Physics 273, Fall 2005
Final Exam

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Name

Closed-book examination. Two pre-prepared 8 ½" x 11" sheets of notes may be used. Calculator may be used. Show work for partial credit. Include UNITS on all answers. Problems are 30 points apiece. Total will be normalized to 100.

EXAM ADVICE: If you don't immediately see what to do on one problem, go on to the next problem and come back to the unfinished problems later.

1. Measurements of Light Intensity

a) In class we measured the light intensity as a function of distance from a light bulb, with the results shown in the table.

i) Write the equation describing the expected behavior and fill in the corresponding values in the table.

ii) Explain the physical basis of the equation you used in part (i) quantitatively. (Be brief).

Position of light bulb = 10 cm

Detector Position (cm)	Measured Intensity (rel. units)	Calculated Intensity (rel. units)
90	.24	
70	.41	
50	1.20	
40	1.78	
30	3.65	
25	6.90	6.90

b) In class we measured the intensity of light transmitted through two polarizing plates as a function of the angle between the transmission axes of the plates, with the results shown in the table.

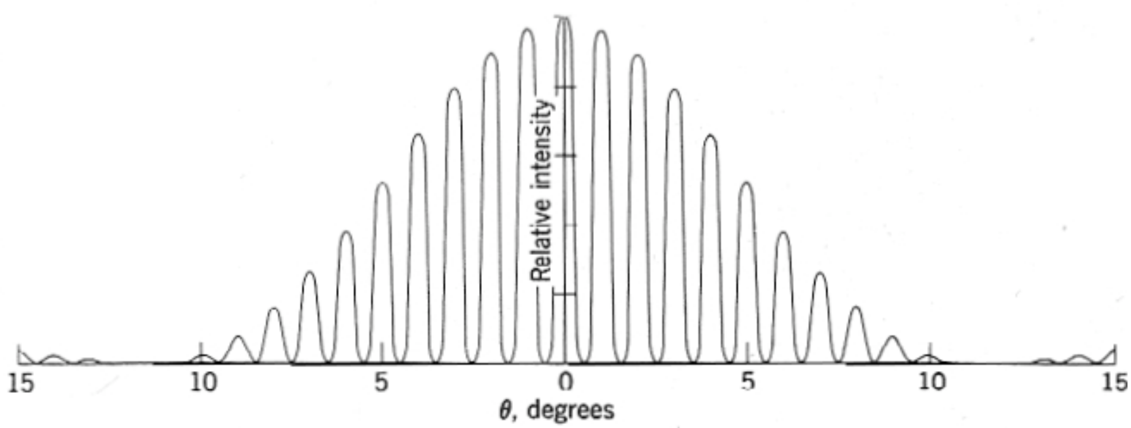
i) Write the equation describing the expected behavior and fill in the corresponding values in the table.

ii) Write the vector equation for the electric field and use it to explain quantitatively the physical basis for the equation you used in part (i). (Be brief.)

Angle (degrees)	**Measured Intensity (rel. units)**	**Calculated Intensity (rel. units)**
0	.415	.415
20	.375	
45	.195	
70	.035	
90	0	

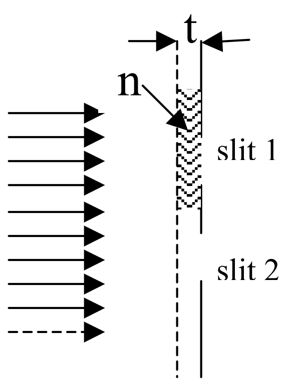
2. Two-slit interference

a) Find the ratio of the slit width to the wavelenth (a/λ) and the slit spacing to the wavelength (d/λ) given the intensity of the light at the detector as a function of detector angle as shown in the figure.



2. Two-slit interference (continued)

b) The light source is a plane wave normally incident on the slits in a medium of refractive index 1. If one of the slits is covered by a thin transparent sheet of thickness t/λ and refractive index n, there will be a phase difference for the light entering slits 1 and 2. Find the phase difference as a function of t/λ. Hint: the phase of the plane wave is the same at all positions as it enters the region marked by the dashed line in the figure.



c) Now consider the light leaving the two slits:

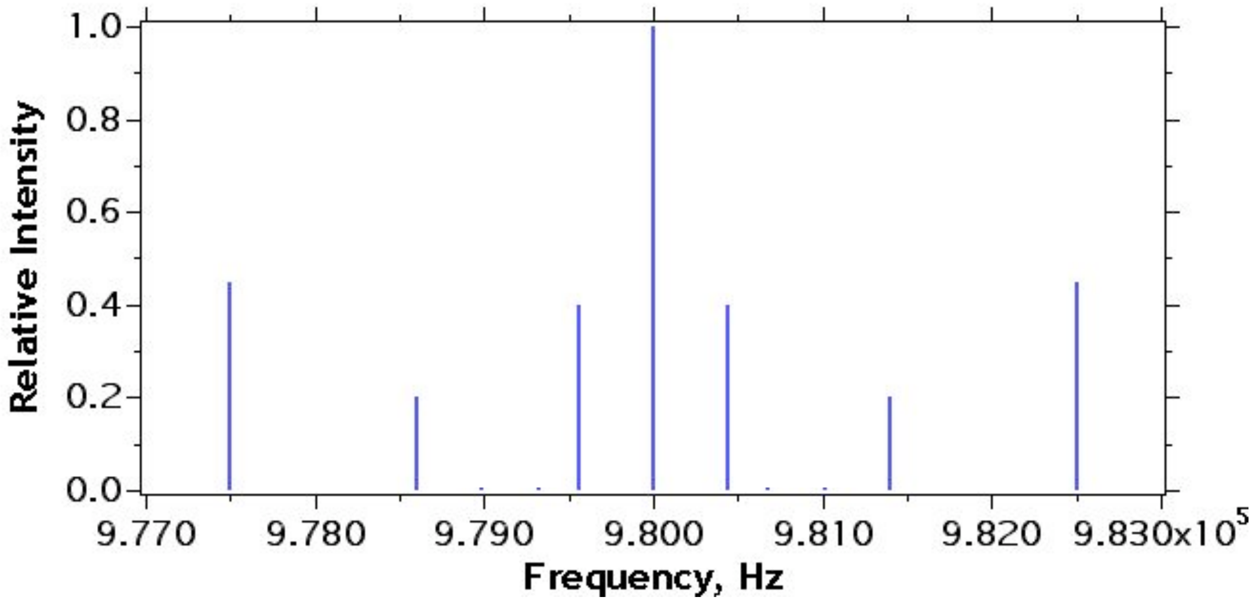
i) Find the equation for the phase difference between the two rays when they reach the detector at angle θ.

ii) At what angle $\theta_o(t)$ is the phase shift at the detector equal to 0?

iii) Find the value of t/λ where $\sin\theta_o(t)$ is equal to one half of λ/d.

3. Waveform analysis

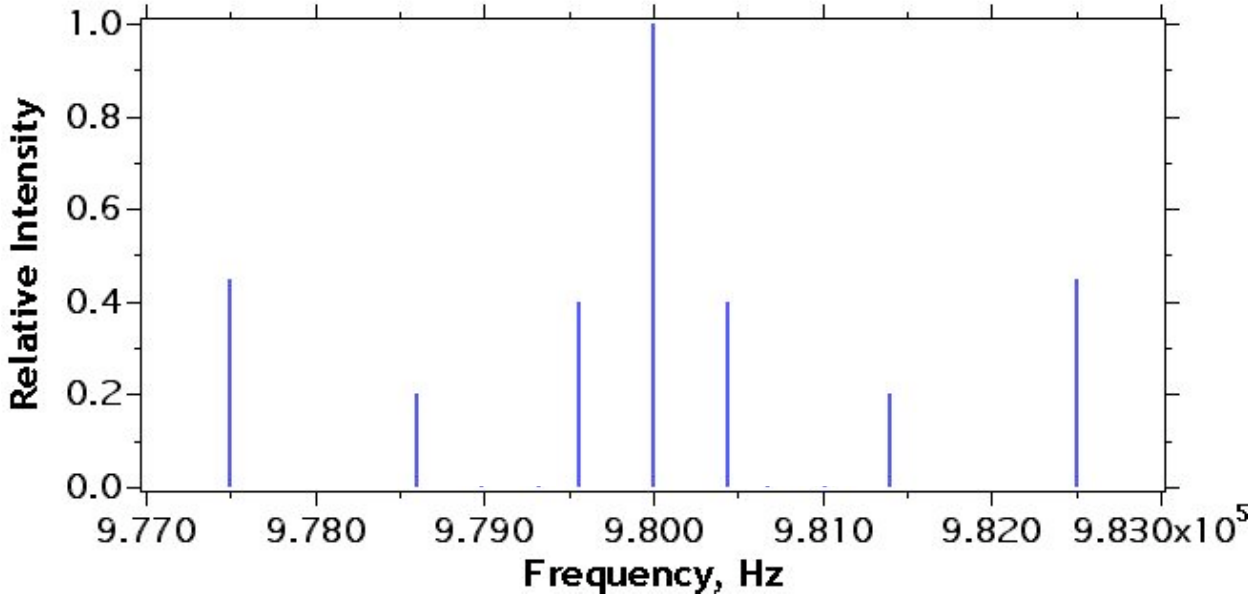
The fourier transform (frequency spectrum) of a waveform is shown in the graph.



a) Estimate the frequencies and relative intensities from the graph and write the waveform as a fourier series (assume all components are cosine functions, and do not multiple factors of 2π into numeric values for f – for instance write $2\pi*9.8x10^5 s^{-1}$ for the angular frequency of the center component in the graph.)

b) If you want to measure the waveform that corresponds to this signal for a limited amount of time t_{meas}, what is the smallest time you can measure and still expect to capture most of the information in the signal?

Problem 3, continued



c) Consider the waveform created by the sum of the three center frequency components and write this waveform in amplitude modulation form. Include the correct amplitude terms.

4. **Standing Wave:** A simple model for the vocal column is a tube with one end closed and the other end open (the open end is the mouth). Assume the speed of sound in air is 346 m/s

a) If the lowest frequency standing wave in the vocal column filled with air is $f_o = 420$ Hz, what is the length of the vocal column?

b) Write the wave equations for the displacement $\xi(x,t)$ and pressure difference $P(x,t)$ for this standing wave. Assume the amplitudes of the waves are ξ_o and P_o respectively.

4. Standing Wave,

c) Draw the waveforms (at maximum amplitude) for the displacement and pressure wave with standing-wave frequency $3f_o$.

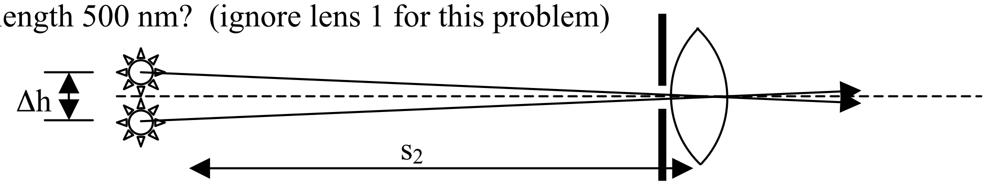
5. **Optics**: A thin lens lens is found to create a virtual image at s_1' = -75cm when the object distance is s_1 = 25cm.

a) Find the focal length f_1 of the lens. Carefully draw the ray diagram demonstrating the image formation.

b) A second lens is place a distance t = 0.5 cm after the first lens. A real image is formed at a distance s_2' = 2.5 cm. Find the focal length of the second lens. Carefully draw the ray diagram demonstrating the image formation.

c) Find the height of the image if the original object height is 20cm.

d) If the light entering the second lens is limited by an aperture of diameter a = 0.1mm, what is the smallest separation Δh of two objects at s_2 = 75.5 cm that can be resolved with light of wavelength 500 nm? (ignore lens 1 for this problem)



6. The surface of a perfect conductor acts as an interface of impedance Z = 0 for incident electromagnetic waves. Consider the case where such a surface lies in the x-y plane, and light polarized in the +x direction is incident normally on the surface. The frequency of the light is 3.0×10^{14} Hz and the amplitude of the electric field is 6.0V/m.

a) What is the wave vector of the incident light? What is the amplitude of the magnetic field. Write the vector wave equations for the electric field and the magnetic field.

b) What are the phase shifts for the electric field and the magnetic field wave upon reflection? Explain why these phase shifts are consistent with the form for an electromagnetic standing wave in a cavity with perfectly reflecting end:

$$E = E_m \hat{x}(\sin\omega t)(\sin kz)$$
$$B = B_m \hat{y}(\cos\omega t)(\cos kz).$$

Problem 6 continued:

c) Evaluate the Poynting vector for a fixed position z. Find the time-average value of the Poynting vector and explain what it means.