Physical Science Unit 6 Study Guide / Notes - Waves

1. **Waves can be classified based on what they are able to travel within and also how they move. (SPS9b)**
    a. A wave is a disturbance that carries energy from one place to another.
        i. Matter is NOT carried with the wave!
        ii. Waves travel through the medium without actually moving the medium with it. Basically the medium stays put while the wave moves some distance
    b. A wave can move through matter (a medium). If it must have a medium, it is called a mechanical wave. If it can travel without a medium (such as in the vacuum of space), it is called an electromagnetic wave.
        i. Mechanical wave: a wave that requires a medium to travel through.
            1. An initial disturbance causes a series of additional disturbances throughout the particles within the medium
                a. Think about a long line of people standing close together. Someone bumps into the person at the back of the line, who then bumps into the person in front of them, etc. There is a disturbance that passes through the line of people. This is similar to how energy disturbs matter as it moves through it as a mechanical wave.
            2. Examples include sound waves or water waves.
        ii. Electromagnetic wave: requires no medium to travel- can travel through a vacuum
            1. Consists of changing electric and magnetic fields
                a. Electric field is a region where particles can be pushed or pulled. Wherever there is an electric charge there is an electric field associated with it.
                b. A moving electric charge is part of an electric current and an electric current is surrounded by a magnetic field A magnetic field is a region in which magnetic forces are present.
                c. When electric field changes – so does the magnetic field. When one vibrates--- so does the other. This oscillation moves through space to cause the energy to travel.
            2. Examples include light and the other waves found on the electromagnetic spectrum.
                a. Electromagnetic waves travel very quickly, at the speed of light – 300,000 km/s.
                b. EM waves reach from the sun to Earth in about 8 minutes.
                c. All waves in the EM spectrum travel at this speed when in a vacuum.
                d. Radio – TV, radio stations, cordless phone signals, airplane communications
                e. Microwaves – cell phones, cook food, Doppler Radar (weather), police radar
                f. Infrared – TV remote control, heat treatments for illness, night vision goggles to see body heat
                g. Visible Light – fiber optics, mirrors & lenses, flashlights, light bulbs, LED bulbs, lasers for laser pointers for surgery and cutting things
                h. Ultraviolet – suntan, kill bacteria & viruses, detect forgery, black light to find blood and saliva

   i. X-ray – see broken bones, look for hidden objects at airports
   j. Gamma rays – kill cancer, sterilize, smoke detectors, check for leaks in the welds of pipes, determine the width of metal sheets, create energy in nuclear fission power plants

c. Waves can also be classified based on how they move in relation to a medium.
   i. Transverse wave - waves that move the medium at right angles to the direction in which the waves are traveling.
      1. Parts of a transverse wave:
         a. Rest position - an imaginary line through the middle of the wave on a diagram. This is the “resting” state of the medium when there is no disturbance going through it.
         b. The crest of a wave is the point on the medium that exhibits the maximum amount of positive or upward displacement from the rest position.
         c. The trough of a wave is the point on the medium that exhibits the maximum amount of negative or downward displacement from the rest position.

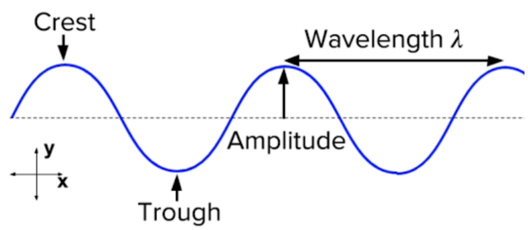
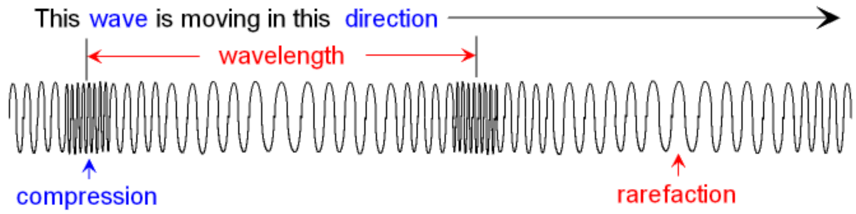


Figure 1: Parts of a transverse wave.

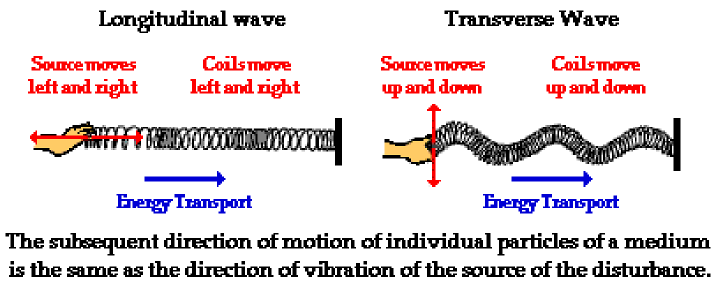
         d. The amplitude of a wave refers to the maximum amount of displacement of a particle on the medium from its rest position.
         e. The wavelength (λ) of a wave is simply the length of one complete wave cycle. For example, from the top of one crest to the top of another.
      2. Examples include a rope attached to a door and moved up and down, or the waves of the electromagnetic spectrum.
   ii. Longitudinal Waves: move particles parallel to the direction the wave is moving, “push-pull” waves.
      1. Parts of a longitudinal wave:
         a. A compression is a point on a medium through which a longitudinal wave is traveling that has the maximum density. The particles of the medium are close together in this region.
         b. A rarefaction is a point on a medium through which a longitudinal wave is traveling that has the minimum density. The particles will be furthest apart in this region.
         c. While a transverse wave has an alternating pattern of crests and troughs, a longitudinal wave has an alternating pattern of compressions and rarefactions.
         d. The wavelength can be determined by measuring the distance between any two corresponding points on adjacent waves. In the case of a longitudinal wave, a wavelength measurement is made by measuring the distance from a compression to the next compression or from a

rarefaction to the next rarefaction.



2. Example: slinky being pulled back and released

iii. Summary:



2. There are many properties of waves, and relationships among them. (SPS9a)

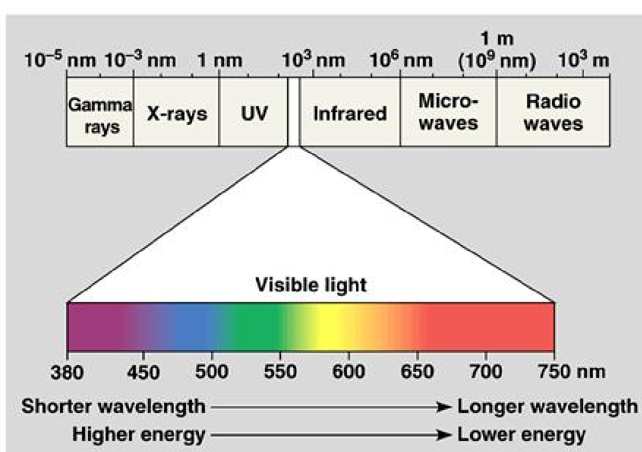
a. Amplitude – in a transverse wave – the height away from the "rest" position. The amplitude in a longitudinal wave is the measure of how compressed or rarefied the medium becomes.
   i. Amplitude is related to how much energy the wave is carrying- more energy = higher amplitude.
   ii. In sound waves, amplitude is perceived as loudness. More amplitude = a louder sound.

b. Frequency (f) – the number of complete waves that pass a given point in a certain period of time.
   i. Frequency is measured in HERTZ; one Hz is a wave that occurs once every second.
   ii. In sound waves, we perceive frequency as pitch. High pitch = high frequency

c. Period (T) - how long it takes for one cycle of a wave to pass.
   i. Typically measured in seconds.
   ii. Period and frequency are inversely related- as one goes up, the other goes down.
      1. $\text{period} = \frac{1}{\text{frequency}}$ $\text{frequency} = \frac{1}{\text{period}}$ $T = \frac{1}{f}$ $f = \frac{1}{T}$

d. The wavelength and frequency of a wave are also inversely related.
   i. As the wavelength increases, the frequency of the wave decreases.

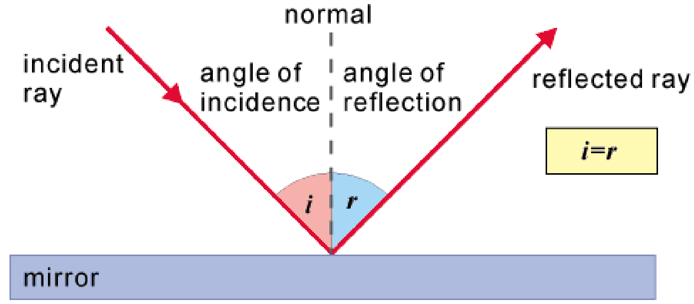
e. Energy is also related to the frequency of a wave. The relationships among the variables are summarized as they relate to electromagnetic waves below:



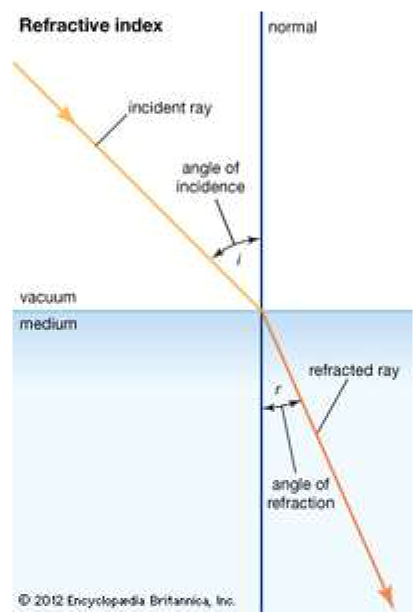
f. Speed of a wave = wavelength x frequency
    i. If the speed of a wave remains constant, as the frequency increases, the wavelength decreases and vice versa.
    ii. Mechanical waves travel fastest through solids due to the particles being closer together.
    iii. The speed of electromagnetic waves also depends on the medium through which it travels, traveling fastest in a vacuum, and then a gas.

3. Waves have several types of behaviors, and their speeds can also be affected. (SPS9c, SPS9d, SPS9e)

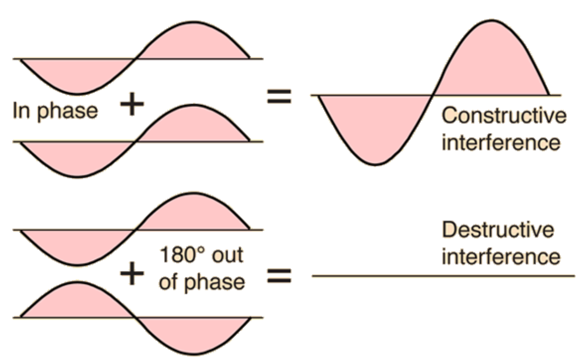
a. Reflection – when a wave reaches a surface and bounces off of it
    i. This happens when a light wave strikes a mirror
    ii. The frequency, wavelength, and speed all remain the same after the reflection
    iii. The law of reflection states that the angle of reflection equals the angle of incidence
    iv. Angle of incidence is the angle of the wave coming into the object reflecting the wave.
    v. Angle of Reflection is the angle bouncing off and going away from the object.



b. Refraction - Waves can bend; this happens when a wave enters a medium and its speed changes; the amount of bending depends on the medium it is entering compared to the medium it is leaving
    i. Every medium has a property called optical density. This refers to how much the substance slows down a ray of light. A higher density means light travels more slowly through the substance.
    ii. As a ray of light hits the boundary of a new medium, its speed often changes. This leads to a bending in the wave.
    iii. Light travels fastest in a vacuum, then gasses, liquids, and slowest in solids.
    iv. Refraction occurs in lenses.

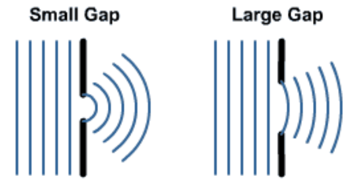


c. Interference occurs when two or more waves meet and they interact as they travel past one another. This interaction is called interference.
    i. Constructive interference – the combining of waves to cause higher amplitude of any of the original waves.
        1. Notice in the image to the right, constructive interference occurs when a crest meets a crest, or a trough meets a trough.
    ii. Destructive Interference – when the combining of the waves produce a new



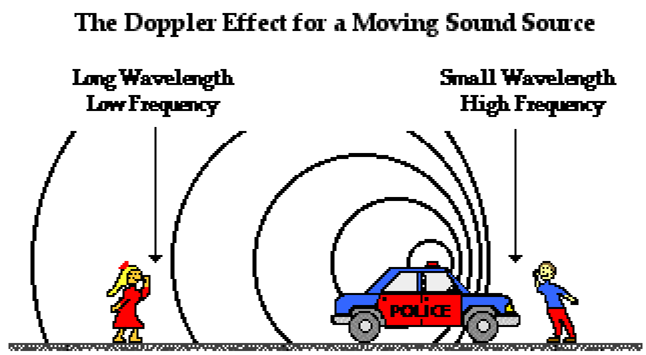
wave with a smaller amplitude than the beginning waves

d. Diffraction - Wave passing a barrier or going through a hole in a barrier bends and causes the wave to wrap around the barrier
    i. A wave diffracts more if its wavelength is large compared to the size of an opening or obstacle
    ii. Interference usually occurs as a result of the diffraction. This causes a diffraction pattern—the pattern of dark and light created when light bends around an edge or edges.



    iii. Because of diffraction, the images of microscopes and telescopes are blurred at high
    iv. Magnification.
    v. The larger the diameter of a lens or mirror used in an optical instrument, the less
    vi. significant the diffraction and the sharper the image.

e. Doppler Effect - is the apparent change in frequency of a wave due to the relative motion of the listener and the source of the sound.
    i. As the relative motion reduces the distance between the source and the observer, the frequency, or pitch, of the sound becomes higher. This is because the waves are closer together as the object moves towards the sound in front of it, all while producing more sound waves.
    ii. As the relative motion increases the distance between the source and the observer, the pitch becomes lower. This is due to the longer distance between the waves.



    iii. The doppler effect also occurs in light waves and is used by astronomers to calculate the speed at which stars are approaching or receding.
    iv. The best known example of the Doppler Effect is the change in pitch of an ambulance's siren as it approaches you and passes you. As it approaches, it often sounds higher in pitch and lower as it moves away.

Important Vocabulary - terms to know

Wave
Medium
Mechanical Wave
Electromagnetic Wave
Electromagnetic Spectrum
Transverse wave
Longitudinal wave
Crest
Trough
Wavelength
Amplitude
Frequency
Period
Rarefaction
Compression
Reflection
Refraction
Interference
Diffraction
Doppler Effect