# Physics 122 – Class #3 – Outline

- Announcements/Reading Assignment
- MORE  mistakes on vectors
- MVSA Method / Snell's Law
- Dispersion
- Total internal reflection
- Ray model of light why lenses work
- Definition of focal length
- Thin lens formula
- Examples

**Physics 122 – Sections 4, 5, 6**
**Prof. Richard Sonnenfeld**

**Labs:** Start this week.

HW-OL-02
(Ray Optics – due Sat 1/24 @23:59)

HW-WR-01
(Ray Optics – due Tue 1/27 in class)
6 Problems … see

http://kestrel.nmt.edu/~rsonnenf/phys122/homework/

**Reading Assignment (next class)**

*You have Read* "Preface to the Student"
*You have actively read* Chapter 3
*You have actively read* Chapter 23 through page 666
*Actively read* the rest of Chapter 23. (You are not responsible for the derivation of the thin lens laws, just understand how to use them … and ray tracing!)

**Concepts to get from reading**

$V = c / n$

How to use snell's law.

Why there is total internal reflection

Why refraction leads to behavior of lenses

How to use the lens equation

- What is focal length
- What is real image?
- What is virtual image?
- How to do ray tracing.

# Ch. 23: Ray Optics Formulae

$v = f\lambda$ General property of waves

$v_n = \frac{c}{n}$ True for light in media

$\theta_1' = \theta_1$ Law of reflection (specular)

$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$ Snell's law (refraction)

$\sin(\theta_c) = n_2/n_1$ Total internal reflection

$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$ Thin lens formula

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# Mistakes on Vectors in Recitation

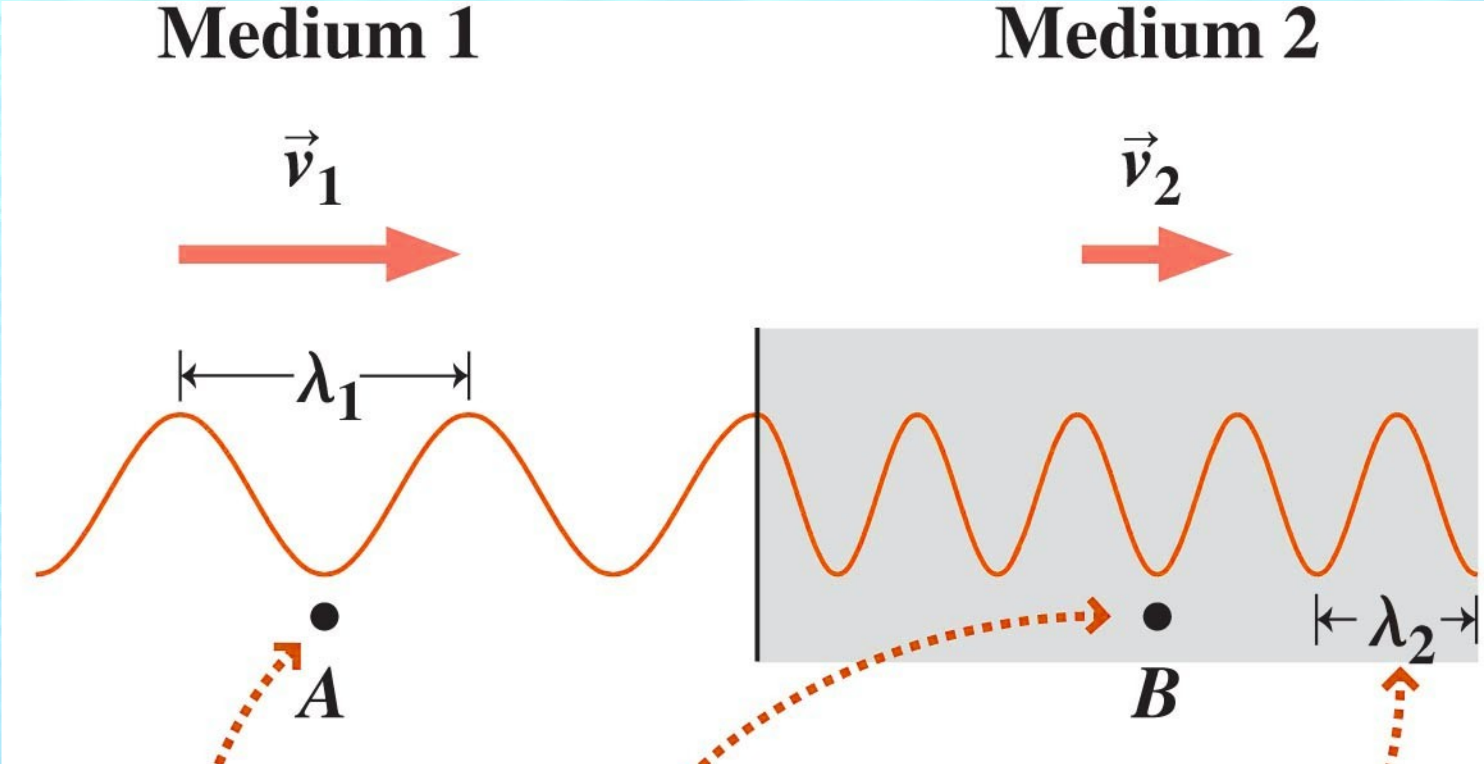
# Light in media

$v = f\lambda$

Nothing can exceed the speed of light… in a vacuum!

$v_n = \frac{c}{n}$

Light in matter travels more slowly
And wavelength changes.



**Clicker Question**

$v = f\lambda$

Green laser light with frequency f,
Wavelength $\lambda = 440$ nm
And speed $v = 3.0 \times 10^8$ m/s
enters a piece of glass with n=1.5

(A) v decreases, f decreases and $\lambda$ is unchanged (still green light)
(B) v decreases, $\lambda$ decreases and f is unchanged.
(C) f increases, $\lambda$ decreases and v is unchanged (speed of light is a constant).
(D) 42

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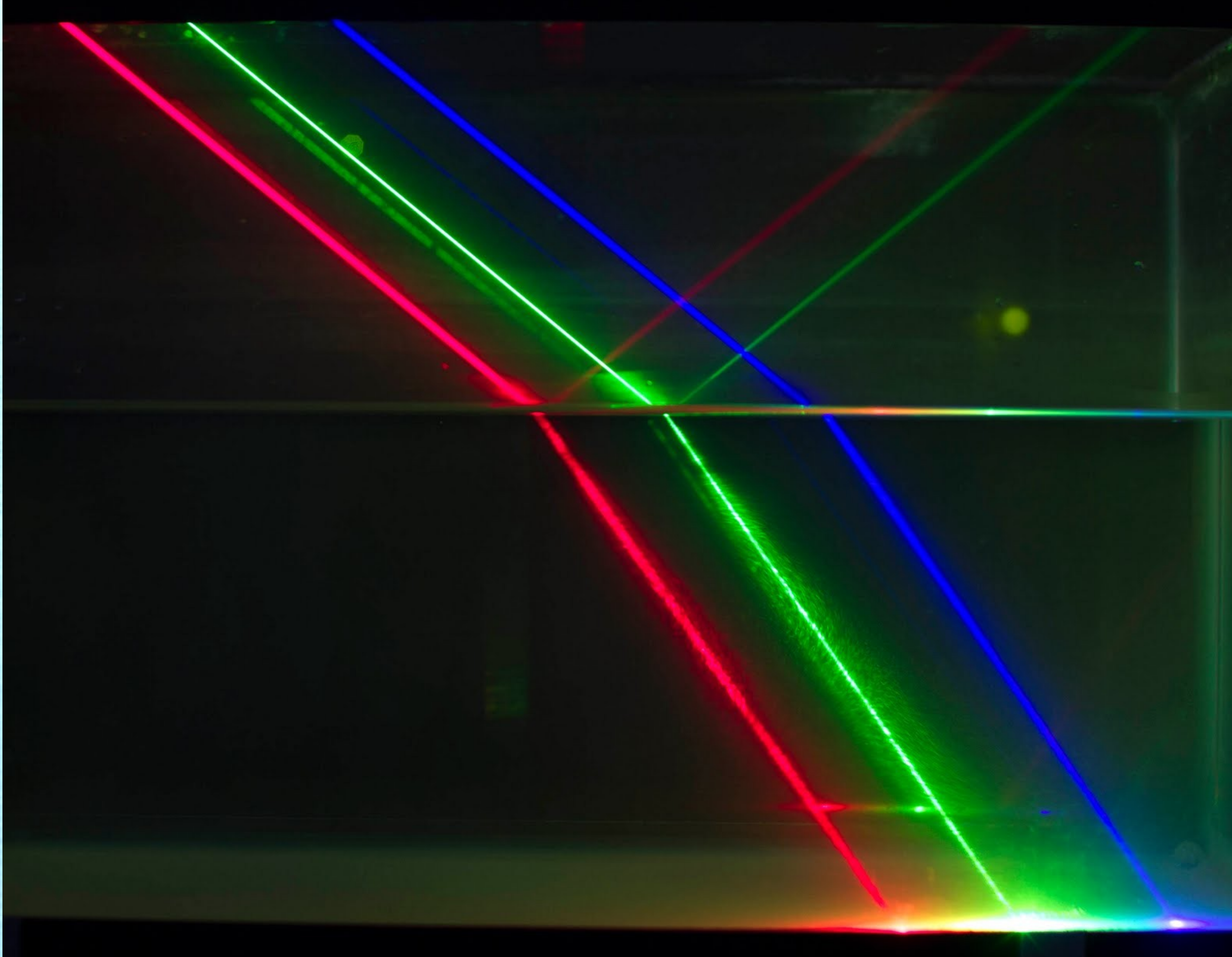
# MVSA – From the beginning

Given a red laser beam in air that enters water in a fish-tank and makes an angle of 39 degrees with the water surface, what angle does the transmitted beam make with the normal once it enters the water? [Similar to homework 23.10]

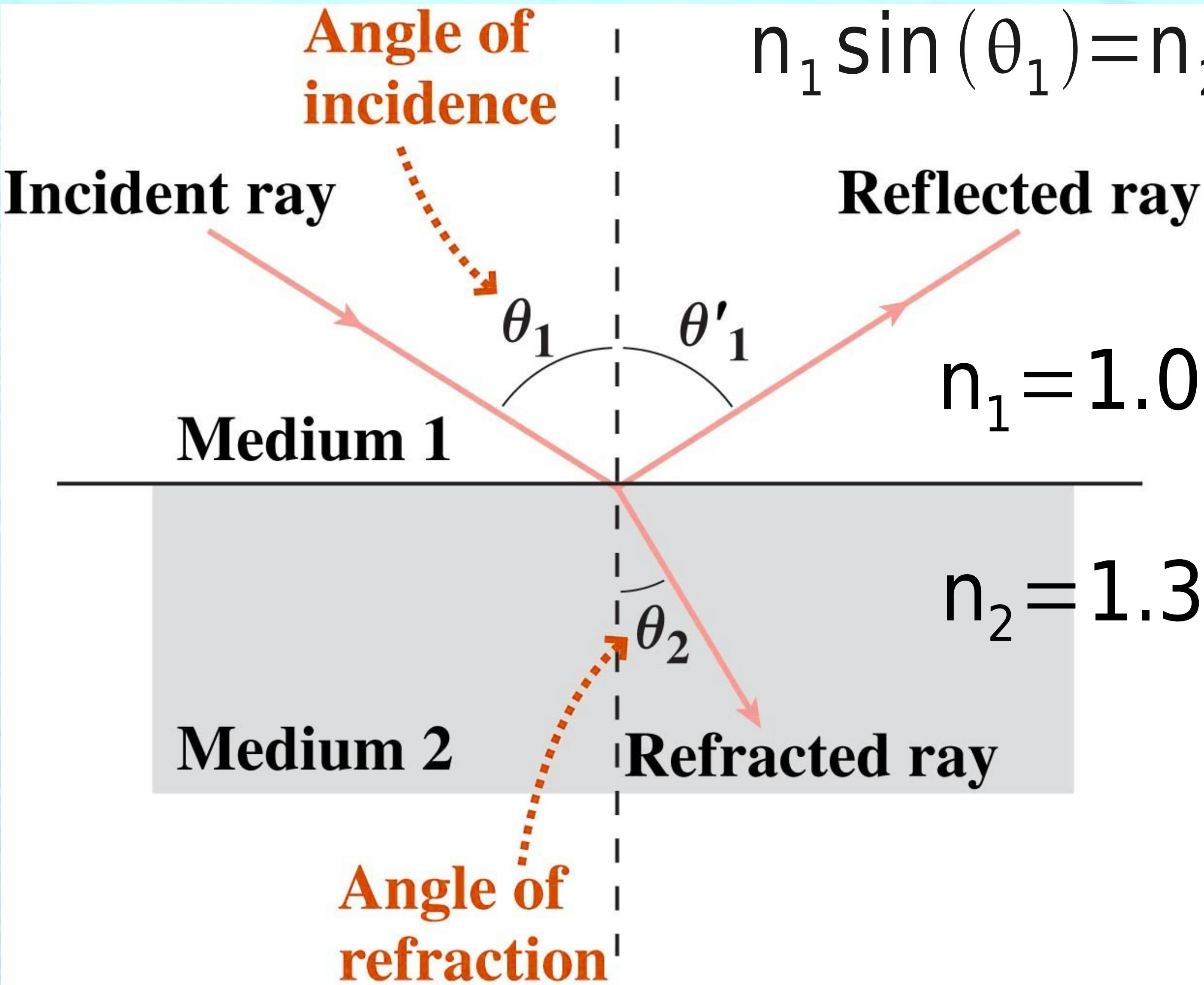
*Model*

1) What law can I use?
2) Oh … it's refraction … Snell's law



# Visualize – Definitions in Snell's law

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





$$n_1 = 1.000;\ \theta_1 = 51.00°$$

$$n_2 = 1.335$$

# MVSA

*Visualize*

Do I know $n_1$, $n_2$, $\theta_1$?

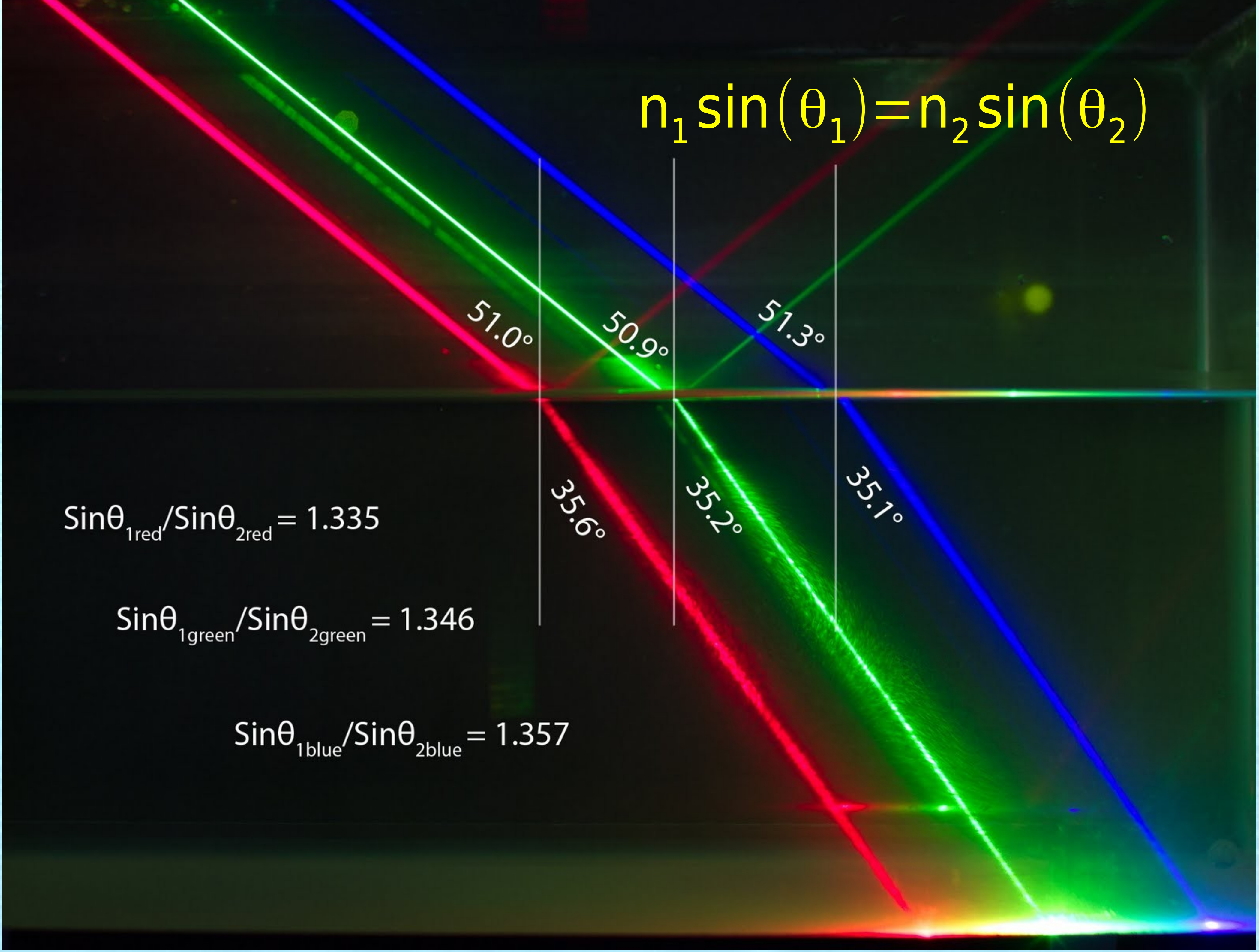
*Solve*

Plug and chug.

*Assess*

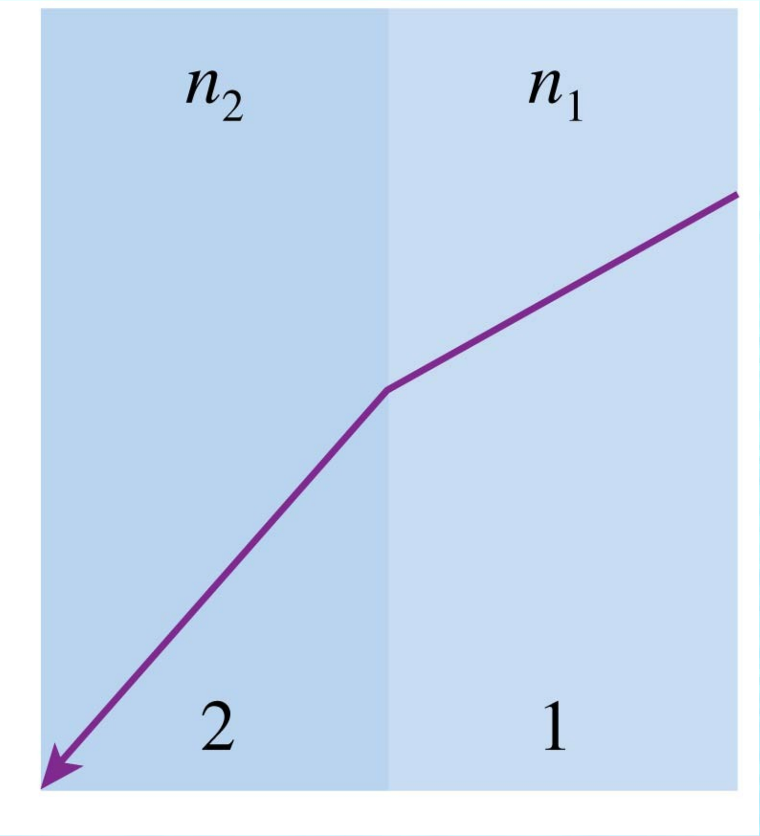
Did the beam bend toward the normal?

Should it?


$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$
51.0°
50.9°
51.3°
35.6°
35.2°
35.1°
$\sin\theta_{1red}/\sin\theta_{2red} = 1.335$
$\sin\theta_{1green}/\sin\theta_{2green} = 1.346$
$\sin\theta_{1blue}/\sin\theta_{2blue} = 1.357$

# Clicker Question

A laser beam passing from medium 1 to medium 2 is refracted as shown. Which is true?




A. $n_1 < n_2$.

B. $n_1 > n_2$.

C. There's not enough information to compare $n_1$ and $n_2$.

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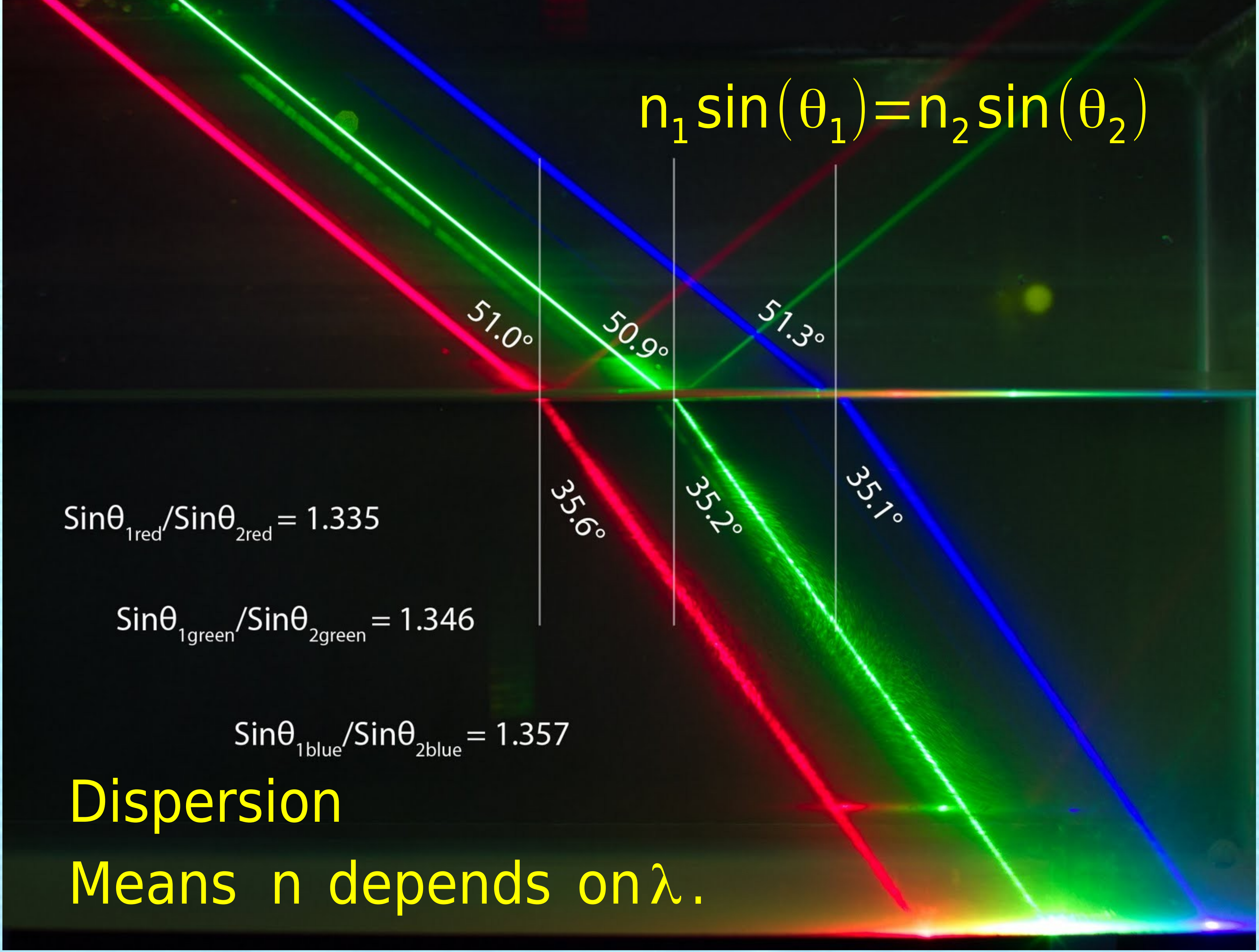
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Dispersion
Means n depends on $\lambda$.

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# Total internal reflection and Snell's Law – DEMO

# Homework, problem 23.14

The glass core of an optical fiber has an index of refraction of 1.60. The index of the cladding is 1.48. What is the maximum angle the light can make with the wall of the core if it is to remain in the fiber.

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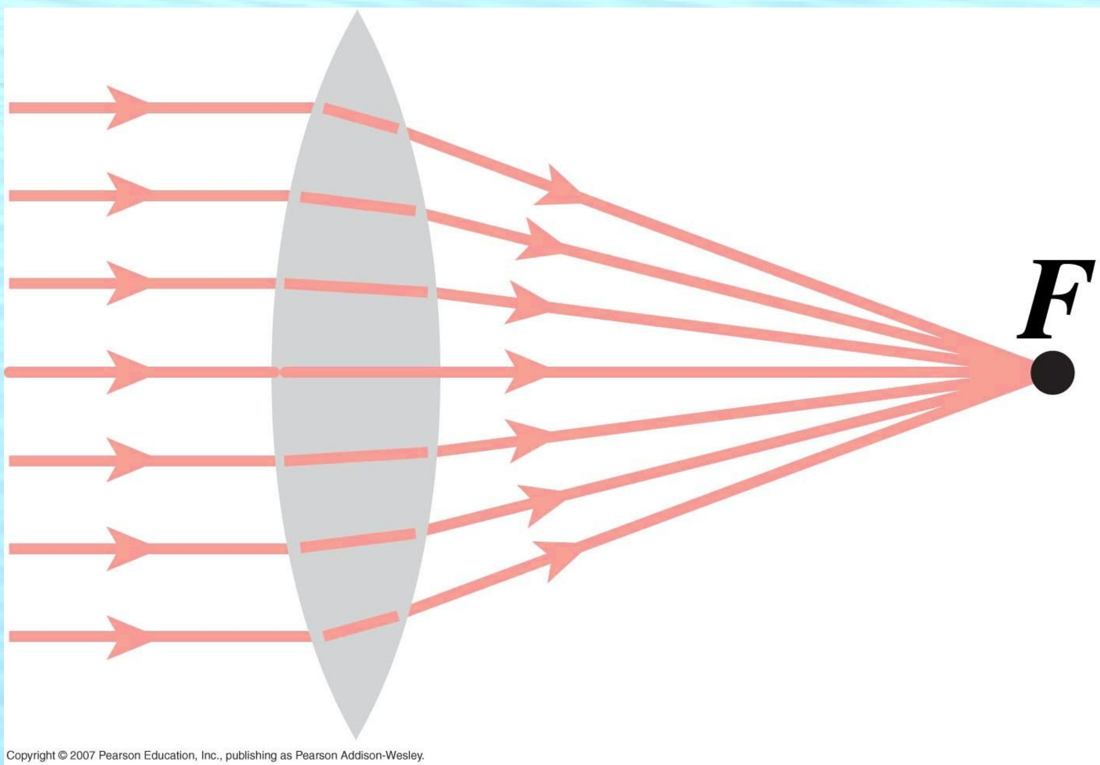
# Ray model of light and focal points – DEMO

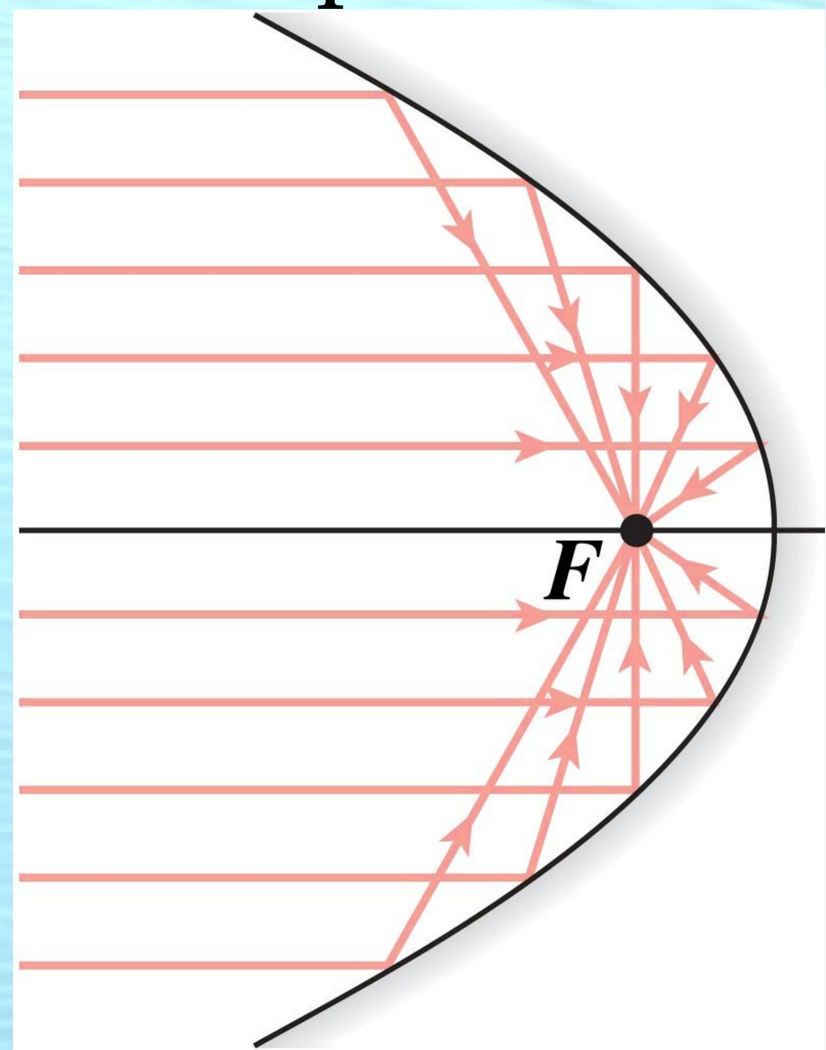
# Focal point

Focal point:

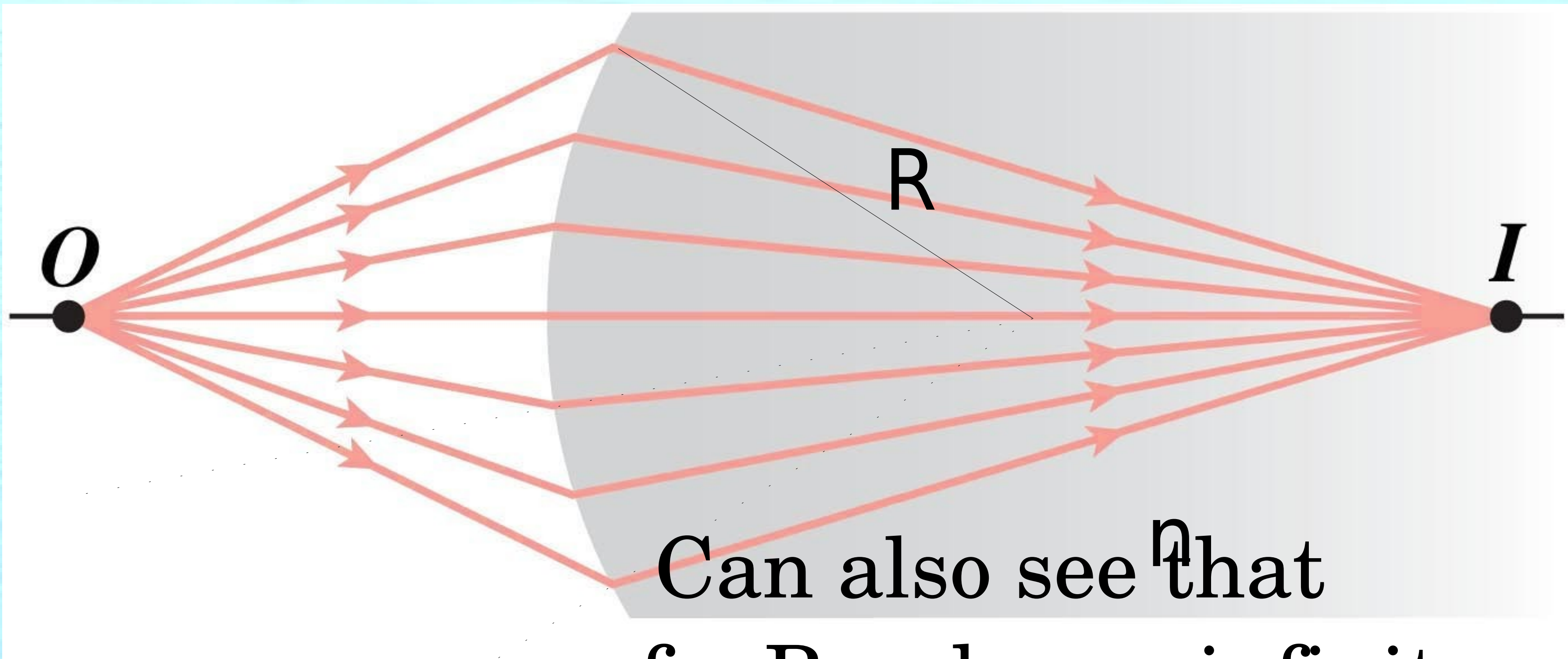
The point at which parallel rays converge.

Focal length: f = distance to focal point.



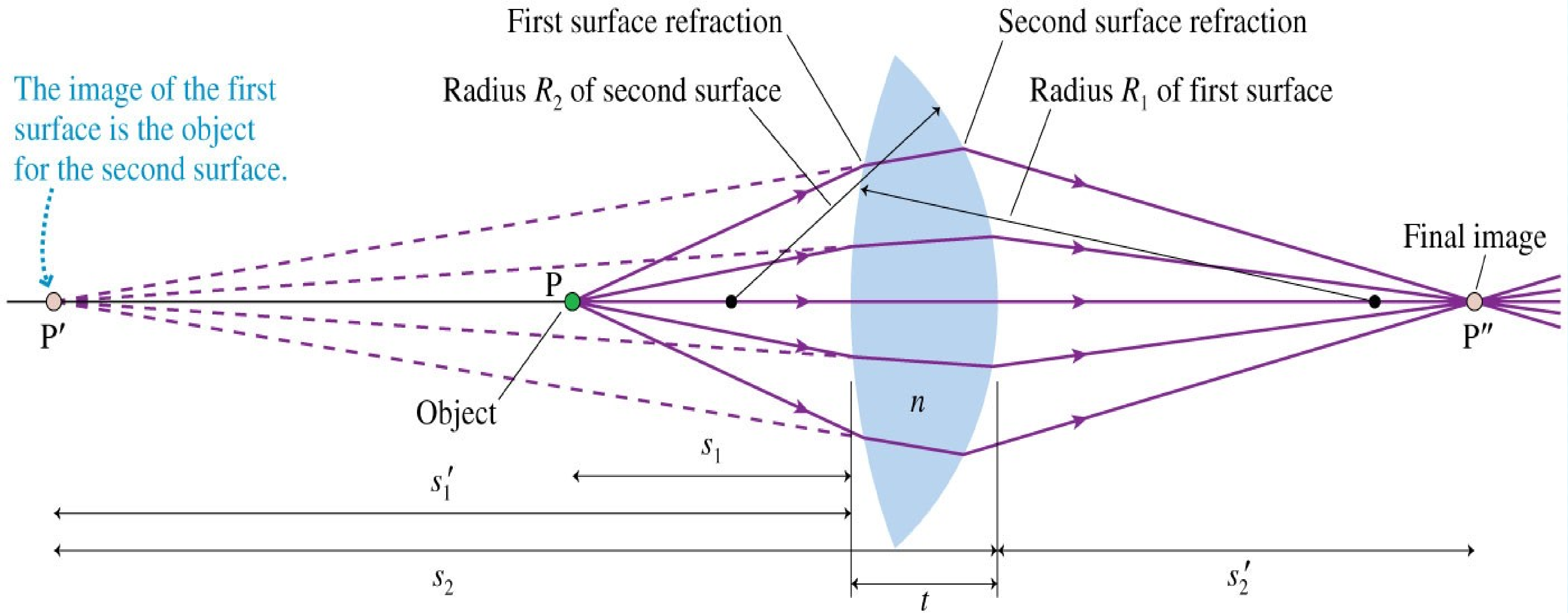
Snell's law in combination with a Curved surface makes lenses work.




Can also see that f > R unless n infinite

$$f = \frac{R}{(n-1)}$$

# Both surfaces of lens help Focus rays



# Image position and magnification

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

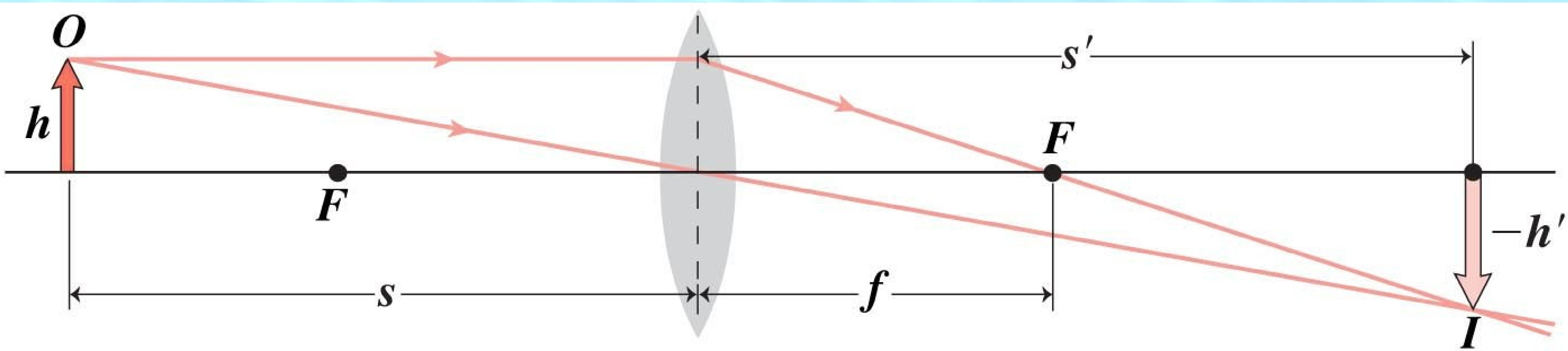
$$m = \frac{-s'}{s}$$

s = distance to object

s' = distance to image

f = focal length

m = magnification



**Convex lenses cause light rays to converge.**

**Concave lenses cause light rays to diverge.**

**Convex mirrors cause light rays to diverge.**

**Concave mirrors cause light rays to converge.**

# Real and virtual images.

Rays meet at a real image. Focus a flame and it will burn.

Real images are on opposite side of lens (and same side of mirror) from object.

Virtual images are on same side of les (and opposite side of mirror) from object.

Real images are inverted, virtual are erect.

**Ray Tracing with Lenses:**
**The principal rays**

P-ray: Ray parallel to symmetry axis goes thru focal point F.
F-ray: Ray thru F comes out parallel to symmetry axis
M-ray: Ray through middle of lens passes straight thru unchanged.

## Ray Tracing:

## Lenses:

Case I: f= 10 cm, s=15 cm.

Case II: f= 10 cm, s=5 cm.

Case III: f=-10 cm, s=15 cm.

## Mirrors:

Case I: f= 10 cm, s=12 cm.

Case II: f=-10 cm, s=5 cm.

Case III: f= -10 cm, s=20 cm.

**Question**

Given an object placed 15 cm from a biconvex lens with focal length 10 cm, find the distance of the image from the lens (and the magnification M).

# Lenses:

Case I: $f = 10$ cm, $s = 15$ cm.

# Ch. 23: Geometrical Optics

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

Relation between object and image distance for single lenses and mirrors.

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

Magnification for single lens or mirror.

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

Lensmaker's formula

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# Next Time

Lenses / Mirrors
Pinhole cameras
Properties of Waves