Ch. 22
Properties of Light

Brief History of the Nature of Light

Up until 19th century light was modeled as a stream of particles.

Newton was a proponent of this theory that provided simple explanations for reflection and refraction.

In the 1600s, Huygens showed that a wave theory of light would also explain these phenomenon.

This theory was not as widely accepted.

Other waves needed a medium to travel through, but light could travel through space.

Also light would diffract since waves diffract.
(This turns out to be true but was hard to show at the time.)

In 1801, Thomas Young showed that light traveling along two different paths produced interference patterns. This could not be explained by the particle theory.

This can be observed performing the “double slit” experiment.

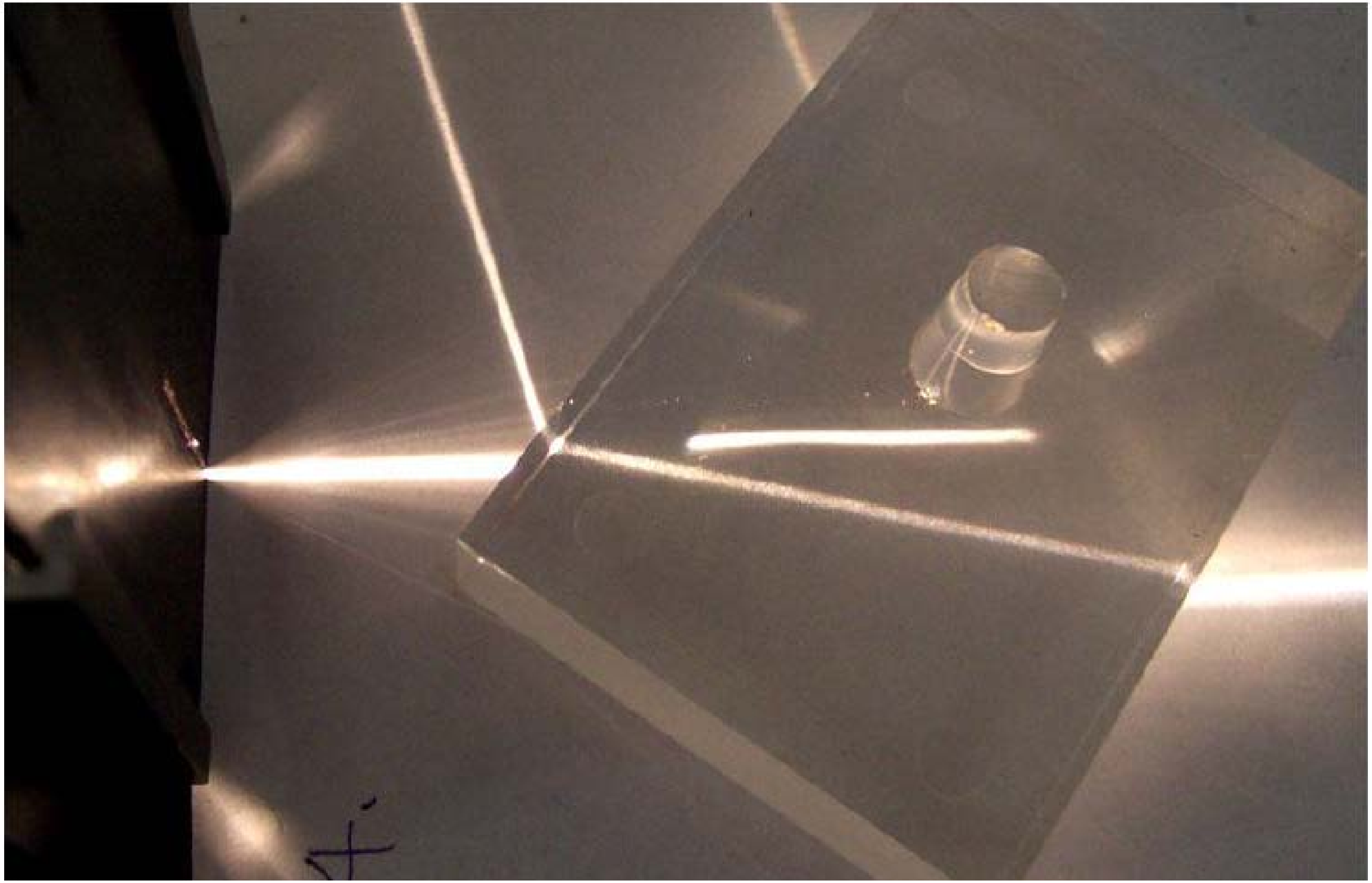
Also light does diffract – which is a wave property.

It turns out that light has some behaviors of light can be explained by treating light as particles, while other behaviors are wave properties.

Model light as a ray traveling in the direction of the light beam. When light rays travel in parallel paths, a wave front in the shape of a plane is produced (figure 22.1).

Light travels in a straight-line path in a homogeneous medium, until it encounters a boundary between two different materials.

When the light hits the boundary, it either is reflected from the boundary, passes into the medium on other side of boundary, or **partially does both**.



When light encounters a boundary, part of the incident beam is reflected back into the first medium.

Reflection from a **smooth surface** is called **specular reflection**. The **reflected rays are parallel** to each other.

Reflection from a **rough surface** produces **diffuse reflection**. The **rays reflect in many directions**.

A surface is **smooth** if variations of the surface are small compared to the wavelength of the incident light. (fig. 22.2-22.3)

Reflection

Draw a line perpendicularly to the boundary.
We call this the normal line.

We measure the angles of incidence and reflection as the angle between the beam of light and the normal line.

Law of reflection: The angle of reflection equals the angle of incidence.

$$\theta_i=\theta_r \qquad \text{or } \theta=\theta'$$

See fig. 22.4

Refraction

This is what happens to light that crosses the boundary between mediums when there is a nonzero angle of incidence.

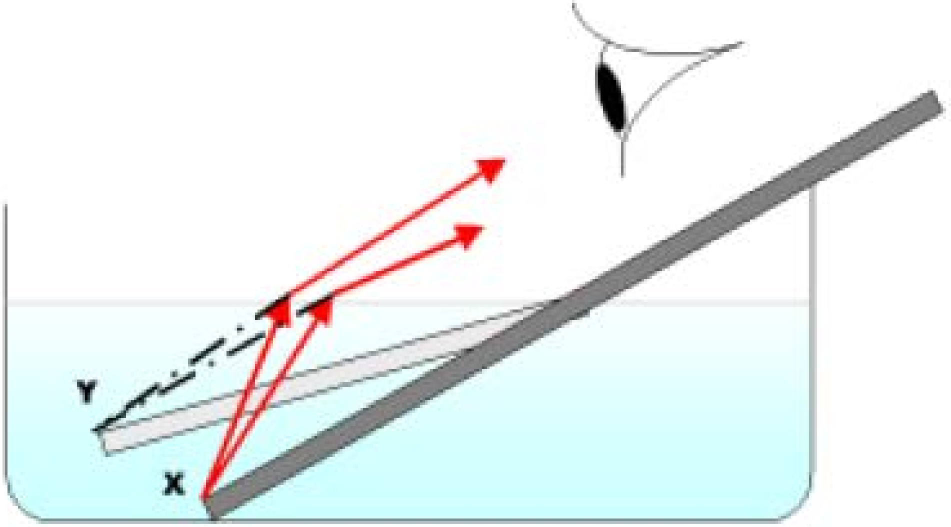
Examples: Light entering a glass block.

Light traveling from below water surface to above.

When light goes from one medium to another, the light can bend.

It will bend as long as it does not hit the boundary at an angle perpendicular to the surface.

Figures 22.6, 22.7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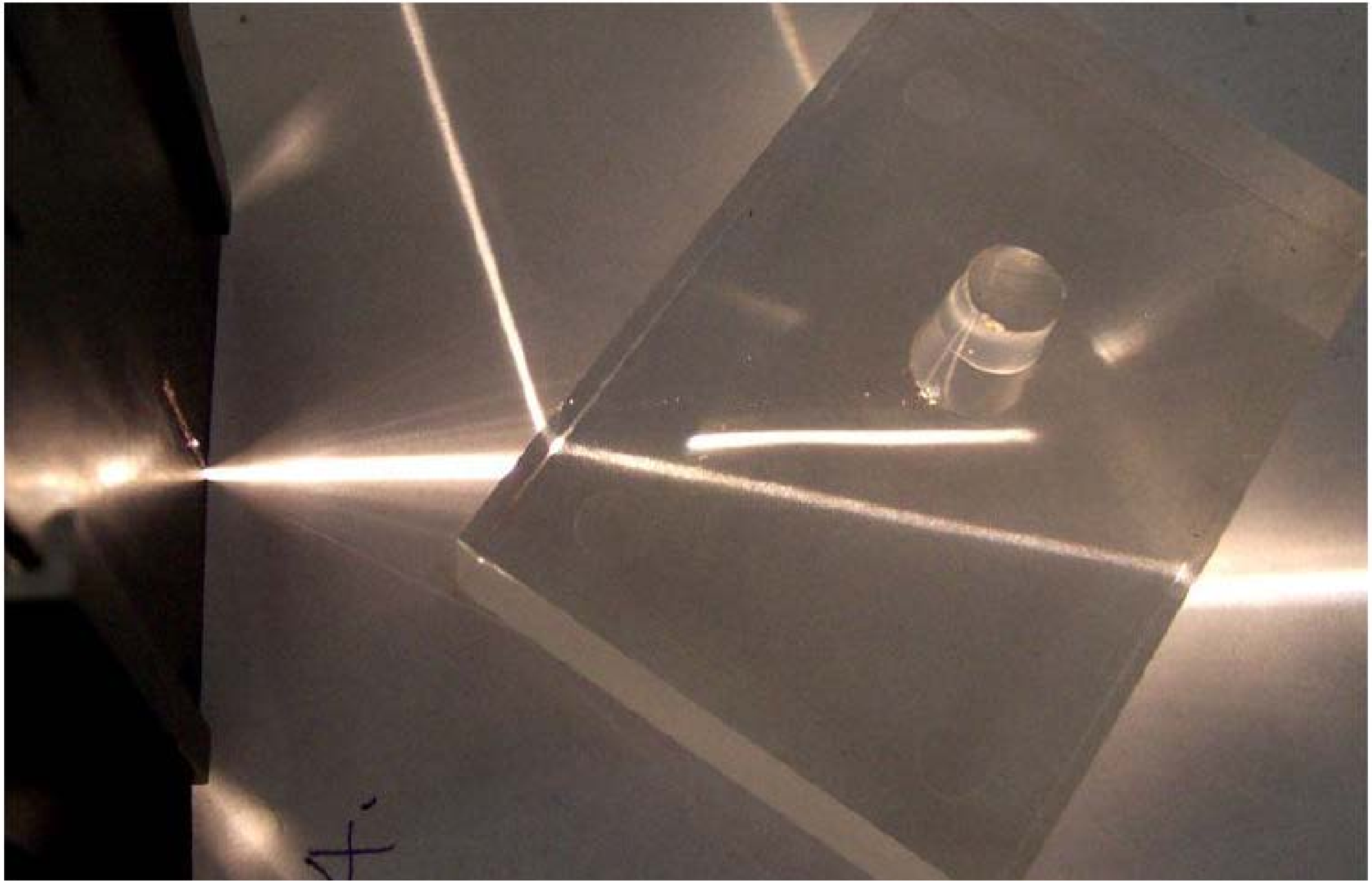

Refraction

Index of refraction: Defines the different mediums that light travels through. Different materials have different indices of refraction.

The index of refraction of a medium is defined as the ratio of the speed of light in vacuum to the speed of light in the medium.

$n = c/v$

c = speed of light in vacuum = 3×10^8 m/s

Because **v is equal to or less than c** …

… **n is always equal to greater than 1**.

Index of Refraction

vacuum n = 1

air n = 1.000293 Pretty accurate to just use 1.

Table 22.1 shows indices or refraction for different materials.

Light is a wave so light can be described via its frequency.

As light travels from one medium to another, the frequency of the light does not change.

For the speed to change, the wavelength has to change.

Figure 22.8

Frequency is constant:

$v_1 = f\,\lambda_1$ and $v_2 = f\,\lambda_2$

Solving for frequency and setting them equal to each other results in:

$v_1/\lambda_1 = v_2/\lambda_2$

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1}$$

$$\lambda_1 n_1 = \lambda_2 n_2$$

Instead of using the ratio of speeds, we can also define the index of refraction as the ratio of the wavelength in vacuum to the wavelength in the medium.

$n = \lambda_0/\lambda_n$

Snell's law of refraction. Used to relate angle of incidence to angle of refraction.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

If light goes from higher n to lower n, the light bends away from the normal.

If light goes from lower n to higher n, the light bends closer to the normal.

see figures 22.9 and 22.10

When light travels through a slab (with parallel sides) of material of index ‘n’ that varies from the surroundings, light refracts at both boundaries.

The result is the path of the light is shifted to the side.

see example 22.2

Dispersion and Prisms

Dispersion – The index of refraction depends on the wavelength of the light.

White light is made up of all the colors of the visible spectrum.

The colors of the spectrum each have their wavelength. Therefore, different colors refract more than others.

figures 22.13, 22.14, 22.15

This will have a consequence in future chapters (chromatic aberration)

When white light enters a prism, the different colors get refracted (bent) by different angles. Thus the prism splits up the white light into the different colors.

figures 22.14, 22.15

Rainbows are a result of dispersion. Drops of water take the place of the prism.

See fig. 22.20.

Huygens' Principle

This is a geometric method of describing reflection and refraction.

Uses the wave nature of light.

Determines the shape of a new wave front from a previous wave front from an earlier time.

Start by treating each point on a given wave front as a source of a new spherical wave. (This gives us wavelets.)

The new wave front will be tangent to the wavelets.

Figure 22.22

You can observe Huygens’ Principle with ocean waves.

If you have a barrier off the coast, you can see plane ocean waves before hitting the barrier.

After passing through any gaps, the ocean waves form circular wave fronts.

The gaps behave as sources for the circular waves (wavelets).

Total internal reflection

Can occur when light goes from medium with higher index of refraction to medium with lower index of refraction.

When the angle of incidence is past a critical value, all the light will be reflected.

The rays will obey the law of reflection.

To find the critical angle set the angle of refraction to 90^0.

When total internal reflection occurs, the angle of refraction found by Snell's Law is 90 degrees.

$$n_1 \sin \theta_c = n_2 \sin 90$$

$$\sin \theta_c = n_2/n_1 \qquad \text{for } n_1 > n_2$$

figures 22.24, 22.25

Example 22.6

http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Refraction/Refraction-Interactive

http://www.reading.ac.uk/virtualexperiments/ves/tir.html

Fiber Optics

These use total internal reflection to carry light from one location to another while losing very little intensity.

Used to “bend” light around corners.

figures 22.28 and 22.29

Applications: shining light around tight corners
looking inside of people
telecommunications