Problem 16.13 (Page 314)

A motor gives disk A an angular acceleration of \( \alpha_A = 0.6 \, t^2 + 0.75 \) (rad/sec\(^2\)), where \( t \) is in seconds. If the initial angular velocity of the disk is \( \omega_0 = 6 \) rad/sec, determine the magnitudes of the velocity and acceleration of block B when \( t = 2 \) seconds.

\[
d\omega = \alpha \, dt
\]

\[
\int_d^{\omega} \, d\omega = \int_0^2 \left(0.6 \, t^2 + 0.75\right) \, dt
\]

\[
\omega - 6 = \left. 0.6 \, t^3 + 0.75 \, t \right|_0^2
\]

\[
\omega = 9.10 \text{ rad/sec}
\]

\[
V_B = r \omega = 0.15 (9.10) = 1.37 \text{ m/sec}
\]

\[
Q_{\text{eq}} = a_t = r \alpha = 0.15 \left[0.6 (2)^2 + 0.75\right]
\]

\[
= 0.472 \text{ m/s}^2
\]
Problem 16.18 (Page 315)

Starting from rest when $s = 0$, pulley $A$ is given an angular acceleration $\alpha = 6 \theta^2$ (rad/sec$^2$), where $\theta$ is in radians. Determine the speed of block $B$ when it has risen $s = 6$ meters. The pulley has an inner hub $D$ which is fixed to $C$ and turns with it.

$$\alpha_A = 6\theta_A = \omega \frac{d\omega}{d\theta_A}$$

$$\int_0^{\theta_A} 6\theta_A d\theta_A = \int_0^\omega \omega_A d\omega_A$$

$$\omega_A = 587.88 \text{ rad/sec}$$

$$r_A \omega_A = r_C \omega_C$$

$$\omega_C = 195.96 \text{ rad/sec}$$

$$v_B = r_D \omega_C = 0.075(195.96)$$

$$= 14.7 \text{ m/sec}$$
Problem 16-38 (Page 324)

The crankshaft AB shown is rotating at a constant angular velocity of \( \omega = 150 \text{ rad/sec} \). Determine the velocity of the piston P at the instant \( \theta = 30^\circ \).

**Vector Method:**

\[
\bar{V}_p = \bar{V}_B + \bar{V}_{p/B}
\]

\[
\bar{V}_B = 0.2(150) = 30 \text{ ft/s}
\]

\[
x = 0.2 \cos 30^\circ + \sqrt{0.75^2 - (0.2 \sin 30^\circ)^2} = 0.9165
\]

\[
\bar{V}_p = 30(-\cos 60^\circ \hat{i} + \sin 60^\circ \hat{j}) + 0.75 \omega_p (\sin \phi \hat{i} + \cos \phi \hat{j})
\]

From Law of Sines:

\[
\frac{0.2}{\sin \phi} = \frac{0.75}{\sin 30^\circ}
\]

\[
\phi = \sin^{-1} 0.133 = 7.66^\circ
\]

\[
x: \quad \bar{V}_p = -30 \cos 60^\circ + 0.75 \omega_p \sin 7.66^\circ
\]

\[
y: \quad 0 = 30 \sin 60^\circ + 0.75 \omega_p \cos 7.66^\circ
\]

\[
\omega_p = -34.95 \text{ r/s} \text{ or } 35.95 \text{ r/s}
\]

\[
\bar{V}_p = -18.5 \text{ ft/s} \text{ or } 18.5 \text{ ft/s}
\]
Problem 16-38 (Page 324)

The crankshaft AB shown is rotating at a constant angular velocity of \( \omega = 150 \text{ rad/sec} \). Determine the velocity of the piston P at the instant \( \theta = 30^\circ \).

**Geometric Method:**

\[
x = .2 \cos \theta + \sqrt{(0.75)^2 - (0.2 \sin \theta)^2}
\]

\[
\frac{dx}{dt} = V_p = -0.2 \sin \theta \frac{d\theta}{dt}
\]

\[
+ \frac{1}{2} \left[ (0.75)^2 - (0.2 \sin \theta)^2 \right]^{-\frac{1}{2}} \left( -2 \right) (0.2 \sin \theta)(0.2 \cos \theta) \frac{d\theta}{dt}
\]

\[
V_p = -0.2 \omega \sin \theta - \frac{(0.2)^2 \omega \sin 2 \theta}{2 \sqrt{(0.75)^2 - (0.2 \sin \theta)^2}}
\]

For \( \theta = 30^\circ \), \( x = 0.916 \text{ ft} \)

\( \omega_{AB} = 150 \text{ rad/sec} \)

\( V_p = -18.5 \text{ ft/sec} \) or \( 18.5 \text{ ft/sec} \)
Problem 16-46 (Page 326)

A bar is confined to move along vertical and inclined surfaces as shown. If the velocity of the roller at A is $v_A = 6$ ft/sec when $\theta = 45^o$, determine the bar's angular velocity, and the velocity of the roller B at this instant.

Method of I.C.

From law of sines:

$$\frac{\sin 60^o}{5} = \frac{\sin 45^o}{v_B} = \frac{\sin 75^o}{v_A}$$

$v_A = 5.577$ ft

$v_B = 4.082$ ft

$v_A = r_A \omega = 6 \text{ ft/sec} = 5.577 \omega$

$\omega = 1.076 \text{ rad/sec}$

$v_B = r_B \omega = 4.082 (1.076) = 4.39 \text{ ft/sec}$
Problem 16-46 (Page 326)

A bar is confined to move along vertical and inclined surfaces as shown. If the velocity of the roller at A is $v_A = 6 \text{ ft/sec}$ when $\theta = 45^\circ$, determine the bar’s angular velocity, and the velocity of the roller B at this instant.

**Vector method:**

$$\vec{V}_B = \vec{V}_A + \vec{V}_{B/A}$$

$$-v_B \cos 30^\circ \hat{i} - v_B \sin 30^\circ \hat{j} = -6 \hat{j}$$

$$+ 5\omega (-\cos 45^\circ \hat{i} + \sin 45^\circ \hat{j})$$

$$x' = -0.866 v_B = -5 \omega (0.707)$$

$$y' = -0.5 v_B = -6 + 5 \omega (0.707)$$

$$v_B = 4.39 \text{ ft/sec}$$

$$\omega = 1.08 \text{ rad/sec}$$
Problem 16-46 (Page 326)

A bar is confined to move along vertical and inclined surfaces as shown. If the velocity of the roller at A is \( v_A = 6 \text{ ft/sec} \) when \( \theta = 45^\circ \), determine the bar’s angular velocity, and the velocity of roller B at this instant.

\[
S_b \cos 30^\circ = 5 \sin \theta
\]
\[
S_b = 5.774 \sin \theta
\]
\[
\frac{dS_b}{dt} = \dot{S}_b = 5.774 \cos \theta \dot{\theta}
\]  
1)
\[
5 \cos \theta = S_A + S_b \sin 30^\circ
\]
\[
-5 \sin \theta \dot{\theta} = \dot{S}_A + \dot{S}_b \sin 30^\circ
\]  
2)

Combining equations 1) + 2)

\[
-5 \sin \theta \dot{\theta} = 5.774 \cos \theta \dot{\theta} \sin 30^\circ
\]
\[
-6
\]
\[
-3.536 \dot{\theta} = -6 + 2.041 \dot{\theta}
\]

\[
\omega = \dot{\theta} = 1.08 \text{ rad/s}
\]

\[
V_b = \dot{S}_b = 5.774 \cos 45^\circ (1.08) = 4.39 \text{ ft/s}
\]
Problem 16.78 (Page 347)

The wheel shown is rotating with an angular velocity $\omega = 8 \text{ rad/sec}$. Use the method of Instantaneous Centers of zero velocity to determine the velocity of the collar A at the instant $\theta = 30^\circ$ and $\phi = 60^\circ$.

$$v_b = 0.15(8) = 1.2 \text{ m/sec}$$

$$\omega_{ab} = 4.16 \text{ rad/sec}$$

$$v_{ic-a} = \sqrt{v_b^2 + \omega_{ab}^2}$$

$$= 5.77$$

$$v_A = 5.77(4.16) = 2.4 \text{ m/sec}$$
Problem 16-92 (Page 348)

Determine the angular velocity of link AB at the instant shown if block C is moving at 12 in/sec.

From the law of sines:

\[
\frac{A}{\sin 45°} = \frac{r_{ic-e}}{\sin 30°} = \frac{r_{ic-c}}{\sin 105°}
\]

\[\begin{align*}
r_{ic-c} &= 5.46 \text{ in} \\
r_{ic-e} &= 2.83 \text{ in}
\end{align*}\]

\[V_c = r_{ic-c} \omega_{bc} = 12 \text{ in/sec}\]

\[\omega_{bc} = 2.196 \text{ rad/sec}\]

\[V_b = \omega_{bc} r_{ic-e} = 6.21 \text{ in/sec}\]

\[V_b = \omega_{AB} r_{AB} = 5 \omega_{AB}\]

\[\omega_{AB} = 1.24 \text{ rad/sec}\]
Due to slipping, points A and B on the rim of a disk have the velocities shown. Determine the velocities of the center point C and point E at this instant.

\[
\frac{1.6 - x}{5} = \frac{x}{10}
\]

\[x = 1.067 \text{ ft/s}\]

\[10 \text{ ft/s} = x \omega \]

\[\omega = 9.375 \text{ rad/s}\]

\[V_C = V_{ic-c} \omega \]

\[= 9.375 (1.067 - 0.8) \]

\[= 2.50 \text{ ft/s}\]

\[V_E = V_{ic-E} \omega = \sqrt{0.8^2 + 0.267^2 (9.375)} \]

\[= 7.91 \text{ ft/s}\]
Problem 16-101 (Page 350, 11th)

The square plate below is confined to move within the slots at A and B. When \( \theta = 30^\circ \), point A is moving at \( v_A = 8 \text{ m/sec} \). Determine the velocity of point D at this instant.

\[
\begin{align*}
  r_{A-IC} &= 0.3 \cos 30^\circ = 0.26 \text{ m} \\
  v_A &= 8 \text{ m/s} = r_{A-IC} \omega \\
  \omega &= 30.79 \text{ rad/sec} \\
  v_{C-IC} &= 0.282 \text{ m} \\
  v_C &= 0.282 (30.79) \\
  &= 8.69 \text{ m/sec} \\
  v_{D-IC} &= 0.186 \text{ m} \\
  v_D &= 0.186 (30.79) = 5.72 \text{ m/sec} \\
  \tan \phi &= \frac{3 \cos 30^\circ - 3 \sin 30^\circ}{3 \sin 30^\circ} = \frac{11}{15} \\
  \phi &= 36.25^\circ \\
  v_D &= 5.72 \text{ m/sec} \quad 36.25^\circ
\end{align*}
\]
Problem 16.109 (Page 360)

The wheel shown is moving to the right such that it has an angular velocity \( \omega = 2 \text{ rad/sec} \) and an angular acceleration \( \alpha = 4 \text{ rad/sec}^2 \) at this instant. If it does not slip at A, determine the linear acceleration of point B on the rim of the wheel.

\[
Q_c = r \alpha = 4(1.45) \\
= 5.8 \text{ ft/s}^2
\]

\[
Q_B = Q_c + Q_{3/c}
\]

\[
= \begin{align*}
\vec{Q}_B &= 5.8 + \frac{2}{2}(1.45) + 4(1.45) \\
&= 5.8 + 1.45 + 6.8
\end{align*}
\]

\[
\begin{align*}
Q_{Bx} &= 5.8 + 0.02 + 2.9 \\
&= 13.72 \text{ ft/s}^2
\end{align*}
\]

\[
\begin{align*}
Q_{By} &= 0 - 2.9 + 5.02 \\
&= 2.12 \text{ ft/s}^2
\end{align*}
\]

\[
Q_B = \sqrt{13.72^2 + 2.12^2} = 13.9 \text{ ft/s}^2
\]

\[
\theta = \tan^{-1} \frac{2.12}{13.72} = 8.80^\circ
\]
The flywheel shown rotates with an angular velocity \( \omega = 2 \text{ rad/sec} \) and an angular acceleration \( \alpha = 6 \text{ rad/sec}^2 \). Determine the angular accelerations of links AB and BC at this instant.

\[
V_A = .3(2) = .6 \text{ m/sec} \quad (\omega)
\]
\[
Q_{A_L} = .3(6) = 1.8 \text{ m/sec}^2 \quad (\alpha)
\]
\[
Q_{A_n} = .3(2^2) = 1.2 \text{ m/sec} \quad (\omega)
\]
\[
\vec{V}_A = \vec{V}_B + \vec{V}_{A/B}
\]
\[
.6 \hat{i} = .4 \omega_{BC} \hat{i} + .5 \omega_{AB} \left( -\frac{3}{5} \hat{i} - \frac{\sqrt{3}}{5} \hat{j} \right)
\]
\[
X: \quad .6 = .4 \omega_{BC} - \frac{3}{5} \omega_{AB}
\]
\[
Y: \quad 0 = -.5 \omega_{AB} \left( \frac{\sqrt{3}}{5} \right) \quad \omega_{AB} = 0 \quad \omega_{BC} = 1.5 \text{ rad/sec}
\]
\[
\vec{Q}_A = \vec{Q}_B + \vec{Q}_{A/B}
\]
\[
= -1.8 \hat{i} - 1.2 \hat{j} = .4 \alpha_{BC} \hat{i} - .4 \omega_{BC} \hat{j} + .5 \alpha_{AB} \left[ -\frac{3}{5} \hat{i} - \frac{\sqrt{3}}{5} \hat{j} \right]
\]
\[
X: \quad -1.8 = .4 \alpha_{BC} - .5 \left( \frac{3}{5} \right) \alpha_{AB}
\]
\[
Y: \quad -1.2 = -.4 \omega_{BC}^2 - .5 \left( \frac{\sqrt{3}}{5} \right) \alpha_{AB}
\]
\[
\alpha_{AB} = \left( 0.75 \text{ rad/sec}^2 \right)
\]
\[
\alpha_{BC} = \left( 3.9 \text{ rad/sec}^2 \right)
\]
Problem 16-112 (Page 361)

At a given instant the wheel below is rotating with an angular velocity and angular acceleration shown. Determine the acceleration of block B at this instant.

\[
\begin{align*}
\mathbf{V}_A &= (0.6 \text{ m/s}) \hat{j} \\
&= 0.6 \cos 30^\circ \hat{i} - 0.6 \sin 30^\circ \hat{j} \\
&= \mathbf{V}_B + \mathbf{V}_{A/B} \\
&= \mathbf{V}_B \hat{j} - 0.5 \cos 45^\circ \hat{i} + 0.5 \sin 45^\circ \hat{j} \\
&= 5.2 = 0.354 \omega_{AB} \quad (\omega_{AB} = 1.47 \text{ rad/s}) \\
\gamma &= -0.3 = \mathbf{V}_B + 0.52 \\
\mathbf{V}_B &= -0.82 \text{ m/s} \hat{j} \\
\mathbf{a}_{AB} &= \mathbf{a}_A + \mathbf{a}_{g/4} \\
&= \mathbf{a}_{AB} = 1.8 \left[ -\cos 30^\circ \hat{i} - \sin 30^\circ \hat{j} \right] \\
&\quad + 1.2 \left[ -\sin 30^\circ \hat{i} + \cos 30^\circ \hat{j} \right] \\
&\quad + 0.5 \omega_{AB}^2 \left[ -\cos 45^\circ \hat{i} - \sin 45^\circ \hat{j} \right] \\
&\quad + 0.5 \alpha_{AB} \left[ \cos 45^\circ \hat{i} - \sin 45^\circ \hat{j} \right] \\
\mathbf{a}_B &= -3.55 \text{ m/s}^2 \hat{j} \\
\alpha_{AB} &= -8.27 \text{ rad/s}^2
\end{align*}
\]