Homework #9

(34-1) a) $f = \frac{c}{\lambda} = \frac{3\times10^{8}\ m/sec}{0.067\times10^{-15}m} = \boxed{4.48\times10^{24}Hz}$

b) $\lambda = \frac{c}{f} = \frac{3\times10^{8}\ m/sec}{30\ 1/sec} = \boxed{10^{7}\ m}$

(34-2) a) From $I = \frac{1}{\mu_0 c}E_{rms}^2 = \frac{1}{\mu_0 c}\left(\frac{E_{max}}{\sqrt{2}}\right)^2 = \frac{1}{2\mu_0 c}E_{max}^2$,

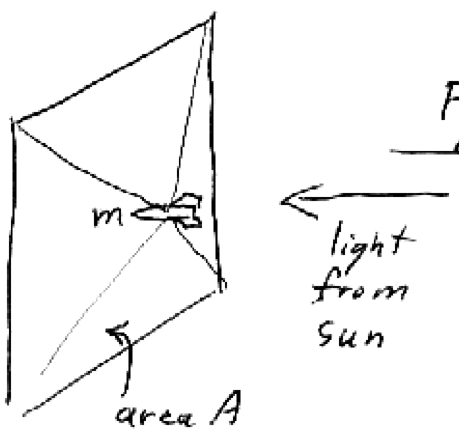
$$E_{max} = \sqrt{2\mu_0 c I} = \sqrt{2(4\pi\times10^{-7}\tfrac{T\cdot m}{A})(3\times10^{8}\tfrac{m}{sec})(10^{-5}\tfrac{W}{m^2})}$$

$$= \boxed{8.68\times10^{-2}\ \tfrac{V}{m}}$$

b) $B_{max} = \frac{E_{max}}{c} = \frac{8.68\times10^{-2}\ V/m}{3\times10^{8}\ m/sec} = \boxed{2.89\times10^{-10}T}$

c) $P = 4\pi r^2 I = 4\pi(10^4 m)^2(10^{-5}\frac{W}{m^2}) = \boxed{1.26\times10^{4}W}$

(34-3)



F_g = force of Sun's gravity on sail + ship

We set the radiation pressure force equal to the gravitational force,

$$F_g = F_{rad}$$

Since $F_{rad} = P_{rad} \times$ sail area

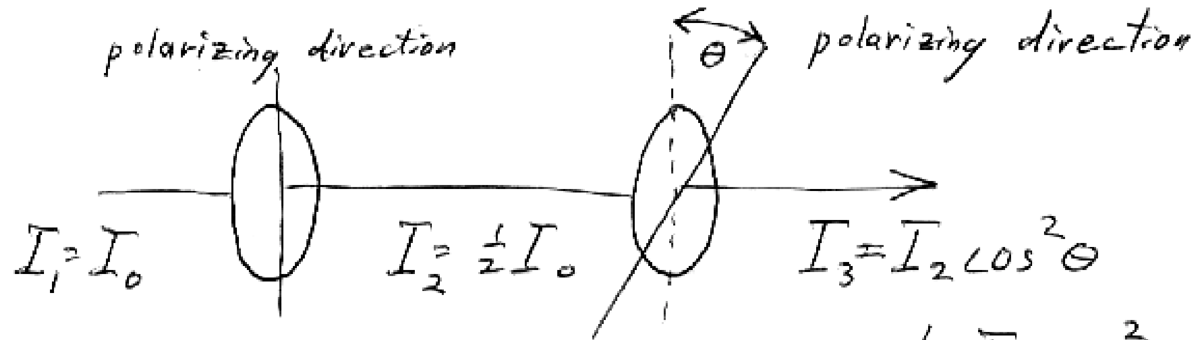
$$G\frac{M_{sun}m}{r^2} = \frac{2I}{c}A \qquad r = \text{Earth-sun distance}$$

$$\Rightarrow A = G\frac{c}{2I}\frac{M_{sun}m}{r^2}$$

$$= (6.67\times10^{-11}\tfrac{Nm^2}{Kg^2})\frac{3\times10^{8}\ m/sec}{2(1365\ W/m^2)}\frac{(1.99\times10^{30}Kg)(1500Kg)}{(1.50\times10^{11}\ m)^2}$$

$$= \boxed{9.72\times10^{5}m^2} \quad (= 986m\times986m\,!)$$

(34-4)



$I_1 = I_0$ $\quad$ $I_2 = \frac{1}{2} I_0$ $\quad$ $I_3 = I_2 \cos^2\theta$

$= \frac{1}{2} I_0 \cos^2\theta$

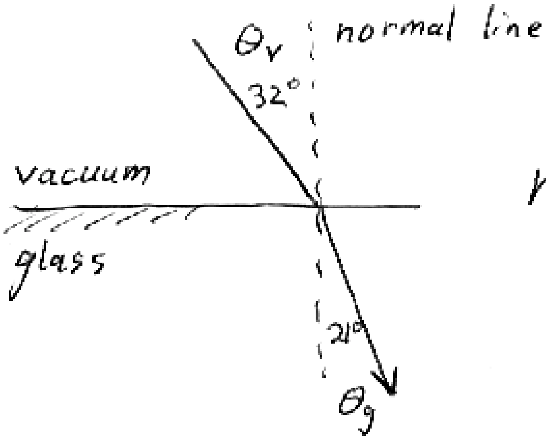
The diagram above shows that the intensity of the unpolarized light is reduced by half by the first polarizing sheet. After the light passes thru the second polarizing sheet, its intensity is reduced by a factor of $\cos^2\theta$, where θ is the angle between the polarizing directions. According to the problem, $I_3 = \frac{1}{3} I_1$, so

$$\frac{1}{2} I_0 \cos^2\theta = \frac{1}{3} I_0$$

$$\cos^2\theta = \frac{2}{3}$$

so $\cos\theta = \sqrt{\frac{2}{3}} = 0.8165$, so $\boxed{\theta = 35.3^\circ}$

(34-5)



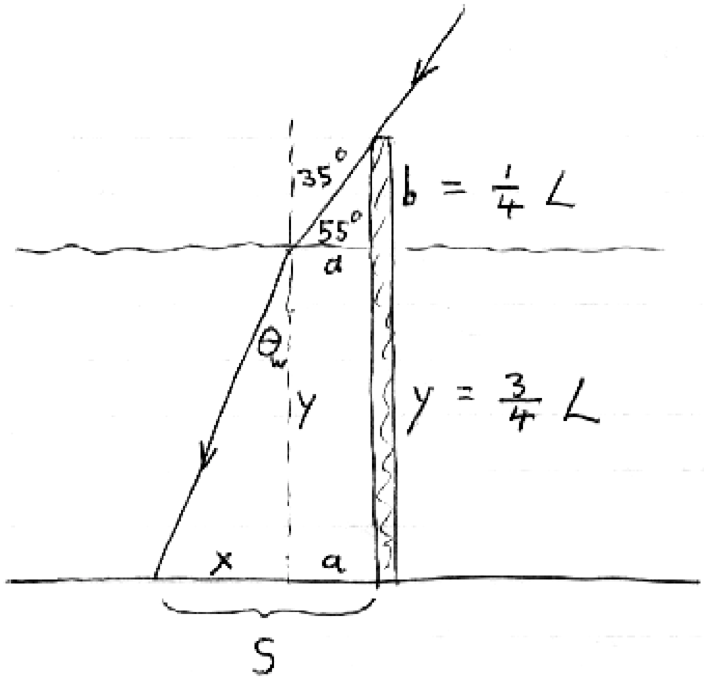
From Snell's law

$$n_v \sin\theta_v = n_g \sin\theta_g$$

with $n_v = 1$.

So $n_g = \frac{(1)\sin 32^\circ}{\sin 21^\circ} = \boxed{1.48}$

(34-6)



L = pole length = 2 m

First, use Snell's law to find angle θ_w:

$$n_{air} \sin\theta_{air} = n_w \sin\theta_w$$

Since $n_{air} = 1$ and $n_w = 1.33$,

$$\sin\theta_w = \frac{n_{air}\sin\theta_{air}}{n_w} = \frac{(1)\sin 35^\circ}{1.33}$$

$$\sin\theta_w = 0.4313 \Rightarrow \theta_w = 25.5^\circ$$

From trigonometry, $x = y\tan\theta_w$ and

$$a = b\tan 35^\circ$$

The shadow's length is

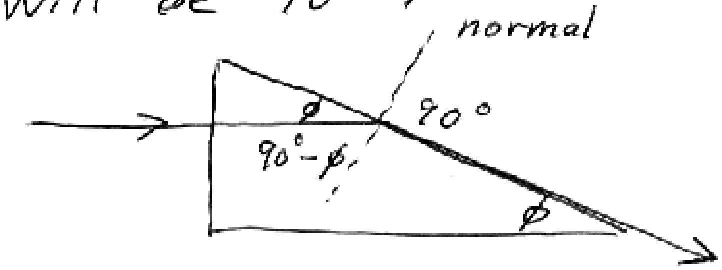
$$S = x + a = y\tan\theta_w + b\tan 35^\circ$$

so $$S = \frac{3}{4}L\tan\theta_w + \frac{1}{4}L\tan 35^\circ$$

$$= \frac{3}{4}(2m)\tan 25.5^\circ + \frac{1}{4}(2m)\tan 35^\circ$$

$$= \boxed{1.07\,m}$$

(34-7) If ϕ barely exceeds its maximum allowed value for total internal reflection, the angle of refraction will be $90°$:



From Snell's law,

$$n_{glass} \sin(90° - \phi) = n \sin 90°$$

$$n_{glass} \cos\phi = n$$

$$\cos\phi = \frac{n}{n_{glass}}$$

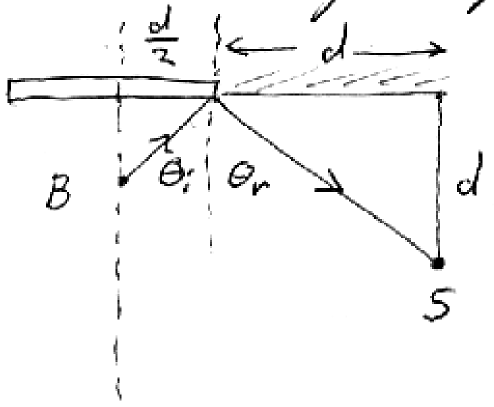
(a) in air, $n = 1$ and

$$\phi = \cos^{-1}\left(\frac{1}{1.52}\right) = \boxed{48.9°}$$

(b) in water, $n = 1.33$ and

$$\phi = \cos^{-1}\left(\frac{1.33}{1.52}\right) = \boxed{29.0°}$$

(35-8) Imagine what the guard will see in the mirror – the burglar will first be visible at the right edge of the mirror:



The angle of incidence equals the angle of reflection, so the large and small triangles are <u>similar</u>

$\Rightarrow$ the burglar is $\frac{d}{2} = \frac{3.0\,m}{2} = \boxed{1.5\,m}$ from the mirror

(35-9) $\frac{1}{p} + \frac{1}{i} = \frac{1}{f} = \frac{2}{r}$ with $r = 35$ cm

Also, for this upright image, the magnification is

$$m = -\frac{i}{p} = 2.5 \Rightarrow i = -2.5p$$

So $\frac{1}{p} - \frac{1}{2.5p} = \frac{2}{r}$

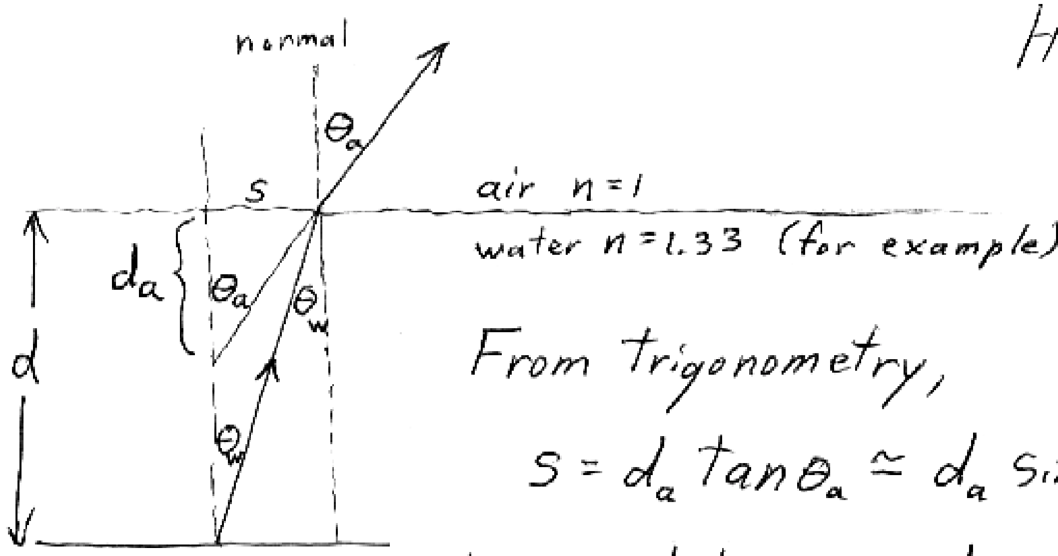
$$\frac{1.5}{2.5p} = \frac{2}{r}$$

$$\frac{3}{5p} = \frac{2}{r}$$

$$10p = 3r$$

$$p = 0.3r = 0.3(35\text{cm}) = \boxed{10.5\text{ cm}}$$

(35-10)



From trigonometry,

$$s = d_a \tan\theta_a \simeq d_a \sin\theta_a$$

and $s = d \tan\theta_w \simeq d \sin\theta_w$

So $\quad d_a \sin\theta_a \simeq d \sin\theta_w$

But from Snell's law,

$$n_{air} \sin\theta_a = n_{water} \sin\theta_w$$

or

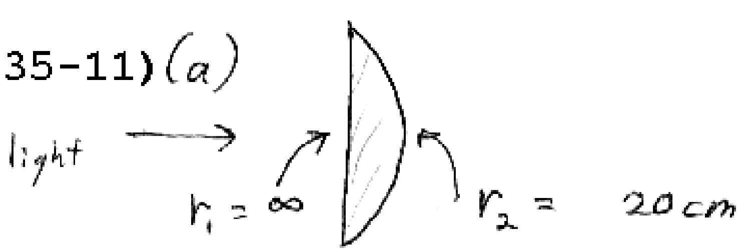
$$(1) \sin\theta_a = n_w \sin\theta_w$$

Thus this becomes

$$d_a\, n_w \sin\theta_w \simeq d \sin\theta_w$$

or $\quad \boxed{d_a \simeq \frac{d}{n_w}}$

(35-11) (a)



$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

$$\frac{1}{f} = (1.5-1)\left(\frac{1}{\infty} + \frac{1}{20\,cm}\right)$$

$$\frac{1}{f} = \frac{0.5}{20\,cm}$$

$\Rightarrow 0.5 f = 20\,cm \quad \Rightarrow \boxed{f = 40\,cm}$

(b) $\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$

$\frac{1}{40cm} + \frac{1}{i} = \frac{1}{40cm}$

$\Rightarrow \frac{1}{i} = 0$ so $\boxed{i = \infty}$

If an object is placed at the focal point of a lens, there is no image formed (real or virtual)

(35-12) First find the image distance

$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$ or $i = \frac{pf}{p-f}$

So $i = \frac{(27m)(75 \times 10^{-3}m)}{27m - 75 \times 10^{-3}m} = 7.52 \times 10^{-2} m$

The height of the image comes from

$\frac{h'}{h} = |m| = |-\frac{i}{p}|$

So $h' = h|-\frac{i}{p}|$

$= 180 cm \left|-\frac{7.52 \times 10^{-2} m}{27m}\right|$

$= \boxed{0.501 cm}$