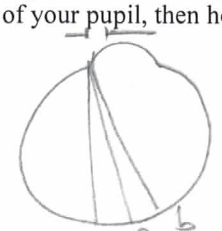
**VS203B**
**Midterm Exam Version A**
Dr. Roorda
Date: April 26, 2011
Permitted aids: pens/pencils, eraser, ruler, calculator
This exam is out of **37** points

**1. (1 point)** Which one of the following statements is **not correct**? The main factors that limit the performance of an anti-reflection coating (ARC) are….

a) …there are no suitable coating materials with an index of refraction that exactly meets the amplitude requirement for total destructive interference.
b) …the anti-reflection coating can only be optimized for one wavelength.
c) …the wavelengths for which the ARC is optimized only applies for one angle of reflection.
d) …the thickness of the coating is variable and so some parts of the ARC will be more effective than others.

**2. (1 point)** If you viewed a vertical array of three spots of light that were red (650 nm), greenish (550 nm) and blue (450 nm) through a pinhole that was displaced toward the left edge of your pupil, then how would the spots appear?

a) blue on the left, then green, then red
b) red on left, then green, then blue
c) green on the left, then red, then blue
d) no relative displacements




· But perceived image is reversed, so subject will see blue, then green, then red

**3. (1 point)** How much does one have to tilt a pair of 5D spectacles to generate 0.5 D of astigmatism?

a) 18.12 deg
b) 5.72 deg
c) 4.27 deg
d) 0.316 deg

$RA = P\phi^2 \Rightarrow \phi = \sqrt{\frac{RA}{P}} = \sqrt{\frac{0.5}{5}} = 0.316 \text{ rad} = 18.12 \text{ deg}$

**4. (1 point)** If the lens above is tilted downward with respect to the line of sight, then which axis is the sagittal axis?

a) vertical axis
b) horizontal axis

**5. (1 point)** Which one of the following statements is **not correct**?

a) In an optical system with centered lenses and spherical surfaces, spherical aberration is the only aberration that is present when imaging objects that are on axis. ✓
b) In an optical system with astigmatism, the tangential line focus is always perpendicular to the tangential axis. ✓
c) Negative spherical aberration is an aberration of an optical system where the power is higher in the center than in the periphery. ✓
d) For off-axis objects, radial astigmatism always causes the tangential focus to lie in front of the image plane and the sagittal focus to land beyond it.

**6. (1 point)** What is the thickness of an $MgF_2$ (n=1.38) anti-reflection coating that will minimize reflection of 450 nm light from a polycarbonate lens?

a) 56.25 nm
b) 81.52 nm
c) 112.50 nm
d) 163.04 nm

$t_{dest} = \frac{1}{4}\frac{\lambda}{n_c} = \frac{1}{4}\frac{450}{1.38} = 81.52 \text{ nm}$

**7. (1 point)** If you added a polycarbonate lens (refractive efficiency of 30.0) to a 10D plastic lens (refractive efficiency of 58) to make it an achromatic lens, then what would the resultant power of the achromat be?

a) 19.33 D
(b) 4.83 D
c) -5.17D
d) -9.33D

$\frac{P_1}{30} + \frac{P_2}{58} = 0 \quad P_1 = -30\left(\frac{10}{58}\right) = -\frac{300}{58} = -5.17\,D$

$-5.17 + 10 = \underline{4.83\,D}$

**8. (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) 0.053 m
b) 0.106 m
(c) 9.40 m
d) 18.80 m

$x = \frac{m\lambda t}{h} \Rightarrow t = \frac{hx}{m\lambda}$

for m=1 (distance to 1st peak)

$t = \frac{(.5\times10^{-3})(1\times10^{-2})}{532\times10^{-9}} = \underline{9.4\ m}$

**9. (5 points total)** Two mutually coherent light waves traveling in glass (n=1.5) each have a frequency of $5 \times 10^{14}$ Hz. The second wave is 45 degrees out of phase with respect to the first wave.

**a) (3 points)** Write the two wave equations (make sure your units are in radians):

$k = \frac{2\pi}{\lambda}, \quad V = \frac{c}{1.5}$

$E_1$ = A sin ( 15,707,963 x - $3.1416\times10^{15}$ t + 0 );

$E_2$ = A sin ( 15,707,963 x - $3.1416\times10^{15}$ t + $\frac{\pi}{4}$ );

$\lambda = \frac{V}{f} = \frac{2\times10^{-8}}{5\times10^{-14}} = 400\times10^{-9}$

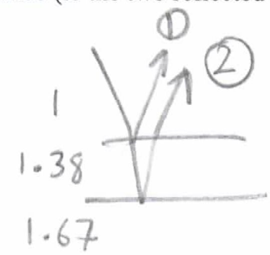
**b) (2 points)** If the two waves have the same amplitudes and a combined intensity of 16 (arbitrary units) then what is the amplitude?

$I_{coh} = A^2 + A^2 + 2A^2 \cos 45$

$16 = A^2(2 + 2\cos 45)$

$\Rightarrow A = \underline{2.16}$

**10. (13 points total)** You are trying to make an anti-reflection coating on a plastic lens (n=1.67) for 550 nm using magnesium fluoride (n = 1.38), but you accidentally make the thickness generate *constructive* rather than destructive interference (ie the two reflected waves are in phase, rather than 180 deg out of phase.




a) **(2 points)** What thickness did you make the coating?

$t_{const} = \frac{1}{2}\frac{550}{1.38} = 199.27$ nm

b) **(4 points)** What is the percentage of reflected intensity of the surface for 550 nm light?

$r_1 = \frac{.38}{2.38} = 0.16$, $r_2 = \frac{.29}{3.05} = .095$

in phase

$I_{coh} = (.16)^2 + (.095)^2 + 2(.16)(.095)\cos(0)$

$= .034625 + .0304$

$= .065 \Rightarrow 6.5\%$

c) **(6 points)** Compute the percentage of reflected intensity for 400 and 700 and plot them on the chart below?

for 400nm light $\Delta waves = \frac{(1.38)(2)t}{400} = 1.375 = 494.95$ deg

for 700nm light $\Delta waves = \frac{(1.38)(2)(t)}{700} = .786 = 282.85$ deg

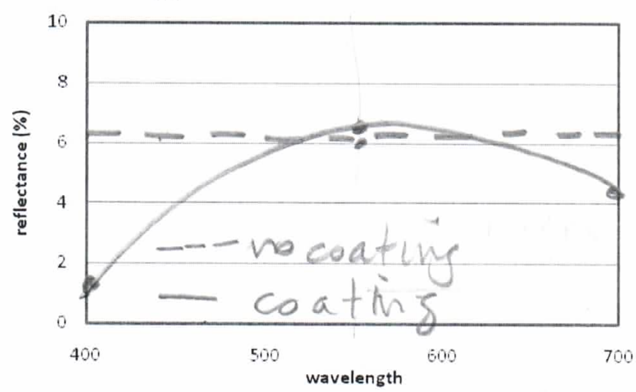
400 $I_{coh} = .034625 + .0304\cos(494.95) = .0131 = 1.31\%$

700 $I_{coh} = .034625 + .0304\cos(282.85) = .041 = 4.1\%$

d) **(1 point)** On the same chart, plot the reflectance of the plastic lens without the coating (assume the index of refraction is the same for all wavelengths)

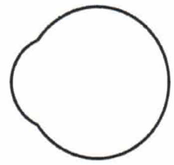
$R = \left[\frac{.67}{2.67}\right]^2 = .0629$

$= 6.3\%$



**11. (7 points total)** The following table shows data on the indices of refraction with wavelength of a plastic material. A block of this plastic is molded into a simple reduced model eye, which has a radius of curvature of its single refracting surface of 5.5 mm.

| Line | wavelength, λ | index, n |
|---|---|---|
| C-line | 656 nm | 1.55 |
| D-line | 589 nm | 1.60 |
| F-line | 486 nm | 1.67 |



a) **(3 points)** What is the power of the reduced eye for the…

$P = \frac{n' - 1}{r}$

C-line? 100

D-line? 109.1

F-line? 121.8

b) **(1 point)** If the eye is emmetropic for the D-line, then what is its axial length?

$f' = \frac{1.60}{109.1} = .01467 = 14.67\text{ mm}$

c) **(1 point)** What is the chromatic aberration of the reduced eye between the F and the C line in diopters?

21.8 D

d) **(1 point)** Is this positive or negative chromatic aberration?

positive

e) **(1 point)** What is the refractive efficiency of this material?

$\frac{n_D - 1}{n_F - n_C} = 5$

**12. (4 points total)** Consider Young's double slit experiment with infinitely small slit apertures. The intensity pattern contains sinusoidal fringes and the minima are black. The ratio between the peak intensity and the minimum intensity is therefore infinite. Now, consider a situation where one of the slits has a filter in front of it that blocks 80% of the light (ie 20% of the intensity is transmitted). What will be the ratio between the peak and minimum intensity?

$A_2^2 = .8 A_1^2$ $A_1^2 = 0.2 A_2^2$

$A_2 = .894 A_1$ $A_1 = .447 A_2$

in phase

@ peak

$I_{coh} = A_1^2 + (.447 A_1)^2 + 2(A_1)(.447)A_1 \cos(0)$

$= A_1^2(1 + .2 + 0.894)$

$= 2.094 A_1^2$

180° out of phase

@ min

$I_{coh} = A_1^2(1 + .2 + 0.894\cos(180))$

$= .3058 A_1^2$

$\text{ratio} = \frac{2.094 A_1^2}{0.3058 A_1^2}$

$= 6.844$