# Physics 116b Test 4 November 12, 2008

Name: Key

This is a 75 minute, closed book examination. Put answers in the boxes provided (if any). If numerical answers are needed, you must include units. Any work needed to justify the answer must be shown in the space provided, or as indicated on a separate piece of paper or elsewhere on the test. A correct answer without the necessary justifying work may not receive any credit. **DO NOT** tear the formula sheet off the back of the exam.

Total points for each problem will appear in the table below and in ( ) beside each problem number. Do what is easiest first. AVOID glancing at anyone else's paper during the exam. No means of communication between other students or outside parties is allowed. **The honor code is in effect.**

You must do all the problems on this test.

| Problem | Description | Max Score | Score |
|---|---|---|---|
| 1 | Short Ans | 20 | |
| 2 | EM waves, Polarization | 10 | |
| 3 | Lenses, Mirrors | 10 | |
| Total | | 40 | |

# 1) Short Answer (Show Your Work!)

a) One of the reasons diamond is so desirable is because the high index of refraction of diamond causes lots of internal reflections. The diamond appears to sparkle! If the critical angle for diamond is about 24 degrees, what is the index of refraction of diamond? (3 pts)

I) 23.8
II) 2.45
III) 1.09
IV) 0.914
V) 0.407

$\theta_c = \sin^{-1}\frac{1}{n_c}$

or $\sin\theta_c = \frac{1}{n_c}$

$n_c = \frac{1}{\sin 24^\circ} = 2.46$

b) If you built 2 identically shaped converging lenses, but you made one out of flint glass (n=1.66) and you made the other out of crown glass (n=1.52), which one has the longest focal length? (explain) (2 pts)

longest means light bent less
n less means less bent, same geometry
n=1.52 has bigger f
also $f \propto \left(\frac{1}{n-1}\right)$

c) A diffraction grating has 2000 lines/cm. Light of wavelength 560nm is incident perpendicular to the plane of the grating. At what angle is the 2nd order maxima found? (3 pts)

I) 0.128 degrees
II) 6.4 degrees
III) 12.9 degrees
IV) 16.2 degrees
V) 34.1 degrees

$d\sin\theta = m\lambda \quad m=2$

$d = 1\text{cm}/2000$

$\theta = \sin^{-1}\left(\frac{2\,(560\times10^{-9}\text{m})}{.01\text{m}/2000}\right)$

$= 12.94^\circ$

# 1) Short Answer cont'd (Show Your Work!)

d) What is the separation between 2 slits if the first minima is found at an angle of 2.3 degrees when light is incident normally on 2 slits and a diffraction / interference pattern forms? Assume the wavelength of the laser you used was 632.8 nm and that the actual width of each slit is irrelevant. (3 pts)

I) 0.32 μm
II) 7.9 μm
III) 15.8 μm
IV) 23.7 μm
V) 31.5 μm

2 slit $d\sin\theta = m\lambda$ maxima

$= (m+\frac{1}{2})\lambda$ minima

1st minima @ $m=0$

$$d = \frac{\frac{1}{2}\lambda}{\sin\theta} = \frac{\frac{1}{2}(632.8\times10^{-9}\,m)}{\sin(2.3^\circ)}$$

$$= 7.88\times10^{-6}\,m$$

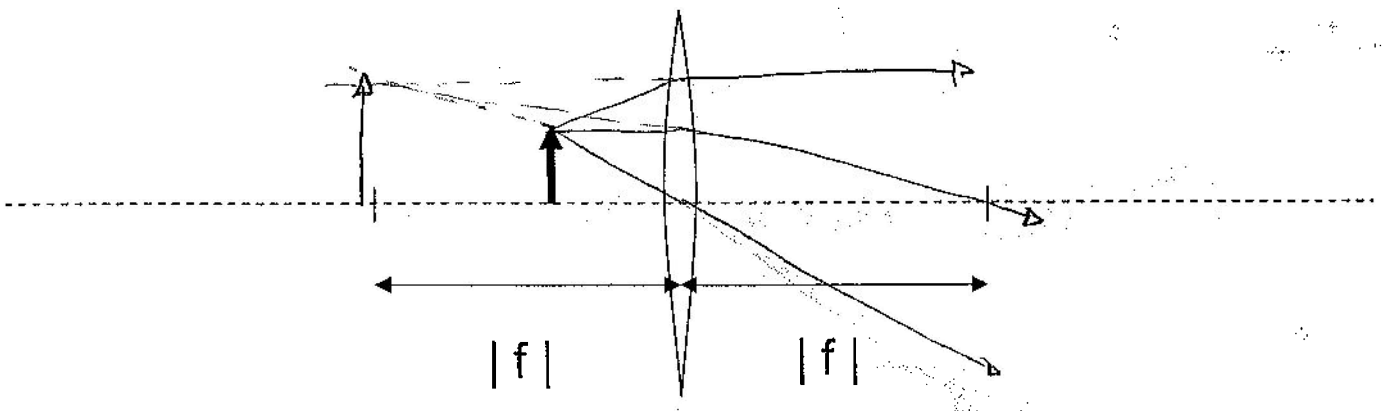
e) About how thick does the wall of a soap bubble need to be in order for you to see a bright spot if 550 nm light is incident normally on the soap bubble? (Assume the soap bubble is mostly water with n=1.33) (3 pts)

I) 103 nm
II) 138 nm
III) 206 nm
IV) 275 nm
V) 414 nm

soap bubble, get a single reflection from greater n so $\Delta\phi = \frac{2t}{\lambda/n}2\pi - \pi = 0$ for 1st maxima

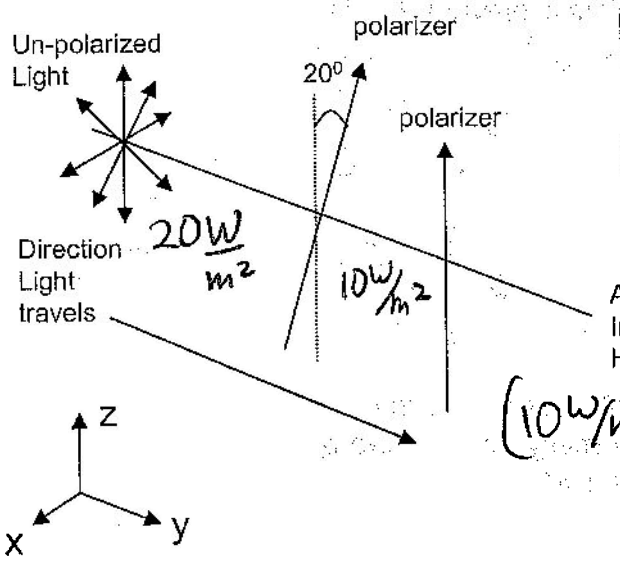
$$t = \frac{\lambda}{4n} = \frac{550nm}{4(1.33)} = 103nm$$

f) Find the image for the object in air and plastic lens shown below using graphical methods (ray tracing) (4 pts.) Is the image real or virtual? (2 pts)



## 2) Polarization (Show your work!)

Un-polarized light is incident upon 2 polarizers. These polarizers have their polarizing axes oriented at 20 degrees relative to each other (as shown below). If the incident light has an average intensity of I = 20 W/m$^2$, what is the average intensity of the transmitted light? (Light is moving in the y direction as shown.)




$(10\,W/m^2)\cos^2 20^\circ = 8.83\,\frac{W}{m^2}$

Transmitted I = $8.83\,\frac{W}{m^2}$ (5 pts)

Describe (with an equation for a traveling wave) the time and position dependent Electric field portion of the transmitted light as a single traveling wave. (Assume the wave travels at a speed of c and has a wavelength of 500nm.) (5pts)

$$\vec{E}(position, time) = (81.6\,N/C)\,\hat{z}\,\sin\left(1.26\times10^{7}\,\frac{}{m}\,y - 3.77\times10^{15}\,\frac{}{s}\,t\right)$$

1) traveling in +y direction, $E_{max}$ in $\hat{z}$

2) $k = \frac{2\pi}{\lambda} = \frac{2\pi}{500\times10^{-9}\,m} = 1.26\times10^{7}/m$

3) $\omega = 2\pi f = 2\pi c/\lambda = kc$

$= (1.26\times10^{7}/m)(3.0\times10^{8}\,m/s) = 3.77\times10^{15}/s$

4) $S_{av} = I_{av} = \frac{E_{max} B_{max}}{2\mu_0}$, $B = \frac{E}{c}$

$I_{av} = \frac{E_{max}^2}{2\mu_0 c}$, $E_{max} = \sqrt{I_{avg} 2\mu_0 c}$

$E_{max} = \sqrt{8.83\,\frac{W}{m^2}\,2\,(4\pi\times10^{-7}\,(\frac{N}{A^2})\,\frac{m}{A}\,3.0\times10^{8}\,m/s)}$

$= 81.6\,N/C$

## 3) Lenses (Show your work!)

An overhead projector is being made with a diverging and a converging lens as shown in the figure below. The |focal length| of the converging lens is |f|= 15 cm, and the |focal length| of the diverging lens is |f|= 20 cm. If the distance from the slide to the first lens is 30cm, and the distance from the second lens to the screen is 200cm, what must the separation, x, between the 2 lenses be in order to make this design work? (5 pts.) What is the overall magnification of the system? (5 pts) (Do not change the 30 cm or the 200 cm, just x!)

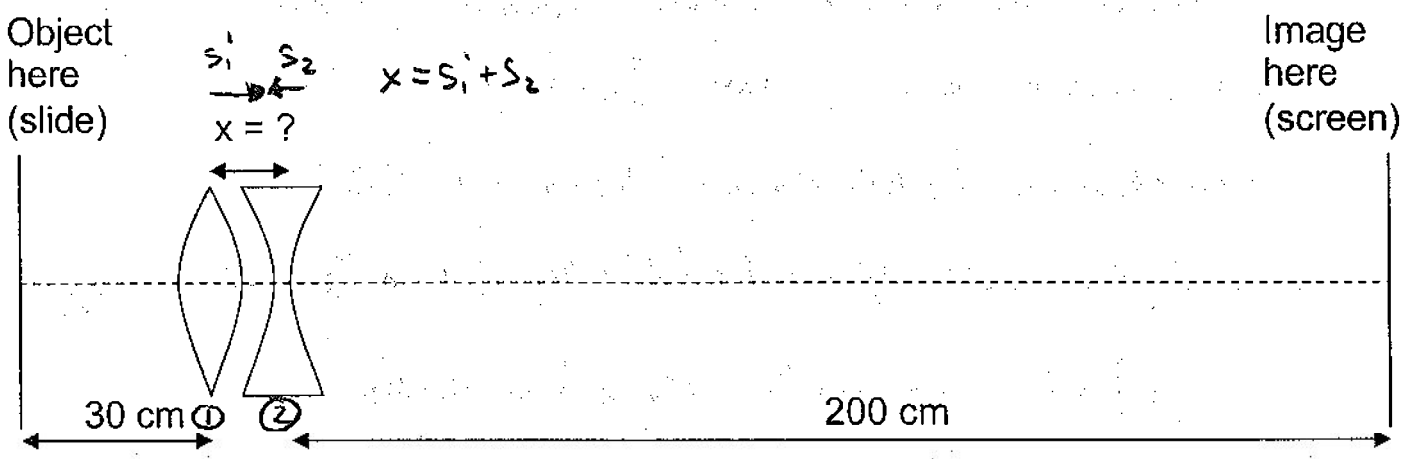



Image from ①

$\frac{1}{30cm} + \frac{1}{s_1'} = \frac{1}{15cm}$

$s_1' = 30cm$ (to right of ①)

Object needed by ②

$\frac{1}{s_2} + \frac{1}{200cm} = \frac{-1}{20cm}$

$\frac{1}{s_2} = \frac{-1}{20cm} - \frac{1}{200cm} = \frac{-11}{200cm}$

$s_2 = -18.18cm$ (also, to right of ②)

distance between ① & ② $= s_1' + s_2$

$= 11.82cm$

can also just reason this out

$x = 11.82cm$

Overall M = $-11.0$

$M_{tot} = M_① \cdot M_②$

$= \left(-\frac{30cm}{30cm}\right)\left(-\frac{200cm}{-18.18cm}\right) = -11.0$