ME 2210 Dynamics Handout #3: Homework: 13.6, 13.10, 13.26, 13.58, 13.65, 13.73, 13.87, 13.95, 13.101, 13.122, 13.133, 13.146, 13.156, 13.166

13.1 A 1300-kg small hybrid car is traveling at 108 km/h. Determine (*a*) the kinetic energy of the vehicle, (*b*) the speed required for a 9000-kg truck to have the same kinetic energy as the car.

13.2 An 870-lb satellite is placed in a circular orbit 3973 mi above the surface of the earth. At this elevation the acceleration of gravity is 8.03 ft/s^2. Determine the kinetic energy of the satellite, knowing that its orbital speed is 12,500 mi/h.

13.5 Determine the maximum theoretical speed that may be achieved over a distance of 360 ft by a car starting from rest assuming there is no slipping. The coefficient of static friction between the tires and pavement is 0.75, and 60 percent of the weight of the car is distributed over its front wheels and 40 percent over its rear wheels. Assume (*a*) front-wheel drive, (*b*) rear-wheel drive.

13.6 Skid marks on a drag race track indicate that the rear (drive) wheels of a car slip for the first 60 ft of the 1320-ft track. (*a*) Knowing that the coefficient of kinetic friction is 0.60, determine the speed of the car at the end of the first 60-ft portion of the track if it starts from rest and the front wheels are just off the ground. (*b*) What is the maximum theoretical speed for the car at the finish line if, after skidding for 60 ft, it is driven without the wheels slipping for the remainder of the race? Assume that while the car is rolling without slipping, 60 percent of the weight of the car is on the rear wheels and the coefficient of static friction is 0.85. Ignore air resistance and rolling resistance.

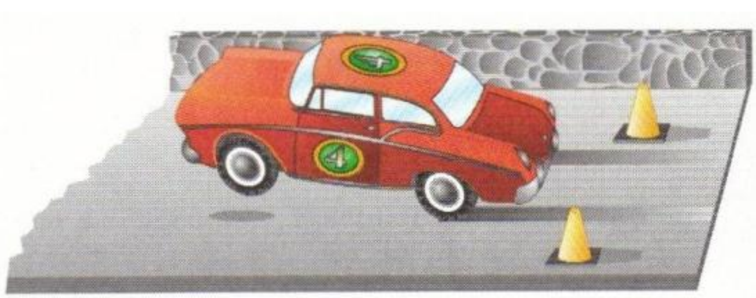

Fig. P13.6

13.7 In an ore-mixing operation, a bucket full of ore is suspended from a traveling crane which moves along a stationary bridge. The bucket is to swing no more than 4 m horizontally when the crane is brought to a sudden stop. Determine the maximum allowable speed v of the crane.

13.8 In an ore-mixing operation, a bucket full of ore is suspended from a traveling crane which moves along a stationary bridge. The crane is traveling at a speed of 3 m/s when it is brought to a sudden stop. Determine the maximum horizontal distance through which the bucket will swing.

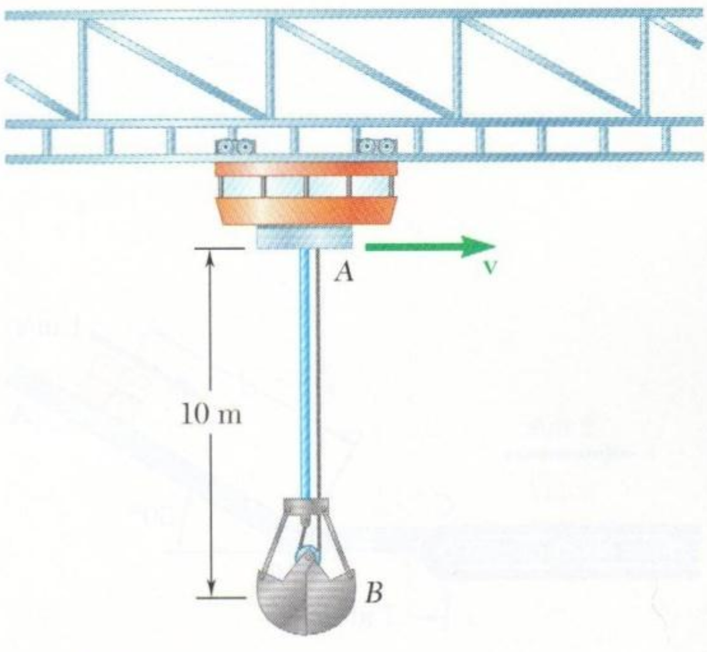

Fig. P13.7 and P13.8

13.9 A package is projected 10 m up a 15° incline so that it just reaches the top of the incline with zero velocity. Knowing that the coefficient of kinetic friction between the package and the incline is 0.12, determine (*a*) the initial velocity of the package at *A*, (*b*) the velocity of the package as it returns to its original position.

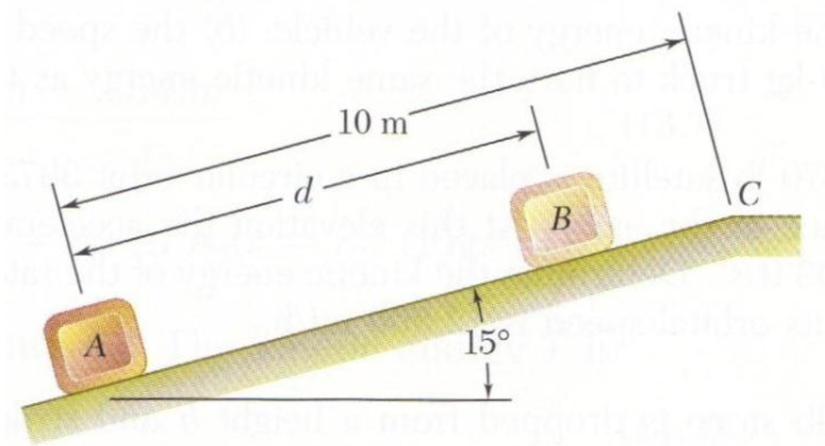

Fig. P13.9 and P13.10

13.10 A package is projected up a 15° incline at A with an initial velocity of 8 m/s. Knowing that the coefficient of kinetic friction between the package and the incline is 0.12, determine (*a*) the maximum distance d that the package will move up the incline, (*b*) the velocity of the package as it returns to its original position.

13.21 The system shown is at rest when a constant 150-N force is applied to collar B. (*a*) If the force acts through the entire motion, determine the speed of collar B as it strikes the support at C. (*b*) After what distance d should the 150-N force be removed if the collar is to reach support C with zero velocity?

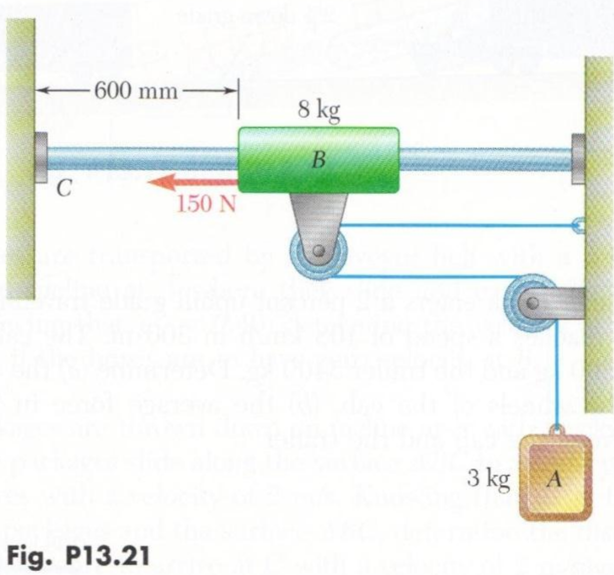

Fig. P13.21

13.26 A 10-lb block is attached to an unstretched spring of constant $k = 12$ lb/in. The coefficients of static and kinetic friction between the block and the plane are 0.60 and 0.40, respectively. If a force **F** is slowly applied to the block until the tension in the spring reaches 20 lb and then suddenly removed, determine (*a*) the speed of the block as it returns to its initial position, (*b*) the maximum speed achieved by the block.

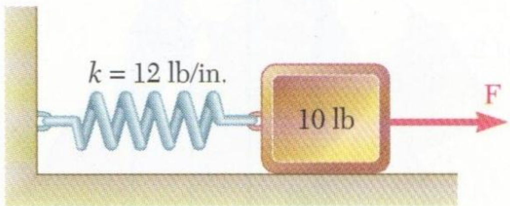

Fig. P13.26 and P13.27

13.27 A 10-lb block is attached to an unstretched spring of constant $k = 12$ lb/in. The coefficients of static and kinetic friction between the block and the plane are 0.60 and 0.40, respectively. If a force **F** is applied to the block until the tension in the spring reaches 20 lb and then suddenly removed, determine (*a*) how far the block will move to the left before coming to a stop, (*b*) whether the block will then move back to the right.

13.39 The sphere at *A* is given a downward velocity $\mathbf{v}_0$ and swings in a vertical circle of radius l and center *O*. Determine the smallest velocity $\mathbf{v}_0$ for which the sphere will reach point *B* as it swings about point *O* (*a*) if AO is a rope, (*b*) if *AO* is a slender rod of negligible mass.

13.40 The sphere at *A* is given a downward velocity $\mathbf{v}_0$ of magnitude 5 m/s and swings in a vertical plane at the end of a rope of length $l = 2$ m attached to a support at *O*. Determine the angle θ at which the rope will break, knowing that it can withstand a maximum tension equal to twice the weight of the sphere.

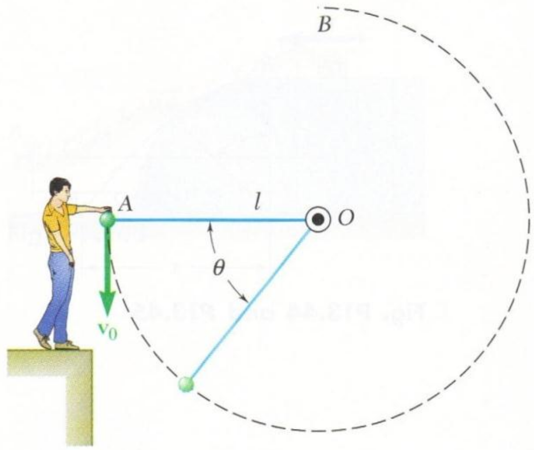

Fig. P13.39 and P13.40

13.46 (*a*) A 120-lb woman rides a 15-lb bicycle up a 3-percent slope at a constant speed of 5 ft/s. How much power must be developed by the woman? (*b*) A 180-lb man on an 18-lb bicycle starts down the same slope and maintains a constant speed of 20 ft/s by braking. How much power is dissipated by the brakes? Ignore air resistance and rolling resistance.

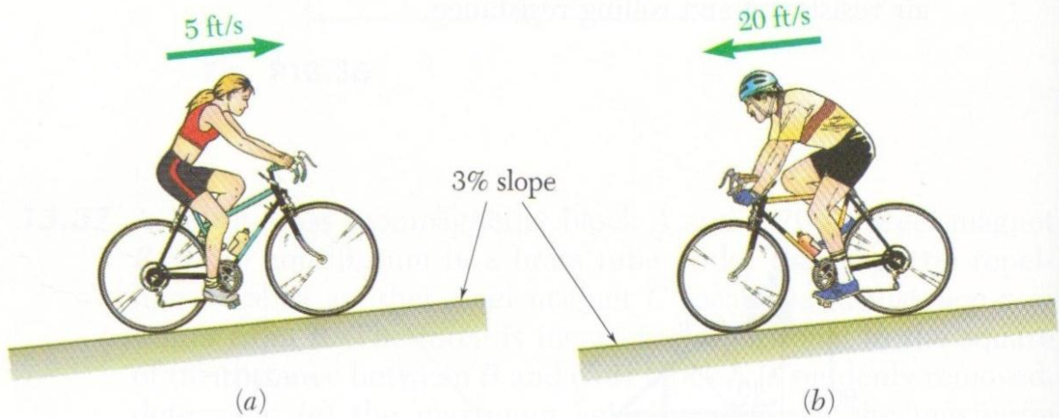

Fig. P13.46

13.52 A 100-ton train traveling on a horizontal track requires 400 hp to maintain a constant speed of 50 mi/h. Determine (*a*) the total force needed to overcome axle friction, rolling resistance, and air resistance, (*b*) the additional horsepower required if the train is to maintain the same speed going up a 1-percent grade.

13.54 The elevator E has a mass of 3000 kg when fully loaded and is connected as shown to a counterweight W of mass 1000 kg. Determine the power in kW delivered by the motor (*a*) when the elevator is moving down at a constant speed of 3 m/s, (*b*) when it has an upward velocity of 3 m/s and a deceleration of 0.5 m/s^2.

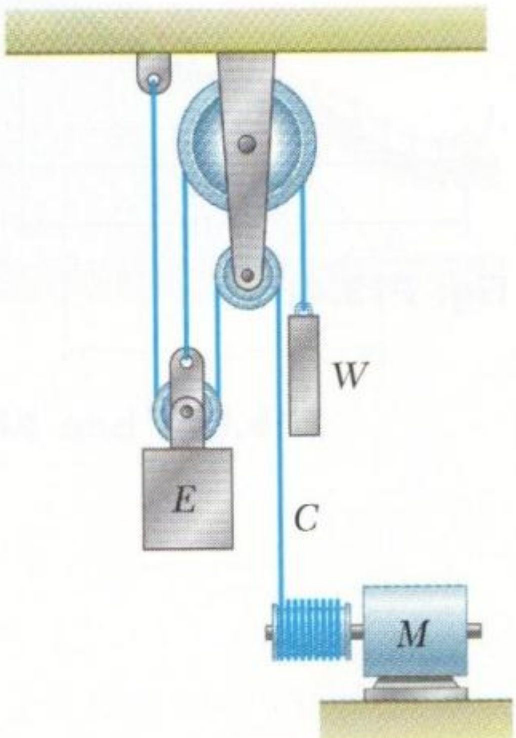

Fig. P13.54

13.55 A force **P** is slowly applied to a plate that is attached to two springs and causes a deflection x_0. In each of the two cases shown, derive an expression for the constant k_e, in terms of k_1 and k_2, of the single spring equivalent to the given system, that is, of the single spring which will undergo the same deflection x_0 when subjected to the same force **P**.

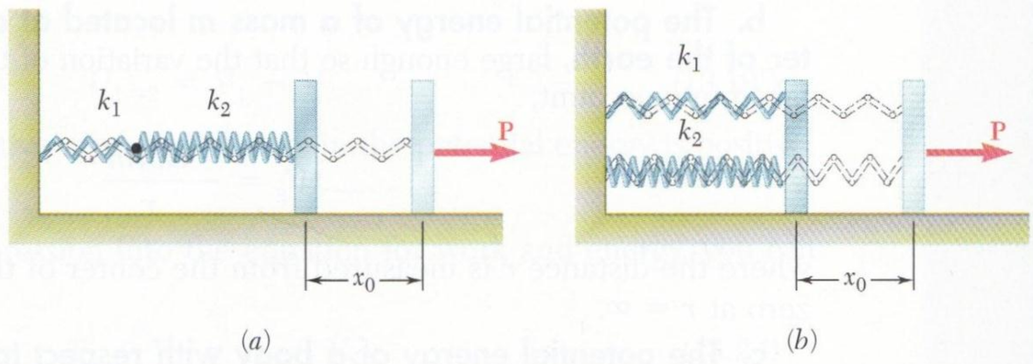

Fig. P13.55

13.56 A block of mass m is attached to two springs as shown. Knowing that in each case the block is pulled through a distance x_0 from its equilibrium position and released, determine the maximum speed of the block in the subsequent motion.

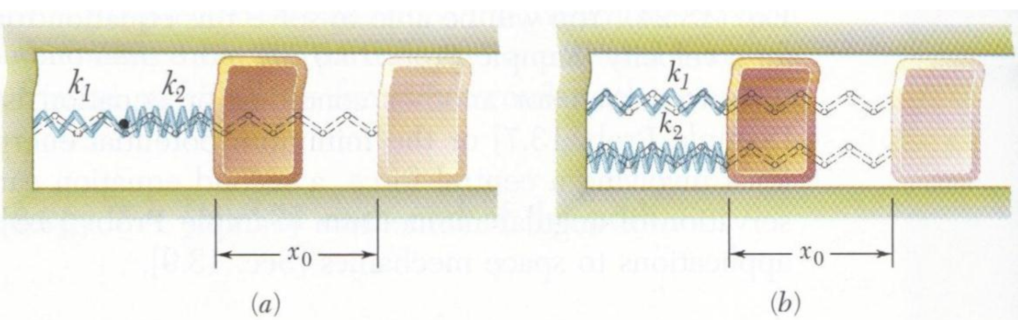

Fig. P13.56

13.57 A 1.2-kg collar C may slide without friction along a horizontal rod. It is attached to three springs, each of constant k = 400 N/m and 150-mm undeformed length. Knowing that the collar is released from rest in the position shown, determine the maximum speed it will reach in the ensuing motion.

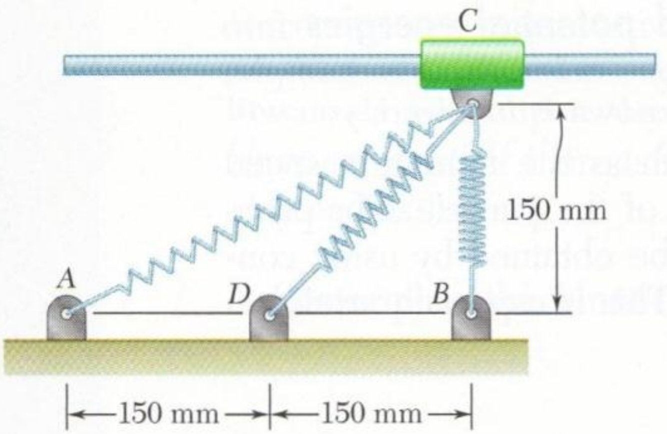

Fig. P13.57

13.58 A 10-lb collar B can slide without friction along a horizontal rod and is in equilibrium at A when it is pushed 5 in. to the right and released. The undeformed length of each spring is 12 in. and the constant of each spring is $k = 1.6$ lb/in. Determine (*a*) the maximum speed of the collar (*b*) the maximum acceleration of the collar.

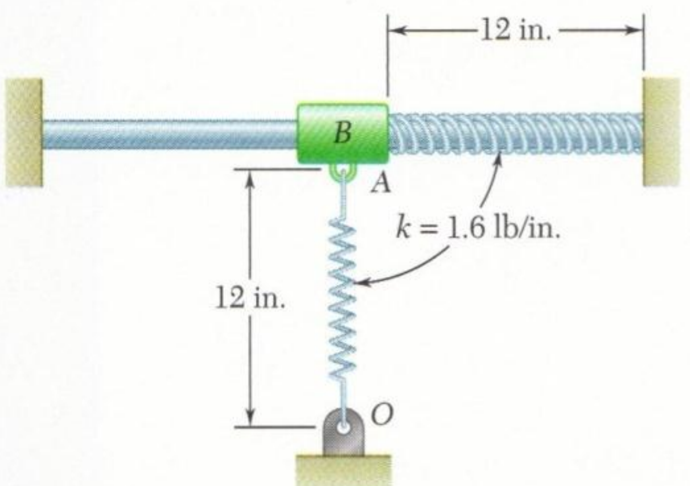

Fig. P13.58

13.62 A 3-kg collar can slide without friction on a vertical rod and is resting in equilibrium on a spring. It is pushed down, compressing the spring 150 mm, and released. Knowing that the spring constant is $k = 2.6$ kN/m, determine (*a*) the maximum height h reached by the collar above its equilibrium position, (*b*) the maximum speed of the collar.

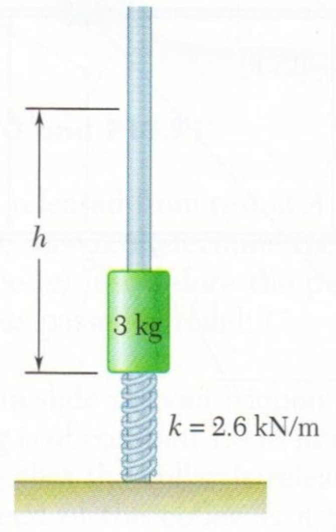

Fig. P13.62

13.64 A thin circular rod is supported in a *vertical plane* by a bracket at A. Attached to the bracket and loosely wound around the rod is a spring of constant $k = 3$ lb/ft and undeformed length equal to the arc of circle AB. An 8-oz collar C, not attached to the spring, can slide without friction along the rod. Knowing that the collar is released from rest when $\theta = 30°$, determine (*a*) the maximum height above point B reached by the collar, (*b*) the maximum speed of the collar.

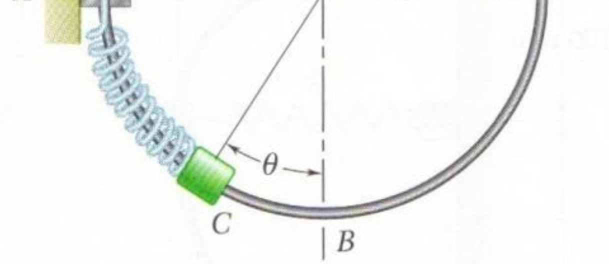

Fig. P13.64 and P13.65

13.65 A thin circular rod is supported in a *vertical plane* by a bracket at A. Attached to the bracket and loosely wound around the rod is a spring of constant $k = 3$ lb/ft and undeformed length equal to the arc of circle AB. An 8-oz collar C, not attached to the spring, can slide without friction along the rod. Knowing that the collar is released from rest at an angle θ with the vertical, determine (*a*) the smallest value of θ for which the collar will pass through D and reach point A, (*b*) the velocity of the collar as it reaches point A.

13.68 A spring is used to stop a 50-kg package which is moving down a 20° incline. The spring has a constant $k = 30$ kN/m and is held by cables so that it is initially compressed 50 mm. Knowing that the velocity of the package is 2 m/s when it is 8 m from the spring and neglecting friction, determine the maximum additional deformation of the spring in bringing the package to rest.

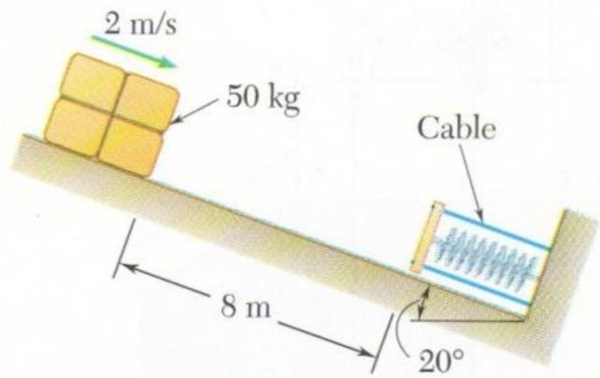

Fig. P13.68

13.69 Solve Prob. 13.68 assuming the kinetic coefficient of friction between the package and the incline is 0.2.

13.72 A 1.2-lb collar can slide without friction along the semicircular rod BCD. The spring is of constant 1.8 lb/in and its undeformed length is 8 in. Knowing that the collar is released from rest at B, determine (*a*) the speed of the collar as it passes through C, (*b*) the force exerted by the rod on the collar at C.

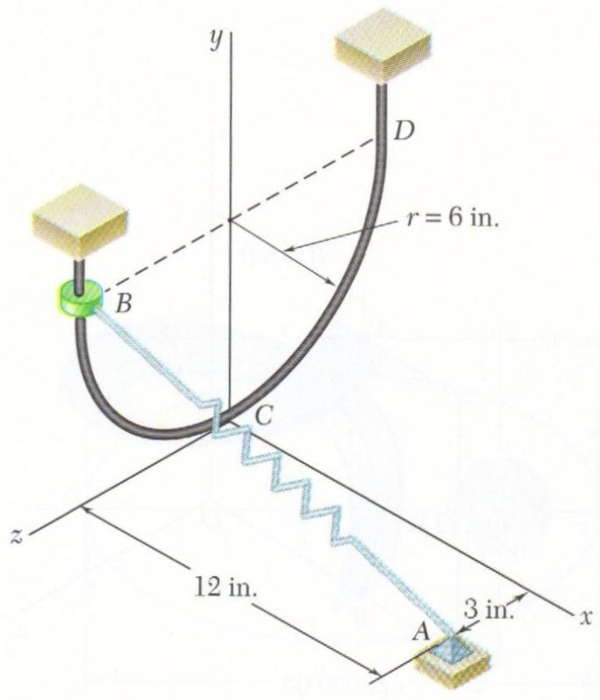

Fig. P13.72

13.73 A 1-lb collar is attached to a spring and slides without friction along a circular rod in a *vertical* plane. The spring has an undeformed length of 5 in. and a constant $k = 10$ lb/ft. Knowing that the collar is released from being held at A determine the speed of the collar and the normal force between the collar and the rod as the collar passes through B.

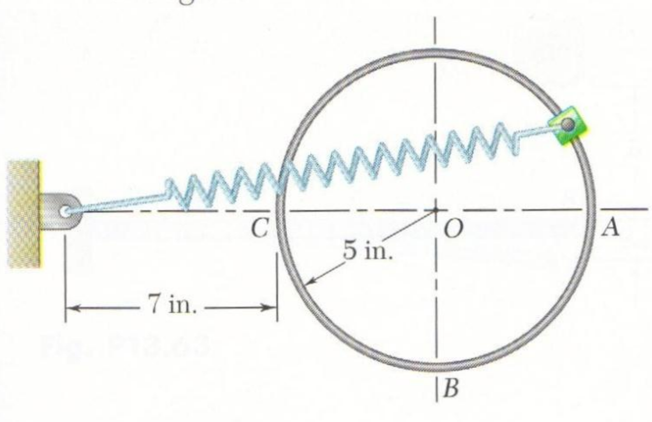

Fig. P13.73

13.85 While describing a circular orbit 300 km above the earth a space vehicle launches a 3600-kg communications satellite. Determine (*a*) the additional energy required to place the satellite in a geosynchronous orbit at an altitude of 35 770 km above the surface of the earth, (*b*) the energy required to place the satellite in the same orbit by launching it from the surface of the earth, excluding the energy needed to overcome air resistance. (A *geosynchronous orbit* is a circular orbit in which the satellite appears stationary with respect to the ground.)

13.87 Knowing that the velocity of an experimental space probe fired from the earth has a magnitude $v_A = 20.2 \times 10^3$ mi/h at point *A*, determine the velocity of the probe as it passes through point *B*.

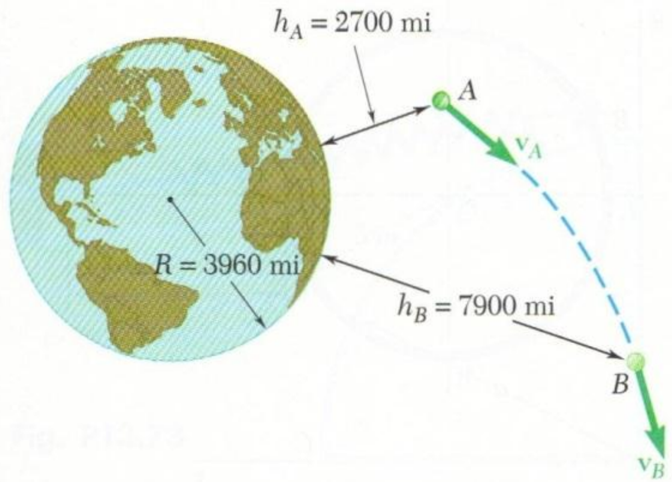

Fig. P13.87

13.90 How much energy per kilogram should be imparted to a satellite in order to place it in a circular orbit at an altitude of (*a*) 600 km, (*b*) 6000 km?

13.95 Collar *A* weighs 10 lb and is attached to a spring of constant 50 lb/ft and of undeformed length equal to 18 in. The system is set in motion with $r = 12$ in., $v_\theta = 16$ ft/s, and $v_r = 0$. Neglecting the mass of the rod and the effect of friction, determine the radial and transverse components of the velocity of the collar when $r = 21$ in.

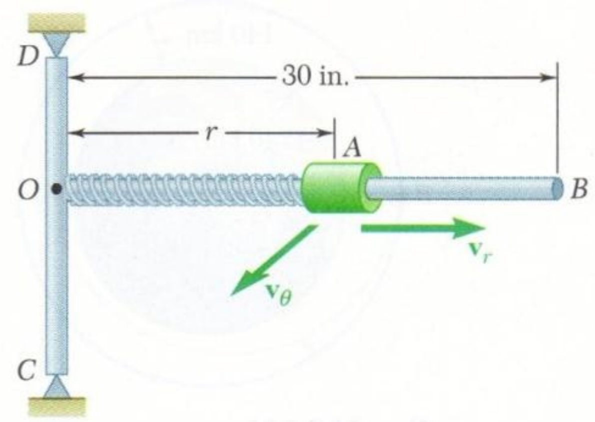

Fig. P13.95

13.98 A 1.8-kg collar A and a 0.7-kg collar B can slide without friction on a frame, consisting of the horizontal rod OE and the vertical rod CD, which is free to rotate about CD. The two collars are connected by a cord running over a pulley that is attached to the frame at O. At the instant shown, the velocity $\mathbf{v}_A$ of collar A has a magnitude of 2.1 m/s and a stop prevents collar B from moving. If the stop is suddenly removed, determine (*a*) the velocity of collar A when it is 0.2 m from O, (*b*) the velocity of collar A when collar B comes to rest. (Assume that collar B does not hit O, that collar A does not come off rod OE, and that the mass of the frame is negligible.)

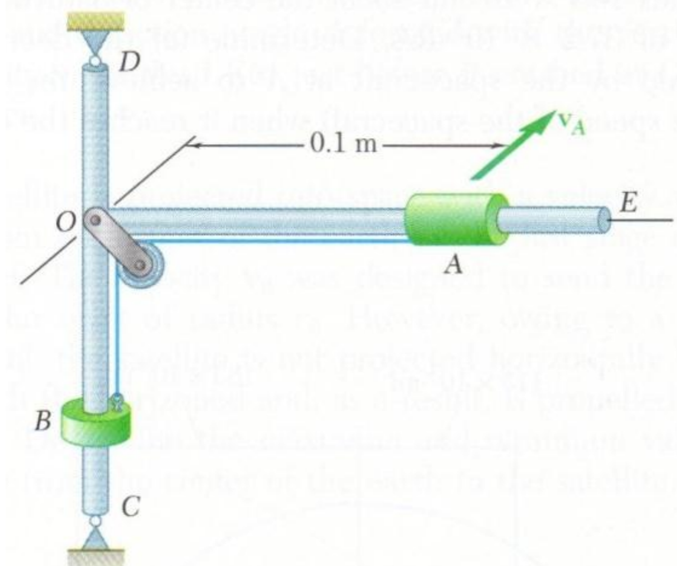

Fig. *P13.98*

13.100 A spacecraft traveling along a parabolic path toward the planet Jupiter is expected to reach point A with a velocity $\mathbf{v}_A$ of magnitude 26.9 km/s. Its engines will then be fired to slow it down, placing it into an elliptic orbit which will bring it to within 100×10^3 km of Jupiter. Determine the decrease in speed Δv at point A which will place the spacecraft into the required orbit. The mass of Jupiter is 319 times the mass of the earth.

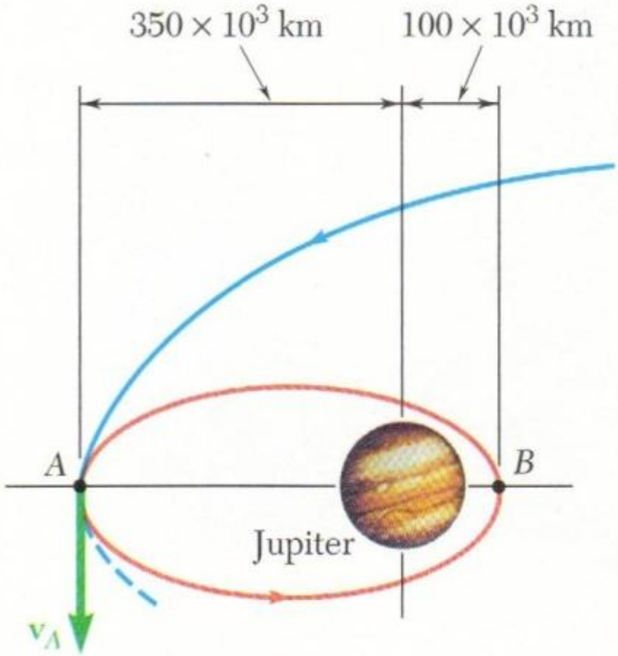

Fig. P13.100

13.101 After completing their moon-exploration mission, the two astronauts forming the crew of an Apollo lunar excursion module (LEM) would prepare to rejoin the command module which was orbiting the moon at an altitude of 140 km. They would fire the LEM's engine, bring it along a curved path to a point A, 8 km above the moon's surface, and shut off the engine. Knowing that the LEM was moving at that time in a direction parallel to the moon's surface and that it then coasted along an elliptic path to a rendezvous at B with the command module, determine (*a*) the speed of the LEM at engine shutoff, (*b*) the relative velocity with which the command module approached the LEM at B. (The radius of the moon is 1740 km and its mass is 0.01230 times the mass of the earth.)

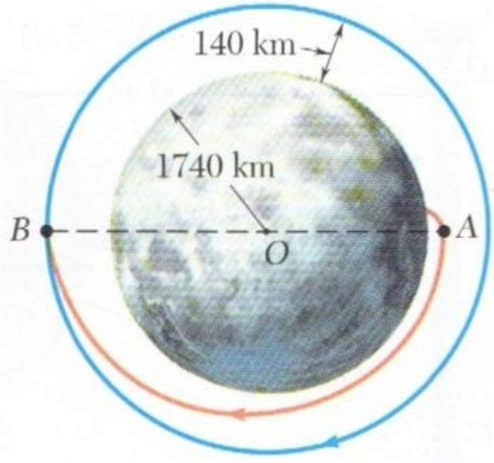

Fig. P13.101

13.119 A 1200-kg automobile is moving at a speed of 90 km/h when the brakes are fully applied, causing all four wheels to skid. Determine the time required to stop the automobile (*a*) on dry pavement ($\mu_k = 0.75$), (*b*) on an icy road ($\mu_k = 0.10$).

13.120 A 40,000-ton ocean liner has an initial velocity of 2.5 mi/h. Neglecting the frictional resistance of the water, determine the time required to bring the liner to rest by using a single tugboat which exerts a constant force of 35 kips.

13.121 The initial velocity of the block in position *A* is 30 ft/s. Knowing that the coefficient of kinetic friction between the block and the plane is $\mu_k = 0.30$, determine the time it takes for the block to reach *B* with zero velocity, if (*a*) $\theta = 0$, (*b*) $\theta = 20°$.

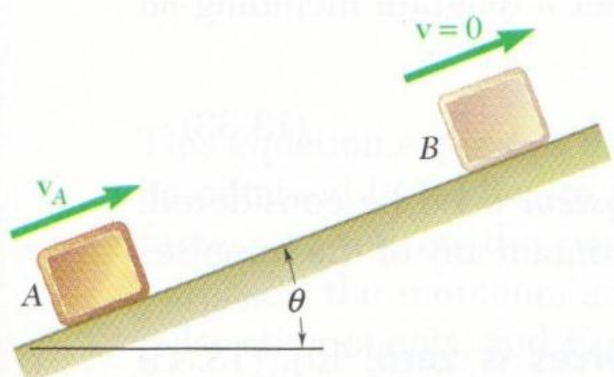

Fig. P13.121

13.122 A 2-kg particle is acted upon by the force, expressed in newtons, $\mathbf{F} = (8 - 6t)\mathbf{i} + (4 - t^2)\mathbf{j} + (4 + t)\mathbf{k}$. Knowing that the velocity of the particle is $\mathbf{v} = (150 \text{ m/s})\mathbf{i} + (100 \text{ m/s})\mathbf{j} - (250 \text{ m/s})\mathbf{k}$ at $t = 0$, determine (*a*) the time at which the velocity of the particle is parallel to the *yz* plane, (*b*) the corresponding velocity of the particle.

13.132 An 8-kg cylinder *C* rests on a 4-kg platform *A* supported by a cord which passes over the pulleys *D* and *E* and is attached to a 4-kg block *B*. Knowing that the system is released from rest, determine (*a*) the velocity of block *B* after 0.8 s, (*b*) the force exerted by the cylinder on the platform.

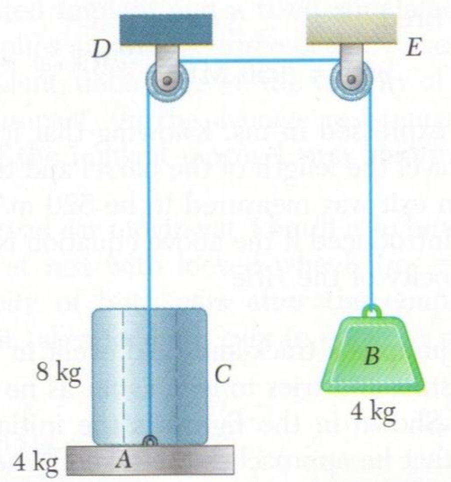

Fig. P13.132

13.133 The system shown is released from rest. Determine the time it takes for the velocity of *A* to reach 1 m/s. Neglect friction and the mass of the pulleys.

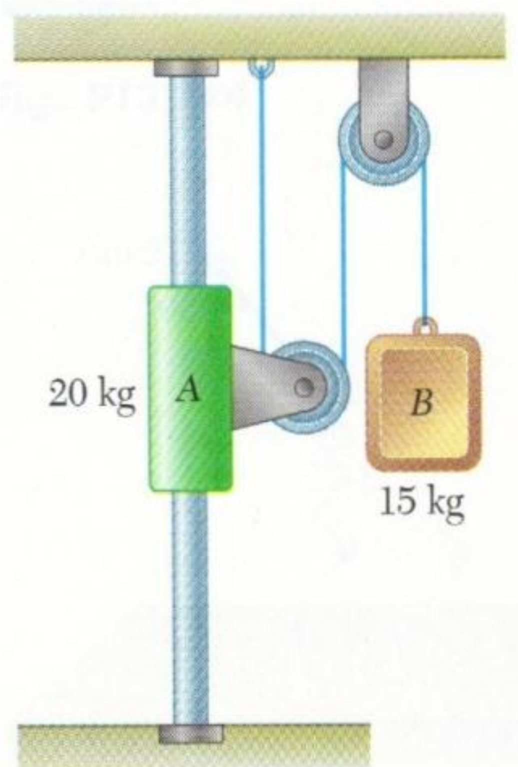

Fig. *P13.133*

13.134 A 4-lb collar which can slide on a frictionless vertical rod is acted upon by a force **P** which varies in magnitude as shown. Knowing that the collar is initially at rest, determine its velocity at (*a*) $t = 2$ s, (*b*) $t = 3$ s.

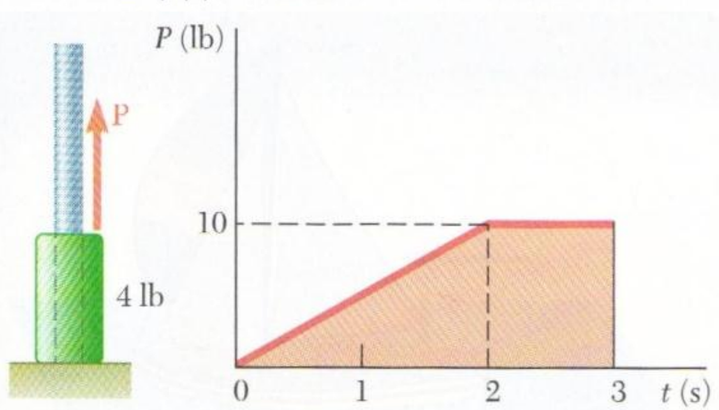

Fig. P13.134 and P13.135

13.136 A 125-lb block initially at rest is acted upon by a force **P** which varies as shown. Knowing that the coefficients of friction between the block and the horizontal surface are $\mu_s = 0.50$ and $\mu_k = 0.40$, determine (*a*) the time at which the block will start moving, (*b*) the maximum speed reached by the block, (*c*) the time at which the block will stop moving.

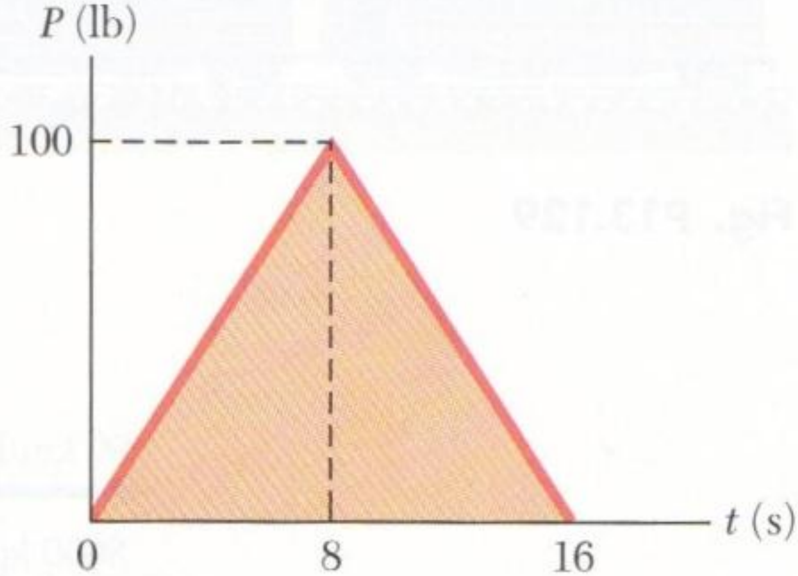

Fig. P13.136

13.140 The triple jump is a track-and-field event in which an athlete gets a running start and tries to leap as far as he can with a hop, step, and jump. Shown in the figure is the initial hop of the athlete. Assuming that he approaches the takeoff line from the left with a horizontal velocity of 10 m/s, remains in contact with the ground for 0.18 s, and takes off at a 50° angle with a velocity of 12 m/s, determine the vertical component of the average impulsive force exerted by the ground on his foot. Give your answer in terms of the weight W of the athlete.

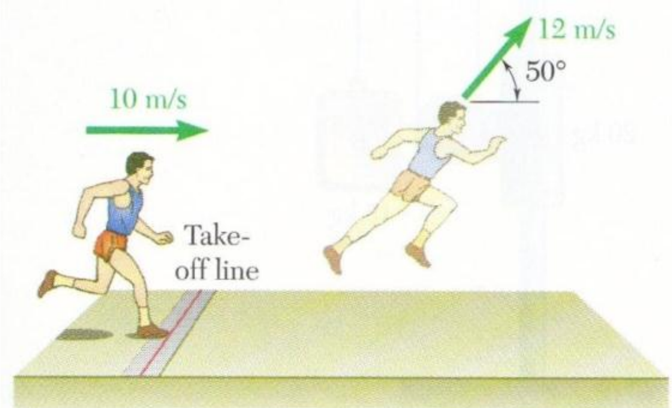

Fig. P13.140

13.141 The last segment of the triple jump track-and-field event is the jump, in which the athlete makes a final leap, landing in a sand-filled pit. Assuming that the velocity of a 185-lb athlete just before landing is 30 ft/s at an angle of 35° with the horizontal and that the athlete comes to a complete stop in 0.22 s after landing, determine the horizontal component of the average impulsive force exerted on his feet during landing.

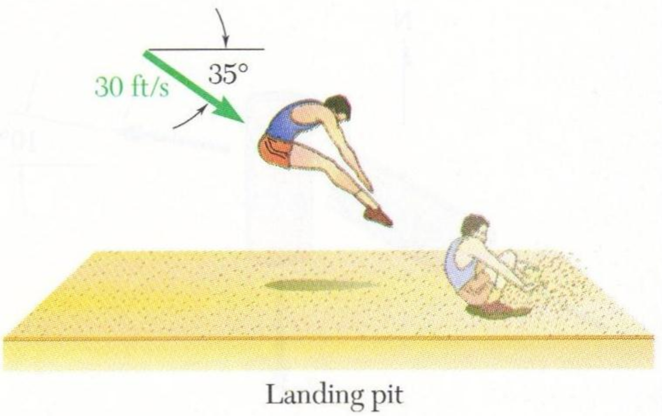

Fig. P13.141

13.146 At an intersection car B was traveling south and car A was traveling 30° north of east when they slammed into each other. Upon investigation it was found that after the crash the two cars got stuck and skidded off at an angle of 10° north of east. Each driver claimed that he was going at the speed limit of 50 km/h and that he tried to slow down but couldn't avoid the crash because the other driver was going a lot faster. Knowing that the masses of cars A and B were 1500 kg and 1200 kg, respectively, determine (*a*) which car was going faster, (*b*) the speed of the faster of the two cars if the slower car was traveling at the speed limit.

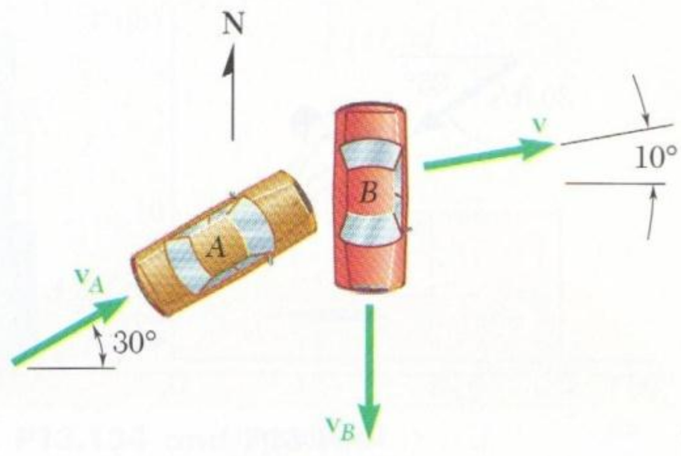

Fig. P13.146

13.147 A mother and her child are skiing together, with the mother holding the end of a rope tied to the child's waist. They are moving at a speed of 7.2 km/h on a flat portion of the ski trail when the mother observes that they are approaching a steep descent. She decides to pull on the rope to decrease the child's speed. Knowing that this maneuver causes the child's speed to be cut in half in 3 s and neglecting friction, determine (*a*) the mother's speed at the end of the 3-s interval, (*b*) the average value of the tension in the rope during that time interval.

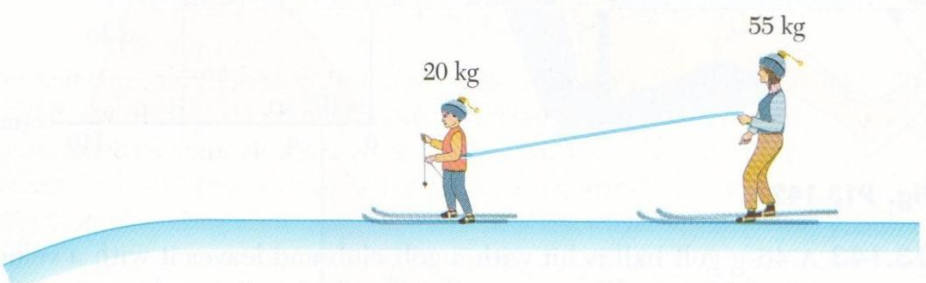

Fig. P13.147

13.148 Bullet B weighs 0.5 oz and blocks A and C both weigh 3 lb. The coefficient of friction between the blocks and the plane is $\mu_k = 0.25$. Initially the bullet is moving at v_0 and blocks A and C are at rest (Fig. 1). After the bullet passes through A it becomes embedded in block C and all three objects come to stop in the positions shown (Fig. 2). Determine the initial speed of the bullet v_0.

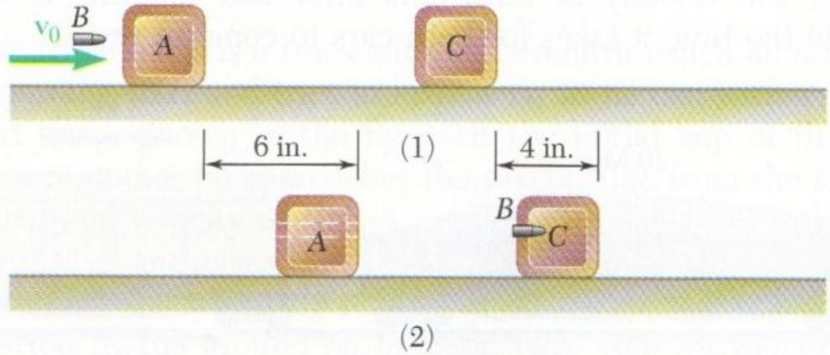

Fig. P13.148

13.151 A 125-g ball moving at a speed of 3 m/s strikes a 250-g plate supported by springs. Assuming that no energy is lost in the impact, determine (*a*) the velocity of the ball immediately after impact, (*b*) the impulse of the force exerted by the plate on the ball.

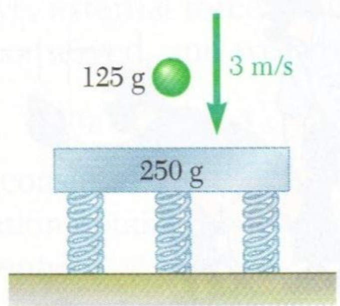

Fig. P13.151

13.152 A bullet of mass m is fired with a velocity $\mathbf{v}_0$ forming an angle θ with the horizontal and gets lodged in a wooden block of mass M. The block can roll without friction on a hard floor and is prevented by springs from hitting the wall. Determine the horizontal and vertical components of the impulse of the force exerted by the block on the bullet.

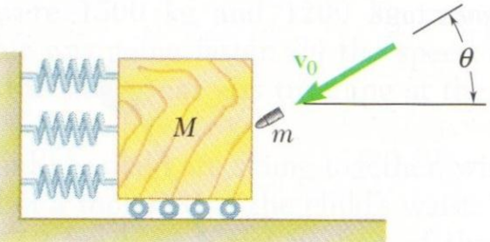

Fig. P13.152

13.155 The coefficient of restitution between the two collars is known to be 0.80. Determine (*a*) their velocities after impact, (*b*) the energy loss during impact.

Fig. P13.155

13.156 Collars *A* and *B*, of the same mass *m*, are moving toward each other with the velocities shown. Knowing that the coefficient of restitution between the collars is 0 (plastic impact), show that after impact (*a*) the common velocity of the collars is equal to half the difference in their speed before impact, (*b*) the loss in kinetic energy is $\frac{1}{4}m(v_A + v_B)^2$.

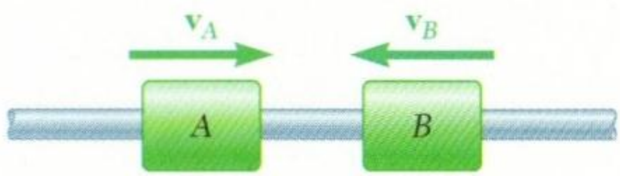

Fig. P13.156

13.159 Two identical cars *A* and *B* are at rest on a loading dock with brakes released. Car *C*, of a slightly different style but of the same weight, has been pushed by dockworkers and hits car *B* with a velocity of 1.5 m/s. Knowing that the coefficient of restitution is 0.8 between *B* and *C* and 0.5 between *A* and *B*, determine the velocity of each car after all collisions have taken place.

Fig. P13.159

13.163 One of the requirements for tennis balls to be used in official competition is that, when dropped onto a rigid surface from a height of 100 in., the height of the first bounce of the ball must be in the range 53 in. $\leq h \leq$ 58 in. Determine the range of the coefficients of restitution of the tennis balls satisfying this requirement.

13.165 A 600-g ball *A* is moving with a velocity of magnitude 6 m/s when it is hit as shown by a 1-kg ball *B* which has a velocity of magnitude 4 m/s. Knowing that the coefficient of restitution is 0.8 and assuming no friction, determine the velocity of each ball after impact.

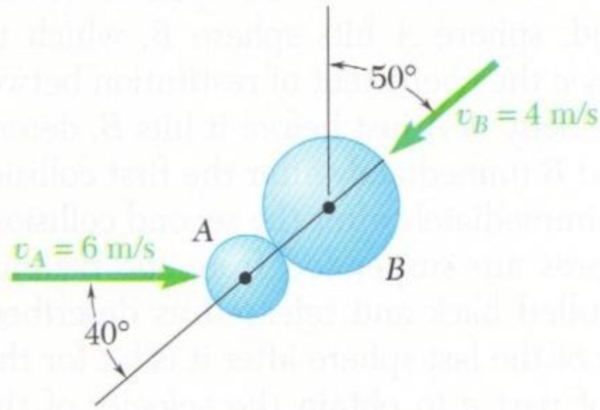

Fig. P13.165

13.166 Two identical hockey pucks are moving on a hockey rink at the same speed of 3 m/s and in parallel and opposite directions when they strike each other as shown. Assuming a coefficient of restitution $e = 1$, determine the magnitude and direction of the velocity of each puck after impact.

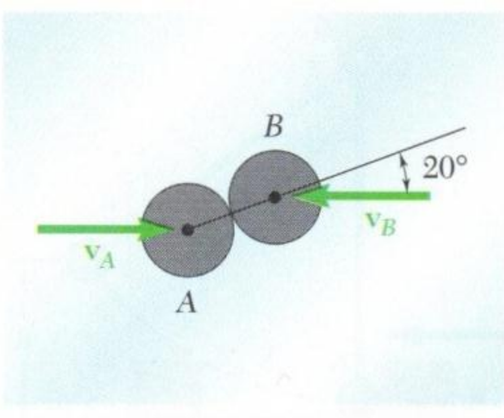

Fig. P13.166

13.170 A girl throws a ball at an inclined wall from a height of 1.2 m, hitting the wall at A with a horizontal velocity $\mathbf{v}_0$ of magnitude 15 m/s. Knowing that the coefficient of restitution between the ball and the wall is 0.9 and neglecting friction, determine the distance d from the foot of the wall to the point B where the ball will hit the ground after bouncing off the wall.

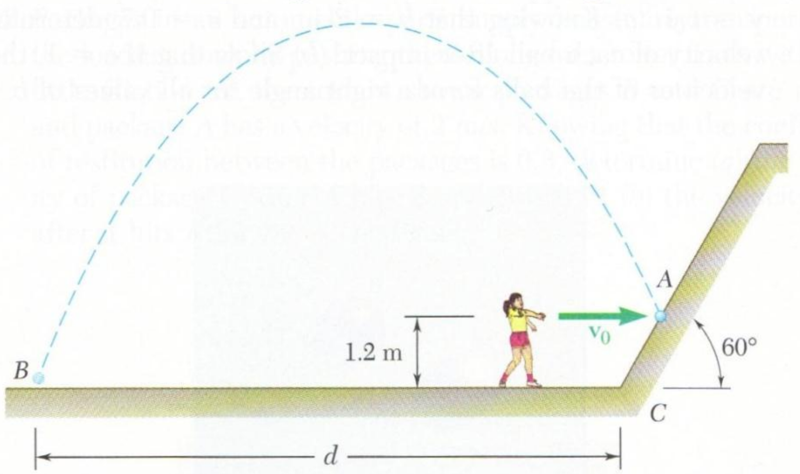

Fig. P13.170

13.171 A ball hits the ground at A with a velocity $\mathbf{v}_0$ of 16 ft/s at an angle of 60° with the horizontal. Knowing that $e = 0.6$ between the ball and the ground and that after rebounding the ball reaches point B with a horizontal velocity, determine (*a*) the distances h and d, (*b*) the velocity of the ball as it reaches B.

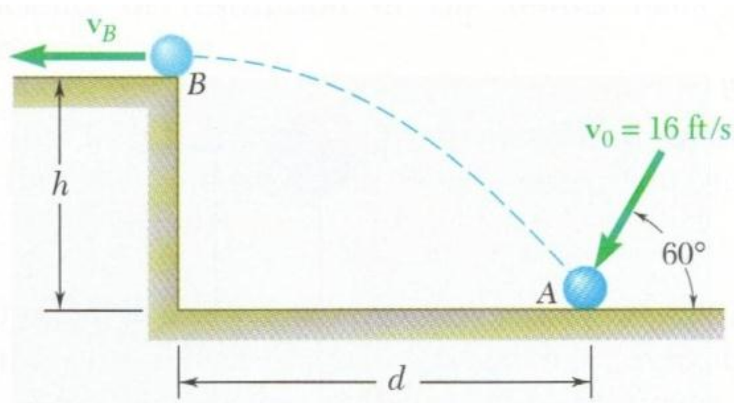

Fig. *P13.171*