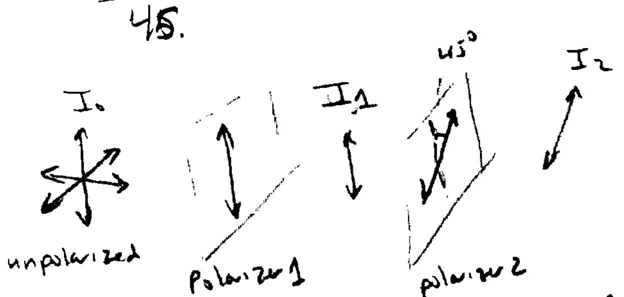
Chapter 22

45.

45. Unpolarized light passes through two polarizers oriented at 45° to one another, what fraction of incident light intensity is transmitted?



The first polarizer transmits ½ of the incident, unpolarized, light

$I_1 = I_o/2$

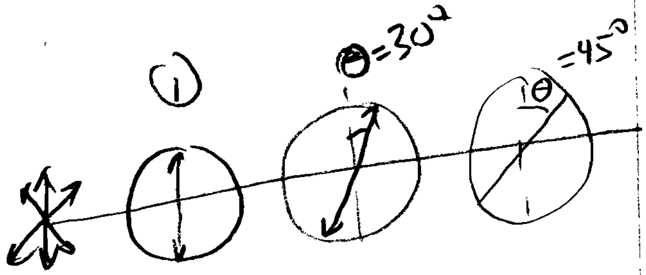
$I_2 = I_1 \cos^2\theta$ where θ = the angle between the incident polarization and the transmission axis on the polarizer

$= \frac{I_o}{2}\cos^2 45°$

$= \frac{I_o}{2}\left(\frac{\sqrt{2}}{2}\right)^2 = I_o \frac{2}{8}$ $\boxed{\frac{I_2}{I_o} = 1/4}$

47. Unpolarized light is incident on a system of three polarizers. The second polarizer is oriented at an angle of 30.0° with respect to the first and the third is oriented at an angle of 45.0° with respect to the first. If the light that emerges from the system has an intensity of 23.0 W/m², what is the intensity of the incident light?

Chapter 22



$I_1 = \frac{1}{2} I_o \quad I_2 = I_1\cos^2\theta = \frac{1}{2} I_o \cos^2 30° = \frac{1}{2} I_o \frac{3}{4} = \frac{3}{8} I_o$

$I_3 = I_2\cos^2\theta = \frac{3}{8} I_o \cos^2(45-30°)$ ← because θ is the angle between the polarizer's transmission axis and the incoming polarization

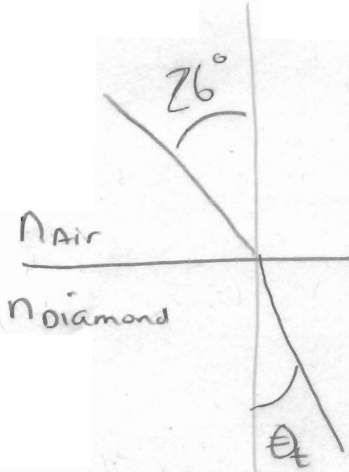
$= \frac{3}{8} I_o (0.933)$

$= 0.35 I_o$

$I_o = \frac{I_3}{0.35} = \frac{23.0\ W/m^2}{0.35} = \boxed{65.7\ W/m^2 = I_o}$

Chapter 23

20. A diamond in air is illuminated with white light. On one particular facet, the angle of incidence is 26.00°. Inside the diamond, red light ($\lambda = 660.0$ nm in vacuum) is refracted at 10.48° with respect to the normal; blue light ($\lambda = 470.0$ nm in vacuum) is refracted at 10.33°. (a) What are the indices of refraction for red and blue light in diamond? (b) What is the ratio of the speed of red light to the speed of blue light in diamond? (c) How would a diamond look if there were no dispersion?



a) λ_{red} 660nm $\theta_t = 10.48°$

λ_{blue} 470nm $\theta_t = 10.33°$

$n_i \sin\theta_i = n_t \sin\theta_t$ SNELL'S LAW

$n_t = \dfrac{n_i \sin\theta_i}{\sin\theta_t}$

$n_{red} = 1.0 \dfrac{\sin 26}{\sin 10.48}$

$= 2.410$

$n_{blue} = 1.0 \dfrac{\sin 26}{\sin 10.33}$

$n_{blue} = 24.45°$

$v = \lambda f$

b) $\dfrac{v_{red}}{v_{blue}} = \dfrac{\lambda_{red}}{\lambda_{blue}}$

$= \dfrac{660nm}{470nm}$

$\dfrac{v_{red}}{v_{blue}} = 1.4$

c) The Diamond would be clear with no color

23. (a) Calculate the critical angle for a diamond surrounded by air. (b) Calculate the critical angle for a diamond under water. (c) Explain why a diamond sparkles less under water than in air.

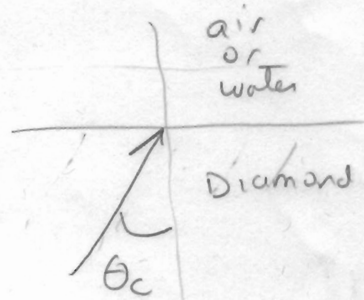
$n_i \sin\theta_c = n_t \sin 90$ (= 1)

$\theta_c = \sin^{-1}(n_t/n_i)$

$n_i = n_{Diamond} = 2.419$

$n_{air} = 1$

$n_{water} = 1.333$



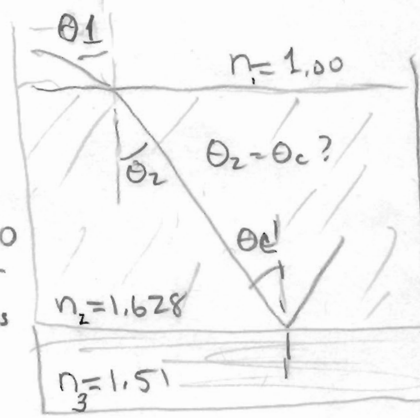
a) AIR $\theta_c = \sin^{-1}(1/2.419)$

$= 24.4°$

b) water $\theta_c = \sin^{-1}(1.33/2.419) = 33°$

c) At the bottom of the diamond, less light is reflected back to the viewer

28. The angle of incidence θ of a ray of light in air is adjusted gradually as it enters a shallow tank made of Plexiglas and filled with carbon disulfide. Is there an angle of incidence for which light is transmitted into the carbon disulfide but not into the Plexiglas at the bottom of the tank? If so, find the angle. If not, explain why not.



$n_1 \sin\theta_1 = n_2 \sin\theta_2 = n_2 \sin\theta_c = n_3 \sin 90$ (For no light into plexiglass)

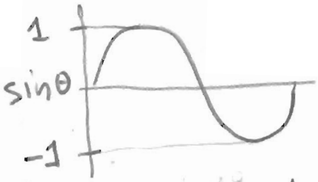
$\sin\theta_1 = n_3$

$\theta_1 = \sin^{-1}(n_3) = \sin^{-1}(1.51)$

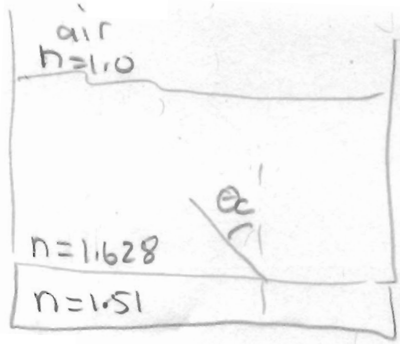
NO The light must go into plexiglass $\sin\theta \leq 1$ always can't be 1.51

28 Continued

$-1 \le \sin\theta \le 1$



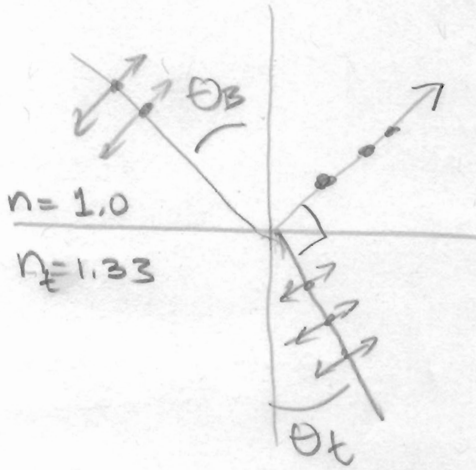
Therefore, the sine of an angle can never be greater than 1.



$\theta_c = \sin^{-1}\left(\frac{n_t}{n_i}\right)$

32.

32. (a) Sunlight reflected from the still surface of a lake is totally polarized when the incident light is at what angle with respect to the horizontal? (b) In what direction is the reflected light polarized? (c) Is any light incident at this angle transmitted into the water? If so, at what angle below the horizontal does the transmitted light travel?



a) $\theta_B = \tan^{-1}\left(\frac{n_t}{n_i}\right) = \tan^{-1}\left(\frac{1.33}{1.0}\right)$

$= 53.1°$

θ_B is with respect to the vertical

$\phi = 90 - \theta_B = 36.9°$ = angle with respect to the horizontal

b) The light is polarized ⊥ to plane of paper parallel to the surface of the lake.

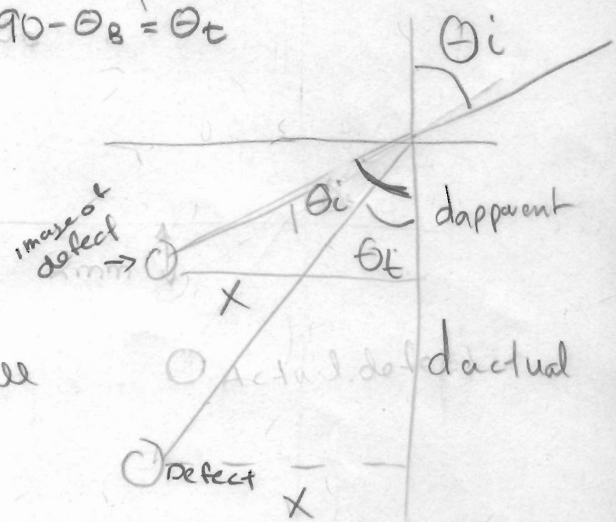
c) Yes $\quad n_i \sin\theta_i = n_t \sin\theta_t$

$\theta_t = \sin^{-1}\left(\frac{n_i}{n_t}\sin\theta_i\right) = \sin^{-1}\left(\frac{1}{1.33}\sin 53.1\right)$

$= 36.9°$ $\quad$ Note: $90 - \theta_B = \theta_t$

35

35. A defect in a diamond appears to be 2.0 mm below the surface when viewed from directly above that surface. How far beneath the surface is the defect?



$\tan\theta_i = \frac{X}{d_{apparent}} \qquad \tan\theta_t = \frac{X}{d_{actual}}$

Since it is viewed from above θ_i is small

$\tan\theta_i \sim \sin\theta_i \qquad n_i \sin\theta_i \sim n_i \tan\theta_i$

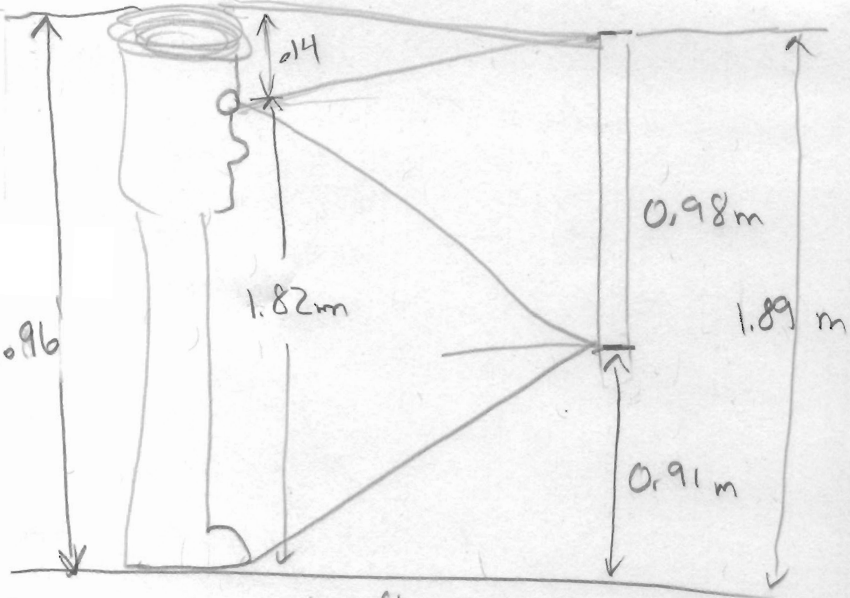
$n_i \sin\theta_i = n_t \sin\theta_t$

$\frac{n_i X}{d_{apparent}} = \frac{n_t X}{d_{actual}} \Rightarrow d_{actual} = \frac{n_t \, d_{apparent}}{n_i} = \frac{(2.419)2\text{mm}}{1}$

$= 4.8\text{mm}$

Chapter 23

39. Daniel's eyes are 1.82 m from the floor when he is wearing his dress shoes, and the top of his head is 1.96 m from the floor. Daniel has a mirror that is 0.98 m in length. How high from the floor should the bottom edge of the mirror be located if Daniel is to see a full-length image of himself? Draw a ray diagram to illustrate your answer.



To see his feet, the bottom of the mirror must catch the ray from his eye to his feet

$\frac{1.82\text{ m}}{2} = 0.91\text{ m}$

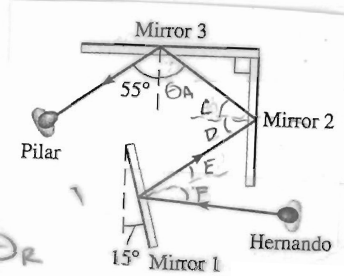
so the bottom should be 0.91 m above the floor.

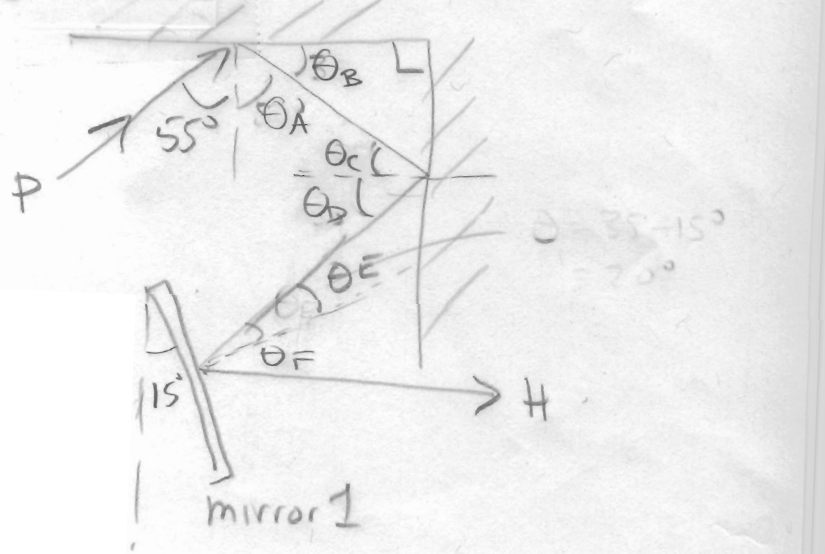
Will he be able to see the top of his head

$1.96 - 1.82 = 0.14\text{ m}$ Divide that by 2 $\frac{0.14}{2} = 0.07$

If the top is at least at $1.82 + 0.07 = 1.89\text{ m}$ he will be able to see the top of his head

42. In an amusement park maze with all the walls covered with mirrors, Pilar sees Hernando's reflection from a series of three mirrors. If the reflected angle from mirror 3 is 55° for the mirror arrangement shown in the figure, what is the angle of incidence on mirror 1?





Since $\theta_i = \theta_R$

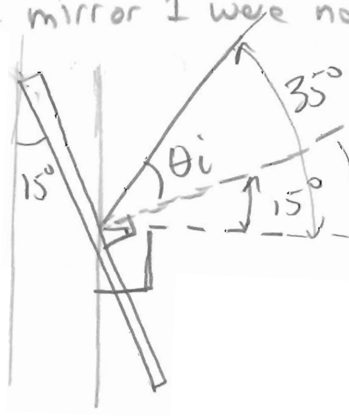
$\theta_A = 55°$

$\theta_B = 90 - 55° = 35°$

$\theta_C = 90 - \theta_A = 35°$

$\theta_D = \theta_C = 35°$

If mirror 1 were not tilted by 15° $\theta_E = 35$



$\theta_r = \theta_i = 35° - 15°$

$= 20° = \theta_i$

surface normal rotates 15° when mirror is rotated 15°

Chapter 23

47. A 1.80-cm-high object is placed 20.0 cm in front of a concave mirror with a 5.00-cm focal length. What is the position of the image? Draw a ray diagram to illustrate.

$f = +5.00\text{ cm}$
$p = 20.0\text{ cm}$
$h = 1.80\text{ cm}$
concave mirror

$q = ?$

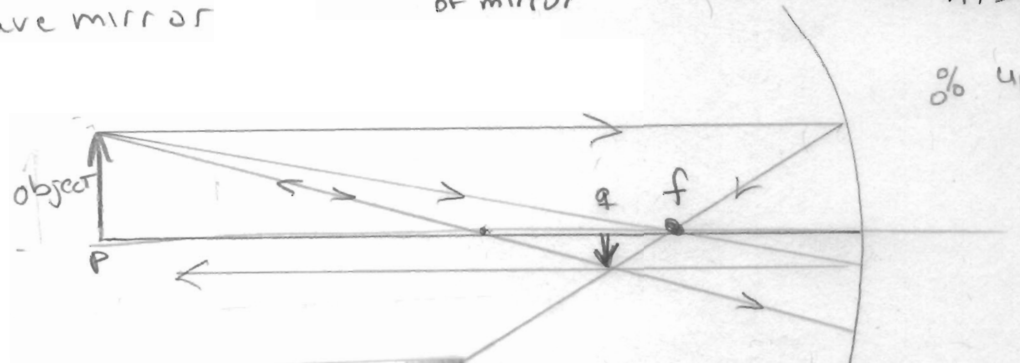
$q = 6.67$ cm infront of mirror

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{p}{fp} - \frac{f}{fp} = \frac{p-f}{fp}$$

$$q = \frac{fp}{p-f} = \frac{(5\text{cm})(20\text{cm})}{20\text{cm} - 5\text{cm}} = \frac{100\text{ cm}^2}{15\text{ cm}}$$

$= 6.67$ cm Real image
In front of mirror
$m = -\frac{p}{q}$
∴ upside down image



48. In her job as a dental hygienist, Kathryn uses a concave mirror to see the back of her patient's teeth. When the mirror is 1.20 cm from a tooth, the image is upright and 3.00 times as large as the tooth. What are the focal length and radius of curvature of the mirror?

$m = +3.00$
$p = 1.20\text{cm}$
$m = -\frac{q}{p}$ ∴ $q = -mp$
$= -3.60\text{cm}$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{q}{pq} + \frac{p}{pq} = \frac{q+p}{pq}$$

$$f = \frac{pq}{q+p} = \frac{(1.20\text{cm})(-3.6\text{cm})}{-3.60\text{ cm} + 1.2\text{cm}} = \frac{-4.32\text{cm}^2}{-2.4\text{ cm}} = +1.8\text{ cm} = f$$

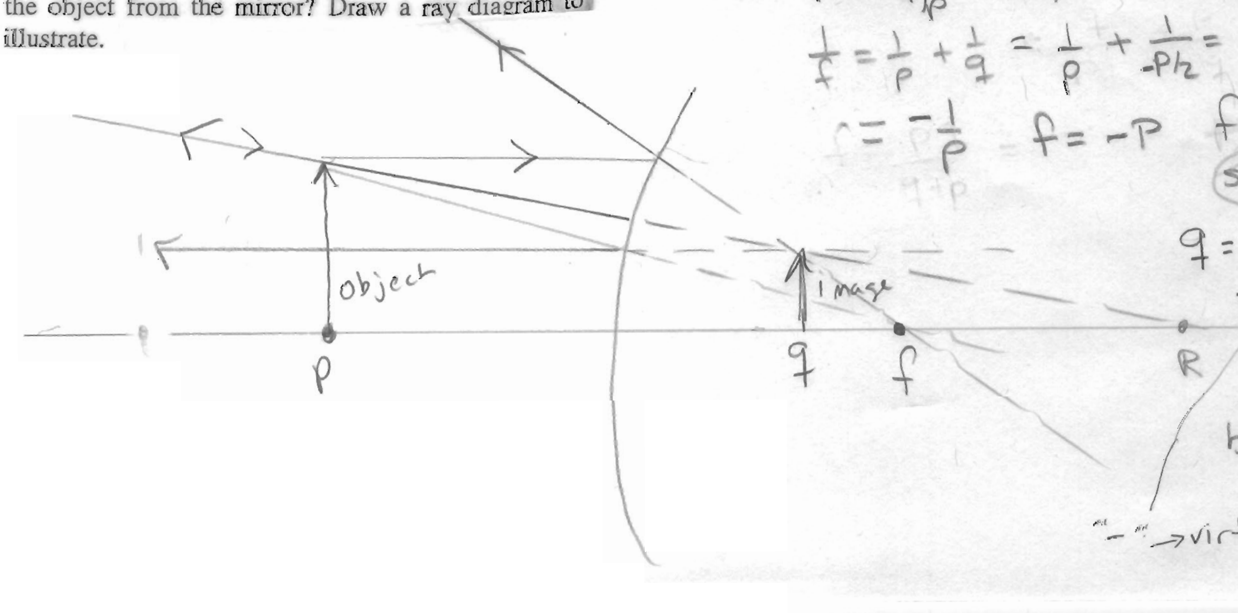
$R = 2f = 3.6$ cm

50. An object is placed in front of a convex mirror with a 25.0-cm radius of curvature. A virtual image half the size of the object is formed. At what distance is the object from the mirror? Draw a ray diagram to illustrate.

$m = 1/2$ virtual → q is negative
$m = -q/p$ $q = -mp = -P/2$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p} + \frac{1}{-P/2} = \frac{1}{P} - \frac{2}{P}$$

$\frac{1}{f} = -\frac{1}{p}$ $f = -P$ $f = -25\text{cm}$
so $p = 25\text{cm}$



$q = -P/2$
$= -12.5\text{cm}$
or
12cm
behind
mirror
"−" → virtual

49. An object is placed in front of a concave mirror with a 25.0-cm radius of curvature. A real image twice the size of the object is formed. At what distance is the object from the mirror? Draw a ray diagram to illustrate.

$f = R/2 = \frac{25.0}{2} = 12.5\,\text{cm}$

$|m| = 2$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ $\qquad m = -q/p$ so $q = -mp$

real image $\Rightarrow$ q is positive

so $m = -2$

$q = 2p$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{2p}$

$= \frac{2+1}{2p} = \frac{3}{2p}$

$f = 2/3\,p \longrightarrow p = 3/2\,f \qquad q = 2p = 3f$

$= \frac{3}{2}(12.5\,\text{cm}) \qquad = 3(12.5\,\text{cm})$

$= 18.75\,\text{cm} \qquad = 37.5\,\text{cm}$