ENGINEERING MECHANICS

DYNAMICS

TENTH EDITION

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APPENDIX D

Review for the Fundamentals of Engineering Examination

The Fundamentals of Engineering (FE) exam is given semiannually by the National Council of Engineering Examiners (NCEE) and is one of the requirements for obtaining a Professional Engineering License. A portion of this exam contains problems in dynamics, and this appendix provides a review of the subject matter most often asked on this exam. Before solving any of the problems, you should review the sections indicated in each chapter in order to become familiar with the boldfaced definitions and the procedures used to solve the various types of problems. Also, review the example problems in these sections.

The following problems are arranged in the same sequence as the topics in each chapter. Besides helping as preparation for the FE exam, these problems also provide additional examples for general practice of the subject matter. Partial solutions and answers to *all the problems* are given at the back of this appendix.

Chapter 12—Review Sections 12.1, 12.4–12.6, 12.8–12.9

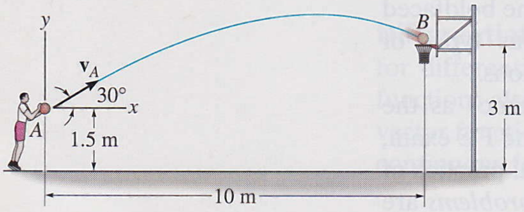
D-1. The position of a particle is $s = (0.5t^3 + 4t)$ ft, where t is in seconds. Determine the velocity and the acceleration of the particle when $t = 3$ s.

D-2. After traveling a distance of 100 m, a particle reaches a velocity of 30 m/s, starting from rest. Determine its constant acceleration.

D-3. A particle moves in a straight line such that $s = (12t^3 + 2t^2 + 3t)$ m, where t is in seconds. Determine the velocity and acceleration of the particle when $t = 2$ s.

D-4. A particle moves along a straight line such that $a = (4t^2 - 2)$ m/s², where t is in seconds. When $t = 0$, the particle is located 2 m to the left of the origin, and when $t = 2$ s, it is 20 m to the left of the origin. Determine the position of the particle when $t = 4$ s.

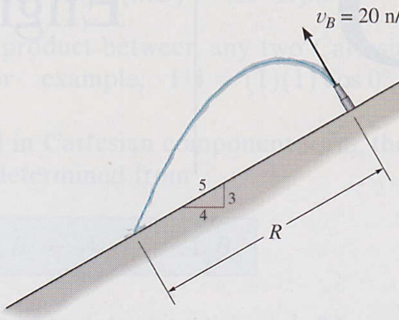
D-5. Determine the speed at which the basketball at A must be thrown at the angle of 30° so that it makes it to the basket at B.



Prob. D–5

D-6. A particle moves with curvilinear motion in the x–y plane such that the y component of motion is described by the equation $y = (7t^3)$ m, where t is in seconds. If the particle starts from rest at the origin when $t = 0$, and maintains a *constant* acceleration in the x direction of 12 m/s², determine the particle's speed when $t = 2$ s.

D-7. Water is sprayed at an angle of 90° from the slope at 20 m/s. Determine the range R.



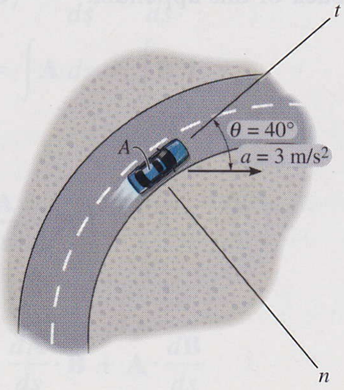
Prob. D–7

D-8. An automobile is traveling with a *constant speed* along a horizontal circular curve that has a radius of $\rho = 250$ m. If the magnitude of acceleration is $a = 1.5$ m/s², determine the speed at which the automobile is traveling.

D-9. A boat is traveling along a circular path having a radius of 30 m. Determine the magnitude of the boat's acceleration if at a given instant the boat's speed is $v = 6$ m/s and the rate of increase in speed is $\dot{v} = 2$ m/s².

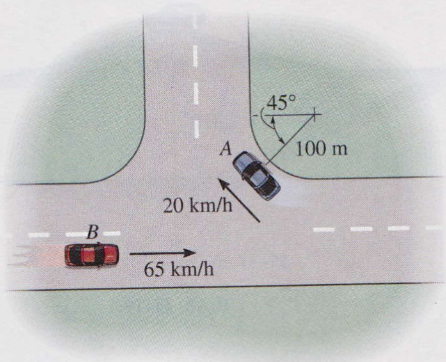
D-10. A train travels along a horizontal circular curve that has a radius of 600 m. If the speed of the train is uniformly increased from 40 km/h to 60 km/h in 5 s, determine the magnitude of the acceleration at the instant the speed of the train is 50 km/h.

D-11. At a given instant, the automobile has a speed of 25 m/s and an acceleration of 3 m/s² acting in the direction shown. Determine the radius of curvature of the path and the rate of increase of the automobile's speed.



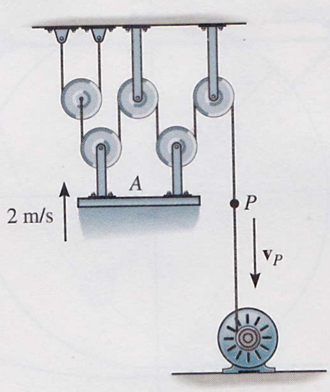
Prob. D–11

D-12. At the instant shown, cars A and B are traveling at the speeds shown. If B is accelerating at 1200 km/h^2 while A maintains a constant speed, determine the velocity and acceleration of A with respect to B.



Prob. D–12

D-13. Determine the speed of point P on the cable in order to lift the platform at 2 m/s.

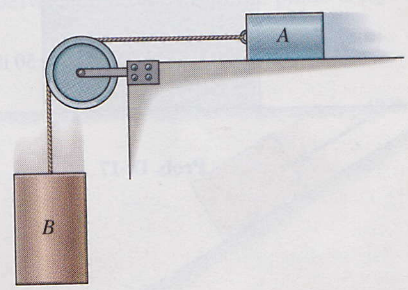


Prob. D–13

Chapter 13—Review Sections 13.1–13.5

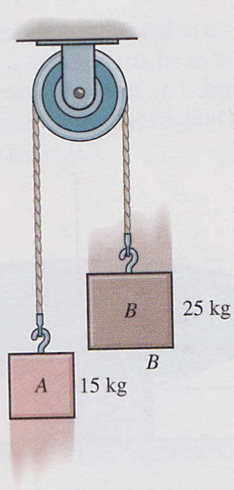
D-14. The effective weight of a man in an elevator varies between 130 lb and 170 lb while he is riding in the elevator. When the elevator is at rest the man weighs 153 lb. Determine how fast the elevator car can accelerate, going up and going down.

D-15. Neglecting friction and the mass of the pulley and cord, determine the acceleration at which the 4-kg block B will descend. What is the tension in the cord? Block A has a mass of 2 kg.



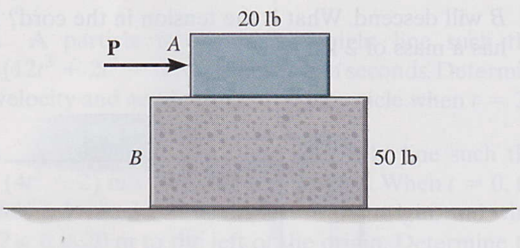
Prob. D–15

D-16. The blocks are suspended over a pulley by a rope. Neglecting the mass of the rope and the pulley, determine the acceleration of both blocks and the tension in the rope.



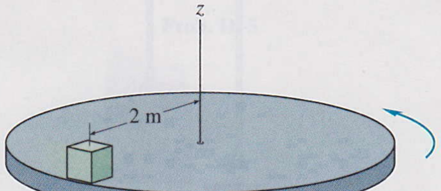
Prob. D–16

D-17. Block B rests upon a smooth surface. If the coefficients of static and kinetic friction between A and B are $\mu_s = 0.4$ and $\mu_k = 0.3$, respectively, determine the acceleration of each block if $P = 6$ lb.



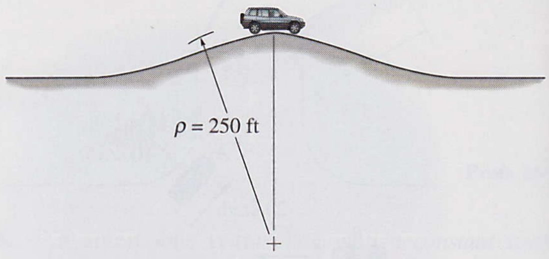
Prob. D–17

D-18. The block rests at a distance of 2 m from the center of the platform. If the coefficient of static friction between the block and the platform is $\mu_s = 0.3$, determine the maximum speed which the block can attain before it begins to slip. Assume the angular motion of the disk is slowly increasing.



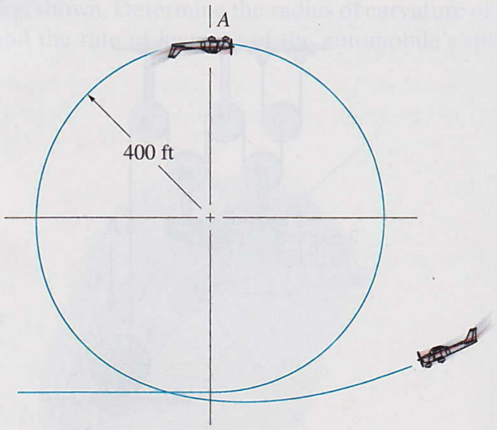
Prob. D–18

D-19. Determine the maximum speed that the jeep can travel over the crest of the hill and not lose contact with the road.



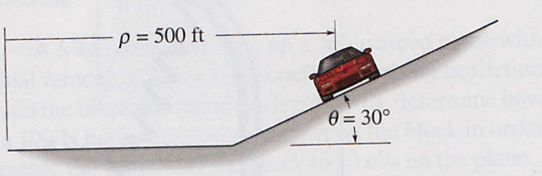
Prob. D–19

D-20. A pilot weighs 150 lb and is traveling at a constant speed of 120 ft/s. Determine the normal force he exerts on the seat of the plane when he is upside down at A. The loop has a radius of curvature of 400 ft.



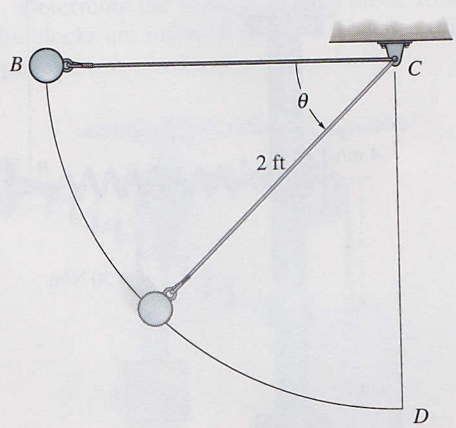
Prob. D–20

D-21. The sports car is traveling along a 30° banked road having a radius of curvature of $\rho = 500$ ft. If the coefficient of static friction between the tires and the road is $\mu_s = 0.2$, determine the maximum safe speed for travel so no slipping occurs. Neglect the size of the car.



Prob. D–21

D-22. The 5-lb pendulum bob B is released from rest when $\theta = 0°$. Determine the tension in string BC immediately after it is released and when the pendulum reaches point D, where $\theta = 90°$.

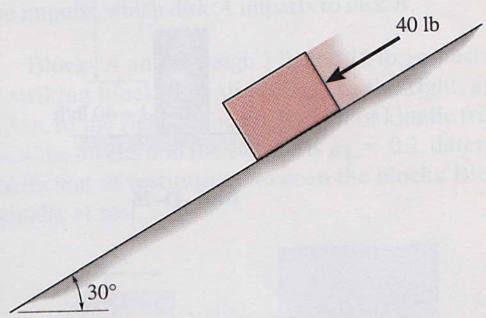


Prob. D–22

Chapter 14—Review All Sections

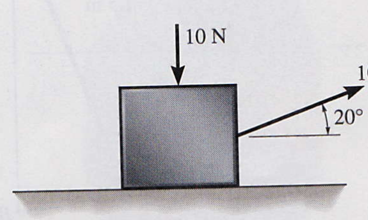
D-23. A 15 000-lb freight car is pulled along a horizontal track. If the car starts from rest and attains a velocity of 40 ft/s after traveling a distance of 300 ft, determine the total work done on the car by the towing force in this distance if the rolling frictional force between the car and track is 80 lb.

D-24. The 20-lb block resting on the 30° inclined plane is acted upon by a 40-lb force. If the block's initial velocity is 5 ft/s down the plane, determine its velocity after it has traveled 10 ft down the plane. The coefficient of kinetic friction between the block and the plane is $\mu_k = 0.2$.



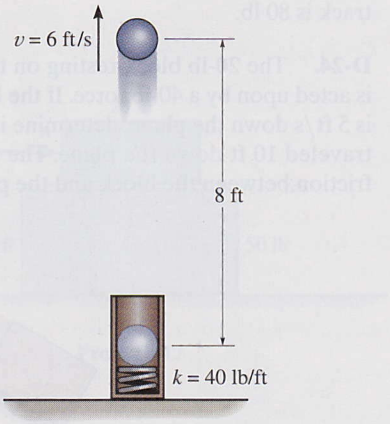
Prob. D–24

D-25. The 3-kg block is subjected to the action of the two forces shown. If the block starts from rest, determine the distance it has moved when it attains a velocity of 10 m/s. The coefficient of kinetic friction between the block and the surface is $\mu_k = 0.2$.



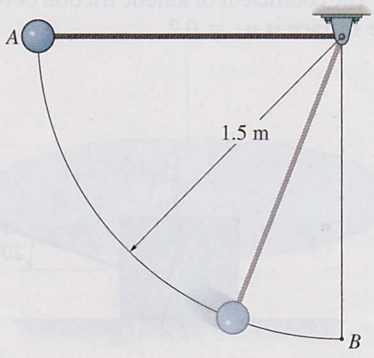
Prob. D–25

D-26. The 6-lb ball is to be fired from rest using a spring having a stiffness of $k = 40$ lb/ft. Determine how far the spring must be compressed so that when the ball reaches a height of 8 ft it has a velocity of 6 ft/s.



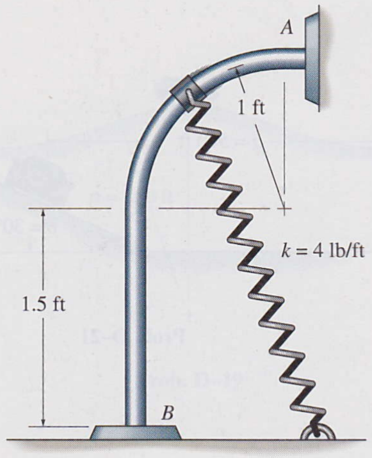
Prob. D–26

D-27. The 2-kg pendulum bob is released from rest when it is at A. Determine the speed of the bob and the tension in the cord when the bob passes through its lowest position, B.



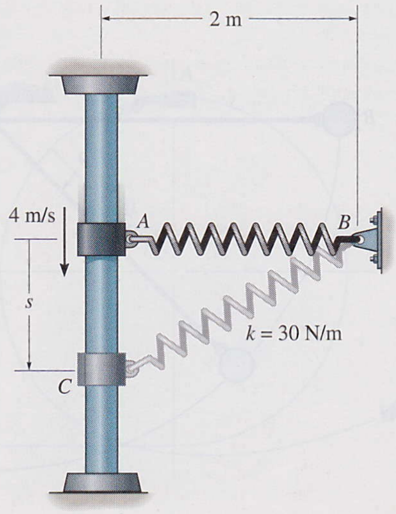
Prob. D–27

D-28. The 5-lb collar is released from rest at A and travels along the frictionless guide. Determine the speed of the collar when it strikes the stop B. The spring has an unstretched length of 0.5 ft.



Prob. D–28

D-29. The 2-kg collar is given a downward velocity of 4 m/s when it is at A. If the spring has an unstretched length of 1 m and a stiffness of $k = 30$ N/m, determine the velocity of the collar at $s = 1$ m.



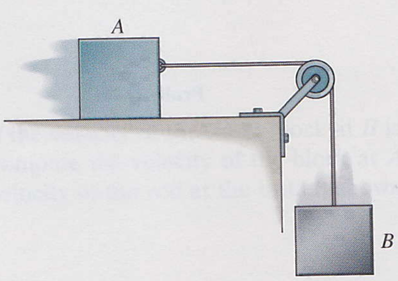
Prob. D–29

Chapter 15—Review Sections 15.1–15.4

D-30. A 30-ton engine exerts a constant horizontal force of $40(10^3)$ lb on a train having three cars that have a total weight of 250 tons. If the rolling resistance is 10 lb per ton for both the engine and cars, determine how long it takes to increase the speed of the train from 20 ft/s to 30 ft/s. What is the driving force exerted by the engine wheels on the tracks?

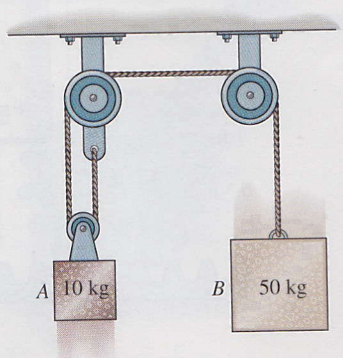
D-31. A 5-kg block is moving up a 30° inclined plane with an initial velocity of 3 m/s. If the coefficient of kinetic friction between the block and the plane is $\mu_k = 0.3$, determine how long a 100-N horizontal force must act on the block in order to increase the velocity of the block to 10 m/s up the plane.

D-32. The 10-lb block A attains a velocity of 1 ft/s in 5 seconds, starting from rest. Determine the tension in the cord and the coefficient of kinetic friction between block A and the horizontal plane. Neglect the weight of the pulley. Block B has a weight of 8 lb.



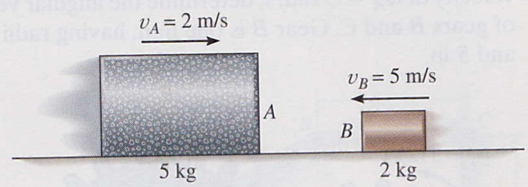
Prob. D–32

D-33. Determine the velocity of each block 10 seconds after the blocks are released from rest. Neglect the mass of the pulleys.



Prob. D–33

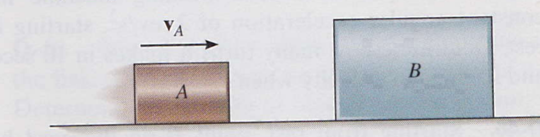
D-34. The two blocks have a coefficient of restitution of $e = 0.5$. If the surface is smooth, determine the velocity of each block after impact.



Prob. D–34

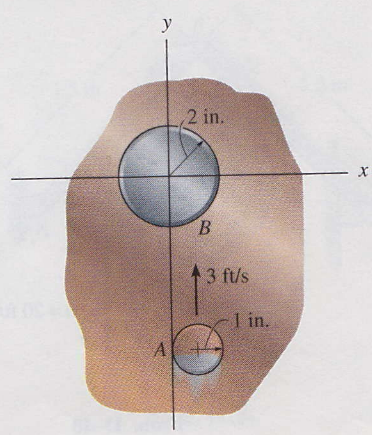
D-35. A 6-kg disk A has an initial velocity of $(v_A)_1 = 20$ m/s and strikes head-on disk B that has a mass of 24 kg and is originally at rest. If the collision is perfectly elastic, determine the speed of each disk after the collision and the impulse which disk A imparts to disk B.

D-36. Blocks A and B weigh 5 lb and 10 lb, respectively. After striking block B, A slides 2 in. to the right, and B slides 3 in. to the right. If the coefficient of kinetic friction between the blocks and the surface is $\mu_k = 0.2$, determine the coefficient of restitution between the blocks. Block B is originally at rest.



Prob. D–36

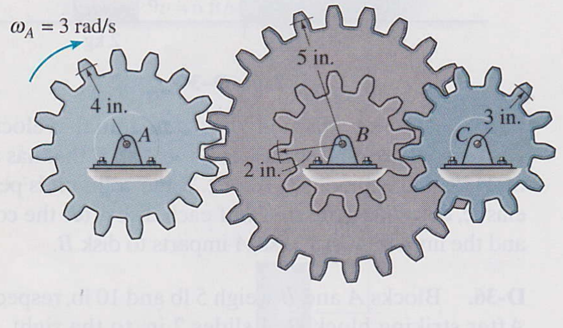
D-37. Disk A weighs 2 lb and is sliding on the smooth horizontal plane with a velocity of 3 ft/s. Disk B weighs 11 lb and is initially at rest. If after the impact A has a velocity of 1 ft/s, directed along the positive x axis, determine the speed of disk B after impact.



Prob. D–37

Chapter 16—Review Sections 16.3, 16.5–16.7

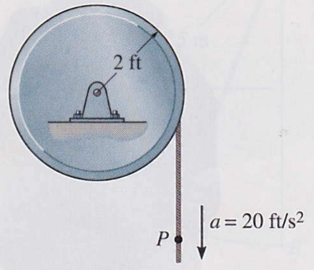
D-38. If gear A is rotating clockwise with an angular velocity of $\omega_A = 3$ rad/s, determine the angular velocities of gears B and C. Gear B is one unit, having radii of 2 in. and 5 in.



Prob. D–38

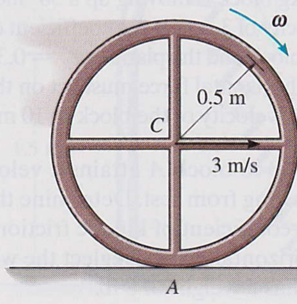
D-39. The spin drier of a washing machine has a constant angular acceleration of 2 rev/s^2, starting from rest. Determine how many turns it makes in 10 seconds and its angular velocity when $t = 5$ s.

D-40. Starting from rest, point P on the cord has a constant acceleration of 20 ft/s^2. Determine the angular acceleration and angular velocity of the disk after it has completed 10 revolutions. How many revolutions will the disk turn after it has completed 10 revolutions and P continues to move downward for 4 seconds longer?



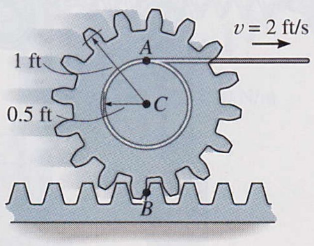
Prob. D–40

D-41. The center of the wheel has a velocity of 3 m/s. At the same time, it is slipping and has a clockwise angular velocity of $\omega = 2$ rad/s. Determine the velocity of point A at the instant shown.



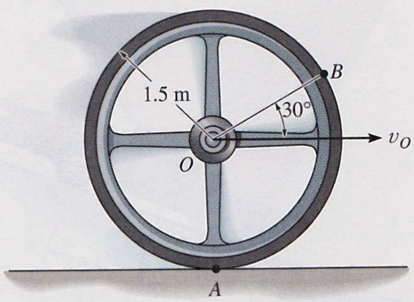
Prob. D–41

D-42. A cord is wrapped around the inner core of the gear and it is pulled with a constant velocity of 2 ft/s. Determine the velocity of the center of the gear, C.



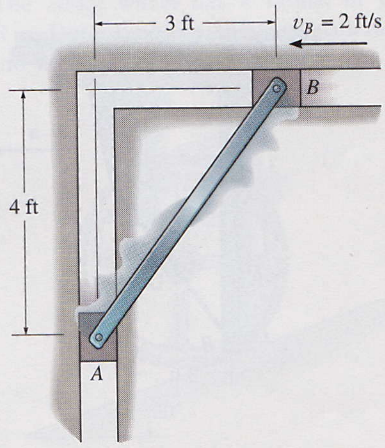
Prob. D–42

D-43. The center of the wheel is moving to the right with a speed of 2 m/s. If no slipping occurs at the ground, A, determine the velocity of point B at the instant shown.



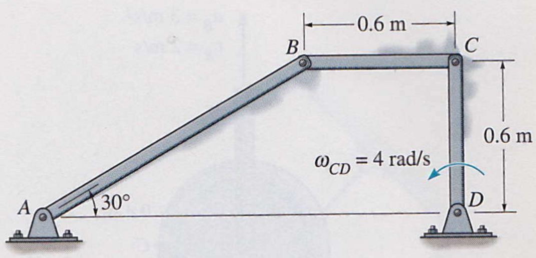
Prob. D–43

D-44. If the velocity of the slider block at B is 2 ft/s to the left, compute the velocity of the block at A and the angular velocity of the rod at the instant shown.



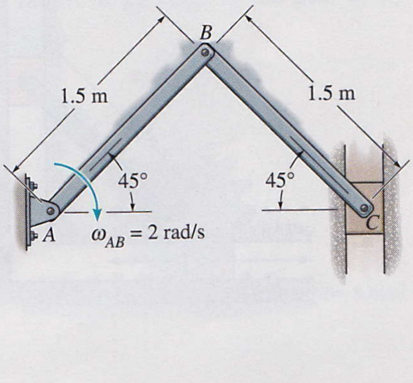
Prob. D–44

D-45. Determine the angular velocity of link AB at the instant shown.



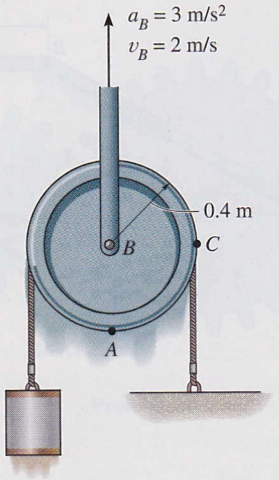
Prob. D–45

D-46. When the slider block C is in the position shown, the link AB has a clockwise angular velocity of 2 rad/s. Determine the velocity of block C at this instant.



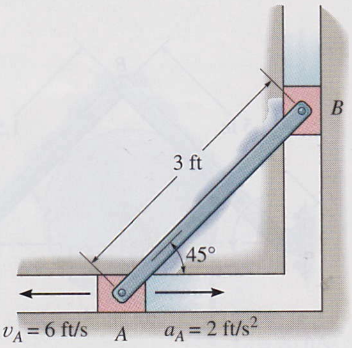
Prob. D–46

D-47. The center of the pulley is being lifted vertically with an acceleration of $3\ \text{m/s}^2$, and at the instant shown its velocity is 2 m/s. Determine the accelerations of points A and B. Assume that the rope does not slip on the pulley's surface.



Prob. D–47

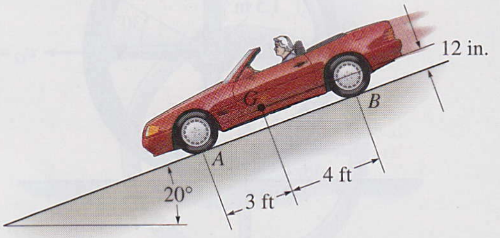
D-48. At a given instant, the slider block A has the velocity and deceleration shown. Determine the acceleration of block B and the angular acceleration of the link at this instant.



Prob. D–48

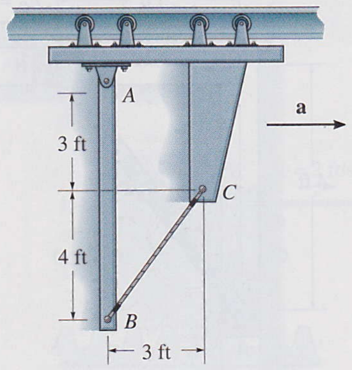
Chapter 17—Review All Sections

D-49. The 3500-lb car has a center of mass located at G. Determine the normal reactions of both front and both rear wheels on the road and the acceleration of the car if it is rolling freely down the incline. Neglect the weight of the wheels.



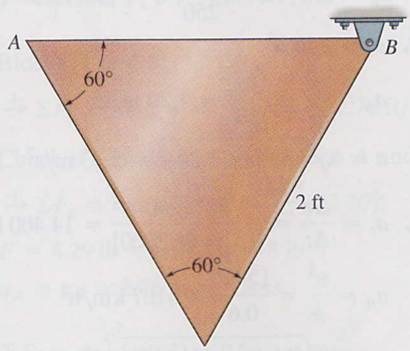
Prob. D–49

D-50. The 20-lb link AB is pinned to a moving frame at A and held in a vertical position by means of a string BC which can support a maximum tension of 10 lb. Determine the maximum acceleration of the link without breaking the string. What are the corresponding components of reaction at the pin A?



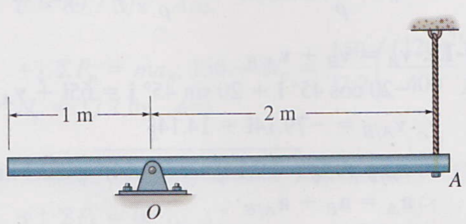
Prob. D–50

D-51. The 50-lb triangular plate is released from rest. Determine the initial angular acceleration of the plate and the horizontal and vertical components of reaction at B. The moment of inertia of the plate about the pinned axis B is $I_B = 2.30\ \text{slug}\cdot\text{ft}^2$.



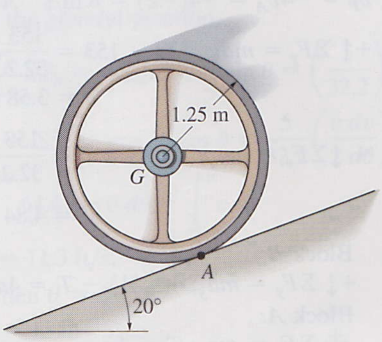
Prob. D–51

D-52. The 20-kg slender rod is pinned at O. Determine the reaction at O just after the cable is cut.



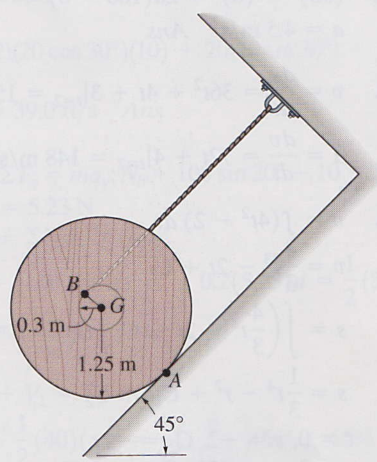
Prob. D–52

D-53. The 20-kg wheel has a radius of gyration of $K_G = 0.8$ m. Determine the angular acceleration of the wheel if no slipping occurs.



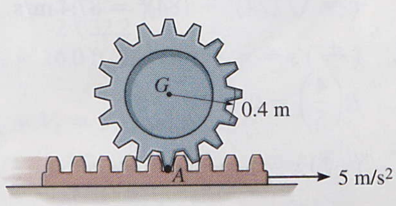
Prob. D–53

D-54. The 15-kg wheel has a wire wrapped around its inner hub and is released from rest on the inclined plane, for which the coefficient of kinetic friction is $\mu_k = 0.1$. If the centroidal radius of gyration of the wheel is $k_G = 0.8$ m, determine the angular acceleration of the wheel.



Prob. D–54

D-55. The 2-kg gear is at rest on the surface of a gear rack. If the rack is suddenly given an acceleration of $5\ \text{m/s}^2$, determine the initial angular acceleration of the gear. The radius of gyration of the gear is $k_G = 0.3$ m.



Prob. D–55

Solutions and Answers

D-1. $v = \frac{ds}{dt} = 1.5t^2 + 4|_{t=3} = 17.5 \text{ ft/s}$ *Ans.*

$a = \frac{dv}{dt} = 3t|_{t=3} = 9 \text{ ft/s}^2$ *Ans.*

D-2. $(30)^2 = (0)^2 + 2a(100 - 0)$

$a = 4.5 \text{ m/s}^2$ *Ans.*

D-3. $v = \frac{ds}{dt} = 36t^2 + 4t + 3|_{t=2} = 155 \text{ m/s}$ *Ans.*

$a = \frac{dv}{dt} = 72t + 4|_{t=2} = 148 \text{ m/s}^2$ *Ans.*

D-4. $v = \int (4t^2 - 2)\, dt$

$v = \frac{4}{3}t^3 - 2t + C_1$

$s = \int \left(\frac{4}{3}t^3 - 2t + C_1\right) dt$

$s = \frac{1}{3}t^4 - t^2 + C_1 t + C_2$

$t = 0, s = -2, C_2 = -2$

$t = 2, s = -20, C_1 = -9.67$

$t = 4, s = 28.7 \text{ m}$ *Ans.*

D-5. $\overset{+}{\rightarrow} s = s_0 + v_0 t$

$10 = 0 + v_A \cos 30^\circ\, t$

$+\uparrow s = s_0 + v_0 t + \frac{1}{2}a_c t^2$

$3 = 1.5 + v_A \sin 30^\circ\, t + \frac{1}{2}(-9.81)t^2$

$t = 0.933, v_A = 12.4 \text{ m/s}$ *Ans.*

D-6. $v = v_0 + a_c t$

$v_x = 0 + 12(2) = 24 \text{ m/s}$

$v_y = \frac{dy}{dt} = 21t^2|_{t=2} = 84 \text{ m/s}$

$v = \sqrt{(24)^2 + (84)^2} = 87.4 \text{ m/s}$ *Ans.*

D-7. $(\overset{+}{\leftarrow})\ s = s_0 + v_0 t$

$R\left(\frac{4}{5}\right) = 0 + 20\left(\frac{3}{5}\right)t$

$(+\uparrow)\ s = s_0 + v_0 t + \frac{1}{2}a_c t^2$

$-R\left(\frac{3}{5}\right) = 0 + 20\left(\frac{4}{5}\right)t + \frac{1}{2}(-9.81)t^2$

$t = 5.10 \text{ s}$

$R = 76.5 \text{ m}$ *Ans.*

D-8. $a_t = 0$

$a_n = a = 1.5 = \frac{v^2}{250};\ v = 19.4 \text{ m/s}$ *Ans.*

D-9. $a_t = 2 \text{ m/s}^2$

$a_n = \frac{v^2}{\rho} = \frac{(6)^2}{30} = 1.20 \text{ m/s}^2$

$a = \sqrt{(2)^2 + (1.20)^2} = 2.33 \text{ m/s}^2$ *Ans.*

D-10. $a_t = \frac{\Delta v}{\Delta t} = \frac{60 - 40}{[(5 - 0)/3600]} = 14\,400 \text{ km/h}^2$

$a_n = \frac{v^2}{\rho} = \frac{(50)^2}{0.6} = 4167 \text{ km/h}^2$

$a = \sqrt{(14.4)^2 + (4.167)^2}\ 10^3 = 15.0(10^3) \text{ km/h}^2$ *Ans.*

D-11. $a_t = 3 \cos 40^\circ = 2.30 \text{ m/s}^2$ *Ans.*

$a_n = \frac{v^2}{\rho};\ 3 \sin 40^\circ = \frac{(25)^2}{\rho},\ \rho = 324 \text{ m}$ *Ans.*

D-12. $\mathbf{v}_A = \mathbf{v}_B + \mathbf{v}_{A/B}$

$-20 \cos 45^\circ\, \mathbf{i} + 20 \sin 45^\circ\, \mathbf{j} = 65\mathbf{i} + \mathbf{v}_{A/B}$

$\mathbf{v}_{A/B} = -79.14\mathbf{i} + 14.14\mathbf{j}$

$v_{A/B} = \sqrt{(-79.14)^2 + (14.14)^2} = 80.4 \text{ km/h}$ *Ans.*

$\mathbf{a}_A = \mathbf{a}_B + \mathbf{a}_{A/B}$

$\frac{(20)^2}{0.1} \cos 45^\circ\, \mathbf{i} + \frac{(20)^2}{0.1} \sin 45^\circ\, \mathbf{j} = 1200\mathbf{i} + \mathbf{a}_{A/B}$

$\mathbf{a}_{A/B} = 1628\mathbf{i} + 2828\mathbf{j}$

$a_{A/B} = \sqrt{(1628)^2 + (2828)^2} = 3.26(10^3) \text{ km/h}^2$ *Ans.*

D-13. $4s_A + s_P = l$

$v_P = -4v_A = -4(-2) = 8 \text{ m/s}$ *Ans.*

D-14. $+\uparrow \Sigma F_y = ma_y;\ 170 - 153 = \frac{153}{32.2}a$

$a = 3.58 \text{ ft/s}^2 \uparrow$ *Ans.*

$+\downarrow \Sigma F_y = ma_y;\ 153 - 130 = \frac{153}{32.2}a'$

$a' = 4.84 \text{ ft/s}^2 \downarrow$ *Ans.*

D-15. Block *B*:

$+\downarrow \Sigma F_y = ma_y;\ 4(9.81) - T = 4a$

Block *A*:

$\overset{+}{\leftarrow} \Sigma F_x = ma_x;\ T = 2a$

$T = 13.1 \text{ N},\ a = 6.54 \text{ m/s}^2$ *Ans.*

D-16. Block A:

$+\downarrow \Sigma F_y = ma_y;\ 15(9.81) - T = -15a$

Block B:

$+\downarrow \Sigma F_y = ma_y;\ 25(9.81) - T = 25a$

$a = 2.45\ \text{m/s}^2,\ T = 184\ \text{N}$ *Ans.*

D-17. Blocks A and B:

$\xrightarrow{+} \Sigma F_x = ma_x;\ 6 = \dfrac{70}{32.2}a;\ a = 2.76\ \text{ft/s}^2$

Check if slipping occurs between A and B.

$\xrightarrow{+} \Sigma F_x = ma_x;\ 6 - F = \dfrac{20}{32.2}(2.76);$

$F = 4.29\ \text{lb} < 0.4(20) = 8\ \text{lb}$

$a_A = a_B = 2.76\ \text{m/s}^2$ *Ans.*

D-18. $\Sigma F_n = m\dfrac{v^2}{\rho};\ (0.3)m(9.81) = m\dfrac{v^2}{2}$

$v = 2.43\ \text{m/s}$ *Ans.*

D-19. $+\downarrow \Sigma F_n = ma_n;\ m(32.2) = m\left(\dfrac{v^2}{250}\right)$

$v = 89.7\ \text{ft/s}$ *Ans.*

D-20. $+\downarrow \Sigma F_n = ma_n;\ 150 + N_p = \dfrac{150}{32.2}\left(\dfrac{(120)^2}{400}\right)$

$N_p = 17.7\ \text{lb}$ *Ans.*

D-21. $\xleftarrow{+} \Sigma F_n = ma_n;\ N_c \sin 30° + 0.2\,N_c \cos 30° = m\dfrac{v^2}{500}$

$+\uparrow \Sigma F_b = 0;$

$N_c \cos 30° - 0.2\,N_c \sin 30° - m(32.2) = 0$

$v = 119\ \text{ft/s}$ *Ans.*

D-22. At B:

$\xrightarrow{+} \Sigma F_n = ma_n,\ T = \left(\dfrac{5}{32.2}\right)\left(\dfrac{(0)^2}{2}\right) = 0$ *Ans.*

In the general position,

$+\nearrow \Sigma F_n = ma_n;\ T - 5 \sin\theta = \left(\dfrac{5}{32.2}\right)\left(\dfrac{v^2}{2}\right)$

$\searrow + \Sigma F_t = ma_t;\ 5 \cos\theta = \dfrac{5}{32.2}\left(\dfrac{v\,dv}{2\,d\theta}\right)$

$\displaystyle\int_0^{90°} 64.4 \cos\theta\, d\theta = \int_0^v v\, dv$

$v = 11.3\ \text{ft/s},$

When $\theta = 90°$;

$T = 15\ \text{lb}$ *Ans.*

D-23. $T_1 + \Sigma U_{1-2} = T_2$

$0 + U_{1-2} - 80(300) = \dfrac{1}{2}\left(\dfrac{15000}{32.2}\right)(40)^2$

$U_{1-2} = 397(10^3)\ \text{ft}\cdot\text{lb}$ *Ans.*

D-24. $T_1 + \Sigma U_{1-2} = T_2$

$\dfrac{1}{2}\left(\dfrac{20}{32.2}\right)(5)^2 + 40(10) -$

$(0.2)(20 \cos 30°)(10) + 20(10 \sin 30°) = \dfrac{1}{2}\left(\dfrac{20}{32.2}\right)v^2$

$v = 39.0\ \text{ft/s}$ *Ans.*

D-25. $+\uparrow \Sigma F_y = ma_y;\ N_b + 100 \sin 20° - 10 - 3(9.81) = 0$

$N_b = 5.23\ \text{N}$

$T_1 + \Sigma U_{1-2} = T_2$

$0 + (100 \cos 20°)d - 0.2(5.23)d = \dfrac{1}{2}(3)(10)^2$

$d = 1.61\ \text{m}$ *Ans.*

D-26. $T_1 + V_1 = T_2 + V_2$

$0 + \dfrac{1}{2}(40)(x)^2 = \dfrac{1}{2}\left(\dfrac{6}{32.2}\right)(6)^2 + 6(8)$

$x = 1.60\ \text{ft}$ *Ans.*

D-27. $T_A + V_A = T_B + V_B$

$0 + 2(9.81)(1.5) = \dfrac{1}{2}(2)(v_B)^2 + 0$

$v_B = 5.42\ \text{m/s}$ *Ans.*

$+\uparrow \Sigma F_n = ma_n;\ T - 2(9.81) = 2\left(\dfrac{(5.42)^2}{1.5}\right)$

$T = 58.9\ \text{N}$ *Ans.*

D-28. $T_A + V_A = T_B + V_B$

$0 + \dfrac{1}{2}(4)(2.5 - 0.5)^2 + 5(2.5)$

$= \dfrac{1}{2}\left(\dfrac{5}{32.2}\right)v_B^2 + \dfrac{1}{2}(4)(1 - 0.5)^2$

$v_B = 16.0\ \text{ft/s}$ *Ans.*

D-29. $T_1 + V_1 = T_2 + V_2$

$\dfrac{1}{2}(2)(4)^2 + \dfrac{1}{2}(30)(2 - 1)^2$

$= \dfrac{1}{2}(2)(v)^2 - 2(9.81)(1) + \dfrac{1}{2}(30)(\sqrt{5} - 1)^2$

$v = 5.26\ \text{m/s}$ *Ans.*

D-30. Three cars:

$\xrightarrow{+} mv_1 + \Sigma \int F\,dt = mv_2$

$$\frac{250(2000)}{32.2}(20) + 40(10^3)(t) - 10(250)t = \frac{250(2000)}{32.2}(30)$$

$t = 4.14$ s *Ans.*

Engine:

$\xrightarrow{+} mv_1 + \Sigma \int F\,dt = mv_2$

$$\frac{30(2000)}{32.2}(20) + F(4.14) - 10(30)(4.14) = \frac{30(2000)}{32.2}(30)$$

$F = 4800$ lb *Ans.*

D-31. $+\nwarrow \Sigma F_y = 0;$

$N_b - 5(9.81)\cos 30^\circ - 100 \sin 30^\circ = 0$

$N_b = 92.48$ N

$+\nearrow mv_1 + \Sigma \int F\,dt = mv_2$

$$5(3) + (100\cos 30^\circ)t - 5(9.81)\sin 30^\circ(t) - 0.3(92.48)t = 5(10)$$

$t = 1.02$ s *Ans.*

D-32. Block B:

$(+\downarrow)\ mv_1 + \int F\,dt = mv_2$

$$0 + 8(5) - T(5) = \frac{8}{32.2}(1)$$

$T = 7.95$ lb *Ans.*

Block A:

$(\xrightarrow{+})\ mv_1 + \int F\,dt = mv_2$

$$0 + 7.95(5) - \mu_k(10)(5) = \frac{10}{32.2}(1)$$

$\mu_k = 0.789$ *Ans.*

D-33. $2s_A + s_B = l$

$2v_A = -v_B$

$+\downarrow m(v_A)_1 + \int F\,dt = m(v_A)_2$

$0 + 10(9.81)(10) - 2T(10) = 10(v_A)_2$

$+\downarrow m(v_B)_1 + \int F\,dt = m(v_B)_2$

$0 + 50(9.81)(10) - T(10) = 50(v_B)_2$

$T = 70.1$ N

$(v_A)_2 = -42.0$ m/s $= 42.0$ m/s $\uparrow$ *Ans.*

$(v_B)_2 = 84.1$ m/s $\downarrow$ *Ans.*

D-34. $\xrightarrow{+} \Sigma mv_1 = \Sigma mv_2;\ 5(2) - 2(5) = 5(v_A)_2 + 2(v_B)_2$

$$\xrightarrow{+} e = \frac{(v_B)_2 - (v_A)_2}{(v_A)_1 - (v_B)_1};\ 0.5 = \frac{(v_B)_2 - (v_A)_2}{2 - (-5)}$$

$(v_A)_2 = -1$ m/s $= 1$ m/s $\leftarrow$ *Ans.*

$(v_B)_2 = 2.5$ m/s $\rightarrow$ *Ans.*

D-35. $\xrightarrow{+} \Sigma mv_1 = \Sigma mv_2;\ 6(20) + 0 = 6(v_A)_2 + 24(v_B)_2$

$$\xrightarrow{+} e = \frac{(v_B)_2 - (v_A)_2}{(v_A)_1 - (v_B)_1};\ 1 = \frac{(v_B)_2 - (v_A)_2}{20 - 0}$$

$(v_A)_2 = -12$ m/s $= 12$ m/s $\leftarrow$ *Ans.*

$(v_B)_2 = 8$ m/s $\rightarrow$ *Ans.*

Disk A:

$mv_1 + \int F\,dt = mv_2;$

$6(20) - \int F\,dt = -6(12)$

$\int F\,dt = 192$ N·s *Ans.*

D-36. After collision: $T_1 + \Sigma U_{1-2} = T_2$

$$\frac{1}{2}\left(\frac{5}{32.2}\right)(v_A)_2^2 - 0.2(5)\left(\frac{2}{12}\right) = 0$$

$(v_A)_2 = 1.465$ ft/s

$$\frac{1}{2}\left(\frac{10}{32.2}\right)(v_B)_2^2 - 0.2(10)\left(\frac{3}{12}\right) = 0$$

$(v_B)_2 = 1.794$ ft/s

$\Sigma mv_1 = \Sigma mv_2$

$$\frac{5}{32.2}(v_A)_1 + 0 = \frac{5}{32.2}(1.465) + \frac{10}{32.2}(1.794)$$

$(v_A)_1 = 5.054$

$$e = \frac{(v_B)_2 - (v_A)_2}{(v_A)_1 - (v_B)_1} = \frac{1.794 - 1.465}{5.054 - 0} = 0.0652$$ *Ans.*

D-37. $\Sigma m(v_x)_1 = \Sigma m(v_x)_2$

$$0 + 0 = \frac{2}{32.2}(1) + \frac{11}{32.2}(v_{Bx})_2$$

$(v_{Bx})_2 = -0.1818$ ft/s

$\Sigma m(v_y)_1 = \Sigma m(v_y)_2$

$$\frac{2}{32.2}(3) + 0 = 0 + \frac{11}{32.2}(v_{By})_2$$

$(v_{By})_2 = 0.545$ ft/s

$$(v_B)_2 = \sqrt{(-0.1818)^2 + (0.545)^2} = 0.575 \text{ ft/s}$$ *Ans.*

D-38. $\omega_B(5) = 3(4)$

$\omega_B = 2.40$ rad/s $\circlearrowleft$ *Ans.*

$\omega_C(3) = 2.40(2)$

$\omega_C = 1.60$ rad/s $\circlearrowright$ *Ans.*

D-39. $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$

$\theta = 0 + 0 + \frac{1}{2}(2)(10)^2 = 100$ rev *Ans.*

$\omega = \omega_0 + \alpha_c t$

$\omega = 0 + 2(5) = 10$ rev/s *Ans.*

D-40. $\alpha = \frac{a_t}{r} = \frac{20}{2} = 10\text{ rad/s}^2$ *Ans.*

10 rev $= 20\pi$ rad

$\omega^2 = \omega_0^2 + 2\,\alpha_c(\theta - \theta_0)$

$\omega^2 = 0 + 2(10)(20\pi - 0)$

$\omega = 35.4\text{ rad/s}$ Ans.

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$

$\theta = 0 + 35.4(4) + \frac{1}{2}(10)(4)^2 = 222\text{ rad}$

$\theta = \frac{222}{2\pi} = 35.3\text{ rev.}$ *Ans.*

D-41. $\mathbf{v}_A = \mathbf{v}_C + \boldsymbol{\omega} \times \mathbf{r}_{A/C}$

$\mathbf{v}_A\mathbf{i} = 3\mathbf{i} + (-2\mathbf{k}) \times (-0.5\mathbf{j})$

$v_A = 2\text{ m/s} \rightarrow$ *Ans.*

D-42. $\mathbf{v}_A = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{A/B}$

$2\mathbf{i} = \mathbf{0} + (-\omega\mathbf{k}) \times (1.5\mathbf{j})$

$\omega = 1.33\text{ rad/s} \circlearrowright$

$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$\mathbf{v}_C\mathbf{i} = \mathbf{0} + (-1.33\mathbf{k}) \times (1\mathbf{j})$

$v_C = 1.33\text{ ft/s} \rightarrow$ *Ans.*

D-43. $\mathbf{v}_O = \mathbf{v}_A + \boldsymbol{\omega} \times \mathbf{r}_{O/A}$

$2\mathbf{i} = \mathbf{0} + (-\omega\mathbf{k}) \times 1.5\mathbf{j}$

$\omega = 1.33\text{ rad/s} \circlearrowright$

$\mathbf{v}_B = \mathbf{v}_O + \boldsymbol{\omega} \times \mathbf{r}_{B/O}$

$\mathbf{v}_B = 2\mathbf{i} + (-1.33\mathbf{k}) \times (1.5\cos 30^\circ\,\mathbf{i} + 1.5\sin 30^\circ\,\mathbf{j})$

$\mathbf{v}_B = \{3\mathbf{i} - 1.73\mathbf{j}\}\text{ m/s}$ *Ans.*

D-44. $\mathbf{v}_A = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{A/B}$

$-v_A\mathbf{j} = -2\mathbf{i} + \omega\mathbf{k} \times (-3\mathbf{i} - 4\mathbf{j})$

$v_A = 1.5\text{ ft/s} \downarrow$ *Ans.*

$\omega = 0.5\text{ rad/s} \circlearrowleft$ *Ans.*

D-45. $v_C = 4(0.6) = 2.4\text{ m/s} \leftarrow$

$\mathbf{v}_B = \mathbf{v}_C + \boldsymbol{\omega} \times \mathbf{r}_{B/C}$

$-v_B\sin 30^\circ\,\mathbf{i} + v_B\cos 30^\circ\,\mathbf{j}$

$= -2.4\mathbf{i} + (\omega_{BC}\mathbf{k}) \times (-0.6\mathbf{i})$

$v_B = 4.80\text{ m/s} \nwarrow \omega_{BC} = 6.93\text{ rad/s} \circlearrowright$

$\omega_{AB} = \frac{4.80}{0.6/\sin 30^\circ} = 4\text{ rad/s} \circlearrowleft$ *Ans.*

D-46. $v_B = 2(1.5) = 3\text{ m/s} \searrow$

$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$-v_C\mathbf{j} = 3\cos 45^\circ\,\mathbf{i} - 3\sin 45^\circ\,\mathbf{j}$

$+ (\omega\mathbf{k}) \times (1.5\cos 45^\circ\,\mathbf{i} - 1.5\sin 45^\circ\,\mathbf{j})$

$v_C = 4.24\text{ m/s} \downarrow$ *Ans.*

$\omega = 2\text{ rad/s} \circlearrowright$

D-47. $\omega = \frac{v_B}{r_{B/C}} = \frac{2}{0.4} = 5\text{ rad/s} \circlearrowright$

$\alpha = \frac{a_B}{r_{B/C}} = \frac{3}{0.4} = 7.5\text{ rad/s}^2 \circlearrowright$

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

$\mathbf{a}_A = 3\mathbf{j} + (-7.5\mathbf{k}) \times (-0.4\mathbf{j}) - (5)^2(-0.4\mathbf{j})$

$\mathbf{a}_A = \{-3\mathbf{i} + 13\mathbf{j}\}\text{ m/s}^2$ *Ans.*

$a_B = 3\text{ m/s}^2$ *Ans.*

D-48. $\mathbf{v}_B = \mathbf{v}_A + \boldsymbol{\omega} \times \mathbf{r}_{B/A}$

$-\mathbf{v}_B\mathbf{j} = -6\mathbf{i} + \omega\mathbf{k} \times (3\cos 45^\circ\,\mathbf{i} + 3\sin 45^\circ\,\mathbf{j})$

$\omega = 2.828\text{ rad/s}\circlearrowright,\ v_B = 6\text{ ft/s} \downarrow$

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

$-a_B\mathbf{j} = 2\mathbf{i} + (\alpha\mathbf{k}) \times (3\cos 45^\circ\,\mathbf{i} + 3\sin 45^\circ\,\mathbf{j})$

$-(2.828)^2\,(3\cos 45^\circ\,\mathbf{i} + 3\sin 45^\circ\,\mathbf{j})$

$a_B = 31.9\text{ ft/s}^2 \downarrow$ *Ans.*

$\alpha = 7.06\text{ rad/s}^2 \circlearrowright$ *Ans.*

D-49. $+\swarrow \Sigma F_x = m(a_G)_x;\ 3500\sin 20^\circ = \frac{3500}{32.2}a_G$

$a_G = 11.0\text{ ft/s}^2$ *Ans.*

$+\nwarrow \Sigma F_y = m(a_G)_y;\ N_A + N_B - 3500\cos 20^\circ = 0$

$\circlearrowright + \Sigma M_G = 0;\ N_B(4) - N_A(3) = 0$

$N_A = 1879\text{ lb}$ *Ans.*

$N_B = 1410\text{ lb}$ *Ans.*

D-50. $\circlearrowright + \Sigma M_A = \Sigma(M_k)_A;\ 10\left(\frac{3}{5}\right)(7) = \frac{20}{32.2}a(3.5)$

$a = 19.32\text{ ft/s}^2$ *Ans.*

$\xrightarrow{+} \Sigma F_x = m(a_G)_x;\ A_x + 10\left(\frac{3}{5}\right) = \frac{20}{32.2}(19.32)$

$A_x = 6\text{ lb}$ *Ans.*

$+\uparrow \Sigma F_y = m(a_G)_y;\ A_y - 20 + 10\left(\frac{4}{5}\right) = 0$

$A_y = 12\text{ lb}$ *Ans.*

D-51. $\circlearrowright + \Sigma M_B = I_B\alpha;\ 50(1) = 2.30\alpha$

$\alpha = 21.7\ \text{rad/s}^2$ *Ans.*

$$a_G = \left(\frac{1}{\cos 30^\circ}\right)(21.7) = 25.1\ \text{m/s}^2$$

$\xrightarrow{+} \Sigma F_x = m(a_G)_x;$

$$B_x = \left(\frac{50}{32.2}\right)25.1 \sin 30^\circ = 19.5\ \text{lb} \quad \textit{Ans.}$$

$+\uparrow \Sigma F_y = m(a_G)_y;$

$$B_y - 50 = -\left(\frac{50}{32.2}\right)25.1 \cos 30^\circ.$$

$B_y = 16.2\ \text{lb}$ *Ans.*

D-52. $\circlearrowleft + \Sigma M_O = I_O\alpha;$

$$20(9.81)(0.5) = \left[\frac{1}{12}(20)(3)^2 + 20(0.5)^2\right]\alpha$$

$\alpha = 4.90\ \text{rad/s}^2$ *Ans.*

D-53. No slipping, so that

$a_G = 1.25\alpha$

$\circlearrowright + \Sigma M_A = \Sigma(M_k)_A;\ 20(9.81)\sin 20^\circ(1.25)$

$= 20(0.8)^2\alpha + (20a_G)(1.25)$

$\alpha = 1.90\ \text{rad/s}^2$ *Ans.*

$a_G = 2.38\ \text{m/s}^2$

D-54. $+\nwarrow \Sigma F_y = 0;\ N_A - 15(9.81)\cos 45^\circ = 0;$

$N_A = 104.1\ \text{N}$

$a_G = \alpha(0.3)$

$\circlearrowright + \Sigma M_B = \Sigma(M_k)_B;\ (0.1)(104.1)(1.55) -$

$15(9.81)\sin 45^\circ(0.3) = -15(0.8)^2\alpha - 15(a_G)(0.3)$

$a_G = 0.413\ \text{m/s}^2$

$\alpha = 1.38\ \text{rad/s}^2$ *Ans.*

D-55. $\xrightarrow{+} \Sigma F_x = m(a_G)_x;\ F_A = 2a_G$

$\circlearrowright + \Sigma M_G = I_G\alpha;\ F_A(0.4) = 2(0.3)^2\alpha$

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

$5\mathbf{i} = a_G\mathbf{i} + (\alpha\mathbf{k}) \times (-0.4\mathbf{j}) - \mathbf{0}$

$5 = a_G + 0.4\alpha$

$F_A = 3.60\ \text{N}$

$a_G = 1.80\ \text{m/s}^2$

$\alpha = 8\ \text{rad/s}^2$ *Ans.*