Spring 2005

Physics 133: Midterm II
Professor Frank De Lucia

3:30 Section
Morning Recitation

Name (1 pt):________________________

Recitation Instructor (1 pt):________________________

There are four pages to this midterm (plus an equation sheet). It is important that you write your name on each page and the name of your recitation instructor on the first page. Each name is worth one point.

Be sure to include the proper units in your answers.

Problem I.1 (10 pts) A movie camera with a single lens of focal length 75 mm takes a picture of a 180-cm-high person standing 27 m away. What is the height of the image of the person on the film? You may assume that because 27 m is >> 75 mm, that the distance between the film and the lens is 75 mm.

$f = 75\times10^{-3}\,m$

$h = 180\times10^{-2}\,m$

$p = 27\,m$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{i}$

$\frac{1}{i} = \frac{1}{f} - \frac{1}{p}$

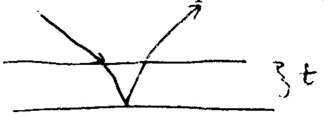
$i = \frac{fp}{p-f} = \frac{(75\times10^{-3}m)(27m)}{27m - 75\times10^{-3}m} = 0.0752\,m = 75.2\,mm$

$m = \frac{-i}{p} = \frac{h'}{h}$

$\frac{-75.2\times10^{-3}m}{27\,m} = -2.78\times10^{-3}$

$h' = (2.78\times10^{-3})(180\,cm) = 0.5\,cm = 5\,mm$

Problem I.2 (10 pts): A piece of plastic (n = 1.4) of thickness t = 0.3 μm is illuminated with light of wavelength 500 nm. What is the phase change attributable to the path length in the plastic?



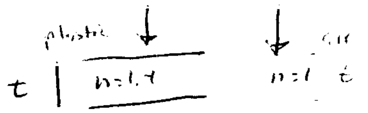
$\Delta\Phi = \frac{2t}{\lambda_n}\times 2\pi$

$= \frac{2tn}{\lambda}\times 2\pi$

$= 3.36\pi\ rad$

$\Delta\Phi = 10.56\ rad$

or



phase difference => (# λ's in plastic − # λ's in air) × 2π

$\lambda_n = \frac{\lambda}{n}$ $\left(\frac{t}{\lambda_n} - \frac{t}{\lambda}\right)\times 2\pi = \left(\frac{t}{\lambda}(n-1)\right)\times 2\pi$

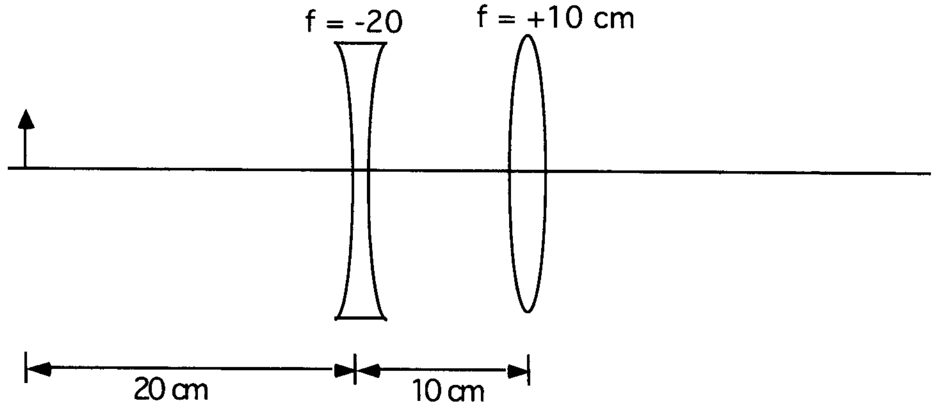
$= 0.48\pi\ rad$

$= 1.51\ rad$

Morning

Name (1 pt): KEY

Problem II.2 (25 pts): Consider the object and two lenses shown in the figure. If the object is 2 cm high and erect,



(a) Where is the image of the first lens relative to the location of the first lens?

$$\frac{1}{p_1}+\frac{1}{i_1}=\frac{1}{f_1}$$

$$\frac{1}{i_1}=\frac{1}{f_1}-\frac{1}{p_1}=\frac{1}{-20}-\frac{1}{20}=-\frac{2}{20}=-\frac{1}{10}=-0.1$$ so $i=-10\,cm$

left of 1st lens

(b) What is the location of the final image?

$$\frac{1}{i_2}=\frac{1}{f_2}-\frac{1}{p_2}=\frac{1}{10}-\frac{1}{20}=\frac{1}{20}$$ so $i_2=20\,cm$

Right of 2nd lens

(c) What is the size of the final image and is it erect or inverted?

$$m_1=-\frac{i_1}{p_1}=+\frac{10}{20}=\frac{1}{2}$$

$$M=m_1m_2=\left(\frac{1}{2}\right)(-1)=-\frac{1}{2}$$

$$m_2=-\frac{i_2}{p_2}=-\frac{20}{20}=-1$$

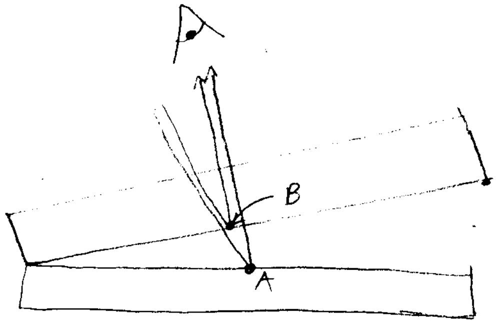
$$h=Mh=\left(-\frac{1}{2}\right)(2)=-1\,cm$$

inverted

(d) Is the final image real or virtual?

Real

Midterm II 3:30pm Lecture
Problem 3 8:30am Recitation



$\lambda = 480\, nm$

$\frac{\lambda}{2}$ phase shift at A

no phase shift at B

Bright fringe ⇒ path length difference
± phase shift
= intiger × λ

call thickness at i^{th} fringe t_i

$(m_i - \frac{1}{2})\lambda = 2t_i \Rightarrow m_i\lambda - \frac{1}{2}\lambda = 2t_i$

$\Rightarrow m_i\lambda = 2t_i + \frac{1}{2}\lambda \Rightarrow m_i = \frac{2t_i}{\lambda} + \frac{1}{2}$

$\Rightarrow \Delta m \equiv m_{16} - m_6 = \left(\frac{2t_{16}}{\lambda} + \frac{1}{2}\right) - \left(\frac{2t_6}{\lambda} + \frac{1}{2}\right)$

$= \frac{2}{\lambda}(t_{16} - t_6) \equiv \frac{2}{\lambda}\Delta t$

$\Rightarrow \Delta t = \frac{\lambda}{2}\Delta m = \frac{480\, nm}{2} \cdot 10 = \boxed{2400\, nm = 2.4\, \mu m}$

Name (1 pt):________________________

Problem IV (25 pts):

In a double slit experiment the wave length of the light λ is 500 nm, the slit separation is 17 μm, and the slit width is 4 μm. In this problem, you will need to consider both the diffraction of the light through each slit and the interference of the light from the two slits.

$d = 17\,\mu m$
$a = 4\,\mu m$
$\lambda = 500\,nm$

(a) At what angle (in radians) is the first minima in the diffraction pattern?

$a \sin\theta = m\lambda$

$m = 1$

$a \sin\theta = \lambda$

$\sin\theta = \frac{\lambda}{a} = \frac{500\,nm}{4000\,nm} = 0.125$ rad

$\theta = 0.125$ rad small angle!

(b) How many interference maxima are located within the central maximum of the diffraction pattern?

$d \sin\theta = m\lambda$ solve for m with $\theta = 0.125$ rad

$m = \frac{d \sin(0.125\,rad)}{\lambda} = \frac{17000\,nm \times 0.125}{500\,nm} = 4.25$

So, on one side there are 4 bright fringes, there are 4 on the other side as well and there is a central max so

$4 + 4 + 1 = 9$ maxima

(c) What is the angular location in radians of the 5th side maxima in the interference pattern?

$d \sin\theta = m\lambda$ $m = 5$

$\sin\theta = \frac{5\lambda}{d}$

$\theta = \frac{5\lambda}{d} = \frac{5 \times 500\,nm}{17000\,nm} = 0.147$ rad

(d) What is the intensity of this maximum relative to that of the central maximum?

$I = I_m (\cos\beta)^2 \left(\frac{\sin\alpha}{\alpha}\right)^2$ $\theta = 0.147$ rad

$\beta = \frac{\pi d}{\lambda}\sin\theta$ } from above $\alpha = \frac{\pi a}{\lambda}\sin\theta$

$= \frac{\pi d}{\lambda} \times \frac{5\lambda}{d}$ $\alpha = \frac{\pi \times 4000\,nm}{500\,nm}\sin(0.147\,rad)$

$\beta = 5\pi$ $\alpha = 3.68$ rad

$\frac{I}{I_m} = \left(\frac{\sin\alpha}{\alpha}\right)^2 = 0.02$