



Forces

Newton's Third Law

CONCEPT EXPLORATION

In the last lesson, we investigated Newton's 2nd law. That law dealt with the relationship between a net or unbalanced force acting on an object and the resulting acceleration that the object experienced due to the unbalanced force. In this lesson we will investigate Newton's 3rd law which deals with the forces that occur between two objects when they interact with one another.



Engagement Questions

Lightly touch a wall with your index finger.

1. Can you feel the wall touching you back? If so, is the wall touching you back softly or with a lot of force?



Touch the wall with a little more force.

2. Does the force of the wall on your finger increase or decrease?



Touch the wall with as much force as you can without injuring yourself.

3. Does the force of the wall on your finger increase even more or does it decrease?



4. In general, what happened to the force that the wall exerted back on you as you increased the force that you exerted on the wall? Did this force seem to increase or did it seem to decrease?



The force that you exerted on the wall with your finger and the force that the wall exerted back on your finger are considered to be an action-reaction pair. Action-reaction pairs occur whenever one object exerts a force on another object.

For example consider the force that a soccer player exerts on a soccer ball with their foot. If you consider the "action" force to be the force of the soccer player's foot on the soccer ball, then the "reaction" force would be the force of the soccer ball back on the player's foot.

In general if an object exerts a force on another object, then the other object exerts a force back on the first object.

It is important to note that action-reaction pairs occur between two different objects. Also, each of the forces that occur are exerted on two different objects.

The comparative size of these action-reaction pairs will be investigated in the following exploration activities as well as their respective directions.





The Challenge

You will determine the comparative magnitude of the forces that make up an action-reaction pair.

Your Ideas about the Challenge

Two students of different size push on each other in the classroom.

5. Which student, do you think, experiences the greater force during these interactions, the larger student or the smaller student?

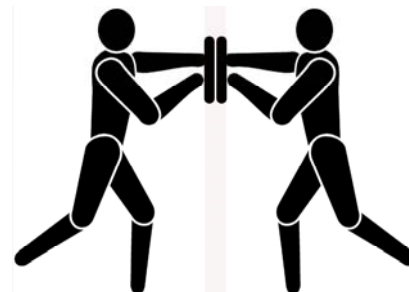


At each lab station you should find 2 bathroom scales.



The Investigation

- A pair of students should pick up the bathroom scales and carefully hold them while they face each other so that the bottom of each bathroom scale makes contact with the bottom of the other scale. Each student should attempt to push in the center of their bathroom scale as they push the scales against one another.
- One student will attempt to push against the scale so that their scale maintains a reading of 5 lbs. The other student will report what their scale reads at this moment. Record this reading in the data table that follows.
- Repeat the procedure in “a” and “b” for forces of 10 lbs, 15 lbs, and 20 lbs.



Data Table

Student A pushing with a force of:	Student B observes a force of:
5 lbs	
10 lbs	
15 lbs	
20 lbs	

6. Did either scale always read a lot more than the other scale or were the two readings on the two scales approximately the same each time?



7. Was the force of the first scale on the second scale and the force of the second scale on the first scale an action-reaction pair? Explain how you know.



Check your work with your teacher.

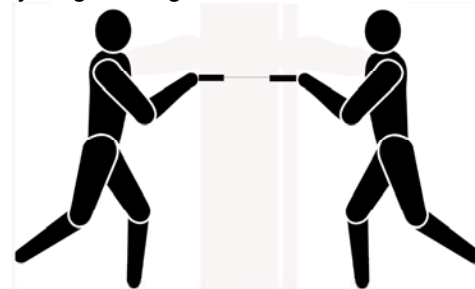


At each lab station you should find two spring scales connected together by a light string.



The Investigation (continued)

- Two students should pick up the spring scales so that each student pulls on the string with their spring scale while facing the other student.
- One student should pull on their spring scale so that they maintain a force of 5 N on their scale. The other student should observe what their scale reads while the 5 N force is being maintained. Record this observed force in the data table that follows.
- Repeat part “b” above while the first student maintains a pull of 10 N on the scale.



Data Table

Newton's 3rd Law

Student A pulling with a force of:	Student B observes a force of:
5 N	
10 N	

8. Was either force significantly bigger than the other force or were they pretty much the same?



9. Was the force of student A pulling on the spring scale of student B and the force of student B pulling back on the spring scale of student A an action-reaction pair? Explain how you know.



10. In general how do the sizes of the action forces seem to compare to the sizes of the reaction forces? Are they bigger, smaller, or the same size?



11. How does the direction of action and reaction forces compare? Are they in the same direction, in the opposite direction, or in some other kind of orientation?



12. A pair of students in your class argue about the size of the forces that make up action-reaction pairs. Indicate whether you agree or disagree with each student and why.

Student A

"If a big object, like a car, hits a little object, like a fly, then the fly obviously gets hit with the bigger force since it will totally get squished."

Student B

"That's not right. The size of the forces could be the same. A small force acting on a car will not affect the car very much. But the same size force on a fly could squish the fly."



Check your work with your teacher.  ☐



Forces Newton's Third Law

CONCEPT DEVELOPMENT

In the exploration activity we saw that the size of the forces that make up an action-reaction pair are the same. You should have also seen that the two forces that make up an action-reaction pair are in the opposite direction. This concept can be formally stated in Newton's 3rd law as follows:

Whenever one body exerts an action force on another body then the other body exerts a reaction force back on the first body that is equal in magnitude but opposite in direction.

Another way that you can consider Newton's 3rd law is that **there must be** a reaction force for every action force. In other words, forces always occur in pairs. Usually you can easily identify the reaction to every action. For example, the reaction to a student hitting the table in front of them with their hand is the table hits the students hand with an equal-size force in the opposite direction.



Engagement Questions

A skydiver falls after jumping out of an airplane.

1. What force makes the skydiver fall?



2. What is the reaction to the force that you mentioned in question 1?



Check your work with your teacher.  ☐



The Challenge

You will determine how Newton's third law applies to different-mass objects that push off of each other. In particular you will consider the different accelerations that the different-mass objects acquire as a result of the push.

Your Ideas about the Challenge

Two different size students, initially at rest on ice skates, push off of one another.

3. Which student experiences the greater force during the push off?

Explain how you know.



4. Which student, do you think, experiences the greater acceleration during the push off?



At each lab station you should find the following materials:
a computer with an interface, two photogates, two carts with flags attached to the top, and a spring.



The Investigation

- The two lab carts should be held together so that they are lined up touching together with the compressed spring in between them.
- The two photogates should be on opposite sides of the two carts so that when the two carts are released the flag attached to the top of each cart will completely pass through the opposite photogate.
- One student should start the timing program.
- Release the carts so that they “spring” away from one another and each cart’s flag passes completely through a photogate.
- Stop each cart after their flag has completely passed through the photogate.
- Record the velocity for each cart in the data table below.
- “Weigh” each cart and record its mass expressed in kilograms in the data table below.

Data Table

	Final Velocity (m/s)	Mass (kg)
Cart 1		
Cart 2		

5. Did either cart have considerably more mass than the other cart?



6. Were the velocities for the two carts pretty much the same magnitude or did one cart have a much greater velocity than the other?



The velocity that you recorded above in the data table would be the final velocity that each cart would have after they had pushed off of one another. The magnitude of the acceleration that each cart experienced would be directly proportional to the magnitude of the final velocity that they acquired. This can be seen from the kinematics equation: $v = v_0 + at$.

$$v = v_0 + at$$

$$a = \frac{v - v_0}{t}$$

Since the initial velocity (v_0) was zero for each cart :

$$a = \frac{v}{t}$$

Since the time of the push off was the same for each cart :

$$a \propto v$$

According to Newton’s 3rd law the size of the force that each cart experienced was exactly the same. You can use Newton’s second law ($F_{\text{net}} = ma$) to make predictions about the size of the acceleration that each body should experience. This acceleration should be inversely proportional with respect to the size of the masses of the two bodies that were involved in the action-reaction interaction.

$$\text{Force on cart 1: } F_1 = m_1 a_1$$

$$\text{Force on cart 2: } F_2 = m_2 a_2$$

$$F_1 = F_2$$

$$m_1 a_1 = m_2 a_2$$

$$\frac{a_1}{a_2} = \frac{m_2}{m_1}$$

7. In the case of the two equal mass carts that you used in the investigation what should the ratio m_2/m_1 be equal to?



8. What should the ratio a_1/a_2 be equal to? Should one acceleration have been bigger than, smaller than, or equal in size to the other one? Explain how you know.



At each lab station you should find the following additional materials:
masses that are equivalent to the mass of a single cart.



The Investigation (continued)

- Place the additional mass on top of one of the carts and secure it in position with some masking tape.
- Repeat the procedure followed in the earlier investigation on the preceding page.

Data Table

	Final Velocity (m/s)	Mass (kg)
Cart 1		
Cart 2		

9. Roughly how much more massive was the heavier cart compared to the lighter cart? Was it the same mass, twice as massive, three times as massive . . . ?



10. Were the velocities for the two carts pretty much the same magnitude or did one cart have a much greater velocity than the other? If so, roughly how much bigger was the final velocity of the faster cart? Was it twice as fast, three times as fast, four times as fast . . . ?



11. Which cart had the greater velocity? Was it the lighter cart or the more massive cart? Explain why you think that this happened in terms of the relative mass of each cart, the force that each one experienced during the push off, and the resulting acceleration for each cart.



Check your work with your teacher.  ☐



Force Newton's Third Law

CONCEPT REFINEMENT

Review

Newton's third law describes the equal magnitude and the opposite direction for the forces that make up an action-reaction pair. This law says that for every force there is an equal reaction force that is in exactly the opposite direction. It also says that there cannot be any isolated forces; all forces occur in pairs.

For the following forces identify the reaction force:



Action force	Reaction force
1. A student touches a wall	
2. A girl's toes strike another girl's shin	
3. A knife slices some bread	
4. The weight of a student	
5. The force of gravity acting on a falling student	

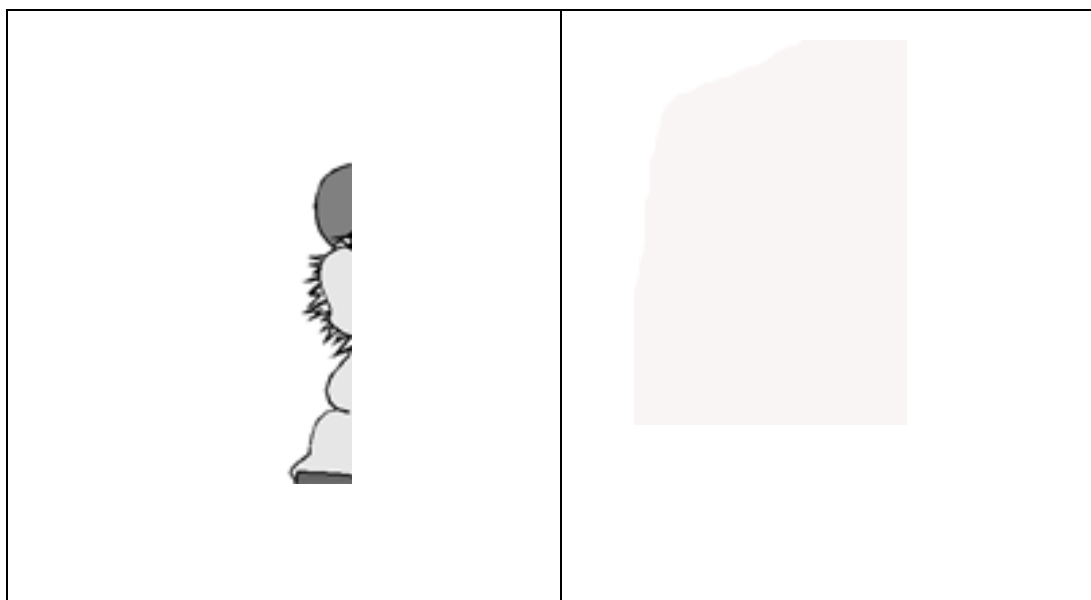
Check your work with your teacher. 

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A man is asked to mow the lawn by his wife.

The man tells his wife that this would be impossible to do. He reasons that no matter how hard he pushes on the lawnmower, the lawnmower will push back on him just as hard. Therefore he won't be able to move the lawnmower.

To convince her husband that he can do this job, she draws separate free-body diagrams for both the lawnmower and the man.



6. Draw and label all of the forces that act on the man while he pushes on the lawnmower. Draw and label all of the forces that act on the lawnmower as the man pushes it. Be sure to include friction in each of your diagrams.



7. What are the horizontal forces that act on the lawnmower?



8. Which of the forces that you mentioned in question 7 would have to be bigger in order for the lawnmower to accelerate forward? Hint: is there an unbalanced-net force acting on the lawnmower?



There should only be one action-reaction pair between all of the forces that you drew in the two diagrams.

9. What are the two forces that make up this action-reaction pair.



10. Do each of the two forces, that make up the action-reaction pair, act on the same object or on different objects?



Check your work with your teacher.



Two 500 g carts are held together with a spring compressed between them.	
A 1 kg (1,000 g) mass is placed on top of one of the 500 g carts.	
The carts are released so that the spring pushes each cart away from the other one. The heavier cart experiences an acceleration of 2 m/s^2 .	

11. Calculate the acceleration of the lighter cart as the two carts push off of one another.



Check your work with your teacher.  ☐