Minds•On Physics Activity

FF•20

Reasoning with Universal Gravitation

Purpose and Expected Outcome

In this activity you will learn more about the Universal law of gravitation, especially as it applies to celestial bodies, such as the Earth and the Moon.

Prior Experience / Knowledge Needed

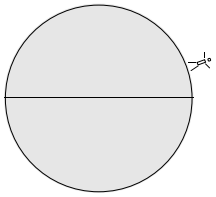
You should be familiar with the Universal law of gravitation as presented in Activity FF•18. You should know the difference between *mass* and *weight*. You should be familiar with situations involving both the Earth and the Moon. You should know how to determine the gravitational force exerted by a celestial body.

Explanation of Activity

Answer the following questions about the gravitational interaction. Be prepared to explain your answers.

A1. A space ship is on a trip from the Earth to the Moon. When the ship is halfway between the Moon and the Earth, what is the direction of the total gravitational force on the ship?

A2. Consider the following thought experiment: You are standing at latitude 20° North on a perfectly spherical planet that is isolated and has a frictionless surface.



(a) What will happen to you? (In other words, will you remain at rest or move? If you move, to where will you move?)

Assume now that there is a small moon orbiting the planet at its equator.

(b) What will happen to you now?

Assume instead that the planet is spinning.

(c) What will happen to you in this situation?

A3. Consider the phenomenon of tides:

- High tides occur twice a day at any given location, approximately 12 hours apart.
- High tides occur on opposite sides of the Earth at roughly the same time of day.

Brainstorm some ideas about the causes of tides. Indicate some possible forces exerted on ocean water. Describe the motion of the ocean water relative to the Earth.

A4. If you were at the bottom of one of the deepest canyons in the ocean would you expect the gravitational force, due to the Earth, to be larger than, smaller than, or the same as it is at the surface? Explain. If you think the gravitational force is larger or smaller, how large is any difference?

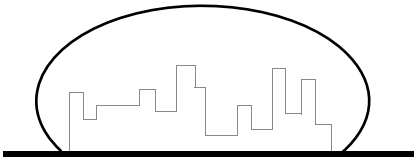
A5. As the Moon orbits the Earth it is attracted to both the Earth and the Sun. Is the total gravitational force on the Moon ever zero?

A6. For the planet Earth to replace the planet Jupiter in its orbit about the Sun, would the Earth's speed be larger than, smaller than, or the same as Jupiter's?

continued

A7. An astronaut is working outside a small space station that is in a circular orbit about the Earth. If the astronaut were to remove all her safety cables so that she was completely free of the space station what would happen to her?

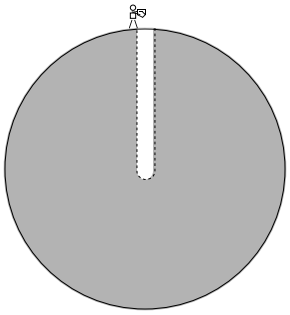
A8. Imagine that a city has been built on the Moon, inside a large, pressurized dome so that humans can breathe normally without using a space suit. Compare each of the following on the Earth vs. inside this dome on the Moon.



(a) your weight;
(b) your mass;
(c) the largest speed you could throw a baseball;
(d) the highest altitude you could throw a baseball;
(e) your ability to push a heavy box along the floor;
(f) your ability to carry a heavy box; and
(g) the distance needed to stop a car traveling at 20mph.

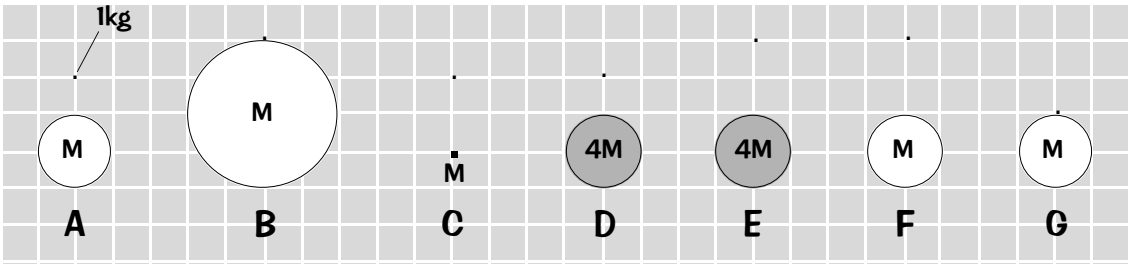
A9. Compare the force that the Sun exerts on the Moon to the force that the Earth exerts on the Moon. Why does the Moon orbit the Earth?

A10. Imagine that a deep hole is made from the surface of the Moon all the way to its center. You drop a large stone into the hole from the surface of the Moon.



(a) How would the gravitational force on the stone change as it went down into the hole?
(b) What would be the gravitational force on the stone when it reached the center?
(c) Sketch the gravitational force as a function of distance from the surface of the Moon.
(d) Sketch the acceleration of the stone as a function of time.
(e) Sketch the speed of the stone as a function of time.

A11. Consider the following planets. A 1kg object is placed at various locations as shown. Put these situations in order from smallest to largest gravitational force on the 1kg object.



Reflection

R1. For which of the situations did you make a diagram? What types of drawings did you use? Were they helpful?

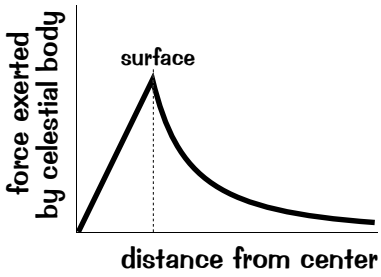
R2. Describe how your understanding of gravitation has changed during the last few weeks.

R3. (a) Planet X has the same mass as the Earth but the same average radius as the Moon. Compare the local gravitational constant on its surface to that of the Earth and the Moon.

(b) Planet Y has the same mass as the Moon but the same average radius as the Earth. Compare the local gravitational constant on its surface to that of the Earth and the Moon.

R4. What are some similarities between the electric force and the gravitational force?

R5. Here is a graph of force vs. distance that was presented earlier (in FF·12). Explain the features of this graph using the Universal law of gravitation and the mathematical model given along with it.



R6. Reconsider situation A10, in which a very deep hole is made in the Moon from its surface to its center.

(a) Which answers would change if the rock were only half as massive? How would they change?

(b) Are your sketches of acceleration and speed vs. time for a stone dropped into the hole consistent with each other? Explain why or why not. If they are not consistent, fix them.