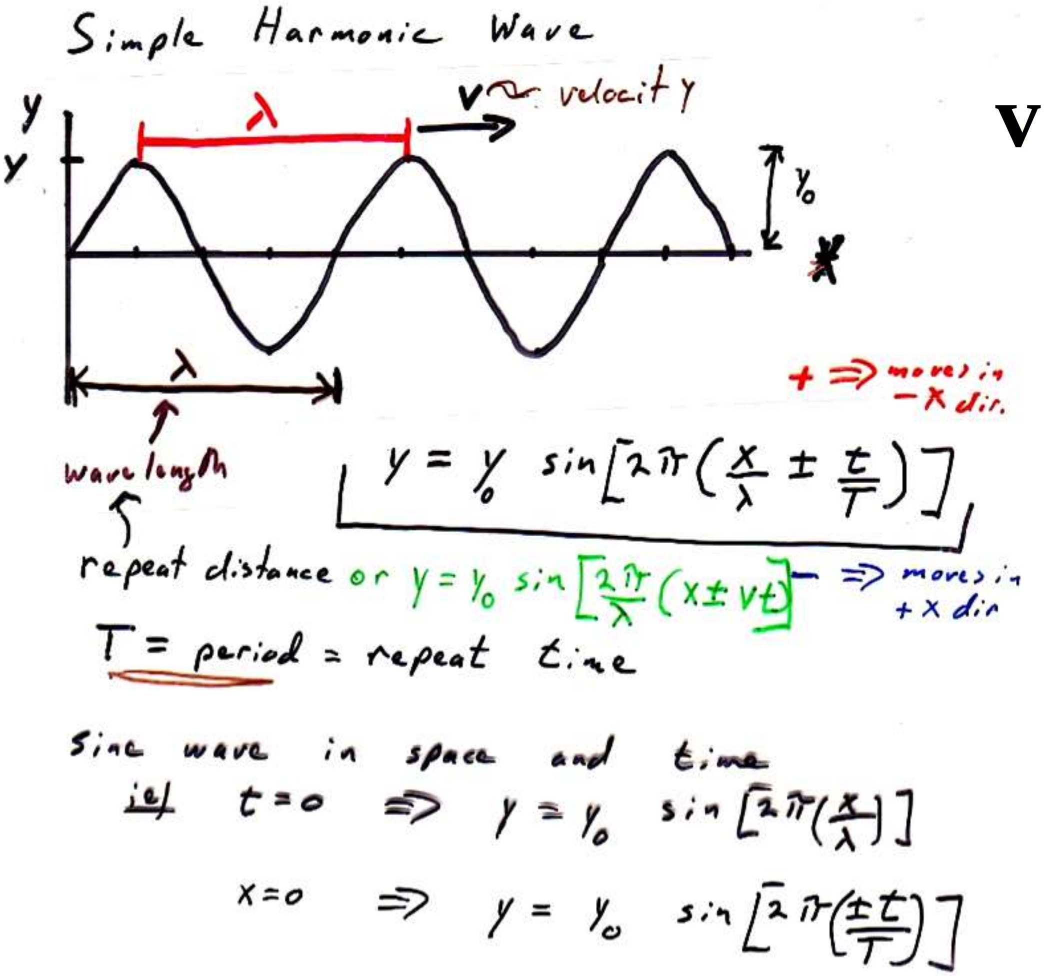
Transverse wave

$$v = \sqrt{\frac{T}{\mu}} \qquad \mu = m/L$$

Longitudinal (compression) wave

$$v = \sqrt{\frac{P}{\rho}}$$



Simple Harmonic Wave

wavelength

repeat distance

+ ⇒ moves in −x dir.

$$y = y_0 \sin\left[2\pi\left(\frac{x}{\lambda} \pm \frac{t}{T}\right)\right]$$

or $y = y_0 \sin\left[\frac{2\pi}{\lambda}(x \pm vt)\right]$ − ⇒ moves in +x dir

T = period = repeat time

Sine wave in space and time

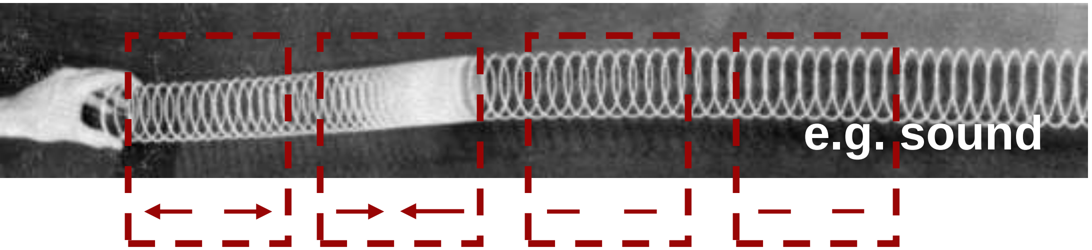
ie/ $t = 0 \Rightarrow y = y_0 \sin\left[2\pi\left(\frac{x}{\lambda}\right)\right]$

$x = 0 \Rightarrow y = y_0 \sin\left[2\pi\left(\frac{\pm t}{T}\right)\right]$

Waves -- Two Types

v= speed of wave- (disturbance from equilibrium)

Longitudinal (compression) wave

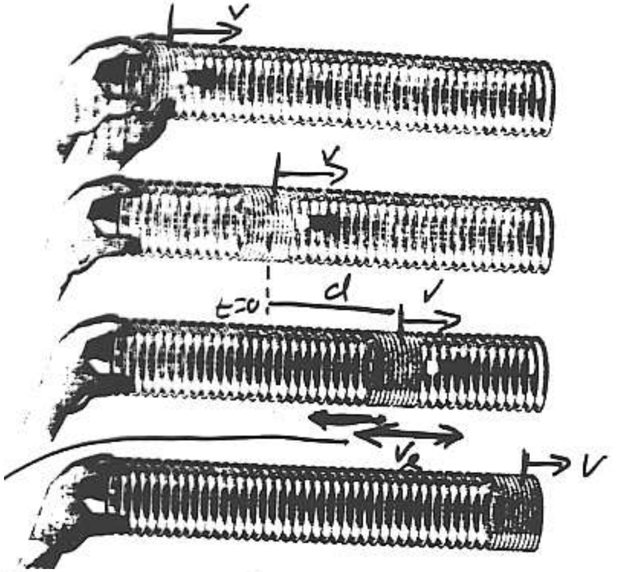


Coils separating

Coils compressed

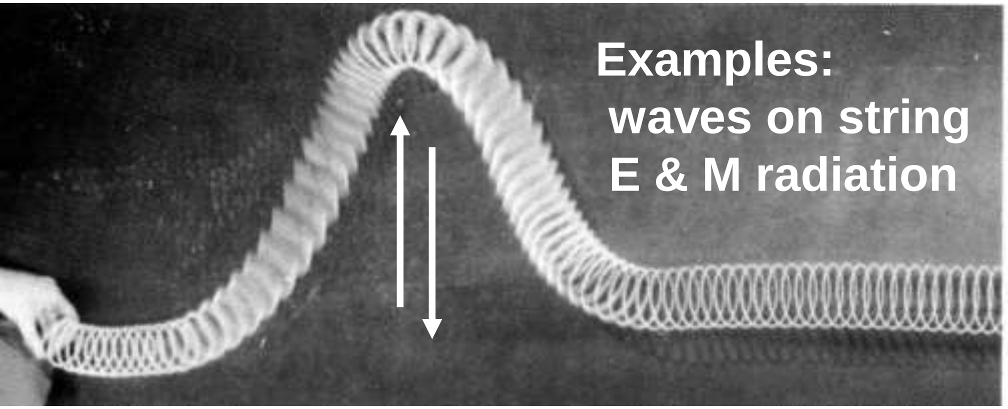
Coils not yet compressed

d = vt



longitudinal particle motion/velocity

Transverse wave



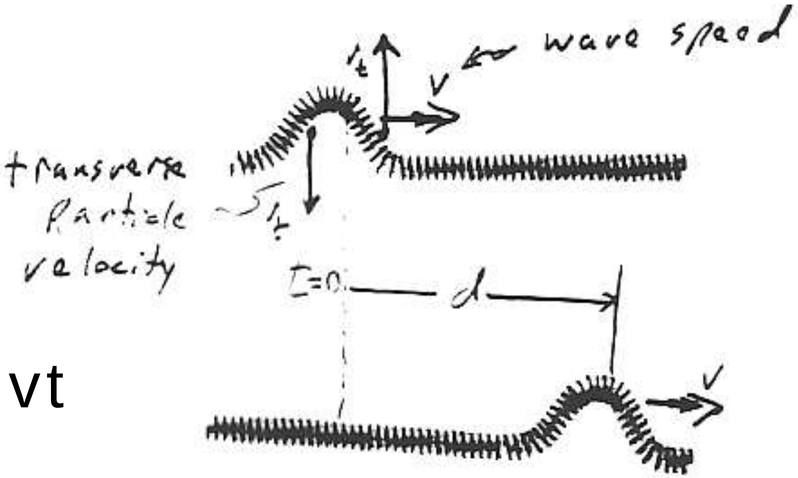
Examples:

waves on string

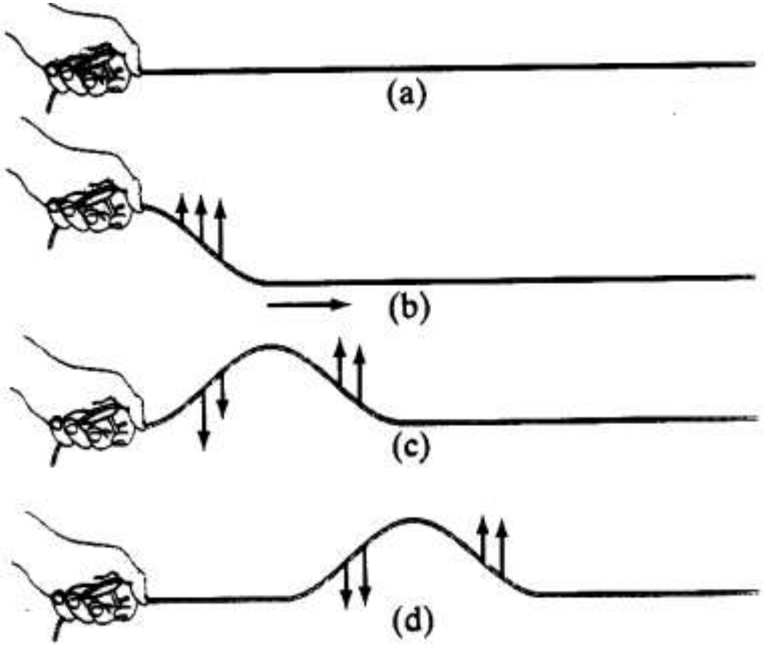
E & M radiation

Coils move up and then back

d = vt



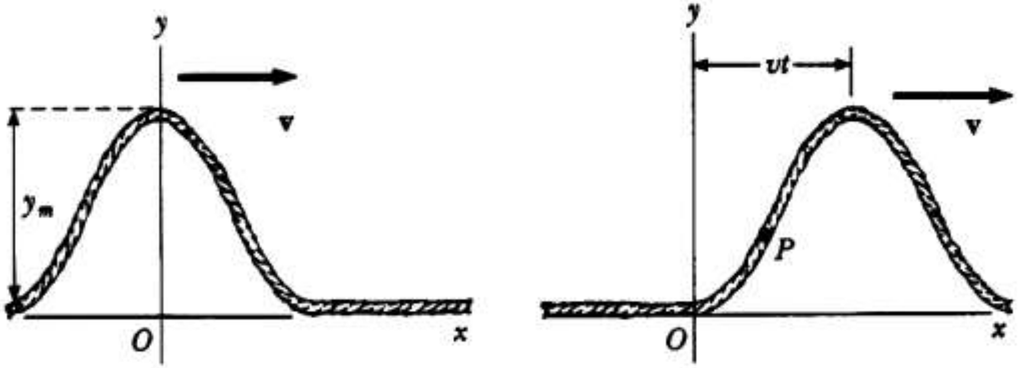
Transverse Wave



Waves on a string:

T = tension in string
ρ = density = m/L (kg/m)
L = string Length
m = string mass

$$\boxed{v = \sqrt{\frac{T}{\rho}}}$$



(a) Pulse at $t = 0$

(b) Pulse at time t

waves on string : T= tension; m=string mass; L=string length

$$\boxed{v = \sqrt{\frac{T}{\mu}}}$$

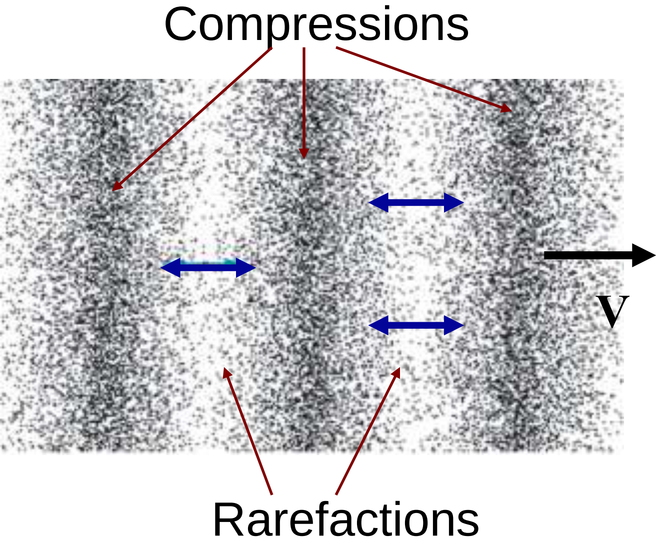
μ=m/L

sound waves : P= gas pressure; m= mass; V=volume ρ=gas density

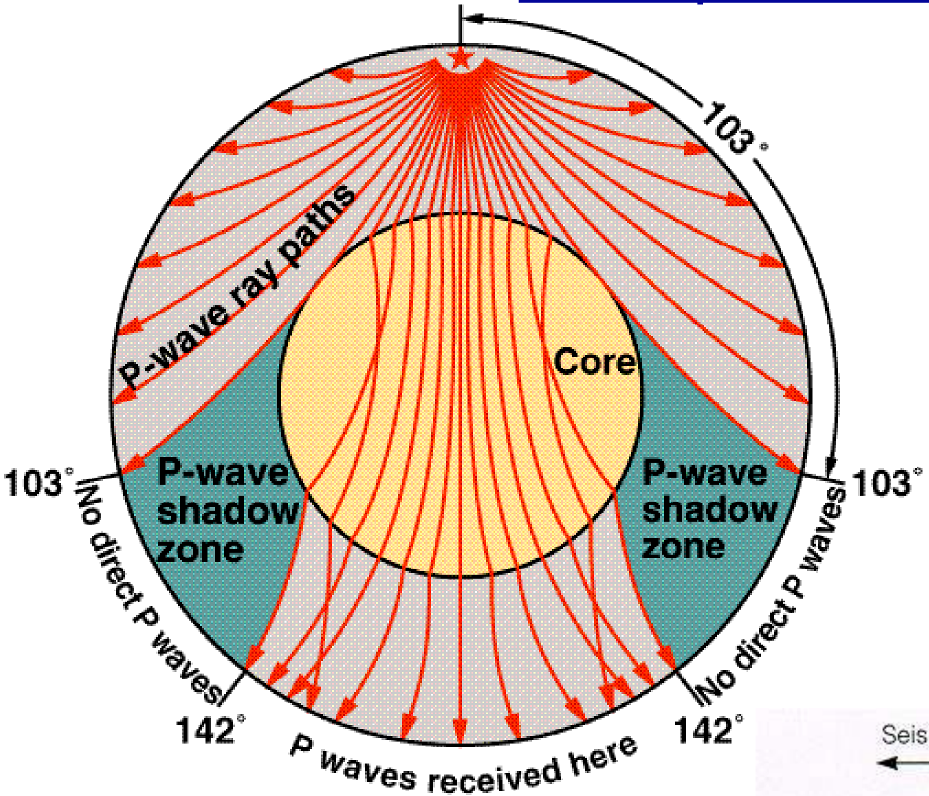
$$\boxed{v = \sqrt{\frac{P}{\rho}}}$$

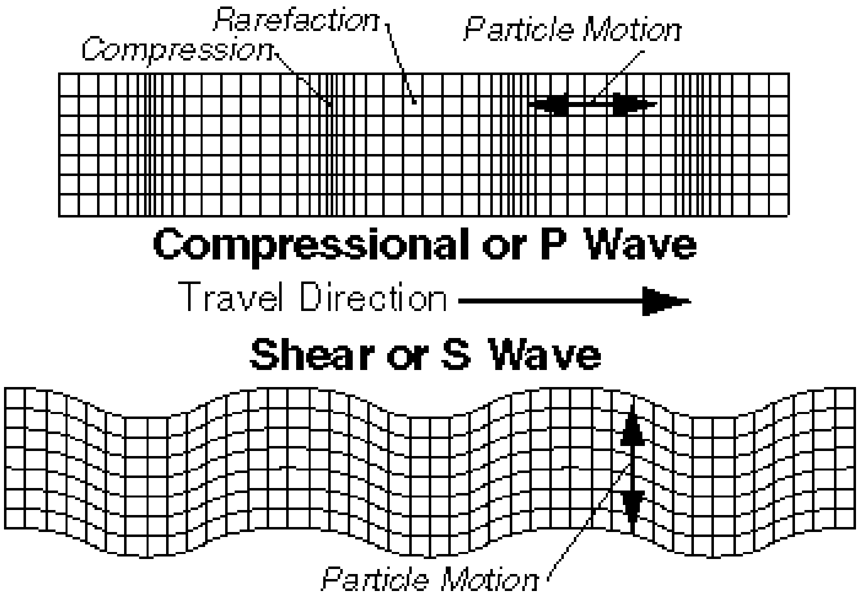
ρ=m/V

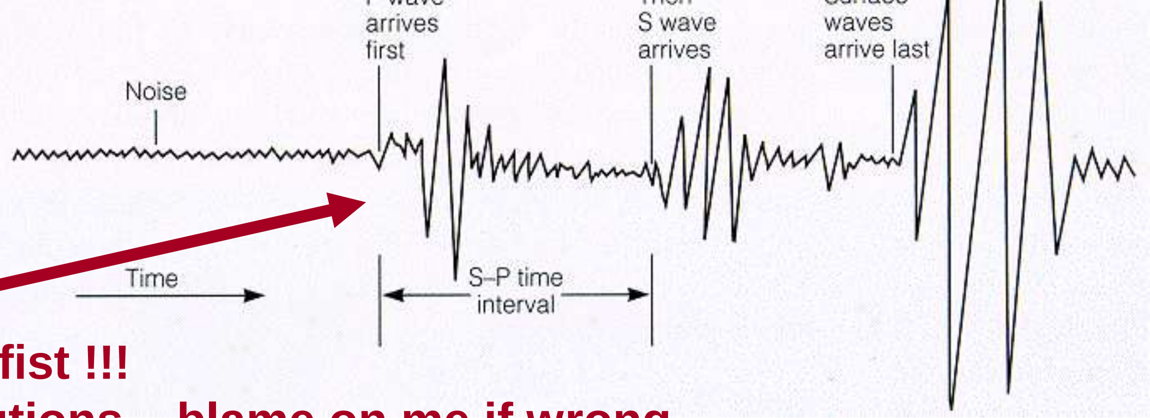
where ρ = mass/volume



Earthquake Waves



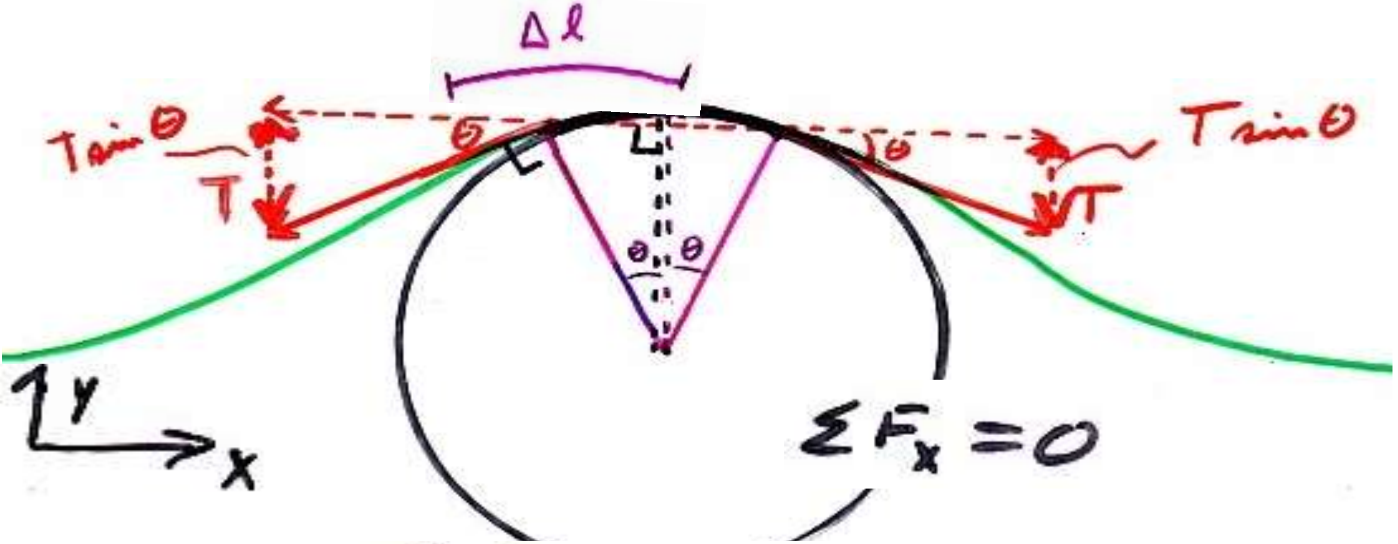




Smaller P-compression waves fist !!!
Some short time to take precautions – blame on me if wrong.

http://www.physics.rutgers.edu/~croft/kobe.wmv

Derivation of wave velocity on rope



$$\sum F_x = 0$$

$$\sum F_y = \underbrace{m}\,a$$

$$\mu = \frac{\text{mass}}{\text{length}}$$

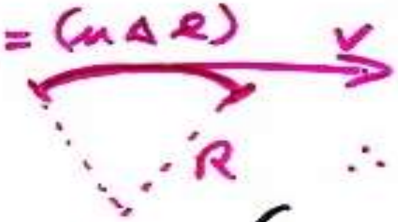
$$-2T(\sin\theta) = \mu(\Delta\ell)(a)$$

Note 1.

θ small $\sin\theta \simeq \frac{\Delta\ell}{2}\frac{1}{R}$

Note 2.

$m = (\mu\Delta\ell)$



∴ $a \cong -\frac{v^2}{R}$

(moving along circle

∴

$$-2T\left(\frac{\Delta\ell}{2R}\right) = -\mu\,\Delta\ell\left(\frac{v^2}{R}\right)$$

Derivation of wave velocity cont.

$$-\cancel{2}\mathbf{T}\left(\frac{\cancel{\Delta\ell}}{\cancel{2}\cancel{\mathbf{R}}}\right)=-\mu\,\cancel{\Delta\ell}\left(\frac{\mathbf{v}^2}{\cancel{\mathbf{R}}}\right)$$

$$\Rightarrow\ \mathbf{T}=\mu\,\mathbf{v}^2\ \Rightarrow\ \mathbf{v}^2=\frac{\mathbf{T}}{\mu}\ \Rightarrow\ \mathbf{v}=\sqrt{\frac{\mathbf{T}}{\mu}}$$

$$\sqrt{\frac{\mathbf{N}}{\mathbf{kg/m}}}=\sqrt{\frac{\mathbf{kg\ m/s^2}}{\mathbf{kg/m}}}=\sqrt{\mathbf{m^2/s^2}}=\mathbf{m/s}$$

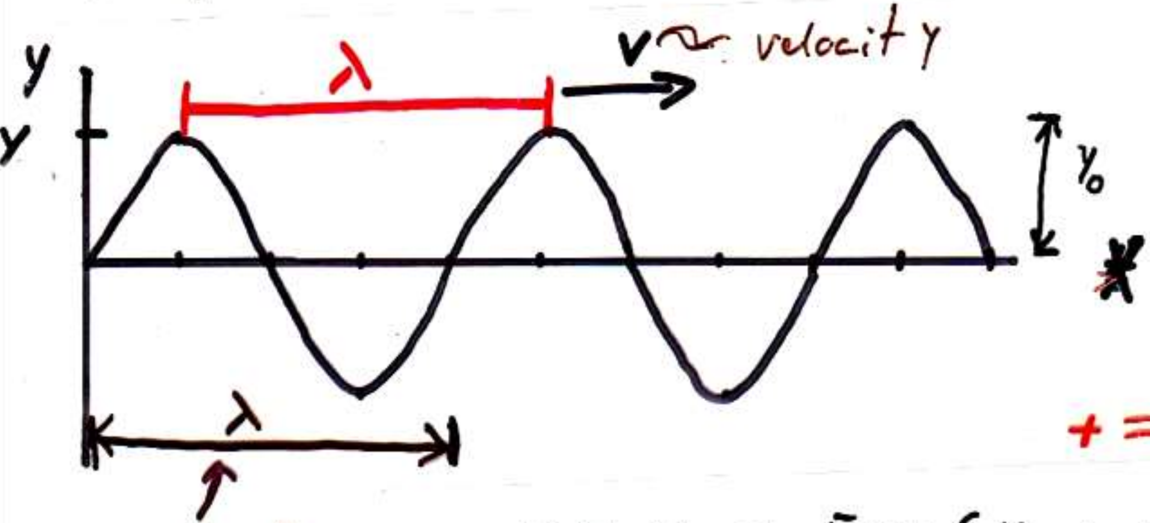
---

sound

$$\mathbf{v}=\sqrt{\frac{\mathbf{P}}{\rho}}$$

$$\sqrt{\frac{\mathbf{N/m^2}}{\mathbf{kg/m^3}}}=\sqrt{\frac{\mathbf{kg\ m/s^2}}{\mathbf{kg/m}}}=\sqrt{\mathbf{m^2/s^2}}=\mathbf{m/s}$$

Simple Harmonic Wave



wavelength

repeat distance

$$y = y_0 \sin\left[2\pi\left(\frac{x}{\lambda} \pm \frac{t}{T}\right)\right]$$

$+ \Rightarrow$ moves in $-x$ dir.

or $y = y_0 \sin\left[\frac{2\pi}{\lambda}(x \pm vt)\right]$

$- \Rightarrow$ moves in $+x$ dir

T = period = repeat time

f = frequency

$\frac{1}{s} = Hz$

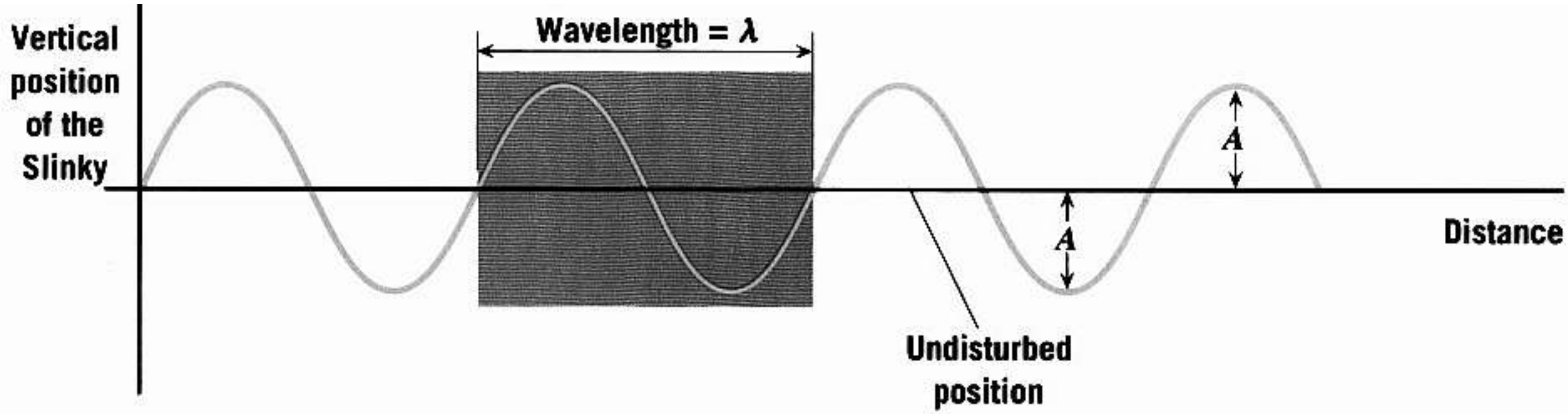
$f = \frac{1}{T}$

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

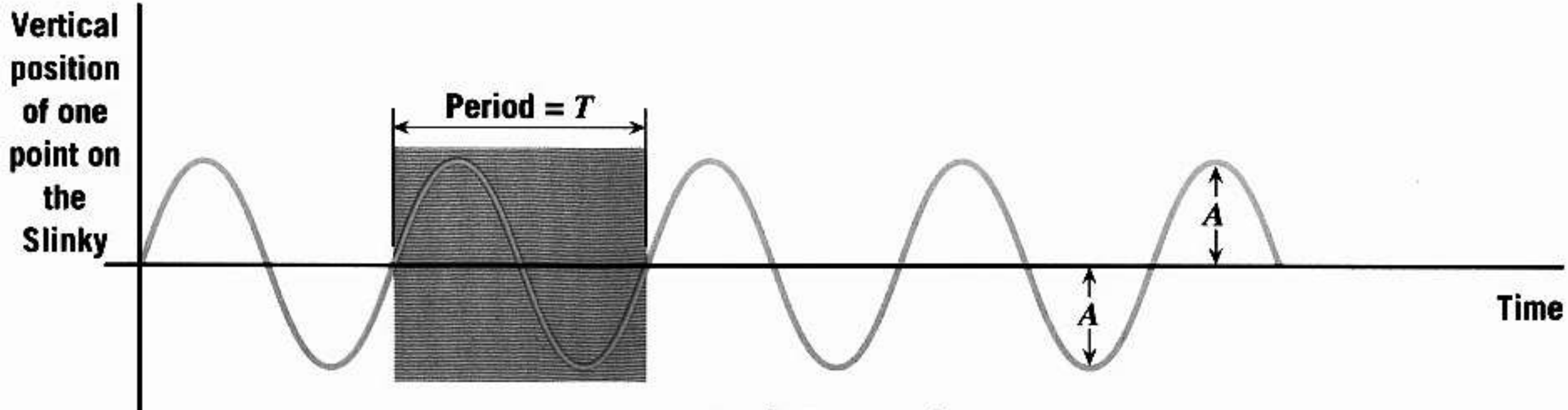
sine wave in space and time

i.e. $t=0 \Rightarrow y = y_0 \sin\left[2\pi\left(\frac{x}{\lambda}\right)\right]$

$x=0 \Rightarrow y = y_0 \sin\left[2\pi\left(\pm\frac{t}{T}\right)\right]$

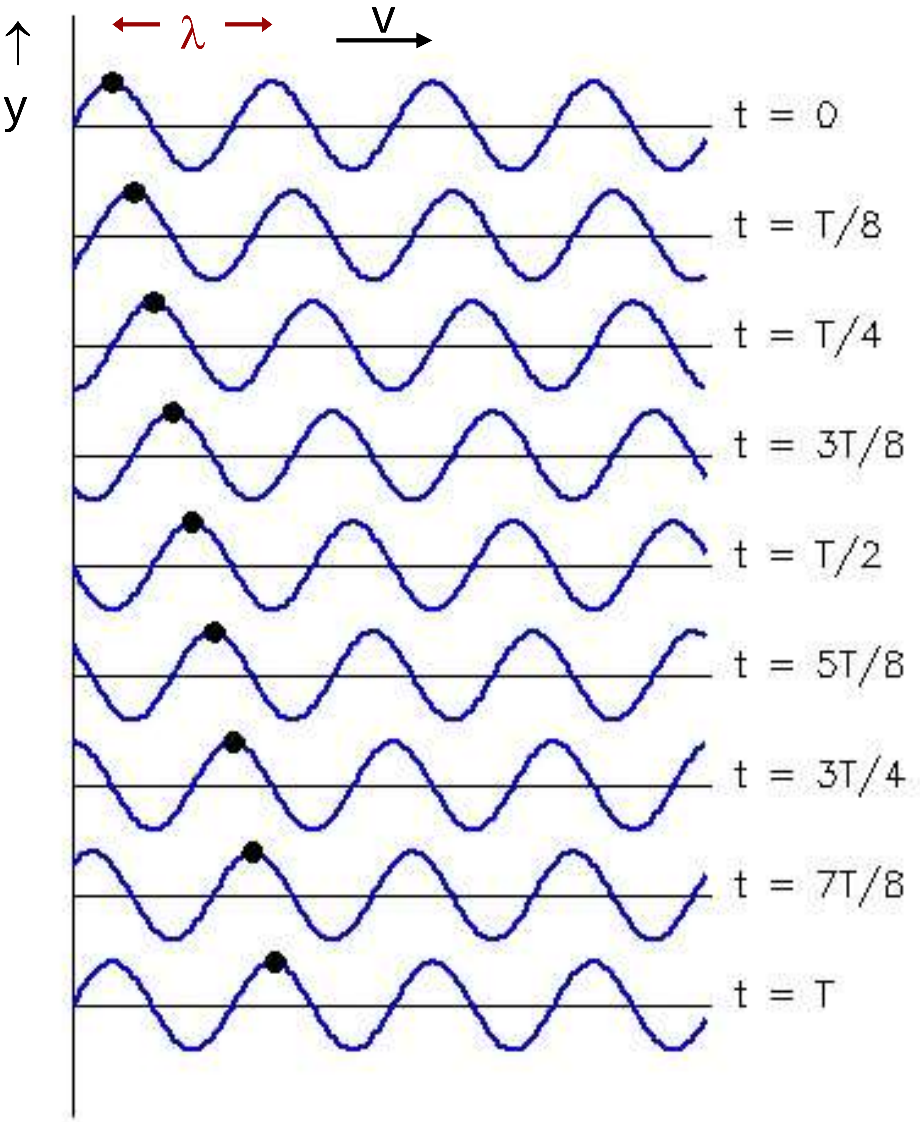


(*a*) At a Particular Time



(*b*) At a Particular Location

Harmonic Waves



$$y = y_0 \sin\left[2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right]$$

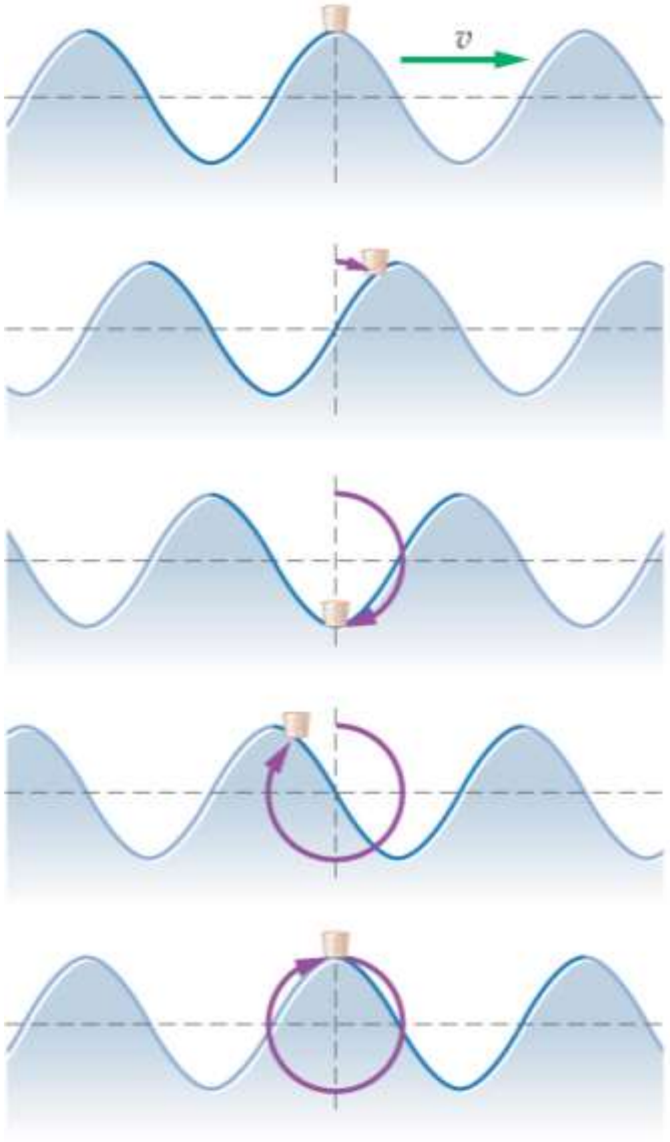
Note: Wave travels a distance of λ in time, T.

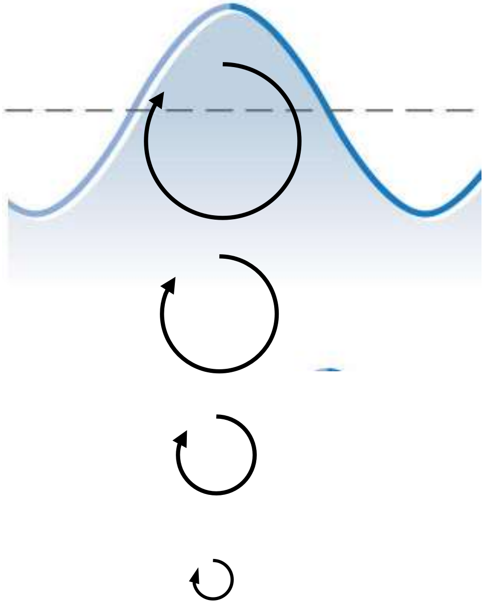
$$\therefore\ vT = \lambda$$

or $v = \frac{\lambda}{T}$

or $\boxed{v = f\lambda}$ $\quad f = \frac{1}{T}$

Aside: Water Waves





water waves- combination of transverse & longitudinal

water waves- more complicated

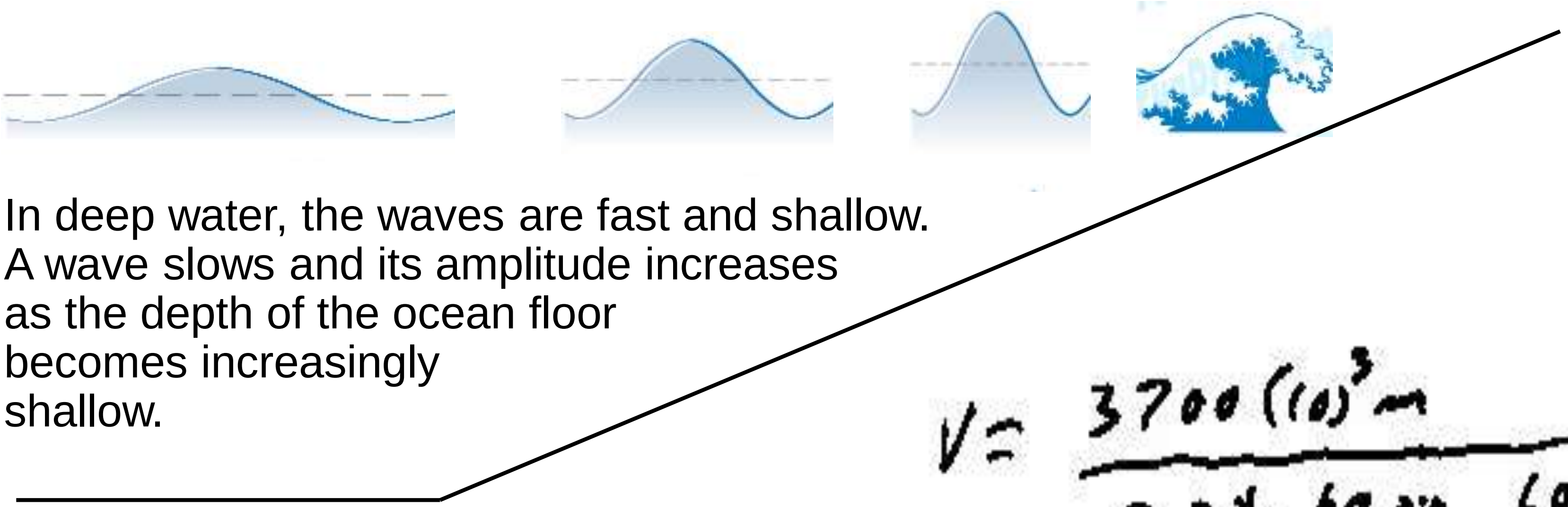
- v depends on depth and λ

Tsunami

A Tsunami in deepwater can travel 3700 km in 5.3 hr. What is the wave speed?

$$V = \frac{\Delta x}{\Delta t} = \frac{3700\ \text{km}}{5.3\ \text{h}} = 195\ \text{m/s}$$

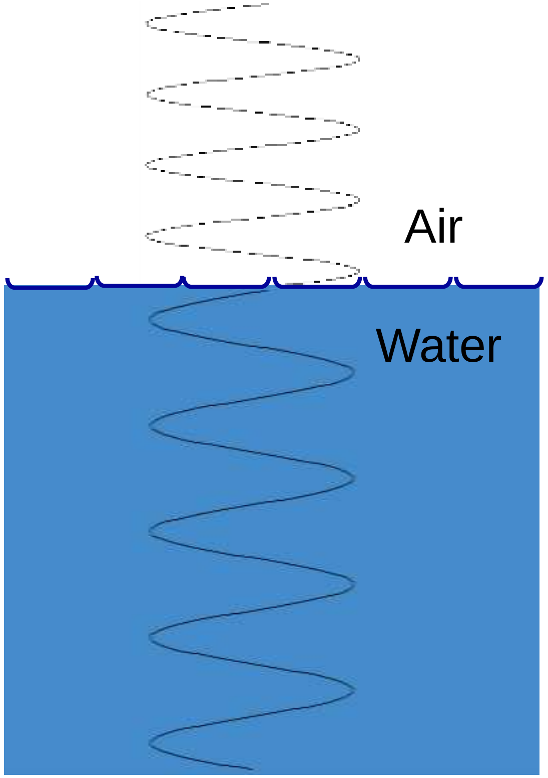
Tidal Wave?



In deep water, the waves are fast and shallow.
A wave slows and its amplitude increases
as the depth of the ocean floor
becomes increasingly
shallow.

$$V = \frac{3700\,(10)^3\ \text{m}}{5.3\ \text{h}\ \frac{60\ \text{min}}{\text{h}} \cdot \frac{60\ \text{s}}{\text{min}}}$$

A sound wave passes from air to water. What is the relation between the wave speed and wavelength in the two media?



$$\lambda_a f = v_a \Rightarrow f = \frac{v_a}{\lambda_a}$$

Hint: f is the same

$$\lambda_w f = v_w \Rightarrow f = \frac{v_w}{\lambda_w}$$

increases

$$\frac{v_a}{\lambda_a} = \frac{v_w}{\lambda_w}$$

increases

Sound Waves

The speed of sound is different in different materials; in general, the denser the material, the faster sound travels through it.

$$\boxed{v = \sqrt{\frac{P}{\rho}}}$$

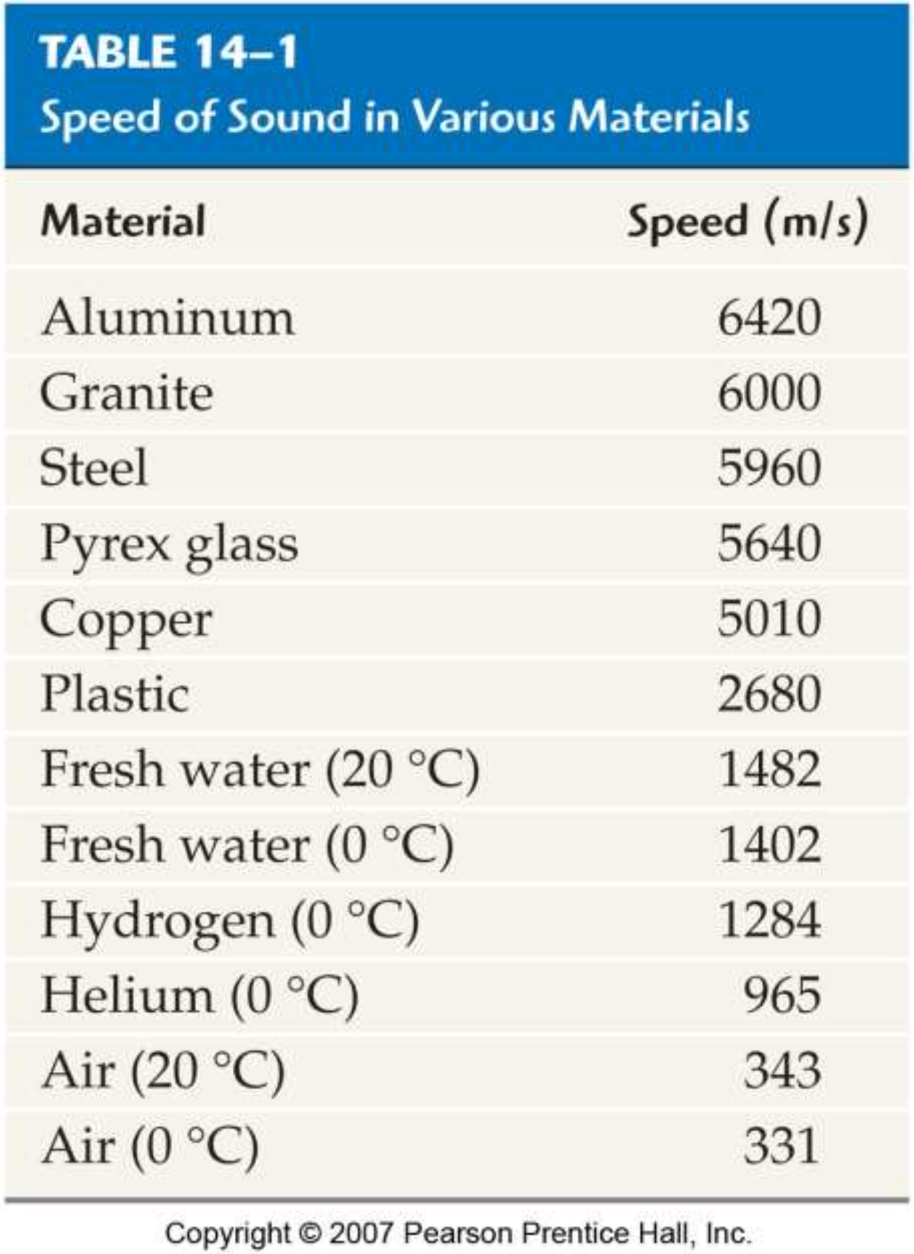


TABLE 14–1
Speed of Sound in Various Materials

Material	Speed (m/s)
Aluminum	6420
Granite	6000
Steel	5960
Pyrex glass	5640
Copper	5010
Plastic	2680
Fresh water (20 °C)	1482
Fresh water (0 °C)	1402
Hydrogen (0 °C)	1284
Helium (0 °C)	965
Air (20 °C)	343
Air (0 °C)	331