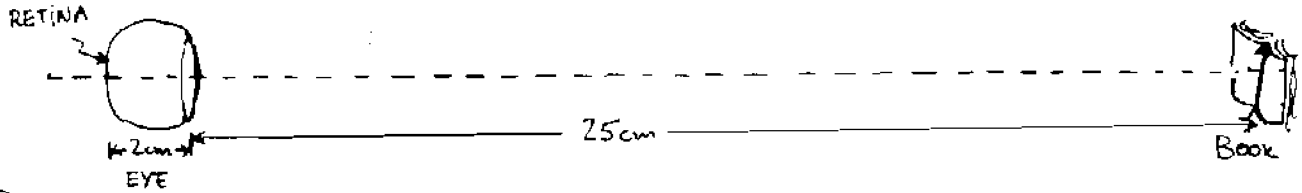
Summer 1994
O. E. Vilches

THIRD MIDTERM

Name..

Please do not forget to write your name!!!! This second midterm consists of 4 problems with several sections and/or questions. It may be worked out in any order. Partial credit will be given in most of the problems. The scoring for this test is summarized in the last page. Please write clearly.

PROBLEM 1 (30 points)



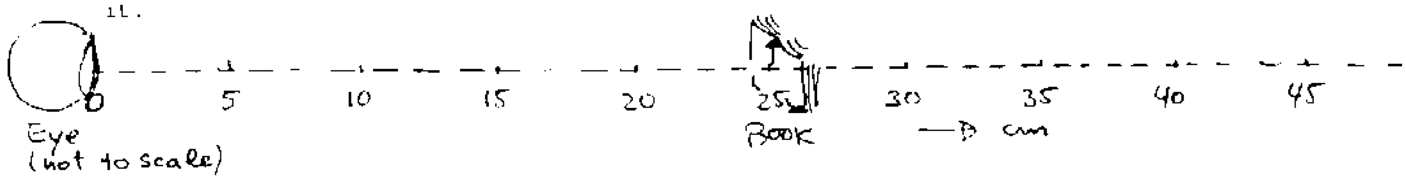
(8) a) The picture above shows a normal eye, which can read a book at the "normal" near point of 25 cm. Assume that the eye is exactly 2 cm long. Calculate the focal length of the eye when it is looking at the book in the picture.

(5) b) Locate the focal point (or points) in the picture above, and using ray tracing find the image of the book formed by the eye (you may use just the arrow)

(4) c) Now imagine a person who is far sighted, which can only see clearly objects further away than 50 cm. If the book is still placed 25 cm in front of the eye, where is the image of the book formed (inside the eye or behind the retina)? Write a short line explaining your choice.

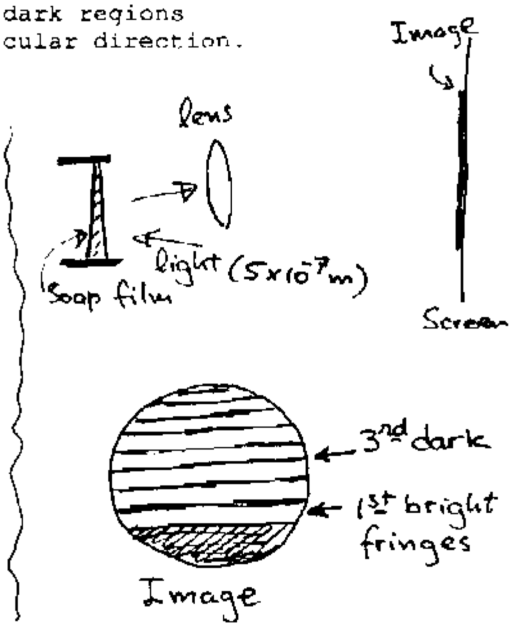
(7) d) Calculate the power of the corrective lenses which would allow the person of part (c) above to read the book, with the book still 25 cm in front of the eyes. Allow 2 cm for the eye to corrective glasses distance.

(6) e) To the sketch below, add the corrective lens and find the image formed by it.



PROBLEM 3 (23 points) (3)

In a lecture demonstration light of 500 nm wavelength (in air) is reflected from a thin soap film of index of refraction 1.25, the reflected light being focused onto a screen several meters away. The image formed on the screen looks like the circle drawn below, where the dark regions correspond to no light being reflected in that particular direction.

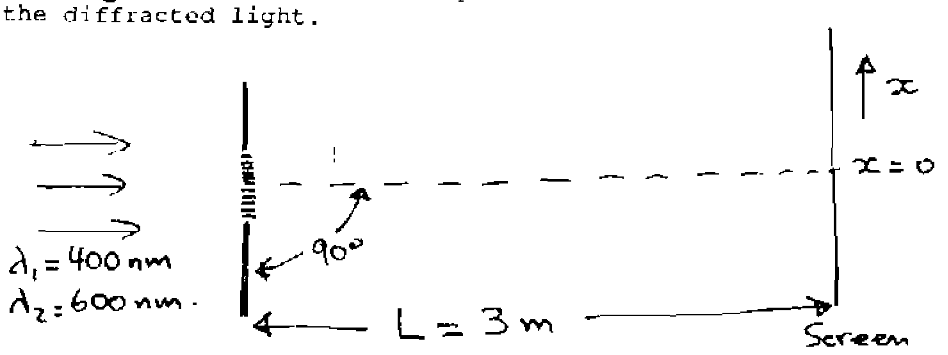


(7) a) Write a short sentence or paragraph explaining why the bottom of the image is dark.

(16) b) Calculate the thickness of the soap film at the first bright fringe and at the third dark fringe.

PROBLEM 4 (27 points) (4)

A diffraction grating with 5000 "slits" over a 1 cm length is illuminated at normal incidence from a source which emits two wavelengths, λ_1 = 400 nm, and λ_2 = 600 nm. A screen is placed at a distance L = 3 meters to view the diffracted light.



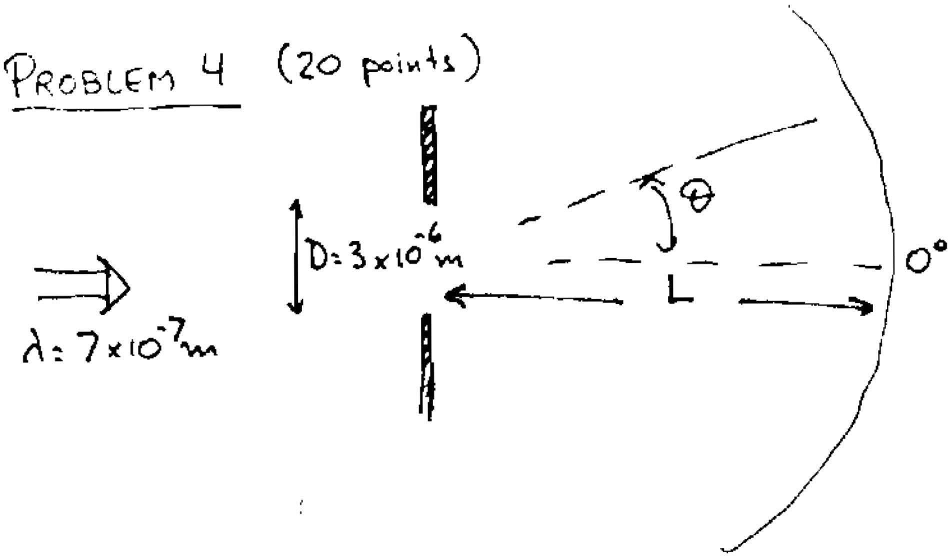
(12) a) Calculate how many "orders" of complete spectra (both wavelengths) one could (at least in principle) observe.

(8) b) Calculate the distance "x" from the center of the screen at which the 3rd order maxima for the 400 nm wavelength will occur.

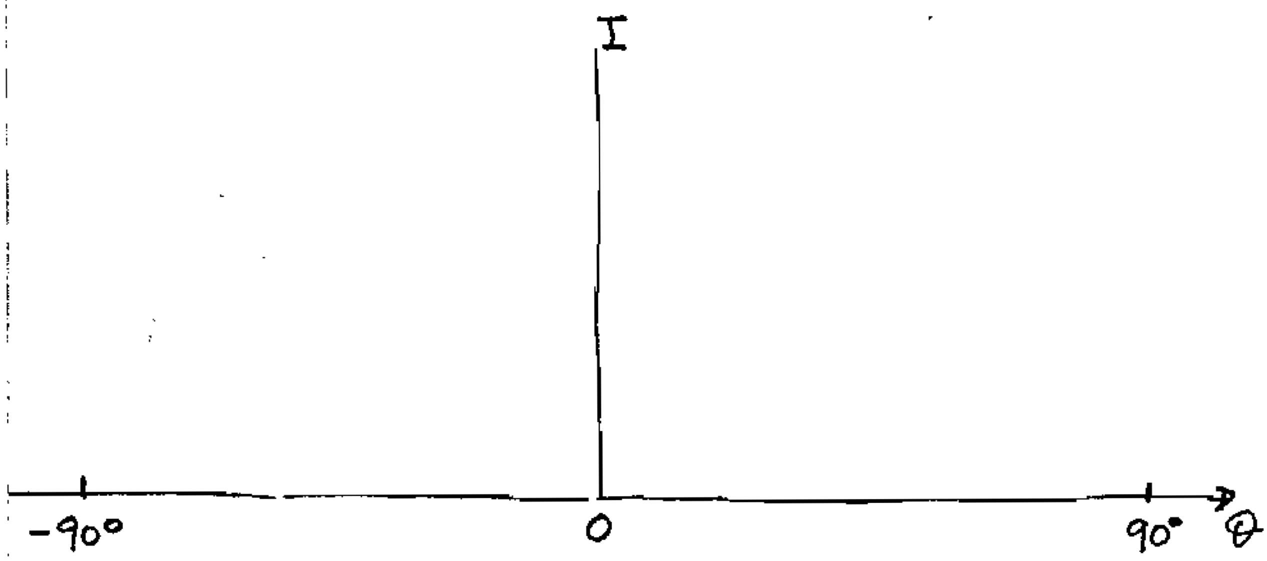
(7) c) Make a very qualitative plot of intensity at the screen vs x for the first two orders of complete spectra (the two wavelengths).

SCORE
P1 (30)
P2 (20)
P3 (23)
P4 (27)
Total (100)

PROBLEM 4 (20 points)



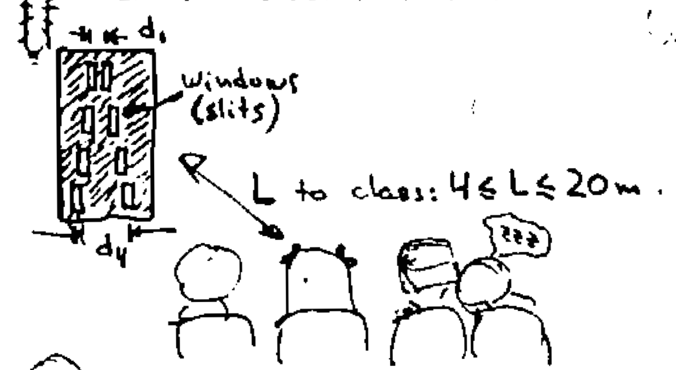
A single slit of width $D = 3\times10^{-6}\,m$ is illuminated by a plane wave of wavelength $\lambda = 7\times10^{-7}\,m$.
Make a graph below of what you expect the intensity to be as you move along the curved path at $L \gg D$ from $\theta = -90°$ to $\theta = +90°$. Your drawing should be quantitatively correct in the angle dependance, and qualitatively correct in the intensity. Some calculation of the angle dependance is necesary.



PROBLEM 5 (24 points)

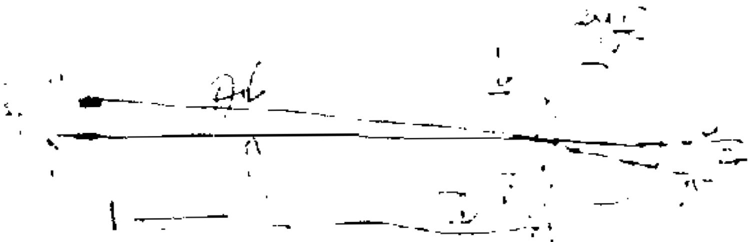
In a popular (or unpopular?) demonstration, a sodium lamp (yellow) illuminates parallel pairs of windows cut in a metal sheet. The wavelength of the Na light is about 550 nanometers. The separation between the window pairs varies as shown in the picture below. Students in the classroom viewing the windows are seated from about 4 to 20 meters away from the demonstration, and their irises are about 0.4 cm diameter.

Use Rayleigh's criterion for a circular aperture.



14

a) Calculate the smallest distance d_1 that the windows in a pair can be separated so that a student in the front row sees all of the windows as pairs, and calculate the minimum distance d_4 for a student in the last row to see at least one set of windows as a pair.



$\sin\theta = \frac{1.22\lambda}{D} \cong \tan\theta = \frac{d_1}{L}$

$d_1 = \frac{1.22\lambda}{D} \times L = \frac{1.22\times5.5\times10^{-7}\,m\times 5}{4\times10^{-3}\,m}$

$d_1 = 8.38\times10^{-4}\,m$

$d_4 = \frac{1.22\lambda}{D}\times 20\,m = \frac{1.22\times5.5\times10^{-7}\,m\times 20\,m}{4\times10^{-3}\,m} = 3.35\times10^{-3}\,m$

b) Imagine that the wavelength emitted by the lamp illuminating the windows could be changed.

5

b1) What can the student in the last row now see if the wavelength of the radiation is changed to red (750 nm) and the distances between the windows remains fixed as calculated in part a)? Write one paragraph to explain your answer.

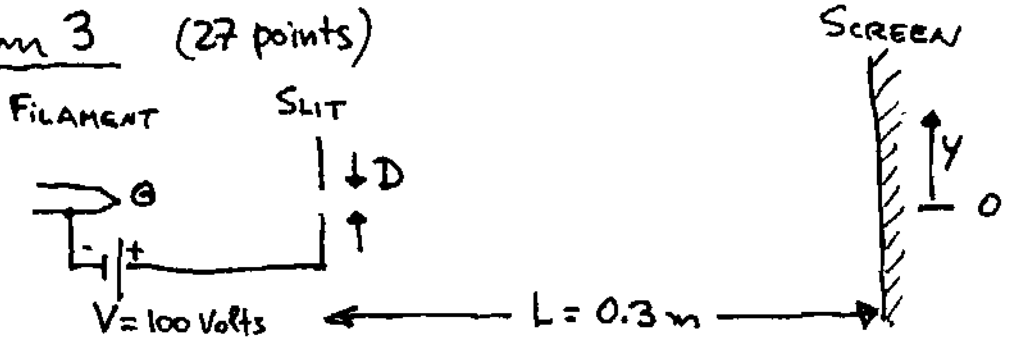
If λ increases, d_4 will have to increase to still see two "slits". Since d_4 is fixed, person in last row will not see any pair of slits as two slits.

5

b2) What can the student in the front row now see if the wavelength of the radiation is changed to violet (400 nm) and the distances between the windows remains fixed as calculated in part a)? Write one paragraph to explain your answer.

If λ decreases, d_1 (or d_4) could be smaller and still see two windows. Thus student in front row can even see (All slits or windows as two) (finish on page 12)(score on p.12)

Problem 3 (27 points)



Electrons are produced by a FILAMENT (with zero initial velocity). They are accelerated by a 100 Volts potential difference and go through a SLIT of diameter D. A screen (like in a TV tube) records the arrival of the electrons. The distance between the SLIT and the SCREEN is $L = 0.3\,m$.

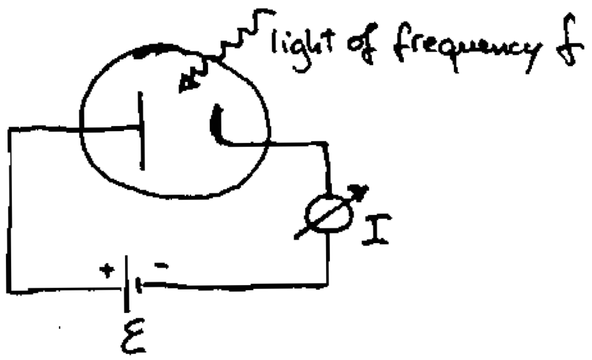
(9) (a) Show that the wavelength of the electrons going through D is 1.23×10^{-10} m.

(10) (b) Calculate the size of the slit D so that the first diffraction zero occurs at $Y = 0.05$ m

(8) (c) Heisenberg's uncertainty principle states that for electrons going through D the uncertainty in the y-position ($\Delta y = D$) and the uncertainty in the y-momentum of the electrons are related by $\Delta y \, \Delta p_y \geq \hbar$. Show that the condition for an electron hitting the screen within the first diffraction zero above or below $\theta = 0$ is in agreement with Heisenberg's principle (work on back, generous credit for a reasonable answer)

PROBLEM 4 (27 Points)

Light of frequency f strikes a metal electrode in a photocell. When electrons are emitted, the ammeter I registers a current



(8) a) If the wavelength of the incident light is 350 nm, and the work function of the metal is 3 eV, calculate the maximum kinetic energy at which an electron can be emitted

SCORE	
Pb. 1 (21)	
Pb. 2 (26)	
Pb. 3 (26)	
Pb. 4 (27)	
Total (100)	

(8) b) Calculate the minimum frequency and maximum wavelength needed to extract an electron from this metal

c) If the power of the laser that produced the incident light of part (a) was 1 mWatt (0.001 Watts) and the frequency f was 8.6×10^{14} Hz, calculate

(5) c_1) The number of photons that strike the metal plate per second

(6) c_2) The maximum possible current that can be generated (Hint: $I = \frac{\Delta Q}{\Delta t}$, 1 Ampere $= \frac{1\text{ Coulomb}}{\text{Second}}$, $e = 1.6 \times 10^{-19}$ C)