Unit 2: Refraction

The Bending of light, and to study this phenomenon

Learning Outcomes

Students should be able to:

1. Define and explain the terms refraction of light, angle of incidence, angle of refraction and normal.
2. Define the refractive index, η of a medium in terms of the ratio of the speed of light in vacuum and in the medium and in terms of the ratio of the real depth and the apparent depth.
3. Define the refractive index, η of a medium in terms of the ratio of the sine of the angle of incidence and sine of the angle of refraction ($\eta = \frac{\sin i}{\sin r}$)
4. List some effects and consequences of refraction.
5. Construct ray diagrams through water and glass to show real and apparent depth.

Refraction

We can observe that the pencil seems to be bent.
What causes this effect?

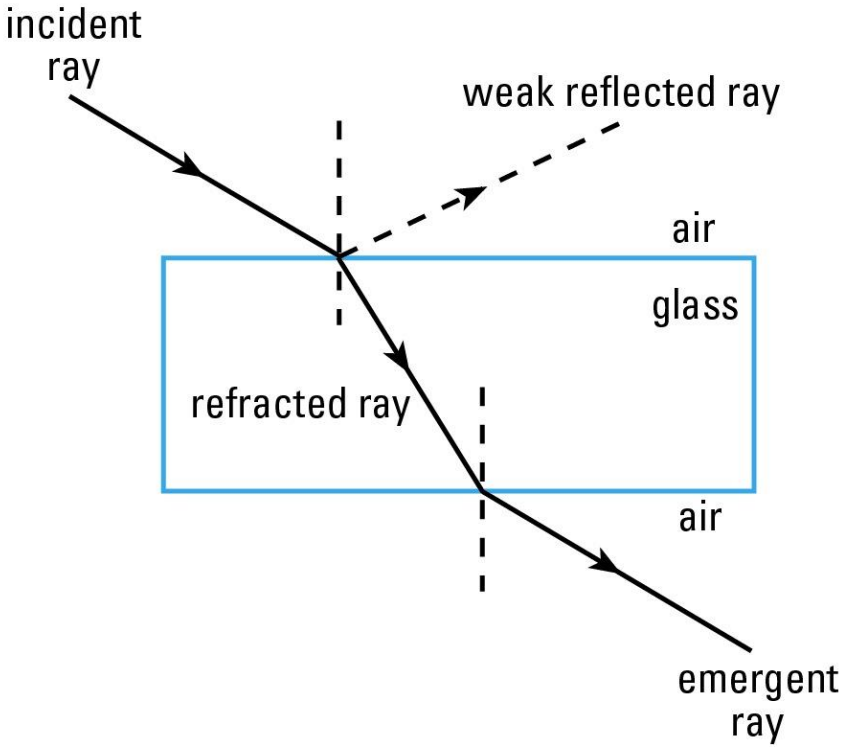
Click for Video

Refraction

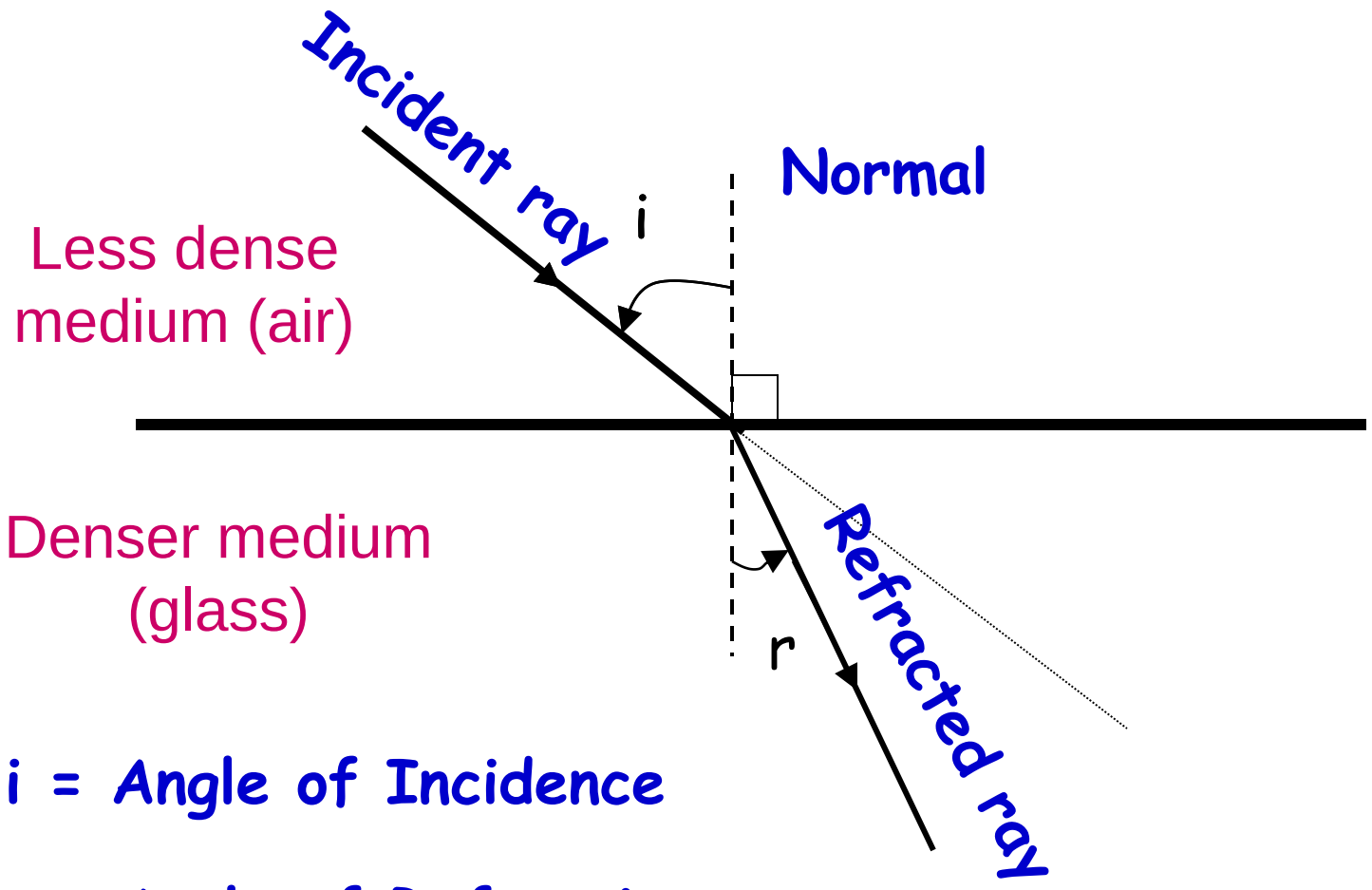
Why do her legs appear shorter?

Refraction

Refraction of light is the bending of light ray as it passes from one medium into another.



Refraction



i = Angle of Incidence

r = Angle of Refraction

Demo

What causes refraction?

- Light travels at different speed in different media.
- For example, in air its speed is 3.0×10^8 m/s, while in glass it is 2.0×10^8 m/s.
- At the boundary of the two media such as air and glass, there is a sudden change in speed of the light. This change in speed causes the path of the light to bend, resulting in **refraction**.

Refractive Index

- Different media (plural form of medium) bends light ray differently.
- The amount of bending depends on the material of the medium itself.
- Each medium has a numerical value attached to it. We call it refractive index.
- When light travels from one medium to another, it undergoes a change of media.
- The higher the difference between these refractive index, the more the light will bend.

Note: The lowest this value can get is 1 (index of air/vacuum)

Refractive Index

The refractive index of a medium, η is defined as the ratio of the speed of light in vacuum and in the medium

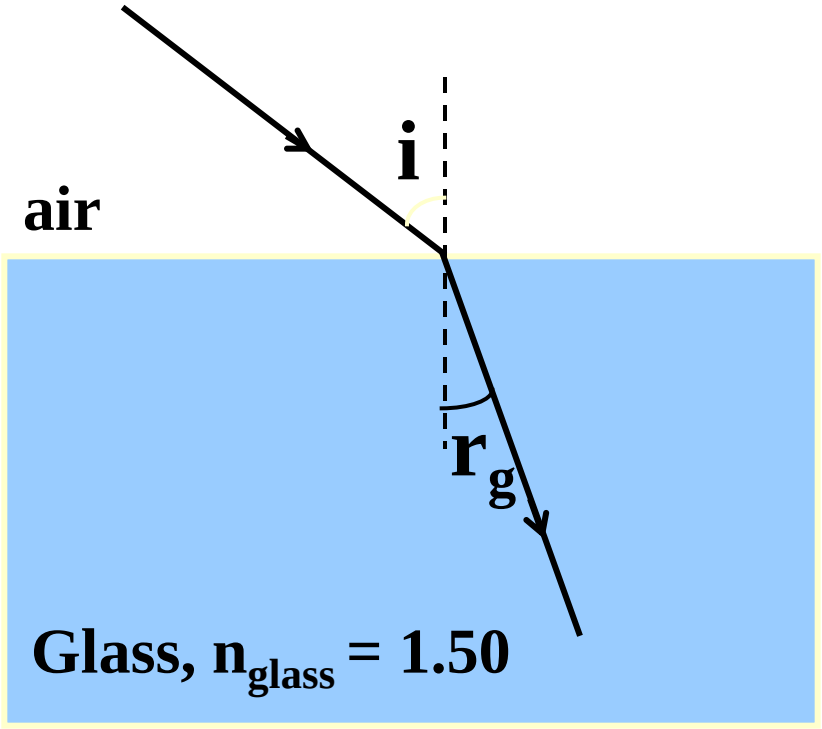
$$\eta = \frac{\text{speed of light in vacuum (or air)}}{\text{speed of light in the medium}} = \frac{c}{v}$$

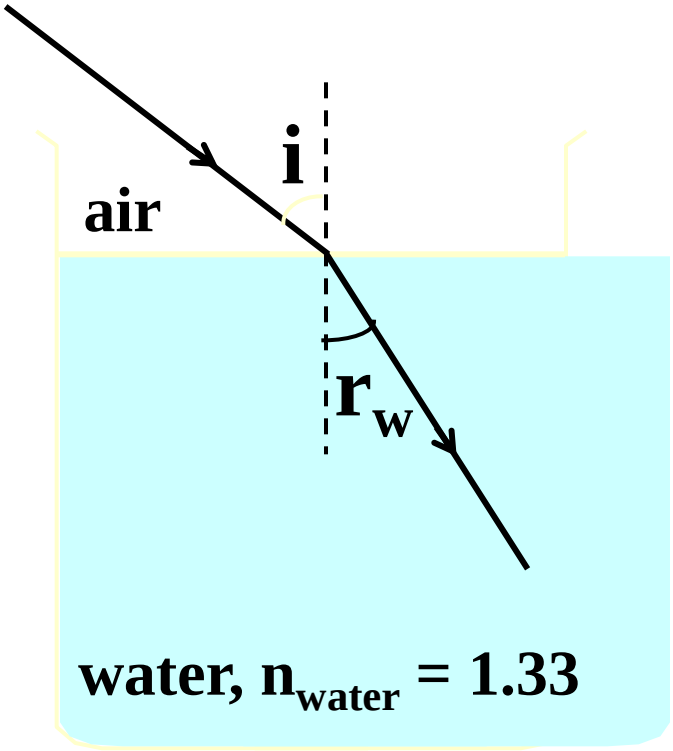
*Note: η is always greater or equal to 1

Test Yourself!

Glass (n_{glass} = 1.50) a higher refractive index than water (n_{water}= 1.33). When a light ray enters glass, it will bend towards the normal more than compared to when it enters water.

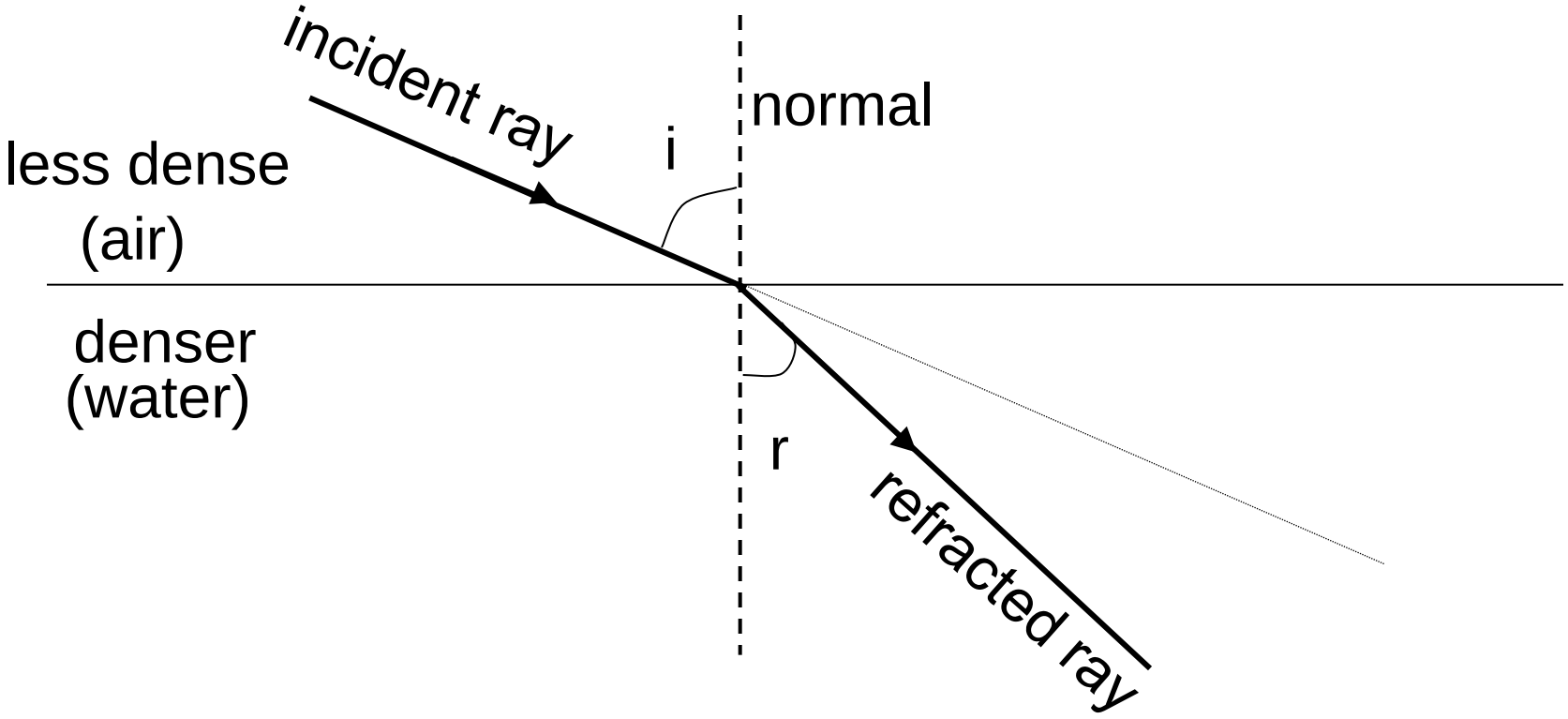
Is this true?





Refraction

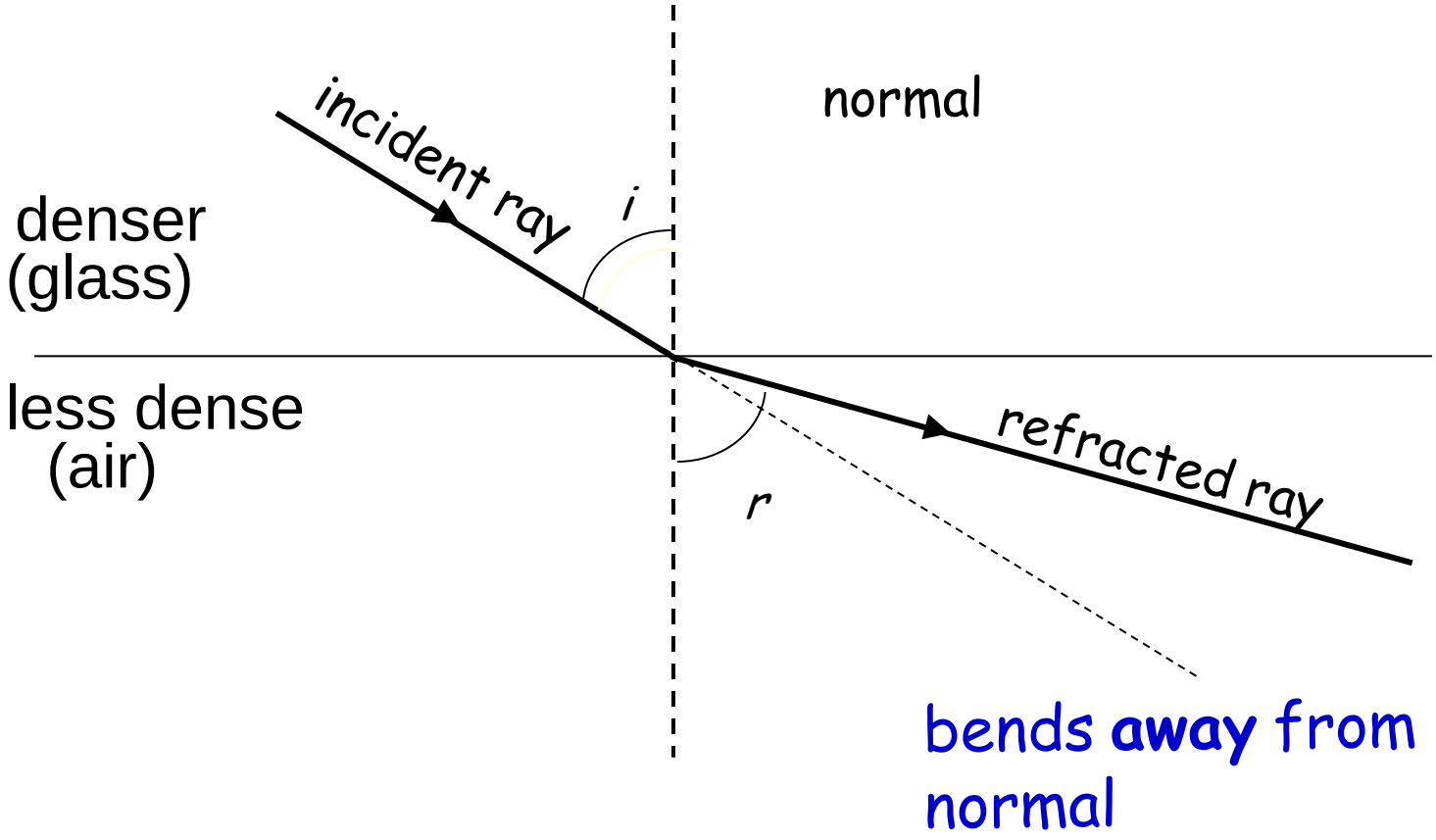
When a ray of light travels from a **less dense to a denser** medium, it **bends towards the normal**



bends towards normal

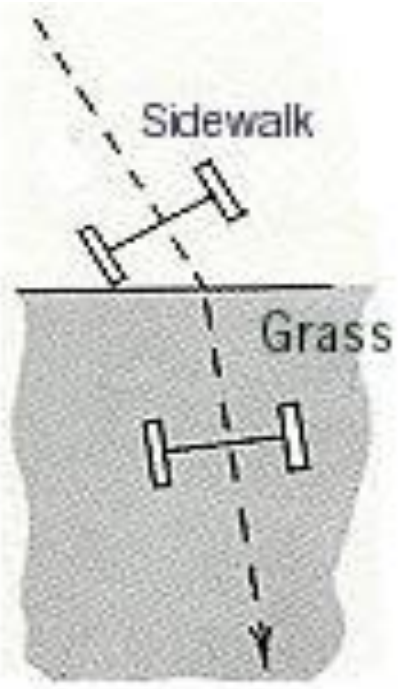
Refraction

When a ray of light travels from a **denser to a less dense** medium, it **bends away from the normal**



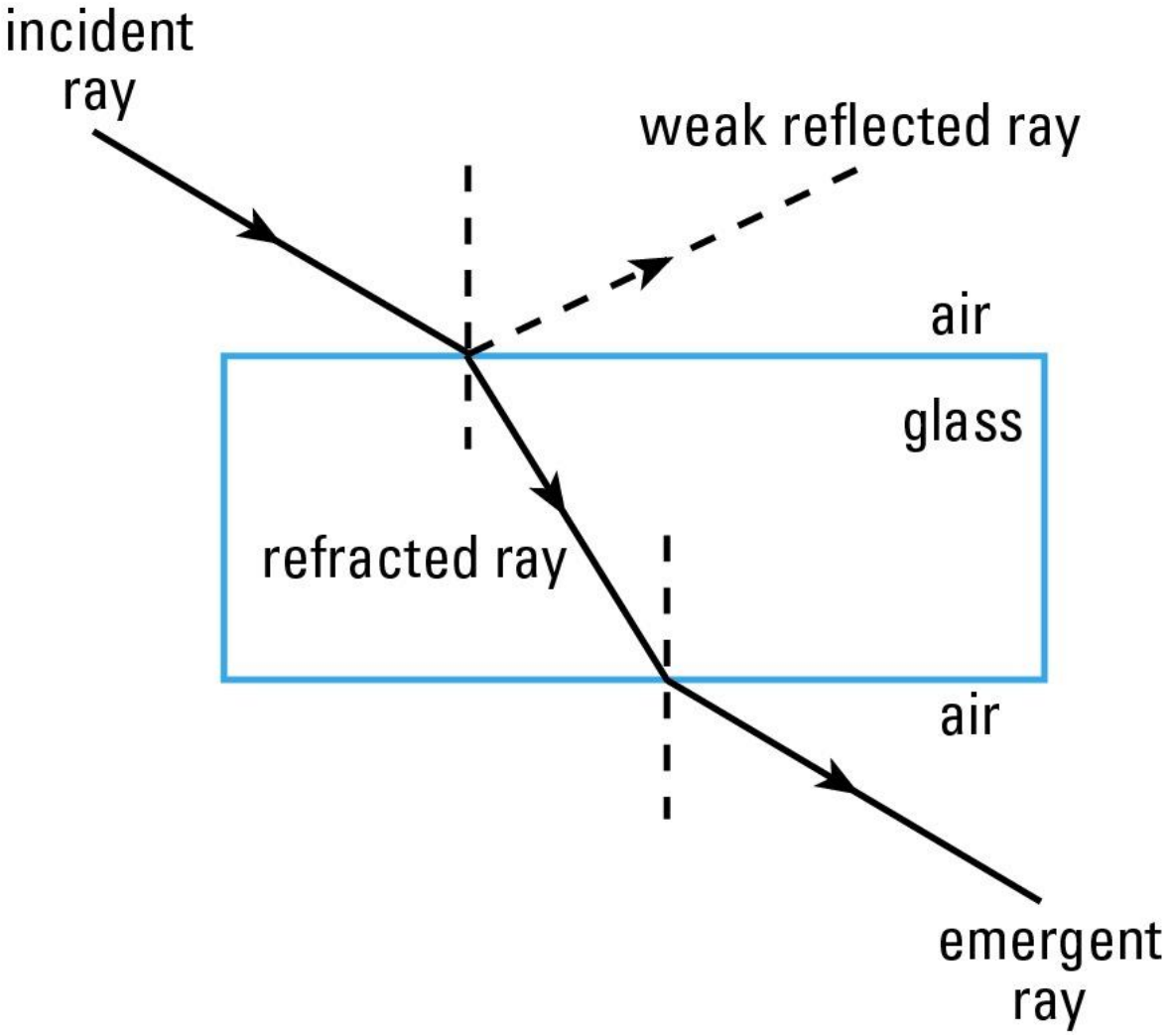
Refraction

When a ray of light travels from a **less dense to a denser** medium, it **bends towards the normal**

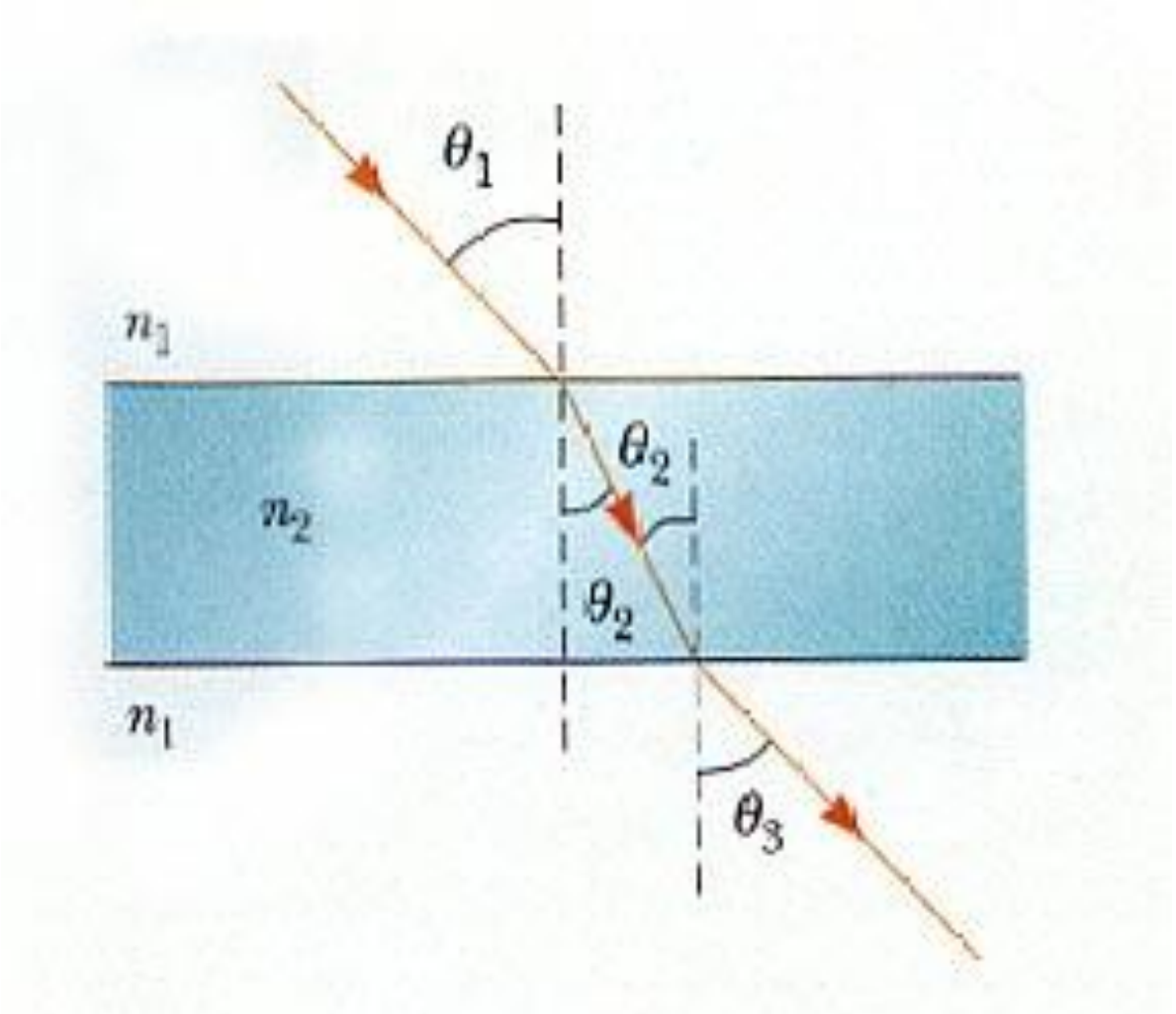


Right front wheel slow down first - bends **towards** normal

Refraction through a glass slab

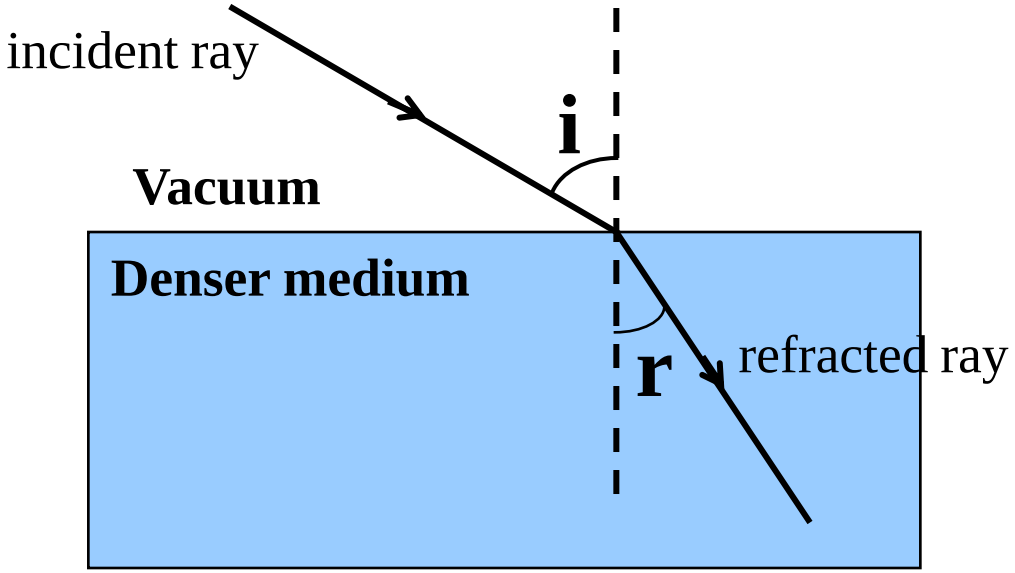


Refraction through a glass slab



Which other angles are equal?

Refractive Index



The refractive index n of a medium is also defined as

$$\eta = \frac{\sin i}{\sin r}$$

when light rays pass from a vacuum into the medium

Refractive Index

Refractive indices of some transparent materials

Medium	Refractive index n	Speed of light ($\times 10^8$ m s^{-1})
Diamond	2.40	1.25
Glass	1.50*	2.00
Perspex	1.50	2.00
Water	1.33	2.25
Ice	1.30	2.30
Air	1.00	3.00

* For glass, the refractive index varies from 1.48 to 1.96, depending on the composition of the glass

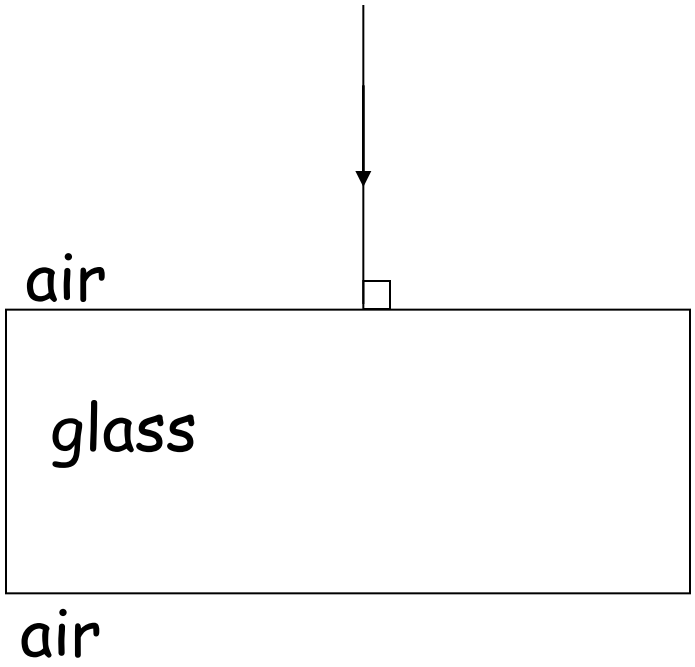
The denser the medium (higher the refractive index), the slower light travels through.

Click for Video

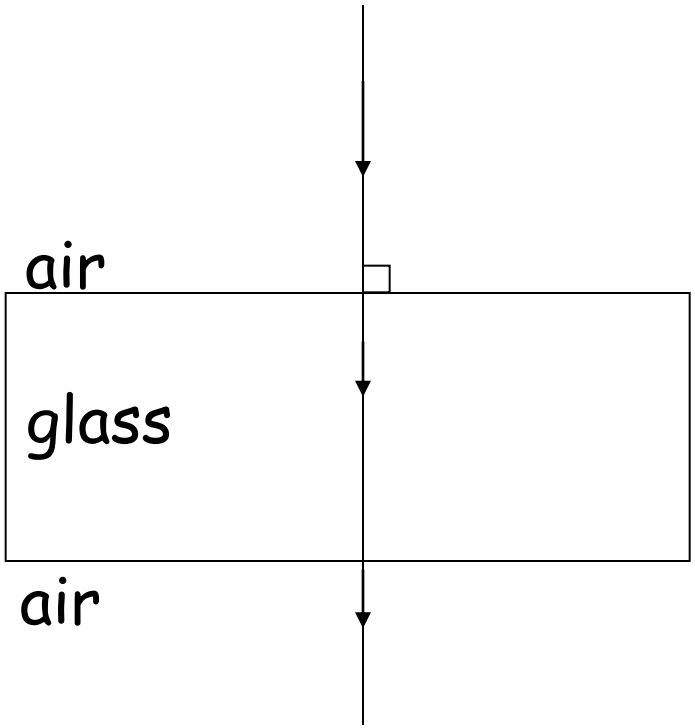
Refraction through a glass slab

What will happen if a ray of light is incident perpendicularly to the surface of the medium (e.g.glass block) ?

What is the angle of incidence?

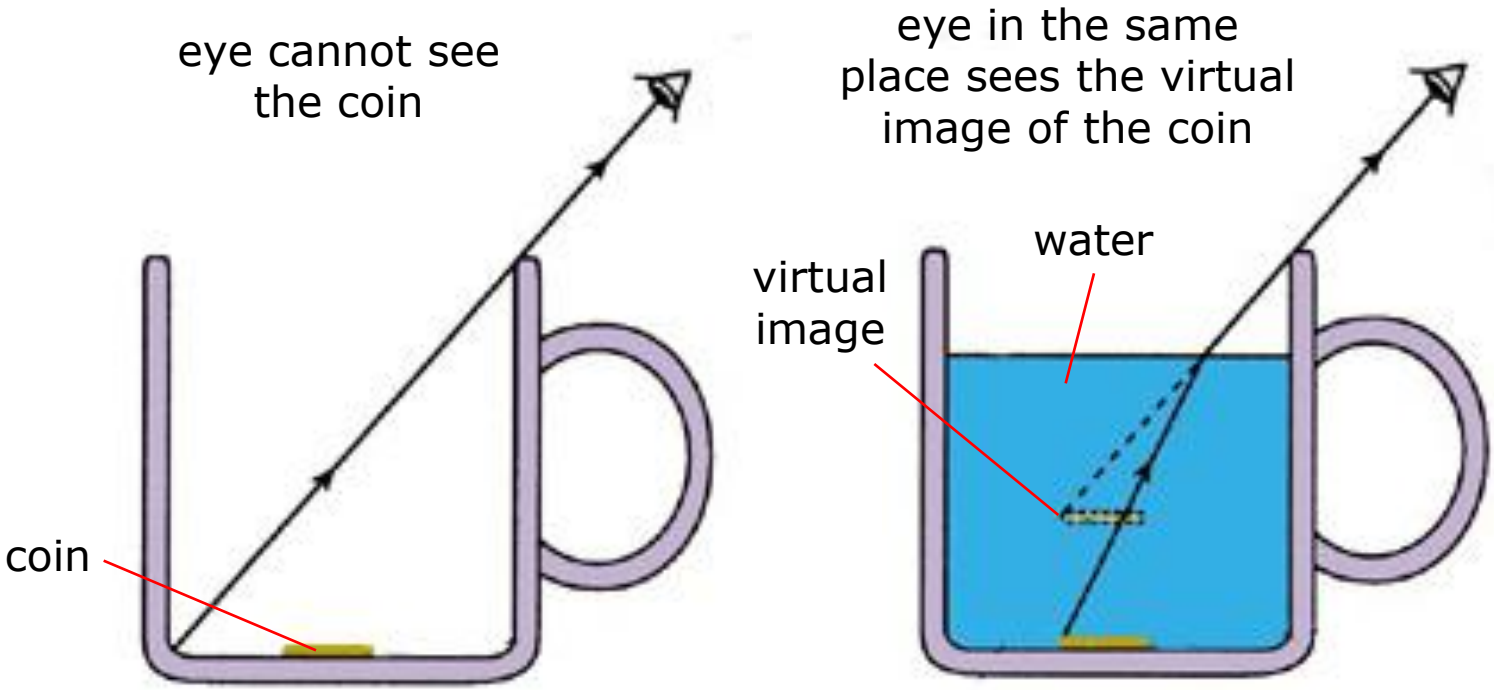


Refraction through a glass slab



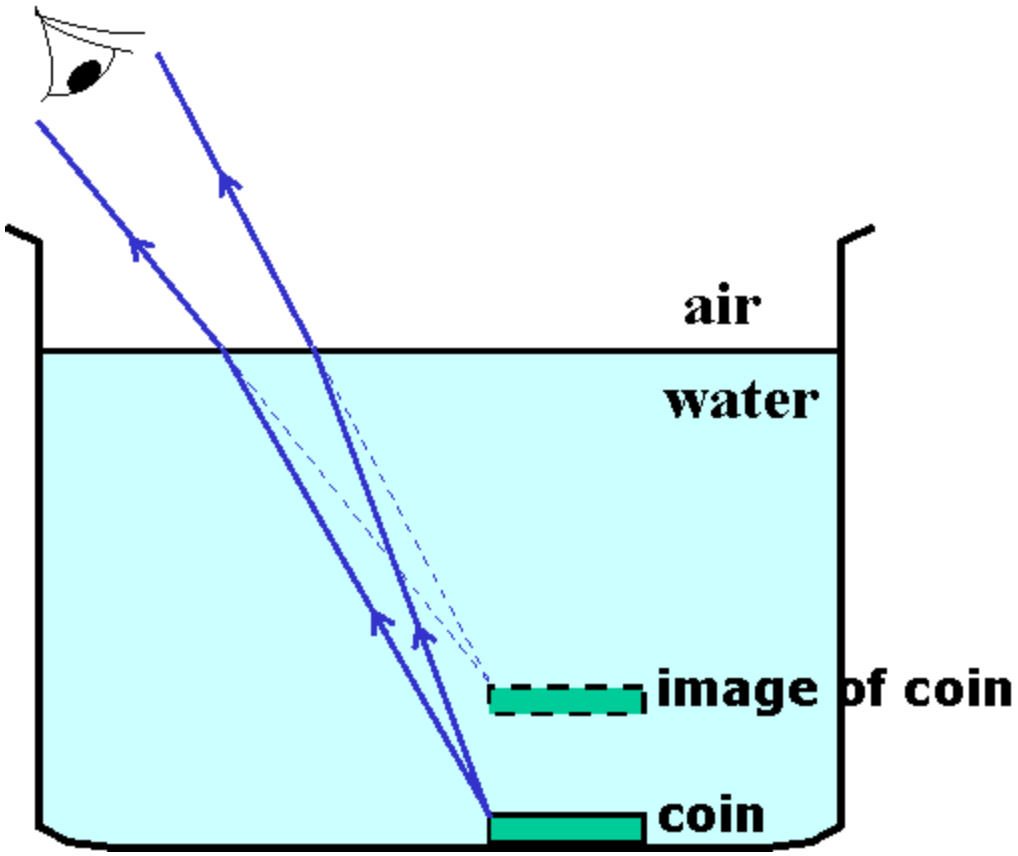
The ray of light will not be refracted.

Refraction



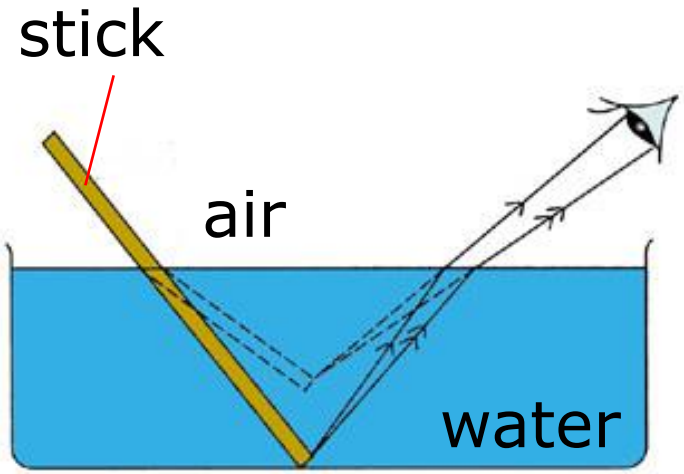
Click for Video

Refraction

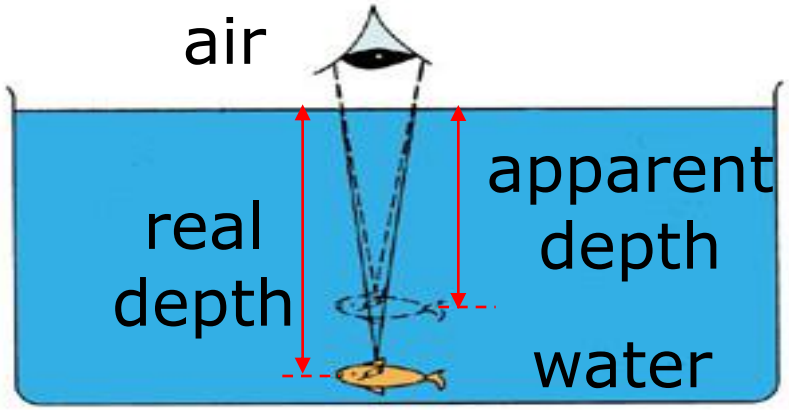


Refraction

eye sees the virtual image of the stick shallower than it actually is



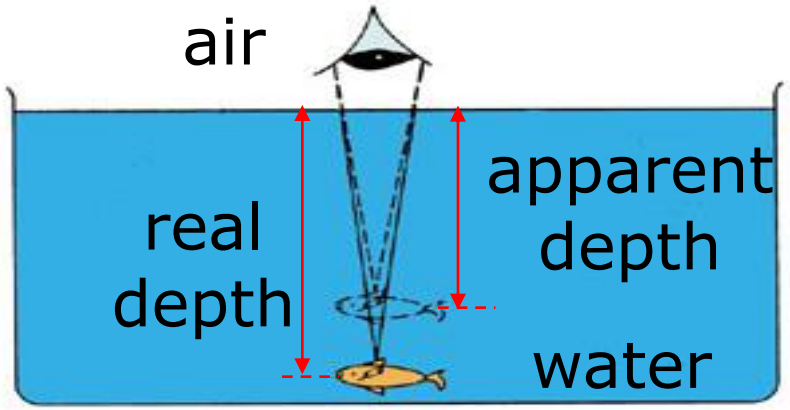
eye sees the virtual image of the fish shallower than it actually is



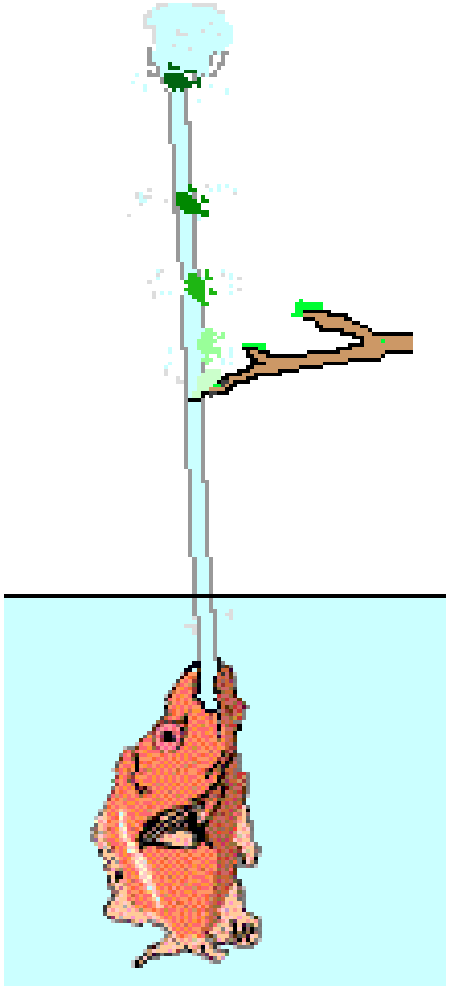
Refractive Index

The refractive index of a medium, η is defined as the ratio of the real depth and the apparent depth

$$\eta = \frac{\text{Real depth}}{\text{Apparent depth}}$$

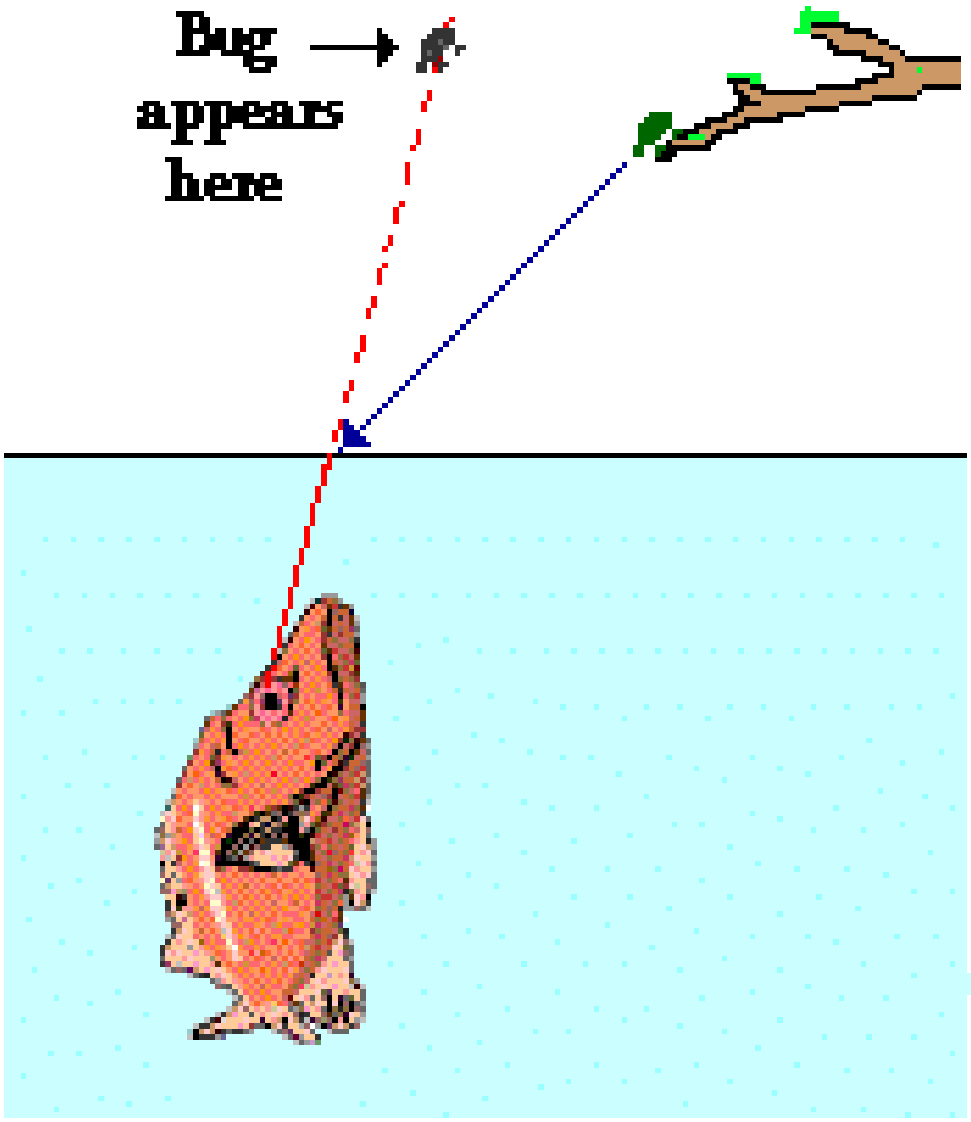


The Secret of the Archer Fish

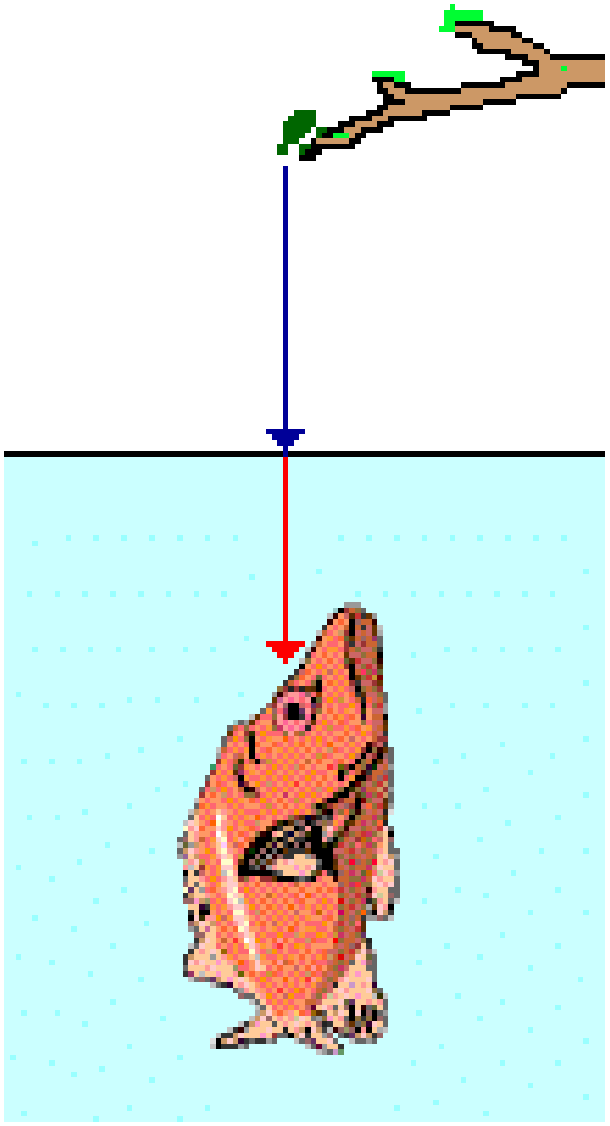


In the quiet waters of the Orient, there is an unusual fish known as the Archer fish. Archer fish finds its prey living outside the water.

The Archer fish will search for prey that is resting upon a branch or twig above the water. The fish then positions itself underneath the prey and with pinpoint accuracy knocks the prey off the branch using a powerful jet of water.



Refraction occurs when sighting at an angle to the normal; the bug appears to be located where it isn't.



Refraction does not occur when sighting along the normal to the surface.

Resources

http://www3.moe.edu.sg/edsoftware/ir/files/physics-refraction/index.htm

http://www.upscale.utoronto.ca/PVB/Harrison/Flash/Optics/Refraction/Refraction.html

http://www.youtube.com/watch?v=fhBZ40jIo4Q (archer fish)

http://groups.physics.umn.edu/demo/optics/6A4030.html (vanishing beaker)