PHYS 212 Second Hour Exam
March 11, 2004

Name KEY
Problem Session:
Hr _____ **Instr** _____

<u>Show all work for full credit</u>! Answers must have correct units and appropriate number of significant digits. For all the problems (except for multiple choice questions), start with either (a) a fundamental equation (b) a sentence explaining your approach; or (c) a sketch.

$c = 3.0 \times 10^8$ m/s $\qquad v_{\text{sound}} = 340$ m/s $\qquad n_{\text{air}} = 1.0$

1. (14 pts) The magnetic field in an electromagnetic traveling plane wave in free space is given by

$$\vec{B} = \left(2\times10^{-12}\,\mathrm{T}\right)\cos\left(10\pi x + 3\times10^{9}\pi t\right)\hat{j},$$

where x is in meters, and t is in seconds.

$k = 10\pi$ rad/m

a) Determine the wavelength of the wave.

$$\lambda = \frac{2\pi}{k} = \frac{2\pi \text{ rad}}{10\pi \text{ rad/m}} = \boxed{0.2\text{ m} = \tfrac{1}{5}\text{ m}}$$

b) Determine the direction of propagation of the wave, i.e., the direction in which the wave is traveling. Circle one:

$+\hat{i}$ $\qquad -\hat{i}$ $\qquad +\hat{j}$ $\qquad -\hat{j}$ $\qquad +\hat{k}$ $\qquad -\hat{k}$

c) Determine an expression for the electric field $\vec{E}$ which accompanies the given $\vec{B}$ in the wave.

$E = Bc = (2\times10^{-12}\,\mathrm{T})(3\times10^{8}\,\mathrm{m/s})$

$$\vec{E} = \left(6\times10^{-4}\,\tfrac{N}{C}\right)\underbrace{\cos\left(10\pi x + 3\times10^{9}\pi t\right)}_{\text{in phase}}\hat{k}$$

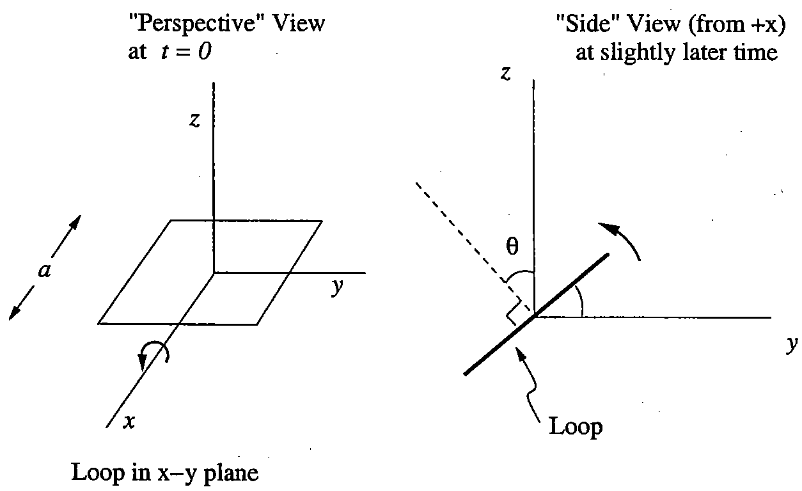
so

$\vec{E}\times\vec{B} \sim \vec{v}$

2. (13 pts) The illustrated square loop of wire with sides of length $a = 2$ cm and resistance $R = 25\Omega$ is located in a uniform magnetic field $\vec{B} = 0.3\hat{k}$ T. The loop rotates about the x axis at a constant rate of 100 revolutions per second, or equivalently, $\omega = 200\pi$ radians/s, so that the angle between the area vector and the $\hat{k}$ direction is given by

$$\theta(t) = 200\pi t .$$

This means that at time $t = 0$ plane of the loop is located in the x-y plane, and at time $t = 2.50$ ms the plane of the loop is in the x-z plane.



a) Determine the magnetic flux through the loop at $t = 0.0$ s.

$\vec{B}$ uniform $\Rightarrow$ $\Phi_m = NBA\cos\theta$

$$= 1 \times 0.3T \times (.02m)^2 \times \cancel{\cos} 0 \quad 1$$

$$= 1.2\times10^{-4}\ T\text{-}m^2 \quad \text{or} \quad 1.24\times10^{-4}\ Wb$$

b) Determine the magnetic flux through the loop at $t = 2.50$ ms.

$$\Phi_m = NBA\cos\theta \qquad\qquad \theta = 200\pi \times 2.5\times10^{-3} = \pi/2$$

$$= 1 \times 0.3T \times (0.2\,m)^2 \times \cancel{\cos}\,\pi/2 \quad 0$$

$$= 0$$

c) Determine the magnitude of the current flowing in the loop at $t = 1.25$ ms.
(You do not need to specify a direction.)

$$|\mathcal{E}| = \left|\frac{d\Phi_m}{dt}\right| = \left|NBA\frac{d}{dt}(\cos\theta)\right|$$

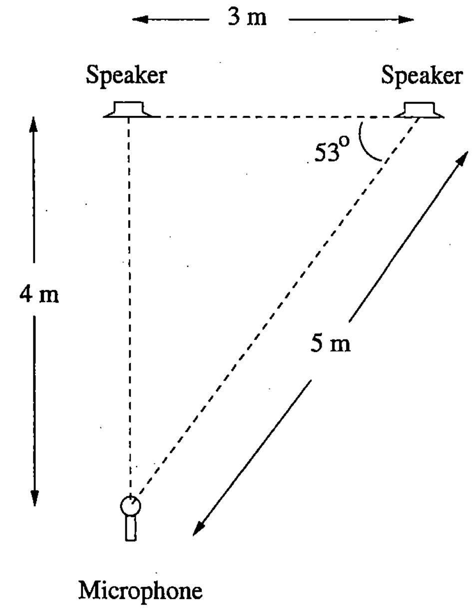
$$= \left|-NBA\sin\theta\frac{d\theta}{dt}\right|$$

$$= 1\times0.3\times(0.2m)^2\sin\pi/4 \times 200\pi$$

$$= 0.053\ V$$

$$I = \mathcal{E}/R = \frac{0.053V}{25\Omega} = 2.1\times10^{-3}A$$

3. (13 pts) The illustrated stereo 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.



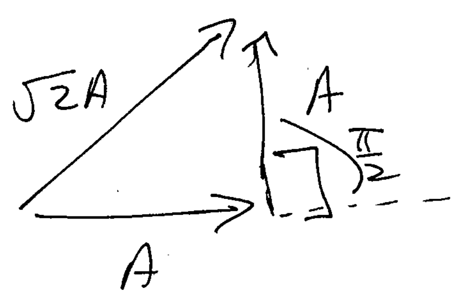
a) When both speakers are on, what is the phase difference between the waves from the individual speakers at the microphone?

$\Delta L = 1$

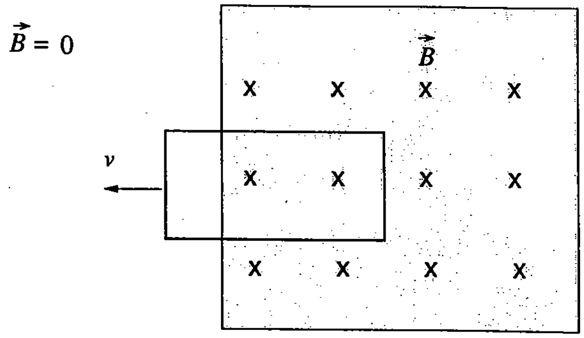
$$\Delta\phi = \frac{2\pi\Delta L}{\lambda} = \boxed{\frac{\pi}{2}}$$

b) Calculate the *amplitude* of the total sound wave detected by the microphone when both speakers are on. Express you answer in terms of A.

Phasor Diagram



4. (8 pts) A rectangular loop of wire is pulled to the left at a constant velocity out of the shaded region which has a uniform magnetic field pointing into the page. From the time the left edge leaves the shaded region until the right edge leaves the shaded region there will be (circle one)



a) a constant clockwise current

b) an increasing clockwise current

c) a decreasing clockwise current

d) a constant counterclockwise current

e) an increasing counterclockwise current

f) a decreasing counterclockwise current

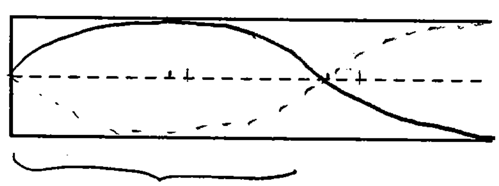
g) no current

– Magnitude of $\Phi_m(t) = BA(t)$. A decreases at constant rate ⇒ EMF constant ⇒ current constant.

– The magnetic field produced by the current counteracts the diminishing flux by pointing in same direction as original $\vec{B}$ field. – into page ⇒ current clockwise.

5. (14 pts) A standing wave is created in the air inside an organ pipe of length 0.20 m, with node-antinode end conditions.

a) Sketch on the diagram below the wave pattern for the second longest wavelength mode.



$\lambda/2$

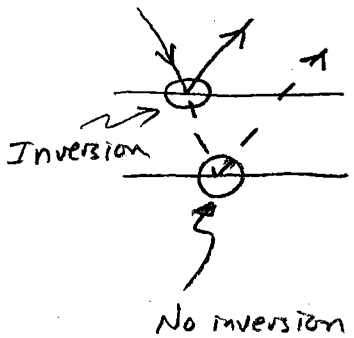
b) Determine the frequency of the second longest wavelength mode.

$\lambda/2 = \frac{2}{3}L \Rightarrow \lambda = \frac{4L}{3}$

Then $V_{sound} = \lambda f = \frac{4L}{3} f \Rightarrow f = \frac{3V_{sound}}{4L}$

$= 1275\ Hz$.

6. (15 pts) A soap film with index of refraction $n = 1.33$ and with air on either side has a thickness of 300 nm. Light with a wavelength $\lambda = 400$ nm in air hits the film at normal incidence. Is this light strongly reflected, not reflected, or something in between? Explain your answer.

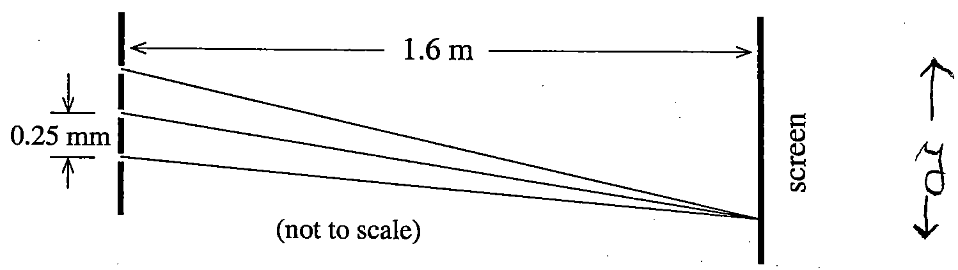


$$\Delta\varphi_{total} = \frac{\Delta L}{\lambda} 2\pi + \Delta\varphi_{reflection}$$
$$= \frac{2t}{\lambda_{film}} 2\pi + (\pi - 0)$$
$$= \frac{2 \times 300\,nm}{300\,nm} 2\pi + \pi$$
$$= 4\pi + \pi$$
$$= 5\pi$$

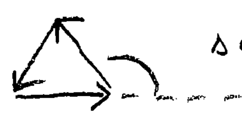
$$\lambda_{film} = \frac{\lambda_{air}}{n_{film}} = \frac{400\,nm}{4/3} = 300\,nm$$

$\Rightarrow$ Destructive interference; No reflection

7. (14 pts) Laser light with wavelength 633 nm passes through three narrow slits with spacing 0.25 mm, as shown. A pattern of bright spots is observed on a screen 1.6 m away.



a) Draw the applicable phasor diagram for the first side minimum.



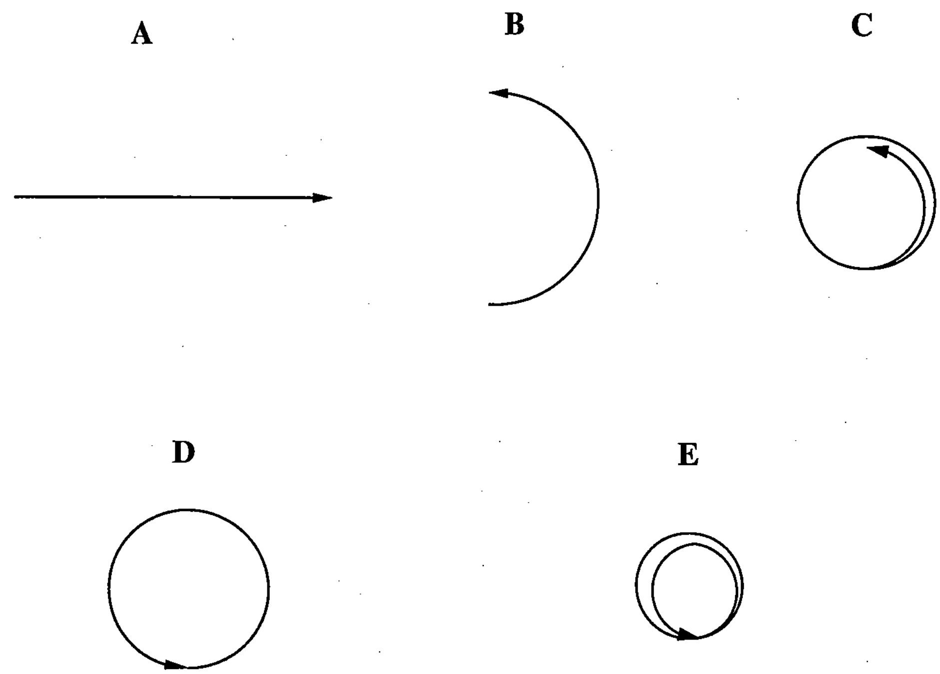
$$\Delta\varphi_{adj} = \frac{2\pi}{3}$$

b) Using your phasor diagram from part a), calculate the width of the central bright spot on the screen.

$$\Delta\varphi_{adj} = \frac{\Delta L}{\lambda} 2\pi$$
$$\rightarrow \frac{\cancel{2\pi}}{3} = \frac{d \sin\theta}{\lambda} \cancel{2\pi}$$
$$\sin\theta = \frac{1}{3}\frac{\lambda}{d}$$
$$\theta = \sin^{-1}\left(\frac{1}{3}\frac{\lambda}{d}\right) = \sin^{-1}\left(\frac{1}{3} \cdot \frac{633 \times 10^{-9}\,m}{.25 \times 10^{-3}\,m}\right) = 8.44 \times 10^{-4}\ \text{radians}$$

$$\text{Width} = 2y = 2L \tan\theta$$
$$= 2 \times 1.6\,m \times \tan(8.44 \times 10^{-4})$$
$$= 2.7 \times 10^{-3}\,m$$

8. (9 pts) Illustrated below are five phasor diagrams for the intensity on a screen due to single slit diffraction. Respond to each of the questions below with the letter (or letters) corresponding to the phasor diagram (or diagrams) which best answer the question.



a) Which phasor diagrams correspond to points on the screen where $\Delta\varphi_{\text{top-bottom}} = 2\pi$? **Answer:** D

b) Which phasor diagrams correspond to points on the screen somewhere within the first side maximum? **Answer:** C

c) Which phasor diagrams correspond to points on the screen somewhere within the central maximum? **Answer:** A, B

d) Which phasor diagrams correspond to points on the screen which correspond to side minima? **Answer:** D, E