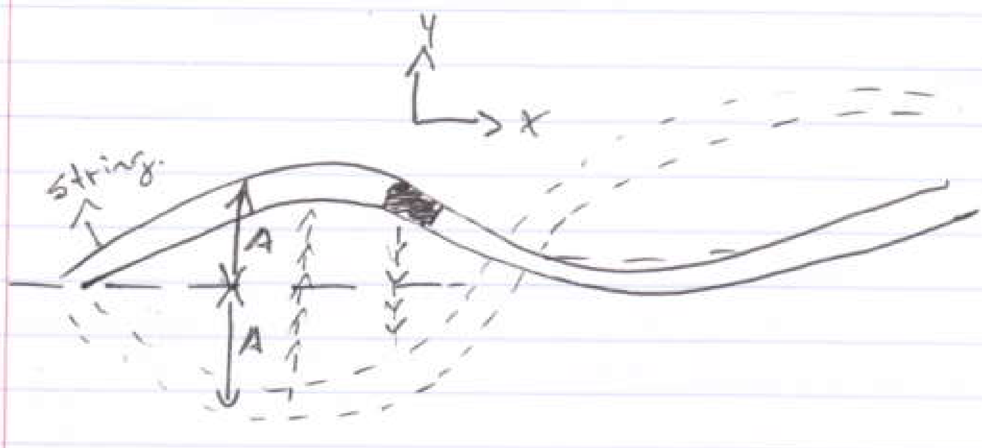
University Physics I

April 12, 2010



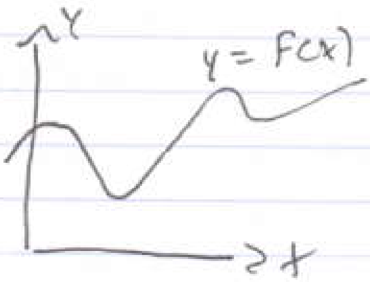
Each string oscillates up and down in simple harmonic motion.

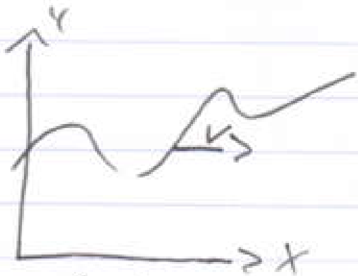
Formula like $y = 5\,cm \cdot \sin\left(\frac{t}{0.3s} + \frac{\pi}{7}\right)$

A, ϕ different for each part of the string.

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

$T = \frac{2\pi}{\omega}$





t = time

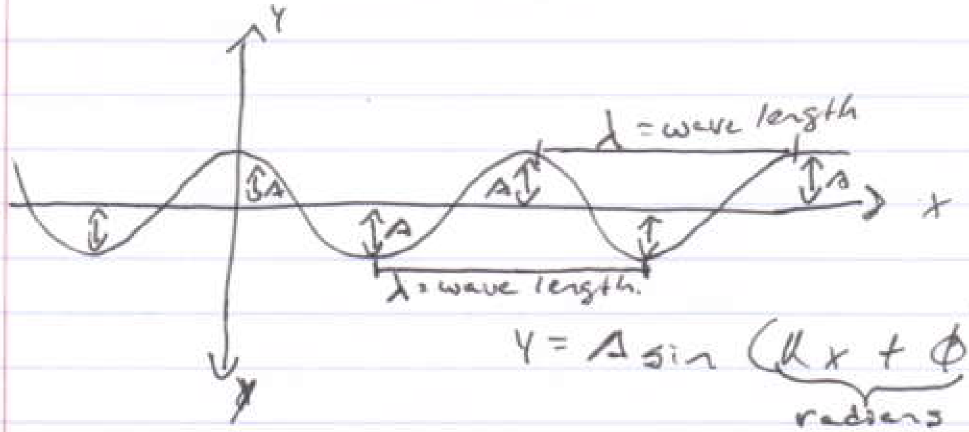
$y = f(x - vt)$

v positive:

Curves move to right at speed v.

v negative:

Curves move to the left at speed $-v$.



$$Y = A\sin(\underbrace{kx + \phi}_{\text{radians}})$$

Y = displacement from equilibrium
k = wave number, not spring constant
k has dimensions $\frac{1}{\text{length}}$

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

Now assume its moving to the right with speed V.

So, $$Y = A\sin(k(x - vt) + \phi)$$

$$Y = A\sin(kx - \underbrace{kvt}_{\omega} + \phi)$$

$$Y = A\sin(kx - \omega t + \phi)$$

The wave moves to the right at speed V. Each piece of the string moves up and down in simple harmonic motion. $\longrightarrow$

At $x = x_0$

$Y = A \sin(K x_0 - \omega t + \phi)$

$A \sin(-\omega t + \phi_0) \rightarrow \Phi = K x_0 + \phi$

T period
ω angular frequency
$\Big\}$ $T = \frac{2\pi}{\omega}$; $\omega = \frac{2\pi}{T}$

K wave number
λ wave length
$\Big\}$ $\lambda = \frac{2\pi}{K}$; $K = \frac{2\pi}{\lambda}$

V = wave velocity $\qquad \omega = K v \Leftrightarrow v = \frac{\omega}{K}$

$$\frac{1}{\text{time}} = \frac{1}{\text{length}} \cdot \frac{\text{length}}{\text{time}}$$

A = amplitude
= max displacement from equilibrium
(same for all parts of the string)

D or Y = displacement from eq $= A \sin(Kx - \omega t + \phi)$
$= A \sin(K(x - vt) + \phi)$

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

$f = 2\pi\omega$; $\omega = \frac{f}{2\pi}$

- Transverse waves $\rightarrow$ waves travel $\perp$ displacement

- Longitudinal waves $\rightarrow$ waves travel $\parallel$ displacement

Last time: mass on spring: $\mathcal{E} = \frac{1}{2} k A^2$ → Amplitude

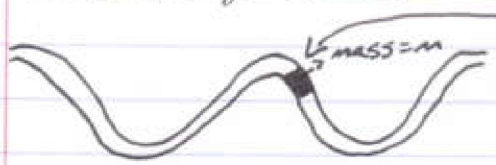
k → spring constant

$$\Updownarrow$$

$$\omega = \sqrt{\frac{k}{m}} \iff k = m\omega^2 \iff \mathcal{E} = \frac{1}{2} m \omega^2 A^2$$

m = mass of object

Travelling waves



Energy $= \frac{1}{2} m \omega^2 A^2$

A and ω can be essentially whatever you want, except if A is too big, the physics gets more complicated.

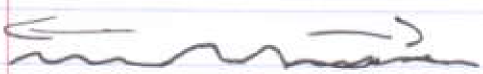
For strings with A not too big,

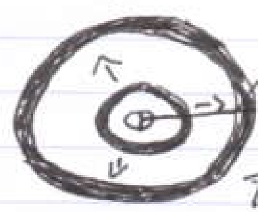
$$|v| = \sqrt{\frac{F_T}{\mu}}$$

μ = "mu" = linear density = $\frac{\text{mass}}{\text{length}}$

F_T = tension force on string.

More on energy: ripples in a pond





$\mathcal{E}_{ring} = \frac{1}{2} m \omega^2 A^2$

Two rings of same thickness have same energy.

continues

If the ω of the central disturbance in constant, then soon ω is the same everywhere

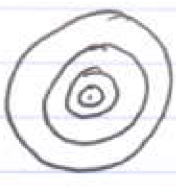
So, if $\frac{1}{2} m_1 \omega^2 A_1^2 = \sigma_1 = \sigma_2 = \frac{1}{2} m_2 \omega^2 A_2^2$

(two rings), then $m_1 A_1^2 = m_2 A_2^2$, so
more mass $\Rightarrow$ smaller amplitude

$$\frac{A_1^2}{A_2^2} = \frac{m_2}{m_1} \Rightarrow \frac{A_1}{A_2} = \sqrt{\frac{m_2}{m_1}} = \frac{1/\sqrt{m_1}}{1/\sqrt{m_2}}$$

$$A \propto \frac{1}{\sqrt{m}} \qquad m \propto R \qquad A \propto = \frac{1}{\sqrt{R}}$$

For sound waves, instead of rings, you have spherical shells.



So now, $m \propto R^2$, so

$$A \propto \frac{1}{\sqrt{m}} \propto \frac{1}{R}$$

$\sigma_{shell} = \frac{1}{2} m \omega^2 A^2 =$ constant (ignore "friction")

$$\text{Intensity} = \frac{\text{energy}}{\text{area}} \propto \frac{\text{constant}}{R^2} \propto \frac{1}{R^2}$$