Problems

Problems 16.1 to 16.8 deal with linear momentum.
Problems 16.9 to 16.16 deal with linear impulse.

16.1 A particle of mass $m = 2$ slugs travels the circular path shown in Figure P16.1 such that $s = \pi(t^2 + 8t)$ where t is measured in seconds and s is measured in feet. Determine the linear momentum of this particle when it is in position 1 and in position 2.

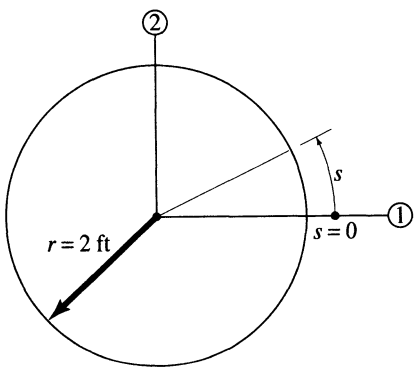

FIGURE P16.1.

16.2 A particle of mass $m = 2$ kg travels a straight-line path, which is directed positively to the right, such that $x = t^3 + t^2 + 10$ where t is in seconds and x is in meters. Determine the linear momentum of this particle when $t = 1$ s and when $t = 2$ s.

16.3 The parametric equations of the path of a particle are given by $x = 2t$ and $y = 4t^2 - 8t + 8$ where t is in seconds and x and y are in feet. If the particle has a mass of one slug, determine (a) the linear momentum of the particle for $t = 1$ s, (b) the path of the particle, and (c) the acceleration of the particle when $t = 1$ s.

16.4 In cylindrical coordinates, the parametric equations of the path of a particle are given in m-s units by $r = 2$, $\theta = 2t$, and $z = 4t$. Determine the velocity $\mathbf{v}$ and acceleration $\mathbf{a}$ of the particle at any time t. If the particle has a mass of 1 kg, determine its linear momentum.

16.5 In plane polar coordinates, the parametric equations of a particle path are given in m-s units by $r = \dfrac{2}{\cos 4t}$ and $\theta = 4t$. Determine the path of the particle and its polar velocity vector when $t = 0.25$ s. If the particle has a mass of 2 kg, determine its linear momentum vector at $t = 0.25$ s. Sketch the path and this vector at $t = 0.25$ s.

16.6 In plane polar coordinates, the parametric equations of a particle path are given in ft-s units by $r = \dfrac{10}{\cos 6t}$ and $\theta = 4t$. Determine the path of the particle and its velocity vector using transverse and radial components at $t = 0.1$ s. If the particle has a mass of 1 slug, determine its linear momentum at this same time.

16.7 A particle of mass 0.5 kg moves on a path in the x-y plane such that $x = \cos \omega t$ and $y = 0.6 \sin \omega t$ in m-s units. For $\omega = 2$ rad/s and $t = 0.2$ s, determine the linear momentum of this particle.

16.8 A particle of 2 kg mass moves along the path in the first quadrant defined by $x = a \cosh \omega t$ and $y = b \sinh \omega t$. For $a = 2$ m, $b = 3$ m, $\omega = 2$ rad/s, and $t = 0.5$ s, determine the linear momentum of this particle.

Problems

Use impulse and momenta diagrams in the solution of the following problems.

16.17 A mass of 1 kg moves along the positive x axis on a horizontal plane with a velocity of 10 m/s. If it is to be brought to rest in 10 s, what constant force F_x must be applied to it? What is the acceleration of this particle?

16.18 A mass of 2 slug travels along the positive y axis on a horizontal plane with a velocity of 20 ft/s. If it is to be brought to rest in 15 s, what constant force F_y must be applied to it? What is the acceleration of this particle?

16.19 Refer to Example 16.5. Let $F(t) = 6t$, and solve the stated problem. $F(t)$ is expressed in N and t in s. All other conditions and numerical values stated in Example 16.5 remain unchanged.

16.20 A variable force expressed in N as a function of time in s is given by $Q(t) = 3t^2$. This force acts horizontally to the right on a mass m which moves along a smooth horizontal plane. Initial and final velocities are v_1 and v_2, respectively. (a) Determine v_2 at any time t_2 as a function of m, v_1, t_1, and t_2. (b) Find v_2 if $m = 1$ kg, $v_1 = 1$ m/s, $t_1 = 2$ s, and $t_2 = 6$ s.

16.21 A variable force expressed in lb as a function of time in s is given by $Q(t) = 4t^3 + 10t$. This force acts horizontally to the right on a mass m which moves along a smooth horizontal plane. Initial and final velocities are v_1 and v_2, respectively. (a) Determine v_2 at any time t_2 as a function of m, v_1, t_1, and t_2. (b) Find v_2 if $m = 2$ slug, $v_1 = 10$ ft/s, $t_1 = 4$ s, and $t_2 = 7$ s.

16.22 Refer to Figure P16.22 where $P(t) = 3t^2 + 5$, t is in seconds, and P is in pounds. The block weighs 32.2 lb and the coefficient of friction is 0.2. If the initial velocity is 2 ft/s to the right, determine the velocity 4 seconds later.

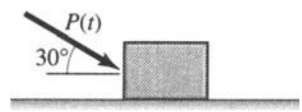

FIGURE P16.22.

16.23 A mass of 4 slug moves from point 1 to point 2 in a time interval $t_2 - t_1$ measured in s as shown in Figure P16.23. Determine the impulse **I** exerted on the mass during this time interval. Assume frictionless conditions.

16.24 Refer to the connected system shown in Figure P16.24 at $t = t_1$. Determine the tension in the cable and the final velocity v_2 at time t_2 as a function of m_A, m_B, v_1, t_1, t_2, and g. Neglect air resistance

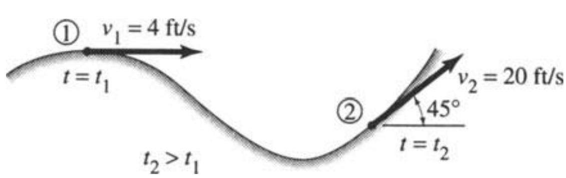

FIGURE P16.23.

Problems

16.31 In Figure P16.31 block A of mass M rests on a frictionless horizontal plane and is initially at rest. Block B of mass m is projected as shown with $v_{B1} = v_0$ such that it impacts block A and they move off together. Neglect impulses associated with body weights and determine (a) the common velocity of these blocks after impact, (b) the impulse components exerted on block B, and (c) the percentage of initial kinetic energy lost in the impact. Express your answers in terms of M, m, v_0 and θ.

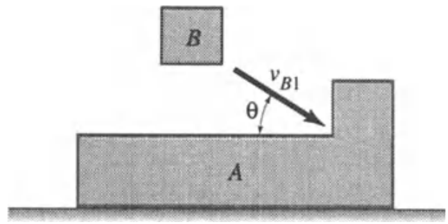

FIGURE P16.31.

16.32 Solve Problem 16.31 for the following inputs $M = 10$ kg, $m = 1$ kg, $v_0 = 1.25$ m/s and $\theta = 50°$.

16.33 Two boats, of mass M_A and M_B, are connected by a slack rope as shown in Figure P16.33. Boat A is initially moving to the left with a velocity $v_{A1} = v_0$ and boat B is at rest. Neglect frictional effects of the water on the boats. Determine (a) the common velocity of both boats after the rope becomes taut and (b) the impulse exerted on boat B by boat A. Express your answers in terms of M_A, M_B and v_0.

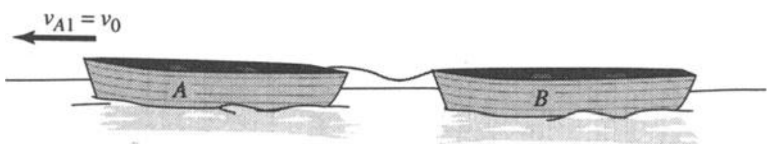

FIGURE P16.33.

16.34 Solve Problem 16.33 if boat B is initially moving to the right with a velocity $v_{B1} = 0.2\, v_0$.

16.35 Swimmer A weighs 130 lb and swimmer C weighs 175 lb. Swimmer A can dive to the left with a relative velocity with respect to the boat B of $v_{A/B} = 10$ ft/s while C can dive to the right with $v_{C/B} = 15$ ft/s. If the boat weighs 395 lb and is initially at rest, determine the final velocity of the boat if (a) swimmers A and C dive simultaneously, (b) swimmer A dives before swimmer C, and (c) swimmer C dives before swimmer A.

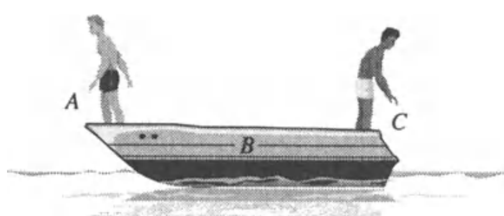

FIGURE P16.35.

16.36 An American Civil War cannon of mass M_c is depicted in Figure P16.36. It can fire a shell of mass m_s with a velocity

16.50 A plan view of a small mass A striking a very massive frictionless wall is shown in Figure P16.50. The speed of mass A before impact is $v_A = 12$ ft/s. The angle of incidence is $\theta_1 = 40°$ and the angle of rebound is $\theta_2 = 65°$. Determine the coefficient of restitution e.

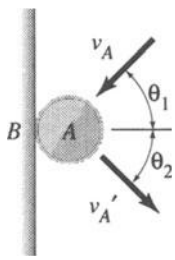

FIGURE P16.50.

16.51 Two disks collide in oblique impact as shown in Figure P16.51. Before impact, their velocities are $v_A = 5$ m/s and $v_B = 4$ m/s. Disk A weighs 40 N and disk B weighs 60 N. The coefficient of restitution is $e = 0.45$. Determine the velocity of each disk after impact.

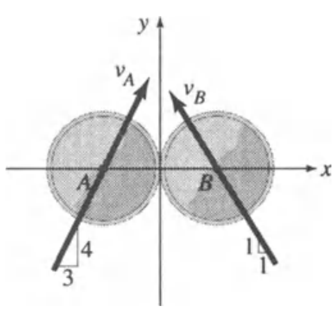

FIGURE P16.51.

16.52 In Figure P16.52, mass A is twice as large as mass B. Both bodies are moving to the right with $v_A = 4$ m/s and $v_B = 2$ m/s. An impact occurs when A overtakes B. Determine the velocity of each mass after impact for (a) $e = 0$, (b) $e = 0.5$, and (c) $e = 1.0$.

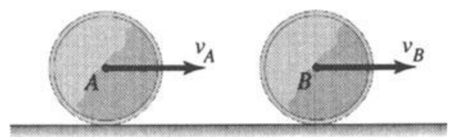

FIGURE P16.52.

16.53 A small sphere A is given a relatively small horizontal speed at a distance $h_1 = 1.00$ m above the relatively massive floor B as shown in Figure P16.53. If the coefficient of restitution $e = 0.25$, determine the maximum height h_2 after the first bounce and the maximum height h_3 after the second bounce. Neglect air resistance.

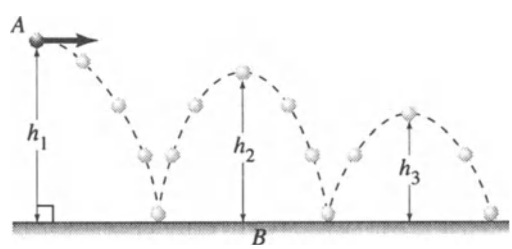

FIGURE P16.53.

16.54 A body weighing 50 N moves with a velocity of 3 m/s directed to the right. It collides with a body weighing 100 N. The impact is central. After impact, the 50 N body moves at a rate of 1 m/s to the right. Determine the initial and final velocities of the 100 N body. Use $e = 0.55$

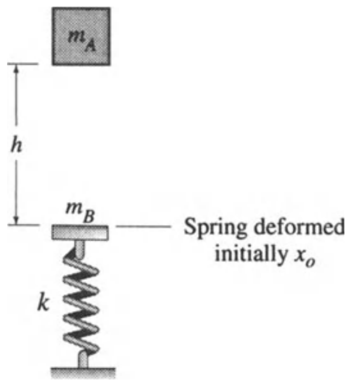

FIGURE P16.89.

m_A just before it impacts m_B, (b) Find the common speed of m_A and m_B just after impact. (c) If $m_A = 2$ slug, $m_B = 4$ slug, $k = 1000$ lb/ft, and $h = 2$ ft, determine the maximum deformation of the spring. Express your answers for parts (a) and (b) in terms of the given quantities m_A, m_B, g, and h.

16.90 In Figure P16.90 mass m_A is released from rest in the position shown and slides down the frictionless inclined plane for a distance s before it impacts m_B. Neglect air resistance and the impulses of the weights and the spring force during the very short time of impact. (a) Determine the speeds of m_A and m_B just after impact in terms of the speed that m_A had just before impact. (b) If $m_A = 5$ kg, $m_B = 2$ kg, $k = 2$ kN/m, $s = 2$ m, $e = 0$ and $\theta = 30°$, determine the maximum spring compression $x_M = x_0 + \Delta x$ where x_0 is its initial deformation.

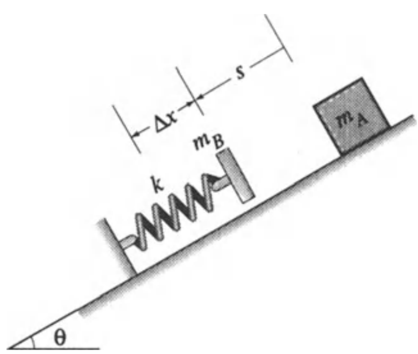

FIGURE P16.90.

16.91 Refer to Figure P16.91, and let $L = 1$ m, $m_A = 2$ kg, $m_B = 4$ kg, $e = 0.6$, $\theta = 30°$ and $\mu = 0.2$. The simple pendulum with bob B is released from rest in the position shown and rotates cw through an angle θ before striking block A, which is at rest. Determine the distance s moved by block A along the horizontal plane before it comes to rest. What is the velocity of bob B immediately after impact? Neglect air resistance, friction at pin O where the pendulum is suspended, and the mass of the light rod OB.

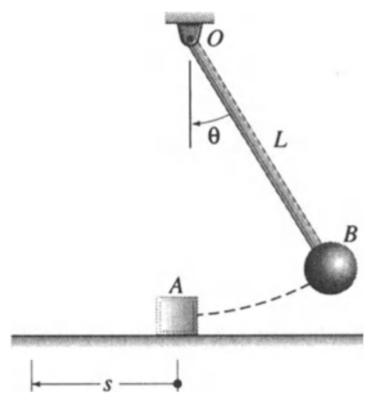

FIGURE P16.91.

16.92 The simple pendulum of Figure P16.91 with bob B is released from rest in the position shown and rotates cw through an angle θ before striking block A, which is at rest. Assign the following numerical values $L = 36$ in, $m_A = 0.1$