Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.1 Recall that waves transmit energy but not matter.
Taxonomy level: 1.2-B Remember Conceptual Knowledge

Previous/Future knowledge: Students have been introduced to the concept of energy in 1st grade related to plants (1-2.1), related to animals in 2nd grade (2-2.1), to light and electricity as forms of energy in 4th grade (4-5.2); and to forms and transformations of energy in 6th grade (6-5.2). Students have not been introduced to the concept of energy being transmitted in waves in previous grades. Students will further develop the quantitative concepts energy transmission in waves in high school Physical Science (PS-7.3 and PS-7.4).

It is essential for students to know that *wave* is a repeating disturbance or vibration that transfers or moves energy from place to place.

- Waves are created when a source of energy (force) causes a vibration.
- A *vibration* is a repeated back-and-forth or up-and-down motion.
- Waves carry energy through empty space or through a *medium* without transporting matter.
- While all waves can transmit energy through a medium, certain waves can also transmit energy through empty space.
- A *medium* is a material through which waves can travel. It can be a solid, liquid, or gas.
- When waves travel through a medium, the particles of the medium are not carried along with the wave.
- When there is no medium, certain waves (electromagnetic) can travel through empty space.

It is not essential for students to know the mechanisms (the oscillations of the fields) by which energy is transferred through empty space.

Assessment Guidelines:
The objective of this indicator is to *recall* that waves transmit energy but not matter; therefore, the primary focus of assessment should be to remember that waves as disturbances or vibrations that transfer energy. However, appropriate assessments should also require students to *recall* the definition of a wave and a medium; *recognize* types of media; recall the ways that waves travel; or *recall* what causes waves.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.2 Distinguish between mechanical and electromagnetic waves.
Taxonomy level: 4.1-B Apply Conceptual Knowledge

Previous/Future knowledge: Students have not been introduced to the concept of mechanical and electromagnetic waves in previous grades. Students will further develop the concepts of the different types of waves in high school Physical Science (PS-7.1-2).

It is essential for students to know the following characteristics of mechanical and electromagnetic waves:
Mechanical waves

- *Mechanical waves* require the particles of the medium to vibrate in order for energy to be transferred.
- For example, water waves, earthquake/seismic waves, sound waves, and the waves that travel down a rope or spring are also mechanical waves.
- Sound waves, as with all mechanical waves, cannot be transferred or transmitted through empty space *(vacuum*).

Electromagnetic waves

- *Electromagnetic waves* are waves that can travel through matter or empty space where matter is not present.
- Some examples are radio waves, microwaves, infrared rays, visible light, ultraviolet rays and x-rays that all travel in *electromagnetic waves*.

Another way to classify waves is by how they move:

- Mechanical waves in which the particles of matter in the medium vibrate by pushing together and moving apart parallel to the direction in which the wave travels are called *compressional* or *longitudinal waves*. The place on the wave that is pushed together is called the *compression* and the place that is moving apart is the *rarefaction*. Examples of mechanical compressional/longitudinal waves might include sound waves and some seismic waves.
- Mechanical waves in which the particles of matter in the medium vibrate by moving back and forth and perpendicular (at right angles) to the direction the wave travels are called *transverse waves*. The highest point of a transverse wave is the *crest* and the lowest point is called a *trough*. Examples of mechanical transverse waves might include some waves in a slinky spring, waves on a rope, strings in a musical instrument, and some seismic waves
- Electromagnetic waves are transverse waves that can travel without a medium through empty space.

It is not essential for students to know that electromagnetic waves are caused by vibrating electric charges, or that they transfer energy between vibrating electric and magnetic fields.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

Assessment Guidelines:

The objective of this indicator is to *distinguish* between mechanical and electromagnetic waves***;*** therefore, the primary focus of assessment should be to make distinctions between the characteristics of electromagnetic and mechanical waves. However, appropriate assessments should require students to *compare* electromagnetic and mechanical waves; *classify* waves as mechanical or electromagnetic based on their characteristics; *exemplify* types of mechanical and electromagnetic waves and/or compressional and transverse waves; or *compare* ways that waves can move.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.3. Summarize factors that influence the basic properties of waves (including frequency, amplitude, wavelength, and speed).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/Future knowledge: Students have not been introduced to the concept of waves in previous grade levels. Students will further develop the concept of waves quantitatively in high school Physical Science (PS-7.4)

It is essential for students to know that the basic properties of waves are influenced by several factors.

Frequency
- *Frequency* is a measure of how many waves pass a point in a certain amount of time.
- The higher the frequency, the closer the waves are together and the greater the energy carried by the waves will be.

Amplitude
- *Amplitude* is a measure of the distance between a line through the middle of a wave and a crest or trough.
- The greater the force that produces a wave, the greater the amplitude of the wave and the greater the energy carried by the wave.
- In a transverse wave the higher the wave, the higher the amplitude.
- Sounds with greater amplitude will be louder; light with greater amplitude will be brighter.

Wavelength
- *Wavelength* is a measure of the distance from the crest on one wave to the crest on the very next wave.
- Shorter wavelengths are influenced by the frequency.
- A higher frequency causes a shorter wavelength and greater energy.

Speed
- *Speed* is a measure of the distance a wave travels in an amount of time.
- The speed of a wave is determined by the type of wave and the nature of the medium.
- As a wave enters a different medium, the wave's speed changes. Waves travel at different speeds in different media.
- All frequencies of electromagnetic waves travel at the same speed in empty space.

NOTE TO TEACHER: Properties of waves will be diagrammed using transverse waves only.

It is not essential for students to know how to calculate the speed of a wave or how to diagram these properties on a longitudinal wave.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

Assessment Guidelines:

The objective of this indicator is to *summarize* factors that influence the basic properties of waves; therefore, the primary focus of assessment should be to generalize major points about how properties of waves (including frequency, amplitude, wavelength, and speed). However, appropriate assessments should also require students to *recognize* the basic properties of waves; *recall* the factors that influence the basic properties of waves; or *interpret* or *illustrate* diagrams of transverse waves by identifying specific characteristics stated previously.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.4 Summarize the behaviors of waves (including refraction, reflection, transmission, and absorption).
Taxonomy level: 2.4-B Understand Conceptual Knowledge

Previous/Future knowledge: In 4th grade (4-5.3), students summarized how light travels and explained what happens when it strikes an object (including reflection, refraction, and absorption). Students have not been introduced to the concept transmission in previous grade levels. Students will further develop the concept of the behavior of waves in Physical Science (PS-7.6).

It is essential for students to know that waves have the following behaviors:

Refraction

- *Refraction* is the bending of waves caused by a change in their speed as they pass from one medium to another. As waves pass at an angle from one medium to another, they may speed up or slow down. The greater the change in speed of the waves, the more the waves will bend.
- Refraction of light going from air through a *convex lens,* for example, can make images appear larger as the light waves bend.
- *Prisms* or *diffraction gratings* separate white light into its different components or colors by bending the light at different angles depending on the frequencies of the light passing through the prism or diffraction grating. Different colors of light have different frequencies.

Reflection

- *Reflection* is the bouncing back of a wave when it meets a surface or boundary that does not absorb the entire wave's energy. All types of waves can be reflected.
- Reflections of sound waves, for example, are called echoes and help bats and dolphins learn about their environments.
- *Plane mirrors* and other smooth surfaces reflect light to form clear images.

Transmission

- *Transmission* of waves occurs when waves pass through a given point or medium.
- Sound waves are transmitted through solids, liquids, and gases.
- Light waves are transmitted through *transparent* materials (may be clear or colored material such as filters) that allow most of the light that strikes them to pass through them.
- Only a small amount of light is reflected or absorbed.
- *Opaque* materials allow no light waves to be transmitted through them.
- *Translucent* materials transmit some light, but cause it to be scattered so no clear image is seen.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

Absorption

- *Absorption* of certain frequencies of light occurs when the energy is not transferred through, or reflected by, the given medium.
- Objects or substances that *absorb* any wavelength of electromagnetic radiation become warmer and convert the absorbed energy to infrared radiation.

It is not essential for students to know the quantitative relationships in refraction, reflection, absorption, or transmission of waves. Students do not have to know about the behavior of diffraction or about polarization of light. Measuring angles of reflection or refraction is not essential. Behaviors using concave lenses or convex mirrors and concave mirrors are beyond this indicator.

Assessment Guidelines:

The objective of this indicator is to *summarize* the behaviors of waves; therefore, the primary focus of assessment should be to generalize major points about the interactions of waves with various materials based on behaviors (including refraction, reflection, transmission, and absorption). However, appropriate assessments should also require students to *recognize* the behaviors of waves; *exemplify* the behaviors of waves based on descriptions of these behaviors; *interpret* diagrams of wave behaviors; *illustrate* wave properties; or *explain* the major effects of wave behavior.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.5 Explain hearing in terms of the relationship between sound waves and the ear.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/Future knowledge: In 3rd grade (3-5.5), students recalled that vibrating objects produce sound and that vibrations can be transferred from one material to another. Students have not been introduced to the concepts of sound waves or their interactions with the ear in previous grades. Students will further develop the concepts of sound waves in high school Physical Science (PS-7.7).

It is essential for students to know the relationship between the ear and sound waves to explain hearing as follows:

- Sound waves are gathered by the *outer ear* which is shaped to help capture the sound waves (energy transferred in particles of air) and send them through the ear canal, which transfers them to the eardrum.
- The vibrations of air particles cause the eardrum to vibrate.
  - If the vibrations follow each other slowly (low frequency) the sound is heard as a low pitch. If the vibrations follow each other in rapid succession (high frequency), the sound is heard as a high pitch.
  - Sound waves with large amplitudes push on the eardrum with more force and are heard as loud sounds. Sound waves with small amplitudes push on the eardrum with less force and are heard as soft sounds.
- Vibrations from the ear drum are transmitted to three small bones of the *middle ear*, which transmit the vibrations to the inner ear.
- The vibrations in the liquid of the *inner ear* cause the tiny hairs to vibrate. The vibrating tiny hairs transmit the energy to nerves attached to the hairs.
- The nerve impulses are transmitted to the brain and interpreted as hearing.

It is not essential for students to know the specific anatomy of the three main parts of the ear in more detail than what is listed above (for example, names of ear bones).

Assessment Guidelines:
The objective of this indicator is to *explain* hearing in terms of the relationship between sound waves and the ear; therefore, the primary focus of assessment should be to develop a cause-and-effect model that shows the functions of the three main parts of the ear and how they transmit and transfer sound waves for hearing to occur in the brain. However, appropriate assessments should also require students to *recognize* the three major parts of the ear; *summarize* how the major parts of the ear transfer sound waves to the brain for interpretation; or *interpret* a diagram of the ear that depicts how sound is transferred and transmitted at each part.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.6 Explain sight in terms of the relationship between the eye and the light waves emitted or reflected by an object.
Taxonomy level: 2.7-B Understand Conceptual Knowledge

Previous/Future knowledge: Students have not been introduced to the concept of the relationship between the eye and light waves in previous grades. They will further develop the concept of light in high school Physical Science (PS-7.6).

It is essential for students to know that the interaction the eye and light emitted or reflected by an object to allow sight to occur as follows:

- Light waves that have been emitted or reflected by an object, enter the eye and first pass through the transparent layer called the *cornea* where they are refracted.
- The light rays are then refracted again as they pass through the transparent *lens* (convex).
- The lens focuses the light waves on the *retina*, located on the back of the inside of the eye.
- The retina is composed of tiny light sensitive nerves that transfer the energy of the light waves to nerve impulses transmitted through the *optic nerve* to the brain for interpretation as *sight*.

It is not essential for students to know about vision problems, such as being nearsighted or farsighted, but these might be interesting topics for discussion.

Assessment Guidelines:
The objective of this indicator is to *explain* sight in terms of the relationship between the eye and the light waves emitted or reflected by an object; therefore, the primary focus of assessment should be to construct a cause-and-effect model of the eye indicating how it interacts with light waves to allow sight to occur. However, appropriate assessments should also require students to *recognize* the functions of the major parts of the eye; *interpret* a diagram of the major parts eye and their functions in transmitting and transferring light to nerve impulses in the brain for sight; *interpret* a diagram showing how light rays travel through the eye; or *summarize* the transfer of light through the major parts of the eye.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.7 Explain how the absorption and reflection of light waves by various materials result in the human perception of color.
Taxonomy level: 2.7-B Understand Conceptual Understanding

Previous/Future knowledge: Students have been introduced to the concept of color (4-5.2) and absorption and reflection of light (4-5.3) in 4th grade. Students have not been introduced to concept of the human perception of color in previous grades. Indicator 8-6.4 also relates color to the wave behaviors of reflection and absorption. Students will further develop the concepts of reflection and interference of light waves in Physical Science (PS-7.6).

It is essential for students to know that the absorption and reflection of light waves by various materials results in human perception of color as follows:

- Most materials absorb light of some frequencies and reflect the rest.
- If a material absorbs a certain frequency of light, that frequency will not be reflected, so its color will not be perceived by the observer.
- If the material does not absorb a certain frequency of light, that frequency will be reflected, so its color will be perceived by the observer.
- If all colors of light are reflected by a material, it will appear white. If all colors of light are absorbed by a material, it will appear black.
- The color that we see depends on (1) the color of light that is shined on the object and (2) the color of light that is reflected by the object. For example, if an object reflects red wavelengths and absorbs all others, the object will appear red in color.
- *Color filters* allow only certain colors of light to pass/transmit through them; they absorb or reflect all other colors. For example, a blue filter only transmits blue light. Objects seen through a blue filter will look blue if the objects reflect blue; objects of other colors will appear black because the other color wavelengths are being absorbed by the filter.

It is not essential for students to know which frequencies of light are perceived as which colors. The mixing of primary colors of light or of primary pigments is also not essential.

Assessment Guidelines:
The objective of this indicator is to *explain* how the absorption and reflection of light waves by various materials result in the human perception of color; therefore, the primary focus of assessment should be to develop a cause-and-effect model that depicts absorption and reflection of light resulting in certain colors being seen. However, appropriate assessment should also require students to *recall* that light is made up of various frequencies that relate to the color perceived by humans; *interpret* a diagram of how colored materials reflect or absorb light; *infer* what is being reflected and what is being absorbed by a colored material; *summarize* the process by which light is absorbed or reflected by various materials; or *exemplify* of light being absorbed or reflected by various materials.

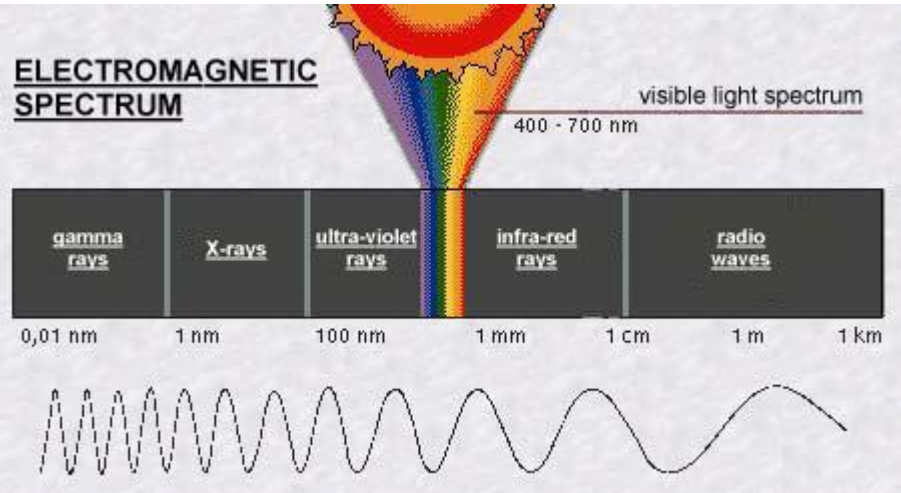
Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

8-6.8 Compare the wavelength and energy of waves in various parts of the electromagnetic spectrum (visible light, infrared, and ultraviolet radiation).
Taxonomy level: 2.6-B Understand Conceptual Knowledge

Previous/Future knowledge: Students have not been introduced to the concept of the electromagnetic spectrum in previous grades. Students are introduced to the concept of electromagnetic waves in this unit in 8th grade (8-6.2). Students will further develop the concept of quantitative relationships in properties of waves in high school Physical Science (PS-7.5).

It is essential for students to know that electromagnetic waves have a wide range of wavelengths. The entire range of wavelengths is called the *electromagnetic spectrum*. The relationship between the wavelength and energy of waves in various parts of the electromagnetic spectrum can be shown as follows:



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Visible light

- *Visible light* is the range of electromagnetic waves that can be detected by the human eye.
- The entire range of visible light is called the *visible light spectrum*.
- The wavelengths of visible light are in the middle range of *wavelengths/frequencies* of electromagnetic waves.
- The longer the wavelength, the lower the energy of the wave is.
- The human eye reacts to different energies and frequencies of light so that different colors are seen.
  - Higher frequencies (shorter wavelengths) are perceived as colors toward the blue-violet range and have higher energy.
  - Lower frequencies (longer wavelengths) are perceived as colors toward the orange-red range and have lower energy.

Waves

8-6 The student will demonstrate an understanding of the properties and behaviors of waves. (Physical Science)

Infrared radiation

- *Infrared radiation* is the range of electromagnetic waves with frequencies lower than red on the visible spectrum, thereby having longer wavelengths and less energy than red wavelengths.
- All objects emit infrared radiation, and hotter objects emit more infrared radiation than cooler objects.
- Heat energy is transmitted by infrared radiation.
- When objects absorb infrared radiation, they become warmer.

Ultraviolet radiation

- *Ultraviolet radiation* is the range of electromagnetic waves with frequencies higher than violet on the visible spectrum, thereby having shorter wavelengths and more energy than violet wavelengths.
- Because of the high energy of ultraviolet radiation, too much exposure is damaging to the eyes and skin.

It is not essential for students to know the specific wavelengths of the various types of electromagnetic radiation, nor do students have to know the relative wavelengths and energies of other forms of radiation than visible light, infrared, and ultraviolet radiation.

Assessment Guidelines:
The objective of this indicator is to *compare* the wavelength and energy of waves in specific parts of the electromagnetic spectrum; therefore, the primary focus of assessment should be to detect similarities and differences related to wavelengths (and therefore frequency) and the energy of infrared, visible, light and ultraviolet waves. However, appropriate assessments should also require students to *recognize* specific parts of the electromagnetic spectrum that are higher or lower in energy, shorter or longer in wavelengths, and higher or lower in frequency; *interpret* a diagram of the electromagnetic spectrum; *infer* which specific parts are higher or lower in wavelength, energy, and frequency; or *classify* waves by specific characteristics.