# Logarithmic and Linear Models of the Electromagnetic Spectrum
(High School)
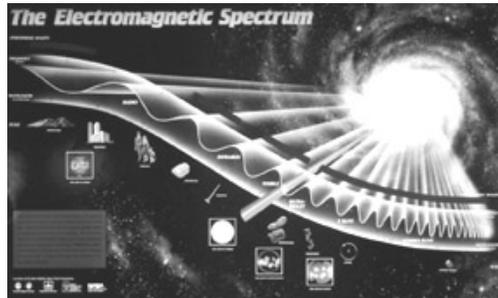
Models of the electromagnetic spectrum similar to the one pictured above are used extensively in textbooks and on posters, and like all other models it contains distortions. The model is extremely useful for showing the frequencies of the different bands of electromagnetic radiation (EMR), and the relationships between frequency and wavelength. However, this is a logarithmic model, and severely distorts the actual width of the different bands of radiation. The result is that looking at this model gives you the wrong idea that the radio band is very large compared to the X-ray band, for example. You are going to construct both models, logarithmic and linear, on the same chart and compare the two models.

1. Use either the template provided or the following instructions to construct the diagram shown below. Tape four pieces of 8 1/2" by 11" paper together end-to-end so that their long sides are on the bottom. The pieces of paper should overlap by 3 cm. Then draw a line down the left side of the chart about 2 cm from the edge (see diagram below). From the line you have just drawn, draw two horizontal lines extending to the right across the pages: one line 8 cm from the top of the chart, and the other line 10 cm below the first horizontal line.
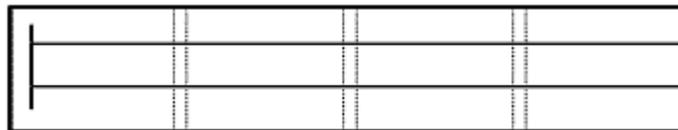
2. The top line will be used to plot the logarithmic model. Along this line, mark off 24 2-cm intervals from the vertical line you drew. Starting at 2 cm, label each interval with increasing powers of ten, from 10^1 to 10^{24}. These numbers represent the frequency in Hertz of the electromagnetic spectrum. Use the information from the Frequency Range Table on the next page to divide your model into the individual bands of electromagnetic radiation. (Use the entire visible band, not the individual colors.)

Frequency Range Table

EMR Bands	Frequency Range (Hertz)
Radio & Microwave	Near 0 to 3.0×10^{12}
Infrared	3.0×10^{12} to 4.6×10^{14}
Visible	4.6×10^{14} to 7.5×10^{14}
Red	4.6×10^{14} to 5.1×10^{14}
Orange	5.1×10^{14} to 5.6×10^{14}
Yellow	5.6×10^{14} to 6.1×10^{14}
Green	6.1×10^{14} to 6.5×10^{14}
Blue	6.5×10^{14} to 7.0×10^{14}
Violet	7.0×10^{14} to 7.5×10^{14}
Ultraviolet	7.5×10^{14} to 6.0×10^{16}
X-ray	6.0×10^{16} to 1.0×10^{20}
Gamma Ray	1.0×10^{20} to...

3. Before you can construct the linear model, it is necessary to convert the frequencies that you used for the logarithmic model. Those numbers simply told you the range of frequencies, or amount of energy, that each of the bands of EMR covers within the spectrum. Now we want to compare the width of each of the individual bands of radiation relative to each other. We can do this by converting all of the bands of EMR to the same frequency range. We will arbitrarily select the frequency range of the visible band, 10^{14}. Convert the frequency numbers for all bands (except visible) in the Frequency Range ConversionTable below to 10^{14} and record them in the table. (There is a tutorial on converting exponents on the last page.)

Frequency Range Conversion Table

EMR Bands	10^{14} Conversions
Radio & Microwave	
Infrared	
Visible	4.6×10^{14} to 7.5×10^{14}
Red	4.6×10^{14} to 5.1×10^{14}
Orange	5.1×10^{14} to 5.6×10^{14}
Yellow	5.6×10^{14} to 6.1×10^{14}
Green	6.1×10^{14} to 6.5×10^{14}
Blue	6.5×10^{14} to 7.0×10^{14}
Violet	7.0×10^{14} to 7.5×10^{14}
Ultraviolet	
X-ray	
Gamma Ray	

4. Mark off 10 10-cm intervals from the vertical line. Starting at the first interval, label each mark as a whole number times 10^{14}, from 1×10^{14} to 10×10^{14}. Label the bottom of your model "Frequency in Hertz." You can now plot some of the 10^{14} frequencies you calculated on the bottom line of your constructed model. Plot the individual colors of the visible spectrum and color them. Compare the two models. Do the results surprise you?

5. How far does the ultraviolet band extend? Calculate the width of the ultraviolet band. What do you think you would need to measure the distance to the end of the UV part of the EMR?

6. X-rays are the next band of radiation. Calculate the distance from the end of the ultraviolet band to the end of the X-ray band. What do you think you would need to measure the distance to the end of the X-Ray band?

7. Based on your results for the width of the X-ray band, what would be your estimate for the width of the gamma ray band of radiation? What would you need to measure the distance?

8. Compare and contrast the distortions between the two models. What is the advantage in using the logarithmic model? What is the advantage in using the linear model? Can you think of any other ways to model the electromagnetic spectrum?

Using Scientific Notation

We use methods such as abbreviations and acronyms to make long words or long phrases easier to write. In this activity we have used the acronym EMR so we do not have to keep writing the words "ElectroMagnetic Radiation". We use acronyms such as NASA so we do not have to write out the words "National Aeronautics and Space Administration". We do the same thing with numbers, by using scientific notation (exponents.) For example, the number 1,000,000 written in scientific notation, or exponential form, is 1×10^6.

$100 = 10 \times 10 = 1 \times 10^2$

$1000 = 10 \times 10 \times 10 = 1 \times 10^3$

$100,000 = 10 \times 10 \times 10 \times 10 \times 10 = 1 \times 10^5$

What if we wanted to express the number 100 [1×10^2] as an exponent of 10^3? The difference between 10^2 and 10^3 is one exponent so we would move the decimal one place. Since we are expressing a number as a larger exponent, the decimal place is moved one place to the left, so 1×10^2 becomes 0.1×10^3

What if we wanted to express the number 100,000 [1×10^5] as an exponent of 10^3?

The difference between 10^5 and 10^3 is two exponents so we would move the decimal two places. Since we are expressing a number as a smaller exponent, the decimal place is moved two places to the right, so 1×10^5 becomes 100×10^3.