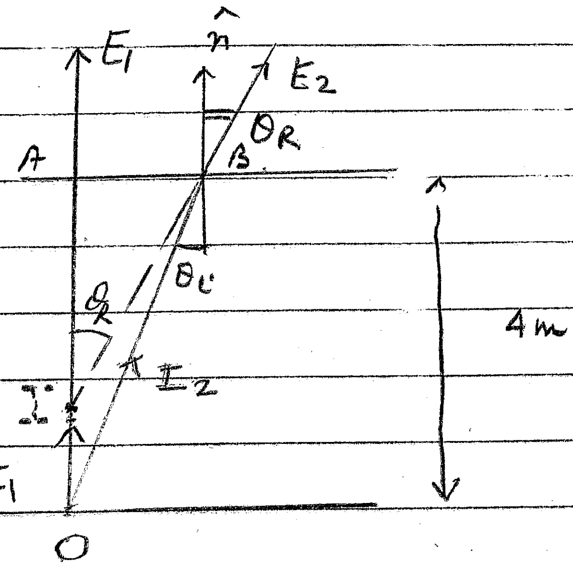
WK-13 [illegible] Solutions

13-1 Penny is object at O. Two rays I_1 and I_2 give E_1 and E_2 forming virtual image at I. All angles are small.



$$\frac{AB}{AI} = \tan\theta_R$$

$$\frac{AB}{AO} = \tan\theta_i$$

$$\frac{AI}{AO} = \frac{\tan\theta_i}{\tan\theta_R} \approx \frac{\sin\theta_i}{\sin\theta_R} \quad \text{[Small angles)}$$

Snell's law $n_{air} \sin\theta_R = n_{water} \sin\theta_i$

so

$$\frac{AI}{AO} = \frac{n_{air}}{n_{water}} = \frac{1}{1.33}$$

$$AI = \frac{4 \times 3}{4} = 3\,m$$

13-2
$$\frac{1}{f} = (n-1)\left[\frac{1}{R_F} - \frac{1}{R_B}\right]$$

The sign convention is: distances along light path +ive, Distances against light path −ive

13-2 Convex Surfaces

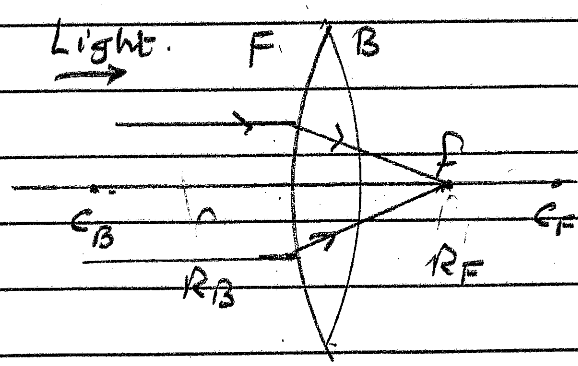
R_F +ive

R_B −ive

f +ive.

Lies to right of lens

Lens is CONVERGENT.



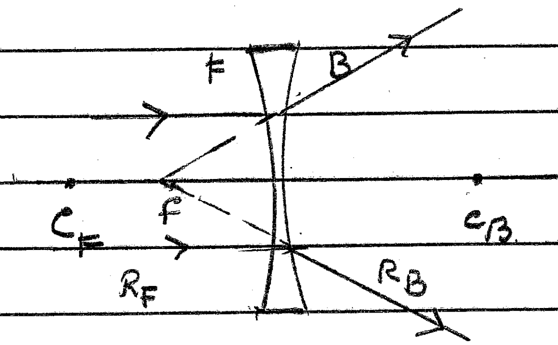
R_F −ive

R_B +ive

f −ive

Lies upstream

lens Divergent

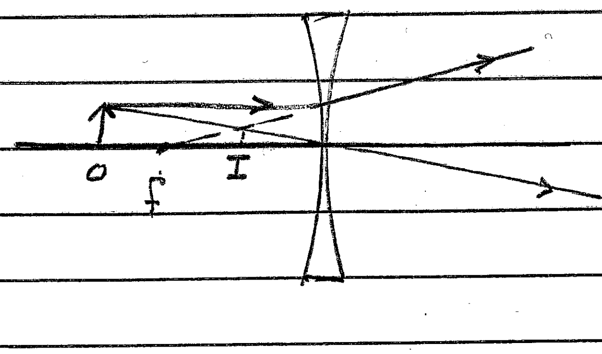


13-3 No. For Divergent lens f is −ive

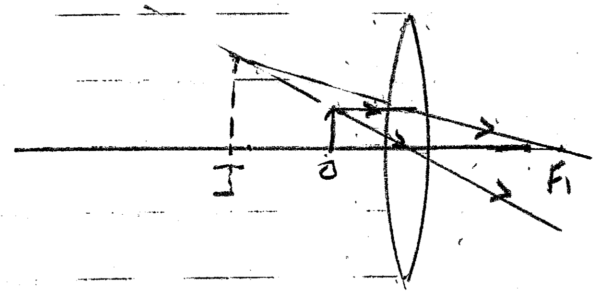
so q is −ive b/c

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

SO ALL IMAGES ARE UPRIGHT, REDUCED, VIRTUAL



13-4 on p. 7



13-5 $$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$p = 5\text{cm}$

$f = 10\text{ cm}$

So q must be -ive

$$\frac{1}{5} + \frac{1}{q} = \frac{1}{10}$$

$$\frac{1}{q} = \frac{1}{10} - \frac{2}{10} = -\frac{1}{10}\text{ cm}^{-1},\quad q = -10\text{cm}.$$

Image is virtual, magnification is 2.

13-6 $$\frac{1}{f} = (n-1)\left[\frac{1}{R_F} - \frac{1}{R_B}\right]$$

$f = 6\text{cm}.\qquad n = 1.5$

R_F and R_B both +ive

$$\frac{R_F}{R_B} = \frac{1}{2} \qquad R_B = 2R_F$$

$$\frac{1}{6} = 0.5\left[\frac{1}{R_F} - \frac{1}{2R_F}\right]$$

$$= 0.5\left[\frac{1}{2R_F}\right] = \frac{1}{4R_F}$$

$$\therefore R_F = 1.5\text{cm},\quad R_B = 3\text{ cm}.$$

13-7 $$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$x = p - f \qquad x' = q - f$$

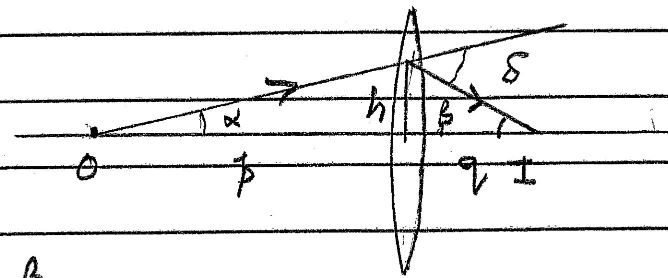
$$\frac{1}{x+f} + \frac{1}{x'+f} = \frac{1}{f}$$

$$(x' + x + 2f)f = xx' + (x+x')f + f^2 \quad \text{so } xx' = f^2.$$

13-8 δ being exterior angle

$\delta = (\alpha + \beta)$.

angles are small so

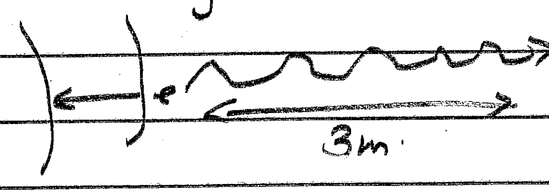


$\tan\delta = \tan\alpha + \tan\beta$.

$= \frac{h}{p} + \frac{h}{q} = \frac{h}{f}$.

so $\delta = \frac{h}{f}$ b/c $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

13-9 In a simple lamp there are an enormous number of electrons each of which makes a "jump" in its atom and produces light of a given frequency. The typical jump time is 10^{-8} sec so a single jump produces a wave train about 3m long



phase ϕ_1

$E = E_m \sin(kx - \omega t + \phi_1)$

However, ~~all~~ the jumps are independent so although frequency is same each has its own phase so phase varies randomly in time

13-10 (S_1) Source 1 $\quad E_1 = E_m \sin(kx - \omega t + \phi_1)$

(S_2) Source 2 $\quad E_2 = E_m \sin(kx - \omega t + \phi_2)$

They are incoherent if $(\phi_1 - \phi_2]$ is random in time.

13-11 Superpose the two waves.

$$E = E_1 + E_2 = \underbrace{2 E_m \cos\left(\frac{\phi_1 - \phi_2}{2}\right)}_{\text{amplitude}} \sin\left(kx - \omega t + \underbrace{\frac{\phi_1 + \phi_2}{2}}_{\text{random}}\right)$$

Intensity $I = \frac{1}{2} \epsilon_0 c \,(\text{amplitude})^2$

$$= \frac{1}{2} \epsilon_0 c \; 4 E_m^2 \cos^2\left(\frac{\phi_1 - \phi_2}{2}\right)$$

Since $(\phi_1 - \phi_2)$ is random, I also varies at random. We can only observe the average

$$\langle I \rangle = \frac{1}{2} \epsilon_0 c \; 4 E_m^2 \left\langle \cos^2 \frac{\phi_1 - \phi_2}{2} \right\rangle$$

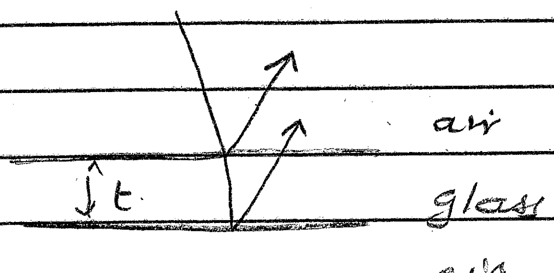
$$= \frac{1}{2} \epsilon_0 c \cdot 4 E_m^2 \cdot \frac{1}{2}$$

which is indeed twice the Intensity from a single source.

13-12 $$(\phi_1 - \phi_2) = \frac{2\pi x}{\lambda}$$

so $$x = \frac{\lambda}{2\pi}(\phi_1 - \phi_2) = \frac{\lambda \cdot \pi}{2\pi} = 350\,nm.$$

13-13 Reflection at top surface Phase change of π. (loses π). radians



Reflection at Bottom Surface NO phase change.

Phase change due to extra path $2t$

$$\Delta\phi = \frac{2\pi}{\lambda_n} \cdot 2t \qquad \lambda_n = \frac{\lambda_0}{n}$$

$$= \frac{2\pi \times 2 \times 580 \times 1.5}{436}$$

$$= 16\pi \text{ (behind) radians}$$

Net phase change is 15π radians

13-14 When you are in the middle $(x_1 - x_2) = 0$ and if you donst hear anything it means that the waves started out of phase at the sources.

In this case

Maxima will ~~pla~~ happen when

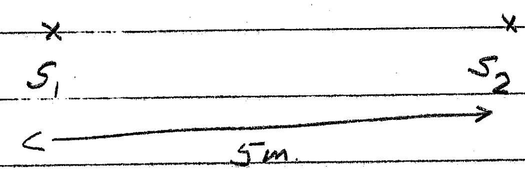
$$(x_1 - x_2) = \left(M + \tfrac{1}{2}\right)\lambda \qquad M = 0, \pm 1, \pm 2, \ldots$$

and minima will occur when

$$(x_1 - x_2) = m\lambda \qquad m = 0, \pm 1, \pm 2$$

The wavelength

$$\lambda = \frac{340}{340} = 1\ \text{m}$$



The separation is 5λ so as you walk from S_1 to S_2 m will change from -5 to $+5$ including zero. So 11 minima in all!

13-4 O should be located at the focal point of the lens as is clear from the ray diagram. Since $p = f$, $q \to \infty$ light becomes parallel, the mirror turns it around and sends it back to O.