Physics 122 – Class #2 – Outline

- Announcements/Questions about handout
- Common mistakes on vectors
- Properties of waves, speed of light, and index of refraction
- Refraction / Snell's Law
- Ray model of light / mirrors
- Color vision

Reading Assignment (next class)

You have Read "Preface to the Student"
You have actively read Chapter 3

Read All of Ch 23
Actively read to page 666
After next lecture, *Actively read* rest of Ch. 23

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.

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

Labs: Start next week.
Online Homework #00
(due today 10:45 am) – 60 of 75 people are registered as of 10:15.

Online HW #01 (Vectors – due Sat 1/17 @23:59)
Online HW #02 (Optics – due Sat 1/24 @23:59)

Office Hours: After class 12:15-1:00. Or make an appt by e-mail. (or txt me – 575-838-7113)

E-mail: mpsonnenfeld@gmail.com

Texts: One copy on reserve in library. (More if we can get more)

You can use 2nd edition for reading purposes
If you buy an MP code by itself, you get electronic version of book.

Questions about Handout?

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Mistakes on Vectors quiz

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Wave Concepts

- ALL Waves have
  - Wavelength (λ)
  - Frequency (f)
  - Speed (v)
  - Amplitude

$$v = f\lambda$$

DEMO: PheT

- Waves on a string
  - Frequency … how many times the wheel goes around in a second.
  - Wavelength … distance between crests and troughs
  - Speed, related to tension in string or density of air, or type of material (for light)

$$v = f\lambda$$

Index of refraction

Waves have different speeds in different materials.

Sound waves are *faster* in water than air.

Seismic waves speed depends on the type of rock they are in.

Light waves are *slower* in water than in air (or vacuum).

Light Waves

- The maximum speed of a light wave is c.

c is speed of light in a vacuum. It's a constant.

$$c = 2.99792458 \times 10^8 \text{ m/s}$$

$$c \sim 3.00 \times 10^8 \text{ m/s}$$

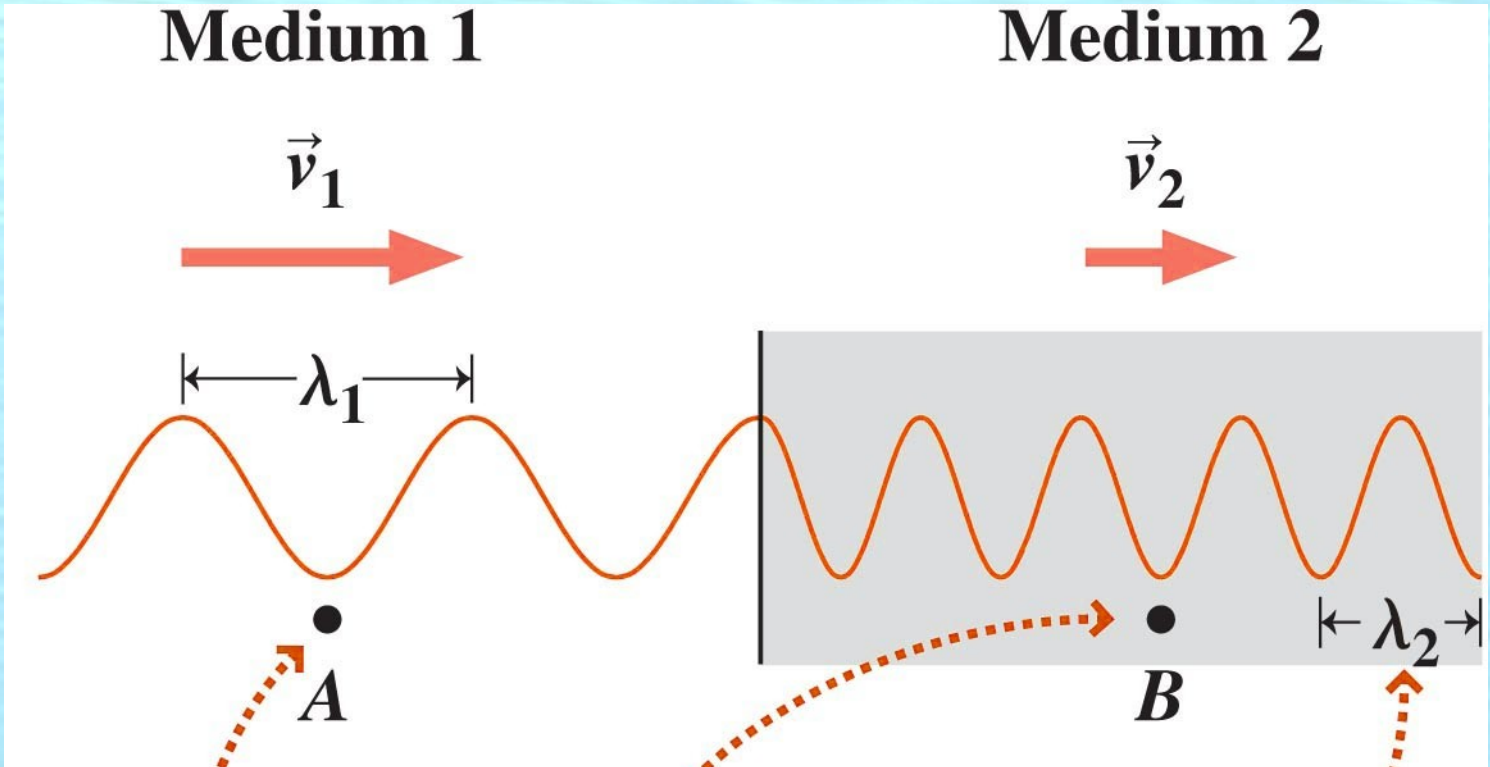
Light in media

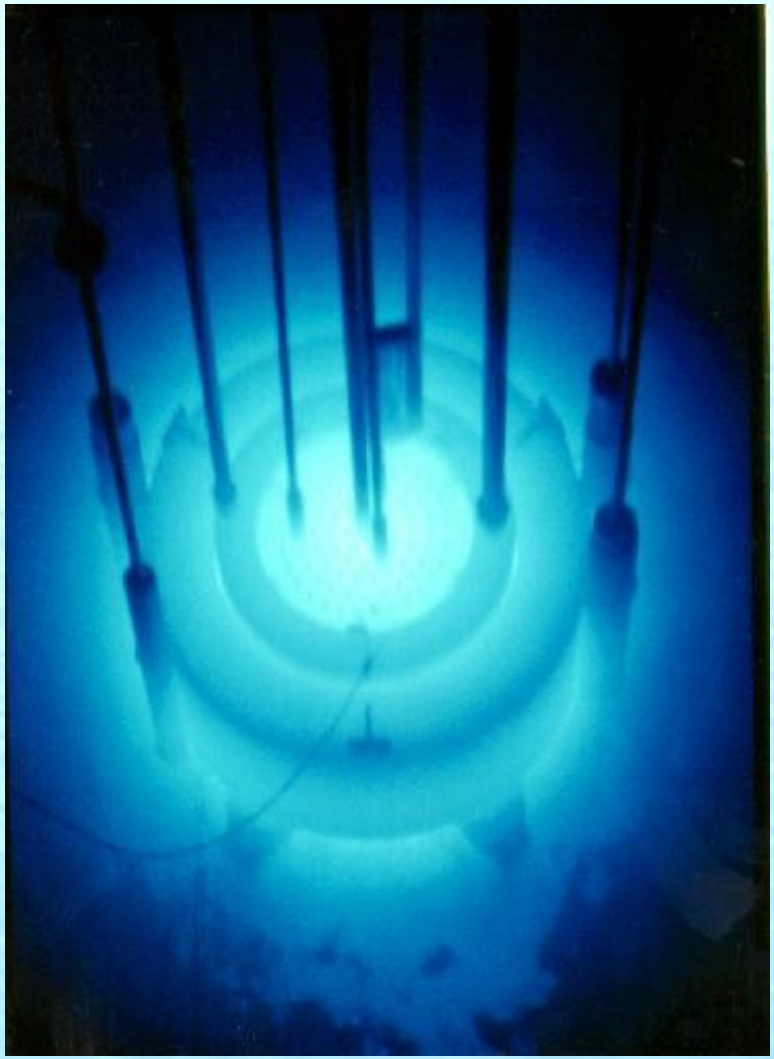
$v = f\lambda$

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

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

Light in matter travels more slowly
And wavelength changes.





Waves in media

Jet exceeds speed of sound:

Shock-wave

Electron exceeds speed of light:

Cerenkov radiation

Homework, problem 23.3

•A 5 cm thick layer of oil is sandwiched between a 1.0 thick sheet of glass and a 2.0 cm thick sheet of polystyrene plastic. Hos long (in ns) does it take light incident perpendicular to the glass to pass through this 8 cm thick sandwich?

Homework, problem 23.3

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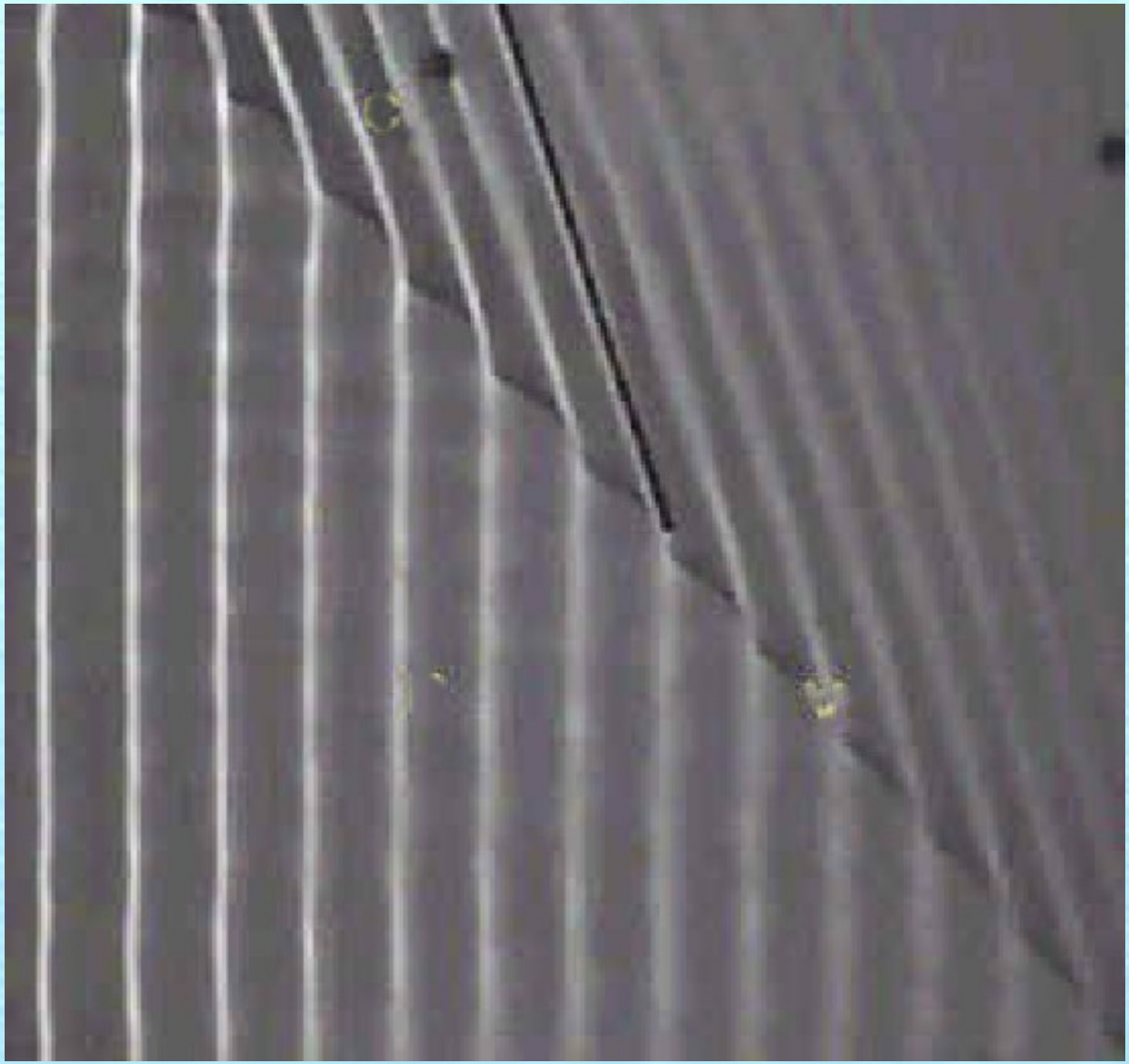
Snell's law $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

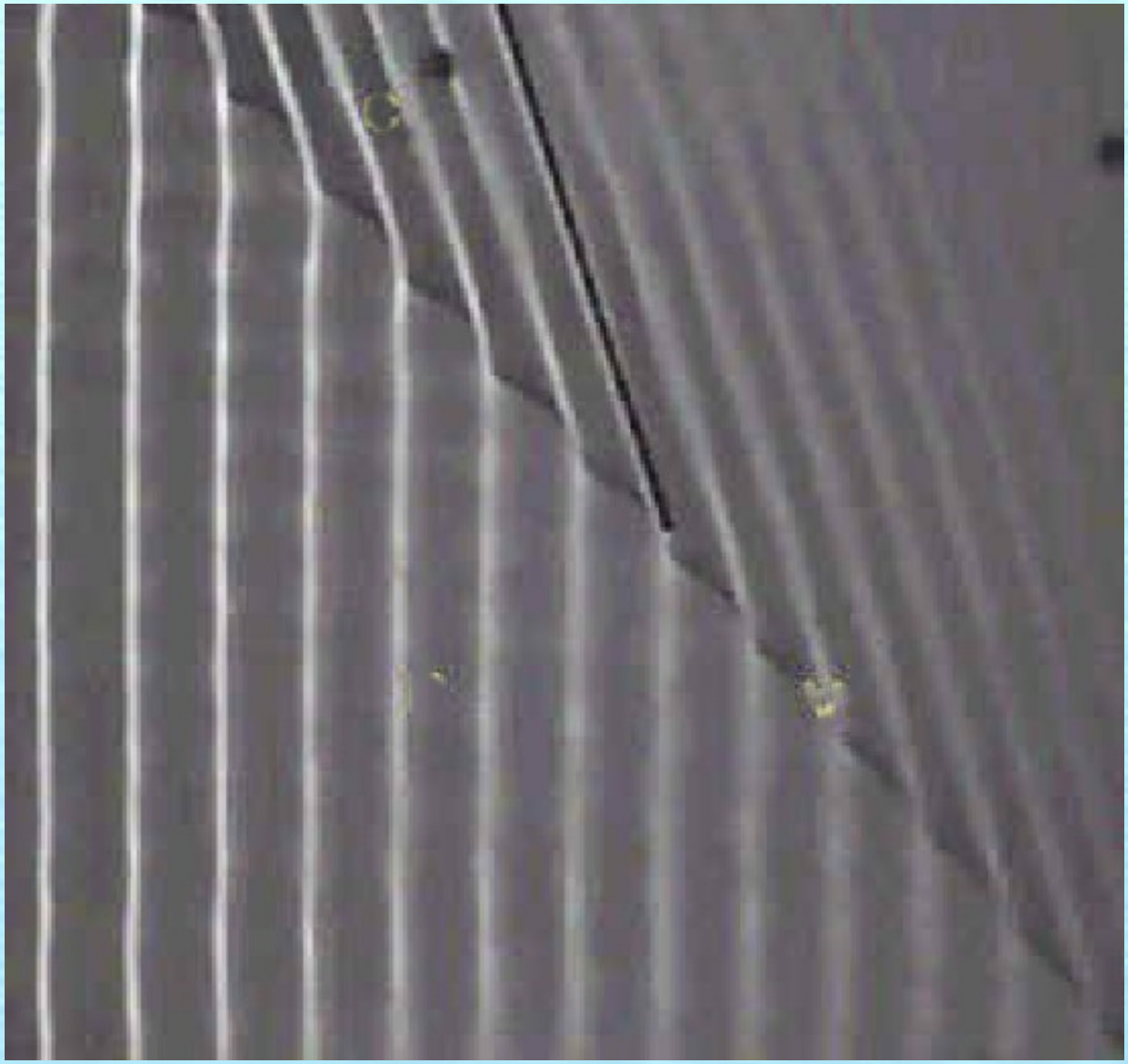
Applies to ALL waves



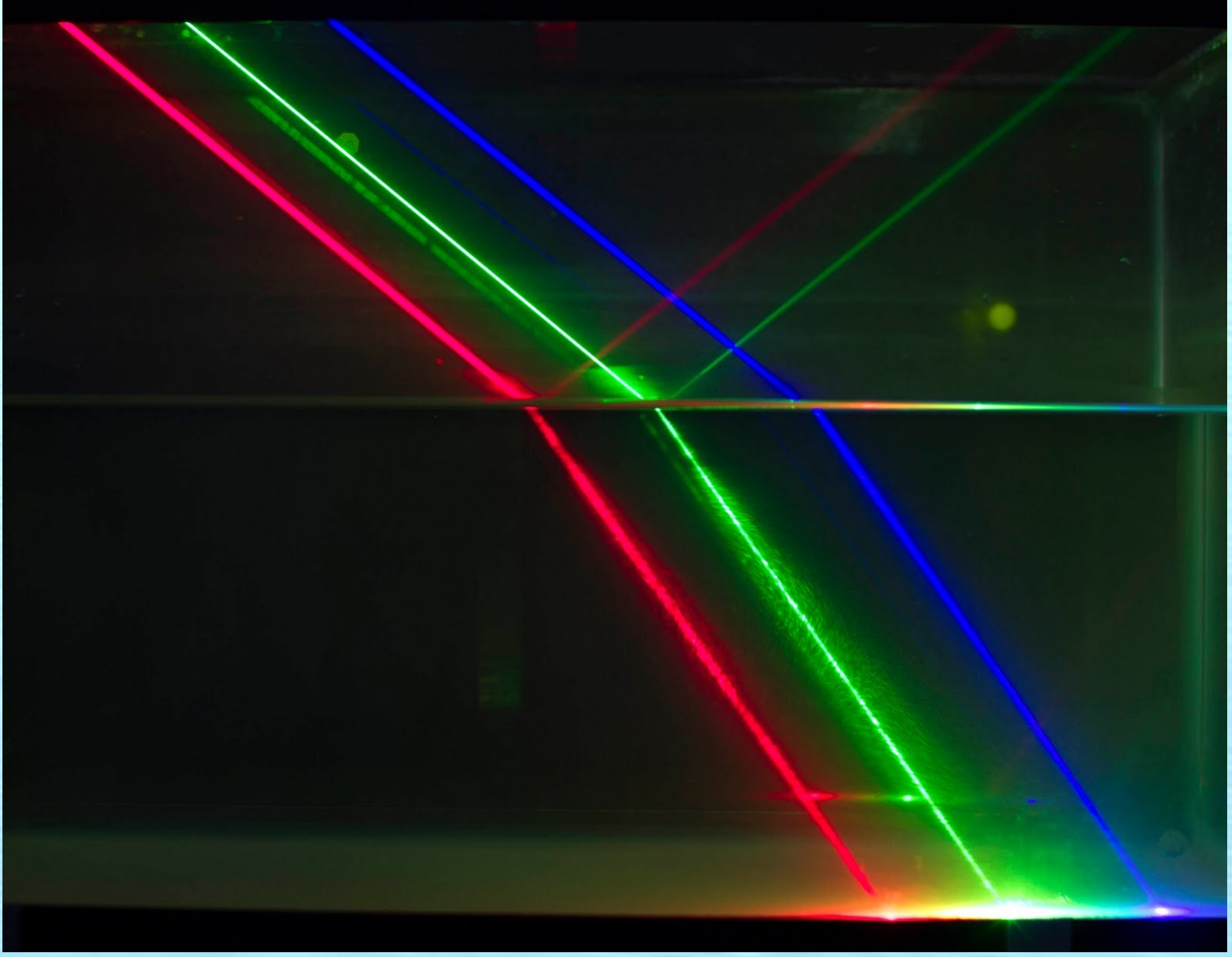
Refraction is CAUSED by the change of speed as light goes from one medium to Another.

Slowing waves bend toward normal

Snell's law
Applies to ALL waves



Once you see that refraction is caused by a speed change, you can understand that it happens with light, sound, water and geologic waves.



Refraction Problem

Given a red laser beam in air (n1=1.00) that enters water (n2=1.33) in a fish-tank at an angle of incidence of 51 degrees, what is the angle of refraction?

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

IDEA Method – Snells Law

Identify

Develop

Execute

Assess

IDEA Method – Snells Law

Skipping to Execute …

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

Given:

$$n_1 = 1.000;\ \theta_1 = 51.00^{o}; n_2 = 1.335$$

What is θ_2 ? (in degrees)

Model/Visualize/Solve/Assess

Model – What is being asked? What is given? What equations or principles might be relevant? Diagram can help you organize your thoughts.

Visualize – Sketch the problem. Can you see a non-mathematical path to a solution? Do you need more ideas? Plug the data you were given into your sketch.

Model/Visualize/Solve/Assess

Solve – Plug and chug. Stick numbers into formulae. Get an answer.

Assess – Did you check that the units come out to what you expect? Can you qualitatively solve the problem? Did the light bend the right way? Is the force the right direction? Should your answer be negative? Are the numbers at all reasonable based on what you know?

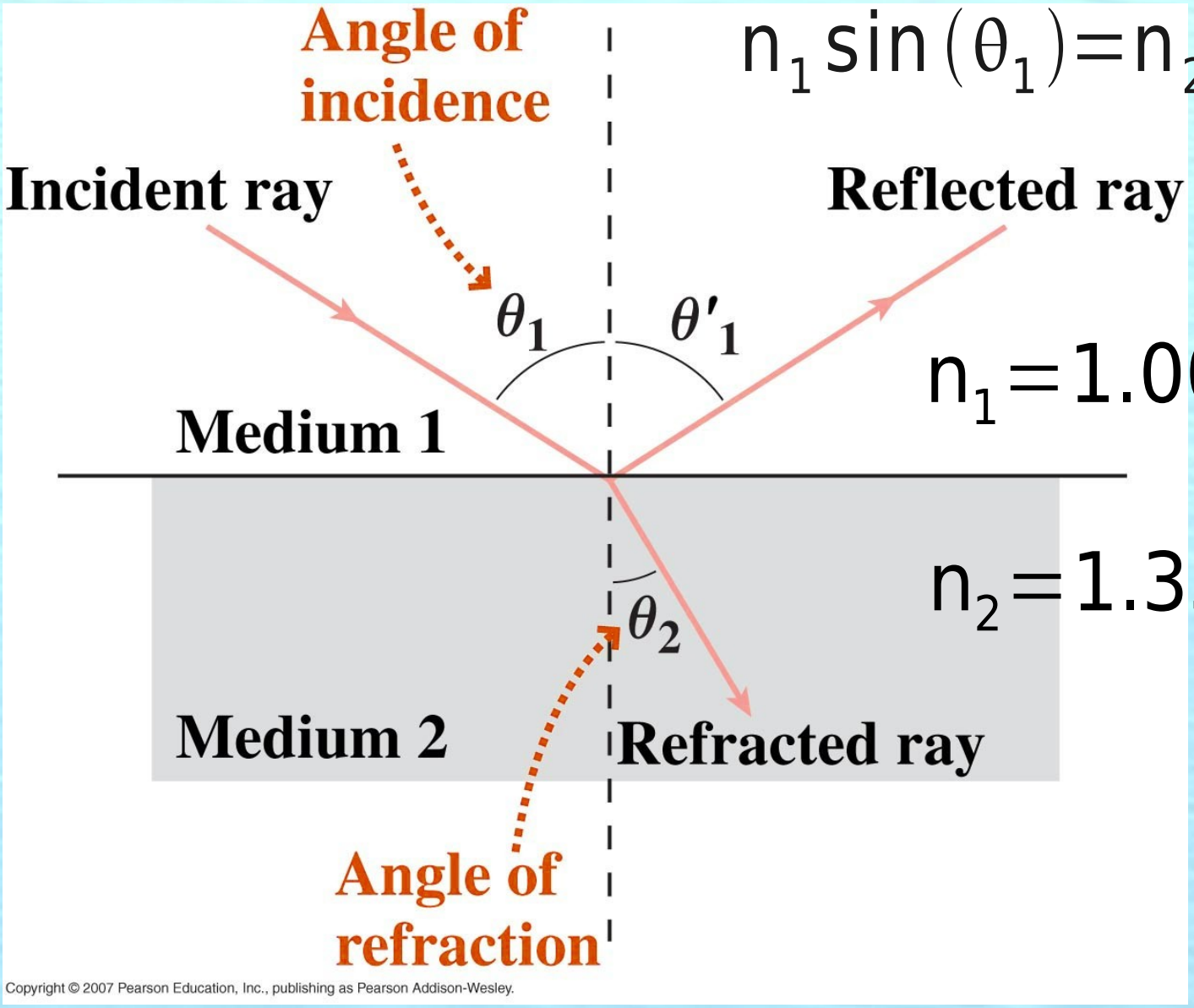
MVSA – From the beginning

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?

Model

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

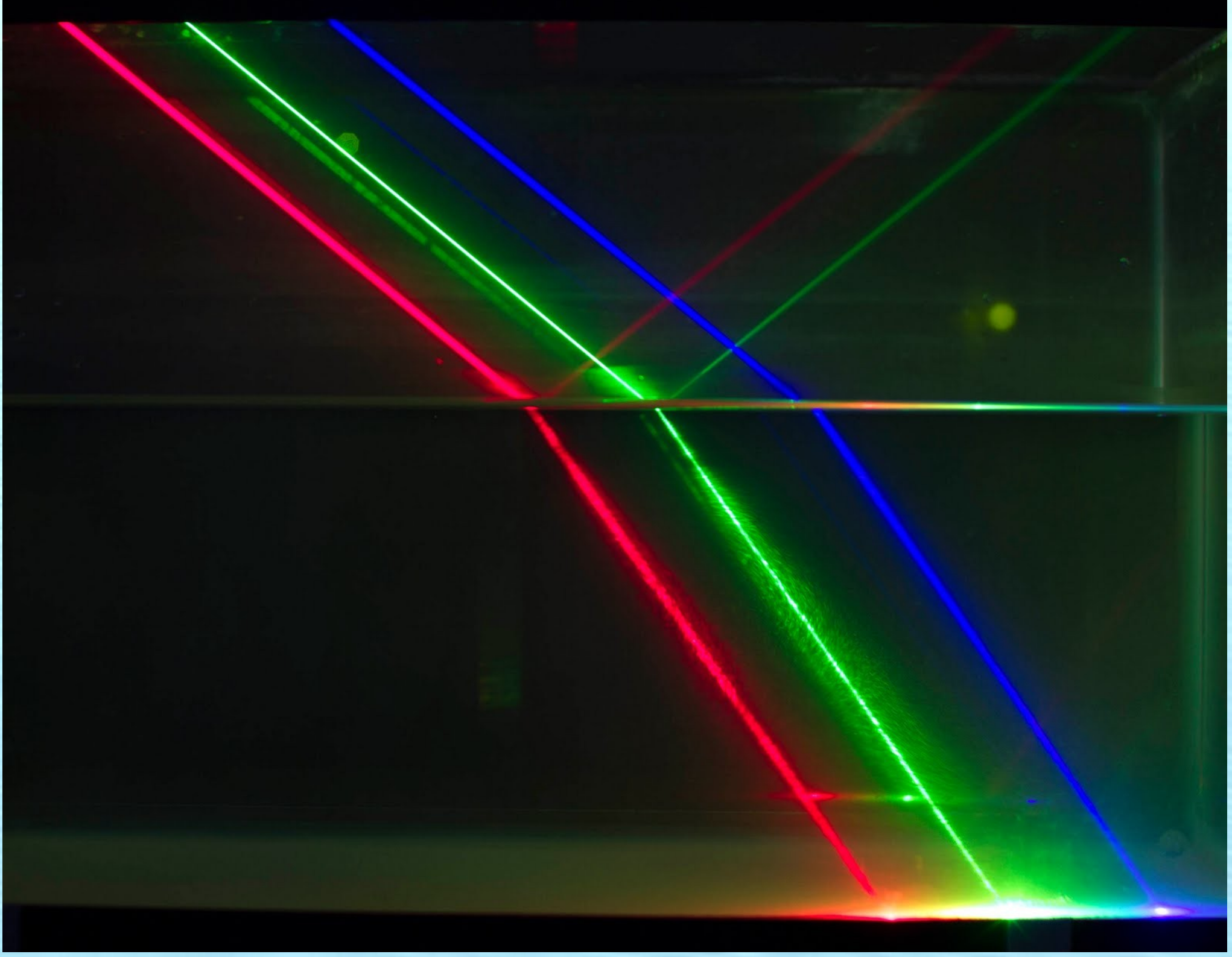
Visualize – Definitions in Snell's law



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

$n_1 = 1.000;\ \theta_1 = 51.00°$

$n_2 = 1.335$



MVSA

Visualize

Do I know n_1, n_2, θ_1?

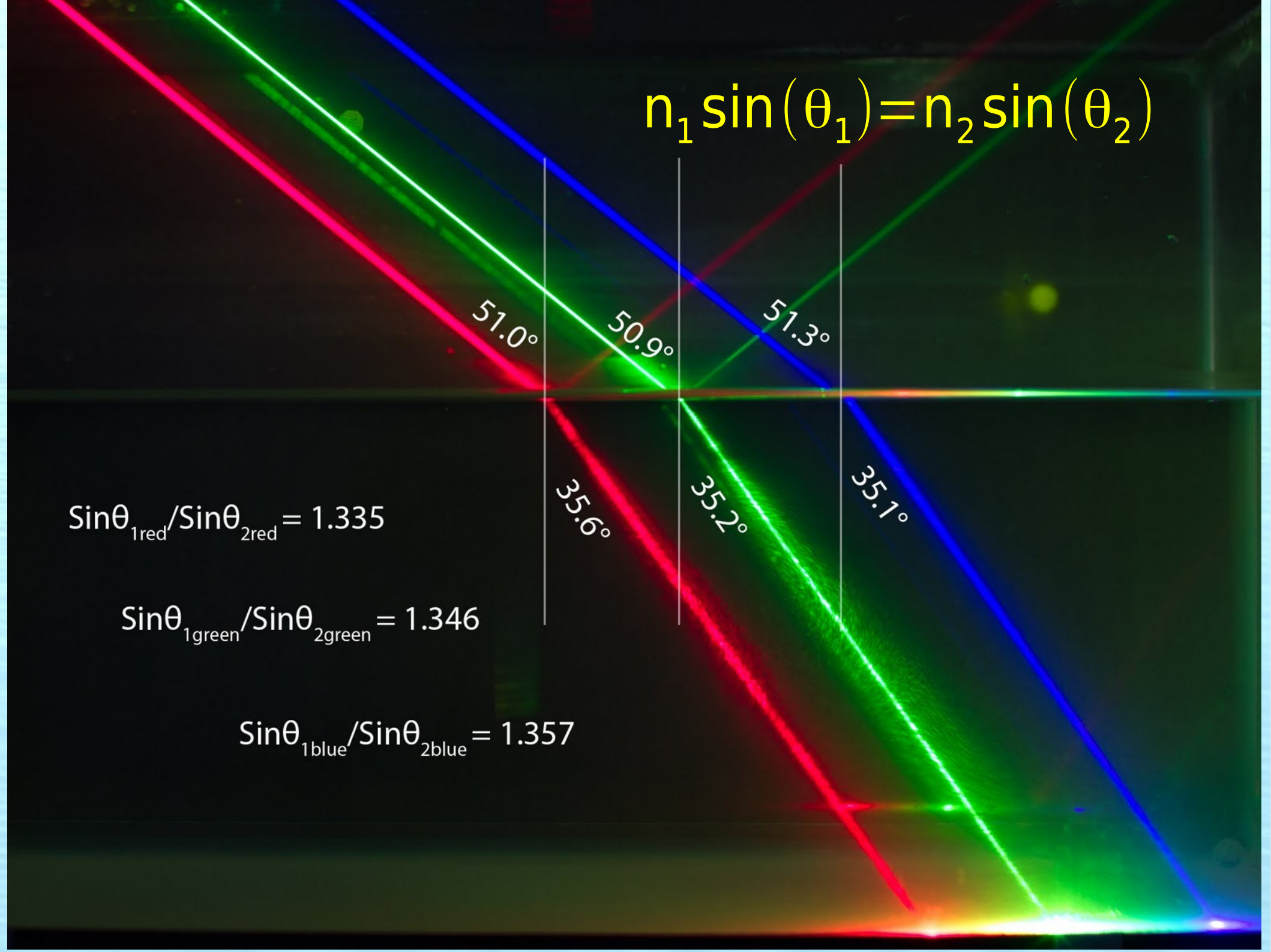
Solve

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°
$\text{Sin}\theta_{1red}/\text{Sin}\theta_{2red} = 1.335$
$\text{Sin}\theta_{1green}/\text{Sin}\theta_{2green} = 1.346$
$\text{Sin}\theta_{1blue}/\text{Sin}\theta_{2blue} = 1.357$

Homework, problem 23.10

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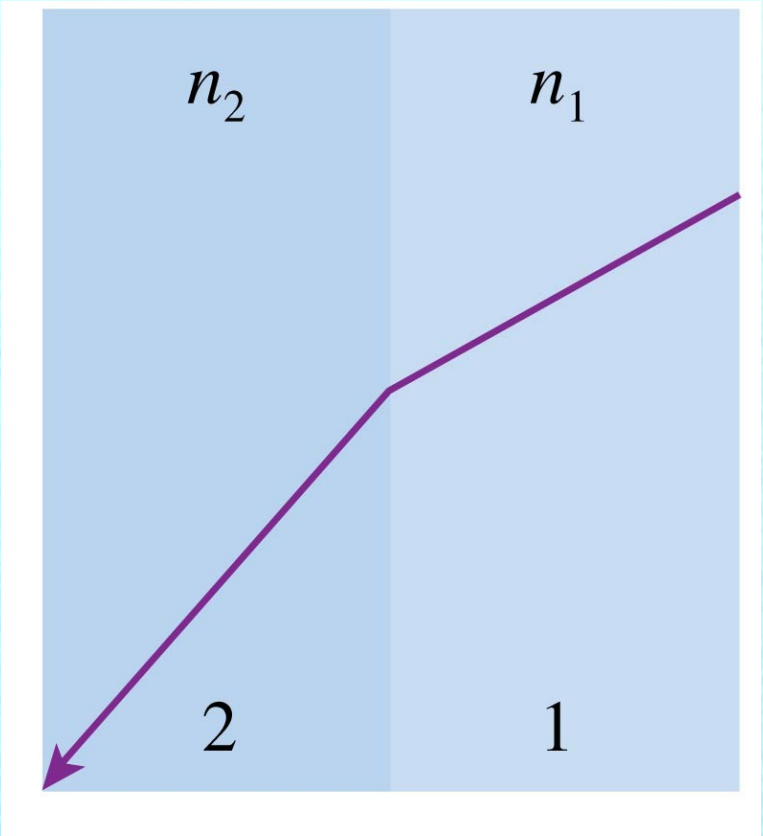
Clicker Question

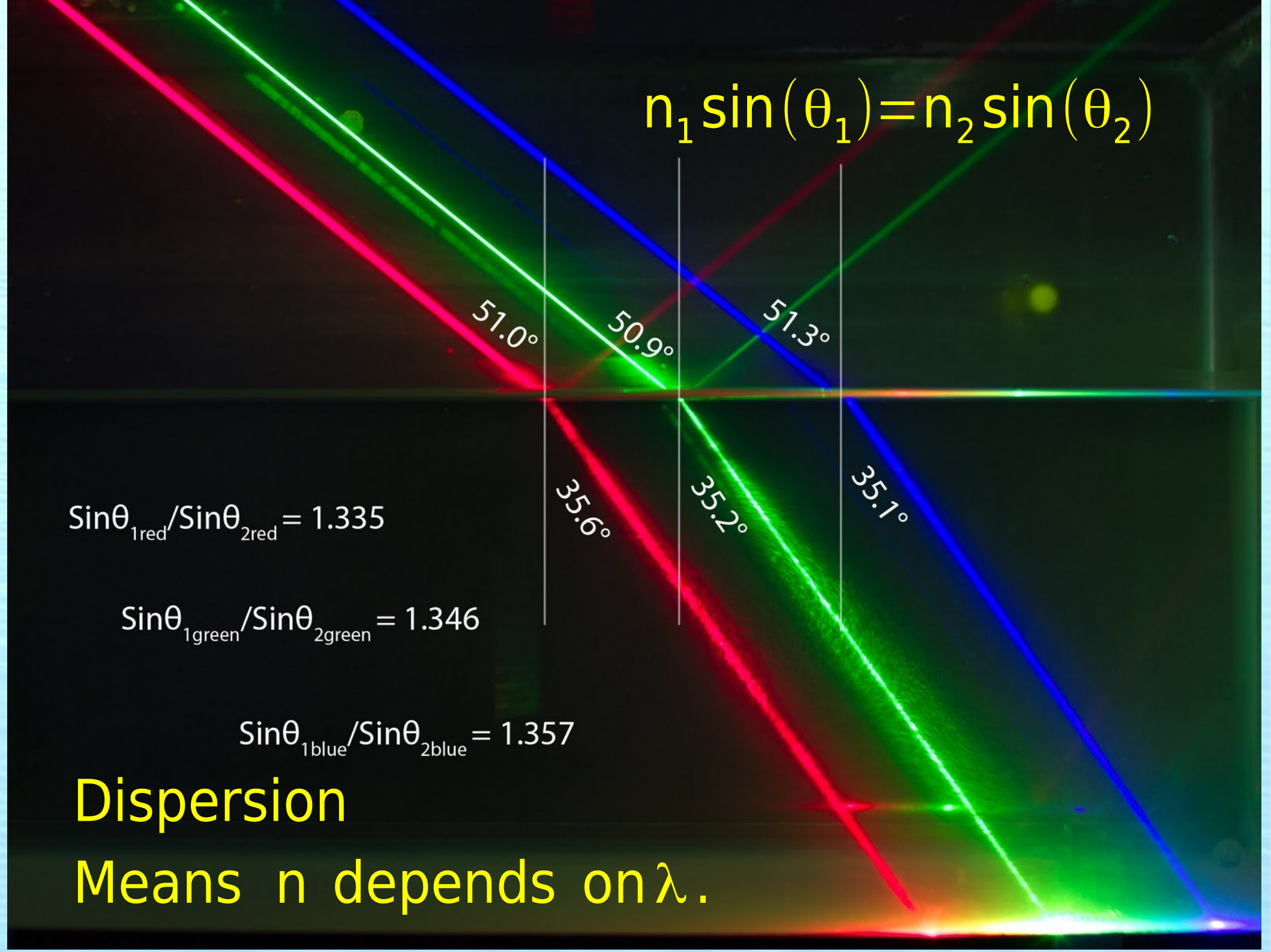
A laser beam passing from medium 1 to medium 2 is refracted as shown. Which is true?



A. $n_1 < n_2$.

B. $n_1 > n_2$.

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


$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$
51.0°
50.9°
51.3°
35.6°
35.2°
35.1°
$\text{Sin}\theta_{1red}/\text{Sin}\theta_{2red} = 1.335$
$\text{Sin}\theta_{1green}/\text{Sin}\theta_{2green} = 1.346$
$\text{Sin}\theta_{1blue}/\text{Sin}\theta_{2blue} = 1.357$
Dispersion
Means n depends on λ.

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

Homework, problem 23.14

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Ray Optics – Why can you see?

Objects emit, reflect or scatter rays in all directions (usually).

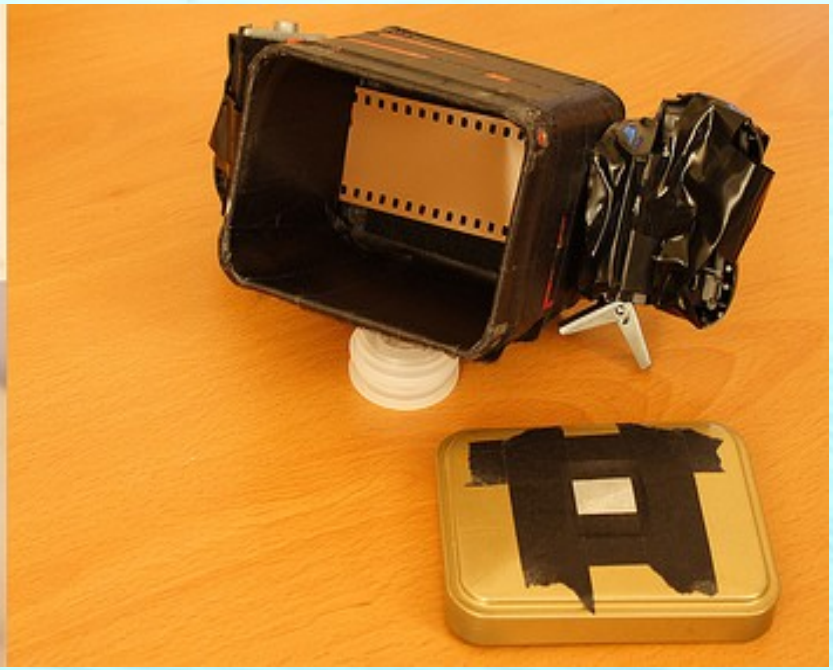
Some ray from the object has to enter your eye for you to see it.

Your eye is like a camera. Images occur because light rays strike your retina at different positions.

Camera Obscura

Pinhole camera

No lens needed!



How Pinhole camera (and your eye) works

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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)

$\sin(\theta_c) = \frac{n_2}{n_1}$ Total internal reflection

Next Time

Total internal reflection
Lenses

End of Class Reminders

Recitations / Labs: Start next week.
Online Homework #00. Till midnight tonight to do it or explain why you can't. Max extension till Tuesday (10:45)
Clickers: Start Tuesday
Online HW #01 (due Fri 1/17 @23:59)
Actively read all of Ch. 23 by next Thursday.