Exam #2

10 MC PROBLEMS (#'s and Concepts)

+

2 WRITTEN PROBLEMS

DEPARTMENTAL POLICY!

LSU | College of Science
Department of Physics and Astronomy

You may not have any personal items with you at your seat during this exam.

Please make sure your phone is turned off, and you have put your phone in your backpack or purse at the front of the room. Turned off does not mean put on silent. It means off.

If you are found with a cell phone, tablet, or any device capable of taking pictures, videos, accessing the Internet, or communicating with other people during this test, and it is turned on and within your reach, you will be reported to the SAA for violating the Student Code of Conduct.

If you need to leave the room for any reason, including but not limited to using the restroom, after you start the test, your test is over. You will have to turn your test in before you leave the room and it will not be returned to you.

Ch 15: Simple Harmonic Motion (mass on a spring)

Using Newton's 2nd Law we found the 2nd order differential equation:

$$kx + m\frac{d^2x}{dt^2} = 0$$

The solution for x is:

$$\boxed{x = A\cos(\omega t + \phi)} \qquad \boxed{\omega = \sqrt{\frac{k}{m}}} \qquad \boxed{A = x_m}$$

From the equation for displacement we can find velocity and acceleration:

$$v = \frac{dx}{dt} = -\omega A\sin(\omega t + \phi) \qquad a = \frac{d^2x}{dt^2} = -\omega^2 A\cos(\omega t + \phi)$$

ϕ shifts displacement at time = 0

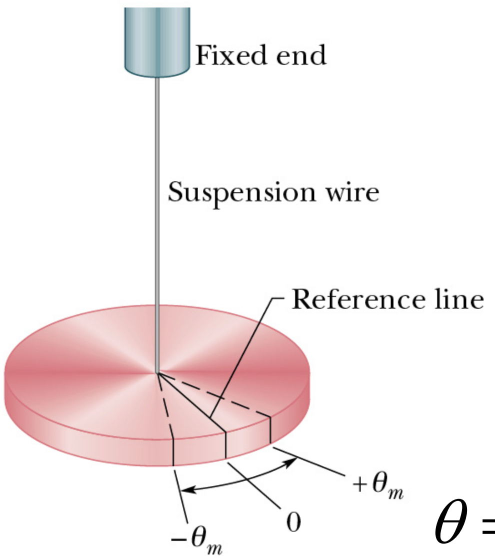
$$\tan\phi = -\frac{v_0}{\omega x_0} \qquad A^2 = x_0^2 + \frac{v_0^2}{\omega^2}$$

E is constant!

$$\boxed{E = KE + U = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2}$$

Ch 15: Simple Harmonic Motion (pendulums)

Torsion pendulum



$$\tau = -\kappa\theta$$

$$\Rightarrow \alpha = -\frac{\kappa}{I}\theta$$

$$\omega = \sqrt{\frac{\kappa}{I}}$$

$$\theta = \theta_m \cos(\omega t + \phi)$$

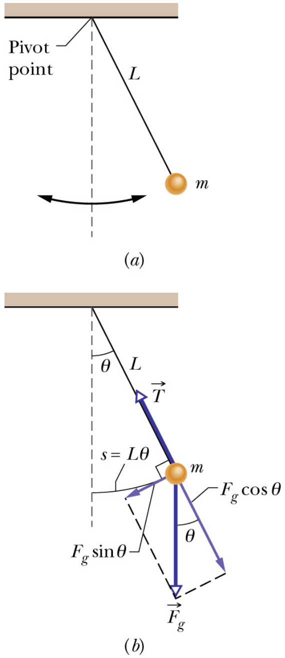
Simple pendulum

$$\tau = I\alpha$$

$$\Rightarrow -Lmg\theta = I\frac{d^2\theta}{dt^2}$$

$$\omega = \sqrt{\frac{Lmg}{mL^2}} = \sqrt{\frac{g}{L}}$$

$$\theta = \theta_m \cos(\omega t + \phi)$$

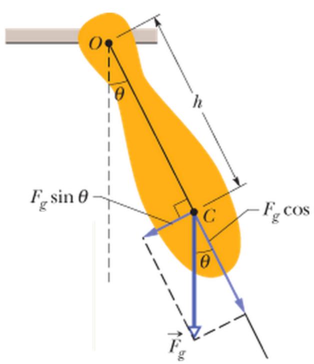


Physical pendulum

$$\omega = \sqrt{\frac{mgh}{I}}$$

$$hmg\theta + I\frac{d^2\theta}{dt^2} = 0$$

$$\theta = \theta_m \cos(\omega t + \phi)$$

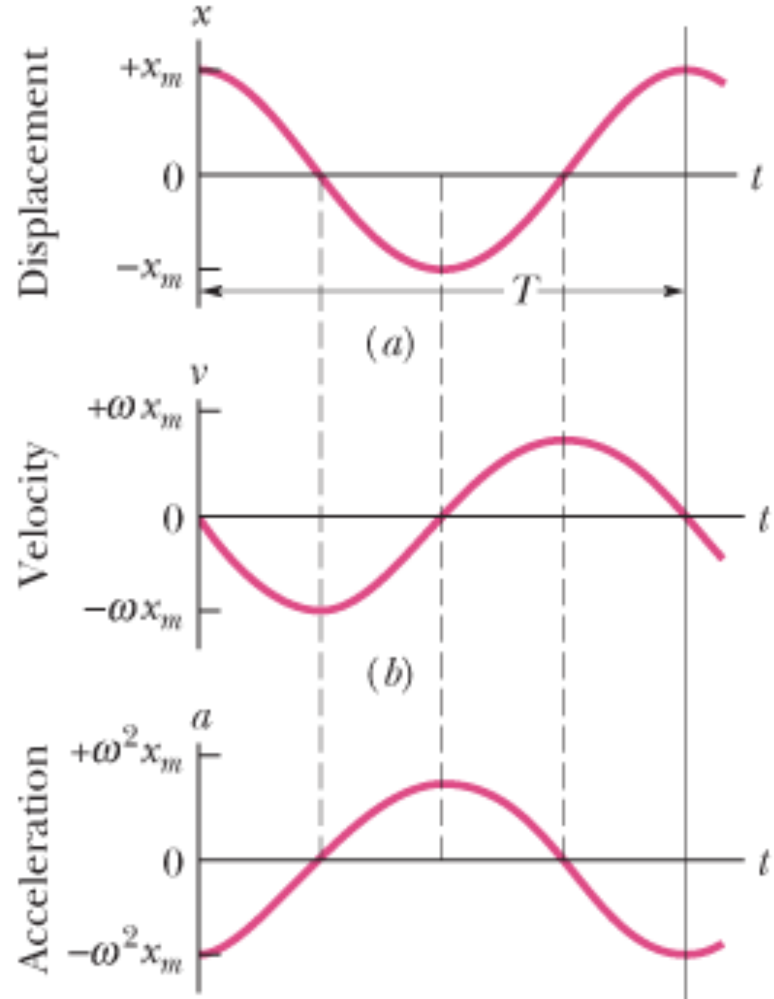


Simple Harmonic Motion

$$x(t) = x_m \cos(\omega t + \phi)$$
$$\theta(t) = \theta_m \cos(\omega t + \phi)$$

$$v = \frac{dx}{dt} = -\omega x_m \sin(\omega t + \phi)$$
$$\frac{d\theta}{dt} = -\omega\theta_m \sin(\omega t + \phi)$$

$$a = \frac{dv}{dt} = -\omega^2 x_m \cos(\omega t + \phi)$$
$$\frac{d^2\theta}{dt^2} = -\omega^2\theta_m \cos(\omega t + \phi)$$

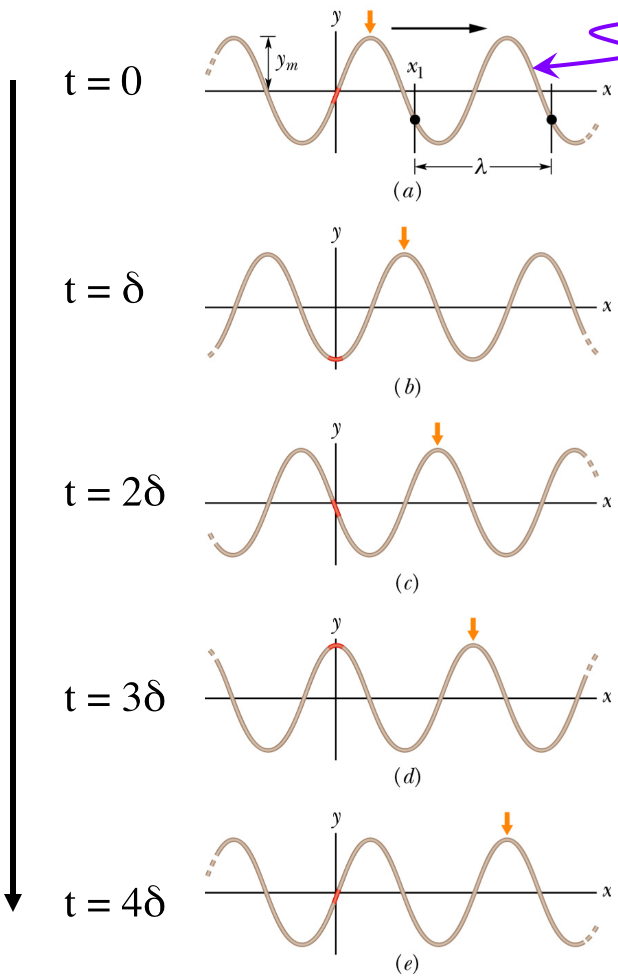


In SHM, the acceleration is proportional to the displacement but opposite sign. The proportionality is the square of the angular frequency.

$$a(t) = -\omega^2 x(t)$$
$$\frac{d^2\theta}{dt^2} = -\omega^2\theta(t)$$

Ch 16: *transverse* traveling wave

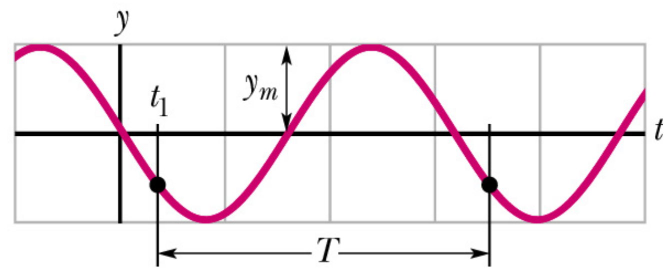
<u>Displacement (y) versus position (x)</u>



$$y(x,0) = y_{\max}\sin(kx) \qquad k = \frac{2\pi}{\lambda}$$

Spatially Periodic (repeats) : $k\lambda = 2\pi$

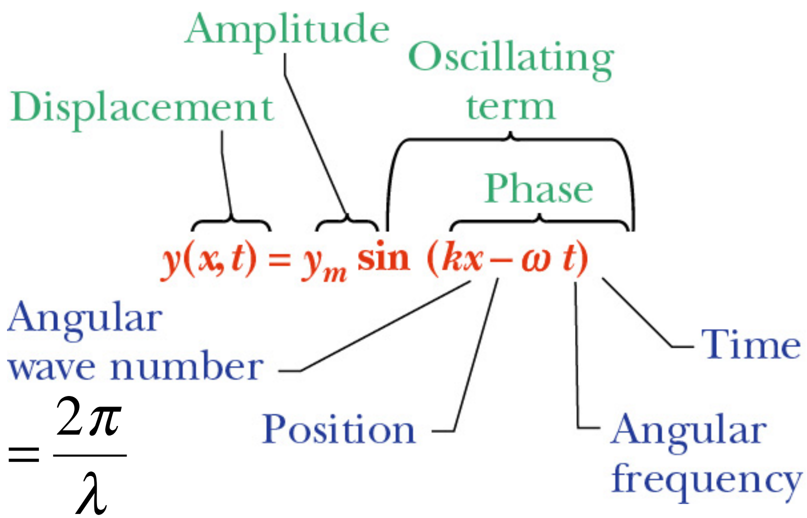
Temporally Periodic (repeats) : $\omega T = 2\pi$



$$y(0,t) = y_{\max}\sin(-\omega t) \qquad \omega = \frac{2\pi}{T}$$

Displacement versus time does not show "shape"

Description of traveling wave: mathematical



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

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

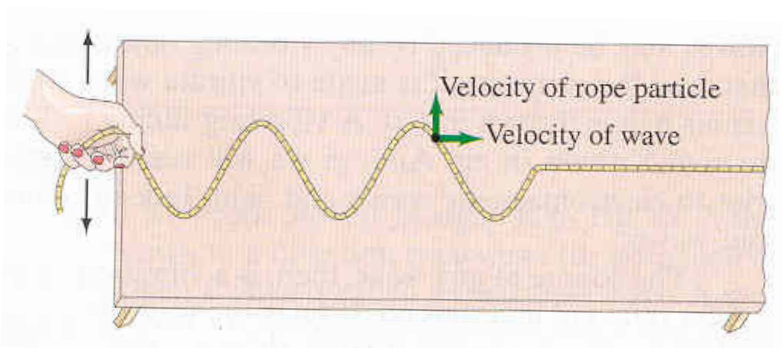
$\underline{phase:\ kx \pm \omega t}$

$kx - \omega t \Rightarrow$ Wave traveling in + x direction

$kx + \omega t \Rightarrow$ Wave traveling in - x direction

In time T (1 period), wave has moved a distance of λ (1 wavelength) :

$$\boxed{v_{wave} = \frac{dx}{dt} = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f}$$



Velocity of particle
(**not** wave velocity)

$$y(x,t) = y_m \sin\left(kx - \omega t\right)$$

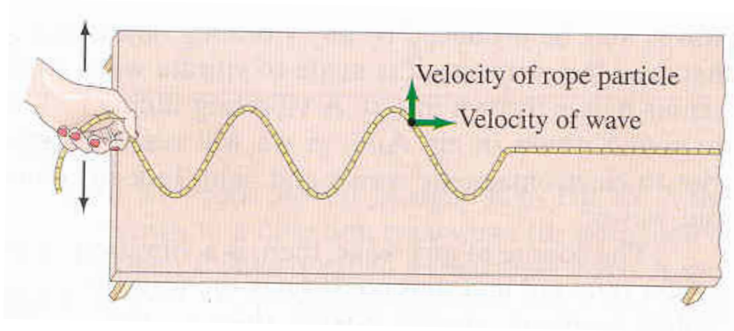
$$v_t(x,t) = \frac{dy(x,t)}{dt} = -\omega y_m \cos\left(kx - \omega t\right) = u$$

$$\left|v_t(x,t)\right|_{\max} = \omega y_m = u_{\max}$$

Ch 16: Waves

Waves traveling on a string

$$v = \sqrt{\frac{\tau}{\mu}} = f\lambda$$



Energy and Power of a wave:

$$\frac{dK}{dt} = \frac{1}{2}\mu v y_m^2 \omega^2 \cos^2\left(kx - \omega t\right) \Rightarrow \left(\frac{dK}{dt}\right)_{avg} = \frac{1}{4}\mu v y_m^2 \omega^2$$

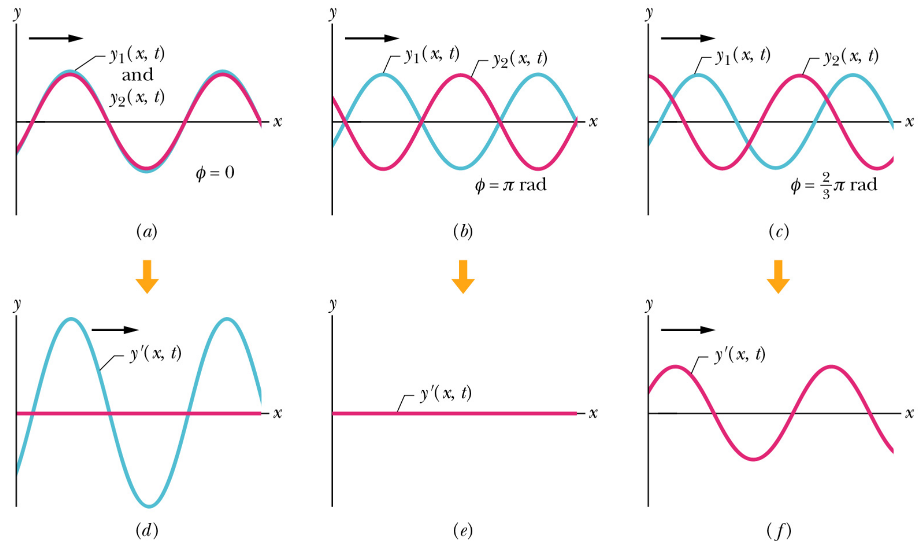
$$\left(\frac{dK}{dt}\right)_{avg} = \left(\frac{dU}{dt}\right)_{avg} \quad \text{and} \quad \left(\frac{dE}{dt}\right)_{avg} = \left(\frac{dK}{dt}\right)_{avg} + \left(\frac{dU}{dt}\right)_{avg}$$

$$P_{avg} = \left(\frac{dE}{dt}\right)_{avg} = \frac{1}{2}\mu v \omega^2 y_m^2 = \frac{1}{2}\left(\sqrt{\mu\tau}\right)\left(\omega y_m\right)^2$$

Interference of waves: Mathematics

when two waves pass through each other
→ they do not disrupt each other
→ resulting wave is algebraic sum

$$\boxed{y'(x,t) = y_1(x,t) + y_2(x,t)}$$



For two waves w/ same k, ω and relative ϕ

$$\begin{aligned} y_1(x,t) &= y_m \sin(kx - \omega t) \\ +y_2(x,t) &= y_m \sin(kx - \omega t + \phi) \\ \hline y_{tot}(x,t) &= y_m \sin(kx - \omega t) + y_m \sin(kx - \omega t + \phi) \\ &= y_m \left[\sin(kx - \omega t) + \sin(kx - \omega t + \phi)\right] \end{aligned}$$

$$y_{tot}(x,t) = \underbrace{2y_m \cos\left(\frac{\phi}{2}\right)}_{\text{amplitude}} \underbrace{\sin\left(kx - \omega t + \frac{\phi}{2}\right)}_{\text{traveling wave along +x direction}}$$

Maximal Constructive: $\phi = n(2\pi)$

Maximal Destructive: $\phi = \left(n + \frac{1}{2}\right)(2\pi)$

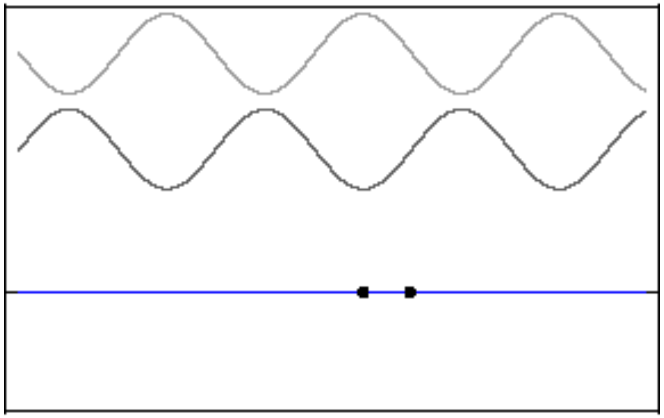
Standing Waves

Here, two sinusoidal waves with same wavelength travel in opposite directions (same $|v_{wave}|$)

$$y_1(x,t) = y_m \sin(kx - \omega t)$$
$$+y_2(x,t) = y_m \sin(kx + \omega t)$$

$$\sin\alpha + \sin\beta = 2\sin\left(\tfrac{1}{2}(\alpha+\beta)\right)\cos\left(\tfrac{1}{2}(\alpha-\beta)\right)$$
$$\alpha = (kx - \omega t) \qquad \& \qquad \beta = (kx + \omega t)$$

$$y_{tot}(x,t) = y_m \sin(kx - \omega t) + y_m \sin(kx + \omega t)$$
$$= \underbrace{2y_m \sin(kx)}_{\text{amplitude at position x}} \underbrace{\cos(\omega t)}_{\text{Oscillating term in time}}$$



Points in space where there is

Destructive Interference

Amplitude is zero when:

kx=π•n n = 0,1,2,3,…

Nodes $x = n\dfrac{\lambda}{2}$

Constructive Interference

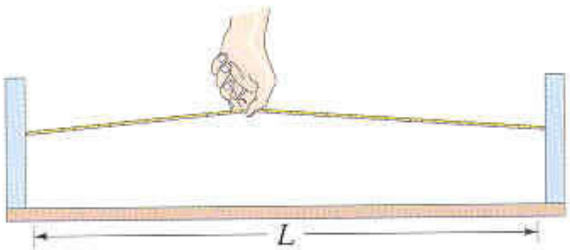
Amplitude is max SOMETIMES when:

kx=π•(n+1/2) n = 0,1,2,3,…

Antinodes $x = \left(n + \dfrac{1}{2}\right)\dfrac{\lambda}{2}$

Standing Waves: Resonant frequencies

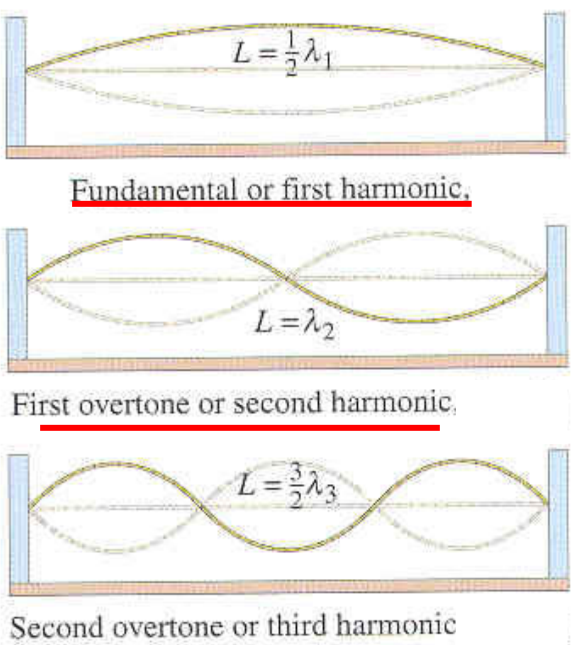
Frequencies at which standing waves are produced are the **Resonant Frequencies**



(a)

$$v_{wave} = \lambda_n f_n$$

Number of Antinodes	$\lambda_n = \dfrac{2L}{n}$	$f_n = \dfrac{n v_{wave}}{2L}$
$n = 1$	$\lambda_1 = 2L$	$f_1 = \dfrac{v_{wave}}{2L}$
$n = 2$	$\lambda_2 = L$	$f_2 = 2 f_1$
$n = 3$	$\lambda_3 = \dfrac{2}{3} L$	$f_3 = 3 f_1$

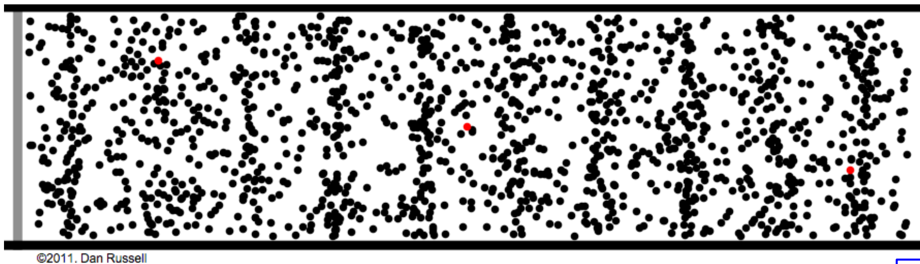


(b)

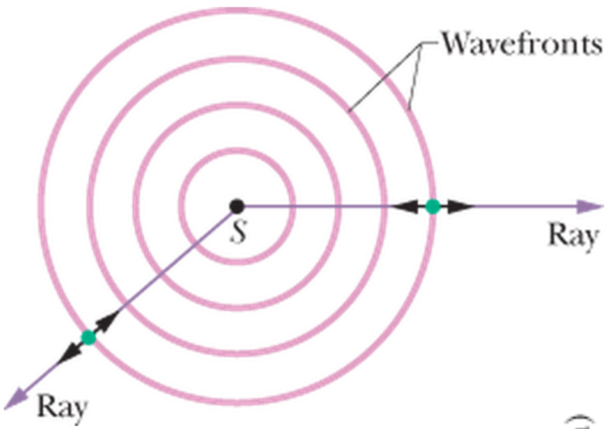
Resonant frequencies are given by n and properties of system (length, tension, and mass density)

$$\boxed{v_w = \sqrt{\frac{T}{\mu}}}$$

Ch. 17: Sound



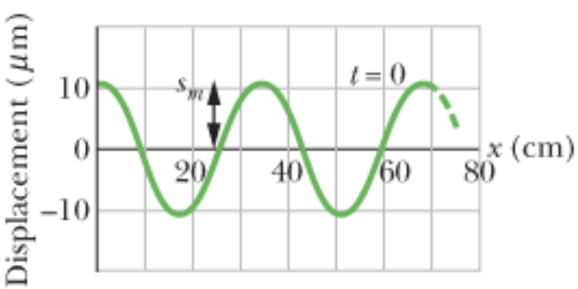
Sound is a longitudinal wave: medium is displaced in same direction that wave travels

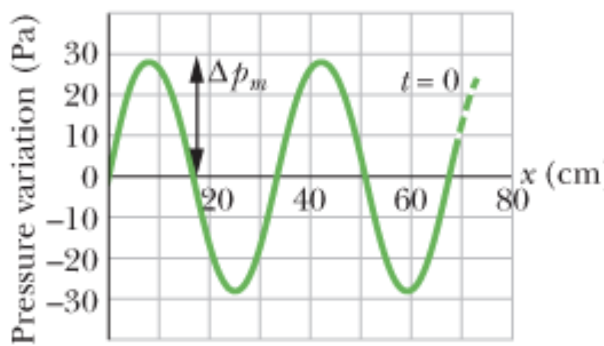


Wavefronts travel out from source with speed: $v = \sqrt{\dfrac{B}{\rho}}$

$$B = -\frac{\Delta p}{\Delta V/V}$$

B is the bulk modulus (compressibility) of medium





Oscillation of displacement of medium and change in pressure:

$$s = s_m \cos(kx - \omega t)$$

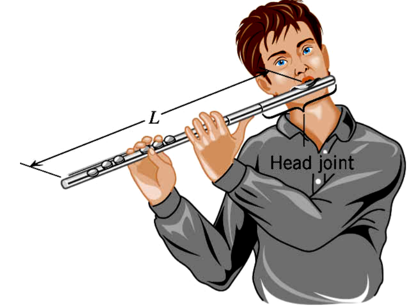
$$\Delta p = \Delta p_m \sin(kx - \omega t)$$

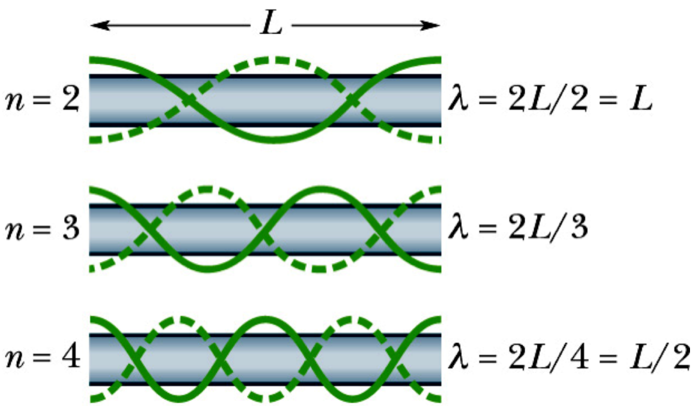
$$\Delta p_m = Bks_m = v^2 \rho k s_m = v \rho \omega s_m$$

Interference: $s_{total}(x,t) = 2s_m \cos\left(\dfrac{\phi}{2}\right)\cos\left(kx - \omega t + \dfrac{\phi}{2}\right)$ $\qquad \phi = \dfrac{\Delta L}{\lambda} 2\pi$

Standing Waves in Pipes

A sound wave in a pipe has a node at a closed end and an antinode at an open end (displacement NOT pressure)

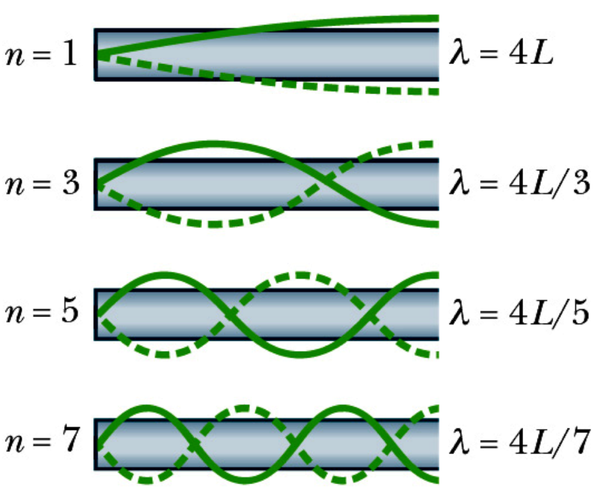




A pipe open on both ends is like a string fixed at both ends

$$f_n = \frac{v}{\lambda} = \frac{v}{2L} n$$

$$n = 1,2,3,4\ldots$$



(b)

A pipe open on one end is

$$f_n = \frac{v}{\lambda} = \frac{v}{4L} n$$

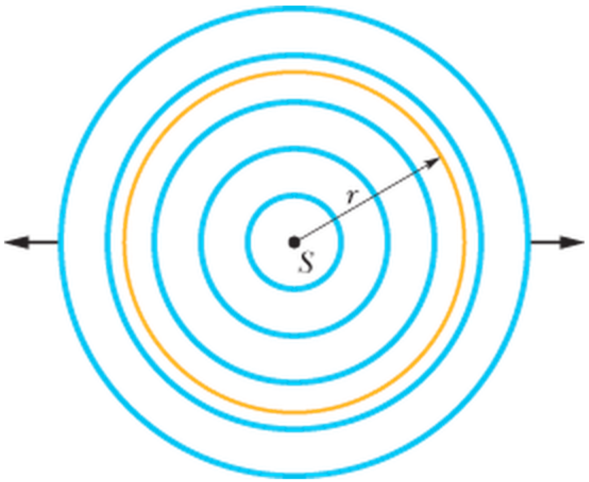
$$n = 1,3,5,7\ldots$$

Only odd harmonics

Intensity

$$\boxed{I = \frac{P_{avg}}{A} = \frac{1}{2}\rho v \omega^2 s_m^2 = \frac{1}{2}\frac{(\Delta p_m)^2}{\rho v}}$$

For a point source that emits sound equally in all directions (isotropically) what is the area the sound passes through?

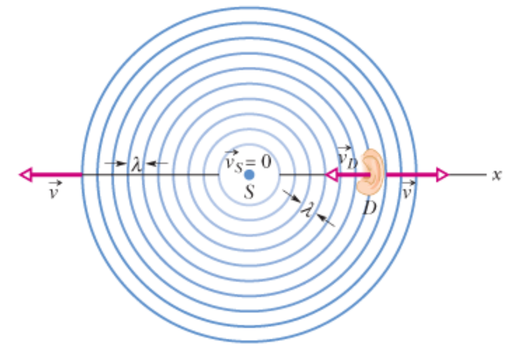


Area of a sphere: $A = 4\pi r^2$

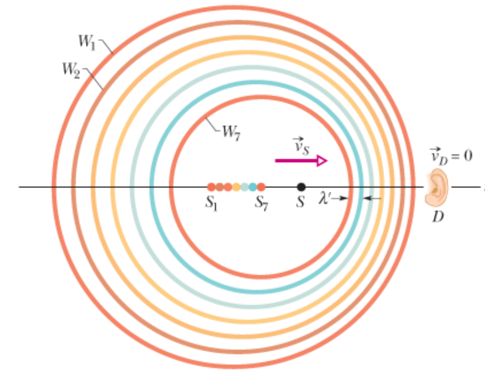
$$I = \frac{P_{avg}}{A} = \frac{P_{source}}{4\pi r^2}$$

The sound level is given by: $\beta = (10\ \text{dB})\log\left(\frac{I}{I_0}\right)$ $\quad I_0 = 10^{-12} W/m^2$

Doppler Shift



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



We can use the formula for the general Doppler effect that accounts for both movements:

- The plus and minus signs depend on which way the detector and source are moving relative to each other
  - **top sign is towards and bottom sign is away**
- The velocities are relative to the velocity of air (i.e. the resting medium is the reference frame)
- *f* is always the frequency emitted by the source