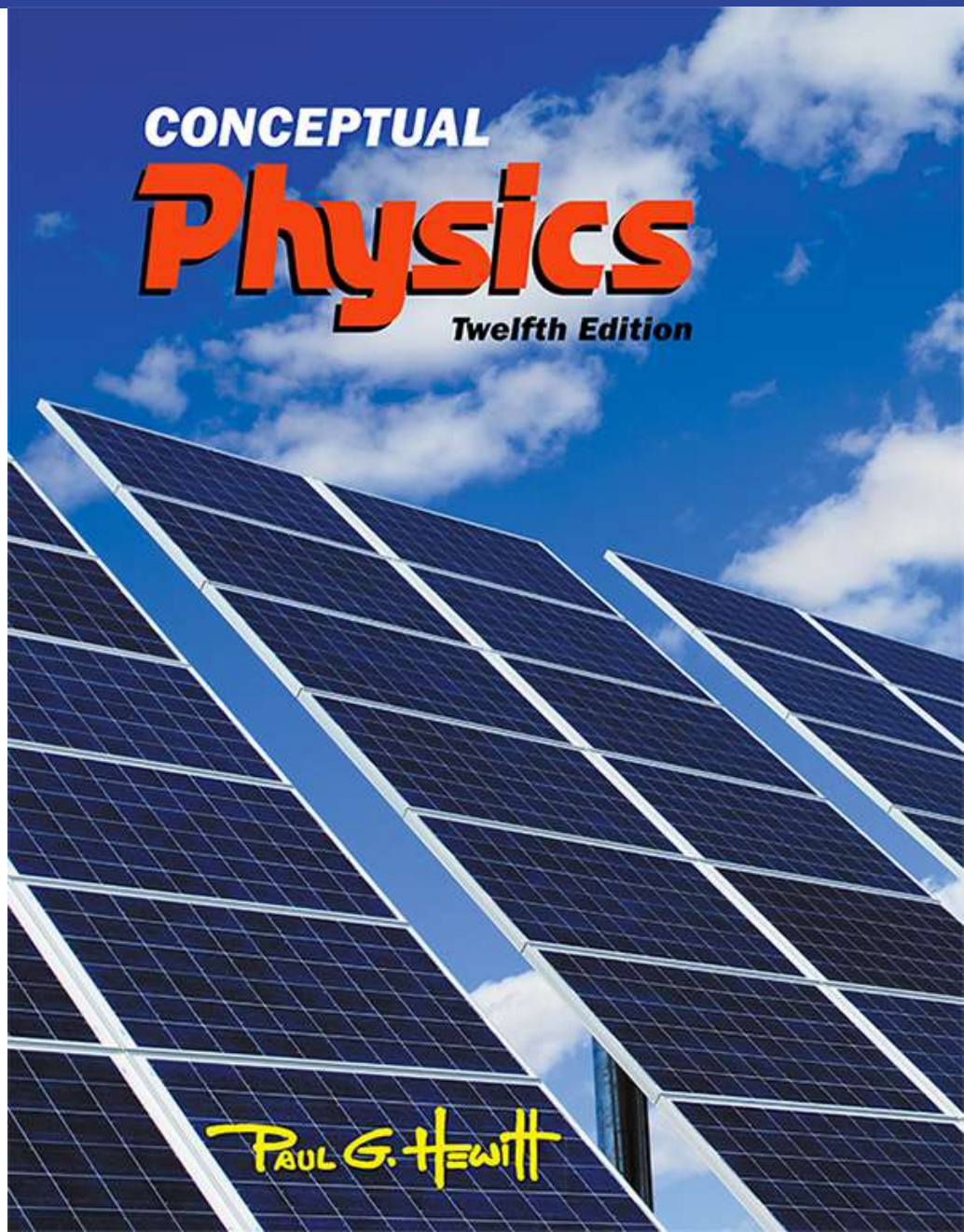
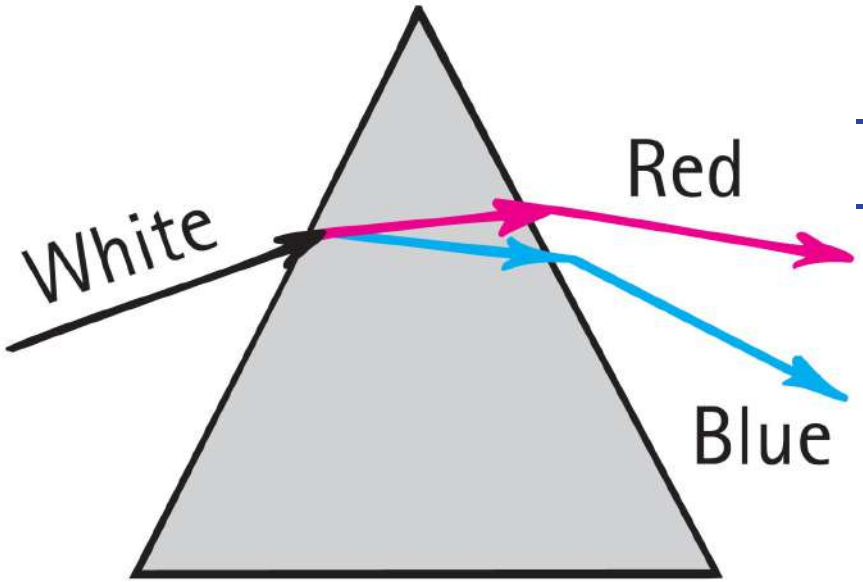
Lecture Outline

Chapter 28: Reflection and Refraction



- Dispersion
  - Process of separation of light into colors arranged by frequency



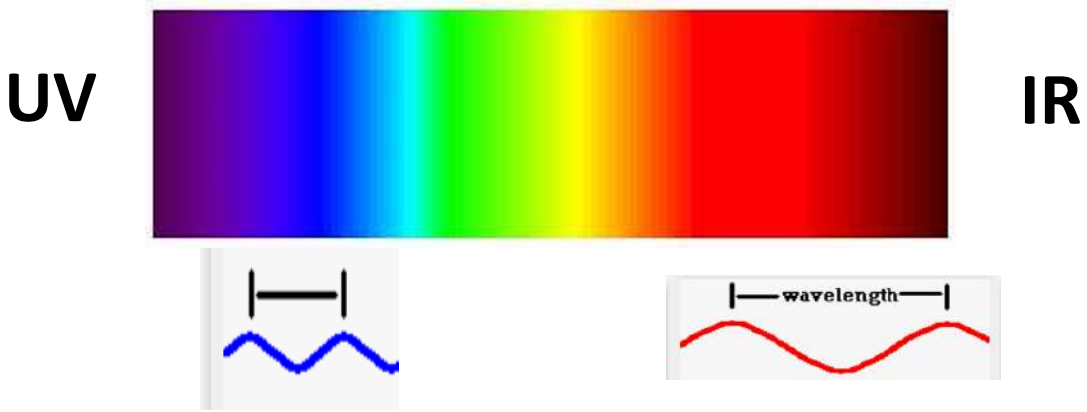
  - low frequency
  - longer wavelength
  - high frequency
  - short wavelength
  - Components of white light are dispersed (spread out) in a prism.

Why does dispersion occur?

UV light resonates the electrons in glass atoms.

So UV is absorbed by glass.

Violet and blue are closest visible colors to UV.



Violet and blue interact with glass atoms more often.

This slows them down more than the longer λ red.

Violet and blue slow down more than longer λ light.

So violet and blue refract (bend) more than red.

Classwork

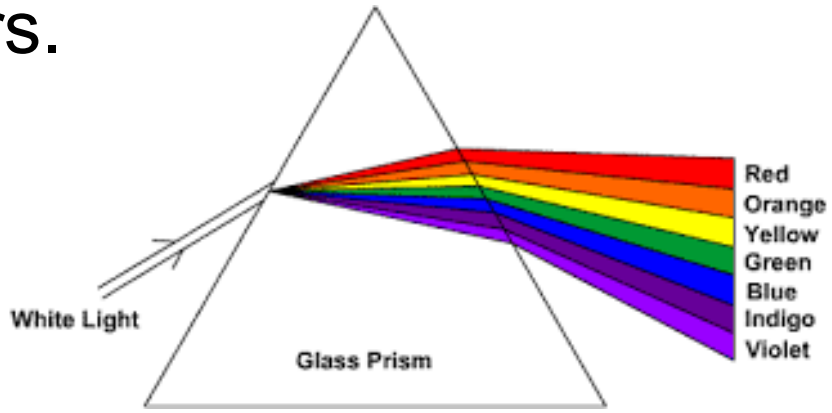
18. Which travels more slowly in glass: red light or violet light?

ROYGBIV again:

Red slows less → refracts less

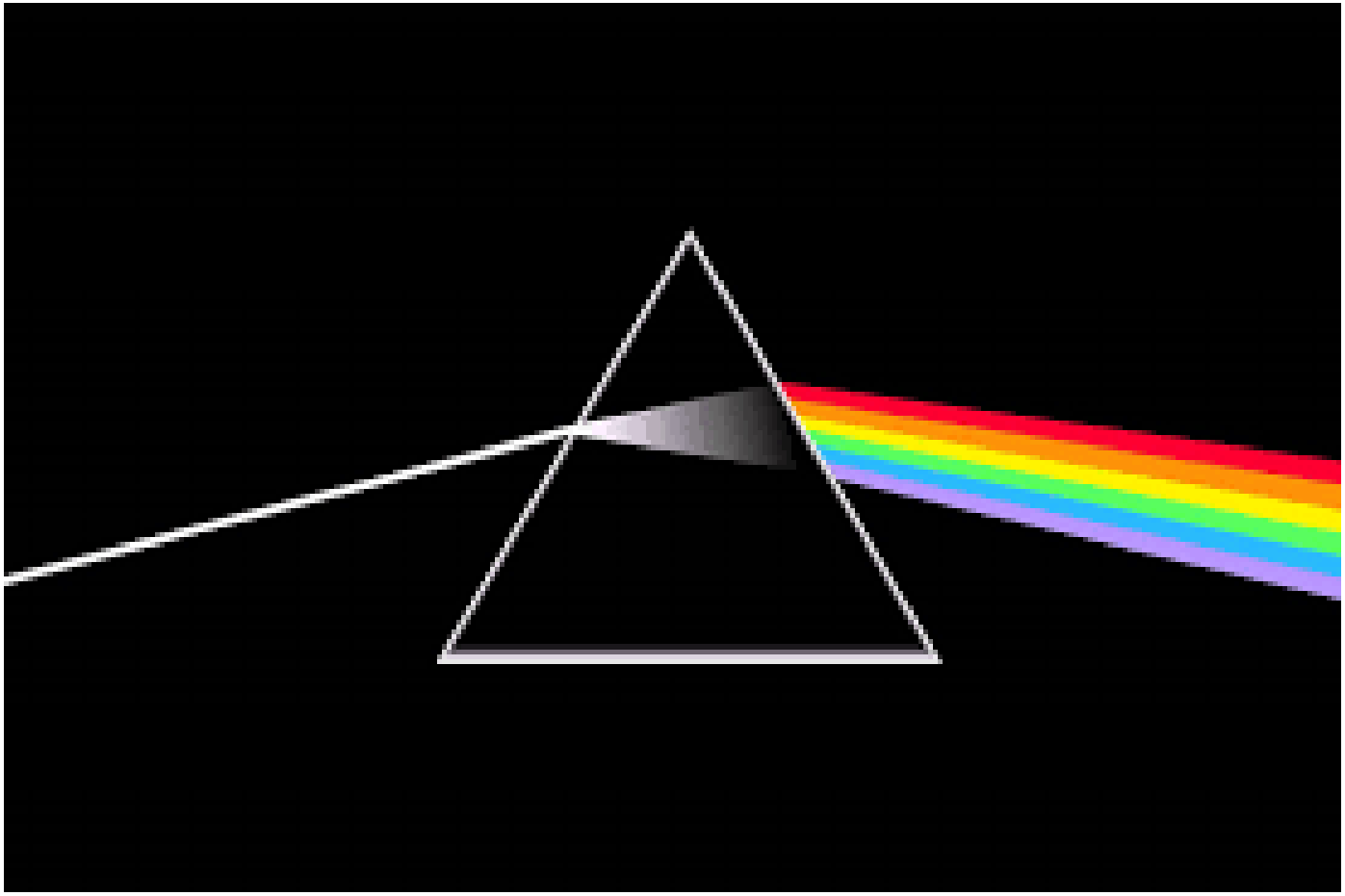
Violet slows more → refracts more

Refraction going into glass spreads the colors.



Refraction leaving the glass spreads them even more because sides of the prism are not parallel.

Famous album cover art stolen from physics!



Dispersion
CHECK YOUR NEIGHBOR

When white light passes through a prism, green light is bent more than

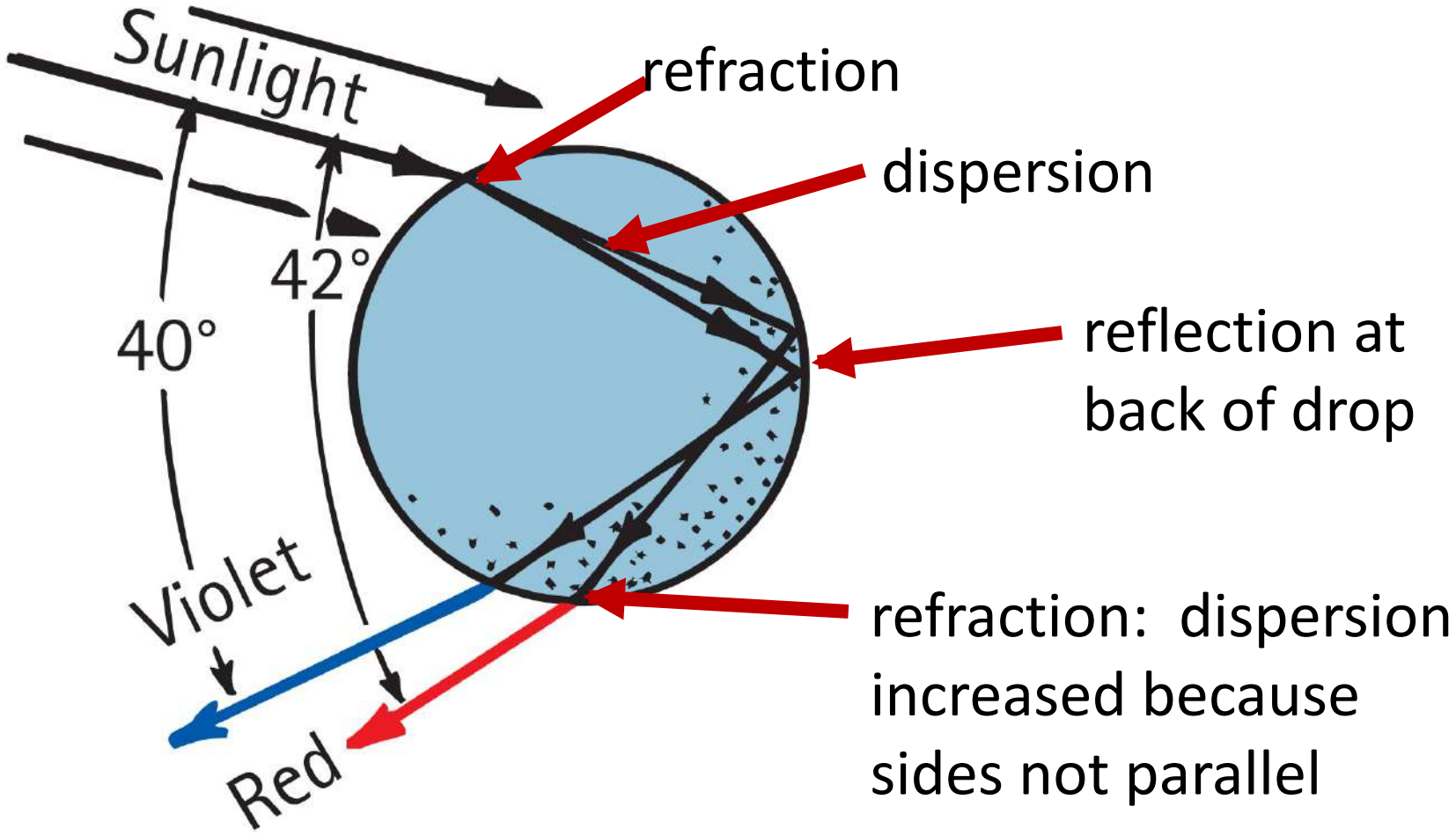
A. blue light.
B. violet light.
C. red light.
D. None of the above.

Dispersion
CHECK YOUR ANSWER

When white light passes through a prism, green light is bent more than

C. red light.

- Rainbows are a result of dispersion by many drops.
- A single drop disperses the spectrum of colors:



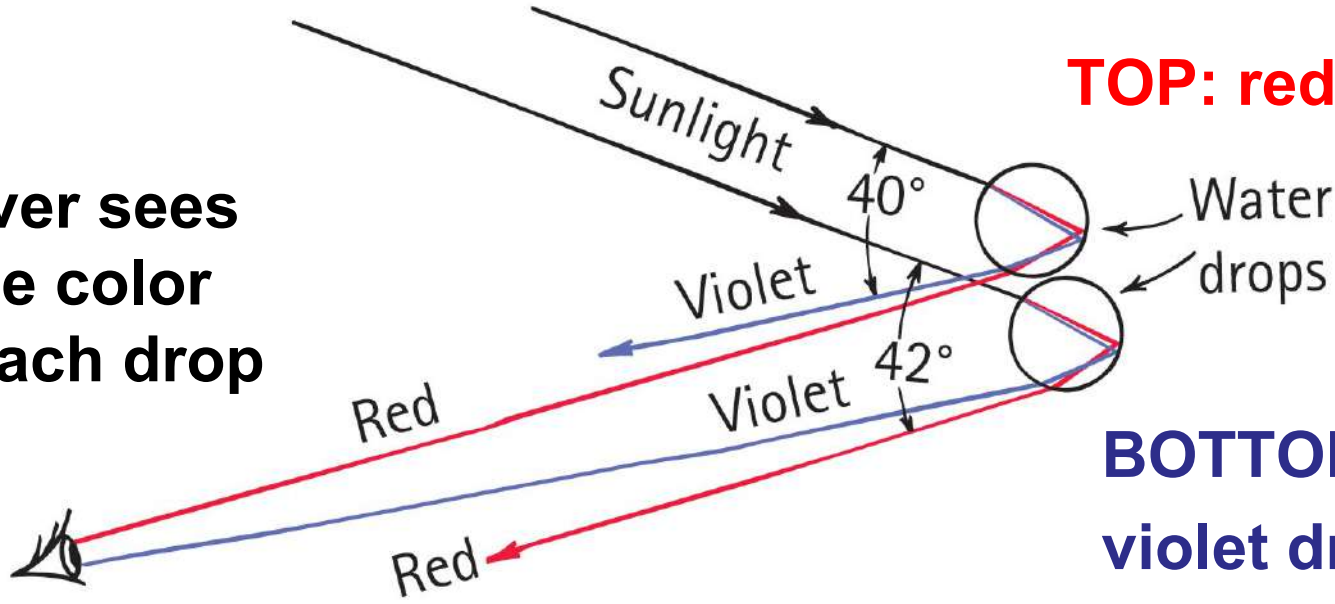
Classwork

19. Does a single raindrop illuminated by sunlight deflect light of a single color, or does it disperse a spectrum of colors?

A color from each rain drop:

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

Observer sees a single color from each drop



TOP: red drop

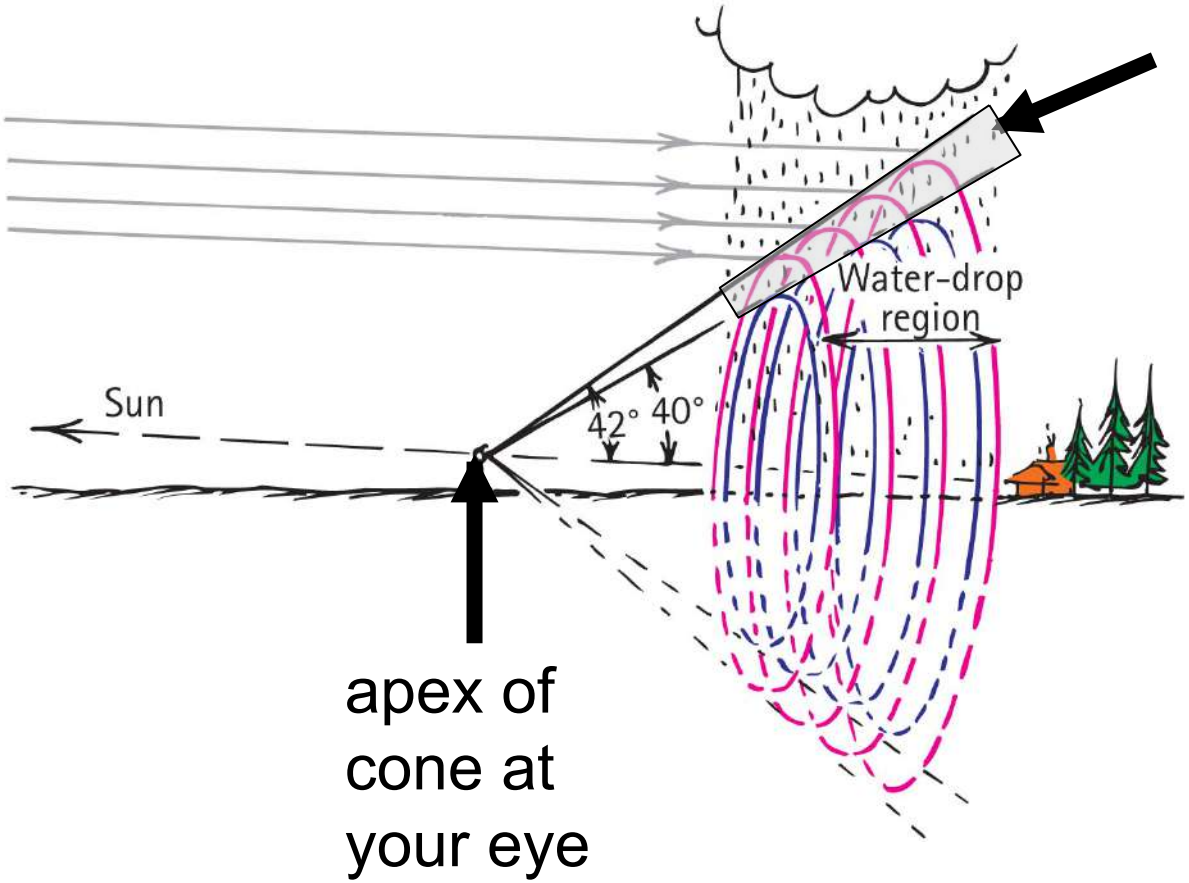
BOTTOM: violet drop

Classwork

20. Does a viewer see a single color or a spectrum of colors coming from a single faraway drop?

Red is along the outer arc:

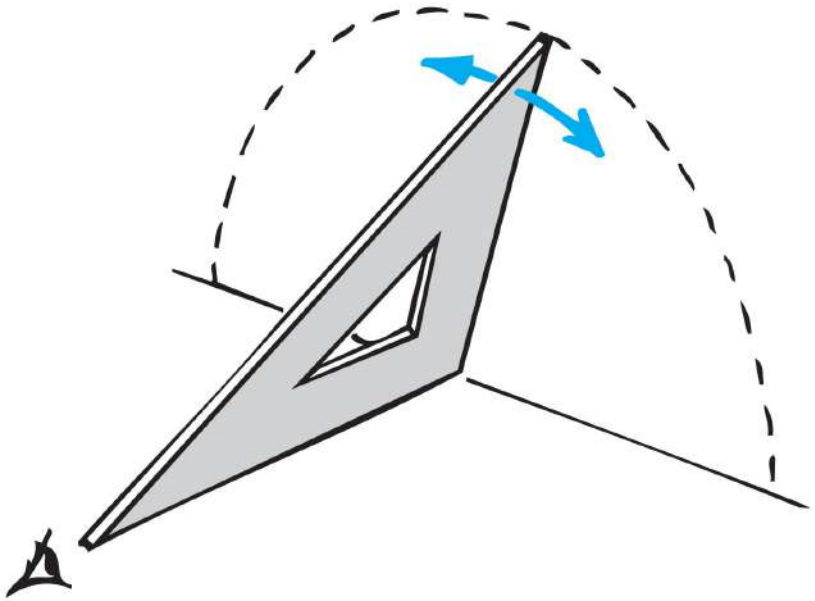
- When your eye is located between the Sun (not shown off to the left) and a water drop region, the rainbow you see is the edge of a three-dimensional cone that extends through the water drop region.



The thicker the region containing water drops, the thicker the conical edge you look through, and the more vivid the rainbow.

The cone has different layers with drops that disperse red to your eye on the outside, orange beneath the red, yellow beneath the orange, and so on, all the way to violet on the inner conical surface.

Only raindrops along the dashed line disperse red light to the observer at an angle; hence, the light forms a bow.



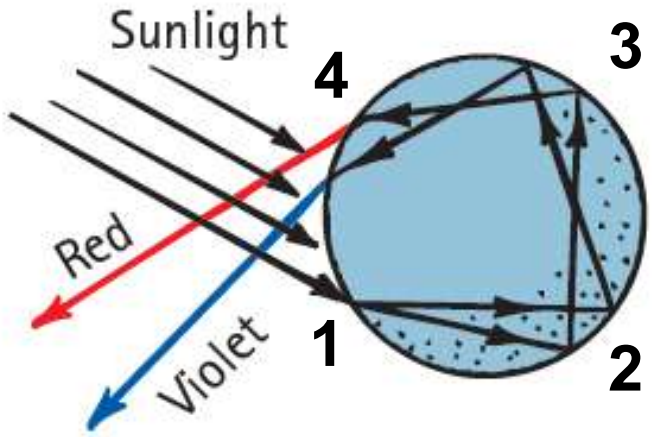
- Rainbow facts
  - An observer is in a position to see only a single color from any one droplet of water.
  - Your rainbow is slightly different from the rainbow seen by others.
  - Your rainbow moves with you. You cannot reach it, or see it from the side…

  - Disk within the bow is brighter because of overlapping of multiple refractions (which don't occur outside the disk).

- **Double Rainbows**

  Secondary rainbow is fainter due to two internal reflections and refracted light loss.

  → See path 1-4 at right:



Bow is reversed in color (due to extra internal reflection).

Classwork

21. Why is a secondary rainbow dimmer than a primary bow?

Double rainbow

Rainbows
CHECK YOUR NEIGHBOR

Compared with the primary rainbow, the secondary bow

A. is dimmer.
B. has colors reversed.
C. is caused by two internal reflections.
D. All of the above.

Rainbows
CHECK YOUR ANSWER

Compared with the primary rainbow, the secondary bow

D. All of the above.

From an airplane…

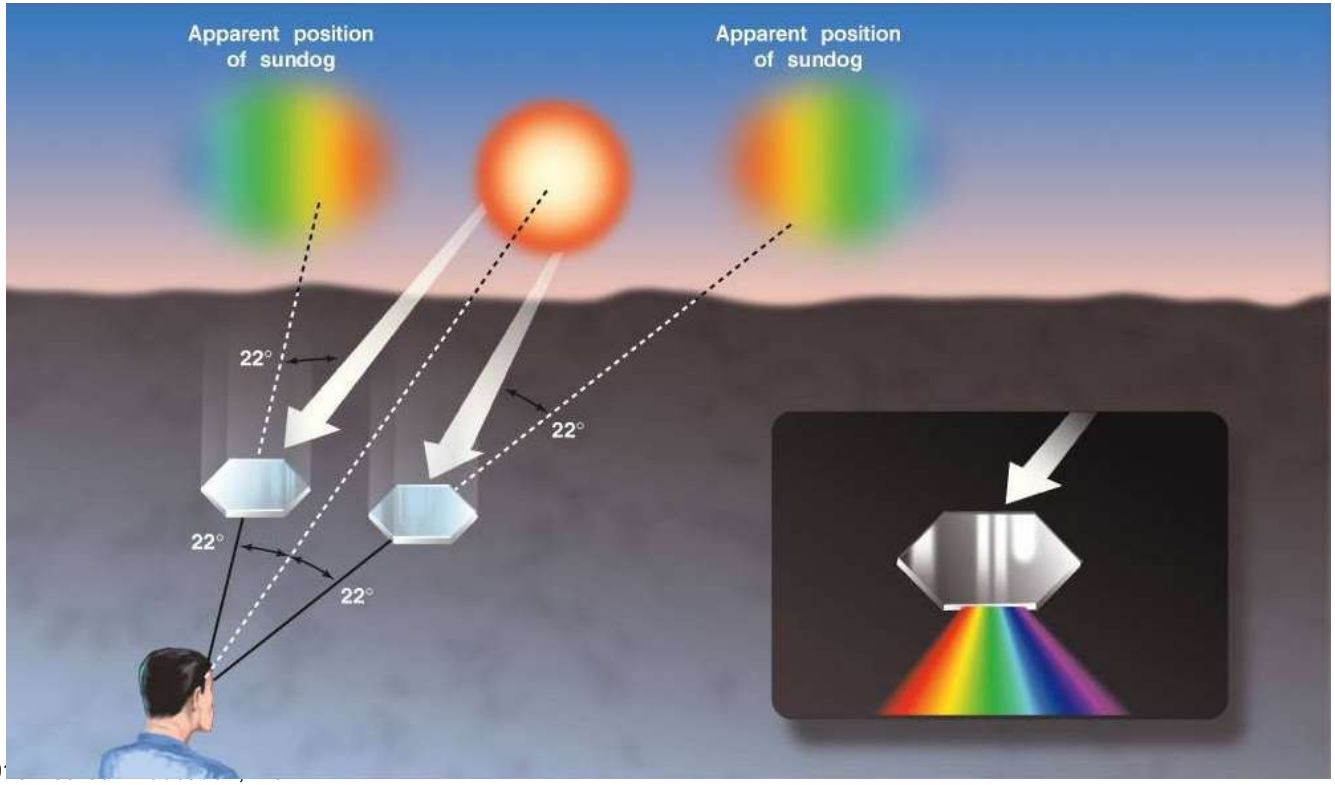
…you can see the entire arc:

Shadow of plane is in center.

Red is still on the outside of arc.

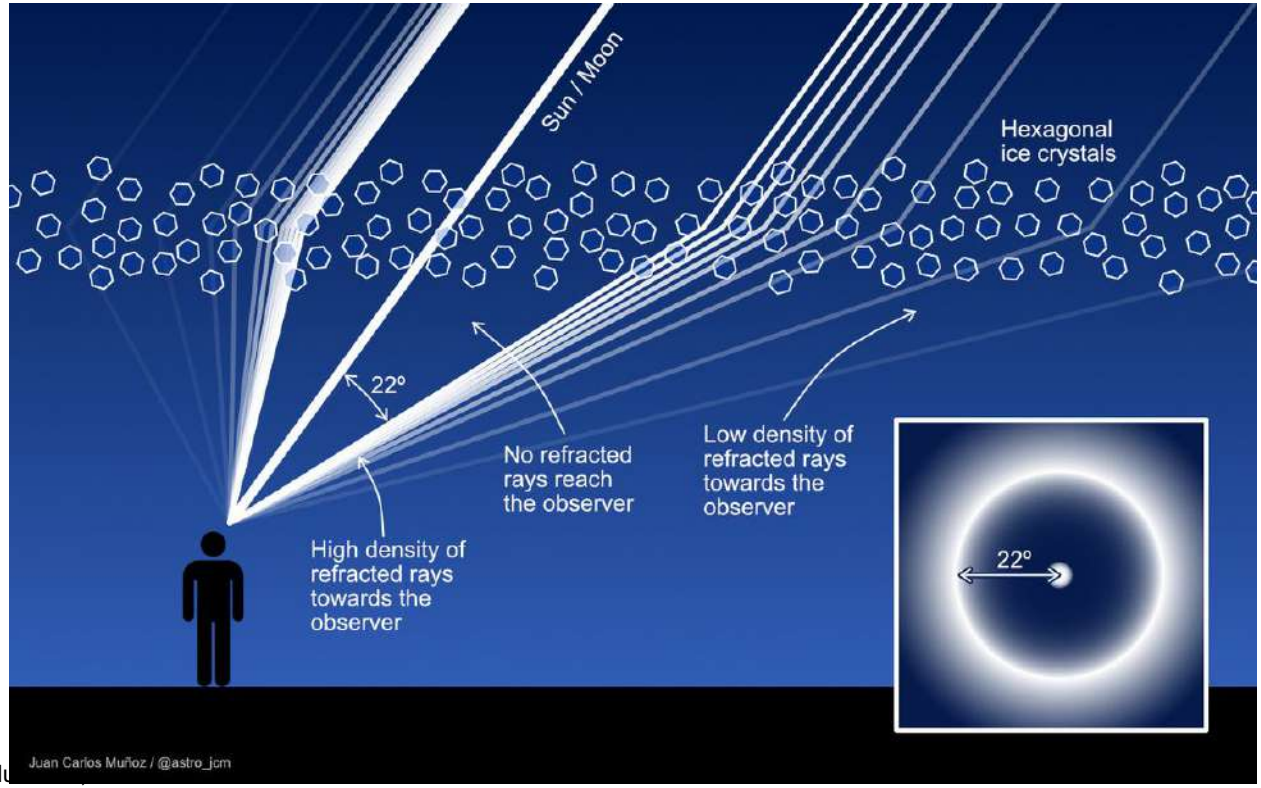
Sundogs

Caused by refraction and scattering of light from ice crystals



Moon halos

Caused by refraction and scattering of light from ice crystals

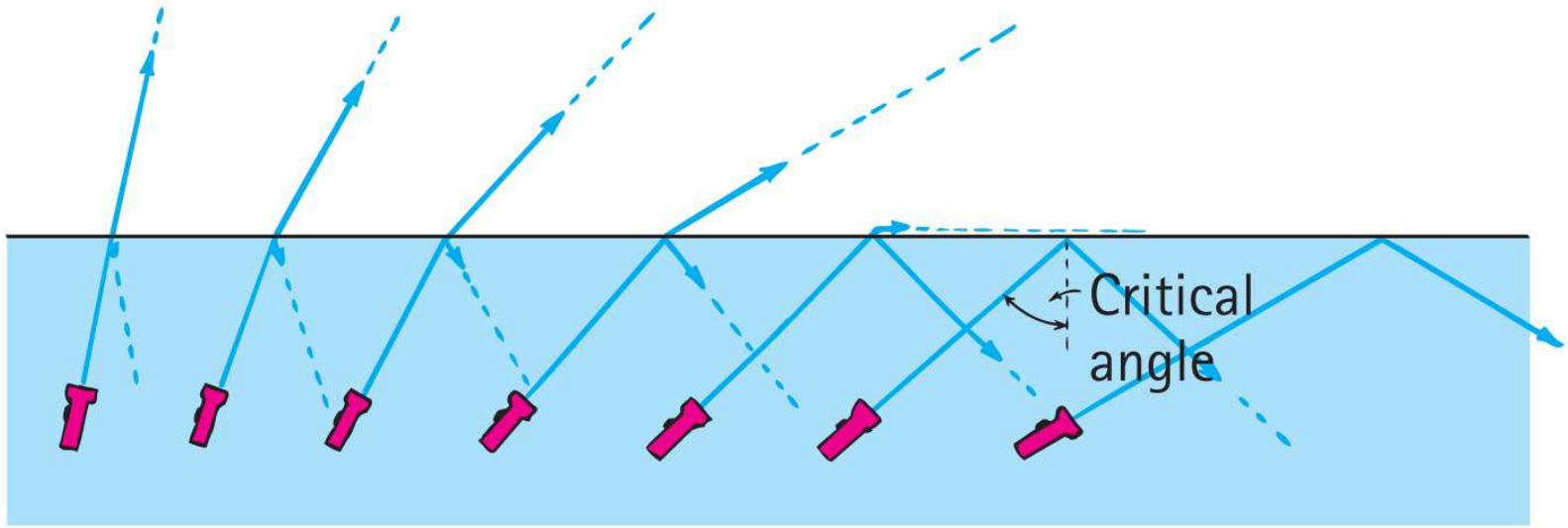


- **Total internal reflection**
  - Total reflection of light traveling in one medium strikes the boundary of another medium and is totally reflected back in (no refraction out).

  Can only happen when light travels from a slower medium into a faster one.

air = fast

water = slow



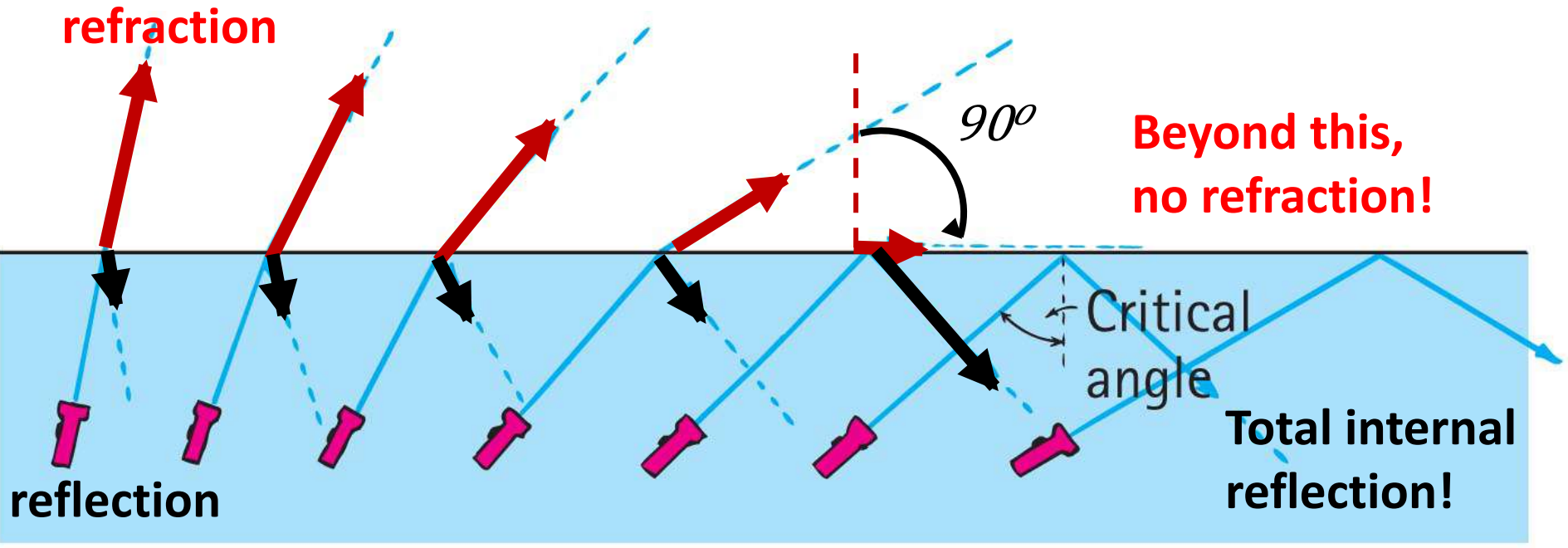
As angle of incidence in water increases….

….angle of refraction increases,

…amount of refracted light (red arrow) decreases,

…amount of reflected light (black arrow) increases.

When angle of refraction = 90°, the angle of incidence is called the *critical angle.*



Classwork

22. What is meant by "critical angle"?

Fish eyes:

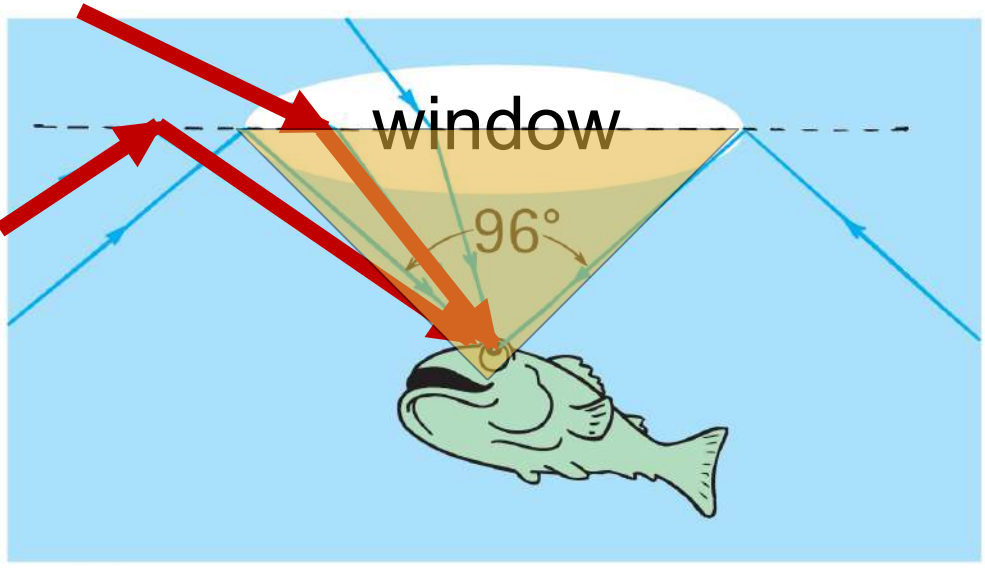
Critical angle for water = 48°

All light incident at > 48° is reflected back.

→ A cone of 2 x 48° = 96° where light gets in or out.

Light from above from horizon to horizon (180°) is compressed into a "window."

→ Fish eye lens



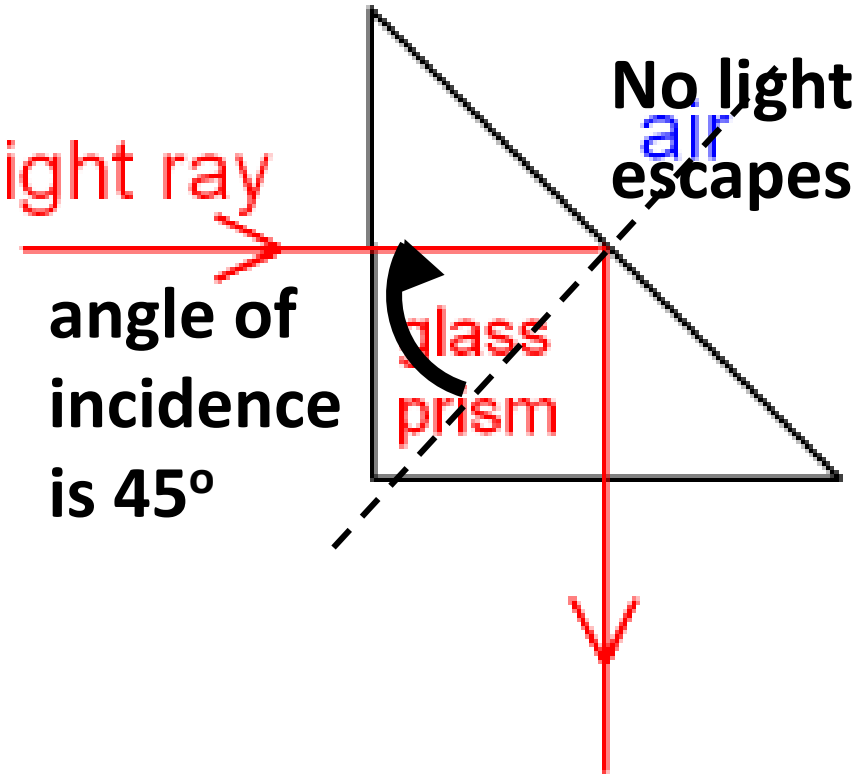
Snell's window:

Glass

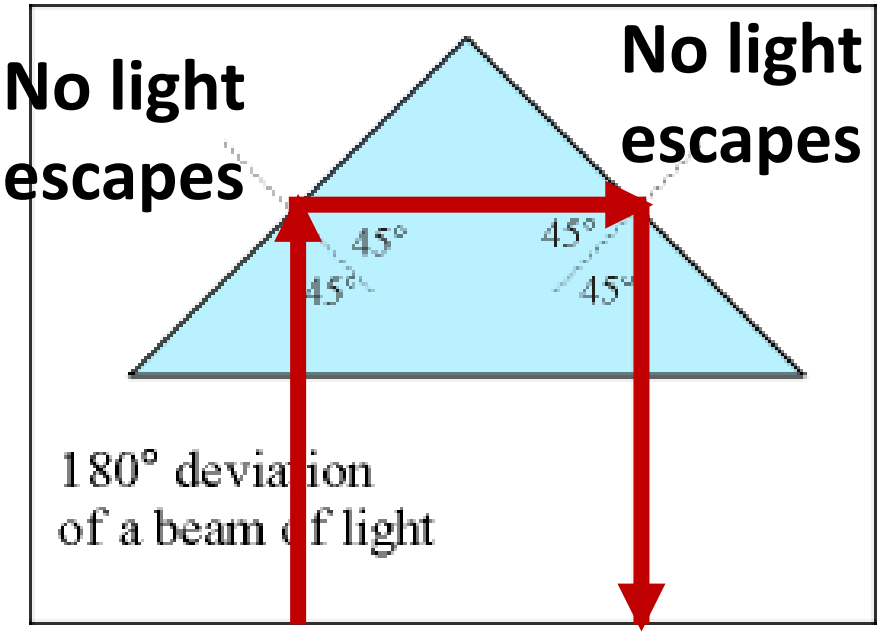
In glass, the critical angle is 43°.

Light incident at > 43° is totally internally reflected.

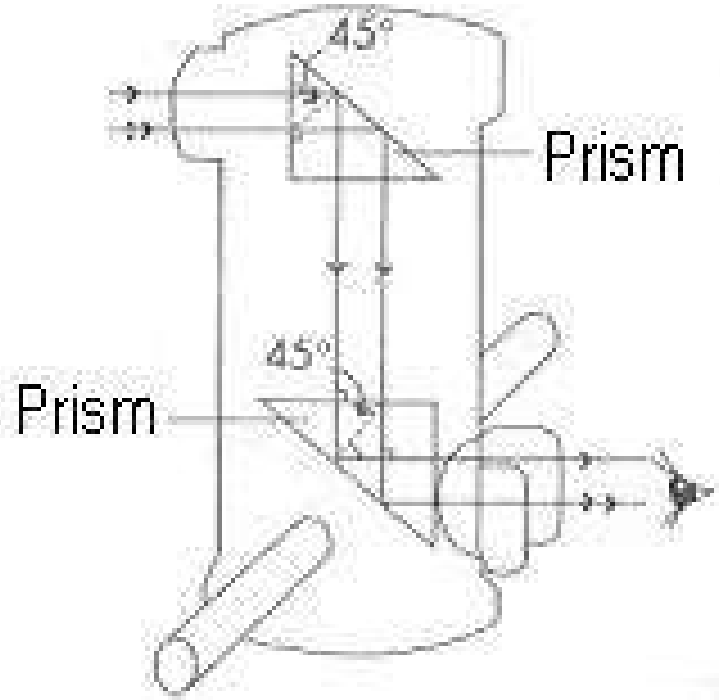
100% reflection is better than the best mirror!

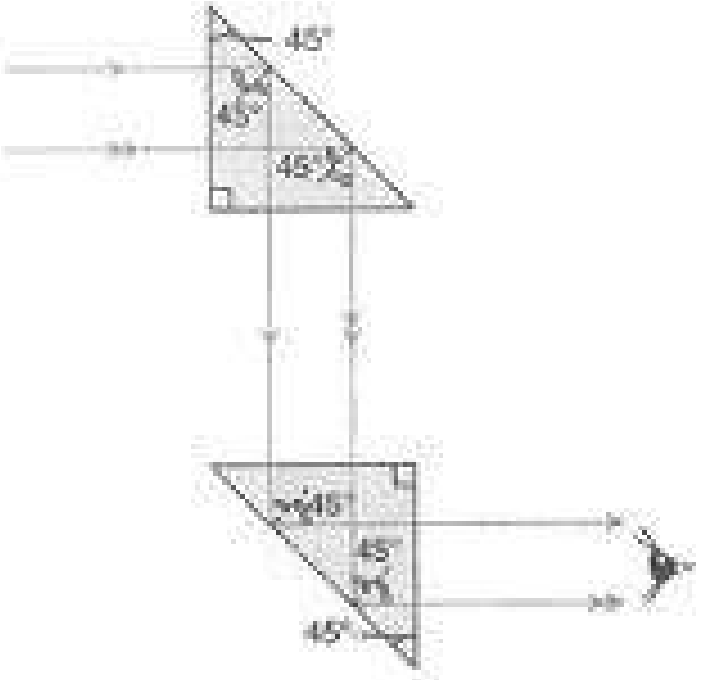


Another example:



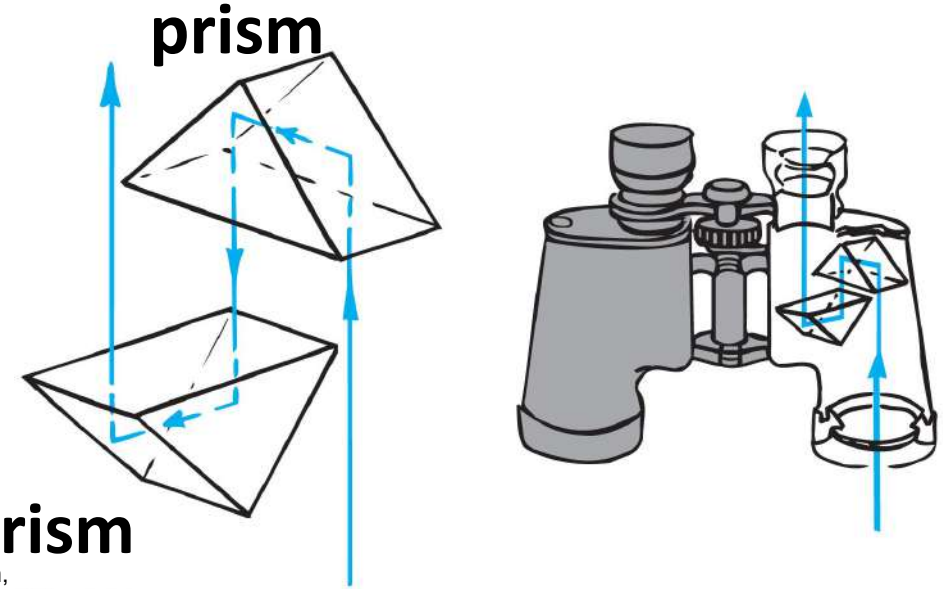
Periscopes use prisms:





Binoculars use prisms:

- Advantages of glass prisms
  - Internally reflect 100%, which is the principal reason for use in many optical instruments
  - Lengthen the light path between lenses, thus eliminating the need for long barrels in binoculars
  - Reflection by prisms reinverts the image in binoculars



Diamonds:

Critical angle = 24.5^{o}

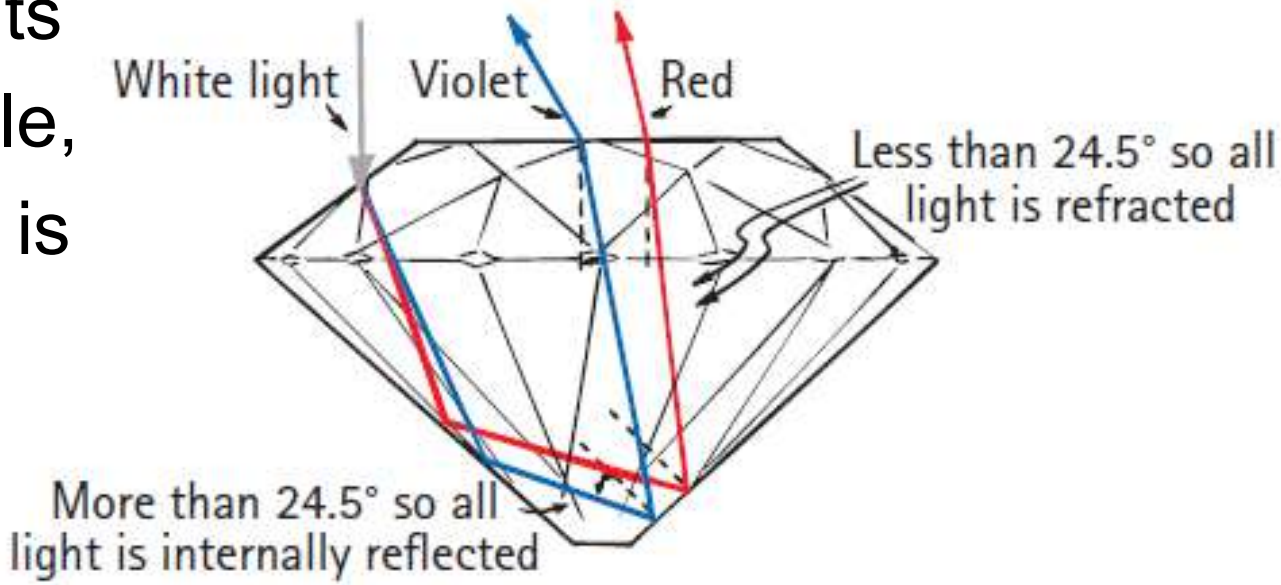
Smaller angle than any other “common” substance

Light is relatively slow in diamond, so…

…there is much refraction and dispersion, and…

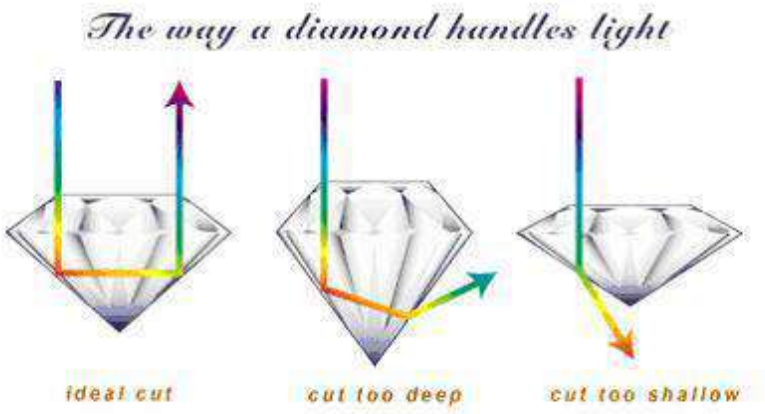
…this occurs as light enters and exits the diamond…

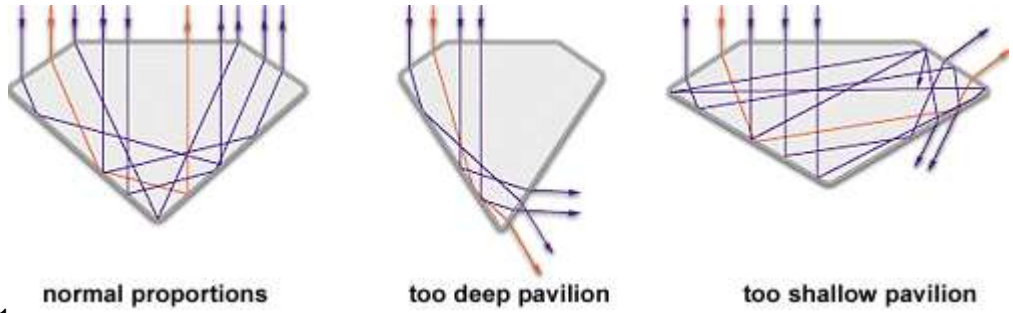
And because of its small critical angle, much of the light is reflected back, so it sparkles!



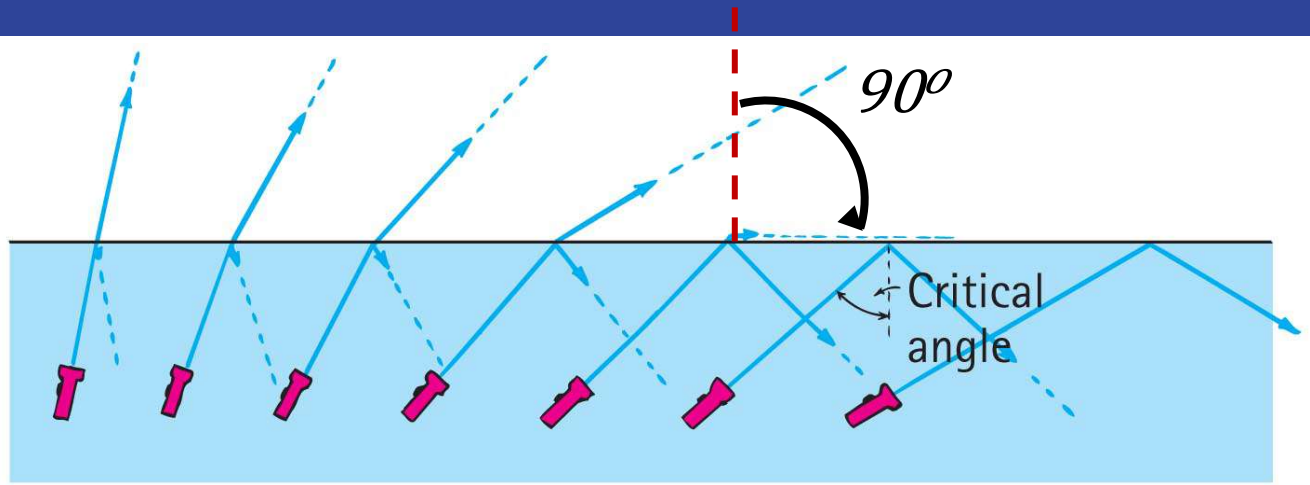
The 4 C's of diamonds:

The "cut" enhances total internal reflection to give diamonds "fire."





Why do critical angles differ?



The more light refracts, …
…the more easily it will reach a refraction of 90^0
…the smaller the critical angle.

→ High refractive index n means smaller critical angle:

material:	**n**	**critical angle**
water	1.33	48°
glass	1.5	43°
diamond	2.42	24.5°

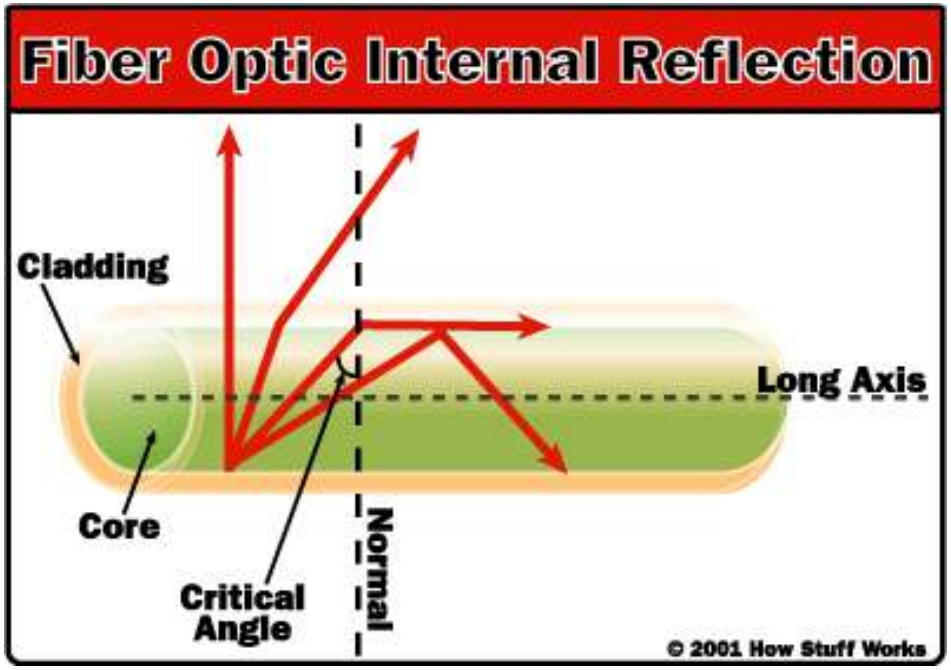
Classwork

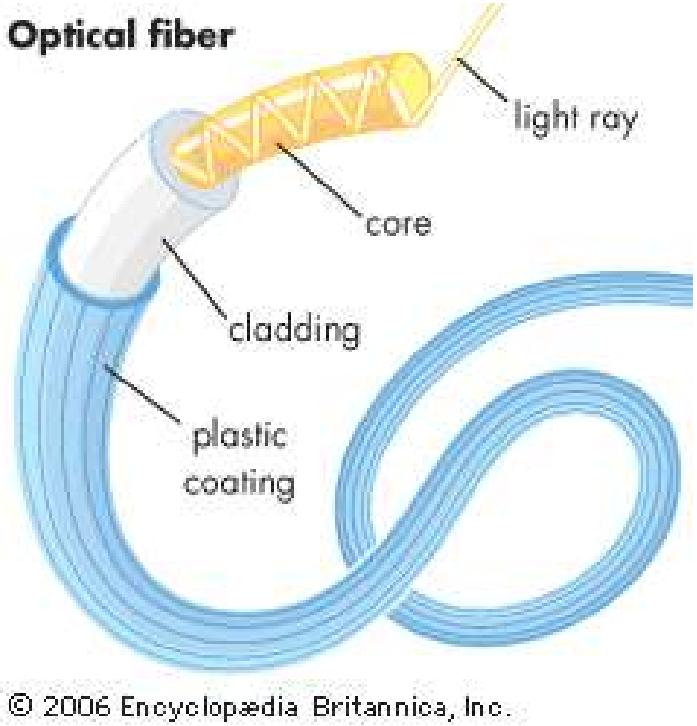
23. At what angle inside glass is light totally internally reflected? At what angle inside a diamond is light totally internally reflected?

Optical fibers or light pipes

Thin, flexible rods of special glass or transparent plastic.

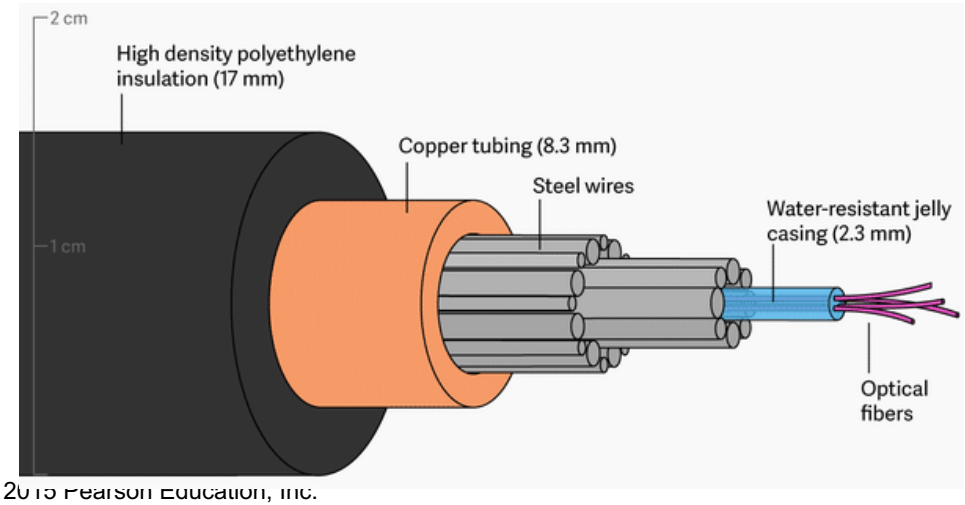
Light from one end of the fiber is total internally reflected to the other end, resulting in nearly the same brightness of light.

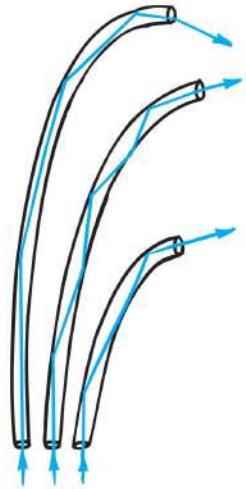


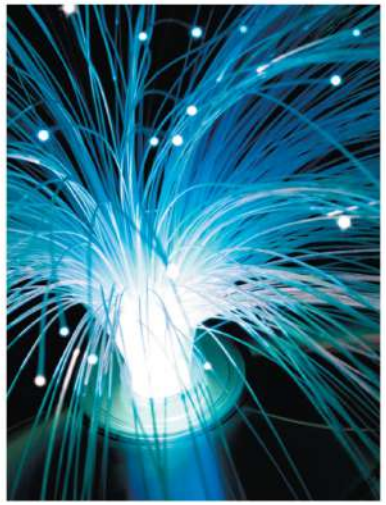


Optical Fibers are used in:

- illuminating instrument displays
- concentrating light in dental procedures
- viewing of inaccessible regions of organs and other devices
- *Communications:*
- Light has a very high frequency → more info than electricity
- No sparking, so less explosion
- Less loss of information, less electrical interference, etc







Classwork

24. Light normally travels in straight lines, but it "bends" in an optical fiber. Explain.