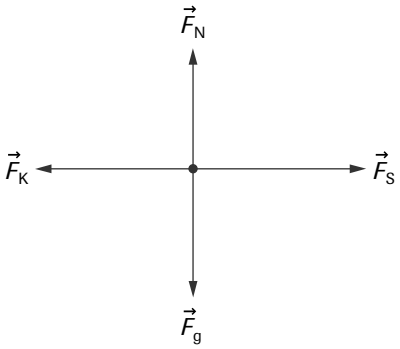
Newton's Third Law

Newton's third law of motion states that for every action, there is an equal and opposite reaction. This exercise is designed to investigate the nature of Newton's third law by looking at some examples of how the law can be used to explain a variety of phenomena.

Sample Problem

A car is travelling east along a paved highway. What is the action-reaction pair of forces? Which force is responsible for the motion of the car?

Solution



The FBD for the car shows the car's tires exert the action force (static friction) on the road. The road exerts a forward reaction force (also static friction) on the car's tires. This reaction force propels the car forward.

Note that the car is propelled by the force of static friction exerted by the road on the car's tires. This force is the only force that is acting on the car in the forward direction. The friction of the road is considered to be a force of static friction if there is no slippage of the tires on the road surface. The forward force is partly counteracted by the kinetic friction of the road exerted on the car's tires and the air resistance exerted on the car. The gravitational force and the normal force are equal in magnitude but opposite in direction. The force the road exerts on the car's tires is the reaction force. This force is exerted in response to the action force the car's tires exert on the road as the wheels turn. The action-reaction forces are equal in magnitude and opposite in direction; however, they act on different objects and, thus, do not counteract one another.

Practice Questions

For each of the following situations, provide an FBD of the object noted in *italics*. Name the action and reaction forces, and identify the force that is responsible for the motion.

1. A *person* walks across the classroom floor.

(continued)

2. A *motorboat* moves through the water.

3. An *airplane* flies through the air.

4. A pair of oars propels a *rowboat* forward.

5. A *balloon* flies erratically through the air as it deflates.

6. A football *player* collides head-on with another player, and both players are brought to rest.

(continued)

7. A *rocket* is propelled forward as its fuel burns.

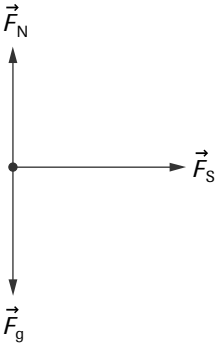
8. As the driver turns the steering wheel, the *car* turns around a corner.

9. A baseball *bat* strikes a fastball.

10. A *helicopter* hovers over a forest fire.

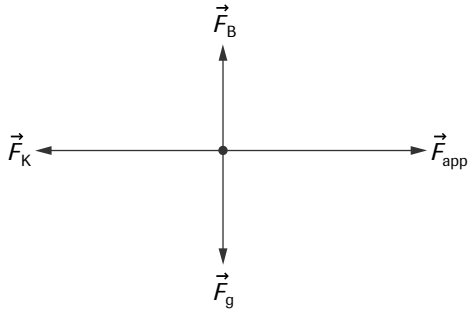
Newton's Third Law, Solution

1. A *person* walks across a classroom floor.



The person's feet exert the action force (static friction) on the floor. The floor exerts a forward reaction force (also static friction) on the person's feet. This reaction force propels the person forward. The normal force and gravity balance one another in the vertical plane.

2. A *motorboat* moves through the water.



The propeller exerts the action force on the water, pushing the water backward. The water exerts the reaction force ($\vec{F}_{app}$) on the propeller of the boat in the forward direction. There is also kinetic friction acting on the boat. The buoyant force ($\vec{F}_B$) acting on the boat in the upward direction is balanced by gravity.

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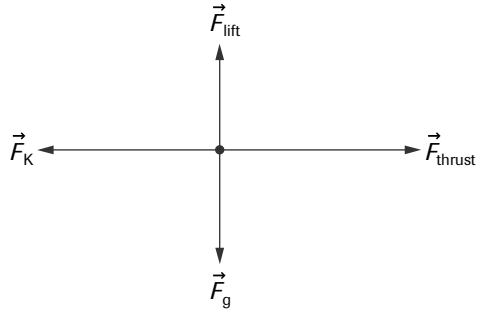
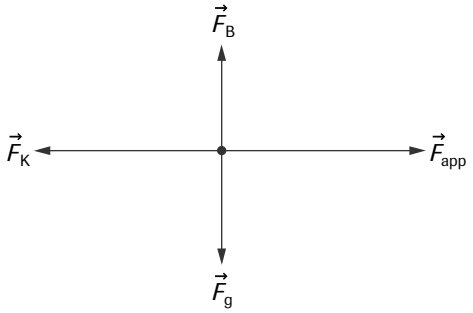
3. An *airplane* flies through the air.



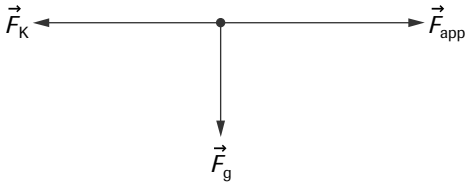
The propeller exerts an action force on the air, pushing the air backward. The air exerts the reaction force ($\vec{F}_{thrust}$) on the propeller in the forward direction. There is also kinetic friction acting on the airplane, an upward lift force ($\vec{F}_{lift}$) provided by the air acting on the wings, and the force of gravity acting downward.

4. A pair of oars propels a *rowboat* forward.



The oars exert an action force on the water, pushing the water backward. The water exerts the reaction force ($\vec{F}_{app}$) on the oars in the forward direction. There is also kinetic friction exerted by the water on the boat, a buoyant force ($\vec{F}_B$), and the force of gravity.

5. A *balloon* flies erratically through the air as it deflates.



The elastic walls of the balloon exert the action force inward on the air inside the balloon. The air exerts an outward reaction force ($\vec{F}_{app}$) on the walls of the balloon. This force acts equally on all points on the inside surface of the balloon. These forces are balanced except at the point opposite the opening of the balloon. The force acting at this position propels the balloon forward. There is also kinetic friction and gravity acting on the balloon.

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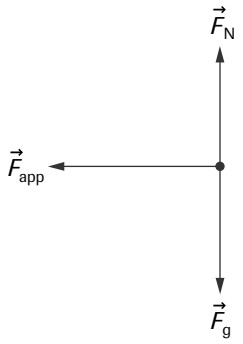
6. A football *player* collides head-on with another player, and both players are brought to rest.



The force player A exerts on player B is the action force. The reaction force ($\vec{F}_{app}$) is the force player B exerts on player A. The reaction force, acting in a direction opposite the player's motion, results in the player experiencing an acceleration that brings him or her to rest.

7. A *rocket* is propelled forward as its fuel burns.

As the fuel burns within the rocket, expanding gases exert action forces against the inside walls of the rocket. The reaction force is exerted by the walls of the rocket against the expanding gases. The action forces are balanced everywhere except along the direction opposite the exhaust port. The thrust force ($\vec{F}_{thrust}$) acting at the nose of the rocket propels the rocket upward against the force of gravity.

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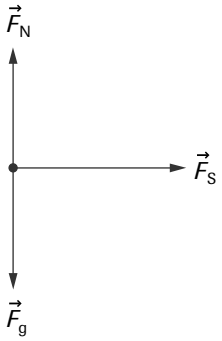
8. As the driver turns the steering wheel, the *car* turns around a corner.



The car's tires exert the action force (static friction) against the road surface. The reaction force (also static friction) is exerted against the tires in the opposite direction. This force directs the car around the corner.

9. A baseball *bat* strikes a fastball.

The action force is the force the bat exerts on the baseball. The reaction force ($\vec{F}_{app}$) is exerted by the ball on the bat.

10. A *helicopter* hovers over a forest fire.

The propeller of the helicopter exerts a downward action force on the air. The air exerts an upward reaction lift force ($\vec{F}_{lift}$) on the propeller (and also the helicopter) that is sufficient to overcome the force of gravity.