Announcements

- Exam Thursday. **Pick up an Exam Info sheet from the front.**
- Optional review session tonight, here, at 8:30 pm.
- Last year's exam is available on the Solutions page.
- Graded group exercise in problem session tomorrow.
- Graded post-exam activity in problem session on Friday.

What Will You Be Tested On?

- PHYS 212 exams are not evaluating if you are "good at math" or "good at physics". This exam will test your mastery of the material covered in Unit 2 of PHYS 212.
- This includes:
  - Lectures 8-14
  - Problem Session (assigned problems)
  - Some PHYS 211 content used in this unit (equipartition, vector addition, oscillations, . . .)
- We thoroughly check our exams to eliminate bias with respect to race, gender, or culture.

You're allowed one index card for Unit 2. Things you might put on it:

- Fundamental equations
- Basic derivatives and integrals: x^n, e^x, $\sin x$, $\cos x$
- Prefixes: you should know nano, micro, milli, centi, kilo, mega, and giga.
- Examples. How to find the distance on the screen for the second side minimum for two-slit interference.
- Step-by-step methods.
- Maybe a chart of which $\Delta\phi$ gives maxima and minima for double slit, multi-slit, and single slit.

You are also allowed to bring your sheet from the previous exam.

PHYS 212 Second Exam
March 20, 2025

Name ________________________
P. S. Instructor: ______________
P. S. Time: _______

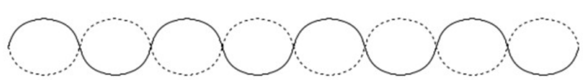
Show all work for full credit! Answers must have correct units. For all problems (except multiple choice questions) start with either (a) a generally applicable equation, or (b) a sentence explaining your approach.

$$k = 8.99 \times 10^9\,\mathrm{N{\cdot}m^2/C^2} \qquad \epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/N{\cdot}m^2} \qquad c = 3.00 \times 10^8\,\mathrm{m/s}$$

$$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T{\cdot}m/A} = 1.26 \times 10^{-6}\,\mathrm{T{\cdot}m/A} \qquad v_{\text{sound}} = 340\,\mathrm{m/s}$$

$$h = 6.63 \times 10^{-34}\,\mathrm{J{\cdot}s} = 4.14 \times 10^{-15}\,\mathrm{eV{\cdot}s} \qquad hc = 1240\,\mathrm{eV{\cdot}nm} \qquad 1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$$

$$g = 9.80\,\mathrm{N/kg} \qquad m_e = 9.11 \times 10^{-31}\,\mathrm{kg} \qquad m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$$



Don't take shortcuts!

- Show all work. We grade the process and not the answer, so you need to communicate your approach.
- A generally applicable equation such as

$$|\mathcal{E}| = \left|\frac{d\Phi_B}{dt}\right|$$

can be used without explanation. Starting with

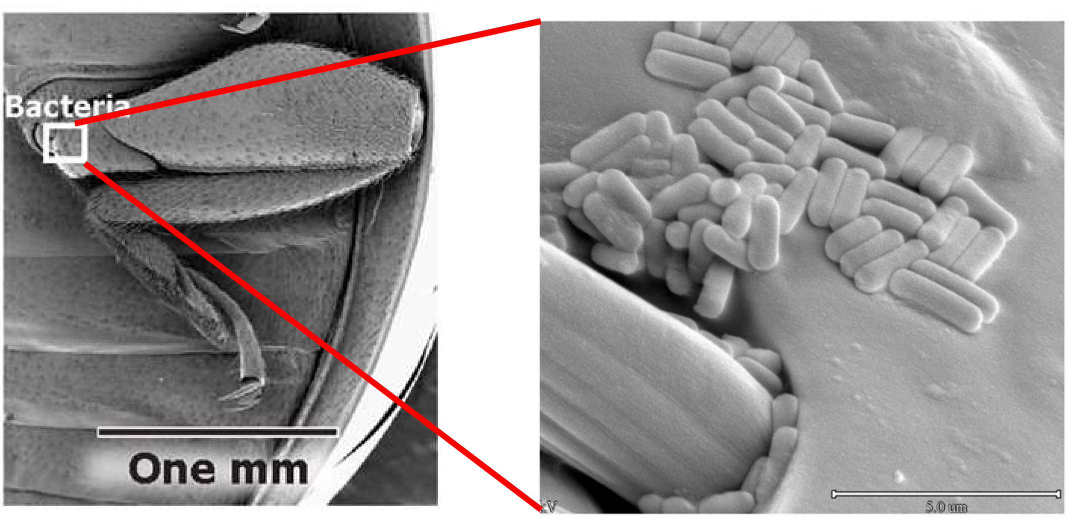
$$|\mathcal{E}| = \frac{d}{dt}(BA)$$

is not valid.

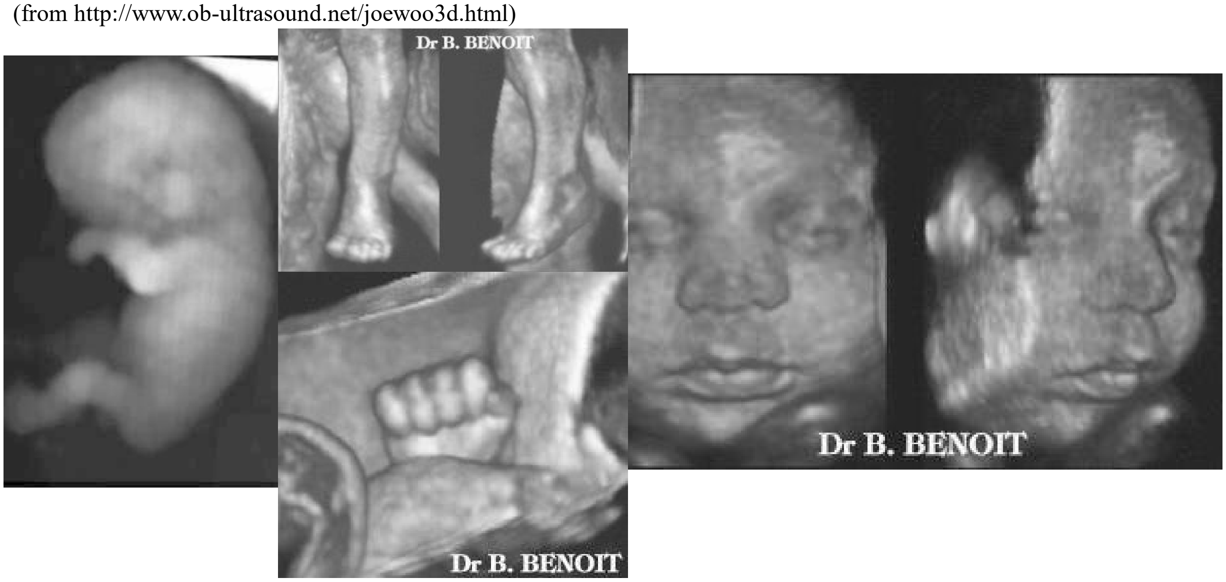
- If using a specialized equation that is valid only for a particular situation, you must state the assumptions.

$$\Delta r_{\text{adj}} = d\sin\theta \qquad \text{because } d \ll L$$

Electron microscope images of bacteria on a leg of a lady bug (From http://home.att.net/~woody.white/)



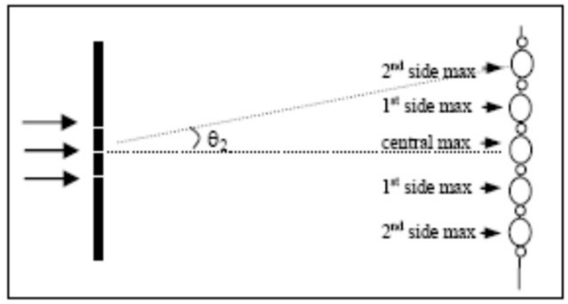
Ultrasound images of fetuses (feti? fetoxen?)
(from http://www.ob-ultrasound.net/joewoo3d.html)



<u>ConcepTest #1, Lecture 14</u>: If the information on a CD was already packed together as close as an infrared beam can probe, then how was it possible to fit more data on a disk with the same size for DVDs and Blu-ray disks?

1. It wasn’t possible. DVDs and Blu-ray disks were never successful.
2. DVDs and Blu-ray disks used higher frequency electromagnetic waves to read the disks.
3. DVDs and Blu-ray disks uses lower frequency electromagnetic waves to read the disks.

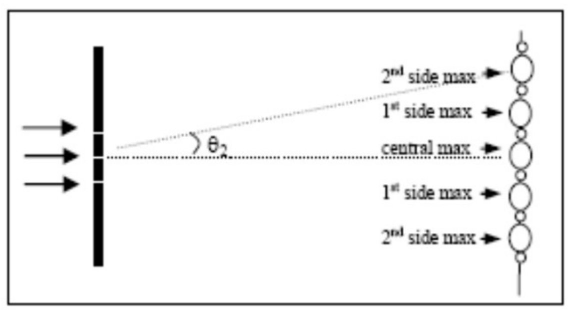
<u>Example 1:</u> Light of wavelength 510 nm falls on a barrier with 3 thin slits each spaced 2.5 μm apart from its adjacent slit as shown in the figure. A pattern of dots appears on a distant screen. Determine the angle θ_2 for the 2nd major bright side maximum.



<u>ConcepTest #2, Lecture 14</u>: Which of the following is the sequence that you'll use to solve this problem?

1. Start with geometry → determine Δr → determine $\Delta\phi$ → maybe phasor addition
2. Use the interference pattern → determine $\Delta\phi$ → determine Δr → geometry (e.g., find θ or d).

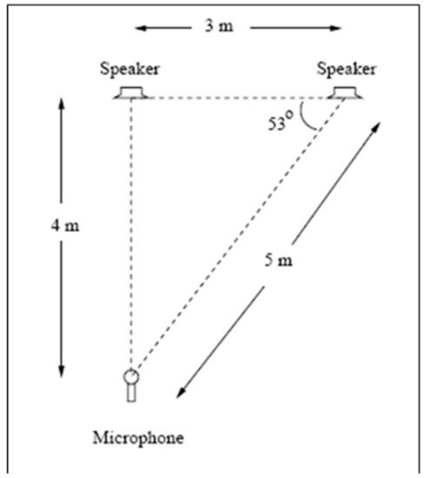
<u>Example 1:</u> Light of wavelength 510 nm falls on a barrier with 3 thin slits each spaced 2.5 μm apart from its adjacent slit as shown in the figure. A pattern of dots appears on a distant screen. Determine the angle θ_2 for the 2nd major bright side maximum.



<u>ConcepTest #3, Lecture 14:</u> What is the phase difference for this problem?

1. $\Delta\phi_{adj} = 0$	4. $\Delta\phi_{adj} = 2\pi$ rad
2. $\Delta\phi_{adj} = \pi/2$ rad	5. $\Delta\phi_{adj} = 3\pi$ rad
3. $\Delta\phi_{adj} = \pi$ rad	6. $\Delta\phi_{adj} = 4\pi$ rad

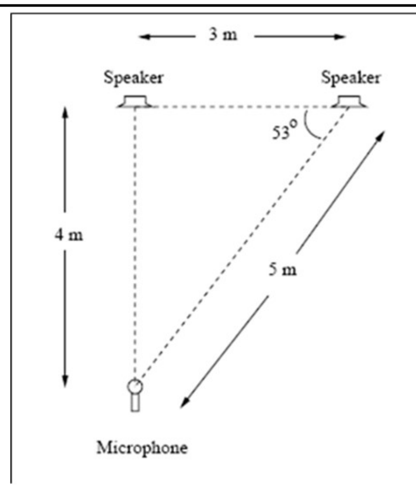
<u>Example 2:</u> The illustrated speakers emit sound waves that are in phase as they leave the speakers. The waves have a frequency of 85 Hz and a wavelength of 4 m. The stereo is adjusted so that the individual sound waves from the speakers have identical amplitudes A at the microphone. Calculate the amplitude of the total sound wave detected by the microphone when both speakers are on.



<u>ConcepTest #4, Lecture 14</u>: Which of the following is the sequence that you'll use to solve this problem?

1. Start with geometry → determine Δr → determine $\Delta\phi$ → maybe phasor addition
2. Start with interference pattern → determine $\Delta\phi$ → determine Δr → geometry (e.g., find θ or d).

<u>Example 2:</u> The illustrated speakers emit sound waves that are in phase as they leave the speakers. The waves have a frequency of 85 Hz and a wavelength of 4 m. The stereo is adjusted so that the individual sound waves from the speakers have identical amplitudes A at the microphone. Calculate the amplitude of the total sound wave detected by the microphone when both speakers are on.



<u>ConcepTest #5, Lecture 14:</u> What *is* Δr for this problem?

1. 1 m	4. (1 m) * sin(37°)
2. 3 m	5. (3 m) * sin(53°)
3. (1 m) * sin(53°)	6. (3 m) * sin(37°)

Summary of phase differences

For interference of two waves:
$\Delta\phi = 0, \pm 2\pi, \pm 4\pi, \pm 6\pi, \ldots$ rad for constructive interference
$\Delta\phi = \pm\pi, \pm 3\pi, \pm 5\pi, \ldots$ rad for destructive interference

For N waves: key is a phasor diagram with N phasors (vectors) and appropriate phase angles. If slits – consider phase difference between adjacent slits:
$\Delta\phi_{adj} = 0, \pm 2\pi, \pm 4\pi, \pm 6\pi, \ldots$ rad for constructive interference
Use phasor diagram to get $\Delta\phi_{adj}$ for destructive interference

For single slit diffraction:
$\Delta\phi_{top\text{-}bottom} = \pm 2\pi, \pm 4\pi, \pm 6\pi, \ldots$ for *destructive* interference (0 for constructive).

Relate to path length difference: $\boxed{\Delta\phi = 2\pi\frac{\Delta r}{\lambda}}$

Path length difference: $\Delta r = |r_2 - r_1|$

a. If geometry clean, then just do $\Delta r = |r_1 - r_2|$. Best approach if available – always try this first.

b. If screen very far away ($L \gg d$), or if looking for angle, use $\Delta r = d\sin\theta$ (or $a\sin\theta$ for single slit)

Don't forget: tanθ = opposite/adjacent! Useful for relating angle to distance on screen.

ConcepTest #6, Lecture 14, Lightning Round

For each of the following cases, put up a "1" if the the approach (including units) is correct, and a "2" if not.

(a) What is the energy of a photon with a frequency 5×10^{15} Hz?

$E_{ph} = hf = 4.14x10^{-15}\ eV\text{-}s * 5x10^{15}\ s^{-1} = \ldots$

(b) What is the wavelength of an electron with an energy of 20 eV?

$K = p^2/2m \rightarrow p = \sqrt{2mK} \rightarrow \lambda = h/p = (4.14x10^{-15} eV - s)/\sqrt{2 * 9.1x10^{-31} kg * 20eV} = \ldots$

(c) What is the wavelength of a 20 eV photon?

$E_{ph} = hc/\lambda \rightarrow \lambda = hc/E_{ph} = (1240\ eV\text{-}nm)/(20\ eV) = \ldots$

(d) What is the wavelength of a 20 eV electron?

$E_{ph} = hc/\lambda \rightarrow \lambda = hc/E_{ph} = (1240\ eV\text{-}nm)/(20\ eV) = \ldots$

ConcepTest #7, Lecture 14

The electric field in an electromagnetic plane wave in a vacuum is given by

$$\vec{E} = 6.0\times10^4 \cos(8.0\pi y + 2.4\times10^9 \pi t)\hat{k}$$

where E is in N/C, y is in meters and t is in seconds.

(a) The wave propagates in which direction?

1. $+\hat{\imath}$	2. $-\hat{\imath}$	3. $+\hat{\jmath}$
4. $-\hat{\jmath}$	5. $+\hat{k}$	6. $-\hat{k}$

(b) What is the direction of the electric field $\vec{E}$ at the origin ($y = 0$) at time $t = 0$?

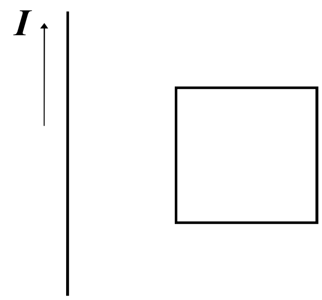
1. $+\hat{\imath}$	2. $-\hat{\imath}$	3. $+\hat{\jmath}$
4. $-\hat{\jmath}$	5. $+\hat{k}$	6. $-\hat{k}$

ConcepTest #8, Lecture 14

Which of the following statements is true about electromagnetic waves? (Put up any card that is appropriate.)

1. Light is an electromagnetic wave.
2. An electromagnetic wave is a stream of charged particles.
3. Electromagnetic waves are longitudinal waves.
4. Electromagnetic waves can travel through a vacuum.
5. Electromagnetic waves always travel at a speed 3.0×10^8 m/s in a vacuum.
6. None of the other statements are true.

ConcepTest #9, Lecture 14



(a) The current in the wire is decreased. What is the direction of the current induced in the square loop?

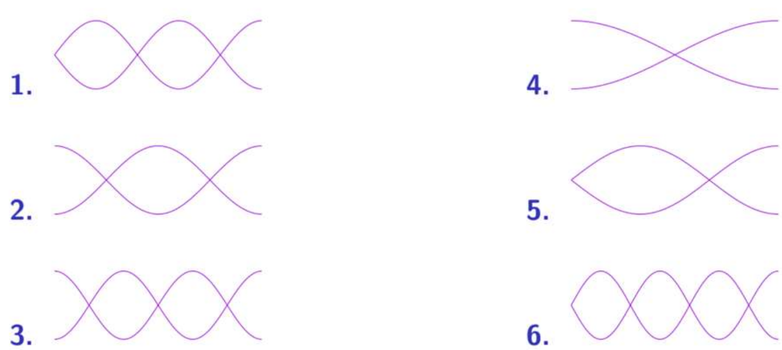
1 = "Clockwise"
2= "Counter-Clockwise"
3= "There is no induced current"
4= "Not enough information"

(b) The current is now held constant, but the loop is moved to the right with a constant speed. What is the direction of the current induced in the loop?

1 = "Clockwise"
2="Counter-Clockwise"
3="There is no induced current"
4="Not enough information"

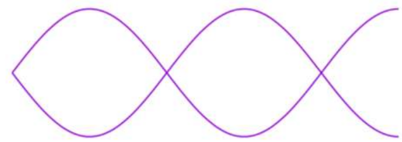
ConcepTest #10, Lecture 14

I blow on a slide whistle (open one side, closed the other) and create an awful squawking sound that corresponds to the third lowest frequency. Which of the following diagrams depicts the nodes and antinodes for this standing wave?



ConcepTest #11, Lecture 14

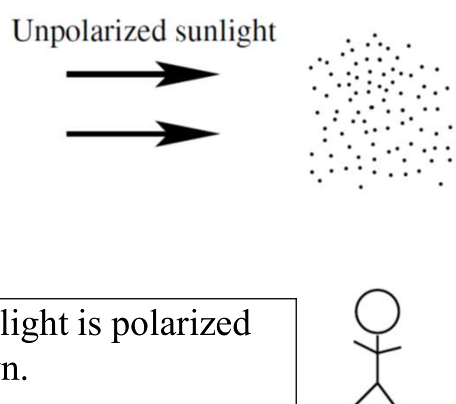
I blow on a slide whistle (open one side, closed the other) and create an awful squawking sound that corresponds to the third lowest frequency with the standing wave shown to the right. If the slide whistle 20 cm long, what is the wavelength oof the standing wave??



1. 20 cm
2. 25 cm
3. 40 cm
4. 12 cm
5. 10 cm
6. 16 cm

ConcepTest #12, Lecture 14 (From Test #2, 2017; also an A-problem from supplement.)

(12 pts) It is late in the afternoon and the sun is just above the horizon. You stare straight up at the blue sky above you, looking through the polarizer piece from your toy kit. You turn the polarizer, observing the light scattered from the molecules in the sky. State what you observe as you turn the polarizer, and give an explanation of *why* you observe this.



1. The light that you see is unpolarized	3. The light is polarized up-down.
2. The light is polarized left-right.	4. The light is polarized in-out

Brainstorm, Lecture 14

When dealing with Doppler fetal heartbeat monitors, the frequency of the ultrasound is typically 1 MHz or larger, while the frequency shifts due to the Doppler effect are as low as 100 Hz, a factor of 10,000 smaller. How can you detect such a small shift with any accuracy?