16–58.

If the block at C is moving downward at 4 ft/s, determine the angular velocity of bar AB at the instant shown.

**SOLUTION**

**Kinematic Diagram:** Since link AB is rotating about fixed point A, then \( v_B \) is always directed perpendicular to link AB and its magnitude is \( v_B = \omega_{AB} r_{AB} = 2\omega_{AB} \). At the instant shown, \( v_B \) is directed towards the negative y axis. Also, block C is moving downward vertically due to the constraint of the guide. Then \( v_C \) is directed toward negative y axis.

**Velocity Equation:** Here, \( r_{C/A} = [3 \cos 30^\circ i + 3 \sin 30^\circ j] \) ft. Applying Eq. 16–16, we have

\[
\mathbf{v}_C = \mathbf{v}_B + \omega_{BC} \times r_{C/B}
\]

\[
-4j = -2\omega_{AB} j + (\omega_{RC} k) \times (2.598i + 1.50 j)
\]

Equating i and j components gives

\[
0 = -1.50\omega_{RC} \quad \omega_{RC} = 0
\]

\[
-4 = 2.598(0) - 2\omega_{AB} \quad \omega_{AB} = 2.00 \text{ rad/s}
\]

**Ans.**
If the flywheel is rotating with an angular velocity of \( \omega_A = 6 \text{ rad/s} \), determine the angular velocity of rod \( BC \) at the instant shown.

**SOLUTION**

**Rotation About a Fixed Axis:** Flywheel \( A \) and rod \( CD \) rotate about fixed axes, Figs. \( a \) and \( b \). Thus, the velocity of points \( B \) and \( C \) can be determined from

\[
v_B = \omega_A \times r_B = (-6\mathbf{k}) \times (-0.3\mathbf{j}) = [-1.8\mathbf{i}] \text{ m/s}
\]

\[
v_C = \omega_{CD} \times r_C = (\omega_{CD}\mathbf{k}) \times (0.6 \cos 60^\circ \mathbf{i} + 0.6 \sin 60^\circ \mathbf{j})
\]

\[
= -0.5196\omega_{CD}\mathbf{i} + 0.3\omega_{CD}\mathbf{j}
\]

**General Plane Motion:** By referring to the kinematic diagram of link \( BC \) shown in Fig. \( c \) and applying the relative velocity equation, we have

\[
v_B = v_C + \omega_{BC} \times r_{BC}
\]

\[-1.8\mathbf{i} = -0.5196\omega_{CD}\mathbf{i} + 0.3\omega_{CD}\mathbf{j} + (\omega_{BC}\mathbf{k}) \times (-1.5\mathbf{i})
\]

\[-1.8\mathbf{i} = -0.5196\omega_{CD}\mathbf{i} + 0.3\omega_{CD}\mathbf{j} - 1.5\omega_{BC}\mathbf{j}
\]

Equating the \( \mathbf{i} \) and \( \mathbf{j} \) components

\[-1.8 = -0.5196\omega_{CD}
\]

\[0 = 0.3\omega_{CD} - 1.5\omega_{BC}
\]

Solving,

\[\omega_{CD} = 3.46 \text{ rad/s}
\]

\[\omega_{BC} = 0.693 \text{ rad/s}
\]

**Ans.**
16–111.

Crank $AB$ rotates with the angular velocity and angular acceleration shown. Determine the acceleration of the slider block $C$ at the instant shown.

**SOLUTION**

**Angular Velocity:** Since crank $AB$ rotates about a fixed axis, Fig. $a$,

$$v_B = \omega_{AB} r_B = 4(0.4) = 1.6 \text{ m/s}$$

The location of the $IC$ for link $BC$ is indicated in Fig. $b$. From the geometry of this figure,

$$r_{B/IC} = 0.4 \text{ m}$$

Then

$$\omega_{BC} = \frac{v_B}{r_{B/IC}} = \frac{1.6}{0.4} = 4 \text{ rad/s}$$

**Acceleration and Angular Acceleration:** Since crank $AB$ rotates about a fixed axis, Fig. $a$

$$a_B = \alpha_{AB} \times r_B - \omega_{AB}^2 r_B$$

$$= (-2\mathbf{k}) \times (0.4 \cos 30^\circ \mathbf{i} + 0.4 \sin 30^\circ \mathbf{j}) - 4^2(0.4 \cos 30^\circ \mathbf{i} + 0.4 \sin 30^\circ \mathbf{j})$$

$$= [-5.143 \mathbf{i} - 3.893 \mathbf{j}] \text{ m/s}^2$$

Using this result and applying the relative acceleration equation by referring to Fig. $c$,

$$a_C = a_B + \alpha_{BC} \times r_{C/B} - \omega_{BC}^2 r_{C/B}$$

$$a_c \mathbf{i} = (-5.143 \mathbf{i} - 3.893 \mathbf{j}) + (\alpha_{BC} \mathbf{k}) \times (0.4 \cos 30^\circ \mathbf{i} - 0.4 \sin 30^\circ \mathbf{j}) - 4^2(0.4 \cos 30^\circ \mathbf{i} - 0.4 \sin 30^\circ \mathbf{j})$$

$$a_c \mathbf{i} = (0.2\alpha_{BC} - 10.69) \mathbf{i} + (0.3464\alpha_{BC} - 0.6928) \mathbf{j}$$

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

$$a_c = 0.2\alpha_{BC} - 10.69$$

$$0 = 0.3464\alpha_{BC} - 0.6928$$

Solving Eqs. (1) and (2),

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

$$a_C = -10.29 \text{ m/s}^2 = 10.3 \text{ m/s}^2$$

**Ans.**
The wheel rolls without slipping such that at the instant shown it has an angular velocity \( \omega \) and angular acceleration \( \alpha \). Determine the velocity and acceleration of point \( B \) on the rod at this instant.

**SOLUTION**

\[
\vec{v}_B = \vec{v}_A + \vec{v}_{B/A(Pin)}
\]

\[
\vec{v}_B = \frac{1}{\sqrt{2}} \left( \omega \sqrt{2a} + 2\omega \left( \frac{a}{2} \right) \right)
\]

\[
+ \uparrow O = \frac{1}{\sqrt{2}} \left( \omega \sqrt{2a} + 2\omega \left( \frac{\sqrt{3}}{2} \right) \right)
\]

\[
\omega' = \omega \sqrt{3}
\]

\[
v_B = 1.58 \omega a
\]

\[
\vec{a}_A = \vec{a}_O + \vec{a}_{AO(Pin)}
\]

\[
(a_A)_x = (a_A)_y = \alpha a + \alpha(a) + \omega^2 a
\]

\[
\omega^2 = \frac{\omega}{\sqrt{3}}
\]

\[
v_B = 1.58 \omega a
\]

\[
\vec{a}_B = \vec{a}_A + \vec{a}_{B/A(Pin)}
\]

\[
a_B = \alpha a - \omega^2 a + 2a(a') \left( \frac{1}{2} \right) - 2a \left( \frac{\omega}{\sqrt{3}} \right)^2 \left( \frac{1}{2} \right)
\]

\[
O = -\alpha a + 2a(\omega) \left( \frac{2}{\sqrt{3}} \right) + 2a \left( \frac{\omega}{\sqrt{3}} \right)^2 \left( \frac{1}{2} \right)
\]

\[
\alpha' = 0.577\alpha - 0.1925\omega^2
\]

\[
a_B = 1.58\alpha a - 1.77\omega^2 a
\]
The trailer with its load has a mass of 150 kg and a center of mass at $G$. If it is subjected to a horizontal force of $P = 600$ N, determine the trailer’s acceleration and the normal force on the pair of wheels at $A$ and at $B$. The wheels are free to roll and have negligible mass.

SOLUTION

Equations of Motion: Writing the force equation of motion along the $x$ axis,

$$\sum F_x = m(a_G)_x; \quad 600 = 150a \quad \Rightarrow \quad a = 4 \text{ m/s}^2 \quad \text{Ans.}$$

Using this result to write the moment equation about point $A$,

$$\zeta + \sum M_A = (M_k)_A; \quad 150(9.81)(1.25) - 600(0.5) - N_B(2) = -150(4)(1.25)$$

$$N_B = 1144.69 \text{ N} = 1.14 \text{ kN \quad \text{Ans.}}$$

Using this result to write the force equation of motion along the $y$ axis,

$$\sum F_y = m(a_G)_y; \quad N_A + 1144.69 - 150(9.81) = 150(0)$$

$$N_A = 326.81 \text{ N} = 327 \text{ N \quad \text{Ans.}}$$
The uniform bar of mass \( m \) is pin connected to the collar, which slides along the smooth horizontal rod. If the collar is given a constant acceleration of \( \mathbf{a} \), determine the bar's inclination angle \( \theta \). Neglect the collar's mass.

**SOLUTION**

*Equations of Motion:* Writing the moment equation of motion about point \( A \),

\[
\sum M_A = (M_k)_A; \quad mg \sin \theta \left( \frac{L}{2} \right) = ma \cos \theta \left( \frac{L}{2} \right)
\]

\[
\theta = \tan^{-1}\left( \frac{a}{g} \right)
\]

Ans.
Determine the acceleration of the 150-lb cabinet and the normal reaction under the legs A and B if $P = 35$ lb. The coefficients of static and kinetic friction between the cabinet and the plane are $\mu_s = 0.2$ and $\mu_k = 0.15$, respectively. The cabinet’s center of gravity is located at $G$.

**SOLUTION**

**Equations of Equilibrium:** The free-body diagram of the cabinet under the static condition is shown in Fig. a, where $P$ is the unknown minimum force needed to move the cabinet. We will assume that the cabinet slides before it tips. Then, $F_A = \mu_s N_A = 0.2 N_A$ and $F_B = \mu_k N_B = 0.2 N_B$.

$$\sum F_x = 0; \quad P - 0.2 N_A - 0.2 N_B = 0 \quad (1)$$
$$\sum F_y = 0; \quad N_A + N_B - 150 = 0 \quad (2)$$
$$\sum M_A = 0; \quad N_B(2) - 150(1) - P(4) = 0 \quad (3)$$

Solving Eqs. (1), (2), and (3) yields

$$P = 30 \text{ lb} \quad N_A = 15 \text{ lb} \quad N_B = 135 \text{ lb}$$

Since $P < 35$ lb and $N_A$ is positive, the cabinet will slide.

**Equations of Motion:** Since the cabinet is in motion, $F_A = \mu_k N_A = 0.15 N_A$ and $F_B = \mu_k N_B = 0.15 N_B$. Referring to the free-body diagram of the cabinet shown in Fig. b,

$$\sum F_x = m(a_G) \quad 35 - 0.15 N_A - 0.15 N_B = \left( \frac{150}{32.2} \right) a \quad (4)$$
$$\sum F_y = m(a_G) \quad N_A + N_B - 150 = 0 \quad (5)$$
$$\sum M_G = 0; \quad N_B(2) - 0.15 N_B(3.5) - 0.15 N_A(3.5) - N_A(1) - 35(0.5) = 0 \quad (6)$$

Solving Eqs. (4), (5), and (6) yields

$$a = 2.68 \text{ ft/s}^2 \quad \text{Ans.}$$
$$N_A = 26.9 \text{ lb} \quad N_B = 123 \text{ lb} \quad \text{Ans.}$$