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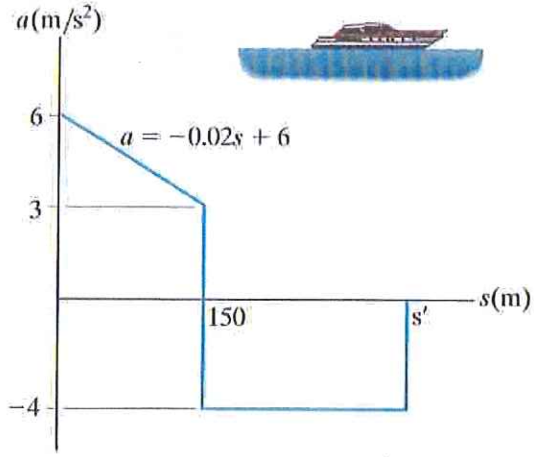
Ans: 36.7 m/s, 319 m

12–62. The boat travels in a straight line with the acceleration described by the $a-s$ graph. If it starts from rest, construct the $v-s$ graph and determine the boat's maximum speed. What distance s' does it travel before it stops?



$\boxed{V_{max} \text{ occurs at } S = 150 \text{ m}}$

$a\,ds = v\,dv$

$\int_0^{150} a\,ds = \int_0^{v} v\,dv$

$\frac{v^2}{2}\Big|_0^{v} = \int_0^{150} a\,ds = \text{area} = \frac{1}{2}(6+3)(150)$

$\boxed{v = 36.74 \text{ m/s}}$ max v.

$S' = ?$ $\rightarrow v = 0$

$\int_0^{s'} a\,ds = \int_0^{0} v\,dv = 0$

$\frac{1}{2}(6+3)(150) - 4(s' - 150) = 0$

$\boxed{s' = 319 \text{ m}}$

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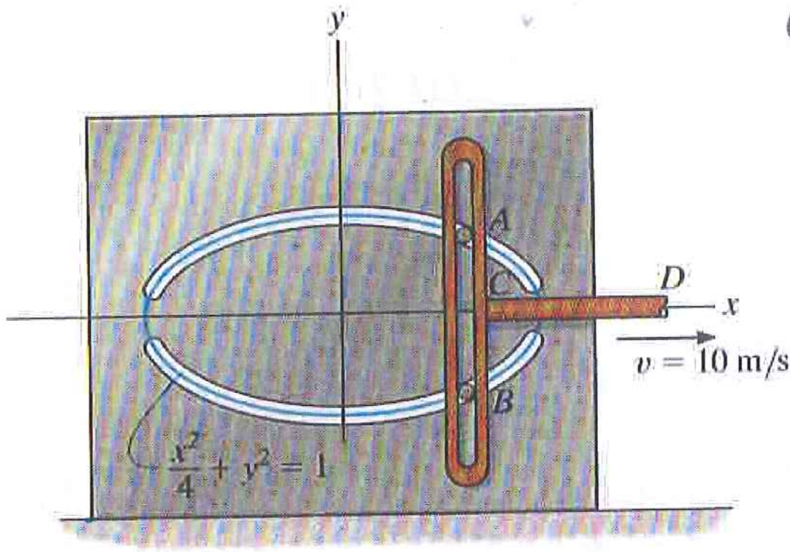
Ans: 10.4 m/s, 38.5 m/s²

12–78. Pegs *A* and *B* are restricted to move in the elliptical slots due to the motion of the slotted link. If the link moves with a constant speed of 10 m/s, determine the magnitude of the velocity and acceleration of peg *A* when $x = 1$ m.



Prob. 12–78

Constraint eq

$$\frac{x^2}{4} + y^2 = 1$$

Dot it

$$\frac{1}{2}x\dot{x} + 2y\dot{y} = 0$$

Plug in $x = 1$ $\dot{x} = 10$
$y = \frac{\sqrt{3}}{2}$

$$\Rightarrow \dot{y} = -2.887$$

$$v = \sqrt{\dot{x}^2 + \dot{y}^2} = \sqrt{10^2 + 2.887^2} = \boxed{10.4\ m/s}$$

Dot again on $\frac{1}{2}x\dot{x} + 2y\dot{y} = 0$

$$\frac{1}{2}(\dot{x}^2 + x\ddot{x}) + 2(\dot{y}^2 + y\ddot{y}) = 0$$

Plug in $\ddot{x} = 0$ $\dot{x} = 10$, $x = 1$, $y = \frac{\sqrt{3}}{2}$, $\dot{y} = -2.887$

$$\Rightarrow \ddot{y} = -38.49 \quad a = \sqrt{\ddot{x}^2 + \ddot{y}^2} = \boxed{38.49\ m/s^2}$$

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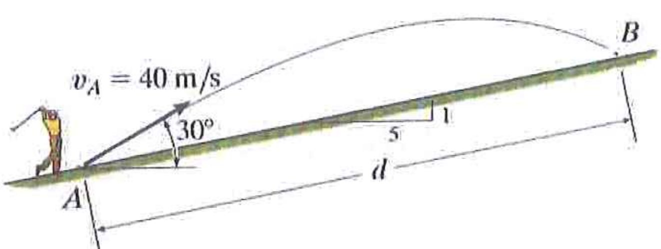
Ans: 94.1 m

12–98. The golf ball is hit at A with a speed of $v_A = 40\,\text{m/s}$ and directed at an angle of 30° with the horizontal as shown. Determine the distance d where the ball strikes the slope at B.

$$V_{0x} = 40\cos 30° = 34.64$$
$$V_{0y} = 40\sin 30° = 20$$



$$\begin{cases} X = V_{0x}\,t \\ y = V_{0y}\,t - \frac{1}{2} g t^2 \end{cases}$$

At B $\quad X = d\left(\frac{5}{\sqrt{26}}\right), \quad y = d\left(\frac{1}{\sqrt{26}}\right)$

$$\Rightarrow \begin{cases} d\left(\frac{5}{\sqrt{26}}\right) = 34.64\,t \\ d\left(\frac{1}{\sqrt{26}}\right) = 20t - \frac{1}{2}(9.81)\,t^2 \end{cases}$$

Solve $\Rightarrow$ $\boxed{\begin{array}{l} d = 94.1\text{ m} \\ t = 2.664\text{ s} \end{array}}$

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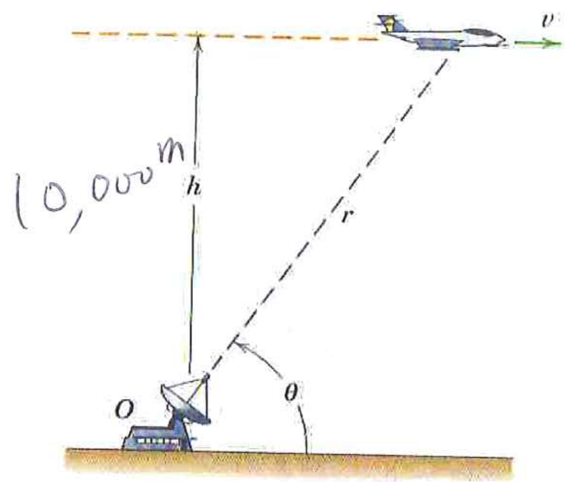
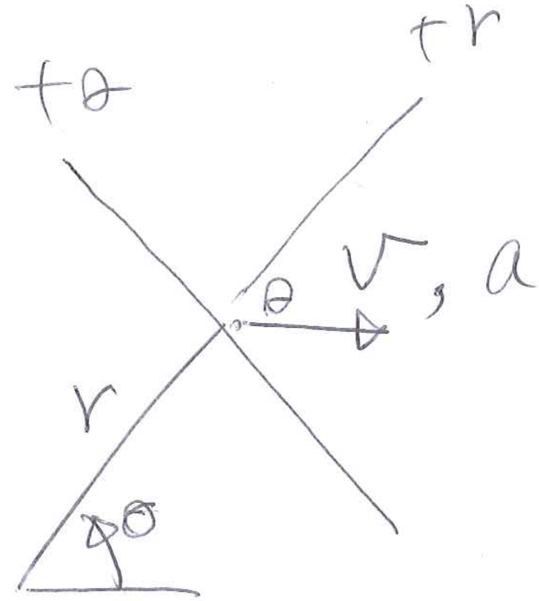
2/139 A jet plane flying at a constant speed v at an altitude h = 10 km is being tracked by radar located at O directly below the line of flight. If the angle θ is decreasing at the rate of 0.020 rad/s when θ = 60°, determine the value of $\ddot{r}$ at this instant and the magnitude of the velocity **v** of the plane.

Ans. $\ddot{r}$ = 4.62 m/s², v = 960 km/h





$$\begin{cases} v_r = v\cos\theta = \dot{r} \\ v_\theta = -v\sin\theta = r\dot{\theta} \end{cases}$$

$\dot{\theta} = -0.02 \quad r = 11547$

$\Rightarrow v = -\dfrac{(11547)(-0.02)}{\sin 60^\circ}$

$= \boxed{266.67 \text{ m/s}}$

$= \boxed{960 \text{ km/h}}$

$r\sin 60^\circ = 10{,}000$

$r = 11{,}547 \text{ m}$

Do the same on a

$$\begin{cases} a_r = \cancel{a\cos\theta} = \ddot{r} - r\dot{\theta}^2 \\ a_\theta = \cancel{-a\sin\theta} = r\ddot{\theta} + 2\dot{r}\dot{\theta} \end{cases}$$

const. v

$\ddot{r} = r\dot{\theta}^2 = 11{,}547(-0.02)^2 = \boxed{4.62 \text{ m/s}^2}$

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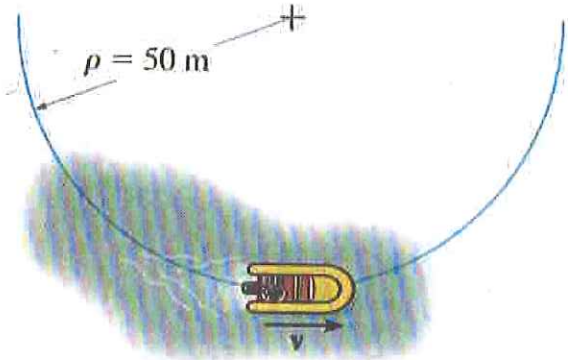
Ans= 1.8 m/s, 1.2 m/s²

12–118. Starting from rest, the motorboat travels around the circular path, $\rho = 50$ m, at a speed $v = (0.2t^2)$ m/s, where t is in seconds. Determine the magnitudes of the boat's velocity and acceleration at the instant $t = 3$ s.



$\dot{v} = a_t$ (not a)

$= 0.4t$

$a_n = \frac{v^2}{\rho} = \frac{(0.2t^2)^2}{50}$

plug in $t = 3s$. $\Rightarrow$ $\begin{cases} v = 1.8 \text{ m/s} \\ a_t = 1.2 \text{ m/s}^2 \\ a_n = 0.0648 \text{ m/s}^2 \end{cases}$

$a = \sqrt{a_t^2 + a_n^2} = \boxed{1.2017 \text{ m/s}^2}$

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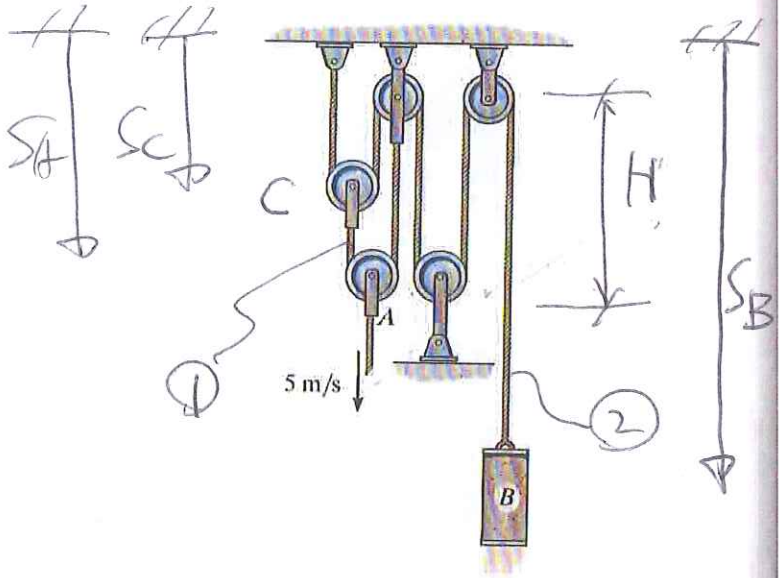
Ans: 20 m/s

12–198. If end A of the rope moves downward with a speed of 5 m/s, determine the speed of cylinder B.



Prob. 12–198

$$\begin{cases} L_1 = S_A + (S_A - S_C) = 2S_A - S_C \\ L_2 = S_B + 2H + 2S_C \end{cases}$$

$$\begin{cases} \dot{L}_1 = 2\dot{S}_A - \dot{S}_C = 0 \\ \dot{L}_2 = \dot{S}_B + 2\dot{S}_C = 0 \end{cases}$$

Plug in

$\dot{S}_A = 5$

$\Rightarrow$ $\dot{S}_C = 10$

$\dot{S}_B = -20$

$\Rightarrow$ $\boxed{V_B = 20\ m/s \uparrow}$

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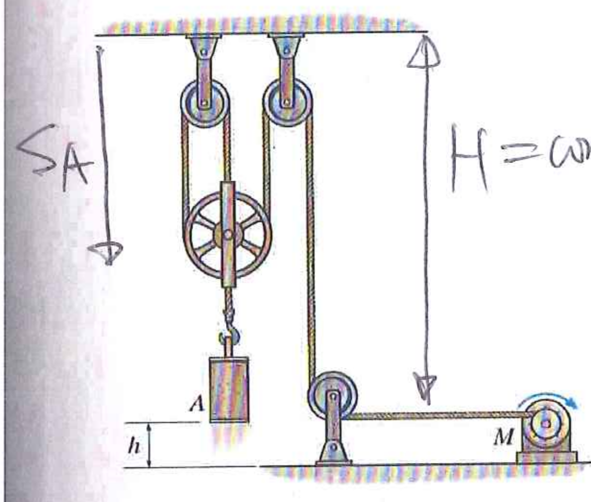
Ans: 1.67 m/s

•**12–201.** If the rope is drawn towards the motor M at a speed of $v_M = (5t^{3/2})$ m/s, where t is in seconds, determine the speed of cylinder A when $t = 1$ s.



Probs. 12–200/201

$D = \text{const}$

$$L = 3S_A + H + D$$

$$\dot{L} = 3\dot{S}_A = -V_M$$

$$\dot{S}_A = -\frac{1}{3}V_M$$

$$= -\frac{1}{3}(5t^{3/2})$$

plug in $t=1$ $\quad \dot{S}_A = -\frac{5}{3} = -1.67$ m/s

$$\boxed{V_A = 1.67 \text{ m/s} \uparrow}$$

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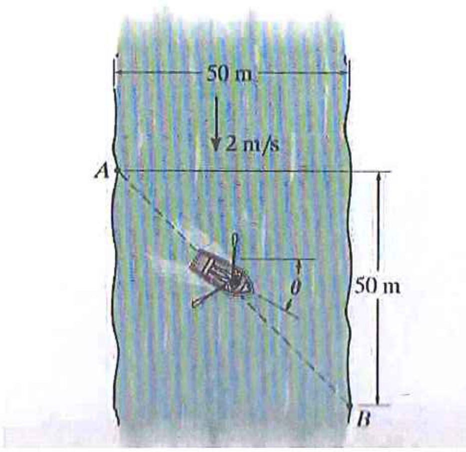
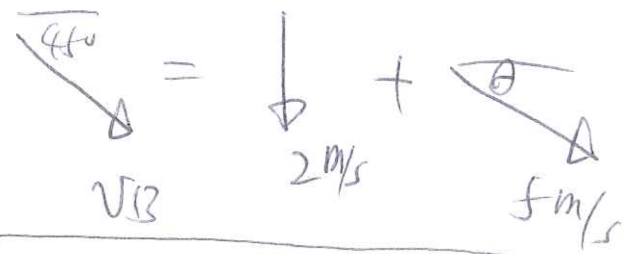
Ans: 6.21 m/s, 11.4 s

12–231. A man can row a boat at 5 m/s in still water. He wishes to cross a 50-m-wide river to point *B*, 50 m downstream. If the river flows with a velocity of 2 m/s, determine the speed of the boat and the time needed to make the crossing.



$$\underset{\sim}{V_B} = \underset{\sim}{V_W} + \underset{\sim}{V_{B/W}}$$



$\xrightarrow{+}$ $V_B \cos 45° = 0 + 5\cos\theta$ ①

$+y \downarrow$ $V_B \sin 45° = 2 + 5\sin\theta$ ②

① ⇒ $V_B = \dfrac{5\cos\theta}{\cos 45°}$ ⇒ plug into ②

$5\cos\theta = 2 + 5\sin\theta$ $\qquad X = \sin\theta$, $\cos\theta = \sqrt{1-X^2}$

⇒ $5(\sqrt{1-X^2}) = 2 + 5X$

⇒ $50X^2 + 20X - 21 = 0$ $\qquad X = \begin{cases} -0.8782 \; ✗ \\ 0.4782 \; ✓ \end{cases}$

$\theta = \sin^{-1} X = 28.57°$

$V_B = 6.21$ m/s $\qquad t = \dfrac{50\sqrt{2}}{V_B} = 11.4$ s

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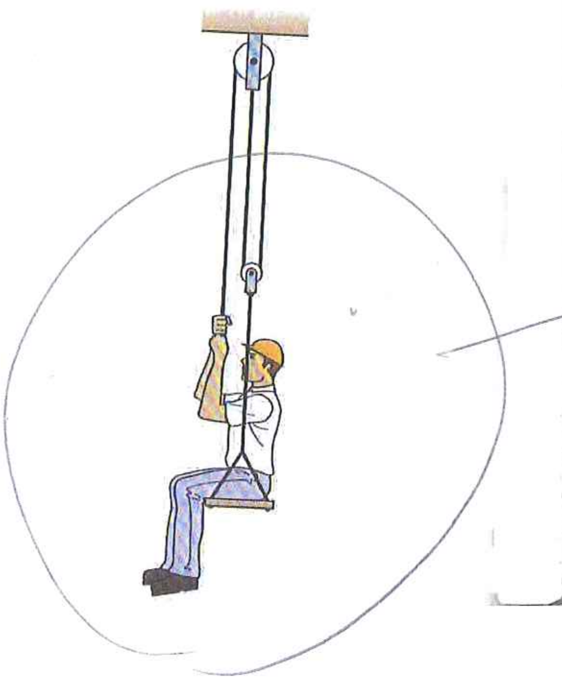
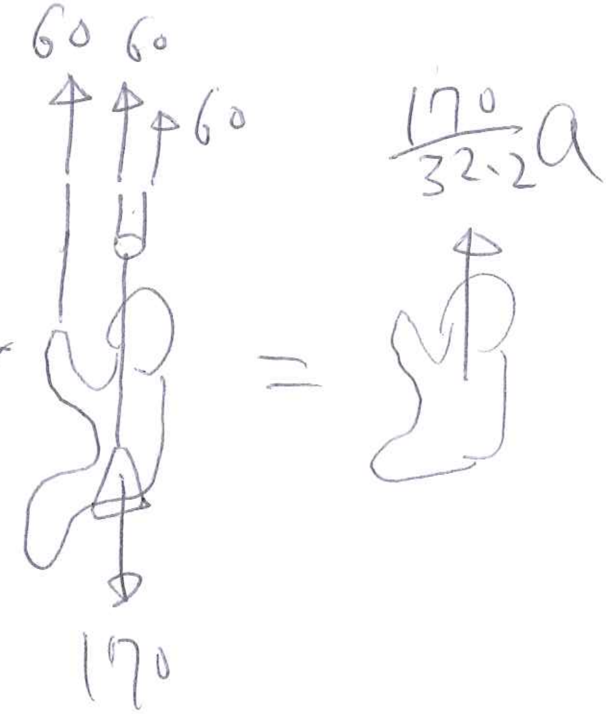
Ans: 1.894 ft/s²

3/8 The 170-lb man in the bosun's chair exerts a pull of 60 lb on the rope for a short interval. Find his acceleration. Neglect the mass of the chair, rope, and pulleys.



FBD



$$+\uparrow \Sigma F_y = m a_y$$

$$180 - 170 = \frac{170}{32.2} a$$

$$\boxed{a = 1.894 \text{ ft/s}^2 \uparrow}$$

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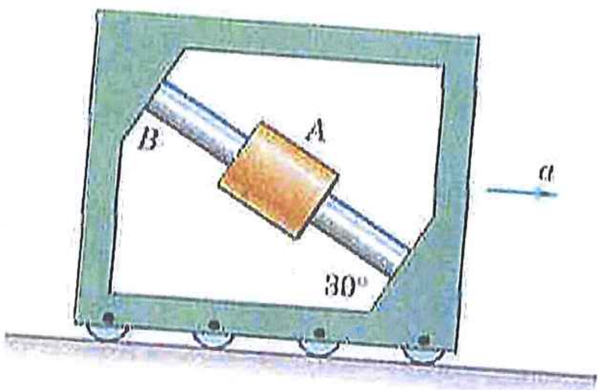
3/15 The collar A is free to slide along the smooth shaft B mounted in the frame. The plane of the frame is vertical. Determine the horizontal acceleration a of the frame necessary to maintain the collar in a fixed position on the shaft.

Ans. $a = 5.66\ \text{m/s}^2$



FBD   KD

$+\uparrow \Sigma F_y = 0$ Why 0?

$N\cos 30° - mg = 0$ $\boxed{N = \frac{mg}{\cos 30°}}$

$\xrightarrow{+} \Sigma F_x = ma_x$ $N \sin 30° = ma$

$\cancel{m}g \tan 30° = \cancel{m}a$

$\boxed{a = 5.66\ m/s^2}$ $\rightarrow$

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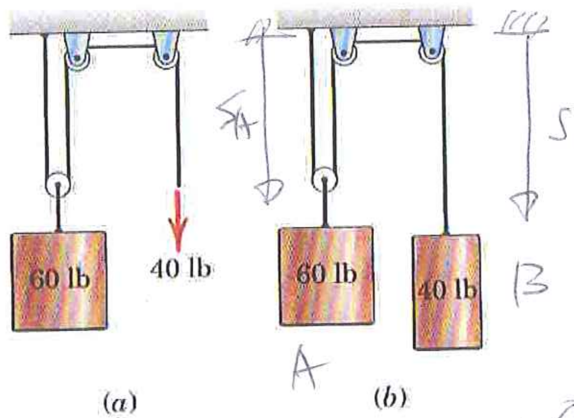
3/23 Determine the vertical acceleration of the 60-lb cylinder for each of the two cases. Neglect friction and the mass of the pulleys.

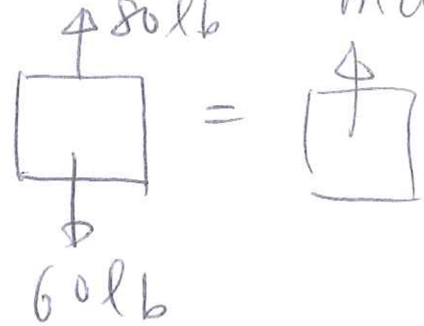
Ans. (*a*) $a = 10.73$ ft/sec^2 up
(*b*) $a = 2.93$ ft/sec^2 up



Problem 3/23

(a)

FBD



$+\uparrow \Sigma F = ma$

$80 - 60 = \frac{60}{32.2} a$

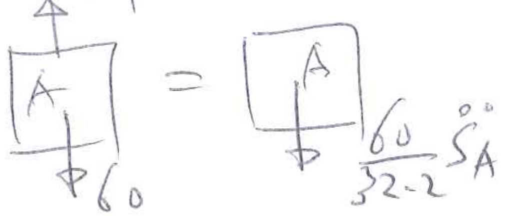
$\boxed{a = 10.73\ ft/s^2}$

(b) $L = 2S_A + S_B$

$\ddot{L} = 2\ddot{S}_A + \ddot{S}_B = 0$

$\boxed{\ddot{S}_B = -2\ddot{S}_A}$

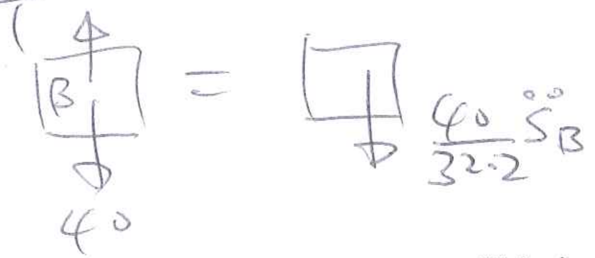
A: FBD KD



$+\downarrow \Sigma F = ma$

$60 - 2T = \frac{60}{32.2}\ddot{S}_A$ — (1)

B



$+\downarrow \Sigma F = ma$

$40 - T = \frac{40}{32.2}\underbrace{(-2\ddot{S}_A)}_{\ddot{S}_B}$ — (2)

Solve (1) & (2)

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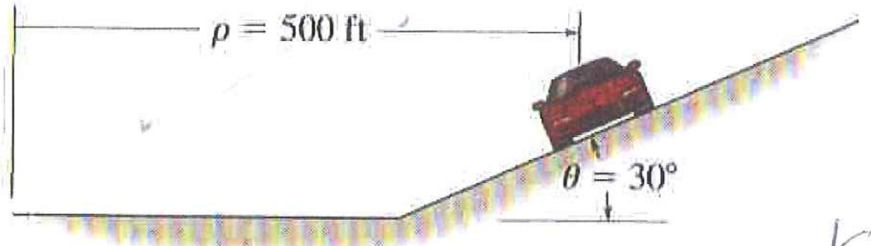
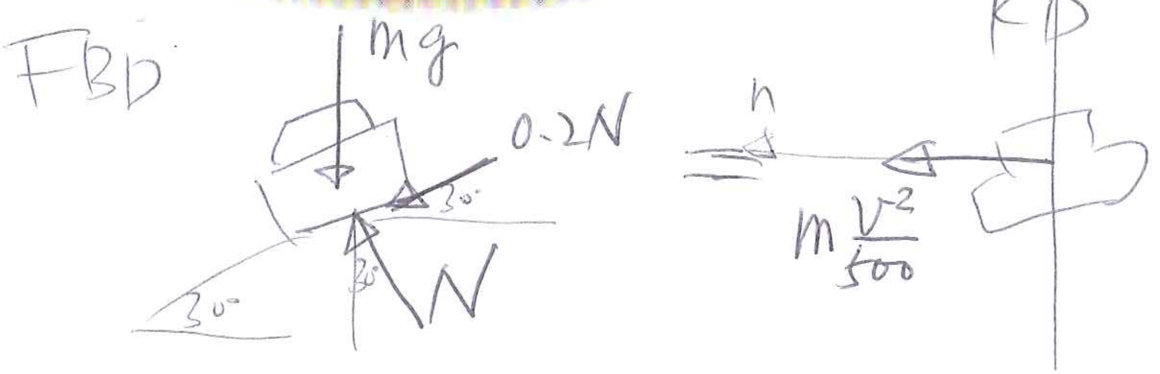
Ans: $V = 119$ ft/s

F13–10. The sports car is traveling along a 30° banked road having a radius of curvature of $\rho = 500$ ft. If the coefficient of static friction between the tires and the road is $\mu_s = 0.2$, determine the maximum safe speed so no slipping occurs. Neglect the size of the car.





$+\uparrow \Sigma F_b = 0 \quad N\cos 30° - 0.2N\sin 30° - mg = 0$

$$N = \frac{mg}{\cos 30° - 0.2\sin 30°} = 1.3054\, mg$$

$\overset{+}{\leftarrow} \Sigma F_n = m a_n$

$$0.2N\cos 30° + N\sin 30° = m\frac{v^2}{500}$$

$$1.3054\,\cancel{m}g\,(0.2\cos 30° + \sin 30°) = \cancel{m}\frac{v^2}{500} \qquad g = 32.2$$

$$\boxed{v = 119 \text{ ft/s}}$$

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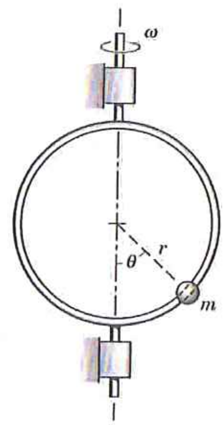
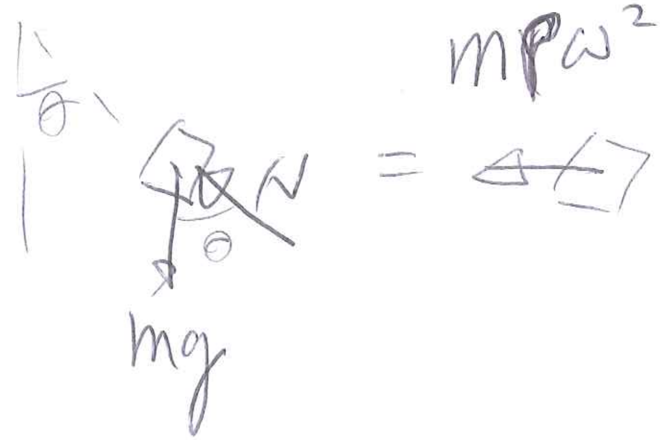
$a_n = \frac{v^2}{\rho} = \rho\omega^2$

A small bead of mass m is carried by a circular hoop of radius r which rotates about a fixed vertical axis. Show how one might determine the angular speed ω of the hoop by observing the angle θ which locates the bead. Neglect friction in your analysis, but assume that a small amount of friction is present to damp out any motion of the bead relative to the hoop once a constant angular speed has been established. Note any restrictions on your solution.

Ans. $\omega = \sqrt{\frac{g}{r\cos\theta}}$



FBD   KD



$\boxed{\rho = r\sin\theta}$

$+\uparrow \sum F_b = 0$

$N\cos\theta - mg = 0$

$\boxed{N = \frac{mg}{\cos\theta}}$

$\overset{+}{\leftarrow} \sum F_n = ma_n$

$N\sin\theta = m\rho\omega^2$

$\cancel{m}g\tan\theta = \cancel{m}r\sin\theta\,\omega^2$

$\frac{g}{r\cos\theta} = \omega^2 \Rightarrow \boxed{\omega = \sqrt{\frac{g}{r\cos\theta}}}$

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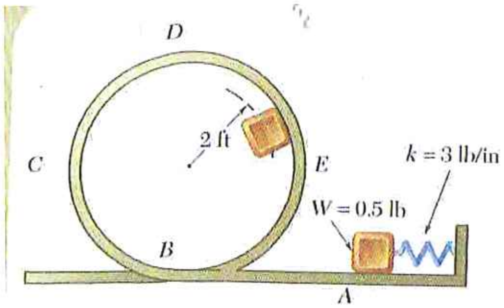
Ans: 4.47"



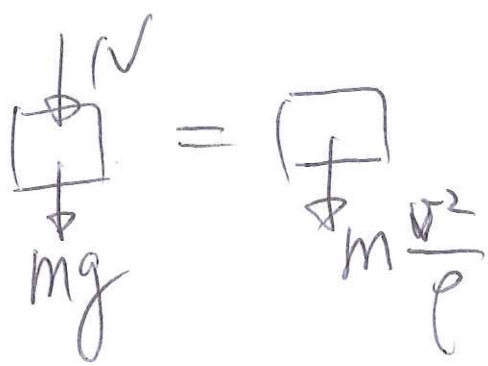
SAMPLE PROBLEM 13.7

The 0.5-lb pellet is pushed against the spring at A and released from rest. Neglecting friction, determine the smallest deflection of the spring for which the pellet will travel around the loop $ABCDE$ and remain at all times in contact with the loop.

$k = 3\ lb/in$

$= 36\ lb/ft$

At D



$+\downarrow \Sigma F_n = m a_n \qquad mg + \cancel{N}^{0} = m\frac{v^2}{\rho}$

$v = \sqrt{\rho g} = \sqrt{2(32.2)}$

$= \boxed{8.025\ ft/s}$

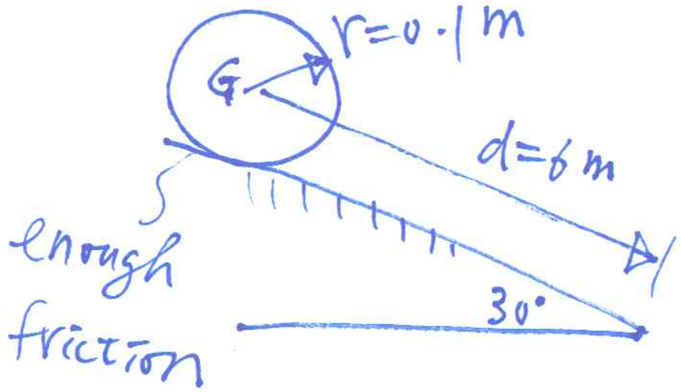
From A to D

$\cancel{T_1}^{0} + V_1 + \cancel{U_{1-2}}^{0}_{\text{non}} = T_2 + V_2$

$\frac{1}{2}(36)x^2 = \frac{1}{2}\frac{0.5}{32.2}(8.025)^2 + 0.5(4)$

$x = 0.3727\ ft = \boxed{4.47''}$

Disk $m = 2\,kg$



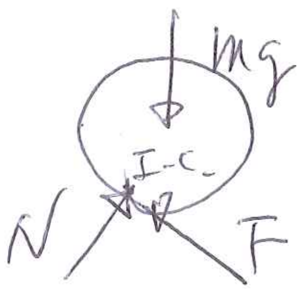
Released from rest

Find V_G at the bottom.

Assume rolling

Ans: $V_G = 6.264\ m/s$ ↘

Sol:



Rolling friction does no work. Why?

I.C. has no velocity.

$$\cancel{T_1}^{\,0} + V_1 + \cancel{U^{non}_{1-2}}^{\,0} = T_2 + V_2$$

$$2(9.81)(6\sin 30^\circ) = \frac{1}{2}(2)V_G^2 + \frac{1}{2}\left[\frac{1}{2}(2)(0.1)^2\right]\omega^2$$

$$\text{Also } \omega = \frac{V_G}{r} = 10\,V_G$$

$$\Rightarrow \boxed{V_G = 6.264\ m/s} \searrow$$

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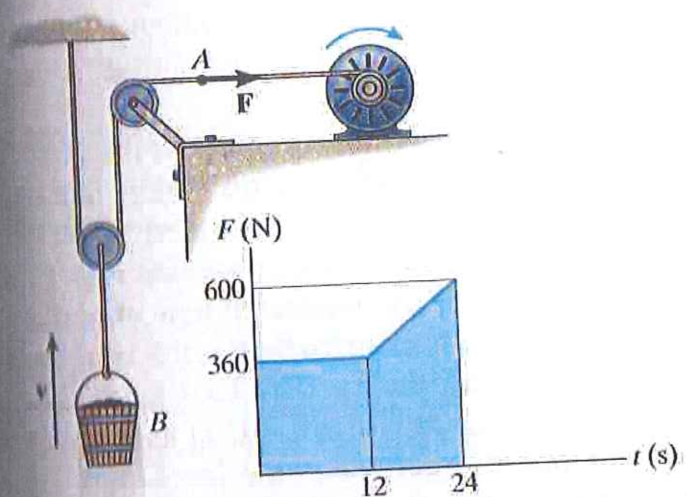
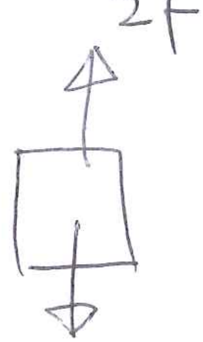
Ans: 16.6 m/s

14-28. The winch delivers a horizontal towing force **F** to its cable at *A* which varies as shown in the graph. Determine the speed of the 80-kg bucket when $t = 24$ s. Originally the bucket is released from rest.



FBD



$80(9.81) = 784.8\ N$

$+\uparrow \quad \cancel{L_1}^{0} + \int_0^{24} \Sigma F\, dt = L_2$

$\int_0^{24} 2F\, dt - 784.8(24) = 80\, v$

$2(\text{area}) - 784.8(24) = 80\, v$

$2\left[(360)(12) + \frac{1}{2}(360 + 600)(12)\right] - 784.8(24) = 80\, v$

$\boxed{v = 16.6\ m/s}$

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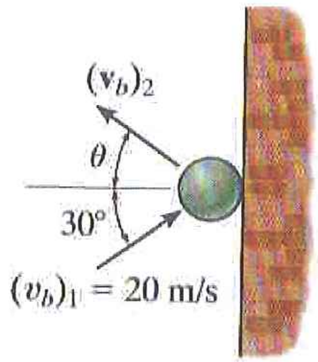
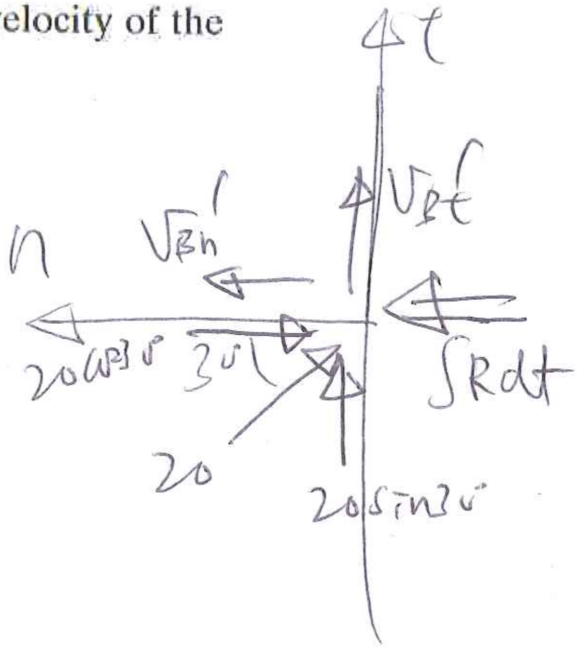
Ans: 16.4 m/s, 37.6°

F15–17. The ball strikes the smooth wall with a velocity of $(v_b)_1 = 20$ m/s. If the coefficient of restitution between the ball and the wall is $e = 0.75$, determine the velocity of the ball just after the impact.



F15–17



$$V_{Bt}' = V_{Bt} = 20\sin 30° = 10 \uparrow$$

$$e = \left|\frac{sep}{app}\right|_n = \frac{V_{Bn}'}{20\cos 30°} = 0.75$$

$$V_{Bn}' = 12.99$$

$$V_B' = \sqrt{12.99^2 + 10^2} = \boxed{16.4 \text{ m/s}}$$

$$\theta = \tan^{-1}\frac{10}{12.99} = \boxed{37.6°}$$

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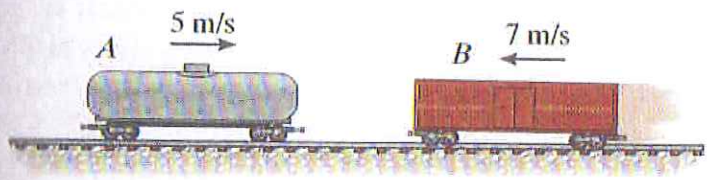
F15-14. The 15-Mg tank car A and 25-Mg freight car B travel towards each other with the velocities shown. If the coefficient of restitution between the bumpers is $e = 0.6$, determine the velocity of each car just after the collision.



Ans: $v_{B2} = 0.2\ \text{m/s} \rightarrow$
$v_{A2} = 7\ \text{m/s} \leftarrow$

Assume

$\leftarrow V_{A2} \qquad \rightarrow V_{B2}$

$\xrightarrow{+}\quad \underset{\sim}{L}_1 + \int \Sigma \underset{\sim}{F}\, dt = \underset{\sim}{L}_2$

$$(15\times\cancel{10^3})(5) - (25\times\cancel{10^3})(7) = -(15\times\cancel{10^3})V_{A2} + (25\times\cancel{10^3})V_{B2} \quad \text{— (1)}$$

$$e = \left(\frac{\text{sep}}{\text{app}}\right)_n = \frac{V_{A2} + V_{B2}}{12} = 0.6 \quad \text{— (2)}$$

Solve (1), (2)

$$\boxed{\begin{aligned} V_{A2} &= 7\ \text{m/s} \\ V_{B2} &= 0.2\ \text{m/s} \end{aligned}}$$

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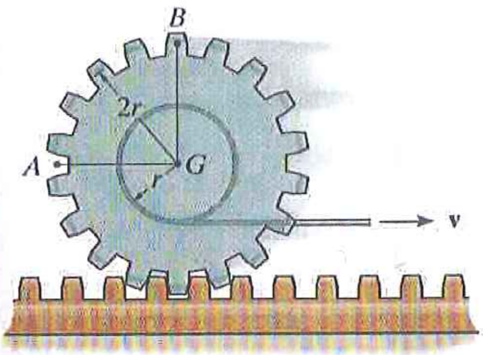
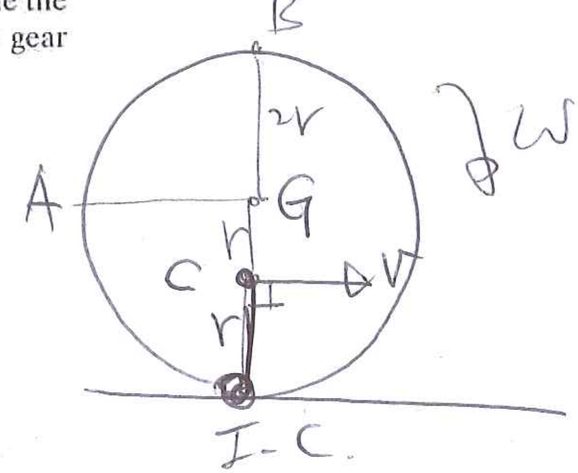
$v_B = 4v \rightarrow$ $\qquad a_B = \frac{2v^2}{r} \downarrow$

$v_A = 2\sqrt{2}v$ 45° $\qquad a_A = \frac{2v^2}{r} \rightarrow$

16–126. A cord is wrapped around the inner spool of the gear. If it is pulled with a constant velocity **v**, determine the velocities and accelerations of points A and B. The gear rolls on the fixed gear rack.





$$\boxed{\omega = \frac{v}{r_{C/IC}}} = \frac{v}{r}$$

$$v_B = \omega r_{B/IC} = \frac{v}{r}(4r) = 4v \rightarrow$$

$$v_A = \omega r_{A/IC} = \frac{\cancel{v}}{\cancel{r}}\left[\sqrt{2}(2\cancel{r})\right] = \boxed{2\sqrt{2}v \; 45°}$$

(a part skipped)

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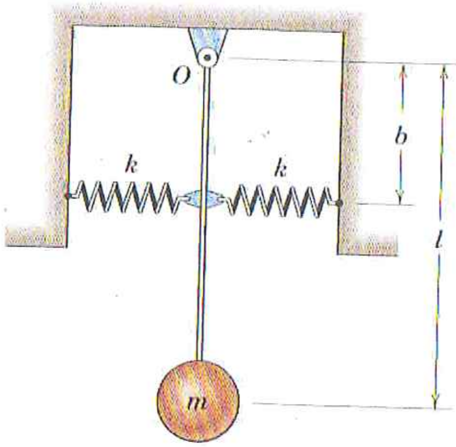
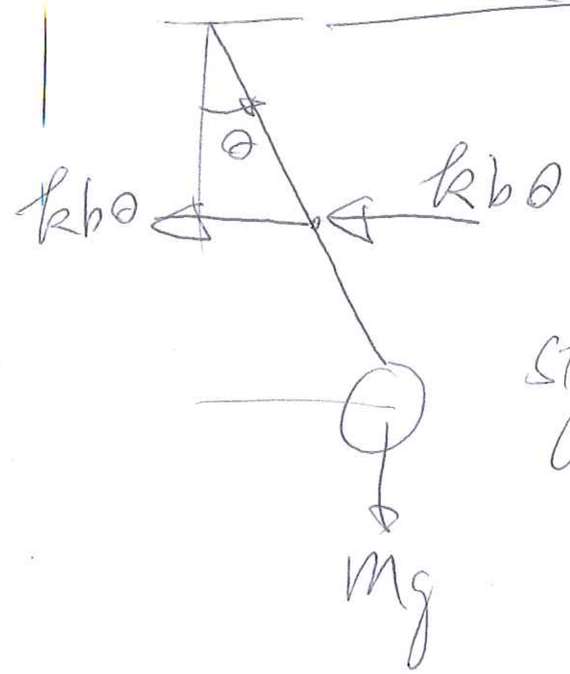
Ans: $\dfrac{2\pi}{\sqrt{\frac{g}{l}+\frac{2kb^2}{ml^2}}}$

8/74 Derive the differential equation for small oscillations of the spring-loaded pendulum and find the period τ. The equilibrium position is vertical as shown. The mass of the rod is negligible.

small θ



Problem 8/74



$\sin\theta \simeq \theta$

$\cos\theta \simeq 1$

$\circlearrowleft_{+} \ \Sigma M_o = I_o \alpha$

$$-mgl\sin\theta - 2kb\theta(b\cos\theta) = (ml^2)\ddot{\theta}$$

$$ml^2\ddot{\theta} + (mgl + 2kb^2)\theta = 0$$

$$\omega_n = \sqrt{\frac{mgl+2kb^2}{ml^2}} = \sqrt{\frac{g}{l}+\frac{2kb^2}{ml^2}}$$

$$\tau = \frac{2\pi}{\omega_n} = \frac{2\pi}{\sqrt{\frac{g}{l}+\frac{2kb^2}{ml^2}}}$$