Mr. Renwick's Physics 11
Worksheet – Introduction to Waves

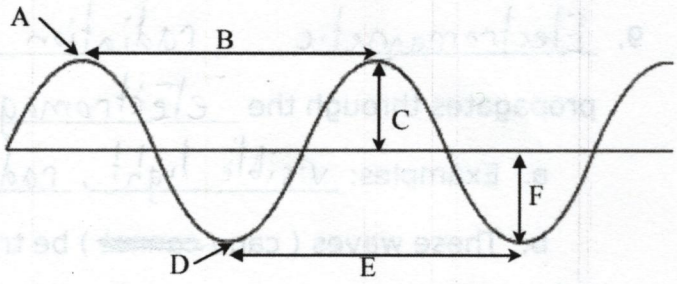
Name: _____
Block: _____

Learning Intention

- Learn some of the vocabulary associated with waves.
- Learn some of the properties of waves and how to classify some types of waves.

Definitions and Formulas

1. A wave is a disturbance in a medium, transferring energy without transferring matter.
   a. Waves are modelled mathematically using sinusoidal waveforms.
2. Label each part of the diagram of a wave:



   a. peak/crest
   b. wavelength
      ↳ from peak-to-peak
   c. amplitude
   d. trough
   e. wavelength - from trough to trough
   f. amplitude

3. Frequency: How many waves pass by a point in a given amount of time. It is measured in s^{-1}, also known as Hertz (Hz).
4. Period: The amount of time it takes for a complete wave to pass by a point.

See over →

5. Frequency and period are related with the equation:

$T = \frac{1}{f}$ $\quad f = \frac{1}{T}$

T: period (s)
f: frequency (Hz)

6. In a longitudinal wave, the waves oscillate parallel to the direction of travel.
7. In a transverse wave, the waves oscillate perpendicular to the direction of travel.
8. Mechanical wave: A wave which travels through a physical medium.
   a. Examples: surf waves and earthquake
   b. These waves (~~can~~ / cannot) be transmitted through the vacuum of space
9. Electromagnetic radiation (EMR) wave: A wave which propagates through the electromagnetic field.
   a. Examples: visible light, radio waves, and X-rays
   b. These waves (can / ~~cannot~~) be transmitted through the vacuum of space
10. Transmission occurs whenever a wave passes through a medium.
    a. In a given medium, the speed of a given type of wave is constant.
11. Reflection occurs when a wave reaches the boundary between two mediums, and bounces back to the original medium.
    a. In sound waves, this is known as an echo.
12. When passing from one medium to another, the frequency (~~does~~ / doesn't) change, and the wavelength (does / ~~doesn't~~) change.
13. Waves obey the Universal Wave Equation:

$v = f\lambda$

v: speed (m/s)
f: frequency (Hz)
λ: wavelength (m)

lambda, Greek lowercase L

14. Waves also obey the principal of superposition.

a. Constructive interference occurs when peaks of one wave are added to peaks of another wave, or troughs of one wave are added to troughs of another.

b. Destructive interference occurs when peaks of one wave are added to troughs of another wave.

c. Total destructive interference yields absolutely no resulting wave. This effect is partially achieved in noise-cancelling headphones.

15. Beats occur when two similar but different frequencies interfere, resulting in an oscillation of the volume at a particular frequency.

a. The frequency is calculated as:

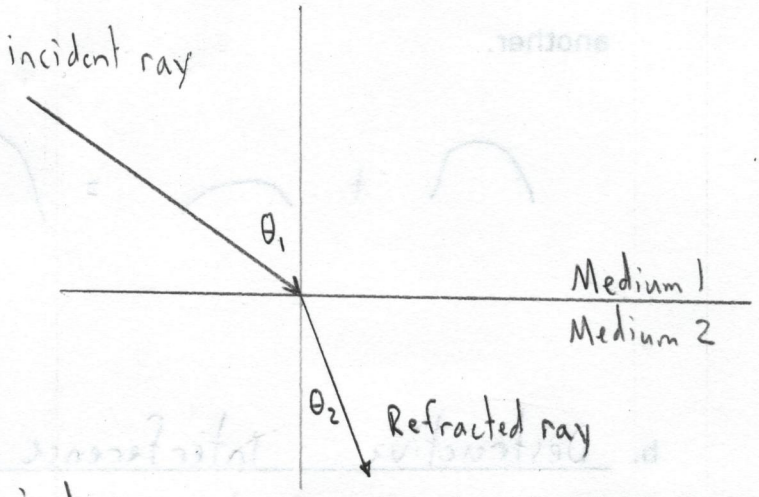
$$f_{beat} = |f_1 - f_2|$$

See over →

16. Refraction is the bending of a wave when it passes from one medium to another.

a. It is modeled mathematically using Snell's Law:

$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \frac{n_1}{n_2}$$



b. The refractive index represents how fast light passes through a medium:

$$n = \frac{c}{v}$$

n: refractive index (unitless)

c: speed of light in a vacuum

3.00×10^8 m/s

v: speed of light in the medium (m/s)

17. Diffraction is the bending of a wave as it passes beside an object, or through a slit. It is modeled as:

$$d\sin\theta_{min} = n\lambda$$

d: size of slit (m)

θ_{min}: the angle with minimum intensity (degrees)

n: an integer greater than 0

λ: wavelength (m)

18. The Doppler Effect is the apparent change in the frequency of waves when there is relative motion between the emitter and the receiver. When a mosquito flies towards your ear, this effect is responsible for the increase in the pitch of its wings flapping.

19. Linear polarization occurs when a circular transverse wave is confined to only vibrate in one plane. This effect is used for IMAX 3D movies.

Questions

1. An Intel Core i7-9700K processor can execute instructions at a frequency of up to 4.9 GHz. How quickly can it execute each instruction?
2. In 1992, the rapper Twista set a Guinness World Record for the fastest rapper, taking only 0.0893 seconds to pronounce each syllable. What was the frequency of him rapping a syllable?
3. Red light has a wavelength of 700 nm and a speed of 3.00×10^8 m/s in a vacuum. Red light can be slowed to a speed of 61 km/h.
    1. What is the frequency of red light in a vacuum?
    2. What is the frequency of red light at 61 km/h?
    3. What is the wavelength of red light at 61 km/h?
4. The velocity of a wave is 14 m/s in one medium, and 9.0 m/s in the second. If an incident ray has an angle of 75°, what is the angle of refraction?

See over →

5. Which will diffract more, sound or light? Why?
6. A blue light with a frequency of 750 terahertz passes by a 0.010 mm opening while moving through a vacuum.
   1. What is the wavelength of the light?
   2. What is the diffraction angle in degrees?

Answers

1. $T = 2.0 \times 10^{-10}$ s = 0.20 ns
2. f = 11.2 Hz
3. 1. $f = 4.3 \times 10^{14}$ Hz
   2. $f = 4.3 \times 10^{14}$ Hz
   3. $\lambda =$ ~~5.1×10^{-13} m~~ 4.0×10^{-14} m
4. $\theta = 38°$
5. Sound, because it has a longer wavelength.
6. 1. $\lambda = 4.0 \times 10^{-7}$ m
   2. $\theta = 2.3°$

1. $T = \frac{1}{f} = \frac{1}{4.9\times10^{9}\ Hz} = 2.0\times10^{-10}\ s = 0.20\ ns$

2. $f = \frac{1}{T} = \frac{1}{0.0893\ s} = 11.2\ Hz$

3. 1. $f = \frac{v}{\lambda} = \frac{3.00\times10^{8}\ m/s}{700\times10^{-9}\ m} = 4.3\times10^{14}\ Hz$

2. Frequency does not change going from one medium to another

$f = 4.3\times10^{14}\ Hz$

3. $\lambda = \frac{v}{f} = \frac{61\ km/h \times \frac{1\ m/s}{3.6\ km/h}}{4.3\times10^{14}\ Hz} = 4.0\times10^{-14}\ m$

4. $\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} \Rightarrow \sin\theta_2 = \sin\theta_1 \times \frac{v_2}{v_1}$

$\theta_2 = \sin^{-1}\left(\sin\theta_1 \times \frac{v_2}{v_1}\right) = \sin^{-1}\left(\sin 75 \times \frac{9}{14}\right) = 38.38°$

$\theta_2 = 38°$

6. 1. $\lambda = \frac{v}{f} = \frac{3.0\times10^{8}\ m/s}{750\times10^{12}\ Hz} = 4.0\times10^{-7}\ m$

2. $\sin\theta_{min_1} = \frac{n\lambda}{d}$

$\theta_{min_1} = \sin^{-1}\left(\frac{n\lambda}{d}\right) = \sin^{-1}\left(\frac{1\times4.0\times10^{-7}\ m}{0.010\times10^{-3}\ m}\right) = 2.3°$

3. $\theta_{min_2} = \sin^{-1}\left(\frac{n\lambda}{d}\right) = \sin^{-1}\left(\frac{2\times4.0\times10^{-7}\ m}{0.010\times10^{-3}\ m}\right) = 4.6°$