Close Reading and Text Dependent Questions in Science
How To Get and Hold Onto A Moon (Force and Motion—Grade 7)

The text selection, *How To Get and Hold Onto A Moon,* is found in *FOSS Student Resource Book*, *Force and Motion,* pgs. 69-70.

HOW TO GET AND HOLD ONTO A MOON

Counting out from the Sun, our planet, Earth, is the first one keeping company with a satellite, or moon. Mercury, the closest planet to the Sun, doesn't have a moon, nor does Venus. Mars, the fourth planet out, has two moons, but they are really just a couple of Mars's big old rocks that probably ended up in orbit after they were fully formed. And it is suspected that Earth didn't have a moon at first, but acquired one early in its history as a result of a gigantic planetary collision.

Had you been on Earth to witness the event, the troublemaker would have first appeared as a dot in the heavens. Over a period of days and weeks it would grow bigger and bigger until it completely filled the field of view above Earth in that direction. Then it struck. Because the colliding objects were so large, the impact itself seemed to happen in slow motion, lasting several minutes, even though the planetesimal was traveling at perhaps 40,000 km/h.

Look in the Student Learning Outcome Document for guidance on when this should be taught.
http://bpscurriculumandinstruction.weebly.com/student-learning-outcomes-by-grade.html

HOW TO GET AND HOLD ON TO A MOON

Counting out from the Sun, Earth is the first planet with a satellite, or moon. Mercury, closest planet to the Sun, doesn't have a moon, nor does Venus. Mars, the fourth planet out, has two moons, but they are probably just a couple of big old rocks that ended up in Mars' orbit after they were fully formed.

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MAKING THE MOON

Earth was pretty much formed as a planet. Most of the dust and gas in the region had been pulled in, and the proto-Earth was revolving around the Sun more or less in the orbit it travels today. However, these were the early days of the Solar System. There were a lot of large chunks of matter flying around in unstable orbits. Some of the chunks were huge—the size of small planets.

Planetary scientists now think that one of these large planetesimals, perhaps the size of Mars, was traveling around the Sun in an exaggerated elliptical orbit. It's not known why it had such a peculiar orbit—perhaps it was pulled by the gravitational influence of a large planet, or perhaps there were lots of such strange objects early in the Solar System's history. Anyway, it ended up heading for Earth.

Had you been on Earth to witness the event, the incoming object would have first appeared as a dot in the heavens. Over a period of days and weeks, it grew bigger and bigger until it completely filled the field of view above Earth. Then it struck. Because the colliding object was so large, the impact itself seemed to happen in slow motion, lasting several minutes, even though the planetesimal was traveling at perhaps 40,000 km/h.

What chaos must have followed the crash! The incoming object was destroyed on impact, reduced to vapor, dust, and chunks. Large surviving parts were driven deep into the interior of Earth. A significant portion of Earth was destroyed as well. The energy that resulted from the crash produced an explosion of unimaginable magnitude.

The force of the impact threw a tremendous quantity of matter into motion—at least 20 billion cubic kilometers of matter. One portion of the matter, the pieces traveling at

the highest speeds, flew out into space, never to be seen again. Another portion of the matter flew up into the air and then was pulled back to Earth by gravity. Some of the falling matter fell back almost immediately as huge rocks, some a little later as granules of various sizes, and some months or even years later in the form of dust and chemicals held aloft in the atmosphere.

A third and significant portion of the debris didn't fly off into space, and it didn't return to Earth. It began orbiting Earth in a disk, like the rings of Saturn. The ring was probably about two Earth diameters from the surface of Earth.

Over the next millions of years, the force due to gravitation started bringing the pieces of matter together. Tiny grains formed larger and larger chunks, which eventually all pulled together to form the Moon.

We had a moon where previously there was none, and it must have been a sight hanging up there maybe 30,000 km above Earth, rather than the 385,000-km distance we see today.

GRAVITY AND ITS EFFECTS

Gravity is one of the four known forces in the universe. Gravity, along with electromagnetism and two forces at work in the nucleus of atoms, makes everything in the world behave in ways we understand. It is the force due to gravitation that causes two masses to attract each other. Gravitational force exerted by a small mass, like a marble or an apple, is so small that we can't detect it. But the force exerted by a large mass, like a planet or a star, is tremendous. The larger the mass, the stronger the force due to gravitation.

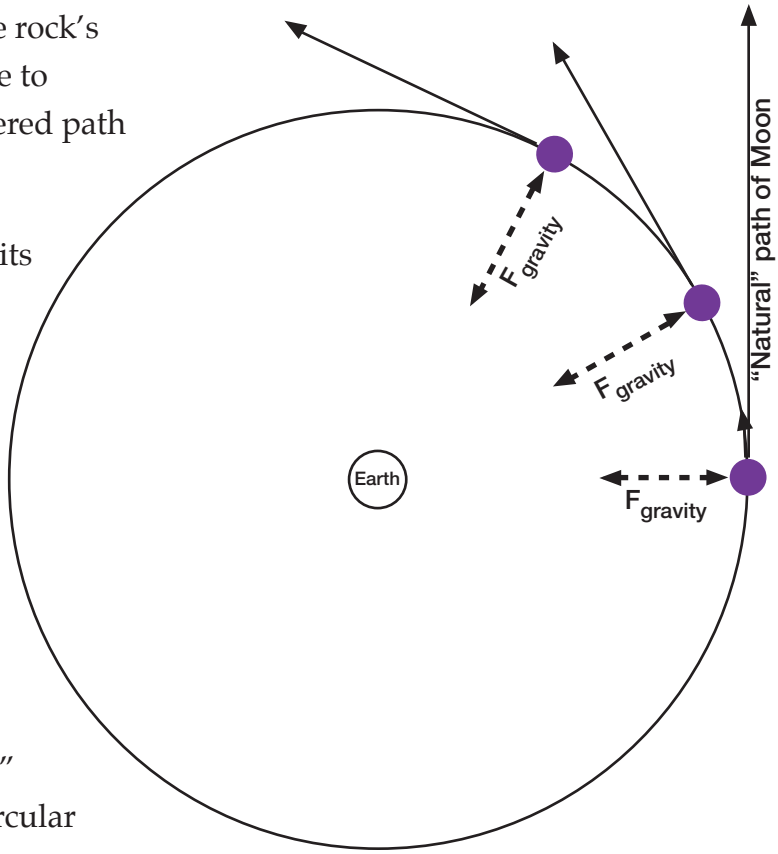
The gravitational force plays two major roles in planetary system formation. Gravitational force pulls bits of matter together to form massive objects. If a little bit of matter is pulled together, the shape of the object might be irregular because the gravity will not be strong. Asteroids are funny shapes because of their low mass. If a lot of matter accumulates, however, the mass will be pulled into a sphere. The other role of gravitation is to hold planets and satellites in orbit. The straight-line paths of planets are deflected into circular paths by the constant application of a force. That force is the universal force of gravitation.

GRAVITY VERSUS VELOCITY

When the planetesimal hit Earth, matter flew everywhere. Pieces of matter launched with high velocity escaped Earth's gravitational attraction and began a phase of existence as loose space debris. Matter that didn't achieve escape velocity continued to be influenced by Earth's gravity. It's just that simple.

Before we think more about the matter that didn't fly into space, consider another piece of information about the behavior of mater. Isaac Newton figured out that an object in motion will travel in a straight line forever unless it is acted on by a force that changes its direction. In other words, things don't travel in curves, circles, spirals, zigzags, or any other nonstraight paths unless something acts on them to change their motion.

Back to the impact debris. Some of the matter fell back to Earth in the usual way. But some of the matter that flew out in a straight line had its path altered by the force due to Earth's gravity. Take a rock the size of a trash can as an example. It flew off in a straight line like that shown on the illustration labeled "Natural" path of Moon. If there were no gravity, the rock would keep going off into space. However, the force of gravity pulls the rock toward Earth. The pull didn't bring the rock to Earth's surface, but it did change the direction of the rock's travel. Remember, an object travels in a straight line until acted on by a force. The force that changed the rock's direction of travel in this case was due to Earth's gravity. The continuously altered path of the rock brought it into orbit.



Imagine taking a yo-yo by the end of its string and swinging it around over your head in a nice circle. If you let go of the string, what happens? The yo-yo stops going in a circle and flies off in a straight line. As long as you keep applying a force (pulling on the string) to change the direction of the yo-yo, it continues to orbit your fist.

Force due to gravitation is the "string" pulling on the Moon to keep it in a circular path. Similarly, gravitation is the force keeping Earth in a circular orbit around the Sun. In fact, everything that is going around something else in the Solar System is doing so because of gravitational force. Gravity rules!

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Student Questions

1. What is another word for *satellite* as explained in the first sentence? What did the author use to signify this definition? Pick another place in the first sentence where the author does the same thing.

2. In the third paragraph the author says "perhaps, one of these large planetesimals, perhaps the size of Mars, was traveling around the sun in an exaggerated elliptical orbit." What is the author referencing?

3. Describe what happened to the planetesimal after it crashed into the Earth.

4. What was the result of the "third and significant portion of the debris" from the crash, described in paragraph 7? In your own words describe how this happened. Describe what happened to the other two portions of the debris.

5. What can you conclude about the moon today with the statement, “It must have been a sight hanging up there maybe 30,000 km above Earth, rather than the 385,000 km distance we see today?”

6. What force causes two masses to be attracted to each other? Why can’t we feel the gravitational pull of an apple?

7. Explain how gravity affected the debris from the impact event so that the debris began to orbit the Earth.

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Sample Answers

1. **What is another word for "*satellite*" as explained in the first sentence? What did the author use to signify this definition? Pick out one more place in this first sentence that the author does the same thing.**
   Another word for satellite is moon. The author also does it to name "our planet, Earth." [Teacher note: It is really important that students understand how the comma is used in this first sentence. This is often something that students do not understand. A comma is also used a few other times in the first paragraph to clarify a word. Ex. "Mercury, the closest planet to the Sun,…]

2. **In the third paragraph the author says "perhaps one of these large planetesimals, perhaps the size of Mars, was traveling around the sun in an exaggerated elliptical orbit." What is the author referencing?**
   The author is referring to one of the large chunks of material flying around during the early days of the Solar System.

3. **Describe what happened to the planetesimal after it crashed into the Earth.**
   It was destroyed, being reduced to vapor, dust, and chunks.

4. **What was the result of the "third and significant portion of the debris" from the crash, described in paragraph 7? In your own words describe how this happened. Describe what happened to the other two portions of the debris.**
   The third portion resulted in a ring around the Earth, which gradually collected into chunks and then formed the Moon. The rest of the debris either flew out into space or returned to Earth.

5. **What can you conclude about the Moon today with the statement, "It must have been a sight hanging up there maybe 30,000 km above Earth, rather than the 385, 000km distance we see today?"**
   The Moon is further away now.

6. **What causes two masses to attract to each other? Why can't we feel the gravitational pull of an apple?**
   Gravity is the force that causes two masses to attract one another. An apple has too small of a mass for us to detect it.

7. **Explain how gravity affected the debris from the impact event so that the debris began to orbit the Earth.**
   Gravity pulled the debris back to Earth and held some of the debris in orbit around the Earth. Some of the debris was pulled down to Earth's surface, while some remained in orbit and eventually formed the Moon.