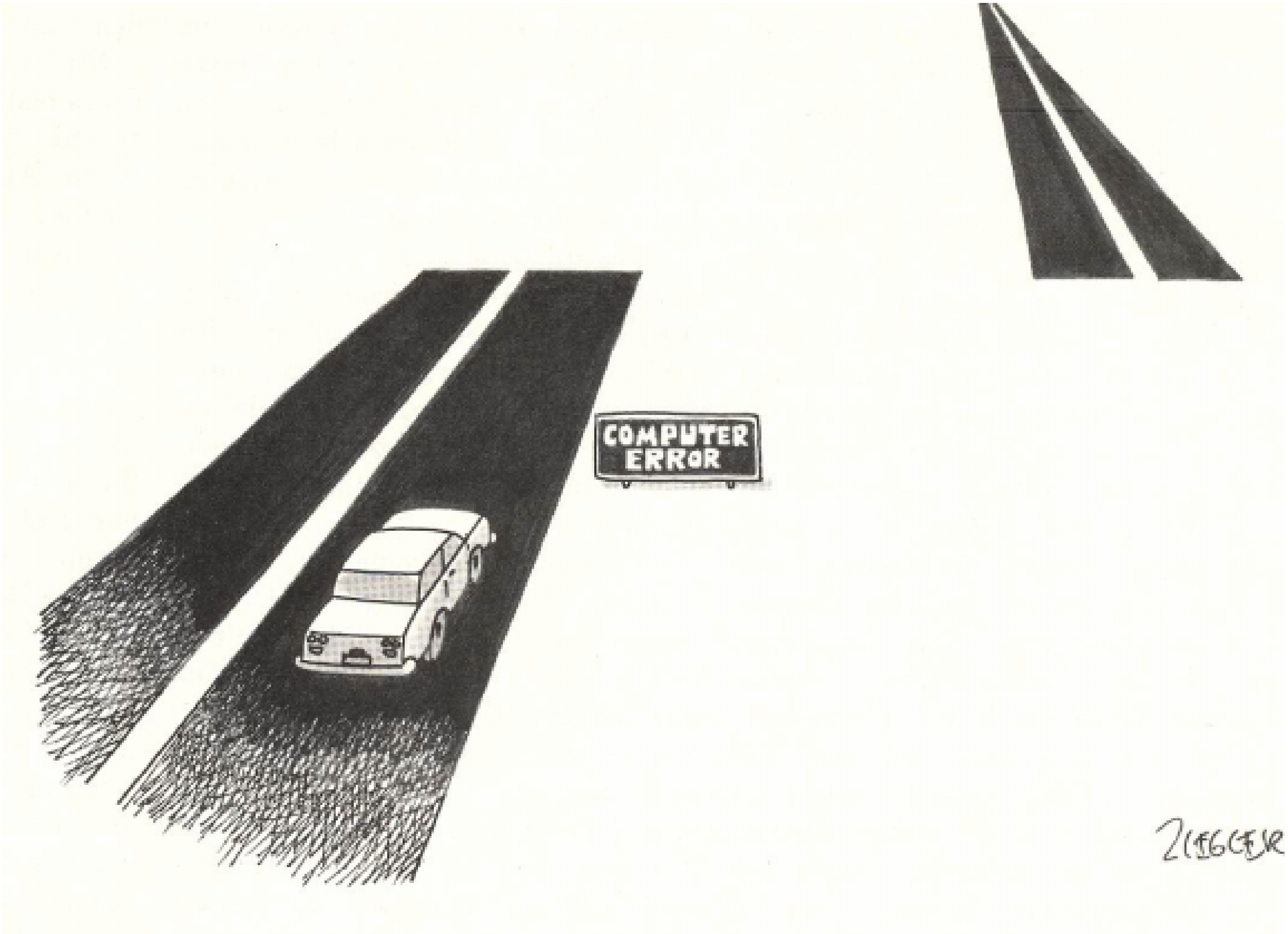


November 19th

Interference

Chapter 36

Schedule

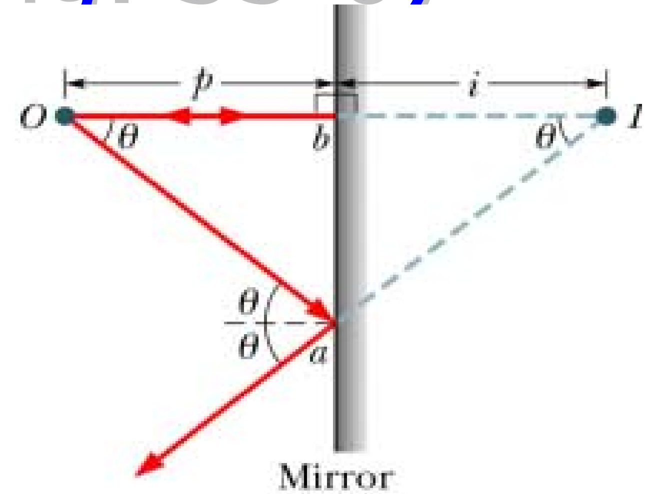
- HW set #11 will open Tues. Nov. 18th and is due on Tues. Nov. 25th at noon.
  - Third mid-term is Nov. 25th at 6pm
- HW set #12 will open Wed. Nov. 26th and is due on Wed. Dec. 3rd at 7am.
- Corrections for the third exam will open Wed. Nov. 26th at 5pm and are due Mon. Dec. 8th at 7am.
  - Final exam is Dec. 8th at 5:45-7:45pm.

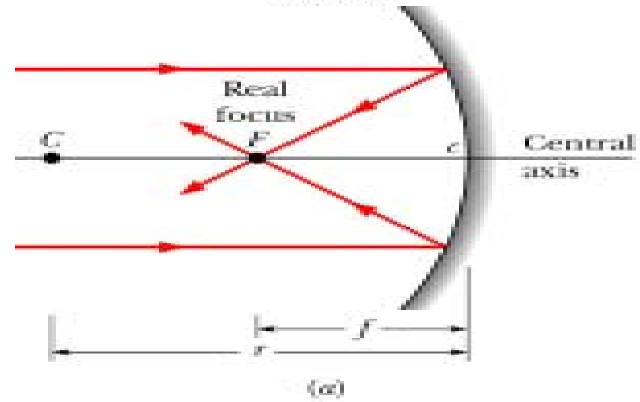
Midterm Exam #3

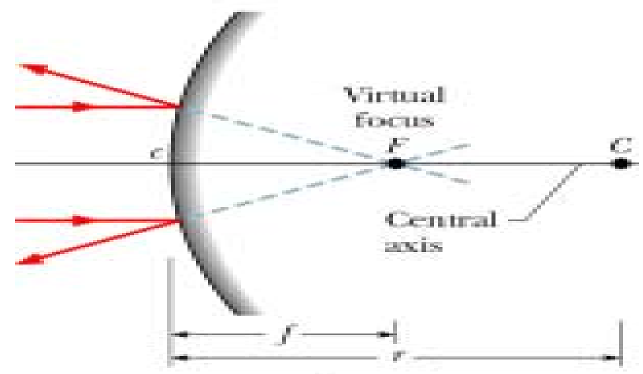
- Last mid-term is Tues. Nov. 25th at 6pm.
  - Section 1 in N100 BCC (Business College)
  - Section 2 in 158 NR (Natural Resources)
- Covers homework sets #9, 10 and 11!
  - Chapters 32-35 in textbook
- Allowed one page (both sides) of notes and calculator.
- Bring photo id.
- Email Prof. Tollefson (tollefson@pa.msu.edu) if need make-up exam and explain why.
  - Make-up exam will be Wed. Nov. 26th at 8am
- Review in class on Monday.

Review – Mirrors (Fig. 35-6)

- Plane – flat mirror
- Concave – caved in away from object
- Convex – flexed out toward object
- Real images on side where object is, virtual images on opposite side
- Plane and convex mirrors make only virtual images
- Concave mirrors can produce both real and virtual images







Review – mirrors (Fig. 35-7)

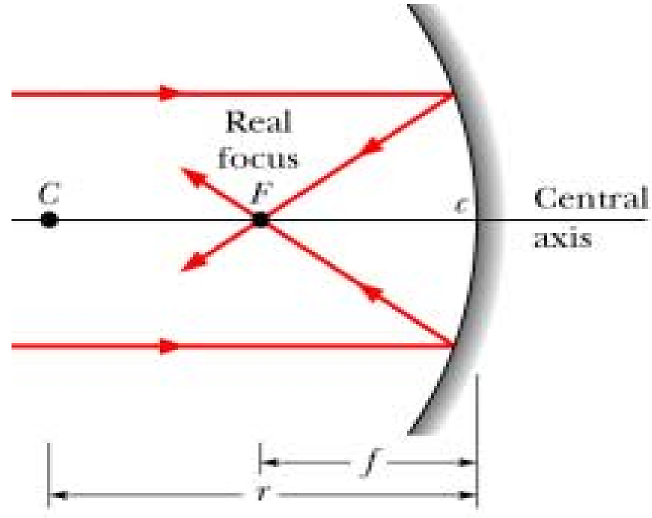
- Spherical mirrors have focal point, r is radius of curvature

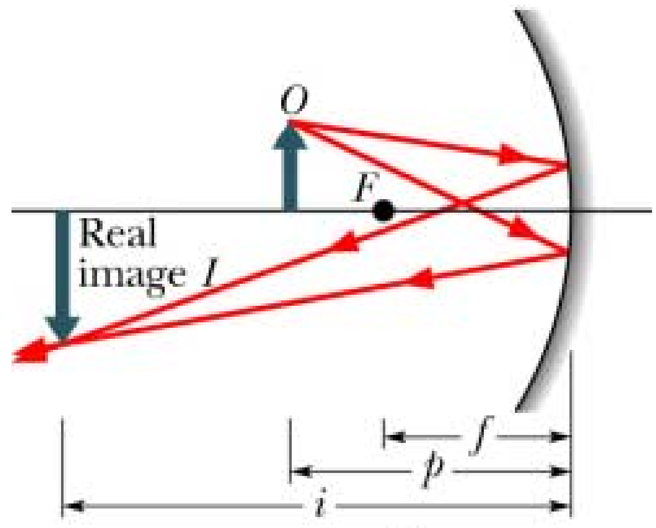
$$f = \tfrac{1}{2} r$$

- Find focal length, *f* from

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

  - Object distance *p* is +
  - Image distance *i* is + for real images, - for virtual images
  - f is + for concave, - for convex





Review - mirrors

- Ratio of image's height h' to object's height h is called lateral magnification, m

$$|m| = \frac{h'}{h}$$

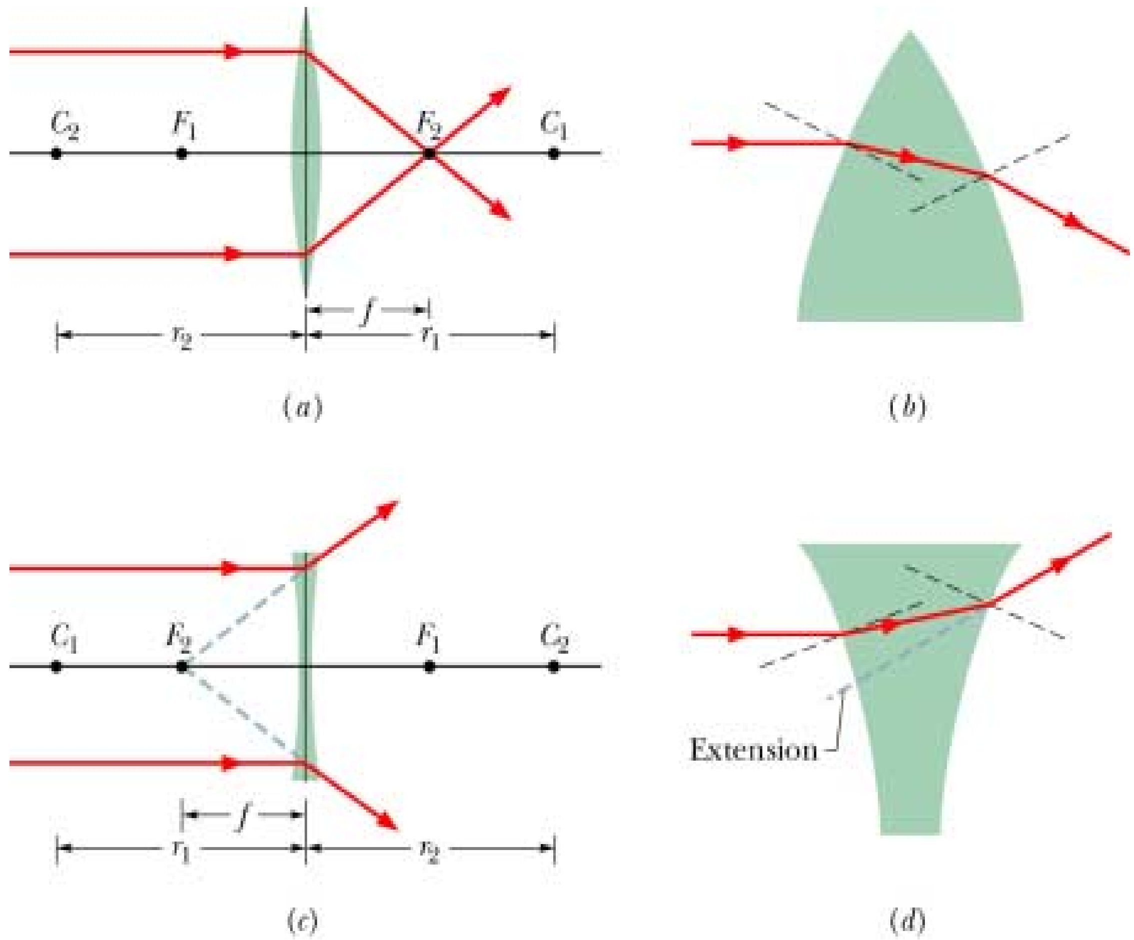
- Magnification also equal to

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

- m is + if image has same orientation as object
- m is – if image is inverted from object
- Plane mirror $m = +1$

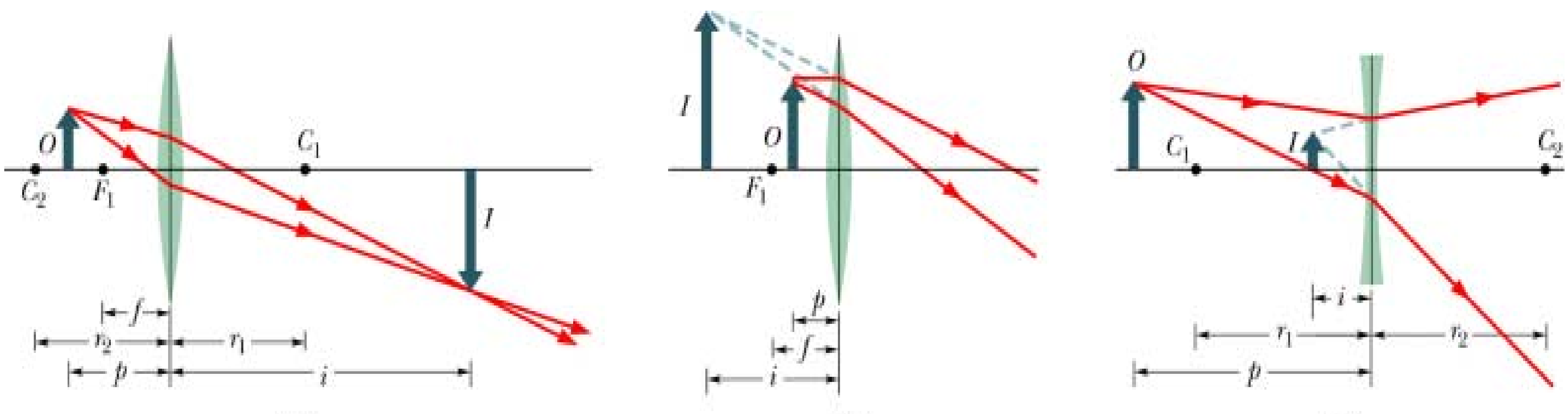
Review - Thin lenses (Fig. 35-12)

- Light rays bent by refraction form an image
- Converging – lens with convex refracting sides
- Diverging – lens with concave sides



Review - Thin lenses (Fig. 35-13)

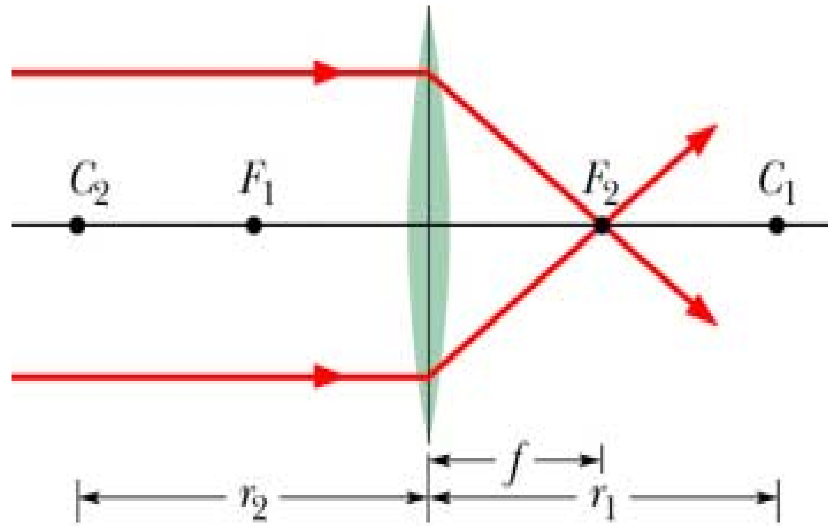
- Real images form on opposite side of lens from object, virtual images on same side
- Diverging lens only produces smaller, same orientation, virtual images (like convex mirror)
- Converging lens (like concave mirror) can produce both real and virtual images depending on where the object is in relation to the lens' focal point



Review - Thin lenses (Fig. 35-12)

- Thin lenses have a focal point on each side of lens
- Focal length, f same as mirror

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



- Lens maker's equation – for lens in air, r_1 is radius of lens surface nearest the object, r_2 is other surface
  - r is + for convex surface, - for concave surface

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

Review - Thin lenses (Fig. 35-4)

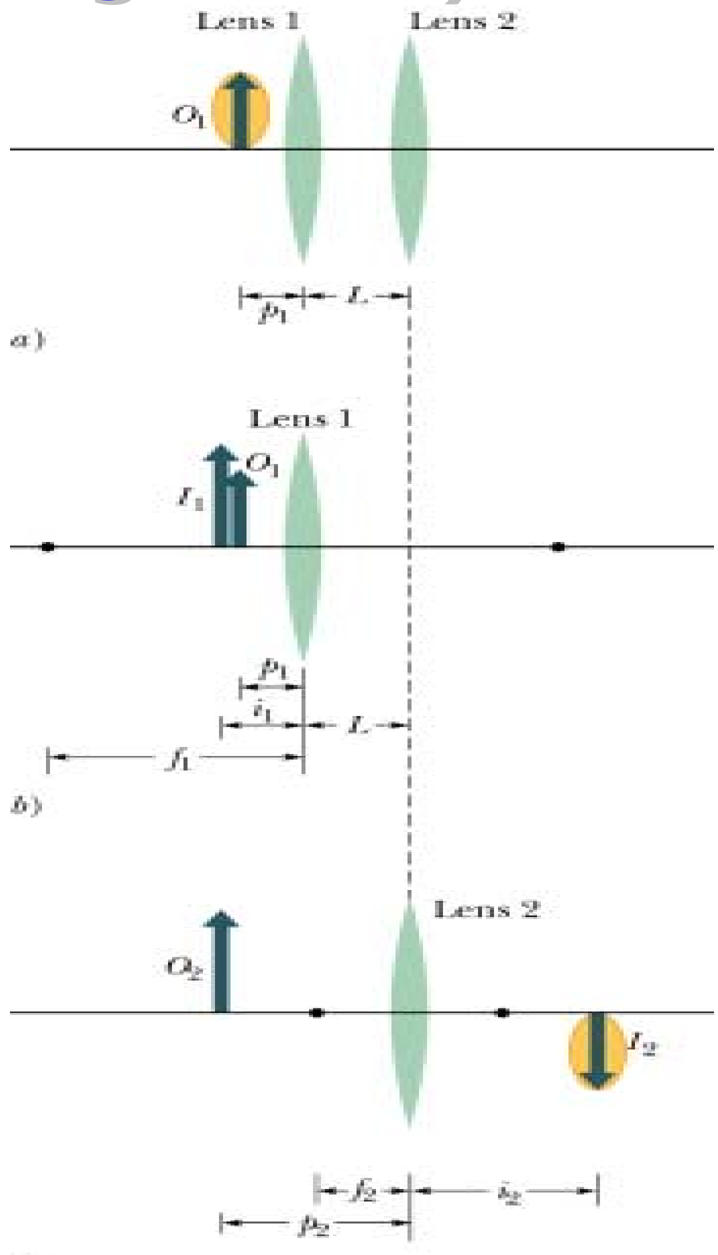
- Lateral magnification m same as for mirror

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

- For a system of lenses or mirrors the total magnification M is product of each m

$$M = m_1 m_2 m_3 \ldots$$

- Work through system of lenses one by one – use image from one lens as object for next lens



Review - Thin lenses

Converging lens = concave mirror

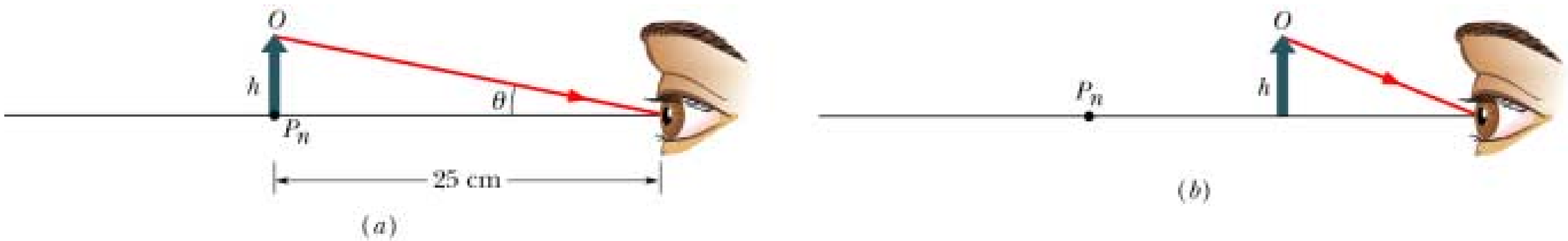
Diverging lens = convex mirror

Thin Lens Type	Object Location	Image Location	Image Size	Image Type	Image Orient-ation	Sign of *f*	Sign of *i*	Sign of *m*
Converging	$p < f$	Anywhere	Bigger	Virtual	Same	+	-	+
Converging	$f < p < 2f$	$i > 2f$	Bigger	Real	Invert	+	+	-
Converging	$p = 2f$	$i = 2f$	Equal	Real	Invert	+	+	-
Converging	$p > 2f$	$2f > i > f$	Smaller	Real	Invert	+	+	-
Diverging	Anywhere	$\lvert i\rvert < \lvert f\rvert$	Smaller	Virtual	Same	-	-	+

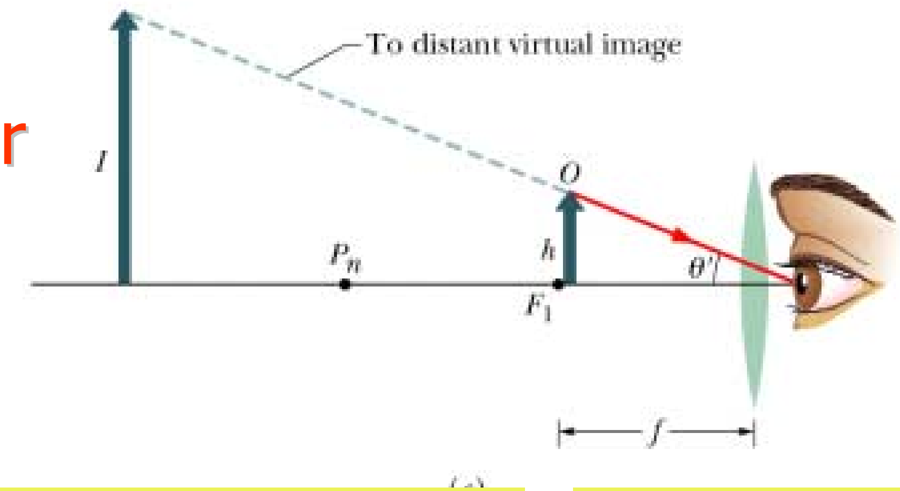
Human Eye

- Has a converging lens which makes real, inverted images at the retina
- Near point is the closest distance which our lens can focus light on the retina
  - Distance increases with age
  - Typically at age 10 is 18cm, at 20 is 25cm, at 40 is 50cm, at 60 is 500cm or more
  - For problems will use 25cm for human eye
- Nearsighted – correct with a diverging lens
- Farsighted – correct with converging lens

Magnifying Lenses (Fig. 35-16)



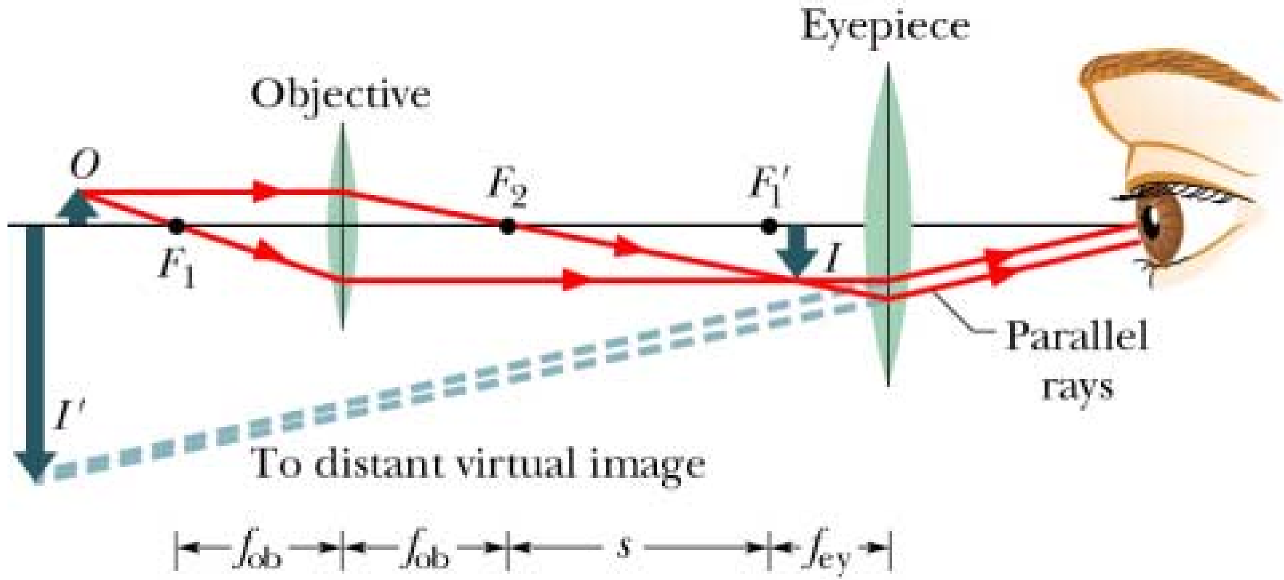
- Object closer than near point: image blurred
- Use magnifying lenses
- Angular magnification:



$$m = -\theta' / \theta$$ BUT $$\theta \approx h / 25\ cm$$ $$\theta' \approx h / f$$

- Simple magnifier: $$m \approx -25\ cm / f$$

Compound microscope (Fig. 35-17)



- Lateral magnification

$$m = -i / p = -s / f_{ob}$$

- s is length of tube

- Microscope

$$M = m_\theta m = -\frac{s}{f_{ob}} \frac{25\ cm}{f_{ey}}$$

Telescope (Fig. 35-18)

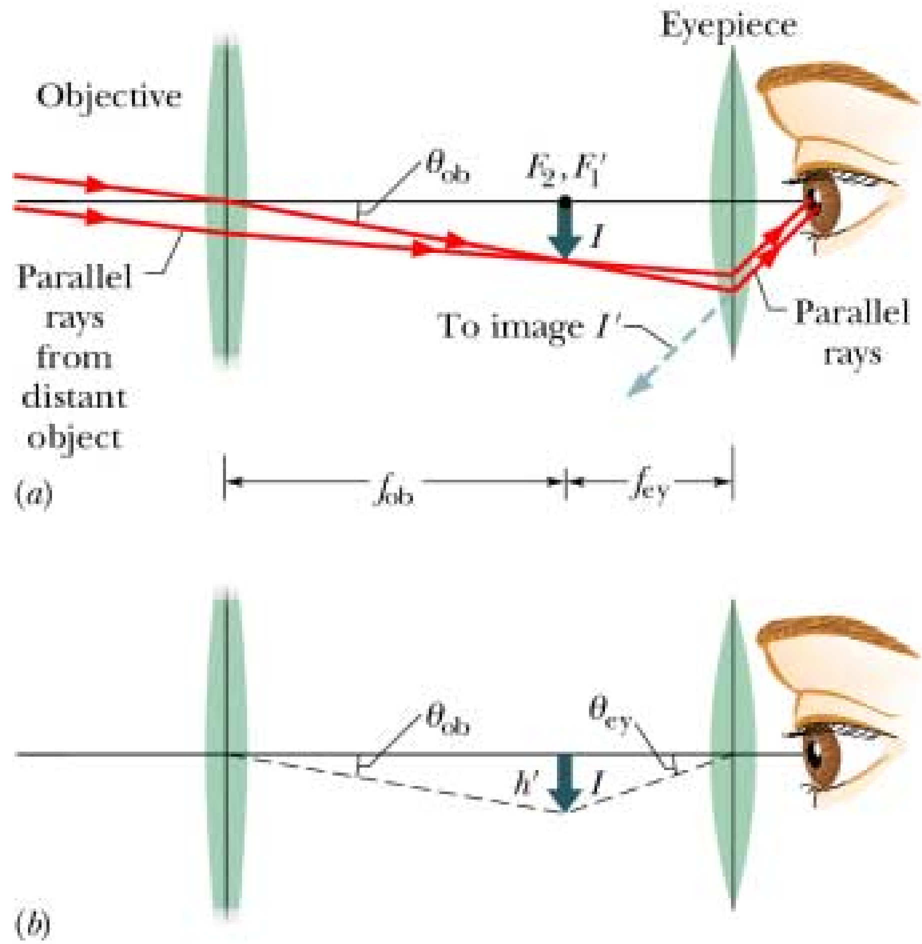
- Refracting telescope
  - Two lenses - objective and eyepiece

$$m = -\theta_{ey} / \theta_{ob}$$

$$\theta_{ob} \approx h' / f_{ob} \qquad \theta_{ey} \approx h' / f_{ey}$$

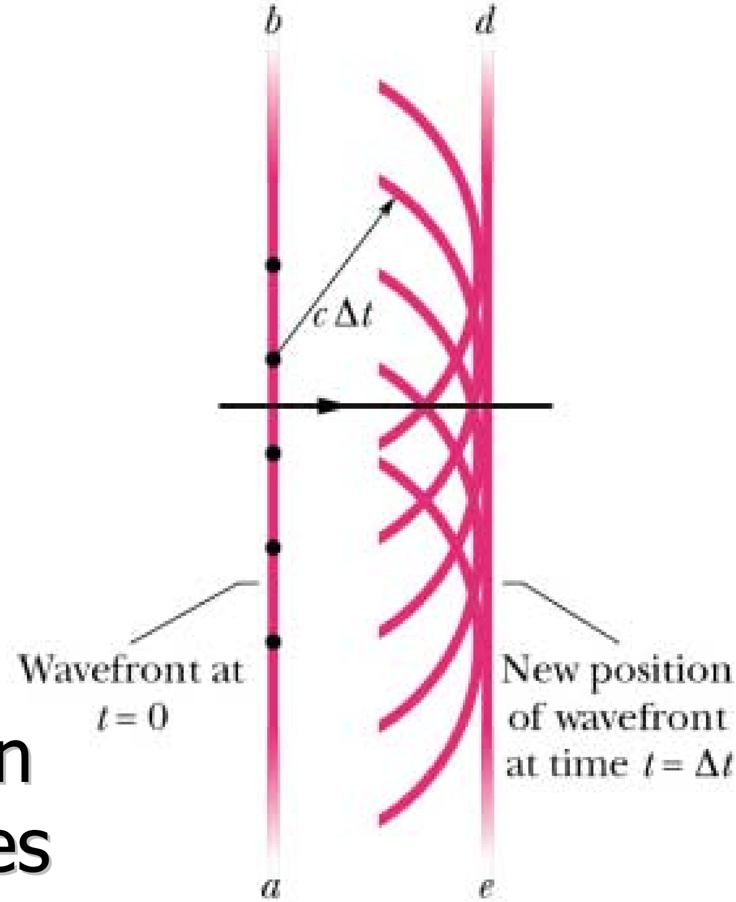
$$m = -f_{ob} / f_{ey}$$

- Reflecting telescope
  - Mirror and lens
  - f_{ob} is focal length of objective mirror



Light as a wave (Fig. 36-1)

- Light is an EM wave
- Interfering light waves combine to enhance or suppress colors in sunlight
  - Soap bubbles, oil slicks
- Interference best evidence that light is a wave
- Huygen's principle – points on wavefront act as point sources of spherical wavelets, at time t new position of wavefront is tangent to wavelets



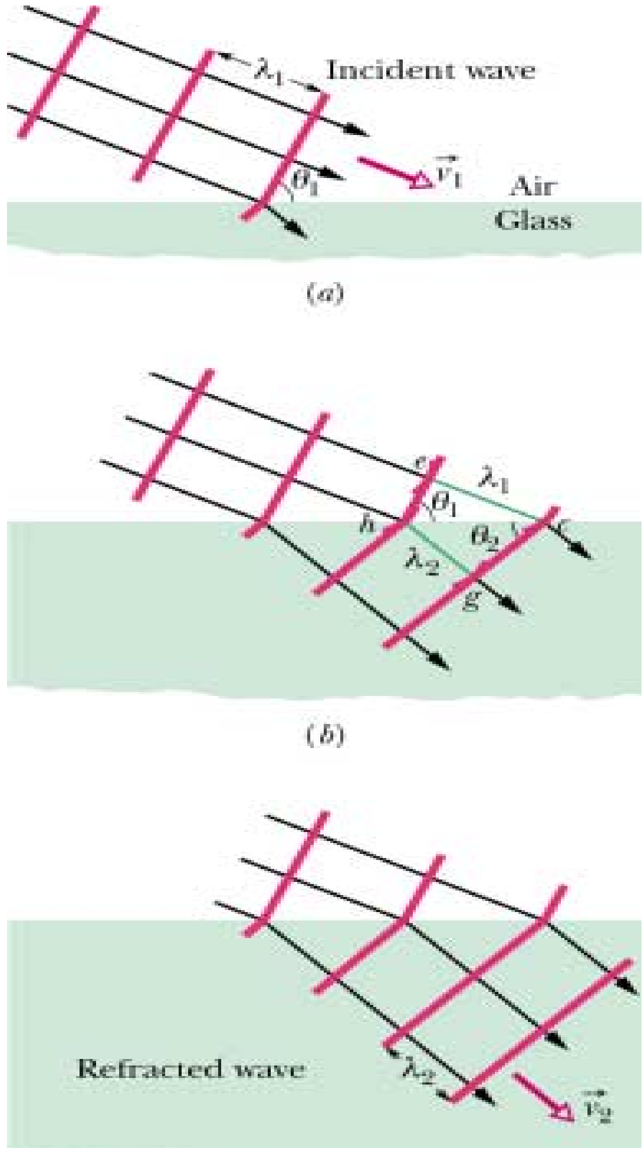
Index of refraction (Fig. 36-2)

- Can use Huygen's principle and geometry to prove Snell's law (see section 36-2)

$$n_2 \sin\theta_2 = n_1 \sin\theta_1$$

- Wavelength of light in two different media, 1 and 2, are proportional to

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$



Index of refraction

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

- Frequency of light in medium is same as in vacuum
- Wavelength and velocity of light change in a medium and depend on its index of refraction, *n*
- Velocity of light in a medium is always smaller than speed of light in vacuum, *c*
- Wavelength of light in a medium, λ_n is smaller than in vacuum, λ and related by

$$\lambda_n = \frac{\lambda}{n}$$

Quiz 13

- Focal length equation
  - Image distance *i* is + for real images, - for virtual images

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

- Lateral magnification, *m*

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

$$|m|=\frac{h'}{h}$$

- *m* is + if image has same orientation as object
- *m* is – if image is inverted from object