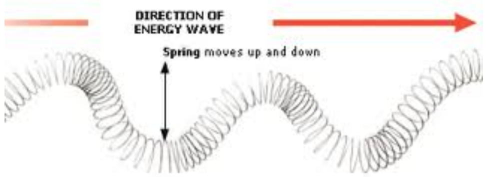
Ch 16 - Waves and Sound

Demo -

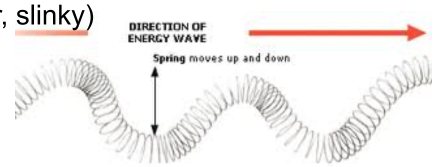
Slinky



Wave - a periodic disturbance that moves through space

Waves = energy NOT Matter

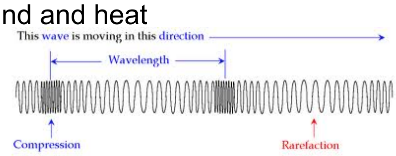
Medium = matter wave travels through (ex. water, air, slinky)



Types of Waves

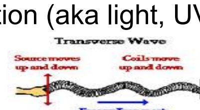
1) Longitudinal

- vibrates parallel motion
- requires a medium
- ex: sound and heat

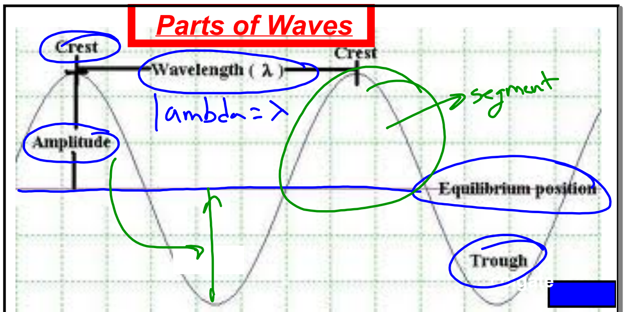


2) Transverse

- vibrates perpendicular to motion
- does NOT require a medium
- ex. radiation (aka light, UV, IR, etc)



Parts of Waves

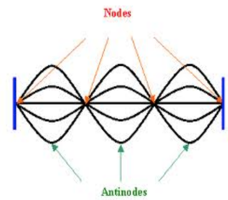


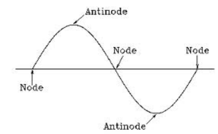
wavelength = distance between 2 identical points

amplitude = height of wave from equilibrium

frequency = number of cycles per second

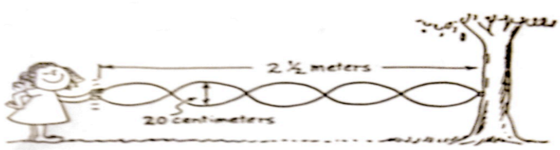
period = time for one cycle





Nodes = no motion

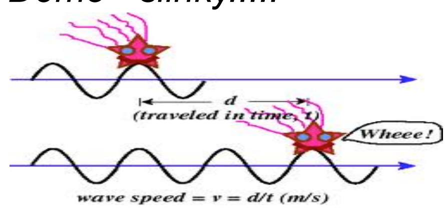
Anti~~does~~ nodes = max motion



IN THE STANDING WAVE SHOWN,
WHAT IS ITS AMPLITUDE ?
WHAT IS ITS WAVELENGTH ?
HOW MANY NODES ARE THERE ?

What effects speed of wave?

Demo - slinky.....



Speed of wave

- depends on TENSION of string or spring
- depends on medium
- waves travel at the SAME speed in the SAME medium

Equations for Wave Speed

v = x/t so....for a wave

v = λ/T but T = 1/f so...

$v = \lambda f$ ***True for ALL waves

$$v = \sqrt{\frac{F}{m/L}}$$

***True only for strings/ springs

F = Tension m/L = linear density

for SHM remember

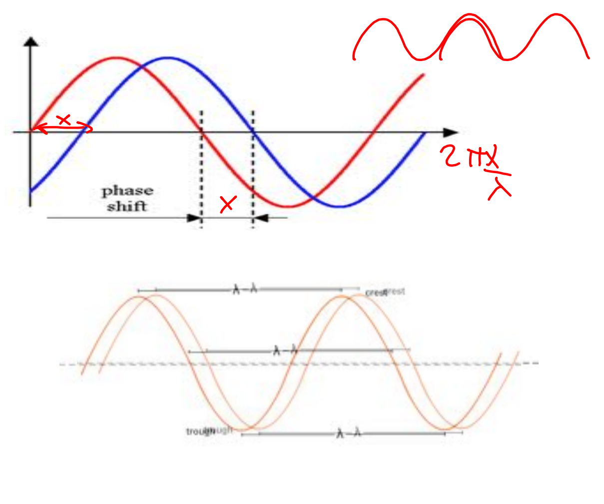
x = Asinωt or Asin(2πft)

so for waves

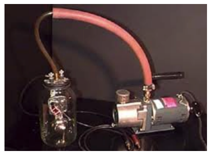
y = distance in y direction = propagation so...

$y = A\sin(2\pi ft \pm 2\pi x/\lambda)$

where 2πx = + or - shift for the start of the wave compared to full wavelength)



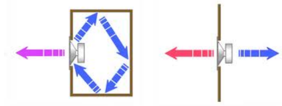
Sound Waves



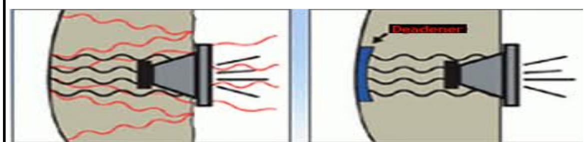
- Due to vibrations
- Requires molecules to vibrate or no sound

Physics of speakers:

Front and back waves are shift by

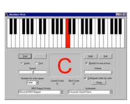


180º or λ/2 = destructive interference



by blocking "back" waves, sound improves

Definitions of wave terms for sound



frequency = pitch

<20 Hz = infrasonic (below human hearing)

>20kHz = ultrasonic (above human hearing)

adults lose high frequency (cell phone ringers)

amplitude = loudness

ear perceives as pressure, high pressure = pain...normal conversation = .03 Pa

Speed of Sound

- Fastest in solids - due to elasticity NOT density
- 4x faster in water than air
- 17 x faster in steel than air
- ***v_{air} = 343 m/s*** (this is the WAVE not the molecules)

Remember the ***molecule speed*** is relative to temperature - 3/2kT = 1/2mv² = KE

$k_B = 1.38 \times 10^{-23}$ J/K

Speed of SOUND WAVES in different types of media

$v^2 = \gamma kT/m$	GAS	$\gamma = c_p/c_v$ = constant m= mass of ONE molecule
$v^2 = B_{ad}/\rho$	LIQUID	B_{ad} = bulk modulus ρ = density
$v^2 = Y/\rho$	SOLID	Y = Young's modulus ρ = density

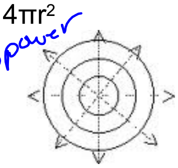
ρ = rho = density

Sound Intensity

- Energy passing through unit area (perpendicular to ray) per second
- I = Energy/second/area = P/A = W/m^2
- Follow inverse square law
- Normally a point source and since Surface area of sphere = $4\pi r^2$

$$I = \frac{P}{4\pi r^2}$$

P → power



Sound Intensity Level

- Sound intensity relative to human hearing
- dB = decibels

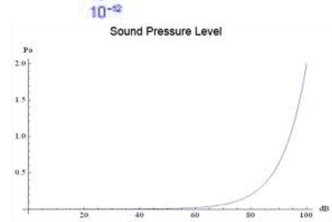
$$\beta = 10\log(I/I_o)$$

- I = actual intensity
- I_o = min intensity a human can hear = 10^{-12} W/m^2

Approximate sound levels and intensities within human hearing range

Source of sound	Intensity level (dB)	Intensity ($W\ m^{-2}$)	Perception
jet plane at 30 m	140	100	extreme pain
threshold of pain	125	3	pain
pneumatic drill	110	10^{-1}	very loud
siren at 30 m	100	10^{-2}	
loud car horn	90	10^{-3}	loud
door slamming	80	10^{-4}	
busy street traffic	70	10^{-5}	noisy
normal conversation	60	10^{-6}	moderate
quiet radio	40	10^{-8}	quiet
quiet room	20	10^{-10}	very quiet
rustle of leaves	10	10^{-11}	
threshold of hearing	0	10^{-12}	

$$\beta = 10\log(I/I_o)$$



LOG rules to remember.....

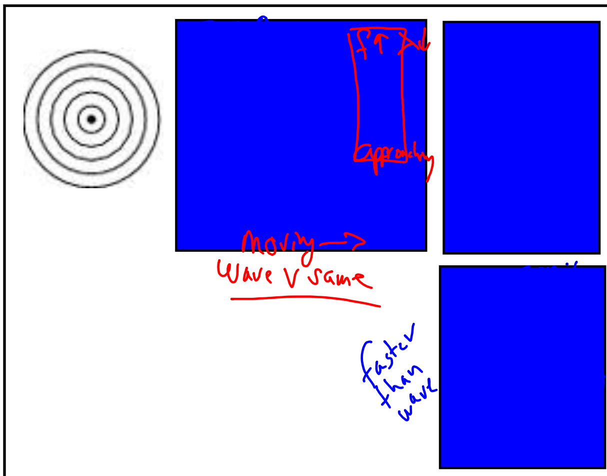
$$\log(x \times y) = \log(x) + \log(y)$$

$$\log\left(\frac{x}{y}\right) = \log(x) - \log(y)$$

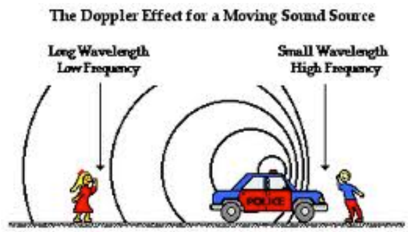
$$\log(x^a) = a \times \log(x)$$

Doppler Demo......

http://www.sciencejoywagon.com/physicszone/lesson/otherpub/wfendt/plrsci/media/soundwav.htm



Doppler Effect = apparent change in frequency due to relative motion



Moving Source-

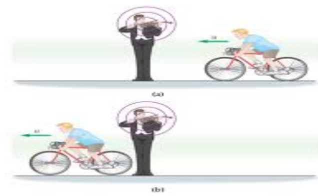
$f' = f(1/(1-v_s/v))$ $\frac{f}{1-v_s/v}$ — **source away**

$f' = f(1/(1+v_s/v))$ $\frac{f}{1+\frac{v_s}{v}}$ — **source towards**

v_s = speed of source(car) v = speed of wave

f' = apparent freq f = actual freq

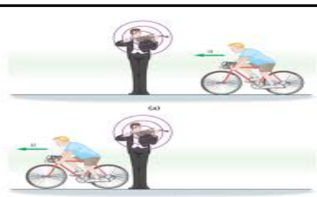
note as v_s ↑ v_s/v ↑ so f' changes more



Moving observer:

$f' = f(1-v_o/v)$ — **observer away**

$f' = f(1+v_o/v)$ — **observer towards**



Moving observer:

$f' = f(1-v_o/v)$

$f' = f(1+v_o/v)$

Moving observer AND source:

$$f' = f\left(\frac{1 \pm \frac{v_o}{v}}{1 \mp \frac{v_s}{v}}\right)$$