**LAB: ELLIPTICAL ORBITS**

**Purpose:** The purpose of this lab is to study the properties of ellipses and to compare the shapes of the planet's orbits. After you have completed this lab, you should be able to:

1. Draw an ellipse.
2. Measure the major axis (m) and the focal distance (c) of an ellipse.
3. Calculate the eccentricity (e) of an ellipse.
4. Compare the shapes of ellipses of different eccentricities.

**Background:** For centuries it was believed that the orbits of the planets had to be perfect circles. Unfortunately, this model was unable to predict the locations of the planets accurately. In 1609, Johannes Kepler proposed another model that worked much better at predicting where the planets would be. Kepler proposed that the shapes of the planet's orbits were ellipses and that the sun was at a special place in the ellipse called the focus. Observations since Kepler's time have confirmed his discoveries.

An ellipse is a slightly flattened circle. Its largest diameter is called the major axis. The shortest distance across the ellipse is called the minor axis. Two points located on the major axis are called the foci (plural of focus). They are all shown in the drawing below. The furthest point from the ellipse to a focus is referred to as the aphelion. The closest point from the ellipse to a focus is referred to as the perihelion. During the northern hemisphere’s summer the sun is at the aphelion, while during the northern hemisphere’s winter the sun is at the perihelion.

The flatness or “out-of-roundness” of an ellipse is described by its eccentricity. The eccentricity (e) can be obtained by measuring the length of the major axis (m) and the distance between the 2 foci (c). The eccentricity is a ratio, therefore it has no units and is given by the equation:

\[
e = \frac{c}{m}
\]

All the planets’ orbits are elliptical. However, the extent of their eccentricity varies. The following describes a mechanical method of creating an ellipse. The odds of creating an ellipse equal to that of one of the planets is astronomical. Therefore, you will compare the eccentricities of the 4 ellipses you draw to the eccentricities of the planets to discover how eccentric the planets’ orbits are.
**Materials:** 2 thumbtacks, metric ruler, pencil, 4 sheets of blank paper, board, 30 centimeter long string, calculator

**Procedure:**
1. Read the entire lab before doing anything.
2. To draw an ellipse:
   - first place a clean sheet of paper lengthwise on the board.
   - Put the 2 thumbtacks about 5 centimeters apart near the center of the cardboard.
   - Tie the ends of the 20 centimeter long string together, making a loop.
   - Put the loop of string around the tacks and pull the string tight with a pencil. Keeping the pencil straight up and the string tight, slide the pencil along the string to draw the ellipse. See the diagram below to show how to loop the string and use the pencil.

3. Remove your paper from the cardboard and mark the foci.
   - Draw the major axis.
   - Measure the length of the major axis (m) and the focal distance (c). Make all measurements in metric. Note these on the data table.
   - Calculate the eccentricity of your ellipse. Note this on the data table.
   - Label this as "Ellipse 1".
4. Using a clean sheet of paper and the same string as above, draw another ellipse with the foci (thumb tacks) farther apart. Then repeat step 3. Label this as "Ellipse 2".
5. Using a clean sheet of paper and the same string as above, put your tacks as far apart from each other as possible. Draw an ellipse. This would be the most eccentric an ellipse could be. Then repeat step 3. Label this as "Ellipse 3".
6. Using a clean sheet of paper and the same string as above, draw an ellipse which has the smallest eccentricity you can possibly make. Then repeat step 3. Label this as "Ellipse 4".
**Analysis:** Answer these questions in complete sentences on a separate sheet.
1. How many foci are needed to draw an ellipse?
2. All the planet’s orbits are elliptical. What is at one foci of the ellipses’ of the planets?
3. What two measurements are needed to calculate eccentricity?
4. What does increasing the focal distance do to the shape of the ellipse?
5. Is an ellipse with a higher eccentricity number rounder or flatter?
6. Using Table A, list the planets from highest eccentricity to the lowest eccentricity.
7. Earth’s orbit is closest in shape to which ellipse that you drew?
8. Does Earth’s orbital path look more like an ellipse or a circle?
9. Pluto’s orbit is closest in shape to which ellipse that you drew?
10. Does Pluto’s orbital path look more like an ellipse or a circle?

<table>
<thead>
<tr>
<th>Ellipse #</th>
<th>Focal Distance (cm)</th>
<th>Major Axis (cm)</th>
<th>Eccentricity</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
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**Table A**

<table>
<thead>
<tr>
<th>Planet</th>
<th>Eccentricity</th>
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<tbody>
<tr>
<td>Mercury</td>
<td>0.206</td>
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<tr>
<td>Venus</td>
<td>0.007</td>
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<tr>
<td>Earth</td>
<td>0.017</td>
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<tr>
<td>Mars</td>
<td>0.093</td>
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<tr>
<td>Jupiter</td>
<td>0.048</td>
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<tr>
<td>Saturn</td>
<td>0.056</td>
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<tr>
<td>Uranus</td>
<td>0.047</td>
</tr>
<tr>
<td>Neptune</td>
<td>0.008</td>
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<tr>
<td>Pluto</td>
<td>0.247</td>
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