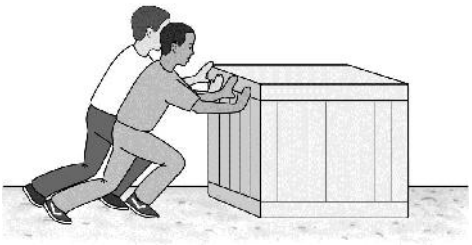
Unit 2 Cycle 2

Beginnings: What if there is more than one force?

Purpose

In the previous Cycle of activities you examined what effect a force has on the motion of an object. However, often more than one force acts on a single object at the same time. For example, as two men push a heavy box across the floor, they are each applying a "forward" force to it. At the same time a "backward" frictional force is also being applied to the box by the floor. In this Cycle of activities we will examine what effect such a ***combination of forces*** has on an object?



To start this Cycle we will think about what happens when a combination of forces acts on an object that is not moving.

The big question we will address in this *Beginnings* activity is:

What happens when a combination of forces acts on an object that is not moving?

What do we think?

Two brothers are arguing over a stuffed toy and begin to pull on it in opposite directions. The toy was not moving when they started pulling.

What do you think would happen if the forces applied to the toy by the two brothers have exactly the same strength? Would it start to move or not? If so, in which direction?

What do you think would happen if the strength of one brother's pull was greater than that of the other brother? Would the toy start to move or not? If so, in which direction?

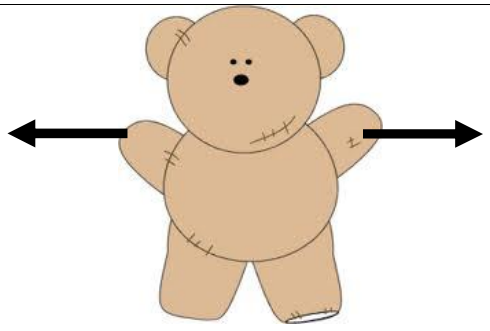
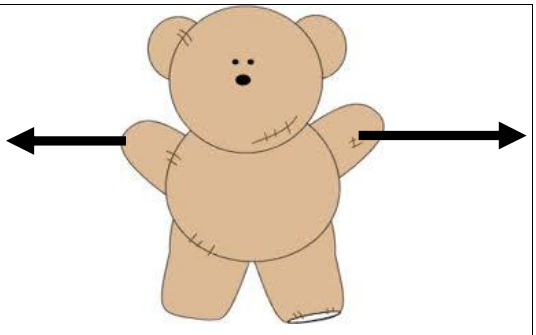
Your teacher will lead a class discussion about everyone's answers to these questions, and the explanations of their thinking.

Balanced and Unbalanced Combinations of Forces

When equal strength forces act on an object in opposite directions we say the forces are ***balanced***. When the two brothers pulled equally hard on the toy, their forces were balanced.

When the strengths of the force acting in opposite directions are not the same, we say the forces are ***unbalanced***. When one brother pulled harder on the toy than the other, the combination of their forces was unbalanced.

We can draw a ***force diagram*** for an object using arrows to show the forces acting on it. The length of the arrows shows the strength of the forces. Force diagrams for the toy when the two brothers were pulling on it, are shown below.

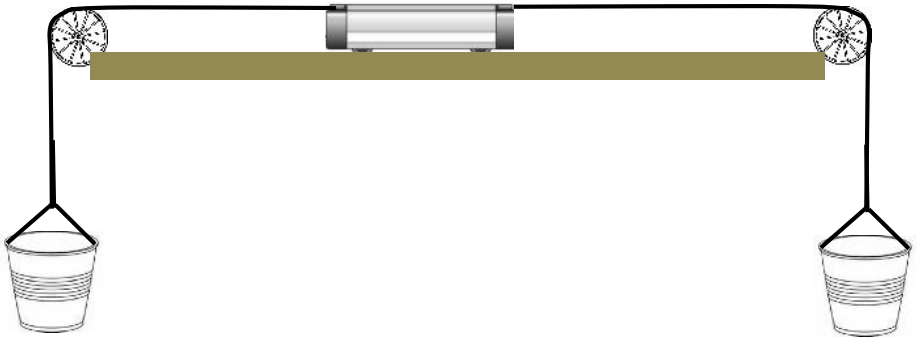
	
Balanced Forces: The two brothers apply equal strength forces in opposite directions. (Both force arrows are the same length.)	**Unbalanced Forces:** One brother applies a stronger force than the other brother. (One force arrow is longer than the other.)

Activity: Two forces in opposite directions

Your class will work together for this activity. The class will need:

- Computers on which to view movies, or a way for the whole class to view a projected movie.

STEP 1: The object to be used to test the effect of combinations of forces is a low-friction cart on a track. A string is tied to each end of the cart and these strings pass over pulleys at each end of the track. A cup is hanging from the end of each string.



When objects, such as sugar cubes, are added to the cups, they will pull downward on the string. The string, in turn, will apply a force to the cart. When the cart is released it will be free to move and you will be able to see what effect the combination of the two forces acting on the cart has.

Your teacher may direct you to watch a movie showing this setup.

Now, suppose the cart was held still, an equal number of sugar cubes were placed in each of the two cups, and then the cart was released.

Do you think the cart would start to move when released, or not? Why do you think so?

Now suppose more sugar cubes were placed in one cup than in the other while it was being held still.

Do you think the cart would start to move now when released, or not? Why do you think so?

Your teacher will lead a class discussion about these questions.

STEP 2: Your teacher will direct you to watch a movie in which various numbers of sugar cubes are added to the two cups in the setup.

The movie will start by testing some combinations for which there are equal numbers of sugar cubes in both cups

In this case are the forces acting on the cart balanced or unbalanced? How do you know?

Describe what happens to the cart after it is released and a balanced combination of forces acts on it. Does it start to move or not?

Do all the balanced combinations of forces tested have the same effect? Why do you think this is?

The second part of the movie shows tests in which the numbers of sugar cubes in the two cups are not equal.

In this case are the forces acting on the cart balanced or unbalanced? How do you know?

Describe what happens to the cart after it is released now. Does it start to move or not?

Do all the unbalanced combinations of forces tested have the same effect? Why do you think this is?

Making Sense

Your teacher will lead a class discussion about what happens when a combination of forces acts on an object that is not moving. Write answers to the following questions after each one is discussed by the class.

1. When a **balanced** combination of forces acts on an object that is not moving, what happens? Is this more like the effect of having no forces, or more like the effect of a single force? Why do you think this is?

2. When an **unbalanced** combination of forces acts on an object that is not moving, what happens? Is this more like the effect of having no forces, or more like the effect of a single force? Why do you think this is?

3. When a single force acts on an object, is it similar to having two forces on an object that are balanced or unbalanced? Explain your thinking.

4. When no forces act on an object is it similar to having two forces on an object that are balanced or unbalanced? Explain your thinking.

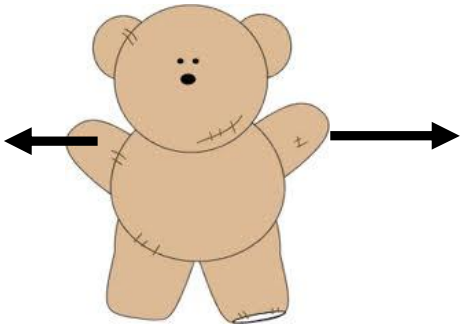
5. Imagine you have a chair that is on wheels. If you push gently on it, it will start to move. Does this mean the forces acting on it are balanced or unbalanced?

6. Now imagine you take the wheels off the chair. If you now push gently on it, it will not start to move. Does this mean the forces acting on it are balanced or unbalanced? How can this be?

Exploration #1: What combinations of forces have the same effect?

Purpose

In the *Beginnings* activity for this Cycle you saw that when an unbalanced combination of forces acts on an object, it will start to move. But, after it has started, would the motion of the cart be **exactly the same** for all unbalanced combinations of forces or would it depend how strong each force was?



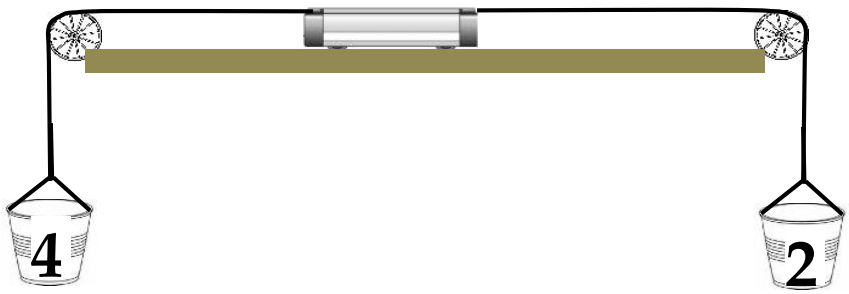
The big question we will address in this *Exploration* activity is:

What unbalanced combinations of forces have exactly the same effect on an object?

What do we think?

In the previous activity you saw a low-friction cart being acted on by various combinations of forces. In that activity, we were interested only in which combinations started the cart moving and which did not. In this lesson we will be interested in which combinations make the cart move in exactly the same manner.

Suppose you had a setup like that shown below, with 4 sugar cubes in one cup and 2 in the other. You know that if this cart was released it would start to move to the left. We will judge the manner in which it moves from the amount of distance it travels in a certain amount of time.



Suggest two or three other arrangements of sugar cubes you could put in the two cups that would make the cart move in exactly the same manner as the 4 and 2 combination. (That is, make the cart travel the same distance as the 4 and 2 combination in the same amount of time.)

Explain why you think your arrangements would work.

Your teacher will lead a class discussion about everyone's answers to this question, and the explanations.

Activity #1: Which combinations behave the same?

Your class will work together for this activity. The class will need:

- Computers on which to view movies, or a way for the whole class to view a projected movie.

STEP 1: One suggestion that has been made is that it is only the strongest force that determines how an object behaves, and that the weaker force will not make any difference. If this is true, then any combination that has 4 sugar cubes in one cup and 1, 2, or 3 sugar cubes in the other cup, should behave in exactly the same manner.

Do you think a 4 and 1 or a 4 and 3 combination will behave in exactly the same manner as a 4 and 2 combination, or not? Explain your thinking.

You will now see a movie segment in which 4 and 1, 4 and 2, and 4 and 3 combinations are tested at the same time.

What does the movie show? Do all three combinations behave in exactly the same manner or not?

The idea we were trying to test in this STEP was that when the stronger force stays the same in different combinations of forces, the cart moves in exactly the same manner.

 Does the result of the test you saw in the movie support this idea or not?

STEP 2: Another suggestion that has been made is that it is the ratio of the stronger to the weaker force that determines how an object behaves. For the 4 and 2 combination, the stronger force is twice as big as the weaker force. So, if this idea is correct, then whenever one cup has twice as many sugar cubes as the other cup, such as 6 and 3 or 2 and 1, that combination should have exactly the same effect as the 4 and 2 combination.

 Do you think either a 6 and 3 or a 2 and 1 combination would behave in exactly the same manner as a 4 and 2 combination, or not? Explain your thinking.

You will now see a movie segment in which 6 and 3, 4 and 2, and 2 and 1 combinations are tested at the same time.

 What does the movie show? Do all three combinations behave in exactly the same manner or not?

The idea we were trying to test was that whenever the stronger force is twice as large as the weaker force the cart moves in exactly the same manner.

 Does the result of the test you saw in the movie support this idea or not?

STEP 3: A third suggestion that has been made is that it is how much bigger the stronger force is than the weaker force that determines how an object behaves. For the 4- and 2 combination, the stronger side has two more sugar cubes than the weaker side. This idea suggests that whenever one cup has two more sugar cubes than the other, the combination should have exactly the same effect as the 4 and 2 combination. Examples of such combinations would be 5 and 3 and 3 and 1.

Do you think either a 5 and 3 or a 3 and 1 combination would behave in exactly the same manner as a 4 and 2 combination, or not? Explain your thinking.

Your will now see a movie segment in which 5 and 3, 4 and 2, and 3 and 1 combinations are tested at the same time.

What does the movie show? Do all three combinations behave in exactly the same manner or not?

The idea we were trying to test was that whenever the stronger force is bigger than the weaker force by the same amount, the combinations of forces causes the cart to move in exactly the same manner.

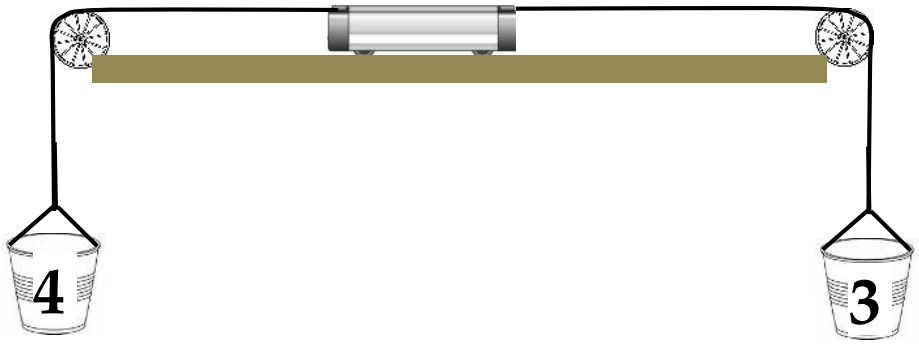
Does the result of the test you saw in the movie support this idea or not?

STEP 4: You have now seen tests of three possible ideas about what unbalanced combinations of forces have the same effect on the cart.

Your teacher will lead a class discussion about these tests

Which of the three ideas you have seen tested seems to be correct?

STEP 5: In STEP 1 you saw that a 4 and 2 combination did not have exactly the same effect on the cart as a 4 and 3 combination.



Use the idea you identified as correct in STEP 4 to suggest two or three different combinations that you think would have exactly the same effect on the cart as a 4 and 3 combination. Explain your thinking.

Your teacher will lead a class discussion about everyone's ideas and then you will see two movie segments that show various combinations tested at the same time as a 4 and 3 combination.

Make a note of the combinations tested in the movie that behave in exactly the same manner as the 4 and 3 combination?

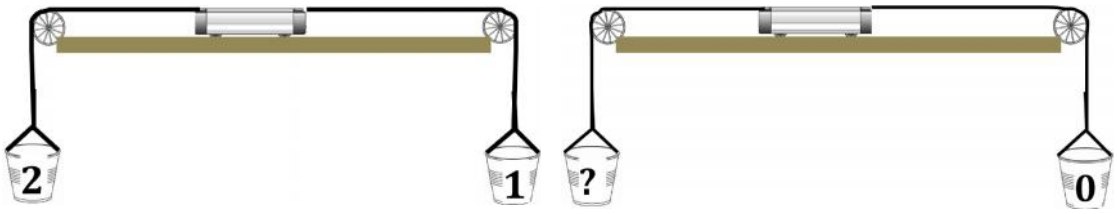
Why do you think all these combinations behaved in the same manner? What did these arrangements have in common?

Activity #2: Combinations for which one force is zero?

Your class will work together for this activity. The class will need:

- Computers on which to view movies, or a way for the whole class to view a projected movie.

STEP 1: Now suppose you wanted to find a combination that behaved in exactly the same way as a 2 and 1 combination, ***but were not allowed to put any sugar cubes in one of the cups***.



Suppose you tested both a 1 and 0 and a 2 and 0 combination alongside a 2 and 1 combination.

Do you think the 1 and 0 combination, the 2 and 0 combination, both, or neither would behave in the same manner as the 2 and 1 combination? Explain your thinking.

You will now see a movie segment in which 2 and 1, 1 and 0, and 2 and 0 combinations are tested at the same time.

What does the movie show? Which combination behaves in exactly the same manner as the 2 and 1 combination, the 1 and 0 or the 2 and 0?

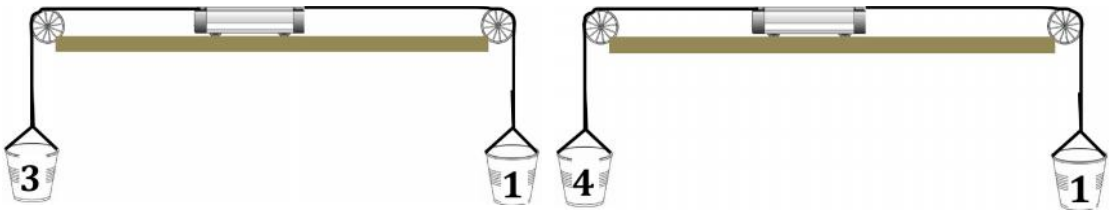
Why do you think this particular combination behaves in the same manner as the 2 and 1 combination?

Net Force

As you have seen, there were many combinations of sugar cubes that would have the same effect on the cart as the 2 and 1 combination (for example, 3 and 2, 4 and 3, etc.). You have also seen that there was one combination in which you needed to put a single sugar cube in only one cup to have the same effect. Because there was a sugar cube in only one cup, and none in the other, there was only a single force acting on the cart in this case. When a combination of forces acts on an object, you can always find a single force that will have exactly the same effect. We call the strength of the single force that will have same effect as a combination of forces the **net force** acting on the object.

For example, if we had 2 sugar cubes in one cup and 1 in the other we could also make the cart behave in exactly the same way by putting only 1 sugar cube in one cup and leaving the other empty. So we can say that the net force acting on the cart was that of only 1 sugar cube.

STEP 2: Now suppose you had a 3 and 1 combination and a 4 and 1 combination.



What is the net force for each of these combinations?

How could you make the cart move in the same manner as each of these, by placing sugar cubes in only one cup?

Your teacher will lead a class discussion about everyone's ideas and then you will see two movie segments in which you will see various combinations tested.

Which combination behaves in exactly the same manner as the 3 and 1 combination, the 2 and 0 or the 3 and 0?

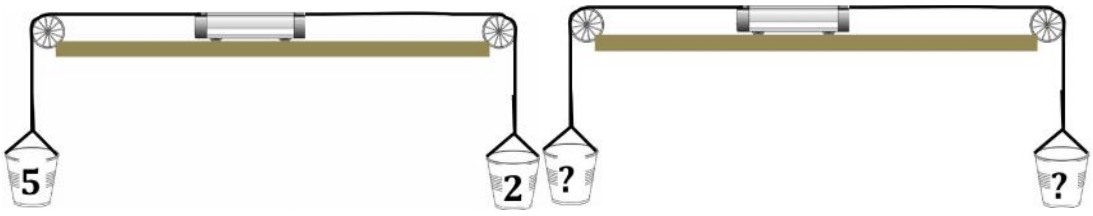
Which combination behaves in exactly the same manner as the 4 ***and*** 1 combination, the 2 ***and*** 0 or the 3 ***and*** 0?

Why do you think it is that these particular combinations behave in the same manner as the 3 ***and*** 1 and 4 ***and*** 1 combinations?

Making Sense

Your teacher will lead a class discussion about combinations of forces and net force. Write answers to the questions below after each one is discussed.

1. Suppose the combination was changed to have 5 sugar cubes in one cup and 2 in the other.



a) Suggest two different arrangements of sugar cubes that would make the cart behave in the same manner as the 5 and 2 combination.

b) What is the net force for the 5 ***and*** 2 arrangement? How do you know?

2 Suppose you had three cups and placed sugar cubes in them as shown below.

What is the net force of this arrangement of sugar cubes? How do you know?

3. Describe how you can find the net force acting for any combination of forces acting on an object.

4. If a balanced combination of forces acts on an object, what is the net force acting on it?

Exploration #2: What effect do combinations of forces have on motion?

Purpose

You now know what happens when a combination of forces (either balanced or unbalanced) acts on an object that is not moving. We will now examine what happens to an object that is already moving when a combination of forces acts on it.

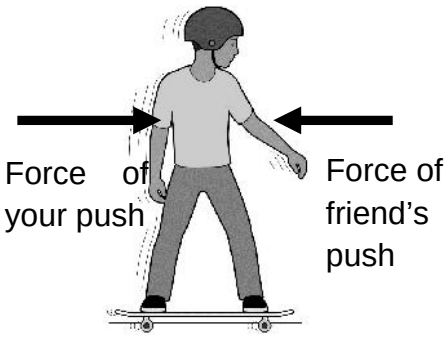
For example, suppose a boy pulls on his toy wagon to start it moving across the floor in the direction of his pull. Because her teddy bear is in the wagon, his sister starts to pull on the wagon in the opposite direction to her brother. How would the speed of the wagon behave now, with this combination of forces acting on it? Would it matter whether the combination of forces was balanced or unbalanced?

The big question we will address in this *Exploration* activity is:

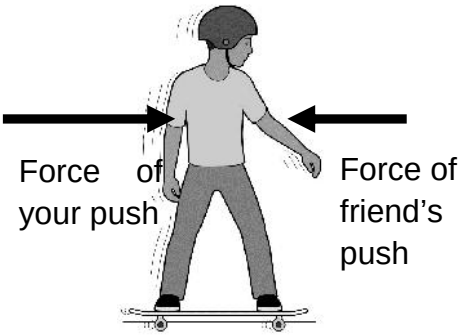
What effect does a combination of forces have on a moving object?

What do we think?

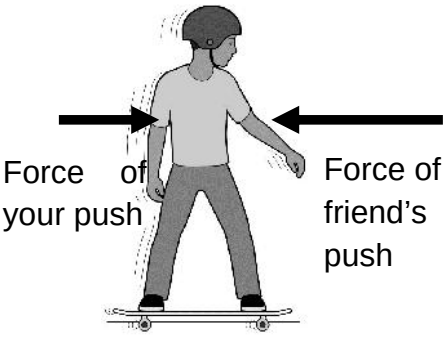
Imagine your friend is already moving along on his skateboard. As he is moving you push on him in the same direction as he is moving, while another friend pushes on him in the opposite direction. What will his motion be like while you are both pushing? Would your answer be different depending on which force was strongest?



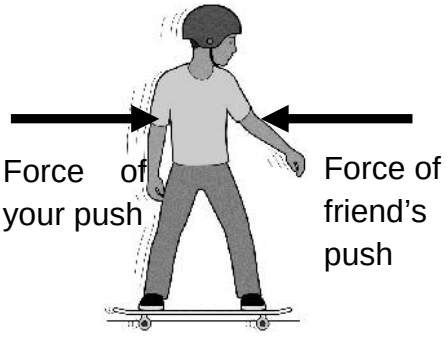
If your forward push was **stronger** than your friend's backward push, do you think the skateboarder's speed would increase, decrease, or stay constant? Why do you think so?



If your forward push was **weaker** than your friend's backward push, do you think the skateboarder's speed would increase, decrease, or stay constant? Why do you think so?



If your forward push was **equal in strength** to your friend's backward push, do you think the skateboarder's speed would increase, decrease, or stay constant? Why do you think so?



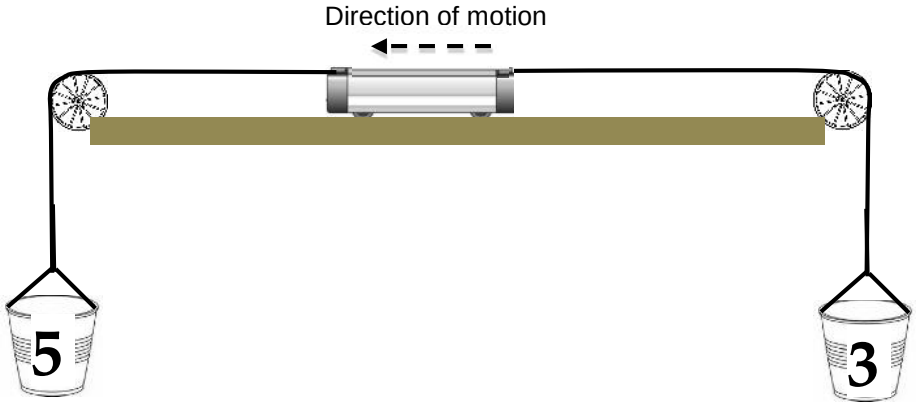
Your teacher will lead a class discussion about everyone's answers to these questions.

Activity #1: How does the speed behave when unbalanced forces act on a moving object?

Your class will work together for this activity. The class will need:

- Computers on which to view movies, or a way for the whole class to view a projected movie.

STEP 1: We will again test our ideas using the setup of a cart on a track and loading sugar cubes into the cups attached to each end. Suppose you had a setup like that shown below, with a 5 and 3 combination of sugar cubes. You know that when this cart is released it will start to move to the left but now we are interested in what happens to its speed **after it starts moving**, while this unbalanced combination of forces is still being applied to it.

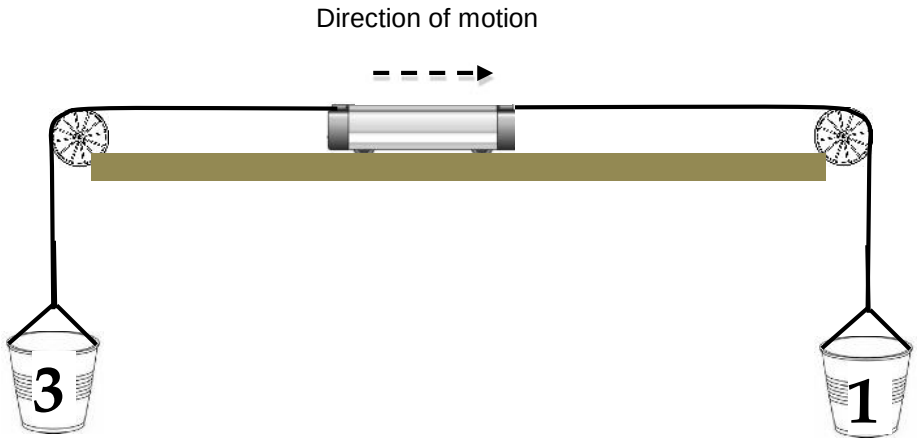


After it starts moving, do you think the cart's speed will increase, decrease, or stay constant? Why do you think so?

Your teacher will show you a movie of this setup. In order to judge what is happening to the cart's speed, its position will be marked with a white dot at one-second time intervals.

After it starts moving does the cart's speed increase, decrease, or stay constant? How does the pattern of dots tell you this?

STEP 2: Now we want to check what happens if the stronger force is pulling in the opposite direction to the cart's motion. To see this we will take the 3 and 1 combination setup shown below, but start it moving to the right with a quick push. After the push is over the stronger force will be pulling on the cart in the opposite direction to its motion.



After the push, while the cart is moving to the right, do you think its speed will increase, decrease, or stay constant? Why do you think so?

Your teacher will show you a movie of this setup. In order to judge what is happening to the cart's speed its position will be marked with a dot at one-second time intervals.

After the quick push is over what happens to the cart's speed at first? Does it increase, decrease, or stay constant? How does the pattern of WHITE dots tell you this?

Why do you think the cart starts moving back in the opposite direction after it has come to a stop?

While the cart is moving back to its starting point does its speed increase, decrease, or stay constant? How does the pattern of RED dots tell you this?

Why do you think the cart's speed behaves like this on the way back to the starting point? What is it about the forces acting on it that makes this happen?

STEP 3: In the previous lesson you saw that when an unbalanced combination of forces acts on an object you can always combine those forces into a single force, called the net force, that would have the same effect.

In the setup you saw in STEP 1, was the net force acting on the cart in the same direction as its motion, or in the opposite direction to its motion?

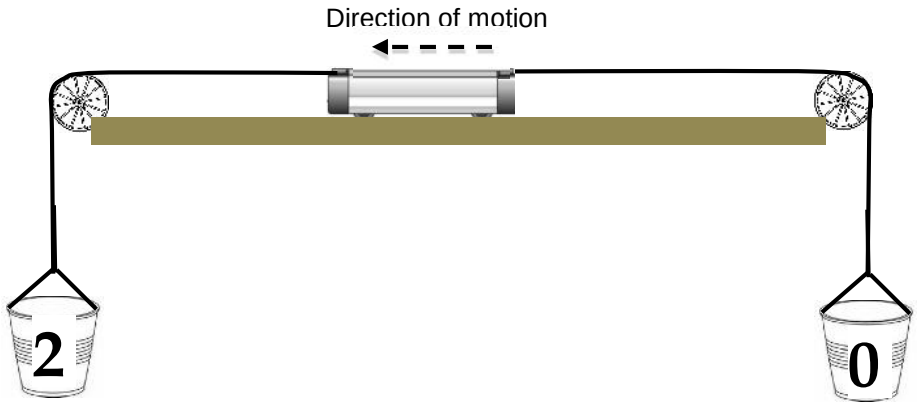
Why might it make sense that when the stronger force is acting in the same direction as the cart's motion, its speed increases?

In the setup you saw in STEP 2, was the net force acting on the cart in the same direction as its motion, or in the opposite direction to its motion?

Why might it make sense that when the stronger force is acting in the opposite direction to the cart's motion, its speed decreases (and it then reverses direction)?

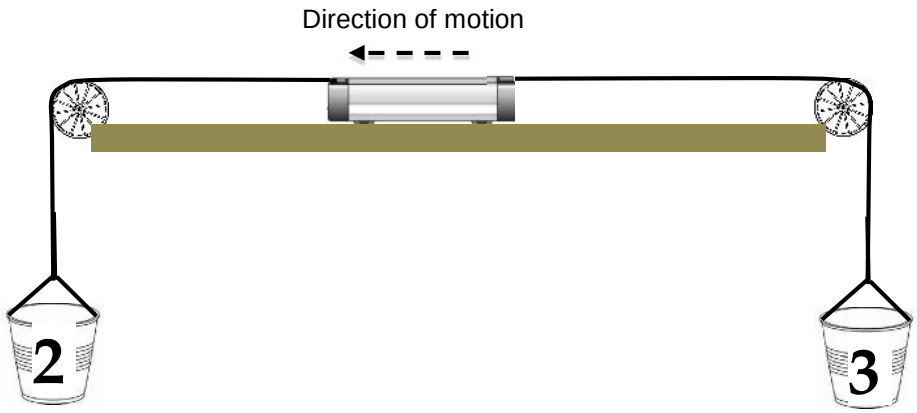
Your teacher will lead a class discussion about these questions.

STEP 4: Now let's check our thinking with a slightly more complicated situation. Suppose we release the cart while a 2 and 0 combination is applied to it.



After it starts moving (with the 2 and 0 combination still being applied), do you think the cart's speed will increase, decrease, or stay constant?

After the cart has been moving for a short time, 3 sugar cubes will be dropped into the right cup, so making the force in the opposite direction stronger than the force in the direction of motion.



After the 3 sugar cubes are dropped into the right cup do you think the speed of the cart will increase, decrease, or stay constant? Why do you think so?

Your teacher will lead a class discussion about this question.

You teacher will show you a movie of this setup. As, usual, in order to judge what is happening to the cart's speed its position will be marked with a dot at one-second time intervals.

After it starts moving, while the 2 and 0 combination is applied to it, does its speed increase, decrease, or stay constant? How does the pattern of WHITE dots tell you this?

Why does its speed behave in this manner at first?

After the 3 sugar cubes are dropped in the right cup, does the cart's speed then increase, decrease, or stay constant? How does the pattern of GREEN dots tell you this?

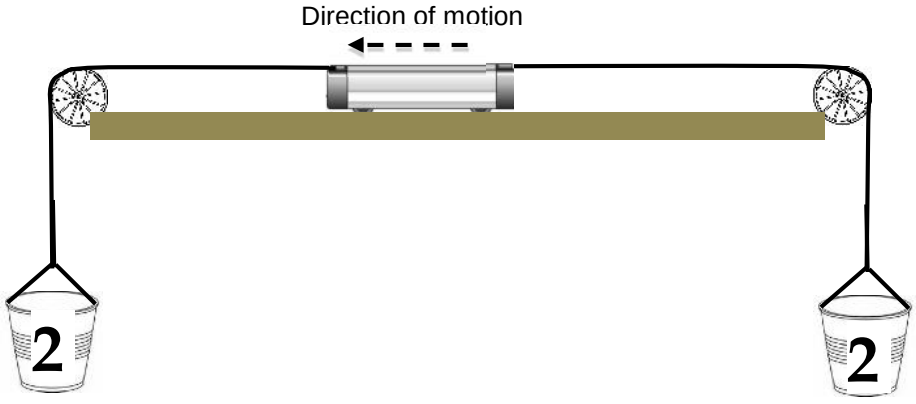
Why do you think the cart the cart's speed behaves differently after the 2 and 0 combination is changed to a 2 and 3 combination?

Activity #2: How does the speed behave when balanced forces act on a moving object?

STEP 1: In the first part of this lesson we investigated how an unbalanced combination of forces affects an object that is already moving. Now we will think about what would happen if balanced forces are applied to an object that is already moving.

We will again test our thinking by releasing the cart while a 2 and 0 combination is applied to it.

However, after the cart has been moving for a short time 2 sugar cubes will be dropped into the right cup, making the forces **exactly balanced**.



After the 2 sugar cubes are dropped into the right cup do you think its speed will increase, decrease, or stay constant, or will something else happen? Why do you think so?

Your teacher will lead a class discussion about this question.

Your teacher will show you a movie of this setup. The white dots will show that its speed was increasing while the 2 and 0 combination was applied.

After the 2 sugar cubes are dropped in the right cup, does the cart's speed then increase, decrease, or stay constant? How does the pattern of GREEN dots tell you this?

Why do you think the cart's speed behaves in this way after the 2 and 0 combination is changed to a 2 and 2 combination?

Making Sense

Your teacher will lead a class discussion about the effect that combinations of forces have on the motion of an object. Write answers to the questions below after each one is discussed.

1. a) When an unbalanced combination of forces acts on a moving object what happens to its speed? Does it change, or does it remain constant?

   b) Why does this make sense in terms of the net force acting on the object?

2. a) When a balanced combination of forces acts on a moving object what happens to its speed? Does it change, or does it remain constant?

   b) Why does this make sense in terms of the net force acting on the object?

3. A car is waiting at a stop light. When the light turns green the car starts moving, getting faster and faster. After a few seconds it reaches 30 mph and then continues at a constant speed down a long straight road for a while. It then slows and stops at the next stop light. For each of these parts of its motion, decide whether the forces acting on the car are balanced or unbalanced. Also explain how you know.

   a) While the car is waiting at the red light, not moving.

   b) While the car is getting faster and faster as it moves away from the light.

   c) While the car is moving at a constant speed of 30 mph down a long straight road.

   d) While the car is getting slower and slower as it approaches the next stop light.

Unit 2 Cycle 2

Application: Balanced or Unbalanced?

Purpose

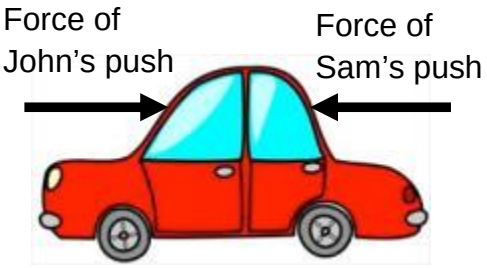
You now know how balanced and unbalanced combinations of forces affect the motion of an object. In this *Application* activity you will practice using these ideas to think about the forces acting on various objects. The big question we will address in this activity is:

How can we tell if the forces acting on an object are balanced or unbalanced?

What do we think?

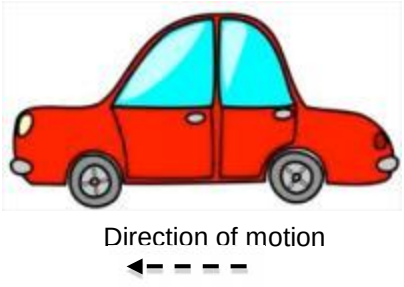
Suppose John and Sam push in opposite directions on a toy car that is standing still.

If the car still does not move while they are pushing on it what can you say about the forces acting on the car? Who is applying the stronger force, John or Sam, or are they the same strength?



Now suppose that after a few seconds, the car starts to move in the direction shown.

As the car is starting to move are the forces acting on it balanced or unbalanced? Who is applying the stronger force now, John or Sam? Draw force arrows on the picture of the car to show your thinking.



After the car starts to move, its speed keeps increasing for a few seconds.

Direction of motion, increasing speed

As the car is moving faster and faster are the forces acting on it balanced or unbalanced? Who is applying the stronger force, John or Sam? Again, draw force arrows on the picture of the car to show your thinking.

After a few seconds the car's speed stops increasing and it then moves at a constant speed for a few more seconds.

Direction of motion, constant speed

While the car is moving at a constant speed are the forces acting on it balanced or unbalanced? Who is applying the stronger force, John or Sam? Again, draw force arrows on the picture of the car to show your thinking.

Finally the car slows and stops.

Direction of motion, decreasing speed

While the car is moving at a slower and slower speed are the forces acting on it balanced or unbalanced? Who is applying the stronger force this time, John or Sam? As usual, draw force arrows on the picture of the car to show your thinking.

Your teacher will lead a class discussion about everyone's answers to these questions.

Activity 1: How does friction compare to your force?

You will work with a partner for this activity. You will need:

- A wooden block

STEP 1: Place the wooden block on the table in front of you. Push it so that it starts to move and keep pushing so it slides across the table at a constant speed. Because it is sliding you know that a friction force must be acting on it, but so is the force of your push.

As the block starts to move which force is strongest, the force of your push or the force of friction? Explain how you know and draw a diagram showing the forces acting on the block to show your thinking.

As the block is sliding across the table at a constant speed which force is strongest, the force of your push or the force of friction? Explain how you know and draw a diagram showing the forces acting on the block to show your thinking.

STEP 2: When you stop pushing on the block it will quickly slow and stop.

While the block is slowing what is the only forward or backward force acting on it? Explain why this force makes it move slower and slower and draw a force diagram to show your thinking.

STEP 3: Now think about the block while it is resting on the table, not moving, and you are not pushing it.

Is there a friction force acting on the block while it is not moving, and you are not pushing it? Carefully explain your reasoning.

Making Sense

Your teacher will lead a class discussion about the forces acting on the block under different conditions. Write answers to the following questions after each one is discussed.

1. For each of the following objects, state whether the forces acting on it are balanced or unbalanced, and how you know.

   a) A race car as it slows after finishing a race.

   b) A snail as it starts to move.

   c) A sports car as it drives down a long straight road at 70 mph.

2. You are used to thinking about a frictional force acting on a moving object. Scientists call this ***kinetic friction***. However, when you attempt to start an object moving, before it starts to move another form of friction (known as ***static friction***) opposes your attempt. Suppose you try to move a heavy couch across the floor, but despite pushing as hard as you can, it does not start to move. Is the static friction force acting in the opposite direction weaker than, equal to, or stronger than your force? Carefully explain how you know.

Application #2: Are the up and down forces balanced or unbalanced?

Purpose

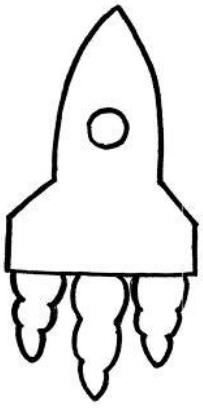
So far all of the examples of combinations of forces you have examined were pushing or pulling objects horizontally. In this *Application* activity you will use the same ideas to think about situations in which the forces act vertically, that is they point upward and downward. The big question we will address in this activity is:

How can we tell if the forces acting upward and downward on an object are balanced or unbalanced?

What do we think?

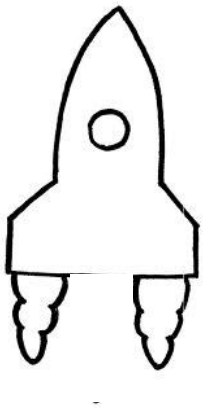
Think about a toy rocket sitting on the launch pad. It has three engines attached to it. When all three engines fire the rocket starts to move upward, getting faster and faster as it climbs.

Which force acting on it do you think is stronger, the gravitational force pulling downward on it, or the total force of all three engines pushing upward on it, or are they the same strength? How do you know? Draw force arrows on the picture to show your thinking.



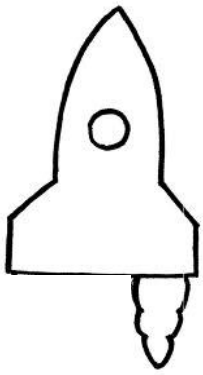
After a few seconds one of the engines stops working, but it continues to climb higher at a constant speed.

Which force acting on the rocket do you think is stronger now, the gravitational force pulling downward on it, or the force of the two engines still upward on it, or are they both the same strength? How do you know? Draw force arrows on the picture to show your thinking.



After yet another few seconds a second engines stop working. The rocket still continues climbing higher, but now gets slower and slower as it climbs

Which force acting on it do you think is stronger now, the gravitational force pulling downward on it, or the force of the one working engine still pushing upward on it, or are they both the same strength? How do you know? Draw force arrows on the picture to show your thinking.



Your teacher will lead a class discussion about everyone's answers to these questions.

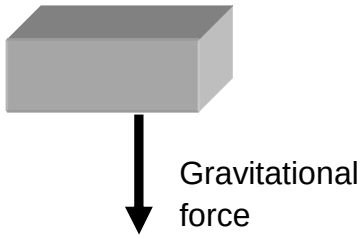
Activity 1: Resting on a surface?

You will work with a partner for this activity. You will need:

- A wooden block

STEP 1: Hold your hand so the palm is a flat surface. Place the block on your hand but do not move it up or down.

You know a gravitational force is pulling the block downward, but there must also be another force acting on the block as it sits at rest on your hand. Explain how you know this.



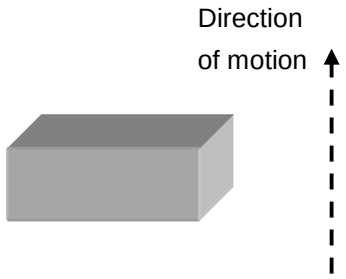
Draw an arrow on the drawing of the block to show which direction you think this other force is acting.

Which other object do you think is applying this force to the block?

What would happen to the block if this other force were taken away? Explain why this would happen.

STEP 2: Now move your hand up, so that the block starts to move upward.

As the block is starting to move upward, are the two forces acting on it balanced or unbalanced? Which of these forces is the strongest, the upward or downward force? Explain how you know.



STEP 3: Finally, put the block on the table in front of you.

Is the table applying a force to the block? If so, in what direction? How do you know?

How do you think the strength of the force applied by the table to the block compares to the strength of the gravitational force acting on it? Are they equal, or is one stronger than the other? Explain how you know.

Your teacher will lead a class discussion about everyone's answers to these questions.

Supporting forces

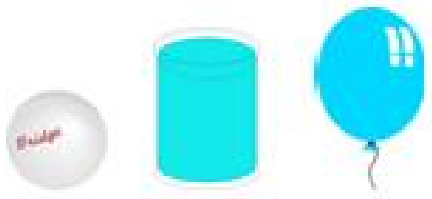
We know that a gravitational force pulls all objects downward, but most objects do not seem to be falling. For instance, as you sit in your chair, a gravitational force is pulling you downward, but you do not fall. However, if someone were to pull your chair away from under you, then you would fall.

If an object is not moving upward or downward, then the downward gravitational force must be exactly balanced by an upward force applied to it by whatever it is resting on. This could be a chair, a table, your hand, or even the floor (or the ground). We will call these ***supporting forces***. We know these forces must be there because if the table or chair were to be suddenly removed then the object would start to fall, telling us the forces acting on it have become unbalanced.

Activity 2: Why do some objects float upward?

The class will work together on this activity. The class will need:

- A small ball
- A pail or bowl of water
- A helium-filled balloon



STEP 1: Your teacher will place the ball in the water so that it is floating on the surface.

Is the water applying a force to the ball? If so, in what direction? How do you know?

How do you think the strength of the force exerted by the water on the ball compares to the strength of the gravitational force pulling downward on it? Are they equal, or is one stronger than the other? Explain how you know.

STEP 2: Your teacher will now hold the ball under the surface of the water and then release it.

 Describe what happens to the ball after it is released.

 Just after the ball is released are the forces acting on it balanced or unbalanced? Explain how you know.

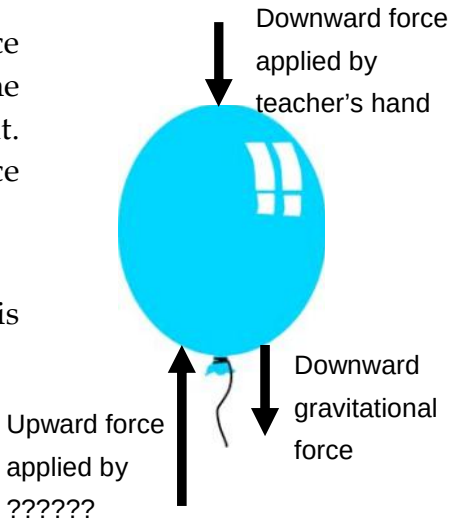
 Just after the ball was released, before it reaches the surface, how do you think the strength of the force applied by the water to the ball compares to the strength of the gravitational force acting on it? Are they equal, or is one stronger than the other? Explain how you know.

STEP 3: Your teacher will now hold the helium-filled balloon so that it is not moving up or down.

 Are the forces acting on the balloon balanced or unbalanced? How do you know?

 Your teacher is applying a force to the balloon to stop it moving, but in which direction is your teacher's force acting, upward or downward? How can you tell? (Hint: what would happen to the balloon if your teacher's hand was not there?)

The balloon is not moving, yet both the force applied by your teacher's hand, and the gravitational force, are acting downward on it. This means there must be some other force pushing it upward.



What object, or substance, do you think is applying this upward force to the balloon?

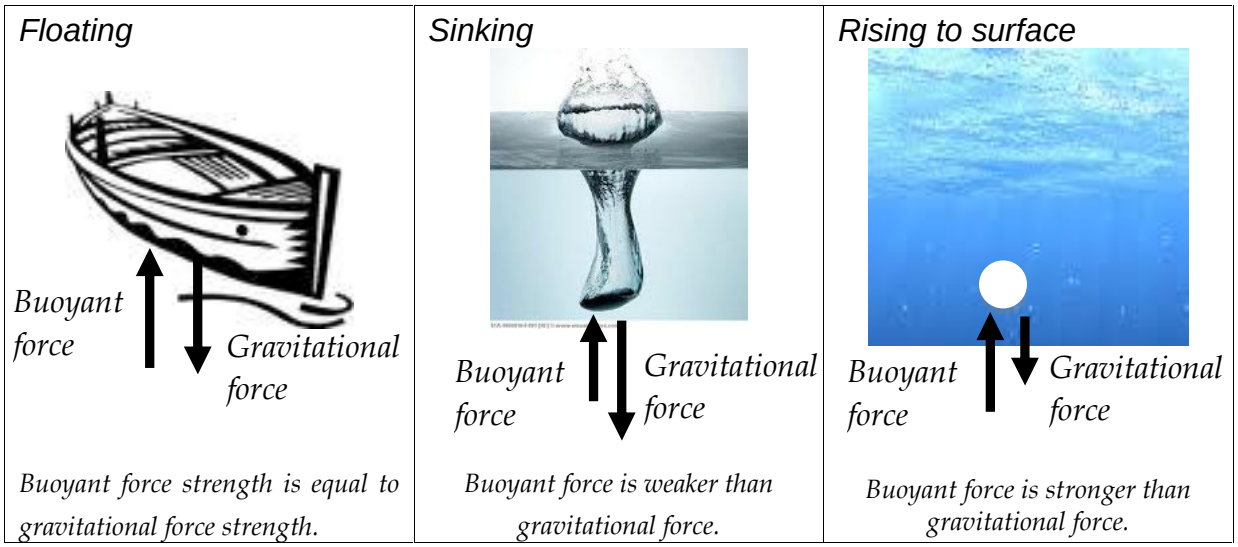
If the force your teacher is applying to the balloon were to be removed, would the forces acting on it be balanced or unbalanced?

What would happen to the balloon if the force your teacher is applying to the balloon were removed? Explain why this would happen in terms of the forces that would still be acting on it.

Buoyant forces

All liquids and gases, such as water and the air, exert force that pushes upward on objects that are placed in them. We call this a ***buoyant force***. If the buoyant force pushing upward on an object in water exactly balances the gravitational force pulling downward on it, then the object will float. An example of this would be a boat floating on a lake. However, if the buoyant force is not strong enough to do this, then the object will sink downward, because the forces acting on it are unbalanced, like a stone tossed into a lake. (It is important to realize that such an object's speed will increase as it continues to sink, because the forces acting on it are unbalanced.)

Finally, it is also possible that the buoyant force may be stronger than the gravitational force, in which case the object will actually start to move upward and rise to the surface. (As it does so, its upward speed will increase because the forces acting on it are unbalanced.) An example of this is a ping-pong ball that is released under water and quickly rises to the surface.



The buoyant force exerted on objects by the air is very weak and can usually be ignored because the gravitational force is much, much stronger. However, in some cases, such as the helium-filled balloon, the gravitational force is actually weaker than the buoyant force and so, if no other forces are present, these objects will actually move upward (with increasing speed), rather than fall downward.

Making Sense

Your teacher will lead a class discussion about forces that act upward and downward on objects. Write answers to the following questions after each one is discussed.

1. For each of the following objects, state whether the upward and downward forces acting on it are balanced or unbalanced, and how you know.

   a) An airplane as it takes off.

   b) A book resting on a table.

   c) An elevator as it moves downward at a constant speed.

   d) A beach ball that is first held under water and then released.