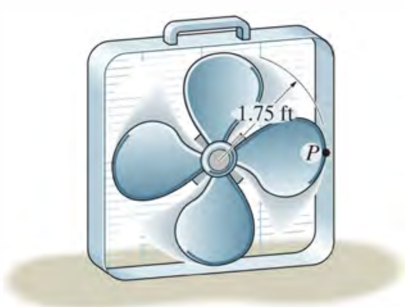
PROBLEMS

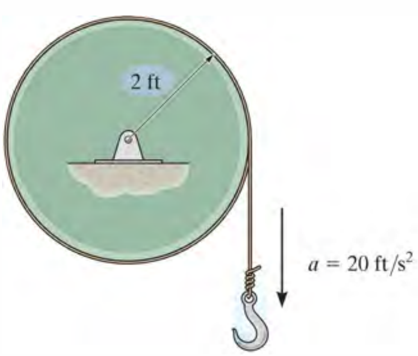
•**16–1.** A disk having a radius of 0.5 ft rotates with an initial angular velocity of 2 rad/s and has a constant angular acceleration of 1 rad/s^2. Determine the magnitudes of the velocity and acceleration of a point on the rim of the disk when $t = 2$ s.

16–2. Just after the fan is turned on, the motor gives the blade an angular acceleration $\alpha = (20e^{-0.6t})$ rad/s^2, where t is in seconds. Determine the speed of the tip P of one of the blades when $t = 3$ s. How many revolutions has the blade turned in 3 s? When $t = 0$ the blade is at rest.



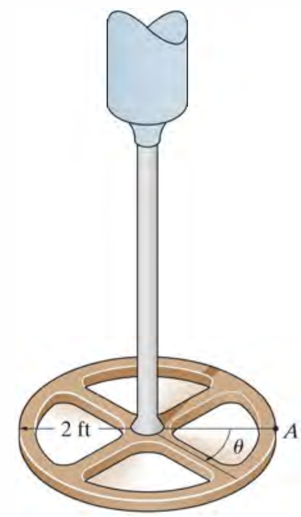
Prob. 16–2

16–3. The hook is attached to a cord which is wound around the drum. If it moves from rest with an acceleration of 20 ft/s^2, determine the angular acceleration of the drum and its angular velocity after the drum has completed 10 rev. How many more revolutions will the drum turn after it has first completed 10 rev and the hook continues to move downward for 4 s?



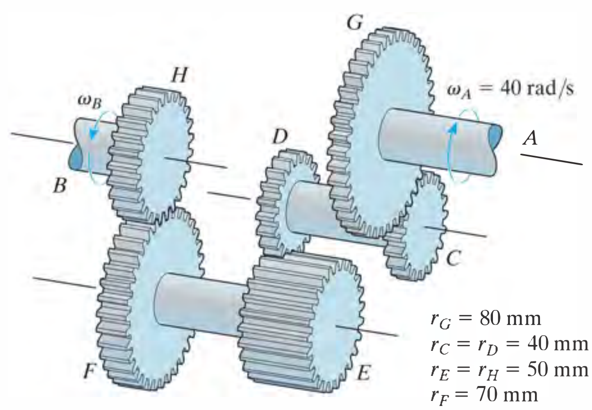
Prob. 16–3

*__16–4.__ The torsional pendulum (wheel) undergoes oscillations in the horizontal plane, such that the angle of rotation, measured from the equilibrium position, is given by $\theta = (0.5 \sin 3t)$ rad, where t is in seconds. Determine the maximum velocity of point A located at the periphery of the wheel while the pendulum is oscillating. What is the acceleration of point A in terms of t?



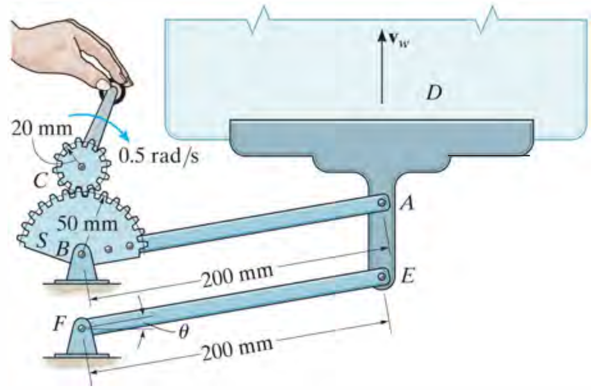
Prob. 16–4

•**16–5.** The operation of reverse gear in an automotive transmission is shown. If the engine turns shaft A at $\omega_A = 40$ rad/s, determine the angular velocity of the drive shaft, ω_B. The radius of each gear is listed in the figure.



Prob. 16–5

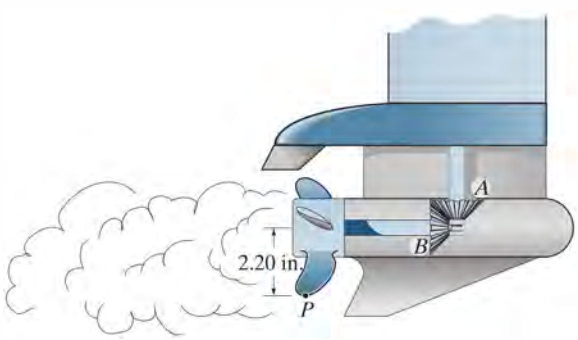
16–6. The mechanism for a car window winder is shown in the figure. Here the handle turns the small cog C, which rotates the spur gear S, thereby rotating the fixed-connected lever AB which raises track D in which the window rests. The window is free to slide on the track. If the handle is wound at 0.5 rad/s, determine the speed of points A and E and the speed v_w of the window at the instant $\theta = 30°$.



Prob. 16–6

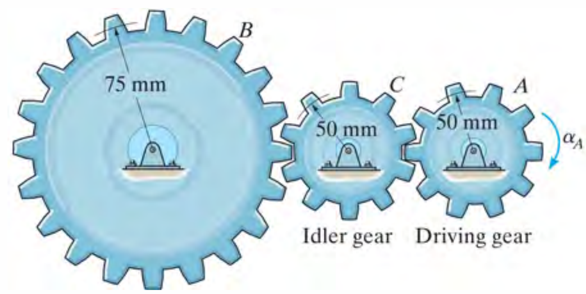
16–7. The gear A on the drive shaft of the outboard motor has a radius $r_A = 0.5$ in. and the meshed pinion gear B on the propeller shaft has a radius $r_B = 1.2$ in. Determine the angular velocity of the propeller in $t = 1.5$ s, if the drive shaft rotates with an angular acceleration $\alpha = (400t^3)$ rad/s^2, where t is in seconds. The propeller is originally at rest and the motor frame does not move.

***16–8.** For the outboard motor in Prob. 16–7, determine the magnitude of the velocity and acceleration of point P located on the tip of the propeller at the instant $t = 0.75$ s.



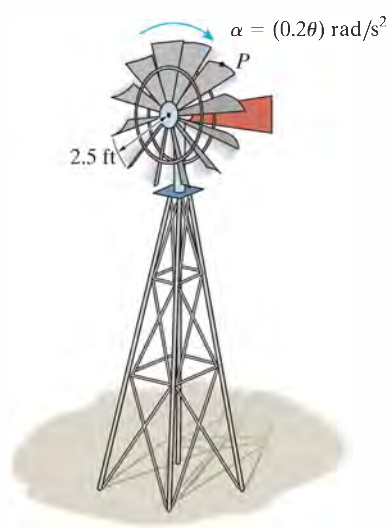
Probs. 16–7/8

•16–9. When only two gears are in mesh, the driving gear A and the driven gear B will always turn in opposite directions. In order to get them to turn in the *same direction* an idler gear C is used. In the case shown, determine the angular velocity of gear B when $t = 5$ s, if gear A starts from rest and has an angular acceleration of $\alpha_A = (3t + 2)$ rad/s^2, where t is in seconds.



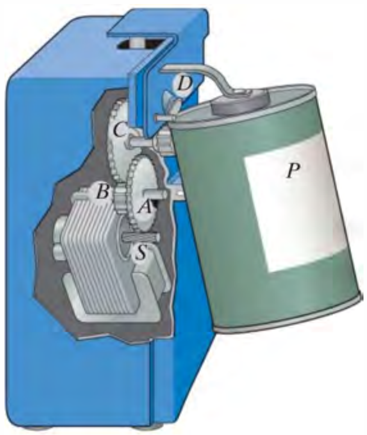
Prob. 16–9

16–10. During a gust of wind, the blades of the windmill are given an angular acceleration of $\alpha = (0.2\theta)$ rad/s^2, where θ is in radians. If initially the blades have an angular velocity of 5 rad/s, determine the speed of point P, located at the tip of one of the blades, just after the blade has turned two revolutions.



Prob. 16–10

16–11. The can opener operates such that the can is driven by the drive wheel D. If the armature shaft S on the motor turns with a constant angular velocity of 40 rad/s, determine the angular velocity of the can. The radii of S, can P, drive wheel D, gears A, B, and C, are $r_S = 5$ mm, $r_P = 40$ mm, $r_D = 7.5$ mm, $r_A = 20$ mm, $r_B = 10$ mm, and $r_C = 25$ mm, respectively.



Prob. 16–11

***16–12.** If the motor of the electric drill turns the armature shaft S with a constant angular acceleration of $\alpha_S = 30$ rad/s^2, determine the angular velocity of the shaft after it has turned 200 rev, starting from rest.

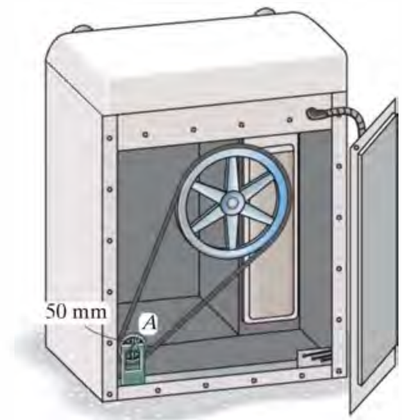
•16–13. If the motor of the electric drill turns the armature shaft S with an angular velocity of $\omega_S = (100t^{1/2})$ rad/s, determine the angular velocity and angular acceleration of the shaft at the instant it has turned 200 rev, starting from rest.

Probs. 16–12/13

16–14. A disk having a radius of 6 in. rotates about a fixed axis with an angular velocity of $\omega = (2t + 3)$ rad/s, where t is in seconds. Determine the tangential and normal components of acceleration of a point located on the rim of the disk at the instant the angular displacement is $\theta = 40$ rad.

16–15. The 50-mm-radius pulley A of the clothes dryer rotates with an angular acceleration of $\alpha_A = (27\theta_A^{1/2})$ rad/s^2, where θ_A is in radians. Determine its angular acceleration when $t = 1$ s, starting from rest.

***16–16.** If the 50-mm-radius motor pulley A of the clothes dryer rotates with an angular acceleration of $\alpha_A = (10 + 50t)$ rad/s^2, where t is in seconds, determine its angular velocity when $t = 3$ s, starting from rest.

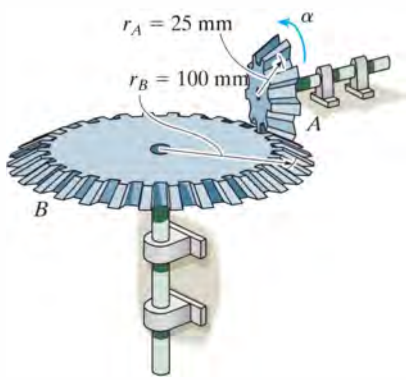


Prob. 16–15/16

•16–17. The vacuum cleaner's armature shaft S rotates with an angular acceleration of $\alpha = 4\omega^{3/4}$ rad/s^2, where ω is in rad/s. Determine the brush's angular velocity when $t = 4$ s, starting from rest. The radii of the shaft and the brush are 0.25 in. and 1 in., respectively. Neglect the thickness of the drive belt.

Prob. 16–17

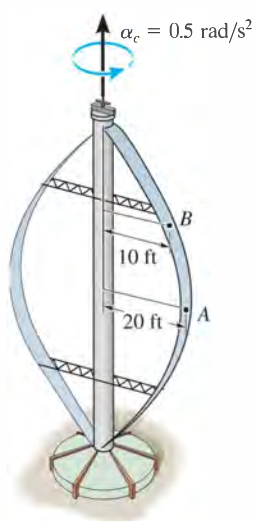
16–18. Gear A is in mesh with gear B as shown. If A starts from rest and has a constant angular acceleration of $\alpha_A = 2\ \text{rad/s}^2$, determine the time needed for B to attain an angular velocity of $\omega_B = 50\ \text{rad/s}$.



Prob. 16–18

16–19. The vertical-axis windmill consists of two blades that have a parabolic shape. If the blades are originally at rest and begin to turn with a constant angular acceleration of $\alpha_c = 0.5\ \text{rad/s}^2$, determine the magnitude of the velocity and acceleration of points A and B on the blade after the blade has rotated through two revolutions.

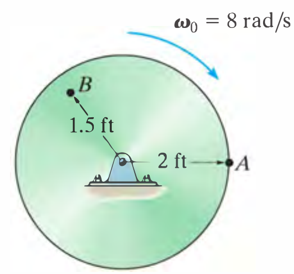
***16–20.** The vertical-axis windmill consists of two blades that have a parabolic shape. If the blades are originally at rest and begin to turn with a constant angular acceleration of $\alpha_c = 0.5\ \text{rad/s}^2$, determine the magnitude of the velocity and acceleration of points A and B on the blade when $t = 4$ s.



Probs. 16–19/20

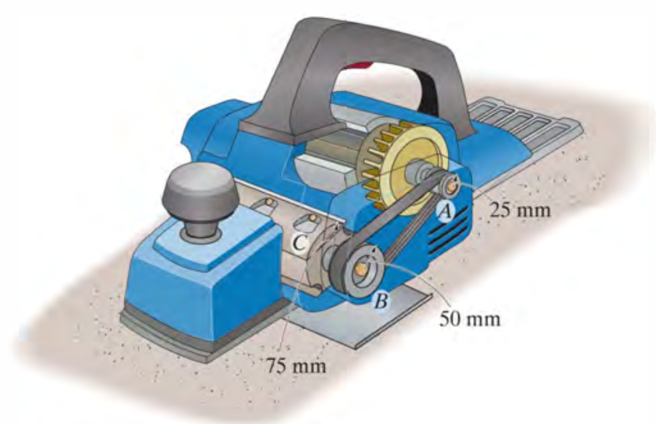
16.21. The disk is originally rotating at $\omega_0 = 8$ rad/s. If it is subjected to a constant angular acceleration of $\alpha = 6\ \text{rad/s}^2$, determine the magnitudes of the velocity and the n and t components of acceleration of point A at the instant $t = 0.5$ s.

16–22. The disk is originally rotating at $\omega_0 = 8$ rad/s. If it is subjected to a constant angular acceleration of $\alpha = 6\ \text{rad/s}^2$, determine the magnitudes of the velocity and the n and t components of acceleration of point B just after the wheel undergoes 2 revolutions.



Probs. 16–21/22

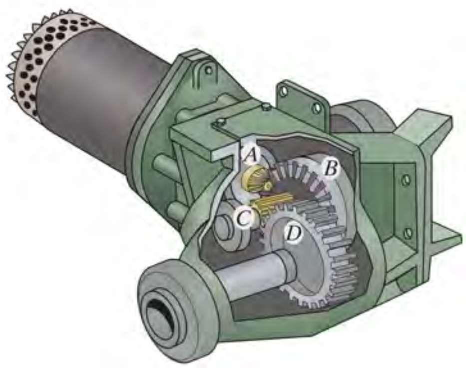
16–23. The blade C of the power plane is driven by pulley A mounted on the armature shaft of the motor. If the constant angular acceleration of pulley A is $\alpha_A = 40\ \text{rad/s}^2$, determine the angular velocity of the blade at the instant A has turned 400 rev, starting from rest.



Prob. 16–23

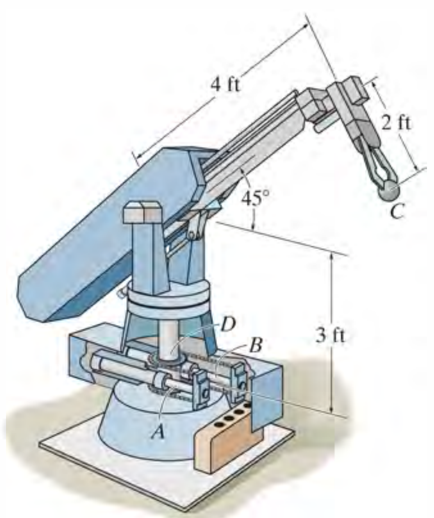
***16–24.** For a short time the motor turns gear A with an angular acceleration of $\alpha_A = (30t^{1/2})\ \text{rad/s}^2$, where t is in seconds. Determine the angular velocity of gear D when $t = 5$ s, starting from rest. Gear A is initially at rest. The radii of gears A, B, C, and D are $r_A = 25$ mm, $r_B = 100$ mm, $r_C = 40$ mm, and $r_D = 100$ mm, respectively.

•16–25. The motor turns gear A so that its angular velocity increases uniformly from zero to 3000 rev/min after the shaft turns 200 rev. Determine the angular velocity of gear D when $t = 3$ s. The radii of gears A, B, C, and D are $r_A = 25$ mm, $r_B = 100$ mm, $r_C = 40$ mm, and $r_D = 100$ mm, respectively.



Probs. 16–24/25

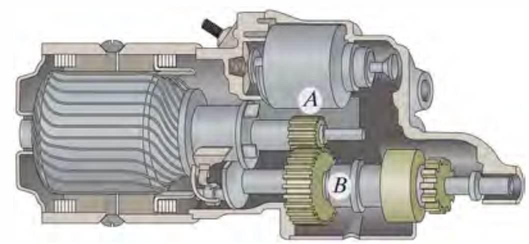
16–26. Rotation of the robotic arm occurs due to linear movement of the hydraulic cylinders A and B. If this motion causes the gear at D to rotate clockwise at 5 rad/s, determine the magnitude of velocity and acceleration of the part C held by the grips of the arm.



Prob. 16–26

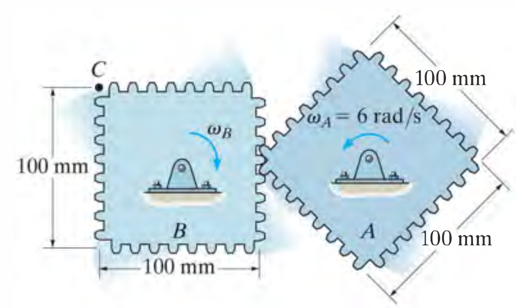
16–27. For a short time, gear A of the automobile starter rotates with an angular acceleration of $\alpha_A = (450t^2 + 60)\ \text{rad/s}^2$, where t is in seconds. Determine the angular velocity and angular displacement of gear B when $t = 2$ s, starting from rest. The radii of gears A and B are 10 mm and 25 mm, respectively.

***16–28.** For a short time, gear A of the automobile starter rotates with an angular acceleration of $\alpha_A = (50\omega^{1/2})\ \text{rad/s}^2$, where ω is in rad/s. Determine the angular velocity of gear B after gear A has rotated 50 rev, starting from rest. The radii of gears A and B are 10 mm and 25 mm, respectively.



Probs. 16–27/28

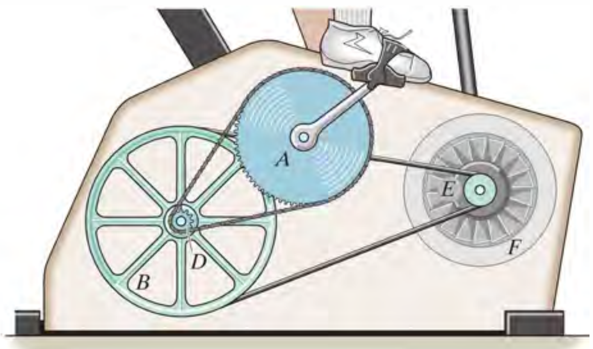
•16–29. Gear A rotates with a constant angular velocity of $\omega_A = 6$ rad/s. Determine the largest angular velocity of gear B and the speed of point C.



Prob. 16–29

16–30. If the operator initially drives the pedals at 20 rev/min, and then begins an angular acceleration of 30 rev/min^2, determine the angular velocity of the flywheel F when $t = 3$ s. Note that the pedal arm is fixed connected to the chain wheel A, which in turn drives the sheave B using the fixed connected clutch gear D. The belt wraps around the sheave then drives the pulley E and fixed-connected flywheel.

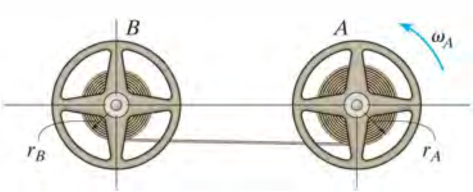
16–31. If the operator initially drives the pedals at 12 rev/min, and then begins an angular acceleration of 8 rev/min^2, determine the angular velocity of the flywheel F after the pedal arm has rotated 2 revolutions. Note that the pedal arm is fixed connected to the chain wheel A, which in turn drives the sheave B using the fixed-connected clutch gear D. The belt wraps around the sheave then drives the pulley E and fixed-connected flywheel.



$r_A = 125$ mm $r_B = 175$ mm
$r_D = 20$ mm $r_E = 30$ mm

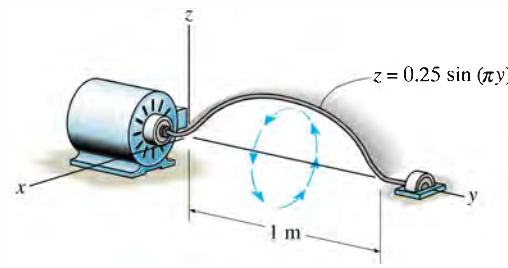
Probs. 16–30/31

*__16–32.__ The drive wheel A has a constant angular velocity of ω_A. At a particular instant, the radius of rope wound on each wheel is as shown. If the rope has a thickness T, determine the angular acceleration of wheel B.



Prob. 16–32

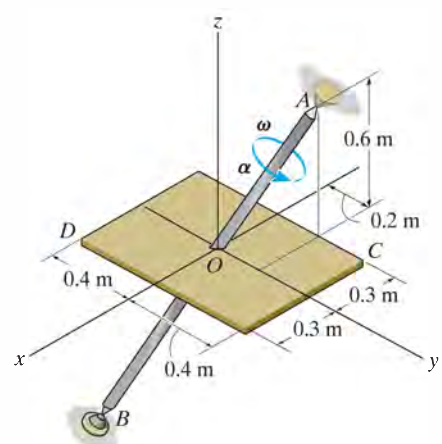
•**16–33.** If the rod starts from rest in the position shown and a motor drives it for a short time with an angular acceleration of $\alpha = (1.5e^t)$ rad/s^2, where t is in seconds, determine the magnitude of the angular velocity and the angular displacement of the rod when $t = 3$ s. Locate the point on the rod which has the greatest velocity and acceleration, and compute the magnitudes of the velocity and acceleration of this point when $t = 3$ s. The rod is defined by $z = 0.25 \sin(\pi y)$ m, where the argument for the sine is given in radians and y is in meters.



Prob. 16–33

16–34. If the shaft and plate rotates with a constant angular velocity of $\omega = 14$ rad/s, determine the velocity and acceleration of point C located on the corner of the plate at the instant shown. Express the result in Cartesian vector form.

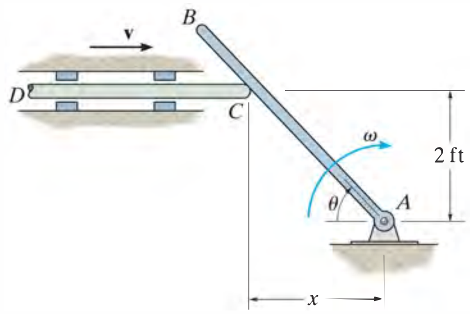
16–35. At the instant shown, the shaft and plate rotates with an angular velocity of $\omega = 14$ rad/s and angular acceleration of $\alpha = 7$ rad/s^2. Determine the velocity and acceleration of point D located on the corner of the plate at this instant. Express the result in Cartesian vector form.



Probs. 16–34/35

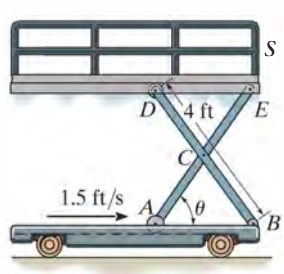
PROBLEMS

***16–36.** Rod CD presses against AB, giving it an angular velocity. If the angular velocity of AB is maintained at $\omega = 5$ rad/s, determine the required magnitude of the velocity $\mathbf{v}$ of CD as a function of the angle θ of rod AB.



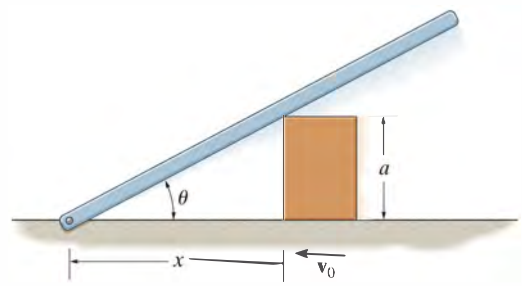
Prob. 16–36

•16–37. The scaffold S is raised by moving the roller at A toward the pin at B. If A is approaching B with a speed of 1.5 ft/s, determine the speed at which the platform rises as a function of θ. The 4-ft links are pin connected at their midpoint.



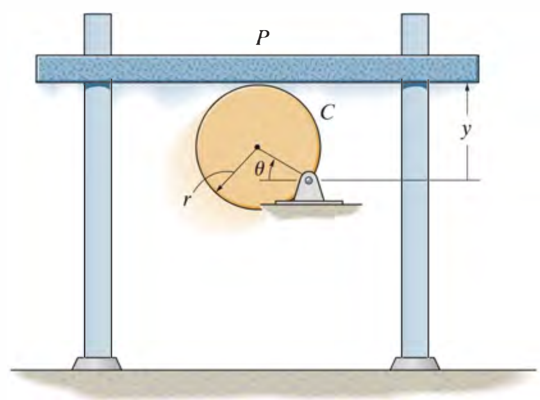
Prob. 16–37

16–38. The block moves to the left with a constant velocity $\mathbf{v}_0$. Determine the angular velocity and angular acceleration of the bar as a function of θ.



Prob. 16–38

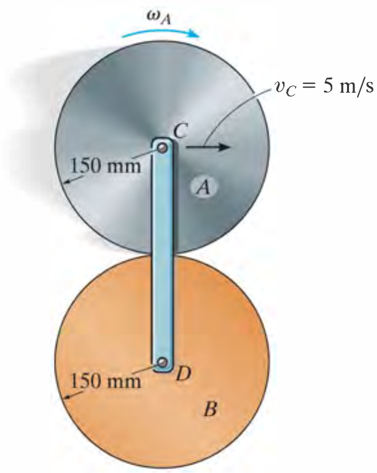
16–39. Determine the velocity and acceleration of platform P as a function of the angle θ of cam C if the cam rotates with a constant angular velocity $\boldsymbol{\omega}$. The pin connection does not cause interference with the motion of P on C. The platform is constrained to move vertically by the smooth vertical guides.



Prob. 16–39

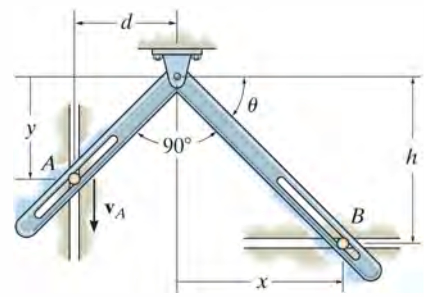
16

***16–40.** Disk A rolls without slipping over the surface of the *fixed* cylinder B. Determine the angular velocity of A if its center C has a speed $v_C = 5$ m/s. How many revolutions will A rotate about its center just after link DC completes one revolution?



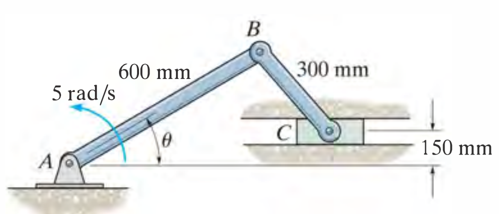
Prob. 16–40

16–42. The pins at A and B are constrained to move in the vertical and horizontal tracks. If the slotted arm is causing A to move downward at $\mathbf{v}_A$, determine the velocity of B as a function of θ.



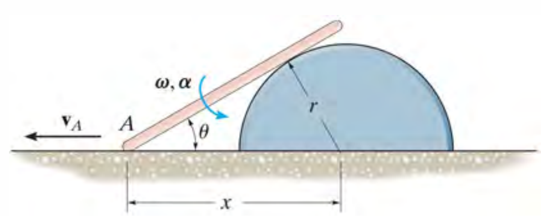
Prob. 16–42

•16–41. Crank AB rotates with a constant angular velocity of 5 rad/s. Determine the velocity of block C and the angular velocity of link BC at the instant $\theta = 30°$.



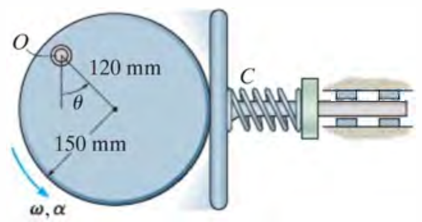
Prob. 16–41

16–43. End A of the bar moves to the left with a constant velocity $\mathbf{v}_A$. Determine the angular velocity $\boldsymbol{\omega}$ and angular acceleration $\boldsymbol{\alpha}$ of the bar as a function of its position x.



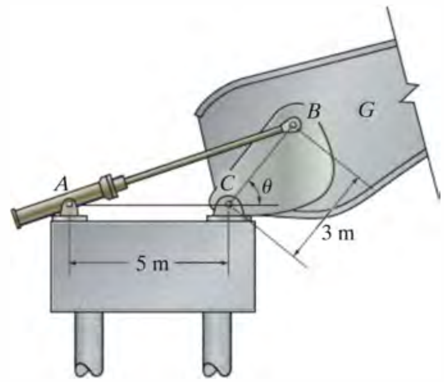
Prob. 16–43

***16–44.** Determine the velocity and acceleration of the plate at the instant $\theta = 30°$, if at this instant the circular cam is rotating about the fixed point O with an angular velocity $\omega = 4$ rad/s and an angular acceleration $\alpha = 2$ rad/s^2.



Prob. 16–44

16–47. The bridge girder G of a bascule bridge is raised and lowered using the drive mechanism shown. If the hydraulic cylinder AB shortens at a constant rate of 0.15 m/s, determine the angular velocity of the bridge girder at the instant $\theta = 60°$.

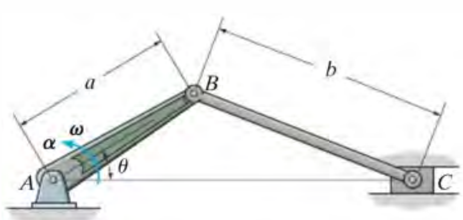


Prob. 16–47

16

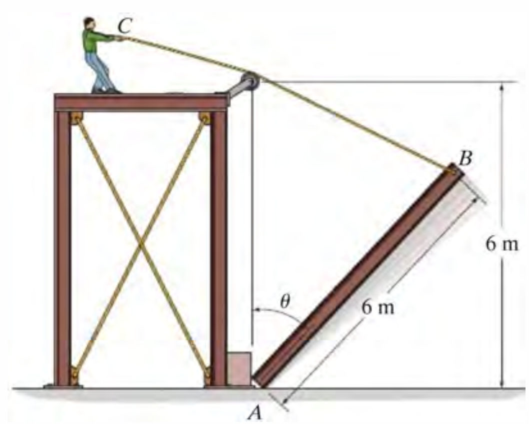
•16–45. At the instant $\theta = 30°$, crank AB rotates with an angular velocity and angular acceleration of $\omega = 10$ rad/s and $\alpha = 2$ rad/s^2, respectively. Determine the velocity and acceleration of the slider block C at this instant. Take $a = b = 0.3$ m.

16–46. At the instant $\theta = 30°$, crank AB rotates with an angular velocity and angular acceleration of $\omega = 10$ rad/s and $\alpha = 2$ rad/s^2, respectively. Determine the angular velocity and angular acceleration of the connecting rod BC at this instant. Take $a = 0.3$ m and $b = 0.5$ m.



Probs. 16–45/46

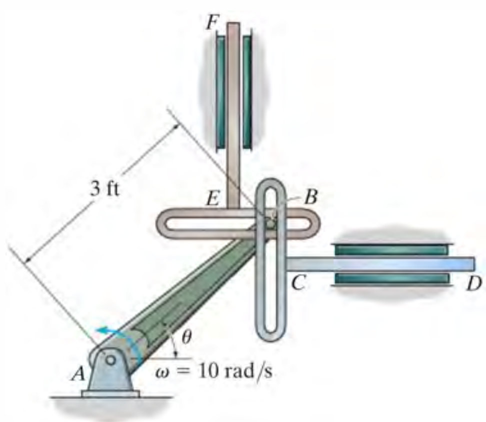
***16–48.** The man pulls on the rope at a constant rate of 0.5 m/s. Determine the angular velocity and angular acceleration of beam AB when $\theta = 60°$. The beam rotates about A. Neglect the thickness of the beam and the size of the pulley.



Prob. 16–48

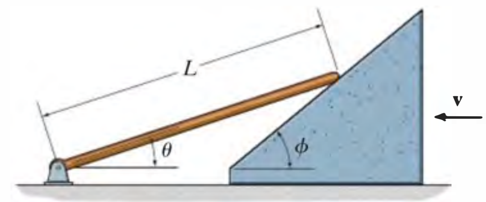
•16–49. Peg B attached to the crank AB slides in the slots mounted on follower rods, which move along the vertical and horizontal guides. If the crank rotates with a constant angular velocity of $\omega = 10$ rad/s, determine the velocity and acceleration of rod CD at the instant $\theta = 30°$.

16–50. Peg B attached to the crank AB slides in the slots mounted on follower rods, which move along the vertical and horizontal guides. If the crank rotates with a constant angular velocity of $\omega = 10$ rad/s, determine the velocity and acceleration of rod EF at the instant $\theta = 30°$.



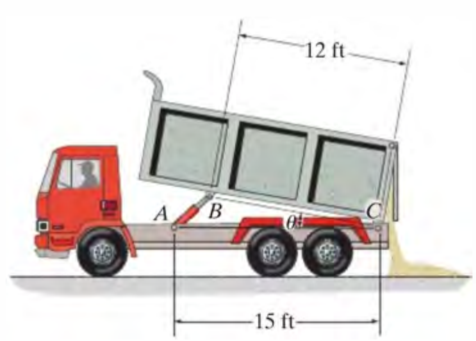
Probs. 16–49/50

***16–52.** If the wedge moves to the left with a constant velocity **v**, determine the angular velocity of the rod as a function of θ.



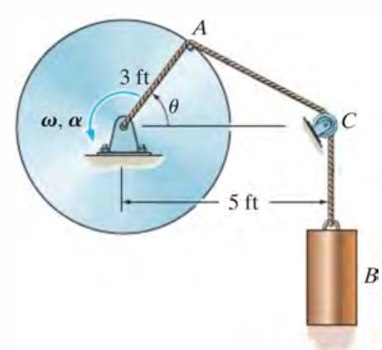
Prob. 16–52

16–51. If the hydraulic cylinder AB is extending at a constant rate of 1 ft/s, determine the dumpster's angular velocity at the instant $\theta = 30°$.



Prob. 16–51

•16–53. At the instant shown, the disk is rotating with an angular velocity of $\boldsymbol{\omega}$ and has an angular acceleration of $\boldsymbol{\alpha}$. Determine the velocity and acceleration of cylinder B at this instant. Neglect the size of the pulley at C.

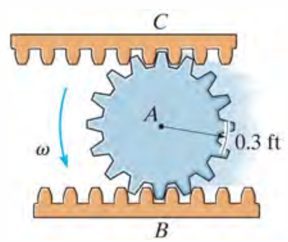


Prob. 16–53

PROBLEMS

16–54. Pinion gear A rolls on the fixed gear rack B with an angular velocity $\omega = 4$ rad/s. Determine the velocity of the gear rack C.

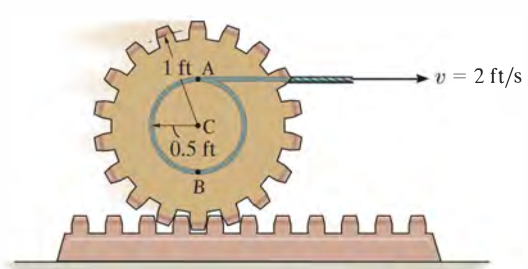
16–55. Pinion gear A rolls on the gear racks B and C. If B is moving to the right at 8 ft/s and C is moving to the left at 4 ft/s, determine the angular velocity of the pinion gear and the velocity of its center A.



Probs. 16–54/55

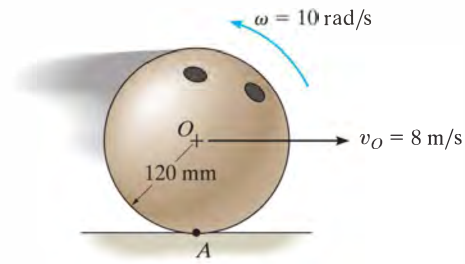
***16–56.** The gear rests in a fixed horizontal rack. A cord is wrapped around the inner core of the gear so that it remains horizontally tangent to the inner core at A. If the cord is pulled to the right with a constant speed of 2 ft/s, determine the velocity of the center of the gear, C.

•16–57. Solve Prob. 16–56 assuming that the cord is wrapped around the gear in the opposite sense, so that the end of the cord remains horizontally tangent to the inner core at B and is pulled to the right at 2 ft/s.



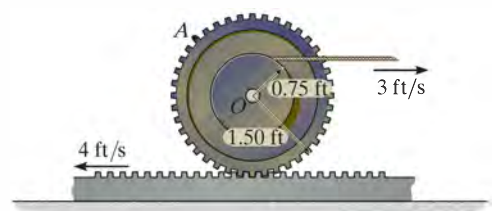
Probs. 16–56/57

16–58. A bowling ball is cast on the "alley" with a backspin of $\omega = 10$ rad/s while its center O has a forward velocity of $v_O = 8$ m/s. Determine the velocity of the contact point A in contact with the alley.



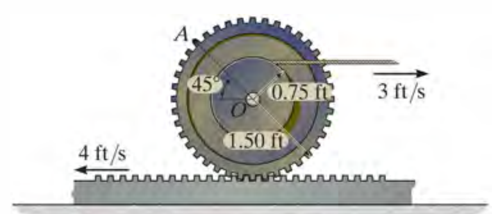
Prob. 16–58

16–59. Determine the angular velocity of the gear and the velocity of its center O at the instant shown.



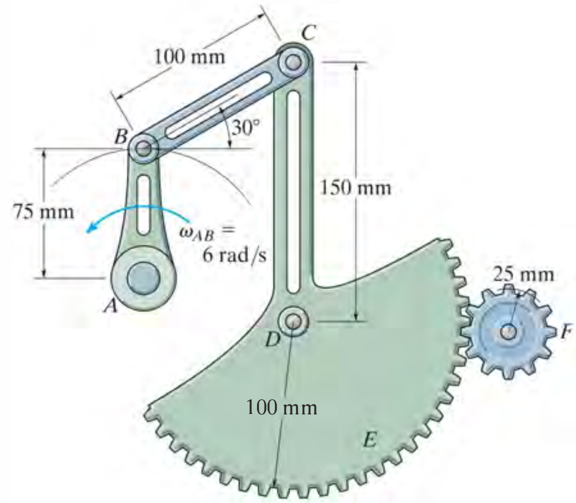
Prob. 16–59

***16–60.** Determine the velocity of point A on the rim of the gear at the instant shown.



Prob. 16–60

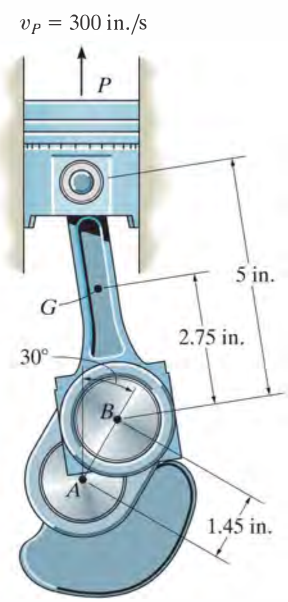
•**16–61.** The rotation of link AB creates an oscillating movement of gear F. If AB has an angular velocity of $\omega_{AB} = 6$ rad/s, determine the angular velocity of gear F at the instant shown. Gear E is rigidly attached to arm CD and pinned at D to a fixed point.



Prob. 16–61

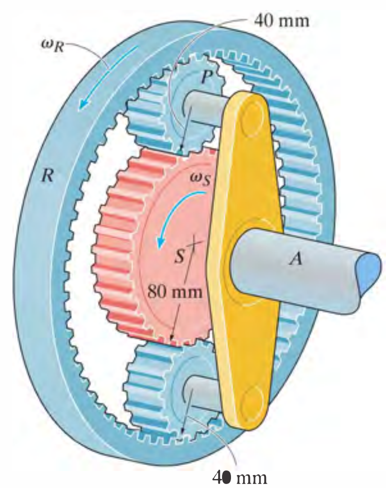
16–62. Piston P moves upward with a velocity of 300 in./s at the instant shown. Determine the angular velocity of the crankshaft AB at this instant.

16–63. Determine the velocity of the center of gravity G of the connecting rod at the instant shown. Piston P is moving upward with a velocity of 300 in./s.



Probs. 16–62/63

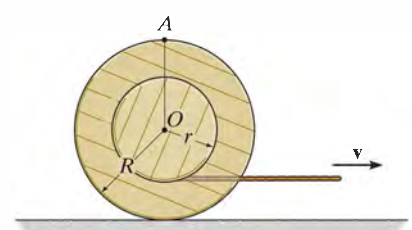
*****16–64.** The planetary gear system is used in an automatic transmission for an automobile. By locking or releasing certain gears, it has the advantage of operating the car at different speeds. Consider the case where the ring gear R is held fixed, $\omega_R = 0$, and the sun gear S is rotating at $\omega_S = 5$ rad/s. Determine the angular velocity of each of the planet gears P and shaft A.



Prob. 16–64

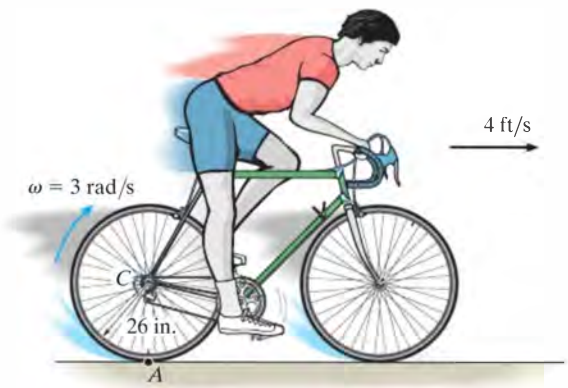
•**16–65.** Determine the velocity of the center O of the spool when the cable is pulled to the right with a velocity of **v**. The spool rolls without slipping.

16–66. Determine the velocity of point A on the outer rim of the spool at the instant shown when the cable is pulled to the right with a velocity of **v**. The spool rolls without slipping.



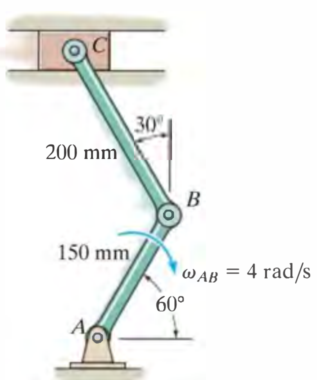
Probs. 16–65/66

16–67. The bicycle has a velocity $v = 4$ ft/s, and at the same instant the rear wheel has a clockwise angular velocity $\omega = 3$ rad/s, which causes it to slip at its contact point A. Determine the velocity of point A.



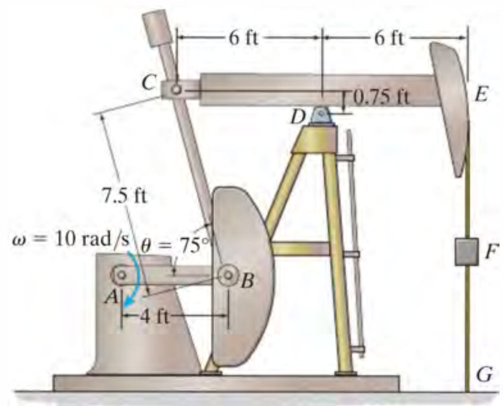
Prob. 16–67

*__16–68.__ If bar AB has an angular velocity $\omega_{AB} = 4$ rad/s, determine the velocity of the slider block C at the instant shown.



Prob. 16–68

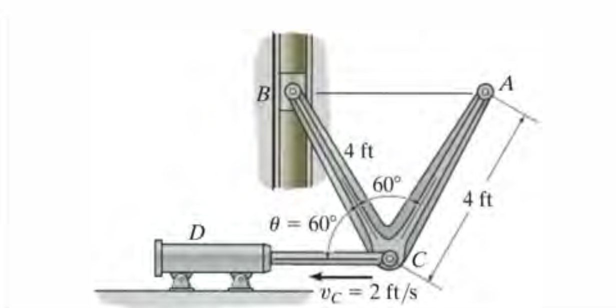
•**16–69.** The pumping unit consists of the crank pitman AB, connecting rod BC, walking beam CDE and pull rod F. If the crank is rotating with an angular velocity of $\omega = 10$ rad/s, determine the angular velocity of the walking beam and the velocity of the pull rod EFG at the instant shown.



Prob. 16–69

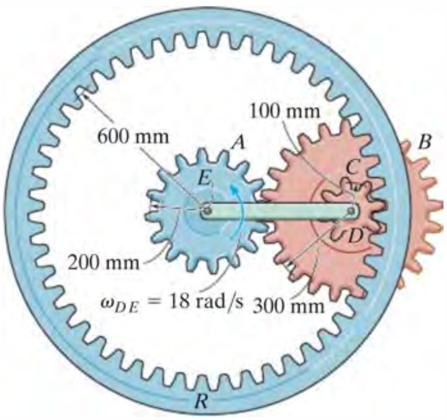
16–70. If the hydraulic cylinder shortens at a constant rate of $v_C = 2$ ft/s, determine the angular velocity of link ACB and the velocity of block B at the instant shown.

16–71. If the hydraulic cylinder shortens at a constant rate of $v_C = 2$ ft/s, determine the velocity of end A of link ACB at the instant shown.



Probs. 16–70/71

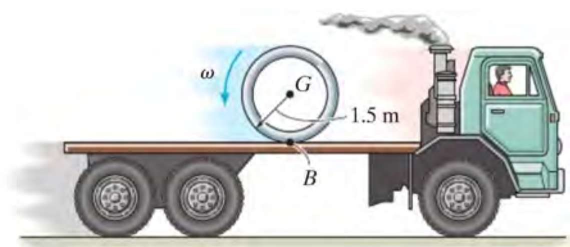
***16–72.** The epicyclic gear train consists of the sun gear A which is in mesh with the planet gear B. This gear has an inner hub C which is fixed to B and in mesh with the fixed ring gear R. If the connecting link DE pinned to B and C is rotating at $\omega_{DE} = 18$ rad/s about the pin at E, determine the angular velocities of the planet and sun gears.



Prob. 16–72

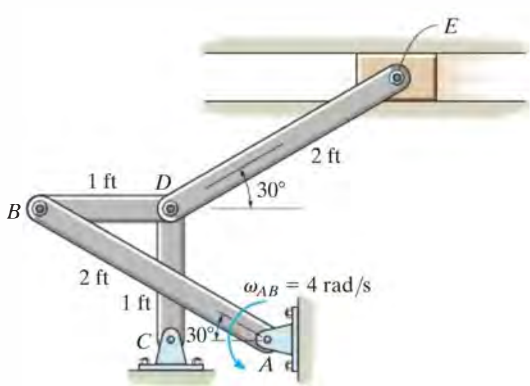
16–74. At the instant shown, the truck travels to the right at 3 m/s, while the pipe rolls counterclockwise at $\omega = 8$ rad/s without slipping at B. Determine the velocity of the pipe's center G.

16–75. At the instant shown, the truck travels to the right at 8 m/s. If the pipe does not slip at B, determine its angular velocity if its mass center G appears to remain stationary to an observer on the ground.



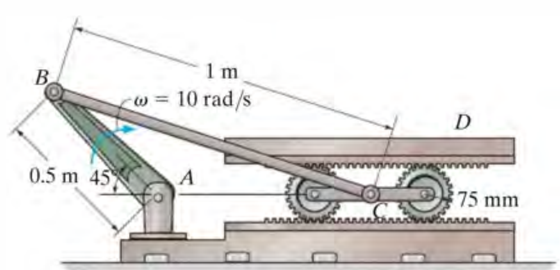
Probs. 16–74/75

•16–73. If link AB has an angular velocity of $\omega_{AB} = 4$ rad/s at the instant shown, determine the velocity of the slider block E at this instant. Also, identify the type of motion of each of the four links.



Prob. 16–73

***16–76.** The mechanism of a reciprocating printing table is driven by the crank AB. If the crank rotates with an angular velocity of $\omega = 10$ rad/s, determine the velocity of point C at the instant shown.



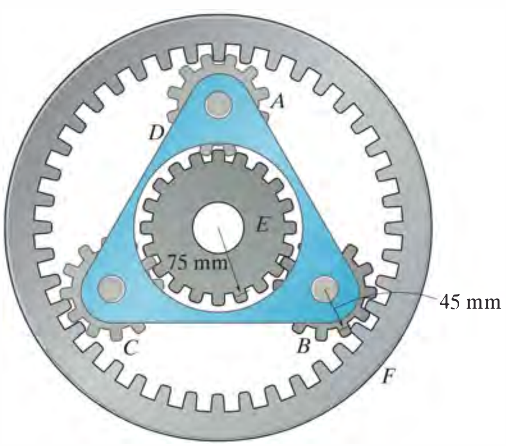
Prob. 16–76

16

•16–77. The planetary gear set of an automatic transmission consists of three planet gears *A*, *B*, and *C*, mounted on carrier *D*, and meshed with the sun gear *E* and ring gear *F*. By controlling which gear of the planetary set rotates and which gear receives the engine's power, the automatic transmission can alter a car's speed and direction. If the carrier is rotating with a counterclockwise angular velocity of $\omega_D = 20$ rad/s while the ring gear is rotating with a clockwise angular velocity of $\omega_F = 10$ rad/s, determine the angular velocity of the planet gears and the sun gear. The radii of the planet gears and the sun gear are 45 mm and 75 mm, respectively.

16–78. The planetary gear set of an automatic transmission consists of three planet gears *A*, *B*, and *C*, mounted on carrier *D*, and meshed with sun gear *E* and ring gear *F*. By controlling which gear of the planetary set rotates and which gear receives the engine's power, the automatic transmission can alter a car's speed and direction. If the ring gear is held stationary and the carrier is rotating with a clockwise angular velocity of $\omega_D = 20$ rad/s, determine the angular velocity of the planet gears and the sun gear. The radii of the planet gears and the sun gear are 45 mm and 75 mm, respectively.

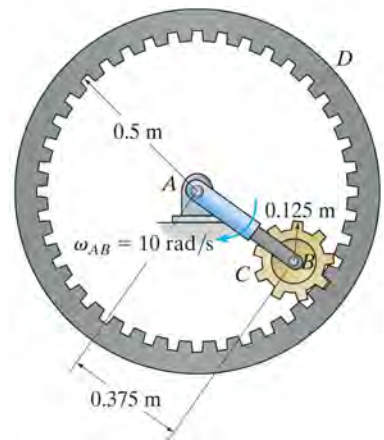
16



Probs. 16–77/78

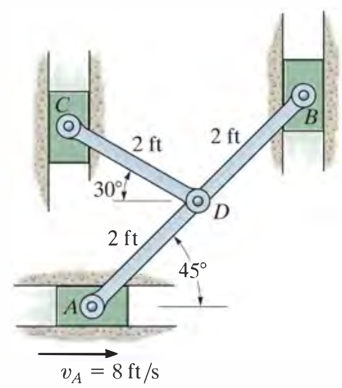
16–79. If the ring gear *D* is held fixed and link *AB* rotates with an angular velocity of $\omega_{AB} = 10$ rad/s, determine the angular velocity of gear *C*.

***16–80.** If the ring gear *D* rotates counterclockwise with an angular velocity of $\omega_D = 5$ rad/s while link *AB* rotates clockwise with an angular velocity of $\omega_{AB} = 10$ rad/s, determine the angular velocity of gear *C*.



Probs. 16–79/80

•16–81. If the slider block *A* is moving to the right at $v_A = 8$ ft/s, determine the velocity of blocks *B* and *C* at the instant shown. Member *CD* is pin connected to member *ADB*.



Prob. 16–81

PROBLEMS

16–82. Solve Prob. 16–54 using the method of instantaneous center of zero velocity.

16–83. Solve Prob. 16–56 using the method of instantaneous center of zero velocity.

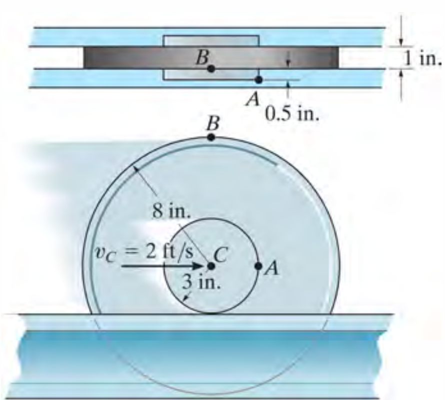
***16–84.** Solve Prob. 16–64 using the method of instantaneous center of zero velocity.

•16–85. Solve Prob. 16–58 using the method of instantaneous center of zero velocity.

16–86. Solve Prob. 16–67 using the method of instantaneous center of zero velocity.

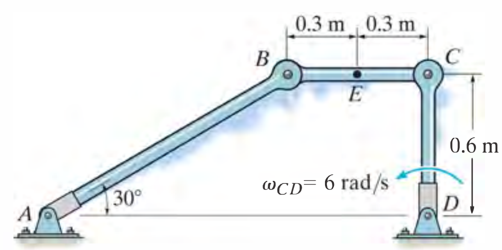
16–87. Solve Prob. 16–68 using the method of instantaneous center of zero velocity.

***16–88.** The wheel rolls on its hub without slipping on the horizontal surface. If the velocity of the center of the wheel is $v_C = 2$ ft/s to the right, determine the velocities of points A and B at the instant shown.



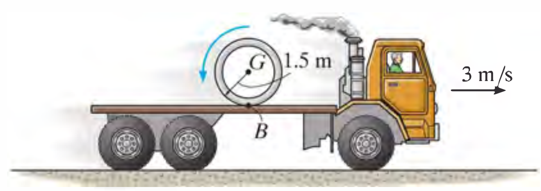
Prob. 16–88

•16–89. If link CD has an angular velocity of $\omega_{CD} = 6$ rad/s, determine the velocity of point E on link BC and the angular velocity of link AB at the instant shown.



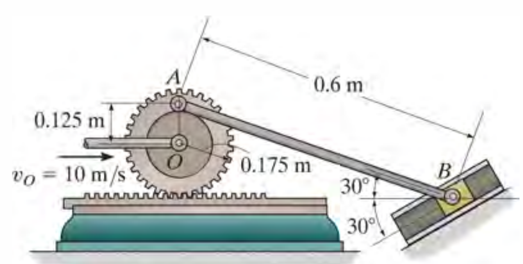
Prob. 16–89

16–90. At the instant shown, the truck travels to the right at 3 m/s, while the pipe rolls counterclockwise at $\omega = 6$ rad/s without slipping at B. Determine the velocity of the pipe's center G.



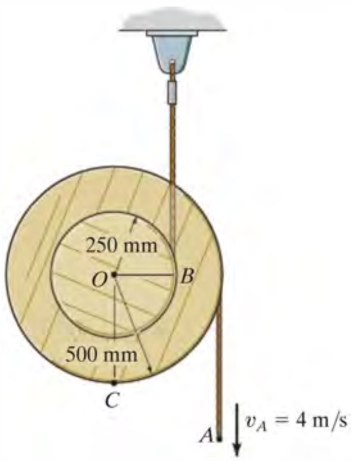
Prob. 16–90

16–91. If the center O of the gear is given a velocity of $v_O = 10$ m/s, determine the velocity of the slider block B at the instant shown.



Prob. 16–91

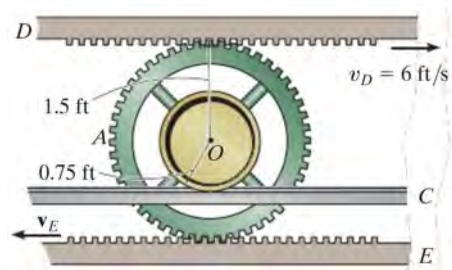
***16–92.** If end A of the cord is pulled down with a velocity of $v_A = 4$ m/s, determine the angular velocity of the spool and the velocity of point C located on the outer rim of the spool.



Prob. 16–92

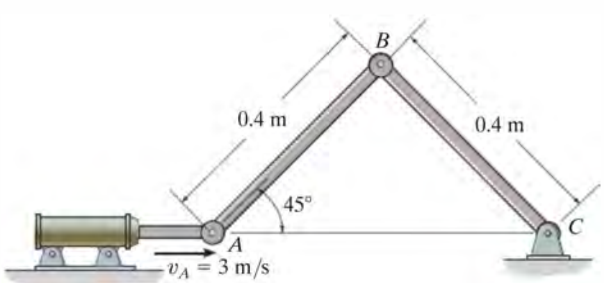
16–94. The wheel is rigidly attached to gear A, which is in mesh with gear racks D and E. If D has a velocity of $v_D = 6$ ft/s to the right and wheel rolls on track C without slipping, determine the velocity of gear rack E.

16–95. The wheel is rigidly attached to gear A, which is in mesh with gear racks D and E. If the racks have a velocity of $v_D = 6$ ft/s and $v_E = 10$ ft/s, show that it is necessary for the wheel to slip on the fixed track C. Also find the angular velocity of the gear and the velocity of its center O.



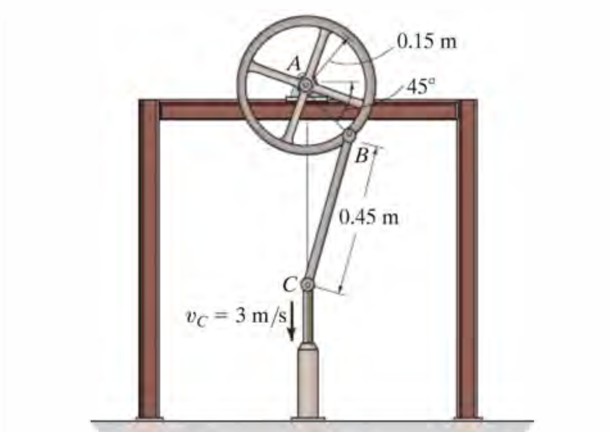
Probs. 16–94/95

•16–93. If end A of the hydraulic cylinder is moving with a velocity of $v_A = 3$ m/s, determine the angular velocity of rod BC at the instant shown.



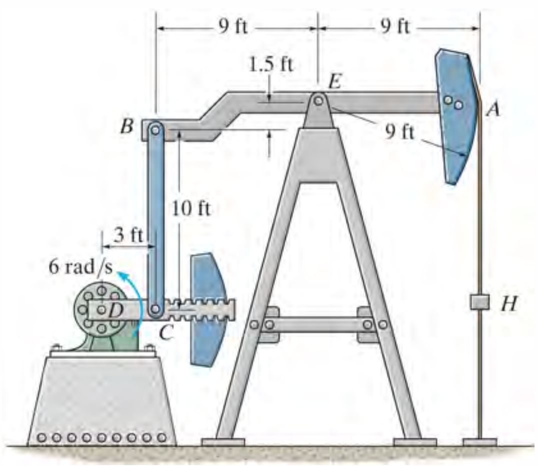
Prob. 16–93

***16–96.** If C has a velocity of $v_C = 3$ m/s, determine the angular velocity of the wheel at the instant shown.



Prob. 16–96

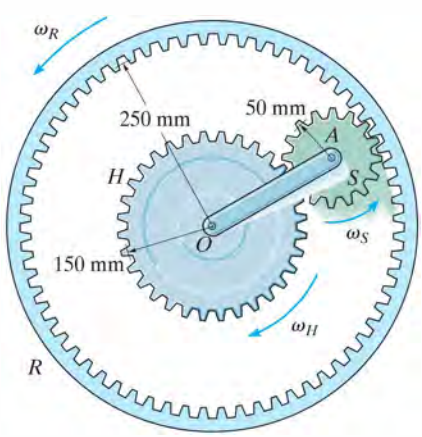
•16–97. The oil pumping unit consists of a walking beam *AB*, connecting rod *BC*, and crank *CD*. If the crank rotates at a constant rate of 6 rad/s, determine the speed of the rod hanger *H* at the instant shown. *Hint:* Point *B* follows a circular path about point *E* and therefore the velocity of *B* is *not* vertical.



Prob. 16–97

16–98. If the hub gear *H* and ring gear *R* have angular velocities $\omega_H = 5$ rad/s and $\omega_R = 20$ rad/s, respectively, determine the angular velocity ω_S of the spur gear *S* and the angular velocity of arm *OA*.

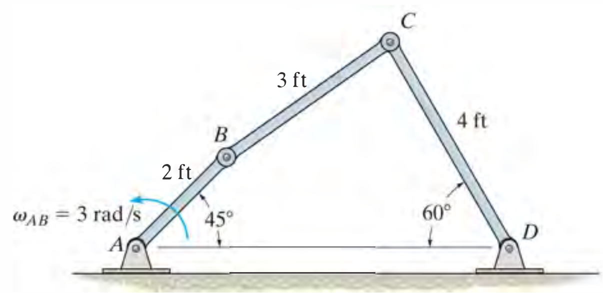
16–99. If the hub gear *H* has an angular velocity $\omega_H = 5$ rad/s, determine the angular velocity of the ring gear *R* so that the arm *OA* which is pinned to the spur gear *S* remains stationary ($\omega_{OA} = 0$). What is the angular velocity of the spur gear?



Probs. 16–98/99

***16–100.** If rod *AB* is rotating with an angular velocity $\omega_{AB} = 3$ rad/s, determine the angular velocity of rod *BC* at the instant shown.

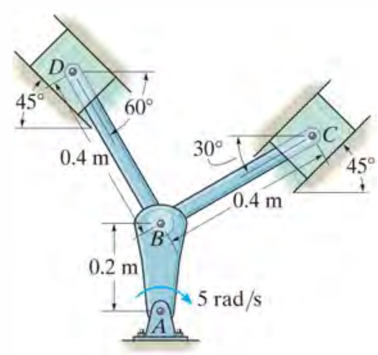
•16–101. If rod *AB* is rotating with an angular velocity $\omega_{AB} = 3$ rad/s, determine the angular velocity of rod *CD* at the instant shown.



Probs. 16–100/101

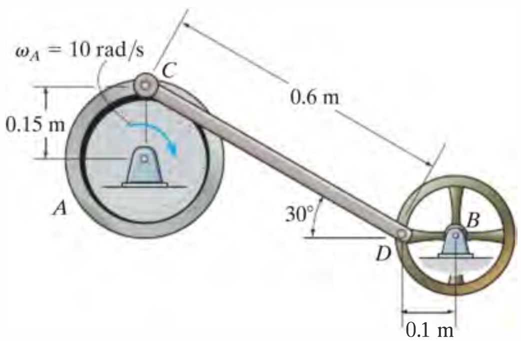
16–102. The mechanism used in a marine engine consists of a crank *AB* and two connecting rods *BC* and *BD*. Determine the velocity of the piston at *C* the instant the crank is in the position shown and has an angular velocity of 5 rad/s.

16–103. The mechanism used in a marine engine consists of a crank *AB* and two connecting rods *BC* and *BD*. Determine the velocity of the piston at *D* the instant the crank is in the position shown and has an angular velocity of 5 rad/s.



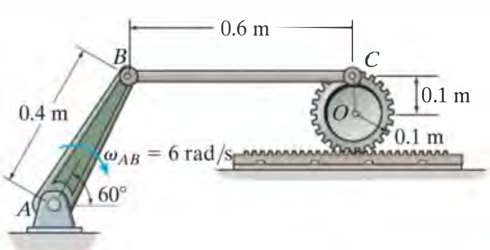
Probs. 16–102/103

***16–104.** If flywheel A is rotating with an angular velocity of $\omega_A = 10$ rad/s, determine the angular velocity of wheel B at the instant shown.



Prob. 16–104

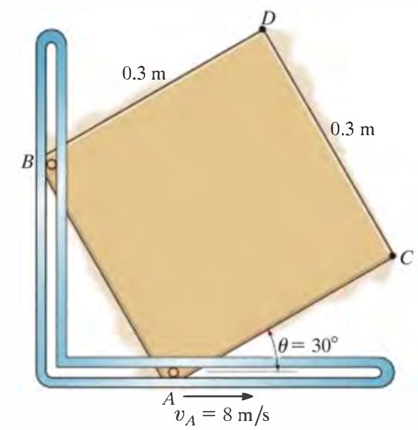
•16–105. If crank AB is rotating with an angular velocity of $\omega_{AB} = 6$ rad/s, determine the velocity of the center O of the gear at the instant shown.



Prob. 16–105

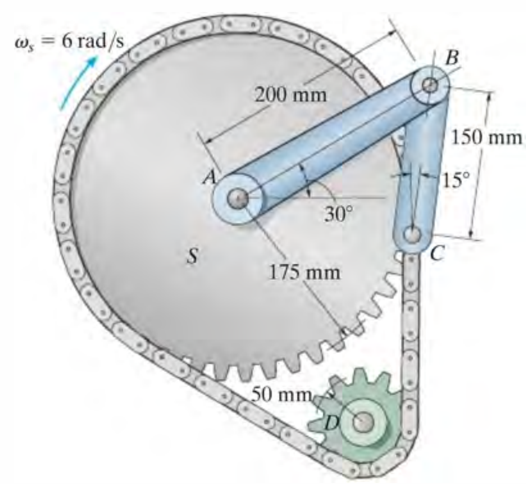
16–106. The square plate is constrained within the slots at A and B. When $\theta = 30°$, point A is moving at $v_A = 8$ m/s. Determine the velocity of point C at this instant.

16–107. The square plate is constrained within the slots at A and B. When $\theta = 30°$, point A is moving at $v_A = 8$ m/s. Determine the velocity of point D at this instant.



Probs. 16–106/107

***16–108.** The mechanism produces intermittent motion of link AB. If the sprocket S is turning with an angular velocity of $\omega_S = 6$ rad/s, determine the angular velocity of link AB at this instant. The sprocket S is mounted on a shaft which is separate from a collinear shaft attached to AB at A. The pin at C is attached to one of the chain links.

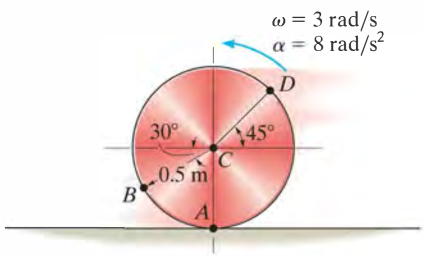


Prob. 16–108

PROBLEMS

•16–109. The disk is moving to the left such that it has an angular acceleration $\alpha = 8\ \text{rad/s}^2$ and angular velocity $\omega = 3\ \text{rad/s}$ at the instant shown. If it does not slip at A, determine the acceleration of point B.

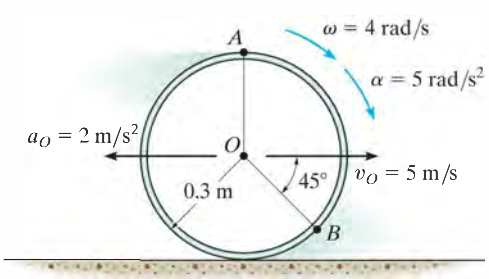
16–110. The disk is moving to the left such that it has an angular acceleration $\alpha = 8\ \text{rad/s}^2$ and angular velocity $\omega = 3\ \text{rad/s}$ at the instant shown. If it does not slip at A, determine the acceleration of point D.



Probs. 16–109/110

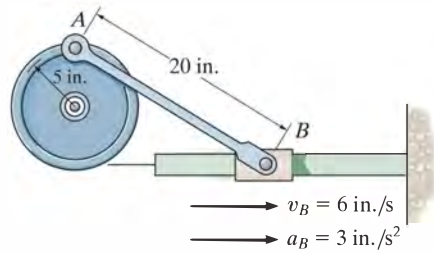
16–111. The hoop is cast on the rough surface such that it has an angular velocity $\omega = 4\ \text{rad/s}$ and an angular acceleration $\alpha = 5\ \text{rad/s}^2$. Also, its center has a velocity $v_O = 5\ \text{m/s}$ and a deceleration $a_O = 2\ \text{m/s}^2$. Determine the acceleration of point A at this instant.

***16–112.** The hoop is cast on the rough surface such that it has an angular velocity $\omega = 4\ \text{rad/s}$ and an angular acceleration $\alpha = 5\ \text{rad/s}^2$. Also, its center has a velocity of $v_O = 5\ \text{m/s}$ and a deceleration $a_O = 2\ \text{m/s}^2$. Determine the acceleration of point B at this instant.



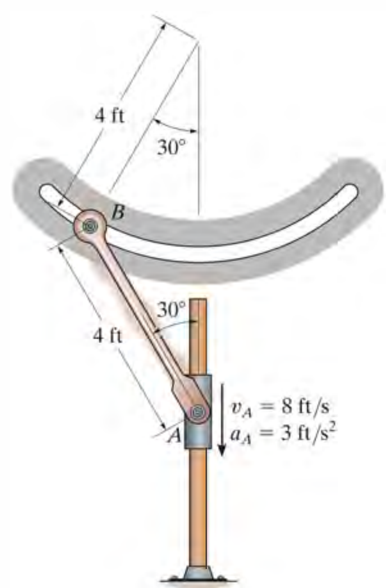
Probs. 16–111/112

•16–113. At the instant shown, the slider block B is traveling to the right with the velocity and acceleration shown. Determine the angular acceleration of the wheel at this instant.



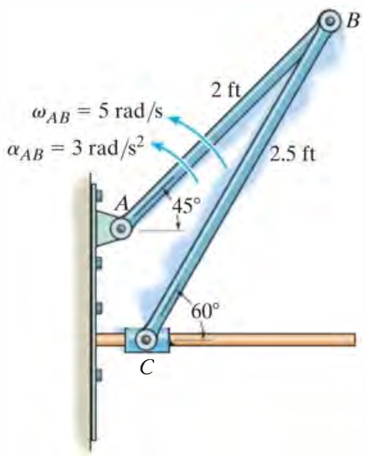
Prob. 16–113

16–114. The ends of bar AB are confined to move along the paths shown. At a given instant, A has a velocity of 8 ft/s and an acceleration of $3\ \text{ft/s}^2$. Determine the angular velocity and angular acceleration of AB at this instant.



Prob. 16–114

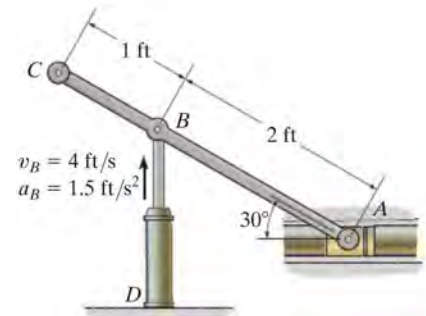
16–115. Rod AB has the angular motion shown. Determine the acceleration of the collar C at this instant.



Prob. 16–115

•16–117. The hydraulic cylinder D extends with a velocity of $v_B = 4$ ft/s and an acceleration of $a_B = 1.5$ ft/s^2. Determine the acceleration of A at the instant shown.

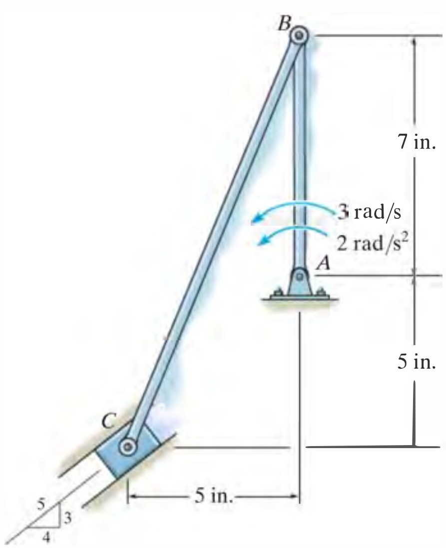
16–118. The hydraulic cylinder D extends with a velocity of $v_B = 4$ ft/s and an acceleration of $a_B = 1.5$ ft/s^2. Determine the acceleration of C at the instant shown.



Probs. 16–117/118

16

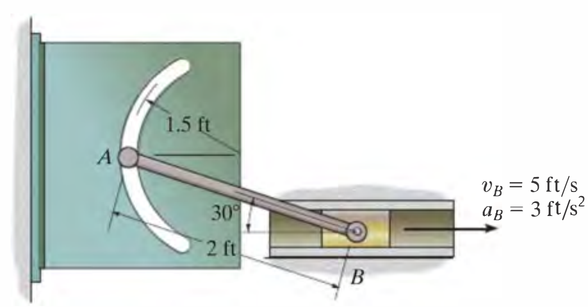
***16–116.** At the given instant member AB has the angular motions shown. Determine the velocity and acceleration of the slider block C at this instant.



Prob. 16–116

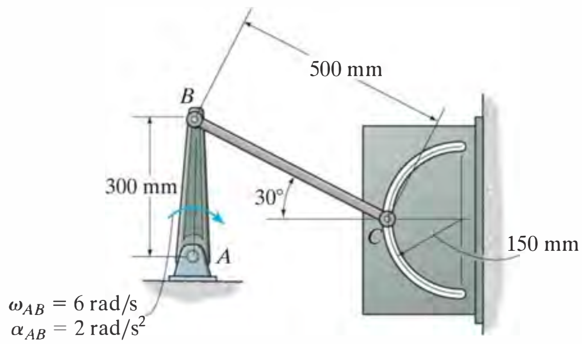
16–119. The slider block moves with a velocity of $v_B = 5$ ft/s and an acceleration of $a_B = 3$ ft/s^2. Determine the angular acceleration of rod AB at the instant shown.

***16–120.** The slider block moves with a velocity of $v_B = 5$ ft/s and an acceleration of $a_B = 3$ ft/s^2. Determine the acceleration of A at the instant shown.



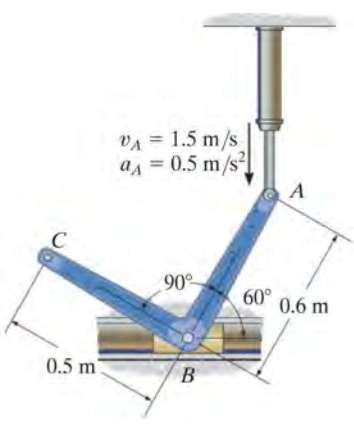
Probs. 16–119/120

•16–121. Crank AB rotates with an angular velocity of $\omega_{AB} = 6 \text{ rad/s}$ and an angular acceleration of $\alpha_{AB} = 2 \text{ rad/s}^2$. Determine the acceleration of C and the angular acceleration of BC at the instant shown.



Prob. 16–121

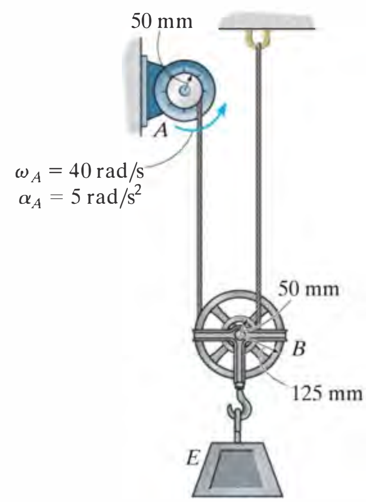
16–122. The hydraulic cylinder extends with a velocity of $v_A = 1.5 \text{ m/s}$ and an acceleration of $a_A = 0.5 \text{ m/s}^2$. Determine the angular acceleration of link ABC and the acceleration of end C at the instant shown. Point B is pin connected to the slider block.



Prob. 16–122

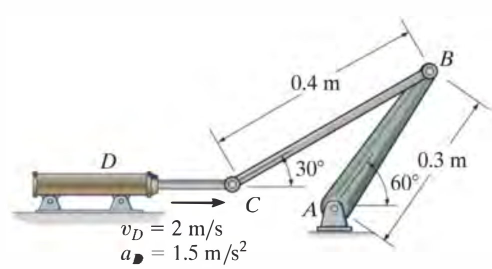
16–123. Pulley A rotates with the angular velocity and angular acceleration shown. Determine the angular acceleration of pulley B at the instant shown.

***16–124.** Pulley A rotates with the angular velocity and angular acceleration shown. Determine the acceleration of block E at the instant shown.



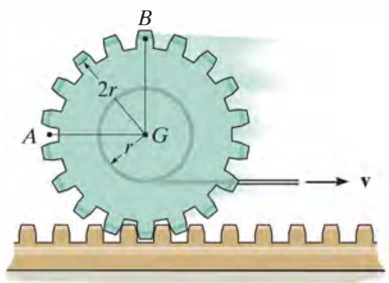
Probs. 16–123/124

•16–125. The hydraulic cylinder is extending with the velocity and acceleration shown. Determine the angular acceleration of crank AB and link BC at the instant shown.



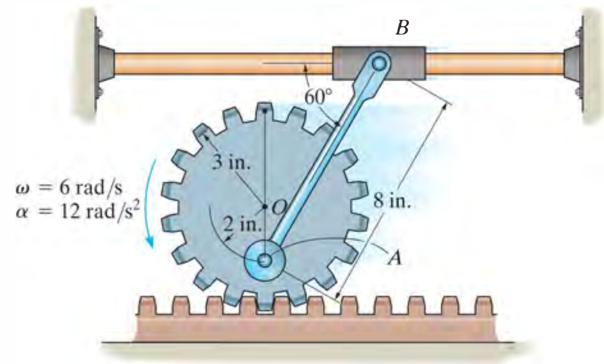
Prob. 16–125

16–126. A cord is wrapped around the inner spool of the gear. If it is pulled with a constant velocity **v**, determine the velocities and accelerations of points A and B. The gear rolls on the fixed gear rack.



Prob. 16–126

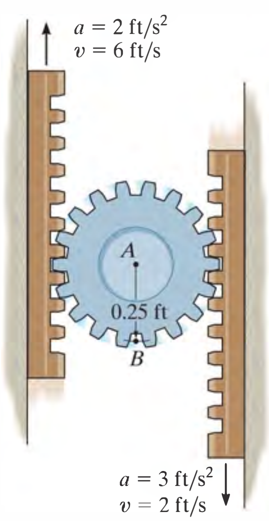
*16–128. At a given instant, the gear has the angular motion shown. Determine the accelerations of points A and B on the link and the link's angular acceleration at this instant.



Prob. 16–128

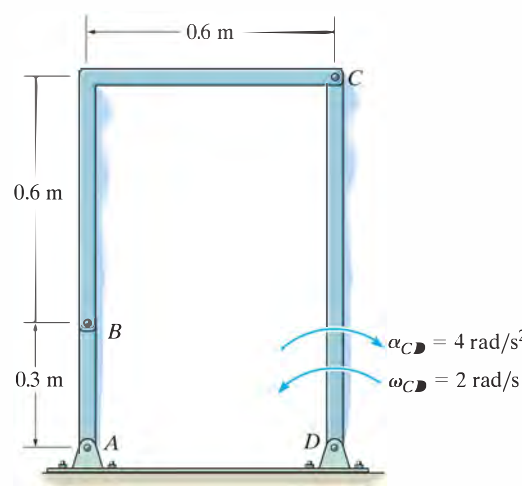
16

16–127. At a given instant, the gear racks have the velocities and accelerations shown. Determine the acceleration of points A and B.



Prob. 16–127

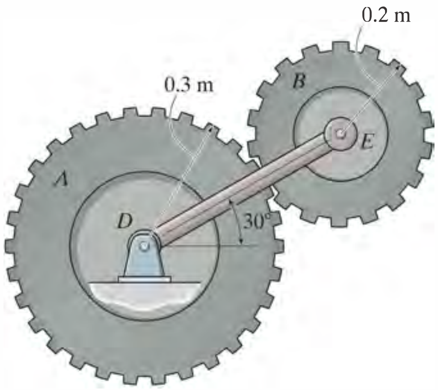
•**16–129.** Determine the angular acceleration of link AB if link CD has the angular velocity and angular deceleration shown.



Prob. 16–129

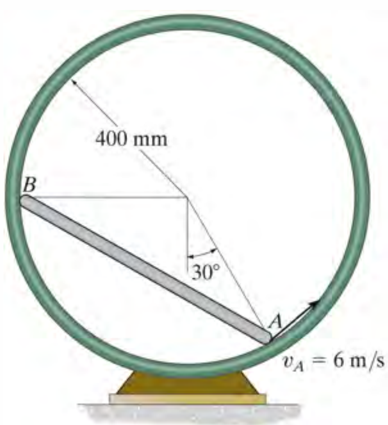
16–130. Gear A is held fixed, and arm DE rotates clockwise with an angular velocity of $\omega_{DE} = 6$ rad/s and an angular acceleration of $\alpha_{DE} = 3 \text{ rad/s}^2$. Determine the angular acceleration of gear B at the instant shown.

16–131. Gear A rotates counterclockwise with a constant angular velocity of $\omega_A = 10$ rad/s, while arm DE rotates clockwise with an angular velocity of $\omega_{DE} = 6$ rad/s and an angular acceleration of $\alpha_{DE} = 3 \text{ rad/s}^2$. Determine the angular acceleration of gear B at the instant shown.



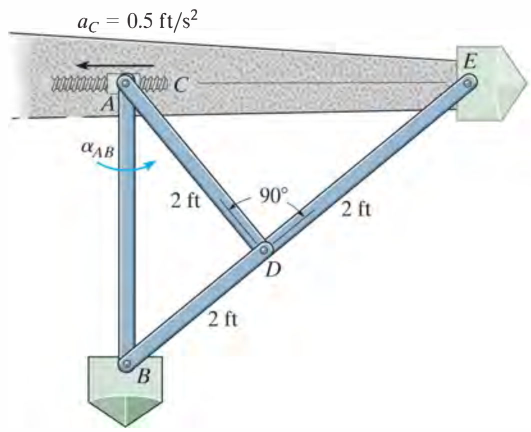
Probs. 130/131

*16–132. If end A of the rod moves with a constant velocity of $v_A = 6$ m/s, determine the angular velocity and angular acceleration of the rod and the acceleration of end B at the instant shown.



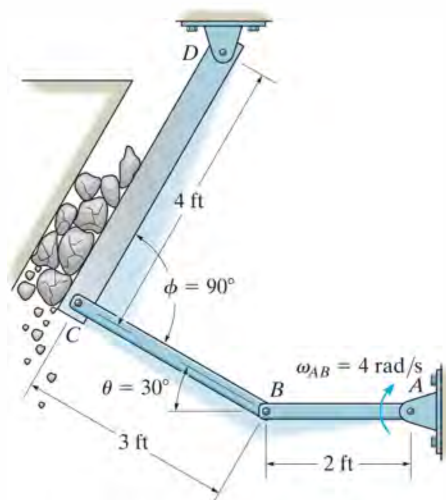
Prob. 16–132

•**16–133.** The retractable wing-tip float is used on an airplane able to land on water. Determine the angular accelerations α_{CD}, α_{BD}, and α_{AB} at the instant shown if the trunnion C travels along the horizontal rotating screw with an acceleration of $a_C = 0.5 \text{ ft/s}^2$. In the position shown, $v_C = 0$. Also, points A and E are pin connected to the wing and points A and C are coincident at the instant shown.



Prob. 16–133

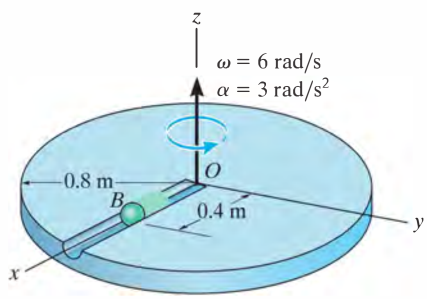
16–134. Determine the angular velocity and the angular acceleration of the plate CD of the stone-crushing mechanism at the instant AB is horizontal. At this instant $\theta = 30°$ and $\phi = 90°$. Driving link AB is turning with a constant angular velocity of $\omega_{AB} = 4$ rad/s.



Prob. 16–134

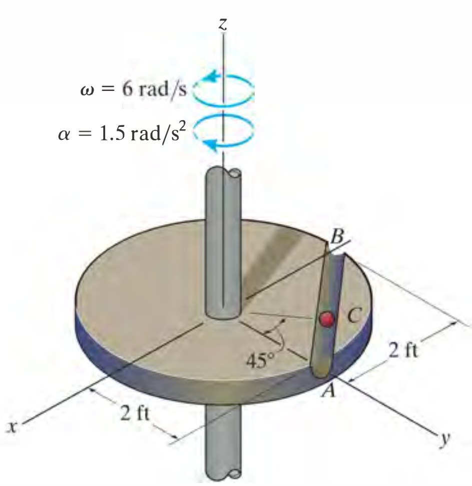
PROBLEMS

16–135. At the instant shown, ball *B* is rolling along the slot in the disk with a velocity of 600 mm/s and an acceleration of 150 mm/s^2, both measured relative to the disk and directed away from *O*. If at the same instant the disk has the angular velocity and angular acceleration shown, determine the velocity and acceleration of the ball at this instant.



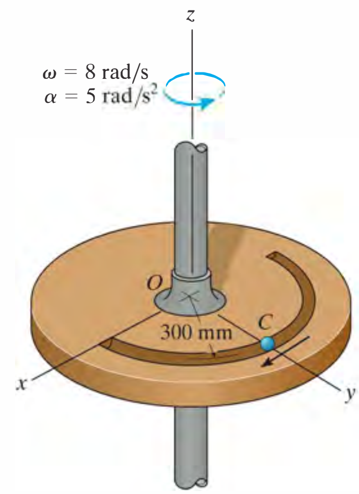
Prob. 16–135

***16–136.** Ball *C* moves along the slot from *A* to *B* with a speed of 3 ft/s, which is increasing at 1.5 ft/s^2, both measured relative to the circular plate. At this same instant the plate rotates with the angular velocity and angular deceleration shown. Determine the velocity and acceleration of the ball at this instant.



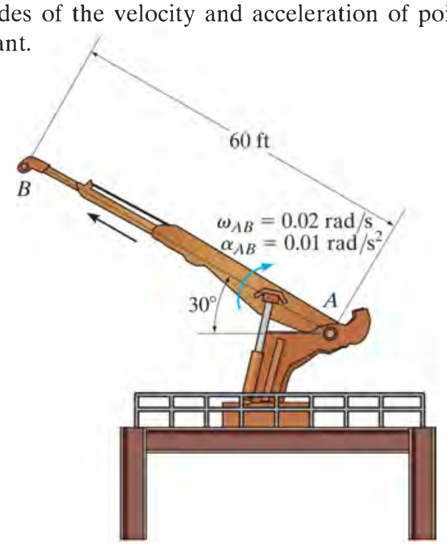
Prob. 16–136

•16–137. Ball *C* moves with a speed of 3 m/s, which is increasing at a constant rate of 1.5 m/s^2, both measured relative to the circular plate and directed as shown. At the same instant the plate rotates with the angular velocity and angular acceleration shown. Determine the velocity and acceleration of the ball at this instant.



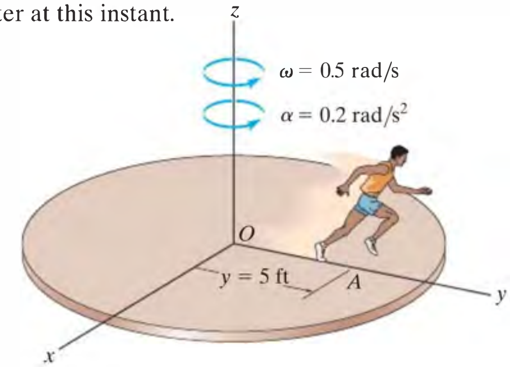
Prob. 16–137

16–138. The crane's telescopic boom rotates with the angular velocity and angular acceleration shown. At the same instant, the boom is extending with a constant speed of 0.5 ft/s, measured relative to the boom. Determine the magnitudes of the velocity and acceleration of point *B* at this instant.



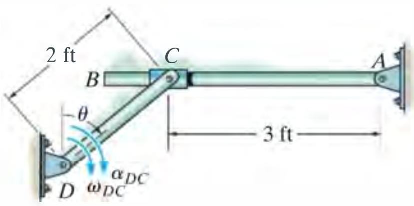
Prob. 16–138

16–139. The man stands on the platform at O and runs out toward the edge such that when he is at A, $y = 5$ ft, his mass center has a velocity of 2 ft/s and an acceleration of 3 ft/s^2, both measured relative to the platform and directed along the positive y axis. If the platform has the angular motions shown, determine the velocity and acceleration of his mass center at this instant.



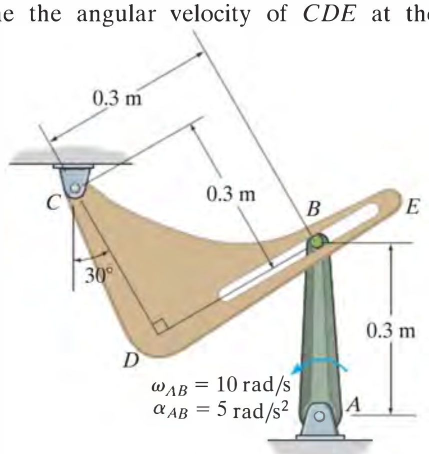
Prob. 16–139

***16–140.** At the instant $\theta = 45°$, link DC has an angular velocity of $\omega_{DC} = 4$ rad/s and an angular acceleration of $\alpha_{DC} = 2$ rad/s^2. Determine the angular velocity and angular acceleration of rod AB at this instant. The collar at C is pin connected to DC and slides freely along AB.



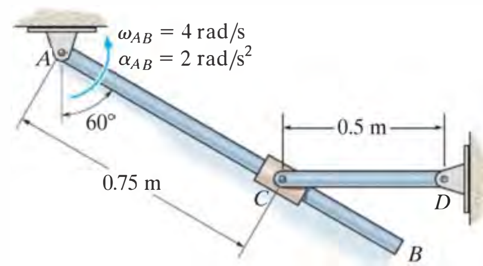
Prob. 16–140

•**16–141.** Peg B fixed to crank AB slides freely along the slot in member CDE. If AB rotates with the motion shown, determine the angular velocity of CDE at the instant shown.



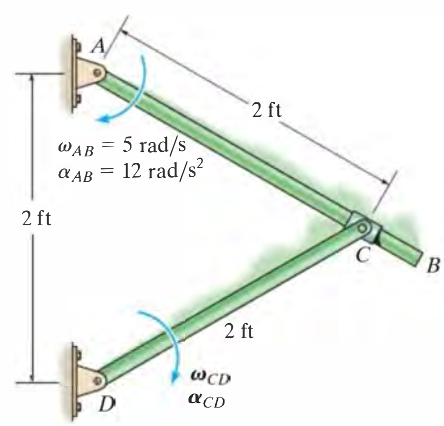
Prob. 16–141

16–142. At the instant shown rod AB has an angular velocity $\omega_{AB} = 4$ rad/s and an angular acceleration $\alpha_{AB} = 2$ rad/s^2. Determine the angular velocity and angular acceleration of rod CD at this instant. The collar at C is pin connected to CD and slides freely along AB.



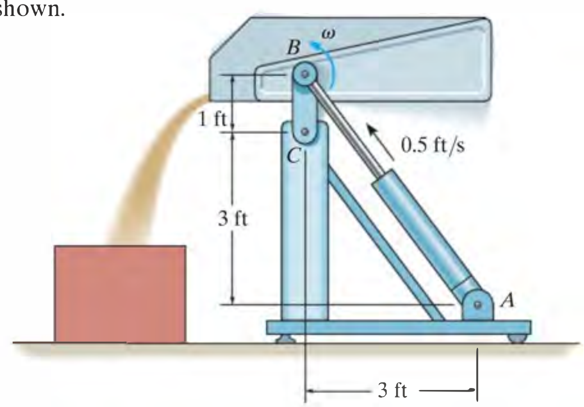
Prob. 16–142

16–143. At a given instant, rod AB has the angular motions shown. Determine the angular velocity and angular acceleration of rod CD at this instant. There is a collar at C.



Prob. 16-143

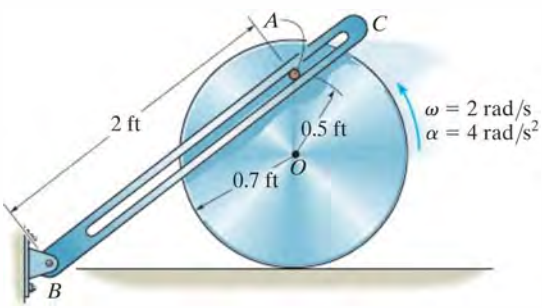
***16–144.** The dumpster pivots about C and is operated by the hydraulic cylinder AB. If the cylinder is extending at a constant rate of 0.5 ft/s, determine the angular velocity $\boldsymbol{\omega}$ of the container at the instant it is in the horizontal position shown.



Prob. 16–144

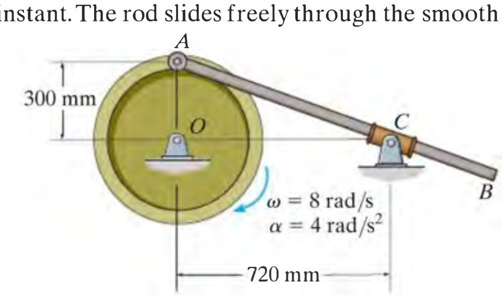
16

•16–145. The disk rolls without slipping and at a given instant has the angular motion shown. Determine the angular velocity and angular acceleration of the slotted link BC at this instant. The peg at A is fixed to the disk.



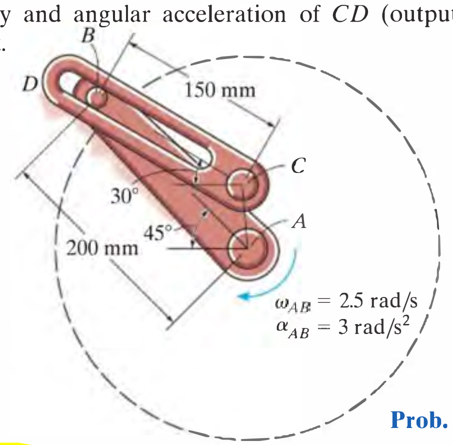
Prob. 16–145

16–146. The wheel is rotating with the angular velocity and angular acceleration at the instant shown. Determine the angular velocity and angular acceleration of the rod at this instant. The rod slides freely through the smooth collar.



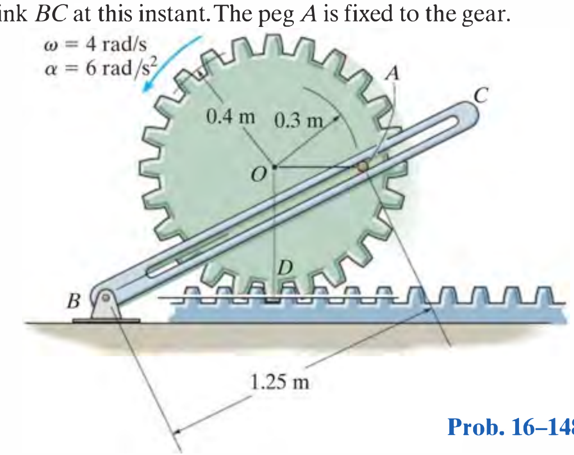
Prob. 16–146

16–147. The two-link mechanism serves to amplify angular motion. Link AB has a pin at B which is confined to move within the slot of link CD. If at the instant shown, AB (input) has an angular velocity of $\omega_{AB} = 2.5$ rad/s and an angular acceleration of $\alpha_{AB} = 3\ \text{rad/s}^2$, determine the angular velocity and angular acceleration of CD (output) at this instant.



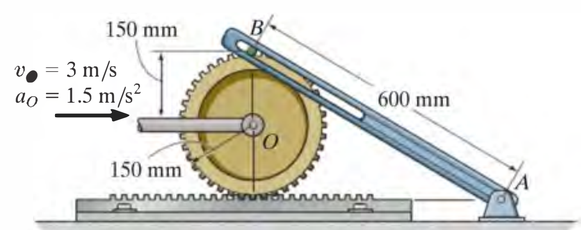
Prob. 16–147

***16–148.** The gear has the angular motion shown. Determine the angular velocity and angular acceleration of the slotted link BC at this instant. The peg A is fixed to the gear.



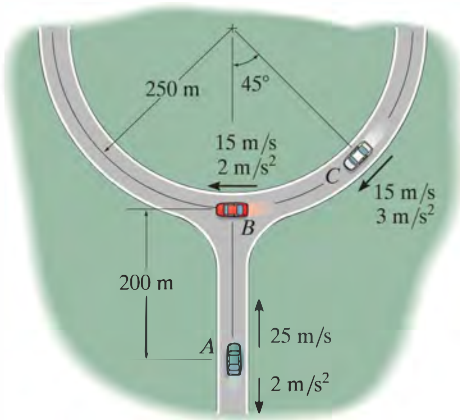
Prob. 16–148

•16–149. Peg B on the gear slides freely along the slot in link AB. If the gear's center O moves with the velocity and acceleration shown, determine the angular velocity and angular acceleration of the link at this instant.



Prob. 16–149

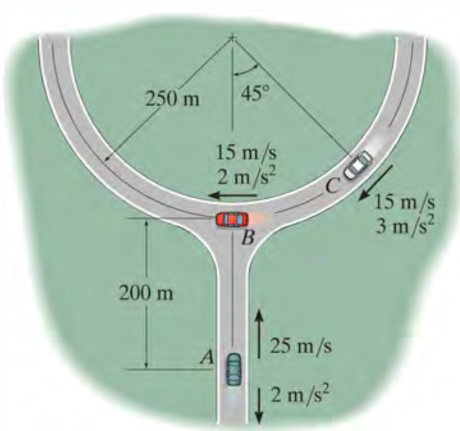
16–150. At the instant shown, car A travels with a speed of 25 m/s, which is decreasing at a constant rate of $2\ \text{m/s}^2$, while car B travels with a speed of 15 m/s, which is increasing at a constant rate of $2\ \text{m/s}^2$. Determine the velocity and acceleration of car A with respect to car B.



Prob. 16–150

16–151. At the instant shown, car A travels with a speed of 25 m/s, which is decreasing at a constant rate of $2\ \text{m/s}^2$, while car C travels with a speed of 15 m/s, which is increasing at a constant rate of $3\ \text{m/s}^2$. Determine the velocity and acceleration of car A with respect to car C.

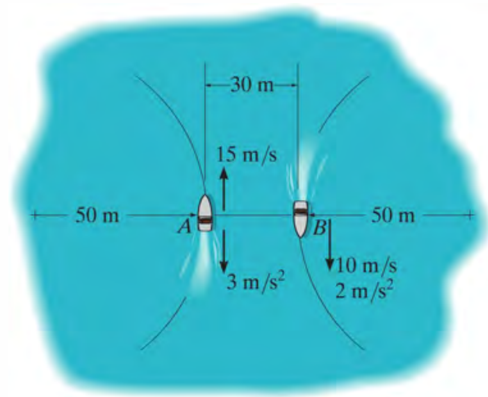
***16–152.** At the instant shown, car B travels with a speed of 15 m/s, which is increasing at a constant rate of $2\ \text{m/s}^2$, while car C travels with a speed of 15 m/s, which is increasing at a constant rate of $3\ \text{m/s}^2$. Determine the velocity and acceleration of car B with respect to car C.



Probs. 16–151/152

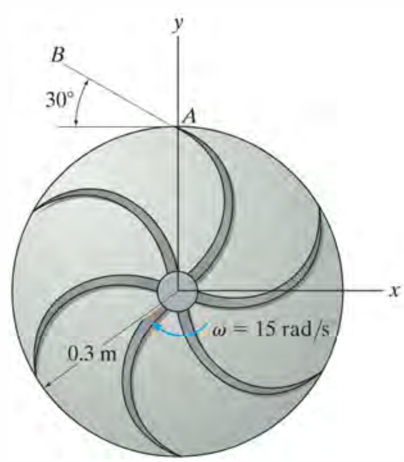
•16–153. At the instant shown, boat A travels with a speed of 15 m/s, which is decreasing at $3\ \text{m/s}^2$, while boat B travels with a speed of 10 m/s, which is increasing at $2\ \text{m/s}^2$. Determine the velocity and acceleration of boat A with respect to boat B at this instant.

16–154. At the instant shown, boat A travels with a speed of 15 m/s, which is decreasing at $3\ \text{m/s}^2$, while boat B travels with a speed of 10 m/s, which is increasing at $2\ \text{m/s}^2$. Determine the velocity and acceleration of boat B with respect to boat A at this instant.



Probs. 16–153/154

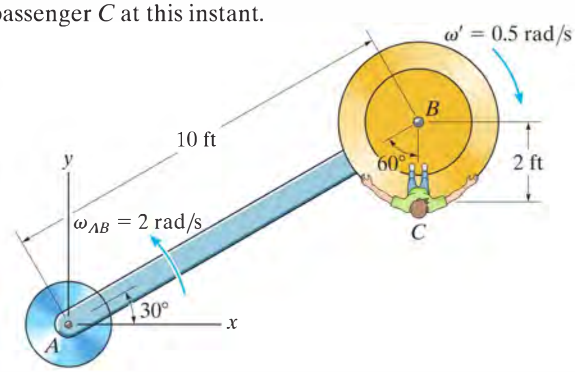
16–155. Water leaves the impeller of the centrifugal pump with a velocity of 25 m/s and acceleration of $30\ \text{m/s}^2$, both measured relative to the impeller along the blade line AB. Determine the velocity and acceleration of a water particle at A as it leaves the impeller at the instant shown. The impeller rotates with a constant angular velocity of $\omega = 15$ rad/s.



Prob. 16–155

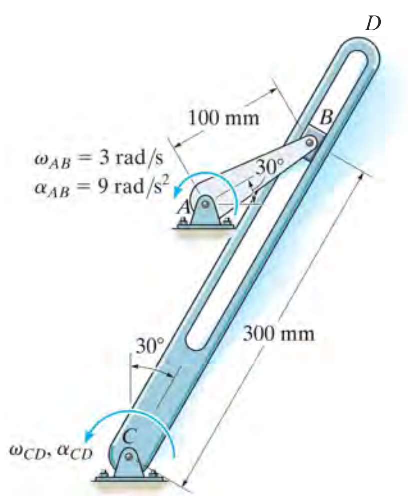
***16–156.** A ride in an amusement park consists of a rotating arm AB having a constant angular velocity $\omega_{AB} = 2$ rad/s about point A and a car mounted at the end of the arm which has a constant angular velocity $\boldsymbol{\omega}' = \{-0.5\mathbf{k}\}$ rad/s, measured relative to the arm. At the instant shown, determine the velocity and acceleration of the passenger at C.

•16–157. A ride in an amusement park consists of a rotating arm AB that has an angular acceleration of $\alpha_{AB} = 1$ rad/s^2 when $\omega_{AB} = 2$ rad/s at the instant shown. Also at this instant the car mounted at the end of the arm has an angular acceleration of $\boldsymbol{\alpha}' = \{-0.6\mathbf{k}\}$ rad/s^2 and angular velocity of $\boldsymbol{\omega}' = \{-0.5\mathbf{k}\}$ rad/s, measured relative to the arm. Determine the velocity and acceleration of the passenger C at this instant.



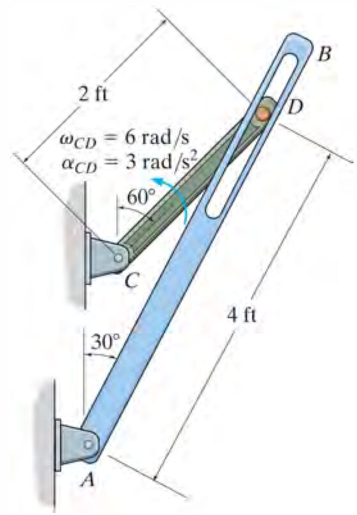
Probs. 16–156/157

16–158. The "quick-return" mechanism consists of a crank AB, slider block B, and slotted link CD. If the crank has the angular motion shown, determine the angular motion of the slotted link at this instant.



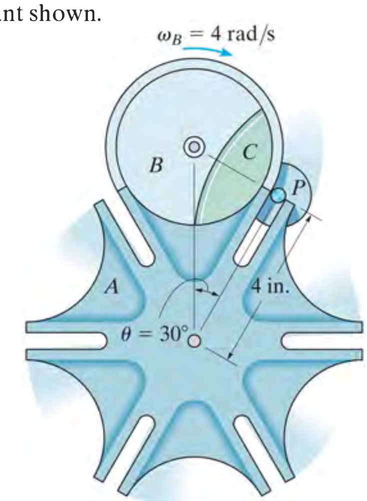
Prob. 16–158

16–159. The quick return mechanism consists of the crank CD and the slotted arm AB. If the crank rotates with the angular velocity and angular acceleration at the instant shown, determine the angular velocity and angular acceleration of AB at this instant.



Prob. 16–159

***16–160.** The Geneva mechanism is used in a packaging system to convert constant angular motion into intermittent angular motion. The star wheel A makes one sixth of a revolution for each full revolution of the driving wheel B and the attached guide C. To do this, pin P, which is attached to B, slides into one of the radial slots of A, thereby turning wheel A, and then exits the slot. If B has a constant angular velocity of $\omega_B = 4$ rad/s, determine $\boldsymbol{\omega}_A$ and $\boldsymbol{\alpha}_A$ of wheel A at the instant shown.



Prob. 16–160