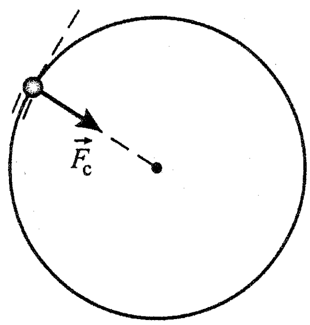
13 •

Determine the Concept The terminal speed of a sky diver is given by $v_t = (mg/b)^{1/n}$, where b depends on the shape and area of the falling object as well as upon the properties of the medium in which the object is falling. The sky diver's orientation as she falls determines the surface area she presents to the air molecules that must be pushed aside. $\boxed{(d) \text{ is correct.}}$

14 ••

Determine the Concept In your frame of reference (the accelerating reference frame of the car), the direction of the force must point toward the center of the circular path along which you are traveling; that is, in the direction of the centripetal force that keeps you moving in a circle. The friction between you and the seat you are sitting on supplies this force. The reason you seem to be "pushed" to the outside of the curve is that your body's inertia "wants" , in accordance with Newton's law of inertia, to keep it moving in a straight line–that is, tangent to the curve.



***15** •

Determine the Concept The centripetal force that keeps the moon in its orbit around the earth is provided by the gravitational force the earth exerts on the moon. As described by Newton's 3rd law, this force is equal in magnitude to the force the moon exerts on the earth. $\boxed{(d) \text{ is correct.}}$

16 •

Determine the Concept The only forces acting on the block are its weight and the force the surface exerts on it. Because the loop-the-loop surface is frictionless, the force it exerts on the block must be perpendicular to its surface.

Point A: the weight is downward and the normal force is to the right. — Free-body diagram 3

Point B: the weight is downward, the normal force is upward, and the normal force is greater than the weight so that their difference is the centripetal force. — Free-body diagram 4

Point C: the weight is downward and the normal force is to the left.

Free-body diagram 5

Point D: both the weight and the normal forces are downward.

Free-body diagram 2

17 ••

Picture the Problem Assume that the drag force on an object is given by the Newtonian formula $F_D = \frac{1}{2}CA\rho v^2$, where A is the projected surface area, v is the object's speed, ρ is the density of air, and C a dimensionless coefficient.

Express the net force acting on the falling object:

$$F_{net} = mg - F_D = ma$$

Substitute for F_D under terminal speed conditions and solve for the terminal speed:

$$mg - \tfrac{1}{2}CA\rho v_T^2 = 0$$

or

$$v_T = \sqrt{\frac{2mg}{CA\rho}}$$

Thus, the terminal velocity depends on the ratio of the mass of the object to its surface area.

For a rock, which has a relatively small surface area compared to its mass, the terminal speed will be relatively high; for a lightweight, spread-out object like a feather, the opposite is true.

Another issue is that the higher the terminal velocity is, the longer it takes for a falling object to reach terminal velocity. From this, the feather will reach its terminal velocity quickly, and fall at an almost constant speed very soon after being dropped; a rock, if not dropped from a great height, will have almost the same acceleration as if it were in free-fall for the duration of its fall, and thus be continually speeding up as it falls.

An interesting point is that the average drag force acting on the rock will be larger than that acting on the feather precisely *because* the rock's average speed is larger than the feather's, as the drag force increases as v^2. This is another reminder that force is not the same thing as acceleration.

The definition of μ_k is:

$$\mu_k = \frac{f_k}{F_n} \qquad (1)$$

Apply $\sum F_y = ma_y$ to the box:

$$F_n - w = ma_y = 0 \text{ because } a_y = 0$$

Solve for F_n:

$$F_n = w = 600 \text{ N}$$

Apply $\sum F_x = ma_x$ to the box:

$$F_{app} - f_k = ma_x$$

or, because $a_x = 0$,

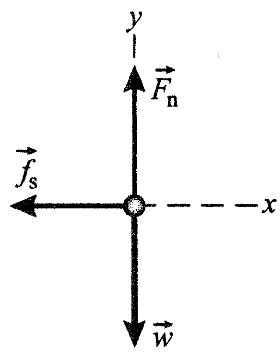
$$F_{app} = f_k = 250\,\text{N}$$

Substitute numerical values in equation (1) and evaluate μ_k:

$$\mu_k = \frac{250\,\text{N}}{600\,\text{N}} = \boxed{0.417}$$

27 •

Picture the Problem Assume that the car is traveling to the right and let the positive *x* direction also be to the right. We can use Newton's 2nd law of motion and the definition of μ_s to determine the maximum acceleration of the car. Once we know the car's maximum acceleration, we can use a constant-acceleration equation to determine the least stopping distance.



(*a*) Apply $\sum F_x = ma_x$ to the car:

$$-f_{s,max} = -\mu_s F_n = ma_x \qquad (1)$$

Apply $\sum F_y = ma_y$ to the car and solve for F_n:

$$F_n - w = ma_y = 0$$

or, because $a_y = 0$,

$$F_n = mg \qquad (2)$$

Substitute (2) in (1) and solve for and evaluate $a_{x,max}$:

$$a_{x,max} = \mu_s g = (0.6)(9.81\,\text{m/s}^2) = \boxed{-5.89\,\text{m/s}^2}$$

(*b*) Using a constant-acceleration equation, relate the stopping distance of the car to its initial velocity and its acceleration and solve for its displacement:

$$v^2 = v_0^2 + 2a\Delta x$$

or, because $v = 0$,

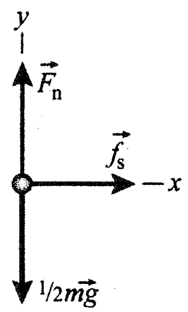
$$\Delta x = \frac{-v_0^2}{2a}$$

Substitute numerical values and evaluate Δx:

$$\Delta x = \frac{-(30\,\text{m/s})^2}{2(-5.89\,\text{m/s}^2)} = \boxed{76.4\,\text{m}}$$

***28 •**

Picture the Problem The free-body diagram shows the forces acting on the drive wheels, the ones we're assuming support half the weight of the car. We can use the definition of acceleration and apply Newton's 2nd law to the horizontal and vertical components of the forces to determine the minimum coefficient of friction between the road and the tires.



(*a*) $\boxed{\text{Because } \mu_s > \mu_k,\ f \text{ will be greater if the wheels do not slip.}}$

(*b*) Apply $\sum F_x = ma_x$ to the car:

$$f_s = \mu_s F_n = ma_x \quad (1)$$

Apply $\sum F_y = ma_y$ to the car and solve for F_n:

$$F_n - \tfrac{1}{2}mg = ma_y$$

or, because $a_y = 0$,

$$F_n = \tfrac{1}{2}mg$$

Substituting for Fn in equation (1) and solving for μ_s yields:

$$\tfrac{1}{2}\mu_s mg = ma_x \text{ or } \mu_s = \frac{2a_x}{g} \quad (2)$$

The acceleration of the car is given by:

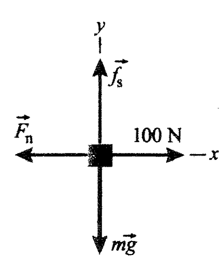
$$a_x = \frac{\Delta v}{\Delta t} = \frac{(90\,\text{km/h})(1000\,\text{m/km})}{12\,\text{s}}$$
$$= 2.08\,\text{m/s}^2$$

Substitute numerical values in equation (2) and evaluate μ_s:

$$\mu_s = \frac{2(2.08\,\text{m/s}^2)}{9.81\,\text{m/s}^2} = \boxed{0.424}$$

29 •

Picture the Problem The block is in equilibrium under the influence of the forces shown on the free-body diagram. We can use Newton's 2nd law and the definition of μ_s to solve for f_s and F_n.

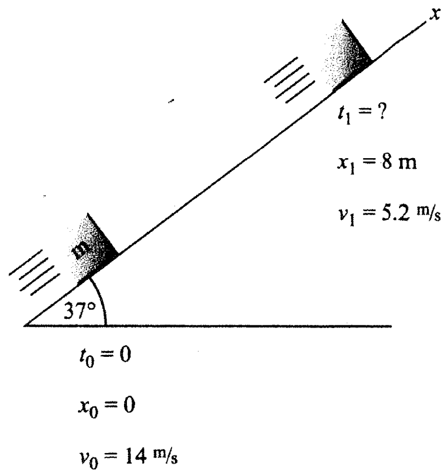


Substitute numerical values and evaluate Δx_{min}:

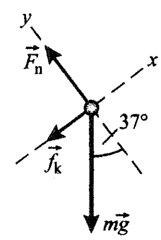
$$\Delta x_{min} = \sqrt{\frac{-(80\,\text{km/h})^2(1000\,\text{km/m})^2(1\,\text{h}/3600\,\text{s})^2}{2(-2.943\,\text{m/s}^2)}} = \boxed{9.16\,\text{m}}$$

39 ••

Picture the Problem We can find the coefficient of friction by applying Newton's 2nd law and determining the acceleration from the given values of displacement and initial velocity. We can find the displacement and speed of the block by using constant-acceleration equations. During its motion up the incline, the sum of the kinetic friction force and a component of the object's weight will combine to bring the object to rest. When it is moving down the incline, the difference between the weight component and the friction force will be the net force.



(*a*) Draw a free-body diagram for the block as it travels up the incline:



Apply $\sum \vec{F} = m\vec{a}$ to the block:

$$\sum F_x = -f_k - mg\sin 37° = ma \quad (1)$$

and

$$\sum F_y = F_n - mg\cos 37° = 0 \quad (2)$$

Substitute $f_k = \mu_k F_n$ and F_n from (2) in (1) and solve for μ_k:

$$\mu_k = \frac{-g\sin 37° - a}{g\cos 37°} = -\tan 37° - \frac{a}{g\cos 37°} \quad (3)$$

Using a constant-acceleration equation, relate the final velocity of the block to its initial velocity, acceleration, and displacement:

$$v_1^2 = v_0^2 + 2a\Delta x$$

Solving for a yields:

$$a = \frac{v_1^2 - v_0^2}{2\Delta x}$$

Substitute numerical values and evaluate a:

$$a = \frac{(5.2\,\text{m/s})^2 - (14\,\text{m/s})^2}{2(8\,\text{m})} = -10.6\,\text{m/s}^2$$

Substitute for a in (3) to obtain:

$$\mu_k = -\tan 37° - \frac{-10.6\,\text{m/s}^2}{(9.81\,\text{m/s}^2)\cos 37°} = \boxed{0.599}$$

(b) Use the same constant-acceleration equation used above but with $v_1 = 0$ to obtain:

$$0 = v_0^2 + 2a\Delta x$$

Solve for Δx to obtain:

$$\Delta x = \frac{-v_0^2}{2a}$$

Substitute numerical values and evaluate Δx:

$$\Delta x = \frac{-(14\,\text{m/s})^2}{2(-10.6\,\text{m/s}^2)} = \boxed{9.25\,\text{m}}$$

(c) When the block slides down the incline, f_k is in the positive x direction:

$$\sum F_x = f_k - mg\sin 37° = ma$$

and

$$\sum F_y = F_n - mg\cos 37° = 0$$

Solve equation (3) for a to obtain:

$$a = g(\mu_k \cos 37° - \sin 37°)$$

Substitute numerical values and evaluate a:

$$a = (9.81\,\text{m/s}^2)[(0.599)\cos 37° - \sin 37°] = -1.21\,\text{m/s}^2$$

Use the same constant-acceleration equation used in part (b) to obtain:

$$v^2 = v_0^2 + 2a\Delta x$$

Set $v_0 = 0$ and solve for v:

$$v = \sqrt{2a\Delta x}$$

Substitute numerical values and evaluate v:

$$v = \sqrt{2(-1.21\,\text{m/s}^2)(-9.25\,\text{m})} = \boxed{4.73\,\text{m/s}}$$

Apply $\sum \vec{F} = m\vec{a}$ to block 2:

$$\sum F_x = m_2 g \sin\theta - T_2 - f_{k,2} = m_2 a$$

and

$$\sum F_y = F_{n,2} - m_2 g \cos\theta = 0$$

Letting $T_1 = T_2 = T$, use the definition of the kinetic friction force to eliminate $f_{k,1}$ and $F_{n,1}$ between the equations for block 1 and $f_{k,2}$ and $F_{n,1}$ between the equations for block 2 to obtain:

$$m_1 a = m_1 g \sin\theta + T - \mu_1 m_1 g \cos\theta \qquad (1)$$

and

$$m_2 a = m_2 g \sin\theta - T - \mu_2 m_2 g \cos\theta \qquad (2)$$

Add equations (1) and (2) to eliminate T and solve for a:

$$a = \boxed{g\left(\sin\theta - \frac{\mu_1 m_1 + \mu_2 m_2}{m_1 + m_2}\cos\theta\right)}$$

(*b*) Rewrite equations (1) and (2) by dividing both sides of (1) by m_1 and both sides of (2) by m_2 to obtain.

$$a = g\sin\theta + \frac{T}{m_1} - \mu_1 g\cos\theta \qquad (3)$$

and

$$a = g\sin\theta - \frac{T}{m_2} - \mu_2 g\cos\theta \qquad (4)$$

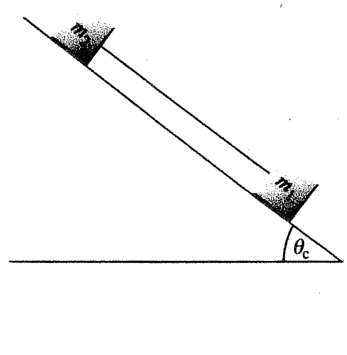
Subtracting (4) from (3) and rearranging yields:

$$T = \boxed{\left(\frac{m_1 m_2}{m_1 - m_2}\right)(\mu_1 - \mu_2) g\cos\theta}$$

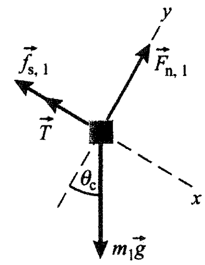
If $\mu_1 = \mu_2, T = 0$ and the blocks move down the incline with the same acceleration of $g(\sin\theta - \mu\cos\theta)$. Inserting a stick between them can't change this; therefore, the stick must exert no force on either block.

45 ••

Picture the Problem The pictorial representation shows the orientation of the two blocks on the inclined surface. Draw the free-body diagrams for each block and apply Newton's 2nd law of motion and the definition of the static friction force to each block to obtain simultaneous equations in θ_c and T.



(*a*) Draw the free-body diagram for the lower block:



Apply $\sum \vec{F} = m\vec{a}$ to the block:

$$\sum F_x = m_1 g \sin\theta_c - f_{s,1} - T = 0 \quad (1)$$

and

$$\sum F_y = F_{n,1} - m_1 g \cos\theta_c = 0 \quad (2)$$

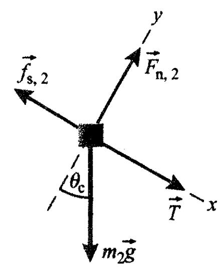
The relationship between $f_{s,1}$ and $F_{n,1}$ is:

$$f_{s,1} = \mu_{s,1} F_{n,1} \quad (3)$$

Eliminate $f_{s,1}$ and $F_{n,1}$ between (1), (2), and (3) to obtain:

$$m_1 g\sin\theta_c - \mu_{s,1} m_1 g\cos\theta_c - T = 0 \quad (4)$$

Draw the free-body diagram for the upper block:



Apply $\sum \vec{F} = m\vec{a}$ to the block:

$$\sum F_x = T + m_2 g \sin\theta_c - f_{s,2} = 0 \quad (5)$$

and

$$\sum F_y = F_{n,2} - m_2 g \cos\theta_c = 0 \quad (6)$$

The relationship between $f_{s,2}$ and $F_{n,2}$ is:

$$f_{s,2} = \mu_{s,2} F_{n,2} \quad (7)$$

Eliminate $f_{s,2}$ and $F_{n,2}$ between (5), (6), and (7) to obtain:

$$T + m_2 g\sin\theta_c - \mu_{s,2} m_2 g\cos\theta_c = 0 \quad (8)$$

Add equations (4) and (8) to eliminate T and solve for θ_c:

$$\theta_c = \tan^{-1}\left[\frac{\mu_{s,1} m_1 + \mu_{s,2} m_2}{m_1 + m_2}\right]$$

Substitute numerical values and evaluate θ_c:

$$\theta_c = \tan^{-1}\left[\frac{(0.4)(0.2\,\text{kg}) + (0.6)(0.1\,\text{kg})}{0.1\,\text{kg} + 0.2\,\text{kg}}\right]$$

$$= \boxed{25.0°}$$

(*b*) Because θ_c is greater than the angle of repose $(\tan^{-1}(\mu_{s,1}) = \tan^{-1}(0.4) = 21.8°)$ for the lower block, it would slide if $T = 0$. Solve equation (4) for T:

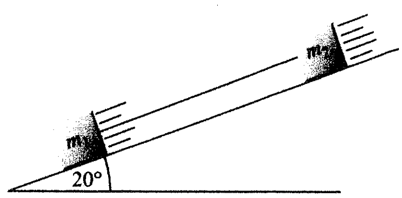
$$T = m_1 g(\sin\theta_C - \mu_{s,1}\cos\theta_C)$$

Substitute numerical values and evaluate T:

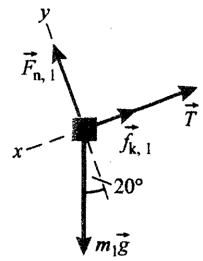
$$T = (0.2\,\text{kg})(9.81\,\text{m/s}^2)[\sin 25° - (0.4)\cos 25°] = \boxed{0.118\,\text{N}}$$

46 ••

Picture the Problem The pictorial representation shows the orientation of the two blocks with a common acceleration on the inclined surface. Draw the free-body diagrams for each block and apply Newton's 2nd law and the definition of the kinetic friction force to each block to obtain simultaneous equations in a and T.



(*a*) Draw the free-body diagram for the lower block:



Apply $\sum \vec{F} = m\vec{a}$ to the lower block:

$$\sum F_x = m_1 g\sin 20° - f_{k,1} - T = m_1 a \quad (1)$$

and

$$\sum F_y = F_{n,1} - m_1 g\cos 20° = 0 \quad (2)$$

Express the relationship between $f_{k,1}$ and $F_{n,1}$:

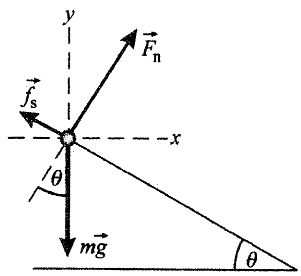
$$f_{k,1} = \mu_{k,1} F_{n,1} \quad (3)$$

Eliminate $f_{k,1}$ and $F_{n,1}$ between (1), (2), and (3) to obtain:

$$m_1 g\sin 20° - \mu_{k,1} m_1 g\cos 20° - T = m_1 a \quad (4)$$

59 •••

Picture the Problem The free-body diagram shows the forces acting on the 0.5 kg block when the acceleration is a minimum. Note the choice of coordinate system is consistent with the direction of $\vec{F}$. Apply Newton's 2nd law to the block and solve the resulting equations for a_{min} and a_{max}.



(*a*) Apply $\sum \vec{F} = m\vec{a}$ to the 0.5-kg block:

$$\sum F_x = F_n \sin\theta - f_s \cos\theta = ma \quad (1)$$

and

$$\sum F_y = F_n \cos\theta + f_s \sin\theta - mg = 0 \quad (2)$$

Under minimum acceleration, $f_s = f_{s,max}$. Express the relationship between $f_{s,max}$ and F_n:

$$f_{s,max} = \mu_s F_n \quad (3)$$

Substitute $f_{s,max}$ for f_s in equation (2) and solve for F_n:

$$F_n = \frac{mg}{\cos\theta + \mu_s \sin\theta}$$

Substitute for F_n in equation (1) and solve for $a = a_{min}$:

$$a_{min} = g\frac{\sin\theta - \mu_s \cos\theta}{\cos\theta + \mu_s \sin\theta}$$

Substitute numerical values and evaluate a_{min}:

$$a_{min} = \left(9.81\,\text{m/s}^2\right)\frac{\sin35° - (0.8)\cos35°}{\cos35° + (0.8)\sin35°} = -0.627\,\text{m/s}^2$$

Treat the block and incline as a single object to determine F_{min}:

$$F_{min} = m_{tot}a_{min} = (2.5\text{ kg})(-0.627\text{ m/s}^2) = \boxed{-1.57\,\text{N}}$$

To find the maximum acceleration, reverse the direction of $\vec{f}_s$ and apply $\sum \vec{F} = m\vec{a}$ to the block:

$$\sum F_x = F_n \sin\theta + f_s \cos\theta = ma \quad (4)$$

and

$$\sum F_y = F_n \cos\theta - f_s \sin\theta - mg = 0 \quad (5)$$

Proceed as above to obtain:

$$a_{max} = g\frac{\sin\theta + \mu_s \cos\theta}{\cos\theta - \mu_s \sin\theta}$$

Substitute numerical values and evaluate a_{max}:

$$a_{max} = (9.81\,\text{m/s}^2)\frac{\sin 35° + (0.8)\cos 35°}{\cos 35° - (0.8)\sin 35°} = 33.5\,\text{m/s}^2$$

Treat the block and incline as a single object to determine F_{max}:

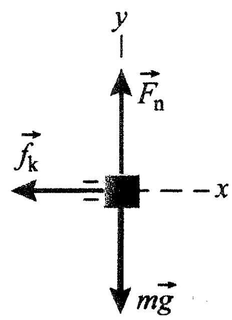
$$F_{max} = m_{tot}a_{max} = (2.5\text{ kg})(33.5\text{ m/s}^2) = \boxed{83.8\,\text{N}}$$

(*b*) Repeat (*a*) with $\mu_s = 0.4$ to obtain:

$$F_{min} = \boxed{5.75\,\text{N}} \text{ and } F_{max} = \boxed{37.5\,\text{N}}$$

60 •

Picture the Problem The kinetic friction force f_k is the product of the coefficient of sliding friction μ_k and the normal force F_n the surface exerts on the sliding object. By applying Newton's 2nd law in the vertical direction, we can see that, on a horizontal surface, the normal force is the weight of the sliding object. Note that the acceleration of the block is opposite its direction of motion.



(*a*) Relate the force of kinetic friction to μ_k and the normal force acting on the sliding wooden object:

$$f_k = \mu_k F_n = \frac{0.11}{(1 + 2.3\times10^{-4}v^2)^2}mg$$

Substitute $v = 10$ m/s and evaluate f_k:

$$f_k = \frac{0.11(100\,\text{kg})(9.81\,\text{m/s}^2)}{(1 + 2.3\times10^{-4}(10\,\text{m/s})^2)^2} = \boxed{103\,\text{N}}$$

(*b*) Substitute $v = 20$ m/s and evaluate f_k:

$$f_k = \frac{0.11(100\,\text{kg})(9.81\,\text{m/s}^2)}{(1 + 2.3\times10^{-4}(20\,\text{m/s})^2)^2} = \boxed{90.5\,\text{N}}$$

61 ••

Picture the Problem The pictorial representation shows the block sliding from left to right and coming to rest when it has traveled a distance Δx. Note that the direction of the motion is opposite that of the block's acceleration. The acceleration and stopping distance of the blocks can be found from constant-acceleration equations. Let the direction of motion of the sliding blocks be the positive x direction. Because the surface is horizontal, the normal force acting on the sliding block is the block's weight.

Use the right triangle in the diagram to relate r, L, and θ:

$$r = L\cos\theta \qquad (3)$$

Eliminate T and r between equations (1), (2), and (3) and solve for v:

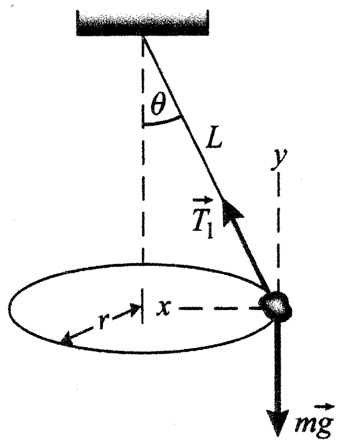
$$v = \sqrt{gL\cot\theta\cos\theta}$$

Substitute numerical values and evaluate v:

$$v = \sqrt{(9.81\,\text{m/s}^2)(0.8\,\text{m})\cot 20°\cos 20°} = \boxed{4.50\,\text{m/s}}$$

67 •

Picture the Problem The free-body diagram showing the forces acting on the stone is superimposed on a sketch of the stone rotating in a horizontal circle. The only forces acting on the stone are the tension in the string and the gravitational force. The centripetal force required to maintain the circular motion is a component of the tension. We'll solve the problem for the general case in which the angle with the vertical is θ by applying Newton's 2nd law of motion to the forces acting on the stone.



(*a*) Apply $\sum\vec{F} = m\vec{a}$ to the stone:

$$\sum F_x = T\sin\theta = ma_c = m\frac{v^2}{r} \qquad (1)$$

and

$$\sum F_y = T\cos\theta - mg = 0 \qquad (2)$$

Eliminate T between equations (1) and (2) and solve for v:

$$v = \sqrt{rg\tan\theta}$$

Substitute numerical values and evaluate v:

$$v = \sqrt{(0.35\,\text{m})(9.81\,\text{m/s}^2)\tan 30°} = \boxed{1.41\,\text{m/s}}$$

(*b*) Solve equation (2) for T:

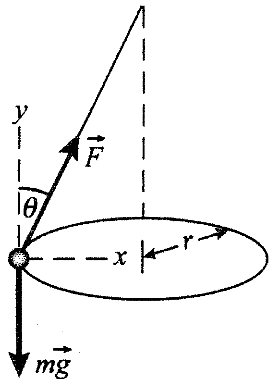
$$T = \frac{mg}{\cos\theta}$$

Substitute numerical values and evaluate T:

$$T = \frac{(0.75\,\text{kg})(9.81\,\text{m/s}^2)}{\cos 30°} = \boxed{8.50\,\text{N}}$$

73 ••

Picture the Problem The diagram to the right has the free-body diagram for the child superimposed on a pictorial representation of her motion. The force her father exerts is $\vec{F}$ and the angle it makes with respect to the direction we've chosen as the positive y direction is θ. We can infer her speed from the given information concerning the radius of her path and the period of her motion. Applying Newton's 2nd law will allow us to find both the direction and magnitude of $\vec{F}$.



Apply $\sum \vec{F} = m\vec{a}$ to the child:

$$\sum F_x = F\sin\theta = m\frac{v^2}{r}$$

and

$$\sum F_y = F\cos\theta - mg = 0$$

Eliminate F between these equations and solve for θ to obtain:

$$\theta = \tan^{-1}\left[\frac{v^2}{rg}\right]$$

Express v in terms of the radius and period of the child's motion:

$$v = \frac{2\pi r}{T}$$

Substitute for v in the expression for θ to obtain:

$$\theta = \tan^{-1}\left[\frac{4\pi^2 r}{gT^2}\right]$$

Substitute numerical values and evaluate θ:

$$\theta = \tan^{-1}\left[\frac{4\pi^2(0.75\,\text{m})}{(9.81\,\text{m/s}^2)(1.5\,\text{s})^2}\right] = \boxed{53.3°}$$

Solve the y equation for F:

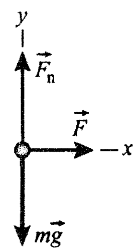
$$F = \frac{mg}{\cos\theta}$$

Substitute numerical values and evaluate F:

$$F = \frac{(25\,\text{kg})(9.81\,\text{m/s}^2)}{\cos 53.3°} = \boxed{410\,\text{N}}$$

84 •

Picture the Problem The force F the passenger exerts on the armrest of the car door is the radial force required to maintain the passenger's speed around the curve and is related to that speed through Newton's 2nd law of motion.



Apply $\sum F_x = ma_x$ to the forces acting on the passenger:

$$F = m\frac{v^2}{r}$$

Solve this equation for v:

$$v = \sqrt{\frac{rF}{m}}$$

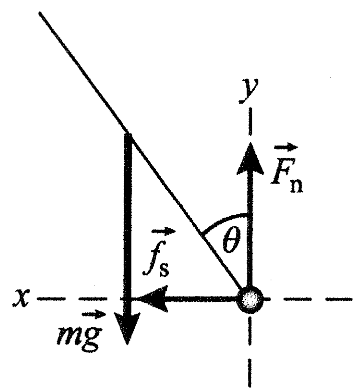
Substitute numerical values and evaluate v:

$$v = \sqrt{\frac{(80\,\text{m})(220\,\text{N})}{70\,\text{kg}}} = 15.9\,\text{m/s}$$

and $\boxed{(a)\text{ is correct.}}$

***85** •••

Picture the Problem The forces acting on the bicycle are shown in the force diagram. The static friction force is the centripetal force exerted by the surface on the bicycle that allows it to move in a circular path. $\vec{F}_n + \vec{f}_s$ makes an angle θ with the vertical direction. The application of Newton's 2nd law will allow us to relate this angle to the speed of the bicycle and the coefficient of static friction.



(a) Apply $\sum \vec{F} = m\vec{a}$ to the bicycle:

$$\sum F_x = f_s = \frac{mv^2}{r}$$

and

$$\sum F_y = F_n - mg = 0$$

Relate F_n and f_s to θ:

$$\tan\theta = \frac{f_s}{F_n} = \frac{\frac{mv^2}{r}}{mg} = \frac{v^2}{rg}$$

Solve for v: $v = \sqrt{rg\tan\theta}$

Substitute numerical values and evaluate v:

$$v = \sqrt{(20\,\text{m})(9.81\,\text{m/s}^2)\tan 15°} = \boxed{7.25\,\text{m/s}}$$

(*b*) Relate f_s to μ_s and F_n: $f_s = \frac{1}{2} f_{s,\max} = \frac{1}{2}\mu_s mg$

Solve for μ_s and substitute for f_s to obtain:

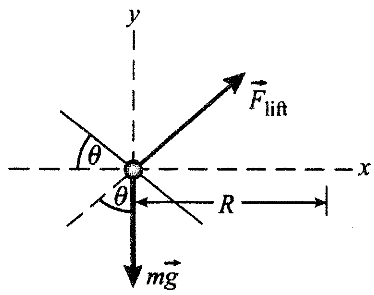
$$\mu_s = \frac{2f_s}{mg} = \frac{2v^2}{rg}$$

Substitute numerical values and evaluate μ_s

$$\mu_s = \frac{2(7.25\,\text{m/s})^2}{(20\,\text{m})(9.81\,\text{m/s}^2)} = \boxed{0.536}$$

86 ••

Picture the Problem The diagram shows the forces acting on the plane as it flies in a horizontal circle of radius R. We can apply Newton's 2[nd] law to the plane and eliminate the lift force in order to obtain an expression for R as a function of v and θ.



Apply $\sum \vec{F} = m\vec{a}$ to the plane:

$$\sum F_x = F_{\text{lift}}\sin\theta = m\frac{v^2}{R}$$

and

$$\sum F_y = F_{\text{lift}}\cos\theta - mg = 0$$

Eliminate F_{lift} between these equations to obtain:

$$\tan\theta = \frac{v^2}{Rg}$$

Solve for R:

$$R = \frac{v^2}{g\tan\theta}$$

Substitute numerical values and evaluate R:

$$R = \frac{\left(480\frac{\text{km}}{\text{h}} \times \frac{1\,\text{h}}{3600\,\text{s}}\right)^2}{(9.81\,\text{m/s}^2)\tan 40°} = \boxed{2.16\,\text{km}}$$

Substitute numerical values and evaluate v_{max}:

$$v_{max} = \sqrt{(0.8243)(30\,\text{m})(9.81\,\text{m/s}^2)} = \boxed{15.6\,\text{m/s} = 56.1\,\text{km/h}}$$

Drag Forces

92 •

Picture the Problem We can apply Newton's 2nd law to the particle to obtain its equation of motion. Applying terminal speed conditions will yield an expression for b that we can evaluate using the given numerical values.

Apply $\sum F_y = ma_y$ to the particle:

$$mg - bv = ma_y$$

When the particle reaches its terminal speed $v = v_t$ and $a_y = 0$:

$$mg - bv_t = 0$$

Solve for b to obtain:

$$b = \frac{mg}{v_t}$$

Substitute numerical values and evaluate b:

$$b = \frac{(10^{-13}\,\text{kg})(9.81\,\text{m/s}^2)}{3\times10^{-4}\,\text{m/s}} = \boxed{3.27\times10^{-9}\,\text{kg/s}}$$

93 •

Picture the Problem We can apply Newton's 2nd law to the Ping-Pong ball to obtain its equation of motion. Applying terminal speed conditions will yield an expression for b that we can evaluate using the given numerical values.

Apply $\sum F_y = ma_y$ to the Ping-Pong ball:

$$mg - bv^2 = ma_y$$

When the Ping-Pong ball reaches its terminal speed $v = v_t$ and $a_y = 0$:

$$mg - bv_t^2 = 0$$

Solve for b to obtain:

$$b = \frac{mg}{v_t^2}$$

Substitute numerical values and evaluate b:

$$b = \frac{(2.3\times10^{-3}\,\text{kg})(9.81\,\text{m/s}^2)}{(9\,\text{m/s})^2} = \boxed{2.79\times10^{-4}\,\text{kg/m}}$$

***94** •

Picture the Problem Let the upward direction be the positive y direction and apply Newton's 2nd law to the sky diver.

(*a*) Apply $\sum F_y = ma_y$ to the sky diver:

$F_d - mg = ma_y$

or, because $a_y = 0$,

$$F_d = mg \qquad (1)$$

Substitute numerical values and evaluate F_d:

$$F_d = (60\,\text{kg})(9.81\,\text{m/s}^2) = \boxed{589\,\text{N}}$$

(*b*) Substitute $F_d = b v_t^2$ in equation (1) to obtain:

$$bv_t^2 = mg$$

Solve for b:

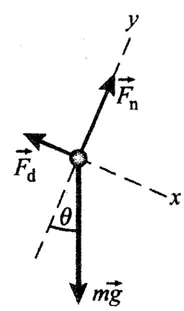
$$b = \frac{mg}{v_t^2} = \frac{F_d}{v_t^2}$$

Substitute numerical values and evaluate b:

$$b = \frac{589\,\text{N}}{(25\,\text{m/s})^2} = \boxed{0.942\,\text{kg/m}}$$

95 ••

Picture the Problem The free-body diagram shows the forces acting on the car as it descends the grade with its terminal velocity. The application of Newton's 2nd law with $a = 0$ and F_d equal to the given function will allow us to solve for the terminal velocity of the car.



Apply $\sum F_x = ma_x$ to the car:

$mg\sin\theta - F_d = ma_x$

or, because $v = v_t$ and $a_x = 0$,

$$mg\sin\theta - F_d = 0$$

Substitute for F_d to obtain:

$$mg\sin\theta - 100\,\text{N} - (1.2\,\text{N}\cdot\text{s}^2/\text{m}^2)v_t^2 = 0$$