

## PHY132 Introduction to Physics II

### Class 5 – **Outline:**

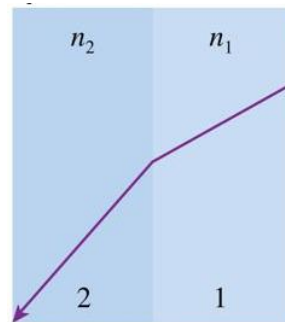
- Ch. 23, sections 23.1-23.5
- Reflection
- Refraction
- Total Internal Reflection
- Image Formation
- Colour and Dispersion



<http://physics.tutorvista.com/light/index-of-refraction.html>

### **Class 5 Preclass Quiz on MasteringPhysics**

- This was due this morning at 8:00am
- 674 students submitted the quiz on time
- 96% got: “Specular Reflection” is reflection by a flat, smooth object. The “law of reflection” is obeyed.
- 79% got: “Dispersion” is when the index of refraction varies slightly with wavelength.
- 57% of students got: Whenever the ray bends away from the normal, it means the waves are speeding up. That means  $n_2 < n_1$ .
- 70% got: there is only a critical angle (for possible total internal reflection) when  $n_2 < n_1$ .



### **Class 5 Preclass Quiz – Student Comments...**

- *“I don't know whether this is relevant but: how come when you shine your pointer in Con Hall, we see the green dot on screen, but we don't see a ray of green light travelling from the pointer to the screen?”*
- *“So all objects emit light?”*
- **Harlow answer:** No. Most of them are diffuse reflectors.
- *I have a few questions: 1) You mentioned that when 2 light waves cross, they do not interfere with each other. If so, then how is thin film interference possible?*
- **Harlow answer:** They certainly do interfere with each other!! But they do not bounce off one another and go in different directions..
- *2) Do we have to memorize the wavelengths of light given in the book?*
- **Harlow answer:** No.

### **Class 5 Preclass Quiz – Student Comments...**

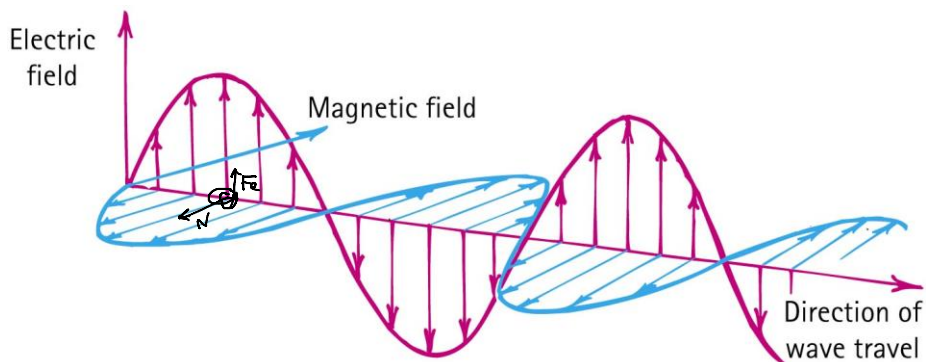
- *when are your office hours??*
- Mondays 1:00-2:00, Thursdays and Fridays 11:00-noon.
- *How do one-way mirrors work? Is it something like thin-film optical coatings?*
- **Harlow answer:** Nope. It's just a thin coating of aluminum on glass, so it is partially reflective and partially transmitting. And there is nothing one-way about it all mirrors are two-way. But if you keep one room in relative darkness and keep the other room quite bright, the people in the darker room will be able to see the brighter room, but not vice-versa.
- *After a full semester of completely new material, there is finally a topic that I have learned before from grade 10 science. :)*

- What is light?
- Light is an electromagnetic wave – and is highly useful in our everyday life!



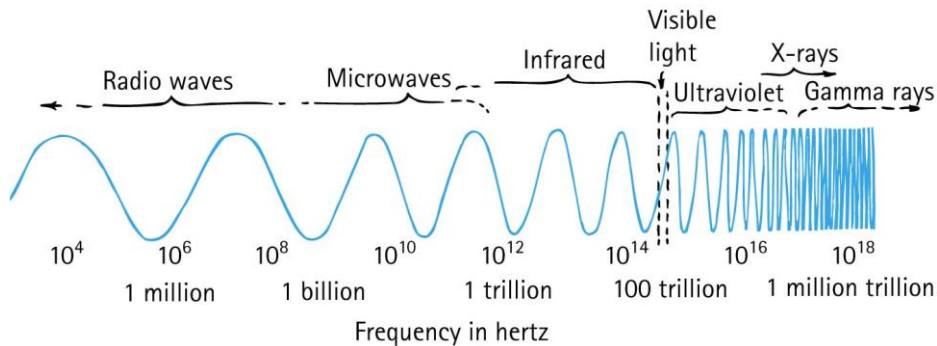
## Electromagnetic Waves

The electric and magnetic fields of an electromagnetic wave are perpendicular to each other and to the direction of motion of the wave.



# Electromagnetic Spectrum

- In a vacuum, all electromagnetic waves move at the same speed
- We classify electromagnetic waves according to their frequency (or wavelength)
- Light is one kind of electromagnetic wave



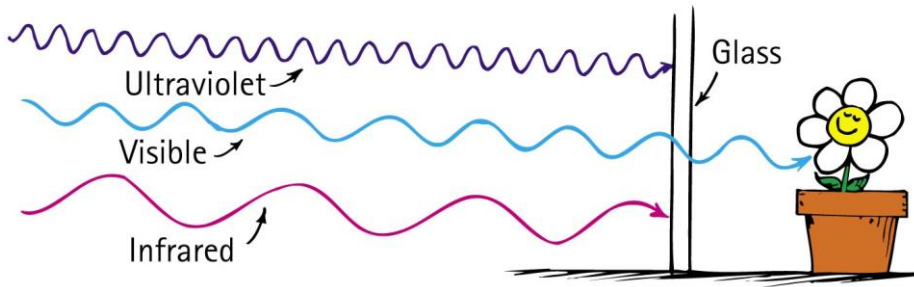
## Electromagnetic Waves CHECK YOUR NEIGHBOUR

If a certain material is “transparent” (ie, not opaque), what does this mean?

- A. Electromagnetic waves of all frequencies can pass straight through it
- B. Electromagnetic waves of all frequencies are reflected from its surface
- C. Electromagnetic waves of all frequencies are absorbed throughout its volume
- D. Electromagnetic waves of a certain frequency can pass straight through it

# Transparent Materials

Glass blocks both infrared and ultraviolet, but it is transparent to visible light.



# Opaque Materials

- Most things around us are **opaque**—they absorb light without re-emitting it.
- Vibrations given by light to their atoms and molecules are turned into random kinetic energy—into internal energy.
- These materials become slightly warmer.



# Opaque Materials

## Metals

- Light shining on metal forces free electrons in the metal into vibrations that emit their own light as reflection.



### Reflection CHECK YOUR NEIGHBOUR

Which reflects more light, a white piece of paper or a black piece of paper?

- A. Black
- B. White
- C. About the same

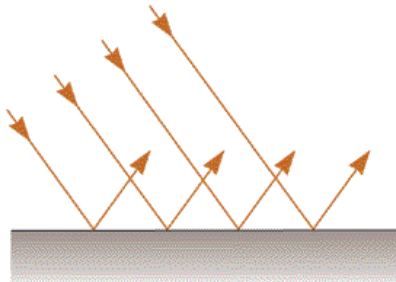
## Reflection

### CHECK YOUR NEIGHBOUR

Which reflects more light, a white piece of paper or a mirror?

- A. White Paper
- B. Mirror
- C. About the same

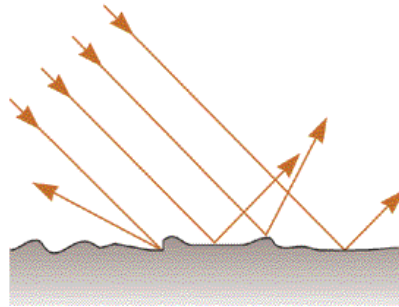
## Specular Reflection



### Mirrors

- The surface is *flat* at distance scales near or above the wavelength of light
- It looks “shiny”, and you can see images in it.

## Diffuse Reflection

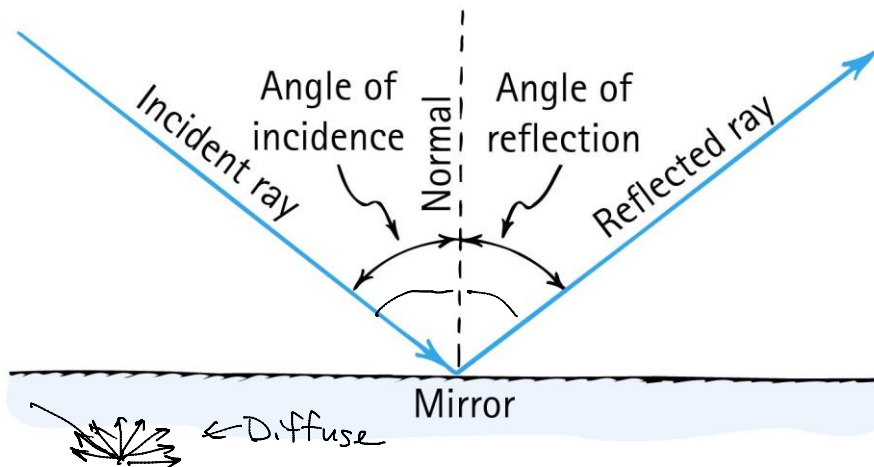


### White Paper

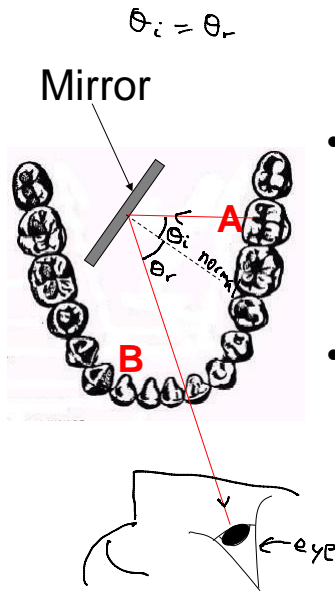
- The surface is *rough* at distance scales near or above the wavelength of light
- Almost **all** surfaces reflect in this way!

## Law of Specular Reflection

The angle of reflection equals the angle of incidence.





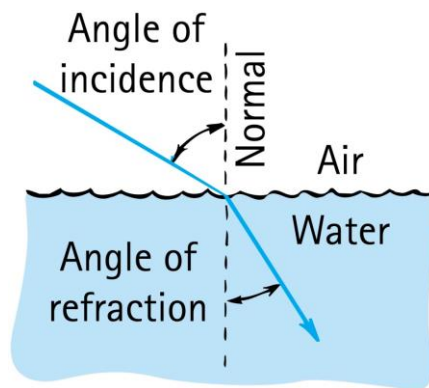


- A dentist uses a mirror to look at the back of a second molar (A).
- Next, she wishes to look at the back of a lateral incisor (B), which is  $90^\circ$  away.
- By what angle should she rotate her mirror?

- A.  $90^\circ$
- B.  $45^\circ$
- C.  $180^\circ$

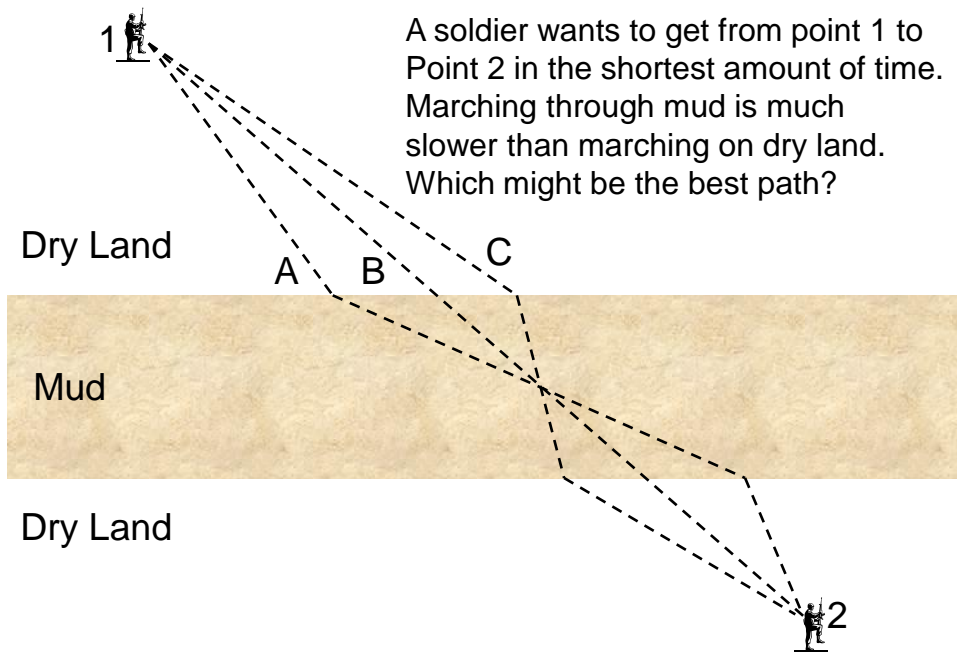
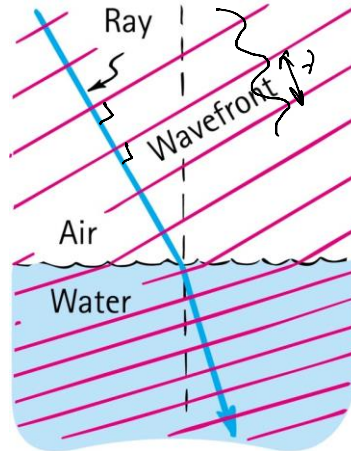
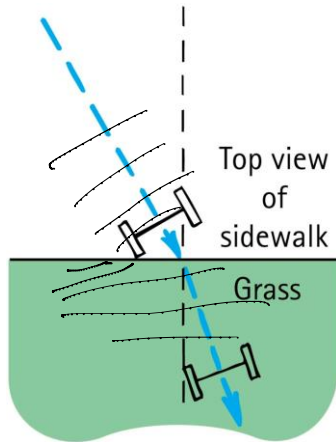
## Refraction

When light bends in going obliquely from one medium to another, we call this process refraction.



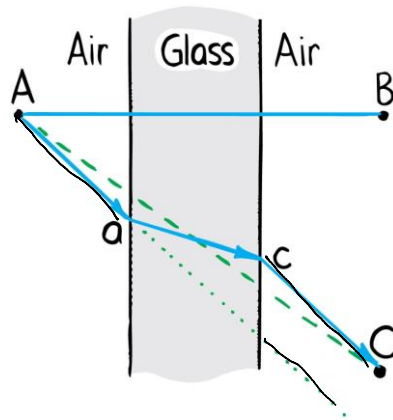
# Cause of Refraction

- Bending of light when it passes from one medium to another
- Caused by change in speed of light



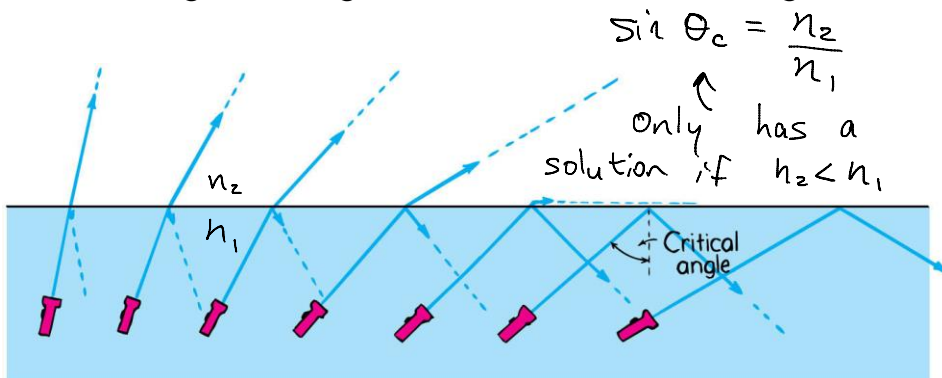
# Refraction

Light travels slower in glass than in air, so it minimizes the time it spends in the glass.

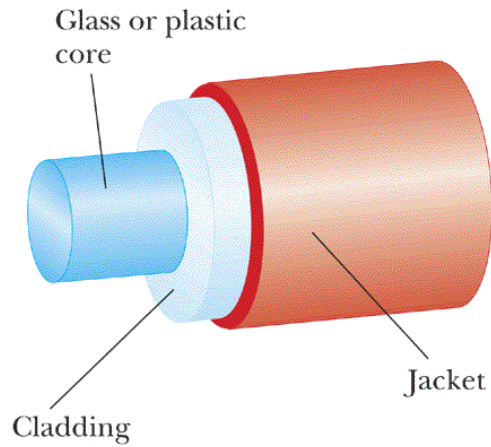


# Total Internal Reflection

- Total reflection of light traveling within a medium that strikes the boundary of another medium at an angle at, or greater than, the critical angle



# An Optical Fibre



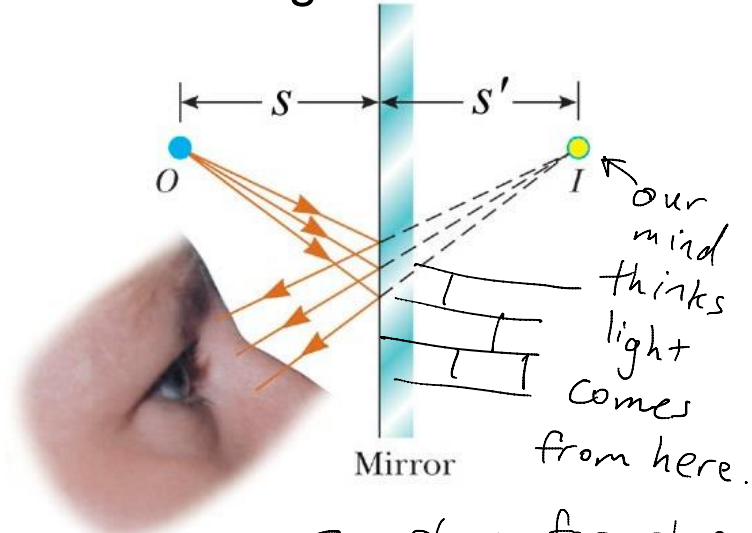
Speed of light in cladding is *higher* than speed of light in core.

## Medical Fibrescopes



Video-laryngoscopy with a flexible fibrescope

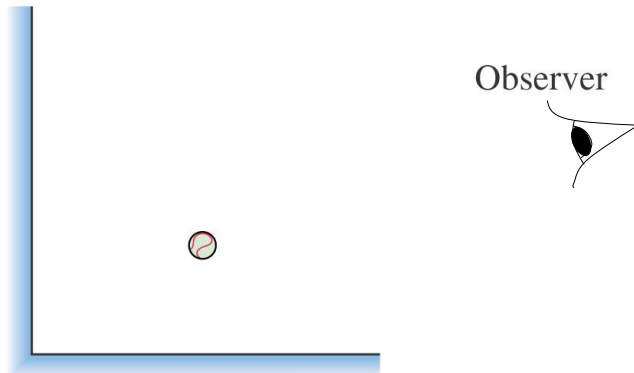
# Virtual Image Formation

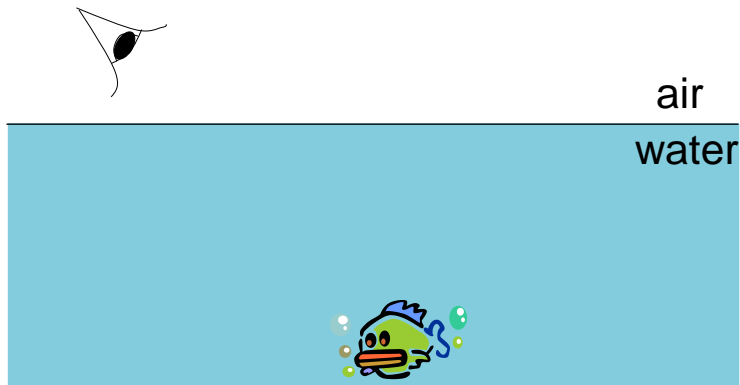


No light rays actually pass through or even near the image, so it is "virtual".

Two plane mirrors form a right angle. How many images of the ball can the observer see in the mirrors?

- A. 1
- B. 2
- C. 3
- D. 4

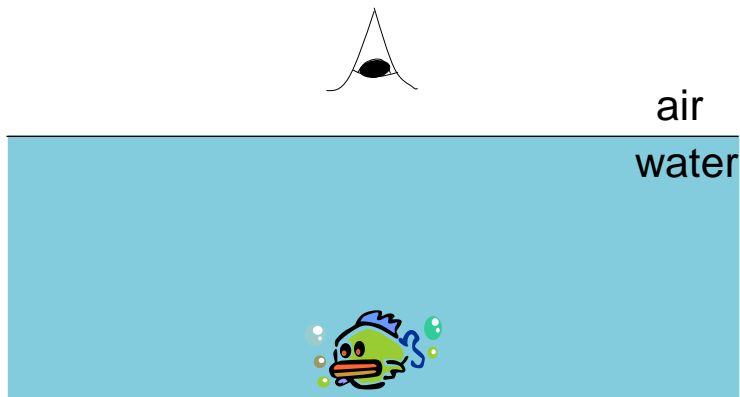




A fish swims below the surface of the water.

An observer sees the fish at:

- A. a greater depth than it really is.
- B. its true depth.
- C. a smaller depth than it really is.

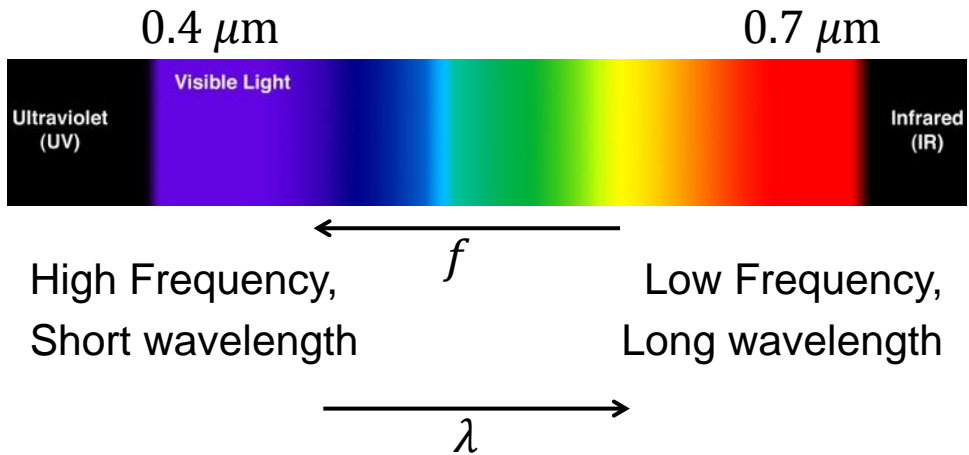


A fish swims *directly* below the surface of the water. An observer sees the fish at:

- A. a greater depth than it really is.
- B. its true depth.
- C. a smaller depth than it really is.

# Color

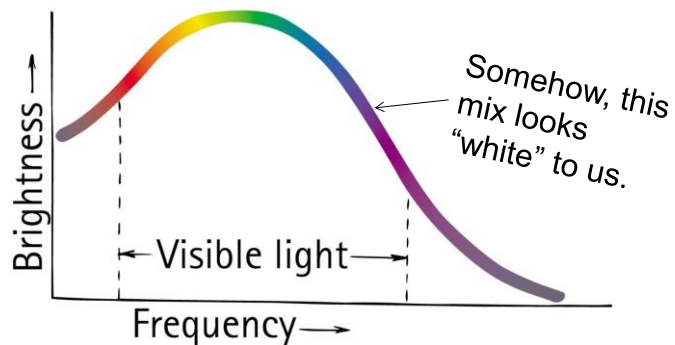
Color we see depends on frequency of light.



## Mixing Colored Light

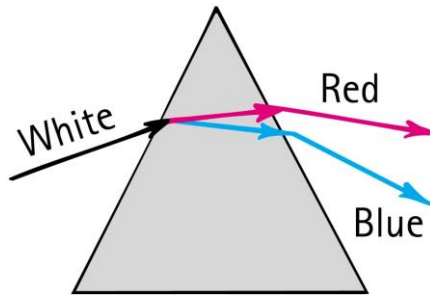


The spectrum of sunlight is a graph of brightness versus frequency.



# Dispersion

- Process of separation of light into colors arranged by frequency

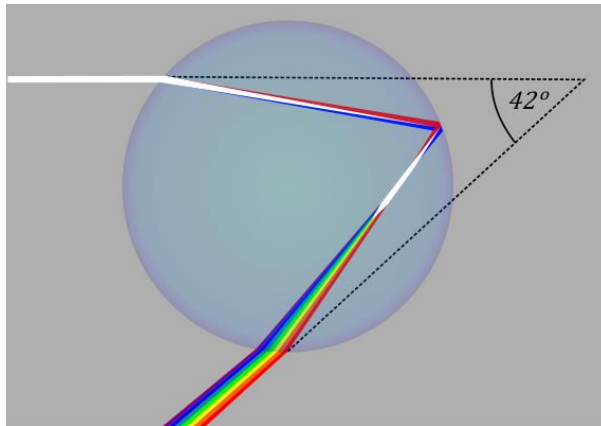


- Components of white light are dispersed in a prism (and in a diffraction grating).

# Rainbows

Rainbows are a result of dispersion by many drops.

- Dispersion of light by a single drop





# Rainbows

Radius of circle is about  $41^\circ$

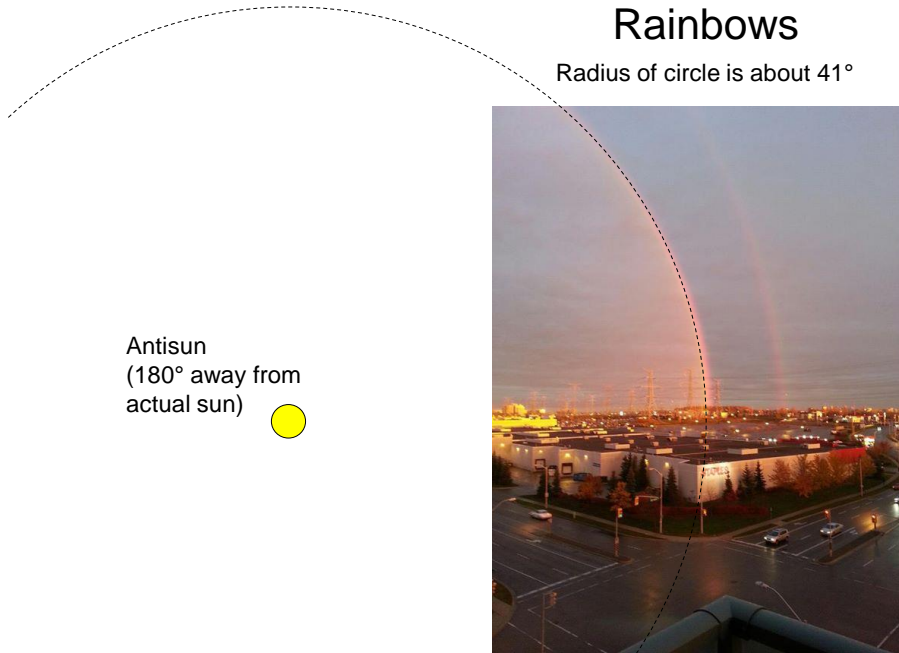
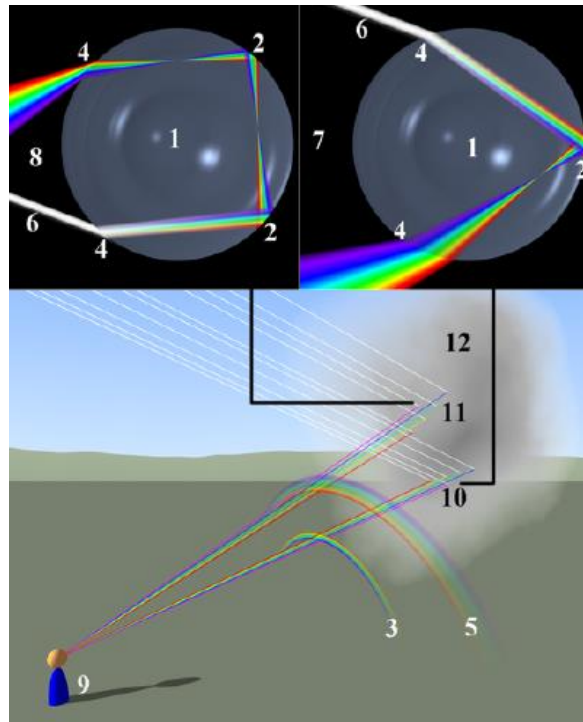


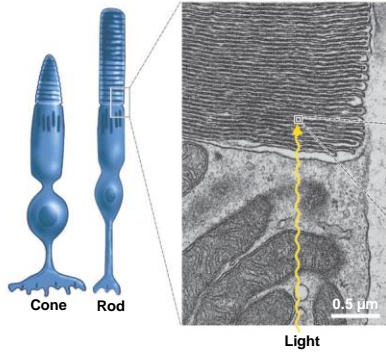
Image by Bitu Janzadah. ©2014. [https://fbcdn-sphotos-g-a.akamaihd.net/hphotos-ak-ash2/s720x720/560575\\_10151053440411899\\_1380323186\\_n.jpg](https://fbcdn-sphotos-g-a.akamaihd.net/hphotos-ak-ash2/s720x720/560575_10151053440411899_1380323186_n.jpg)

# Double-rainbow

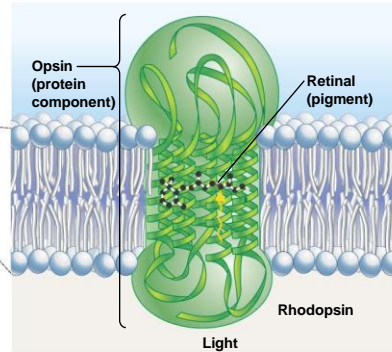
The second rainbow has blue on the top, and a radius of about  $53^\circ$



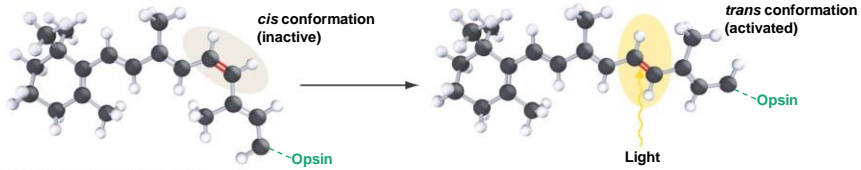
(a) Rods and cones contain stacks of membranes.



(b) Rhodopsin is a transmembrane protein complex.



(c) The retinal molecule inside rhodopsin changes shape when retinal absorbs light.



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Slide courtesy of Ross Koning, Biology Department, Eastern Connecticut State University  
<http://plantphys.info/sciencematters/vision.ppt>

Stare at the dot on the nose for 15 seconds.



What do you see on this blank white slide? Blink if needed!

This is called an “after image”  
Does it move around as you move your gaze?

## Before Class 6 on Wednesday

- Please read Knight Pgs. 670-686: Ch. 23, sections 23.6-23.8
- Please do the short pre-class quiz on MasteringPhysics by tomorrow night.
- Something to think about: What is the difference between a converging and diverging lens? Which type can be used to focus sunlight onto a piece of paper and burn a hole?

