13.15 The subway train shown is traveling at a speed of 30 mi/h when the
brakes are fully applied on the wheels of cars B and C, causing
them to slide on the track, but are not applied on the wheels of
car A. Knowing that the coefficient of kinetic friction is 0.35
between the wheels and the track, determine (a) the distance
required to bring the train to a stop, (b) the force in each
coupling.

![Fig. P13.15](image_url)

13.16 Solve Prob. 13.15 assuming that the brakes are applied only on the
wheels of car A.

13.17 A trailer truck enters a 2 percent downhill grade traveling at
108 km/h and must slow down to 72 km/h in 300 m. The cab has
a mass of 1800 kg and the trailer 5400 kg. Determine (a) the aver-
age braking force that must be applied, (b) the average force
exerted on the coupling between cab and trailer if 70 percent
of the braking force is supplied by the trailer and 30 percent by
the cab.

![Fig. P13.17](image_url)

13.18 A trailer truck enters a 2 percent uphill grade traveling at 72 km/h
and reaches a speed of 108 km/h in 300 m. The cab has a mass
of 1800 kg and the trailer 5400 kg. Determine (a) the average force
at the wheels of the cab, (b) the average force in the coupling
between the cab and the trailer.

![Fig. P13.18](image_url)
13.19 Two identical blocks are released from rest. Neglecting the mass of the pulleys and the effect of friction, determine (a) the velocity of block B after it has moved 2 m, (b) the tension in the cable.

![Fig. P13.19 and P13.20](image)

13.20 Two identical blocks are released from rest. Neglecting the mass of the pulleys and knowing that the coefficients of static and kinetic friction are $\mu_s = 0.30$ and $\mu_k = 0.20$, determine (a) the velocity of block B after it has moved 2 m, (b) the tension in the cable.

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](image)

13.22 Blocks A and B have masses of 11 kg and 5 kg, respectively, and they are both at a height $h = 2$ m above the ground when the system is released from rest. Just before hitting the ground block A is moving at a speed of 3 m/s. Determine (a) the amount of energy dissipated in friction by the pulley, (b) the tension in each portion of the cord during the motion.
13.39 The sphere at A is given a downward velocity \( v_0 \) and swings in a vertical circle of radius \( l \) and center \( O \). Determine the smallest velocity \( v_0 \) 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 \( v_0 \) 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 \( \theta \) at which the rope will break, knowing that it can withstand a maximum tension equal to twice the weight of the sphere.

13.41 A section of track for a roller coaster consists of two circular arcs \( AB \) and \( CD \) joined by a straight portion \( BC \). The radius of \( AB \) is 90 ft and the radius of \( CD \) is 240 ft. The car and its occupants, of total weight 560 lb reach point A with practically no velocity and then drop freely along the track. Determine the normal force exerted by the track on the car as the car reaches point B. Ignore air resistance and rolling resistance.

13.42 A section of track for a roller coaster consists of two circular arcs \( AB \) and \( CD \) joined by a straight portion \( BC \). The radius of \( AB \) is 90 ft and the radius of \( CD \) is 240 ft. The car and its occupants, of total weight 560 lb, reach point A with practically no velocity and then drop freely along the track. Determine the maximum and minimum values of the normal force exerted by the track on the car as the car travels from A to D. Ignore air resistance and rolling resistance.

13.43 A small sphere \( B \) of mass \( m \) is released from rest in the position shown and swings freely in a vertical plane, first about \( O \) and then about the peg \( A \) after the cord comes in contact with the peg. Determine the tension in the cord (a) just before the sphere comes in contact with the peg, (b) just after it comes in contact with the peg.
13.63 It is shown in mechanics of materials that when an elastic beam \( AB \) supports a block of weight \( W \) at a given point \( B \), the deflection \( y_m \) (called the static deflection) is proportional to \( W \). Show that if the same block is dropped from a height \( h \) onto the end \( B \) of a cantilever beam \( AB \) and does not bounce off, the maximum deflection \( y_m \) in the ensuing motion can be expressed as
\[
y_m = y_n \left( 1 + \sqrt{1 + 2h/y_n} \right).
\]
Note that this formula is approximate, since it is based on the assumption that there is no energy dissipated in the impact and that the weight of the beam is small compared to the weight of the block.

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 \( \theta = 30^\circ \), determine (a) the maximum height above point \( B \) reached by the collar, (b) the maximum speed of the collar.

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 \( \theta \) with the vertical, determine (a) the smallest value of \( \theta \) for which the collar will pass through \( D \) and reach point \( A \), (b) the velocity of the collar as it reaches point \( A \).

13.66 A 2.7-lb collar can slide along the rod shown. It is attached to an elastic cord anchored at \( F \), which has an undeformed length of 0.9 ft and spring constant of 5 lb/ft. Knowing that the collar is released from rest at \( A \) and neglecting friction, determine the speed of the collar (a) at \( B \), (b) at \( E \).
13.67 The system shown is in equilibrium when $\phi = 0$. Knowing that initially $\phi = 90^\circ$ and that block $C$ is given a slight nudge when the system is in that position, determine the speed of the block as it passes through the equilibrium position $\phi = 0$. Neglect the weight of the rod.

![Diagram](image)

Fig. P13.67

13.68 A spring is used to stop a 50-kg package which is moving down a $20^\circ$ 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.

![Diagram](image)

Fig. P13.68

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

13.70 A 300-g pellet is released from rest at $A$ and slides with friction along the surface shown. Determine the force exerted on the pellet by the surface $(a)$ just before the pellet reaches $B$, $(b)$ immediately after it has passed through $B$.

![Diagram](image)

Fig. P13.70 and P13.71

13.71 A 300-g pellet is released from rest at $A$ and slides without friction along the surface shown. Determine the force exerted on the pellet by the surface $(a)$ just before the pellet reaches $C$, $(b)$ immediately after it has passed through $C$.

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 $C$.

![Diagram](image)

Fig. P13.72
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) \(\theta = 20^\circ\).

13.122 A 2-kg particle is acted upon by the force, expressed in newtons, \(F = (8 - 6t)i + 4tj + (4 + t)k\). Knowing that the velocity of the particle is \(v = (150 \text{ m/s})i + (100 \text{ m/s})j - (250 \text{ m/s})k\) 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.

13.123 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 shortest possible time for the car to travel the initial 60-ft portion of the track if it starts from rest with its front wheels just off the ground. (b) Determine the minimum time for the car to run the whole race if, after skidding for 60 ft, the wheels roll without sliding for the remainder of the race. Assume for the rolling portion of the race that 60 percent of the weight is on the rear wheels and that the coefficient of static friction is 0.85. Ignore air resistance and rolling resistance.

13.124 A truck is traveling on a level road at a speed of 90 km/h when its brakes are applied to slow it down to 30 km/h. An antiskid braking system limits the braking force to a value at which the wheels of the truck are just about to slide. Knowing that the coefficient of static friction between the road and the wheels is 0.65, determine the shortest time needed for the truck to slow down.

13.125 A truck is traveling down a road with a 4-percent grade at a speed of 60 mi/h when its brakes are applied to slow it down to 20 mi/h. An antiskid braking system limits the braking force to a value at which the wheels of the truck are just about to slide. Knowing that the coefficient of static friction between the road and the wheels is 0.60, determine the shortest time needed for the truck to slow down.
13.126 Baggage on the floor of the baggage car of a high-speed train is not prevented from moving other than by friction. Determine the smallest allowable value of the coefficient of static friction between a trunk and the floor of the car if the trunk is not to slide when the train decreases its speed at a constant rate from 200 km/h to 90 km/h in a time interval of 12 s.

13.127 Solve Prob. 13.126, assuming that the train is going down a 5-percent grade.

13.128 A sailboat weighing 980 lb with its occupants is running down wind at 8 mi/h when its spinnaker is raised to increase its speed. Determine the net force provided by the spinnaker over the 10-s interval that it takes for the boat to reach a speed of 12 mi/h.

13.129 A light train made of two cars travels at 45 mi/h. Car A weighs 18 tons, and car B weighs 13 tons. When the brakes are applied, a constant braking force of 4300 lb is applied to each. Determine (a) the time required for the train to stop after the brakes are applied, (b) the force in the coupling between the cars while the train is slowing down.

13.130 Solve Prob. 13.129, assuming that a constant braking force of 4300 lb is applied to car B but that the brakes on car A are not applied.

13.131 A trailer truck with a 2000-kg cab and an 8000-kg trailer is traveling on a level road at 90 km/h. The brakes on the trailer fail and the antiskid system of the cab provides the largest possible force which will not cause the wheels of the cab to slide. Knowing that the coefficient of static friction is 0.65, determine (a) the shortest time for the rig to come to a stop, (b) the force in the coupling during that time.

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.

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.
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.

13.142 An estimate of the expected load on over-the-shoulder seat belts is to be made before designing prototype belts that will be evaluated in automobile crash tests. Assuming that an automobile traveling at 45 mi/h is brought to a stop in 110 ms, determine (a) the average impulsive force exerted by a 200-lb man on the belt, (b) the maximum force $F_m$ exerted on the belt if the force-time diagram has the shape shown.

![Force-time diagram](image)

13.143 A 46-g golf ball is hit with a golf club and leaves it with a velocity of 50 m/s. We assume that for $0 \leq t \leq t_0$, where $t_0$ is the duration of the impact, the magnitude $F$ of the force exerted on the ball can be expressed as $F = F_m \sin (\pi t/t_0)$. Knowing that $t_0 = 0.5$ ms, determine the maximum value $F_m$ of the force exerted on the ball.

13.144 The design for a new cementless hip implant is to be studied using an instrumented implant and a fixed simulated femur. Assuming the punch applies an average force of 2 kN over a time of 2 ms to the 200 g implant, determine (a) the velocity of the implant immediately after impact, (b) the average resistance of the implant to penetration if the implant moves 1 mm before coming to rest.

13.145 A 20 Mg railroad car moving at 4 km/h is to be coupled to a 40 Mg car which is at rest with locked wheels ($\mu_k = 0.30$). Determine (a) the velocity of both cars after the coupling is completed, (b) the time it takes for both cars to come to rest.

![Railroad cars](image)
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.

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.

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 \( v_0 \).