Newton's Third Law

Newton realized that a force is not a thing in itself but part of an **interaction** between one thing and another. For example, consider the interaction between a hammer and a nail. The hammer exerts a force on the nail, driving it into a board. But the nail also exerts a force on the hammer, causing it to come to a halt. So, in the interaction between the hammer and the nail, there are a pair of forces, one acting on the nail and the other acting on the hammer. These observations led Newton to his third law: the law of action and reaction.

Newton's third law states:

> Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object.

One force is called the **action force**. The other is called the **reaction force**.

Example

1. In walking, you interact with the floor. You push back on the floor (action) and the floor pushes forward on you (reaction).

2. In swimming, you interact with the water. You push backward on the water (action) and the water pushes forward on you (reaction).

3. A balloon pushes escaping air backward (action) and the escaping air pushes the balloon forward (reaction).

4. A car pushes backward on the road (action) and the road pushes forward on the car (reaction).

Identifying Action and Reaction

Sometimes it is difficult to identify the action and reaction forces in an interaction. For example, what are the action and reaction forces in the case of a falling boulder? The action force is clearly that Earth is pulling down on the boulder, but what is the reaction force?

It turns out there is a simple recipe for treating action and reaction forces. First identify the interaction. Let's say one object, A, is interacting with another object, B. The action and reaction forces can then be stated in the form

Action: Object A exerts a force on object B.

Reaction: Object B exerts a force on object A.

Thus, for the falling boulder, if the action force is Earth pulling down on the boulder, then the reaction force is the boulder pulling up on Earth.

Action and Reaction on Different Masses

When a cannon is fired, there is an interaction between the cannon and the cannonball. The force the cannon exerts on the cannonball is exactly equal and opposite to the force the cannonball exerts on the cannon, so the cannon recoils.

Q. Why does the cannonball move so fast compared to the cannon?

A. Let F = 500 N represent both the action and reaction forces. The mass of the cannon is 250 kg and the mass of the cannonball is 25 kg. The acceleration of the cannonball and cannon are

Cannonball

$$\begin{aligned} a &= \frac{F}{m} \\ &= \frac{500\text{ N}}{25\text{ kg}} \\ &= 20\text{ m/s}^2 \end{aligned}$$

Cannon

$$\begin{aligned} a &= \frac{F}{m} \\ &= \frac{500\text{ N}}{250\text{ kg}} \\ &= 2\text{ m/s}^2 \end{aligned}$$

The cannonball has a considerably higher acceleration because of its much smaller mass. Thus, the cannonball moves much faster because of its higher acceleration.

Note: Rocket propulsion works in a very similar way.

Do Action and Reaction Forces Cancel?

It would seem, since they are equal and opposite, that action and reaction forces should cancel to zero. This is not, however, the case. Action and reaction forces are like apples and oranges, in that they act on different objects. You can’t cancel a force on an orange with a force on an apple.

Motion Worksheet #8

1. In the interaction between a hammer and the nail it hits, is a force exerted on the nail? On the hammer? How many forces occur in this interaction?

2. When a hammer exerts a force on a nail, how does the amount of force compare with that of the nail on the hammer?

3. When you walk along a floor, what pushes you along?

4. When swimming, you push water backward – call this action. What is the reaction force?

5. If the action is a bowstring acting on an arrow, identify the reaction force.

6. When you jump up, the world recoils downward. Why can't this motion of the world be noticed?

7. When a cannon is fired, how does the size of the force of the cannon on the cannonball compare with the force of the cannonball on the cannon? How does the acceleration of the cannon compare with that of the cannonball? Defend your answer.

8. If you hit a wall with a force of 200 N, how much force is exerted on you?

9. Your weight is the result of the gravitational force of Earth on your body. What is the corresponding reaction force?

10. Consider the two forces acting on a person who stands still, namely, the downward pull of gravity and the upward support of the floor. Are these forces equal and opposite? Do they comprise an action-reaction pair? Why or why not?

11. If you walk on a log that is floating in the water, the log moves backward. Why?

12. Why is it easier to walk on a carpeted floor than on a smooth, polished floor?

13. If you step off a ledge, you accelerate noticeably toward Earth because of the gravitational interaction between you and Earth. Does Earth accelerate toward you as well? Explain.

14. Suppose you are weighing yourself while standing next to the bathroom sink. Using the idea of action and reaction, explain why the scale reading will be less when you push down on the top of the sink. Why will the scale reading be more if you pull up on the bottom of the sink?

15. What is the reaction force to an action force of 1000 N exerted by Earth on an orbiting communications satellite?

16. If action equals reaction, why isn't Earth pulled into orbit around a communications satellite?

17. If a bicycle and a massive truck have a head-on collision, upon which vehicle is the impact force greater? Which vehicle undergoes the greater change in its motion? Defend your answers.

18. A speeding bus makes contact with a bug that splatters onto the windshield. Because of the sudden force, the unfortunate bug undergoes a sudden deceleration. Is the corresponding force that the bug exerts against the windshield greater, less, or the same? Is the resulting deceleration of the bus greater than, less than, or the same as that of the bug?

19. Your teacher challenges you and your best friend to each pull on a pair of scales attached to the ends of a horizontal rope, in tug-of-war fashion, so that the readings on the scales will differ. Can this be done? Explain.

Motion Worksheet #8 Key

1. Yes; yes; two.
2. Same; both are part of one interaction.
3. The floor.
4. Water pushing you forward.
5. Arrow acting on the bowstring.
6. The acceleration is too small to be observed because of Earth's large mass.
7. Same; acceleration is large for the cannonball, but small for the cannon.
8. 200 N
9. Your body pulling on Earth.
10. Yes, they are the only forces acting on a non-accelerating person; No, they are not part of an action-reaction pair because they act on the same object.
11. The backward force on the log moves it backward.
12. One can exert a greater horizontal force on a carpet than on a polished floor because of the greater friction. This in turn provides a greater reaction force to provide traction for walking.
13. Yes, but the accelerations produced by these equal forces are quite unequal because of the great difference in mass between you and Earth.
14. When you push down on the sink, the sink pushes you up. This tends to lift you off the scale and decrease the reading on the scale. If you pull up on the sink, it will push down on you and increase the scale reading.
15. 1000 N
16. Because Earth's mass is too large.
17. The impact force is the same on both. Because of the bicycle's smaller mass, the change in motion is greater for the bicycle.
18. Both forces have the same magnitude. The bug undergoes a much greater deceleration than the bus because it has much less mass.

19. You can't do it. It is impossible for one end of the rope to be under greater tension than the other end.