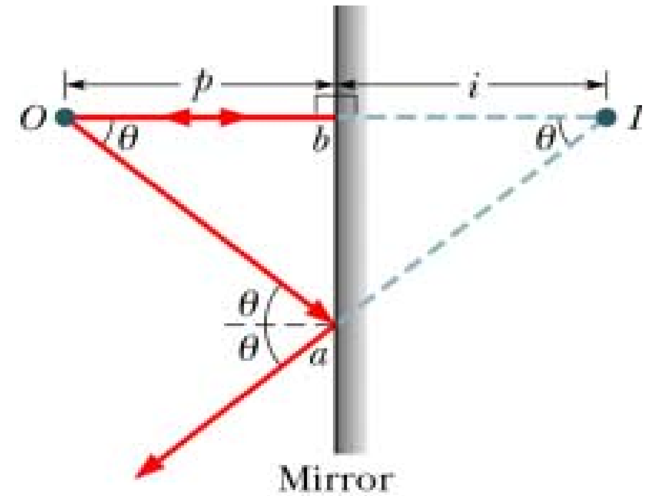
Lecture 36

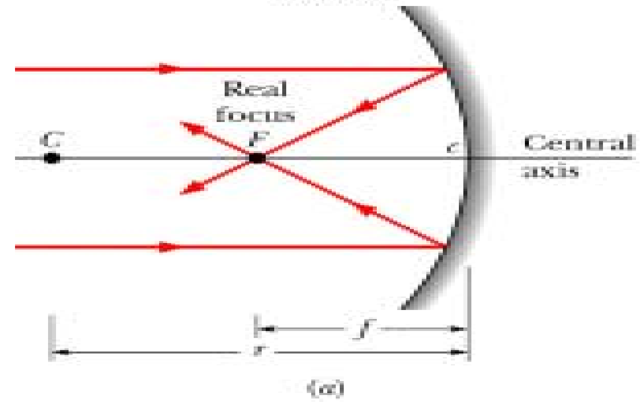
Chapter 35 - 36

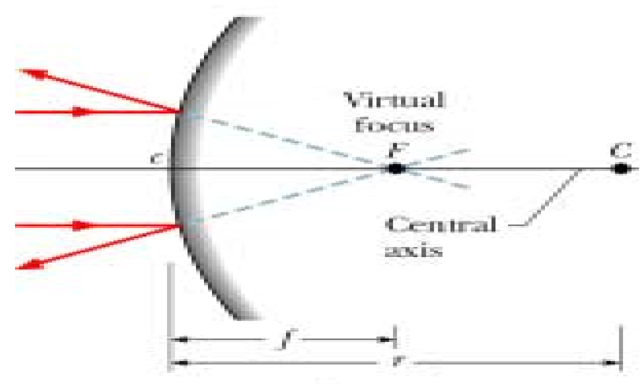
Images & Interference

Review

- Mirrors
  - 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

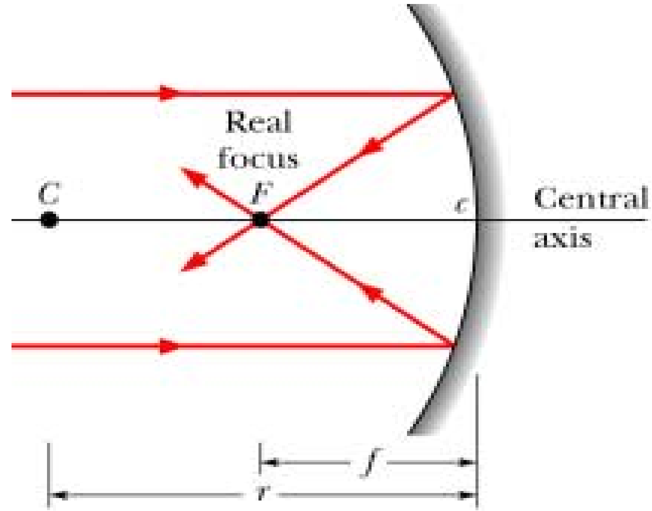
- Spherical mirrors have focal point, r is radius of curvature

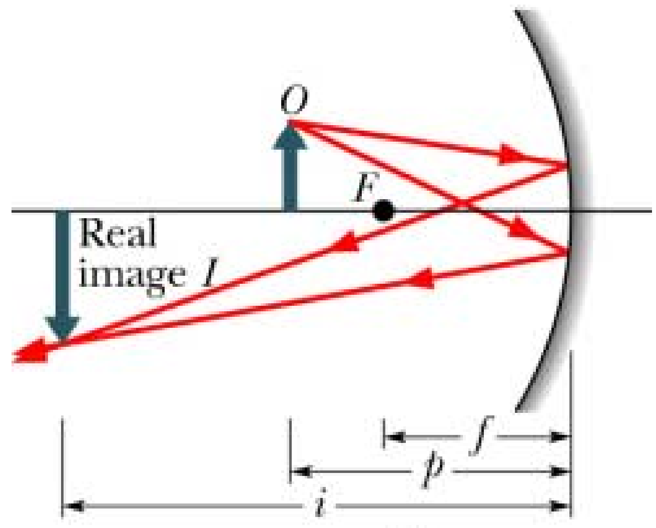
$$f = \tfrac{1}{2} r$$

- 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

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

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

- Magnification also equal to

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

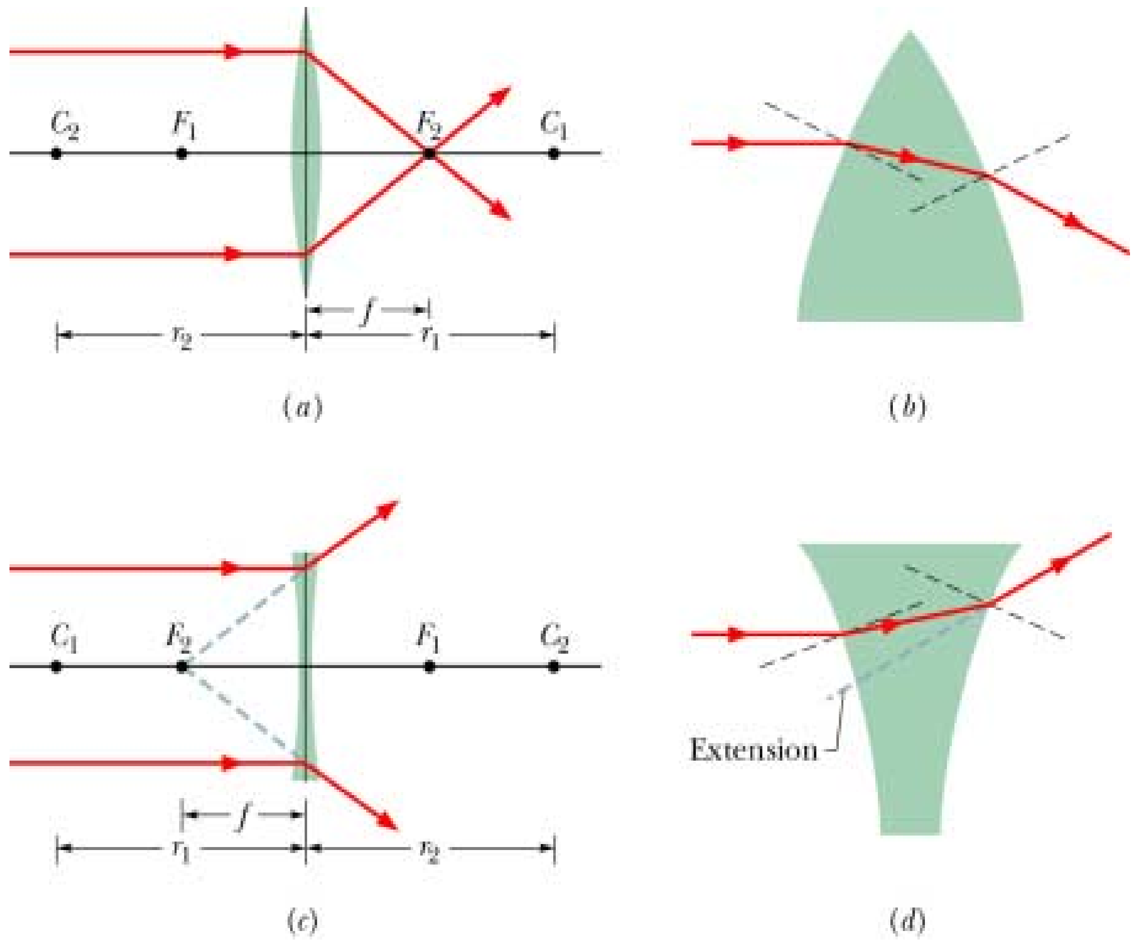
- *m* is + if image has same orientation as object
- *m* is – if image is inverted from object
- Plane mirror *m* =+1

Review - Mirrors

Mirror Type	Object Location	Image Location	Image Size	Image Type	Image Orient-ation	Sign of *f*	Sign of *i*	Sign of *m*
Plane	Anywhere	i = **-** p	Equal	Virtual	Same	∞	**-**	**+1**
Concave	p < f	Anywhere	Bigger	Virtual	Same	**+**	**-**	**+**
Concave	f < p < 2f	i > 2f	Bigger	Real	Invert	**+**	**+**	**-**
Concave	p = 2f	i = 2f	Equal	Real	Invert	**+**	**+**	**-**
Concave	p > 2f	2f > i > f	Smaller	Real	Invert	**+**	**+**	**-**
Convex	Anywhere	|i| < |f|	Smaller	Virtual	Same	**-**	**-**	**+**

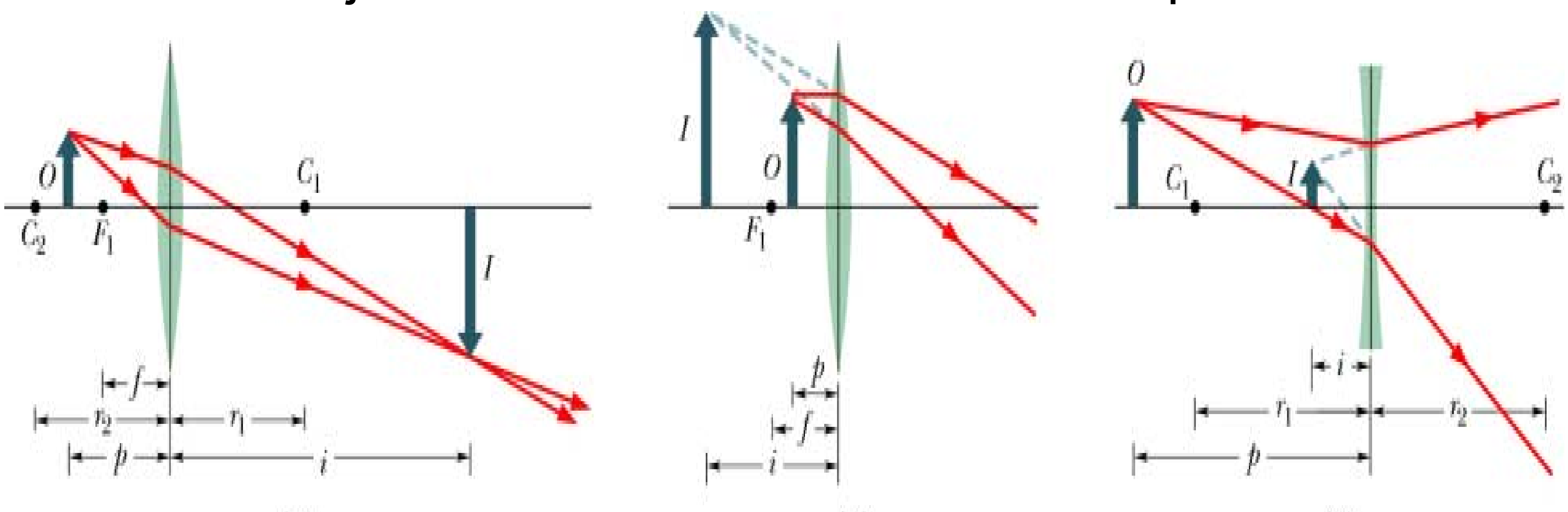
Review

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



Review

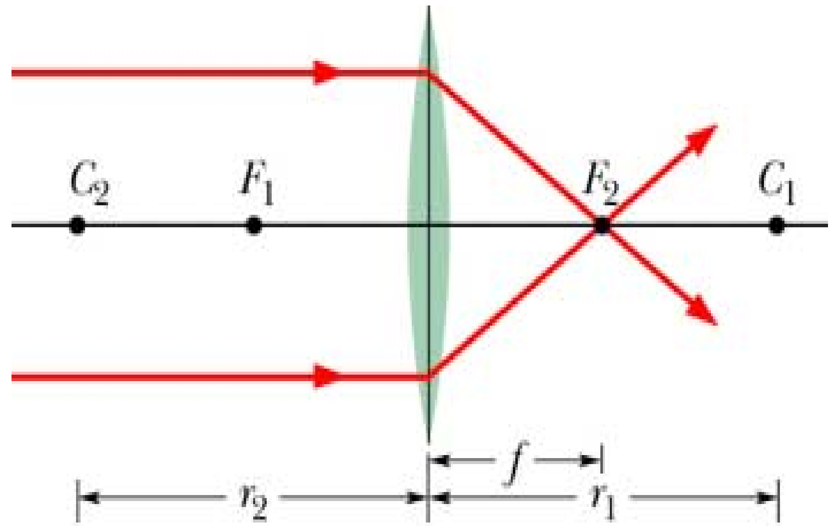
- Thin Lenses
  - Real images form on opposite side of lens from object, virtual images on same side
  - Diverging lens only produces smaller, same orientation, virtual images (like convex mirror)
  - Converging lens (like concave mirror) can produce both real and virtual images depending on where the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



Review

- Thin lenses 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

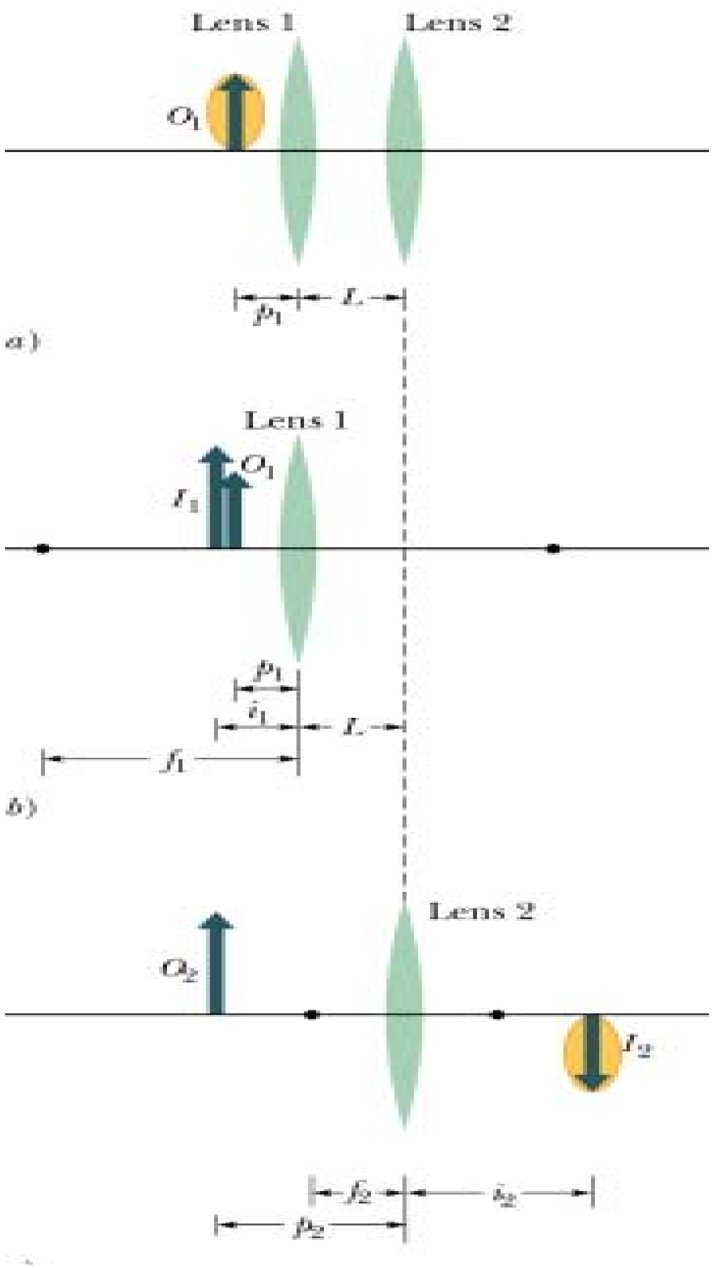
- Thin lenses -
  - Lateral magnification *m* same as for mirror

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

  - 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	|i| < |f|	Smaller	Virtual	Same	-	-	+

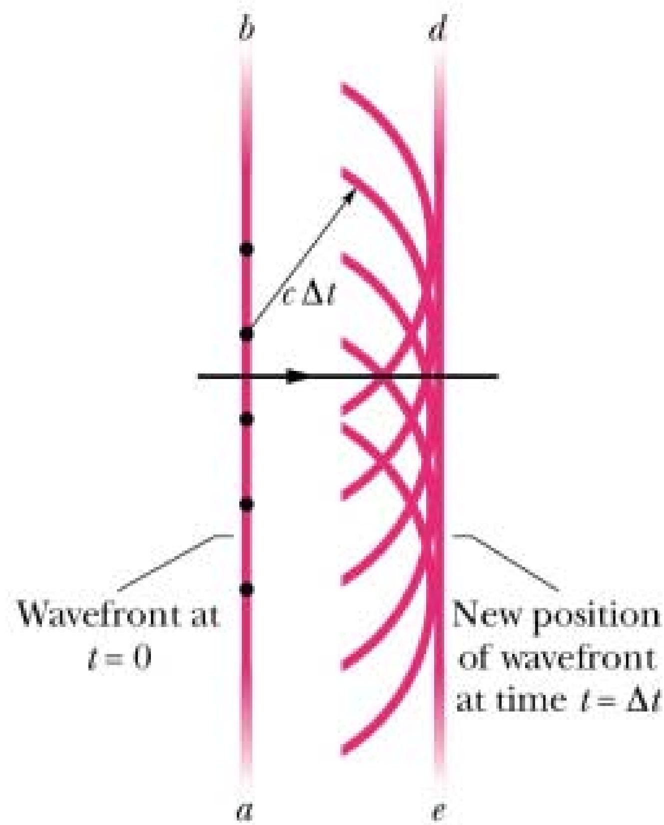
Lecture 36 (cont.)

Chapter 36

Interference

Interference (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



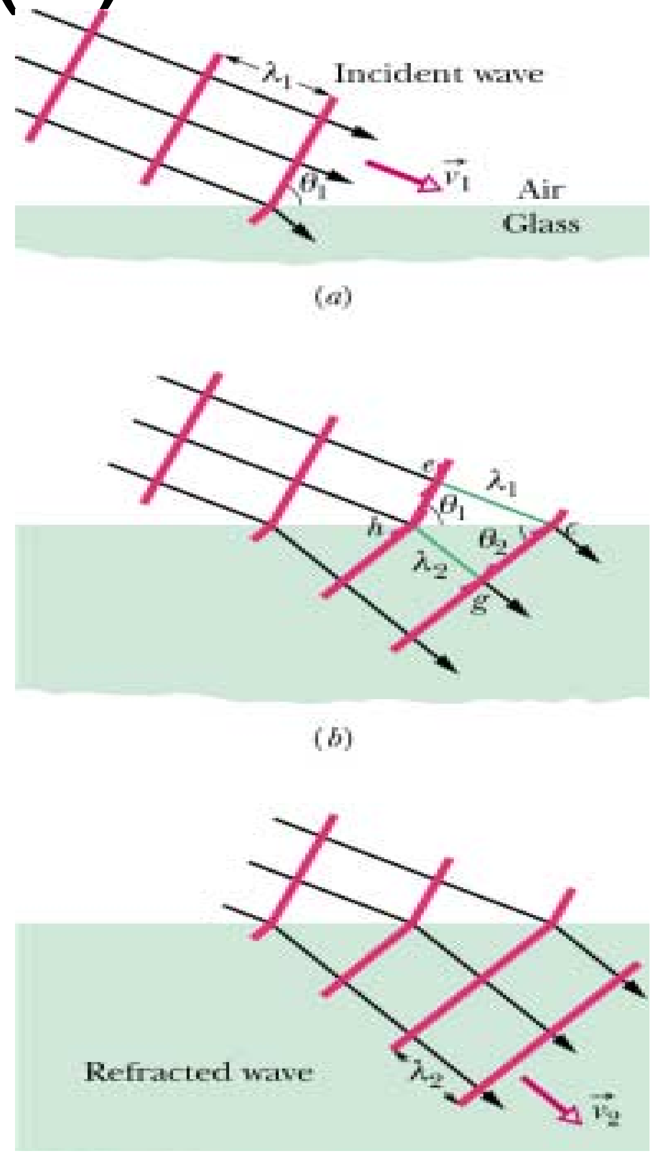
Interference (2)

- 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

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



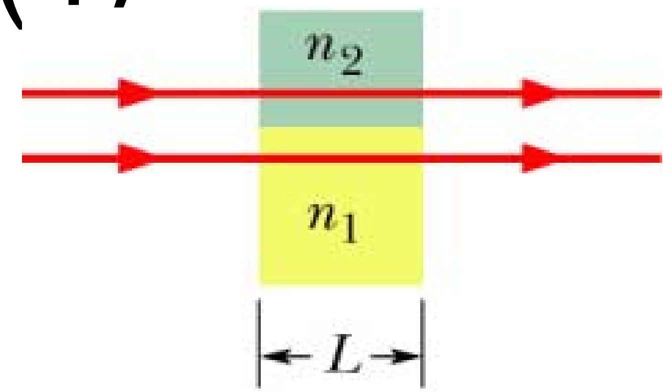
Interference (3)

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

- 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

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

Interference (4)



- Phase difference between 2 light waves can change if waves travel through different media with different *n*
- Number of wavelengths in media

$$N_1 = \frac{L}{\lambda_{n1}} = \frac{Ln_1}{\lambda}$$

$$N_2 = \frac{L}{\lambda_{n2}} = \frac{Ln_2}{\lambda}$$

- Pha

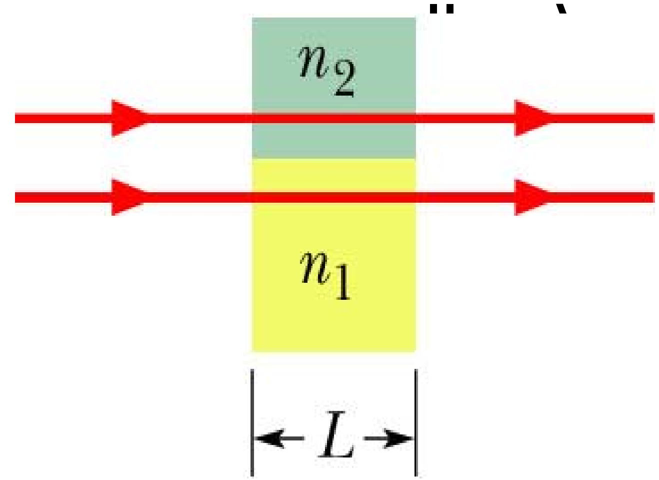
$$N_2 - N_1 = \frac{Ln_2}{\lambda} - \frac{Ln_1}{\lambda} = \frac{L}{\lambda}(n_2 - n_1)$$

Interference (5)

- Checkpoint #2 – Rays have same wavelength and initially in phase. A) If 7.6 wavelengths fit within top material and 5.5 fit within bottom, which has greater index of refraction, *n* ?
- Larger *n* produce

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

- Which material has smaller λ?
- Smaller λ, more wavelengths same distance

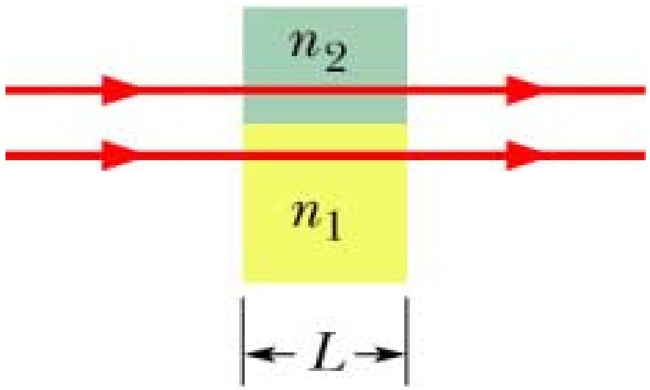


Top material has greater index of refraction, *n*

Interference (6)

- Checkpoint #2 – Rays have same wavelength and initially in phase. B) After material will interference of waves give brightest, bright intermediate, dark intermediate illumination or darkness?
- Look at phase difference in of λ

$$N_2 - N_1 = \frac{L}{\lambda}(n_2 - n_1)$$



- Given # of wavelengths for material

$$N_2 - N_1 = 7.6 - 5.5 = 2.1$$

- Waves are 2.1 wavelengths out of phase after passing through materials

Interference (7)

- Checkpoint #2 – B) After material will interference of waves give brightest, bright intermediate, dark intermediate illumination or darkness?

- If phase difference is an integer # of wavelengths (0,1,2,…) then waves are in phase and have full constructive interference (brightest spot)
- Effective phase difference is decimal fraction
- Total phase difference = 2.1
- Effective phase difference = 0.1

Interference (8)

- Checkpoint #2 – B) After material will interference of waves give brightest, bright intermediate, dark intermediate illumination or darkness?

- If phase difference is 0.5 wavelengths (half a wavelength) then waves are completely out of phase and fully destructive interference (dark spot)
- Our effective phase difference of 0.1 is closer to 0 than 0.5 so intermediate bright spot but not the brightest.

Interference (9)

- For interference pattern to appear waves must have a constant phase difference
- If phase difference does not vary with time waves are coherent
- Light is produced by emission from individual atoms
- Atoms in conventional light (light bulbs, sunlight) are in random phases so light is incoherent
- Lasers are designed so atoms emit coherent and monochromatic light