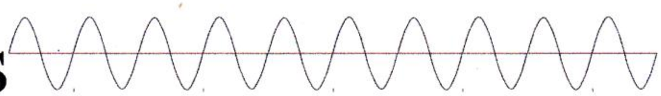
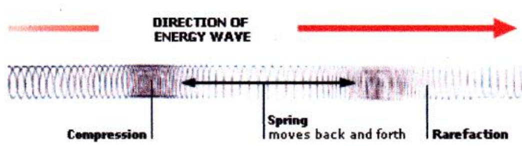
Waves

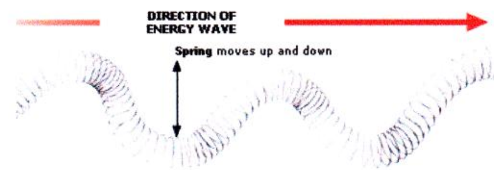


Revised 011310
answers

A wave is nature's way of transmitting energy from one place to another. In its simplest form, it consists of a **pulse**, a single disturbance that moves (propagates) through a medium. Most waves and pulses require a medium. A **medium** is the air or water or substance through which the wave moves. The medium for sound waves is usually the air. For a whale, water would be the medium for carrying sound.

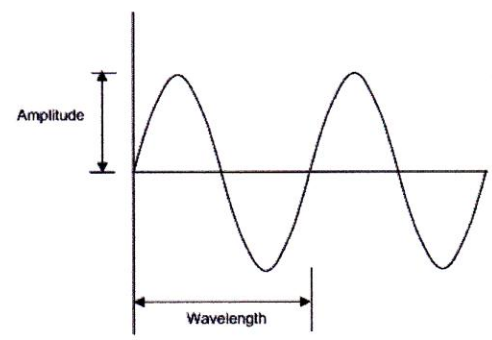
Pulses and waves take one of two forms: **longitudinal** or **transverse**. Another term for "longitudinal" is "compressional". In a longitudinal pulse, a portion of the medium is compressed, and this region of compressed matter moves through the medium. In the slinky demo several coils were compressed and then released. The compression moved the length of the slinky and were reflected at the other end. The direction of travel of the longitudinal pulse is parallel to the slinky. Sound waves are longitudinal waves.



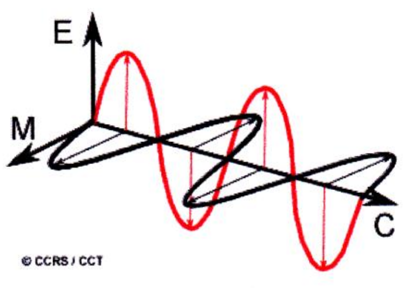


Transverse waves are produced when the medium is moved from side to side. The direction of travel of the transverse waves is perpendicular to the direction of travel.

Transverse waves are represented by a sine wave.

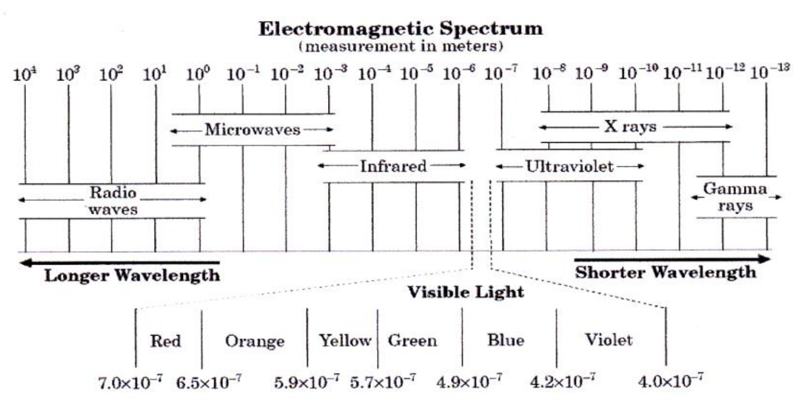


Not all waves require a medium. **Electromagnetic waves** (electromagnetic energy) do not require a medium. EM waves can travel through a vacuum.

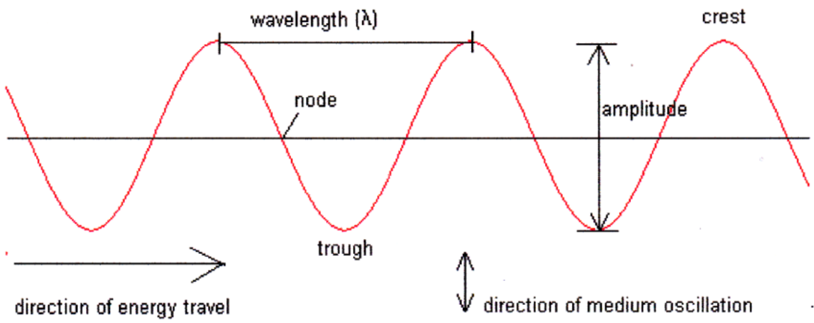


The EM wave is its own medium. The EM wave consists of alternating electric and magnetic fields. Energy from the electric field is transferred to the magnetic field and vice versa.

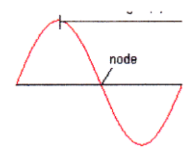
Light waves and radio waves are forms of electromagnetic energy. These waves do not require a medium and can travel through space at 3.00 x 10^8 m/s. The only difference between light waves and radio waves is the wavelength. The shorter the wavelength the greater the energy of the wave.



The anatomy of a wave.



Here we have a representation of transverse waves. We would refer to this as a continuous wave. In the continuous wave are many repeating cycles. A cycle is one complete oscillation.



The distance from a point on one cycle to a corresponding point on the next cycle is called the **wavelength**. The symbol for wavelength is the Greek letter *lambda* (λ). The maximum displacement of the wave is the **amplitude** and is proportional to the distance between the **crest** and the **trough**. The amplitude represents the energy in the wave. The greater the amplitude, the greater the energy. The point where there is no displacement of the medium is called a **node**. There are seven nodes in the diagram above.

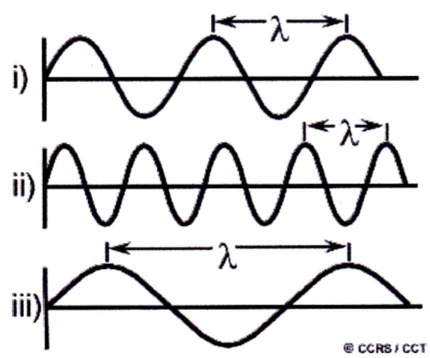
Something that is closely related to the wavelength is the frequency. The **frequency** is the number of times per second that the medium goes through an oscillation (cycle). Frequency is given the symbol f, and is expressed in units of Hertz (Hz). Hertz are "reciprocal seconds", or 1/s. A frequency of 10 Hz tells us that the wave goes through 10 oscillations per second. The electricity that we use in our homes is called alternating current and it has a frequency of 60 Hz. The frequencies of radio stations is much greater. A station in the FM broadcast band might operate on 99.9 megahertz (MHz).

As we saw with the slinky demonstration, frequency and wavelength are inversely proportional. As the frequency increases, the wavelength decreases.

The frequency and wavelength are connected by the speed of the wave by the following equation.

$$v = f\lambda$$

where v is the speed in meters per second, f is the frequency is Hz (1/s), and λ is the wavelength in meters.



i) medium frequency and wavelength

ii) higher frequency and shorter wavelength

iii) lower frequency and longer wavelength

Q. For example, a TV station broadcasts on frequency of 210 MHz (channel 13). Radio and TV waves travel at the speed of light, 3.00 x10^8 m/s. Find the wavelength of the TV electromagnetic waves.

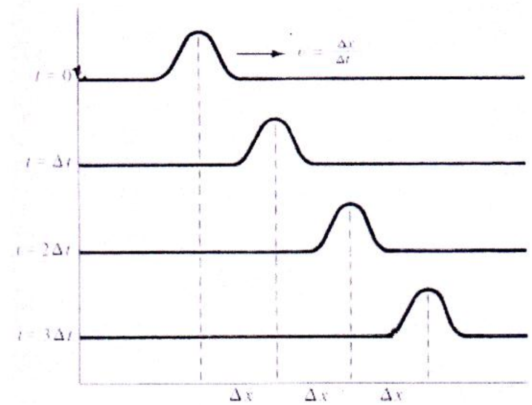
From $v = f\lambda$ we solve for lambda (λ), and then plug in the values and solve for the wavelength. Note that the frequency is in megahertz, (and *mega-* means 1,000,000) so the frequency is 2.10 x 10^8 1/s.

$$\lambda = \frac{v}{f} = \frac{3.00\times10^8\ \mathrm{m/s}}{2.10\times10^8\ 1/\mathrm{s}} = 1.43\,\mathrm{m}$$

Q. Or this one. Water waves are moving along a pier. The waves have a distance of 2.0 m from crest to trough and they are moving at 1.0 m/s. What is the frequency of the water waves?

$$f = \frac{v}{\lambda} = \frac{1.0\,\mathrm{m/s}}{4.0\,\mathrm{m}} = 0.25\ 1/\mathrm{s}\ \text{or}\ 0.25\,\mathrm{Hz}$$

Why did we use 4.0 m as the wavelength?



The **speed** of a wave, or in this case a pulse, is computed from the distance it travels and the time required.

$$v = \frac{\Delta s}{\Delta t}$$

This diagram illustrates a pulse moving the same distance, Δx, in equal time intervals, Δt.

Q. A wave travels 35 meters in 7 seconds. What is the speed of the wave?

$$v = \frac{\Delta s}{\Delta t} = \frac{35\,\text{m}}{7\,\text{s}} = 5\,\text{m/s}$$

The speed of waves depends very much on the characteristics of the medium. The speed of sound in air is around 340 m/s. But in water, the speed of sound is much greater, around 1300 m/s and in a piece of iron the speed of sound is over 5000 m/s. The "harder" the medium, the faster will be the speed of sound, or any wave, in that medium.

We can also describe a wave by giving the **period**. The period of a wave is the time required for one complete cycle to pass a point. The period, given by the symbol T, is usually expressed in seconds. It is important to note that the period is the reciprocal of the frequency, and of course, frequency is the reciprocal of the period.

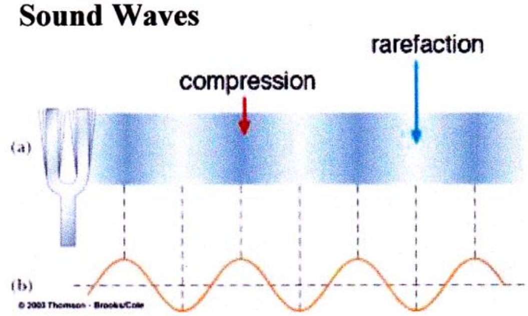
$$T = \frac{1}{f}$$

Q. What is the period of a wave with a frequency of 50 Hz?

$$T = \frac{1}{f} = \frac{1}{50\ 1/\text{s}} = 0.02\,\text{s}$$

The time it takes for one complete cycle to pass a point when the frequency is 50 Hz is only 0.02 seconds.

Sound Waves



Sound waves are longitudinal waves, sometimes called compressional waves, because when something is vibrating in air, it is alternatingly compressing the air, just as this tuning fork in the diagram.

The tuning fork (a), vibrating back and forth, creates regions of **compression** and **rarefaction**, where more air molecules are compressed into a small space, which is followed by an region with fewer air molecules (rarefaction).

The sine curve (b) represents the density of the air as the longitudinal wave passes through it. The wavelength of longitudinal waves is the distance from one area of maximum compression to the next.

Review activity – Fill in the blanks with the best choice of terms. The box contains some choices. Some may not be used at all , and some may be used more than once.

amplitude
compression
compressional
crest
decreases
electric
electromagnetic
energy
frequency
gas
hardness
Hertz
increases
liquid
longitudinal
magnetic
mechanical
medium
period
pulse
rarefaction
seconds
single
solid
temperature
transverse
trough
$v = f\lambda$
wave
wavelength

1. A single disturbance that propagates (moves) through a medium is a ______.
2. A continuous disturbance that propagates (moves) through space and time is a _____.
3. A continuous disturbance that propagates (moves) through a medium is a ________ wave
4. A continuous disturbance consisting of alternating electric and magnetic fields that can propagate (move) through a vacuum is an ________________ wave.
5. Waves whose disturbance is perpendicular to the direction of travel are called __________.
6. Waves whose disturbance is parallel to the direction of travel are called ___________ .
7. The distance between corresponding points on successive waves is the ____________.
8. The time required for one wave to pass a point is the __________.
9. The number of waves that pass a point in one second is the ___________.
10. The magnitude of the displacement of a wave is the ___________.
11. The mathematical relationship between the speed of a wave and the frequency and wavelength is given by _______.
12. The substance through which a mechanical waves passes is the _________.
13. The maximum positive displacement of a wave is the __________.
14. The maximum negative displacement of a wave is the __________.
15. The unit of frequency is the ________________.
16. A pulse or a wave transmits ____________.
17. Mechanical waves require a _______________.
18. Electromagnetic waves do not require a _______________.
19. Electromagnetic waves consist of alternating ________ and _______ fields.
20. Mechanical waves can be ___________ waves where the disturbance is perpendicular to the direction of travel, or ______________ waves, where the disturbance is parallel to the direction of travel.

21. A pulse is a ________ disturbance that moves through a medium. A pulse may be either __________ or ____________.

22. The ____________ is the distance between corresponding points on successive waves.

23. The ___________ is the number of waves that pass a point in 1 second.

24. The ___________ is the rate at which the wave front moves through a medium.

26. The Hertz is the unit of __________, and it is equal to 1/________.

27. The ____________ of a wave is the reciprocal of its period.

28. There is an interval of 3 seconds between water waves. What is the frequency of the waves? __________

29. The equation $v = f\lambda$ shows the mathematical relationship between ______, ________ and ___________.

30. As the wavelength increases, the frequency ___________.

31. The speed of a transverse wave in a long spring is 4.5 m/s. If the frequency is 3 Hz, what will be the wavelength? __________

32. Sound waves are __________ waves, also called ____________ waves.

33. The speed of sound is greatest in a _______ and least in a ______.

34. The speed of sound increases with the increasing ___________ of the medium.

35. The speed of sound is affected by the ___________ of the medium. The greater the __________ of the medium, the greater is the speed of sound.

36. Sound waves consist of alternating regions called __________ and __________. The air is most dense where there is ___________ and least dense where there is ____________.

37. Sound travels about 1 mile in 5 seconds. What is the approximate speed of sound in air in feet per second? In meters per second? ___________ and ___________. (See the lightning, count the seconds till the thunder, divide by 5 to get the number of miles away the lightning was.)

More on waves can be found at http://www.physicsclassroom.com/Class/waves/u10l1a.cfm
Review activity – Fill in the blanks with the best choice of terms. The box contains some choices. Some may not be used at all , and some may be used more than once.