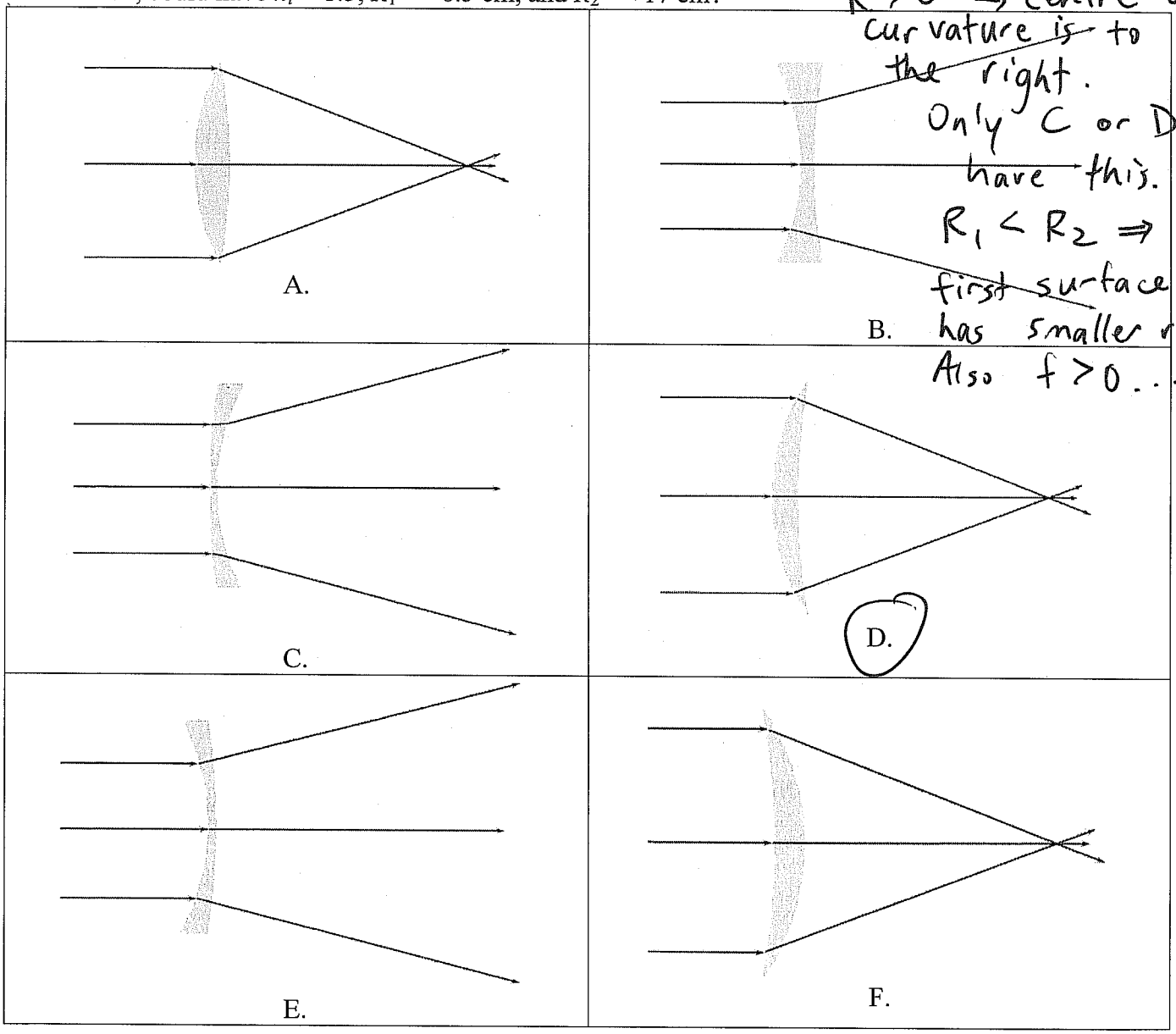
Test 2 Answers - Harlow.

Multiple Choice Part (6 points) D C B A B A

Circle the letter of the best answer for each question.

1. The Lensmaker's Formula is Hecht Equation 5.17, and it is also on the front page of this test, along with the appropriate sign conventions for R_1 and R_2. Which one of the lenses, shown below in cross-section, could have $n_l = 1.5$, $R_1 = +6.5$ cm, and $R_2 = +17$ cm?



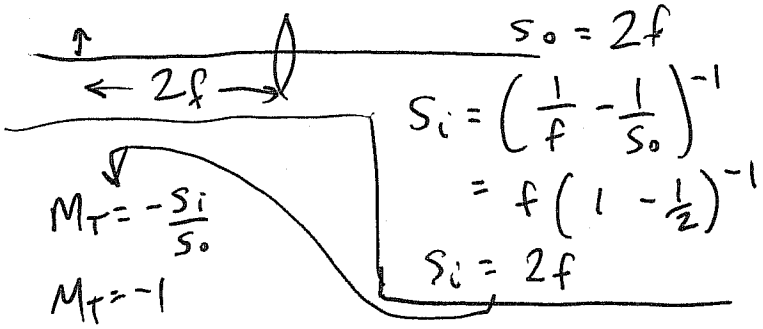
$R > 0 \rightarrow$ centre of curvature is to the right. Only C or D have this.

$R_1 < R_2 \Rightarrow$ first surface has smaller radius

Also $f > 0$...

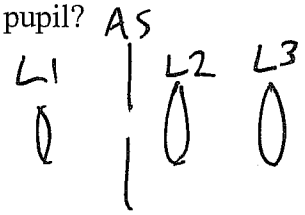
2. An object with a height y_o is held a distance $2f$ in front of a lens of positive focal length f. What is the height of the image, y_i? [Positive values correspond to an erect image, negative values correspond to an inverted image.]

A. $2y_o$
B. $-\frac{y_o}{2}$
C. $-y_o$
D. $-2y_o$
E. No real image is formed in this case.



3. When light enters a camera, it first encounters a lens L1, then an aperture stop AS, then a second lens L2, and finally a third lens L3 before falling on the detector. The aperture stop has a much smaller diameter than any of the three lenses. What is the entrance pupil?

A. The image of AS formed by L2 and L3.
B. The image of AS formed by L1.
C. The image of AS formed by L1, L2 and L3.
D. AS
E. L3



4. The Nikon Coolpix S800C 16MP camera has a focal length of 45 mm, and its focal ratio is f/3.2. What is the diameter of the lens?

A. 1.4 cm
B. 3.2 cm
C. 4.5 cm
D. 7.1 cm
E. 14 cm

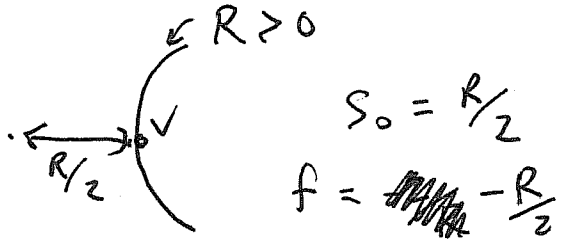
$f = 45\,m$

$\frac{f}{D} = 3.2$

$D = \frac{f}{3.2} = \frac{4.5\,cm}{3.2} = 1.4\,cm$

5. A small object is held a distance $R/2$ to the left of a shiny silver bowling ball of radius R. The ball acts like a mirror, and we call the point on the surface of the ball nearest to the object V. Where does the image of the small object form?

A. $R/4$ to the left of V
B. $R/4$ to the right of V
C. $R/2$ to the left of V
D. $R/2$ to the right of V
E. R to the left of V
F. R to the right of V



$s_i = \left(\frac{1}{f} - \frac{1}{s_o}\right)^{-1} = \left(-\frac{2}{R} - \frac{2}{R}\right)^{-1}$

$= \left(-\frac{4}{R}\right)^{-1} = -R/4$

$s_i < 0$ means virtual image → to the right of V.

6. Two perfect blackbodies emit different spectra. The first blackbody has a temperature T_1 and a peak wavelength in the green region of 500 nm. The second blackbody has a temperature T_2 and a peak in the near infrared at 1000 nm. What is the ratio T_1/T_2?

(A.) 2
B. ½
C. 4
D. ¼
E. 16
F. $^1/_{16}$

Wien's Law:

$$\lambda_1 T_1 = \lambda_2 T_2$$

$$\frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} = \frac{1000}{500} = 2$$

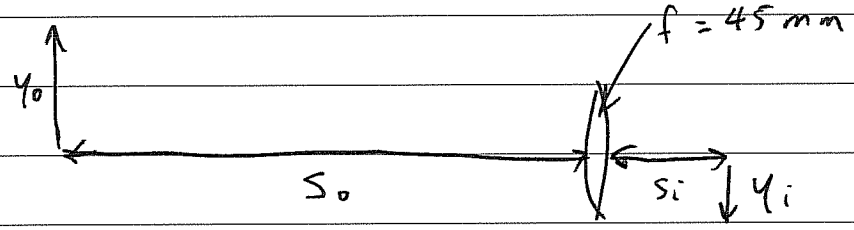
LA 1.

$f = 45\ mm$

$y_i = 6.2\ mm$ ← To just fit on detector.

$s_o = 2.5\ m = 2500\ mm$

$y_o = ?$



$$|M_T| = \frac{y_i}{y_o} = \frac{s_i}{s_o} \Rightarrow \boxed{y_o = y_i \frac{s_o}{s_i}}$$

$$s_i = \left(\frac{1}{f} - \frac{1}{s_o}\right)^{-1} = \left(\frac{1}{45} - \frac{1}{2500}\right)^{-1}$$

$s_i = 45.823\ mm$

$$y_o = 6.2\ mm \left(\frac{2500}{45.823}\right)$$

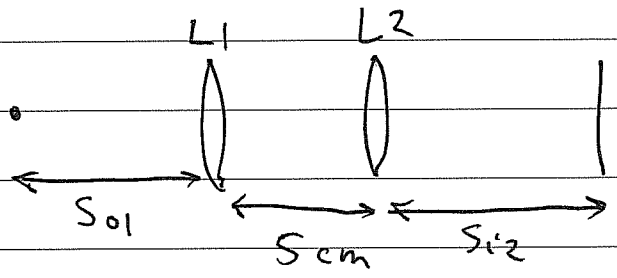
$y_o = 338\ mm$

$$\boxed{y_o = 0.34\ m}$$ ← maximum object size.

for $M_T = \frac{f}{s_o}$ $y_o =$ [redacted] cm → 2/3

344 mm

LA2.



$S_{o1} = 15$ cm

(a) $$s_{i1} = \left(\frac{1}{f_1} - \frac{1}{s_{o1}}\right)^{-1} = \left(\frac{1}{9} - \frac{1}{15}\right)^{-1}$$

$s_{i1} = +22.5$ cm.

$\Rightarrow s_{o2} = 5\text{ cm} - s_{i1} = 5 - 22.5$

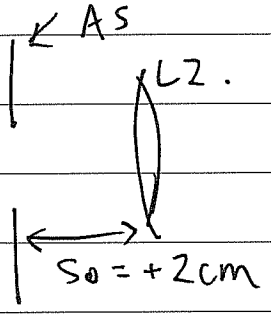
$s_{o2} = -17.5$ cm ← virtual object.

$$s_{i2} = \left(\frac{1}{f_2} - \frac{1}{s_{o2}}\right)^{-1} = \left(\frac{1}{3} - \frac{1}{-17.5}\right)^{-1}$$

$s_{i2} = 2.56$ cm

The detector should be placed 2.6 cm to the right of L2.

(b)



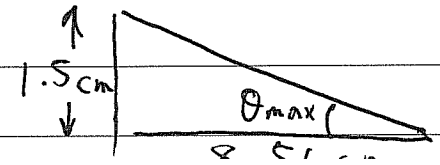
$$s_i = \left(\frac{1}{f_2} - \frac{1}{s_o}\right)^{-1} = \left(\frac{1}{3} - \frac{1}{2}\right)^{-1}$$

$s_i = -6$ cm

$$M_T = -\frac{s_i}{s_o} = -\frac{6}{2} = -3.$$

Exit Pupil is 6 cm to the left of L2, and has a diameter of 3.0 cm.

(c) Exit Pupil is 6 cm + 2.56 cm to the left of the detector.

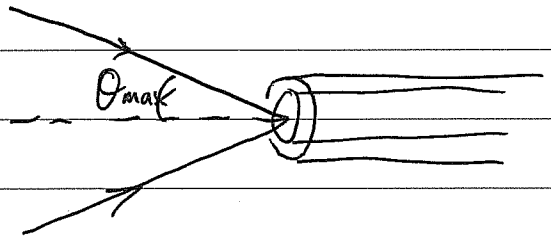


$$\theta_{max} = \tan^{-1}\left(\frac{1.5}{8.56}\right)$$

$\theta_{max} = 9.9°$ $= 0.173$ rad.

LA2 continued → part d

(d)



$n_i = 1$

$$\text{Numerical Aperture} = NA = \sin\theta_{max} = \sqrt{n_f^2 - n_c^2}$$

$$\sin^2\theta_{max} = n_f^2 - n_c^2$$

$$n_c = \sqrt{n_f^2 - \sin^2\theta_{max}}$$

$$= \sqrt{1.6^2 - (\sin 9.939^\circ)^2}$$

$$n_c = 1.59$$

LA 3

$$\frac{R_{ab}}{R_{st}} = \frac{N_i}{N_j} = \exp\left(\frac{h\nu}{kT}\right)$$

$$= \exp\left(\frac{6.63\times10^{-34}\,(5.8\times10^{14})}{1.38\times10^{-23}\,(5400)}\right)$$

$$\boxed{\frac{R_{ab}}{R_{st}} = 174}$$