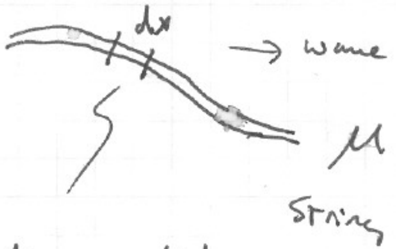
Waves carry energy
(move masses as they travel)

→ light waves carry energy from sun to us
→ earthquake waves can destroy buildings
→ Sound waves can burst eardrums



$\mu = $ mass/length

Mass $= \mu\, dx$

Consider Harmonic wave — Mass moves in SHM

has energy

Amplitude

$E = \frac{1}{2} k x^2$ where $x = A$

$k = m\omega^2$

dE in a dx of wave

$\therefore$

$$dE = \frac{1}{2}\mu (dx)\, \omega^2 A^2$$

$\omega^2 \equiv \frac{k}{m}$

wave moves w/ $v = dx/dt$

Energy passing thru a point in time dt

$$dE = \frac{1}{2}\mu\omega^2 A^2 v\, dt$$

$$\boxed{\frac{dE}{dt} = \frac{1}{2}\mu\omega^2 v A^2}$$

Rate of energy transfer through a point

⇒ Power
Watts

More generally $\boxed{\frac{dE}{dt} \propto A^2 v}$

Will see much more of this next Semester

Intensity of wave $\equiv$ Power$/M^2$ = Watts$/M^2$

energy transported by wave per unit time across a unit area $\perp$ to direction of flow

Intensity of Sound $.3 \; W/M^2$

Useage ...

Reference intensity to some common reference

$$\beta \text{ (decibel)} = 10 \log \frac{I}{I_0}$$

dB

$1 \times 10^{-12} \; W/M^2$ Threshold intensity for hearing of Ave. person

	dB
Threshold of hearing	0
whisper	~20
Street traffic	~70
Siren @ 30 m	100
Rock Concert / Pain Threshold	~120
Jet engine at 30m	~140

Example

Stereo advertisement

Flat response ± 3 dB from 30 Hz to 18,000 Hz

What does this mean in relative intensity variation?

Ave intensity I_1, $\therefore$ variation

$$I = I_1 + 3\text{dB}$$

$$\beta - \beta_1 = 10 \log \frac{I}{I_0} - 10 \log \frac{I_1}{I_0}$$

$$3\text{dB} = 10 \log \frac{I}{I_1} \Rightarrow \frac{I}{I_1} = 2.0$$

variation in intensity is factor of two!

Interference of Waves

or → when waves interact.

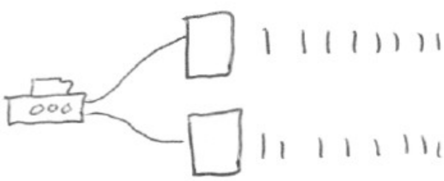
You talked about Superposition of Waves

when you talked about beats

Now look at waves of same frequency from

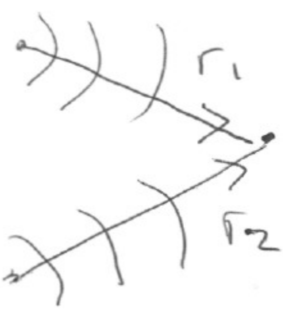
different sources.... say two speakers hooked

to a stereo



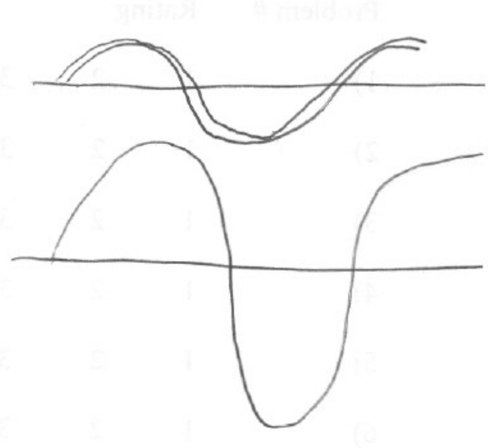
Sound is longitudinal of course, but ~~to~~ easier to

see with transverse waves so think of water.



Same distance

Superposition

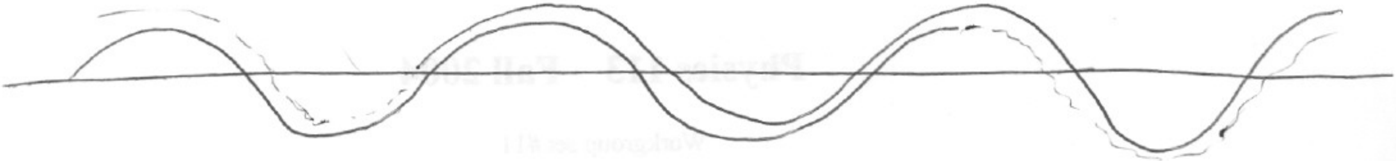


Now call path difference Δr,

So Δr is the difference in the distance

the two waves have traveled $\Delta r = r_2 - r_1$

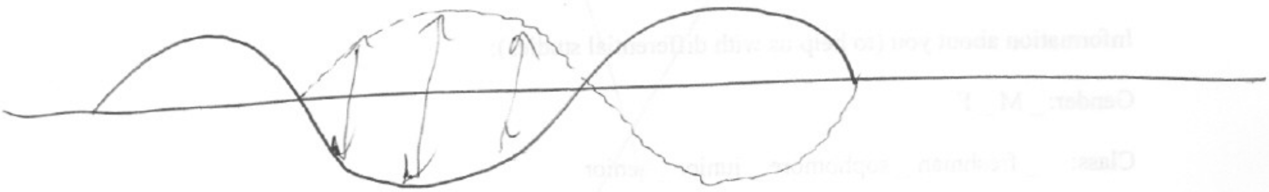
Now, if off by 1λ



same thing, they add → bigger wave.

$\Delta r = r_2 - r_1 = n\lambda \quad n = 0, 1, 2 \ldots$ Constructive Interference

Now → off by $\frac{1}{2}\lambda$



when you add those points → one ⊕ one ⊖

we get $\underline{\underline{\text{zero}}}$ at all points

Destructive Interference

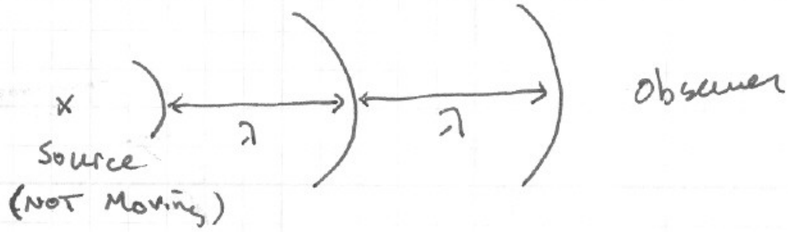
→ off by $\frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2} \Rightarrow \Delta r = \frac{n\lambda}{2}, n = 1, 3, 5, \ldots$

What is different between this and standing waves?

Standing wave → no energy flow in either direction

Traveling wave w/ int → energy flow.

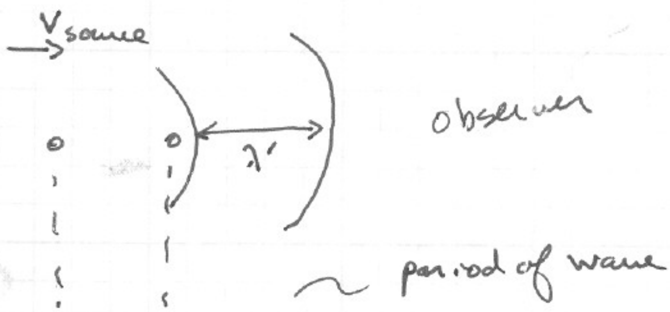
Doppler shift of Sound frequency



λ = Distance between wave crests

Suppose Source Moves!

Velocity of wave in Medium NOT affected by Source movement $\equiv V_w$



$d = V_{source} T$ $\qquad T = \frac{1}{f} \qquad V_{wave} = \lambda f$

$$\lambda = d + \lambda'$$

$$\lambda' = \lambda - d = \lambda - V_s \frac{1}{f} = \lambda - V_s \frac{\lambda}{V_{wave}}$$

$$\lambda' = \lambda \left(1 - \frac{V_s}{V_w}\right)$$

or $\boxed{\Delta\lambda = \lambda \frac{V_s}{V_w}}$

what is usually "heard" or Measured is frequency

$$\boxed{f' = \frac{V_w}{\lambda'} = \frac{V_w}{\lambda(1 - V_s/V_w)} = \frac{f}{\left(1 - \frac{V_s}{V_w}\right)}}$$

Source Moving Toward STATionary observer

$$f' > f$$

Can derive for source moving away from observer

$$\boxed{f' = \frac{f}{\left(1 + \frac{v_s}{V_w}\right)}}$$

known as Doppler shift of frequency

- train whistle
- Demos
- Similar thing for light

  ↳ receding galaxies