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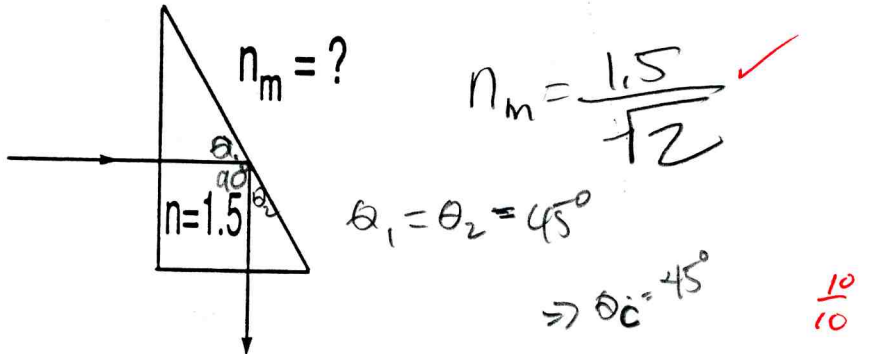
University of California

Physics 141

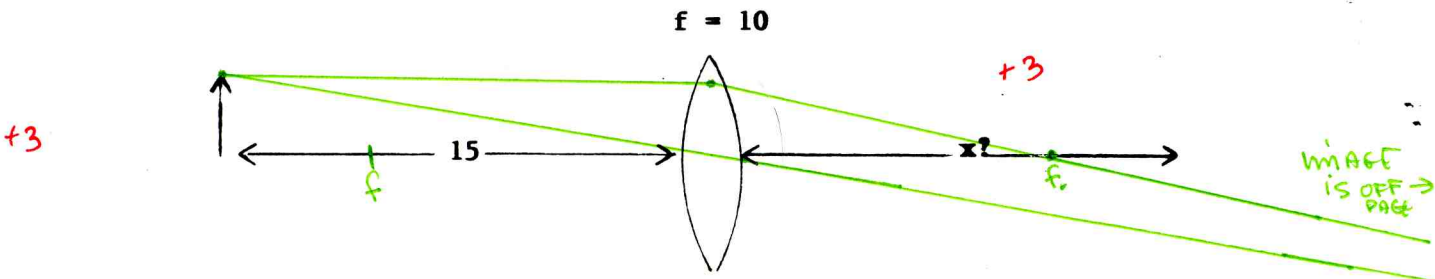
Winter 1993

MIDTERM EXAM
(Please show all of your work)

1. Right angle prisms are used to reflect light through 90° by means of total internal reflection as shown. Consider a prism made of glass with $n=1.5$ immersed in a medium of refractive index n_m . What is the maximum value n_m may have if the prism is to deflect all of the light by 90° ?

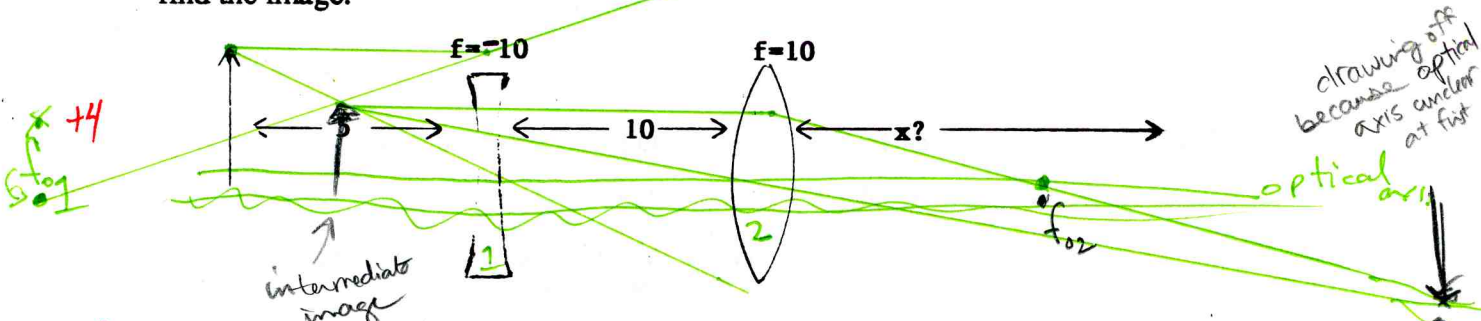


2. a) Draw the ray tracing diagram for an object 15 cm before a lens of focal length $f=10$ cm.



b) Determine the image location, x , and the magnification. *30 cm to the right of the lens. $M_T = -2$*

c) A second lens, $f=-10$ cm, is added 10 cm before the first lens. Draw the ray diagram to find the image.



d) Verify your drawing by calculating the new image location and magnification.

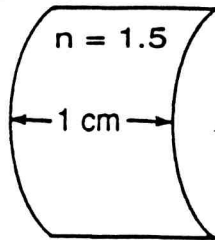
e) Is the image real or virtual? *New image at +40 cm from second lens. $M_T = -2$*

f) How would one achieve the same image location and orientation with a single mirror?

Start with

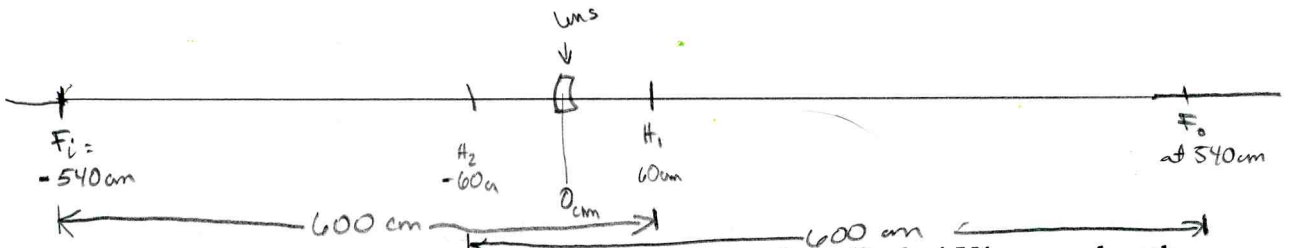
3. A meniscus lens 1 cm thick has a refractive index $n=1.5$ and 10 cm radii of curvature as shown. Treat the lens as a thick lens.

$$R_1=10 \text{ cm} \quad R_2=10 \text{ cm}$$



- +5 a) What is the focal length of this lens? $f=600 \text{ cm}$
- +4 b) Where are the principal planes located? $H_1 = +60 \text{ cm}$ $H_2 = -60 \text{ cm}$
- +5 c) Show the foci, the first and second principal points, and the lens in a sketch. Indicate distances clearly in cm. Label the object focus F_o and the image focus F_i .

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4. An electric field polarized in the y-direction is a wave of amplitude 4 V/m, wavelength $\lambda=500 \text{ nm}$, is traveling in the x-direction, and has value 2 V/m at the origin at time $t=0$:

$$|E(x=0, y=0, z=0, t=0)| = 2$$

The wave is traveling in vacuum ($c=\omega/k=3 \times 10^8 \text{ m/s}$)

- +5 a) Write this wave in the form $E=E_0 \cos(\mathbf{k} \cdot \mathbf{r} - \omega t + \phi)$, where $\mathbf{r}=x\hat{x}+y\hat{y}+z\hat{z}$. What is E_0 , k , ω , and ϕ ? $E = \hat{y} 4 \left(\frac{V}{m}\right) \cos\left[\frac{2\pi}{500} \times 10^9 \text{ m}^{-1} x - \left(\frac{6\pi}{500} \times 10^{14} \text{ s}^{-1}\right) t + \frac{\pi}{3}\right]$ $E_0 = 4 \frac{V}{m}$ $k = \frac{2\pi}{500 \text{ nm}}$
- +4.5 b) What is the intensity of the light with this E field? $I = \frac{1}{2} E_0^2 = 8 \frac{W}{m^2}$ $I = \frac{c \epsilon_0}{2} |E_0|^2$ $\omega = ck = \frac{2\pi}{500 \text{ nm}} \times 3 \times 10^8 \frac{m}{s}$
- +5 c) The wave passes into glass with $n=1.4$. What are λ_g , ω_g , and k_g in the glass? $\lambda_g = \frac{500}{1.4} \text{ nm}$ $\omega_g = \omega_0 = c \lambda_0 = \frac{2\pi}{500 \text{ nm}} (3 \times 10^8 \frac{m}{s})$ $k_g = \frac{2\pi}{\lambda_g} = \frac{2\pi(1.4)}{500 \text{ nm}}$ $\phi = \frac{\pi}{3}$
- d) If $n(\lambda) = 1.2 + (5 \times 10^4 \text{ nm}^2)/\lambda^2$, what are the phase and group velocities in the glass?

$$\text{Phase velocity} = \frac{\omega_g}{k_g} = \frac{c \lambda_0 \lambda_g}{2\pi} = \frac{(3 \times 10^8 \text{ m/s})(500 \text{ nm})}{2\pi(1.4)}$$

+5 group velocity = $\frac{d\omega}{dk} = v \left(1 - \frac{k}{n} \frac{dn}{dk}\right) = v \left[1 - \frac{k^2}{n} \left(\frac{2(5 \times 10^4 \text{ nm}^2)}{4\pi^2}\right)\right]$

where $k_g = \frac{2\pi(1.4)}{500 \text{ nm}}$ $n=1.4$

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