MechFamily

كن أنت التغيير

اللجنة الأكاديمية في قسم الهندسة الميكانيكية

Final Suggested Dynamics Spring 2026

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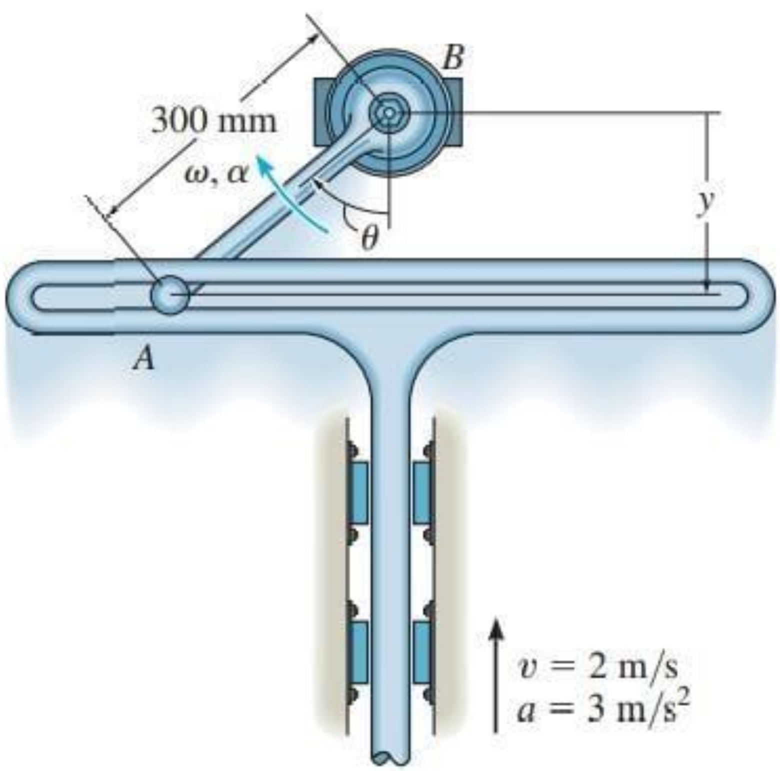
16–41. At the instant $\theta = 50°$, the slotted guide is moving upward with an acceleration of $3\ m/s^2$ and a velocity of $2\ m/s$. Determine the angular acceleration and angular velocity of link AB at this instant. *Note:* The upward motion of the guide is in the negative y direction.



Prob. 16–41

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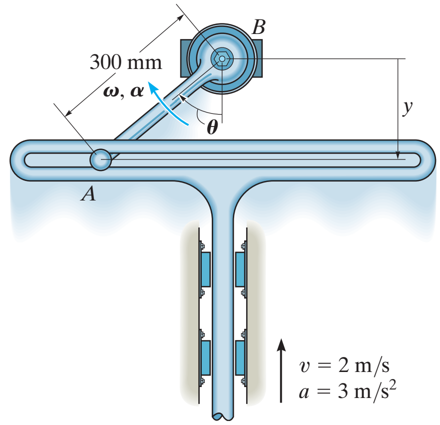
16–41.

At the instant $\theta = 50°$, the slotted guide is moving upward with an acceleration of $3\ \text{m/s}^2$ and a velocity of $2\ \text{m/s}$. Determine the angular acceleration and angular velocity of link AB at this instant. *Note:* The upward motion of the guide is in the negative y direction.



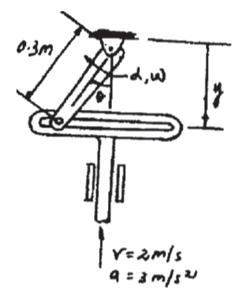
SOLUTION

$$y = 0.3\cos\theta$$

$$\dot{y} = v_y = -0.3\sin\theta\dot{\theta}$$

$$\ddot{y} = a_y = -0.3\left(\sin\theta\ddot{\theta} + \cos\theta\dot{\theta}^2\right)$$

Here $v_y = -2\ \text{m/s}$, $a_y = -3\ \text{m/s}^2$, and $\dot{\theta} = \omega, \dot{\theta} = \omega, \ddot{\theta} = \alpha, \theta = 50°$.

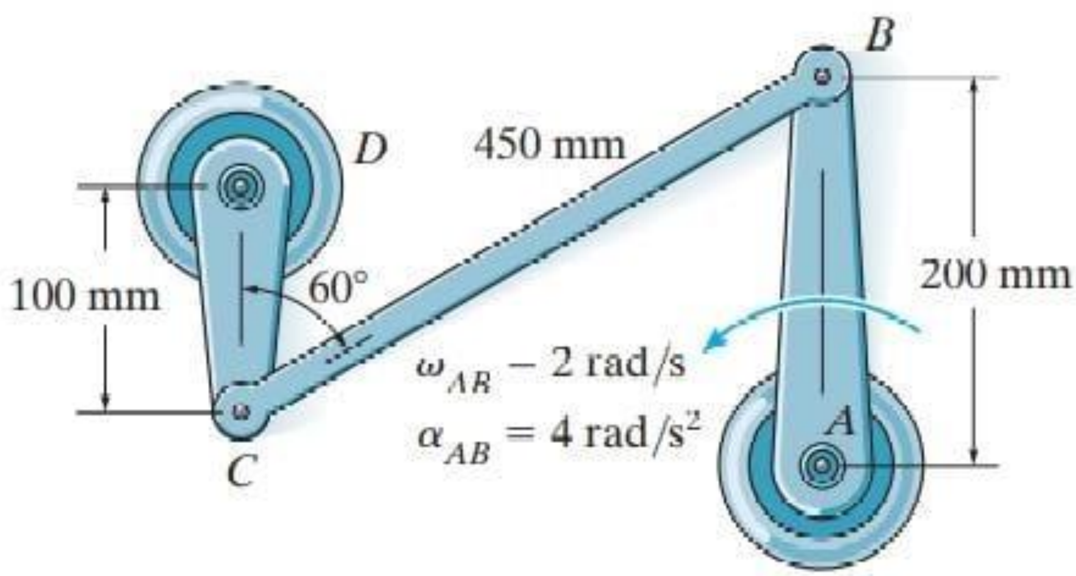


$-2 = -0.3\sin 50°(\omega)$ $\qquad \omega = 8.70\ \text{rad/s}$ **Ans.**

$-3 = -0.3[\sin 50°(\alpha) + \cos 50°(8.70)^2]$ $\qquad \alpha = -50.5\ \text{rad/s}^2$ **Ans.**

Ans:
$\omega = 8.70\ \text{rad/s}$
$\alpha = -50.5\ \text{rad/s}^2$

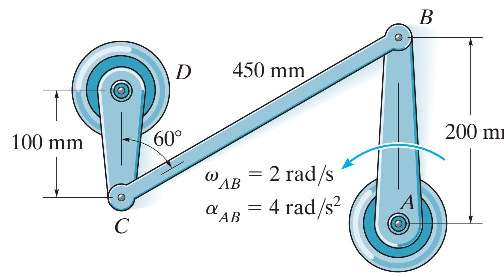
16–109. Member AB has the angular motions shown. Determine the angular velocity and angular acceleration of members CB and DC.



Prob. 16–109

16–109.

Member AB has the angular motions shown. Determine the angular velocity and angular acceleration of members CB and DC.



SOLUTION

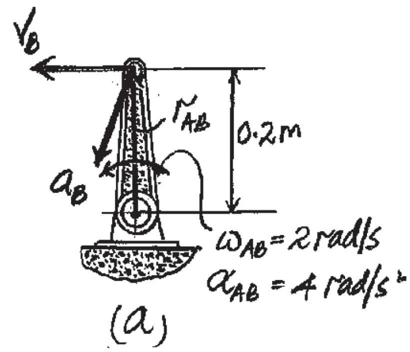
Rotation About A Fixed Axis. For crank AB, refer to Fig. *a*.

$$v_B = \omega_{AB} r_{AB} = 2(0.2) = 0.4 \text{ m/s} \leftarrow$$

$$\mathbf{a}_B = \boldsymbol{\alpha}_{AB} \times \mathbf{r}_{AB} - \omega_{AB}^2 \mathbf{r}_{AB}$$

$$= (4\mathbf{k}) \times (0.2\mathbf{j}) - 2^2(0.2\mathbf{j})$$

$$= \{-0.8\mathbf{i} - 0.8\mathbf{j}\} \text{ m/s}^2$$



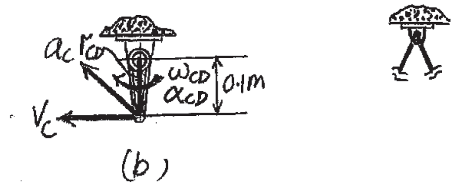
For link CD, refer to Fig. *b*.

$$v_C = \omega_{CD} r_{CD} = \omega_{CD}(0.1)$$

$$\mathbf{a}_C = \alpha_{CD} \times \mathbf{r}_{CD} - \omega_{CD}^2 \mathbf{r}_{CD}$$

$$= (-\alpha_{CD}\mathbf{k}) \times (-0.1\mathbf{j}) - \omega_{CD}^2(-0.1\mathbf{j})$$

$$= -0.1\alpha_{CD}\mathbf{i} + 0.1\omega_{CD}^2\mathbf{j}$$

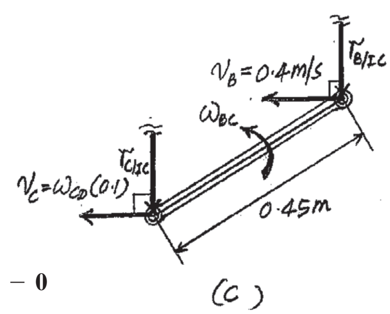


General Plane Motion. The IC of link CD can be located using $\mathbf{v}_B$ and $\mathbf{v}_C$ of which in this case is at infinity as indicated in Fig. *c*. Thus, $r_{B/IC} = r_{C/IC} = \infty$. Thus, kinematics gives

$$\omega_{BC} = \frac{v_B}{r_{B/IC}} = \frac{0.4}{\infty} = 0 \qquad \textbf{Ans.}$$

Then

$$v_C = v_B; \qquad \omega_{CD}(0.1) = 0.4 \qquad \omega_{CD} = 4.00 \text{ rad/s} \circlearrowright \qquad \textbf{Ans.}$$



Applying the relative acceleration equation by referring to Fig. *d*,

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

$$-0.1\alpha_{CD}\mathbf{i} + 0.1(4.00^2)\mathbf{j} = (-0.8\mathbf{i} - 0.8\mathbf{j}) + (\alpha_{BC}\mathbf{k}) \times (-0.45 \sin 60°\mathbf{i} - 0.45 \cos 60°\mathbf{j}) - \mathbf{0}$$

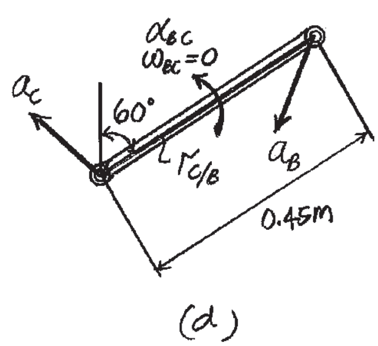
$$-0.1\alpha_{CD}\mathbf{i} + 1.6\mathbf{j} = (0.225\alpha_{BC} - 0.8)\mathbf{i} + (-0.8 - 0.3897\alpha_{BC})\mathbf{j}$$

Equating $\mathbf{j}$ components,

$$1.6 = -0.8 - 0.3897\alpha_{BC}; \qquad \alpha_{BC} = -6.1584 \text{ rad/s}^2 = 6.16 \text{ rad/s}^2 \circlearrowright \qquad \textbf{Ans.}$$

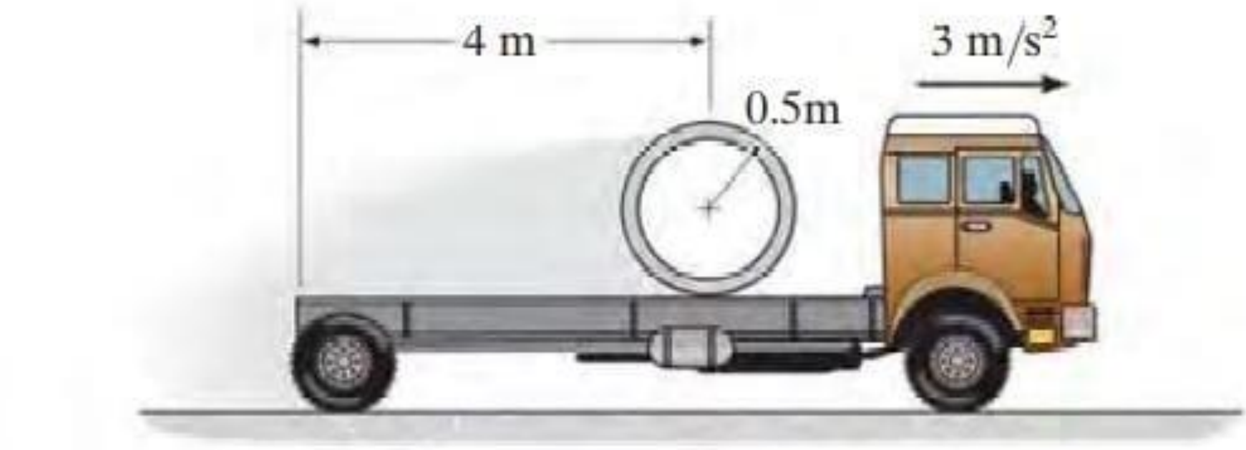
Then $\mathbf{i}$ components give

$$-0.1\alpha_{CD} = 0.225(-6.1584) - 0.8; \qquad \alpha_{CD} = 21.86 \text{ rad/s}^2 = 21.9 \text{ rad/s}^2 \circlearrowright \qquad \textbf{Ans.}$$



Ans:
$\omega_{BC} = 0$
$\omega_{CD} = 4.00$ rad/s $\circlearrowright$
$\alpha_{BC} = 6.16$ rad/s² $\circlearrowright$
$\alpha_{CD} = 21.9$ rad/s² $\circlearrowright$

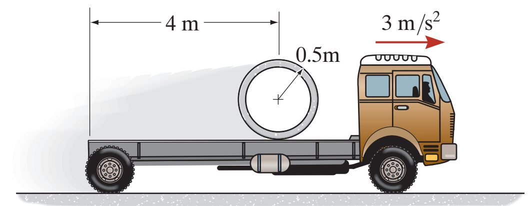
17–109. The 500-kg concrete culvert has a mean radius of 0.5 m. If the truck has an acceleration of $3\,\mathrm{m/s^2}$, determine the culvert's angular acceleration. Assume that the culvert does not slip on the truck bed, and neglect its thickness.



Prob. 17–109

17–109.

The 500-kg concrete culvert has a mean radius of 0.5 m. If the truck has an acceleration of $3\,\text{m/s}^2$, determine the culvert's angular acceleration. Assume that the culvert does not slip on the truck bed, and neglect its thickness.



SOLUTION

Equations of Motion: The mass moment of inertia of the culvert about its mass center is $I_G = mr^2 = 500\left(0.5^2\right) = 125\ \text{kg}\cdot\text{m}^2$. Writing the moment equation of motion about point A using Fig. a,

$$\circlearrowleft + \Sigma M_A = \Sigma(M_k)_A; \quad 0 = 125\alpha - 500a_G(0.5) \qquad \textbf{(1)}$$

Kinematics: Since the culvert does not slip at A, $(a_A)_t = 3\ \text{m/s}^2$. Applying the relative acceleration equation and referring to Fig. b,

$$\mathbf{a}_G = \mathbf{a}_A + \alpha \times \mathbf{r}_{G/A} - \omega^2 r_{G/A}$$

$$a_G\mathbf{i} = 3\mathbf{i} + (a_A)_n\,\mathbf{j} + (\alpha\mathbf{k} \times 0.5\mathbf{j}) - \omega^2(0.5\mathbf{j})$$

$$a_G\mathbf{i} = (3 - 0.5\alpha)\mathbf{i} + \left[(a_A)_n - 0.5\omega^2\right]\mathbf{j}$$

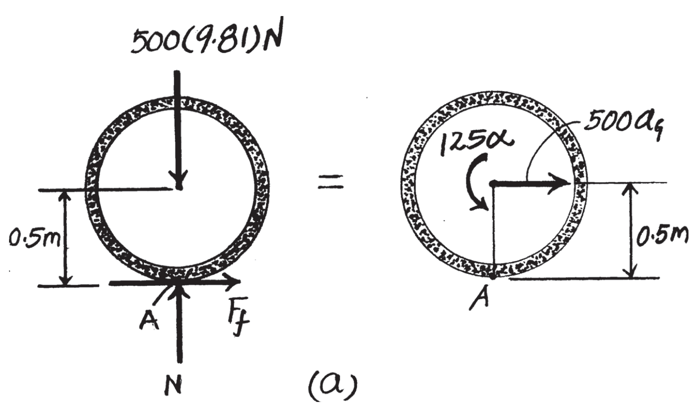
Equating the **i** components,

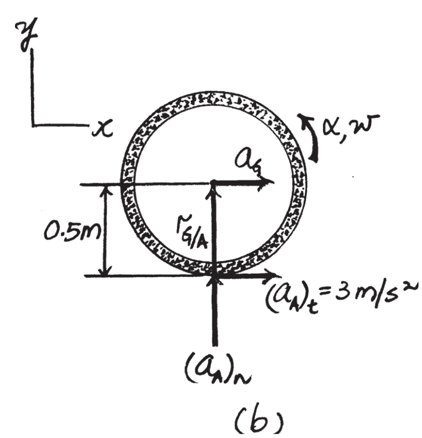
$$a_G = 3 - 0.5\alpha \qquad \textbf{(2)}$$

Solving Eqs. (1) and (2) yields

$$a_G = 1.5\ \text{m/s}^2 \rightarrow$$

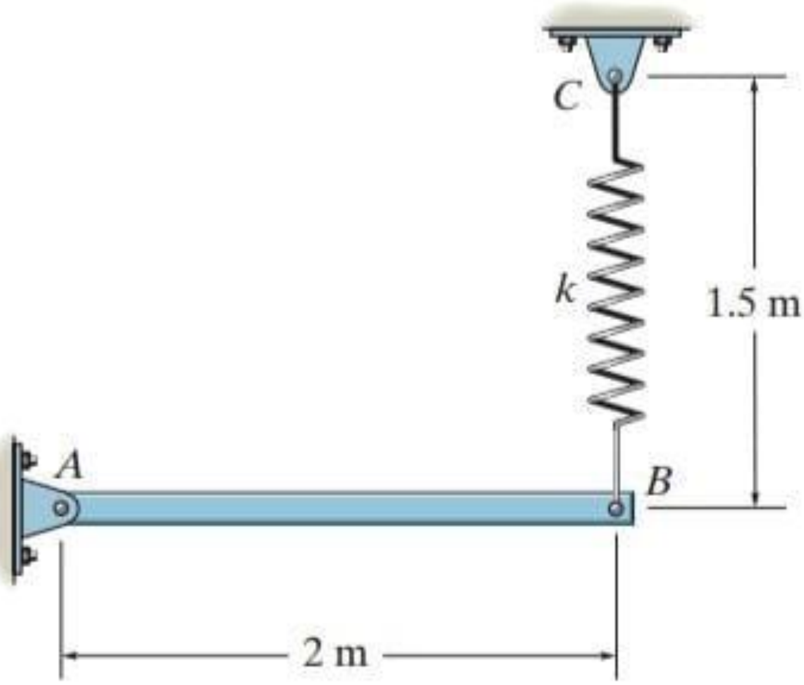
$$\alpha = 3\ \text{rad/s}^2 \qquad \textbf{Ans.}$$





Ans:
$\alpha = 3\ \text{rad/s}^2$

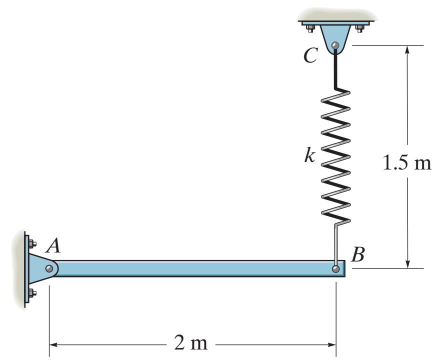
18–58. The slender 6-kg bar AB is horizontal and at rest and the spring is unstretched. Determine the stiffness k of the spring so that the motion of the bar is momentarily stopped when it has rotated clockwise 90° after being released.



Prob. 18–58

18–58.

The slender 6-kg bar AB is horizontal and at rest and the spring is unstretched. Determine the stiffness k of the spring so that the motion of the bar is momentarily stopped when it has rotated clockwise 90° after being released.



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 and required to stop finally, $T_1 = T_2 = 0$.

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

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

$$(V_g)_2 = mgy_2 = 6(9.81)(-1) = -58.86 \text{ J}$$

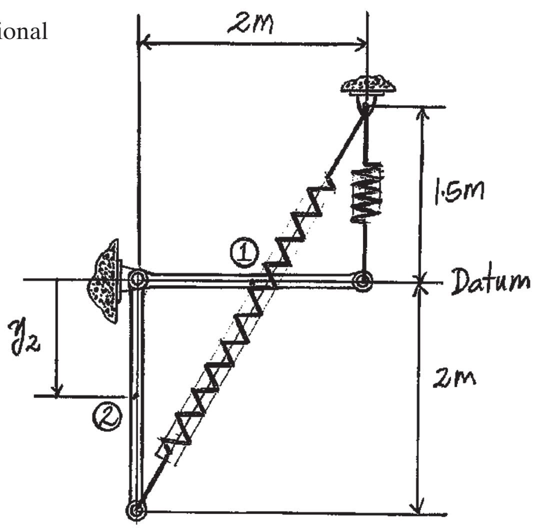
The stretch of the spring when the bar is at position ② is

$$x_2 = \sqrt{2^2 + 3.5^2} - 1.5 = 2.5311 \text{ m}$$

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

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

$$(V_e)_2 = \frac{1}{2}k\left(2.5311^2\right) = 3.2033k$$



(a)

Conservation of Energy.

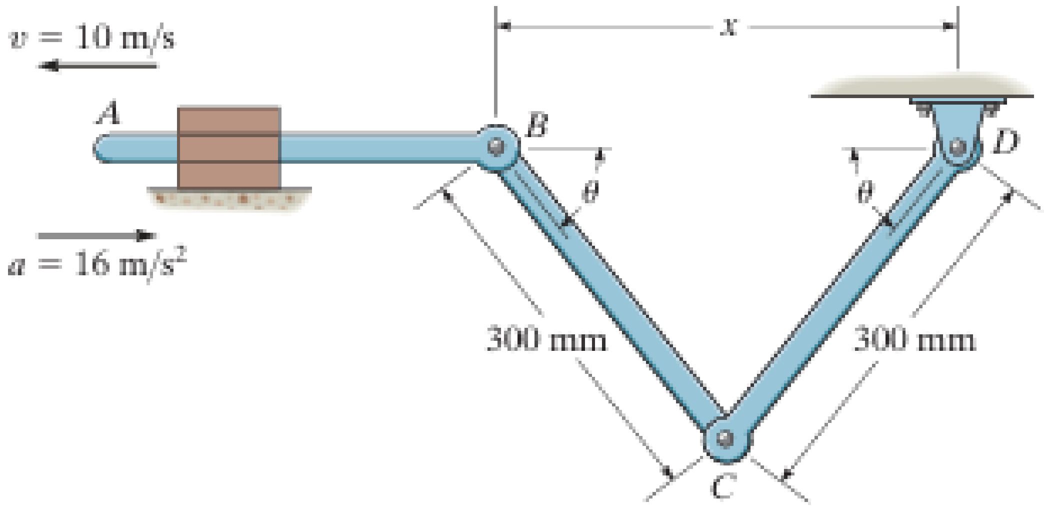
$$T_1 + V_1 = T_2 + V_2$$

$$0 + (0 + 0) = 0 + (-58.86) + 3.2033k$$

$$k = 18.3748 \text{ N/m} = 18.4 \text{ N/m}$$ **Ans.**

Ans:
$k = 18.4$ N/m

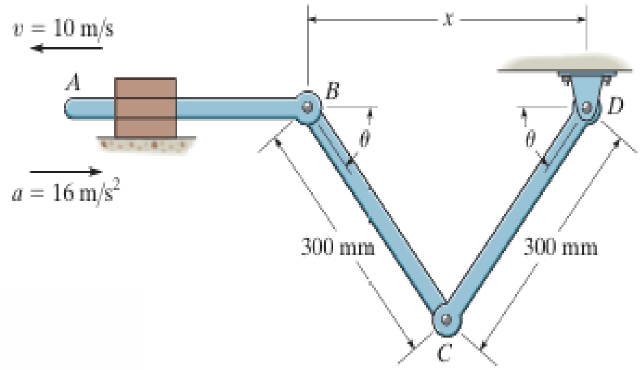
16–42. At the instant shown, $\theta = 60°$, and rod AB is subjected to a deceleration of 16 m/s^2 when the velocity is 10 m/s. Determine the angular velocity and angular acceleration of link CD at this instant.



Prob. 16–42

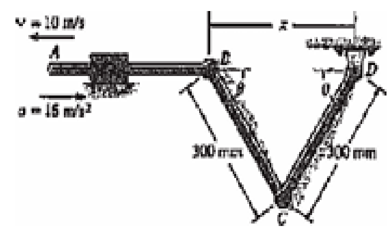
16–42.

At the instant shown, $\theta = 60^\circ$, and rod AB is subjected to a deceleration of $16\ \text{m/s}^2$ when the velocity is $10\ \text{m/s}$. Determine the angular velocity and angular acceleration of link CD at this instant.



SOLUTION

$$x = 2(0.3)\cos\theta$$



$$x = -0.6\sin\theta(\dot{\theta}) \quad \textbf{(1)}$$

$$\ddot{x} = -0.6\cos\theta(\dot{\theta})^2 - 0.6\sin\theta(\ddot{\theta}) \quad \textbf{(2)}$$

Using Eqs. (1) and (2) at $\theta = 60^\circ$, $\dot{x} = 10\ \text{m/s}$, $\ddot{x} = -16\ \text{m/s}^2$.

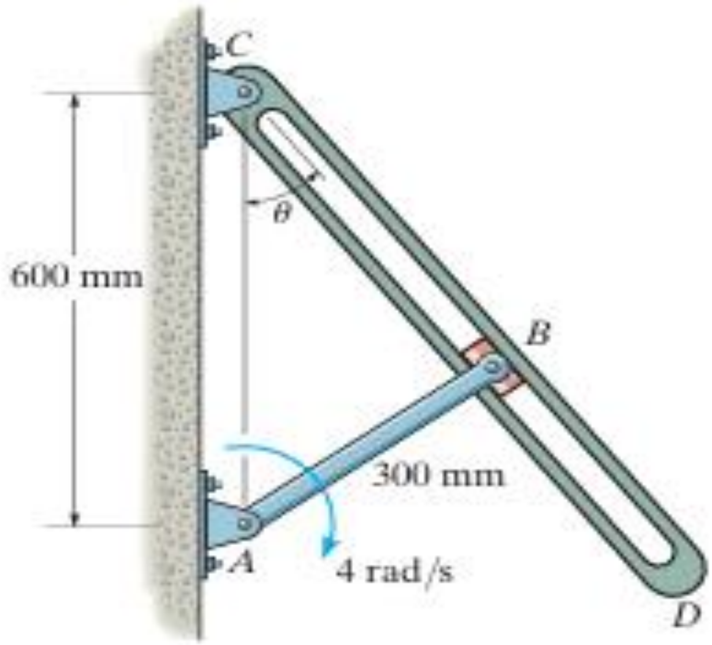
$$10 = -0.6\sin 60^\circ(\omega)$$

$$\omega = -19.245 = -19.2\ \text{rad/s} \quad \textbf{Ans.}$$

$$-16 = -0.6\cos 60^\circ(-19.245)^2 - 0.6\sin 60^\circ(\alpha)$$

$$\alpha = -183\ \text{rad/s}^2 \quad \textbf{Ans.}$$

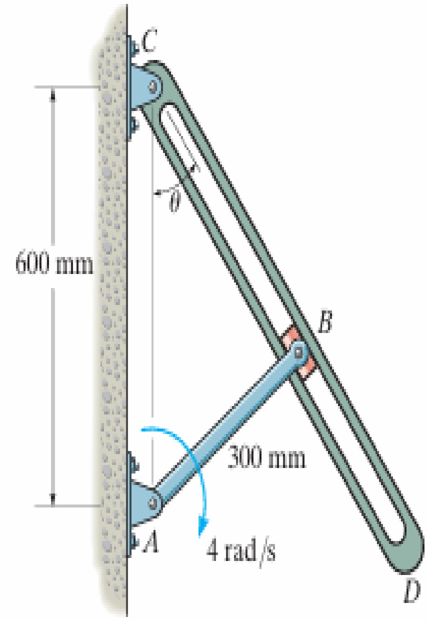
16–43. The crank AB is rotating with a constant angular velocity of 4 rad/s. Determine the angular velocity of the connecting rod CD at the instant $\theta = 30°$.



Prob. 16–43

16–43.

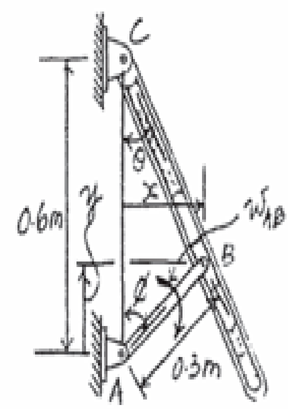
The crank AB is rotating with a constant angular velocity of 4 rad/s. Determine the angular velocity of the connecting rod CD at the instant $\theta = 30°$.



SOLUTION

Position Coordinate Equation: From the geometry,

$$0.3 \sin \phi = (0.6 - 0.3 \cos \phi) \tan \theta \qquad \textbf{[1]}$$



Time Derivatives: Taking the time derivative of Eq. [1], we have

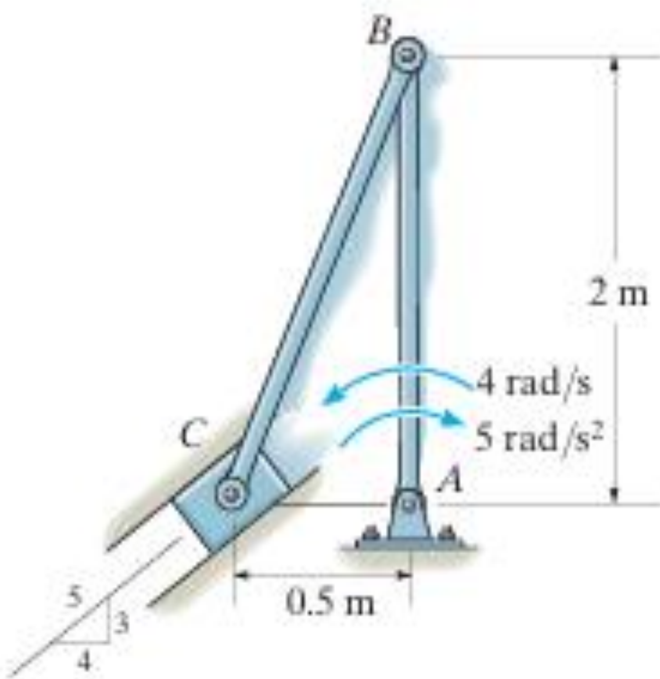
$$0.3 \cos \phi \frac{d\phi}{dt} = 0.6\sec^2\theta\frac{d\theta}{dt} - 0.3\left(\cos\theta \sec^2\theta\frac{d\theta}{dt} - \tan\theta \sin\theta\frac{d\phi}{dt}\right)$$

$$\frac{d\theta}{dt} = \left[\frac{0.3(\cos\phi - \tan\theta \sin\phi)}{0.3\sec^2\theta(2 - \cos\phi)}\right]\frac{d\phi}{dt} \qquad \textbf{[2]}$$

However, $\frac{d\theta}{dt} = \omega_{BC}$, $\frac{d\phi}{dt} = \omega_{AB} = 4$ rad/s. At the instant $\theta = 30°$, from Eq. [3], $\phi = 60.0°$. Substitute these values into Eq. [2] yields

$$\omega_{BC} = \left[\frac{0.3(\cos 60.0° - \tan 30° \sin 60.0°)}{0.3\sec^2 30°\,(2 - \cos 60.0°)}\right](4) = 0 \qquad \textbf{Ans.}$$

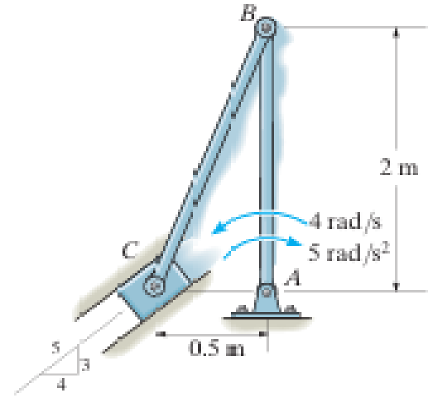
16–106. Member AB has the angular motions shown. Determine the velocity and acceleration of the slider block C at this instant.



Prob. 16–106

16–106.

Member AB has the angular motions shown. Determine the velocity and acceleration of the slider block C at this instant.



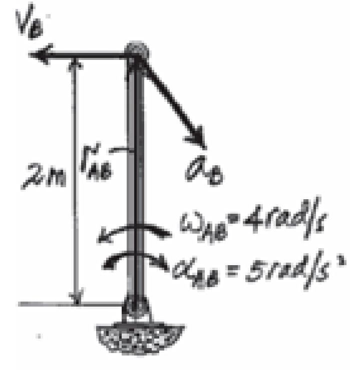
SOLUTION

Rotation About A Fixed Axis. For member AB, refer to Fig. a.

$$v_B = \omega_{AB} r_{AB} = 4(2) = 8 \text{ m/s} \leftarrow$$

$$\mathbf{a}_B = \boldsymbol{\alpha}_{AB} \times \mathbf{r}_{AB} - \omega_{AB}^2 \mathbf{r}_{AB}$$

$$= (-5\mathbf{k}) \times (2\mathbf{j}) - 4^2(2\mathbf{j}) = \{10\mathbf{i} - 32\mathbf{j}\} \text{ m/s}^2$$



(a)

General Plane Motion. The IC for member BC can be located using $\mathbf{v}_B$ and $\mathbf{v}_C$ as shown in Fig. b. From the geometry of this figure

$$\phi = \tan^{-1}\left(\frac{3}{4}\right) = 36.87^\circ \qquad \theta = 90^\circ - \phi = 53.13^\circ$$

Then

$$\frac{r_{B/IC} - 2}{0.5} = \tan 53.13; \qquad r_{B/IC} = 2.6667 \text{ m}$$

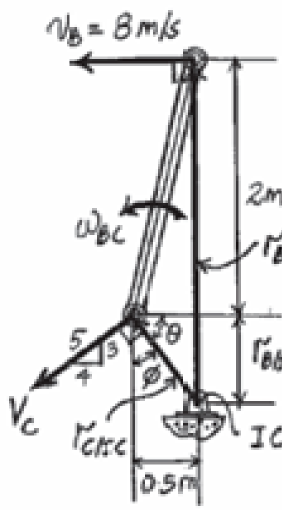
$$\frac{0.5}{r_{C/IC}} = \cos 53.13; \qquad r_{C/IC} = 0.8333 \text{ m}$$

The kinematics gives

$$v_B = \omega_{BC} r_{B/IC}; \qquad 8 = \omega_{BC}(2.6667)$$

$$\omega_{BC} = 3.00 \text{ rad/s} \circlearrowleft$$

$$v_C = \omega_{BC} r_{C/IC} = 3.00(0.8333) = 2.50 \text{ m/s} \swarrow \qquad \textbf{Ans.}$$



(b)

Applying the relative acceleration equation by referring to Fig. c,

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

$$-a_C\left(\frac{4}{5}\right)\mathbf{i} - a_C\left(\frac{3}{5}\right)\mathbf{j} = (10\mathbf{i} - 32\mathbf{j}) + \alpha_{BC}\mathbf{k} \times (-0.5\mathbf{i} - 2\mathbf{j}) - (3.00^2)(-0.5\mathbf{i} - 2\mathbf{j})$$

$$-\frac{4}{5}a_C\mathbf{i} - \frac{3}{5}a_C\mathbf{j} = (2\alpha_{BC} + 14.5)\mathbf{i} + (-0.5\alpha_{BC} - 14)\mathbf{j}$$

Equating $\mathbf{i}$ and $\mathbf{j}$ components

$$-\frac{4}{5}a_C = 2\alpha_{BC} + 14.5 \qquad \textbf{(1)}$$

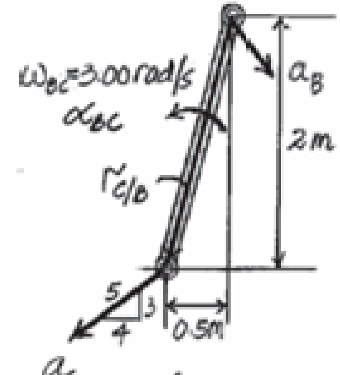
$$-\frac{3}{5}a_C = -0.5\alpha_{BC} - 14 \qquad \textbf{(2)}$$

Solving Eqs. (1) and (2),

$$a_C = 12.969 \text{ m/s}^2 = 13.0 \text{ m/s}^2 \swarrow \qquad \textbf{Ans.}$$

$$\alpha_{BC} = -12.4375 \text{ rad/s}^2 = 12.4 \text{ rad/s}^2 \circlearrowright \qquad \textbf{Ans.}$$

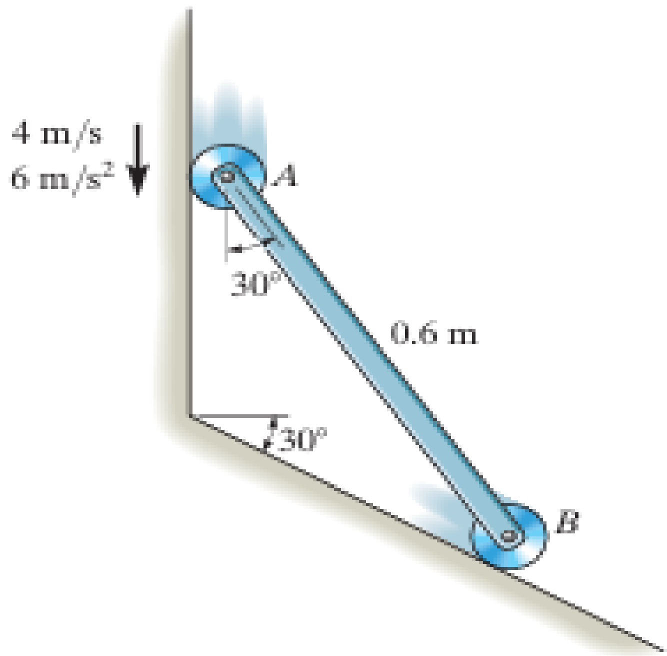
The negative sign indicates that α_{BC} is directed in the opposite sense from what is shown in Fig. (c).



(c)

Ans:
$a_C = 13.0 \text{ m/s}^2 \swarrow$
$\alpha_{BC} = 12.4 \text{ rad/s}^2 \circlearrowright$

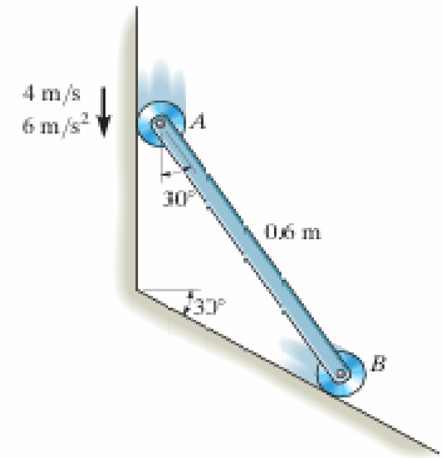
16–107. At a given instant the roller A on the bar has the velocity and acceleration shown. Determine the velocity and acceleration of the roller B, and the bar's angular velocity and angular acceleration at this instant.



Prob. 16–107

16–107.

At a given instant the roller A on the bar has the velocity and acceleration shown. Determine the velocity and acceleration of the roller B, and the bar's angular velocity and angular acceleration at this instant.



SOLUTION

General Plane Motion. The IC of the bar can be located using $\mathbf{v}_A$ and $\mathbf{v}_B$ as shown in Fig. a. From the geometry of this figure,

$$r_{A/IC} = r_{B/IC} = 0.6 \text{ m}$$

Thus, the kinematics give

$$v_A = \omega r_{A/IC}; \qquad 4 = \omega(0.6)$$

$$\omega = 6.667 \text{ rad/s} = 6.67 \text{ rad/s} ↻ \qquad \textbf{Ans.}$$

$$v_B = \omega r_{B/IC} = 6.667(0.6) = 4.00 \text{ m/s} ↘ \qquad \textbf{Ans.}$$

Applying the relative acceleration equation, by referring to Fig. b,

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

$$a_B \cos 30°\mathbf{i} - a_B \sin 30°\mathbf{j} = -6\mathbf{j} + (\alpha\mathbf{k}) \times (0.6 \sin 30°\mathbf{i} - 0.6 \cos 30°\mathbf{j}) - (6.667^2)(0.6 \sin 30°\mathbf{i} - 0.6 \cos 30°\mathbf{j})$$

$$\frac{\sqrt{3}}{2} a_B\mathbf{i} - \frac{1}{2}a_B\mathbf{j} = \left(0.3\sqrt{3}\alpha - 13.33\right)\mathbf{i} + (0.3\alpha + 17.09)\mathbf{j}$$

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

$$\frac{\sqrt{3}}{2} a_B = 0.3\sqrt{3}\alpha - 13.33 \qquad \textbf{(1)}$$

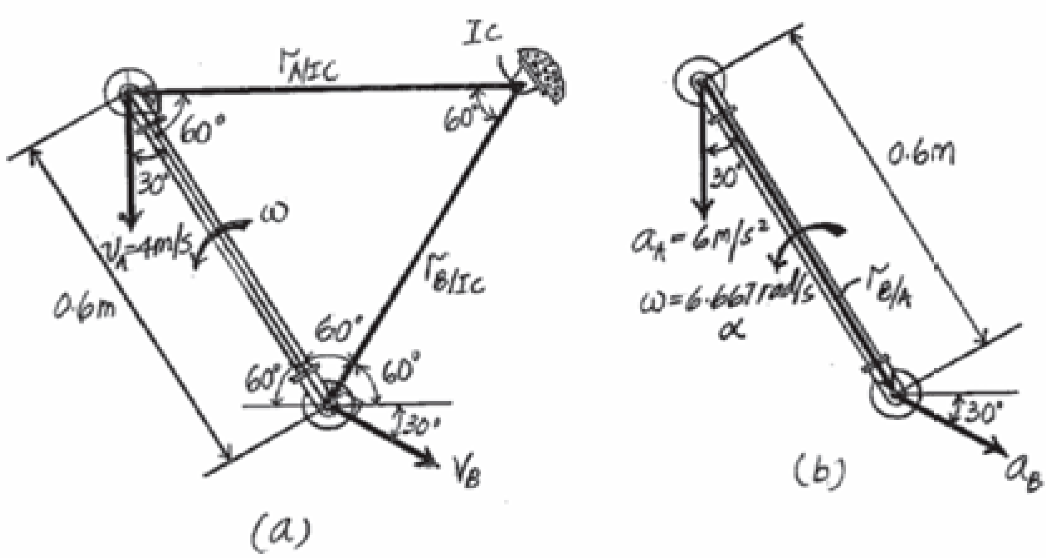
$$-\frac{1}{2}a_B = 0.3\alpha + 17.09 \qquad \textbf{(2)}$$

Solving Eqs. (1) and (2)

$$\alpha = -15.66 \text{ rad/s}^2 = 15.7 \text{ rad/s}^2 ↻ \qquad \textbf{Ans.}$$

$$a_B = -24.79 \text{ m/s}^2 = 24.8 \text{ m/s}^2 ↖ \qquad \textbf{Ans.}$$

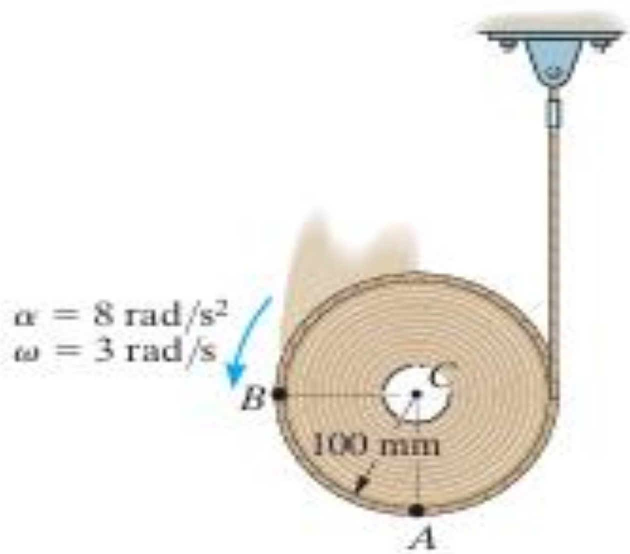
The negative signs indicate that $\boldsymbol{\alpha}$ and $\mathbf{a}_B$ are directed in the senses that opposite to those shown in Fig. b



Ans:
$\omega = 6.67$ rad/s ↻
$v_B = 4.00$ m/s ↘
$\alpha = 15.7$ rad/s² ↻
$a_B = 24.8$ m/s² ↖

16–113. The reel of rope has the angular motion shown. Determine the velocity and acceleration of point A at the instant shown.

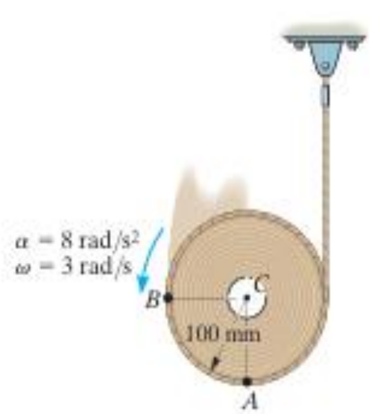
16–114. The reel of rope has the angular motion shown. Determine the velocity and acceleration of point B at the instant shown.



Probs. 16–113/114

16–113.

The reel of rope has the angular motion shown. Determine the velocity and acceleration of point A at the instant shown.



SOLUTION

General Plane Motion. The IC of the reel is located as shown in Fig. a. Here,

$$r_{A/IC} = \sqrt{0.1^2 + 0.1^2} = 0.1414 \text{ m}$$

Then, the Kinematics give

$$v_A = \omega r_{A/IC} = 3(0.1414) = 0.4243 \text{ m/s} = 0.424 \text{ m/s} \measuredangle 45^\circ \qquad \textbf{Ans.}$$

Here $a_C = \alpha r = 8(0.1) = 0.8 \text{ m/s}^2 \downarrow$. Applying the relative acceleration equation by referring to Fig. b,

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

$$\mathbf{a}_A = -0.8\mathbf{j} + (8\mathbf{k}) \times (-0.1\mathbf{j}) - 3^2(-0.1\mathbf{j})$$

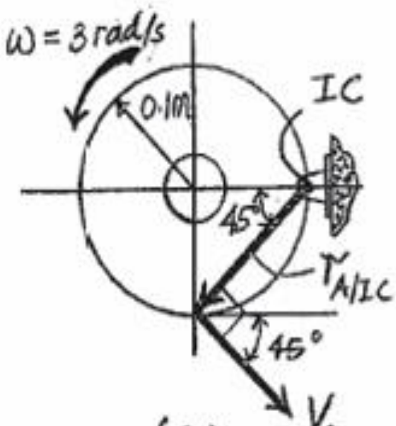
$$= \{0.8\mathbf{i} + 0.1\mathbf{j}\} \text{ m/s}^2$$

The magnitude of $\mathbf{a}_A$ is

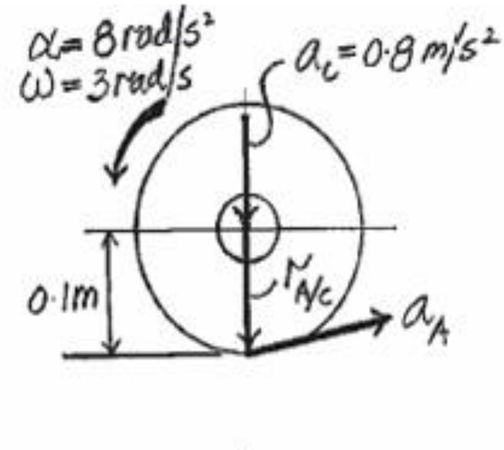
$$a_A = \sqrt{0.8^2 + 0.1^2} = 0.8062 \text{ m/s}^2 = 0.806 \text{ m/s}^2 \qquad \textbf{Ans.}$$

And its direction is defined by

$$\theta = \tan^{-1}\left(\frac{0.1}{0.8}\right) = 7.125^\circ = 7.13^\circ \measuredangle \qquad \textbf{Ans.}$$



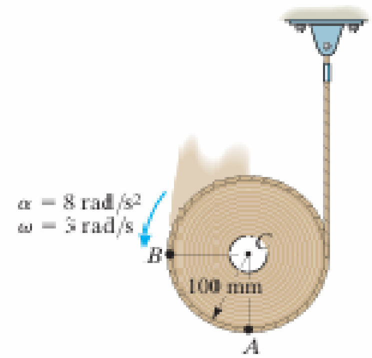
(a)



(b)

16–114.

The reel of rope has the angular motion shown. Determine the velocity and acceleration of point B at the instant shown.



SOLUTION

General Plane Motion. The IC of the reel is located as shown in Fig. a. Here, $r_{B/FC} = 0.2$ m. Then the kinematics gives

$$v_B = \omega r_{B/IC} = (3)(0.2) = 0.6\ \text{m/s}\downarrow \qquad \textbf{Ans.}$$

Here, $a_C = \alpha r = 8(0.1) = 0.8\ \text{m/s}^2\downarrow$. Applying the relative acceleration equation,

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

$$\mathbf{a}_B = -0.8\mathbf{j} + (8\mathbf{k})\times(-0.1\mathbf{i}) - 3^2(-0.1\mathbf{i})$$

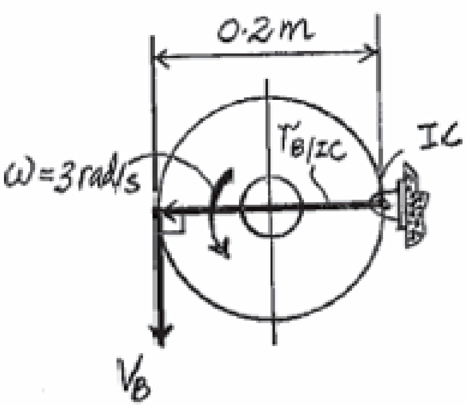
$$= \{0.9\mathbf{i} - 1.6\mathbf{j}\}\ \text{m/s}^2$$

The magnitude of $\mathbf{a}_B$ is

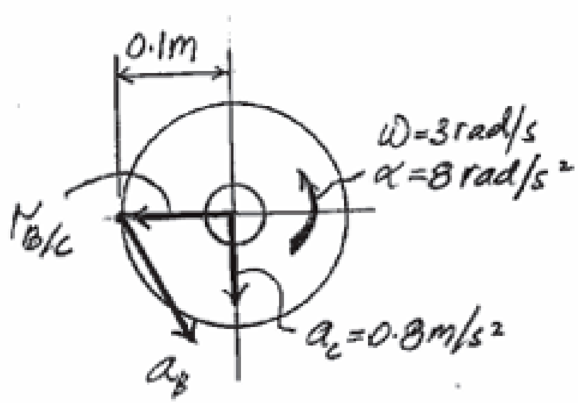
$$a_B = \sqrt{0.9^2 + (-1.6)^2} = 1.8358\ \text{m/s}^2 = 1.84\ \text{m/s}^2 \qquad \textbf{Ans.}$$

And its direction is defined by

$$\theta = \tan^{-1}\left(\frac{1.6}{0.9}\right) = 60.64^\circ = 60.6^\circ \qquad \textbf{Ans.}$$

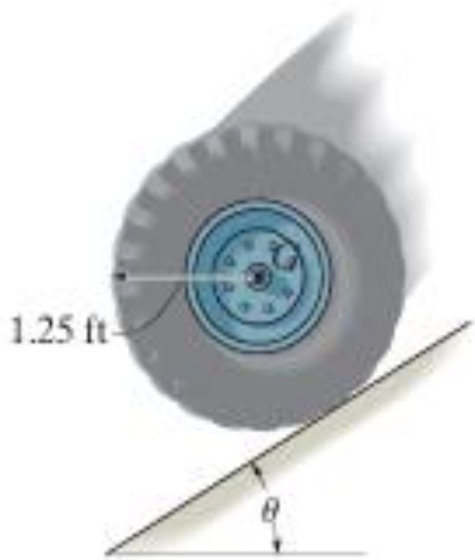


(a)



(b)

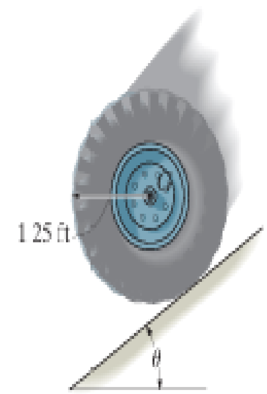
17–95. The tire has a weight of 30 lb and a radius of gyration of $k_G = 0.6$ ft. If the coefficients of static and kinetic friction between the tire and the plane are $\mu_s = 0.2$ and $\mu_k = 0.15$, determine the maximum angle θ of the inclined plane so that the tire rolls without slipping.



Probs. 17–94/95

17–94.

The tire has a weight of 30 lb and a radius of gyration of $k_G = 0.6$ ft. If the coefficients of static and kinetic friction between the wheel and the plane are $\mu_s = 0.2$ and $\mu_k = 0.15$, determine the tire's angular acceleration as it rolls down the incline. Set $\theta = 12°$.

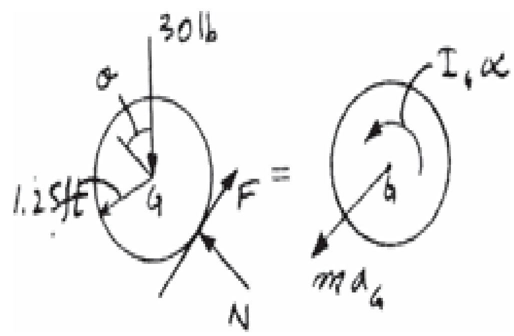


SOLUTION

$+\swarrow \Sigma F_x = m(a_G)_x; \quad 30 \sin 12° - F = \left(\frac{30}{32.2}\right) a_G$

$+\nwarrow \Sigma F_y = m(a_G)_y; \quad N - 30 \cos 12° = 0$

$\zeta + \Sigma M_G = I_G \alpha; \quad F(1.25) = \left[\left(\frac{30}{32.2}\right)(0.6)^2\right]\alpha$



Assume the wheel does not slip.

$$a_G = (1.25)\alpha$$

Solving:

$F = 1.17$ lb

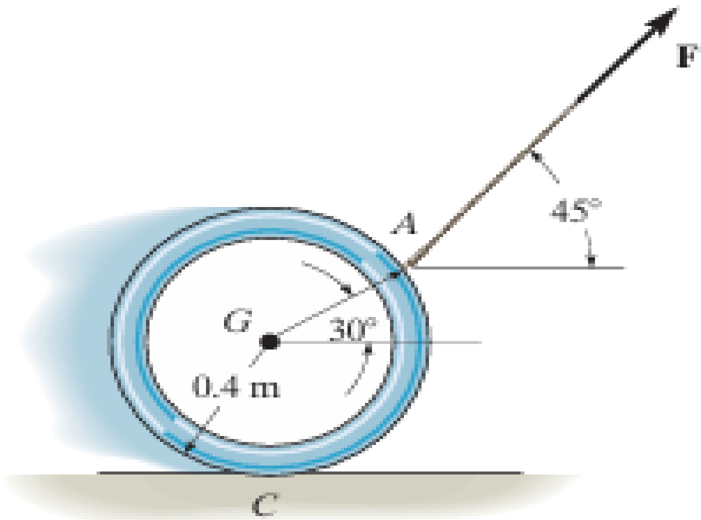
$N = 29.34$ lb

$a_G = 5.44$ ft/s^2

$\alpha = 4.35$ rad/s^2 **Ans.**

$F_{max} = 0.2(29.34) = 5.87 \text{ lb} > 1.17 \text{ lb}$ **OK**

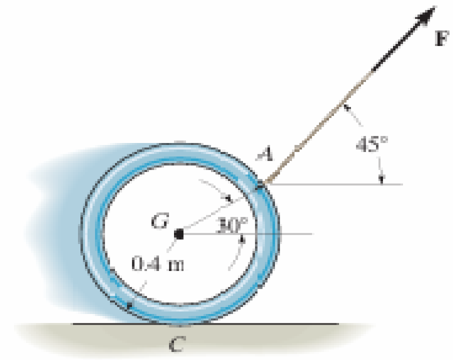
17–101. If the coefficient of static friction at C is $\mu_s = 0.3$, determine the largest force **F** that can be applied to the 5-kg ring, without causing it to slip. Neglect the thickness of the ring.



Probs. 17–100/101

17–101.

If the coefficient of static friction at C is $\mu_s = 0.3$, determine the largest force **F** that can be applied to the 5-kg ring, without causing it to slip. Neglect the thickness of the ring.



SOLUTION

Equations of Motion: The mass moment of inertia of the ring about its center of gravity G is $I_G = mr^2 = 10(0.4^2) = 1.60\ \text{kg}\cdot\text{m}^2$. Here, it is required that the ring is on the verge of slipping at C, $F_f = \mu_s N = 0.3\ N$. Referring to the FBD and kinetic diagram of the ring, Fig. a

$+\uparrow \Sigma F_y = m(a_G)_y; \qquad F \sin 45° + N - 10(9.81) = 10(0) \qquad$ **(1)**

$\overset{+}{\rightarrow} \Sigma F_x = m(a_G)_x; \qquad F \cos 45° - 0.3\ N = 10a_G \qquad$ **(2)**

$\circlearrowleft + \Sigma M_G = I_G\alpha; \qquad F \sin 15°(0.4) - 0.3\ N(0.4) = -1.60\alpha \qquad$ **(3)**

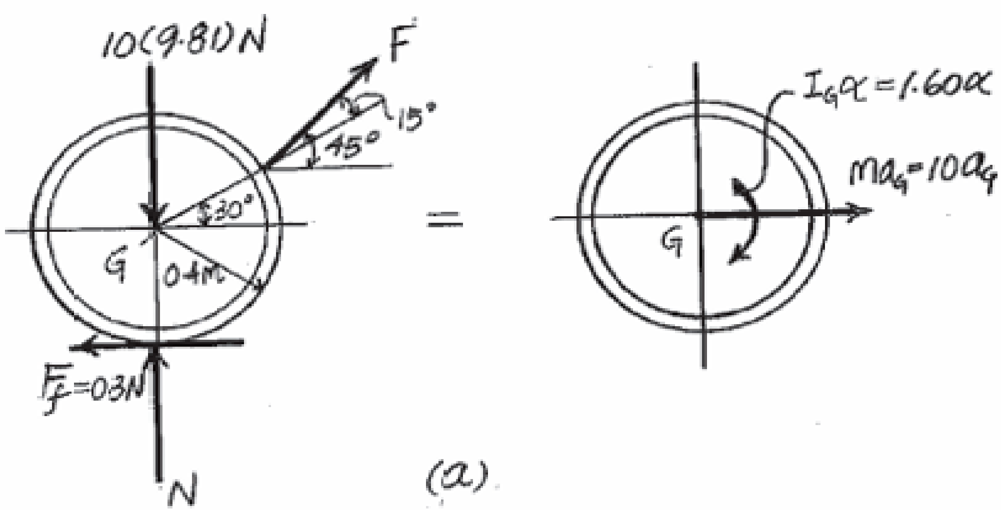
Kinematics. Since the ring rolls without slipping,

$$a_G = \alpha r = \alpha(0.4) \qquad \textbf{(4)}$$

Solving Eqs. (1) to (4),

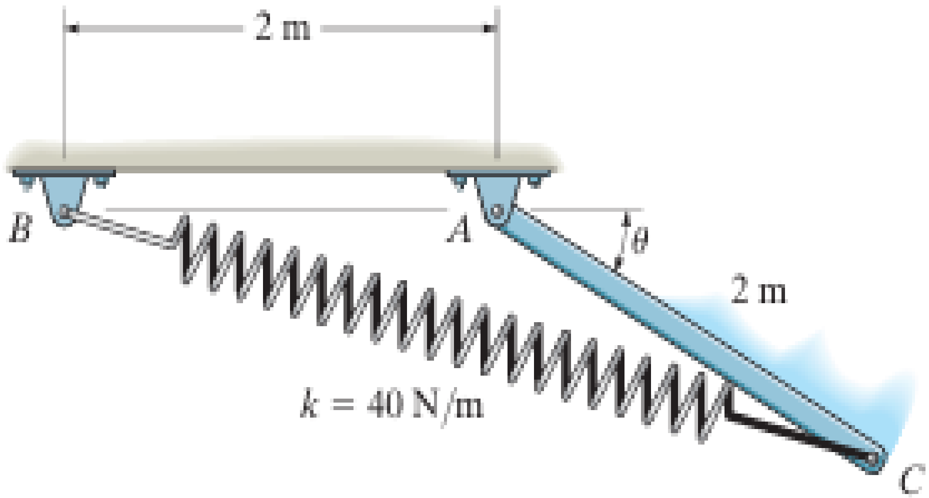
$$F = 42.34\ \text{N} = 42.3\ \text{N} \qquad \textbf{Ans.}$$

$N = 68.16\ \text{N} \qquad \alpha = 2.373\ \text{rad/s}^2 \circlearrowright \qquad a_G = 0.9490\ \text{m/s}^2 \rightarrow$



(a)

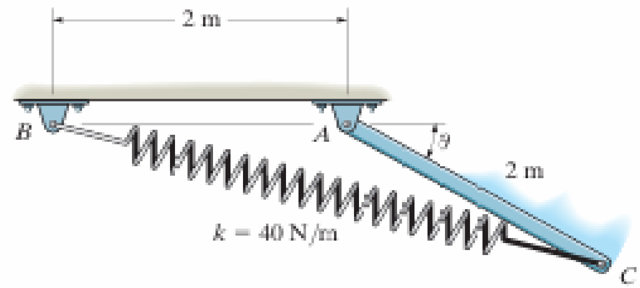
18–45. The 12-kg slender rod is attached to a spring, which has an unstretched length of 2 m. If the rod is released from rest when $\theta = 30^\circ$, determine its angular velocity at the instant $\theta = 90^\circ$.



Prob. 18–45

18–45.

The 12-kg slender rod is attached to a spring, which has an unstretched length of 2 m. If the rod is released from rest when $\theta = 30^\circ$, determine its angular velocity at the instant $\theta = 90^\circ$.



SOLUTION

Kinetic Energy. The mass moment of inertia of the rod about A is $I_A = \frac{1}{12}(12)(2^2) + 12(1^2) = 16.0\ \text{kg}\cdot\text{m}^2$. Then

$$T = \frac{1}{2}I_A\omega^2 = \frac{1}{2}(16.0)\,\omega^2 = 8.00\,\omega^2$$

Since the rod is released from rest, $T_1 = 0$.

Potential Energy. With reference to the datum set in Fig. *a*, the gravitational potential energies of the rod at positions ① and ② are

$$(V_g)_1 = mg(-y_1) = 12(9.81)(-1\sin 30^\circ) = -58.86\ \text{J}$$

$$(V_g)_2 = mg(-y_2) = 12(9.81)(-1) = -117.72\ \text{J}$$

The stretches of the spring when the rod is at positions ① and ② are

$$x_1 = 2(2\sin 75^\circ) - 2 = 1.8637\ \text{m}$$

$$x_2 = \sqrt{2^2 + 2^2} - 2 = 0.8284\ \text{m}$$

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

$$(V_e)_1 = \frac{1}{2}kx_1^2 = \frac{1}{2}(40)\left(1.8637^2\right) = 69.47\ \text{J}$$

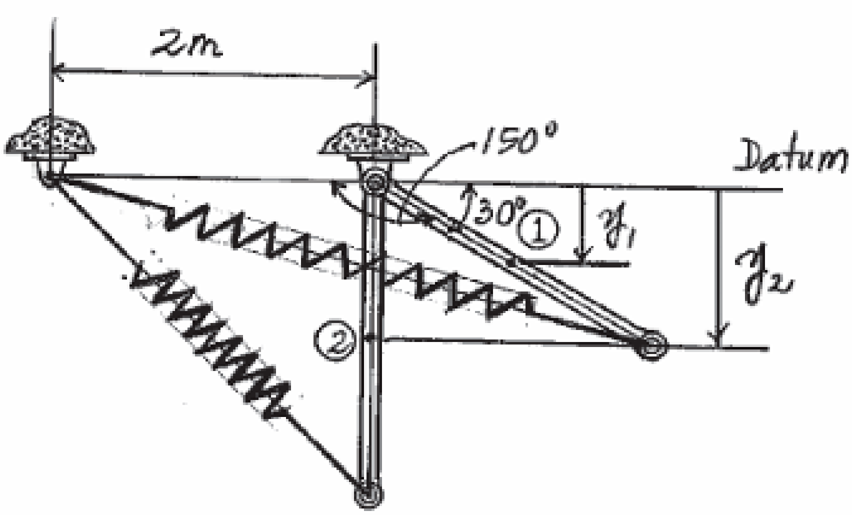
$$(V_e)_2 = \frac{1}{2}kx_2^2 = \frac{1}{2}(40)\left(0.8284^2\right) = 13.37\ \text{J}$$

Conservation of Energy.

$$T_1 + V_1 = T_2 + V_2$$

$$0 + (-58.86) + 69.47 = 8.00\omega^2 + (-117.72) + 13.73$$

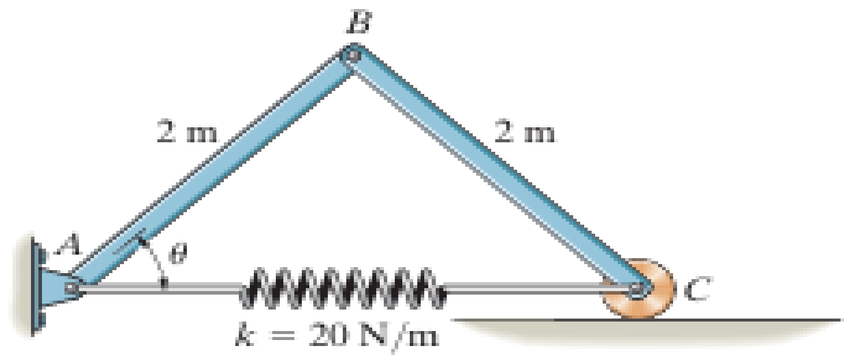
$$\omega = 3.7849\ \text{rad/s} = 3.78\ \text{rad/s}$$ **Ans.**



(a)

Ans:
$\omega = 3.78\ \text{rad/s}$

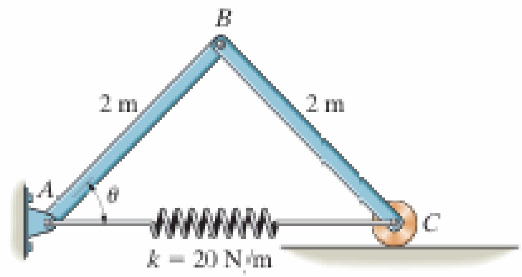
18–53. The two 12-kg slender rods are pin connected and released from rest at the position $\theta = 60^\circ$. If the spring has an unstretched length of 1.5 m, determine the angular velocity of rod BC, when the system is at the position $\theta = 30^\circ$.



Prob. 18–53

18–53.

The two 12-kg slender rods are pin connected and released from rest at the position $\theta = 60°$. If the spring has an unstretched length of 1.5 m, determine the angular velocity of rod BC, when the system is at the position $\theta = 30°$.



SOLUTION

Kinetic Energy. Since the system is released from rest, $T_1 = 0$. Referring to the kinematics diagram of rod BC at final position with IC so located, Fig. *a*

$$r_{B/IC} = r_{C/IC} = 2 \text{ m} \qquad r_{G/IC} = 2 \sin 60° = \sqrt{3} \text{ m}$$

Thus,

$$(V_B)_2 = (\omega_{BC})_2 r_{B/IC}; \qquad (V_B)_2 = (\omega_{BC})_2(2)$$

$$(V_C)_2 = (\omega_{BC})_2 r_{C/IC}; \qquad (V_C)_2 = (\omega_{BC})_2(2)$$

$$(V_G)_2 = (\omega_{BC})_2 r_{G/IC}; \qquad (V_G)_2 = (\omega_{BC})_2(\sqrt{3})$$

Then for rod AB,

$$(V_B)_2 = (\omega_{AB})_2 r_{AB}; \qquad (\omega_{BC})_2(2) = (\omega_{AB})_2(2)$$

$$(\omega_{AB})_2 = (\omega_{BC})_2$$

Thus,

$$T_2 = \frac{1}{2}I_A(\omega_{AB})_2^2 + \frac{1}{2}I_G(\omega_{BC})_2^2 + \frac{1}{2}m_r(V_G)_2^2$$

$$= \frac{1}{2}\left[\frac{1}{3}(12)(2^2)\right](\omega_{BC})_2^2 - \frac{1}{2}\left[\frac{1}{12}(12)(2^2)\right](\omega_{BC})_2^2 + \frac{1}{2}(12)[(\omega_{BC})_2\sqrt{3}]^2$$

$$= 28.0(\omega_{BC})_2^2$$

Potential Energy. With reference to the datum set in Fig. *b*, the initial and final gravitational potential energy of the system are

$$(V_g)_1 = 2mgy_1 = 2[12(9.81)(1 \sin 60°)] = 203.90 \text{ J}$$

$$(V_g)_2 = 2mgy_2 = 2[12(9.81)(1 \sin 30°)] = 117.72 \text{ J}$$

The stretch of the spring when the system is at initial and final position are

$$x_1 = 2(2 \cos 60°) - 1.5 = 0.5 \text{ m}$$

$$x_2 = 2(2 \cos 30°) - 1.5 = 1.9641 \text{ m}$$

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

$$(V_e)_1 = \frac{1}{2}kx_1^2 = \frac{1}{2}(20)(0.5^2) = 2.50 \text{ J}$$

$$(V_e)_2 = \frac{1}{2}kx_2^2 = \frac{1}{2}(20)(1.9641^2) = 38.58 \text{ J}$$