Note on Posted Slides

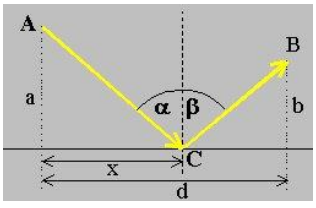
- These are the slides that I intended to show in class on Wed. Apr. 3, 2013.
- They contain important ideas and questions from your reading.
- Due to time constraints, I was probably not able to show all the slides during class.
- They are all posted here for completeness.

PHY205H1S
Physics of Everyday Life
Class 22: Reflection and Refraction

- Law of Reflection
- Virtual Image Formation
- Image Reversal
- Concave Mirrors
- Diffuse Reflection
- Refraction
- Dispersion, Rainbows
- Total Internal Reflection
- Lenses
- Real Image Formation

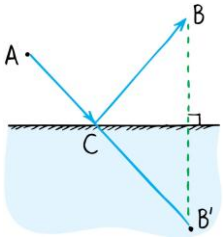
History of Light

- 50 A.D. – **Hero** of Alexandria explained Euclid's Law of Reflection by proposing that light always takes the shortest path between two points.



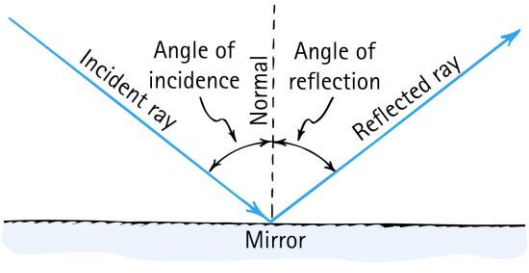
Fermat's Principle of Least Time

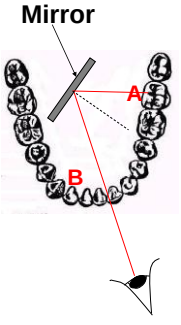
- In 1657 Pierre de Fermat modified Hero's proof to be a path of least time.
- B' is a point along the normal to B, the same distance behind the mirror as B is in front of the mirror
- B' is the virtual image of B
- A-C-B is the path along which light takes the shortest time to go from A to the mirror to B



Law of Reflection

The angle of reflection equals the angle of incidence.

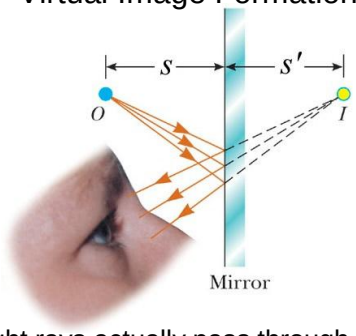




- A dentist uses a mirror to look at the back of a second molar (A).
- Next, she wishes to look at the back of a lateral incisor (B), which is 90° away.
- By what angle should she rotate her mirror?

A. 90°
B. 45°
C. 180°

Virtual Image Formation



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

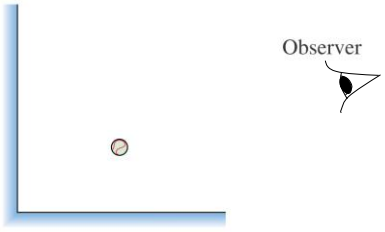
Two plane mirrors form a right angle. How many images of the ball can the observer see in the mirrors?

A. 1

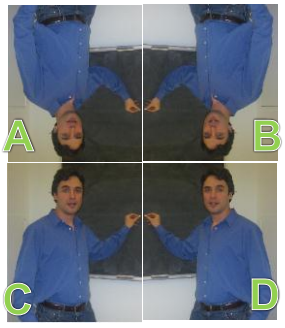
B. 2

C. 3

D. 4

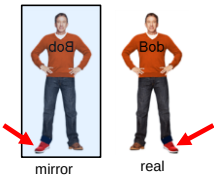


- Which picture is most likely a mirror image of Harlow?

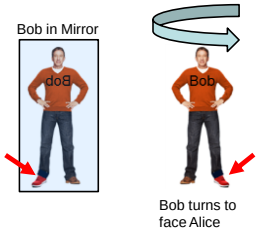


Virtual Image Formation

- Alice looks at Bob’s image a mirror and sees he has a red shoe on the foot to Alice’s left.
- Then she asks Bob to turn and face her, so she can compare the image to what Bob looks like in real life.
- Bob takes a couple of steps forward, turns around and faces Alice.
- Alice notes that the red shoe is now on the foot on the right.
- Alice concludes: *“Mirrors reverse left and right, not up and down.”* Is this true? Can you see any flaws in Alice’s reasoning?

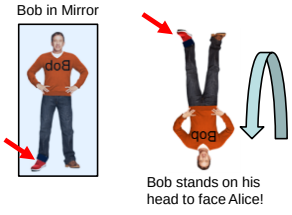


Virtual Image Formation



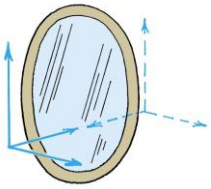
- Bob ***chooses*** to rotate around a vertical axis, and therefore he looks flipped left-to-right.
- But if Bob wants to turn to face Alice, is there any other way to do it?

Virtual Image Formation



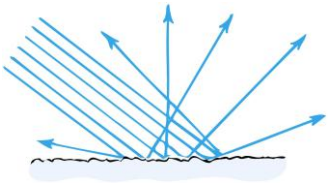
- If Bob had chosen to face Alice by standing on his head, he would have been flipped up-to-down, and ***not*** left-to-right!

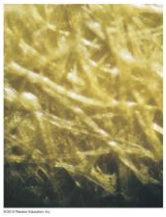
- What ***really*** happens is the image is reversed front-to-back



Diffuse reflection

- When light strikes a rough or irregular surface and reflects in many directions
- Almost everything we see is due to diffuse reflection from surfaces around us.

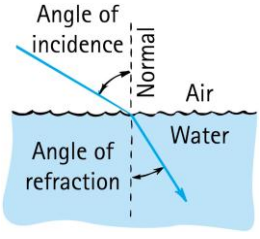




Magnified view of the surface of ordinary paper

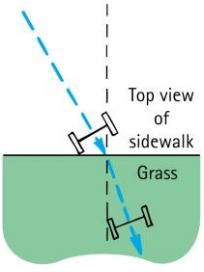
Refraction

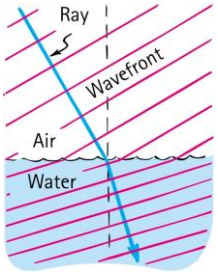
When light bends in going obliquely from one medium to another, we call this process refraction.



Cause of Refraction

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





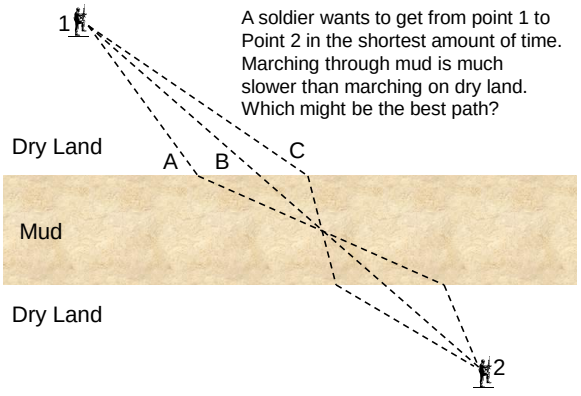
Index of Refraction

$$v_{medium} = \frac{c}{n}$$

- v_{medium} is the speed of light in a transparent medium.
- c is the speed of light in a vacuum (c=3.00×10^8 m/s)
- n is a dimensionless constant: $n \geq 1$
- n=1 in a vacuum

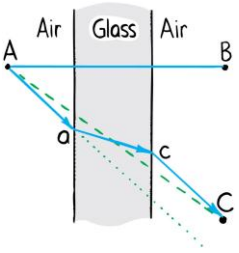
TABLE 23.1 Indices of refraction

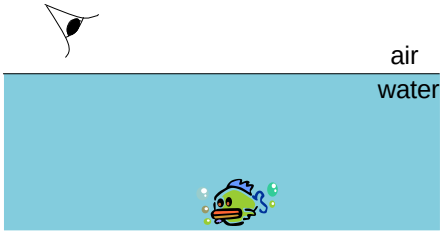
Medium	n
Vacuum	1.00 exactly
Air (actual)	1.0003
Air (accepted)	1.00
Water	1.33
Ethyl alcohol	1.36
Oil	1.46
Glass (typical)	1.50
Polystyrene plastic	1.59
Cubic zirconia	2.18
Diamond	2.41
Silicon (infrared)	3.50



Refraction

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

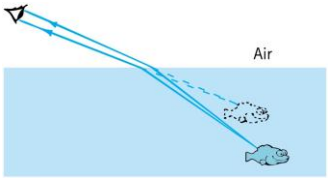




A fish swims below the surface of the water.
An observer sees the fish at:

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

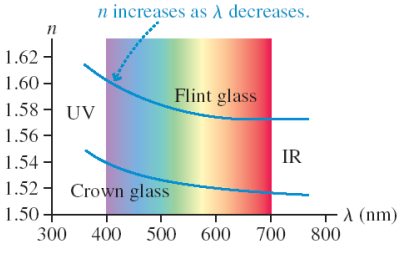
Illusion caused by refraction



- Objects submerged in water appear closer to the surface.

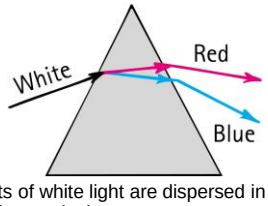
Dispersion

The slight variation of index of refraction with wavelength is known as dispersion. Shown is the dispersion curves of two common glasses. Notice that *n* is larger when the wavelength is shorter, thus violet light refracts more than red light.



Dispersion

- Process of separation of light into colors arranged by frequency

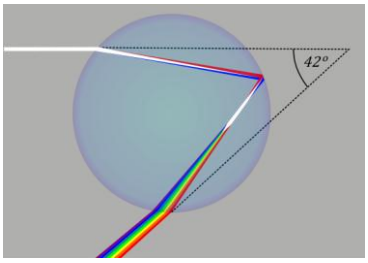


- Components of white light are dispersed in a prism (and in a diffraction grating).

Rainbows

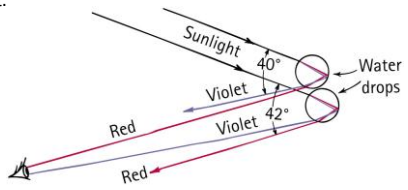
Rainbows are a result of dispersion by many drops.

- Dispersion of light by a single drop

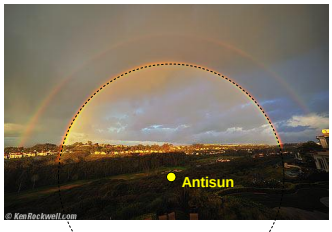


Rainbows

- Sunlight incident on two sample raindrops, as shown, emerges from them as dispersed light.
- The observer sees the red light from the upper drop and the violet light from the lower drop.
- Millions of drops produce the whole spectrum of visible light.



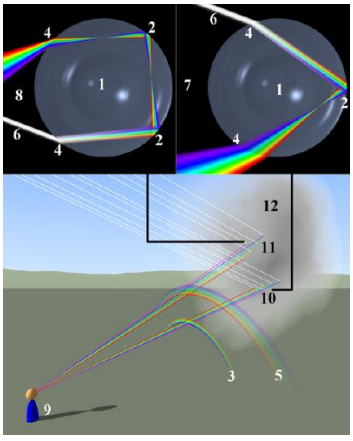
Rainbows



Radius of circle is about 41°

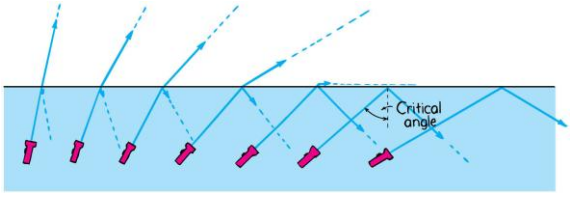
Double-rainbow

The second rainbow has blue on the top, and a radius of about 53°



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



Discussion Question

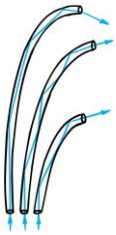
- Light waves with speed v_1 are incident upon the flat surface of a material in which they have speed v_2.
- For what condition is **total internal reflection** possible?

A. $v_2 > v_1$
B. $v_2 < v_1$
C. $v_2 = v_1$
D. All of the above

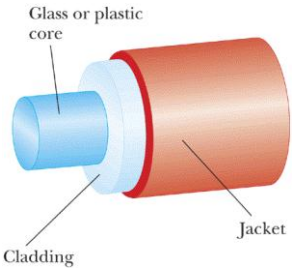
Total Internal Reflection

Optical fibers or light pipes

- Thin, flexible rods of special glass or transparent plastic.
- Light from one end of the fiber is total internally reflected to the other end, resulting in nearly the same brightness of light.

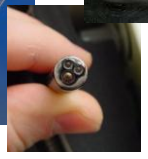


An Optical Fibre



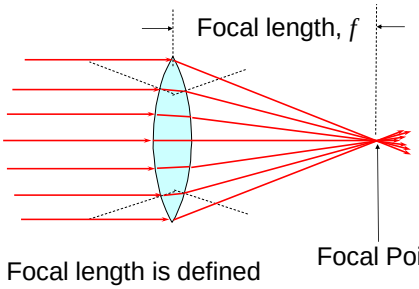
Speed of light in cladding is ***higher*** than speed of light in core.

Medical Fibrescopes



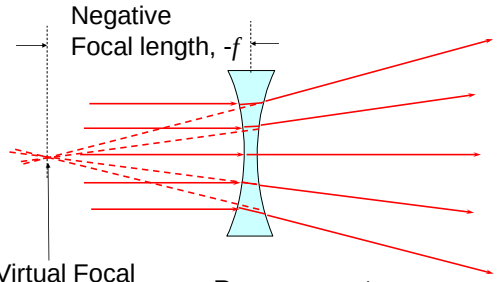
Video-laryngoscopy with a flexible fiberscope

Converging Lens



NOTE: Focal length is defined for initially parallel rays.

Diverging Lens

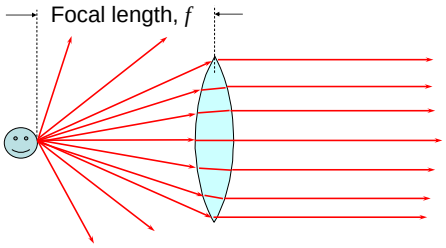


Discussion Question

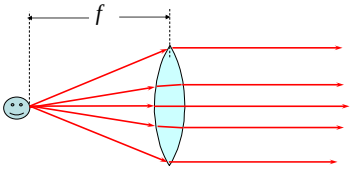
- Which kind of lens can form a real image?

A. Diverging lens
B. Converging lens

Diverging rays through a Converging Lens



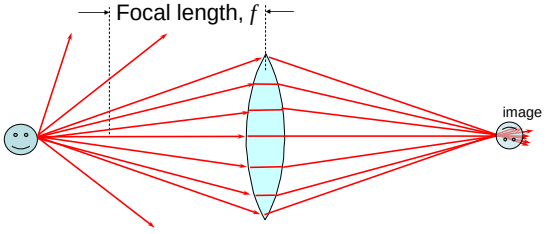
If an object emits rays at the focal point, they end up being parallel on the other side of the converging lens.



What will happen to the rays emerging to the right of the lens if the face is moved a little further away from the lens?

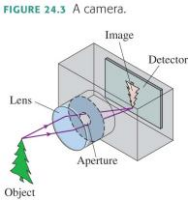
A. They will remain parallel.
B. They will diverge (spread out).
C. They will converge (toward a focus).

Real Image Formation



Light rays actually pass through the image, and a screen can be placed there, so it is "real".

The Camera



- A camera "takes a picture" by using a lens to form a real, inverted image on a light-sensitive detector in a light-tight box.
- We can model a combination lens as a single lens with an effective focal length (usually called simply "the focal length")
- A *zoom lens* changes the effective focal length by varying the spacing between the converging lens and the diverging lens.

This is the end!!!!

The final exam, will be:

Tuesday, Apr. 30 at 2:00pm sharp

Room is based on your last name:

- **A-DO:** SS2102
- **DU-H:** SS2117
- **I-LEQ:** SS2118
- **LI-LO:** SS2135

= Sid Smith

- **LU- "WANG, X" (ie first initial ≤ X):** NR25 = William Doo Auditorium, New College, 45 Wilcocks St
- **"WANG, Y" (ie first initial ≥ Y) -ZHANG:** SEEL = Seeley Hall, Trinity College, 6 Hoskin Ave
- **ZHAO-ZOU:** WI1017 = Wilson Hall, New College, 40 Wilcocks St.

This is the end!!!!

The final exam will cover the entire course, including all of the assigned reading plus tutorial materials and what was discussed in class.

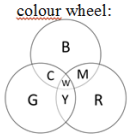
Approximately even spread over the course material

- Aids allowed [don't forget to bring these!]:
  - A calculator without communication capability.
  - Up to three 8×13 cm index cards or equivalent area, which may be written upon on both sides.

Final Exam: First Page

Assume that the acceleration due to gravity in all problems is $g = 10$ m/s^2. Unless otherwise indicated in a particular question, you may assume the density of water is 1000 kg/m^3, the speed of sound in air is 340 m/s, and air resistance is negligible. Common Prefixes: m = "milli-" = 10^{-3} c = "centi-" = 10^{-2} k = "kilo-" = 10^3 M = "mega-" = 10^6

colour wheel:

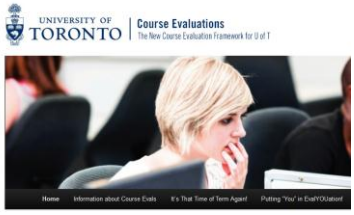


Written A:	/4
Written B:	/4
Written C:	/4
Written D:	/4
Written E:	/4
Written F:	/4

+ 24 multiple choice worth 2 points each. Exam total possible is 72.

Please Fill Out the Online Survey For This Course!!!!!!

- Your feedback is vital to me. I promise I will read every word you type in the online evaluations.
- The online system is open now (you should have received an email already)
- The deadline is ***this*** Tuesday – please don't forget!!



Keep in Touch!!

- My office hours Apr. 8 through 30 are:
  - Mondays 2-3 and 4-5
  - Wednesdays 2-3
  - Fridays 9-10
- I am in MP121-B and my land-line is 416-946-4071 (please don't send text messages to my land-line)
- Please email me (jharlow@physics.utoronto.ca) with any questions, or if you'd like to make an appointment outside my office hours.
- Keep in touch! This course has been a lot of fun for me and I'd love to hear how you are doing in the future.