Physics 122 – Class #8 – Outline

- Announcements
- Superposition
  - Interference
  - Beats
  - Harmonics
    - Strings
    - Tubes

Announcements

For next Tuesday Read Chapter 22
(Wave Optics)
(will post what you can omit after class)

No cell phones during tests (or quizzes)

Written HW

Written HW is all about showing work. Almost always there should be a sketch. If there is NOT a sketch, there usually needs to be an explanation of a result. On HW WR-01, 3 of the 4 optics problems said MEASURE the location and height of image in a ray-tracing diagram and compare it to calculation.

Absence of a proper (3”x3”) sketch can cost you up to half the points (starting w/ HW WR-03)

Online Homework #4

Is due Saturday (as usual). There was an extraneous note …

We are covering today what you need.

I will be adding some hints after class.

Superposition – Key Point

- *Superposition just means "adding things"*.
- You get "beats" by adding waves of slightly different frequency.
- You get standing waves by adding traveling waves going in opposite directions.
- You get interference by adding waves of same frequency and different phase.
- The math of Ch. 21/22 is just adding sine-waves in different ways.

Math of Standing Sine Waves

Given $D_1(x,t)=A\sin(kx-\omega t)$ $D_2(x,t)=A\sin(kx+\omega t)$

Find D_1+D_2

Angle sum. identity:

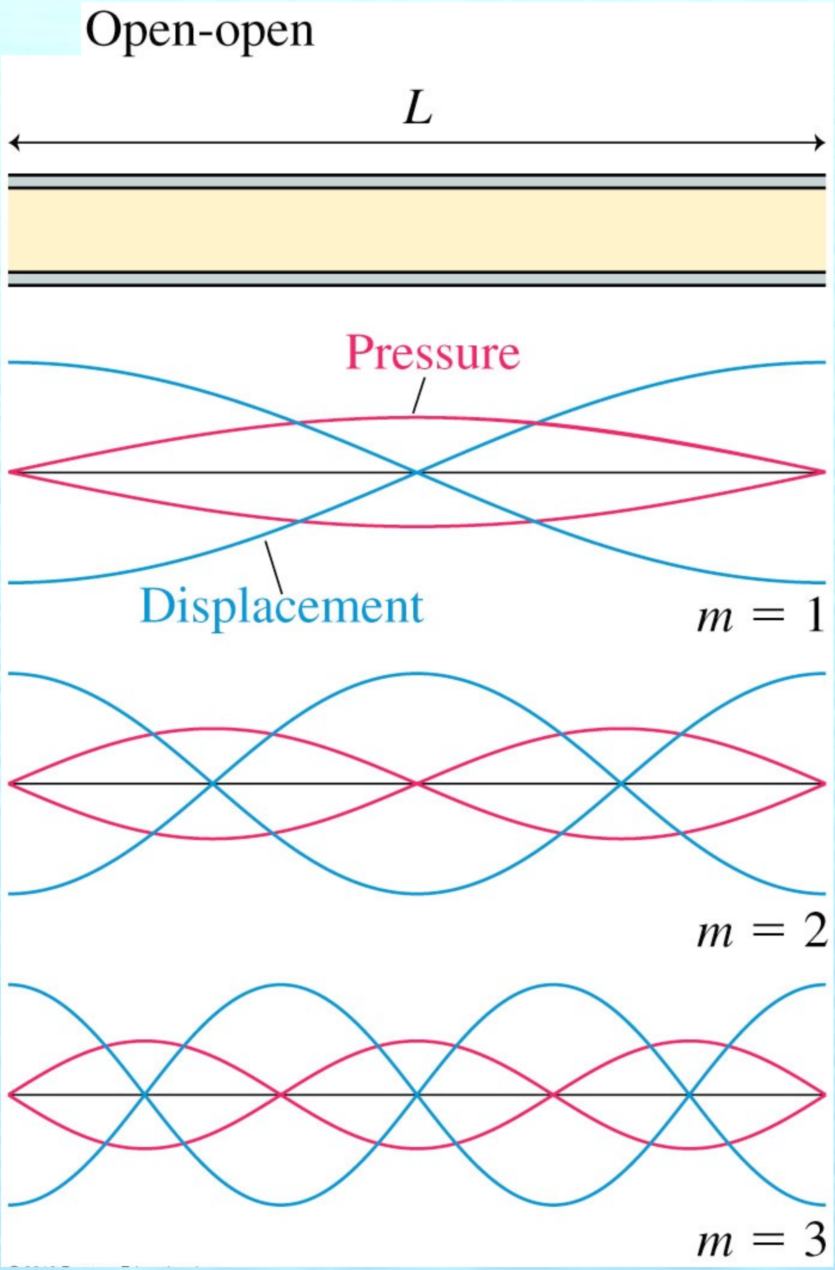
$$\sin(a\pm b)=\sin(a)\cos(b)\pm\cos(a)\sin(b)$$

Standing Sound Waves

Shown are displacement and pressure graphs for the first three standing-wave modes of a tube open at both ends:

$$\lambda_m = \frac{2L}{m}$$

The boundary conditions for An open tube are that there can be no pressure peak at the ends but there can be net displacement.

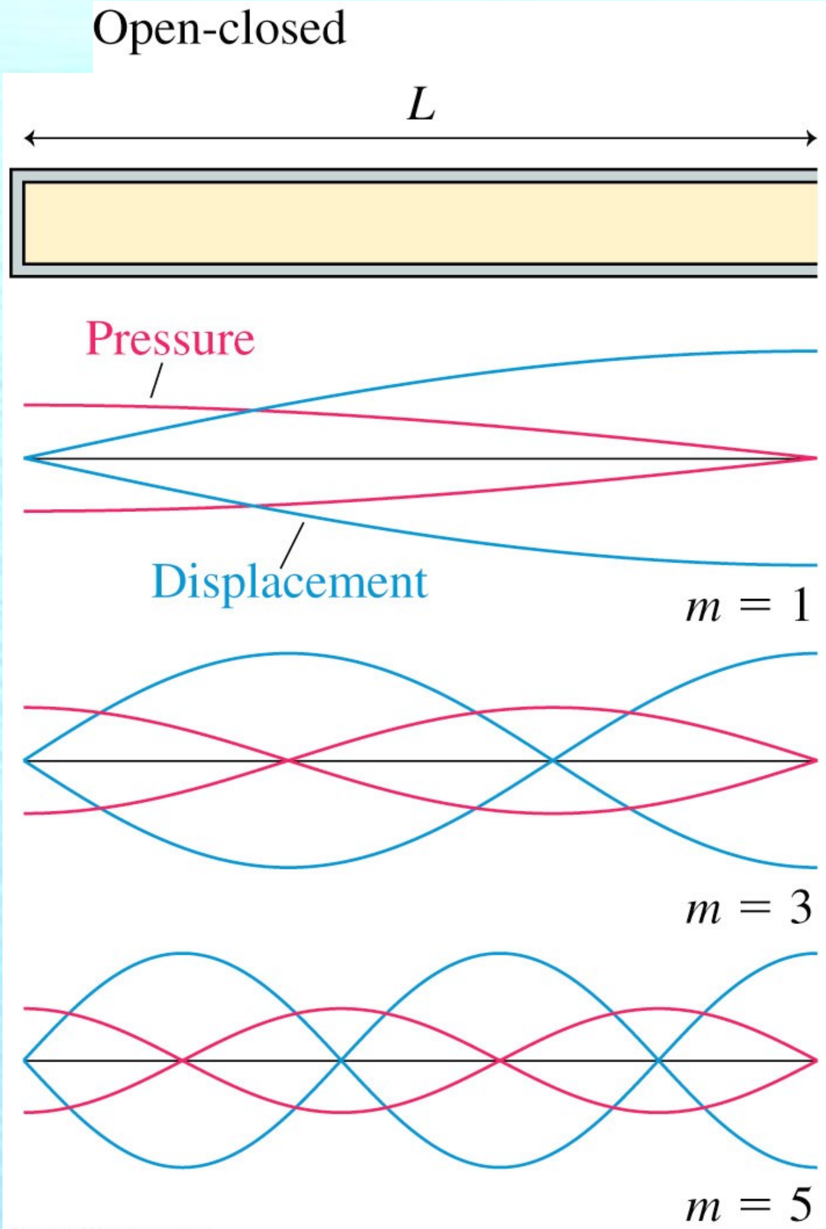


Standing Sound Waves

Shown are displacement and pressure graphs for the first three standing-wave modes of a tube open at one end but closed at the other:

$$\lambda_m = \frac{4L}{m}$$

In this case only, m is an odd #. I think Knight breaks with musical convention here to keep the physics simple



Problem 21.11

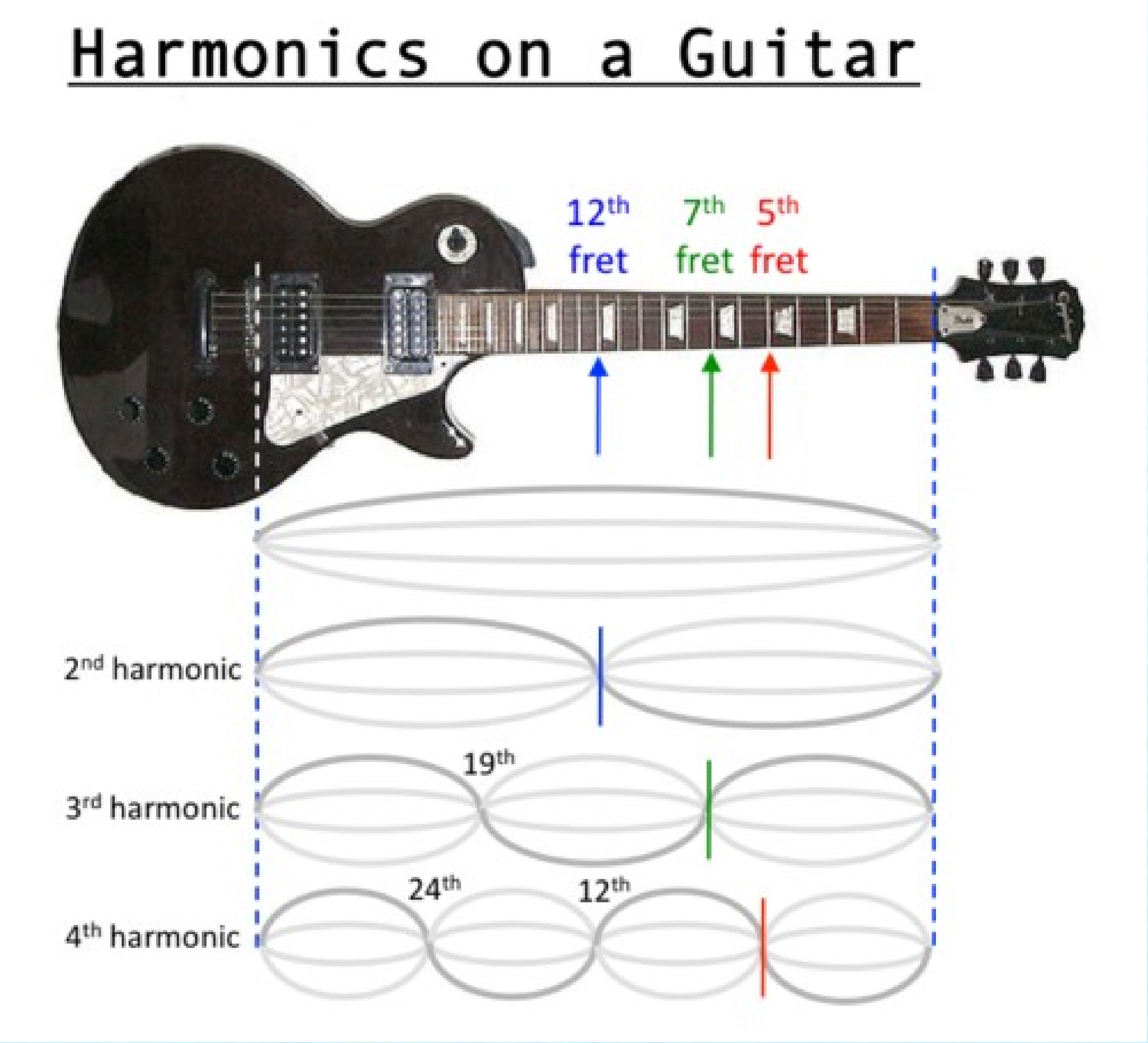
A heavy piece of hanging sculpture is suspended by a 90 cm long, 5.0 g steel wire. When the wind blows hard, the wire hums at 80 Hz. What is the mass of the sculpture?

Problem 21.17

- The lowest note in a grand piano has a frequency of 27.5 Hz. The entire string is 2.0 long and has a mass of 500 g. The vibrating section of the string is 1.9 m long. What tension is needed to tune the string?

$$m\frac{\lambda}{2}=L$$

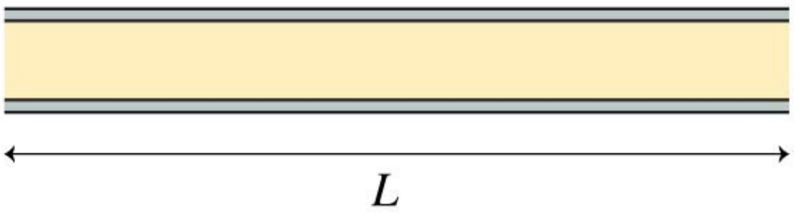
$$\lambda_m=\frac{2L}{m}$$

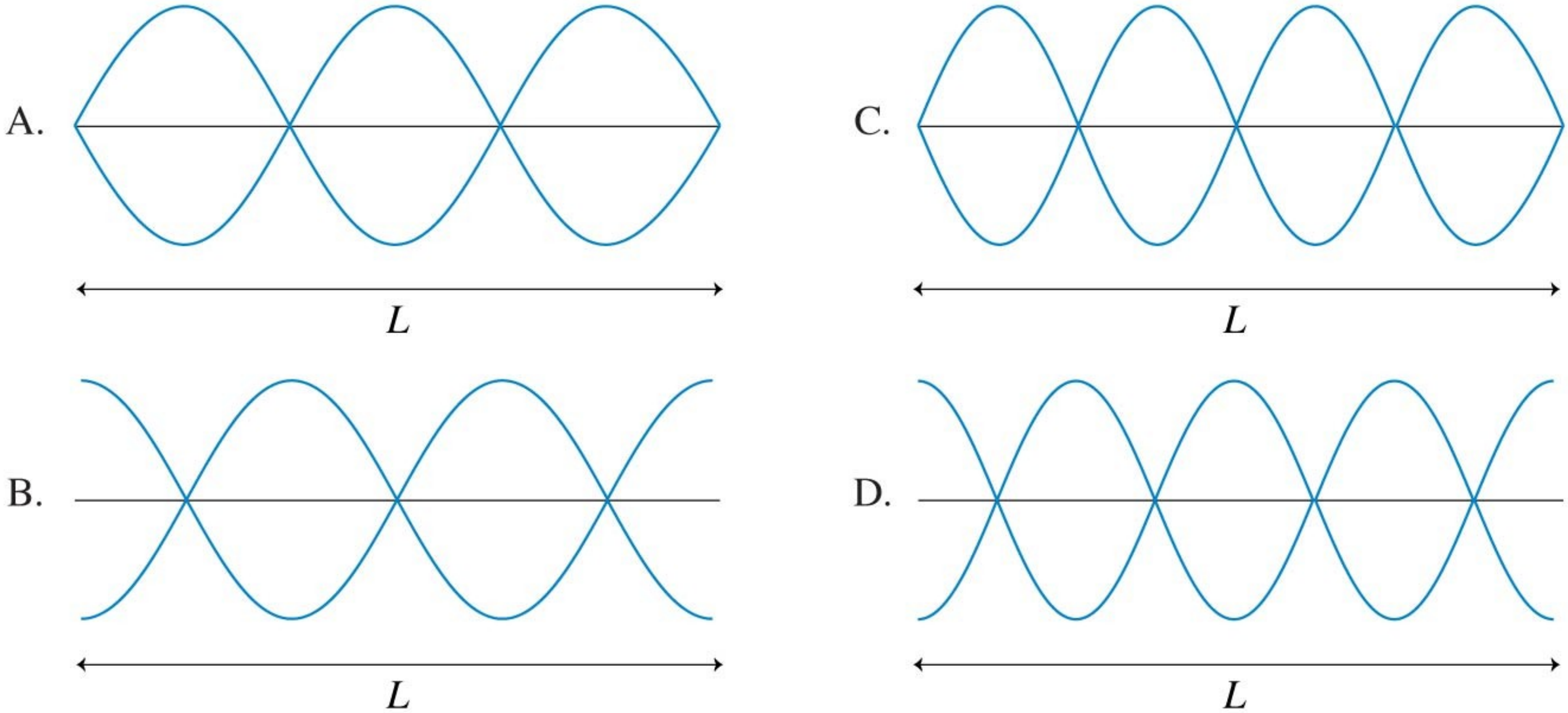


- The fundamental is also called the first harmonic

Clicker Questions

An open-open tube of air has length L. Which is the pressure graph of the third harmonic standing wave in this tube?





Interference

- **Two sine waves of the same frequency and nearly the same phase add.**
  - The waves are said to be “in phase” and they “constructively interfere” with one another
- **Two sine waves of the same frequency and nearly a phase difference of “pi” cancel eachother.**

The waves are said to be “out of phase” and they “destructively interfere” with one another

Wave terminology

$$D(x,t) = A\sin(kx - \omega t + \Phi_0)$$

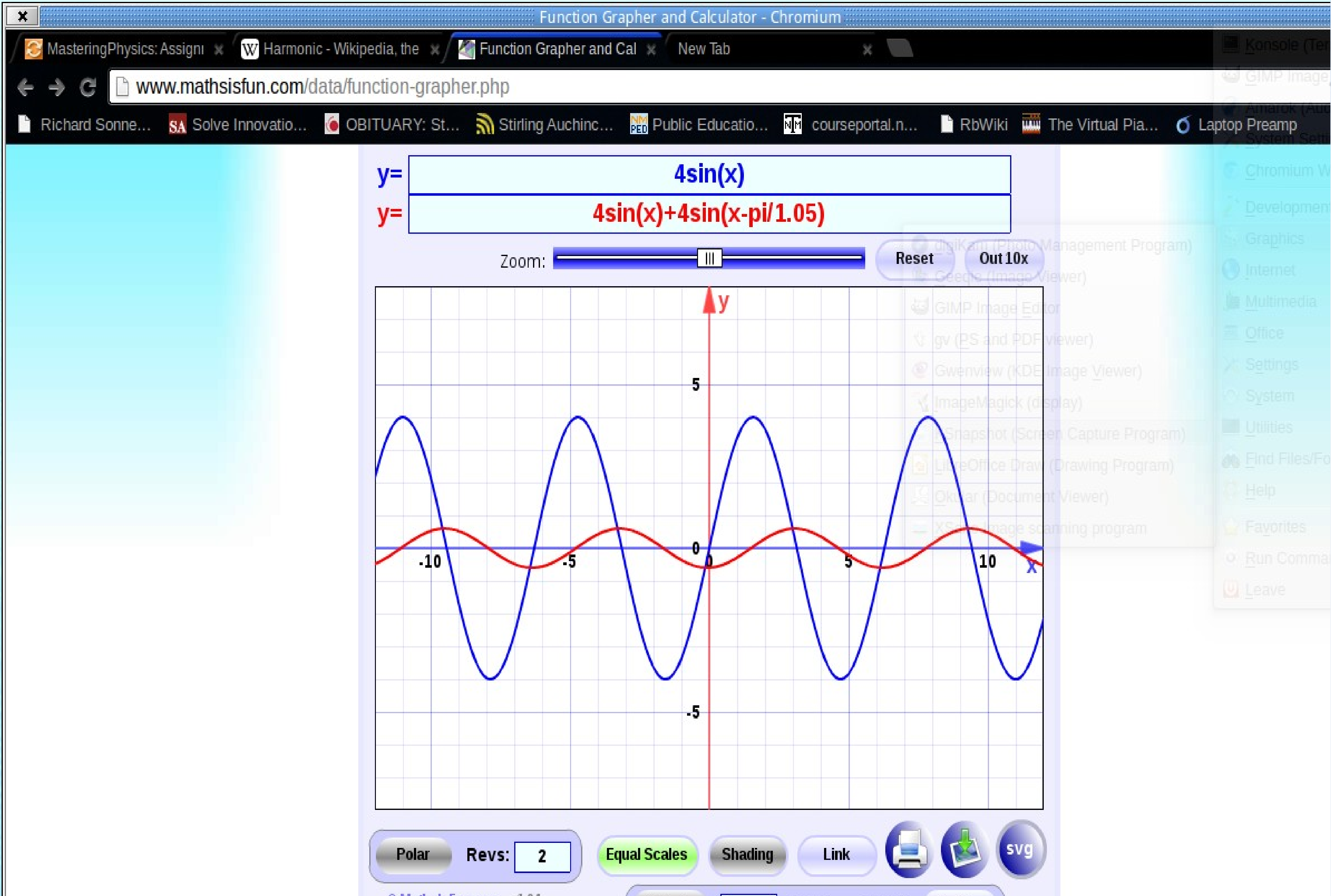
Φ_0 Is "initial phase"

$kx - \omega t + \Phi_0$ Is just "phase" and it varies with time and position

Condition for constructive interference is that phase differs by 2*pi*n

Condition for destructive interference is that phase differs by 2*pi*n + pi

Destructive Interference



Clicker Question

Given $D_1(x) = A\sin(kx)$

Which of the following will NOT interfere with the wave DESTRUCTIVELY

[A] $D_2(x) = A\sin(kx - 9\pi)$

[B] $D_2(x) = A\sin(kx + \pi)$

[C] $D_2(x) = A\sin(kx + 2\pi)$

[D] $D_2(x) = A\sin(kx + 3\pi)$

[E] $D_2(x) = A\sin(kx - \pi)$

Interference and Phase

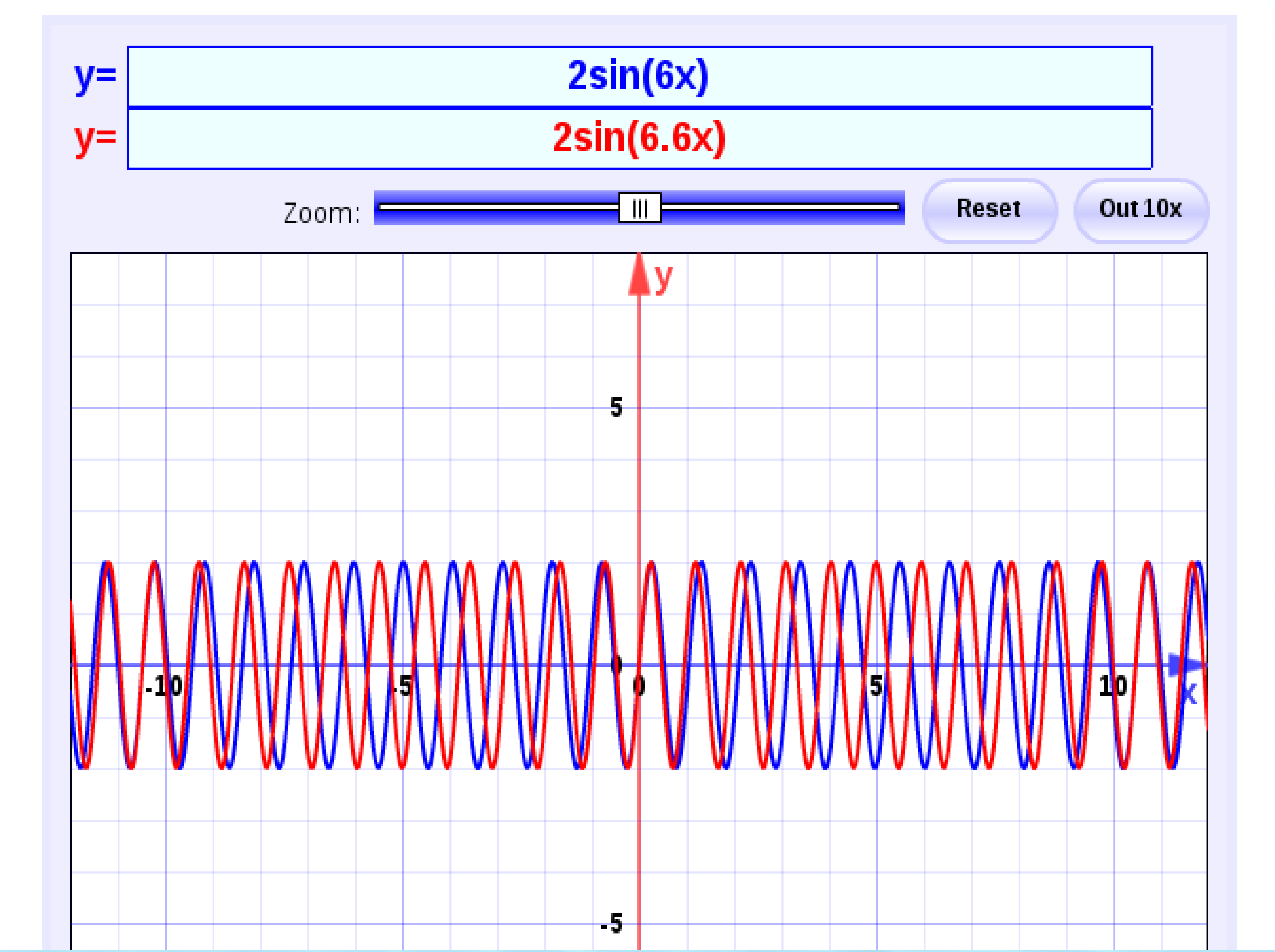
- Waves (of same frequency) will be in constructive interference any time their phase differs by a multiple of 2 pi.

- They will be in destructive interference whenever phase differs by pi PLUS a multiple of 2 pi.

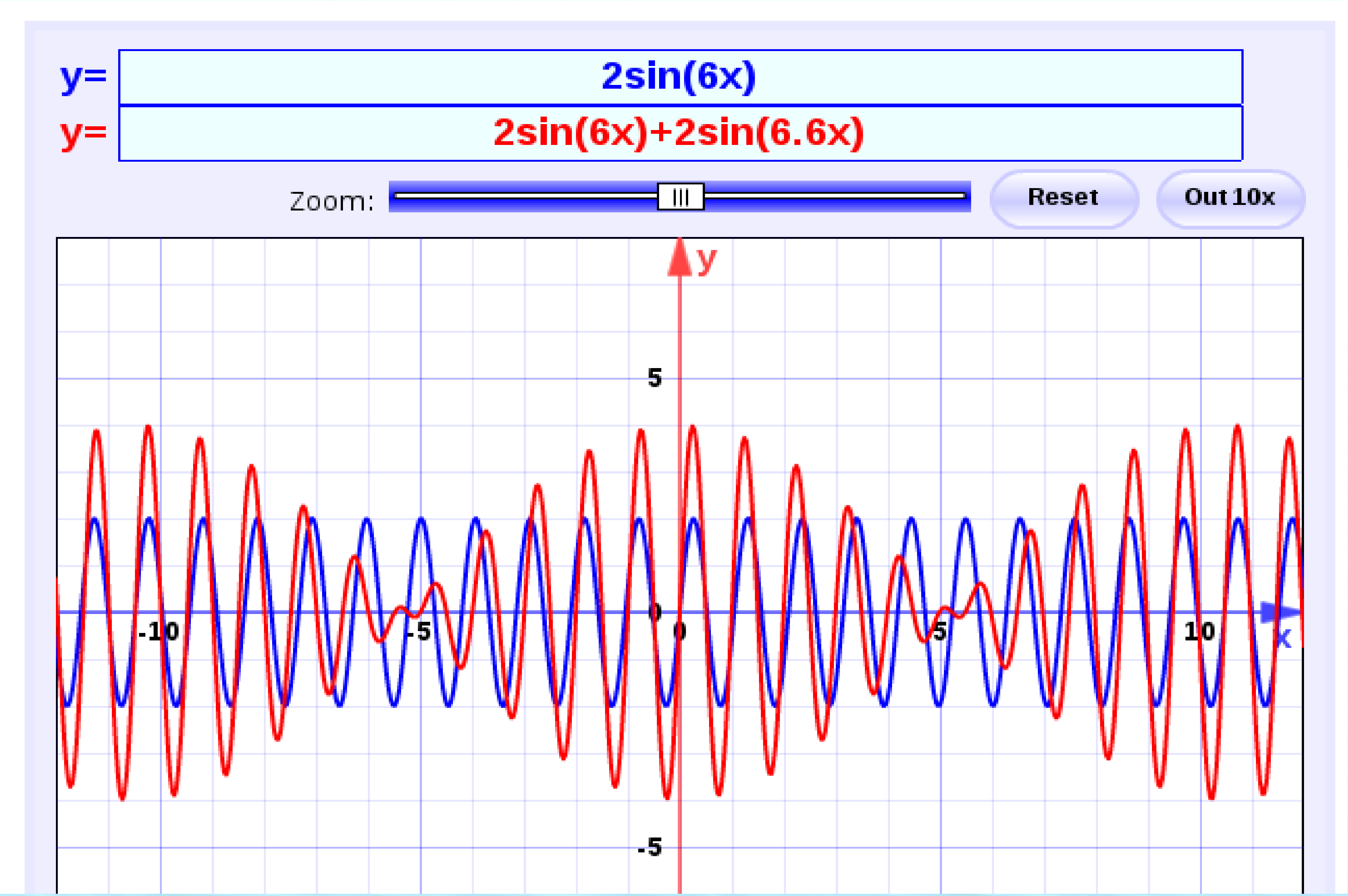
Interference and Beats

- Two waves that began “in phase” but have slightly different frequencies will go back and forth between “in phase” and “out of phase”. This phenomenon is called “beats”.
- The beat frequency is the difference of the two frequencies

Beats



Beats



Math of Beats

Given $D_1(t) = A\sin(\omega_1 t)$ $D_2(t) = A\sin(\omega_2 t)$

$$D_1 + D_2 = 2A\cos\left[\frac{(\omega_1 - \omega_2)t}{2}\right]\sin\left[\frac{(\omega_1 + \omega_2)t}{2}\right]$$

DEMO

Interference

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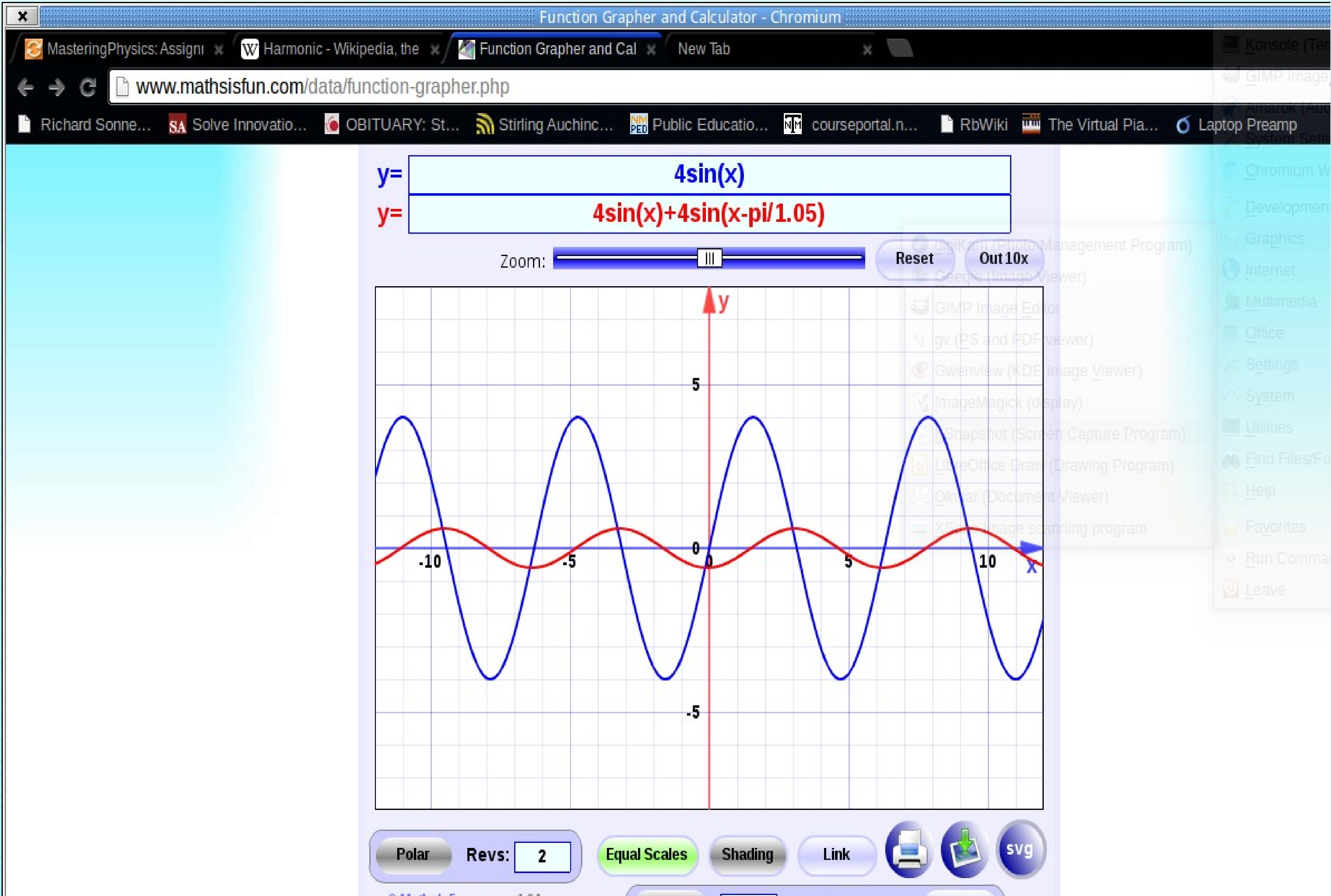
Destructive Interference



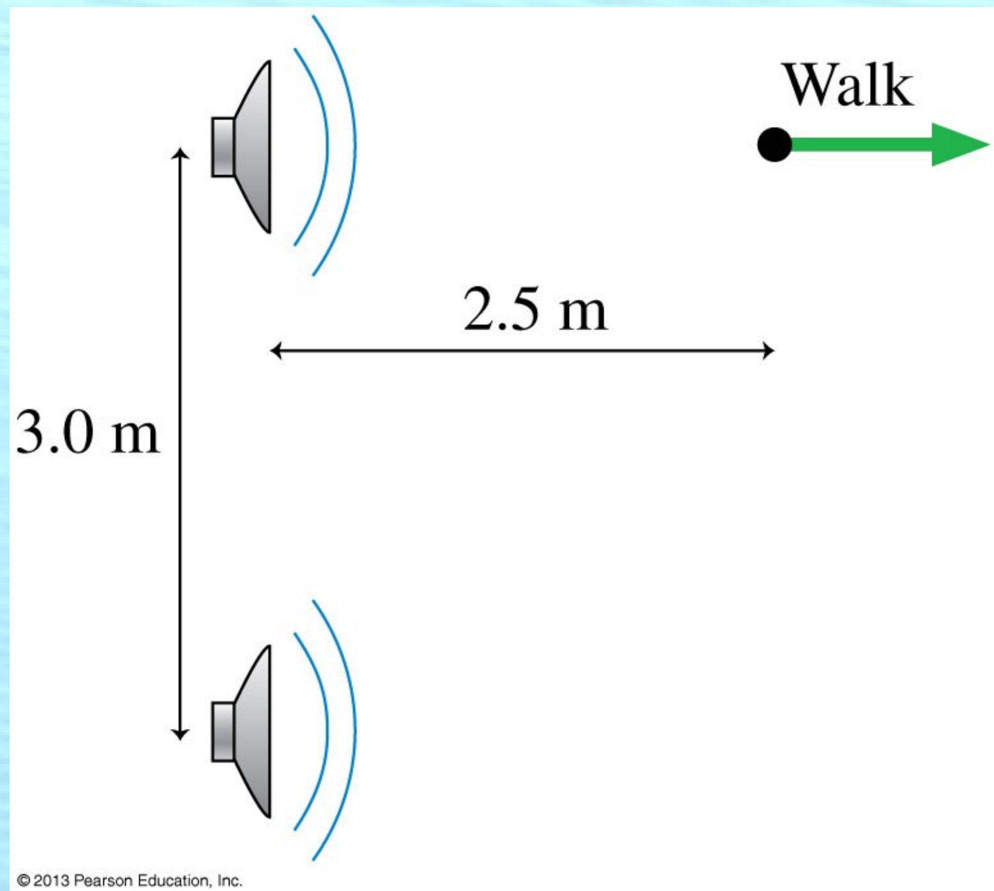
Ways interference can happen

Two waves can travel the same distance and start “out of phase” (different phi0).
Two waves can start “in phase” and Travel different distances
Two waves can start in phase but have slightly different frequencies and go in and out of phase (beats)

pHeT

Like problem 21.64

- Given two speakers in phase at 343 Hz in air at 20 C. You stand directly in front of one, beginning 10 m away and walk toward it.
- At what distances is the sound intensity a minimum?



Clickers

Given f=343 Hz and v=343 m/s and two sound waves of equal amplitude emitted in phase by two speakers. at what possible distance differences between the speakers will you get constructive interference?

A. 10 cm, 20 cm, 30 cm
B. 1 m, ½ m, 1/3 m
C. 1 m, 2 m, 3 m
D. 1 m, 3 m, 5 m
E. C and D

Clickers

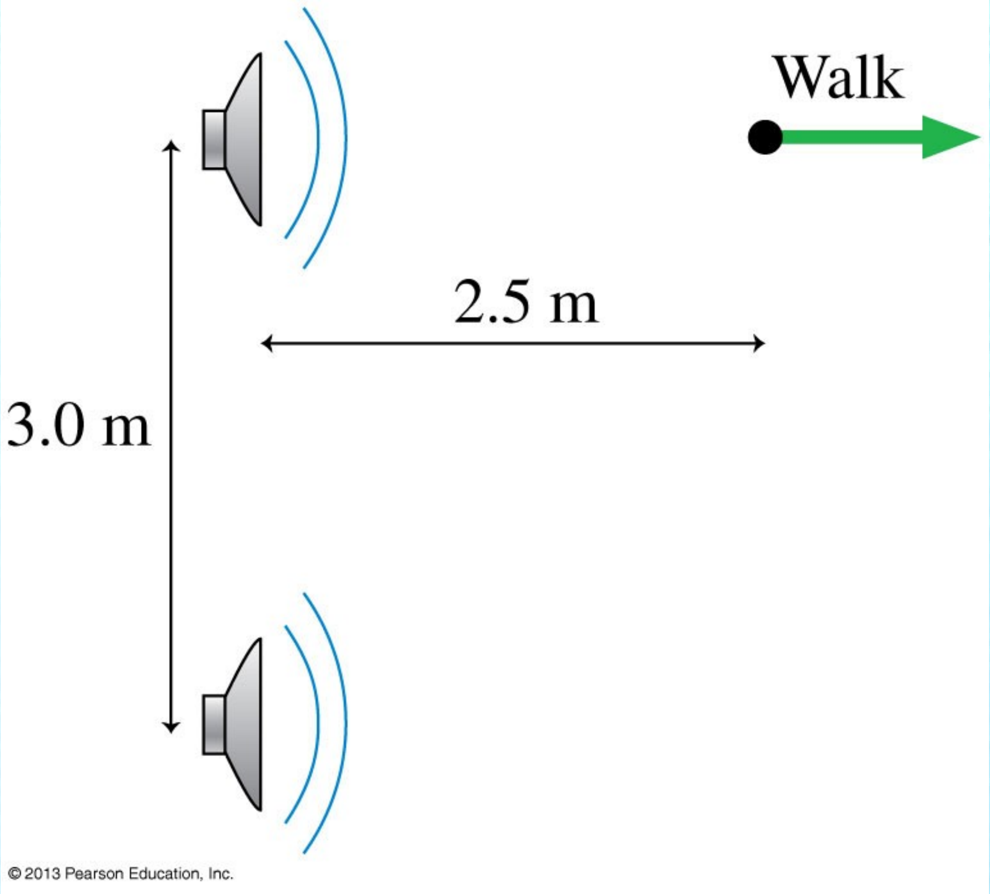
Given f=343 Hz and v=343 m/s and two sound waves of equal amplitude emitted in phase by two speakers. at what possible distance differences between the speakers will you get destructive interference?

A. 0.5 m, 1.5 m, 2.5 m
B. 0.5 m, 1.0 m, 1.5 m
C. 1.5 m, 2.0 m, 2.5 m
D. 0.25 m, 0.75 m, 1.25 m

Like problem 21.64

f= 343 Hz in air at 20 C.

- v= 343 m/s
- d=3.0 m
- r=?



Problem 2 on HW-OL-04

Two loudspeakers, A and B, are driven by the same amplifier and emit sinusoidal waves in phase. The frequency of the waves emitted by each speaker is 165 Hz. You are 8.00 m from speaker A. Take the speed of sound in air to be 330 m/s.

What is the closest you can be to speaker B and be at a point of perfectly destructive interference?

Like Problem 2 on HW-OL-04

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Worked problems