

Major Concepts in Physics

Lecture 4.

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<http://physics/courses/PHY102.08Spring>

Today: Quantitative aspects of waves

- Review: basic properties of waves
 - Examples
- Review: standing waves
 - Examples
- Review: interference, Young's double slits
 - Examples

Basic Ideas

- Waves – matter when disturbed typically gives rise to waves – oscillations of particles of medium in time and space that transfer energy from place to place
- Several types: longitudinal (eg sound) and transverse (eg light)
 - Propagating and stationary (standing waves)
- Examples: sound, light, water, seismic, strings, plates

Key formulae

- Time period T and frequency $f=1/T$
- Also, angular frequency $\omega= 2\pi /T =2\pi f$
- Wavelength λ and wavenumber $k= 2\pi /\lambda$
- Wave speed $v=f\lambda=\omega/k$
- Amplitude A
- Wave function:

$$y=Asin(\omega t-kx)$$

Example:

A transverse sinusoidal wave is represented by the following equation

$$y = 0.2\sin(20t - 0.1x) \text{ m}$$

Assuming that the units of the quantities in the equation are meters and seconds, find:

- a) the amplitude of the wave;
- b) the wavelength;
- c) the time period;
- d) the velocity of propagation (state the direction of propagation);

Answer

a) The amplitude of the wave is:

$$A = 0.2 \text{ m}$$

b) The wavelength:

$$\lambda = 2\pi/k = 2\pi/(0.1) = 20\pi \text{ m}$$

c) the time period:

$$\omega = 2\pi/T, \text{ then } T = 2\pi/\omega = 2\pi/20 = \pi/10 \text{ s}$$

d) the velocity of propagation (state the direction of propagation):

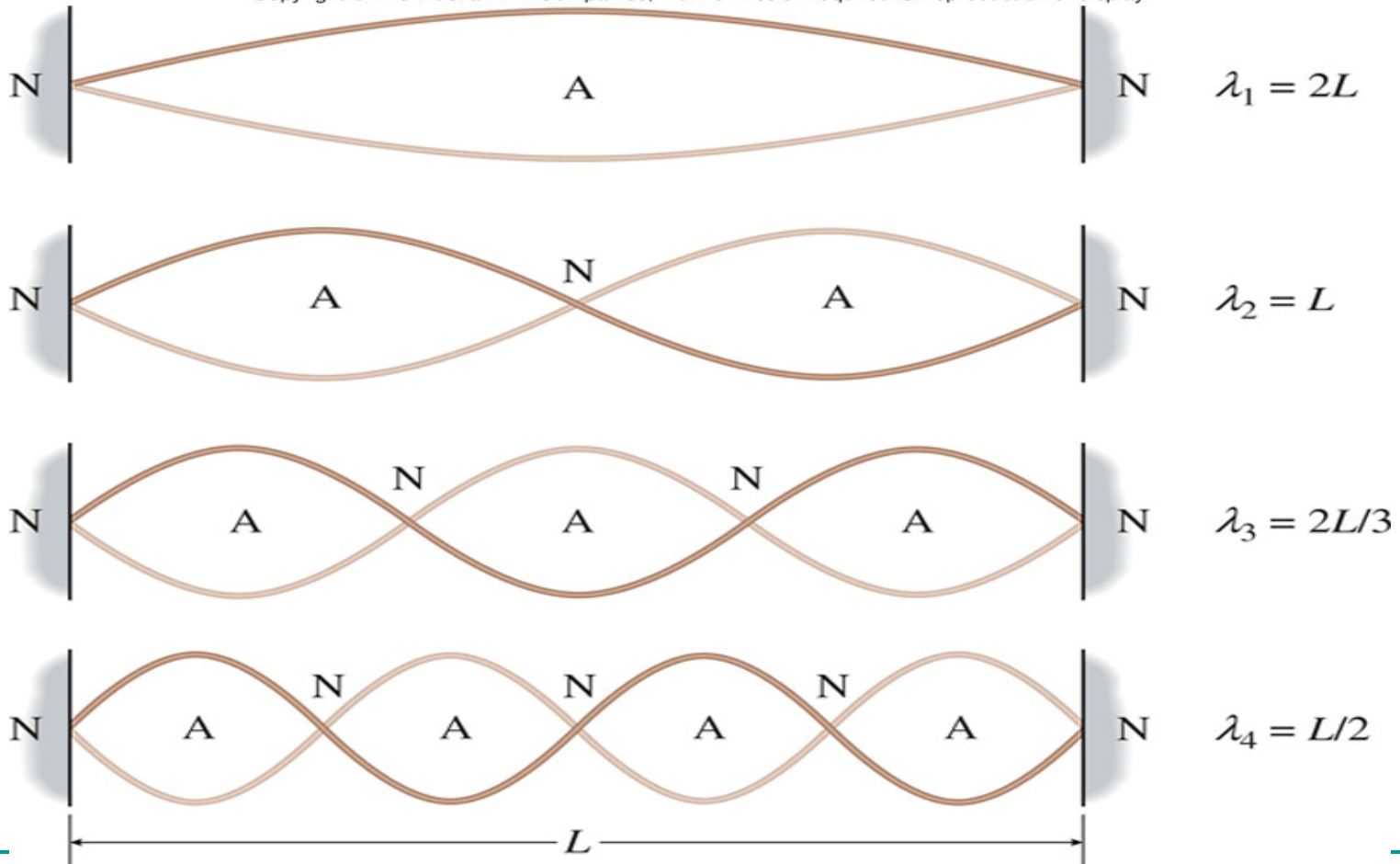
$$v = \lambda/T = 200 \text{ m/s}$$

Standing wave

- Two waves of equal amplitude traveling in opposite directions add to give a **standing wave (stationary wave)**
- In such a wave all positions oscillate in phase at same frequency – no energy transferred
- At some positions – no motion – **Nodes**
- Allowed wavelengths determined by **geometry**

Standing waves – string fixed at ends

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Sound waves in tube

- Waves consist of longitudinal variations of pressure
- Two types of standing wave picture:
 - Displacement picture – motion of air molecules
 - Pressure picture
- Open tube: pressure pictures looks like waves on string

Eg. standing waves are set up in tube of length 0.5m. If both ends are open what is the wavelength of the fundamental mode ?

- A: 0.5 m
- B: 1.0 m
- C: 0.25 m
- D: 2.0 m

If speed of sound is 300 m/s what is the frequency produced ?

- A: 300 Hz
- B: 150 Hz
- C: need more information
- D: 600 Hz

What is the frequency of 1st harmonic ?

- A: 150 Hz
- B: 600 Hz
- C: 900 Hz
- D: 1200 Hz

One of the ends is now closed. What is now the wavelength of the fundamental ?

- A: 1.0 m
- B: 0.5 m
- C: 2.0 m
- D: 1.5 m

Demo

- Pressure waves in flammable gas ...

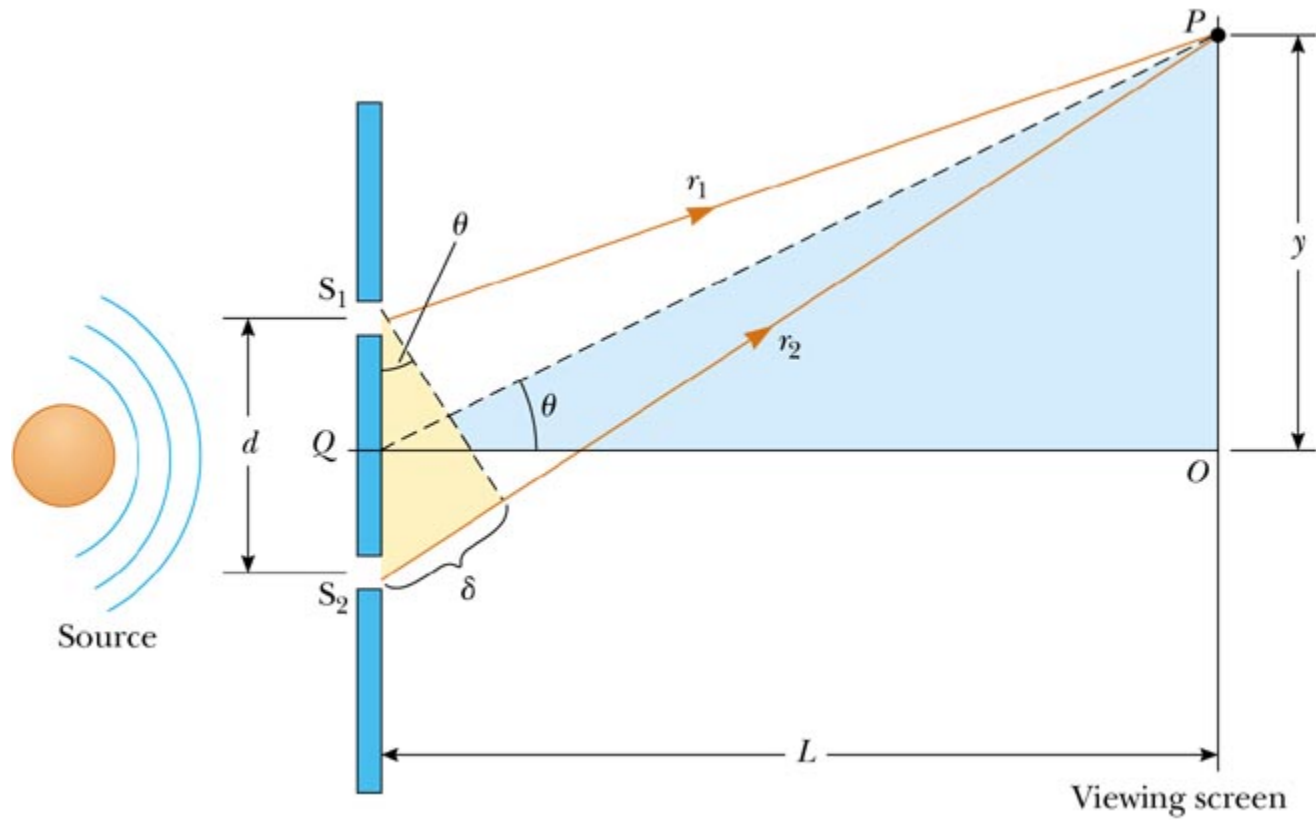
Conclusion:

- Not just length of tube but also boundary conditions determine allowed modes
- Resonance: if drive system at one of the allowed frequencies get a maximum response
 - Eg sound waves in tubes, gas tube, vibrating plate, bowl of water ...

Interference

- Phenomena occurs when two (or more) waves cross.
- Principle of superposition says that resultant wave is sum of input waves
- Two principle types: constructive and destructive – wave crests add or subtract.
- Waves must be coherent

Young's double slit experiment

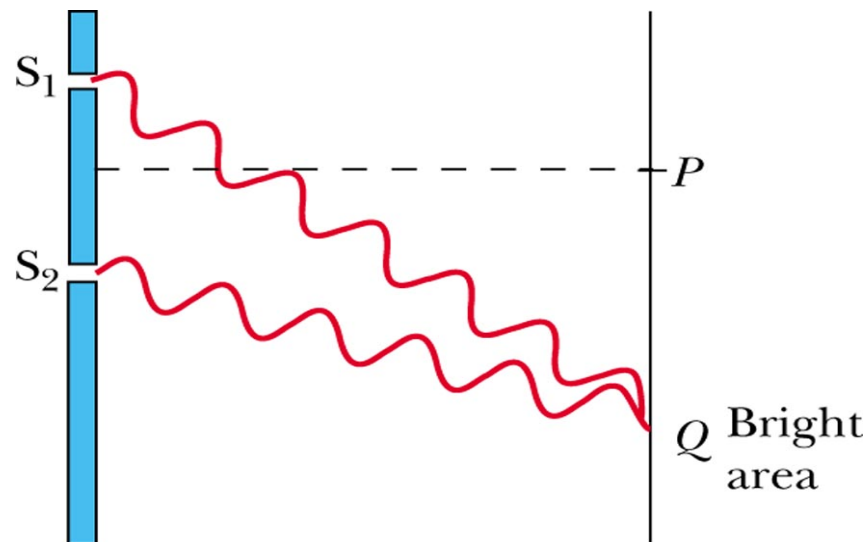


Demo

- Laser/ double slit experiment

Constructive Interference

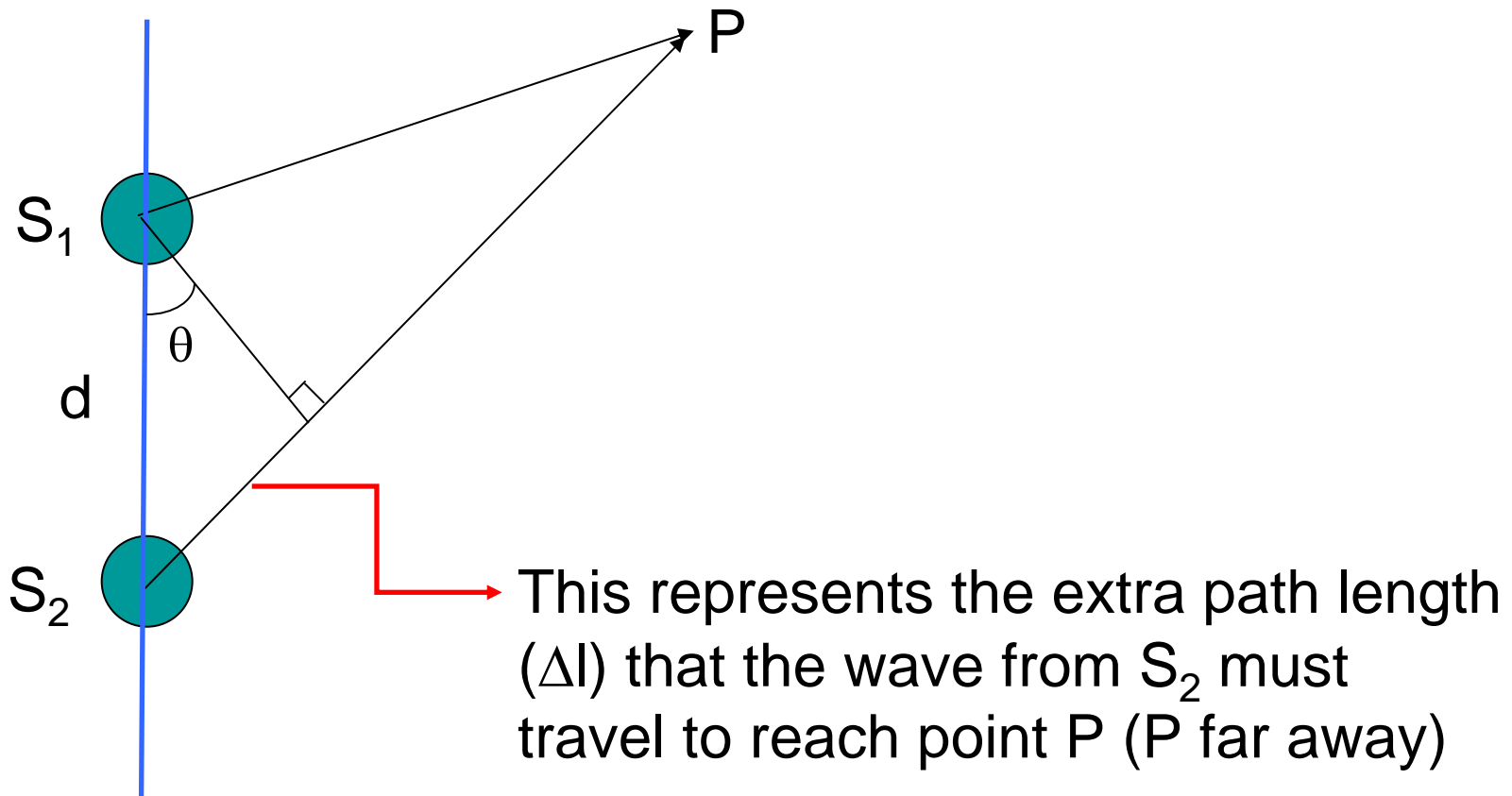
- To interfere constructively an integer number of wave crests must fit into the difference in path length for the two waves



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(b)

Coherent waves can become out of phase if they travel different distances to the point of observation.



$$\Delta l = d \sin \theta$$

Geometry

- $y/L = \tan \theta = \sin \theta = \theta$ approx for small θ
- $d \sin \theta = m \lambda$ for bright fringe
- Therefore:

$$y = L m \lambda / d$$

m integer called the order. Note: equal spacing for bright fringes ...

Conditions for interference

$$y_{\text{bright}} = \frac{\lambda L}{d} m \quad m = 0, \pm 1, \pm 2, \dots$$

$$y_{\text{dark}} = \frac{\lambda L}{d} \left(m + \frac{1}{2} \right) \quad m = 0, \pm 1, \pm 2, \dots$$