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Refraction of Light

Grade 10

Intro to Refraction

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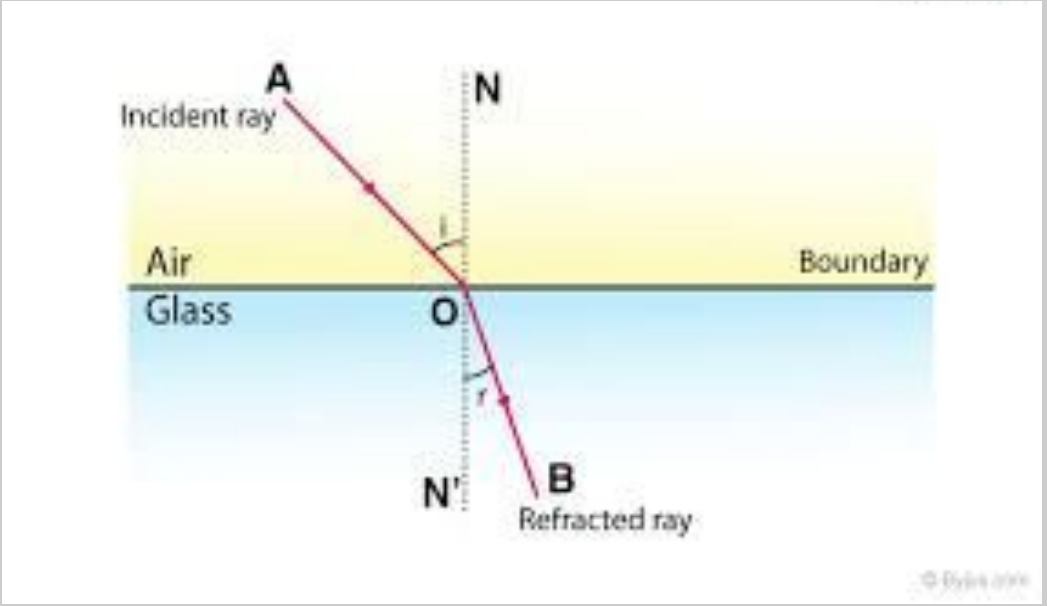
- Take 3 cups from the front, labeled 1,2,3.
- Observe each straw through the side of the cup as you slowly turn the cup. DO NOT STIR THE CONTENTS!
- Write down your observations.
- In which container does the straw appear broken?
- Are all amounts of break the same?
- When does the straw not appear to be broken?

Refraction of Light

- Refraction- light bends or changes direction at the boundary of between two media.

- The beam in the first medium is called the incident ray. The incident ray hits the boundary at an angle of incidence.
- The beam in the second medium is called the refracted ray. The refracted ray leaves at an angle of refraction.

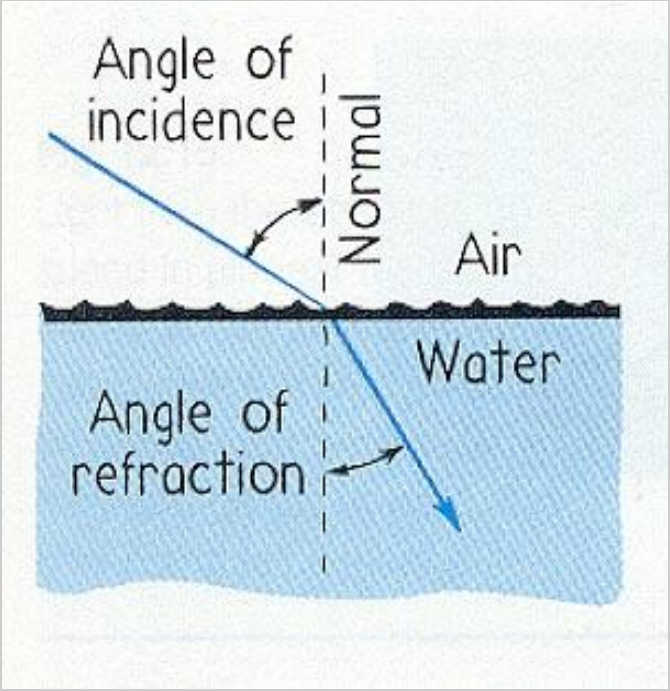


http://videos.howstuffworks.com/animal-planet/27704-fooled-by-nature-archer-fish-video.htm

Refraction of light

- Note that when light moves from air to water it bends toward the normal, making the angle of incidence greater than the angle of refraction.

- Light bending toward the normal indicates the speed is slower
- Light bending away from the normal indicates the speed is faster
- The changing speed is what causes the change in direction!
- When light strikes a surface along the perpendicular, the angle of incidence is zero, and the angle of refraction is also zero.



Refraction when light passes from denser to rarer medium

When light passes from a denser to a rarer medium, it gets deflected away from the normal and in this case the angle of refraction is greater than the angle of incidence.

Refraction when light passes from rarer to denser medium

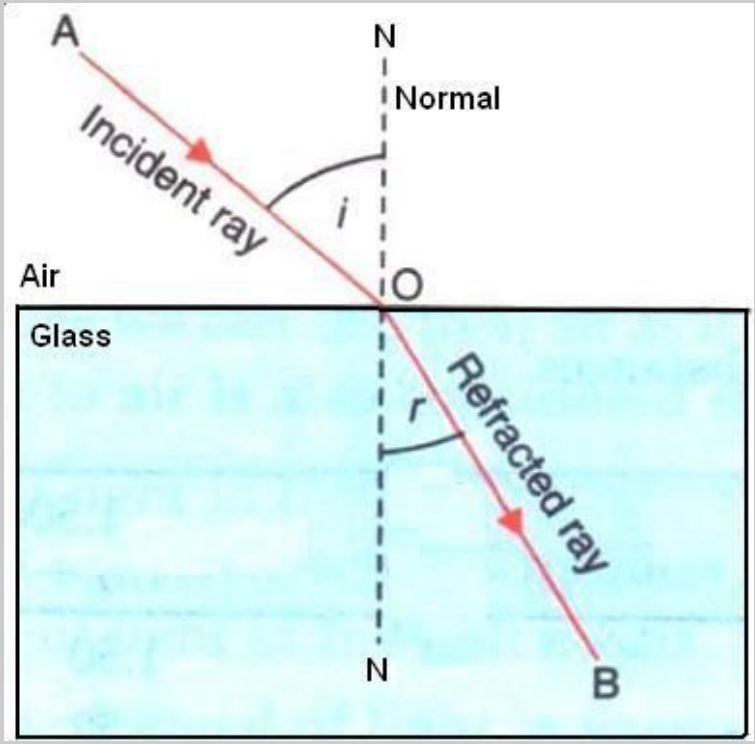
Likewise when it passes from rarer to denser, it moves towards normal and in this case the angle of refraction is less than the angle of incidence.

Laws of refraction

1. Law of Refraction
   These are the laws obeyed by the surface from wherever the refraction takes place :

   - Incident ray, normal ray and the refracted ray all lie in the same plane.
   - The ratio of sine of angle of incidence to the sine of the angle of refraction is always constant for a particular pair of media.

i.e.: sin i/sin r = constant (Snell's law)



Snell's Law

- Snell's law describes the relationship between the angle of incidence and the angle of refraction.
- The degree to which light is bend depends on the medium and the density of the medium.
- Snell's Law states that the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.
- For light going from a vacuum into another medium, the constant, n, is called the index of refraction.

Equation for Snell's Law

- Snell's Law is written as:

$$n = \frac{sin\theta_i}{sin\theta_r}$$

n = index of refraction

θ_i = angle of incidence

θ_r = angle of refraction

Index of Refraction

- The index of refraction is also a measure of a medium's optical density. *(As the optical density increases the value of n increases)*
- In this case, n, represents how much slower the light travels in the medium as compared to a vacuum.
- The index of refraction can be determined using the following equation:

$$n_{material} = \frac{c}{v_{material}}$$

Index of Refraction

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- Each material has a specific index of refraction

Medium	Index of Refraction
Vacuum	1.00
Air	1.0003
Water	1.33
Ethanol	1.36
Crown Glass	1.52
Diamond	2.42

Exploring Glass Slab Experiment

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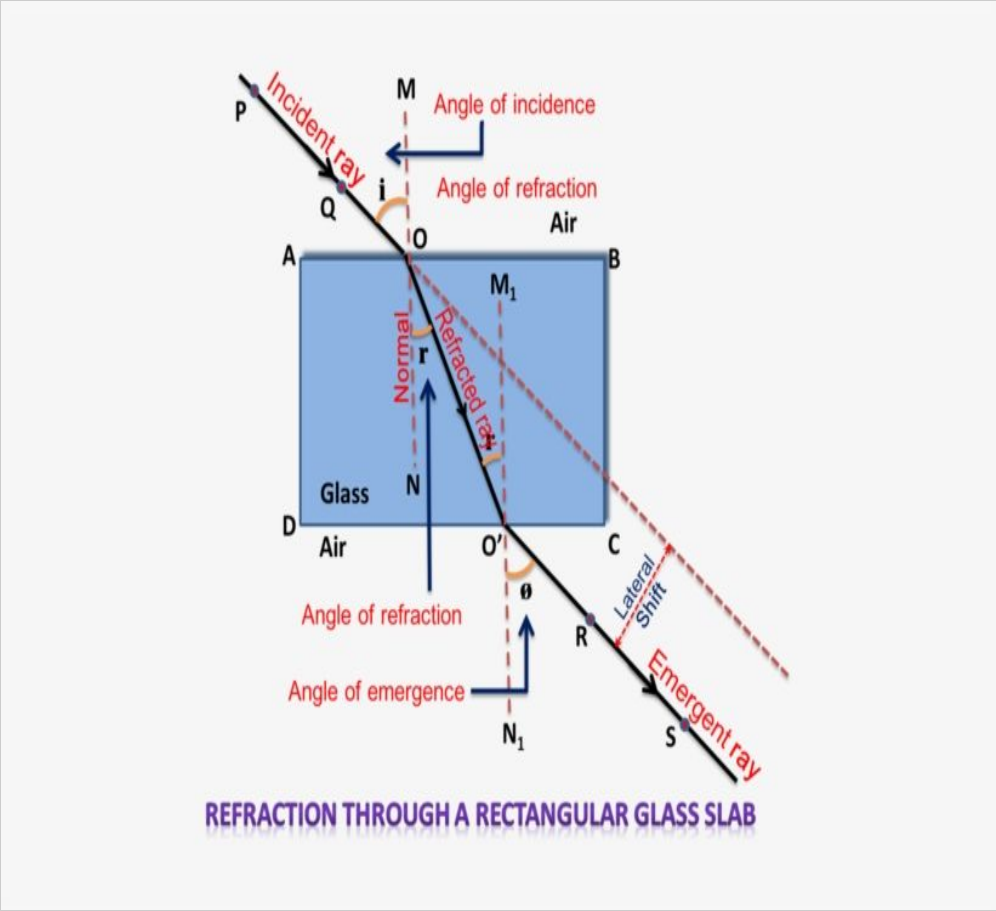
https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html



Atmospheric Refraction

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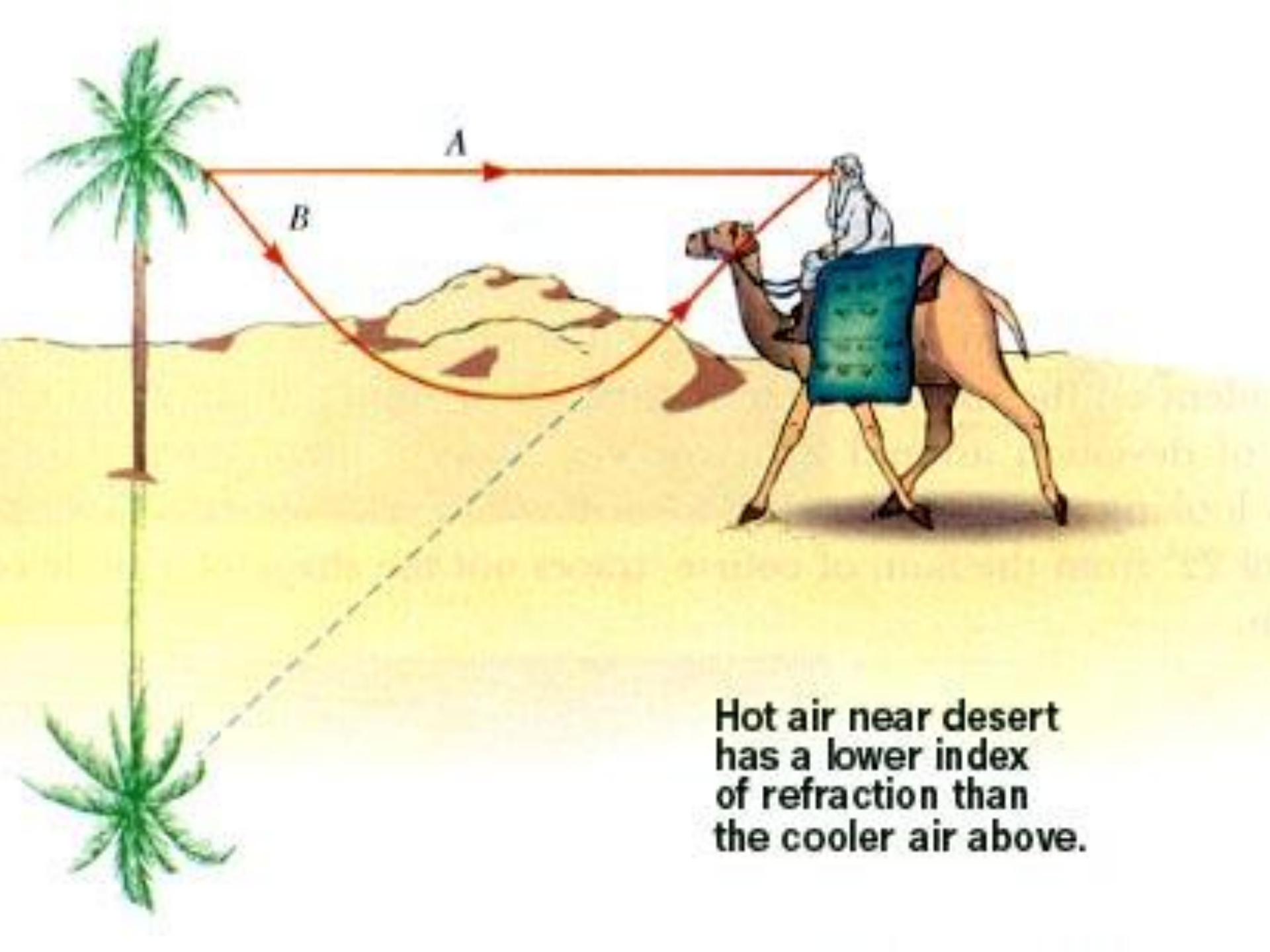
- Mirages, floating images that appear in the distance, are due to the refraction of light in the Earth's atmosphere.
- On hot days, a hot layer of air is in contact with the ground with cooler air above it
- Light travels faster in the hot air
- This increase in speed causes a bending of the light rays
- The image appears upside down to the observer


MIRAGE



Hot air near desert has a lower index of refraction than the cooler air above.

Dispersion of Light

- The splitting of white light into its spectrum that is 7 colours is called dispersion.
- Red light is bent the least, while violet light is bent the most.
- The index of refraction depends on the color, or frequency, of light.
- A rainbow is a natural dispersion of light

Condition for total internal reflection

If a ray of light is passing from optically denser to optically rarer medium is incident at an angle greater than the critical angle, the ray is totally reflected back to denser medium thereby causing Total internal Reflection

Total Internal Reflection

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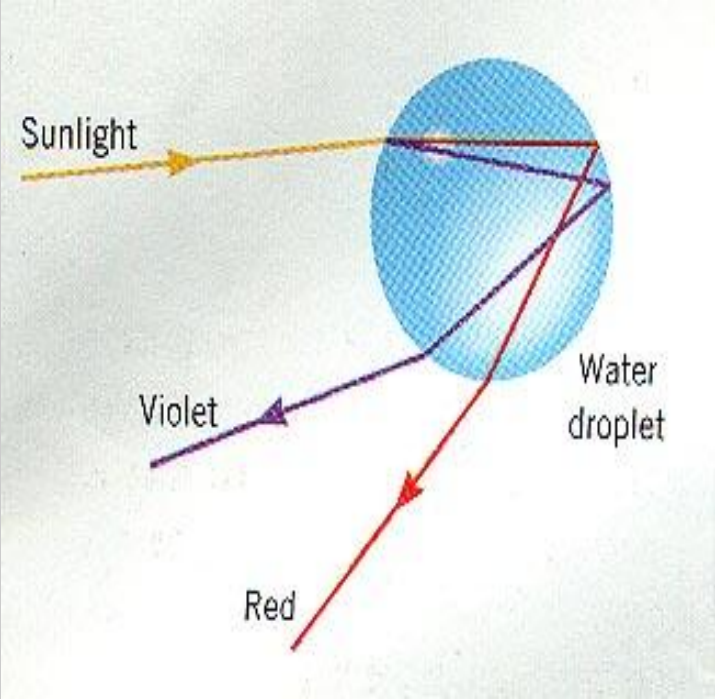
- Remember: a light wave is transporting energy!
- When light hits a boundary some energy is transmitted to the new medium, some energy is reflected.
- Total internal reflection occurs when all light is reflected, and there is no refracted ray
- This can only occur when light travels from a higher density to a lower density

Rainbow formation

https://javalab.org/en/rainbow_formation_en/



(We see the rainbow when the sun is behind the us and water droplets in the front.

The sunlight is a mixture of seven colours,. The atmosphere contains a large number of water droplets after raining stopped.

When sunlight is strike on a water droplet, there is

- refraction and dispersion of light as it passes from air to water
- internal reflection of light inside the droplet and
- refraction of light as it passes from water to air.

(2) The refractive index of water is different for different colours, being maximum for violet and minimum for red. Hence, there is dispersion of light into different colours as it passes from air to water. As shown in Fig

A rainbow is a natural phenomenon caused by, combined effect of refraction, dispersion of light and total internal reflection.

Few important questions

A. What is the reason for the twinkling of stars?

The correct reason for the twinkling of stars is changing refractive index of the atmospheric gases.

We can see the Sun even when it is little below the horizon because of refraction of light.

If the refractive index of glass with respect to air is 3/2, what is the refractive index of air with respect to glass?

Refractive index of air with respect to glass is 2/3.