# Unit 1 – Energy I Standards

**Earth Science 9. California Geology.** Students should already know that mountains, faults, and volcanoes in California result from plate tectonic activity and that flowing surface water is the most important agent in shaping the California landscape. The topics in this standard set can be covered as a separate unit or as a part of a unit included in other topics addressed by the standards.

**9. The geology of California underlies the state's wealth of natural resources as well as its natural hazards. As a basis for understanding this concept:**

**9c. *Students know*** the importance of water to society; the origins of California's fresh water, and the relationship between supply and need. Water is especially important in California because its economy is based on agriculture and industry, both of which require large quantities of water. California is blessed with an abundance of fresh water, which is supplied by precipitation and collected from the melting of the snow pack in watersheds located in the Sierra Nevada and in other mountain ranges. This process ensures a slow runoff of water following the winter rains and snowfall. But the water is not distributed evenly. Northern California receives most of the rain and snowfall, and southern California is arid to semiarid. The natural distribution of water is adjusted through engineered projects that transport water in canals from the northern to the southern part of the state.

**Earth 7. Biogeochemical Cycles.** Students who complete high school biology/life sciences before they take earth sciences will already have learned about biogeochemical cycles. Through standards presented in lower grade levels, other students should have been ex-posed to life cycles, food chains, and the movement of chemical elements through biological and physical systems. Students should also have studied chemical changes in organisms and should know that through photosynthesis solar energy is used to create the molecules needed by plants. In this standard set students will learn that within the biogeochemical cycles, matter is transferred between organisms through food webs or chains. Matter can also be transferred from these cycles into physical environments where the cycling elements are held in reservoirs. Matter can be transferred back into biological cycles through physical processes, such as volcanic eruptions and products of the rock cycle, particularly those from weathering.

**7. Each element on Earth moves among reservoirs, which exist in the solid earth, in oceans, in the atmosphere, and within and among organisms as part of biogeochemical cycles. As a basis for under-standing this concept:**

**7a. *Students know*** the carbon cycle of photosynthesis and respiration and the nitrogen cycle.

**7b. *Students know*** the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.

**Physics 4. Waves.** Students can be introduced to this standard set by learning to distinguish between mechanical and electromagnetic waves. In general, a *wave* is defined as the propagation of a disturbance. The nature of the disturbance may be mechanical or electromagnetic. Mechanical waves, such as ocean waves, acoustic waves, seismic waves, and the waves that ripple down a flag stretched taut by a wind, require a medium for their propagation and gradually lose energy to that medium as they travel. Electromagnetic waves can travel in a vacuum and lose no energy even over great distances. When electromagnetic waves travel through a medium, they lose energy by absorption, a phenomenon that explains why light signals sent through the most transparent of optical fibers still need to be amplified and repeated. In contrast, light emitted from distant galaxies has traveled great distances without the aid of amplification, an indication that a relatively small amount of material is in the light's path.

Waves transfer energy from one place to another without net circulation or displacement of matter. Light, sound, and heat energy can be transmitted by waves across distances measured from fractions of a centimeter to many millions of kilometers. Exertion of a direct mechanical force, such as a push or a pull, on a physical body is an example of energy transfer by direct contact. However, for transfer to occur, objects do not need to be in direct physical contact with a source of energy. For instance, light transmits from a distant star, heat radiates from a fire, and sound propagates from distant thunder. Energy may be transferred by radiation, for example, from the Sun to Earth; therefore, radiation is also an example of a non-contact energy transfer. Both sight and hearing are senses that can perceive energy patterned to convey information without direct contact between the source and the sensing organ.

**4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:**

**4a.** ***Students know*** waves carry energy from one place to another. Waves may transport energy through a vacuum or through matter. Light waves, for example, transport energy in both fashions, but sound waves and most other waves occur only in matter. However, even waves propagating through matter transport energy without any net movement of the matter, thus differing from other means of energy transport, such as convection, a waterfall, or even a thrown object.

**4c.** ***Students know*** how to solve problems involving wavelength, frequency, and wave speed. All waves have a velocity $v$ (propagation speed and direction), a property that represents the rate at which the wave travels. Only periodic, sustained waves can be easily characterized through the properties of wavelength and frequency. However, most real waves are *composite,* meaning they can be understood as the sum of a few or of many waveforms, each with amplitude, a wavelength, and a frequency.

Wavelength $\lambda$ is the distance between any two repeating points on a periodic wave (e.g., between two successive crests or troughs in a transverse wave or between adjacent compressions or expansions [rarefactions] in a longitudinal wave). Wavelength is measured in units of length. Frequency $f$ is the number of wavelengths that pass any point in space per second. A wave will make any particle it encounters move in regular cycles, and frequency is also the number of such cycles made per second and is often abbreviated as cycles per second. The unit of frequency is the inverse second ($s^{-1}$), a unit also called the hertz (Hz).

Periodic wave characteristics are related to each other. For example, $v = f\lambda$

**4f.** ***Students know*** how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

A characteristic and unique property of waves is that two or more can occupy the same region of space at the same time. At a particular instant, the crest of one wave can overlap the crest of another, giving a larger displacement of the medium from its condition of equilibrium *(constructive interference);* or the crest of one wave can over-lap the trough of another, giving a smaller displacement *(destructive interference).* The effect of two or more waves on a test particle is that the net force on the particle is the algebraic sum of the forces exerted by the various waves acting at that point.

If two overlapping waves traveling in opposite directions have the same frequency, the result is a standing wave. There is a persistent pattern of having no displacement in some places, called *nulls* or *nodes,* and large, oscillating displacements in others, called *maxima* or *antinodes.* If two overlapping waves have nearly the same frequency, a node will slowly change to a maximum and back to a node, and a maximum will slowly change to a node and back to a maximum. For sound waves this periodic change leads to audible, periodic changes from loud to soft, known as *beats.*

*Diffraction* describes the constructive and destructive patterns of waves created at the edges of objects. Diffraction can cause waves to bend around an obstacle or to spread as they pass through an aperture. The nature of the diffraction patterns of a wave interacting with an object depends on the ratio of the size of the obstacle to the wavelength. If this ratio is large, the shadows are nearly sharp; if it is small, the shadows may be fuzzy or not appear at all. Therefore, a hand can block a ray of light, whose average wavelength is about 500 nm, but cannot block an audible sound, whose average wavelength is about 100 cm. The bending of water waves around a post and the diffraction of light waves when passing through a slit in a screen are examples of diffraction patterns.

*Refraction* describes a change in the direction of a wave that occurs when the wave encounters a boundary between one medium and another provided that the media have either different wave velocities or indexes of refraction and provided that the wave arrives at some angle to the boundary other than perpendicular. At a sharp boundary, the change in direction is abrupt; however, if the transition from one medium to another is gradual, so that the velocity of the wave changes slowly, then the change in the wave's direction is also gradual. Therefore, a ray of light that passes obliquely from air to water changes its direction at the water's surface, but a ray that travels through air that has a temperature gradient will follow a bent path. A ray of light passing through a saturated solution of sugar (sucrose) and water, which has an index of refraction of 1.49, will not change direction appreciably on entering a colorless, transparent piece of quartz submersed in the solution because the quartz has an almost identical index of 1.51. The match in indexes makes the quartz nearly invisible in the sugar-water solution.

Another interesting phenomenon, the *Doppler effect*, accounts for the shift in the frequency of a wave when a wave source and an observer are in motion relative to each other compared with when they are at relative rest. This effect is most easily understood when the source is at rest in some medium and the observer is approaching the source at constant speed. The interval in time between each successive wave crest is shorter than it would be if the observer were at rest, and so the frequency observed is larger. The general rule, for observers moving at velocities much less than the velocity of the wave in its medium, is that the change in frequency depends only on the velocity of the observer relative to the source. Therefore, the shriek of an ambulance siren has a higher pitch when the source approaches and a lower pitch when the source recedes. For an observer following the ambulance at the same speed, the siren would sound normal. Similar shifts are observed for visible light.

*Polarization* is a property of light and of other transverse waves. *Transverse waves* are those in which the displacement of a test particle is always perpendicular to the direction in which the wave travels. When that displacement is always parallel to a particular direction, the wave is said to be *(linearly) polarized.* A ray of light emitted from a hot object, like a lamp filament or the sun, is unpolarized; such a ray consists of many component waves overlapped so that there is no special direction perpendicular to the ray in which a test particle is favored to move. The components of an unpolarized ray can be sorted to select such a special direction and so make one or more polarized rays. An unpolarized ray that is partly reflected and partly transmitted by an angled sheet of glass is split into rays that are polarized; an unpolarized ray can become polarized by going through a material that allows only waves corresponding to one special direction to pass through. Polarized sunglasses and stretched cellophane wrap are examples of polarizing materials.