Solutions to Physics 108 M.T. (2018)

1-(a) From

$$\frac{n_1}{S_o} + \frac{n_3}{S_i} = \frac{n_2 - n_1}{R_1} + \frac{n_3 - n_2}{R_2}$$

and $S_o = +\infty$, $n_3 = n_w = 1.33$,

$$S_i^{-1} = \frac{1}{n_3}\left(\frac{n_2 - n_1}{R_1} + \frac{n_3 - n_2}{R_2}\right)$$

Since $n_2 - n_1 = n_c - n_w = 0.043$, $n_3 - n_2 = n_w - n_c = -0.043$, $R_1 = +7.3\,mm$, $R_2 = +5.6\,mm$,

$$S_i = \frac{n_3}{(n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

$$= \frac{1.333}{0.043\left(\frac{1}{7.3} - \frac{1}{5.6}\right)}$$

$$= \frac{1.333}{0.043(0.136 - 0.179)}$$

$$= -546\,mm$$

1-(5) If now $n_1 = n_{air} = 1.000$, then

$$\frac{1}{S_i} = \frac{1}{n_w}\left(\frac{n_c - n_{air}}{7.3} + \frac{n_w - n_c}{5.6}\right)$$

$$= \frac{1}{1.333}\left(\frac{0.376}{7.3} - \frac{0.043}{5.6}\right)$$

$$= \frac{1}{1.333}\left(0.0515 - 0.0077\right)$$

$$= \frac{0.044}{1.333}$$

$\therefore\ S_i = +30\ \text{mm}$

1-(c) Since the image in Part (G) is at a distance

$$|S_i| = 20 \cdot S_o = 100\text{ cm} > d_o = 25\text{ cm},$$

in front of the lens, one can see it clearly behind the lens.

The angular size of the image at S_i is the same as the angular size of the object y_o at $S_o = 4.75$ cm:

$$\alpha = \frac{y_o}{S_o} = \frac{y_i}{|S_i|} = \frac{1\text{ cm}}{4.75\text{ cm}} = 0.21\text{ rad}.$$

2-(a) From

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

and

$$m = \frac{y_i}{y_o} = -\frac{s_i}{s_o}$$

If we want $s_i = +10 s_o > 0$, then we need

$$\frac{1}{s_o} + \frac{1}{10 s_o} = \frac{1}{f}$$

$$\therefore \frac{1}{s_o}\left(\frac{11}{10}\right) = \frac{1}{f}$$

$$\therefore s_o = \frac{11}{10} f = +5.5 \text{ cm}.$$

2-(b) If we want $s_i = -20 s_o$, then

$$\frac{1}{s_o} + \frac{1}{-20 s_o} = \frac{1}{f}$$

$$\Rightarrow \frac{1}{s_o}\left(1 - \frac{1}{20}\right) = \frac{1}{f} \Rightarrow s_o = \frac{19}{20} f = +4.75 \text{cm}$$

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3-(a) At the focal plane of the concave mirror, the size of the Moon is simply

$$d_{Moon} = \alpha_{Moon} * f_{mirror}$$

$$= (0.0085 \text{ rad}) \cdot \left(\frac{1}{2}|R|\right)$$

$$= 0.0085 * 125 \text{ cm}$$

$$= 1.06 \text{ cm}.$$

3-(g) Method #1:

The angular size of the Moon α is amplified by

$$M_A = \frac{f_{Mirror}}{f_e} = \frac{125\text{ cm}}{2.5\text{ cm}} = 50$$

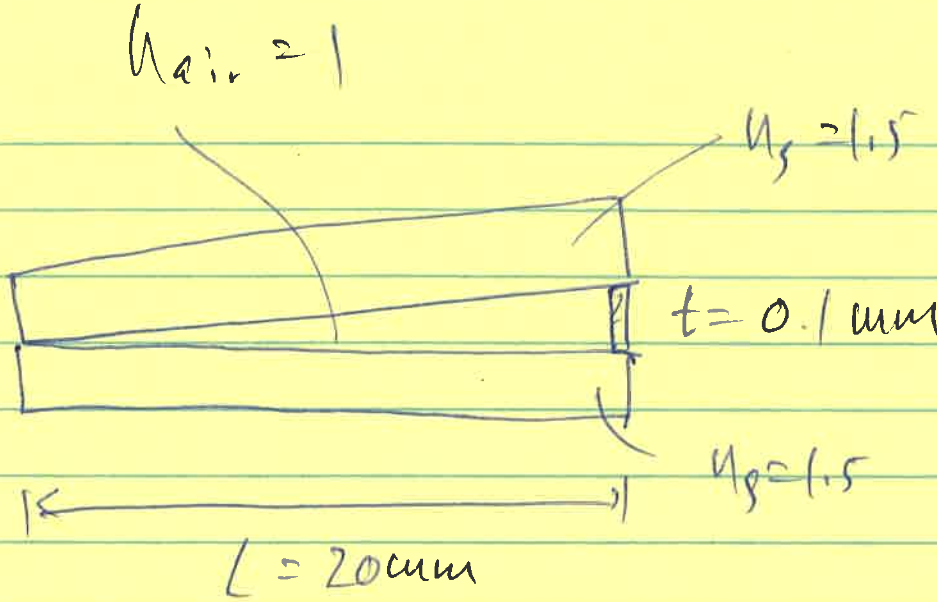
Thus

$$\alpha'_{Moon} = M_A \cdot \alpha_{Moon} = 0.425 \text{ rad}!$$

Method #2:

$$\alpha'_{Moon} = \frac{d_{Moon}}{f_e} = \frac{1.06\text{ cm}}{2.5\text{ cm}} = 0.425 \text{ rad}$$

4-(a)



Since the neighboring fringes are separated by a thickness change

$$\delta t = \frac{\lambda_0}{2 n_{air} \cos\theta_{air}} = \frac{\lambda_0}{2}$$

The total number of fringes is

$$N = \frac{t}{\delta t} = \frac{2t}{\lambda_0}$$

Take $\lambda_0 = 0.5\ \mu m = 5\times10^{-4}$ mm,

$$N = \frac{0.2\,\text{mm}}{5\times10^{-4}\,\text{mm}} = 400$$

Thus the fringe spacing laterally is

$$\delta L = \frac{L}{N} = \frac{20\,\text{mm}}{400} = 0.05\,\text{mm} = 50\ \mu m.$$

4-(b) Let the thickness of the spacer be t.
since

$$N = 20 = \frac{t}{\delta t} = \frac{2t}{\lambda_0} = \frac{2t}{0.5\,\mu m}$$

$$\therefore t = \frac{N \cdot \lambda_0}{2} = 5\,\mu m$$

4-(c) If the gap in Part (b) is filled with water, the height change δt is then given by

$$\delta t = \frac{\lambda_0}{2 n_w \cdot \cos\theta_w}$$

From Snell's law, $n_{air} \sin 45^\circ = n_w \sin\theta_w$

$$\therefore \theta_w = \sin^{-1}\left(\frac{\sin 45^\circ}{n_w}\right) = 32^\circ$$

$$\cos\theta_w = \cos 32^\circ = 0.85.$$

$$\therefore \delta t = \frac{0.5\,\mu m}{2 \times 1.33 \times 0.85} = 0.222\,\mu m$$

$$\therefore N = \frac{t}{\delta t} = \frac{5\,\mu m}{0.2222\,\mu m} \cong 22 \text{ fringes.}$$