SPEED OF LIGHT (AND OTHER ELECTROMAGNETIC ENERGY WAVES)*

Introduction:

The following facts are important to remember:

- Mechanical waves, such as sound waves, must transfer energy through a substance or medium.
- Electromagnetic waves—such as light waves, radio frequency waves, X-rays, and microwaves—can transfer energy in a vacuum, without a medium.
- Electromagnetic waves are created by electrically charged particles that move.
- All types of electromagnetic waves travel at the same speed.
- Both types of waves are initiated by something that vibrates.

Today you will calculate the speed of radio frequency waves, a type of electromagnetic wave. You will then compare this value to the value you calculated yesterday for the speed of sound.

Speed of Radio Frequency Waves in Space:

The table below shows the distance of representative planets from Earth and the calculated time it would take for a radio frequency wave to travel from Earth to that planet.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from Earth in km</th>
<th>Seconds needed for radio frequency wave to travel between planet and Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>92,000,000</td>
<td>306</td>
</tr>
<tr>
<td>Jupiter</td>
<td>629,000,000</td>
<td>2096</td>
</tr>
<tr>
<td>Saturn</td>
<td>1,277,000,000</td>
<td>4256</td>
</tr>
<tr>
<td>Uranus</td>
<td>2,721,000,000</td>
<td>9070</td>
</tr>
</tbody>
</table>
Graph the data. First convert the distance in km to a number that is easier to work with. Convert each distance into millions of km (distance in km given in table/1,000,000). Convert the time in seconds to time in minutes: time (minutes) = time (seconds) ÷ 60.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from Earth in km</th>
<th>Distance from Earth in 1,000,000 km</th>
<th>Seconds needed for radio frequency waves to travel between planet and Earth</th>
<th>Minutes needed for radio frequency waves to travel between planet and Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>92,000,000</td>
<td></td>
<td>306</td>
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</table>

Graph the data: (on the next page)

- Label the x-axis “time in minutes” and the y-axis ”distance in millions of km.” Which is the
  - Manipulated/independent variable: __________________________
  - Responding/dependent variable: __________________________
- Decide on an appropriate interval for both the x- and y-axes.
- Plot the data.
- Draw a line connecting the points on your graph.
1. On your graph, what two ordered pairs represent Mercury and Jupiter?
   Mercury (____ min, _____ millions of km)
   Jupiter (____ min, _____ millions of km)

2. On your graph, what two ordered pairs represent Saturn and Uranus?
   Saturn (____ min, _____ millions of km)
   Uranus (____ min, _____ millions of km)

3. Determine the unit rate of change (slope) along the line on your graph.

   Unit rate of change = \( \frac{\Delta y}{\Delta x} = \frac{(y_2 - y_1)}{(x_2 - x_1)} = \frac{\Delta \text{distance}}{\Delta \text{time}} \)

<table>
<thead>
<tr>
<th>Ordered Pair used for calculation ((x_1, y_1)) ((x_2, y_2))</th>
<th>(\Delta) Distance (millions of km) (\Delta y)</th>
<th>(\Delta) Time (min) (\Delta x)</th>
<th>Unit Rate of Change (slope) (\frac{\Delta y}{\Delta x})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury and Jupiter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturn and Uranus</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Is change in distance divided by the change in time different for the two sets of points?
   ____________________________

5. What does the unit rate of change represent? ____________________________
6. Convert your calculated value to a value in km/second.

\[
\text{millions of km \times \frac{1 \text{ minute}}{60 \text{ seconds}} \times \frac{1,000,000 \text{ km}}{1 \text{ million of km}} =}
\]

\[
\text{\_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ km/second}
\]

7. The speed of light is about 300,000 km/second. How does your value for the speed of radio frequency waves compare with this?

________________________________________________________________________

8. Calculate the percent error.

\[
\frac{300,000 \text{ km/sec} - \text{your calculated value}}{300,000 \text{ km/second}} = \frac{\_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_}{300,000 \text{ km/second}}
\]

\[
= \frac{\_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_}{100} = \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ 
\]

9. Compare the speed of radio frequency (or light) waves to that of sound.

Speed of radio frequency waves and light waves: \______________

Speed of sound (calculated yesterday): \______________

Comparison: \______________

10. The general equation for a line is \( y = mx + b \) where \( m \) represents the constant rate of change and \( b \) represents the value of \( y \) when \( x = 0 \) (also called the \( y \)-intercept). If time = 0 minute, what is the distance that radio frequency waves have traveled? \______________

11. What is the \( y \)-intercept? \______________

12. Write the equation for the line that you drew on the graph.
13. How long would it take for a radio frequency wave to reach Mars (78,000,000 km from Earth) and Neptune (4,347,000,000 km from Earth)?

   a. Use the graph to estimate the time.

      Earth to Mars estimate: _______________________
      Earth to Neptune estimate: ____________________

   b. Use the equation for the line to calculate the time.

      Earth to Mars calculation:

      Earth to Neptune calculation:

**Question of the Day:**

Why is it that you see lightning before you hear the thunder associated with it?

*The idea for this activity was adapted from “How Long Does It Take to Say Hello?” in Out of This World, AIMS Education Foundation, 2007, p. 122.*