Understanding Concepts

1. Why must an object at rest have either no force or a minimum of two forces acting on it?

2. Whiplash injuries are common in automobile accidents where the victim’s car is struck from behind. Explain how such accidents illustrate Newton’s laws of motion, and how the laws can be applied in the development of safer car seat designs.

3. If you get to your feet in a canoe and move toward the front, the canoe moves in the opposite direction. Explain why.

4. How would you determine the mass of an object in interstellar space, where the force of gravity approaches zero?

5. In a disaster film, an elevator full of people falls freely when the cable snaps. The film depicts the people pressed upward against the ceiling. Is this good physics? Why or why not?

6. In the amusement park ride in Figure 1, cars and passengers slide down the incline before going around vertical loops. The incline is at an angle of 36° to the horizontal. If friction is negligible, what is the magnitude of the acceleration of the cars down the incline?

7. Two veggieburger patties, in contact with each other, are being pushed across a grill. The masses of the burgers are 113 g and 139 g. Friction is negligible. The applied horizontal force of magnitude $5.38 \times 10^{-2}$ N is exerted on the more massive burger. Determine (a) the magnitude of the acceleration of the two-burger system, and (b) the magnitude of the force exerted by each of the two burgers on the other.

8. Three blocks, of masses $m_1 = 26$ kg, $m_2 = 38$ kg, and $m_3 = 41$ kg, are connected by two strings over two pulleys, as in Figure 2. Friction is negligible. Determine (a) the magnitude of the acceleration of the blocks, and (b) the magnitude of the tension in each of the two strings.

9. A mountain climber of mass 67.5 kg is using a rope to hang horizontally against a vertical cliff, as in Figure 3. The tension in the rope is 729 N [27.0° below the horizontal]. Determine the force exerted by the cliff on the climber’s feet.

10. A child is pulling a wagon of mass 7.38 kg up a hill inclined at an angle of 14.3° to the horizontal. The child applies a force parallel to the hill. The acceleration of the wagon is 6.45 cm/s² up the hill. Friction is negligible. Determine the magnitude of (a) the force applied by the child, and (b) the normal force on the wagon.

11. Which is more likely to break when loaded with wet laundry—a clothesline with a significant sag, or a clothesline with almost no sag? Use diagrams to explain why.

12. In most sports, athletic shoes should have a high coefficient of friction, so that the person wearing the shoe can stop and turn quickly. In which sports would this be a disadvantage?
13. Why do people take very short steps on slippery surfaces?

14. A student is pushing horizontally on a table \( (m = 16 \, \text{kg}) \) to move it across a horizontal floor. The coefficient of kinetic friction between the table and the floor is 0.61.
   (a) Determine the magnitude of the applied force needed to keep the table moving at constant velocity.
   (b) If the applied force were 109 N and the table were to start from rest, how long would the table take to travel 75 cm?

15. A rope exerts a force of magnitude 21 N, at an angle 31° above the horizontal, on a box at rest on a horizontal floor. The coefficients of friction between the box and the floor are \( \mu_s = 0.55 \) and \( \mu_k = 0.50 \). The box remains at rest. Determine the smallest possible mass of the box.

16. A skier on a slope inclined at 4.7° to the horizontal pushes on ski poles and starts down the slope. The initial speed is 2.7 m/s. The coefficient of kinetic friction between skis and snow is 0.11. Determine how far the skier will slide before coming to rest.

17. A passenger is standing without slipping in a forward-accelerating train. The coefficient of static friction between feet and floor is 0.47.
   (a) Draw an FBD for the passenger in Earth’s frame of reference.
   (b) Draw an FBD for the passenger in the train’s frame of reference.
   (c) Determine the maximum required acceleration of the train relative to the track if the passenger is not to slip.

18. You throw a baseball eastward. The ball has a fast clockwise spin when viewed from above. In which direction does the ball tend to swerve? Show your reasoning.

19. It takes 30.0 s to fill a 2.00-L container with water from a hose with constant radius 1.00 cm. The hose is held horizontally. Determine the speed of the water being ejected from the hose.

### Applying Inquiry Skills

20. A varying net force is applied to a loaded wagon. Table 1 gives the resulting accelerations. Plot a graph of the data. Use the information on the graph to determine the mass of the wagon.

<table>
<thead>
<tr>
<th>Net Force (N [fwd])</th>
<th>0</th>
<th>10.0</th>
<th>20.0</th>
<th>30.0</th>
<th>40.0</th>
<th>50.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration (m/s² [fwd])</td>
<td>0</td>
<td>0.370</td>
<td>0.741</td>
<td>1.11</td>
<td>1.48</td>
<td>1.85</td>
</tr>
</tbody>
</table>

21. The apparatus in Figure 4 determines the coefficient of static friction between two surfaces. The force sensor measures the minimum horizontal force, \( F_{\text{app}} \), needed to prevent the object from sliding down the vertical slope.
   (a) Draw an FBD of the object against the wall. Use this FBD to derive an expression for the coefficient of static friction in terms of \( m, g \), and \( F_{\text{app}} \).
   (b) Design and carry out an investigation to determine the coefficient of static friction between two appropriate surfaces. Use the technique sketched in Figure 4 and two other techniques. Compare the results, describing the advantages and disadvantages of each technique.

![Figure 4](block-force-sensor-wall.png)

22. Obtain a piece of paper about 10 cm by 20 cm and fold it into the shape of an airplane wing, as in Figure 5(a). Tape the ends together. Hold the middle of the wing with a pencil, as in Figure 5(b), blowing across the wing as indicated. Repeat the procedure for the situation shown in Figure 5(c). Explain what you observe.

### Making Connections

23. High-speed movies reveal that the time interval during which a golf club is in contact with a golf ball is typically 1.0 ms, and that the speed of the ball when it leaves the club is about 65 m/s. The mass of a golf ball is 45 g.
(a) Determine the magnitude of the average force exerted by the club on the ball. (For this calculation, you can neglect the force of gravity.)
(b) Why is it reasonable to neglect the force of gravity in calculating the average force exerted by the club?
(c) What does the term “high-speed movies” mean?

Extension
24. You are a gymnast of mass 72 kg, initially hanging at rest from a bar. You let go of the bar and fall vertically 92 cm to the floor below. Upon landing, you bend your knees, bringing yourself to rest over a distance of 35 cm. The floor exerts a constant force on your body as you slow down. Determine (a) your speed at impact, and (b) the magnitude of the force the floor exerts on you as you slow down.

25. A box of mass \( m = 22 \) kg is at rest on a ramp inclined at 45° to the horizontal. The coefficients of friction between the box and the ramp are \( \mu_s = 0.78 \) and \( \mu_k = 0.65 \).
(a) Determine the magnitude of the largest force that can be applied upward, parallel to the ramp, if the box is to remain at rest.
(b) Determine the magnitude of the smallest force that can be applied onto the top of the box, perpendicular to the ramp, if the box is to remain at rest.

26. In the oscilloscope shown in Figure 6, an electron beam is deflected by an electric force produced by charged metal plates AD and BC. In the region ABCD, each electron experiences a uniform downward electric force of \( 3.20 \times 10^{-15} \) N. Each electron enters the electric field along the illustrated axis, halfway between A and B, with a velocity of \( 2.25 \times 10^7 \) m/s parallel to the plates. The electric force is zero outside ABCD. The mass of an electron is \( 9.11 \times 10^{-31} \) kg. The gravitational force can be neglected during the short time interval an electron travels to the fluorescent screen, S. Determine how far an electron is below the axis of entry when it hits the screen.

27. Tarzan \( (m = 100 \) kg) holds one end of an ideal vine (infinitely strong, completely flexible, but having zero mass). The vine runs horizontally to the edge of a cliff, then vertically to where Jane \( (m = 50 \) kg) is hanging on, above a river filled with hungry crocodiles. A sudden sleet storm has removed all friction. Assuming that Tarzan hangs on, what is his acceleration toward the cliff edge?

28. Two blocks are in contact on a frictionless table. A horizontal force is applied to one block as shown in Figure 7. If \( m_1 = 2.0 \) kg, \( m_2 = 1.0 \) kg, and \( |\vec{F}| = 3.0 \) N, find the force of contact between the two blocks.

29. A 2.0-kg chicken rests at point C on a slack clothesline ACB as shown in Figure 8. C represents chicken, not centre—real problems don’t have to be symmetrical, you know! CA and CB slope up from the horizontal at 30° and 45°, respectively. What minimum breaking strength must the line have to ensure the continuing support of the bird?