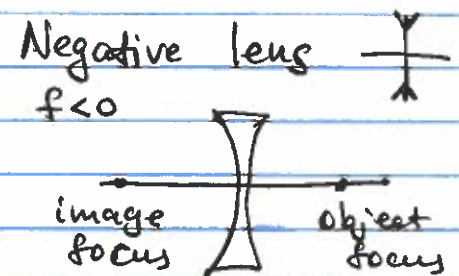
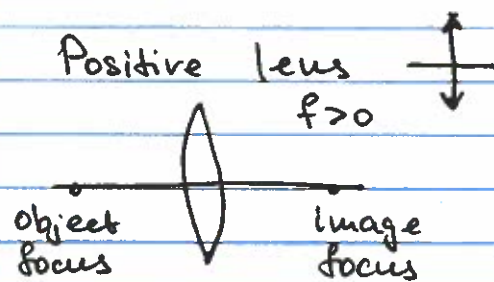


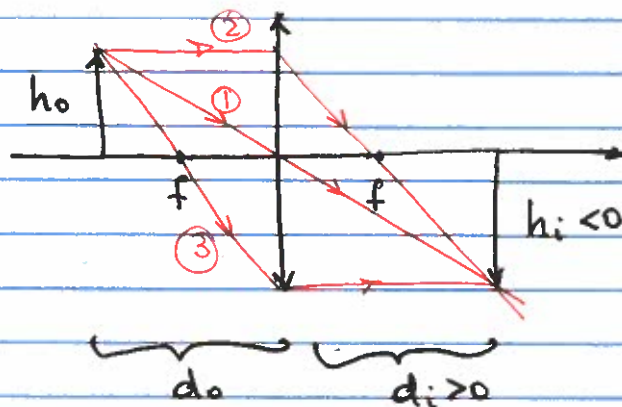
Quick summary of relevant topics for the first midterm

Principle rays

1. The ray traveling through the center of the lens doesn't change direction
2. The ray traveling parallel to the optical axis continues through the image focus
3. The ray crossing object focus continues parallel to the axis after the lens



Example : positive lens

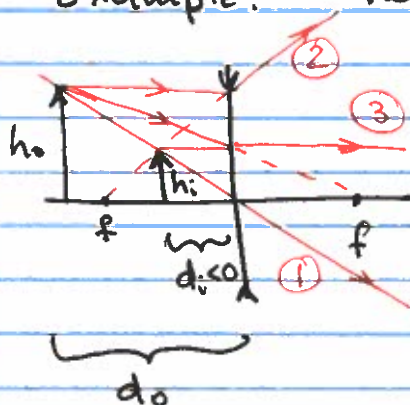


real image $d_i > 0$
(beams cross)
inverted image
 $h_i < 0$

Magnification

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} < 0$$

Example: negative lens



virtual ~~to~~ image $d_i < 0$
beams never cross

erect image $h_i > 0$

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} > 0$$

Calculations: same formula for any lens

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

f can be positive
or negative

If d_o and f are known

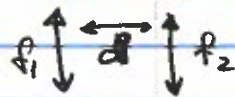
$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \Rightarrow d_i = \frac{f \cdot d_o}{d_o - f}$$

$$m = -\frac{d_i}{d_o} = -\frac{f}{d_o - f}$$

System of lenses: the image ~~for~~
of the first lens becomes the object
for the next lens

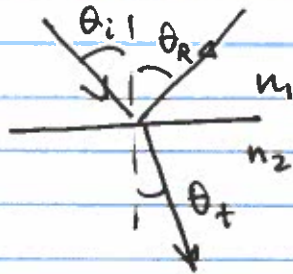
Effective ~~lens~~ focal length for two lenses

$$\frac{1}{f_{\text{eff}}} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$



Reflection: $\theta_i = \theta_r$

Reflection $n_1 \sin \theta_i = n_2 \sin \theta_t$



Critical angle for total internal reflection

$$\sin \theta_i^{(cr)} = n_1/n_2$$

if $\theta_i > \theta_i^{(cr)}$ no light can be transmitted, 100% reflection

Occurs only when light travels from more optically dense medium ($n_1 > n_2$)

General description of an electromagnetic wave

$$\vec{E}(x,t) = \vec{E}_0 \cos(kx - \omega t)$$

$$\vec{B}(x,t) = \vec{B}_0 \cos(kx - \omega t)$$

$\vec{E}_0$ polarization direction

$$|\vec{E}_0| = \frac{|\vec{B}_0|}{c} \text{ in vacuum}$$

In vacuum speed of light c

ω - in rad/s - angular frequency

$$\lambda = \frac{2\pi c}{\omega} - \text{wavelength}$$

$$f = \frac{\omega}{2\pi} = c/\lambda - \text{in Hz} - \text{frequency}$$

$$\text{Wavevector } k = \frac{2\pi}{\lambda} = \frac{\omega}{c} = \frac{2\pi f}{c}$$

In a material with the refractive index n
 ω, f don't change

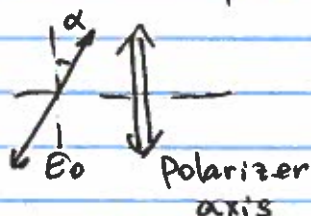
$$\lambda_{\text{mat}} = \frac{\lambda_0}{n} \text{ and } k_{\text{mat}} = \frac{2\pi}{\lambda_{\text{mat}}} = \frac{2\pi n}{\lambda_0}$$

Speed of light in the material

$$v = c/n$$

Linear polarization: direction along which $\vec{E}_0$ is directed. For em wave propagating along x, $\vec{E}_0$ is in y-z plane

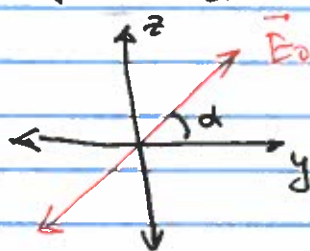
Linear polarizer



Transmitted intensity

$$I_{tr} = I_{in} \cos^2 \alpha$$

For many applications it is convenient / necessary to present a light polarization as a combination of two orthogonal polarizations (for example, parallel and perpendicular to the polarizer axis)



$$\vec{E}_0 = (E_0 \cos \alpha) \hat{y} + (E_0 \sin \alpha) \hat{z}$$

We can even write such wave as a combination of two orthogonally polarized e-m waves

$$\vec{E}(x,t) = [E_0 \cos \alpha] \hat{y} \cos(kx - \omega t) + [E_0 \sin \alpha] \hat{z} \cos(kx - \omega t)$$

Circularly polarized light

$$\vec{E}(x,t) = \frac{E_0}{\sqrt{2}} \hat{y} \cos(kx - \omega t) \pm \frac{E_0}{\sqrt{2}} \hat{z} \sin(kx - \omega t)$$