Physics 122 – Class #6

Questions?
Announcements/reminders

MP HW02 and written HW02 are due next Tuesday, September 9.

Read actively the rest of Ch.21
Start reading Ch.22

Always check the class website to make sure of assignments and due dates.
(http://www.physics.nmt.edu/~saska/phys122.html)

Help sessions:
https://www.dropbox.com/s/8cmkmaad8fch65y/Phys122OSLSched.docx
Announcements/reminders

Written HW problems. There are always 6 + 1 problems assigned. 6 are mandatory, 1 is extra credit!

Exam?  - 9/23  or 9/25
Physics 122 – Class #6

Last class: Traveling Waves (the Doppler effect, power, intensity, equation of sinusoidal waves ...)

Today: Superposition.
Superposition Principle
Superposition Principle

\( D_r(x,t) = D_1(x,t) + D_2(x,t) \)
Standing waves

The red wave is traveling to the right. The green wave is traveling to the left.

At this time the waves exactly overlap and the superposition has a maximum amplitude.

At this time a crest of the red wave meets a trough of the green wave. The waves cancel.

$X_n$ - position of nodes

$X_a$ - position of antinodes

$V_{wave} = 0 \frac{m}{s}$
Standing waves

\[ T \propto P \propto E \propto A^2 \]

The nodes and antinodes are spaced \( \lambda/2 \) apart.
Standing waves

2 waves with same f, A traveling in opposite direction.

\[ D_1(x,t) = A \sin(kx - \omega t) \]

\[ D_2(x,t) = A \sin(kx + \omega t) \]

\[ D_r(x,t) = D_1(x,t) + D_2(x,t) = A \sin(kx) \cos(\omega t) - \frac{A \cos(kx) \sin(\omega t)}{2} + A \sin(kx) \cos(\omega t) + \frac{A \cos(kx) \sin(\omega t)}{2} = 2A \sin(kx) \cos(\omega t) = A(x) \]
Standing waves

\[ A(x) = 2a \sin(kx) \]

For \( \sin(kx) = 1 \) \( \Rightarrow \) \( kx_n = (2n+1) \frac{\pi}{2} \), \( n = 0, 1, 2, \ldots \)

\[ kx_n = \frac{2\pi x}{\lambda} \]

\[ X_n = (2n+1) \frac{\lambda}{4} \]

\( n = 0, 1, 2, \ldots \)
Standing waves on a string

At minima we have for \( \sin (kx) = 0 \)

\[ \Rightarrow kx_m = m\alpha, \quad m = 0, 1, 2, \ldots \]

\[ \frac{2\pi}{\lambda} x_m = m \frac{\lambda}{2} \Rightarrow x_m = m \frac{\lambda}{2} \]

\[ A = 0 \text{ (nodes)} \]
Standing waves on a string

Force from string on the wall

Force from wall on the string

inverted pulse
Standing waves on a string

Boundary conditions for fixed ends:

\[ D(0,t) = 0 \]
\[ D(L,t) = 0 \]

\[ D(x,t) = 2a \sin(kx) \cos(\omega t) = 0 \quad \checkmark \]

\[ D(L,t) = 2a \sin(kL) \cos(\omega t) = 0 \quad \text{in order for this to be true at any time,} \]

\[ \sin(kL) = 0 \quad \text{must} \]

\[ kL = m\pi \]

\[ m = 1, 2, 3, \ldots \]
Standing EM Waves

\[ \frac{2\pi}{\lambda_m} L = m \pi \]

\[ \lambda_m = \frac{2L}{m} \]

\[ f_m = \frac{V}{\lambda_m} = \frac{V}{2L} \]

 Fundamental mode
 or fundamental
 or first harmonic

For string \( V = \sqrt{\frac{Ts}{\mu}} \)

\[ f_m = \frac{m}{2L} \sqrt{\frac{Ts}{\mu}} \]

\( f_m = mf \)

\( m = 1, 2, 3, \ldots \)

\( f_m \) - normal modes, harmonics
Standing Sound Waves

Same stuff applies as for standing waves on a string...though sound waves are longitudinal waves.

$m$ is the # of antinodes on a standing wave

$m = 2, n = 1$

$\lambda_1 = 2L$

$\lambda_2 = L$
Standing Sound Waves

Same stuff applies as for standing waves on a string...though sound waves are longitudinal waves.

http://www.acs.psu.edu/drussell/Demos/StandingWaves/StandingWaves.html

pressure waves

displacement waves

All that was true for transverse SW is true for longitudinal SW
Standing Sound Waves

At open end different boundary conditions ... different normal modes.

Fixed boundary \( \Rightarrow D \) (at the boundary) = 0

Open boundary \( \Rightarrow P = P_{\text{atm}} \)  
(node for pressure, 
but anti-node for displacement)
Standing Sound Waves

Closed-closed

Open-open

Open-closed

\[ \lambda_m = \frac{2L}{m}, \quad m = 1, 2, 3, \ldots \]

\[ \bar{f}_m = m \frac{V}{2L} = m \bar{f}_1 \]

\[ \lambda_m = \frac{4L}{m}, \quad m = 1, 3, 5, \ldots \]

\[ \bar{f}_m = \frac{m \bar{V}}{4L} \]
Example 21.6

**Flutes and clarinets**

A clarinet is 66.0 cm long. A flute is nearly the same length, with 63.5 cm between the hole the player blows across and the end of the flute. What are the frequencies of the lowest note and the next higher harmonic on a flute and on a clarinet? The speed of sound in warm air is 350 m/s.

**Model**  The flute is an open-open tube, open at the end as well as at the hole the player blows across. A clarinet is an open-closed tube because the player’s lips and the reed seal the tube at the upper end.

\[ L_{\text{clar}} = 66.0 \text{ cm} = 0.660 \text{ m} \]
\[ L_{\text{flute}} = 63.5 \text{ cm} = 0.635 \text{ m} \]
\[ v = 350 \text{ m/s} \]
Example 21.6 continues ...

Clarinet is open-closed tube.
Flute is open-open tube.

\[ f_{\text{clar}} = ? \quad f_{\text{flute}} = ? \]

\[ f_{\text{clar}} = \frac{1}{4L_{\text{clar}}} \quad v = \frac{3}{2} = 133.15 \text{ Hz} \left( \frac{1}{5} \right) \]

\[ f_{\text{flute}} = \frac{1}{2L_{\text{flute}}} \quad v = \frac{5}{2} = 275 \text{ Hz} \]

\[ f_{m} = \frac{m}{4L_{\text{clar}}} \Rightarrow f_{3} = \frac{3}{4L_{\text{clar}}} \quad v = 3f_{k_{\text{clar}}} = 399.75 \text{ Hz} \]

\[ f_{m} = \frac{m}{2L_{\text{flute}}} \quad v \Rightarrow f_{2} = \frac{1}{2f_{4_{\text{flute}}}} \quad v = 2f_{4_{\text{flute}}} = 550 \text{ Hz} \]
Example 21.3  The standing light wave inside a laser

Helium-neon lasers emit the red laser light commonly used in classroom demonstrations and supermarket checkout scanners. A helium-neon laser operates at a wavelength of precisely 632.9924 nm when the spacing between the mirrors is 310.372 mm.

a. In which mode does this laser operate?
b. What is the next longest wavelength that could form a standing wave in this laser cavity?

Model  The light wave forms a standing wave between the two mirrors.
Example 21.3 continues ...
Interference of waves

Two overlapped sound waves

Speaker 2  Speaker 1  Point of detection