DAY 1

PH 424, 2013

Why study waves?

- Build a musical instrument
- Calculate Atomic wavefns of electrons bound to atomic nuclei
- Build a laser
- Invent radio communication.
- Design buildings that don't fall down.

Send signals without launching projectiles

Demo with stretched rope, send pulses.
- ~~All molecules end up back where they started~~
- Rope ends up back where it started

c.f. paper airplane

These examples come from all realms of physic

- Classical mechanics
- Quantum mechanics
- Electromagnetism.

In each subject we find situations where this eq^n arises:

$$\frac{\partial^2}{\partial x^2}\psi(x,t) = \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\psi(x,t)$$

This eq^n unifies the "1d waves paradigm".

you'll be amazed how challenging it is to cover every aspect in 3 weeks time.

Go over the course website:

Day by day summaries
Homework due dates.
Look at hw1, hw2 (Start thinking about Friday prob now).
Office hours, Instructor/t.a.
Grade = HW, Lab, final.
Final on a Monday night.
Show example of web resources.

Need to transition off of the spins paradigm.

Recall the oscillations paradigm,

we will draw heavily from language you already learned.

~~How do I~~ What eqn can I use to describe the height of one white ball?

$$A \sin(\omega t + \phi)$$

I'll need to ~~call~~ give this fn a name

$$\psi(x=4, t) = A \sin(\omega t + \phi)$$

Notice that ψ can have different meanings for different types of waves. Transverse, Longitudinal, $\vec{E}$-field etc.

		Dimension	Unit
	ψ	length	
	A	length	
angular freq	ω	$\frac{1}{\text{time}}$	rad/s
	t	time	
phase const	ϕ	dimensionless	rad

You learned about two types of freq in oscillations

ω	f
rad/s	cycles/s

$$\boxed{\omega = 2\pi f}$$

The argument of the sin function, $\omega t - \phi$, is called the phase. The phase changes with time.

Period $T = \frac{1}{f} = \frac{2\pi}{\omega}$

Recall that $A\sin(\omega t+\phi)$ is not the only mathematical way to describe an oscillation

$$A\cos(\omega t+\phi'),$$
$$B_1\cos(\omega t) + B_2\sin(\omega t),$$
$$Ce^{i\omega t} + C^* e^{-i\omega t},$$
$$\mathrm{Re}\left[De^{i\omega t}\right]$$

all equivalent.

Look at wave machine again.

We have a collection of oscillators.
Any one point is described by $A\sin(\omega t+\phi)$
each point has different ϕ.

Freeze wave at $t=0$.

$$\psi(x, t=0) = 10\,\mathrm{cm}\ \sin\left(\frac{2\pi}{50\,\mathrm{cm}}x\right)$$

White board exercise

$$\psi(x) = (0.5\,\text{ft}) \sin\left(\frac{2\pi}{1\,\text{ft}}\, x\right)$$

call this const "k", the wave vector.

kx is a phase.

When kx changes from 0 to 2π the wave has gone thru one cycle (traversed one wavelength λ).

i.e. $k\lambda = 2\pi$

$$\boxed{k = \frac{2\pi}{\lambda}}$$

Analogy between k & ω

When we freeze time, k describes spatial variation in phase

when we ~~[illegible]~~ look at a single point in space, ω describes temporal variation in phase.

A 1d wave fn must include both t & x dependence.

$$\Psi(x,t) = \underbrace{\qquad\qquad\qquad\qquad}$$

put together something that uses ~~an~~ ωt and kx.

This wave is transmitting information from left → right or right → left.

How quickly is this information moving?

$$\left(\text{Some people may remember} \quad v_{phase} = \frac{\lambda}{T} \quad \left(= \frac{2\pi}{k}\frac{\omega}{2\pi} = \frac{\omega}{k} \right) \right)$$

I want to highlight a more direct and insightful way to find v_{phase}.

Freeze time and find a point where ~~4~~

$$\Psi(x,t) = A\sin(\underbrace{kx - \omega t}_{= \pi/2}) \text{ is max}$$

switch on time again,

This max position ~~m~~ is moving.

$$kx_{peak} - \omega t = \pi/2 \quad \text{for all } t.$$

$$\Rightarrow \quad x_{peak} = \frac{\omega}{k} t + \pi/2$$

x_{peak} is moving at a speed $\frac{\omega}{k}$.

$$\boxed{v_{phase} = \frac{\omega}{k}}$$

points of constant phase move at this rate.

There is another natural velocity to calculate for a ~~spatial~~ wave fn where ψ is spatial displacement, $\frac{\partial \psi}{\partial t}$.

The velocity of an individual oscillator going back and forth. It goes positive/negative/positive/negative. Never a const. We will seldom be concerned with this velocity.

$\psi(x,t) = A \sin(kx - \omega t)$ is only one of many forms that a 1d wavefn can take.

Here is another $\psi(x,t) = A e^{-(kx-\omega t)^2}$

Draw at $t=0$ on white board