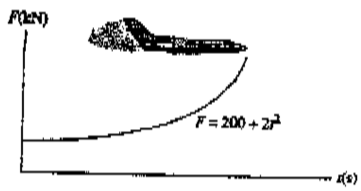
**15-9.** The jet plane has a mass of 250 Mg and a horizontal velocity of 100 m/s when $t = 0$. If *both* engines provide a horizontal thrust which varies as shown in the graph, determine the plane's velocity in $t = 15$ s. Neglect air resistance and the loss of fuel during the motion.

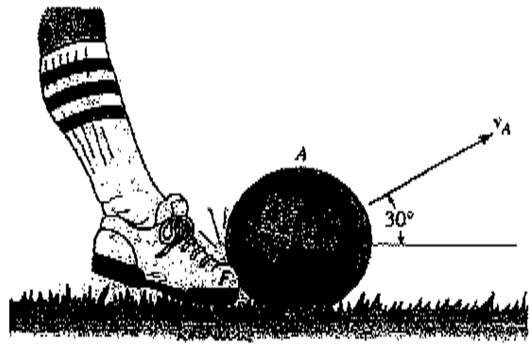



$(\overset{+}{\rightarrow})$ $\quad m(v_x)_1 + \Sigma \int_{t_1}^{t_2} F_x\,dt = m(v_x)_2$

$$250(10^3)(100) + \int_0^{15} 10^3(200 + 2t^2)\,dt = 250(10^3)\,v$$

$v = 121$ m/s $\quad$ **Ans**

**15-10.** A man kicks the 200-g ball such that it leaves the ground at an angle of 30° with the horizontal and strikes the ground at the same elevation a distance of 15 m away. Determine the impulse of his foot $F$ on the ball. Neglect the impulse caused by the ball's weight while it's being kicked.




$(\overset{+}{\rightarrow})$ $\quad s_x = (s_0)_x + (v_0)_x t + \frac{1}{2}a_c t^2$

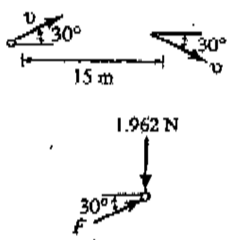
$$15 = 0 + v\cos 30^\circ\, t + 0$$

$(+\uparrow)$ $\quad v_y = (v_0)_y + a_c t$

$$-v\sin 30^\circ = v\sin 30^\circ - 9.81t$$

$t = 1.329$ s

$v = 13.04$ m/s

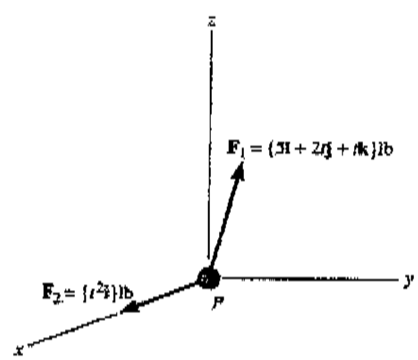



$(\nearrow)$ $\quad mv_1 + \Sigma\int F\,dt = mv_2$

$$0 + \int F\,dt = 0.2(13.04)$$

$I = \int F\,dt = 2.608 = 2.61$ N·s $\measuredangle_{30^\circ}$ $\quad$ **Ans**

**15-11.** The particle $P$ is acted upon by its weight of 3 lb and forces $\mathbf{F}_1$ and $\mathbf{F}_2$, where $t$ is in seconds. If the particle originally has a velocity of $\mathbf{v}_1 = \{3\mathbf{i} + 1\mathbf{j} + 6\mathbf{k}\}$ ft/s, determine its speed after 2 s.




$$mv_1 + \sum \int_0^2 F\,dt = mv_2$$

Resolving into scalar components.

$$\frac{3}{32.2}(3) + \int_0^2 (5 + t^2)\,dt = \frac{3}{32.2}(v_x)$$

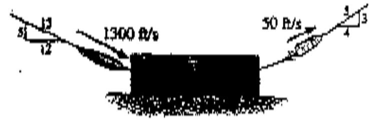
$$\frac{3}{32.2}(1) + \int_0^2 2t\,dt = \frac{3}{32.2}(v_y)$$

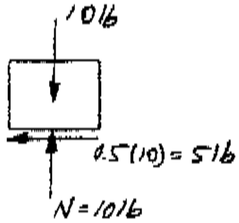
$$\frac{3}{32.2}(6) + \int_0^2 (t - 3)\,dt = \frac{3}{32.2}(v_z)$$

$v_x = 138.96$ ft/s $\quad v_y = 43.933$ ft/s $\quad v_z = -36.933$ ft/s

$v = \sqrt{(138.96)^2 + (43.933)^2 + (-36.933)^2} = 150$ ft/s $\quad$ **Ans**

**15-41.** A 0.03-lb bullet traveling at 1300 ft/s strikes the 10-lb wooden block and exits the other side at 50 ft/s as shown. Determine the speed of the block just after the bullet exits the block. Also, determine the average normal force on the block if the bullet passes through it in 1 ms, and the time the block slides before it stops. The coefficient of kinetic friction between the block and the surface is $\mu_k = 0.5$.




$(\overset{+}{\rightarrow})$ $\quad \Sigma m_1 v_1 = \Sigma m_2 v_2$

$$\left(\frac{0.03}{32.2}\right)(1300)\left(\frac{12}{13}\right) + 0 = \left(\frac{10}{32.2}\right)v_B + \left(\frac{0.03}{32.2}\right)(50)\left(\frac{4}{5}\right)$$

$v_B = 3.48$ ft/s $\quad$ **Ans**

$(+\uparrow)$ $\quad mv_1 + \Sigma \int F\,dt = mv_2$

$$-\left(\frac{0.03}{32.2}\right)(1300)\left(\frac{5}{13}\right) - 10(1)(10^{-3}) + N(1)(10^{-3}) = \left(\frac{0.03}{32.2}\right)(50)\left(\frac{3}{5}\right)$$

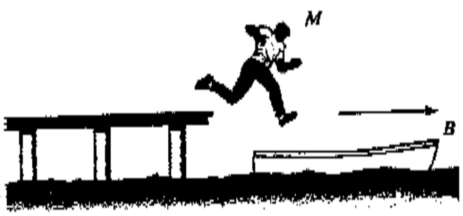
$N = 504$ lb $\quad$ **Ans**

$(\overset{+}{\rightarrow})$ $\quad mv_1 + \Sigma \int F\,dt = mv_2$

$$\left(\frac{10}{32.2}\right)(3.48) - 5(t) = 0$$

$t = 0.216$ s $\quad$ **Ans**

**15-42.** The man $M$ weighs 150 lb and jumps onto the boat $B$ which has a weight of 200 lb. If he has a horizontal component of velocity *relative to the boat* of 3 ft/s, just before he enters the boat, and the boat is traveling $v_B = 2$ ft/s away from the pier when he makes the jump, determine the resulting velocity of the man and boat.




$(\overset{+}{\rightarrow})$ $\quad v_M = v_B + v_{M/B}$

$v_M = 2 + 3$

$v_M = 5$ ft/s

$(\overset{+}{\rightarrow})$ $\quad \Sigma m\, v_1 = \Sigma m\, v_2$

$$\frac{150}{32.2}(5) + \frac{200}{32.2}(2) = \frac{350}{32.2}(v_B)_2$$

$(v_B)_2 = 3.29$ ft/s $\quad$ **Ans**

**15-43.** The man $M$ weighs 150 lb and jumps onto the boat $B$ which is originally at rest. If he has a horizontal component of velocity of 3 ft/s just before he enters the boat, determine the weight of the boat if it has a velocity of 2 ft/s once the man enters it.


$(\overset{+}{\rightarrow})$ $\quad v_M = v_B + v_{M/B}$

$v_M = 0 + 3$

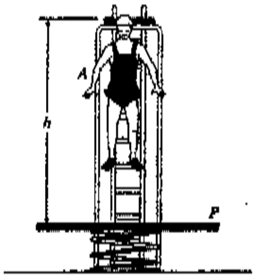
$v_M = 3$ ft/s

$(\overset{+}{\rightarrow})$ $\quad \Sigma m(v_1) = \Sigma m(v_2)$

$$\frac{150}{32.2}(3) + \frac{W_B}{32.2}(0) = \frac{(W_B + 150)}{32.2}(2)$$

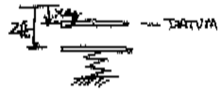
$W_B = 75$ lb $\quad$ **Ans**

**15-62.** The man $A$ has a weight of 100 lb and jumps from rest onto the platform $P$ that has a weight of 60 lb. The platform is mounted on a spring, which has a stiffness $k = 200$ lb/ft. If the coefficient of restitution between the man and the platform is $e = 0.6$, and the man holds himself rigid during the motion, determine the required height $h$ of the jump if the maximum compression of the spring becomes 2 ft.




For the platform after collision:

$60 = 200(x_{eq})$




$x_{eq} = 0.3$ ft

$T_2 + V_2 = T_3 + V_3$

$$\frac{1}{2}\left(\frac{60}{32.2}\right)(v_{p2})^2 + \frac{1}{2}(200)(0.3)^2 + 0 = 0 + \frac{1}{2}(200)(2)^2 - 60(2-0.3)$$

$v_{p2} = 17.612$ ft/s

$(+\downarrow)\quad e = \dfrac{v_{p2} - v_{m2}}{v_{m1} - v_{p1}}$

$$0.6 = \frac{17.612 - v_{m2}}{v_{m1} - 0}$$

$(+\downarrow)\quad \Sigma m v_1 = \Sigma m v_2$

$$\frac{100}{32.2}v_{m1} + 0 = \frac{100}{32.2}(v_{m2}) + \frac{60}{32.2}(17.612)$$

Solving,

$v_{m1} = 17.612$ m/s

$v_{m2} = 7.045$ m/s

For the man just before striking the platform

$T_0 + V_0 = T_1 + V_1$

$$0 + 100\,h = \frac{1}{2}\left(\frac{100}{32.2}\right)(17.612)^2 + 0$$

$h = 4.82$ ft  Ans

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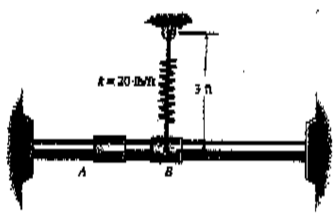
**15-63.** The 10-lb collar $B$ is at rest, and when it is in the position shown the spring is unstretched. If another 1-lb collar $A$ strikes it so that $B$ slides 4 ft on the smooth rod before momentarily stopping, determine the velocity of $A$ just after impact, and the average force exerted between $A$ and $B$ during the impact if the impact occurs in 0.002 s. The coefficient of restitution between $A$ and $B$ is $e = 0.5$.




Collar $B$ after impact:

$T_2 + V_2 = T_3 + V_3$


$$\frac{1}{2}\left(\frac{10}{32.2}\right)(v_B)_2^2 + 0 = 0 + \frac{1}{2}(20)(5-3)^2$$

$(v_B)_2 = 16.05$ ft/s

System:

$(\overset{+}{\rightarrow})\quad \Sigma m_1 v_1 = \Sigma m_1 v_2$

$$\frac{1}{32.2}(v_A)_1 + 0 = \frac{1}{32.2}(v_A)_2 + \frac{10}{32.2}(16.05)$$

$(v_A)_1 - (v_A)_2 = 160.5$

$(\overset{+}{\rightarrow})\quad e = \dfrac{(v_B)_2 - (v_A)_2}{(v_A)_1 - (v_B)_1}$

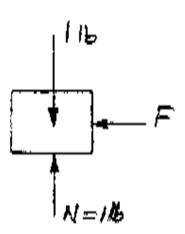
$$0.5 = \frac{16.05 - (v_A)_2}{(v_A)_1 - 0}$$

$0.5(v_A)_1 + (v_A)_2 = 16.05$

Solving:

$(v_A)_1 = 117.7$ ft/s $= 118$ ft/s $\rightarrow$

$(v_A)_2 = -42.8$ ft/s $= 42.8$ ft/s $\leftarrow$  Ans



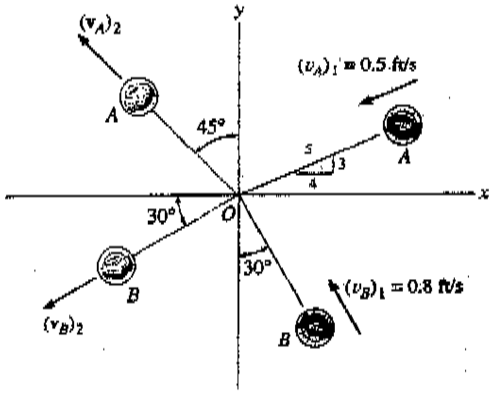

Collar $A$:

$(\overset{+}{\rightarrow})\quad m v_1 + \Sigma \int F\,dt = m v_2$

$$\left(\frac{1}{32.2}\right)(117.7) - F(0.002) = \left(\frac{1}{32.2}\right)(-42.8)$$

$F = 2492.2$ lb $= 2.49$ kip  Ans

**15-83.** Two smooth coins $A$ and $B$, each having the same mass, slide on a smooth surface with the motion shown. Determine the speed of each coin after collision if they move off along the dashed paths. *Hint:* Since the line of impact has not been defined, apply the conservation of momentum along the $x$ and $y$ axes, respectively.




$$\Sigma m v_1 = \Sigma m v_2$$

$(\overset{+}{\rightarrow})$ $$-m(0.8)\sin 30^\circ - m(0.5)\left(\tfrac{4}{5}\right) = -m(v_A)_2 \sin 45^\circ - m(v_B)_2 \cos 30^\circ$$

$$0.8 = 0.707(v_A)_2 + 0.866(v_B)_2$$

$(+\uparrow)$ $$m(0.8)\cos 30^\circ - m(0.5)\left(\tfrac{3}{5}\right) = m(v_A)_2 \cos 45^\circ - m(v_B)_2 \sin 30^\circ$$

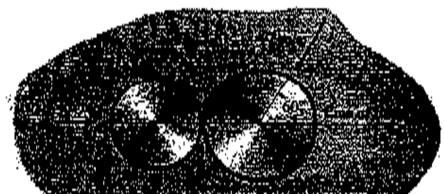
$$-0.3928 = -0.707(v_A)_2 + 0.5(v_B)_2$$

Solving,

$(v_B)_2 = 0.298$ ft/s **Ans**

$(v_A)_2 = 0.766$ ft/s **Ans**

***15-84.** The two disks $A$ and $B$ have a mass of 3 kg and 5 kg, respectively. If they collide with the initial velocities shown, determine their velocities just after impact. The coefficient of restitution is $e = 0.65$.



$(v_{A_x})_1 = 6$ m/s $\quad (v_{A_y})_1 = 0$

$(v_{B_x})_1 = -7\cos 60^\circ = -3.5$ m/s $\quad (v_{B_y})_1 = -7\sin 60^\circ = -6.062$ m/s

$(\overset{+}{\rightarrow})$ $$m_A(v_{A_x})_1 + m_B(v_{B_x})_1 = m_A(v_{A_x})_2 + m_B(v_{B_x})_2$$

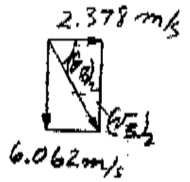
$$3(6) - 5(3.5) = 3(v_A)_{x2} + 5(v_B)_{x2}$$

$(\overset{+}{\rightarrow})$ $$e = \frac{(v_{B_x})_2 - (v_{A_x})_2}{(v_{A_x})_1 - (v_{B_x})_1}; \quad 0.65 = \frac{(v_{B_x})_2 - (v_{A_x})_2}{6 - (-3.5)}$$

$$(v_{B_x})_2 - (v_{A_x})_2 = 6.175$$

Solving,

$(v_{A_x})_2 = -3.80$ m/s $\quad (v_{B_x})_2 = 2.378$ m/s




$(+\uparrow)$ $$m_A(v_{A_y})_1 = m_A(v_{A_y})_2$$

$$(v_{A_y})_2 = 0$$

$(+\uparrow)$ $$m_B(v_{B_y})_1 = m_B(v_{B_y})_2$$

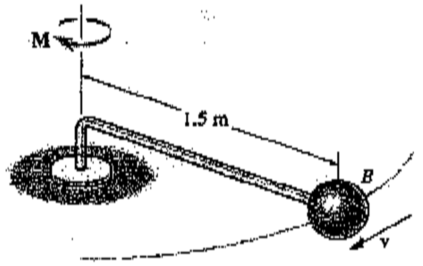
$$(v_{B_y})_2 = -6.062 \text{ m/s}$$

$(v_A)_2 = \sqrt{(3.80)^2 + (0)^2} = 3.80$ m/s $\leftarrow$ **Ans**

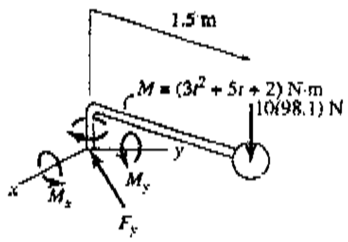
$(v_B)_2 = \sqrt{(2.378)^2 + (-6.062)^2} = 6.51$ m/s **Ans**

$(\theta_B)_2 = \tan^{-1}\left(\dfrac{6.062}{2.378}\right) = 68.6^\circ$ **Ans**

**15-99.** The ball $B$ has a mass of 10 kg and is attached to the end of a rod whose mass may be neglected. If the rod is subjected to a torque $M = (3t^2 + 5t + 2)$ N · m, where $t$ is in seconds, determine the speed of the ball when $t = 2$ s. The ball has a speed $v = 2$ m/s when $t = 0$.




*Principle of Angular Impluse and Momentum:* Applying Eq. 15-22, we have

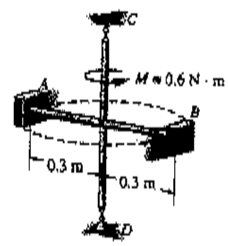



$$(H_z)_1 + \sum \int_{t_1}^{t_2} M_z dt = (H_z)_2$$

$$1.5(10)(2) + \int_0^{2s} (3t^2 + 5t + 2)dt = 1.5(10)v$$

$v = 3.47$ m/s Ans

*__15-100.__ The two blocks $A$ and $B$ each have a mass of 400 g. The blocks are fixed to the horizontal rods, and their initial velocity is 2 m/s in the direction shown. If a couple moment of $M = 0.6$ N·m is applied about $CD$ of the frame, determine the speed of the blocks when $t = 3$ s. The mass of the frame is negligible, and it is free to rotate about $CD$. Neglect the size of the blocks.

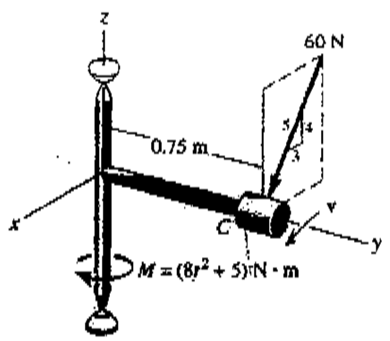


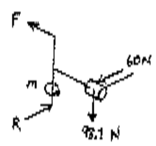

$$(H_O)_1 + \Sigma \int_{t_1}^{t_2} M_O dt = (H_O)_2$$

$$2[0.3(0.4)(2)] + 0.6(3) = 2[0.3(0.4)v]$$

$v = 9.50$ m/s Ans

**15-101.** The small cylinder $C$ has a mass of 10 kg and is attached to the end of a rod whose mass may be neglected. If the frame is subjected to a couple $M = (8t^2 + 5)$ N · m, where $t$ is in seconds, and the cylinder is subjected to a force of 60 N, which is always directed as shown, determine the speed of the cylinder when $t = 2$ s. The cylinder has a speed $v_0 = 2$ m/s when $t = 0$.



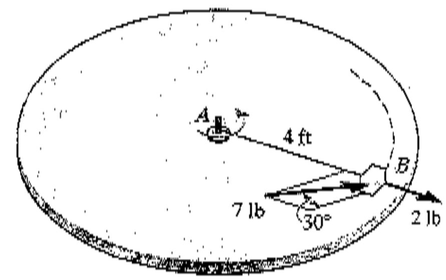

$$(H_z)_1 + \Sigma \int M_z\, dt = (H_z)_2$$

$$(10)(2)(0.75) + 60(2)(\tfrac{3}{5})(0.75) + \int_0^2 (8t^2 + 5)dt = 10v(0.75)$$

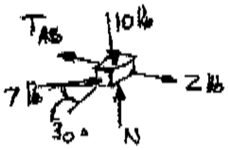
$$69 + [\tfrac{8}{3}t^3 + 5t]_0^2 = 7.5v$$

$v = 13.4$ m/s Ans

**15–106.** The 10-lb block is originally at rest on the smooth surface. It is acted upon by a radial force of 2 lb and a horizontal force of 7 lb, always directed at 30° from the tangent to the path as shown. Determine the time required to break the cord, which requires a tension $T = 30$ lb. What is the speed of the block when this occurs? Neglect the size of the block for the calculation.




$\Sigma F_n = ma_n;$




$$30 - 7\sin 30° - 2 = \frac{10}{32.2}\left(\frac{v^2}{4}\right)$$

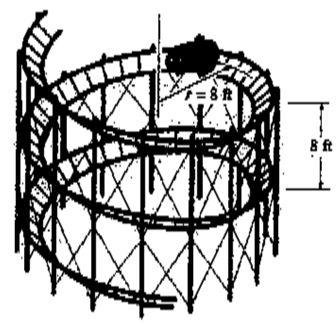
$v = 17.764$ ft/s

$$(H_A)_1 + \Sigma\int M_A\,dt = (H_A)_2$$

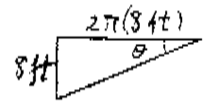
$$0 + (7\cos 30°)(4)(t) = \frac{10}{32.2}(17.764)(4)$$

$t = 0.910$ s  **Ans**

**15-107.** The 800-lb roller-coaster car starts from rest on the track having the shape of a cylindrical helix. If the helix descends 8 ft for every one revolution, determine the time required for the car to attain a speed of 60 ft/s. Neglect friction and the size of the car.

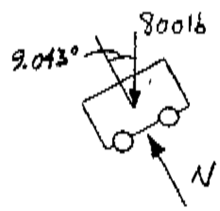



$$\theta = \tan^{-1}\left(\frac{8}{2\pi(8)}\right) = 9.043°$$




$\Sigma F_y = 0; \quad N - 800\cos 9.043° = 0$

$N = 790.1$ lb

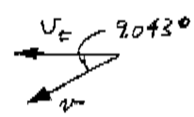



$$v = \frac{v_t}{\cos 9.043°}$$

$$60 = \frac{v_t}{\cos 9.043°}$$

$v_t = 59.254$ ft/s

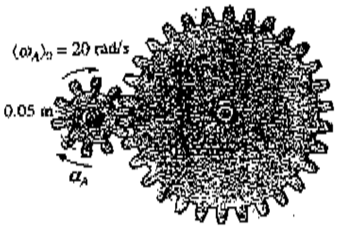
$$H_1 + \int M\,dt = H_2$$




$$0 + \int_0^t 8(790.1\sin 9.043°)dt = \frac{800}{32.2}(8)(59.254)$$

$t = 11.9$ s  **Ans**

**16-22.** A motor gives gear $A$ an angular acceleration of $\alpha_A = (0.25\theta^3 + 0.5)$ rad/s$^2$, where $\theta$ is in radians. If this gear is initially turning at $(\omega_A)_0 = 20$ rad/s, determine the angular velocity of gear $B$ after $A$ undergoes an angular displacement of 10 rev.




$\alpha_A = 0.25\theta^3 + 0.5$

$\alpha\, d\theta = \omega\, d\omega$

$\int_0^{20\pi} (0.25\theta^3 + 0.5)\,d\theta_A = \int_{20}^{\omega_A} \omega_A\, d\omega_A$

$(0.0625\theta^4 + 0.5\theta)\Big|_0^{20\pi} = \frac{1}{2}(\omega_A)^2\Big|_{20}^{\omega_A}$

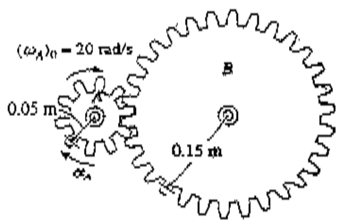
$\omega_A = 1395.94$ rad/s

$\omega_A r_A = \omega_B r_B$

$1395.94(0.05) = \omega_B(0.15)$

$\omega_B = 465$ rad/s **Ans**

**16-23.** A motor gives gear $A$ an angular acceleration of $\alpha_A = (4t^3)$ rad/s$^2$, where $t$ is in seconds. If this gear is initially turning at $(\omega_A)_0 = 20$ rad/s, determine the angular velocity of gear $B$ when $t = 2$ s.




$\alpha_A = 4t^3$

$d\omega = \alpha\, dt$

$\int_{20}^{\omega_A} d\omega_A = \int_0^t \alpha_A\, dt = \int_0^t 4t^3\, dt$

$\omega_A = t^4 + 20$

When $t = 2$ s,

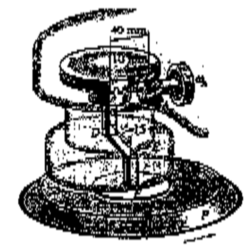
$\omega_A = 36$ rad/s

$\omega_A r_A = \omega_B r_B$

$36(0.05) = \omega_B(0.15)$

$\omega_B = 12$ rad/s **Ans**

***16-24.** For a short time a motor of the random-orbit sander drives the gear $A$ with an angular velocity of $\omega_A = 40(t^3 + 6t)$ rad/s, where $t$ is in seconds. This gear is connected to gear $B$, which is fixed connected to the shaft $CD$. The end of this shaft is connected to the eccentric spindle $EF$ and pad $P$, which causes the pad to orbit around shaft $CD$ at a radius of 15 mm. Determine the magnitudes of the velocity and the tangential and normal components of acceleration of the spindle $EF$ when $t = 2$ s after starting from rest.




$\omega_A r_A = \omega_B r_B$

$\omega_A(10) = \omega_B(40)$

$\omega_B = \frac{1}{4}\omega_A$

$v_E = \omega_B r_E = \frac{1}{4}\omega_A(0.015) = \frac{1}{4}(40)(t^3 + 6t)(0.015)\Big|_{t=2}$

$v_E = 3$ m/s **Ans**

$\alpha_A = \frac{d\omega_A}{dt} = \frac{d}{dt}\left[40(t^3 + 6t)\right] = 120t^2 + 240$

$\alpha_A r_A = \alpha_B r_B$

$\alpha_A(10) = \alpha_B(40)$

$\alpha_B = \frac{1}{4}\alpha_A$

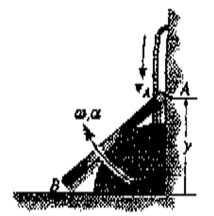
$(a_E)_t = \alpha_B r_E = \frac{1}{4}(120t^2 + 240)(0.015)\Big|_{t=2}$

$(a_E)_t = 2.70$ m/s$^2$ **Ans**

$(a_E)_n = \omega_B^2 r_E = \left[\frac{1}{4}(40)(t^3 + 6t)\right]^2 (0.015)\Big|_{t=2}$

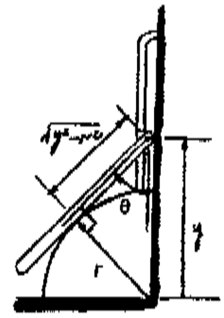
$(a_E)_n = 600$ m/s$^2$ **Ans**

■**16-41.** The end $A$ of the bar is moving downward along the slotted guide with a constant velocity $\mathbf{v}_A$. Determine the angular velocity $\omega$ and angular acceleration $\alpha$ of the bar as a function of its position $y$.




Position coordinate equation :

$$\sin\theta = \frac{r}{y}$$




Time derivatives :

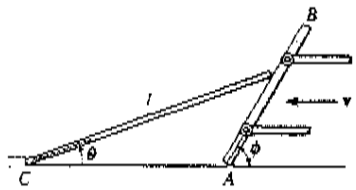
$$\cos\theta\dot{\theta} = -\frac{r}{y^2}\dot{y} \quad \text{however, } \cos\theta = \frac{\sqrt{y^2-r^2}}{y} \text{ and } \dot{y} = -v_A,\ \dot{\theta} = \omega$$

$$\left(\frac{\sqrt{y^2-r^2}}{y}\right)\omega = \frac{r}{y^2}v_A \qquad \omega = \frac{rv_A}{y\sqrt{y^2-r^2}} \qquad \textbf{Ans}$$

$$\alpha = \dot{\omega} = rv_A\left[-y^{-2}\dot{y}(y^2-r^2)^{-\frac{1}{2}} + (y^{-1})\left(-\tfrac{1}{2}\right)(y^2-r^2)^{-\frac{3}{2}}(2y\dot{y})\right]$$

$$\alpha = \frac{rv_A^2\,(2y^2-r^2)}{y^2(y^2-r^2)^{\frac{3}{2}}} \qquad \textbf{Ans}$$

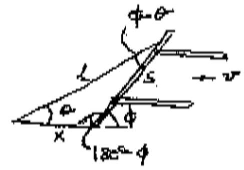
**16-42.** The inclined plate moves to the left with a constant velocity $\mathbf{v}$. Determine the angular velocity and angular acceleration of the slender rod of length $l$. The rod pivots about the step at $C$ as it slides on the plate.




$$\frac{x}{\sin(\phi-\theta)} = \frac{l}{\sin(180°-\phi)} = \frac{l}{\sin\phi}$$

$$x\sin\phi = l\sin(\phi-\theta)$$

$$\dot{x}\sin\phi = -l\cos(\phi-\theta)\,\dot{\theta}$$




Thus

$$\omega = \frac{-v(\sin\phi)}{l\cos(\phi-\theta)} \qquad \textbf{Ans}$$

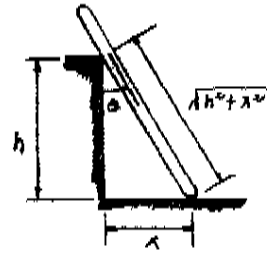
$$\ddot{x}\sin\phi = -l\cos(\phi-\theta)\ddot{\theta} - l\sin(\phi-\theta)(\dot{\theta})^2$$

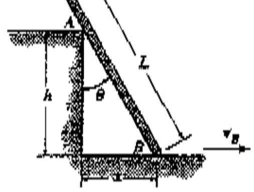
$$0 = -\cos(\phi-\theta)\alpha - \sin(\phi-\theta)\,\omega^2$$

$$\alpha = \frac{-\sin(\phi-\theta)}{\cos(\phi-\theta)}\left(\frac{v^2\sin^2\phi}{l^2\cos^2(\phi-\theta)}\right)$$

$$\alpha = \frac{-v^2\sin^2\phi\sin(\phi-\theta)}{l^2\cos^3(\phi-\theta)} \qquad \textbf{Ans}$$

**16-43.** The bar remains in contact with the floor and with point $A$. If point $B$ moves to the right with a constant velocity $\mathbf{v}_B$, determine the angular velocity and angular acceleration of the bar as a function of $x$.




Position coordinate equation :

$$\tan\theta = \frac{x}{h}$$

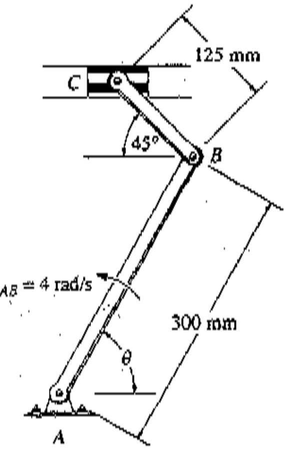
Time derivatives :

$$\sec^2\theta\dot{\theta} = \frac{1}{h}\dot{x} \quad \text{However, } \sec\theta = \frac{\sqrt{h^2+x^2}}{h} \text{ and } \dot{x} = v_B,\ \dot{\theta} = \omega$$

$$\left(\frac{\sqrt{h^2+x^2}}{h}\right)^2\omega = \frac{1}{h}v_B \qquad \omega = \frac{h}{h^2+x^2}v_B \qquad \textbf{Ans}$$

$$\alpha = \dot{\omega} = v_B h\left[-(h^2+x^2)^{-2}(2x\dot{x})\right] \qquad \alpha = \frac{-2xh}{(h^2+x^2)^2}v_B^2 \qquad \textbf{Ans}$$

**16-54.** The shaper mechanism is designed to give a slow cutting stroke and a quick return to a blade attached to the slider at $C$. Determine the velocity of the slider block $C$ at the instant $\theta = 60°$, if link $AB$ is rotating at 4 rad/s.




$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$-v_C\mathbf{i} = -4(0.3)\sin 30°\mathbf{i} + 4(0.3)\cos 30°\mathbf{j} + \omega\mathbf{k} \times (-0.125\cos 45°\mathbf{i} + 0.125\sin 45°\mathbf{j})$

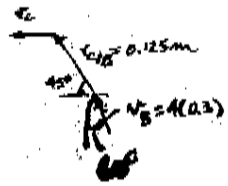
$-v_C = -1.0392 - 0.008839\omega$

$0 = 0.6 - 0.08839\omega$

Solving,

$\omega = 6.79$ rad/s

$v_C = 1.64$ m/s **Ans.**




**16-55.** Determine the velocity of the slider block at $C$ at the instant $\theta = 45°$, if link $AB$ is rotating at 4 rad/s.

$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$-v_C\mathbf{i} = -4(0.3)\cos 45°\mathbf{i} + 4(0.3)\sin 45°\mathbf{j} + \omega\mathbf{k} \times (-0.125\cos 45°\mathbf{i} + 0.125\sin 45°\mathbf{j})$

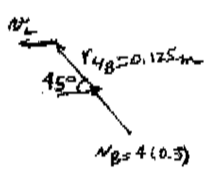
$-v_C = -0.8485 - 0.08839\omega$

$0 = 0.8485 - 0.08839\,\omega$

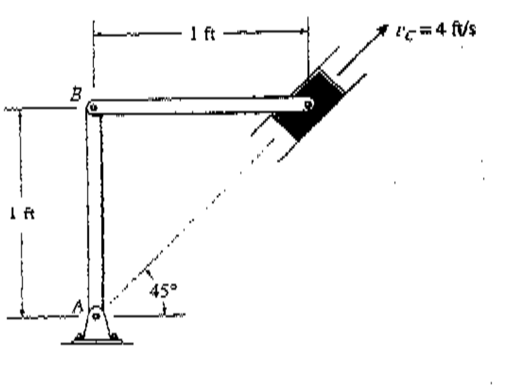
Solving,

$\omega = 9.60$ rad/s

$v_C = 1.70$ m/s Ans




***16-56.** The velocity of the slider block $C$ is 4 ft/s up the inclined groove. Determine the angular velocity of links $AB$ and $BC$ and the velocity of point $B$ at the instant shown.




For link $BC$

$\mathbf{v}_C = \{-4\cos 45°\mathbf{i} + 4\sin 45°\mathbf{j}\}$ ft/s $\quad \mathbf{v}_B = -v_B\mathbf{i} \quad \boldsymbol{\omega} = \omega_{BC}\mathbf{k}$

$\mathbf{r}_{A/B} = \{1\mathbf{i}\}$ ft

$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$-4\cos 45°\mathbf{i} + 4\sin 45°\mathbf{j} = -v_B\mathbf{i} + (\omega_{BC}\mathbf{k}) \times (1\mathbf{i})$

$-4\cos 45°\mathbf{i} + 4\sin 45°\mathbf{j} = -v_B\mathbf{i} + \omega_{BC}\mathbf{j}$

Equating the $\mathbf{i}$ and $\mathbf{j}$ components yields :

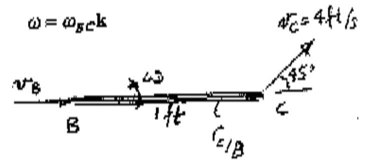
$-4\cos 45° = -v_B \qquad v_B = 2.83$ ft/s Ans

$4\sin 45° = \omega_{BC} \qquad \omega_{BC} = 2.83$ rad/s Ans

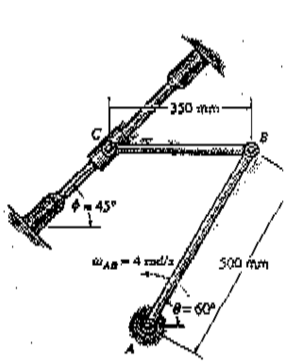
For link $AB$ : Link $AB$ rotates about the fixed point $A$. Hence

$v_B = \omega_{AB}\, r_{AB}$

$2.83 = \omega_{AB}(1) \qquad \omega_{AB} = 2.83$ rad/s Ans



**16-59.** The angular velocity of link $AB$ is $\omega_{AB} = 4$ rad/s. Determine the velocity of the collar at $C$ and the angular velocity of link $CB$ at the instant $\theta = 60°$ and $\phi = 45°$. Link $CB$ is horizontal at this instant. Also, sketch the location of link $CB$ when $\theta = 30°$, $60°$, and $90°$ to show its general plane motion.

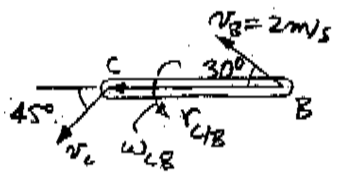



For link $AB$ : Link $AB$ rotates about the fixed point $A$ . Hence

$$v_B = \omega_{AB} r_{AB}$$

$$= 4(0.5) = 2 \text{ m/s}$$

For link $CB$




$\mathbf{v}_B = \{-2\cos 30°\mathbf{i} + 2\sin 30°\mathbf{j}\}$ m/s $\quad \mathbf{v}_C = -v_C \cos 45°\mathbf{i} - v_C \sin 45°\mathbf{j}$

$\boldsymbol{\omega} = \omega_{CB}\mathbf{k} \quad \mathbf{r}_{C/B} = \{-0.35\mathbf{i}\}$ m

$$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$$

$$-v_C \cos 45°\mathbf{i} - v_C \sin 45°\mathbf{j} = (-2\cos 30°\mathbf{i} + 2\sin 30°\mathbf{j}) + (\omega_{CB}\mathbf{k}) \times (-0.35\mathbf{i})$$

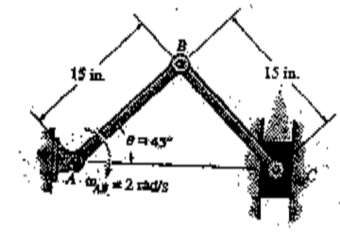
$$-v_C \cos 45°\mathbf{i} - v_C \sin 45°\mathbf{j} = -2\cos 30°\mathbf{i} + (2\sin 30° - 0.35\omega_{CB})\mathbf{j}$$

Equating the $\mathbf{i}$ and $\mathbf{j}$ components yields :

$-v_C \cos 45° = -2\cos 30° \qquad v_C = 2.45$ m/s ↙ **Ans**

$-2.45 \sin 45° = 2\sin 30° - 0.35\omega_{CB} \qquad \omega_{CB} = 7.81$ rad/s ↺ **Ans**

***16-60.** The link $AB$ has a clockwise angular velocity of 2 rad/s. Determine the velocity of block $C$ at the instant $\theta = 45°$. Also, sketch the location of link $BC$ when $\theta = 60°$, $45°$, and $30°$ to show its general plane motion.

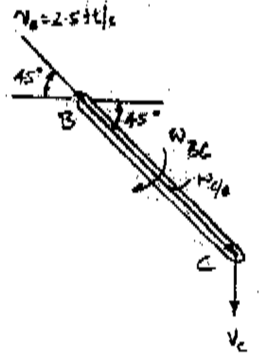



For link $AB$ : Link $AB$ rotates about the fixed point $A$. Hence

$$v_B = \omega_{AB} r_{AB}$$

$$= 2\left(\frac{15}{12}\right) = 2.5 \text{ ft/s}$$

For link $BC$




$\mathbf{v}_B = \{2.5\cos 45°\mathbf{i} - 2.5\sin 45°\mathbf{j}\}$ ft/s $\quad \mathbf{v}_C = -v_C\mathbf{j} \quad \boldsymbol{\omega} = -\omega_{BC}\mathbf{k}$

$\mathbf{r}_{C/B} = \{1.25\cos 45°\mathbf{i} - 1.25\sin 45°\mathbf{j}\}$ ft

$$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$$

$$-v_C\mathbf{j} = (2.5\cos 45°\mathbf{i} - 2.5\sin 45°\mathbf{j}) + (-\omega_{BC}\mathbf{k}) \times (1.25\cos 45°\mathbf{i} - 1.25\sin 45°\mathbf{j})$$

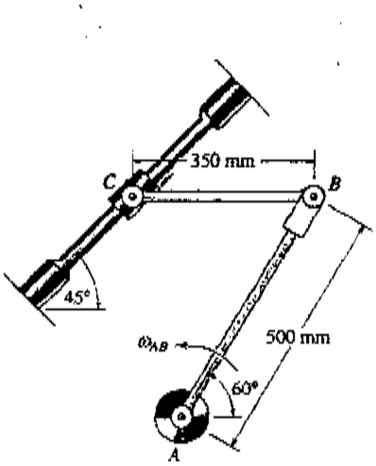
$$-v_C\mathbf{j} = (2.5\cos 45° - 1.25\sin 45°\omega_{BC})\mathbf{i} - (2.5\sin 45° + 1.25\cos 45°\omega_{BC})\mathbf{j}$$

Equating the $\mathbf{i}$ and $\mathbf{j}$ components yields :

$0 = 2.5\cos 45° - 1.25\sin 45°\omega_{BC} \qquad \omega_{BC} = 2$ rad/s

$-v_C = -[2.5\sin 45° + 1.25\cos 45°(2)] \qquad v_C = 3.54$ ft/s ↓ **Ans**

**16-95.** If the collar at $C$ is moving downward to the left at $v_C = 8$ m/s, determine the angular velocity of link $AB$ at the instant shown.




$$\frac{0.350}{\sin 75^\circ} = \frac{r_{IC-B}}{\sin 45^\circ} = \frac{r_{IC-C}}{\sin 60^\circ}$$

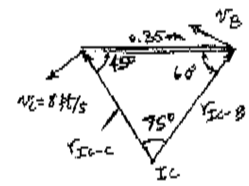
$r_{IC-B} = 0.2562$ m

$r_{IC-C} = 0.3138$ m

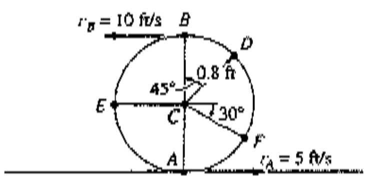
$$\omega_{CB} = \frac{8}{0.3138} = 25.494 \text{ rad/s}$$

$v_B = 25.494(0.2562) = 6.5315$ m/s

$$\omega_{AB} = \frac{6.5315}{0.5} = 13.1 \text{ rad/s} \qquad \textbf{Ans}$$



***16-96.** Due to slipping, points $A$ and $B$ on the rim of the disk have the velocities shown. Determine the velocities of the center point $C$ and point $D$ at this instant.




$$\frac{1.6 - x}{5} = \frac{x}{10}$$

$5x = 16 - 10x$

$x = 1.06667$ ft

$$\omega = \frac{10}{1.06667} = 9.375 \text{ rad/s}$$

$r_{IC-D} = \sqrt{(0.2667)^2 + (0.8)^2 - 2(0.2667)(0.8)\cos 135^\circ} = 1.006$ ft

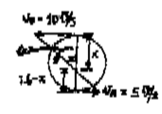
$$\frac{\sin\phi}{0.2667} = \frac{\sin 135^\circ}{1.006}$$

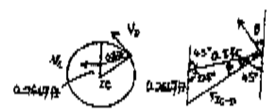
$\phi = 10.80^\circ$

$v_C = 0.2667(9.375) = 2.50$ ft/s **Ans**

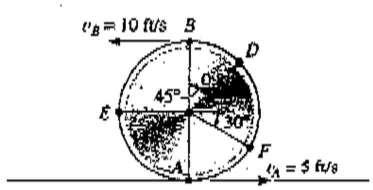
$v_D = 1.006(9.375) = 9.43$ ft/s **Ans**

$\theta = 45^\circ + 10.80^\circ = 55.8^\circ$





**16-97.** Due to slipping, points $A$ and $B$ on the rim of the disk have the velocities shown. Determine the velocities of the center point $C$ and point $E$ at this instant.




$$\frac{1.6 - x}{5} = \frac{x}{10}$$

$5x = 16 - 10x$

$x = 1.06667$ ft

$$\omega = \frac{10}{1.06667} = 9.375 \text{ rad/s}$$

$v_C = \omega(r_{IC-C})$

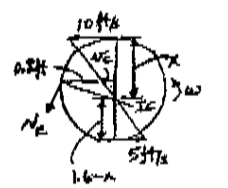
$= 9.375(1.06667 - 0.8)$

$= 2.50$ ft/s **Ans**

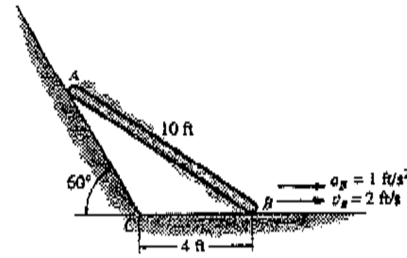
$v_E = \omega(r_{IC-E})$

$= 9.375\sqrt{(0.8)^2 + (0.26667)^2}$

$= 7.91$ ft/s **Ans**



***16-108.** The 10-ft rod slides down the inclined plane, such that when it is at $B$ it has the motion shown. Determine the velocity and acceleration of $A$ at this instant.



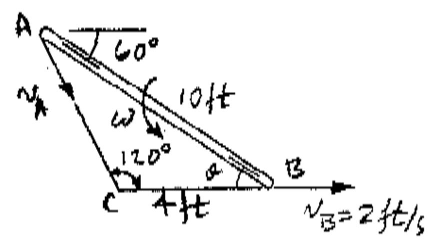

$$(10)^2 = (4)^2 + (AC)^2 - 2(AC)(4)\cos 120°$$

$$(AC)^2 + 4(AC) - 84 = 0$$

Solving for the positive root :

$$AC = 7.381 \text{ ft}$$

$$\frac{\sin\theta}{7.381} = \frac{\sin 120°}{10} \qquad \theta = 39.732°$$




$$\mathbf{v}_A = \mathbf{v}_B + \omega \times \mathbf{r}_{A/B}$$

$$v_A \cos 60°\mathbf{i} - v_A \sin 60°\mathbf{j} = 2\mathbf{i} + \omega\mathbf{k} \times (-10\cos 39.732°\mathbf{i} + 10\sin 39.732°\mathbf{j})$$

$(\overset{+}{\rightarrow})$ $\quad 0.5v_A = 2 - 6.39199\omega$

$(+\uparrow)$ $\quad -0.86603v_A = -7.6904\omega$

Solving :

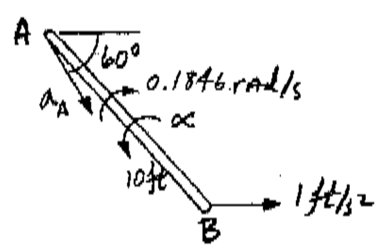
$\omega = 0.1846$ rad/s ↻

$v_A = 1.64$ ft/s ↘ **Ans**

$$\mathbf{a}_A = \mathbf{a}_B + \alpha \times \mathbf{r}_{A/B} - \omega^2 \mathbf{r}_{A/B}$$

$$a_A \cos 60°\mathbf{i} - a_A \sin 60°\mathbf{j} = 1\mathbf{i} + (\alpha\mathbf{k}) \times (-10\cos 39.732°\mathbf{i} + 10\sin 39.732°\mathbf{j})$$

$$- (0.1846)^2(-10\cos 39.732°\mathbf{i} + 10\sin 39.732°\mathbf{j})$$




$(\overset{+}{\rightarrow})$ $\quad 0.5a_A = 1 - 6.3920\alpha + 0.2621$

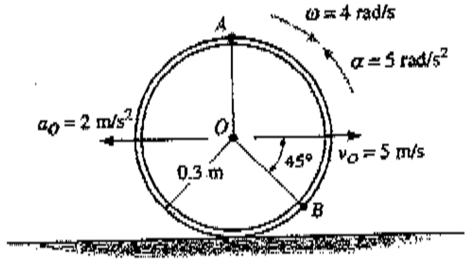
$(+\uparrow)$ $\quad -0.86603a_A = -7.69042\alpha - 0.21791$

Solving :

$a_A = 1.18$ ft/s² ↖ **Ans**

$\alpha = 0.105$ rad/s²

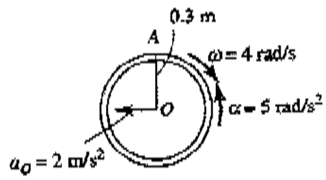
**16-115.** The hoop is cast on the rough surface such that it has an angular velocity $\omega = 4$ rad/s and an angular acceleration $\alpha = 5$ rad/s$^2$. Also, its center has a velocity $v_O = 5$ m/s and a deceleration $a_O = 2$ m/s$^2$. Determine the acceleration of point $A$ at this instant.




$\mathbf{a}_A = \mathbf{a}_O + \mathbf{a}_{A/O}$

$\mathbf{a}_A = \left[\underset{\leftarrow}{2}\right] + \left[\underset{\downarrow}{(4)^2(0.3)}\right] + \left[\underset{\longleftarrow}{5(0.3)}\right]$

$\mathbf{a}_A = \left[\underset{\leftarrow}{3.5}\right] + \left[\underset{\downarrow}{4.8}\right]$




$a_A = 5.94$ m/s$^2$ **Ans**

$\theta = \tan^{-1}\left(\frac{4.8}{3.5}\right) = 53.9°$ **Ans**

Also:

$\mathbf{a}_A = \mathbf{a}_O - \omega^2\mathbf{r}_{A/O} + \alpha \times \mathbf{r}_{A/O}$

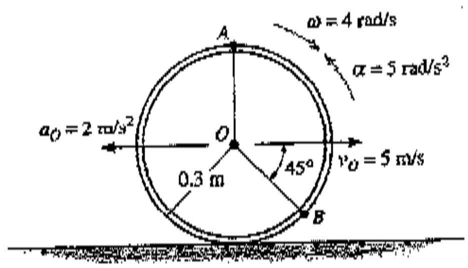
$\mathbf{a}_A = -2\mathbf{i} - (4)^2(0.3\mathbf{j}) + 5\mathbf{k} \times (0.3\mathbf{j})$

$\mathbf{a}_A = \{-3.5\mathbf{i} - 4.8\mathbf{j}\}$ m/s$^2$

$a_A = 5.94$ m/s$^2$ **Ans**

$\theta = \tan^{-1}\left(\frac{4.8}{3.5}\right) = 53.9°$ **Ans**

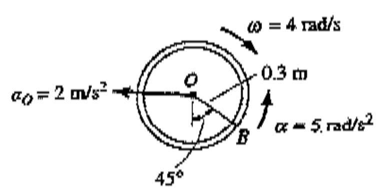
***16-116.** The hoop is cast on the rough surface such that it has an angular velocity $\omega = 4$ rad/s and an angular acceleration $\alpha = 5$ rad/s$^2$. Also, its center has a velocity of $v_O = 5$ m/s and a deceleration $a_O = 2$ m/s$^2$. Determine the acceleration of point $B$ at this instant.




$\mathbf{a}_B = \mathbf{a}_O + \mathbf{a}_{B/O}$

$\mathbf{a}_B = \left[\underset{\leftarrow}{2}\right] + \left[\underset{\swarrow}{5(0.3)}\right] + \left[\underset{\searrow}{(4)^2(0.3)}\right]$

$\mathbf{a}_B = \left[\underset{\leftarrow}{4.333}\right] + \left[\underset{\uparrow}{4.455}\right]$




$a_B = 6.21$ m/s$^2$ **Ans**

$\theta = \tan^{-1}\left(\frac{4.455}{4.333}\right) = 45.8°$ **Ans**

Also:

$\mathbf{a}_B = \mathbf{a}_O + \alpha \times \mathbf{r}_{B/O} - \omega^2\mathbf{r}_{B/O}$

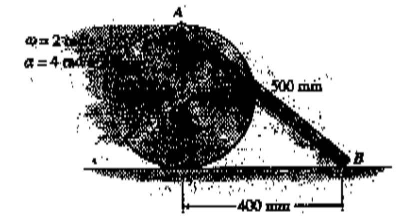
$\mathbf{a}_B = -2\mathbf{i} + 5\mathbf{k} \times (0.3\cos 45°\mathbf{i} - 0.3\sin 45°\mathbf{j}) - (4)^2(0.3\cos 45°\mathbf{i} - 0.3\sin 45°\mathbf{j})$

$\mathbf{a}_B = \{-4.333\mathbf{i} + 4.455\mathbf{j}\}$ m/s$^2$

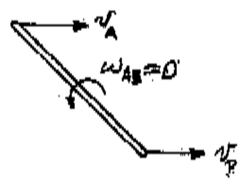
$a_B = 6.21$ m/s$^2$ **Ans**

$\theta = \tan^{-1}\left(\frac{4.455}{4.333}\right) = 45.8°$ **Ans**

**16-126.** The disk rolls without slipping such that it has an angular acceleration of $\alpha = 4\ \text{rad/s}^2$ and angular velocity of $\omega = 2\ \text{rad/s}$ at the instant shown. Determine the accelerations of points $A$ and $B$ on the link and the link's angular acceleration at this instant. Assume point $A$ lies on the periphery of the disk, 150 mm from $C$.




The $IC$ is at $\infty$, so $\omega = 0$.

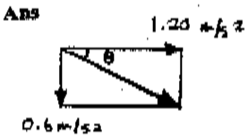


$$\mathbf{a}_A = \mathbf{a}_C + \boldsymbol{\alpha} \times \mathbf{r}_{A/C} - \omega^2 \mathbf{r}_{A/C}$$

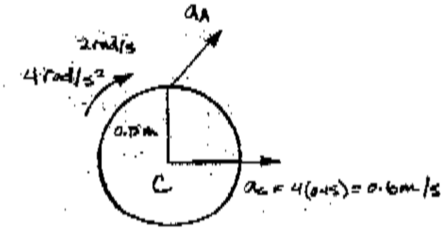
$$\mathbf{a}_A = 0.6\mathbf{i} + (-4\mathbf{k}) \times (0.15\mathbf{j}) - (2)^2(0.15\mathbf{j})$$

$$\mathbf{a}_A = \{1.20\mathbf{i} - 0.6\mathbf{j}\}\ \text{m/s}^2$$

$$a_A = \sqrt{(1.20)^2 + (-0.6)^2} = 1.34\ \text{m/s}^2 \qquad \textbf{Ans}$$



$$\theta = \tan^{-1}\left(\frac{0.6}{1.20}\right) = 26.6^\circ \qquad \textbf{Ans}$$

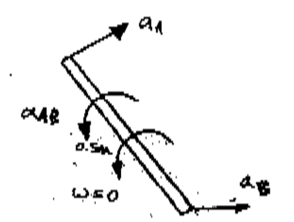


$$\mathbf{a}_B = \mathbf{a}_A + \boldsymbol{\alpha} \times \mathbf{r}_{B/A} - \omega^2 \mathbf{r}_{B/A}$$

$$a_B\mathbf{i} = 1.20\mathbf{i} - 0.6\mathbf{j} + \alpha_{AB}\mathbf{k} \times (0.4\mathbf{i} - 0.3\mathbf{j}) - \mathbf{0}$$

$(\overset{+}{\rightarrow})$ $\quad a_B = 1.20 + 0.3\alpha_{AB}$

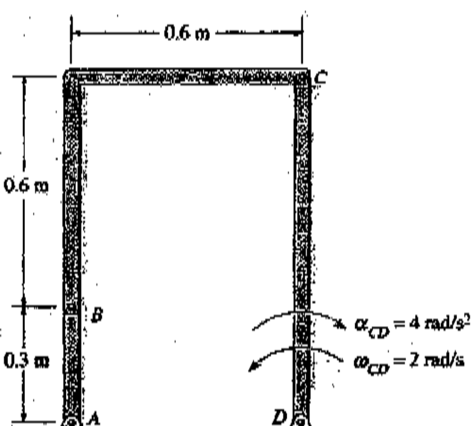
$(+\uparrow)$ $\quad 0 = -0.6 + 0.4\alpha_{AB}$



$\alpha_{AB} = 1.5\ \text{rad/s}^2$ **Ans**

$a_B = 1.65\ \text{m/s}^2 \rightarrow$ **Ans**

**16-127.** Determine the angular acceleration of link $AB$ if link $CD$ has the angular velocity and angular deceleration shown.




$IC$ is at $\infty$, thus

$\omega_{BC} = 0$

$v_B = v_C = (0.9)(2) = 1.8\ \text{m/s}$

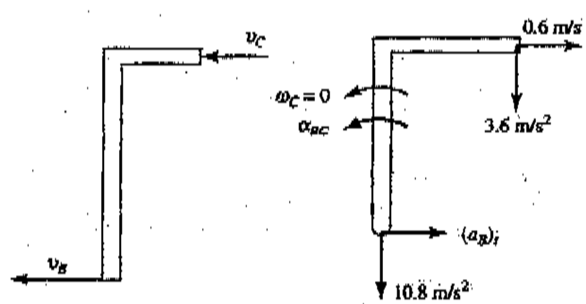
$(a_C)_n = (2)^2(0.9) = 3.6\ \text{m/s}^2 \downarrow$

$(a_C)_t = 4(0.9) = 3.6\ \text{m/s}^2 \rightarrow$

$$(a_B)_n = \frac{(1.8)^2}{0.3} = 10.8\ \text{m/s}^2 \downarrow$$

$$\mathbf{a}_B = \mathbf{a}_C + \boldsymbol{\alpha}_{BC} \times \mathbf{r}_{B/C} - \omega_{BC}^2 \mathbf{r}_{B/C}$$

$$(a_B)_t\mathbf{i} - 10.8\mathbf{j} = 3.6\mathbf{i} - 3.6\mathbf{j} + (\alpha_{BC}\mathbf{k}) \times (-0.6\mathbf{i} - 0.6\mathbf{j}) - \mathbf{0}$$




$(\overset{+}{\rightarrow})$ $\quad (a_B)_t = 3.6 + 0.6\alpha_{BC}$

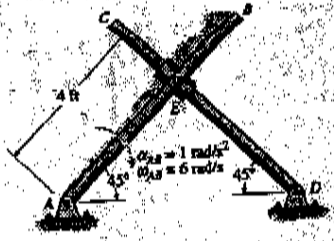
$(+\uparrow)$ $\quad -10.8 = -3.6 - 0.6\alpha_{BC}$

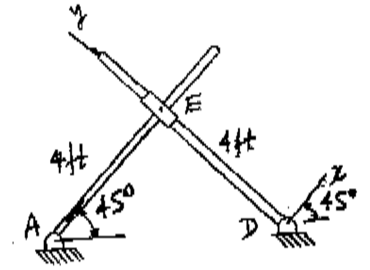
$\alpha_{BC} = 12\ \text{rad/s}^2$

$(a_B)_t = 10.8\ \text{m/s}^2$

$$\alpha_{AB} = \frac{10.8}{0.3} = 36\ \text{rad/s}^2 \qquad \textbf{Ans}$$

**16-133.** The collar $E$ is attached to, and pivots about, rod $AB$ while it slides on rod $CD$. If rod $AB$ has an angular velocity of 6 rad/s and an angular acceleration of 1 rad/s², both acting clockwise, determine the angular velocity and the angular acceleration of rod $CD$ at the instant shown.




Fix axes to $ED$.

$\Omega = \omega_{CD}\mathbf{k}$

$\dot{\Omega} = \alpha_{CD}\mathbf{k}$

$\mathbf{r}_{E/D} = 4\mathbf{j}$

$\mathbf{v}_{E/D} = v_{E/D}\mathbf{j}$

$\mathbf{a}_{E/D} = a_{E/D}\mathbf{j}$

$\mathbf{v}_E = -6(4)\mathbf{j} = -24\mathbf{j}$

$\mathbf{a}_E = -(6)^2(4)\mathbf{i} - 1(4)\mathbf{j} = -144\mathbf{i} - 4\mathbf{j}$

$\mathbf{v}_E = \mathbf{v}_D + \Omega \times \mathbf{r}_{E/D} + (\mathbf{v}_{E/D})_{xyz}$

$-24\mathbf{j} = \mathbf{0} + \omega_{CD}\mathbf{k} \times 4\mathbf{j} + v_{E/D}\mathbf{j}$

$-24\mathbf{j} = -4\omega_{CD}\mathbf{i} + v_{E/D}\mathbf{j}$

Thus,

$\omega_{CD} = 0$ **Ans**

$v_{E/D} = -24$ ft/s

$\mathbf{a}_E = \mathbf{a}_D + \dot{\Omega} \times \mathbf{r}_{E/D} + \Omega \times (\Omega \times \mathbf{r}_{E/D}) + 2\Omega \times (\mathbf{v}_{E/D})_{xyz} + (\mathbf{a}_{E/D})_{xyz}$

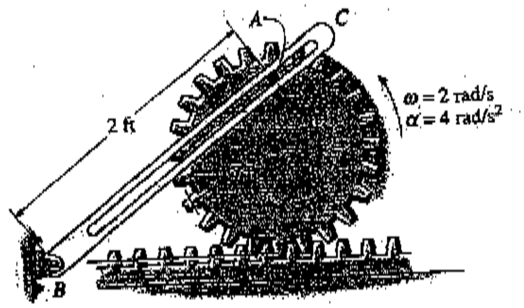
$-144\mathbf{i} - 4\mathbf{j} = \mathbf{0} + \alpha_{CD}\mathbf{k} \times 4\mathbf{j} + \mathbf{0} + \mathbf{0} + a_{E/D}\mathbf{j}$

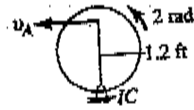
$-144\mathbf{i} - 4\mathbf{j} = -\alpha_{CD}(4)\mathbf{i} + a_{E/D}\mathbf{j}$

$\alpha_{CD} = \frac{144}{4} = 36 \text{ rad/s}^2$ **Ans**

$a_{E/D} = -4 \text{ ft/s}^2$

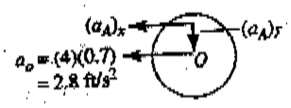
**16-145.** The gear has the angular motion shown. Determine the angular velocity and angular acceleration of the slotted link $BC$ at this instant. The peg at $A$ is fixed to the gear.



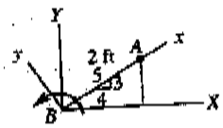

$v_A = (1.2)(2) = 2.4 \text{ ft/s} \leftarrow$

$a_O = 4(0.7) = 2.8 \text{ ft/s}^2$




$\mathbf{a}_A = \mathbf{a}_O + \mathbf{a}_{A/O}$

$\mathbf{a}_A = \underset{\leftarrow}{2.8} + \underset{\leftarrow}{4(0.5)} + \underset{\downarrow}{(2)^2(0.5)}$




$\mathbf{a}_A = \underset{\leftarrow}{4.8} + \underset{\downarrow}{2}$

$\mathbf{v}_A = \mathbf{v}_B + \Omega \times \mathbf{r}_{A/B} + (\mathbf{v}_{A/B})_{xyz}$

$-2.4\mathbf{i} = 0 + (\Omega\mathbf{k}) \times (1.6\mathbf{i} + 1.2\mathbf{j}) + v_{A/B}\left(\frac{4}{5}\right)\mathbf{i} + v_{A/B}\left(\frac{3}{5}\right)\mathbf{j}$

$-2.4\mathbf{i} = 1.6\Omega\mathbf{j} - 1.2\Omega\mathbf{i} + 0.8v_{A/B}\mathbf{i} + 0.6v_{A/B}\mathbf{j}$

$-2.4 = -1.2\Omega + 0.8v_{A/B}$

$0 = 1.6\Omega + 0.6v_{A/B}$

Solving,

$\omega_{BC} = \Omega = 0.720 \text{ rad/s} \circlearrowleft$ **Ans**

$v_{A/B} = -1.92 \text{ ft/s}$

$\mathbf{a}_A = \mathbf{a}_B + \dot{\Omega} \times \mathbf{r}_{A/B} + \Omega \times (\Omega \times \mathbf{r}_{A/B}) + 2\Omega \times (\mathbf{v}_{A/B})_{xyz} + (\mathbf{a}_{A/B})_{xyz}$

$-4.8\mathbf{i} - 2\mathbf{j} = 0 + (\dot{\Omega}\mathbf{k}) \times (1.6\mathbf{i} + 1.2\mathbf{j}) + (0.72\mathbf{k}) \times (0.72\mathbf{k} \times (1.6\mathbf{i} + 1.2\mathbf{j}))$

$+ 2(0.72\mathbf{k}) \times [-(0.8)(1.92)\mathbf{i} - 0.6(1.92)\mathbf{j}] + 0.8a_{B/A}\mathbf{i} + 0.6a_{B/A}\mathbf{j}$

$-4.8\mathbf{i} - 2\mathbf{j} = 1.6\dot{\Omega}\mathbf{j} - 1.2\dot{\Omega}\mathbf{i} - 0.8294\mathbf{i} - 0.6221\mathbf{j} - 2.2118\mathbf{j} + 1.6589\mathbf{i} + 0.8a_{B/A}\mathbf{i} + 0.6a_{B/A}$

$-4.8 = -1.2\dot{\Omega} - 0.8294 + 1.6589 + 0.8a_{B/A}$

$-2 = 1.6\dot{\Omega} - 0.6221 - 2.2118 + 0.6a_{B/A}$

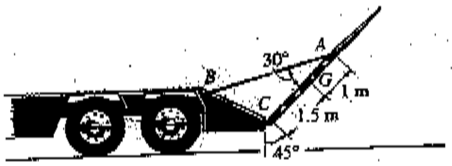
$-4.6913 = -\dot{\Omega} + 0.667a_{B/A}$

$0.5212 = \dot{\Omega} + 0.357a_{B/A}$

$\alpha_{BC} = \dot{\Omega} = 2.02 \text{ rad/s}^2 \circlearrowleft$ **Ans**

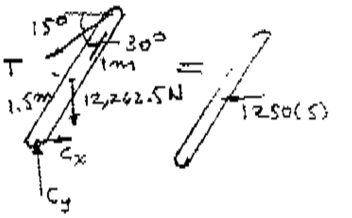
$a_{B/A} = -4.00 \text{ ft/s}^2$

**17-37.** The drop gate at the end of the trailer has a mass of 1.25 Mg and mass center at *G*. If it is supported by the cable *AB* and hinge at *C*, determine the tension in the cable when the truck begins to accelerate at 5 m/s². Also, what are the horizontal and vertical components of reaction at the hinge *C*?




$\circlearrowleft + \Sigma M_C = \Sigma(M_k)_C;\quad T\sin 30°(2.5) - 12\,262.5(1.5\cos 45°) = 1250(5)(1.5\sin 45°)$

$T = 15\,708.4\text{ N} = 15.7\text{ kN}$ **Ans**



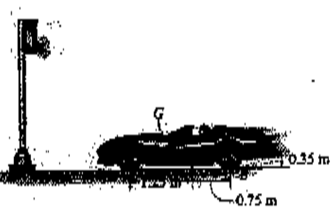

$\overset{+}{\leftarrow}\Sigma F_x = m(a_G)_x;\quad -C_x + 15\,708.4\cos 15° = 1250(5)$

$C_x = 8.92\text{ kN}$ **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y;\quad C_y - 12\,262.5 - 15\,708.4\sin 15° = 0$

$C_y = 16.3\text{ kN}$ **Ans**

**17-38.** The sports car has a mass of 1.5 Mg and a center of mass at *G*. Determine the shortest time it takes for it to reach a speed of 80 km/h, starting from rest, if the engine only drives the rear wheels, whereas the front wheels are free rolling. The coefficient of static friction between the wheels and the road is $\mu_s = 0.2$. Neglect the mass of the wheels for the calculation. If driving power could be supplied to all four wheels, what would be the shortest time for the car to reach a speed of 80 km/h?




$\overset{+}{\leftarrow}\Sigma F_x = m(a_G)_x;\quad 0.2N_A + 0.2N_B = 1500a_G \quad (1)$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A + N_B - 1500(9.81) = 0 \quad (2)$

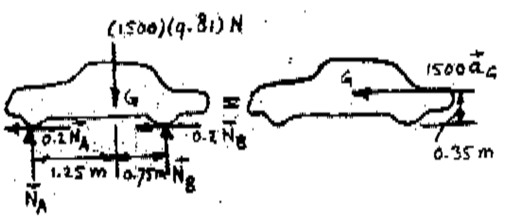
$\circlearrowleft + \Sigma M_G = 0;\quad -N_A(1.25) + N_B(0.75) - (0.2N_A + 0.2N_B)(0.35) = 0 \quad (3)$

For rear – wheel drive :

Set the friction force $0.2N_A = 0$ in Eqs. (1) and (3)

Solving yields :

$N_A = 5.18\text{ kN} > 0$ (OK); $N_B = 9.53\text{ kN}$; $a_G = 1.271\text{ m/s}^2$




Since $v = 80\text{ km/h} = 22.22\text{ m/s}$, then

$(\overset{+}{\leftarrow})\quad v = v_0 + a_G t$

$22.22 = 0 + 1.271t$

$t = 17.5\text{ s}$ **Ans**

For 4 – wheel drive :

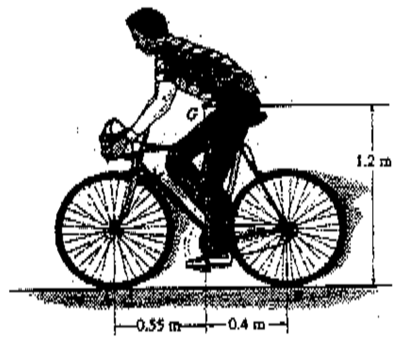
$N_A = 5.00\text{ kN} > 0$ (OK); $N_B = 9.71\text{ kN}$; $a_G = 1.962\text{ m/s}^2$

Since $v_2 = 80\text{ km/h} = 22.22\text{ m/s}$, then

$v_2 = v_1 + a_G t;\quad 22.22 = 0 + 1.962t$

$t = 11.3\text{ s}$ **Ans**

*17-48. The bicycle and rider have a mass of 80 kg with center of mass located at $G$. Determine the minimum coefficient of kinetic friction between the road and the wheels so that the rear wheel $B$ starts to lift off the ground when the rider applies the brakes to the front wheel. Neglect the mass of the wheels.




$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\quad \mu_k N_A = 80 a_G$

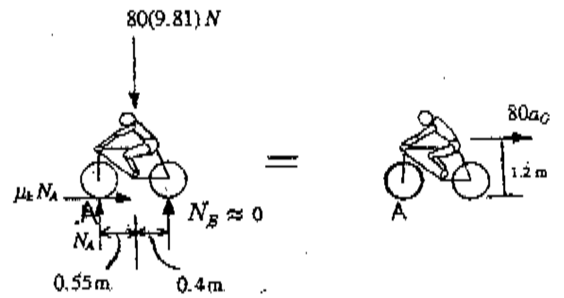
$+\uparrow \Sigma F_y = m(a_G)_y;\quad N_A - 80(9.81) = 0$

$\circlearrowleft + \Sigma M_A = \Sigma (M_k)_A;\quad 80(9.81)(0.55) = 80 a_G (1.2)$

$N_A = 785$ N

$a_G = 4.50$ m/s$^2$

$\mu_k = 0.458$ **Ans**

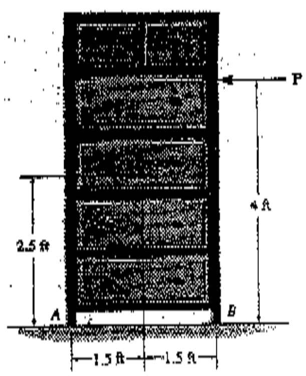



Also :

$\circlearrowleft + \Sigma M_G = 0:\quad N_A(0.55) - \mu_k N_A(1.2) = 0$

$\mu_k = 0.458$ **Ans**

17-49. The dresser has a weight of 80 lb and is pushed along the floor. If the coefficient of static friction at $A$ and $B$ is $\mu_s = 0.3$ and the coefficient of kinetic friction is $\mu_k = 0.2$, determine the smallest horizontal force $P$ needed to cause motion. If this force is increased slightly, determine the acceleration of the dresser. Also, what are the normal reactions at $A$ and $B$ when it begins to move?

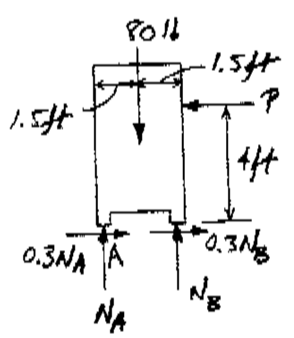



For slipping :

$\xrightarrow{+} \Sigma F_x = 0:\quad -P + 0.3(N_A + N_B) = 0$

$+\uparrow \Sigma F_y = 0;\quad N_A + N_B - 80 = 0$

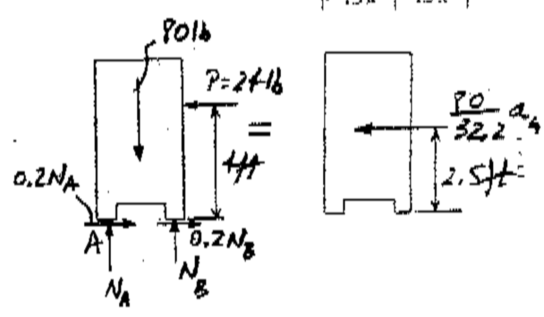
$P = 24$ lb **Ans**




For tipping $N_B = 0$, $N_A = 80$ lb.

$\circlearrowleft + \Sigma M_A = 0;\quad P(4) - 80(1.5) = 0$

$P = 30 \text{ lb} > 24 \text{ lb}$



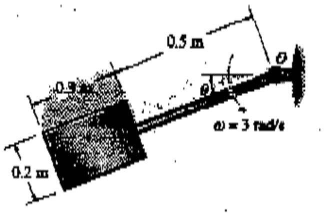

Dresser slips.

$\xleftarrow{+} \Sigma F_x = m(a_G)_x;\quad 24 - 0.2N_A - 0.2N_B = \left(\frac{80}{32.2}\right) a_G$ $\qquad a_G = 3.22$ ft/s$^2$ **Ans**

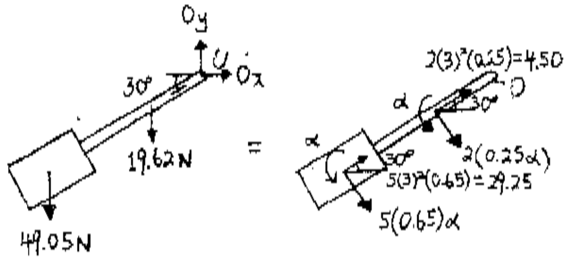
$+\uparrow \Sigma F_y = 0;\quad N_A + N_B - 80 = 0$ $\qquad N_B = 14.7$ lb **Ans**

$\circlearrowleft + \Sigma M_A = \Sigma (M_k)_A;\quad 24(4) + N_B(3) - 80(1.5) = \left(\frac{80}{32.2}\right) a_G (2.5)$ $\qquad N_A = 65.3$ lb **Ans**

**17-58.** The pendulum consists of a uniform 5-kg plate and a 2-kg slender rod. Determine the horizontal and vertical components of reaction that the pin $O$ exerts on the rod at the instant $\theta = 30°$, at which time its angular velocity is $\omega = 3$ rad/s.




$$I_O = \frac{1}{12}(5)\left[(0.3)^2 + (0.2)^2\right] + 5(0.65)^2 + \frac{1}{3}(2)(0.5)^2 = 2.333 \text{ kg}\cdot\text{m}^2$$




$\circlearrowleft + \Sigma M_O = I_O\alpha;$ $\quad 19.62(0.25\cos 30°) + 49.05(0.65\cos 30°) = 2.333\alpha$

$$\alpha = 13.65 \text{ rad/s}^2$$

$\xrightarrow{+} \Sigma F_x = m(a_G)_x;$ $\quad O_x = 4.50\cos 30° + 2(0.25)(13.65)\sin 30° + 29.25\cos 30° + 5(0.65)(13.65)\sin 30°$

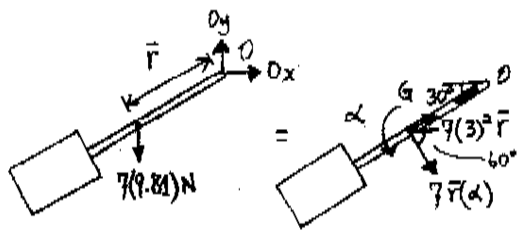
$O_x = 54.8$ N **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y;$ $\quad O_y - 49.05 - 19.62 = (29.25 + 4.50)\sin 30° - [5(0.65)(13.65) + 2(0.25)(13.65)]\cos 30°$

$O_y = 41.2$ N **Ans**

Also, the problem can be solved as follows :

$$\bar{r} = \frac{\Sigma \bar{r} m}{\Sigma m} = \frac{(0.25)(2) + 0.65(5)}{7} = 0.5357 \text{ m}$$




$+\Sigma M_O = I_O\alpha;$ $\quad 7(9.81)(0.5357\cos 30°) = 2.333\alpha$

$$\alpha = 13.65 \text{ rad/s}^2$$

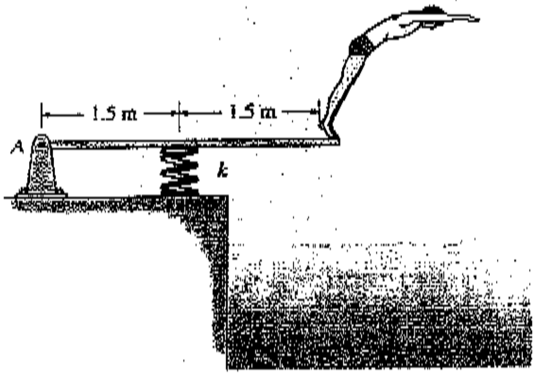
$\xrightarrow{+} \Sigma F_x = m(a_G)_x;$ $\quad O_x = 7(3)^2(0.5357\cos 30°) + 7(0.5357)(13.65)\cos 60°$

$O_x = 54.8$ N **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y;$ $\quad O_y - 7(9.81) = 7(3)^2(0.5357)(\sin 30°) - 7(0.5357)(13.65)\sin 60°$

$O_y = 41.2$ N **Ans**

*17-72. Determine the angular acceleration of the 25-kg diving board and the horizontal and vertical components of reaction at the pin A the instant the man jumps off. Assume that the board is uniform and rigid, and that at the instant he jumps off the spring is compressed a maximum amount of 200 mm, $\omega = 0$, and the board is horizontal. Take $k = 7$ kN/m.




$\circlearrowleft + \sum M_A = I_A\alpha;\quad 1.5(1400 - 245.25) = \left[\frac{1}{3}(25)(3)^2\right]\alpha$

$+\uparrow \sum F_t = m(a_G)_t;\quad 1400 - 245.25 - A_y = 25(1.5\alpha)$

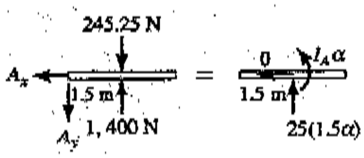
$\overset{+}{\leftarrow} \sum F_n = m(a_G)_n;\quad A_x = 0$

Solving,

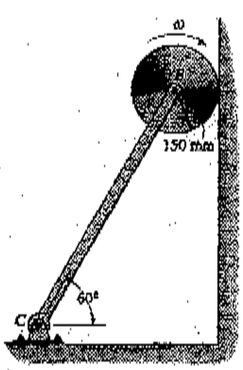
$A_x = 0$ **Ans**

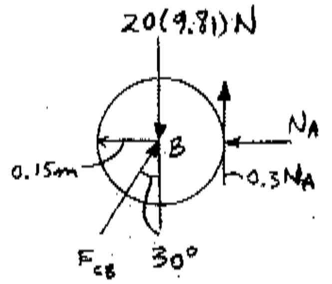
$A_y = 289$ N **Ans**

$\alpha = 23.1$ rad/s$^2$ **Ans**




17-73. The disk has a mass of 20 kg and is originally spinning at the end of the strut with an angular velocity of $\omega = 60$ rad/s. If it is then placed against the wall, for which the coefficient of kinetic friction is $\mu_k = 0.3$, determine the time required for the motion to stop. What is the force in strut $BC$ during this time?




$\overset{+}{\rightarrow} \Sigma F_x = m(a_G)_x;\quad F_{CB}\sin 30° - N_A = 0$

$+\uparrow \Sigma F_y = m(a_G)_y;\quad F_{CB}\cos 30° - 20(9.81) + 0.3N_A = 0$

$\circlearrowleft + \Sigma M_B = I_B\,\alpha;\quad 0.3N_A\,(0.15) = \left[\frac{1}{2}(20)(0.15)^2\right]\alpha$

$N_A = 96.6$ N

$F_{CB} = 193$ N **Ans**

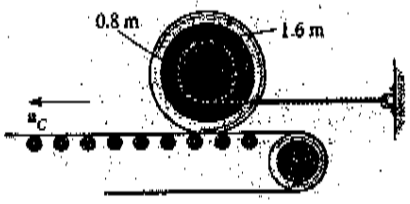
$\alpha = 19.3$ rad/s$^2$

$\circlearrowleft + \omega = \omega_0 + \alpha_c t$

$0 = 60 + (-19.3)t$

$t = 3.11$ s **Ans**

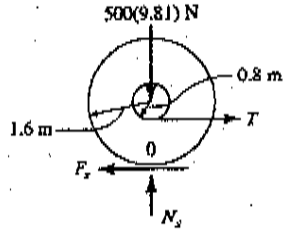
**17-93.** The spool has a mass of 500 kg and a radius of gyration $k_G = 1.30$ m. It rests on the surface of a conveyor belt for which the coefficient of static friction is $\mu_s = 0.5$ and the coefficient of kinetic friction is $\mu_k = 0.4$. If the conveyor accelerates at $a_C = 1$ m/s$^2$, determine the initial tension in the wire and the angular acceleration of the spool. The spool is originally at rest.




$\xrightarrow{+} \sum F_x = m(a_G)_x; \quad -F_s + T = 500a_G$

$+\uparrow \sum F_y = m(a_G)_y; \quad N_s - 500(9.81) = 0$

$\circlearrowleft + \sum M_G = I_G\alpha; \quad F_s(1.6) - T(0.8) = 500(1.30)^2\alpha$

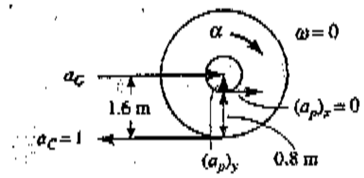



$\mathbf{a}_P = \mathbf{a}_G + \mathbf{a}_{P/G}$

$(a_P)_y\mathbf{j} = a_G\mathbf{i} - 0.8\alpha\mathbf{i}$

$a_G = 0.8\alpha$

$N_s = 4905$ N




Assume no slipping

$\alpha = \dfrac{a_C}{0.8} = \dfrac{1}{0.8} = 1.25$ rad/s   **Ans**

$a_G = 0.8(1.25) = 1$ m/s$^2$

$T = 2.32$ kN   **Ans**

$F_s = 1.82$ kN

Since

$(F_s)_{max} = 0.5(4.905) = 2.45 > 1.82$

(No slipping occurs)

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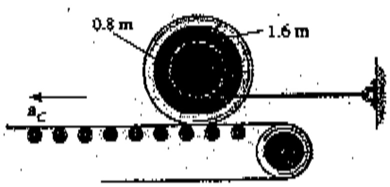
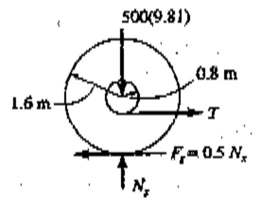
**17-94.** The spool has a mass of 500 kg and a radius of gyration $k_G = 1.30$ m. It rests on the surface of a conveyor belt for which the coefficient of static friction is $\mu_s = 0.5$. Determine the greatest acceleration $a_C$ of the conveyor so that the spool will not slip. Also, what are the initial tension in the wire and the angular acceleration of the spool? The spool is originally at rest.




$\xrightarrow{+} \sum F_x = m(a_G)_x; \quad T - 0.5N_s = 500a_G$

$+\uparrow \sum F_y = m(a_G)_y; \quad N_s - 500(9.81) = 0$

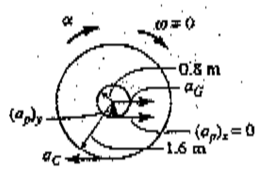
$\circlearrowleft + \sum M_G = I_G\alpha; \quad 0.5N_s(1.6) - T(0.8) = 500(1.30)^2\alpha$




$a_P = a_C + a_{P/G}$

$(a_P)_y\mathbf{j} = a_G\mathbf{i} - 0.8\alpha\mathbf{i}$

$a_G = 0.8\alpha$




Solving;

$N_s = 4905$ N

$T = 3.13$ kN   **Ans**

$\alpha = 1.684$ rad/s   **Ans**

$a_G = 1.347$ m/s$^2$   **Ans**

Since no slipping

$\mathbf{a}_C = \mathbf{a}_G + \mathbf{a}_{C/G}$

$a_C = 1.347\mathbf{i} - (1.684)(1.6)\mathbf{i}$

$a_C = 1.35$ m/s$^2$   **Ans**

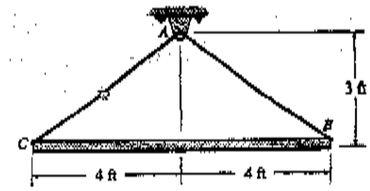
Also,

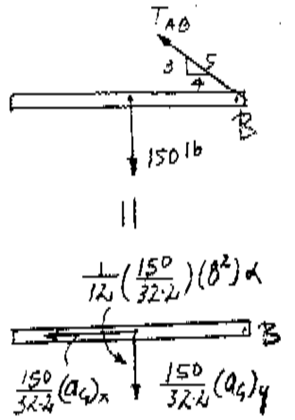
$\circlearrowleft + \sum M_{IC} = I_{IC}\alpha; \quad 0.5N_s(0.8) = [500(1.30)^2 + 500(0.8)^2]\alpha$

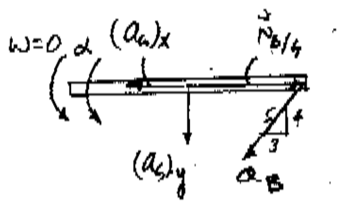
Since $N_s = 4905$ N

$\alpha = 1.684$ rad/s

**17-103.** The slender 150-lb bar is supported by two cords $AB$ and $AC$. If cord $AC$ suddenly breaks, determine the initial angular acceleration of the bar and the tension in cord $AB$.




Equations of motion :

$\overset{+}{\leftarrow} \Sigma F_x = m(a_G)_x$ ; $\quad \frac{4}{5}T_{AB} = \left(\frac{150}{32.2}\right)(a_G)_x \qquad (1)$

$+\uparrow \Sigma F_y = m(a_G)_y$ ; $\quad \frac{3}{5}T_{AB} - 150 = -\left(\frac{150}{32.2}\right)(a_G)_y \qquad (2)$

$\circlearrowleft + \Sigma M_B = \Sigma (M_k)_B$ : $\quad 150(4) = \frac{1}{12}\left(\frac{150}{32.2}\right)(8)^2\alpha + \left(\frac{150}{32.2}\right)(a_G)_y\,(4) \qquad (3)$

Kinematics :

$\mathbf{a}_B = \mathbf{a}_G + (\mathbf{a}_{B/G})_t + (\mathbf{a}_{B/G})_n$

$$\left[\begin{array}{c} a_B \\ \tfrac{5}{3}\!\!\measuredangle^{4} \end{array}\right] = \left[\begin{array}{c}(a_G)_x \\ \leftarrow\end{array}\right] + \left[\begin{array}{c}(a_G)_y \\ \downarrow\end{array}\right] + \left[\begin{array}{c}4\alpha \\ \uparrow\end{array}\right] + [0]$$

$(\overset{+}{\leftarrow}) \qquad \frac{3}{5}a_B = (a_G)_x \qquad (4)$

$(+\downarrow) \qquad \frac{4}{5}a_B = (a_G)_y - 4\alpha \qquad (5)$

Solving Eqs. (1) – (5) yields :

$\alpha = 4.18\ \text{rad/s}^2 \qquad T_{AB} = 43.3\ \text{lb}$ **Ans**

$(a_G)_y = 26.63\ \text{ft/s}^2 \qquad (a_G)_x = 7.43\ \text{ft/s}^2 \qquad a_B = 12.38\ \text{ft/s}^2$