NOTES: General Wave Properties and Sound

(Information related to the Following online reading chapters: *Waves*, *Sound Waves and Music*, and *Light Waves and Color*)

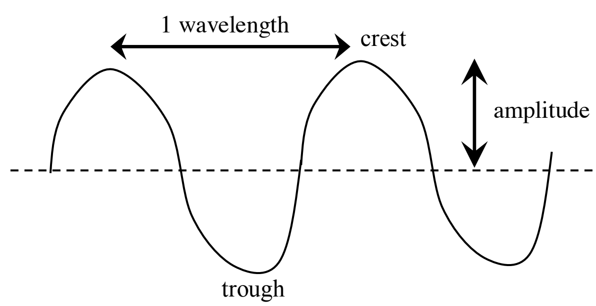
Forrest /A.P. Physics 1: 2019 *Your name:* ______________________________

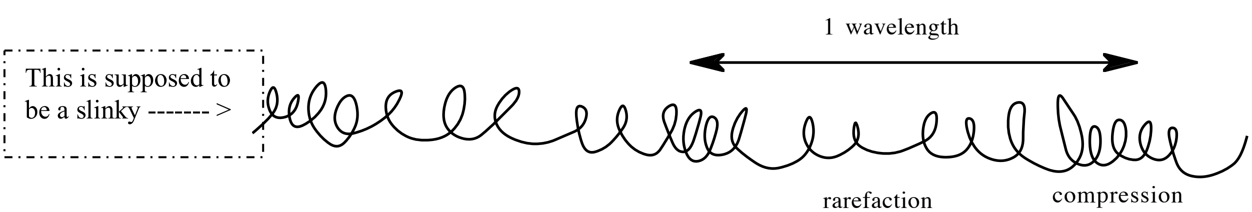
Waves are unique, in that they carry energy, which may or may not pass through matter. They also have some very fundamental properties not shared by non-waves. Later, we shall see this poses a dilemma, as light (and all other electromagnetic waves) can be considered both waves AND particles.

NOTE: Be careful!! When most people think of waves they think of the ocean. The breakers that come ashore are NOT waves, they may have been wavelike at one time, but once they break they turn much more complex and wave properties alone can't describe them!

The general equation for waves is: **v = (f)(λ)** where **v** = the velocity of the wave (in m/s), **f** is the frequency or number of waves per second (hertz) and the Greek symbol **Lambda (λ)** is the wavelength (in meters). If you recall from the ticker-timer labs, the period (**T**) of time between events (waves in this case) is measured in seconds. So, $T = 1/f$.

In **transverse** waves, the energy disturbance is perpendicular to the wave motion.
DEMO W. SLINKY.
There are easily identifiable crests, troughs, and wavelengths.
Examples of transverse waves include light, deep ocean waves, trampoline motion, etc.





In contrast, in **compressional** (or longitudinal) waves the energy moves parallel to the wave motion. Examples of compressional waves include sound waves. These waves contain compressions and rarefactions, and also have identifiable wavelengths. *DEMO W. SLINKY*

Mechanical waves are those that need a material (or medium) through which they must travel (water and sound waves are among these). **Electromagnetic** waves (light, heat, radio) do NOT need a medium.

The velocity of a wave is independent of amplitude. The velocity of a wave depends <u>only</u> on:

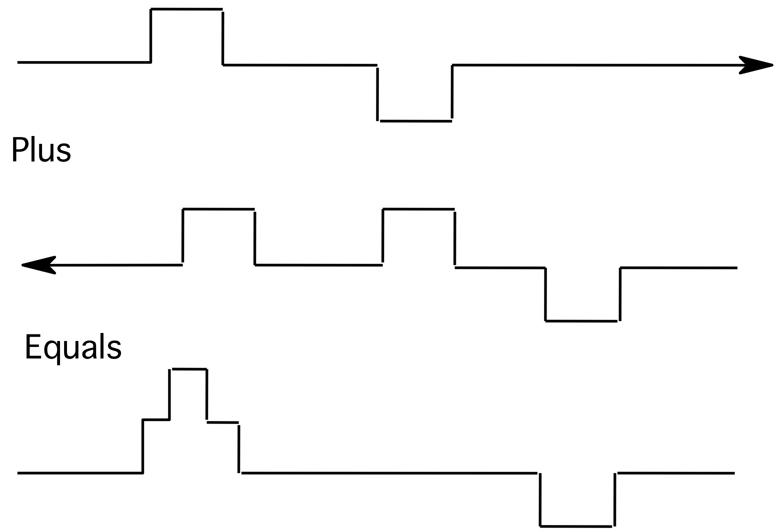
the medium (or material) through which the wave travels

REMEMBER ---> Waves carry energy, not material! *See DVD video clip with boat*

Note to self: Remember to get out oscilloscope and "see" musical instruments' wave patterns.

All waves have some common properties:

2) **Interference**. Waves can constructively or destructively interfere with each other. However, since waves carry energy and not matter, once two wave pulses pass through each other they continue on independently, as if they had never interacted. An Example of this is the Superposition Principle. *See DVD for examples of superposition*.



Beats occur when two waves of a similar frequency interfere with each other. With sound waves, this often produces an undesirable thrumming sound. In fact, preventing beats is accomplished by properly tuning a musical instrument which is why a tuning fork (either metallic or electronic) is often used to tune musical instruments. DEMO with music and keyboard as well as sound pipes! See the online chapter *Sounds Waves and Music* Lesson 3a – 'Interference and Beats' for information on interference AND beats! NOTE: *Demo. w keyboard!*

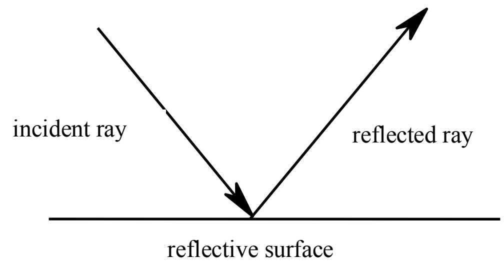
Another property of sound (also discussed in *Sound Waves and Music* Lesson 3b – The Doppler Effect) is the **Doppler Effect**. This is a change in the frequency of a wave when either the source of the wave ort the observer of the wave has a motion relative to the other. The most common application of the Doppler effect is with sound waves.

If the source of the sound and the observer are moving together, the frequency of the wave increases, since the wave fronts are 'squished' together. Therefore the frequency of the wave reaching the observer goes up, and the pitch of the sound is higher. If the relative motion of the sound source and the observer is that they are moving apart, then the frequency (or pitch) decreases. This is kind of hard to explain, but humans (and animals such as bats) are very good at using the Doppler effect to determine if an object is moving toward them or away from them. *Demo. with 'Doppler football'.*

When two waves of the same frequency, wavelength and amplitude interfere with each other, a **Standing Wave** is formed. This causes complete wave cancellation at some areas (nodes) and amplification at other areas (antinodes). *See DVD standing wave demo*. Also, DEMO with the drill/nail apparatus and strobe light. The online chapter *Sounds Waves and Music* Lesson 4c – 'Standing Wave Patterns' shows the first three harmonics (of 0.5 wavelength, 1.0 wavelength, and 1.5 wavelengths). For fixed ends, the wavelength of the fundamental frequency is always 1/2 the length of the vibrating body. **Resonance** (Lesson 5a from *Sound Waves and Music)* occurs when standing waves feed back on themselves, resulting in a great amplification of energy. This can occur in speakers, or when marching in step across a bridge (this is dangerous!) or when something coincides with an object's natural frequency. All objects have a 'natural frequency'. This depends on the size of the object, and is generally a higher frequency for smaller objects. DEMO with TUNING FORKS! ALSO SEE BRIDGE VIDEO!

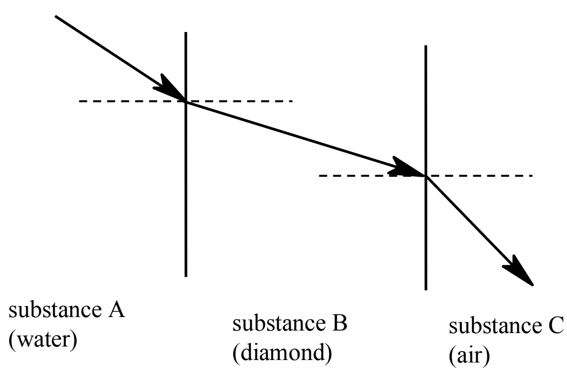
AP Physics 2 topics are mostly on this page…

2) **Reflection**. This can be partial or complete. No matter what the shape of the surface, the angle (from normal) which a wave strikes a surface is the same angle at which it is reflected.



Transverse waves may 'flip' or reverse phase when they reflect. See Lesson 3a (Boundary Behavior) of your online reading in the chapter 'Waves' for specific examples. ***Demo this with slinky, if not done earlier.***

3) **Refraction.** This is the bending of waves when they pass through a material of different density. In general waves slow down when they pass to a more dense substance. This is easily seen in ocean waves (and also occurs when the waves pass from a deep area to a shallow area) and is also easily seen with light bending through glass or water. The light waves bend because they slow down passing through a more dense substance.



When waves slow down (such as going from dense water to even more dense diamond, they bend towards the normal. When waves speed up, such as going from diamond to much less dense air, they bend away from the normal. *See carpet cars DVD demo.*

See Lesson 2a 'The Mathematics of Refraction' in the online reading chapter *Refraction and the Ray Model of Light* for more examples and pictures.

Question? How can refraction explain WHY we see sunlight before sunrise and after sunset? Remember the atmosphere is NOT a vacuum - it can also slightly refract light.

4) **Diffraction**. This is the tendency for waves to bend around an opening. In order for this to be noticeable, the opening needs to be about the same size as the wavelength. *See Wave DVD 2 for demo*. Diffraction is a special form of interference. Also, **DEMO with laser and diffraction grating**, and a flash photograph with 'rainbow glasses'. This principle was first identified by the great Christian Huygens many years ago, and is described in more detail in the online reading chapter *Waves* Lesson 3b – Reflection, Refraction and Diffraction.

Scattering is a type of diffraction. Here, small particles cause diffraction of waves (most commonly seen in light waves). Very small particles (like ozone molecules) scatter waves with the shortest wavelengths (which is blue light). This is why we have a blue sky and yellow/red sunsets!

5) **Polarization** is a characteristic of light where certain waves of light are 'filtered out' by a Polaroid film or selectively reflected. Normally waves are produced in all different alignments/directions, but when waves are polarized they are all aligned in a certain plane. See the online reading chapter *Light Waves and Color* Lesson 2d – polarization and the diagrams to help picture this. A LASER not only produces polarized waves, but it makes waves all having the same wavelength - this is a specific condition known as coherent light. **DEMO with polarization filters**.

This year we're not going to emphasize electromagnetic waves, but instead focus on sound waves (mechanical waves) and a bit of resonance. Therefore, there's really only one general wave equation up to this point:

$$V = (f)*(\lambda)$$

With V being the wave's velocity (normally in m/s), F being the wave's frequency (in waves/sec passing a stationary point – AKA 'Hertz'), and λ being the wavelength of the wave (usually in meters).

Waves can be:

Mechanical waves	OR	Electromagnetic waves
Which can be:		Which must be:
Either compressional (longitudinal) or transverse		Transverse
Mechanical waves need a medium through which they can travel (air, water, metals)		Electromagnetic waves do NOT need a medium to travel (they can go through empty space)
Examples: Sound, water, slinky waves		Examples: See the diagram below

In mechanical waves, the speed is determined by the medium through which the waves travel.

For electromagnetic waves, ***all*** of the waves travel at 3.0×10^8 m/s in the vacuum of space. When EM waves go through other materials, they can change apparent speed, as we'll discuss in class with the topic of refraction.

For ALL waves, the frequency of the wave is determined by what makes the wave, NOT what material (or medium) the wave passes through. As such, the frequency will not change when a wave passes through different materials, even though the wavelength and speed may change.

Diagram of the electromagnetic spectrum. All of the types of waves listed are EM waves