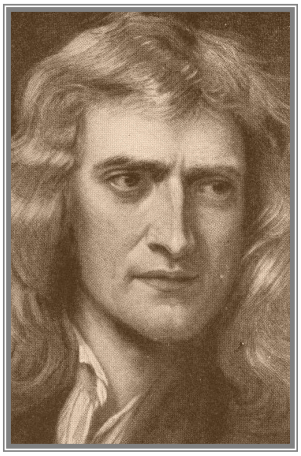
Name_____ Period_____ Date_____

NEWTON'S LAWS OF MOTION

If I am anything, which I highly doubt,
I have made myself so by hard work.
– Isaac Newton

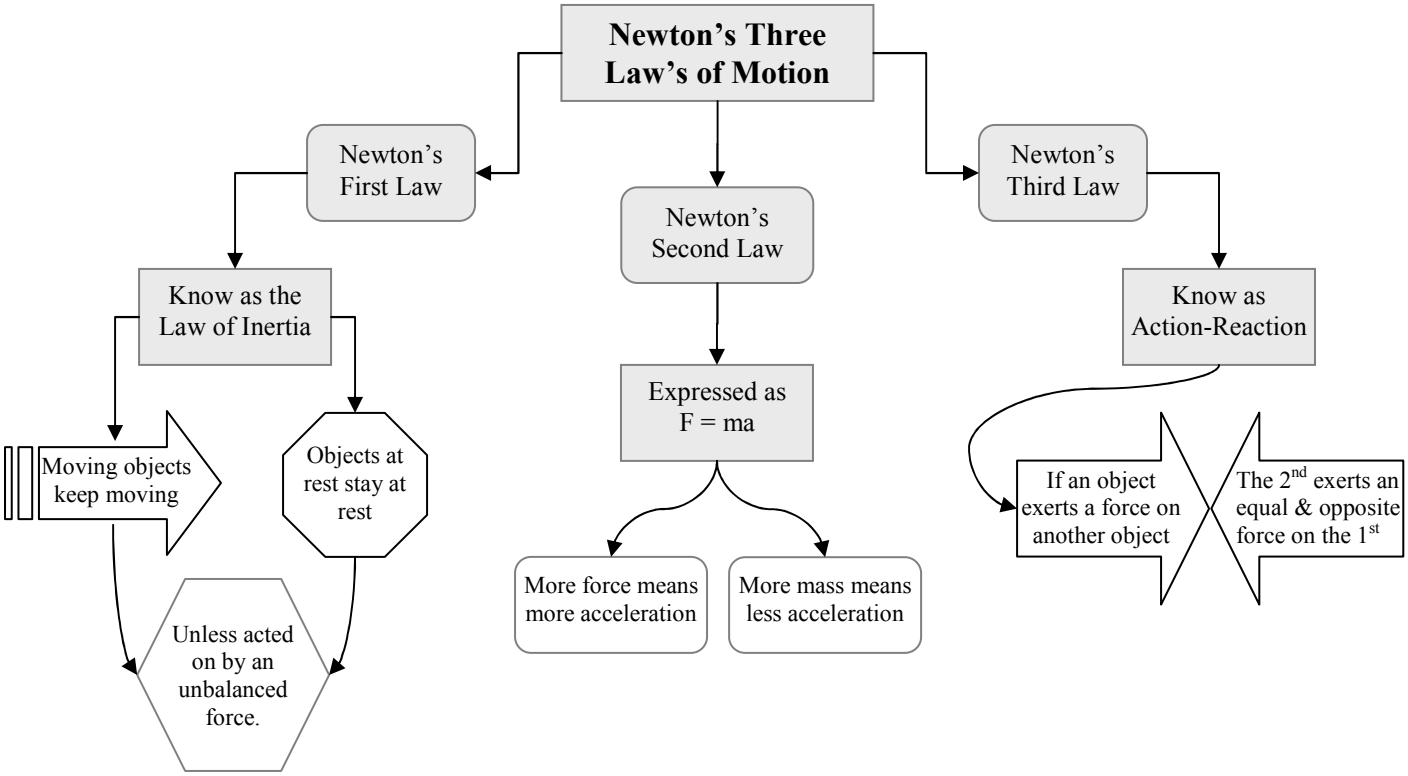


Goals:

1. Students will use conceptual and mathematical models to predict and understand patterns in motion. (3.1.10.B-C)
2. Students will be able to apply Newton's laws of motion to solve problems related to forces and mass. (3.4.10.C, 3.1.10.E)
3. Students will integrate new information into existing theories and explain implied results. (3.2.10.A)

Information

A ***Force*** is defined most simply as any push or pull.



Critical Thinking Questions – Part I

1. Which law is associated with inertia?

2. If you increase the force on an object what happens to the acceleration?

3. If you use the same force on a less massive object what happens to the acceleration?

4. Which law states force is dependent on the mass and acceleration of an object?

5. What causes an object to slowdown or speed-up?

6. What law is known as the law of action-reaction?

7. Which law explains why when you bump into something you fall backwards?

8. If you double the force of an object what happens to the acceleration?

9. If you double the mass of an object what happens to the acceleration?

10. Force is measured in newtons (N). A newton is based on base units in the metric system. What is a newton equal to in terms of units of mass and acceleration?

Exercises

1. When Jane drives to work, she always places her purse on the passenger's seat. By the time she gets to work, her purse has fallen on the floor in front of the passenger seat. One day, she asks you to explain why this happens in terms of physics. What do you say?

2. You are waiting in line to use the diving board at your local pool. While watching people dive into the pool from the board, you realize that using a diving board to spring into the air before a dive is a good example of Newton's third law of motion. Explain how a diving board illustrates Newton's third law of motion.

3. You know the mass of an object and the force applied to the object to make it move. Which of Newton's laws of motion will help you calculate the acceleration of the object?

4. How many newtons of force are represented by the following amount: 3 $kg \cdot m/sec^2$? Justify your answer.

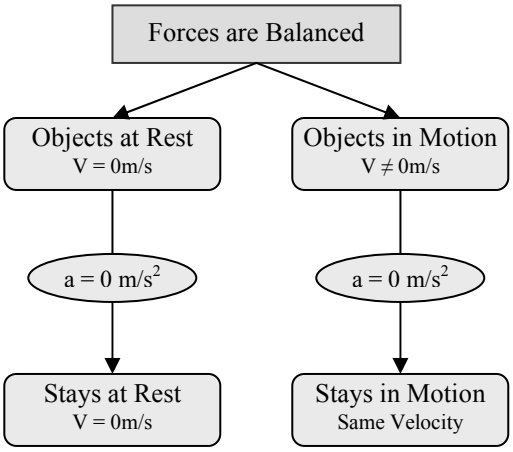
5. Your shopping cart has a mass of 65 kilograms. In order to accelerate the shopping cart down an aisle at 0.3 m/sec^2, what force would you need to use or apply to the cart?

6. A small child has a wagon with a mass of 10 kilograms. The child pulls on the wagon with a force of 2 newtons. What is the acceleration of the wagon?

7. You dribble a basketball while walking on a basketball court. List and describe at least 3 pairs of action-reaction forces in this situation.

Information

Newton's First Law



Newton's first law of motion is often stated as an object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

In fact, it is the natural tendency of objects to resist changes in their state of motion. This tendency is described as inertia. A more massive object has a greater tendency to resist changes in its state of motion.

Inertia: the resistance an object has to a change in its state of motion.

Forces are said to be *balanced* when the net force on the object are zero. That is when all the forces are added up the result is zero. For example when you are standing the force of gravity is balanced by the force of the floor holding you up.

Forces are *unbalanced* when the net force is not zero. In a tug-of-war both teams apply forces. For a team to win the forces must be unequal or unbalanced. You want the net force to be in your direction.

Critical Thinking Questions – Part II

1. Restate Newton's first law in terms of acceleration.

2. If the forces are balanced what is the resulting acceleration?

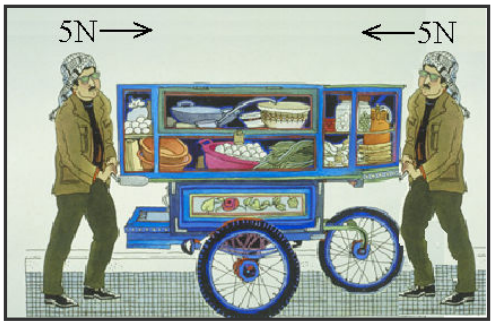
3. An object's resistance to change in motion is dependent solely on what quantity?

4. Inertia is the resistance to change in motion so inertia depends solely on what?

5. What is required to cause acceleration?

6. What is the net force if you push a cart to the right with 5N of force and a friend pushes the cart to the left with 5N of force?

7. What is the net force if you start to pull instead of pushing in #6?



Exercises

1. Imagine a place in the *cosmos* far from all gravitational and frictional influences. Suppose that you visit that place (just suppose) and throw a rock. What will the rock do? Why?

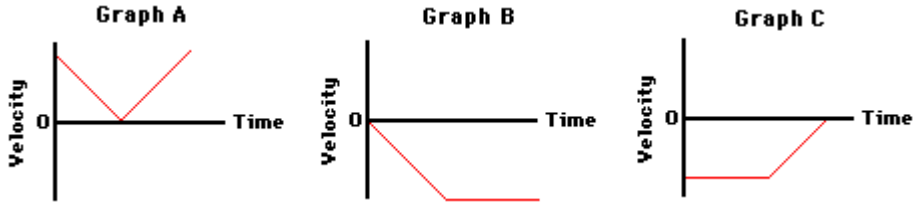
2. Supposing you were in space in a *weightless environment*, would it require a force to set an object in motion? Explain.

3. Why doesn't a ball roll on forever after being kicked at a soccer game?

4. A 2-kg object is moving horizontally with a speed of 4 m/s. How much net force is required to keep the object moving at this speed and in this direction? Explain.

5. Ben Tooclose is being chased through the woods by a bull moose which he was attempting to photograph. The enormous mass of the bull moose is extremely intimidating. Yet, if Ben makes a zigzag pattern through the woods, he will be able to use the large mass of the moose to his own advantage. Explain this in terms of inertia and Newton's first law of motion.

6. Luke Autbeloe drops an approximately 5.0 kg object (weight = 50.0 N) off the roof of his house into the swimming pool below. Upon encountering the pool, the object encounters a 50.0 N upward resistance force (assumed to be constant). Use this description to answer the following questions. *(Down is usually considered a negative direction)*
   a. Which one of the velocity-time graphs best describes the motion of the object? Why?



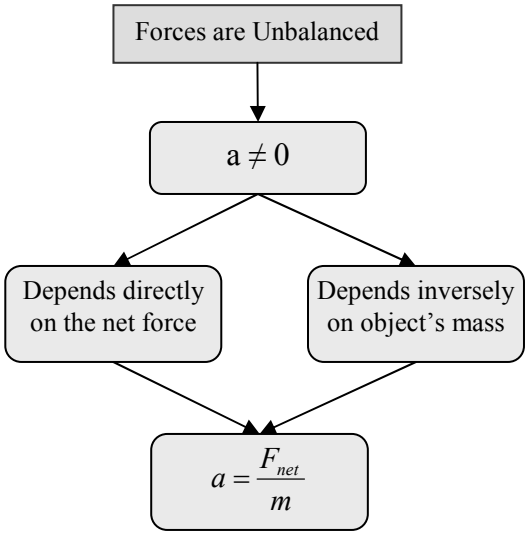
   b. True or False: Once the object hits the water, the forces are balanced and the object will stop. Support your answer with reasoning.

Information

Newton's Second Law

As stated in the first law, the presence of an unbalanced force will accelerate an object - changing either its speed, its direction, or both its speed and direction.

Newton's second law of motion pertains to the behavior of objects for which all existing forces are not balanced. The second law states that the acceleration of an object is dependent upon two variables - the net force acting upon the object and the mass of the object. The acceleration is always in the same direction as the net force.



Mathematically this means:

$$acceleration = \frac{Force_{net}}{mass};$$

commonly written as: $F_{net} = ma$

Do not use the value of merely any force in the above equation. It is the net force which is related to acceleration. The net force is the sum of all the forces acting on an object.

Critical Thinking Questions – Part III

1. What two variables is acceleration dependent on? What is the relationship between these variables and acceleration? (i.e. if you increase one variable what happens to the acceleration?)

2. If an object is not accelerating what can you determine about the sum of all the forces on the object?

3. If the net force on an object is in a negative direction, what will the direction of the resulting acceleration be?

4. If you double the net force on an object what is the result on the acceleration?

5. If you double the mass of an object while leaving the net force unchanged what is the result on the acceleration?

6. A Cadillac Escalade has a mass of 2 569.6 kg, if it accelerates at 4.65m/s^2 what is the net force on the car?

7. A 7.26kg bowling ball (16 pounds) is at rest at the end of a bowling lane. Use this information to answer the following questions.
    a. What is the net force acting on the ball?

    b. You push the ball with a force of 22.8N which induces a -2.3N frictional force. What is the net force while you push the ball?

    c. What is the acceleration caused by your push on the ball?

    d. Following your push the ball rolls down the lane at 4.2m/s. What is the net force on the ball as it rolls down the lane at the constant speed?

    e. CHALLENGE: How long did you push the ball in this situation?

Exercises

8. Complete the following table. Be sure to include units in your answer.

Net Force (N)	Mass (kg)	Acceleration
5.0	2.5	
2.32	12	
18.2	1.967	
0.87	21.2	
180	1.793	

9. Complete the following table. Be sure to include units.

Net Force (N)	Mass (kg)	Acceleration (m/s^2)
	4.0	4.0
25.0		4.998
53	3	
172.44		4.665
	1 225	3.43

10. What is the rate of acceleration of a 2,000-kilogram truck if a force of 4,200 N is used to make it start moving forward?

11. What is the acceleration of a 0.30 kilogram ball that is hit with a force of 25 N?

12. How much force is needed to accelerate a 68 kilogram-skier at a rate of 1.2 m/sec^2?

13. What is the mass of an object that requires a force of 30 N to accelerate at a rate of 5 m/sec^2?

14. What is the force on a 1 000 kilogram-elevator that is falling freely under the acceleration of gravity only ($9.8m/s^2$)?

15. What is the mass of an object that needs a force of 4 500 N to accelerate it at a rate of 5 m/sec^2?

16. What is the acceleration of a 6.4 kilogram bowling ball if a force of 12 N is applied to it?

17. CHALLENGE: What is the mass of an object that needs a force of 6 600 N to increase its speed from rest to 107 m/s in 2.3 seconds?

Information

Newton's Third Law

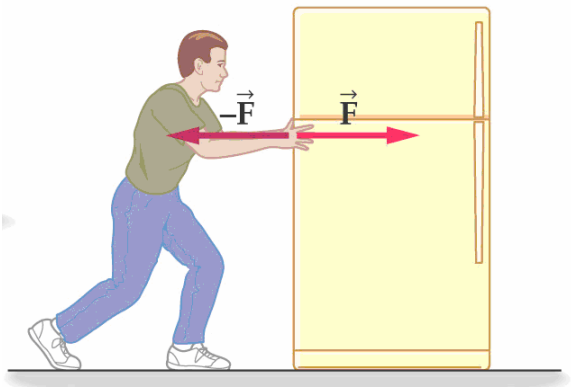
A force is a push or a pull upon an object. This implies there must be two objects; one being pushed and one doing the pushing. Thus, forces result from interactions between objects. According to Newton's Third Law, whenever objects interact with each other they exert forces upon each other. These two forces the objects exert on each other are called *action* and *reaction* forces. Friction is one type of reaction force.

Newton's third law states:

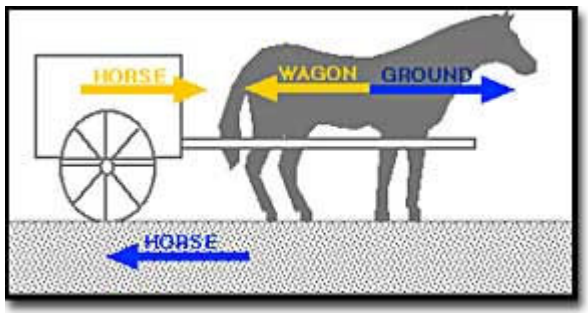
For every action, there is an equal and opposite reaction.

The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the forces on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs - equal and opposite action-reaction force pairs.

Examples:



The man pushes on the refrigerator, and the refrigerator pushes back on the man.



The horse pushes back on the ground and the ground pushes forward on the horse. The horse pulls forward on the wagon and the wagon pulls back on the horse

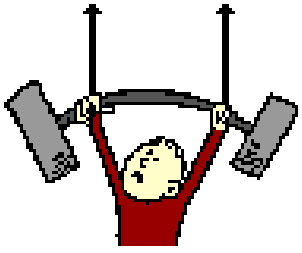
Critical Thinking Questions – Part IV

1) All forces result because of _____ between objects.

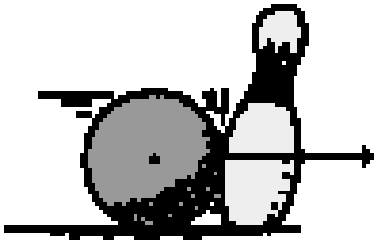
2) Forces come in pairs. What are these pairs called?

3) In the diagrams below the action forces have been labeled with arrows. In each diagram label the reaction forces with arrows.

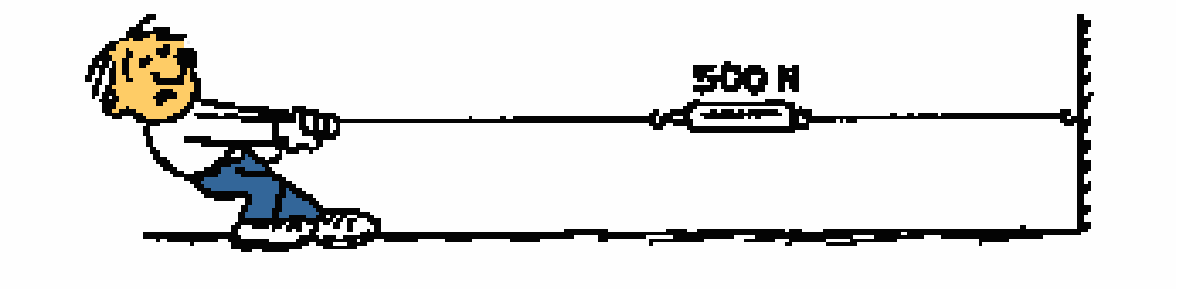
a)



b)



c)



4) In the drawing to above:
   a. How much force is the physics student exerting on the rope? In what direction?

   b. How much force is the wall exerting on the rope? In what direction?

   c. What is the net force on the force gauge?

   d. Would the Physics student be moving? If yes, is he accelerating?

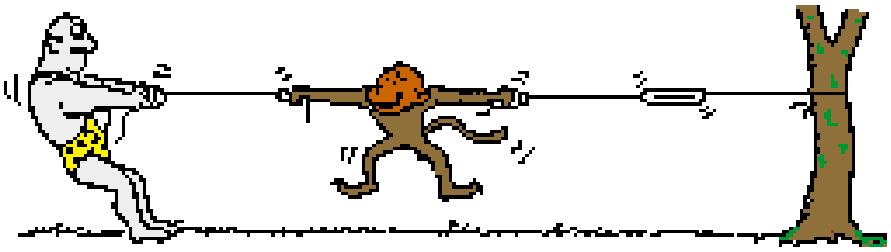
   e. What would happen if the wall stopped exerting any force?

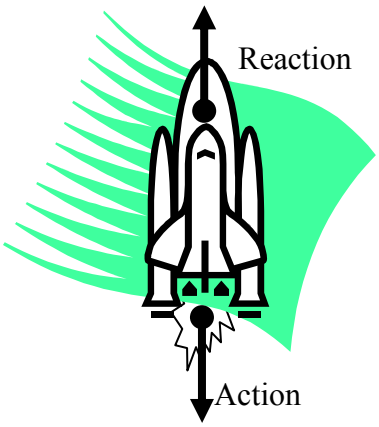
   f. What happens if the Physics student is standing on ice?

   g. What is the force between the student and the ground called?

   h. Draw and label arrows on the diagram to represent three sets of force pairs.

5) On the drawing below draw at least 5 force pairs.



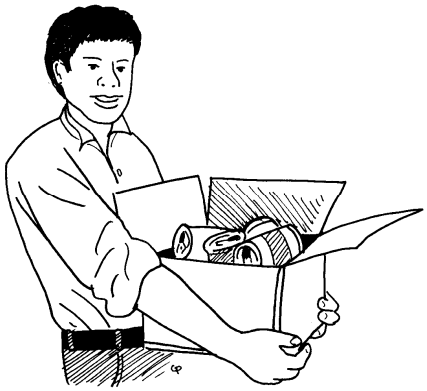


6) The force pairs are drawn on the diagram to the left.
   a. What is the action force acting on?

   b. What is the reaction force acting on?

   c. If the forces are equal and opposite why does the rocket ship move?

7) Manuel is holding a 5 kg box.



   a. How much force is the box exerting on him? In what direction?

   b. How much force is he exerting on it? In what direction?

   c. If Manuel weighs 375 N and is holding the box. How much force is the floor exerting on him? (include direction)

   d. How much force does each of his legs exert?

   e. Draw and label the force arrows between Manuel and the box.

8) While driving down the road, a firefly strikes the windshield of a bus and makes a quite obvious mess in front of the face of the driver. This is a clear case of Newton's third law of motion. The firefly hit the bus and the bus hits the firefly. Which of the two forces is greater: the force on the firefly or the force on the bus? Explain.

9) Many people are familiar with the fact that a rifle recoils when fired. This recoil is the result of action-reaction force pairs. A gunpowder explosion creates hot gases which expand outward allowing the rifle to push forward on the bullet. Consistent with Newton's third law of motion, the bullet pushes backwards upon the rifle. The acceleration of the recoiling rifle is ...
   a. greater than the acceleration of the bullet.
   b. smaller than the acceleration of the bullet.
   c. the same size as the acceleration of the bullet.

   Explain your answer.