Signals Across Space

Trace how frequency, wavelength, and photon energy change across the spectrum.

HS-PSII-9.1 "Develop the relationship among frequency, wavelength, and energy for electromagnetic waves across the entire spectrum."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Circle the two equations and number the seven spectrum regions from lowest to highest frequency so you can trace how wavelength and photon energy change.

What a Space Telescope Detects

1. A space telescope collects radio waves from distant gas and gamma rays from violent stellar events. Both are electromagnetic waves, and in a vacuum both travel at about 3×10^8 meters per second. Their frequencies differ: frequency counts wave cycles passing a point each second, while wavelength measures the distance between neighboring crests.

2. For a wave traveling in a vacuum, speed equals frequency times wavelength: $c = f\lambda$. Since c stays the same, doubling frequency halves wavelength. A photon's energy follows $E = hf$, where h is a fixed constant. More cycles per second mean more energy per photon. The table gives rounded values for five regions.

SAMPLE ELECTROMAGNETIC WAVES IN A VACUUM

Region	Frequency (Hz)	Wavelength (m)	Energy per photon (J)
Radio	1×10^{8}	3	6.6×10^{-26}
Infrared	1×10^{12}	3×10^{-4}	6.6×10^{-22}
Visible	5×10^{14}	6×10^{-7}	3.3×10^{-19}
Ultraviolet	1×10^{16}	3×10^{-8}	6.6×10^{-18}
Gamma ray	1×10^{20}	3×10^{-12}	6.6×10^{-14}

3. Read across the entire spectrum from radio through microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. Moving in that direction, frequency and photon energy increase, while wavelength decreases. These boundaries are approximate, and neighboring regions can overlap. Radio and gamma photons have different energies, yet both travel at the same speed in a vacuum.

2 ANSWER WITH EVIDENCE

Use the passage

1. Compare the radio and infrared entries. By what factor does frequency change? What happens to wavelength and energy per photon by that factor?

2. Use the table to compare visible and ultraviolet waves. How many times greater is the ultraviolet frequency, and how do their wavelengths and photon energies compare?

3. Microwaves and X-rays are not in the table. Which has the higher frequency and photon energy? Which has the longer wavelength? Use their positions in the passage to explain.

4. A signal has half the frequency of the gamma-ray entry. How would its wavelength, photon energy, and speed in a vacuum compare with that entry?

3 YOUR TURN

Your own words

A detector measures a wave at 2×10^{12} Hz in a vacuum. In 3 to 4 sentences, use the table to estimate its wavelength and photon energy, name its spectrum region, and compare its wavelength and photon energy with visible light. Show how doubling a frequency in the table supports your estimates.

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PART 1 · READ AND MARK

Circle the two equations and number the seven spectrum regions from lowest to highest frequency so you can trace how wavelength and photon energy change. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	Compare the radio and infrared entries. By what factor does frequency change? What happens to wavelength and energy per photon by that factor?	**Infrared frequency is 10,000 times the radio frequency. Its wavelength is 10,000 times shorter, and its photon energy is 10,000 times greater.**
2	Use the table to compare visible and ultraviolet waves. How many times greater is the ultraviolet frequency, and how do their wavelengths and photon energies compare?	**Ultraviolet frequency is 20 times greater. Its wavelength is 20 times shorter, and its photon energy is 20 times greater.**
3	Microwaves and X-rays are not in the table. Which has the higher frequency and photon energy? Which has the longer wavelength? Use their positions in the passage to explain.	**X-rays have higher frequency and photon energy. Microwaves have longer wavelengths because they occur earlier in the listed order.**
4	A signal has half the frequency of the gamma-ray entry. How would its wavelength, photon energy, and speed in a vacuum compare with that entry?	**Its wavelength would be twice as long, its photon energy would be half as great, and its speed in a vacuum would be the same.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

This wave is infrared because its frequency is close to the infrared entry. Its frequency is twice that entry's frequency, so its wavelength is half as long, about 1.5×10^{-4} m, and its photon energy is twice as great, about 1.32×10^{-21} J. Compared with visible light, it has a longer wavelength and less energy per photon.

Accept equivalent rounded values in Part 3. For comparisons, look for the inverse relationship between frequency and wavelength and the direct relationship between frequency and photon energy.