Physical Science Study Guide
Unit 7
Wave properties and behaviors, electromagnetic spectrum, Doppler Effect

Objectives:

PS-7.1 **Illustrate** ways that the energy of waves is transferred by interaction with matter (including transverse and longitudinal /compressional waves)
PS-7.2 **Compare** the nature and properties of transverse and longitudinal/compressional mechanical waves
PS-7.3 **Summarize** characteristics of waves (including displacement, frequency, period, amplitude, wavelength, and velocity as well as the relationships among these characteristics)
PS-7.4 **Use the formulas** $v = f \lambda$ and $v = d/t$ to solve problems related to the velocity of waves
PS-7.5 **Summarize** the characteristics of the electromagnetic spectrum (including range of wavelengths, frequency, energy, and propagation without a medium)
PS-7.6 **Summarize** reflection and interference of both sound and light waves and the refraction and diffraction of light waves
PS-7.7 **Explain** the Doppler Effect conceptually in terms of the frequency of the waves and the pitch of the sound

Key Terms and Concepts:

Wave	$V = \lambda * f$	Electromagnetic spectrum-
Medium	$f = 1 / T$	Radio
Energy	Hertz (Hz)	Microwave
Compression wave	Period (T)	Infrared radiation
Mechanical wave	Loudness	Visible light (ROY G BIV)
Transverse wave	Pitch	Ultraviolet (UV)
Crest	Doppler Effect	X-rays
Trough	Resonance	Gamma rays
Node	Sound waves	Speed of light
Antinodes	Constructive interference	Concave (diverging) lens
Rarefaction	Destructive interference	Convex (converging) lens
Wavelength (λ)	Reflection	Incident ray
Amplitude	Refraction	Reflected ray
Frequency (*f*)	Dispersion	
Vibration	Law of reflection	

Characteristics of Waves:

A ***wave*** is a repeating (i.e. rhythmic) disturbance that ***transfers energy*** (not matter) ***through matter or space***. A wave possesses kinetic energy of motion.
Two major types of waves: ***Electromagnetic waves*** may travel through a medium but ***do not need a medium*** for transmission. ***Mechanical waves must have a medium*** through which to move transferring energy through the particles of a medium.
When a wave moves through matter, the matter is disturbed and moves back and forth, but after the wave passes, the matter will be in about the same position that it was before the wave passed.
Waves are not just one or two-dimensional, many waves such as sound and light waves are often three-dimensional.
As the wave moves through a medium, the particles of the medium can be displaced in a variety

of ways (such as parallel or perpendicular to the wave motion), but they are not transported, ***only*** the wave (energy) itself is transmitted progressively from one place to another.

In ***transverse waves***, such as light and water waves, matter moves up and down at right angles to the direction in which the wave moves (direction of propagation). Be able to draw a transverse wave and label all its parts. In ***longitudinal waves (also called compression waves***), such as sound waves, as the wave (energy) moves through the medium, the direction of the back and forth motion of the particles matter vibrates in the same direction as the wave moves. Examples of longitudinal mechanical waves include: "slinky" spring waves, sound waves, primary earthquake waves, shock waves from a sonic boom or explosion. Compression waves travel through solids, liquids, or gases.

Understand the ***wave properties*** of transverse waves - crests and troughs, and of longitudinal waves - ***compressions*** and ***rarefactions***. In a ***transverse wave*** the point of maximum displacement of the particles in a medium from the equilibrium position is called a ***crest*** or ***trough***. In a ***longitudinal wave*** the particles of the medium are pushed closer together to form a high pressure area called a ***compression*** and spread out to form a lower pressure area with fewer particles called a ***rarefaction*.**

Standing waves are reflected waves with the same amplitude, frequency, and speed as the original wave form standing waves. These waves do not move through the medium but cause the medium to vibrate in a loop or series of loops.

When the medium changes, the speed of the waves changes. Examples include; sound travels faster in steel than in air and sound travels faster in warm air than cooler air; light travels faster in air than in glass; and Transverse waves travel slower in a heavy rope than in a light rope.

Be able to solve problems for any variable in the ***Wave Equation***:

$V = \lambda * f \qquad \lambda = V * T \qquad f = 1 / T$

where V = velocity, λ = wavelength (lambda), f = *frequency*, T = *period*

Use of the proper units.

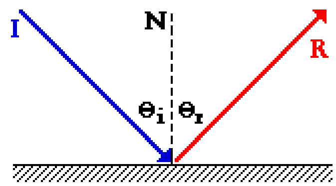
Know the following chart concerning properties of waves:

Type of Wave	**Mechanical**	**Electromagnetic**	
Form	Longitudinal	transverse	modeled as transverse
Description	Compression and rarefaction of matter	sine-wave-shaped movement of matter	oscillating electric and magnetic waves
Measure of wavelength	distance between two successive compressions and rarefactions	distance between two successive crests or troughs	distance between two successive crests or troughs
Measure of amplitude	difference in pressure between maximum compression and the resting state of matter	difference in height between a crest and the resting state of matter	modeled as the difference between maximum field strength and zero

Sound is a ***longitudinal mechanical*** wave, ***requires*** a medium, and can be produced by vibrating objects. Sound, like other waves, ***reflects*** (bounces off a surface it cannot go through). A sound wave's energy travels out in ***all directions*** from a vibrating object. Sound produces echoes when

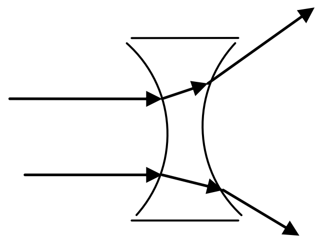
it bounces off hard surfaces. The amplitude of sound waves is determined by the degree of compression (and the degree of rarefaction) compared to the normal pressure of the medium.
Light does ***not*** need a medium through which to travel. Light waves are ***transverse*** waves. Light waves (or other electromagnetic waves) are energy that can be transmitted without mechanical disturbance of the particles of a medium. Light waves (and other electromagnetic waves) travel in straight lines in all directions from the source of the light as long as the medium does not change. Light waves can transmit energy through empty space as from the Sun or stars.
Electromagnetic waves have ***different frequencies*** and ***wavelengths*** but the ***same speed*** (speed of light, $c = 3 \times 10^8$ m/s or 186,282 miles/second). The entire range of frequencies is called the ***electromagnetic spectrum***. Each type wave in electromagnetic spectrum has a particular wavelength (e.g. radio waves long-1000 m wavelength whilst X-rays at 1/10 billionth of a meter) and frequency. Short wavelength = must have large frequency and long wavelength = must have smaller frequency.
Know the ***order*** of electromagnetic waves from low frequency to high frequency: radio waves, microwaves, infrared radiation, visible light (red, orange, yellow, green, blue, violet), ultraviolet (UV), X-rays, and gamma rays.
Understand that the energy of electromagnetic waves is directly proportional to the frequency. Electromagnetic waves with higher frequencies than visible light have more energy, e.g. why UV light can burn your skin, and X-rays and gamma can damage human tissue.
Electromagnetic waves can travel in space with ***no*** medium. Electromagnetic waves slow down when they move from a vacuum to a transparent medium. Electromagnetic waves are ***transverse*** waves. Give real world examples of infrared light, microwave, and radio waves.

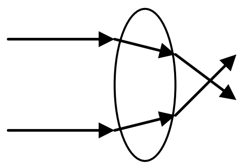
Behavior of Waves*:*
Sound Waves can ***interfere*** with each other changing what you hear. ***Destructive interference*** makes sounds ***quieter***; ***constructive interference*** makes sounds ***louder***. This is because amplitude of a wave is what is affected by interference and a sound wave's ***amplitude*** is heard as ***loudness***. Sound waves reflect in tubes or some musical instruments to produce standing waves which reinforce sound through constructive interference to make the sound louder.
Light waves can interfere and a pattern is often seen with ***light*** (i.e. ***constructive***) and ***dark (***i.e. ***destructive)*** areas created by constructive and destructive interference. The ***amplitude*** of a light wave is observed as ***brightness***. At other times light waves interfere to produce a color pattern. When a color of light interferes destructively, we will not see that color. We will see the colors that are not interfered with destructively. Light waves can reflect off the bottom and top surfaces of thin film, such as oil on water or bubbles, and produce a color pattern due to interference. Light wave can diffract through small slits or around lines to produce light and dark patterns or color patterns due to the interference of light waves.
Light rays reflect and obey the "***Law of Reflection,***" i.e. the angle of incidence is equal to the angle of reflection. The light ray that strikes the surface is called the ***incident ray*** and the light ray that bounces off the surface is called the ***reflected ray***. The line drawn at right angles to the reflecting surface is called the ***normal***. The angle formed between the incident ray and the normal is the angle of incidence; the angle between the reflected ray and the normal is angle of reflection. The incident ray, normal, and reflected ray all lie in the same plane.



Light waves reflect in plain mirrors to produce images. The image appears as far behind the mirror as the object is in front of it. The image and the object appear to be same size. The image is upright.
Light, like other waves, ***can diffract (i.e. bend)*** around a barrier or around the edges of an opening. Waves with a longer wavelength diffract more readily. When light waves diffract interference patterns can often be observed.
Light waves can ***refract*** when they change direction/angle upon entering another medium (e.g. from air to water). In order to refract the wave must change speed when it hits the new medium and the wave must strike the new medium at an angle other than perpendicular. Be able to predict the way that the light rays will bend, i.e. the Law of Refraction: when light rays pass at an oblique (<90º) angle from a less dense medium into a more dense medium, the ray bends toward the normal. When a ray passes at an oblique angle from a more dense medium to a less dense the ray is bent away from the normal.
In the diagram below, light slows down when it enters the prism and bends down when it strikes at this angle. When light exits the prism below, it speeds back up and bends down again.

White light entering ***a prism, the light undergoes refraction (twice, at entry and exit) and then dispersion and white is separated into its spectral colors.*** This is because the ***violet*** end of the spectrum ***slows*** down more than the red end and therefore bends more. This is called dispersion. When the rays of colored light leave the prism they are refracted again in to the spectrum ROY G BIV.
When white light falls on a piece of for example red paper, the paper appears red because the coloring material in the paper reflects red rays and absorbs all the others.
An object that reflects no light, but absorbs all light rays that fall on it, appears black
Lenses may be a ***concave (diverging)*** lens or ***convex (converging)*** lens. A ***convex*** lens is ***thicker*** in the ***middle*** than at the edges. A ***concave*** lens is a lens that is ***thicker*** at the ***edges*** than in the middle.
Be able to draw the resulting rays as light passing through each type of lens drawn below:





Water droplets causing a rainbow demonstrate both refraction and total internal reflection.

<u>Doppler Effect</u>:
The change in frequency in sound you hear due to change in motion (yourself) or change in motion of object causing sound (race car sound coming toward you = higher pitch or frequency, lower pitch going away from you). Other examples, a person on a train platform watching a train go by.
A Doppler shift occurs when a ***wave source*** is ***moving toward*** an observer (i.e. ***stationary***) or away from the observer. A Doppler shift also occurs when the observer is moving toward or away from the wave source. There is no shift (i.e. the same pitch-frequency is heard by both) when the source and observer are not moving toward or away from each other. Understand the apparent frequency shift is due to the relative motion of a wave source and an observer.
When the observer is moving toward a wave source, he/she would perceive a higher frequency than the source is producing. The observer encounters waves more often (i.e. compressed waves) than the source is producing them. If the observer encounters more waves, he/she perceives a higher frequency. The observer would perceive a higher pitch in the case of sound waves.
When the observer is moving away from a wave source he/she would perceive a lower frequency than the source is producing. The waves would have to catch up with him and he/she would encounter fewer (longer wavelength) waves. If the observer encounters fewer waves he/she perceives a lower frequency. The observer would perceive a lower pitch in the case of sound waves.