ACTIVITY 4: Strength of the Gravitational Force.

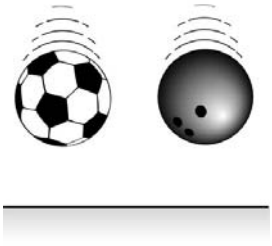
Purpose

In the previous activity you explored how the gravitational force that the Earth exerts on objects makes them fall and speed up as they do so. Do you think that the strength of this gravitational force depends on the mass of the object? For example, does gravity pull with a different strength on a bowling ball and a beach ball? How would this affect the rate at which their speeds increase as they fall, and do any other forces play a role?

How does the strength of the gravitational force affect how objects fall? Do any other forces affect falling objects?

Initial Ideas

If you were to drop a bowling ball and a soccer ball from the same height, which one do you think would reach the floor first? Explain your reasoning.



Participate in a class discussion about everyone's ideas and make a note of any ideas or reasoning different from your own.

Collecting and Interpreting Evidence

Experiment #1: Does the mass of an object affect the strength of the gravitational force of the Earth acting on it?

You will need:

- A 100 g mass and a 1000 g (1 kg) mass

STEP 1: Have one of your team stand with one arm stretched out horizontally, palm upward. Place the 100 g mass on the palm of the outstretched hand.

What forces are acting on the mass as your team member holds it? Are these forces balanced or unbalanced? How do you know?

How does the strength of the force being exerted on the mass by the hand compare with the strength of the gravitational force of the Earth acting on it? Explain your reasoning.

STEP 2: Now have one of your team stand with **both** their arms stretched out horizontally, palms upward. Place the 100 g mass on one palm, and the 1000 g mass on the other. Your team member should note how much 'effort' it takes to hold up both masses and stop them from falling.

Does it require the same 'effort' to hold up both masses, or is it harder to stop one mass from falling than the other? If so, which one?

What do you think this implies about the strength of the force each hand has to exert to stop the masses from falling? Are both hands exerting the same strength force, or is a stronger force required to stop one of the masses falling than the other? If so, which one?

Does your answer to the previous question suggest that the strength of the gravitational force of the Earth pulling downward on both masses is the same, or is it different? Explain your reasoning.

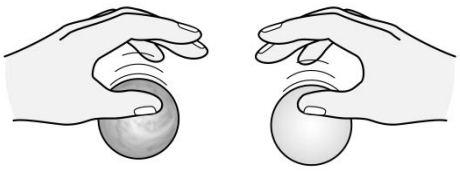
What does this experiment suggest about how the strength of the gravitational force of the Earth acting on an object depends on that object's mass?

Experiment #2: Does the mass of an object affect how it falls?

You will need:

- Several objects with different masses (but similar size and shape)
- Hard board (to drop balls onto)

STEP 1: Imagine you held two balls of a similar size, but different mass, at the same height above the ground and released them.



Which ball do you think would hit the ground first (if either)?

In the Experiment #1 you developed an idea about how the strength of the gravitational force of the Earth acting on an object depends on its mass (if at all). Explain how your answer to the previous question fits, or does not fit, with this idea.

STEP 2: Lay the hard board on the floor. Select two similarly sized objects of different mass and hold them (one in each hand) at the **same height** (about head high) above the board. Release them at the **same time. A**ll your team members should **watch** and **listen** carefully as they hit the board.

Does the more massive object or the less massive one clearly hit the board first, or do they both appear to hit at the same time? (You may want to repeat the experiment to check. Remember to listen if they hit the board at the same time, or at a different time.)

Now, repeat the experiment using different pairs of objects, of varying masses.

Describe your observations about which object hits the board first (if either).

Does there seem to be a relationship between the mass of an object and how quickly it falls? What evidence supports your conclusion?

STEP 3: Your responses to the following questions may help you to understand your observations in STEP 2. **The first three questions refer back to the experiments you performed in Activity 6 of Chapter 2, when you added extra mass to a fan-cart and ran a race between two carts on the simulator.**

If two carts with different masses are each acted on by the **same strength** force, which one will speed up more rapidly, the more massive object or the less massive one? Explain your reasoning.

What would you have to do to the strength of the force acting on the more massive cart, to make it speed up at the same rate as the less massive one? Why would this work?

If two fan-carts, with different masses, ended a race in a tie, would this be evidence that the forces acting on them were the same strength, or different strengths?

In your experiments in this activity you have seen that the same-size objects of different mass all fall at the same rate of increasing speed, and so reach the ground together. What does this result imply about the strength of the force acting on each of them? Is the strength of the force the same on each object, or is it different? Explain your reasoning.

Is your answer to the previous question consistent with what you found out about the relationship between mass and the strength of the gravitational force in Experiment #1 of this activity?

How can it be that the gravitational force of the Earth pulling downward on an object with more mass is stronger than the force on a smaller mass object of the same size, yet they both fall at the same rate of increasing speed? (In thinking about this question you may want to look back at the discussion between two students at the end of Activity 6 of Chapter 2.)

Experiment #3: Does the shape of an object affect how it falls?

You will need:

- A sheet of paper (notebook size)
- A pencil

STEP 1: Do all objects ***really*** fall together? Suppose you were to drop a bowling ball and a feather from the same height, at the same time.

Which one do you think would reach the ground first? Explain your reasoning.

STEP 2: Hold the sheet of paper and the pencil (one in each hand) at the **same height** (about head high) above the ground. Release them at the **same time** and all your team members should watch carefully as they fall.

Does the pencil or the paper hit the floor first? Describe the behavior of the pencil and the paper as they fall.

Why do you think the result of this experiment is different from what you observed in Experiment #2?

STEP 3: Now scrunch the sheet of paper up into a small ball and repeat the experiment.

Now, does the pencil or the paper hit the floor first? Describe the behavior of the pencil and the paper as they fall.

Why do you think the paper behaved differently when you scrunched it up?

Do you think any other force, apart from the gravitational force of the Earth, acts on objects as they fall? If so, does this force affect all objects equally, or does it affect some more than others?

STEP 4: Suppose you were to drop a heavy object (such as a hammer) and a bird's feather from the same height, at the same time.

Which do you think would reach the floor first? Briefly explain your reasoning.

Suppose you could take the hammer and feather to a room where there was no air. All other factors being the same, do you think the lack of air would affect the strength of the **gravitational force of the Earth** acting on the hammer and the feather? If so, why?

Imagine that, in this airless environment, you dropped the hammer and feather from the same height, at the same time? Do you think the result would be different from when you did it in a place where these was air? Explain your reasoning?

Your instructor will show you a demonstration, or a video, of two objects falling when there is no air.

Describe the demonstration (or video) and your observations.

Describe two or three everyday situations where you think the air is exerting a significant force to oppose the motion of an object. What effect does this force have on the object's motion?

STEP 4: Scientists use the term *'air resistance'* or *'drag'* to refer to the force that the air exerts on an object moving through it.

Do you think the strength of the force of air resistance acting on an object depends on how fast the object is moving? (In answering this question you may want to think about the force you feel pushing on your hand when you hold it out of the window of a moving car. As the car speeds up, does this force seem to get weaker, stay the same, or get stronger?)

So what would happen to the strength of the force of air resistance acting on an object if its speed were continuously increasing?

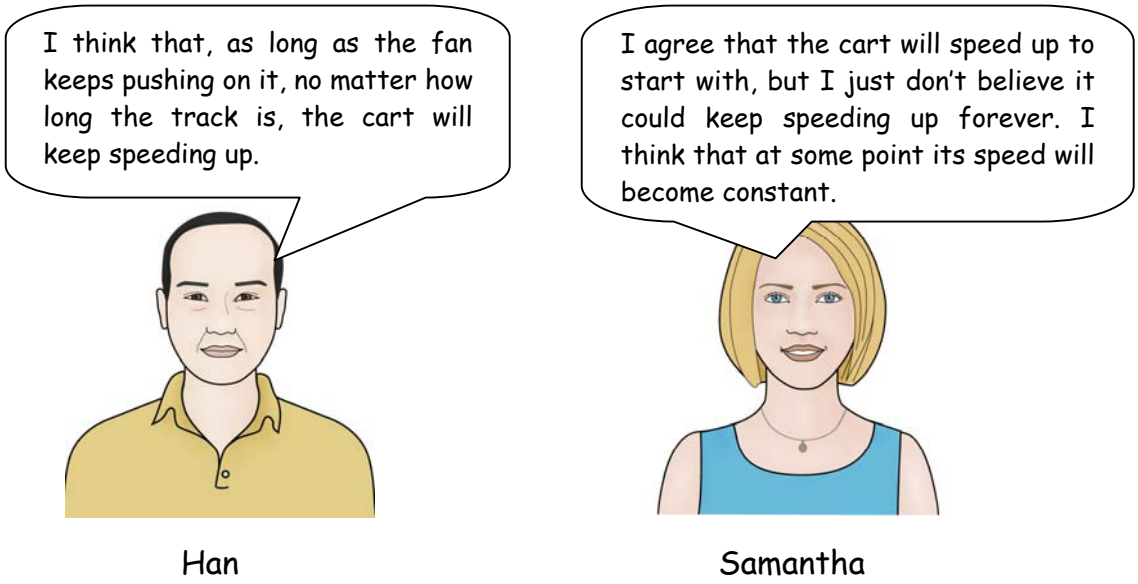
Now consider the case of a fan-cart that is released at the end of a very, very, long track. As the cart moves, two forces will act on it: the force of the fan-unit pushing it forward, and the force of air resistance opposing its motion. (We assume the force of friction between the wheels and the track is negligible.) As the fan-cart speeds up we know that the strength of the force from the fan unit remains constant. However, the force of air resistance starts

out as being very weak (because the speed is low) but increases in strength as the cart speeds up.

During the time the force of air resistance is weaker in strength than the force of the fan unit, what will happen to the speed of the cart? Will it speed up, slow down, or move at constant speed? Explain your reasoning.

Eventually the speed of the cart will be such that the strength of the force of air resistance will be the same as that of the fan unit. What will happen to the cart's speed now? Again, explain your reasoning.

In Activity 2 of Chapter 2, Han and Samantha had the following conversation about the motion of a fan cart. Who do you agree with now? Explain your reasoning.



Summarizing Questions

S1: Does the strength of the gravitational force of the Earth pulling an object toward the ground depend on the object's mass? What evidence supports your answer?

S2: What other force, apart from the gravitational force of the Earth, acts on falling objects? What types of object are affected most by this force?

S3: If the force of air resistance is negligible, does the rate at which a falling object's speed increases depend on its mass? Why do you think this is?

S4: When a skydiver jumps out of an aircraft he speeds up at first but eventually, after he has fallen for a while, his speed actually becomes constant. (This is before he opens his parachute.) Use your ideas about the forces acting on the skydiver as he falls to write a scientific explanation for why this happens.

Explanation: Why does a skydiver speed up at first but eventually fall at a constant speed?

Describe the situation using a diagram: (Hint: you may wish to draw two or three force diagrams for this explanation.)

Write the narrative:

Participate in a class discussion.