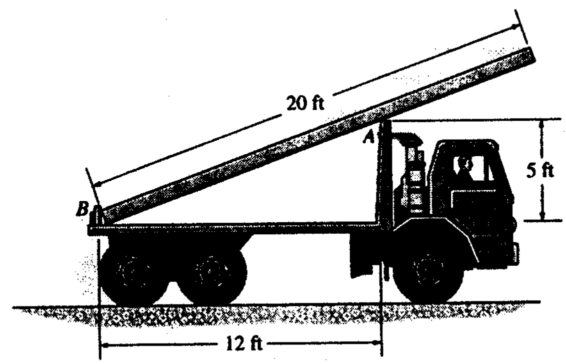
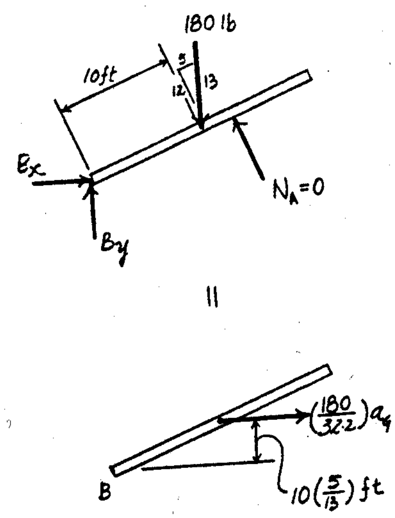
Homework #9 Solutions

17-33. The smooth 180-lb pipe has a length of 20 ft and negligible thickness. It is carried on a truck as shown. Determine the maximum acceleration which the truck can have without causing the normal reaction at A to be zero. Also determine the horizontal and vertical components of force which the truck exerts on the pipe at B.





It is required that $N_A = 0$.

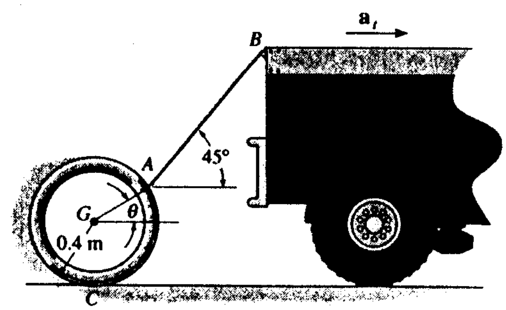
$\circlearrowleft + \Sigma M_B = \Sigma (M_k)_B$: $\quad -180\left(\frac{12}{13}\right)(10) = -\left[\left(\frac{180}{32.2}\right)a_G\right](10)\left(\frac{5}{13}\right)$

$a_G = 77.28 \text{ ft/s}^2 = 77.3 \text{ ft/s}^2$ **Ans**

$\xrightarrow{+} \Sigma F_x = m(a_G)_x$: $\quad B_x = \left(\frac{180}{32.2}\right)(77.28) = 432 \text{ lb}$ **Ans**

$+\uparrow \Sigma F_y = m(a_G)_y$: $\quad B_y - 180 = 0 \quad B_y = 180 \text{ lb}$ **Ans**

17-34. The pipe has a mass of 800 kg and is being towed behind the truck. If the acceleration of the truck is $a_t = 0.5\ \text{m/s}^2$, determine the angle θ and the tension in the cable. The coefficient of kinetic friction between the pipe and the ground is $\mu_k = 0.1$.



$\xrightarrow{+} \Sigma F_x = ma_x$: $\quad -0.1N_C + T\cos 45° = 800(0.5)$

$+\uparrow \Sigma F_y = ma_y$: $\quad N_C - 800(9.81) + T\sin 45° = 0$

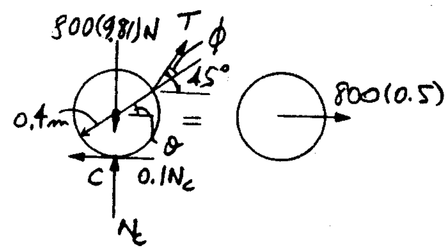
$\circlearrowleft + \Sigma M_G = 0$; $\quad -0.1N_C(0.4) + T\sin\phi(0.4) = 0$

$N_C = 6770.9\ \text{N}$

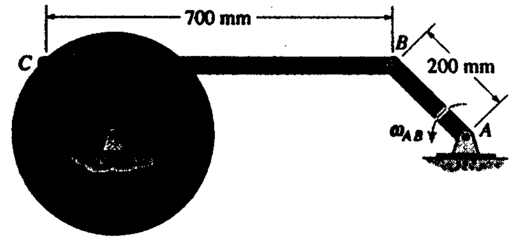
$T = 1523.24\ \text{N} = 1.52\ \text{kN}$ **Ans**

$\sin\phi = \dfrac{0.1(6770.9)}{1523.24} \qquad \phi = 26.39°$

$\theta = 45° - \phi = 18.6°$ **Ans**



17-51. The uniform connecting rod BC has a mass of 3 kg and is pin-connected at its end points. Determine the vertical forces that the pins exert on the ends B and C of the rod at the instant (a) $\theta = 0°$, and (b) $\theta = 90°$. The crank AB is turning with a constant angular velocity $\omega_{AB} = 5$ rads/s.



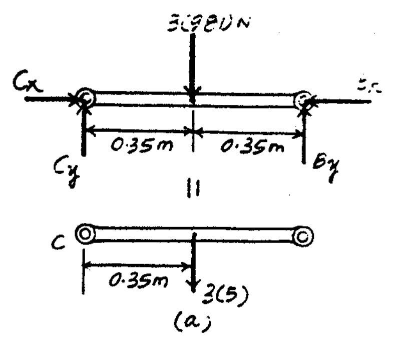
Equation of Motion : Rod BC will always remain in the horizontal and move along a curvilinear path. The acceleration of its mass center G is the same of that for point B and C, i.e: $a_G = a_C = a_B = \omega_{AB}^2 r_{AB} = 5^2(0.2) = 5.00\text{m/s}^2$. When $\theta = 0°$, the acceleration is directed vertically downward. From FBD(a), we have

$$\circlearrowleft + \Sigma M_C = \Sigma (M_k)_C: \quad B_y(0.7) - 3(9.81)(0.35) = -3(5.00)(0.35)$$

$$B_y = 7.215\text{ N} \qquad \textbf{Ans}$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \quad C_y + 7.215 - 3(9.81) = -3(5.00)$$

$$C_y = 7.215\text{ N} \qquad \textbf{Ans}$$



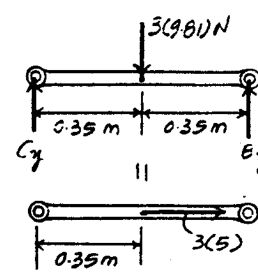
When $\theta = 90°$, the acceleration is directed horizontally to the right. Applying Eq. 17 – 12 to FBD(b), we have

$$\circlearrowleft + \Sigma M_C = \Sigma (M_k)_C: \quad B_y(0.7) - 3(9.81)(0.35) = 0$$

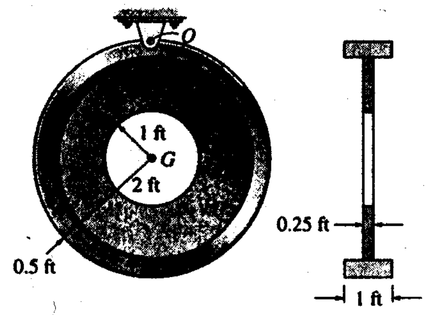
$$B_y = 14.715\text{ N} = 14.7\text{ N} \qquad \textbf{Ans}$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \quad C_y + 14.715 - 3(9.81) = 0$$

$$C_y = 14.7\text{ N} \qquad \textbf{Ans}$$



17-14. Determine the moment of inertia of the assembly about an axis which is perpendicular to the page and passes through point O. The material has a specific weight of $\gamma = 90\ \text{lb/ft}^3$.



$$I_G = \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2.5)^2(1)\right](2.5)^2 - \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2)^2(1)\right](2)^2$$

$$+\frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(2)^2(0.25)\right](2)^2 - \frac{1}{2}\left[\left(\frac{90}{32.2}\right)\pi(1)^2(0.25)\right](1)^2$$

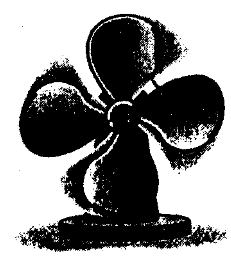
$$= 117.72\ \text{slug}\cdot\text{ft}^2$$

$$I_O = I_G + md^2$$

$$m = \left(\frac{90}{32.2}\right)\pi(2^2 - 1^2)(0.25) + \left(\frac{90}{32.2}\right)\pi(2.5^2 - 2^2)(1) = 26.343\ \text{slug}$$

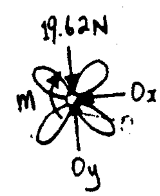
$I_O = 117.72 + 26.343(2.5)^2 = 282\ \text{slug}\cdot\text{ft}^2$ **Ans**

17-55. The fan blade has a mass of 2 kg and a moment of inertia $I_O = 0.18\ \text{kg}\cdot\text{m}^2$ about an axis passing through its center O. If it is subjected to a moment of $M = 3(1 - e^{-0.2t})\ \text{N}\cdot\text{m}$, where t is in seconds, determine its angular velocity when $t = 4$ s starting from rest.



$\circlearrowleft + \Sigma M_O = I_O\alpha;\quad 3\left(1 - e^{-0.2t}\right) = 0.18\alpha$

$$\alpha = 16.67\left(1 - e^{-0.2t}\right)$$



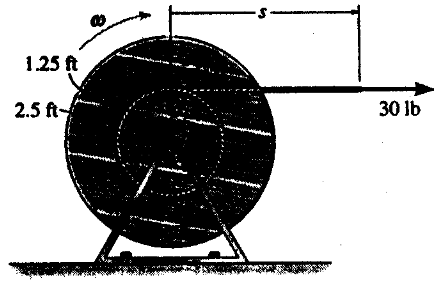
$$d\omega = \alpha\, dt$$

$$\int_0^\omega d\omega = \int_0^4 16.67\left(1 - e^{-0.2t}\right) dt$$

$$\omega = 16.67\left[t + \frac{1}{0.2}e^{-0.2t}\right]_0^4$$

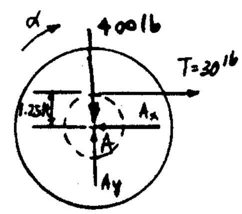
$\omega = 20.8\ \text{rad/s}$ **Ans**

17-58. A cord is wrapped around the inner core of a spool. If the cord is pulled with a constant tension of 30 lb and the spool is originally at rest, determine the spool's angular velocity when $s = 8$ ft of cord has unwound. Neglect the weight of the 8-ft portion of cord. The spool and the entire cord have a total weight of 400 lb, and the radius of gyration about the axle A is $k_A = 1.30$ ft.



$I_A = mk_A^2 = \left(\frac{400}{32.2}\right)(1.30)^2 = 20.99 \text{ slug} \cdot \text{ft}^2$

$\circlearrowright + \Sigma M_A = I_A\,\alpha; \quad 30(1.25) = 20.99(\alpha) \quad \alpha = 1.786 \text{ rad/s}^2$



The angular displacement is $\theta = \frac{s}{r} = \frac{8}{1.25} = 6.4$ rad.

$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$

$\omega^2 = 0 + 2(1.786)(6.4 - 0)$

$\omega = 4.78$ rad/s **Ans**