Chapter 24

Sign Rules:

1.Object distance **s**: When the object is on the same side of the reflecting or refracting surface as the incoming light, the object distance s is positive; otherwise, it is negative

2.Image distance **s'**: When the image is on the same side of the reflecting or refracting surface as the outgoing light, the image distance s' is positive; otherwise, it is negative.

3.Radius of curvature ***R***: When the center of curvature *R* is on the same side as the outgoing (reflected) light, the radius of curvature *R* is positive otherwise, it is negative.

$$m = \frac{-s'}{s} = \frac{y'}{y}$$

m is the magnification, *y'* is the height of the image, *y* is the height of the object and *s'* and *s* are the distances between the mirror or lens and the image and object respectively.

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

The paraxial approximation where *f* is the focal length of the mirror and *f = R/2* the radius of curvature of the mirror divided by 2.

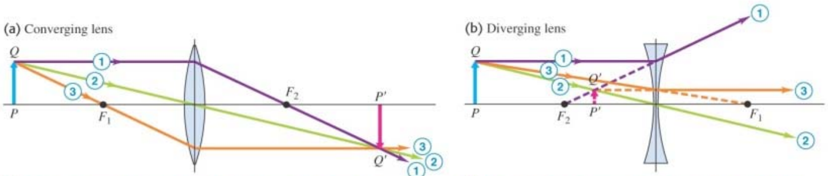
$$\frac{n_a}{s} + \frac{n_b}{s'} = \frac{n_b - n_a}{R}$$

$$m = \frac{y'}{y} = -\frac{n_a s'}{n_b s}$$

The paraxial approximation and magnification relation when incident and outgoing rays are in media with different indices of refraction n_a and n_b outgoing ray

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f} \quad \text{and} \quad \frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

The paraxial approximation for a complex lens with index of refraction *n* and radii of curvature R_1 and R_2.



(a) ① Parallel incident ray refracts to pass through second focal point F_2. ② Ray through center of lens does not deviate appreciably. ③ Ray through the first focal point F_1 emerges parallel to the axis.

(b) ① Parallel incident ray appears after refraction to have come from the second focal point F_2. ② Ray through center of lens does not deviate appreciably. ③ Ray aimed at the first focal point F_1 emerges parallel to the axis.

Chapter 23

$$n = \frac{c}{v}, \quad \lambda = \frac{\lambda_0}{n}$$

The index of refraction, the speed of light and wavelength in vacuum, c and λ_0

$$\theta_{incident} = \theta_{reflected}$$

$$n_a \sin\theta_a = n_b \sin\theta_b$$

Law of reflection and Snell's Law, a and b correspond to different media

$$\sin\theta_{critical} = \frac{n_b}{n_a}$$

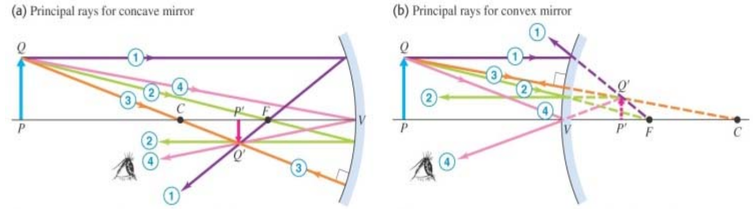
The critical angle corresponds the angle at which total internal reflection occurs

$$I = I\cos^2\phi$$

The intensity through polarizer for incident light that is polarized at angle ϕ

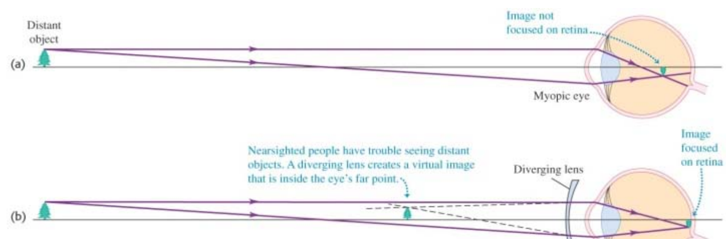
$$I = I_0/2$$

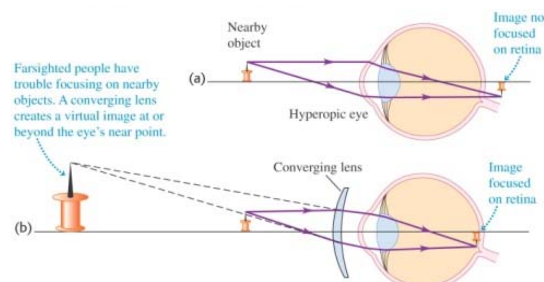
The intensity through polarizer for incident unpolarized light



(a) ① Ray parallel to axis reflects through focal point. ② Ray through focal point reflects parallel to axis. ③ Ray through center of curvature intersects the surface normally and reflects along its original path. ④ Ray to vertex reflects symmetrically around optic axis.

(b) ① Reflected parallel ray appears to come from focal point. ② Ray toward focal point reflects parallel to axis. ③ As with concave mirror: Ray radial to center of curvature intersects the surface normally and reflects along its original path. ④ As with concave mirror: Ray to vertex reflects symmetrically around optic axis.





For a Normal eye:
Near point is 25 cm
Far point is ∞

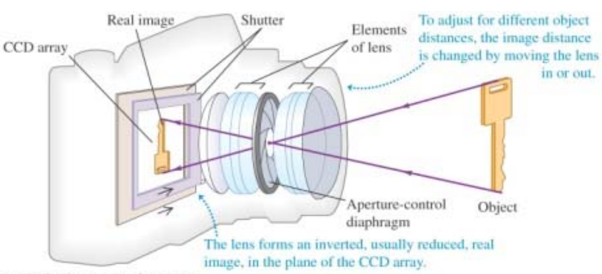
Chapter 25

Camera

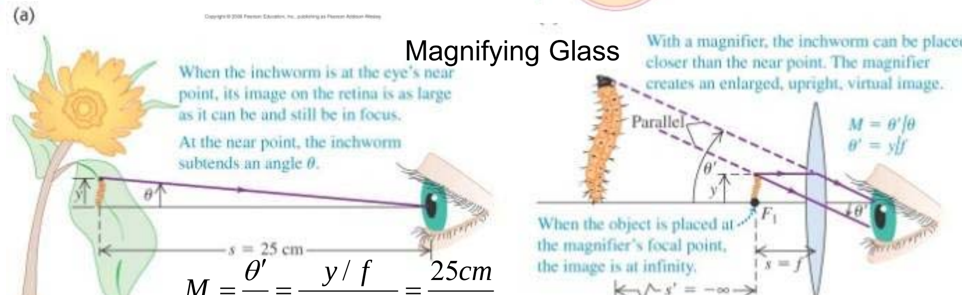
In all devices below $1/s + 1/s' = 1/f$ applies

$$f_{\#} = \frac{f}{D}$$

f# is the fstop, *f* is the focal length and D is the diameter of the aperture The intensity I is proportional to the square of the aperture diameter and the exposure time

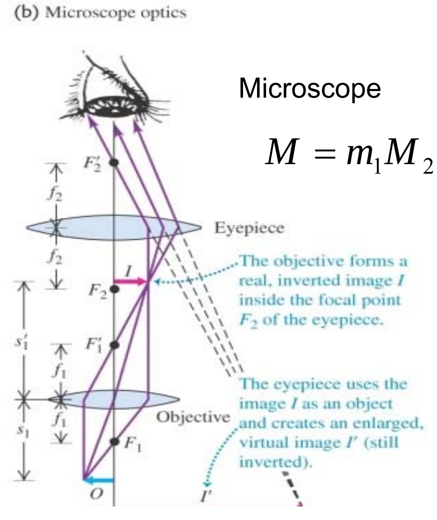


Magnifying Glass



$$M = \frac{\theta'}{\theta} = \frac{y/f}{y/25cm} = \frac{25cm}{f}$$

(b) Microscope optics

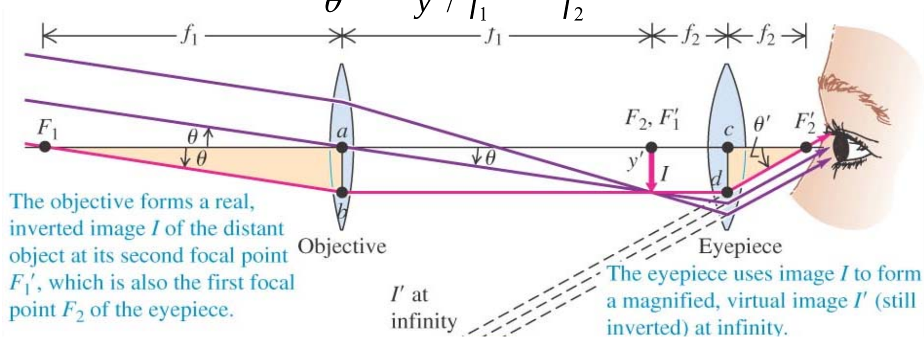


Microscope

$$M = m_1 M_2 = \frac{(25cm)s_1'}{f_1 f_2}$$

Telescope

$$M = \frac{\theta'}{\theta} = -\frac{y'/f_2}{y'/f_1} = -\frac{f_1}{f_2}$$

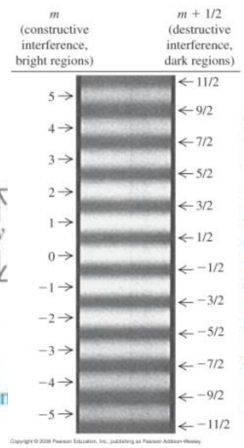


Chapter 26

$r_2 - r_1 = \text{path difference}$

$r_2 - r_1 = m\lambda$ const. interference

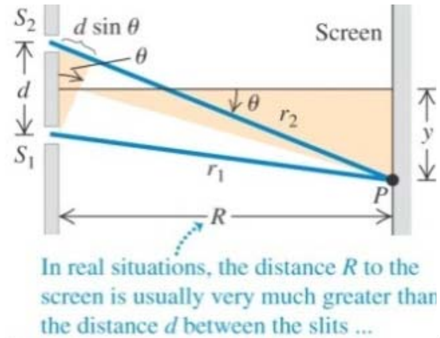
$r_2 - r_1 = \left(m + \frac{1}{2}\right)\lambda$ dest. interference



Double slit

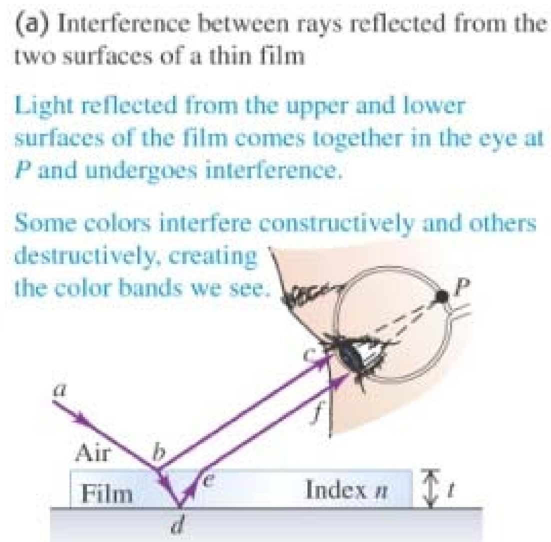
$$\left.\begin{aligned} d\sin\theta &= m\lambda \\ y_m &= R\frac{m\lambda}{d} \end{aligned}\right\} \text{const.}$$

$$\left.\begin{aligned} d\sin\theta &= \left(m+\tfrac{1}{2}\right)\lambda \\ y_m &= R\frac{\left(m+\frac{1}{2}\right)\lambda}{d} \end{aligned}\right\} \text{dest.}$$



d is the separation btw the slits and applies when d is of similar size as the wavelength λ.

Thin films



For thin films the path difference is $2t$. The conditions for constructive or destructive interference

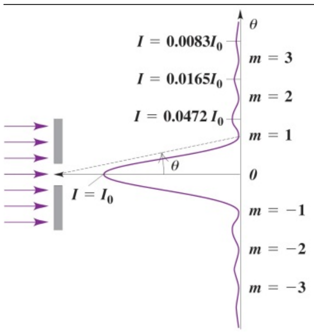
$2t = m\lambda'$ constructive

$2t = \left(m+\frac{1}{2}\right)\lambda'$ destructive

with $\lambda' = \frac{\lambda_0}{n}$

For thin films there is a phase shift (p.s.) of ½ λ' when light reflects from a surface if the incident ray is in media of lower n_a than refracted ray n_b. No p.s. occurs if the convers ie., $n_a > n_b$. An odd number of p.s. will have the effect of swapping the constructive destructive interference criteria for the path difference.

Diffraction from a Single slit



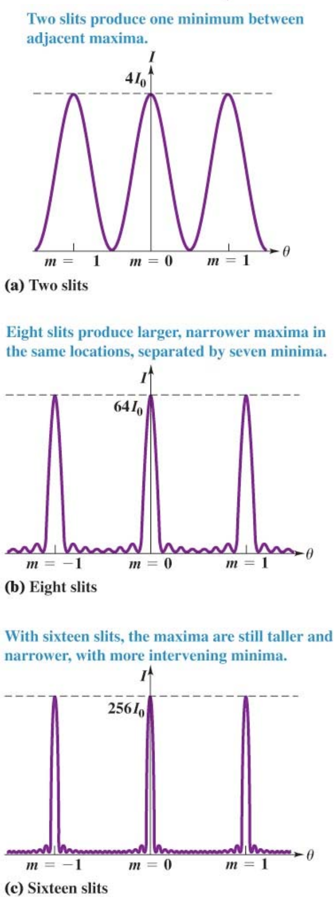
$\text{Path difference} = \frac{a}{2}\sin\theta$

Dark fringe (destructive)

$\frac{a}{2}\sin\theta = \frac{m\lambda}{2}, \quad (m = \pm 1, \pm 2...)$

$y_m = R\frac{m\lambda}{a}, \quad (m = \pm 1, \pm 2...)$

a is the width of the single slit which is much larger than the wavelength of light



Multiple slit diffraction:

The multiple slit problem the conditions found in the double slit exist similarly. The main difference is that the maxima (bright) band get narrower while the dark bands get small bright regions as shown in figure to the left.

$\text{Path difference} = d\sin\theta$

$d\sin\theta = m\lambda, \quad (m = 0, \pm 1, \pm 2...)$

$d\sin\theta = \left(m+\frac{1}{2}\right)\lambda, \quad (m = 0, \pm 1, \pm 2...)$

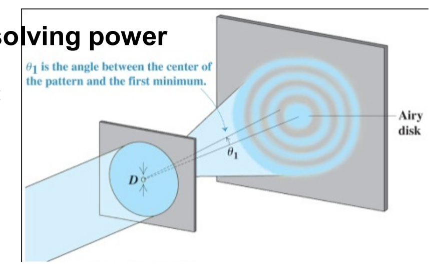
Circular Aperture and resolving power

The first dark ring is:

$\sin\theta_1 = 1.22\frac{\lambda}{D}$

The minimum separation of two object (Rayleigh's criterion)

$\theta_{res} = 1.22\frac{\lambda}{D}$



X-ray Diffraction

The Bragg conditions are (where the bright spots lie)

1. $\theta_a = \theta_r$
2. $2d\sin\theta_a = m\lambda$