REVISION: REFRACTION 29 APRIL 2014

Lesson Description

In this lesson we:

- Revise how to solve refraction problems

Summary

Important Facts about Light

Light travels in straight lines, which explains why we can't see around corners!

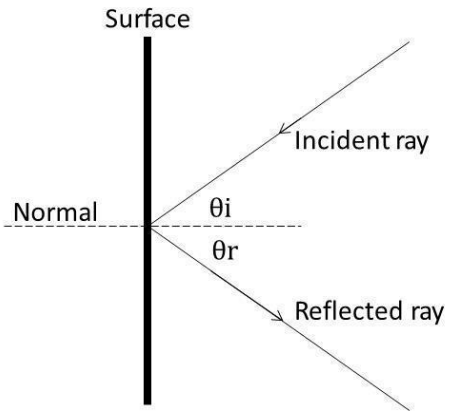
As far as we know nothing travels faster than light. The speed of light is represented by the symbol c, where c = $3 \times 10^8 \text{m.s}^{-1}$in a vacuum. The speed of light in air is approximately equal to c

Reflection of Light

When light shines on a shiny surface such a mirror, the light is reflected back, away from the surface. This reflection is occurs in a regular, specific way.

Important Terminology

- The **normal** is an imaginary line perpendicular (at 90^o) to the surface. All angles are measured from the normal.
- The **incident ray** is the original light ray
- The **reflected ray** is the ray that is reflected off the surface.
- **Θ_i** is the **angle of incidence**. It is the angle between the normal the incident light ray
- **Θ_r** is the **angle of reflection**. It is the angle between the normal the reflected light ray



Laws of Reflection

1. The incident ray, the reflected ray and the normal are all in the same plane
2. The angle of incidence is equal to the angle of reflection.

Refraction of Light

When light shines on a transparent or translucent object, the speed of light changes when entering the new medium. We call the change of speed of light refraction. When the angle of incidence is greater than zero, we may observe a bending of the light as a result of the changing speed.

Refractive index: The refractive index *n* of a material is the ratio of the speed *c* of light in a vacuum to the speed *v* of light in the material.

$$n = \frac{\text{speed of light in a vaccum}}{\text{speed of light in the substance}}$$

Refractive Index of some Common Materials

Substance	Refractive index	Substance	Refractive index
Air	1,0	Perspex	1.50
Ice	1,31	Glass	1,52
Water (20^o)	1.33	Ruby	1,76
Ethanol	1,36	Cubic zirconia	2,18
Plastic	1,46	Diamond	2,42
Sapphire	1,76	Amber	1,55

A substance with a higher refractive index is called optically more dense

Snell's Law of Refraction:

When light travels from a material with refractive index n_1 into a material with refractive index n_2, the refracted ray, the incident ray and the normal to the interface between the materials all lie in the same plane.

The angle of refraction, θ_r, is related to the angle of incidence, θ_i, by:

$$n_1 \sin \theta_i = n_2 \sin \theta_r$$

Total Internal Reflection

Consider a ray of light moving from water to air. It will speed up and will change direction by moving **away** from the normal i.e. angle of refraction (air) r > i angle of incidence (water)

There is a certain angle of incidence when the angle of refraction ray is 90^o, i.e. along the water surface. In this case we say that the angle of incidence is equal to the **critical angle.**

Any ray of light that strikes the barrier at an angle of incidence greater than the critical angle, cannot be move into the air. It is reflected back into the water. This phenomenon is known as **total internal refraction.**

The conditions for total internal refraction to take place:

1. Light ray must move from greater optical density to a medium with lower optical density
2. Angle of incidence must be greater than the critical angle

Application of Total Internal Refraction

The principle of Total Internal Reflection applies to:

1. The Periscope
2. Binoculars
3. Fibre Optics

Improve your Skills

Refraction

Question 1

Explain what happens to light when it falls on

a.) a mirror

b.) black cloth

c.) window glass

Question 2

A beam of light moves from air into glycerine. The speed of light in this solution is found to be 2,04 x 10^8 m.s^{-1}. Calculate the refractive index of glycerine

Question 3

Draw a ray diagram to illustrate how light is refracted when passing through a rectangular glass block with a refractive index, n = 1,49 if

a.) the angle of incidence i = 0º

b.) the angle of incidence i = 34º

Question 4

Draw a ray diagram to illustrate how light is refracted when passing through a triangular glass prism with a refractive index, n = 1,49. Let the angle of incidence be 40º

Total Internal Reflection

Question 1

A rectangular glass prism has a critical angle of 42^o. Draw a sketch to show what happens when light move inside the glass towards the air and strikes the boundary with:

a.) an angle of incidence i = 35 ^{o}

b.) an angle of incidence i = 42 ^{o}

c.) an angle of incidence i = 60 ^{o}

Question 2

Draw diagrams to show how you can use prisms to turn light through:

a.) 90^o

b.) 180^o

c.) Which glass triangular prism should be used if the critical angle of glass is 42º?

Refraction Calculations

Question 1

A ray of light is shone through a ruby. Calculate the speed of light through the sapphire.

Question 2

Calculate the refractive index of a cubic zirconia if an angle of incidence of 30^0 causes an angle of refraction of $13{,}26^o$ when light moves from air into a cubic zirconia.

Question 3

The refractive index of gallium phosphide is 3.5. If a ray of light moves from air through the gallium phosphide with an angle of incidence of 40^o, calculate the angle of refraction.

Question 4

A layer of oil (n = 1,45) floats on water (n = 1,33). The angle of refraction of a ray of light moving from the oil into the water is 35^o.

a.) Calculate the angle of incidence with which the light hits the oil.

b.) Under what conditions will total internal reflection take place for these materials. Support your answer with a calculation.