PHYS 212 Second Hour Exam
March 10, 2005

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 some combination of (a) a fundamental equation (b) a sentence explaining your approach; or (c) a sketch.

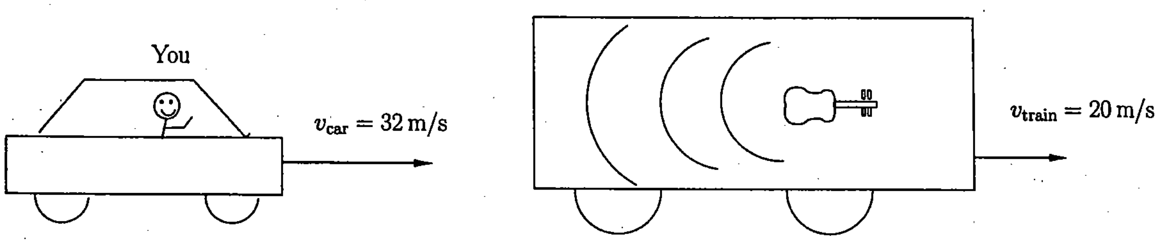
$v_{sound} = 340$ m/s $\quad c = 3.0\times10^8$ m/s $\quad k = 8.99\times10^9$ Nm^2/C^2 $\quad \mu_0 = 4\pi\times10^{-7}$ N/A^2

1. (8 pts) Which of the following are examples of electromagnetic waves? Circle as many as are appropriate.

(a) Visible light	(b) The flow of electrons in a circuit containing a battery and a light bulb.
(c) The signal that enables a cellular phone to communicate with other cell phones.	(d) The signal that your car radio picks up from the broadcast tower.
(e) The sound that you hear from your radio.	(f) Radar used to determine speed of passing cars.

2. (8 pts) Your string quartet is supposed to perform on a luxury train trip, but you missed the departure. You jump in your car to catch up to the train. The train is traveling east at 20 m/s and your car is traveling east at 32 m/s as the rest of the quartet starts to tune up. A violin player on the train plays an A, a note which she hears with a frequency of 440 Hz. The frequency of the note that you hear is (circle one):

(i) Smaller than 440 Hz	(ii) Equal to 440 Hz
(iii) Greater than 440 Hz.	(iv) There isn't enough information to choose between the other three.

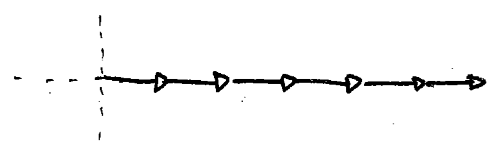


3. (10 pts) One widely used method of medical imaging uses reflections of ultrasound to determine the internal structure of the human body. Explain briefly in the box below the main reason high frequency ultrasonic sound waves are used rather than lower frequency audio sound waves.

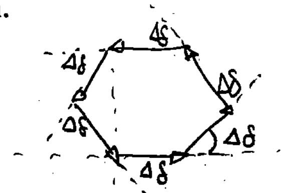
Recall that two objects can only be resolved when the angular separation between them is greater that $\frac{1.22\lambda}{d}$ where d is the separation between the objects. We get a better resolution when $\lambda < d$. Now $\lambda = v/f$ and to the resolution will be better for smaller objects as f increases. Thus ultrasonic waves offer better resolution and enable one to see more detail.

4 (14 pts) Light from a laser is passing through 6 narrow, equally spaced adjacent slits.

(a) Draw a phasor diagram corresponding to the central maximum in the resulting interference pattern.



(b) Draw another phasor diagram corresponding to the first side **minimum** of the interference pattern.



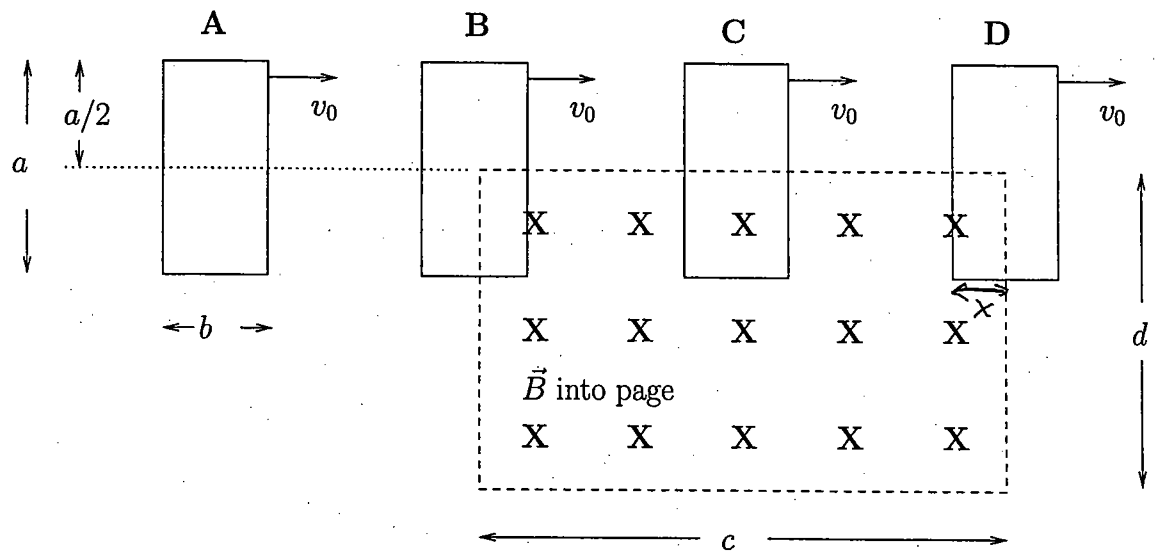
All exterior angles identical

(c) From your drawing in part (b), determine the phase difference between light from two adjacent slits. **Label this phase difference on your diagram from part (b).**

Sum exterior angles $= 2\pi$

$\Rightarrow \quad 6\Delta\delta = 2\pi \quad \Rightarrow \quad \Delta\delta = \pi/3 \quad (60^\circ)$

5. (17 pts) A loop of wire with resistance R and mass m moves at a constant speed v_0 through the illustrated region. There is a uniform magnetic field pointing into the page with magnitude B_0 within the dashed rectangle – everywhere else the field is zero. Four positions of the loop are indicated as it moves from left to right. All lengths are labeled in the figure.



(a) Indicate the direction of the current induced in the loop when it is at position **A**: (Circle one) , , or "ZERO"

No change in flux $\rightarrow \varepsilon = 0 \Rightarrow I = 0$

(b) Indicate the direction of the current induced in the loop when it is at position **B**: (Circle one) , , or "ZERO"

Φ increases, so $\vec{B}_{ind}$ opposite $\vec{B}_{ext}$ $\rightarrow \vec{B}_{ind}$ out of page $\Rightarrow$ I CCW

(c) Indicate the direction of the induced current in the loop when it is at position **C**: (Circle one) , , or "ZERO" (Circle one.)

No change in flux $\rightarrow \varepsilon = 0 \rightarrow I = 0$

(d) Starting from Faraday's Law calculate (in terms of any constants and the variables in this problem) the induced current that flows in the loop at position D. **Be sure to include the direction of the current flow (if any).**

$$\varepsilon = \left|\frac{d\Phi}{dt}\right| \qquad \Phi = NBA\cos\theta = 1 \cdot B \cdot \frac{a}{2} \cdot x \cdot \cos 0^\circ = Bax/2$$

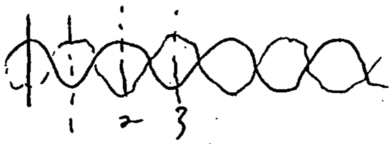
$$\varepsilon = \left|\frac{d\Phi}{dt}\right| = \left|\frac{d}{dt}\left(\frac{Bax}{2}\right)\right| = \left|\frac{Ba}{2}\frac{dx}{dt}\right| = \frac{Bav_0}{2}$$

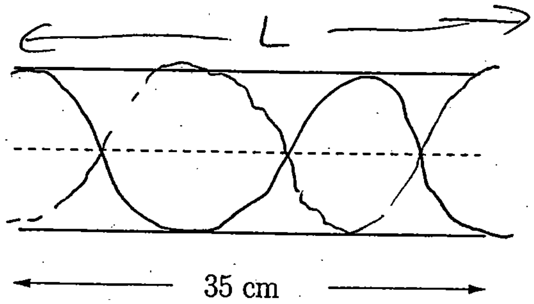
$$|I| = |\varepsilon|/R = \boxed{\frac{Bav_0}{2R}}$$

6. (14 pts) Consider an organ pipe with length 35 cm and with both ends open.

(a) On the illustration of the organ pipe below, draw a sketch of the standing wave (the displacement wave) corresponding to the third-lowest frequency.

antinodes at both ends





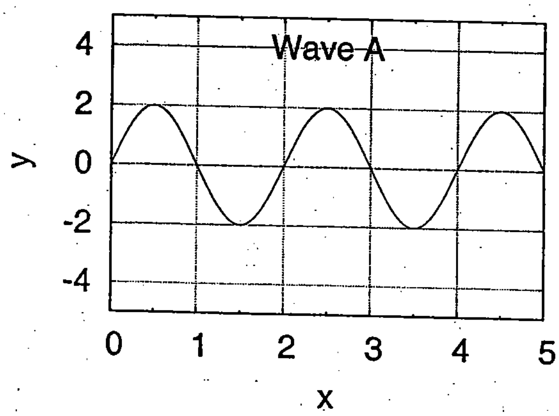
(b) **Using your sketch from part (a)**, determine the wavelength and frequency for this note.

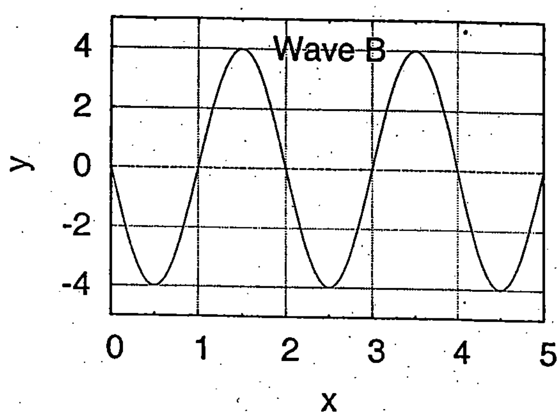
$1\frac{1}{2}\lambda = L \Rightarrow \lambda = \frac{2}{3}L = \frac{2}{3}\cdot 35\,cm = 23.3\,cm$

$\lambda f = v \Rightarrow f = \frac{v}{\lambda} = \frac{340\,m/s}{0.233\,m} = 1457\,s^{-1}$

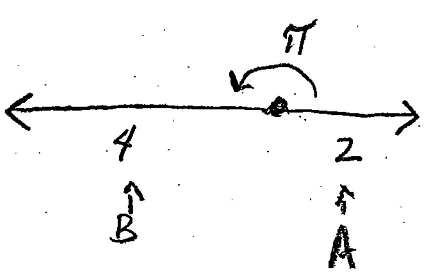
$\rightarrow$ 1460 Hz

7. (12 pts) The graphs below show snapshots of two traveling waves on a string at the same instant in time.

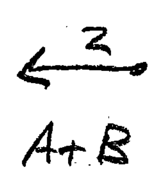




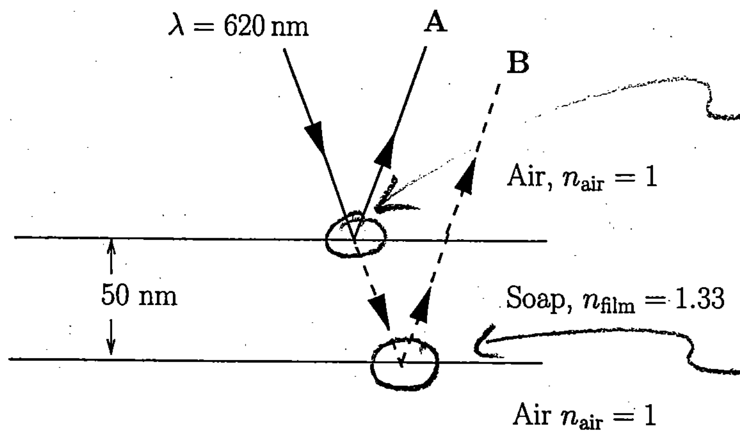
Draw a phasor diagram which represents the superposition of these two waves. The diagram should be clearly labeled ~~to show what represents "Wave A", what~~ represents "Wave B", and what represents the superposition of the two ("A+B").



Superposition:



8. (17 pts) A soap film with a thickness of 50 nm is illuminated at normal incidence (i.e., perpendicular to the surface) by monochromatic red light with a wavelength of 620 nm in air. (Note: In the illustration the beam does not come in at exactly normal incidence; this is only for clarity in indicating the distinct paths of the reflections.) The film is composed predominantly of water with index of refraction 1.33 and is surrounded on both sides by air.



Inversion; π Phase Shift

No inversion; No phase shift

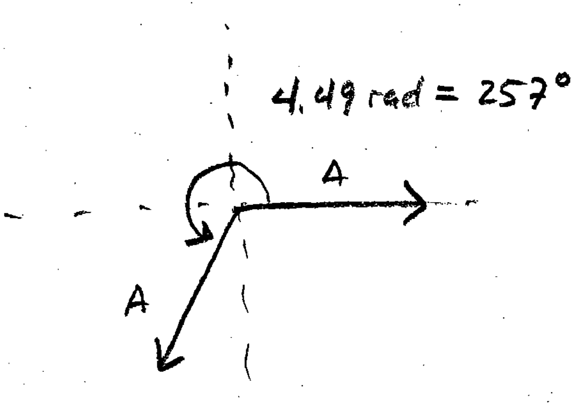
(a) Calculate the wavelength of the light inside the film.

$$\lambda_{film} = \frac{\lambda_{air}}{n_{film}} = \frac{620\,nm}{1.33} = 466\,nm$$

(b) Calculate the **total** phase difference between the red light on path **A** (i.e., light reflected from the top surface of the film) and the red light on path **B** (i.e., light that enters the film, reflects from the bottom surface and comes back out the top).

$$\Delta\delta_{total} = \Delta\delta_{path} + \Delta\delta_{ref} = \frac{2t}{\lambda_{film}} \cdot 2\pi + (\pi - 0) = \frac{100\,nm}{466\,nm} 2\pi + \pi$$
$$= 4.49 \text{ radians}$$

(c) Assuming that the amplitude of each of the two reflected beams is A, determine the total amplitude for reflected red light off of this film.



	x	y
	A	0
	$A\cos 4.49 = -0.221A$	$A\sin 4.49 = -0.975A$
	$A \times .779$	$-A \times 0.975$

Net Amplitude $= A\sqrt{.779^2 + 0.975^2} = 1.25A$