Science Investigation of Apophis

Objectives
- Students will use the Periodic Table of Elements to solve problems using atomic symbols and atomic numbers
- Students will solve problems to understand information contained in the Periodic Table of Elements
- Students will learn about atoms, protons, neutrons, and electrons
- Students will solve density problems using information gathered from asteroids
- Students will compare and contrast the surface of the Earth and Moon
- Students will understand the natural forces that cause weathering, erosion, and deposition
- Students will discover the Law of Conservation of Energy
- Students will understand the difference between potential and kinetic energy
- Students will compare and contrast natural disasters on the Earth
- Students will understand the force of gravity and its implications in the solar system
- Students will understand the places of the planets in the solar system
- Students will convey thoughts of scientific observations of this lesson in a science journal writing activity

Suggested Grade Level
5th - 8th

Subject Area
Science

Timeline
One to two class periods

Standards

Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Physical Science
- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy
Earth and Space Science
- Structure of the Earth system
- Earth’s history
- Earth in the solar system

Science and Technology
- Abilities of technological design
- Understanding about science and technology

Science in Personal and Social Perspectives
- Natural hazards
- Risks and benefits
- Science and technology in society

History and Nature of Science
- Science as a human endeavor
- Nature of science
- History of science

Background
With the close-approach of asteroid Apophis, it is of vital importance to understand exactly what elements the asteroid is composed of. The composition and nature of these elements will dictate what course of action scientists may take to save the Earth, if necessary. Students will use the Periodic Table of Elements to fill in tables in the lesson, to learn how to use the Periodic Table, and to understand the elements that compose the table. Students will also use various science concepts such as the law of Conservation of Energy, kinetic and potential energy, and gravity to answer questions regarding asteroid Apophis.

It is important for students to understand the Law of Conservation of energy. The law states: that energy can neither be created nor destroyed. If Apophis were to strike the Earth all of the kinetic energy that Apophis contains will be transferred in some way to the Earth system if they were to collide. One such example would be the evaporation of the ocean in the vicinity of the impact due to heat energy. Other energy would be transferred to tsunamis and earthquakes.

The force of gravity is also important. It is Earth’s gravity that will ultimately affect Apophis. If Earth’s gravity has the correct amount of pull on the asteroid, Apophis will pass through the “keyhole”-a narrow section of space where, if an object passes through, it will send that object on a collision course with Earth. Students will also compare the Earth and the Moon to gain a better understanding of natural forces that affect the Earth.

Students must also be introduced to the three main classifications of asteroids. Asteroids are classified according to their chemical composition. Those types include C-type or carbonaceous, S-type or silicaceous, and M-type or metallic.
C-type asteroids are usually made of carbon. Other elements may include silicon, magnesium, iron, and sulfur. These asteroids are very brittle. S-type asteroids are usually made of silicates, or rocky material with some iron mixed in. The elements that make up S-type asteroids are magnesium and iron.

Sometimes they have olivine \((\text{MgSiO}_4) + (\text{Fe}_2\text{SiO}_4)\), and pyroxene \((\text{FeSiO}_3) + (\text{MgSiO}_3) + (\text{CaSiO}_3)\) a type of igneous rock. M-type asteroids are mostly made of iron and nickel. They are the most dense, but also the most rare.

Concepts contained in this lesson may be taught prior to using the science investigation, or the activities in the lesson may be used as a tool to introduce the concepts.

Materials

Periodic tables (an interactive periodic table can be found here: http://www.corrosionsource.com/handbook/periodic/), Science Investigation worksheets, pencils, plastic sheets, large aluminum pans, flour, cocoa powder, three types of rocks approximately the same size, but with varying densities (for the C-type, pumice or sandstone; for the S-type, olivine; for the M-type, iron-nickel, centimeter rulers, meter sticks)

Lesson

1. Conduct a brief pre-knowledge assessment with the students to find out how much they know about celestial bodies and the solar system. A K-W-L strategy works well. Also, find out how much vocabulary they are familiar with that is associated with this lesson.

2. Discuss or review with students that asteroid Apophis is composed of various elements, found on the Periodic Table of Elements. Depending on the composition of Apophis, varying strategies will need to be used to save the Earth if that becomes necessary.

3. Review the Periodic Table with students. Have students note common elements that they are familiar with. Also, discuss with students elemental compounds, such as \(\text{H}_2\text{O}\) and \(\text{CO}_2\). This means that there are two hydrogen atoms for every oxygen atom in every molecule of water.

4. Discuss with students how the table is constructed. Each element in the table is organized and represented in a particular manner. Each box in the table has information about a particular element. Each box contains the element’s name, atomic number, atomic symbol, and its atomic mass. The elements are arranged according to their atomic number, that is, the number of protons each atom contains. The element carbon has an atomic number of 6; therefore, an atom of carbon has 6 protons. An atom’s number of protons and electrons is always equal. Therefore, carbon has 6 electrons. The element’s atomic mass is the sum of the mass of the element’s protons, neutrons, and electrons. Carbon has an atomic mass of 12.0107 amu (atomic mass units). An atom’s number of neutrons can generally be taken by subtracting the atom’s atomic mass (rounded to the nearest whole number) and subtracting the number of
protons. The final piece of information contained in each box is the
element’s atomic symbol. This is represented by a large letter. Carbon’s
atomic symbol is designated by the letter “C.”

5. Students will fill in the chart with the correct atomic numbers, symbols and
masses for the elements that are suspected to compose the asteroid
Apophis.

6. For the next set of questions ask students to calculate the densities of two
known asteroids. This will give a range of densities in which Apophis may
fit. The formula for calculating density is: \( \rho = \frac{m}{v} \). The results of these
densities correlates to how much destruction an object may create. For
example, Barringer Crater in Arizona was created by a nickel-iron
meteorite approximately 50 m across. This meteorite created a crater
1,200 m across and was equivalent to a 10-20 megaton explosion.
Apophis, depending on its density, would impact the Earth and leave an
approximately 10,000 m wide crater and an explosion equivalent to 880
megatons-or 65,500 times greater than the nuclear bomb dropped on
Hiroshima in WWII.

7. The next part of the investigation has to do with discovering the natural
forces of the Earth that hide impact craters. Students will compare and
contrast the pictures of the Earth and the Moon. Due to the close
proximity of the two celestial bodies, it is assumed that the Earth would
have as many, if not more, impact craters due to its stronger gravitational
pull. Therefore, forces on the Earth cover visible impact craters. It is only
with sophisticated satellite technology that we are able to discover the
underground remnants of these craters. A discussion of the forces of
weather, erosion, deposition, and plate tectonics may be included here.

8. To understand the power that would be transferred from Apophis to Earth
in an impact, students must understand the law of Conservation of
Energy. The law states: Energy may be neither created nor destroyed.
An amount of energy may undergo a transformation or may be transported
to another location, but the total amount of energy does not change.
Within a CLOSED SYSTEM, energy may be transformed from one form to
another, but the total amount cannot change. In an OPEN SYSTEM, there
are exchanges of energy with the surrounding environment. During these
exchanges, however, the change in total system energy must exactly
equal the energy exchanged. Conservation of energy is the First Law of
Thermodynamics. Students must also understand the principles of kinetic
ergy and potential energy. Kinetic energy is the amount of energy an
object possesses due to its motion. Kinetic energy can be calculated by
the formula: \( E_k = \frac{1}{2}mv^2 \) (m=mass and v=volume). Potential energy is
energy which results from position or configuration. An object may have
the capacity for doing work as a result of its position in a gravitational field.
9. Next, students have the opportunity to demonstrate knowledge of gravity. It will be the Earth’s gravitational pull on Apophis that will determine if Apophis will pass through the “keyhole” or the small area in space in which an object passes through, which then will cause a collision between Earth and that object.

10. Finally, students will be able to share their thoughts, feelings and observations in the journal writing at the end of the investigation.

Extensions

Students can experiment and observe how varying densities of objects influence the size of impact craters. In this experiment, students will drop objects with various densities into a simulated planet surface and observe the impact craters. The students must be provided with three objects, approximately the same size, with varying densities to represent the various types of asteroids. Have students predict or hypothesize what will happen during this experiment.

1. Lay out plastic sheets on the floor.
2. Place aluminum pans in the middle of the plastic sheets.
3. Fill the bottom of the pan with flour, about one inch deep.
4. Cover the flour with cocoa powder so that no flour is showing, about ¼ inches deep.
5. Have students mass each of their rocks on a triple-beam balance.
6. Next, have students calculate each rock’s volume. This can be done by filling a beaker half-way with water. Record the volume of water. Drop the rock gently into the beaker. Record the increase in water volume. By subtracting the first recording from the second, the student can calculate the volume of each rock.
7. Finally, have the students calculate the density of each rock. This can by accomplished by multiplying the mass and the volume.
8. Have students drop the rocks, one at a time, from about one meter. When one rock has been dropped, have students observe what happens after the collision. Students can draw and describe the impact crater of each rock on the observation sheet (include the color and composition of the ejecta). Students must also very carefully measure the width of the crater. Drop the next rock in a different location. Repeat the observation. Drop the last rock, and repeat the observation. (If you have enough time and materials each rock can be dropped in the center of the pan. After each “collision,” new cocoa powder and flour may be used to fill in the crater.)
9. Students can then compare the different craters and observe that even though the rocks were the same size, the craters were different sizes. Conclusion: The greater the density of the rock, the greater the size of the impact crater.
**Evaluation/Assessment**
Students may be evaluated on the Science Investigation packet and the quality of the experiment on the Extension section.

**Resources**
National Science Standards: [http://www.nap.edu/readingroom/books/nses/](http://www.nap.edu/readingroom/books/nses/)

NASA: [http://www.nasa.gov](http://www.nasa.gov)

**Science Investigation**

Name __________________________

Date _________________

Background: There are three types of asteroids. They are classified according to their chemical composition. Those types include C-type or carbonaceous, S-type or silicaceous, and M-type or metallic.

Use the periodic table to answer the following questions.

1. C-type asteroids are usually made of carbon. Other elements may include silicon, magnesium, iron, and sulfur. Write the atomic symbol and atomic number for these elements.

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Atomic Symbol</th>
<th>Atomic #</th>
<th># of Protons</th>
<th># of Neutrons</th>
<th># of Electrons</th>
<th>Atomic mass</th>
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</thead>
<tbody>
<tr>
<td>Carbon</td>
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<tr>
<td>Silicon</td>
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<td>Magnesium</td>
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<td>Iron</td>
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<td>Sulfur</td>
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</tbody>
</table>

2. S-type asteroids are usually made of silicates, or rocky material with small amounts of iron mixed in. The elements that make up S-type asteroids are magnesium and iron. Sometimes they have olivine \((\text{MgSiO}_4) + (\text{Fe}_2\text{SiO}_4)\), and pyroxene \((\text{FeSiO}_3) + (\text{MgSiO}_3) + (\text{CaSiO}_3)\) a type of igneous rock. Fill in the table below using the Periodic Table.

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Atomic Symbol</th>
<th>Atomic #</th>
<th># of Protons</th>
<th># of Neutrons</th>
<th># of Electrons</th>
<th>Atomic mass</th>
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</thead>
<tbody>
<tr>
<td>Calcium</td>
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<td>Mg</td>
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<td>Iron</td>
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<td>8</td>
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</tbody>
</table>
3. M-type asteroids are mostly made of iron and nickel. They are the most dense, but also the most rare. Fill in the table below using the Periodic Table.

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Atomic Symbol</th>
<th>Atomic #</th>
<th># of Protons</th>
<th># of Neutrons</th>
<th># of Electrons</th>
<th>Atomic mass</th>
</tr>
</thead>
</table>

4. The amount of destruction an asteroid could cause when impacting an object is dependent upon its density. It is unknown what Apophis's density is because we don't know what it is made of. We do know that Apophis is either an S-type or an M-type asteroid. We can hypothesize, then, what it is made of due to its brightness. Below, we are going to calculate a range of densities that Apophis may have.

Formula for density: \[ \rho = \frac{m}{v} \]

\[ m = \text{mass} \]

\[ v = \text{volume} \]

Asteroid Eros is an S-type asteroid with a mass of \( 7.2 \times 10^{15} \text{ kg} \) (7,200,000,000,000,000 kg). If Eros has a volume of \( 3 \times 10^{15} \text{ cm}^3 \) (3,000,000,000,000,000 cm\(^3\)), what is its density in g/cm\(^3\)?

____________________________
5. Asteroid 16 Psyche is an M-type asteroid with a mass of $1.7 \times 10^{19}$ kg (17,000,000,000,000,000,000 kg). If 16 Psyche has a volume of $6.3 \times 10^{18}$ cm$^3$ (6,300,000,000,000,000,000 cm$^3$), what would be its density in g/cm$^3$?

____________________________

So the range of Apophis’ density would be from:

___________________________ to ______________________

6. Look at the pictures on the next two pages. The first is a picture of the Earth. The second is a picture of the Moon. Compare and contrast these two pictures paying close attention to the number of impact craters.
Why do you think the Moon shows more impact craters than the Earth?

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7. Natural forces on the Earth cause weathering, erosion, and deposition which erase evidence of impact craters. Write the definitions of these words below.

Weathering:
__________________________________________________________________________
__________________________________________________________________________

Erosion:
__________________________________________________________________________
__________________________________________________________________________

Deposition:
__________________________________________________________________________
__________________________________________________________________________

8. Draw examples of each of these below.

___________________________________________________________
___________________________________________________________
___________________________________________________________

10. What is the definition of kinetic energy? Write it below.

___________________________________________________________
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11. What is the definition of potential energy? Write it below.

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12. Does Apophis have potential or kinetic energy? Circle one.

Potential       Kinetic

13. Taking into consideration the Law of Conservation of Energy, if Apophis impacts the Earth, what types of energy will the kinetic energy be turned into?

______________________________________________________________
______________________________________________________________
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14. If Apophis were to strike the Earth, it would be considered a natural disaster. It would not make life on Earth extinct, but it would cause considerable damage around the Pacific Ocean. In 2005, Hurricane Katrina, another natural disaster, struck the Gulf Coast of the United States. Discuss what would happen if Apophis were to hit between Hawaii and California in the Pacific Ocean. Compare and contrast the two disasters.
15. Below is a graphic of Apophis (2004 MN4) and its orbit around the sun.

What force keeps Apophis in its orbit?
_____________________________

16. Below is a graphic of Apophis passing the Earth in the year 2029.

What force, generated by the Earth, makes Apophis change its path?
_____________________________
17. Cut out these pictures of objects in the solar system and their names.
Paste them on the correct blank space on the previous pages.
Science Journal Writing

Write down the ideas you learned during this unit. Remember, you are writing as a scientist. You may write down other hypotheses or ideas that you may have.

Date ___________________

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Extension Activity
C-type Asteroid

Type of rock: _____________________________________________________

Mass: __________________________

Volume: _________________

Draw the impact crater below.

Width of impact crater: _________________________________________

Observations: _____________________________________________________
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Extension Activity
S-type Asteroid

Type of rock: _____________________________________________________

Mass: ___________________

Volume: _________________

Draw the impact crater below.

Width of impact crater: _________________________________________

Observations: _____________________________________________________
________________________________________________________________
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Extension Activity
M-type Asteroid

Type of rock: ________________________________

Mass: ______________

Volume: ______________

Draw the impact crater below.

Width of impact crater: ________________________________

Observations: ________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

Hypothesis & Conclusion
Write down your conclusions after doing this activity. What hypothesis did you make? What observations did you make? Were you correct? Give details supporting why you were correct or incorrect.

Date ___________________

Hypothesis:

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Conclusion:

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