Physics 294H

- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **Help-room hours: 12:40-2:40 Monday (note change); 3:00-4:00 PM Friday**
  - **36.73 hand-in problem for next Wed**
- Quizzes by iclicker (sometimes hand-written)
- Average on 2nd exam (so far)=71/120
- **Final exam Thursday May 5 10:00 AM – 12:00 PM 1420 BPS**
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

Index of refraction

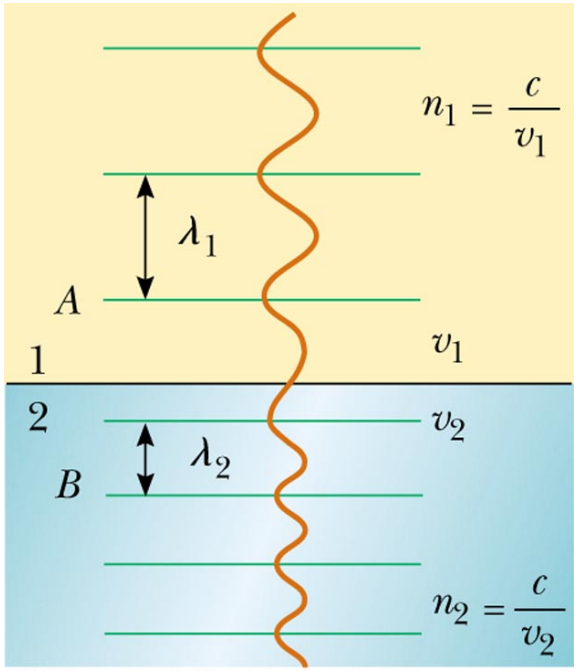
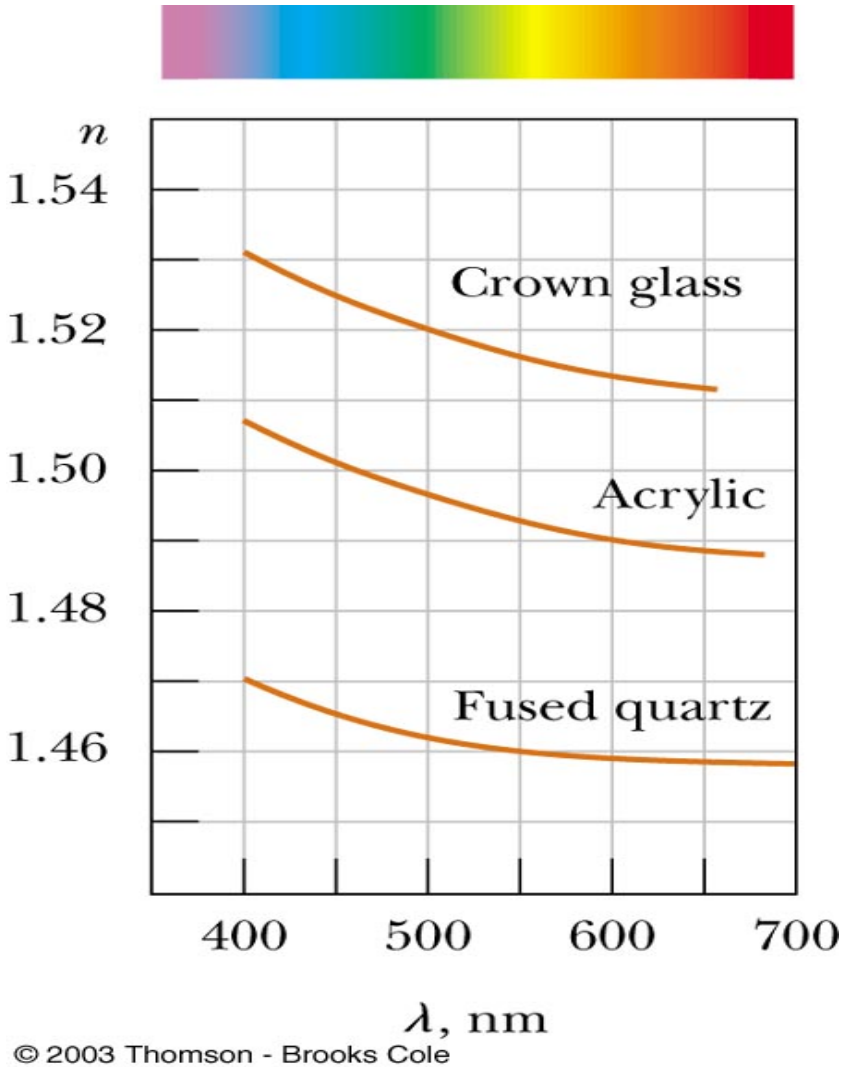


TABLE 22.1 **Indices of Refraction for Various Substances, Measured with Light of Vacuum Wavelength $\lambda_0 = 589$ nm**

Substance	Index of Refraction	Substance	Index of Refraction
Solids at 20°C		**Liquids at 20°C**	
Diamond (C)	2.419	Benzene	1.501
Fluorite (CaF_2)	1.434	Carbon disulfide	1.628
Fused quartz (SiO_2)	1.458	Carbon tetrachloride	1.461
Glass, crown	1.52	Ethyl alcohol	1.361
Glass, flint	1.66	Glycerine	1.473
Ice (H_2O) (at 0°C)	1.309	Water	1.333
Polystyrene	1.49		
Sodium chloride (NaCl)	1.544	**Gases at 0°C, 1 atm**	
Zircon	1.923	Air	1.000 293
		Carbon dioxide	1.000 45

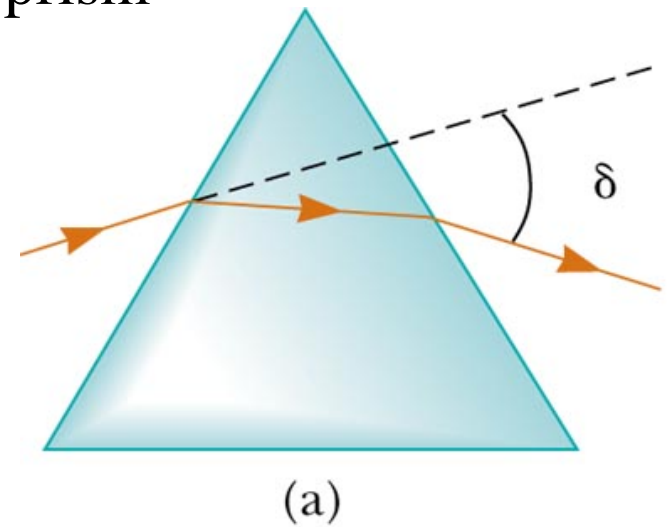
Dispersion

- The index of refraction depends on the wavelength of light
  - $n=f(\lambda)$
  - this means that the dielectric constant κ must also depend on wavelength
- This is called dispersion

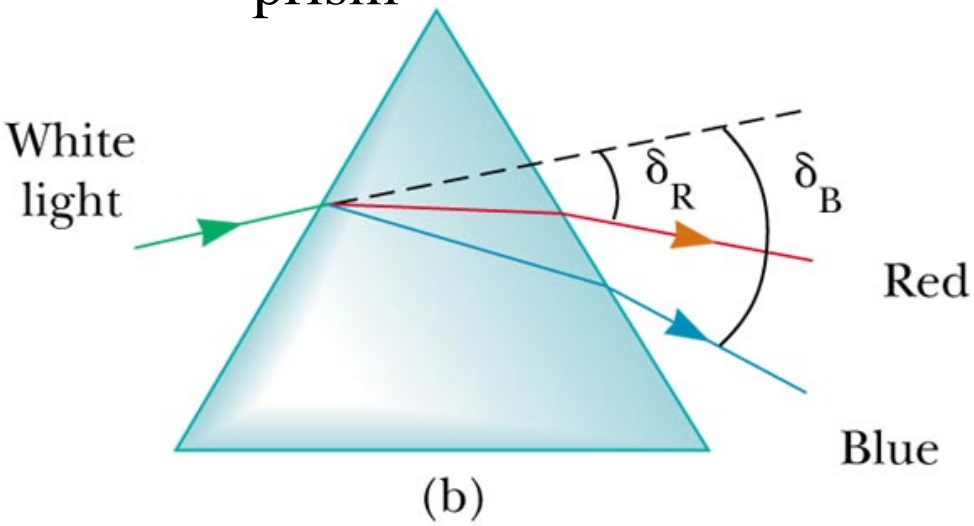


Consequences of dispersion

red light passing through a prism



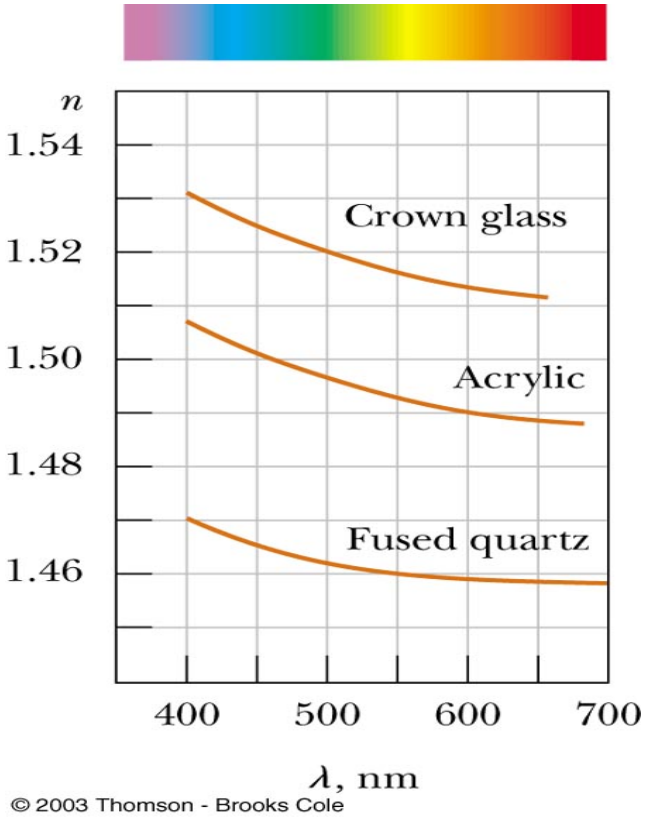
white light passing through a prism

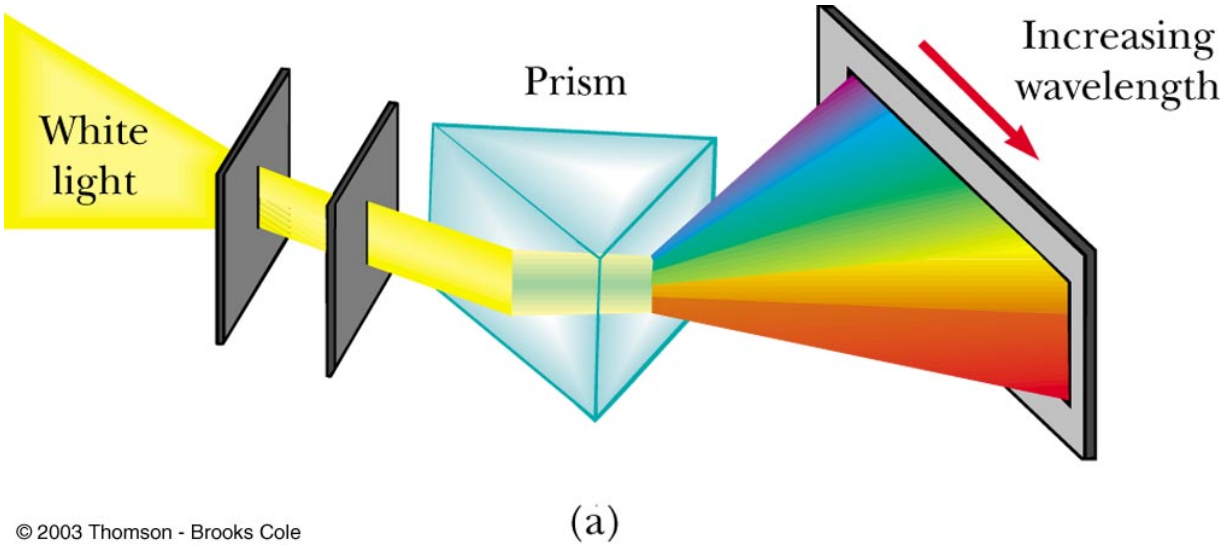


each wavelength has a different index of refraction and so refracts at a different angle

Dispersion

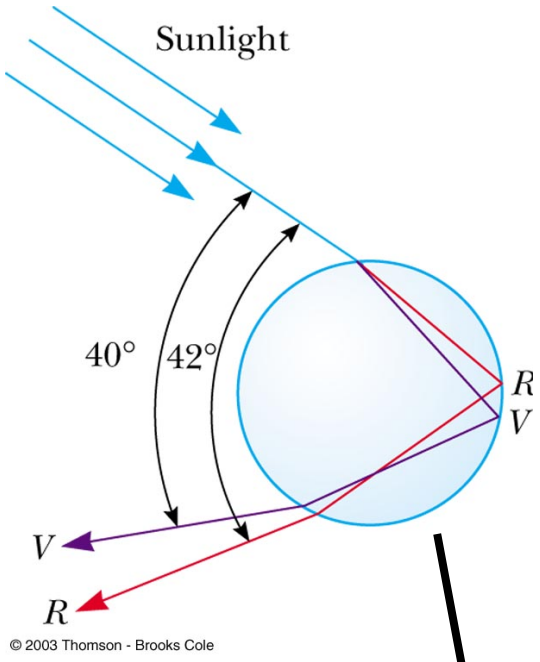
Index of refraction for blue light is larger than for red light, so blue light bends more than red light



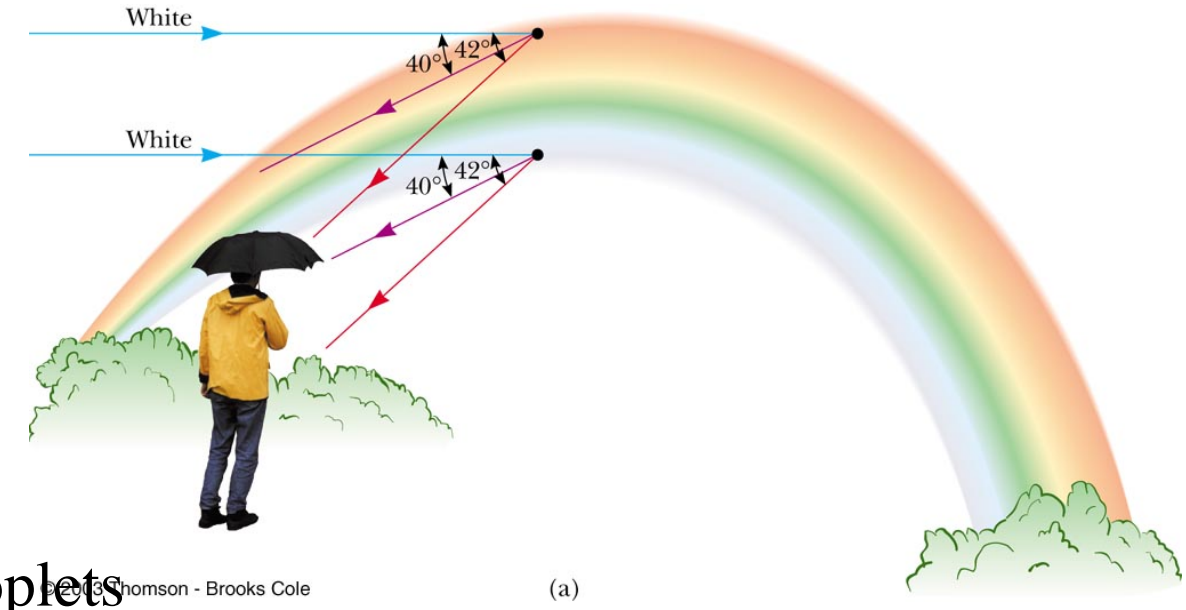


(a)

How rainbows form



red light from high in the sky reaches your eye; violet light from lower in the sky does the same

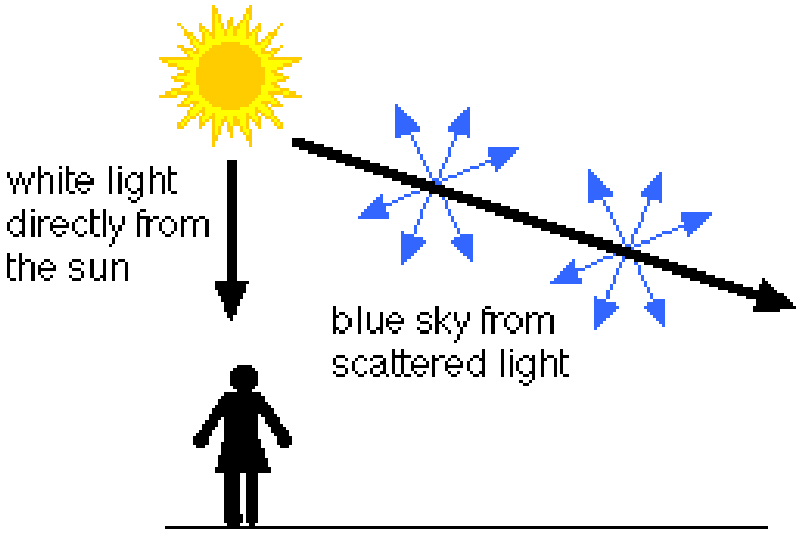


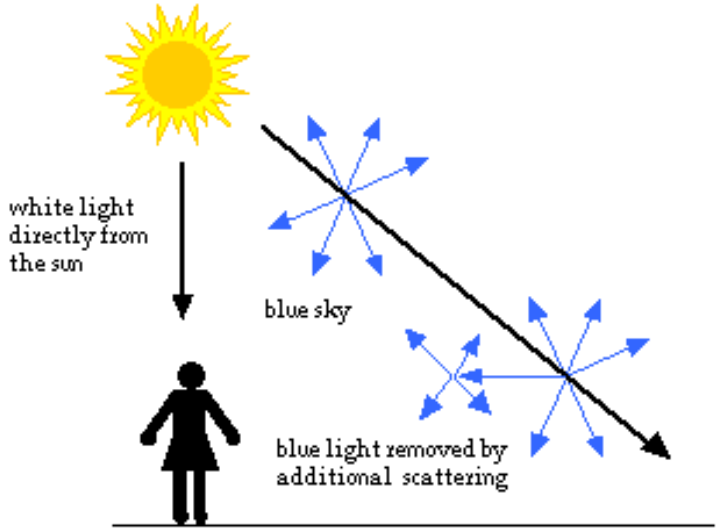
water droplets

Sometimes there can be a double rainbow, when there are two internal reflections, but the order of colors will be reversed.

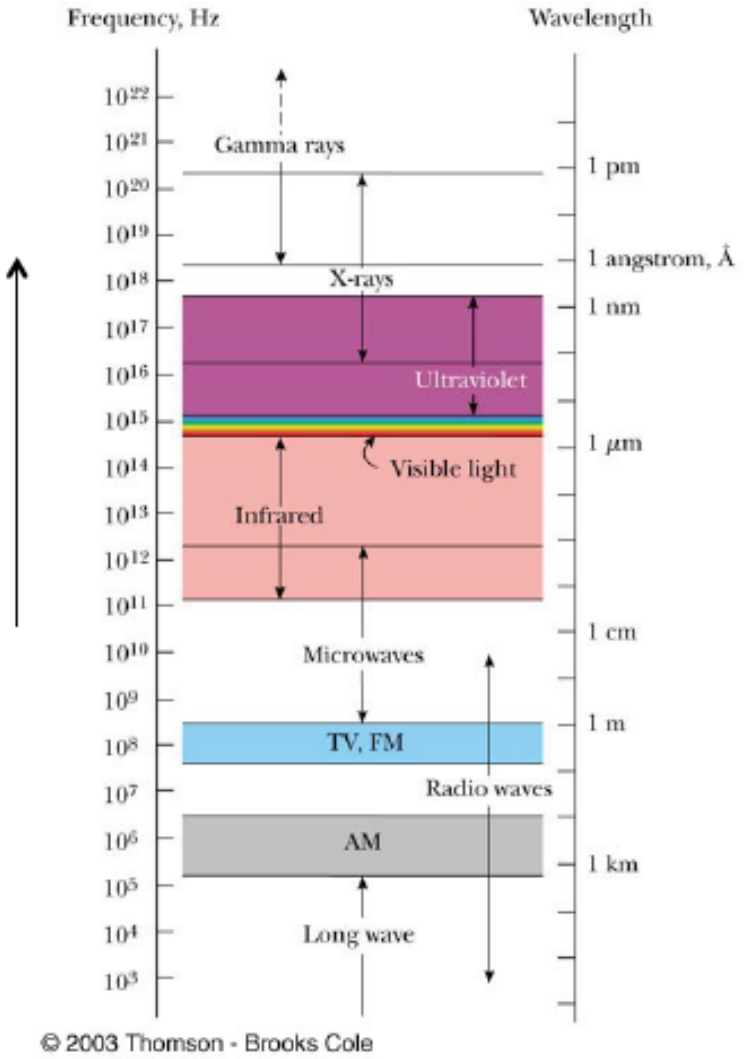
Why is the sky blue?

- Light from the Sun has all of the colors of the visible spectrum (but is peaked towards yellow)
- The cross section (probability) for scattering of light from air molecules goes as f^4 (frequency to the 4th power)
- So blue light is scattered preferentially and when you look away from the sun, all you see is the scattered blue component of sunlight
- The sky is paler towards the horizon



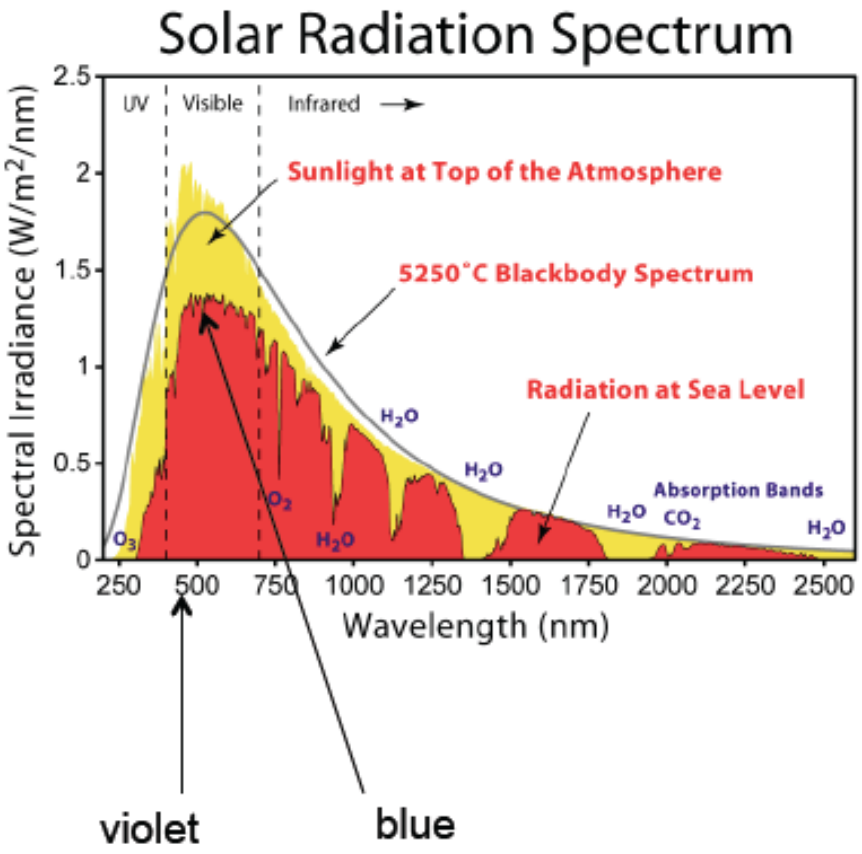


- Why is the sky not violet?
- Violet light has a higher frequency than blue light and so should be scattered even more than blue light

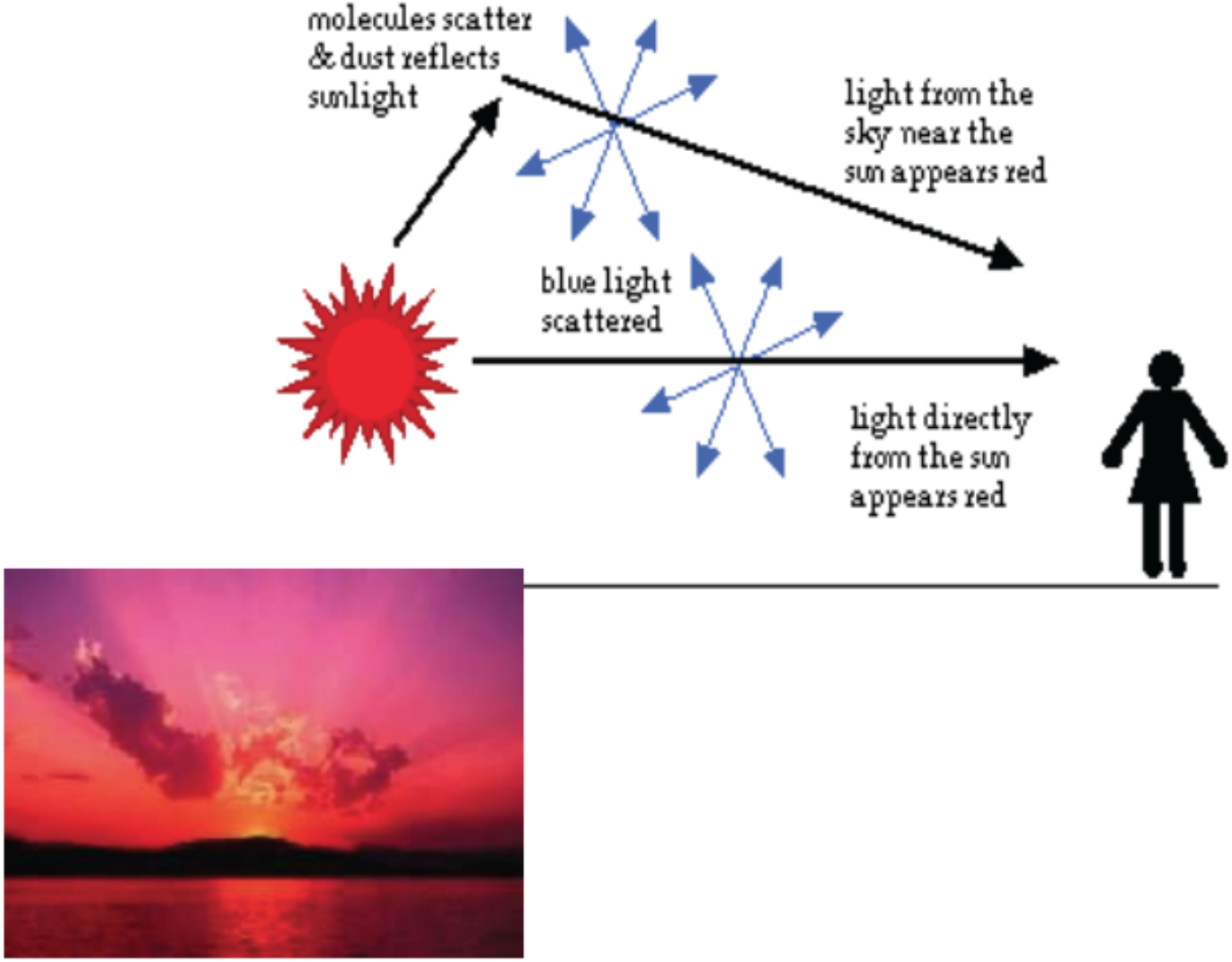


Answer

- The answer is somewhat involved
- First of all, there is less violet light in the output of the Sun than blue light
- Also, more of the violet light gets absorbed in the Earth's atmosphere
- And, our eyes are less sensitive to violet light than to blue light
- So the sky appears blue, and not violet, to us

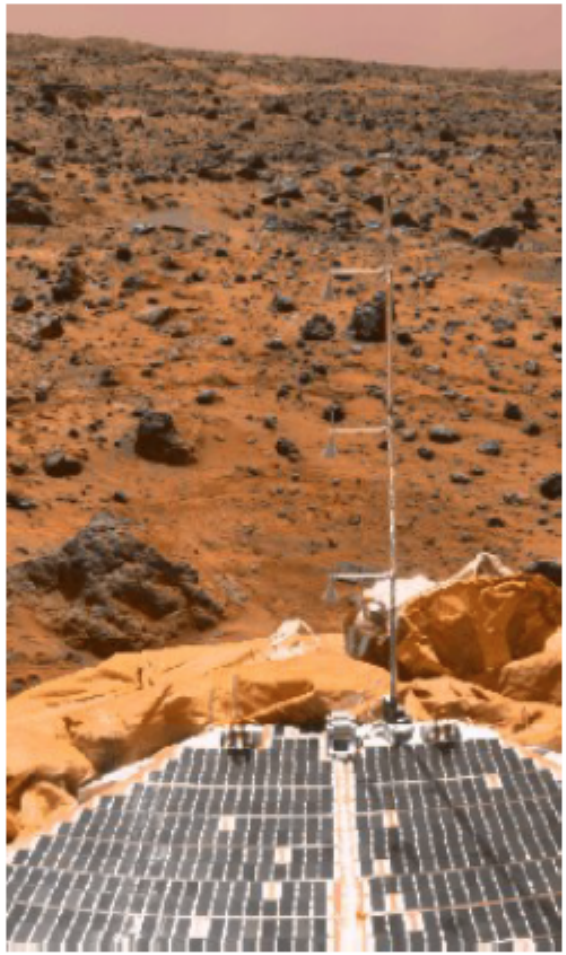


Why is the sunset red?



Sky on Mars

- Has a tan tint to it since there's usually a far amount of dust in the air, and the dust scatters the red light preferentially

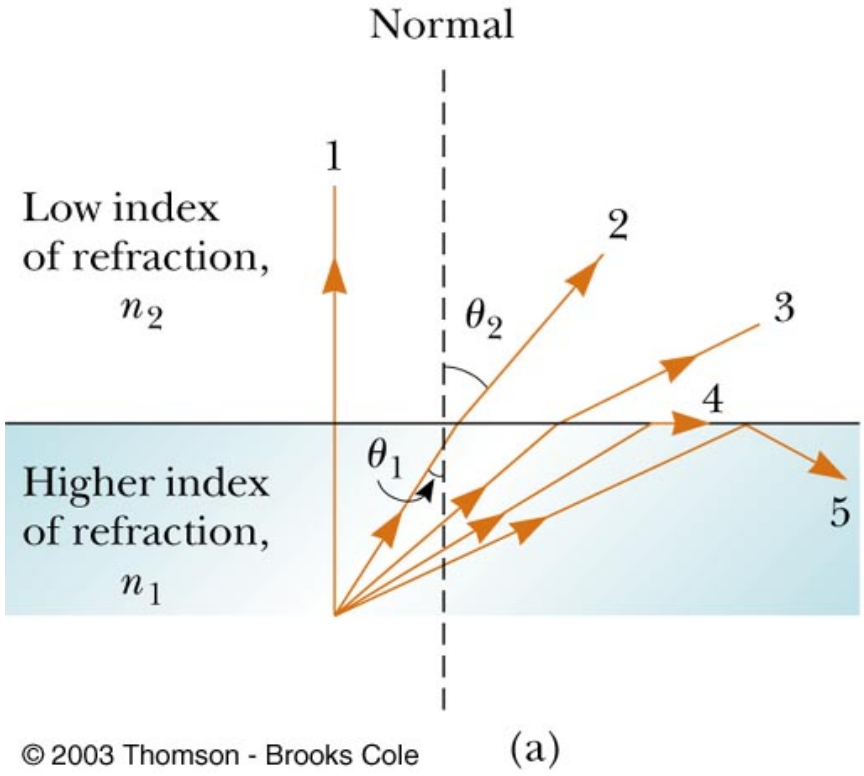


Why are clouds white?

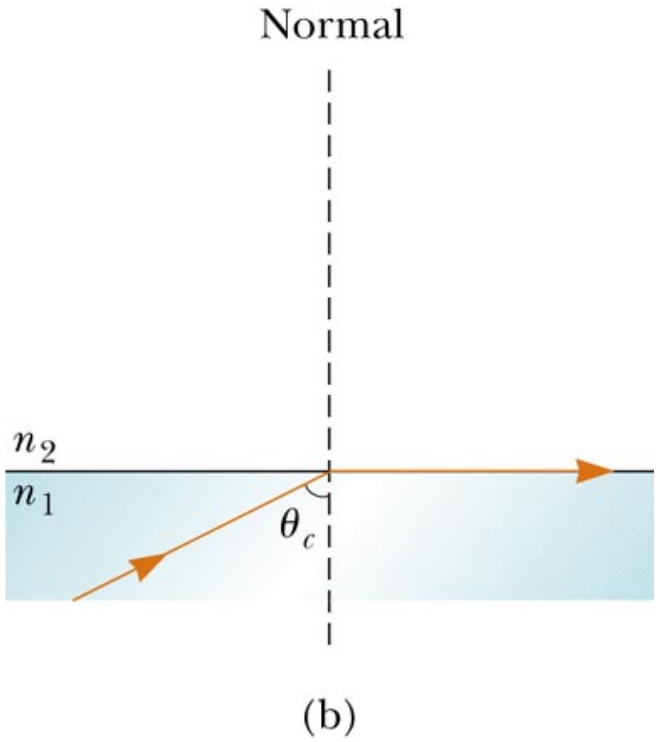
- Clouds are made up of clusters of water droplets of a variety of sizes
- Tiniest clusters tend to reflect blue light, slightly larger clusters, green light…and so on
- The overall result is a white cloud
- Larger clusters of light absorb much of the light that falls on them
- Therefore clouds with a lot of large clusters (i.e. rainclouds) appears to be a dark gray

Total internal reflection

When light travels from a medium with a larger index of refraction to a lower index of refraction, it bends out



(a)

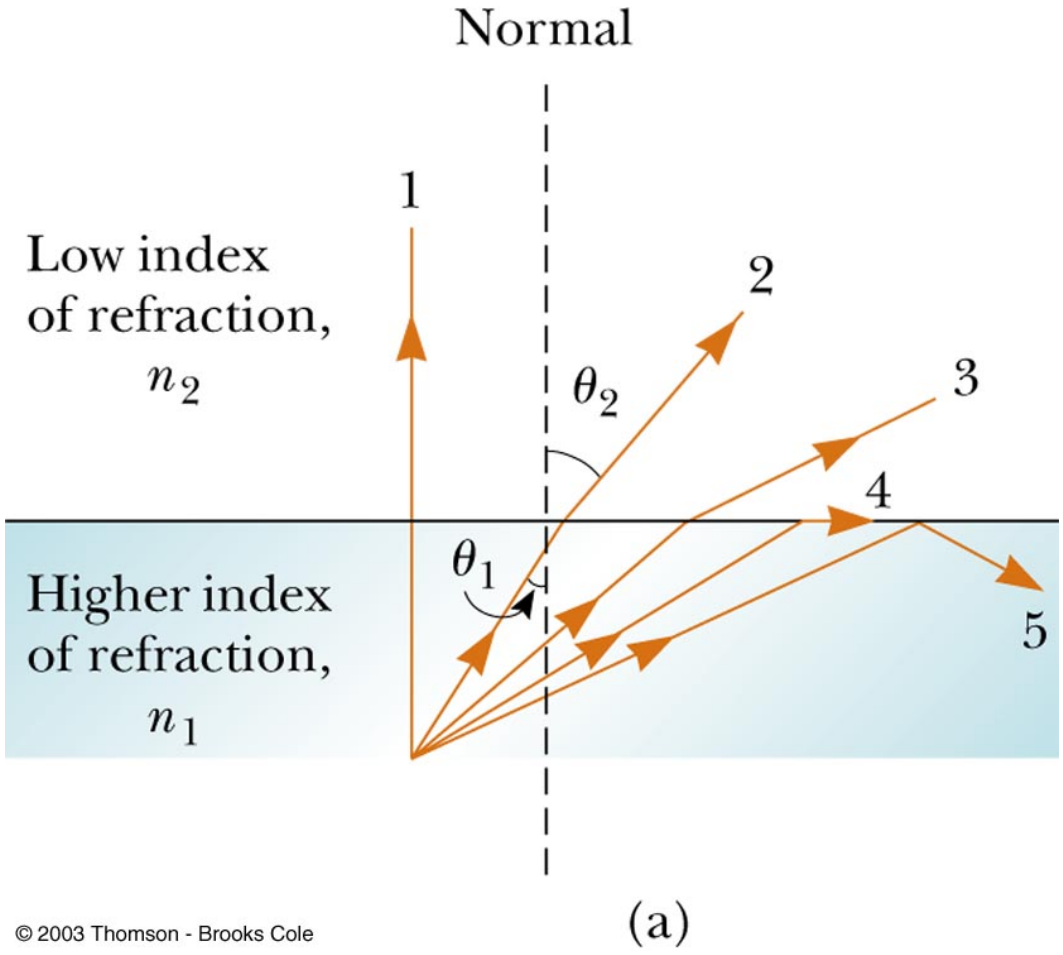


(b)

At some incident angle, the refracted angle is 90°; any angles greater than that and no light makes it into the refracted medium

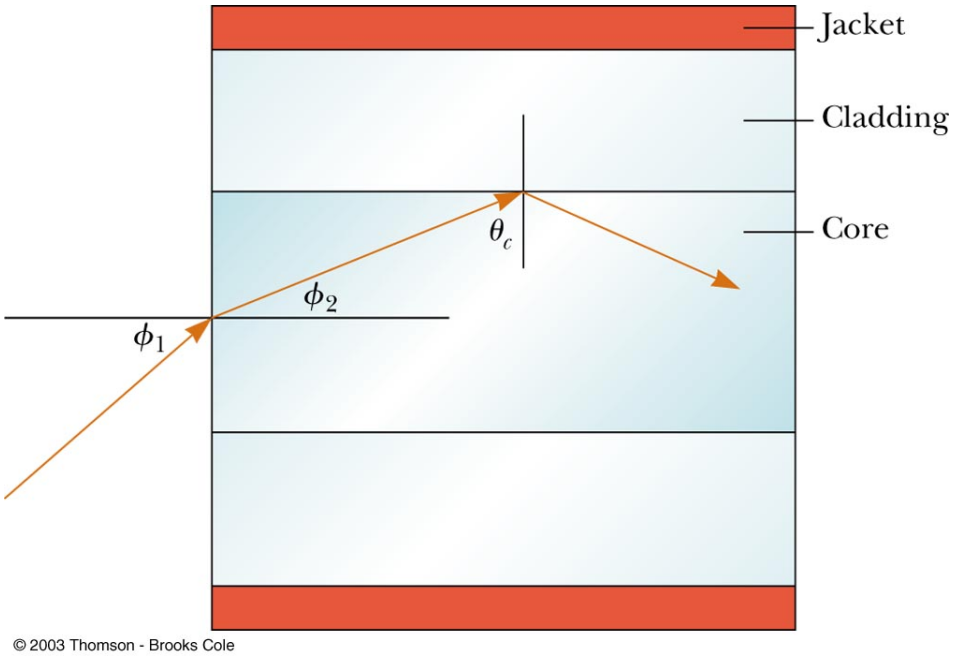
Total internal reflection

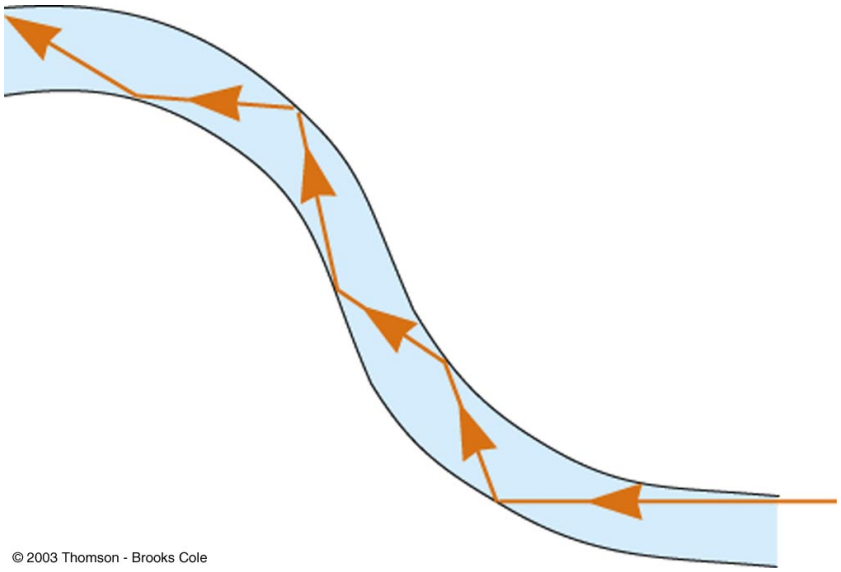
when θ_2 is 90°,
θ_1 is called θ_c
$n_1 \sin \theta_c = n_2 \sin 90^o$
$\theta_c = \sin^{-1} (n_2/n_1)$



Fiber optics

Used for example for fiber optic transmission of phone calls

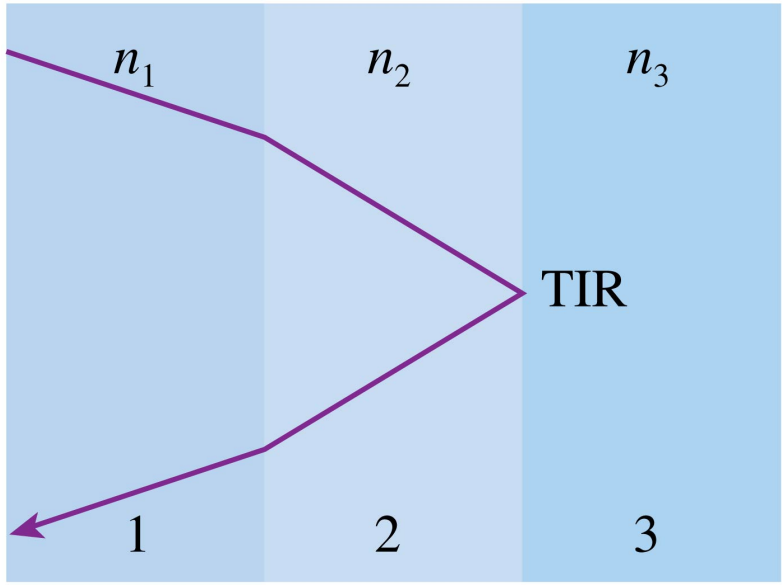




Cladding has a lower index of refraction than core so for any angles greater than the critical angle, the light is totally internally reflected

and used extensively in the detectors that I build for my experiments

A laser beam undergoes two refractions plus total internal reflection at the interface between medium 2 and medium 3. Which is true?



A. $n_1 < n_3$.

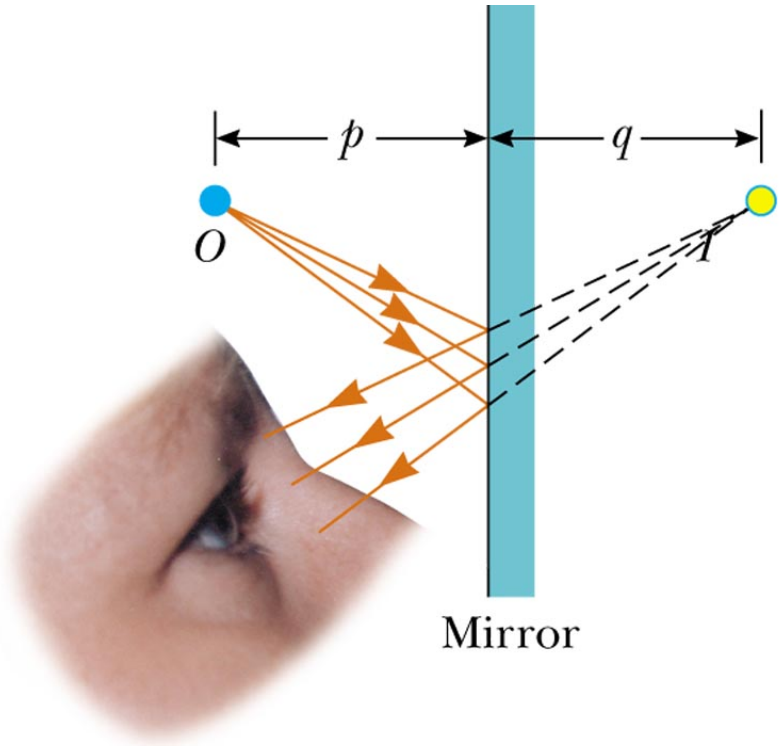
B. $n_1 > n_3$.

C. There's not enough information to compare n_1 and n_3.

Geometric optics: mirrors and lenses

- Look at images formed when light waves fall on mirrors and lenses
  - reflection and refraction taking place
- Continue to have situations where light travels in straight lines
  - geometric optics applies
  - deal with rays to indicate the direction of travel of light

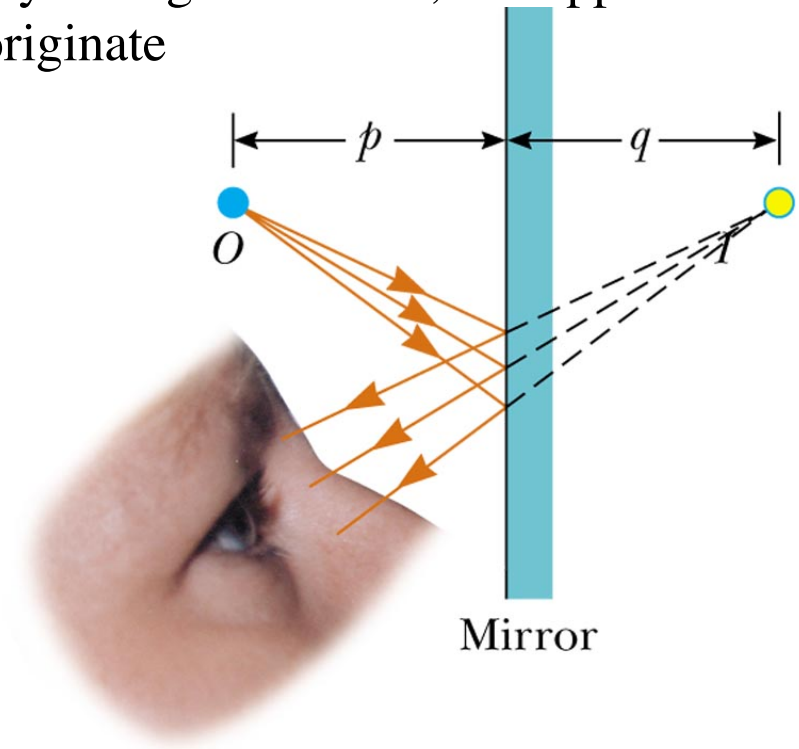
Example: the plane mirror
Consider image formed in a plane mirror



Plane mirror

- Label p the object distance
- Look at rays coming from object
- Rays diverge when reflecting off of the mirror, but appear to originate from a point behind the mirror
- Point I is called the image of the object and q is called the image distance
- **Lots** of definitions with this subject

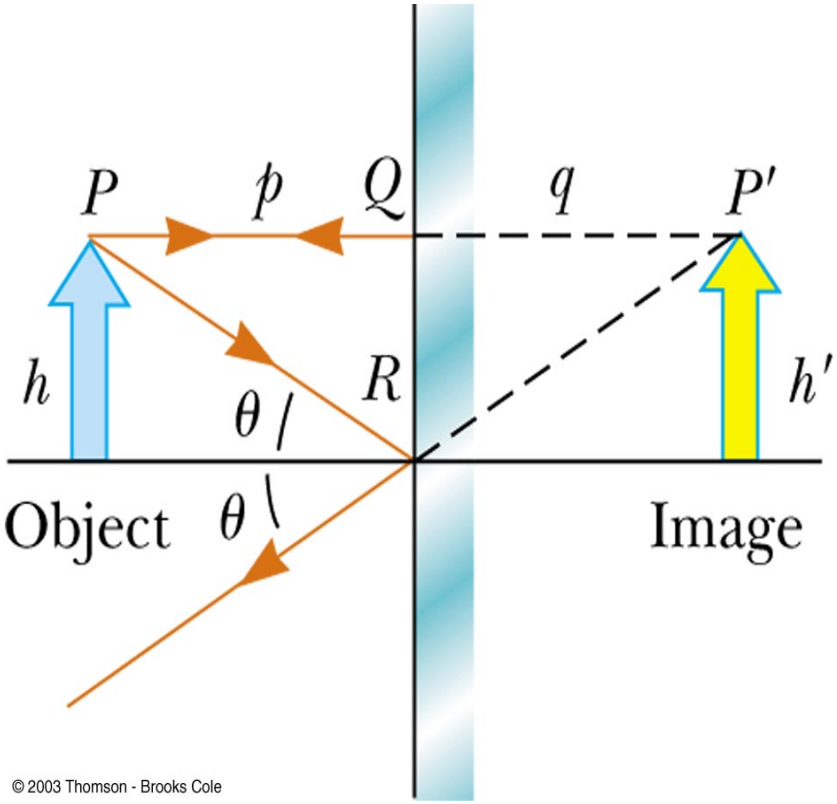
Images are formed at the point where the rays of light intersect, OR appear to originate



If the rays of light actually pass through the image point, the image is *real*; if they only appear to originate from that point, the image is *virtual*

Ray tracing: finite size object

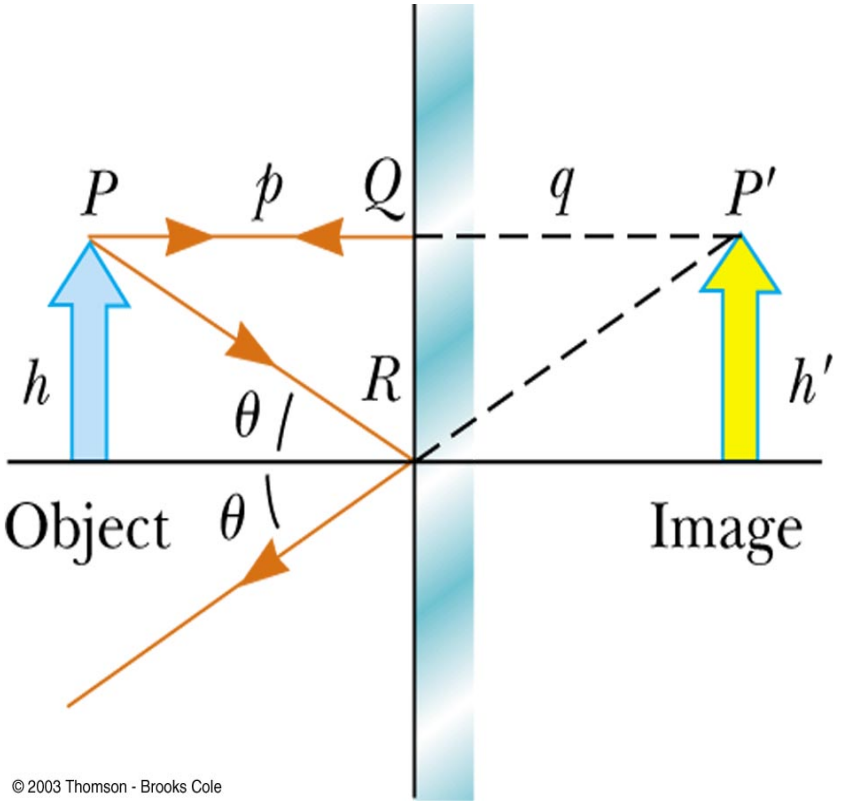
- To find out where an image is formed, have to follow at least two rays of light
- Consider the two rays coming from the object P as they reflect off of the mirror
- Trace the two reflected rays back to where they appear to originate from (behind the mirror)
- Triangles PQR and P' QR are identical, which means that p=q
  - image distance = object distance
  - the image is as far behind the mirror as the object is in front of it



Also, h=h' ; the image size equals the object size

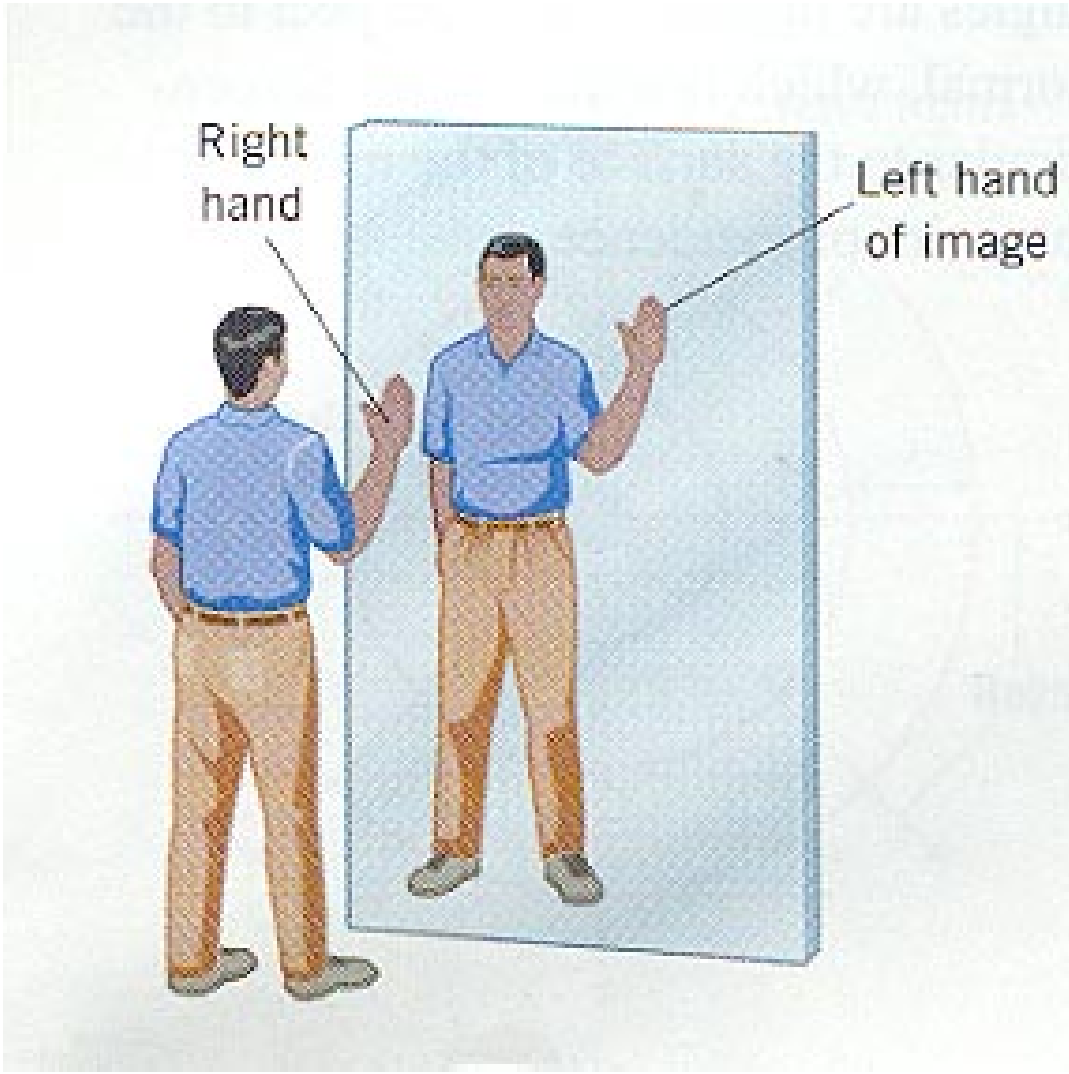
Plane mirror

- Define lateral magnification M
  - $M = \frac{\text{image height}}{\text{object height}} = \frac{h'}{h}$
- For plane mirrors
  - object is as far behind the mirror as object is in front
  - image is unmagnified (M=1), *virtual* (not physically there) and upright



…but there is a left-right reversal in the mirror

Probably more accurate to say there is a front-back reversal



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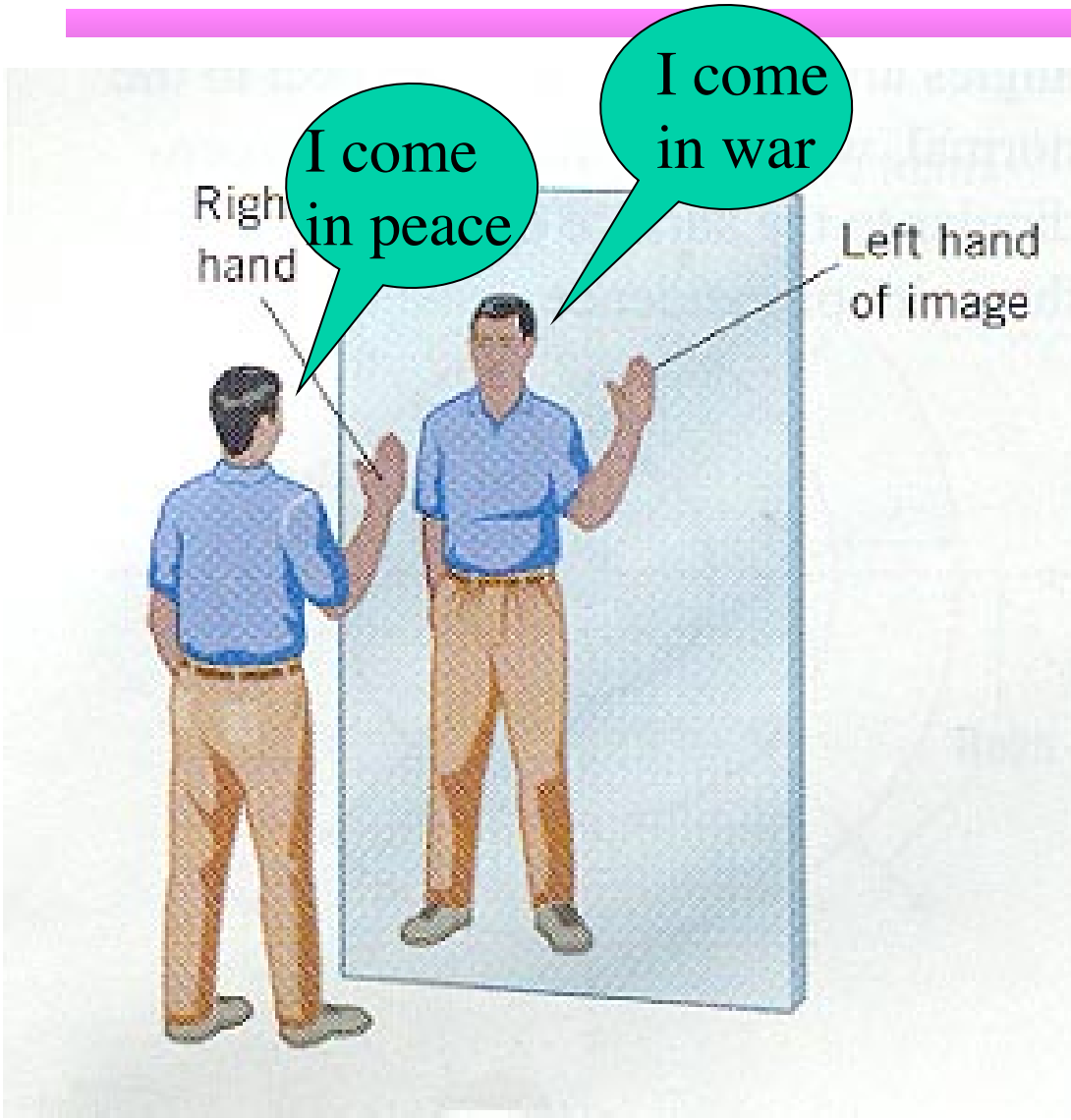
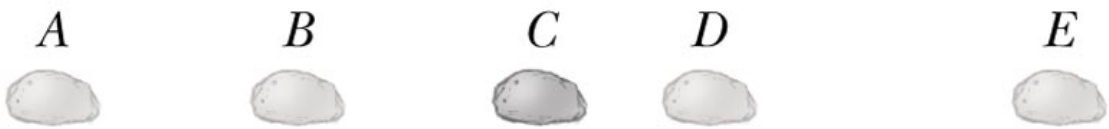
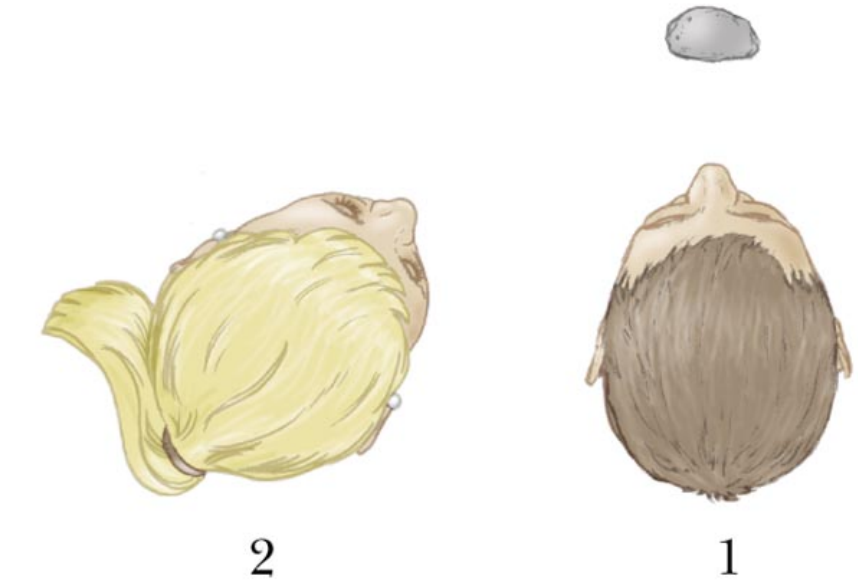


Where does the rock appear?

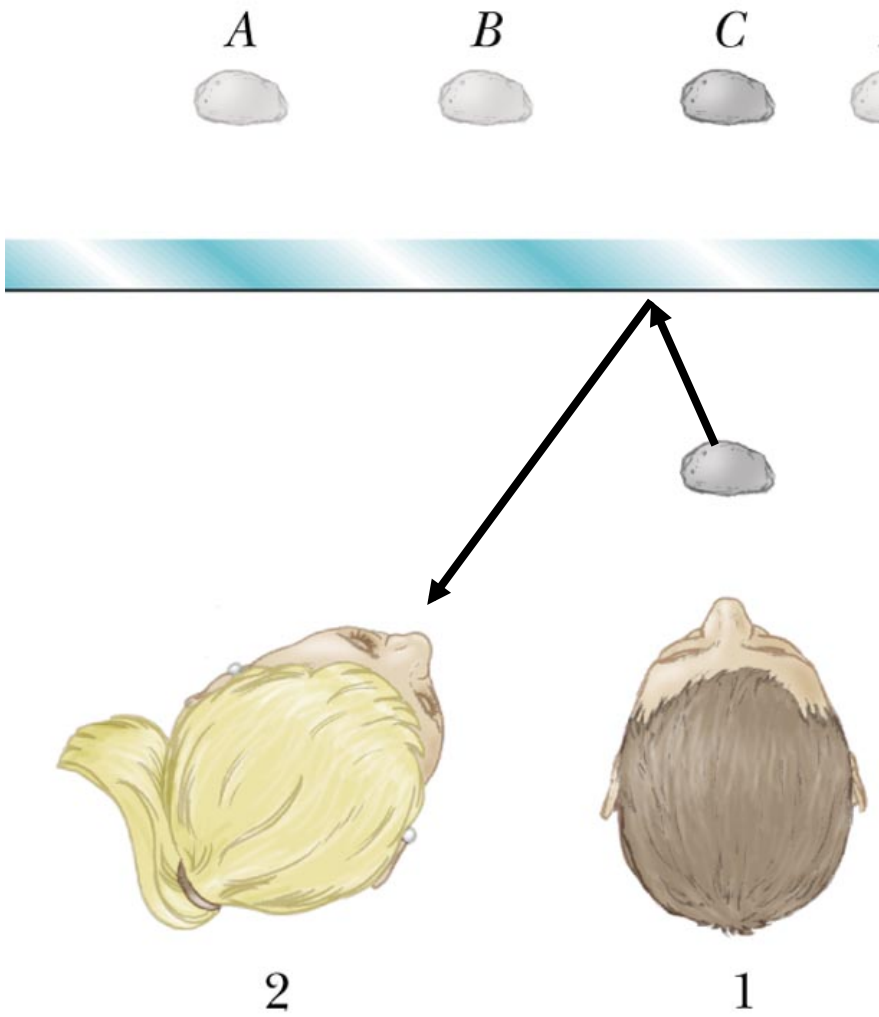




For observer 1, it's at C

What about for observer 2?

Where does the rock appear?



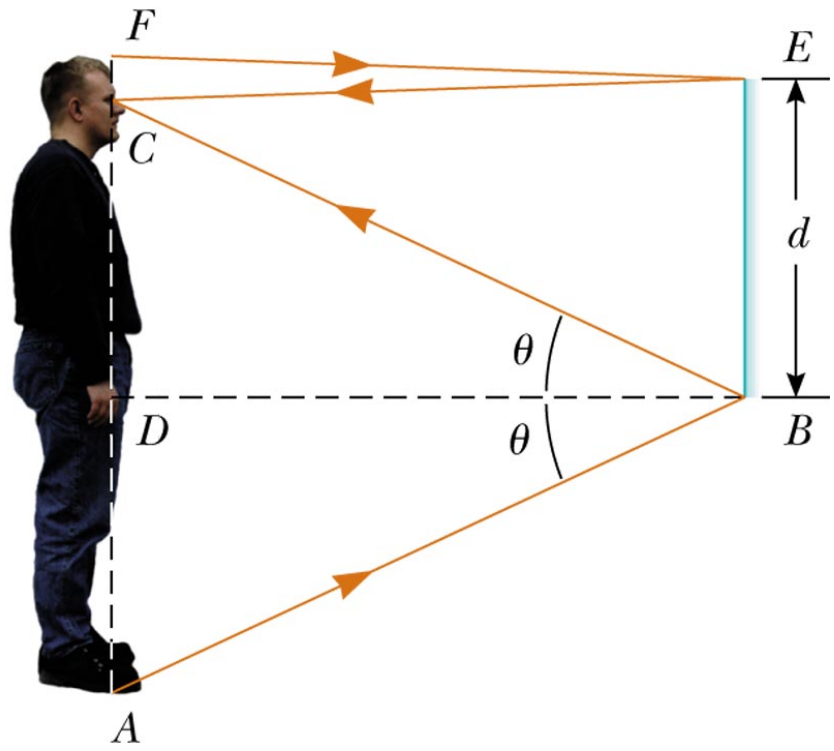
For observer 1, it's at C

What about for observer 2?

C

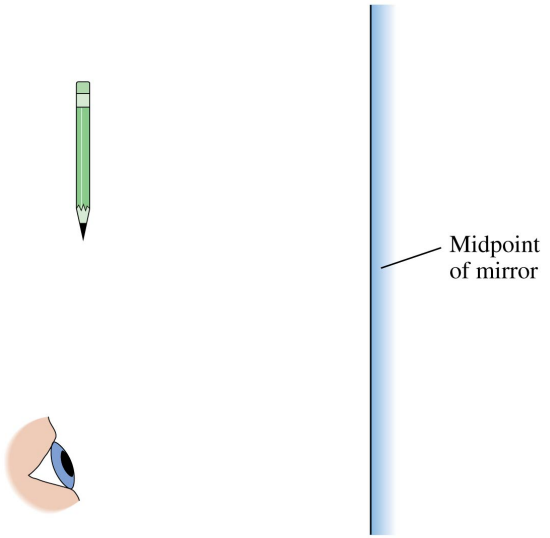
How big does a full-length mirror have to be?

- …in order to be able to see your entire body
- Mirror must be half of the height of the man in order for him to see his full reflection



You are looking at the image of a pencil in a mirror. What do you see in the mirror if the top half of the mirror is covered with a piece of dark paper?

A. The full image of the pencil.
B. The top half only of the pencil.
C. The bottom half only of the pencil.
D. No pencil, only the paper.



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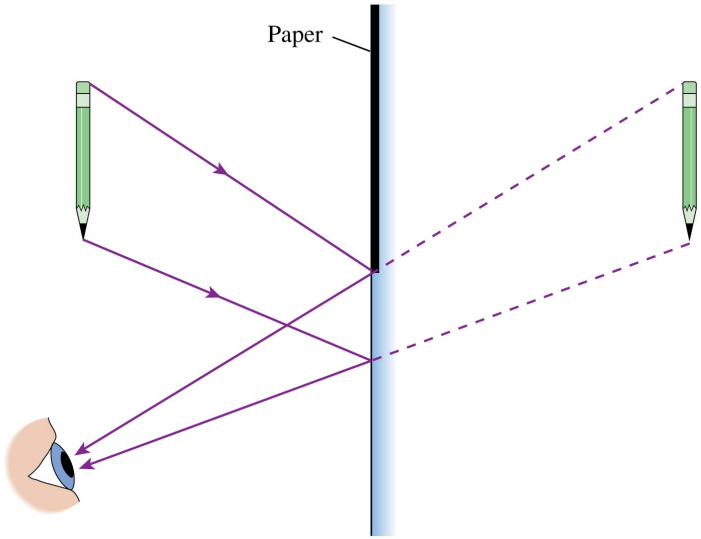


✔ **A. The full image of the pencil.**

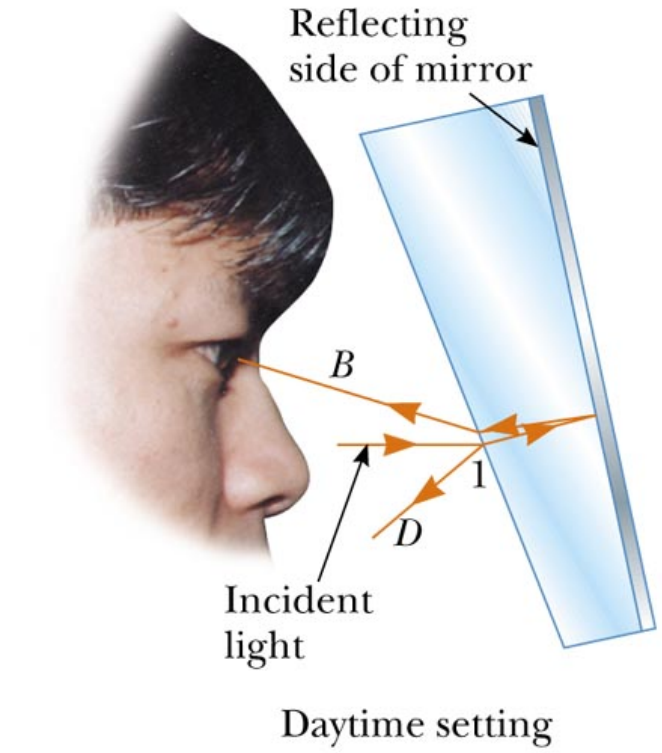
B. The top half only of the pencil.

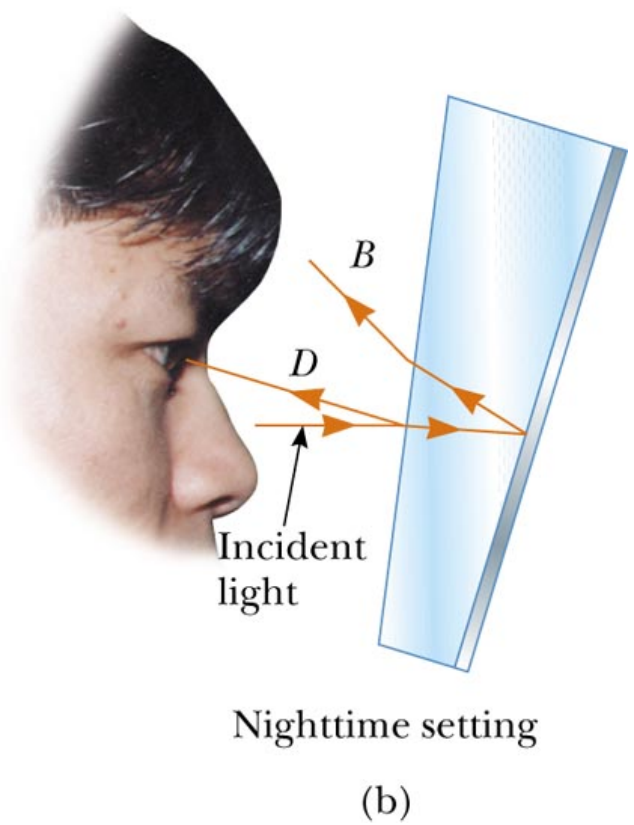
C. The bottom half only of the pencil.

D. No pencil, only the paper.

Another question you've always wondered about

How does the day/night setting work in a car's rear-view mirror?





Incident light refracts into glass, reflects off back surface and then refracts into eye

Only small amount of light reflected from front surface makes it into eye