Introduction:

When we discuss electromagnetic waves we usually think of visible light, but visible light actually makes up only a small fraction of the electromagnetic spectrum. The electromagnetic spectrum is the total range of frequency or wavelengths of electromagnetic waves. The spectrum’s range extends from the long wavelengths of radio waves to the short wavelengths of gamma waves. Below is a diagram of the electromagnetic spectrum.

Electromagnetic waves are similar in many ways to the mechanical waves you have probably studied in class, therefore many of the terms and mathematical equations used for mechanical waves can be used in the study of electromagnetic waves.

For simplicity we can think of an electromagnetic wave as energy that is moving from place to place and travels in the form of a transverse wave. Illustrated below is the relationship of wavelength and frequency of a transverse wave.

**Wavelength:** The distance from one crest of a wave to the next and is denoted by the Greek letter lambda (\(\lambda\)). In the image above the wavelength is about 7.5 units.

**Frequency:** The number of crests, troughs, or any other point on the wave that passes a given point in a unit time interval. (f)

**Amplitude:** The maximum displacement of the wave from an equilibrium position. In the image above the equilibrium position is 0 so the amplitude is 1. There is positive and negative displacement for each wavelength. The displacement is proportional to the amount of energy, the greater the displacement the larger the amount of energy associated with the wave.
Wavelength and frequency are inversely proportional, meaning that if the frequency goes up, the wavelength goes down. The same is true vice versa. Also, all forms of electromagnetic radiation travel at the same high velocity, the speed of light (c). The current accepted value for the speed of light is \(2.99792458 \times 10^8\) meters per second (m/s). For our lab the rounded value of \(3.00 \times 10^8\) m/s is acceptable.

The relationship between frequency, wavelength, and the speed of electromagnetic radiation is given by:

\[ c = f \times \lambda \]

In the lab we will be using Smiley (4.6m radio telescope) to measure the radio emission of two astronomical radio sources, but a different frequencies. We will calculate the wavelengths of the two frequencies of radio waves emitted from the radio sources.

**Prelab Questions:**

1. A source emits radio waves with a wavelength of 6 cm. What is the frequency of the radio emission?

2. Radio waves travel at the speed of light. The Galileo spacecraft orbiting Jupiter sends a signal 670 million km to earth. How long does the signal take the reach earth? Remember that velocity = distance/time.
3. Compare the wavelength of a radio wave with a frequency of 1.42 GHz to the wavelength of a visible light wave with a frequency of $6 \times 10^{14}$ Hz.

4. Curious question: Why can your radio pick up radio waves though walls, yet you ca nott see through walls?

**Procedure:**

1. Log into the Smiley Observation Control Room. For information on how to use Smiley please see the Smiley Users Manual.

2. With **Map** selected click on one of the objects which is currently above the horizon and click on **GO**. An object is below the horizon if its altitude is negative. If you see this, stop the telescope and choose another object.

3. Watch the coordinates on the control panel and wait for Smiley to reach its destination. Use **HandPaddle** to position Smiley as close as you can do the source.

4. In **Spectrum** mode choose the **Base Frequency** to be 1.42 GHz. Also choose your **IF GAIN** to be somewhere around 17 and your **PLOT RATE** to be 1x.

5. Record the maximum intensity (the peak in your intensity) in the data table below.

6. While on the same object choose the **Base Frequency** to be 4.8 GHz. Without readjusting the **PLOT RATE** or the **IF GAIN**.

7. Record the maximum intensity in the data table below by following the procedure you used in **Lab 1**. This procedure entailed saving your scan, then opening the data file, then listing the points to find your peak intensity.

8. Next, calculate the wavelength using the equation above. Also take the ratio of the maximum intensity at 1.42 GHz to the maximum intensity at 4.8 GHz and record in the data table below.

9. Repeat steps 2-8 for two more objects.
<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Wavelength</th>
<th>Maximum Signal</th>
<th>Ratio of Maximum Intensities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Object 1</strong></td>
<td>1.42 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.8 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Object 2</strong></td>
<td>1.42 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.8 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Object 3</strong></td>
<td>1.42 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.8 GHz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Discussion:**

1. What can you observe from the ratios calculated in your results? Is the 1.42 GHz signal stronger or weaker than the 4.8 GHz signal?

2. The sun is much more intense in the visible part of the electromagnetic spectrum than in the radio. This suggests that higher frequencies are more intense. Is this what you observed?

**Conclusion:**

This section is your opportunity to describe the observations you made. Feel free to comment on any aspect, including problems, how difficult/easy the observations were, and what makes sense and what does not.