SECTION 4.1

Changes in Motion

Force

Force is an action applied to an object that may change the object's motion. A force applied to an object that is not moving may cause it to move.

KEY TERM

force

Forces can cause accelerations.

Sometimes a force can change the velocity of an object. There are three ways this can happen. A force can cause an object to move. This happens when you throw a ball. A force can cause a moving object to stop. This occurs when you catch a ball. A force can cause a moving object to change direction. This is what happens when you hit a baseball with a bat. A ball hit by a bat flies off in a different direction.

The force causes a change in velocity with respect to time. Another way to say this is the force causes an acceleration.

The SI unit of force is the newton.

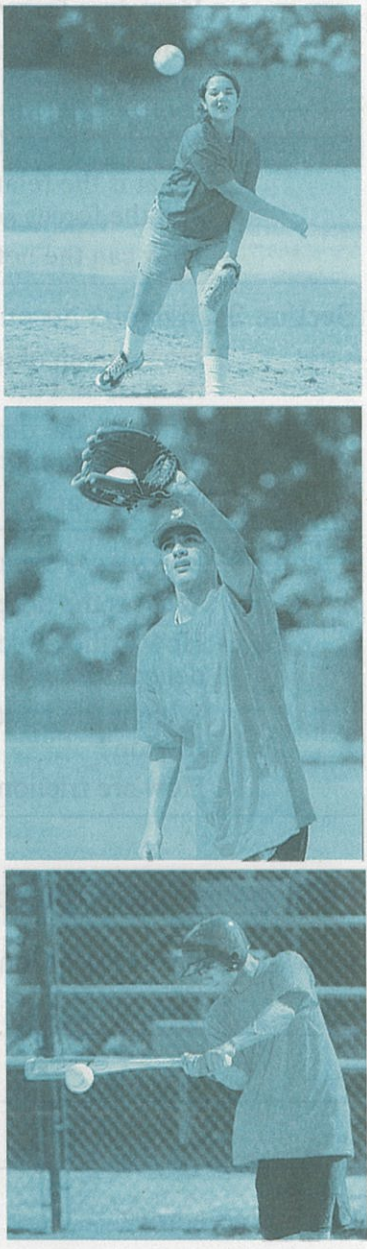
The SI unit of force is the newton. It was named after the English scientist Sir Isaac Newton. The newton is written as N. It is defined as the amount of force needed to accelerate a 1 kg mass 1 m/s^2.

$$1\ \text{N} = 1\ \text{kg} \times 1\ \text{m/s}^2$$

An important measure of gravitational force is weight. The weight of an object is based on the magnitude of the gravitational force affecting it.

READING CHECK

1. What are the three ways in which a force can change the velocity of an object?



(a) (b) (c)

A force can cause objects to (a) start moving, (b) stop moving, and/or (c) change direction.

Many terms and units you use every day to talk about weight are really units of force that can be converted to newtons.

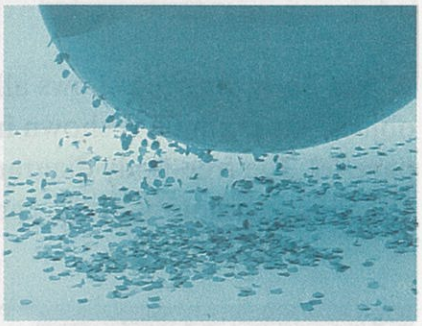
Units of Mass, Acceleration, and Force

System	Mass	Acceleration	Force
SI	kg	m/s^2	$N = kg \cdot m/s^2$
cgs	g	cm/s^2	$dyne = g \cdot cm/s^2$
Avoirdupois	slug	ft/s^2	$lb = slug \cdot ft/s^2$

Forces can act through contact or at a distance.

You know that a wagon moves if you pull it. The wagon also moves if you push it. Pushes and pulls are contact forces. A *contact force* results from physical contact between two objects.

Field forces do not require physical contact. An example of a field force is gravitational force. Think about an object that is falling to Earth. The object is pulled toward Earth by Earth's gravity. Earth exerts a force on the object even though the object and Earth are not in contact. Another example of a field force is the attraction or repulsion between electric charges. You can rub a balloon against your hair and then hold the balloon over a table covered with bits of paper. The paper bits will be pulled upward to the balloon.



An electric field around the rubbed balloon exerts a force that pulls the paper.

Critical Thinking

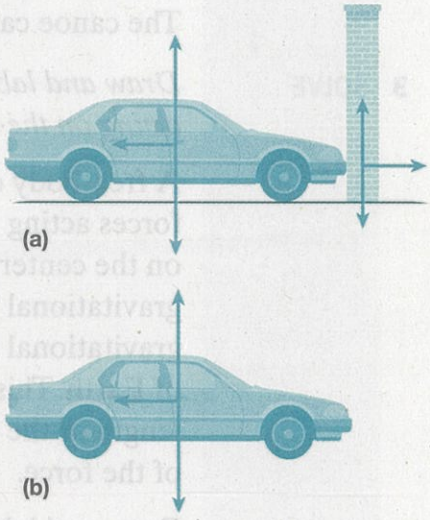
2. Identify Identify the contact forces and the field forces shown in the photo of the balloon.

Force Diagrams

The acceleration of an object depends on the *magnitude* of the force. Magnitude is the same as size. The *direction* in which the object moves depends on the direction of the force.

Force is a vector.

Force is a vector quantity because it depends on both magnitude and direction. A *force diagram* shows all forces affecting a situation. The force vectors are shown as arrows. The tail of the arrow is attached to the object on which the force is acting. A force vector points in the direction of the force. The magnitude of the force is indicated by the relative length of the vector arrow. An example of a force diagram is shown on the top right.



(a) This is a force diagram. Vector arrows represent all the forces acting on a situation.
(b) A free-body diagram shows only the forces acting on the object of interest. The car is the object in this diagram.

A free-body diagram helps analyze a situation.

A *free-body diagram* shows all of the forces acting on a single object. An example is shown in **(b)** in the car diagram on page 69. The free-body diagram shows only the forces affecting the motion of the car.

SAMPLE PROBLEM

A park ranger in a canoe is observing wildlife on the shore. Earth's gravitational force on the ranger is 760 N downward. Its gravitational force on the boat is 190 N downward. The water keeps the canoe afloat by exerting a 950 N force upward on it. Draw a free-body diagram of the canoe.

SOLUTION

1 ANALYZE

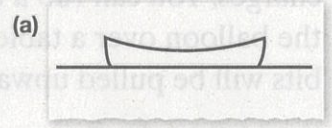
Identify the forces acting on the object and the directions of the forces.

- Earth exerts a force of 190 N downward on the canoe.
- The park ranger exerts a force of 760 N downward on the canoe.
- The water exerts an upward force of 950 N on the canoe.

2 PLAN

Draw a diagram to represent the isolated object.

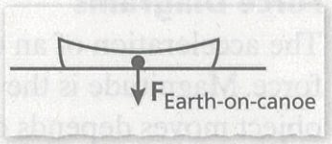
The canoe can be represented as shown in *a*.



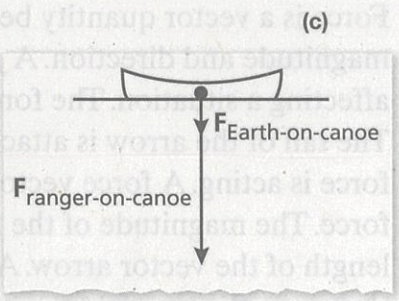
3 SOLVE

Draw and label vector arrows for all external forces acting on the object.

A free-body diagram of the canoe will show all the forces acting on the canoe as if the forces are acting on the center of the canoe. Draw and label the gravitational force acting on the canoe. The gravitational force is directed toward the center of Earth. This is shown in *b*. Be sure that the length of the arrow represents the magnitude of the force.



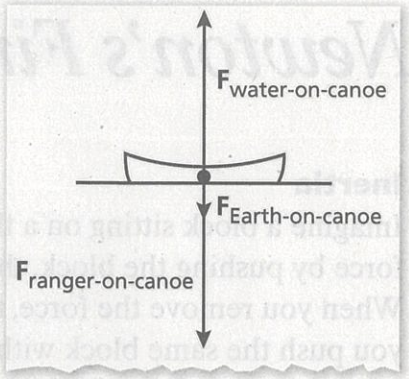
Draw and label the downward force that is exerted on the boat by Earth's gravitational attraction on the ranger. This is shown in *c*.



SAMPLE PROBLEM (continued)

Draw and label the upward force exerted by the water on the canoe as shown in *d*. This diagram is the completed free-body diagram of the floating canoe.

(d)



PRACTICE

A physics book is at rest on a desk. Gravity pulls the book down. The desk exerts an upward force on the book that is equal in magnitude to the gravitational force. Draw a free-body diagram of the book.

SECTION 4.1 REVIEW

REVIEWING MAIN IDEAS

1. List one example of each of the following.
   - **a.** force causing an object to start moving
   - **b.** force causing an object to stop moving
   - **c.** force causing an object to change its direction of motion

2. Give one example of a field force described in this section. Give one example of a contact force you observe in everyday life.

3. What is the SI unit of force? What is this unit equivalent to in terms of fundamental units?

4. Why is force a vector quantity?