Minds•On Physics Activity

FF•9

Exploring the Gravitational Interaction

Purpose and Expected Outcome

The gravitational force law for objects at the surface of the Earth was covered in prior activities. In this activity you will examine your own model of the gravitational force near the Earth and use it to predict, explain, and hypothesize about gravitational phenomena. In a later activity you will learn about a more general gravitational force law which describes the interaction between any two objects having mass.

Prior Experience / Knowledge Needed

Very little prior experience is needed to do this activity. If you have lived on the surface of a large, celestial body for most of your life, then you are ready to do this activity. If, however, you have spent most of your life inside a space station or other interplanetary vehicle, then some of the situations may be unfamiliar to you. You should be familiar with the empirical force law for gravitation and be able to apply it to different situations.

FORCE & GRAVITATION

One of the most fundamental concepts in physics is that of *force*. When you were studying forces earlier in the course, we asserted that evidence of a force could be found in the deformation of an object or in changes in the motion of an object. For example, a water balloon will deform when allowed to rest on a table or accelerate when dropped.

You live in a world where most objects remain stationary on horizontal surfaces or fall if unsupported by some object. In this world, all objects seem to experience a force directed downward toward the ground. This force has been given the name *gravity* or *gravitational attraction*.

This downward force is attributed to the Earth. How do you know this is correct? What evidence do you have that the cause of this force is the Earth?

Explanation of Activity

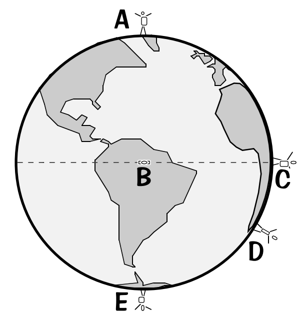
There are two parts in this activity. In the first part, you will explore various features to see which determine the gravitational interaction. In the second part, you will explore more deeply the nature of the gravitational interaction.

PART A: Exploring the Gravitational Force

Answer the following questions related to the gravitational force that the Earth exerts on people and objects on the surface of the Earth. Be prepared to explain your answers.

A1. Five people are standing at various parts of the Earth, as shown.

Person A: at the North Pole
Person B: on the equator in South America
Person C: on the equator in Africa
Person D: in South Africa
Person E: at the South Pole



(a) Draw a free-body diagram for each of the five people.

(b) Which person has the largest gravitational force on him/her? Explain.

(c) Which person has the smallest gravitational force on him/her? Explain.

A2. What would happen to the gravitational force if the Earth had no atmosphere? In other words, would its strength change if all the air were removed from the surface of the Earth? How would it change? Would its direction change? How would it change?

A3. (a) What would happen to the gravitational force if the Earth were not spinning?

(b) What would happen to the gravitational force if the Earth were spinning twice as fast as it does now (i.e., once every 12 hours instead of once every 24 hours)?

A4. What would happen to the gravitational force if the Earth were not orbiting the Sun, but rather, was in the middle of space without anything nearby?

A5. (a) What would happen to the gravitational force if there were no Moon orbiting the Earth?

(b) What would happen to the gravitational force if there were no other planets orbiting the Sun? (In other words, what if the Earth were the only planet orbiting the Sun?)

A6. (a) Is the gravitational force stronger at night or during the day? Explain.

(b) Is the gravitational force stronger in summer or in winter? Explain.

PART B: Determining the Nature of the Gravitational Force

Answer each of the following questions and provide a brief explanation of your reasoning.

B1. Does the gravitational force act on air? Explain why or why not.

B2. Consider the following observations:

i. If the amount of material is doubled, the weight of material is doubled.

ii. When you drop two stones, they accelerate toward the Earth at the same rate — if air resistance is small — even if one of the stones is much larger than the other. Even a feather and stone will accelerate at the same rate in a vacuum.

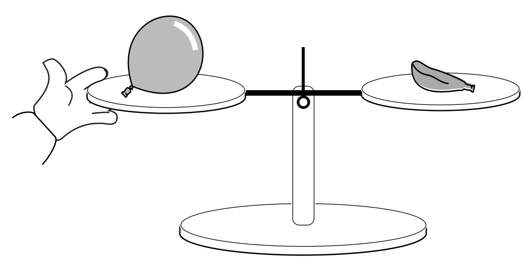
What can you conclude about the gravitational force from these observations?

B3. Does helium have mass? Does helium have weight? When helium is put into a balloon, the balloon rises. Does the gravitational force on the balloon point up? How would you determine the direction of the gravitational force on the balloon?

B4. Can you detect any change in the weight of an object when you insert another object — for instance, a table — between it and the Earth? In other words, can you shield an object and prevent it from experiencing a gravitational force? If so, give some examples.

B5. If you hang a heavy object from a spring scale inside a bell jar, and then remove the air from inside the bell jar so that you have a perfect vacuum, what would happen to the scale reading? Explain your prediction. If equipment is available, check your prediction.

B6. Two identical balloons are placed on a two-pan balance scale as shown. One of the balloons is filled with air. Which way do you think the balance will tilt when the person removes his hand? Explain why you think so. Check your prediction.



B7. (a) Do objects floating in water experience a gravitational force? How do you know? Are the strength and direction of this force the same as when the object is not in water? Explain.

(b) Do fish experience a gravitational force on them? Explain why or why not.

(c) Does an object that has sunk to the bottom of a pool experience a gravitational force? Are the strength and direction of this force the same as when the object is not in water? Explain.

Reflection and Integration of Ideas

R1. (a) If two objects have the same acceleration, do they also have the same net force on them? Explain why or why not.

(b) Is the gravitational attraction the same on all objects? Explain.

(c) Why do most objects fall with about the same acceleration? Why do some objects not fall with this acceleration?

R2. If all objects with mass fall to the Earth, why does all the air in the atmosphere not fall to the ground?

R3. There is less oxygen to breathe at the top of a very high mountain. Why is there more oxygen closer to the surface of the Earth? Is there also more of the other elements in air, such as nitrogen?

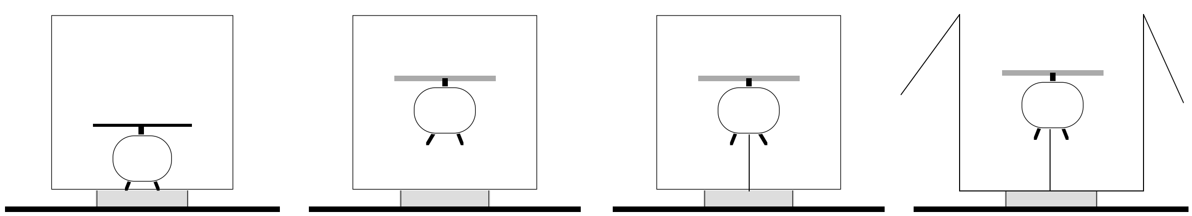
R4. Assume you have a remote-controlled toy helicopter and a large box. On a standard bathroom scale, the box weighs 6lb, and the helicopter weighs 1lb. You put the toy helicopter inside the box and seal it so that no air can get into or out of the box.

(a) When the box and toy are put onto the scale, what will the reading be? Explain.

(b) When the helicopter is made to hover inside the box, without touching any of the six sides of the box, what will the reading be? Explain.

(c) If the helicopter is strong enough, is it possible to lift the box off the scale, for instance, by attaching a piece of string to the bottom of the box and to the bottom of the helicopter?

(d) If the top of the box is open, is it possible for the helicopter to lift the box off the scale?



(a) (b) (c) (d)