ANSWER KEY

name: _____

VS203B
Midterm Exam A
Dr. Roorda
Date: April 24, 2007
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 0.1 mm, the wavelength of the light incident on the slits is 550 nm, and the distance to the screen is 5 m, then what is the separation between peaks in the interference pattern?

a) 5.50 cm
b) 2.75 cm
c) 1.10 cm
d) 0.55 cm

b

$y = \frac{m\lambda s}{a} = \frac{(1)(550\times10^{-9})(5)}{0.1\times10^{-3}} = 0.0275\,m = 2.75\,cm$

2. (1 point) How much does one have to tilt a pair of 5D spectacles to generate 0.25 D of astigmatism.

a) 12.8 deg.
b) 4.46 deg
c) 4.27 deg
d) 2.23 deg

a

$RA = P\phi^2 \quad \phi^2 = \frac{0.25}{5} \Rightarrow \phi = 0.223\ rad = 12.8\ deg.$

3. (1 point) If the lenses are tilted downward, which axis has the higher power?

a) horizontal axis
b) vertical axis

b

4. (1 point) What is the correct term to define the axis with the higher power?

a) tangential axis
b) sagittal axis

a

5. (1 point) What is the optimal thickness for a magnesium fluoride (index of refraction = 1.38) coating in glass (n=1.5) to reduce reflections of 800nm infrared light?

a) 579.7 nm
b) 400 nm
c) 200 nm
d) 144.9 nm

d

$t_{best} = \frac{1}{4}\frac{\lambda}{n_c} = \frac{1}{4}\frac{800\times10^{-9}}{1.38} = 144.9\ nm$

6. (1 point) The mirror on one arm of a Michelson interferometer is attached to a aluminum rod. When the rod is heated, the aluminum expands, pushing the mirror forward. If the interference at the center of the bull's eye pattern for 632 nm light goes through 8 full light-dark cycles, then how much has the aluminum bar expanded?

a) 5.056 microns
b) 2.528 microns
c) 1.264 microns
d) 0.632 microns

b

1 light/dark cycle for every ½ wave of movement.
∴ for 8 cycles, we need to move mirror 4 waves
$4\times632\,nm = 2{,}528\,nm = 2.528$ microns

7. (1 point) Choose the correct definition

a) The sagittal plane contains the optical axis and is perpendicular to the tangential plane
b) The sagittal plane contains the chief ray and is perpendicular to the tangential plane

b

8. (1 point) Choose the correct definition. In an optical system with centered spherical surfaces.

a) spherical aberration does not exist off axis
b) coma does not exist on-axis

b

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11. (16 points total) Consider a reduced eye, 25 mm axial length with a single refracting surface and a nominal index of refraction for the 589 nm (D line) of 1.5. Yellow orange light at 589 nm light is properly focused onto the retina. Blue light at 486 nm (F-line) focuses at 24.5 mm and red light at 656 focuses at 25.2 mm.

a) (2 points) What is the nominal power of the eye?

$$F_D = \frac{n_D}{f_D} = \frac{1.5}{0.025} = 60D$$

b) (2 points) What is the radius of curvature (in mm) of the refracting surface?

$$F_D = \frac{n_D - 1}{r} = \frac{0.5}{r} \qquad r = \frac{0.5}{60} = 0.00833\,m = 8.3\,mm$$

c) (2 points) What is the index of refraction for blue light? (hint: use the equation $\frac{n'}{f'} = \frac{n'-1}{r}$)

$$\frac{n_F}{f'_F} = \frac{n_F - 1}{r} \Rightarrow n_F\left(\frac{1}{f'_F} - \frac{1}{r}\right) = \frac{1}{r} \qquad n_F = \frac{-\frac{1}{r}}{\left(\frac{1}{f'_F} - \frac{1}{r}\right)}$$

$$= \frac{-120}{40.816 - 120} = 1.515$$

d) (2 points) What is the power of the eye for blue light?

$$F_F = \frac{n_F}{f'_F} = \frac{1.515}{.0245} = 61.86D$$

e) (2 points) What is the index of refraction for red light? (see above hint from part c)

$$n_c = \frac{-\frac{1}{r}}{\left(\frac{1}{f'_c} - \frac{1}{r}\right)} = \frac{-120}{(39.68 - 120)} = 1.494$$

f) (2 points) What is the power of the eye for red light?

$$F_c = \frac{n_c}{f'_c} = \frac{1.494}{.0252} = 59.28D$$

g) (2 points) What is the chromatic aberration of the eye?

$$CA = F_F - F_c = 61.86 - 59.28 = 2.57D$$

h) (2 points) What is the refractive efficiency of the reduced eye media?

$$CA = \frac{F_D}{\nu} \Rightarrow \nu = \frac{F_D}{CA} = \frac{60}{2.57} = 23.33$$

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Problems

9. (6 points total) Consider two mutually coherent waves of wavelength 600 nm and each with an amplitude of 5 units. The intensity of the two waves combined is 15 units.

a) **(3 points)** What is the phase difference between the two waves in radians?

phase difference = ?

$$I_{coherent} = A_1^2 + A_2^2 + 2A_1A_2\cos(\rho_1 - \rho_2)$$

$$15 = 5^2 + 5^2 + 2(5)(5)\cos(\rho_1 - \rho_2)$$

$$15 = 50\left(1 + \cos(\rho_1 - \rho_2)\right)$$

$$\frac{15}{50} - 1 = \cos(\rho_1 - \rho_2)$$

$$(\rho_1 - \rho_2) = \cos^{-1}\left(\frac{15}{50} - 1\right)$$

$$= 2.346 \text{ rad}$$

b) **(2 points)** What is the phase difference between the two waves in meters?

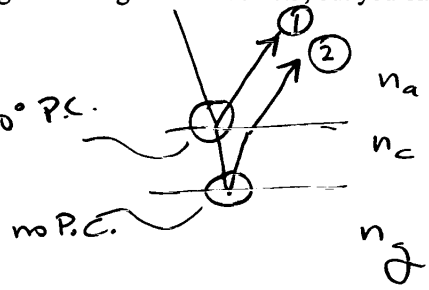
$$\frac{2.346}{2\pi} \times 600 = 224 \text{ nm} = 224 \times 10^{-9} \text{ m}$$

c) **(1 point)** What phase difference in degrees would be required to make the resultant intensity 0?

180°

10. (6 points total) You want to construct a coating that minimizes reflection of 600 nm light from a glass of index 1.5, but you only have a coating material with an index of refraction of 1.7.

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



Opposite rules compared to standard A.R.C. 180° P.C.

$$\therefore t_{dest} = \frac{m}{2}\frac{\lambda}{n_c} = \frac{1}{2}\frac{600}{1.7}$$

$$= 176.5 \text{ nm}$$

b) **(4 points)** What is the percentage of reflected intensity of the surface for 600 nm light?

$$r_1 = \left|\frac{1.7 - 1}{1.7 + 1}\right| = 0.259$$

$$r_2 = \left|\frac{1.7 - 1.5}{1.7 + 1.5}\right| = 0.0625$$

$$I_{coherent} = (0.259)^2 + (0.0625)^2 + 2(0.259)(0.0625)\cos(180)$$

$$= 0.0386$$

$$= 3.86\%$$

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12. (4 points) Design an achromatic doublet comprised of BK7 (refractive efficiency = 58.0) and polycarbonate (refractive efficiency = 30.0) that has a power of 5.00 D.

① $F_1 + F_2 = 5$

② $\frac{F_1}{58} + \frac{F_2}{30} = 0 \Rightarrow F_2 = -\frac{30}{58} F_1$ ③

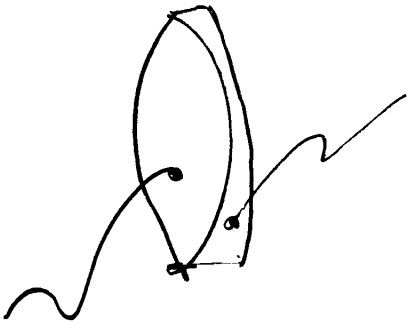
Sub ③ into ①

$$F_1\left(1 - \frac{30}{58}\right) = 5$$

$$F_1 = \underline{10.35\ D}$$

$$F_2 = 5 - F_1$$

$$= \underline{-5.35}\ D$$



F_2 (Polycarbonate)

$= \underline{-5.35\ D}$

F_1 (BK7)

$= \underline{10.35\ D}$