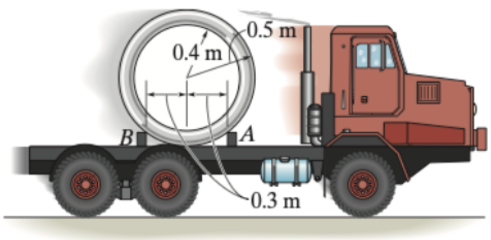
***17–32.**

The pipe has a mass $M$ and is held in place on the truck bed using the two boards $A$ and $B$. Determine the acceleration of the truck so that the pipe begins to lose contact at $A$ and the bed of the truck and starts to pivot about $B$. Assume board $B$ will not slip on the bed of the truck, and the pipe is smooth. Also, what force does board $B$ exert on the pipe during the acceleration?




## SOLUTION

Units Used: $\quad kN = 10^3\ N$

Given:

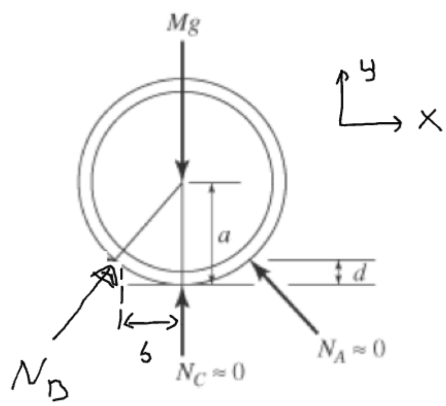
$M = 460\ kg$

$a = 0.5\ m$

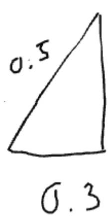
$b = 0.3\ m$

$c = 0.4\ m$

$g = 9.81\ m/s^2$




orientation of $N_B$:




$\sqrt{0.5^2 - 0.3^2} = 0.4$

Moving in translation:

$\Sigma F_x = \frac{0.3}{0.5} N_B - \frac{0.3}{0.5} N_A = m a_x$ | $\Sigma F_y = \frac{0.4}{0.5} N_B + \frac{0.4}{0.5} N_A + N_c - mg = 0$

when contact is loss, $N_A = N_c = 0$, then

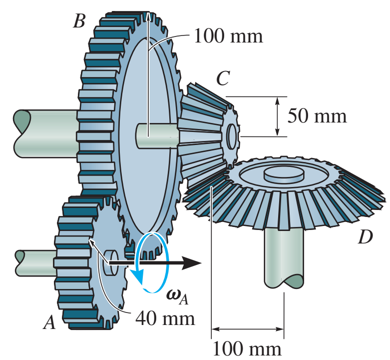
From $\Sigma F_y$: $\frac{0.4}{0.5} N_B - mg = 0 \Rightarrow \underline{N_B = 5640\ N}$

From $\Sigma F_x$: $\frac{0.3}{0.5} N_B = m a_x \Rightarrow \underline{a_x = 7.36\ m/s^2}$

**Ans:**
$a_t = 7.36\ m/s^2$
$N_B = 5.64\ kN$

**16–23.**

If the motor turns gear $A$ with an angular acceleration of $\alpha_A = 3\ \text{rad/s}^2$ when the angular velocity is $\omega_A = 60\ \text{rad/s}$, determine the angular acceleration and angular velocity of gear $D$.




## SOLUTION

***Angular Motion:*** The angular velocity and acceleration of gear $B$ must be determined first. Here, $\omega_A r_A = \omega_B r_B$ and $\alpha_A r_A = \alpha_B r_B$. Then,

$$\omega_B = \frac{r_A}{r_B}\omega_A = \left(\frac{40}{100}\right)(60) = 24.0\ \text{rad/s}$$

$$\alpha_B = \frac{r_A}{r_B}\alpha_A = \left(\frac{40}{100}\right)(3) = 1.20\ \text{rad/s}^2$$

Since gear $C$ is attached to gear $B$, then $\omega_C = \omega_B = 24.0\ \text{rad/s}$ and $\alpha_C = \alpha_B = 1.20\ \text{rad/s}^2$. Realizing that $\omega_C r_C = \omega_D r_D$ and $\alpha_C r_C = \alpha_D r_D$, then

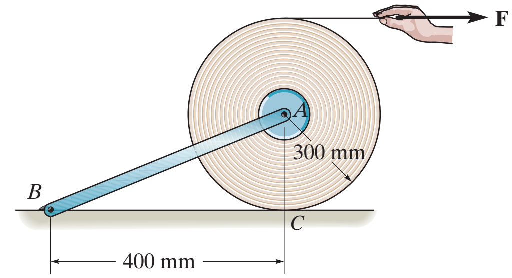
$$\omega_D = \frac{r_C}{r_D}\omega_C = \left(\frac{50}{100}\right)(24.0) = 12.0\ \text{rad/s} \qquad \textbf{Ans.}$$

$$\alpha_D = \frac{r_C}{r_D}\alpha_C = \left(\frac{50}{100}\right)(1.20) = 0.600\ \text{rad/s}^2 \qquad \textbf{Ans.}$$

**Ans:**
$\omega_D = 12.0\ \text{rad/s}$
$\alpha_D = 0.600\ \text{rad/s}^2$

***17–80.**

The 20-kg roll of paper has a radius of gyration $k_A = 120$ mm about an axis passing through point $A$. It is pin supported at both ends by two brackets $AB$. The roll rests on the floor, for which the coefficient of kinetic friction is $\mu_k = 0.2$. If a horizontal force $F = 60$ N is applied to the end of the paper, determine the initial angular acceleration of the roll as the paper unrolls.




## SOLUTION

**Equations of Motion.** The mass moment of inertia of the paper roll about $A$ is $I_A = mk_A^2 = 20(0.12^2) = 0.288\ \text{kg}\cdot\text{m}^2$. Since it is required to slip at $C$, the friction is $F_f = \mu_k N = 0.2$ N. Referring to the FBD of the paper roll, Fig. $a$

$$\overset{+}{\rightarrow} \Sigma F_x = m(a_G)_x; \qquad 0.2\,\text{N} - F_{AB}\left(\frac{4}{5}\right) + 60 = 20(0) \qquad \textbf{(1)}$$

$$+\uparrow \Sigma F_y = m(a_G)_y; \qquad \text{N} - F_{AB}\left(\frac{3}{5}\right) - 20(9.81) = 20(0) \qquad \textbf{(2)}$$

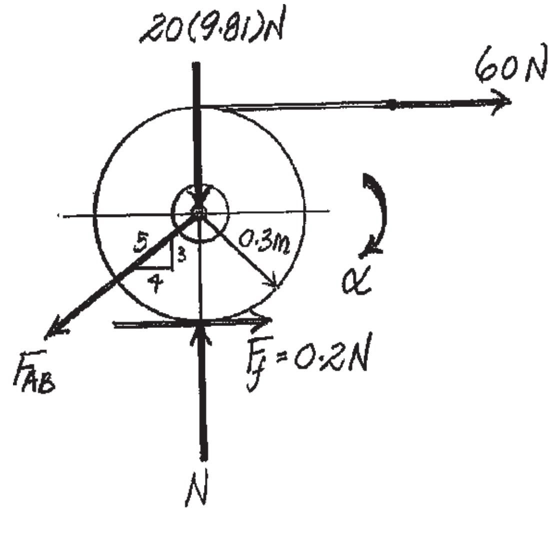
Solving Eqs. (1) and (2)

$$F_{AB} = 145.94\ \text{N} \qquad \text{N} = 283.76\ \text{N}$$

Subsequently

$$\circlearrowleft + \Sigma M_A = I_A\alpha; \qquad 0.2(283.76)(0.3) - 60(0.3) = 0.288(-\alpha)$$

$$\alpha = 3.3824\ \text{rad/s}^2 = 3.38\ \text{rad/s}^2 \qquad \textbf{Ans.}$$

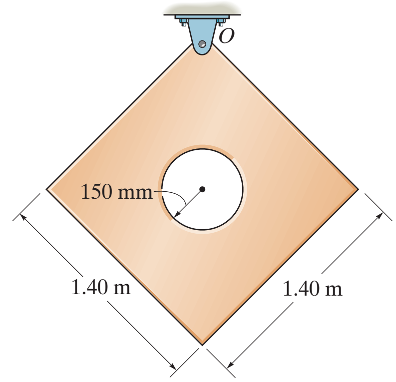



(a)

**Ans:**
$\alpha = 3.38\ \text{rad/s}^2$

**17–18.**

Determine the moment of inertia about an axis perpendicular to the page and passing through the pin at $O$. The thin plate has a hole in its center. Its thickness is 50 mm, and the material has a density $\rho = 50\ \text{kg/m}^3$.




## SOLUTION

$$I_G = \frac{1}{12}\left[50(1.4)(1.4)(0.05)\right]\left[(1.4)^2 + (1.4)^2\right] - \frac{1}{2}\left[50(\pi)(0.15)^2(0.05)\right](0.15)^2$$

$$= 1.5987\ \text{kg}\cdot\text{m}^2$$

$$I_O = I_G + md^2$$

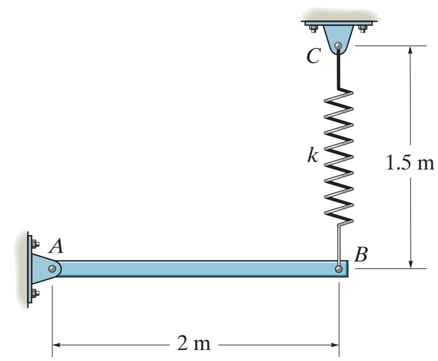
$$m = 50(1.4)(1.4)(0.05) - 50(\pi)(0.15)^2(0.05) = 4.7233\ \text{kg}$$

$$I_O = 1.5987 + 4.7233(1.4 \sin 45°)^2 = 6.23\ \text{kg}\cdot\text{m}^2$$ **Ans.**

**Ans:**
$I_O = 6.23\ \text{kg}\cdot\text{m}^2$

***18–56.**

The slender 6-kg bar $AB$ is horizontal and at rest and the spring is unstretched. Determine the angular velocity of the bar when it has rotated clockwise 45° after being released. The spring has a stiffness of $k = 12$ N/m.




## SOLUTION

***Kinetic Energy.*** The mass moment of inertia of the bar about $A$ is $I_A = \frac{1}{12}(6)(2^2) + 6(1^2) = 8.00\ \text{kg}\cdot\text{m}^2$. Then

$$T = \frac{1}{2} I_A\,\omega^2 = \frac{1}{2}(8.00)\,\omega^2 = 4.00\,\omega^2$$

Since the bar is at rest initially, $T_1 = 0$.

***Potential Energy.*** with reference to the datum set in Fig. $a$, the gravitational potential energies of the bar when it is at positions ① and ② are

$$(V_g)_1 = mgy_1 = 0$$

$$(V_g)_2 = mgy_2 = 6(9.81)(-1 \sin 45°) = -41.62\ \text{J}$$

From the geometry shown in Fig. $a$,

$$a = \sqrt{2^2 + 1.5^2} = 2.5\ \text{m} \qquad \phi = \tan^{-1}\left(\frac{1.5}{2}\right) = 36.87°$$

Then, using cosine law,

$$l = \sqrt{2.5^2 + 2^2 - 2(2.5)(2)\cos(45° + 36.87°)} = 2.9725\ \text{m}$$

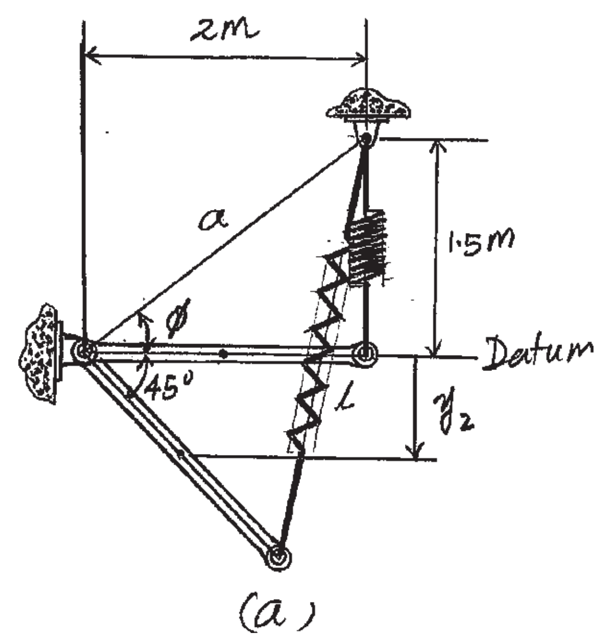
Thus, the stretch of the spring when the bar is at position ② is

$$x_2 = 2.9725 - 1.5 = 1.4725\ \text{m}$$

Thus, the initial and final elastic potential energies of the spring are

$$(V_e)_1 = \frac{1}{2}kx_1^2 = 0$$

$$(V_e)_2 = \frac{1}{2}(12)(1.4725^2) = 13.01\ \text{J}$$




(a)

***Conservation of Energy.***

$$T_1 + V_1 = T_2 + V_2$$

$$0 + (0 + 0) = 4.00\,\omega^2 + (-41.62) + 13.01$$

$$\omega = 2.6744\ \text{rad/s} = 2.67\ \text{rad/s}$$ **Ans.**

**Ans:**
$\omega = 2.67$ rad/s