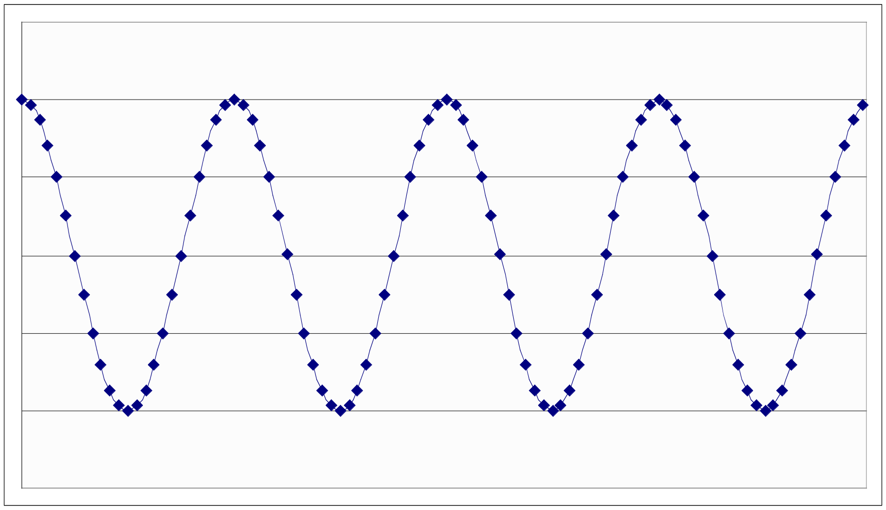
Name ________________________________ Period _________

Notes - Waves and Electromagnetic Radiation (POGIL)

The figure below represents part of a wave. The entire wave can be thought of as extending indefinitely in both directions. One important characteristic of a wave is the wavelength (λ = lambda), which is the distance between any two adjacent, identical points.



1. On the figure above, draw a line connecting two points whose separation is equal to the wavelength (λ) of the wave. Label a crest (highest point), trough (lowest point), rest (middle), and amplitude (rest to crest).

Definitions: f = frequency λ= wavelength c = speed of light = 3×10^8m/s h = Planck's constant = 6.63×10^{-34} Js $c = \lambda f$ Energy= $E_{photon}=hf$

The frequency (f) of a wave is defined as the number of wavelengths per second that travel past a given point. $c= f\lambda$ Speed is constant in a given material; therefore, as frequency increases, wavelength decreases.

2. a. For a wave traveling at a given speed, c, how does the frequency depend on the wavelength.

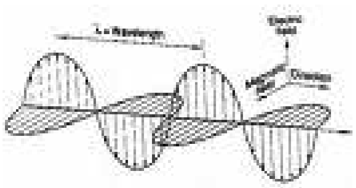
b. Write the formula showing the relationship between f, λ, and c for a wave.

c. Indicate whether the following statement is true or false, and explain your reasoning:
For waves traveling at the same speed, the longer the wavelength the greater the frequency.

Model 2: Electromagnetic Radiation and Photons.

Light can be thought of as an electromagnetic wave or electromagnetic radiation having a paricular wavelength and frequency. In addition, Albert Einstein proposed almost a century ago that electromagnetic radiation can be viewed as a stream of particles known as photons, each of which has a particular amount of energy associated with it. Specifically, he proposed the following equation: $E_{photon} = hf$ where h is called Planck's constant.

Type of Radiation	Wavelength, λ (in m)	Frequency, f (in s^{-1})
Radio	1.00×10^{2}	3.00×10^{6}
Microwaves	1.00×10^{-2}	3.00×10^{10}
Infrared	1.00×10^{-5}	3.00×10^{13}
Red light	7.00×10^{-7}	4.29×10^{14}
Green light	5.00×10^{-7}	6.00×10^{14}
Violet light	4.00×10^{-7}	7.50×10^{14}
UV	1.00×10^{-8}	3.00×10^{16}
X-rays	1.00×10^{-10}	3.00×10^{18}
Gamma	1.00×10^{-12}	3.00×10^{20}



Regions of EMS

Region	Wavelength
Radiowave	3 km- 30 cm
Microwave	30 cm-1mm
Infrared (IR)	1 mm-800nm
Visible	800 nm-400nm
Ultraviolet (UV)	400 nm-10 nm
X-ray	10 nm-0.1nm
Gamma ray	<0.1 nm

The table above lists the wavelengths (λ) and frequencies (f) of various forms of electromagnetic radiation. The frequency of a wave is the number of waves (or cycles) that pass a given point in a given amount of time.

3. a. Using $c = f\lambda$, find the speed of radio waves and green light. How do they compare?

b. What are the units for speed?

c. Are λ and f directly or inversely related? Explain

4. A certain photon has a wavelength of 100 nm. In what region of the electromagnetic spectrum should this photon be classified?

5. What is the value of Planck's constant including units?

6. What is the speed of electromagnetic radiation (light waves)?

7. Write the equation that relates the energy of a photon and its frequency. Is the energy of a photon proportional or inversely proportional to f?

8. Place the following types of radiation in order of increasing energy per photon.

a. green light from a mercury lamp

b. x-rays from an instrument in a dentist office
c. ultraviolet radiation from a tanning bed.
d. an FM music station at 106.1 FM.

9. Which color in the visible spectrum has the highest frequency? Which has the lowest frequency?

10. Is the radiation used in a microwave even higher or lower in frequency than your favorite tanning bed?

11. Which type of radiation involves less energy: radio or red light?

12. Which radiation has the higher frequency: UV or microwaves?

13. Which radiation has the longer wavelength: x-rays or visible light?

14. Which is the more energetic, a red photon ($\lambda \approx 700$ nm) or a blue photon ($\lambda \approx 400$ nm). Explain your choice.

Examples:
What is the wavelength of Gamma radiation with a frequency of $3.00 \times 10^{20}\ s^{-1}$

$\lambda = c / f$ $\quad \lambda = \dfrac{3 \times 10^{8}\ m/s}{3 \times 10^{20}\ s} = 1 \times 10^{-12}$ m

What is the energy of Gamma radiation with a frequency of $3.00 \times 10^{20} s^{-1}$

$E = hf$ $\quad E = (6.63 \times 10^{-34}\ Js)(3.00 \times 10^{20}\ s^{-1}) = 1.99 \times 10^{-13}$ J

15. Assuming a microwave oven operates at a frequency of $1.00 \times 10^{11}\ s^{-1}$.
a. What is the wavelength of this radiation in meters?

b. What is its energy per photon? $E = \dfrac{hc}{l}$

16. Orange light has a frequency of $4.8 \times 10^{14}\ s^{-1}$.
a. What is the wavelength of orange light in meters?

b. What is the energy of one quantum of orange light?

17. You have an X-ray with a wavelength of 1×10^{-10}m.
a. What is the frequency of the X-ray in s^{-1}?

b. What is the energy from the X-ray? $E = \dfrac{hc}{l}$