Physics 218
Waves and Thermodynamics

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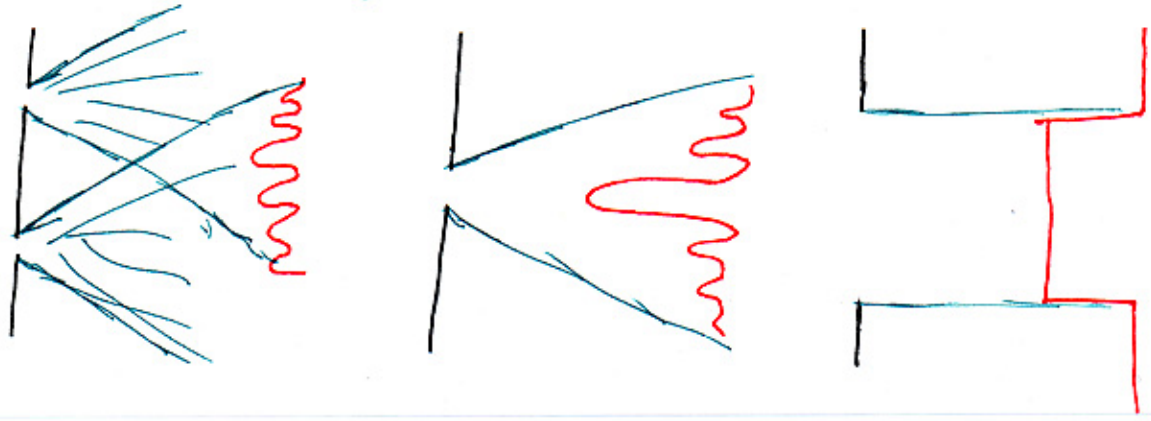
- First homework due THIS MONDAY
- First lab starts A WEEK FROM MONDAY

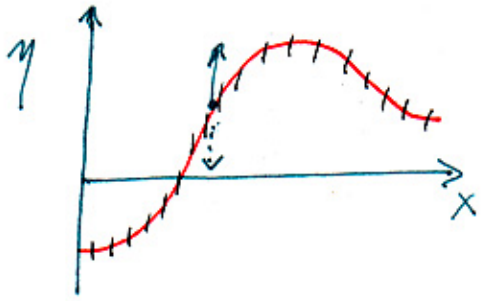
COURSE INCLUDES

- Deriving New Physical Laws ← Wave Equations, Diffusion Equations, Modern Methods
- Continuum Physics ← Elasticity, Wave Motion, Heat Transport ...
- Partial Differential Equations $\partial^2\eta/\partial t^2 = c^2 \partial^2\eta/\partial x^2$
- Fourier Analysis - $\sin kx$, $\cos kx$, e^{ikx}
- Interference, Diffraction, Geometrical Optics



The Wave Equation for a Stretched String via Free Body Diagram

Demo: Pluck stretched string upwards



$\eta(x,t)$ = Height of string at position x, time t

Describe string as many small chunks

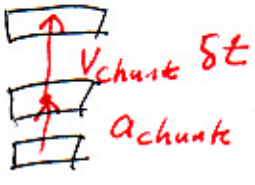
- moving up & down in time
  Transverse Wave!
  motion perpendicular to wire
- feeling only neighboring chunks Locality
- ignore gravity, friction

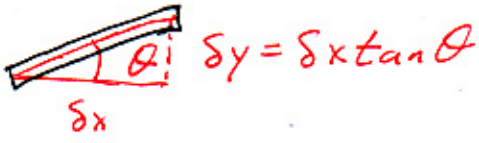
Exercise! Partial Derivatives
Fill in the Formulas

Chunk Velocity $\partial\eta/\partial t$

Chunk Acceleration $\partial^2\eta/\partial t^2$

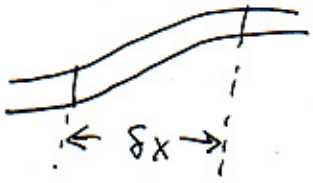
Chunk Slope $\partial\eta/\partial x$





$$\frac{\partial\eta}{\partial x} \approx \frac{\delta y}{\delta x} = \tan\theta$$

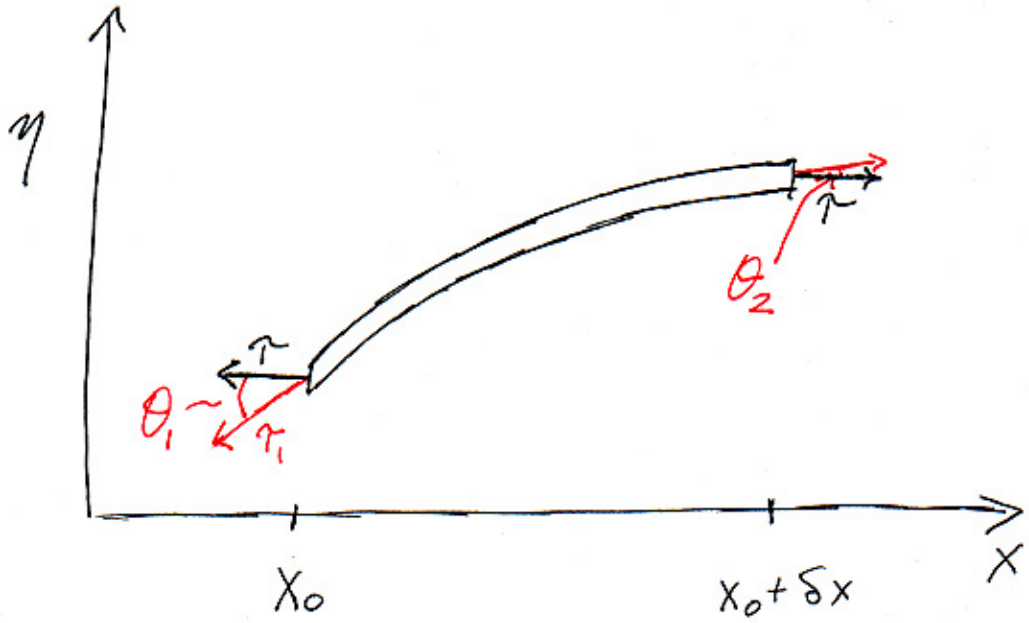
Chunk Mass



$\lambda_0 = $ mass / length of string

$m = \lambda_0 \, \delta x$

Chunk Free Body Diagram



- Derivation differs from text (same limit small angles)
- Pretend perfectly transverse

  X-forces must balance: $\tau_1 \cos\theta_1 = \tau_2 \cos\theta_2 = \tau$

Exercise: What is the y-component of τ_1, in terms of τ and θ_1?

Net force $= \tau[\tan\theta_2 - \tan\theta_1] = \tau\left[\frac{\partial \eta}{\partial x}(x_0+\delta x) - \frac{\partial \eta}{\partial x}(x_0)\right]$

$$F = \tau \, \delta x \, \partial^2\eta / \partial x^2$$

Equation of Motion

$$ma = F$$

$$(\lambda_0 \delta x)(\partial^2\eta/\partial t^2) = \tau\, \delta x\, \partial^2\eta/\partial x^2$$

Wave Equation for String

$$\boxed{\partial^2\eta/\partial t^2 = \tau/\lambda_0\ \partial^2\eta/\partial x^2}$$

What units does τ/λ_0 have?

- What units does $\partial^2\eta/\partial t^2$ have? cm/s^2
- What units does $\partial^2\eta/\partial x^2$ have? $1/cm$

τ/λ_0 has units of cm^2/sec^2 = velocity^2

$$\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2}$$ where c is a velocity for the string