans.}$$

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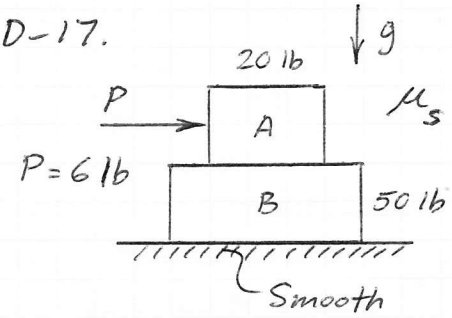
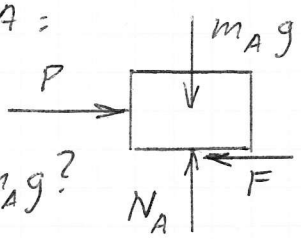
D-17.




$\mu_s = 0.4, \mu_k = 0.3$

Does A slide relative to B?

FBD of A:

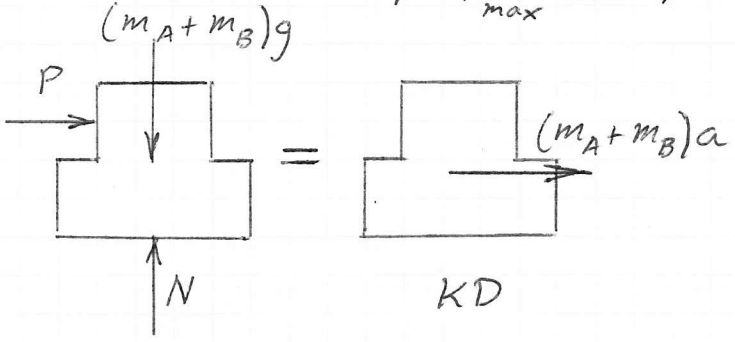



Is $P < F_{max} = \mu_s N_A = \mu_s m_A g$?

$P = 6$ lb

$F_{max} = (0.4)(20) = 8$ lb

$P < F_{max} \Rightarrow$ A does not slide relative to B.




$$\rightarrow \Sigma F = (m_A + m_B) a$$

$$P = (m_A + m_B) a$$

$$6 = \frac{1}{32.2}(20 + 50) a$$

$$a = 2.76 \text{ ft/s}^2$$

$$\underline{a}_A = \underline{a}_B = 2.76 \text{ ft/s}^2 \rightarrow \quad \text{Ans.}$$

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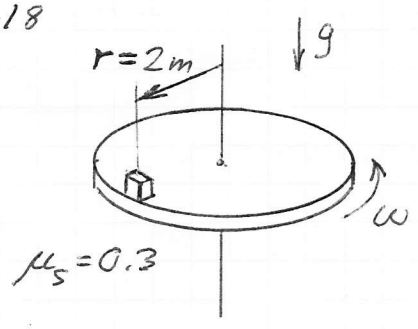
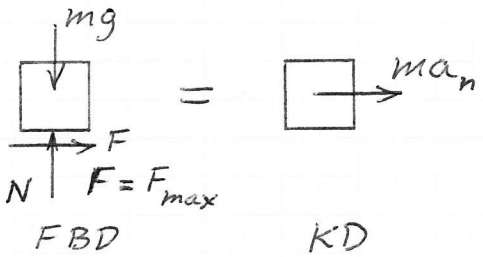
D-18




$$\Sigma F_n = m a_n$$

$$F = F_{max} = \mu_s m g = m a_n = m \omega^2 r$$

D-18. Cont'd

$$(0.3)m\overset{9.81}{g} = m\omega^2(2)$$

$$\omega = 1.213 \text{ rad/s}$$

$$v = \omega r = 2.43 \text{ m/s} \quad \text{Ans.}$$

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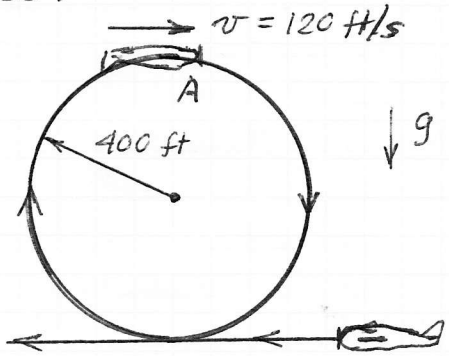
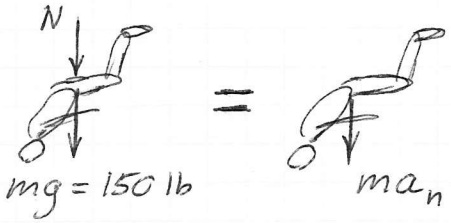
D-20.




FBD KD

$$\downarrow \Sigma F_n = ma_n$$

$$N + mg = ma_n = m\frac{v^2}{\rho}$$

$$N = m(a_n - g) = \frac{150}{32.2}\left(\frac{120^2}{400} - 32.2\right) = 17.70 \text{ lb}$$

$$\underline{N} = 17.70 \text{ lb} \downarrow \quad \text{Ans.}$$

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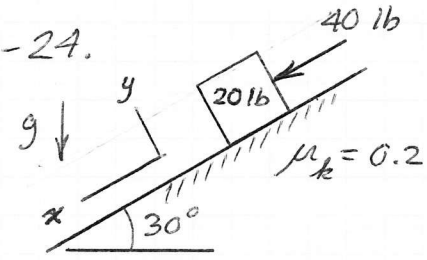
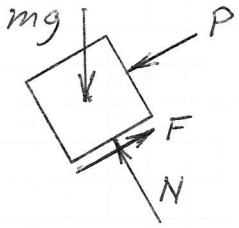
Chpt. 14

D-24.




FBD

$$\Sigma F_y = 0$$

$$N = mg\cos 30°$$

$$F = \mu_k N$$

$$= \mu_k mg\cos 30°$$

$$= (0.2)(20)\cos 30° = 3.46 \text{ lb}$$

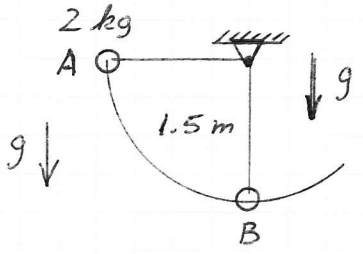
$$U_{1\to 2} = \Delta T + \Delta V_g$$

$$(P - F)\Delta x = \frac{1}{2}m(v_2^2 - v_1^2) + mg\Delta h$$

$$(40 - 3.46)10 = \frac{1}{2}\frac{20}{32.2}(v_2^2 - 25) - (20)(10)\sin 30°$$

$$\underline{v_2} = 39.0 \text{ ft/s} \; \overset{30°}{\searrow} \quad \text{Ans.}$$

D-27.



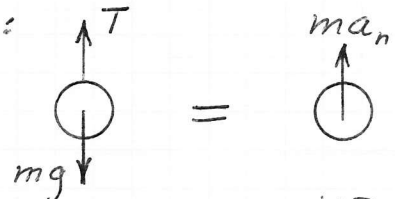

$$\Delta T + \Delta V_g = 0$$

$$\frac{1}{2} m v_2^2 = -mg\,\Delta h$$

$$v_2^2 = (9.81)(1.5)(2) = 29.43$$

$$v_2 = 5.42 \text{ m/s} \quad \text{Ans.}$$

At B:




$$\Sigma F_n = ma_n$$

$$T - mg = m\frac{v_2^2}{r}$$

$$T = 2\left(\frac{29.43}{1.5} + 9.81\right) = 58.9 \text{ N} \quad \text{Ans.}$$

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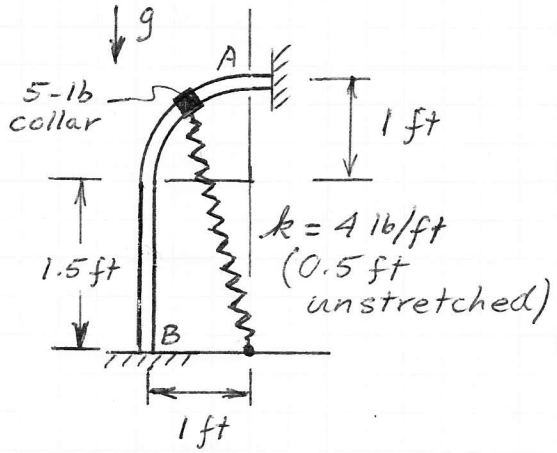
D-28.




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

$$\frac{1}{2} m v_2^2 + mg\,\Delta h + \frac{1}{2} k\left(x_2^2 - x_1^2\right) = 0$$

$$\frac{1}{2}\left(\frac{5}{32.2}\right) v_2^2 - (5)(2.5) + \frac{1}{2}(4)\left[(1-0.5)^2 - (2.5-0.5)^2\right] = 0$$

$$v_2^2 = \frac{(20)(64.4)}{5}$$

$$v_2 = 16.05 \text{ ft/s} \quad \text{Ans.}$$

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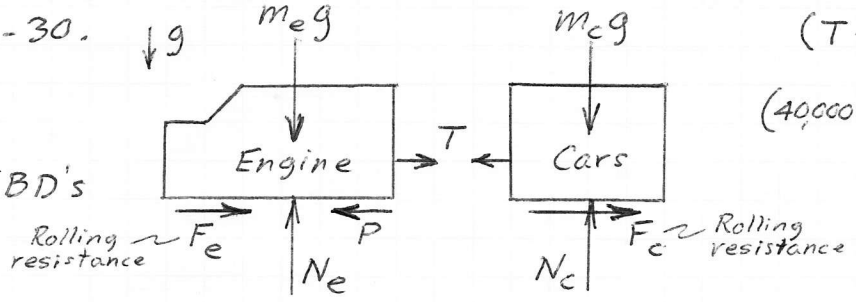
Chpt. 15

D-30.




Cars: $\Sigma F\,\Delta t = \Delta(m_c v)$

$$(T - F_c)\,\Delta t = m_c\,\Delta v$$

$$(40{,}000 - 2500)\,\Delta t = \frac{(250)(2000)}{32.2}(30-20)$$

$$\Delta t = 4.14 \text{ s} \quad \text{Ans.}$$

$m_e g = 30$ tons | $T = (4)(10^4)$ lb | $m_c g = 250$ tons

$F_e = (30)(10)$ lb | | $F_c = (250)(10)$ lb

$P$ = driving force

D-30. Cont'd

Engine: $\Sigma F \Delta t = \Delta(m_e v)$

$$(P - T - F_e)\Delta t = m_e \Delta v$$

$$(P - 40{,}000 - 300)\,4.14 = \frac{(30)(2000)}{32.2}(30-20)$$

$$P = 44{,}800 \text{ lb} \quad \text{Ans.}$$

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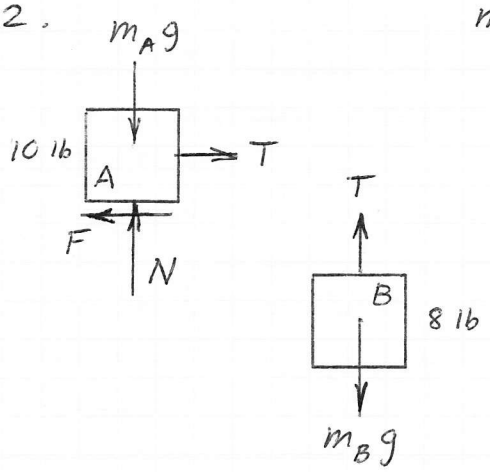
D-32.




$m_A$ & $m_B$: $\Sigma F \Delta t = \Delta(\Sigma m v)$

$$(-F + m_B g)\Delta t = (m_A + m_B)\Delta v$$

$$(-F + 8)5 = \frac{(10+8)}{32.2}(1)$$

$$F = 7.89 \text{ lb}$$

$$F = \mu_k N = \mu_k 10$$

$$\mu_k = 0.789 \quad \text{Ans.}$$

$m_B$: $\Sigma F \Delta t = \Delta(m_B v)$

$$(m_B g - T)\Delta t = m_B \Delta v$$

$$(8 - T)5 = \frac{8}{32.2}(1) \Rightarrow T = 7.95 \text{ lb} \quad \text{Ans.}$$

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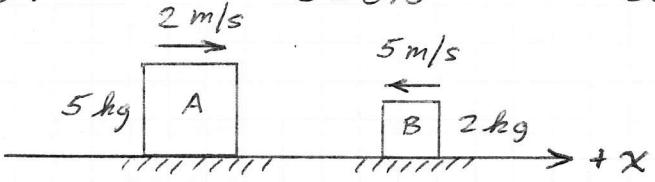
D-34 $e = 0.5$




Conservation of total linear momentum:

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B' \quad (1)$$

$$v_A = 2\,\frac{m}{s}, \quad v_B = -5\,\frac{m}{s} \quad (2)$$

$$e = \frac{v_B' - v_A'}{v_A - v_B} \quad (3).$$

(2) → (1) $\Rightarrow$ $(5)(2) - (2)(5) = 5v_A' + 2v_B'$

$$0 = 5v_A' + 2v_B' \quad (4)$$

(2) → (3) $\Rightarrow$ $0.5 = \dfrac{v_B' - v_A'}{2+5}$

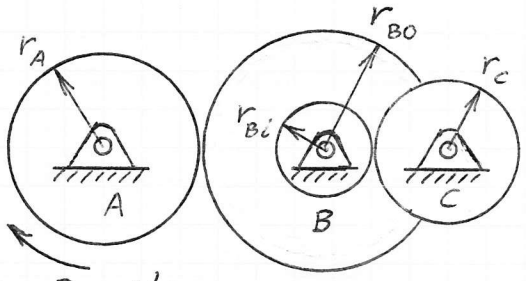
$$3.5 = -v_A' + v_B' \quad (5)$$

(4) + 5×(5) $\Rightarrow$ $(3.5)(5) = 7v_B'$

$v_B' = 2.5$ m/s or $\underline{v}_B' = 2.5\,\frac{m}{s} \rightarrow$

$v_A' = -1$ m/s or $\underline{v}_A' = 1\,\frac{m}{s} \leftarrow$ } Ans.

D-38.




$\omega_A = 3$ rad/s

$r_A = 4$ in. $\quad r_{BO} = 5$ in. $\quad r_c = 3$ in.

$r_{Bi} = 2$ in.

$r_A \omega_A = r_{BO} \omega_B$

$\omega_B = \frac{4}{5}(3) = 2.4$

$\underline{\omega_B = 2.4 \frac{\text{rad}}{\text{s}}}$ ↶ ← Ans.

$r_{Bi} \omega_B = r_c \omega_c$

$\omega_c = \frac{2}{3}(2.4)$

$\underline{\omega_c = 1.6 \frac{\text{rad}}{\text{s}}}$ ↷ ← Ans.

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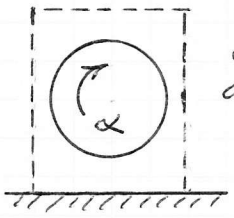
D-39.




$\theta = 0$, $\omega = 0$, at $t = 0$.

$\alpha = 2$ rev/s$^2$

$\omega = \alpha t = 2t$ @ $t = 5$s: $\omega = 10 \frac{\text{rev}}{\text{s}}$

$\theta = \frac{\alpha t^2}{2} = t^2$ @ $t = 10$s: $\theta = 100$ revs.

Ans. ↓

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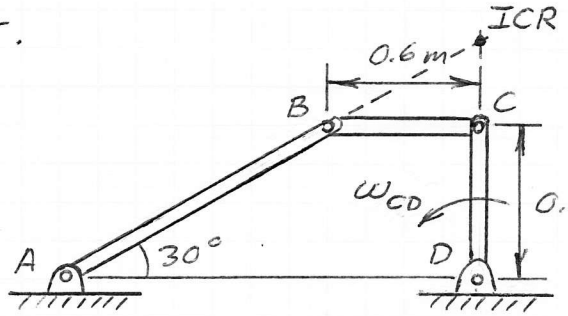
D-45.




$\omega_{CD} = 4$ rad/s

Establish ICR for member BC.

$v_c = \omega_{CD} \overline{CD}$ ←

$\omega_{BC} = \frac{v_c}{\overline{IC}} = \frac{v_c}{\overline{BC} \tan 30°}$ ↻

$v_B = \omega_{BC} \overline{IB} = \omega_{BC} \frac{\overline{BC}}{\cos 30°}$ 60° ↗

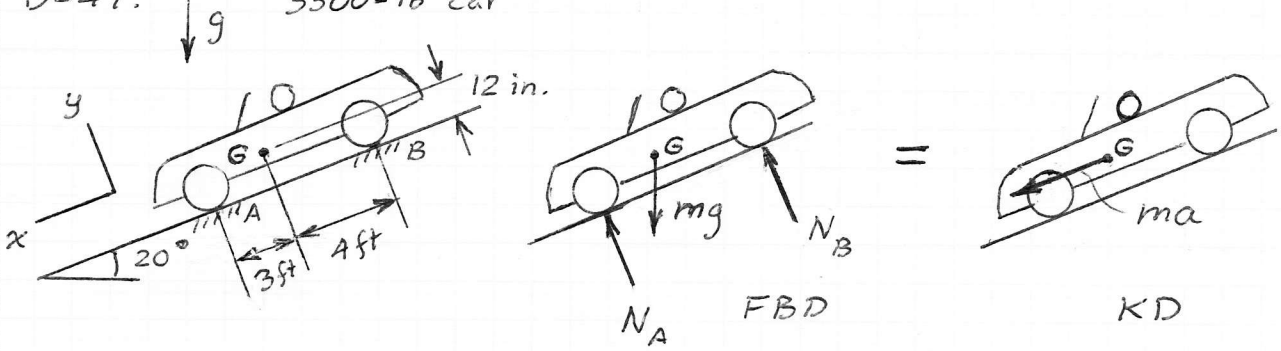
$\omega_{AB} = \frac{v_B}{\overline{AB}} = \frac{v_B}{\overline{CD}/\sin 30°}$

$\omega_{AB} = \frac{1}{\frac{\overline{CD}}{\sin 30°}} \left( \frac{\omega_{CD} \overline{CD}}{\overline{BC} \tan 30°} \right) \frac{\overline{BC}}{\cos 30°}$

$= \omega_{CD}$

$\underline{\omega_{AB} = 4 \text{ rad/s}}$ ↷ ← Ans.

D-49.




$$\Sigma F_x = ma$$

$$mg\sin 20^\circ = ma$$

$$a = g\sin 20^\circ = (32.2)\sin 20^\circ$$

$$a = 11.01\ ft/s^2 \quad \text{Ans.}$$

$$\circlearrowleft \Sigma M_G = 0 \Rightarrow -3N_A + 4N_B = 0 \quad (1)$$

$$\Sigma F_y = 0 \Rightarrow N_A + N_B = mg\cos 20^\circ \quad (2)$$

$$(1) + 3\times(2) \qquad 7N_B = (3)(3500)\cos 20^\circ$$

$$N_B = 1410\ lb \quad \text{Ans.}$$

$$(1) \Rightarrow N_A = 1879\ lb \quad \text{Ans.}$$

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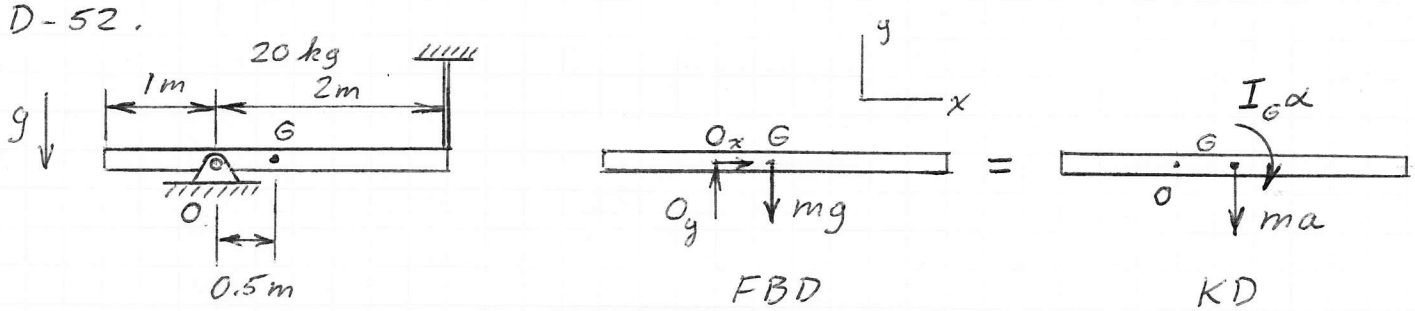
D-52.




$$\Sigma F_x = 0 \Rightarrow O_x = 0 \quad \text{Ans}$$

$$\circlearrowright \Sigma M_o = ma\,\overline{OG} + I_G\alpha = ma\,\overline{OG} + \frac{1}{12}mL^2\frac{a}{\overline{OG}}$$

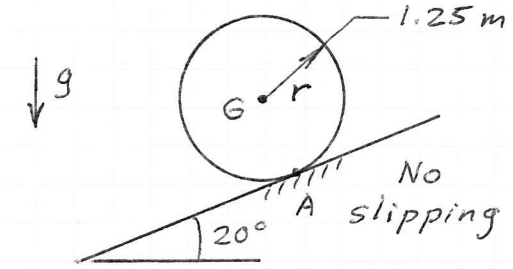
$$mg\,\overline{OG} = ma\,\overline{OG}\left[1 + L^2/(12\,\overline{OG}^2)\right]$$

$$9.81 = a\left[1 + 9/(12)(0.25)\right] \Rightarrow a = 2.45\ \frac{m}{s^2}$$

$$\Sigma F_y = ma \Rightarrow O_y - mg = -ma$$

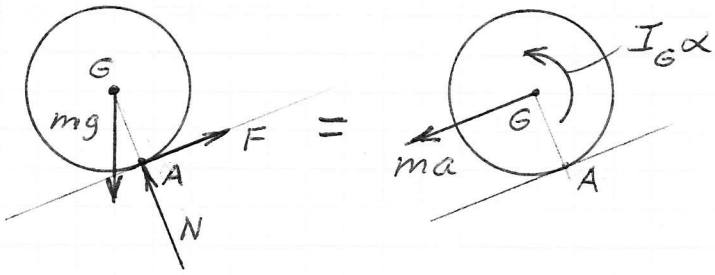
$$O_y = (20)(9.81) - (20)(2.45) \Rightarrow \underline{O_y = 147.2\ N}\uparrow \quad \text{Ans}$$

D-53.




20-kg wheel; $k_G = 0.8$ m

$k_G$ = radius of gyration




FBD KD

$a = r\alpha$

$$\curvearrowright \Sigma M_A = ma r + I_G \alpha$$

$$mgr\sin 20^\circ = mr^2\alpha + k_G^2 m\alpha$$

$$(9.81)(1.25)\sin 20^\circ = \left[(1.25)^2 + (0.8)^2\right]\alpha$$

$$\underline{\alpha} = 1.904 \ \frac{\text{rad}}{\text{s}^2} \curvearrowleft$$ ← Ans.

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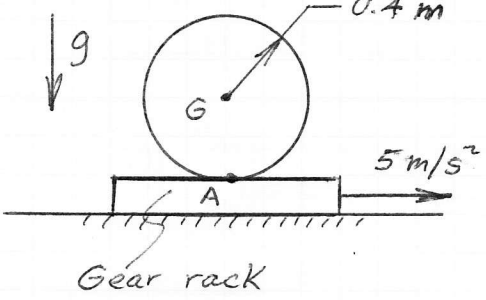
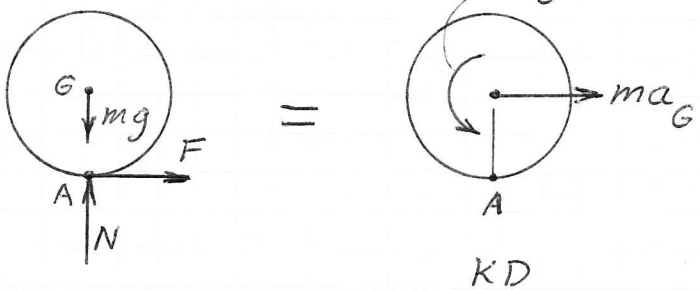
D-55.

2-kg gear; $k_G = 0.3$ m




FBD KD

$$\Sigma F_x = m a_G$$

$$F = m a_G$$

$$\Sigma F_y = 0 \Rightarrow N = mg$$

$$\curvearrowright \Sigma M_A = m a_G \overline{AG} - I_G \alpha$$

$$0 = m(a_A - \alpha \overline{AG})\overline{AG} - k_G^2 m\alpha$$

$$\alpha\left(\overline{AG}^2 + k_G^2\right) = a_A \overline{AG}$$

$$\alpha = \frac{(5)(0.4)}{0.4^2 + 0.3^2} = 8$$

$$\underline{\alpha} = 8 \ \frac{\text{rad}}{\text{s}^2} \curvearrowleft$$ ← Ans.

$$\underline{a}_G = \underline{a}_A + \underline{a}_{G/A}$$

$$a_{G/A} = \alpha \overline{AG}$$

$a_G \rightarrow \quad \leftarrow a_{G/A}$

$\rightarrow a_A$

$$a_G = a_A - a_{G/A}$$