Section 2.12: Newton's Third Law of Motion

Newton's Third Law is of called Newton's Law of Action and Reaction. It states that for each action force there is an equal but opposite reaction. In other words,

If Object A exerts a force on Object B
then
Object B exerts an equal but opposite force on Object A

Mathematically: $F_{AB} = - F_{BA}$ ($F_{A\ on\ B} = - F_{B\ on\ A}$)

There are two important things to point out:
(1) the minus sign indicates that the directions are opposite.
(2) there are two objects and the so-called "action" and "reaction" forces act on different objects (namely each other).

It does not matter which force is called the action force and which force is called the reaction force. **What is important is that neither force can exist without the other. For every action force there must be and equal but opposite reaction force.** In other words, in every interaction, the forces always occur in pairs.

Examples

Examples

1 You interact with the floor when you walk. You push backward on the floor and the floor simultaneously pushes you forward.

$$F_{YF} = - F_{FY}$$

2 The tires of a car interact with the road to produce the car's motion. The tires push backward against the road and the road simultaneously pushes forward on the tires.

$$F_{TR} = - F_{RT}$$

3 When swimming, you interact with the water. You push backward on the water and the water pushes you forward.

$$F_{YW} = - F_{WY}$$

Notice that the interactions in the above examples depend on friction. For example, a person trying to walk on ice, where the friction is minimal, may not be able to exert an action force against the ice. Without the action force, there cannot be a reaction force, and thus no resulting forward motion. It is these reaction forces, those acting in the direction of our resulting accelerations that account for our motion in these cases.

Newton's Third Law states that for every action there is an equal but opposite reaction which means that forces always act in pairs. If this is the case, why do object move?

Pull

An object can still move because action-reaction forces always act on different objects.

To determine if and how an object moves we need to draw a FBD for that object and analyze the forces that are acting on the object. If Fnet = 0, the object is at rest or moving at a constant speed in a straight line. If Fnet $\neq 0$, the object is accelerating.

Recipe for Identifying Action-Reaction Forces

Identify the interacting objects A and B. If the action force is A on B then the reaction force is B on A.

Examples

1. Identify the action and reaction forces in the following situations and draw a FBD for each object.

   A You are supporting a 5 N force on your outstretched hand.

Action: Your hand is pushing up on the book with a force of 5 N.
$F_{HB} = 5$ N

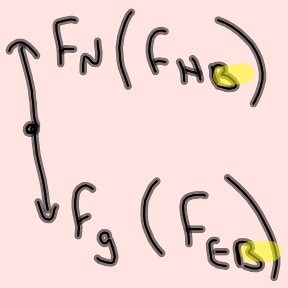
Reaction: The book is pushing down on your hand with a force of 5 N.
$F_{BH} = -5$ N

Action: The book is pulling up on the earth. F_{BE}
Reaction: The earth is pulling down on the book. F_{EB}

$F_{BE} = 5N$
$F_{EB} = -5N$

Action: Your hand is pulling up on the earth. F_{HE}
Reaction: The earth is pulling down on your hand. F_{EH}

FBD



B A falling rock

Pull

Action: The earth is pulling down on the rock. F_{ER}
Reaction: The rock is pulling up on the earth. F_{RE}

$$F_{ER} = -F_{RE}$$

FBD:

C Picking up a bowling ball. Why does the bowling ball move upward?

Pull

Action: Your hand exerts an upward force on the ball. F_{HB}
Reaction: The ball exerts a downward force on your hand. F_{BH}

$$F_{HB} = -F_{BH}$$

Pull

Action: The earth exerts a downward force on the ball. F_{EB}
Reaction: The ball exerts an upward force on the earth. F_{BE}

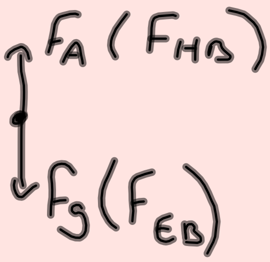
$$F_{EB} = -F_{BE}$$

Pull

Action: The earth exerts a downward force on your hand. F_{EH}
Reaction: Your hand exerts an upward force on the earth. F_{HE}

$$F_{EH} = -F_{HE}$$

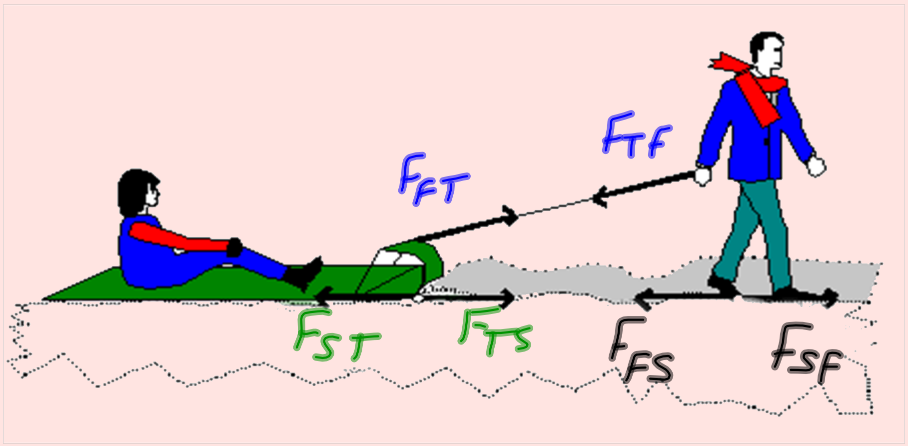
FBD:



Pull

When you lift the ball, the force exerted by your hand on the ball (F_{HB} or F_A) is greater than the force of gravity (F_{EB} or F_g). Hence there is an unbalanced force action upward which means the ball will accelerate upward.

D A father pulls his daughter on a toboggan. Why does the toboggan move?



F_{FS}-force of father pushing backward on the snow.

F_{SF} - force of snow pushing forward on the father.

F_{FT} - force of father pulling forward on toboggan

F_{TF} - force of toboggan pulling backward on father

F_{TS}-force of toboggan pushing forward on snow.

F_{ST}-force of snow pushing backward on toboggan.

Pull

If we want to determine if the toboggan will move forward, we need only consider the forces that act on the toboggan. There are two:

- The backward force of the snow on the toboggan (F_{ST} of F_F).
- The forward force of the father on the toboggan (F_{FT} or F_A).

If the force that the father exerts on the toboggan is greater than the force of the snow on the toboggan, the toboggan will experience an unbalanced force and it will accelerate and move forward.

2 Mary and Jane both want to dance with John. Mary pulls on one of his arms with 50 N and Jane pulls on his other arm in the opposite direction with a force of 50 N. Do these forces make an action-reaction pair? Explain.

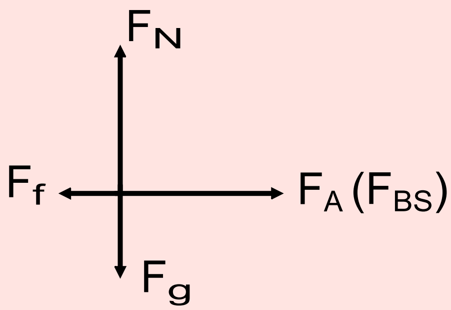
- Even though the forces are equal and opposite, they are not an action-reaction pair.
- Both forces are acting on THE SAME OBJECT (John).
- **In an action-reaction pair, each force acts on a DIFFERENT object.**

3 A boy rows his boat toward the wharf and when he is a couple of feet from the wharf, he attempts to leap to shore. Explain, with reference to Newton's Second and Third Law, why he may fall into the river.

The boy exerts a backward force on the boat and the boat exerts an equal but opposite force on the boy. However, since both objects are free to move, the boy's force on the boat accelerates it in one direction and the boat's force against the boy accelerates him in the opposite direction. The amount of acceleration on each is inversely proportional to the mass. If the boy misjudges the distance, he may end up in the water.

4 A skater standing at the side of a skating rink pushes against the boards and glides of in the other direction. Explain with reference to Newton's Second and Third Law.

Action Force: The skater exerts an force against the boards.
Reaction Force: The boards exert a force against the skater in the opposite direction.



Since the reaction force of the boards on the skater is greater than the force of friction on the skater, there is an unbalanced force on the skater. Hence, the skater will accelerate in the direction of the net force.