ANSWER KEY

VS203B midterm exam version A

name: _____

No partial Grades

VS203B
Midterm Exam Version A
Dr. Roorda
Date: May 8, 2008
Permitted aids: pens/pencils, eraser, ruler, calculator
This exam is out of 40 points

1. (1 point) If the separation between two slits on an aperture is 0.5 mm, then how far away would you have to place a screen to get the separation between the peaks in the interference pattern for 532 nm light to be exactly 1 cm?

C
a) 0.053 m
b) 0.106 m
c) 9.40 m
d) 18.80 m

separation between peak $y = \frac{\lambda s}{a} \Rightarrow s = \frac{ay}{\lambda}$

$= \frac{(.5\times10^{-3})(1\times10^{-2})}{532\times10^{-9}} = 9.398$

2. (1 point) The space shuttle slowly approaches the Space station. At what distance can you no longer perceive them as two distinct objects? (Assume the following: distance form Earth = 350 km, primary wavelength = 550 nm, no blur from aberrations or atmospheric turbulence, space shuttle and space station are effectively point sources, pupil size = 5 mm)

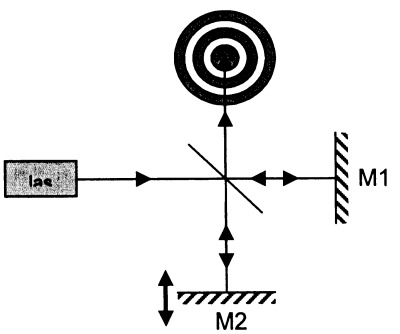
b
a) 4.7 m
b) 47 m
c) 470 m
d) 4.7 km

$y = \frac{1.22\lambda s}{a} = \frac{(1.22)(550\times10^{-9})(350\times10^{3})}{5\times10^{-3}}$

$= 46.97$

3. (1 point) In a Michelson interferometer (shown to the right), what is the minimum distance you would have to displace mirror M2 to change the intensity of the central peak in the interference pattern from a maximum to a minimum?

a
a) 1/4 wavelength
b) 1/2 wavelength
c) 1 wavelength
d) 2 wavelengths



4. (1 point) If a spherical lens with 10 D of power in air has a positive spherical aberration of 1 D at the edge of it lens, what is the focal length of the lens for marginal rays (rays entering at the edge of the lens)?.

C
a) 0.09 cm
b) 1.10 cm
c) 9.09 cm
d) 11.11 cm

power @ edge = 11D $f = \frac{1}{.11} = 9.09$ cm

5. (1 point) In a diffraction-limited optical system, how will an increase in pupil size affect the Airy disc image of a point object?

d
a) The size of the Airy disc will increase proportionately with pupil diameter.
b) The size of the Airy disc will increase slightly.
c) The Airy disc will get brighter but will not change in size.
d) The Airy disc will get brighter and smaller.

6. (1 point) What is the optimal thickness for a magnesium fluoride (index of refraction = 1.38) coating on glass (n=1.5) to reduce reflections of 650nm infrared light?

a
a) 117.8 nm
b) 162.5 nm
c) 235.5 nm
d) 325 nm

$t = \frac{1}{4}\frac{\lambda}{n_c} =$

ANSWER KEY

VS203B midterm exam version B

name: _____

VS203B
Midterm Exam Version B
Dr. Roorda
Date: May 8, 2008
Permitted aids: pens/pencils, eraser, ruler, calculator
This exam is out of 40 points

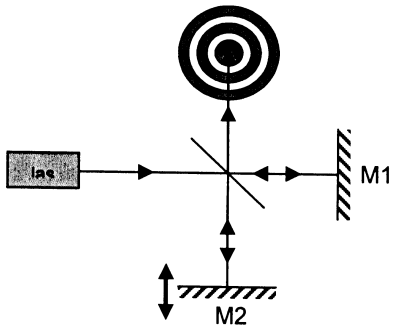
* no partial grade on multiple choice.

1. (1 point) The space shuttle slowly approaches the Space station. At what distance can you no longer perceive them as two distinct objects? (Assume the following: distance form Earth = 350 km, primary wavelength = 550 nm, no blur from aberrations or atmospheric turbulence, space shuttle and space station are effectively point sources, pupil size = 5 mm)

a) 4.7 km
b) 470 m
c) 47 m
d) 4.7 m

c

2. (1 point) In a Michelson interferometer (shown to the right), what is the minimum distance you would have to displace mirror M2 to change the intensity of the central peak in the interference pattern from a maximum to a minimum?



a) 2 wavelengths
b) 1 wavelength
c) 1/2 wavelength
d) 1/4 wavelength

d

3. (1 point) If a spherical lens with 10 D of power in air has a positive spherical aberration of 1 D at the edge of it lens, what is the focal length of the lens for marginal rays (rays entering at the edge of the lens)?.

a) 11.11 cm
b) 9.09 cm
c) 1.10 cm
d) 0.09 cm

b

4. (1 point) If the separation between two slits on an aperture is 0.5 mm, then how far away would you have to place a screen to get the separation between the peaks in the interference pattern for 532 nm light to be exactly 1 cm?

a) 18.80 m
b) 9.40 m
c) 0.106 m
d) 0.053 m

b

5. (1 point) In a diffraction-limited optical system, how will an increase in pupil size affect the Airy disc image of a point object?

a) The Airy disc will get brighter and smaller.
b) The Airy disc will get brighter but will not change in size.
c) The size of the Airy disc will increase slightly.
d) The size of the Airy disc will increase proportionately with pupil diameter.

a

6. (1 point) What is the optimal thickness for a magnesium fluoride (index of refraction = 1.38) coating on glass (n=1.5) to reduce reflections of 650nm infrared light?

a) 325 nm
b) 235.5 nm
c) 162.5 nm
d) 117.8 nm

d

Problems

7. (4 points) Consider a thin film coating of thickness 200 nm (n = 1.30) on glass (n= 1.5). Select the wavelengths for which reflections are maximized (select 2 out of the 8 below) and the wavelengths for which reflections are minimized (select 2 out of the 8 below). Circle the correct answer (*you must select only four options*)

λ =200 nm	reflection **max** or **min**
λ =260 nm	reflection **max** or **min**
λ =267 nm	reflection **max** or **min**
λ =347 nm	reflection **max** or **min**
λ =400 nm	reflection **max** or **min**
λ =520 nm	reflection **max** or **min**
λ =800 nm	reflection **max** or **min**
λ =1040 nm	reflection **max** or **min**

$$t_{dest} = \frac{(m+1/2)}{2}\frac{\lambda}{n_c}$$

$$\lambda = \frac{2tn_c}{(m+1/2)} = \frac{520}{(m+1/2)}$$

$$\lambda_{m=0} = \frac{520}{.5} = 1040$$

$$\lambda_{m=1} = 346.67$$

$$t_{const} = \frac{m}{2}\frac{\lambda}{n_c}$$

$$\lambda = \frac{2tn_c}{m} = \frac{520}{m}$$

$$\lambda_{m=1} = 520$$

$$\lambda_{m=2} = 260$$

partial grades:
- subtract (1) if max & min are reversed
- subtract (2) if n_c is not considered

---

8. (6 points total) Two mutually coherent waves traveling in air each have a frequency of 5×10^{14} Hz. The first wave has an amplitude of 5 units and the second wave has an amplitude of 10 units. The second wave is phase delayed from the first wave by ¼ of a wave.

grading: all are worth (0.5) pts.

a) (4 points) Write the two wave equations (make sure units are in radians):

E_1 = 5 sin(10,471,975 x - 3.1416×10^{15} t + 0);

E_2 = 10 sin(10,471,975 x - 3.1416×10^{15} t + $\pi/2$);

b) (2 points) What is the resultant intensity of these two combined waves?

$I = A_1^2 + A_2^2 + 2A_1A_2\cos(\phi_1 - \phi_2)$ ← (1) pt for eqn

$= 5^2 + 10^2 + 100\cos(\pi/2)$

$= 0$

$= 125$ ← (1) pt for correct answer.

$\omega = 2\pi f$

$\frac{\omega}{k} = v \quad k = \frac{\omega}{v}$

name: _____

9. (8 points total) Your patient's myopia continues to progress but he is too cheap to purchase a new pair of glasses every year. As a solution, you suggest that he tilt his glasses downward to increase the spectacle power.

a) (4 points) How much does he have to tilt his pair of -8D spectacles (n = 1.5) downward to get a spherical equivalent power of -8.5 D?

$$SE = \frac{P\left[1+\frac{4\phi^2}{3}\right] + P\left[1+\frac{\phi^2}{3}\right]}{2}$$

$$-8.5 = \frac{-8\left(2+\frac{5\phi^2}{3}\right)}{2}$$

$$2\left(\frac{-8.5}{-8}\right) - 2 = \frac{5\phi^2}{3}$$

$$\phi = \sqrt{\frac{3}{5}\left(2\left(\frac{-8.5}{-8}\right)-2\right)}$$

$$= .274 \text{ rad.}$$

$$= 15.69 \text{ deg}$$

b) (2 points) What is the astigmatism in this case?

$$RA = P\phi^2 = -8(.274^2) = .6D$$

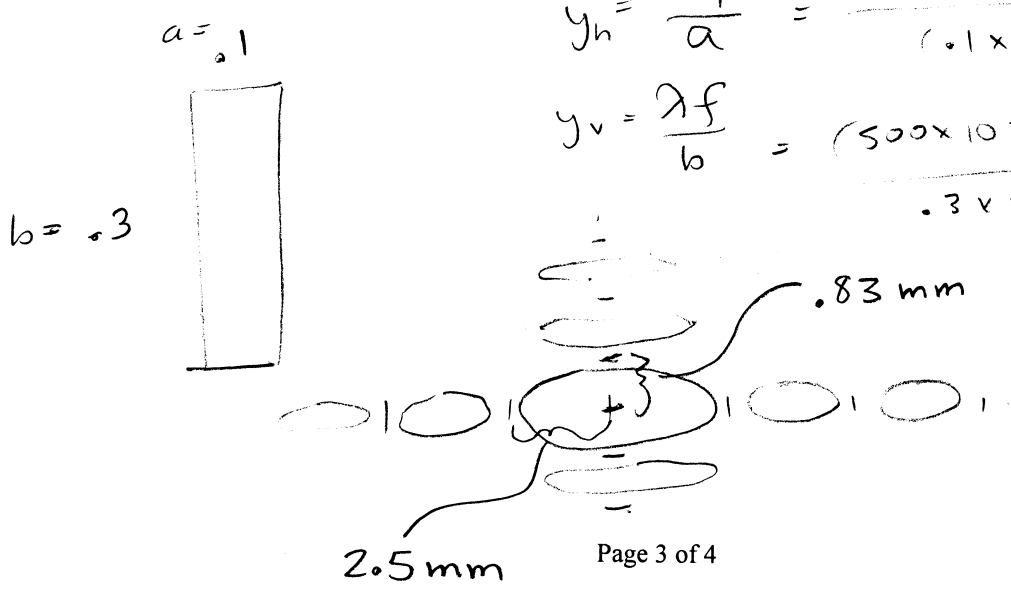
c) (1 point) Which axis has the higher power (in magnitude)? vertical

d) (1 point) What axis is the saggital axis? horizontal

10. (5 points total) Consider a slit aperture that is 0.1 mm wide and 0.3 mm tall placed against a lens with a 50 cm focal length. What is the separation in mm between the peak and the first minimum in the horizontal and vertical directions for a diffraction pattern generated through this aperture with 500 nm light?

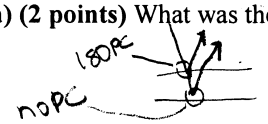
$$y_h = \frac{\lambda f}{a} = \frac{(500\times10^{-9})(.5)}{(.1\times10^{-3})} = .0025\text{m}$$ (horizontal)

$$y_v = \frac{\lambda f}{b} = \frac{(500\times10^{-9})(.5)}{.3\times10^{-3}} = .00083$$



11. (11 points total) A newly graduated OD from the University of Waterloo in his first job at Lens Crafters thought he would make his millions by selling less-expensive anti-reflection coatings that use an index of refraction that is higher than that of the glass (rather than a conventional ARC which has a lower refractive index than the spectacle index). He used a coating material with an index of refraction of 1.9 on a glass spectacle of index 1.5 and sold lenses with coatings designed to reduce reflections for 550 nm light.

a) (2 points) What was the thickness of the coating?

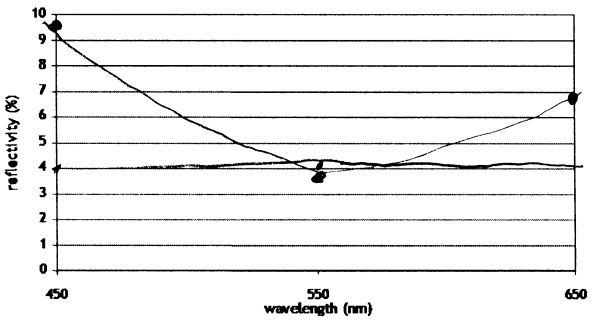


$\therefore t_{dest} = \frac{m}{2}\frac{\lambda}{n_c}$ for $m=1$ $t = \frac{1}{2}\frac{\lambda}{n_c} = \frac{1}{2}\left(\frac{550\times10^{-9}}{1.9}\right) = 145\text{nm}$

A group of patients filed a class-action lawsuit against the OD, claiming that the antireflection coatings were not effective and were not worth the money. They hired you to support their case and testify in court.

b) (6 points) Plot the reflectivity of the surface at 450, 550 and 650 with the coating (assume that the index of refraction of the glass and coating is constant for all wavelengths).

$r_1 = \frac{1.9-1}{1.9+1} = .310$, $r_2 = \frac{1.9-1.5}{1.9+1.5} = \frac{.4}{3.4} = .118$



for 450, phase delay is $2\pi\left(\frac{2tn_c}{\lambda}\right)$

$= \frac{2\pi\,550}{\lambda} = \frac{2\pi\,550}{450} = 7.679$

for 550, $\frac{2\pi\,550}{550} = 2\pi = 6.283$

for 650, $\frac{2\pi\,550}{650} = 5.317$

there is also a phase difference by reflection of ½ wave, or 1π

for 450 $I = (.310)^2 + (.118)^2 + 2(.310)(.118)\cos(7.679+\pi)$

$= 9.73\%$

for 550 $I = (.310)^2 + (.118)^2 + 2(.310)(.118)\cos(6.283+\pi)$

$= 3.68\%$

for 650 $I = (.310)^2 + (.118)^2 + 2(.310)(.118)\cos(5.317+\pi)$

$= 6.8\%$

c) (2 points) On the same graph, plot the reflectivity of the glass surface (ie no coating) at 450, 550 and 650 (*hint: based on the assumption that the index of refraction is the same for all wavelengths, the reflectance will also be the same for all wavelengths*)

$R = \left(\frac{1.5-1}{1.5+1}\right)^2 = 4\%$

d) (1 point) Will the patients win the case (Y or N)?