An Exploration of the Planet Mercury

On August 3, 2004, NASA launched a spacecraft from Cape Canaveral for a scientific investigation of the planet Mercury. Mercury is named for the mythological messenger of the gods, and appropriately the investigation is known as “MESSENGER.” However, MESSENGER is an acronym for “MErcury Surface, Space ENvironment, GEochemistry, and Ranging.” Upon completing this lesson plan you will be familiar with MESSENGER's mission, the spacecraft, the plan for orbital insertion around Mercury, and the timeline for the mission. One focus will be to construct a “Magnetic Field Detector” and simulate how the MESSENGER spacecraft will study Mercury’s magnetic field.

Researching MESSENGER

NASA, the Carnegie Institution of Washington, and The Johns Hopkins University Applied Physics Laboratory provide a Web site that will assist you with your research of the MESSENGER mission at http://messenger.jhuapl.edu

1. What are the six main questions scientists hope to answer about Mercury when the MESSENGER spacecraft starts to collect and send back information?

   a. __________________________________________________________
   b. __________________________________________________________
   c. __________________________________________________________
   d. __________________________________________________________
   e. __________________________________________________________
   f. __________________________________________________________

2. The diagram of the MESSENGER spacecraft shown below points out the instruments scientists will use to collect data on Mercury’s surface, interior and surrounding environment. The instruments are labeled with acronyms that you will interpret and relate to the six questions in Part 1.
“Interpret” each acronym by stating what its stands for, briefly “Explain” what the instrument measures, and identify the scientific “Question(s)” for which this instrument will gather information.

a. **EPPS-EPS**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

b. **EPPS-FIPS**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

c. **MLA**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

d. **MASCS**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

e. **MAG**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

f. **GRNS-NS**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

g. **XRS**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

h. **GRNS-GRS**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

i. **MDIS**
   Interpret: __________________________________________________________
   Explain: __________________________________________________________
   Question(s): ______________________________________________________ (use question number(s) from Part 1)

3. MESSENGER’s method of travel from launch on Earth to an orbit around the Sun, and then an orbit around Mercury, used concepts called “gravity assist” and “Mercury Orbit Insertion.” This method is described in the following quote from the MESSENGER Web site:

   “MESSENGER uses gravity assists from both Venus and Mercury (two each) to lower its speed relative to Mercury at orbit insertion. In a gravity assist, a spacecraft flies close by a planet and picks up a tiny amount of the planet’s angular momentum around the Sun. The planet is so massive (compared to the spacecraft) that its orbit does not change. But each gravity assist changes the shape, size and tilt of MESSENGER’s orbit until the spacecraft has enough propellant to insert into its planned scientific orbit around Mercury. “Mercury orbit insertion” is the
mission planners’ term for the maneuver that will move MESSENGER from an orbit around the Sun to an orbit around Mercury.”

The MESSENGER Web site offers a variety of animations that you can download to watch simulations of MESSENGER's launch, deployment of instruments, and path from launch to orbit around Mercury. The animation we will study may be found at http://messenger.jhuapl.edu/the_mission/ani.html

It may take several minutes for the animation to load.

When the orbital animation is properly loaded, the beginning of the animation will look something like the picture below.

![Animation of MESSENGER's orbit](image)

Play around with the controls at the bottom of the animation screen and become familiar with how the advance, back-up, pause and start buttons work. Also note that at the top of the animation screen appears a calendar and clock that can be used to follow the timeline for important events in the orbital history of MESSENGER. As you watch the animation note the dates that the following important events occur in the table below, and explain (using terms like gravity assist and orbital insertion) what is happening to the orbital path of MESSENGER from start to finish.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 23, 2004</td>
<td>Deep Space Maneuver (DSM) performed.</td>
</tr>
<tr>
<td>June 20, 2004</td>
<td>MESSENGER enters orbit around Mercury.</td>
</tr>
</tbody>
</table>

In the animation and the following table, DSM stands for “Deep Space Maneuver.” During a DSM, MESSENGER's thrusters (rockets) are turned on and use a propellant to make a course correction or stabilize MESSENGER's orbit.
<table>
<thead>
<tr>
<th>EVENT</th>
<th>DATE</th>
<th>EVENT EXPLANATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venus Flyby 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venus Flyby 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury Flyby 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury Flyby 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSM 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSM 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orbital Insertion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To assist you in completing the table above, and to help you further understand the path that MESSENGER took from Earth to orbit around Mercury, check out this Web page: [http://messenger.jhuapl.edu/the_mission/mission_design.html](http://messenger.jhuapl.edu/the_mission/mission_design.html)

When you have completed the table you can see how close you came to the dates for each orbital event by looking at the MESSENGER timeline at [http://messenger.jhuapl.edu/the_mission/MESSENGERTimeline/TimeLine_content.html](http://messenger.jhuapl.edu/the_mission/MESSENGERTimeline/TimeLine_content.html)

Were you surprised to find out that the MESSENGER mission has taken nearly seven years? NASA scientists had a high level of confidence in applying the laws of nature when predicting where MESSENGER would be seven years after launch. Where were you seven years ago? What do you think you will be doing seven years from now?

**ACTIVITY: SIMULATING THE MAGNETIC EXPLORATION OF MERCURY**

On a large clean piece of paper or thin poster board draw the following diagram of the inner part of the Solar System.
On the enlarged diagram, draw the path that you estimate a spacecraft like MESSENGER might experience from its launch from Earth to a flyby near the planet Mercury. Locate the flyby position of Mercury on the poster, and on the opposite side of Mercury's location glue a small ceramic magnet (available from technology stores, home improvement centers, and craft shops).

Following the directions on the next page, acquire the materials and tools and carefully construct the “MAGNETIC FIELD DETECTOR.”

When you have completed and tested your MAGNETIC FIELD DETECTOR, place the probe (coil) on the Earth at the point where the Earth would have been when the MESSENGER spacecraft was launched. Simulating the MESSENGER spacecraft carrying this probe toward Mercury, slide the coil along the orbital path that you estimated and have already drawn.

What happens when the probe experiences a flyby with Mercury? Is the simulated Mercurial field detected by the probe? What happens as the probe continues on its journey with the MESSENGER spacecraft?

ACTIVITY EXTENSIONS - Think of other ways you can use your probe to demonstrate how unseen magnetic fields may reveal patterns in nature.
   1. Hide several ceramic magnets under a piece of cardboard in some geometric form like a triangle, circle, oval, or even a letter like W. See how long it takes someone else to determine the hidden shape with your probe.
   2. Your game/simulation/etc.

The magnetic field detector is based on the physics principle of electromagnetic induction. To learn more about this principle go to the following Web page:

http://regentsprep.org/Regents/physics/phys03/dinduction/default.htm
CONSTRUCTION OF A "MAGNETIC FIELD DETECTOR"

Follow these simple directions to construct a device that will detect the presence of a magnetic field.

MATERIALS and TOOLS

One digital electric multimeter with leads
One 14 inches of magnet wire (20 gauge)
One 1 inch - 2 inch ceramic magnets
Wire cutters or heavy duty scissors
Small piece of fine sand paper or emery

(Materials may be found at local technology stores)

CONSTRUCTION PROCEDURE

1. Cut a 14-inch length of 20 gauge magnet wire.
2. Use the fine sand paper to "strip" 1 inch of the insulating enamel from each end of the 14-inch wire. The ends should appear to be shinier than the part of the wire that remains insulated with a very thin enamel.
3. Wrap the 14-inch long magnet wire around your index finger to form a coil with each end sticking out about 1.5 inches, like the coil shown below.
4. Tightly wrap each of the shiny stripped ends of the coil around each of the wire leads attached to the + and - plug as shown in the diagram. You may hold everything together with electrical or cellophane tape but make sure the leads never touch one another to create a short circuit.
5. Test your "Magnetic Field Detector" by turning the dial on the meter to anywhere between 100ma and 500ma. Move the ceramic magnet very near and across the coil. If you see numbers greater than "0" on the meter, the meter is working and detecting the magnetic field around the ceramic magnet. If it doesn't work, check to make sure all wires are in close contact.