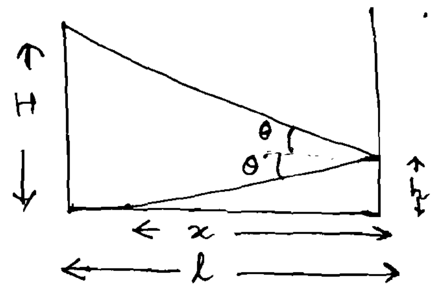
32.4.



We know that the angle of reflection equals angle of incidence.

$$\tan\theta = \frac{h}{x} = \frac{H-h}{l}$$

$$\frac{0.38}{x} = \frac{1.64-0.38}{2.30}$$

$$\therefore x = 0.69\ m$$

32.36. $n = \frac{\text{Speed of light in air}}{\text{speed of light in that medium}} = \frac{c}{0.88\, V_{water}}$

$$= \frac{c}{0.88\left(\frac{c}{n_{water}}\right)} = \frac{n_{water}}{0.88} = \frac{1.33}{0.88} = 1.51$$

32.41. From Snell's law, we have-

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\therefore \theta_1 = \sin^{-1}\left(\frac{n_2}{n_1}\sin\theta_1\right) = \sin^{-1}\left(\frac{1}{1.33}\sin 56^\circ\right) = 38.6^\circ$

32.42. $\theta_{ref.} = 2\theta_{inci.}$

$\theta_2 = 2\theta_1$ (Say)

From Snell's law, we have- ~~sin~~

$n_{air}\sin\theta_1 = n_{glass}\sin\theta_2$

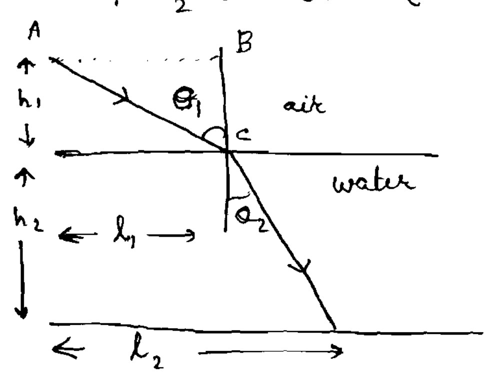
$(1)\sin 2\theta_2 = (1.56)\sin\theta_2$

$\sin 2\theta_2 = 2\sin\theta_2\cos\theta_2 = (1.56)\sin\theta_2$

$\cos\theta_2 = 0.78$

$\therefore \theta_2 = \cos^{-1}(0.78) = 38.74^\circ, \quad \theta_1 = 2\theta_2 = 77.5^\circ$

32.45.



From the triangle ABC,

$$\tan\theta_1 = \frac{l_1}{h_1} = \frac{2.5}{1.3} = 1.92$$

$$\theta_1 = 62.5^\circ$$

Snell's law leads to -

$n_{air}\sin\theta_1 = n_{water}\sin\theta_2$

$(1)\sin 62.5^\circ = (1.33)\sin\theta_2$

$\theta_2 = 41.8^\circ$

we find the horizontal dist. across the pool as -

$l = l_1 + l_2 = h_1 + h_2 \tan\theta_2 = 2.5 + (2.1)\tan 41.8^\circ = 4.38\ m$

32.53. From Snell's law -

$(n_{air}) \sin\theta_1 = \cancel{n_{light}}\ (n_{glass}) \sin\theta_2$

$(1.00) \sin 60^\circ = (1.4831) \sin\theta_{2,\,blue}$ $\quad \theta_{2,\,blue} = 35.727^\circ$

$(1.00) \sin 60^\circ = (1.4754) \sin\theta_{2,\,red}$ $\quad \theta_{2\,red} = 35.943^\circ$

The angle between the refracted beams is -

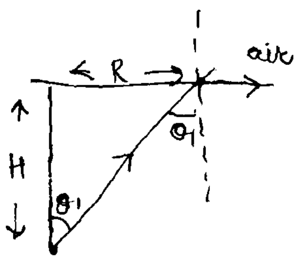
$\theta_{2,\,red} - \theta_{2,\,blue} = 35.943^\circ - 35.727^\circ = 0.216^\circ$

32.58. For obtaining a critical angle, the angle of refraction turns out to be 90:

$n_{liq.} \sin\theta_1 = n_{air} \sin\theta_2$

$n_{liq.} = n_{air} \dfrac{\sin\theta_2}{\sin\theta_1} = (1.00) \dfrac{1}{\sin 49.6} = 1.31$

32.59.



For light not to escape the water, the max angle of incidence can lead to critical angle.

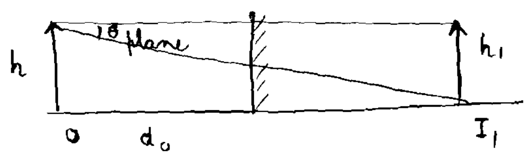
$n_{water} \sin\theta_1 = n_{air} \sin 90^\circ$

$\sin\theta_1 = \dfrac{1}{1.33}$ $\quad \therefore \theta_1 = 48.75^\circ$

If the angle is incident at a greater angle, it will be reflected back.

$R > H \tan\theta_1 = (72) \tan 48.75^\circ = 82.1\ cm$

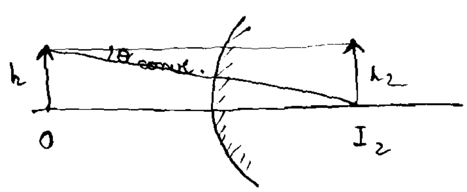
32.75.



For plane mirror, image and object height are same

$d_i = -d_o,\ h_i = h.$

$\theta_{plane} = \dfrac{h_i}{d_o - d_i} = \dfrac{h_o}{2d_o}$



For convex mirror,

$\dfrac{1}{f} = \dfrac{1}{d_o} + \dfrac{1}{d_i}$ $\quad d_i = \dfrac{d_o f}{d_o - f}.$

$d_o - d_i = d_o - \dfrac{d_o f}{d_o - f} = \dfrac{d_o^2 - d_o f - d_o f}{d_o - f}$

$\dfrac{h_i}{h_o} = -\dfrac{d_i}{d_o} \Longrightarrow h_i = -h_o \dfrac{d_i}{d_o} = -\dfrac{h_o f}{d_o - f}$

$\theta_{convex} = \dfrac{h_i}{d_o - d_i} = -\dfrac{h_o f}{(d_o - f)} \times \dfrac{d_o - f}{d_o^2 - 2d_o f} = -\dfrac{h_o f}{d_o^2 - 2d_o f}$

$\theta_{convex} = \frac{1}{2}\theta_{plane}$

$$-\frac{h_o f}{d_o^2 - 2d_o f} = \frac{h_o}{4d_o} \rightarrow -4d_o f = d_o^2 - 2d_o f$$

$$-2d_o f = d_o^2$$

$$\therefore d_o = -2f$$

Radius of mirror $= 2f = -d_o = -3.8\ m$

33.2. a) Since the lens ~~forms~~ focuses a parallel beam of light, it must be a converging or convex lens.

b) Power of the lens – $P = \frac{1}{f} = \frac{1}{0.185m} = 5.41D$

33.4. The lens must be a converging one if we want a real image.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \cancel{d_i = \frac{d_o f}{d_o - f}} =$$

$$f = \frac{d_o d_i}{d_o + d_i} = \frac{(1.85m)(0.483m)}{(1.85 + 0.483)m} = 0.383m$$

$\because d_i > 0$, the image is real.

33.6. a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$

$$d_i = \frac{d_o f}{d_o - f} = \frac{(18\ cm)(28\ cm)}{(18-28)\ cm} = -50.4\ cm$$

The –ve sign implies that we get a virtual image.

b) $m = -\frac{d_i}{d_o} = \frac{-(-50.4)}{18} = 2.8$

33.8. $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} = P$

$$\frac{1}{d_i} = P - \frac{1}{d_o} = \frac{Pd_o - 1}{d_o}$$

$$\therefore d_i = \frac{d_o}{Pd_o - 1} = \frac{0.125m}{(-8.00D)(0.125m) - 1} = -0.0625m = -6.25cm$$

$\because$ Image dist. is negative, the image is virtual.

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$h_i = -\frac{h_o d_i}{d_o} = -\frac{(-6.25cm)(1mm)}{(12.5cm)} = 0.5\ mm$$

We get a virtual, upright image.

33.14. The image and object being real implies that image and object dist. is −ve and +ve resp.

$$m = -\frac{d_i}{d_o} \Rightarrow d_i = -m d_o = 2.95 d_o$$

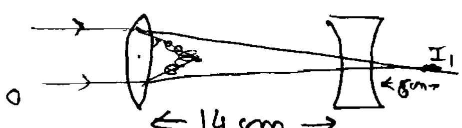
$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} + \frac{1}{2.95 d_o} = \frac{1}{f}$$

$$\frac{(2.95+1)}{2.95 d_o} = \frac{1}{f} \qquad \therefore d_o = \frac{3.95}{2.95} f = \frac{3.95}{2.95} \times 85\text{ cm} = 113.8\text{ cm}$$

$$d_i = 2.95\, d_o = 2.95\,(113.8\text{ cm}) = 335.7\text{ cm}$$

$$d_o + d_i = (335.7 + 113.8)\text{ cm} = 449.5\text{ cm}$$ (dist. between image and object)

33.20.



An object placed at infinity will form its image in the focal pt. of the convex lens.

$d_{I_1} = 20$ cm

This forms an object for the second lens with $d_o = (14-20)\text{ cm} = -6\text{ cm}$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{d_i} = -\frac{1}{33.5} + \frac{1}{6} \qquad \therefore d_i = \frac{6 \times (33.5)}{(-6 + 33.5)} = 7.3\text{ cm}$$

The final image is formed at a dist. of 7.3 cm from diverging lens.

33.34. The exposure is proportional to lens opening area and exposure time. It is f inversely proportional to the sq. of the f stop time. Since the camera used is same, its opening area is same.

$$\frac{t_1}{(f\,stop_1)^2} = \frac{t_2}{(f\,stop_2)^2} \qquad \therefore f\,stop_2 = f\,stop_1 \sqrt{\frac{t_2}{t_1}}$$

$$= 16\sqrt{\frac{\frac{1}{1000}}{\frac{1}{120}}} = 5.54 \text{ or } \frac{f}{5.6}$$

33.35. $f\text{ stop} = \frac{f}{D} = \frac{17\text{ cm}}{6\text{ cm}} = \frac{f}{2.8}$

33.41. The near pt. of the abnormal person is 55 cm. With the object placed at 25 cm from eye like a normal person it is actually $(25-2) = 23$ cm away from the lens. The object kept there should produce a virtual image $55-2 = 53$ cm away from the lens. The power of lens should be

$$P = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \cancel{\frac{1}{0.53\,m}} \quad \frac{1}{0.23\,m} - \frac{1}{0.53\,m} = 2.5\,D$$

virtual image

33.44. a) The ~~power~~ of the lens being negative implies that ~~the~~ lens is a diverging one. Thus the image produced is closer than the object. The person is short sighted.

b) The near point is obtained by finding the image distance for an obje placed at infinity.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} = P$$

$$\frac{1}{\infty} + \frac{1}{d_i} = -4.5\,D \qquad \therefore d_i = -\frac{1}{4.5\,D} = -0.222\,m = -22.2\,cm$$

Far point is the sum of this and dist. between lens and eye.

$\therefore$ Far point. $= (|-22.21| + 2)$ cm $= 24.2$ cm from eye

33.52. $M = \frac{N}{f}$

$$= \frac{25}{13} = 1.9x$$

33.72. The microscope's magnification is given by–

$$M = \frac{N l}{f_o f_e} = \frac{(25\,cm)(17.5\,cm)}{(0.65\,cm)(1.5\,cm)} = 444.7x$$

33.74. $$M \simeq \frac{N l}{f_o f_e} = \frac{(25\,cm)(17\,cm)}{(0.28\,cm)(2.5\,cm)} = 607.1x$$

34.3. For constructive interference, we have–

$$d \sin\theta = m\lambda$$

$$d = \frac{m\lambda}{\sin\theta} = \frac{3(610\times10^{-9}\,m)}{\sin 28^\circ} = 3.9\times10^{-6}\,m$$

34.5. For constructive interfence, l - being dist. between slits, screen

$$d \sin\theta = m\lambda$$

For small angles, $\sin\theta \simeq \theta \simeq \tan\theta \simeq \frac{x}{l}$

$$\frac{dx}{l} = m\lambda \qquad \therefore x = \frac{m\lambda l}{d}$$

$$\Delta x = x_1 - x_2 = \frac{m\lambda_1 l}{d} - \frac{m\lambda_2 l}{d} = \frac{ml}{d}(\lambda_1 - \lambda_2) = \frac{2(1m)(720-660)\times10^{-9}\,m}{6.8\times10^{-4}\,m}$$

$$= 1.76\times10^{-4}\,m$$

34.16. In this there is a change from a constructive to a destructive interfere
This can occur for a phase shift of half a wavelength. The wavelength of light in plastic is shorter than that in air. Thus the number of of ~~w~~ wavelengths in plastic must be $\frac{1}{2}$ greater than the number in air for same thickness. (from phaseshift)

$$N_{plastic} - N_{air} = \frac{t}{\lambda_{plastic}} - \frac{t}{\lambda} = \frac{t\, n_{plas.}}{\lambda} - \frac{t}{\lambda} = \frac{t}{\lambda}(n_{plas.} - 1) = \frac{1}{2}$$

$$t = \frac{\lambda}{2} \cdot \frac{1}{(n_{plas.} - 1)} = \frac{680\,nm}{2(1.6-1)} = 570\,nm$$

34.23. For strong reflection of bright light,

$$\cancel{t} = \frac{\lambda}{4n} \qquad \therefore \lambda = 4nt = 4\,(1.32)(120\,nm) = 634\,nm$$

34.28. For light reflected from oil air ~~water~~ interface there is a phase shift of π. A ray ~~f~~ reflected from oil water interface does not undergo any phase shift due to reflection but due to additional path length $\quad \phi_2 = \frac{2t}{\lambda_{oil}} \times 2\pi$.

$$\phi_{net} = \phi_2 - \phi_1 = \frac{4\pi t}{\lambda_{oil}} - \pi = 2\pi(m) \qquad \text{constructive.}$$

$$\left(\frac{4t}{\lambda_{oil}} - 1\right)\pi = 2\pi m$$

$$\frac{4t}{\lambda_{oil}} = (2m+1) \qquad \therefore t = (2m+1)\frac{\lambda_{oil}}{4}$$

$$t_{650} = \frac{1}{4}(2m+1)\frac{650\,nm}{1.5} = 108\,nm,\ 325\,nm,\ 542\,nm, \ldots$$

$$t_{390} = \frac{1}{4}\left(\frac{390}{1.5}\right)(2m+1) = 65\,nm,\ 195\,nm,\ 325\,nm, \ldots$$

The min. thickness of oil slick is 325 nm. (coincides from t_{650}, t_{390})

35.2. The angle between central max to first dark finge is half of the width of central max.

$$\theta_1 = \frac{1}{2}\Delta\theta = \frac{1}{2} \times 32° = 16°$$

$$\sin\theta_1 = \frac{\lambda}{D} \qquad \therefore \lambda = D\sin\theta_1 = (2.6 \times 10^{-3}\,mm)\sin 16° = 7.17 \times 10^{-4}\,mm$$

$$= 717\,nm$$

35.7. The first min. dist. is computed by considering half the width of first max

$$\tan\theta_1 = \frac{\frac{1}{2}\Delta y_1}{l} \qquad \theta_1 = \tan^{-1}\left(\frac{\frac{\Delta y_1}{2}}{l}\right) = \tan^{-1}\left(\frac{0.06\,m}{2 \times 2.20\,m}\right) = 0.781°$$

$\sin\theta_1 = \frac{\lambda_1}{D}$ $\quad D = \frac{\lambda_1}{\sin\theta_1} = \frac{580\ nm}{\sin 0.781°} = 42,537\ nm$

$\sin\theta_2 = \frac{\lambda_2}{D}$ $\quad \theta_2 = \sin^{-1}\left(\frac{\lambda_2}{D}\right) = \sin^{-1}\left(\frac{460\ nm}{42,537\ nm}\right) = 0.620°$

$\Delta y_2 = 2l\tan\theta_2 = 2(2.20\ m)\tan 0.62° = 0.0476m = 4.8\ cm$

35.25. The angular resolution is given by -

$\theta = 1.22\frac{\lambda}{D}$

$l = r\theta = r \times \frac{1.22\lambda}{D} = (16\ ly)\left(\frac{9.46\times10^{15} m}{1\ ly}\right)\left(\frac{550\times10^{-9} m}{0.66\ m}\right)$

$= 1.5\times10^{11}\ m$

The dist. between earth and stars is the angular resolution times the dist. to stars from earth.

35.32. The inverse of the no. of lines gives the dist. between two gratings. $N = \frac{1}{d}$

$d\sin\theta = m\lambda$

$\lambda = \frac{d\sin\theta}{m} = \frac{\sin\theta}{mN} = \frac{\sin 26°}{3(3500/cm)} = 4.17\times10^{-5}\ cm$

35.36. Like previous problem,

$d\sin\theta = m\lambda$ $\quad \theta = \sin^{-1}\left(\frac{\lambda m}{d}\right) = \sin^{-1}(\lambda m N)$

$\theta_1 = \sin^{-1}((410\times10^{-7} cm)(7800\ lines/cm)) = 18.65°$

$\theta_2 = \sin^{-1}((750\times10^{-7} cm)(7800\ lines/cm)) = 35.80°$

$\Delta y = y_2 - y_1 = l(\tan\theta_2 - \tan\theta_1) = 2.8\ m(\tan 35.8 - \tan 18.65°)$

$= 1.1\ m$

35.71. a) $s = l\theta = l\times\frac{1.22\lambda}{D}$

$\therefore l = \frac{Ds}{1.22\lambda} = \frac{(6\times10^{-3} m)(2m)}{1.22(560\times10^{-9} m)} = 1.8\times10^{4}\ m$

b) $\theta = \frac{1.22\lambda}{D} = \frac{1.22(560\times10^{-9} m)}{6\times10^{-3} m} = 1.139\times10^{-4} rad\left(\frac{180°}{\pi\ rad}\right)\left(\frac{3600''}{1°}\right)$

$= 23''$

The difference arises as we neglected atmospheric effects and abberations in eye.