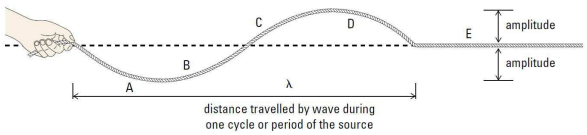
SPH3U UNIVERSITY PHYSICS

WAVES & SOUND

- Speed of Waves (P.388-391)

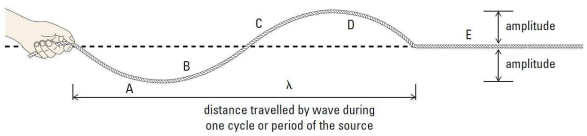
Speed of Waves

When a wave is generated in a spring or a rope, the wave travels one wavelength (λ) along the rope in the time required for one complete vibration of the source. Recall that this time is defined as the period (T) of the source.



Speed of Waves

*Since speed = distance/time, we can say v = λ/T or v = fλ. This equation is known as the **universal wave equation**. It applies to all waves and wave types (transverse, longitudinal, ...), visible and invisible, audible and inaudible.*



Universal Wave Equation

UNIVERSAL WAVE EQUATION

- applies to all waves and wave types (whether or not we can see them or hear them)

$$v = f\lambda$$

where v is the speed (m/s)
f is the frequency (Hz) ☜ *recall 1 Hz = 1/s or 1 s^{-1}*
λ is the wavelength (m)

Universal Wave Equation

PRACTICE

1. Write an equation for each of the following:
   (a) f in terms of v and λ.
   (b) λ in terms of f and v.
   (c) v in terms of T and λ.

   (a) $f = v / \lambda$
   (b) $\lambda = v / f$
   (c) $v = \lambda / T$

Universal Wave Equation

PRACTICE

2. The wavelength of a water wave in a ripple tank is 0.080 m. If the frequency of the wave is 2.5 Hz, what is its speed?

   v = 0.20 m/s

Universal Wave Equation

PRACTICE

3. The period of a sound wave from a piano is 1.20 x 10^{-3} s. If the speed of the wave in air is 3.40 x 10^{2} m/s, what is its wavelength?

   λ = 0.408 m

Universal Wave Equation

PRACTICE

4. The distance between successive crests in a series of water waves is 4.0 m, and the crests travel 9.0 m in 4.5 s. What is the frequency of the wave?

   f = 0.50 Hz

Factors That Affect Wave Speed

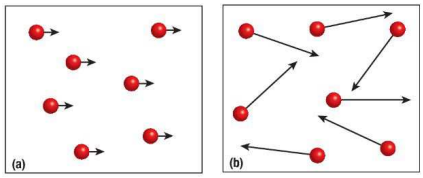
The transfer of energy using waves is more efficient if the particle vibrations do not absorb much energy. For example, a more rigid object such as a soccer ball tends to bounce more effectively if it is fully inflated.

Factors That Affect Wave Speed

So, if the atoms comprising an object are linked by strong intermolecular forces, then the wave energy is transmitted more efficiently and thus the wave speed is faster. However, if these forces are not as strong, then energy transmission is less efficient and thus slower.

Factors That Affect Wave Speed

In the case of gases, you might think that cooler gases (a) are more effective at transmitting sound than warmer gases (b) because they are denser. However, the opposite is true – with an increase in temperature the molecules move faster, jostle the neighbouring molecules more rapidly, and transfer their kinetic energy more efficiently.



Factors That Affect Wave Speed

NOTE!

The speed of a wave along a string, such as a violin or guitar string, is governed by two properties. Firstly, a string's ***linear density*** *determines how much force it takes to make the string vibrate. Secondly, the* ***tension*** *in a string determines how well it transmits energy (a loose string quickly absorbs energy whereas a tight string transmits energy very effectively).*

Factors That Affect Wave Speed

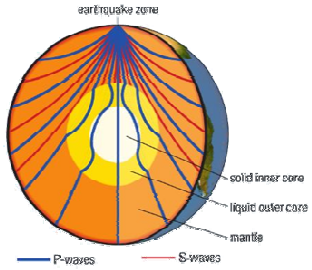
WAVE SPEED FACTORS

- depends on properties of medium (temperature, density, tension, …)
- strong molecular forces = faster energy transfer = higher wave speed (solid > liquid > gas)
- waves travel faster in hotter gases than in cooler gases

Speed of Waves

RECALL!

Earthquakes produce seismic waves, which travel through Earth. Primary waves, or P-waves, are longitudinal and can travel through both solids and liquids. Secondary waves, or S-waves, are transverse and can travel through solids only. When an earthquake occurs, vibrations are recorded at seismological stations around the world.



Speed of Waves

PRACTICE

5. If P-waves travel at ~ 8.0 km/s, and S-waves at ~ 4.5 km/s, calculate how long it takes each wave to travel from an earthquake to a seismological station that is 2.4×10^3 km away. Express your answer in minutes.

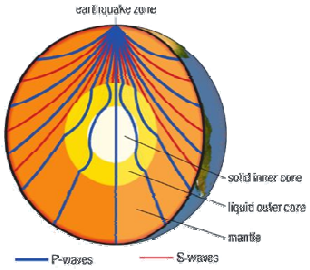
   (a) t_P = 5.0 minutes
   t_S = 8.9 minutes

Speed of Waves

PRACTICE

6. Explain how observing P-waves and S-waves helps geophysicists analyze the structure of Earth's interior.

Recall that P-waves can move through both solid and liquid materials but S-waves can only travel through solid material. As a result, scientists now believe Earth has a liquid outer core because S-waves cannot reach regions around the globe that P-waves can.



✔ Check Your Learning

TEXTBOOK

P.389 Q.1-3 (Practice)
P.391 Q.5,6

ACTIVITY: Investigating Vibrations (Inv.8.3.1/P.402)

① Follow procedure steps 1-11.
② Answer the following: Q.(a)/P.402