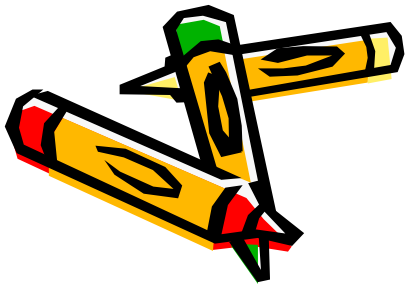
PHYSICS 102N
Spring 2022

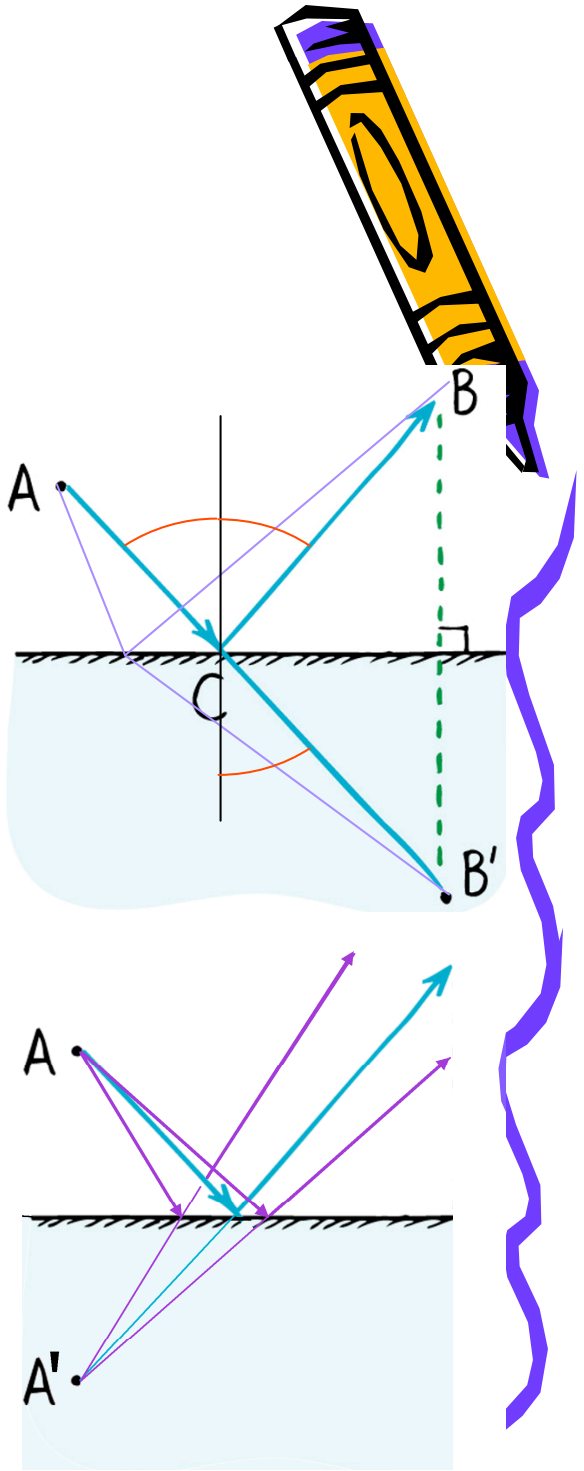
Week 8

Light Waves and Optics

Reflection

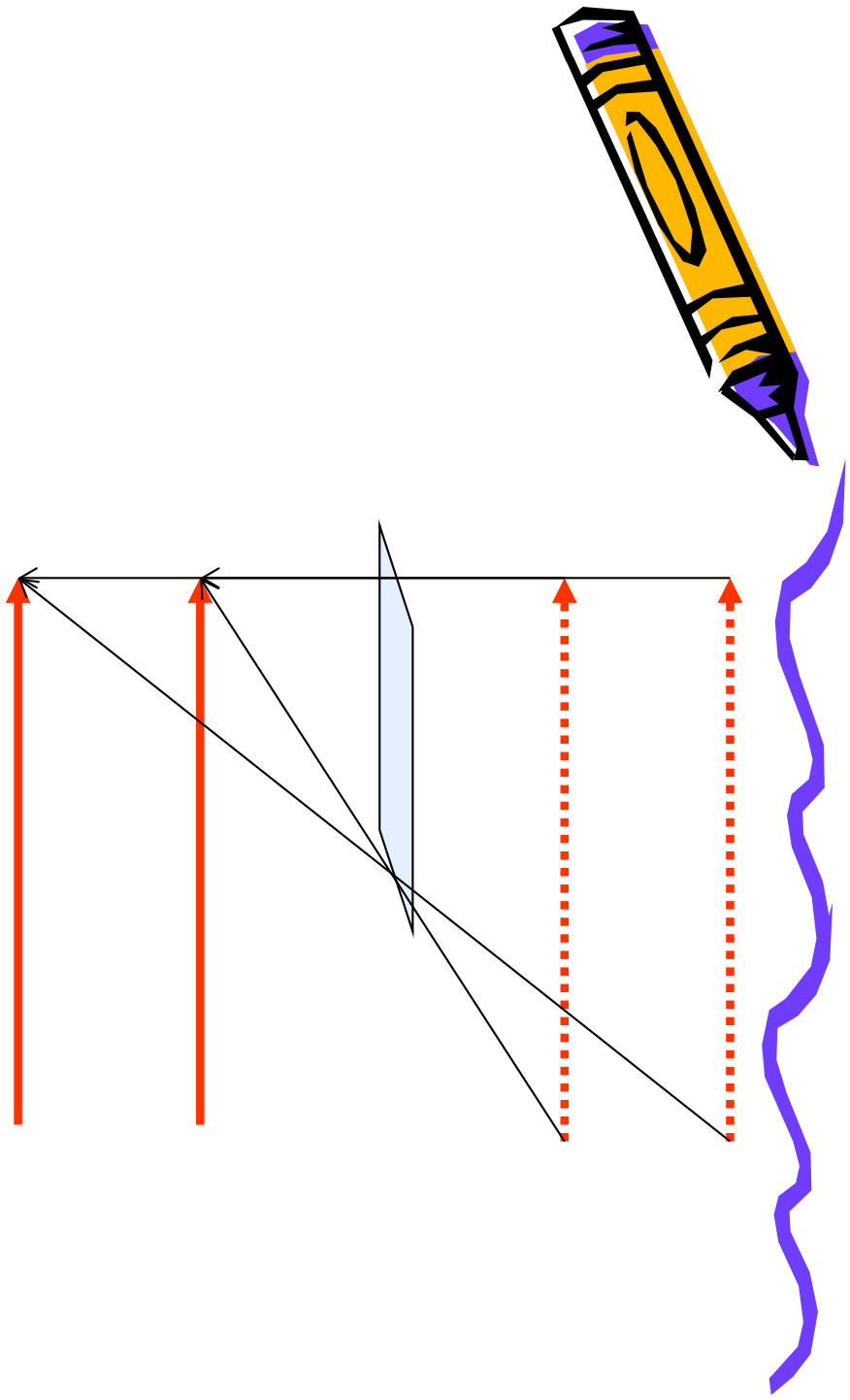
- Principle of least time: Light will travel the path of shortest time => angle of reflection = angle of incidence
- Plane mirror: Construct image by reflecting object on the mirror plane (left-right, up-down unchanged; front-back flipped)





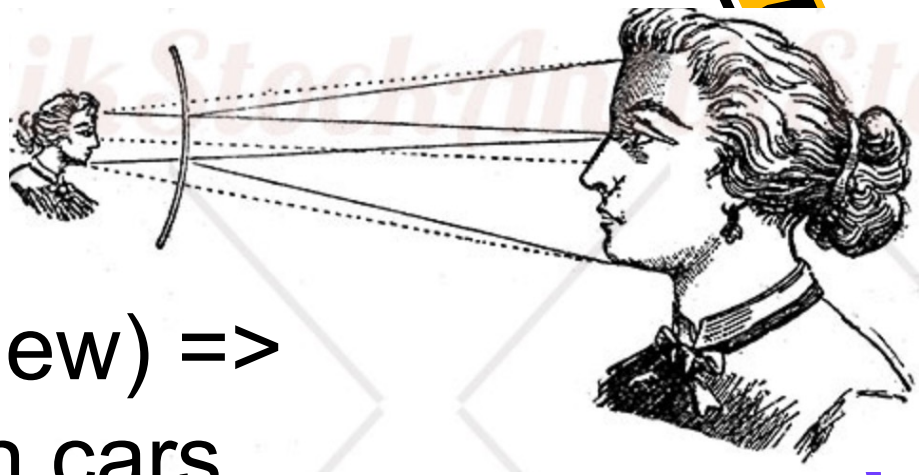
Mirrors

- Plane mirror: Image appears behind mirror, same size as original, but double as far away as mirror => Need only 1/2 size mirror to see full size (Note: if you are 1 m away from the mirror, your image **looks** like that of a person 2 m away)

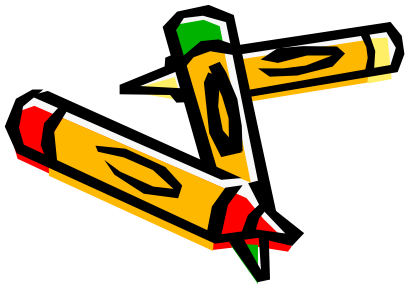


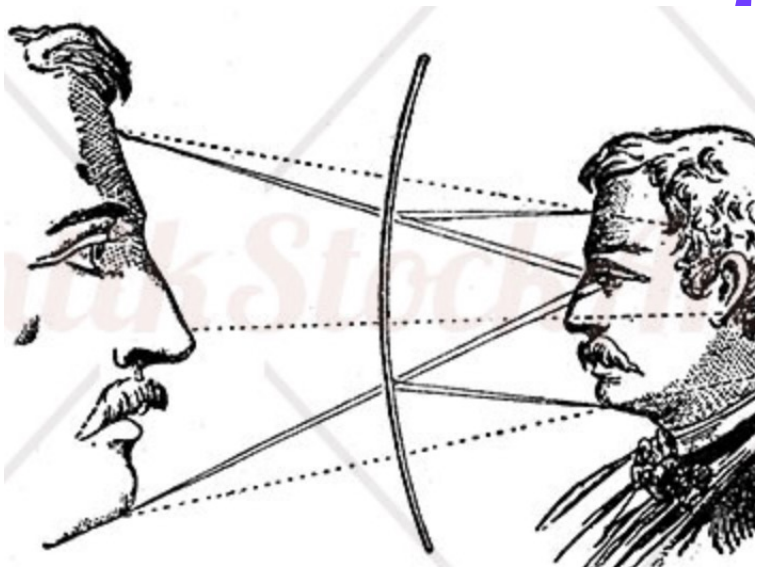
Curved mirror: Distorted image; different size and apparent distance

Imaging with mirrors

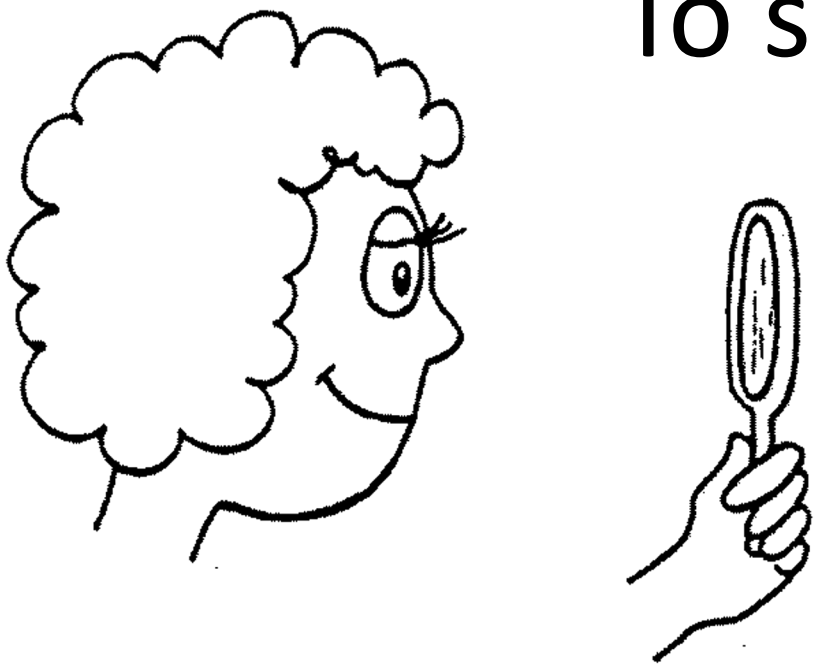


- Convex mirror: Objects appear smaller (but you can see a larger field of view) => some rear-view mirrors on cars
- Concave mirror: Objects appear larger => magnification (e.g., telescopes)
  - Can be used to focus parallel light rays into a single point





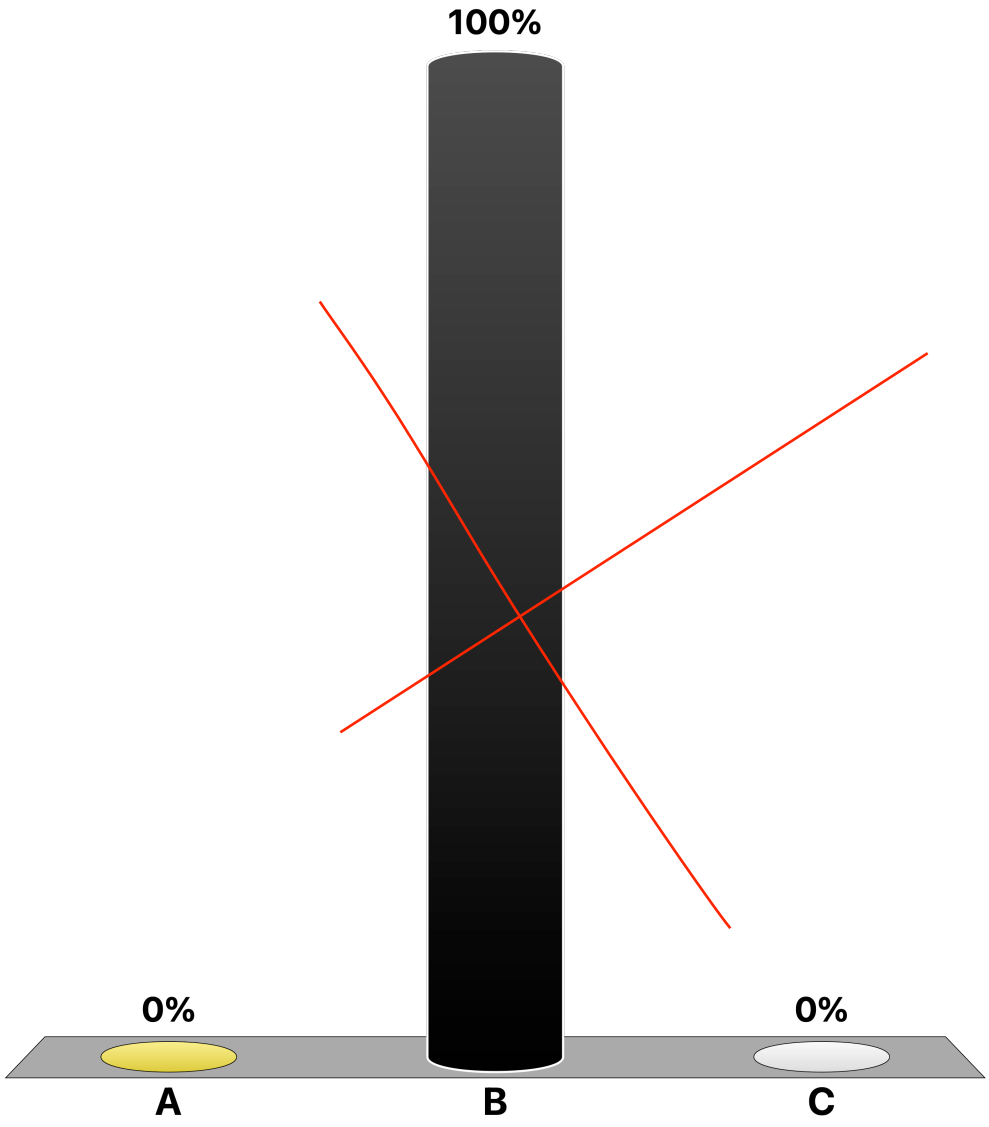
To see more of her head in the mirror, she…

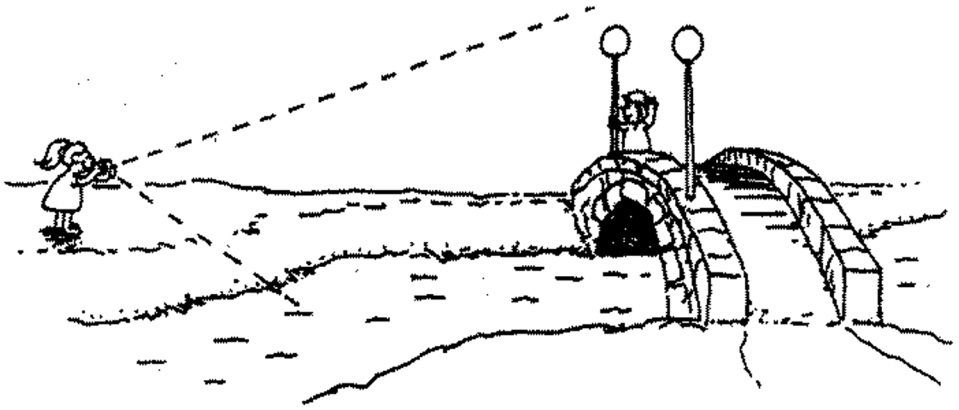


A. should hold the mirror closer.

B. should hold the mirror farther away.

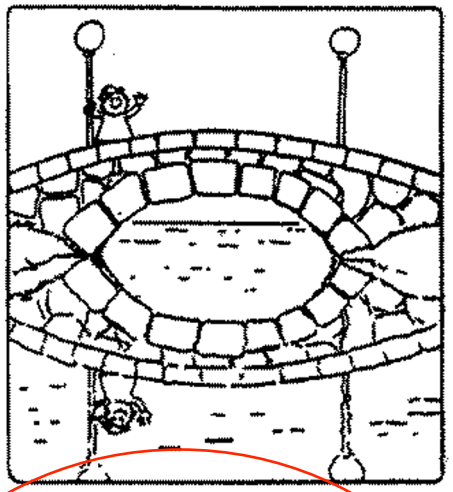
C. needs a bigger mirror.



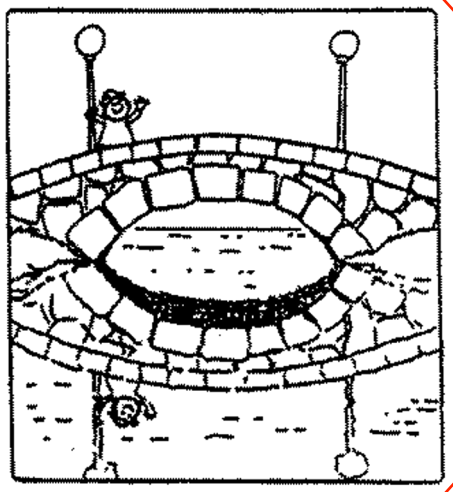


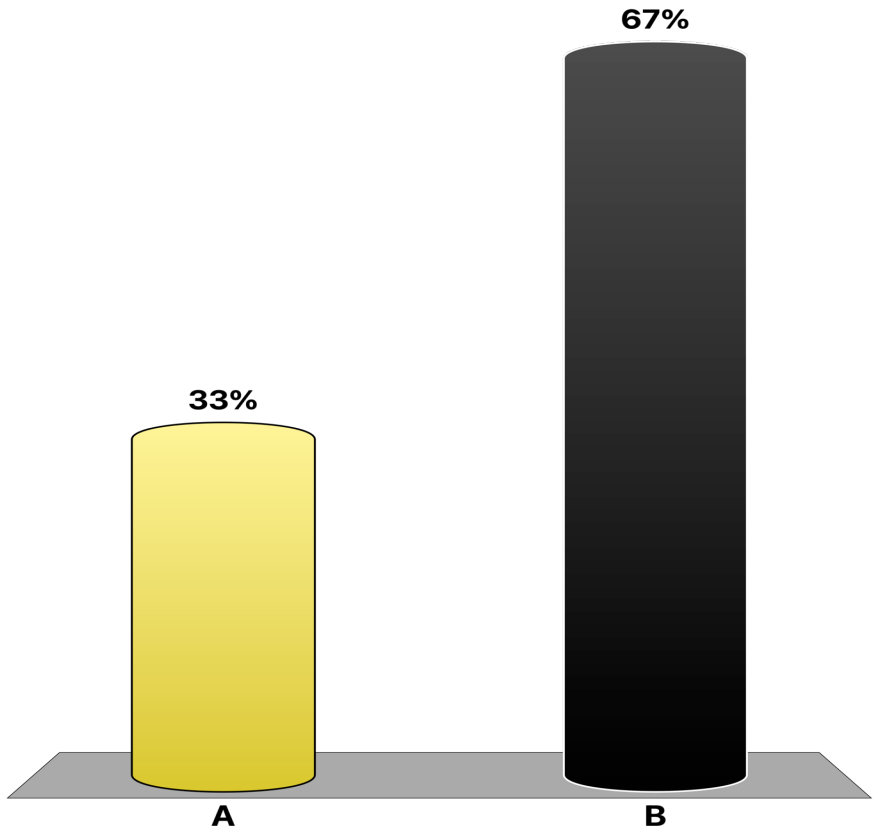
She takes a photograph of her friend standing on the bridge as shown. Which of the two sketches more accurately shows the photograph of the bridge and its reflection?

A.



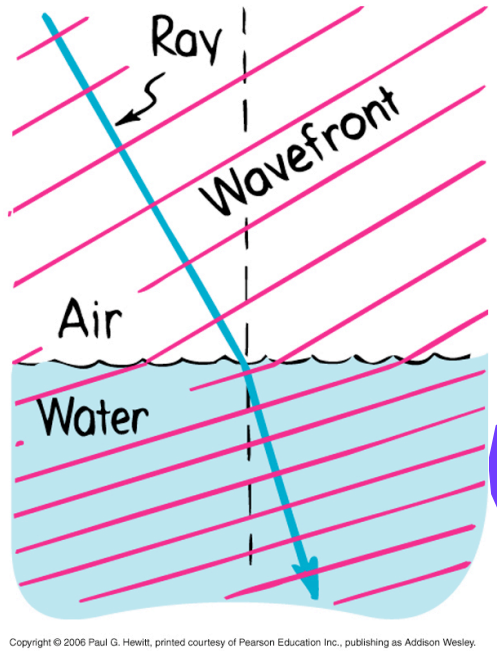
B.





Refraction

- Reminder: waves change direction at interface between different media with different wave velocities
- Two explanations:
  - Principle of least time - cover more distance in medium with larger v_{wave}
  - Bending of wave fronts
    - wave fronts arriving first get slowed down first



- Light: Index of refraction n => $v_{wave} = c/n$
  - Rays get bent towards normal when going from"fast" to "slow" medium ($n_2 > n_1$)

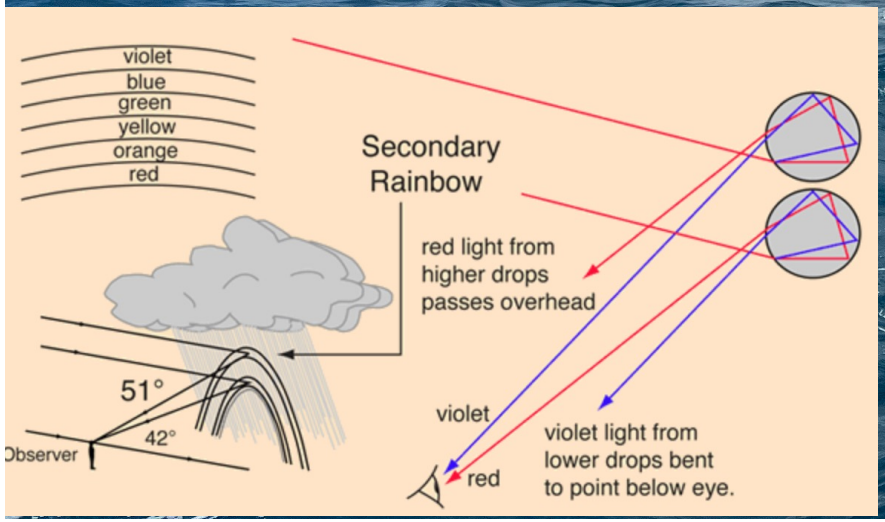
Spearing Fish, Mirages and Sunsets

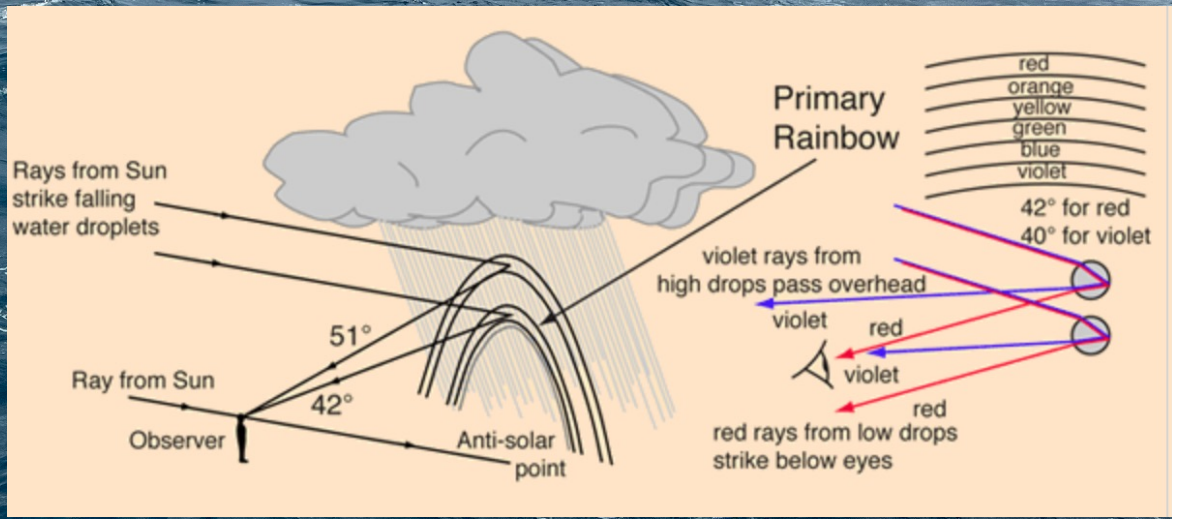
- Light going from an object in one medium to your eye in another doesn't follow a straight line - the object isn't where it appears to be
  - Example: Fish in a lake are really deeper down than apparent
  - Light going through a thick pane of glass is offset
- Light coming from space hitting our atmosphere will bend - when we "see" the sun setting, it's already below the horizon!

- Light can follow curved path if density of medium changes ($n \propto \rho$) => mirage

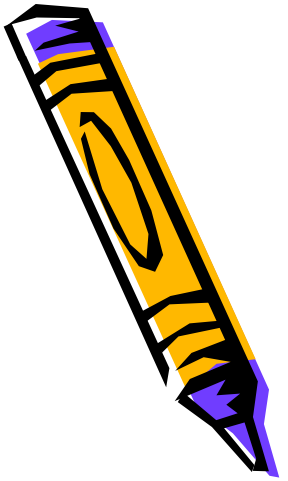
Dispersion

Wave velocity can be frequency-dependent ($n(f)$) -> Different wave lengths get refracted more or less => Prism, rain drops, …

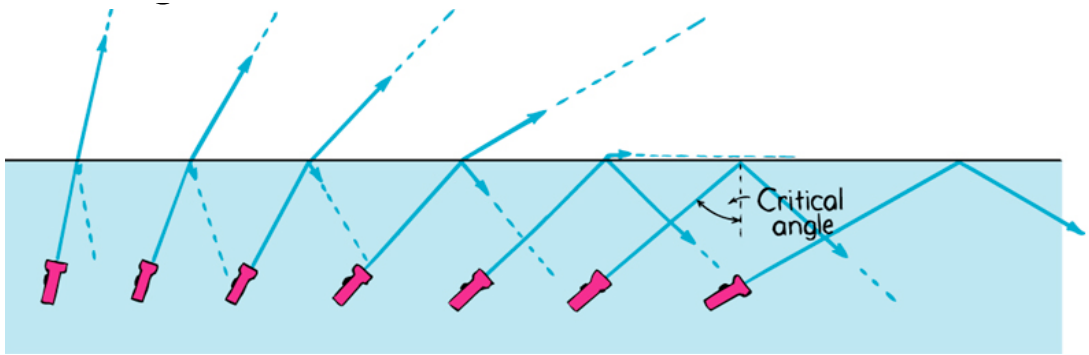




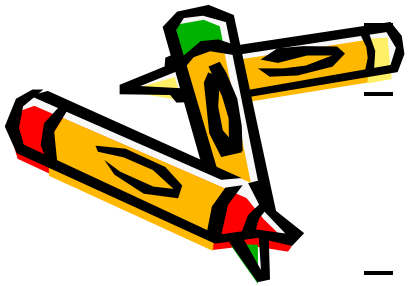
Total Internal Reflection and Dispersion



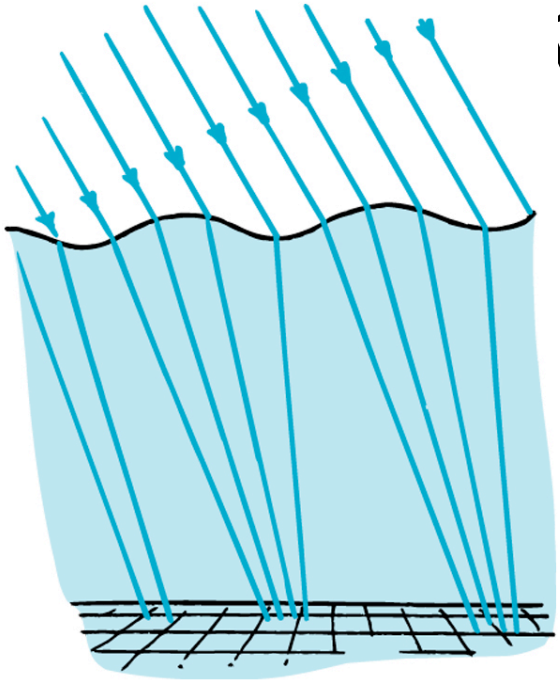
- Light coming **out** of medium with larger *n* will bend away from normal: $\theta_{out} > \theta_{in}$
  - When $\theta_{out} > 90^o$: Total internal reflection
  - Typical values: 48^o for water, 43^o for glass
  - Application: optical fiber (can channel light for miles), prism inside binocular, …



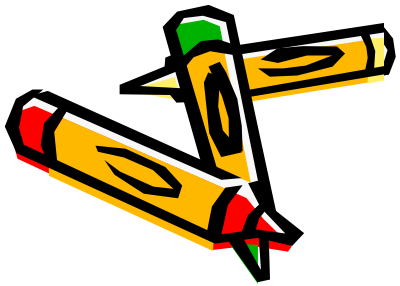
- Index of refraction depends on frequency: Dispersion
  - Blue light often "slower" than red light (because of atomic resonances in the near ultraviolet)
  - Blue light gets bend more by refraction
  - Rainbows (from rain or from lawn sprinklers) - Dispersion and total internal reflection in water drops -> color-dependent apparent angle where light seems to come from
  - Prisms (separation of colors)

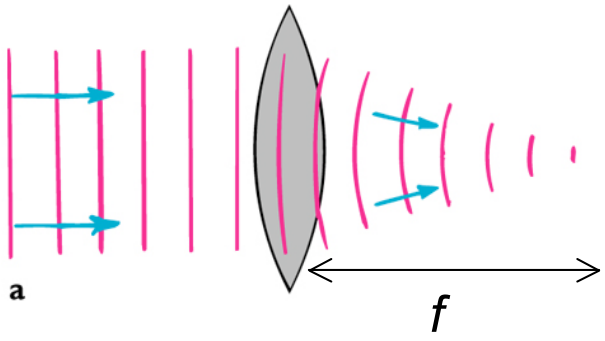


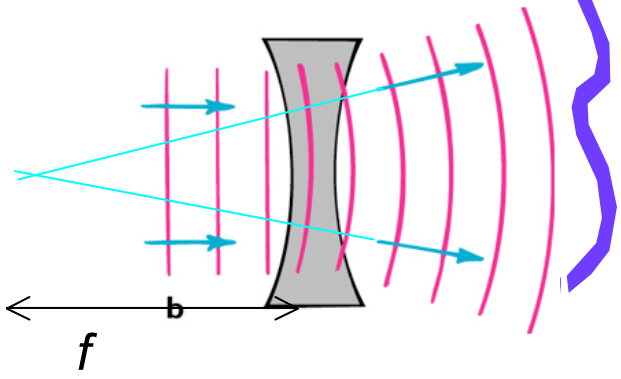
Lenses



- Curved interface surface: Rays further from vertical axis get bent more (swimming pool effect)
- Lens: Precise arrangement of curved surfaces that can gather parallel light (focus -> a; convex lens) or make it appear to come from a focus (disperse -> b; concave lens)
  - Burning holes into paper with sunlight (type of solar energy)
  - Distance from lens to point of convergence: Focal length *f*
    - *f* is shorter if curvature is stronger and if $n_{Lens}/n_{Outside}$ is larger

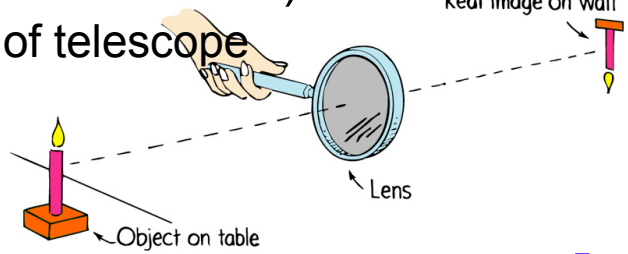


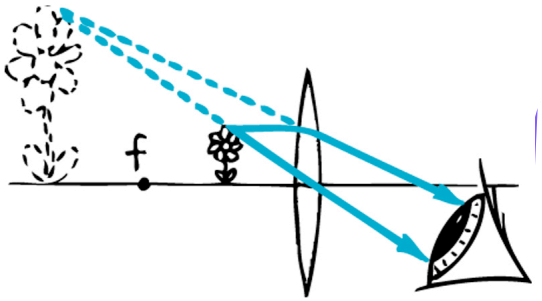


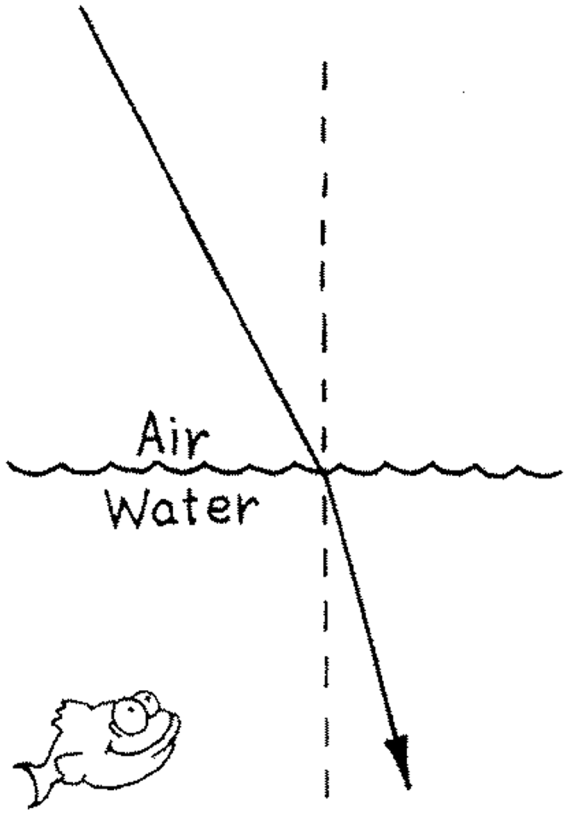


Imaging with lenses

- Convex (focusing) lens
  - Object more distant than *f*: Formation of real, upside-down image on near side of lens (magnified if closer than 2*f*, else smaller)
    - Eye, camera, object lens of projector, object lens of telescope
    - Glasses for far-sighted people: help the eye lens focus (otherwise focus too long)
  - Object at *f*: parallel rays from each point
    - car lights, theater lights, search lights, light source of projector, ocular lens of telescopes etc.
  - Object closer than *f*: Formation of virtual, upright, magnified image on far side of lens
    - magnifying glass, reading glasses
- Concave (diverging) lens
  - Formation of virtual, upright, smaller image on far side of lens
    - Glasses for short-sighted people (eye lens focal length too short)
    - Sometimes ocular lens
    - Usually part of complex object lens (camera, projector, telescope)







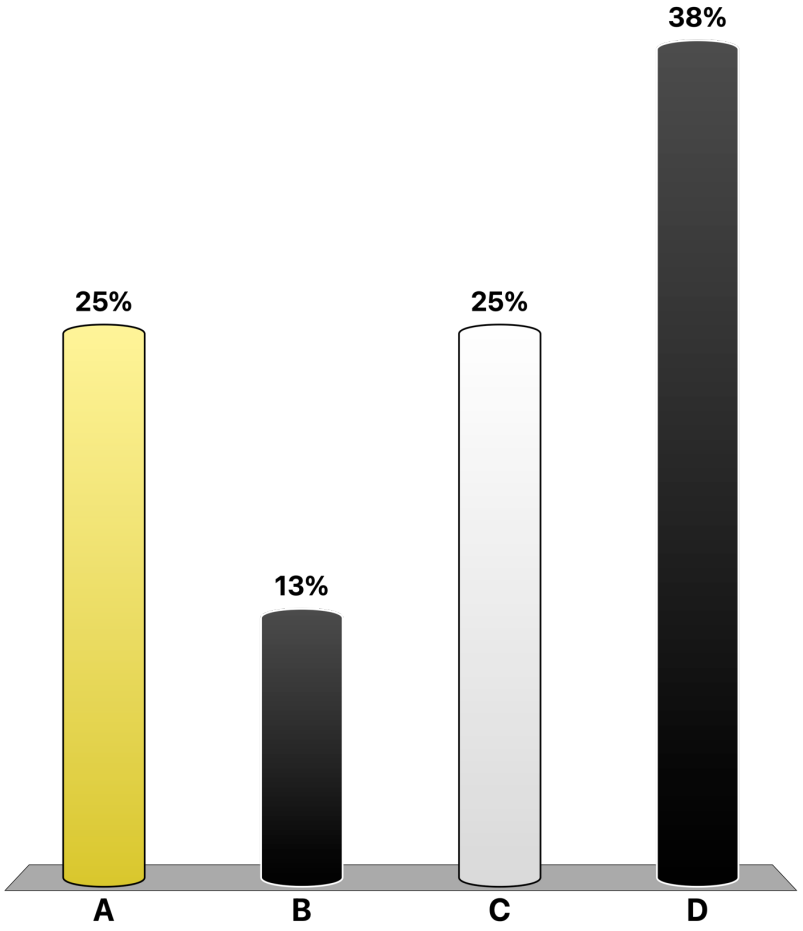
Light rays bend as they pass from air into water at a non–90 degree angle. This is refraction. Which quantity doesn't change when light refracts?

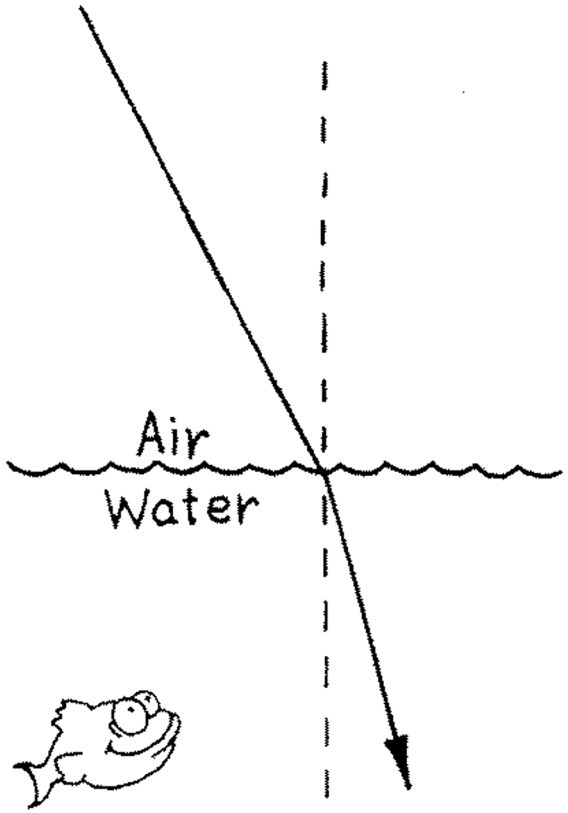
A. Wave velocity

B. Material's index of refraction, *n*

C. Frequency of the light

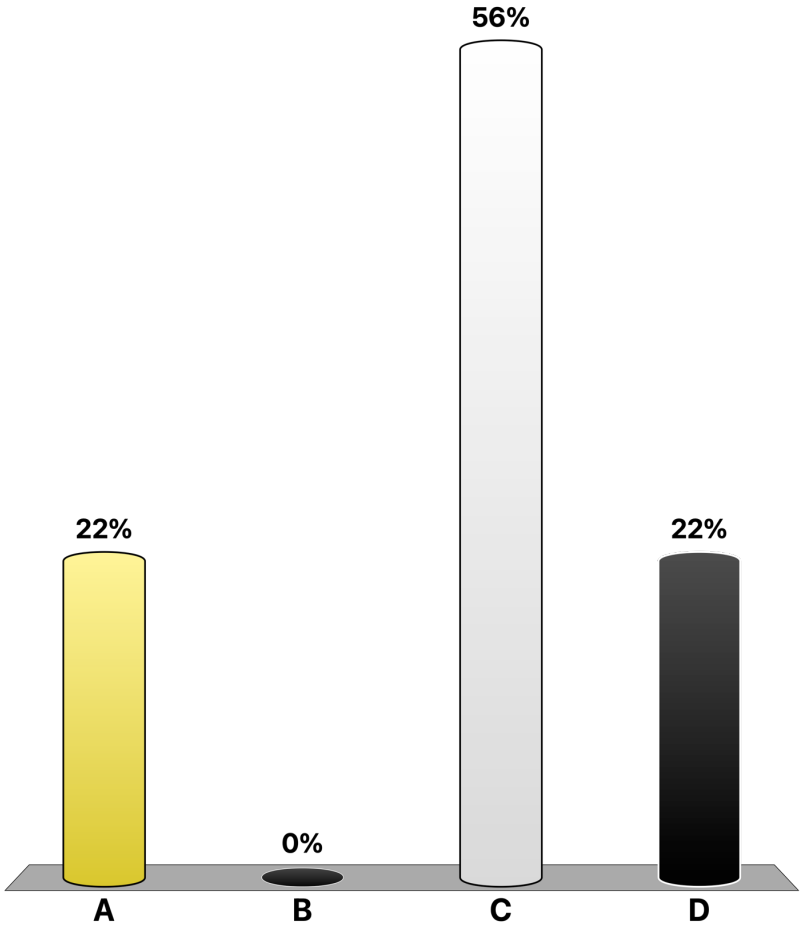
D. Wavelength of the light



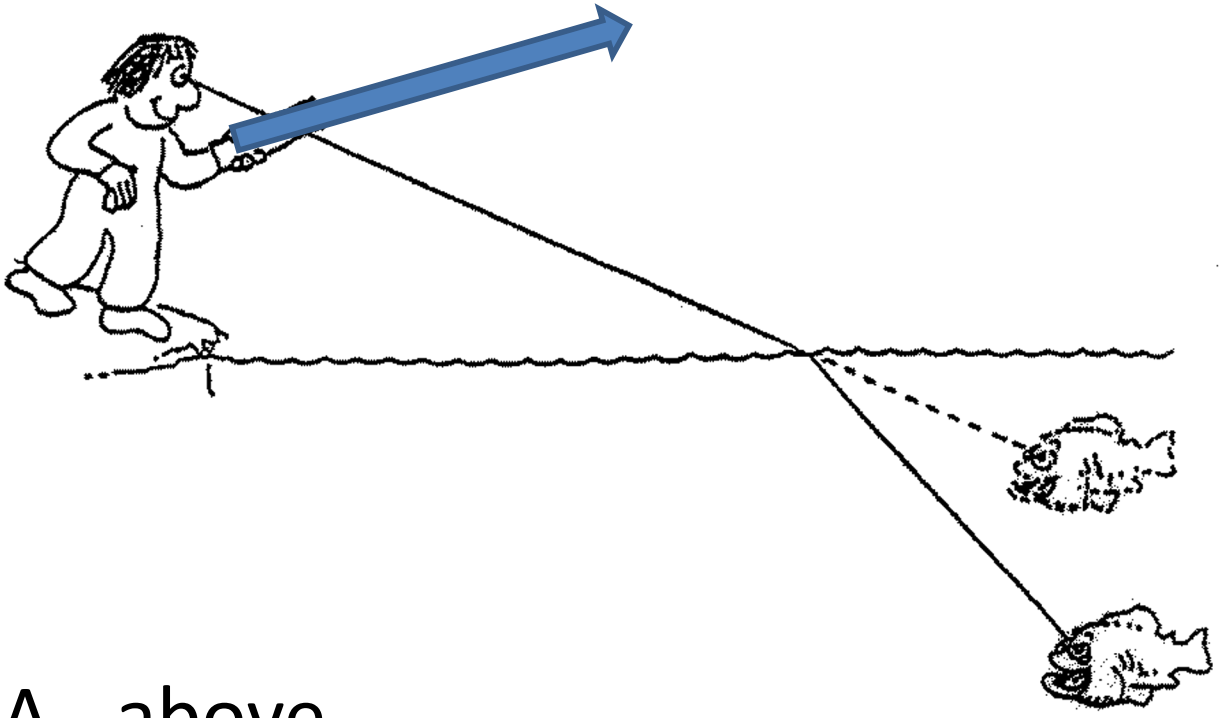


Light rays bend as they pass from air into water at a non–90 degree angle. This is refraction. Which quantity doesn't change when light refracts?

A. Wave velocity
B. Material's index of refraction, *n*
C. Frequency of the light
D. Wavelength of the light



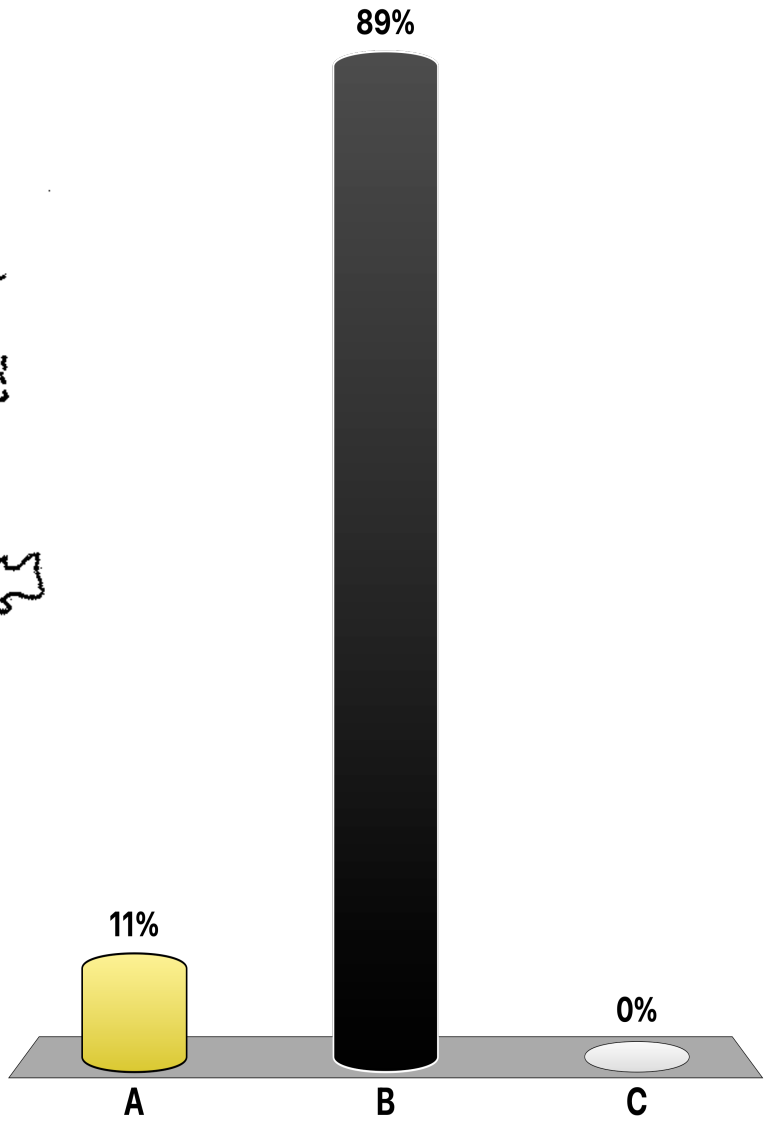
Jose wishes to catch a fish with a spear. In order to make a direct hit, he should aim the spear



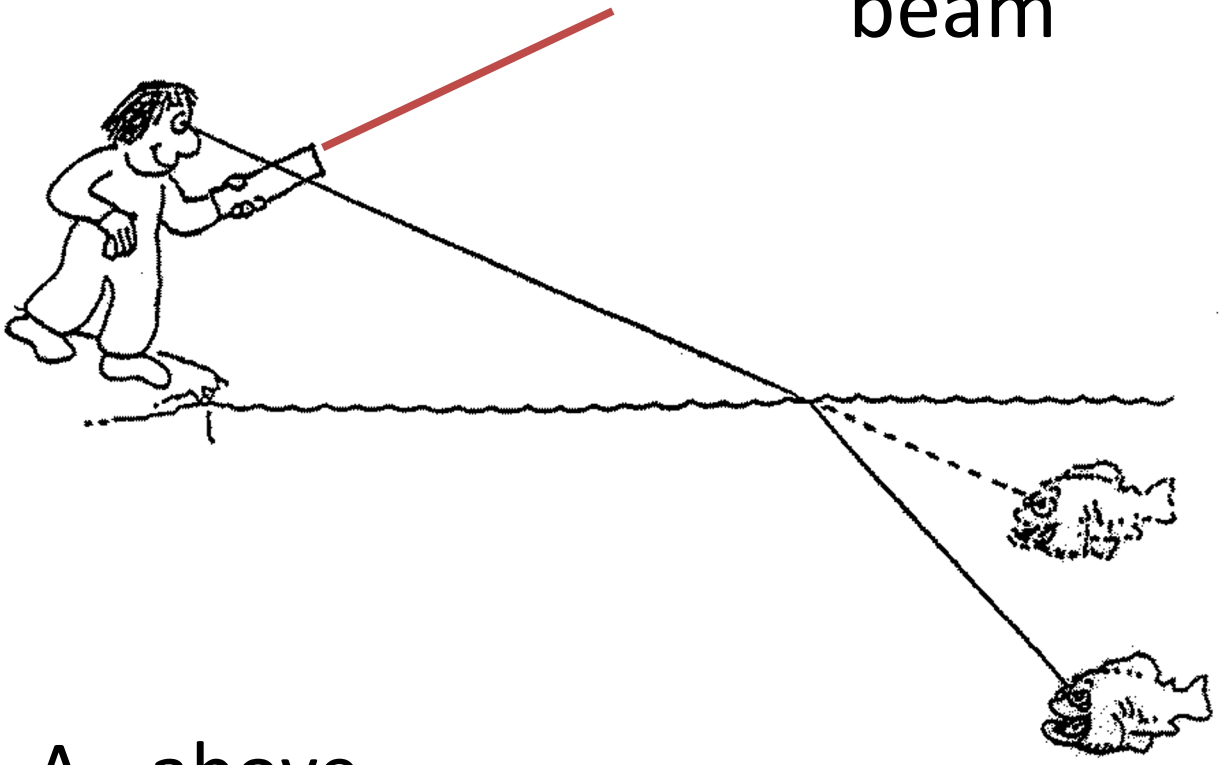
A. above

B. below

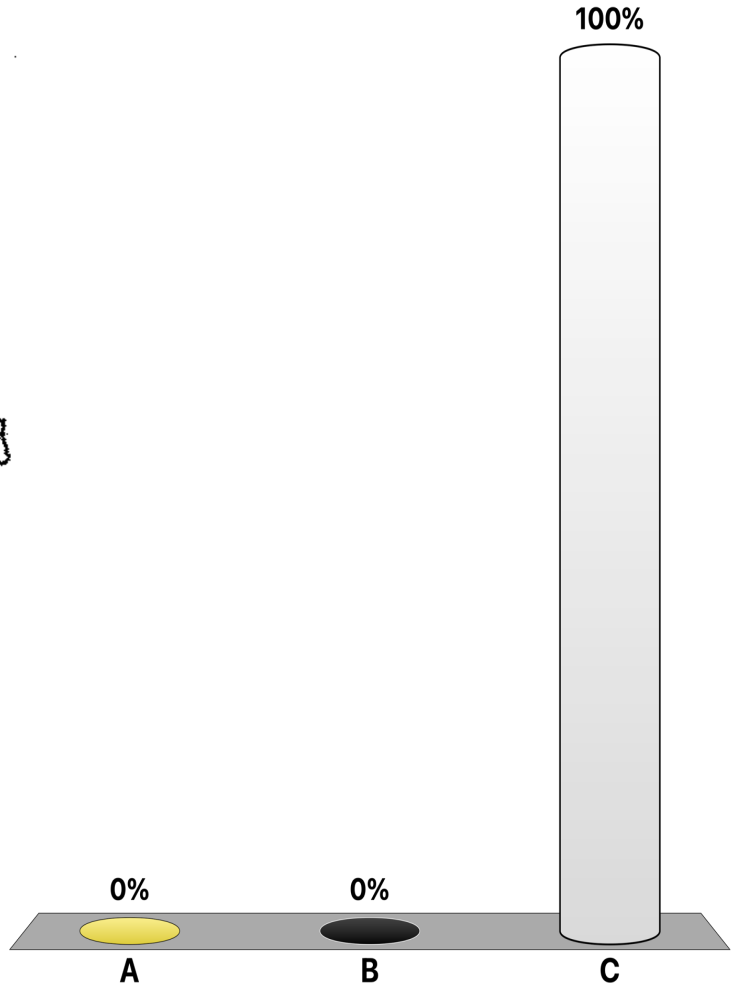
C. directly at the position where he observes the fish to be (apparently).



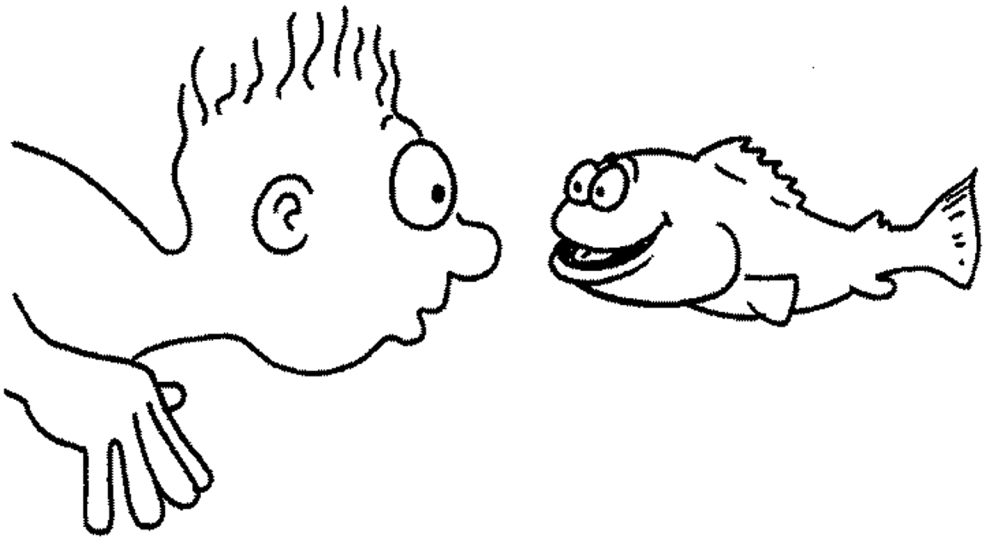
Now Jose wishes to “spear” the fish with a laser. In order to make a direct hit, he should aim the laser beam



A. above
B. below
C. at the position where he observes the fish to be (apparently).

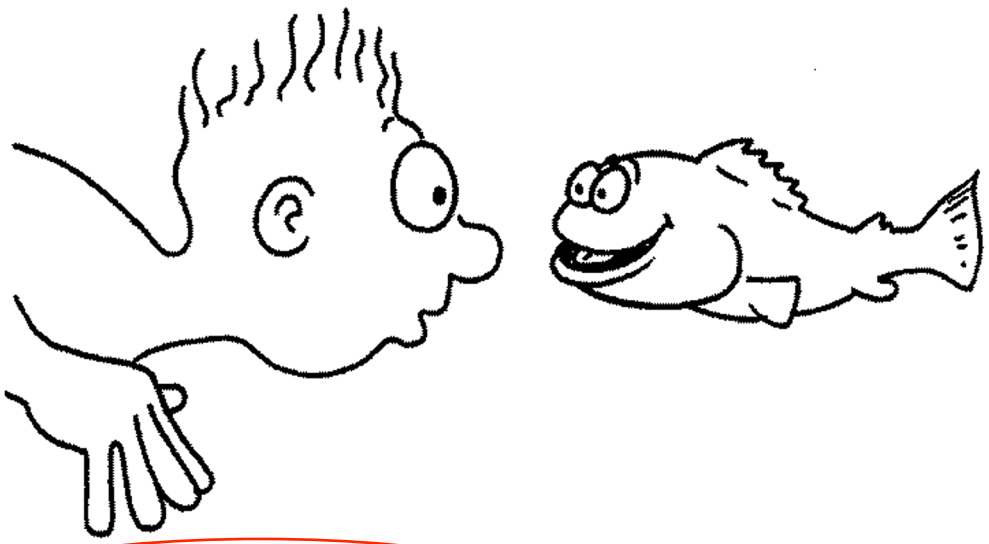


A person who sees more clearly under water than in air without eyeglasses is



A. nearsighted.
B. farsighted.
C. neither (normal vision)

A person who sees more clearly under water than in air without eyeglasses is



A. nearsighted.

B. farsighted.

C. neither (normal vision)