6. Refraction and Dispersion

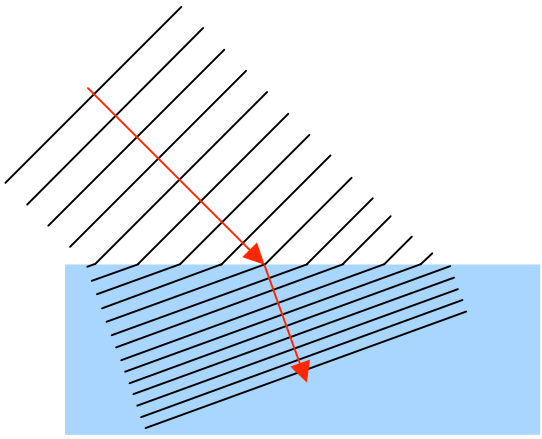
	6. Refraction and Dispersion	Refraction Refraction - Ray/Particle Approach Refraction – Wave Approach	Pg 36 Pg 37 Pg 37-38	Pg 46 1, 2, 5 Pg 46 3
		Law of Refraction Index of Refraction / Snell's Law	Pg 40-41 Pg 41-42	Pg 46 6, 7, 8, 9, 10
		Apparent Depth Mirages Refraction in the Atmosphere Dispersion	Pg 38 Pg 45 Pg 44 Pg 65-66	Pg 46 4a Pg 46 4b Pg 69 1, 3, 5, 6, 7, 8, 9

Refraction of Light Waves

Light travels at different speeds in different materials. In a vacuum, it travels at 3 x 10^8 m/s. In other transparent materials it travels slower.

This reduction in speed causes the wavefront in the material to lag behind the wavefront outside the material. This causes the direction of the wavefront to change as shown in the diagram.

This bending of the wave is called **refraction** is as it passes from one material to another.



Refractive Index

The refractive index $n = \frac{c}{v}$ is equal to the speed of light in a vacuum (c) divided by the speed of light in the material

It is used to compare speeds with the speed of light in a vacuum.
The table below shows the speed of light in different mediums and the refractive index in these materials, using a wavelength of 589nm and a temperature of 20^0.

Medium	Speed of light (ms^{-1})	Absolute refractive index
Vacuum	3.0×10^8	1.00000
Air	3.0×10^8	1.000293
Water	2.25×10^8	1.333
Silica	2.0×10^8	1.458
Glycerine	2.0×10^8	1.473
Diamond	1.24×10^8	2.419

A refractive index of 2 means that light travels twice as slowly in that material as it does in a vacuum.

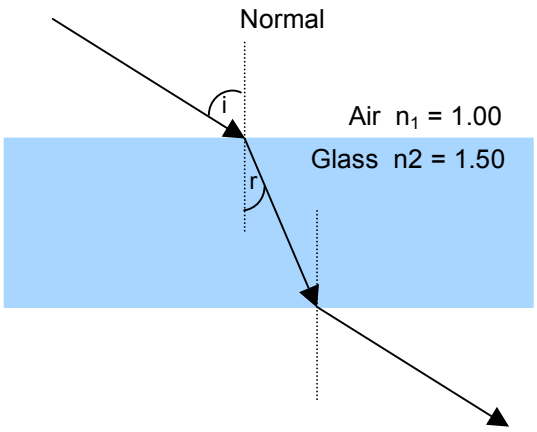
Questions

Which has a higher refractive index – water or air?

The speed of light in perspex is 2.0×10^8 m s^{-1}. Calculate the refractive index of perspex, given that the speed of light in a vacuum is 3.00×10^8 m s^{-1}.

The refractive index of a particular medium is 1.36. Calculate the speed of light in the medium given that the speed of light in a vacuum is 3.00×10^8 m s^{-1}.

Refraction of Light Rays – Snell's Law



Light waves can be simplified as single rays.
The change of direction depends on the initial angle, and the two refractive indices

The larger the change in speed, the large the amount of refraction (a large bend occurs)

We say that a material is optically denser if it has a higher absolute refractive index. Optical density and density are not related.

The amount of refraction can be determined using Snell's Law.

$n_1 \sin i = n_2 \sin r$

or $\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2}$

v_1 = speed of light in medium 1,
v_2 = speed of light in medium 2,
n_1 = absolute refractive index of medium 1
n_2 = absolute refractive index of medium 2

Questions

When light speeds up, does it move towards or away from the normal?

Light moves from water (refractive index of 1.33) to air (refractive index of 1.00). It strikes the surface perpendicular (at an angle of 90º). At what angle does the light come out of the water?

The refractive index of Material A is 1.4. A ray hits the surface at an angle of 30^0 and refracts at an angle of 47^0. Calculate the refractive index for Material B.

The refractive indices for crown glass and alcohol are 1.52 and 1.36 respectively.
A ray of light passes from alcohol to crown glass. If the angle of incidence is 50º, calculate the angle of refraction.

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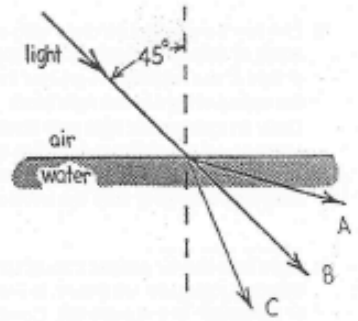
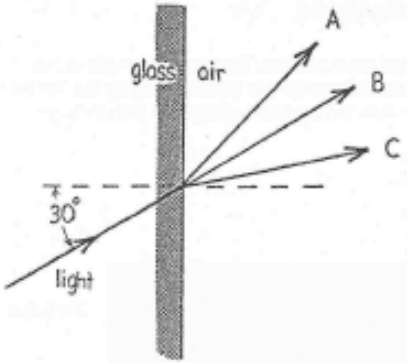
Chapter 28 Reflection and Refraction

More Refraction

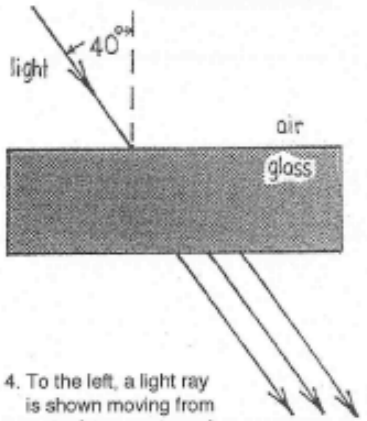
1. The sketch to the right shows a light ray moving from air into water, at 45° to the normal. Which of the three rays indicated with capital letters is most likely the light ray that continues inside the water?

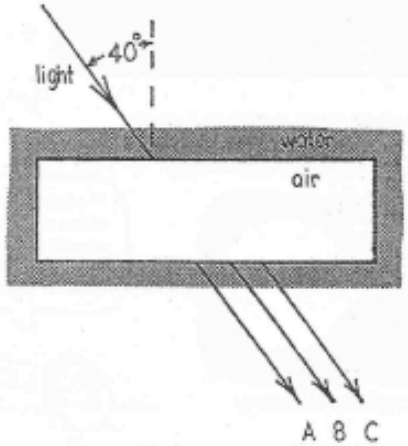




2. The sketch on the left shows a light ray moving from glass into air, at 30° to the normal. Which of the three is most likely the light ray that continues in the air?

3. To the right, a light ray is shown moving from air into a glass block, at 40° to the normal. Which of the three rays is most likely the light ray that travels in the air after emerging from the opposite side of the block? (Sketch the path the light would take inside the glass.)





4. To the left, a light ray is shown moving from water into a rectangular block of air (inside a thin-walled plastic box), at 40° to the normal. Which of the rays is most likely the light ray that continues into the water on the opposite side of the block?

Sketch the path the light would take inside the air.

thanx to Clarence Bakken

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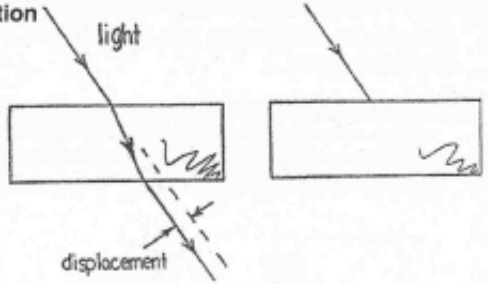
Chapter 28 Reflection and Refraction

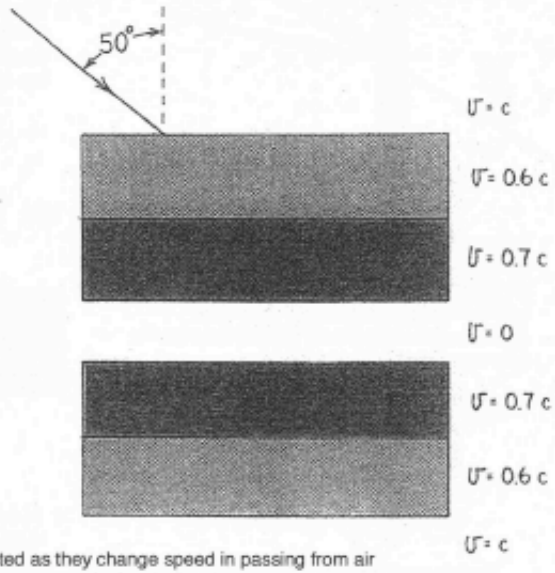
More Refraction*—*continued

5. The two transparent blocks (right) are made of different materials. The speed of light in the left block is greater than the speed of light in the right block. Draw an appropriate light path through and beyond the right block. Is the light that emerges displaced more or less than light emerging from the left block?

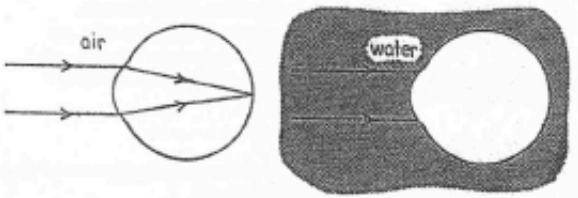


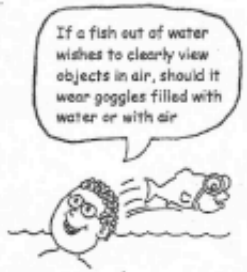
6. Light from the air passes through plates of glass and plastic below. The speeds of light in the different materials are shown to the right (these different speeds are often implied by the "index of refraction" of the material). Construct a rough sketch showing an appropriate path through the system of four plates.

Compared to the 50° incident ray at the top, what can you say about the angles of the ray in the air between and below the block pairs?



7. Parallel rays of light are refracted as they change speed in passing from air into the eye (left below). Construct a rough sketch showing appropriate light paths when parallel light under water meets the same eye (right below).





8. Why do we need to wear a face mask or goggles to see clearly when under water?

Colours have different Refractive Indices

In a vacuum, all wavelengths of light (visible and non-visible) travel at the same speed. In air, all colours approximately travel at the same speed.

However, for other transparent materials, different colours slow down by different amounts. The refractive index of a material is actually an average refractive index for that material. This is because the

refractive index of a material depends on the wavelength of light travelling through the material

For example the refractive index of silica ranges from 1.55 for light at a wavelength of 200nm, to 1.46 for light at 700nm. This is a large difference in speed and therefore a large difference in the angle of refraction.

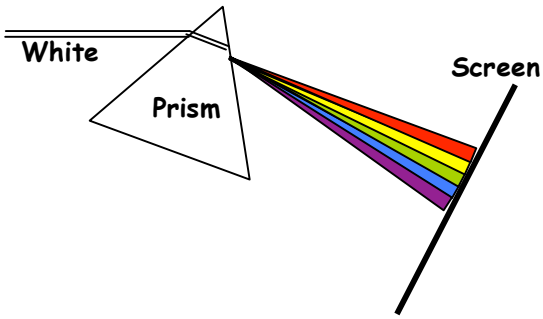
Questions

Based on this information, which is faster in silica, red light or blue light?

Dispersion

When white light is passed through transparent materials, it tends to separate into its constituent colours. This process is known as dispersion.

Dispersion occurs because different colours change speed by different amounts as they change medium, and as a result refract at different angles.



Questions

Consider the diagram to the right. Red has refracted the least amount, whilst blue has refracted much more. Explain why this has occurred.

Which has the higher refractive index – yellow light or green light?

As it moves from water to air, will yellow light move towards or away from the normal?

Which light will bend by a greater amount – yellow or green?

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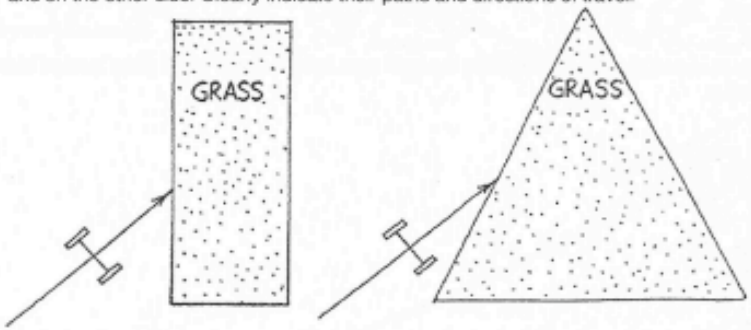
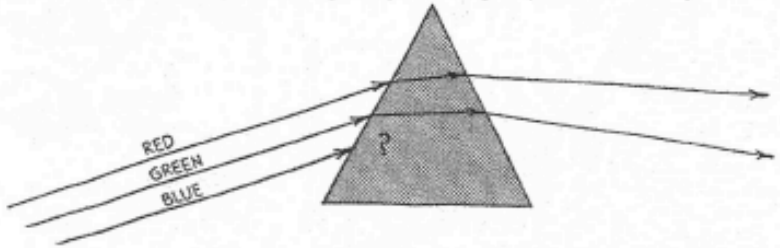
Chapter 28 Reflection and Refraction

Refraction

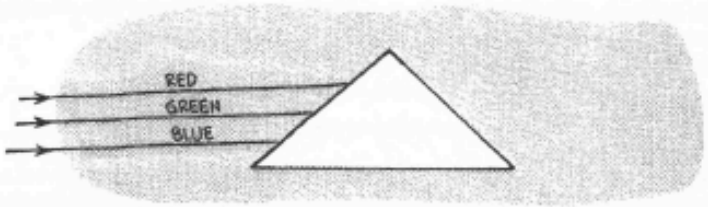
1. A pair of toy cart wheels are rolled obliquely from a smooth surface onto two plots of grass—a rectangular plot on the left, and a triangular plot on the right. The ground is on a slight incline so that after slowing down in the grass, the wheels speed up again when emerging on the smooth surface. Finish each sketch and show some positions of the wheels inside the plots and on the other side. Clearly indicate their paths and directions of travel.



2. Red, green, and blue rays of light are incident upon a glass prism as shown below. The average speed of red light in the glass is less than in air, so the red ray is refracted. When it emerges into the air it regains its original speed and travels in the direction shown. Green light takes longer to get through the glass. Because of its slower speed it is refracted as shown. Blue light travels even slower in glass. Complete the diagram by estimating the path of the blue ray.



3. Below we consider a prism-shaped hole in a piece of glass—that is, an "air prism." Complete the diagram, showing likely paths of the beams of red, green, and blue light as they pass through this "prism" and then into glass.



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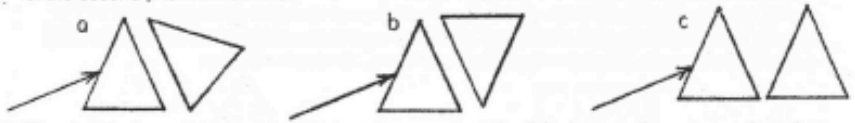
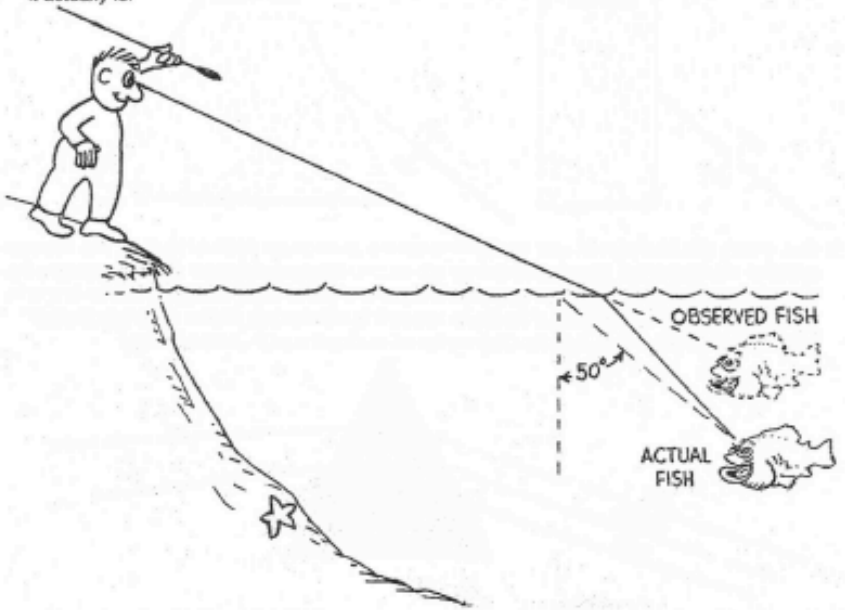
Chapter 28 Reflection and Refraction

Refraction*—*continued

4. Light of different colors diverges when emerging from a prism. Newton showed that with a second prism he could make the diverging beams become parallel again. Which placement of the second prism will do this?



5. The sketch shows that due to refraction, the man sees the fish closer to the water surface than it actually is.



a. Draw a ray beginning at the fish's eye to show the line of sight of the fish when it looks upward at 50° to the normal at the water surface. Draw the direction of the ray after it meets the surface of water.

b. At the 50° angle, does the fish see the man, or does it see the reflected view of the starfish at the bottom of the pond? Explain.

_____

c. To see the man, should the fish look higher or lower than the 50° path? _____

d. If the fish's eye were barely above the water surface, it would see the world above in a 180° view, horizon to horizon. The fisheye view of the world above as seen beneath the water, however, is very different. Due to the 48° critical angle of water, the fish sees a normally 180° horizon-to-horizon view compressed within an angle of _____.