Unit 1

Chapter 6: Newton’s Second Law of Motion-Force and Acceleration

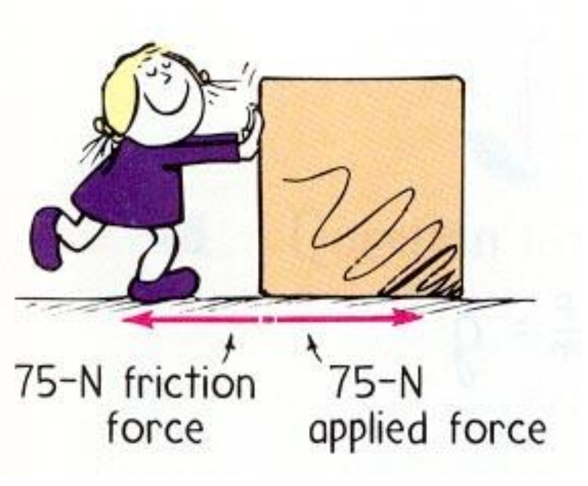
THE BIG IDEA

An object accelerates when a net force acts on it.

I. Force Causes Acceleration (6.1)

A. **Force** causes **acceleration**

1. Acceleration depends on **net force**
2. Objects acceleration is **directly proportional** to the net force acting on it.



acceleration α net force

(the symbol **α** stands for "is directly proportional to.")

II. Mass Resists Acceleration (6.2)

A. **Acceleration** depends on **mass**

1. **acceleration** produced is **inversely proportional** to the **mass**.

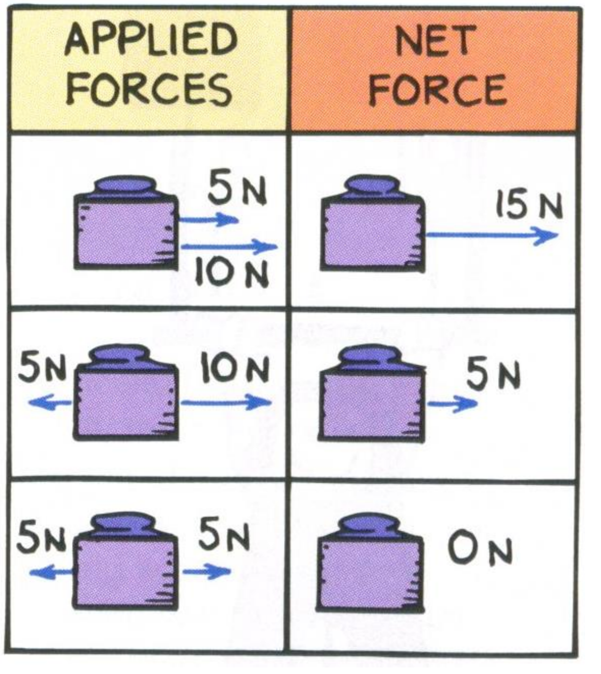
$$acceleration = \frac{1}{mass}$$

2. **Inversely**– means that the two values change in <u>opposite</u> directions

III. Newton's Second Law (6.3)

A. **Newton's Second Law** states:

The **acceleration** produced by a **net force** on an object is directly proportional to the **magnitude of the net force**, is in the same direction as the net force, and is inversely proportional to the **mass** of the object



In equation form:

$$\textbf{\textit{acceleration}} \; \alpha \; \frac{\textbf{\textit{net force}}}{\textbf{\textit{mass}}}$$

1. Using units of **newtons** (N) for force, **kilograms** for mass (kg), and **meters per second squared** (m/s^2) for acceleration, we get the new equation

$$\textbf{acceleration} = \frac{\textbf{net force}}{\textbf{mass}}$$

2. If we let **a** = acceleration, **F** = force, and **m** = mass:

$$a = \frac{F}{m}$$

6.3 Newton’s Second Law

think!

If a car can accelerate at 2 m/s^2, what acceleration can it attain if it is towing another car of equal mass?

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If a car can accelerate at 2 m/s^2, what acceleration can it attain if it is towing another car of equal mass?

Answer: The same force on twice the mass produces half the acceleration, or 1 m/s^2.

6.3 Newton's Second Law

do the math!

A car has a mass of 1000 kg. What is the acceleration produced by a force of 2000 N?

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$$a = \frac{F}{m} = \frac{2000\ \text{N}}{1000\ \text{kg}} = \frac{2000\ \text{kg}\cdot\text{m/s}^2}{1000\ \text{kg}} = 2\ \text{m/s}^2$$

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do the math!

If the force is 4000 N, what is the acceleration?

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$$a = \frac{F}{m} = \frac{4000\ \text{N}}{1000\ \text{kg}} = \frac{4000\ \text{kg·m/s}^2}{1000\ \text{kg}} = 4\ \text{m/s}^2$$

Doubling the force on the same mass simply doubles the acceleration.

6.3 Newton's Second Law

do the math!

How much force, or thrust, must a 30,000-kg jet plane develop to achieve an acceleration of 1.5 m/s^2?

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Arrange Newton's second law to read:

$$\text{force} = \text{mass} \times \text{acceleration}$$

$$F = ma$$

$$= (30{,}000\ \text{kg})(1.5\ \text{m/s}^2)$$

$$= 45{,}000\ \text{kg}\bullet\text{m/s}^2$$

$$= 45{,}000\ \text{N}$$

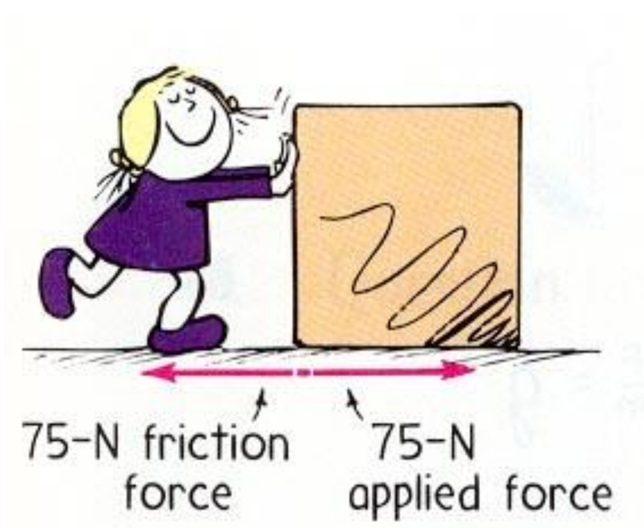
IV. Friction (6.4)

A. Friction is a force

1. Acts on materials that are in **contact** with each other

2. **friction** acts in opposite direction to oppose motion

3. friction mainly due to **irregularities** in the two surfaces.



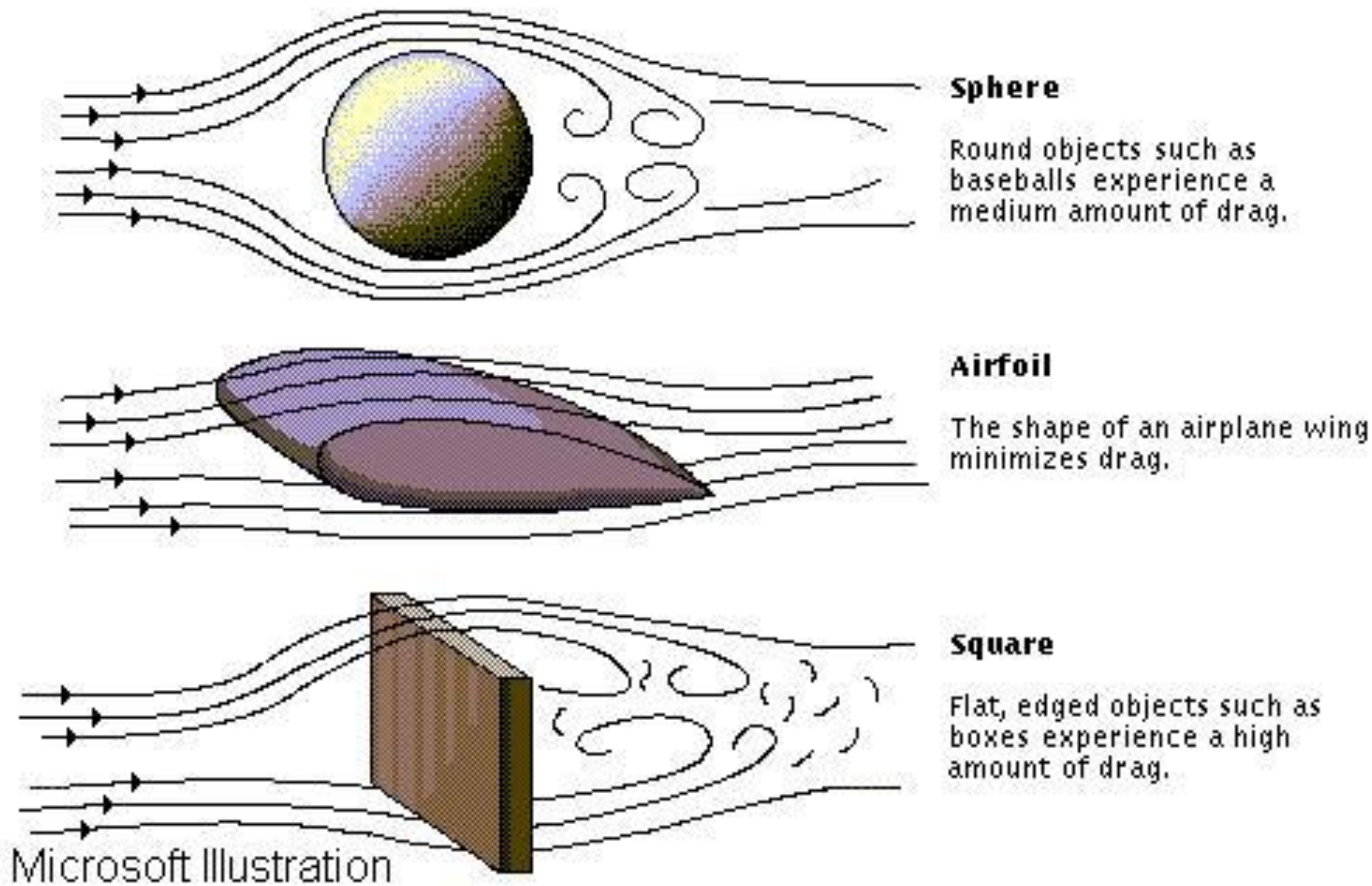
B. Friction <u>not</u> restricted to solids sliding over one another

1. Occurs in **liquids** and **gases**

    a. both called **fluids**

    b. Friction of liquids appreciable even at low speeds.

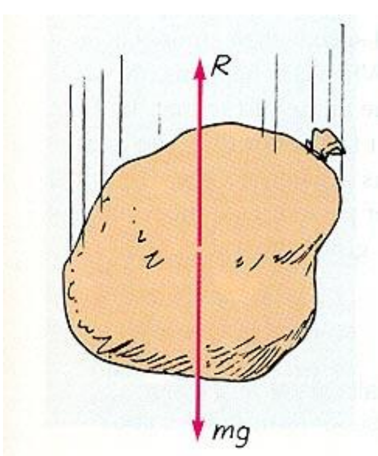
2.**Air resistance** (friction acting on something moving through air) is common form of fluid friction

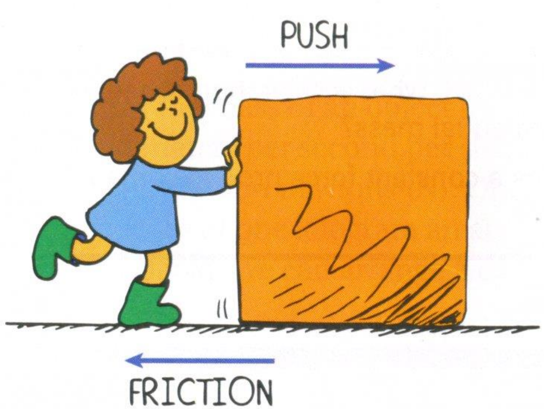


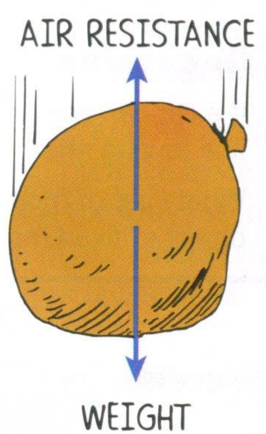
3. When **friction is present**, an object may move with a **constant velocity** even when outside force is applied to it.

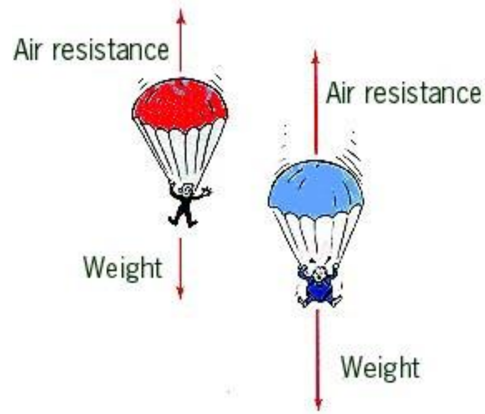
a. In such case, friction force **balances** applied force

b. Can diagram using a **free-body diagram**









6.4 Friction

think!

Two forces act on a book resting on a table: its weight and the support force from the table. Does a force of friction act as well?

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think!

Two forces act on a book resting on a table: its weight and the support force from the table. Does a force of friction act as well?

Answer: No, not unless the book tends to slide or does slide across the table. Friction forces occur only when an object tends to slide or is sliding.

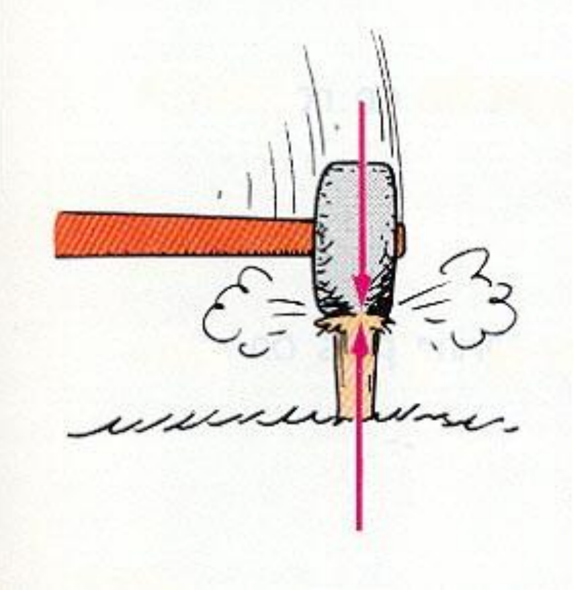
V. Applying force– Pressure (6.5)

A. **Pressure**– amount of force per unit area

B. In equation form:

$$\textit{pressure} = \frac{\textit{force}}{\textit{area of application}}$$

(Pressure is measured in Newton's per square meter, or **pascals**)



$$P = \frac{F}{A}$$

6.5 Applying Force-Pressure

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In attempting to do the bed-of-nails demonstration, would it be wise to begin with a few nails and work upward to more nails?

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think!

In attempting to do the bed-of-nails demonstration, would it be wise to begin with a few nails and work upward to more nails?

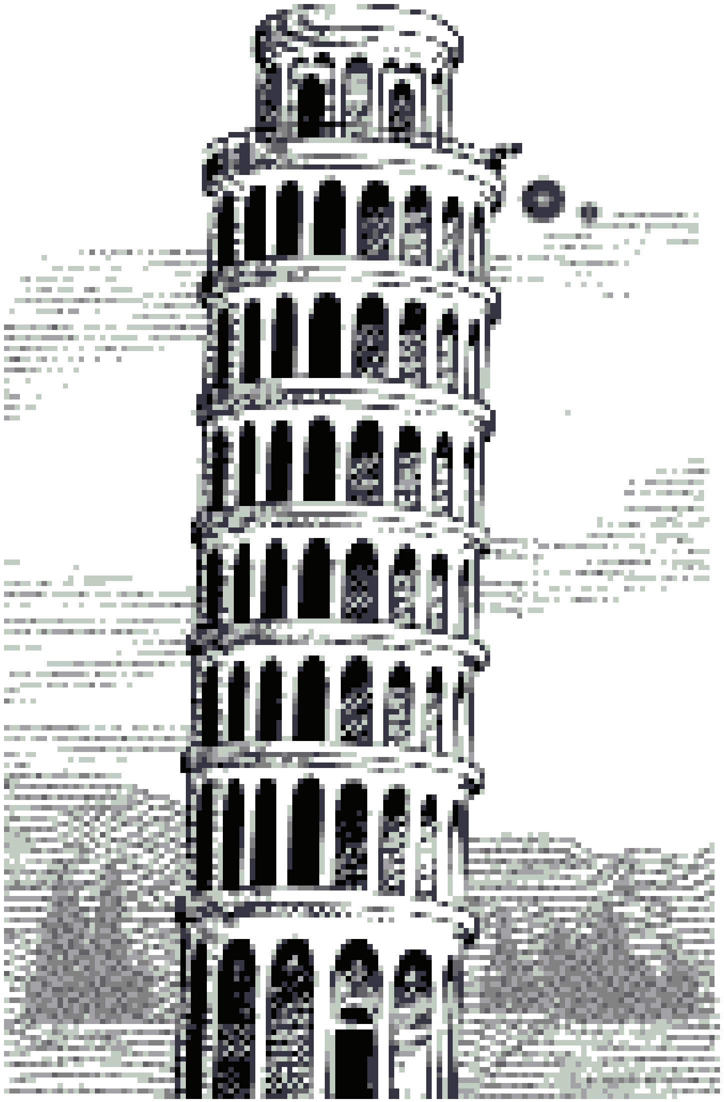
Answer: No, no, no! There would be one less physics teacher if the demonstration were performed with fewer nails. The resulting greater pressure would cause harm.

VI. Free Fall Explained (6.6)

A. Galileo showed falling objects accelerate equally, regardless of their masses

1. strictly true if air resistance is negligible

2. approximately true when air resistance is very small



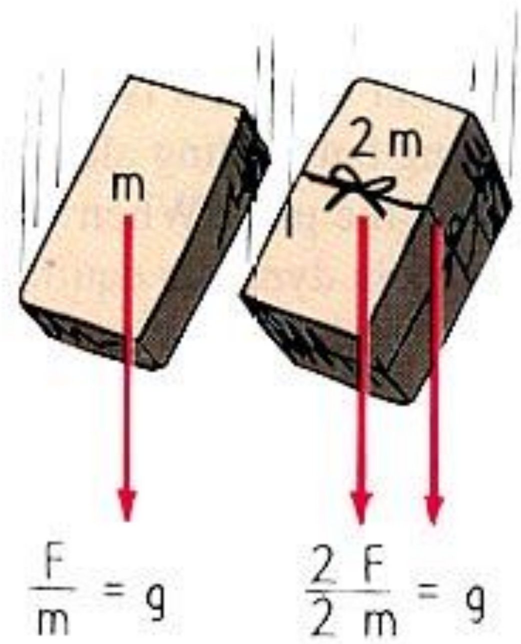
B. **Aristotle** believed that an object weighing tens times as much would fall ten times faster (disproved by Galileo and others

Galileo's famous demonstration at Leaning Tower of Pisa)

C. Use equation for **weight (force of gravity)**:

$$F_g = mg \quad \text{or} \quad F_g = ma$$

Rearrange and get $$a = \frac{F_g}{m}$$

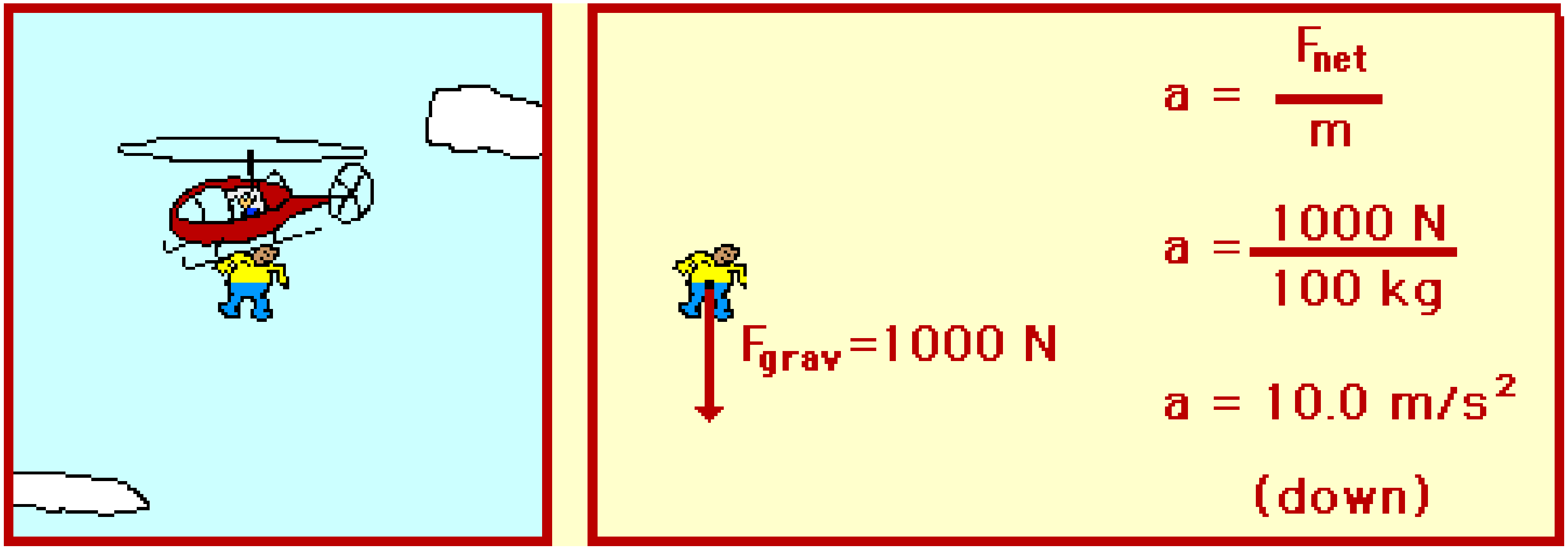


(when mass is also considered, the acceleration of any object is the same)

VII. Falling and Air Resistance (6.7)

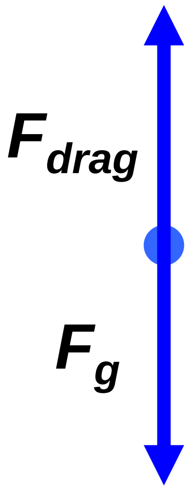
A. Air resistance decreases the net forces acting on a falling object

1. When air resistance equals downward force on falling object (force of gravity–also called **weight**) then net force is **zero** and no further acceleration occurs.



2. **terminal speed**– when acceleration terminates

3. When consider direction (which is down for falling objects) we call this maximum speed **terminal velocity**



B. Air resistance is often negligible at low speeds, but very noticeable at high speeds

6.7 Falling and Air Resistance

think!

Which experiences a greater air resistance force, a falling piece of paper or a falling elephant?

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Answer: The elephant! It has a greater frontal area and falls faster than a piece of paper—both of which mean the elephant pushes more air molecules out of the way. The *effect* of the air resistance force on each, however, is another story!

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If a heavy person and a light person open their parachutes together at the same altitude and each wears the same size parachute, who will reach the ground first?

Answer: The heavy person will reach the ground first. Like a feather, the light person reaches terminal speed sooner, while the heavy person continues to accelerate until a greater terminal speed is reached.

Assessment Questions

1. An object will accelerate when
    a. S*F* = 0.
    b. it is unbalanced.
    c. it is pushed or pulled with a net force.
    d. its mass increases.

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Answer: C

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2. When a net force acts on an object, its acceleration depends on the object's
   a. initial speed.
   b. mass.
   c. volume.
   d. weight.

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Answer: B

Assessment Questions

3. A cart is pushed and undergoes a certain acceleration. Consider how the acceleration would compare if it were pushed with twice the net force while its mass increased by four. Then its acceleration would be
   a. one quarter.
   b. half.
   c. twice.
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4. Friction is a force like any other force and affects motion. Friction occurs in
   a. solids sliding over one another.
   b. fluids.
   c. air.
   d. all of these

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Answer: D

Assessment Questions

5. When you stand on one foot instead of two, the pressure you exert on the ground is

   a. half.

   b. the same.

   c. twice.

   d. quadruple.

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Answer: C

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6. The reason a 20-kg rock falls no faster than a 10-kg rock in free fall is that
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   b. the force of gravity on both is the same.
   c. their speeds are the same.
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Answer: D

Assessment Questions

7. Kevin and Suzanne go sky diving. Kevin is heavier than Suzanne, but both use the same size parachute. Kevin has a greater terminal speed compared with Suzanne because
   a. he has to fall faster for air resistance to match his weight.
   b. gravity acts on him more.
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Answer: A