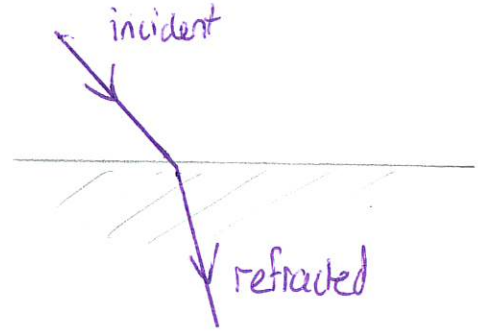
Phys 132 2022

Lecture 38

Weds: Ex: 224, 225, 226, 227, 228, 229, 230, 232

Thurs: Warm Up 14

Refraction



When light passes from one medium into another it will change direction. This is called refraction. The physical cause of this is that the speed of light is different in the two media. We then have:

Speed of light different → $v = \lambda f$ $\Rightarrow \lambda = v/f$ means wavelength changes

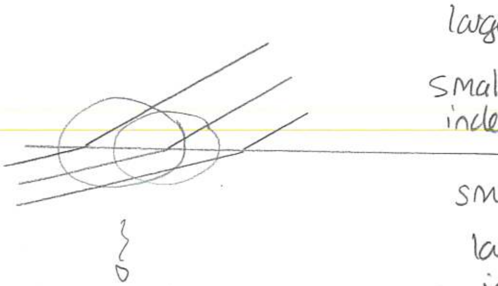
Frequency of light same → $v = \lambda f$ $\Rightarrow \lambda = v/f$ means wavelength changes

A useful quantity in this regard is

> The index of refraction of a medium is
>
> $$n = c/v$$
>
> where v = speed of light in the medium.
> c = " " " in a vacuum.

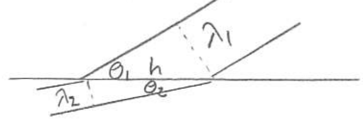
Consider light passing from a medium where the speed is larger to where it is smaller.

Quiz 8 1 ~80% – 100%



Then geometry and trigonometry gives. Then

$$\frac{\lambda_1}{h} = \sin\theta_1 \Rightarrow h = \frac{\lambda_1}{\sin\theta_1}$$



$$\frac{\lambda_2}{h} = \sin\theta_2 \Rightarrow h = \frac{\lambda_2}{\sin\theta_2}$$

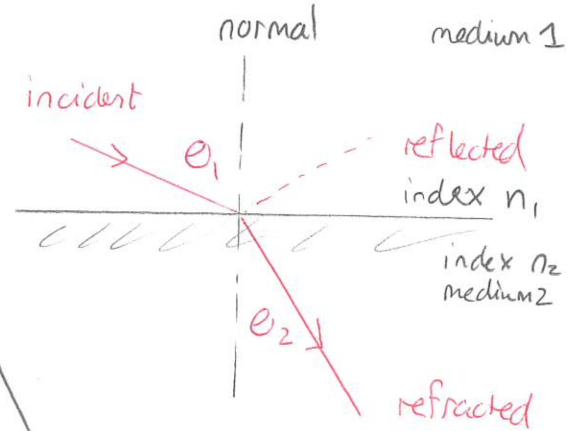
$$\Rightarrow \quad \frac{\lambda_1}{\sin\theta_1} = \frac{\lambda_2}{\sin\theta_2}$$

But $\lambda = v/f = \frac{c/n}{f} = \frac{c}{nf}$ gives:

$$\frac{c}{f n_1 \sin\theta_1} = \frac{c}{f n_2 \sin\theta_2} \quad \Rightarrow \quad n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Simple geometry then yields

Snell's Law:



Let θ_1 be angle between incident and normal. Let θ_2 be angle between refracted and normal. Then

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

where

n_1 = index of refraction in medium 1

n_2 = " " " " " 2

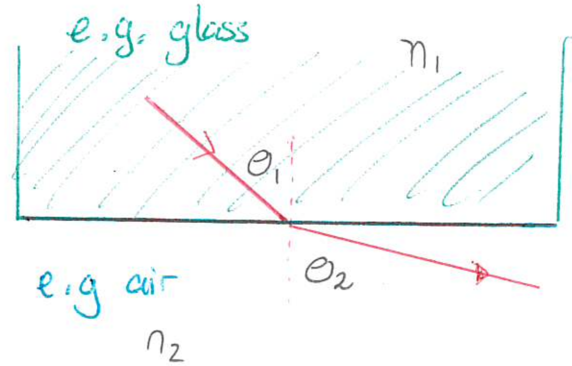
Warm Up 2 (previous Warm Up 1)

Note that Snell's Law implies:

If $n_2 > n_1$ then light bends towards the normal

If $n_2 < n_1$ " " " away from the normal.

Total internal reflection



A special situation arises when light passes from a medium with a larger index of refraction to one with a smaller index of refraction. In the illustrated situation $n_2 < n_1$. We see that a limiting critical situation will occur since

$$\sin\theta_2 = \frac{n_1}{n_2} \sin\theta_1$$

this is larger than 1

233 Critical angle

Light passes from water, with index of refraction 1.33, into air, with index of refraction 1.00.

a) Determine the angle between the refracted ray and the normal for the following angles between the incident ray and the normal: $30°, 45°, 60°$.

b) Determine the maximum angle between the normal and the incident ray such that some light is refracted into the air.

Answer a) $\sin\theta_2 = 1.33 \sin\theta_1$

$\Rightarrow \theta_2 = \arcsin\left[1.33 \sin\theta_1\right]$

θ_1	θ_2
30°	42°
45°	70°
60°	— since $\sin\theta_2 > 1$

b) We need $\sin\theta_2 = 1$

$\Rightarrow \frac{n_1}{n_2}\sin\theta_1 = 1 \Rightarrow \sin\theta_1 = \frac{n_2}{n_1}$

$\Rightarrow \sin\theta_1 = \frac{1}{1.33}$

$\Rightarrow \theta_1 = 48.7°$

In general we see:

> Refraction will only occur when the incident angle is less than the critical angle
>
> $$\theta_c = \arcsin\left(\frac{n_1}{n_2}\right)$$

Beyond this angle all light is reflected back. This is called <u>total internal reflection</u>

Quiz 2

Demo: PhET Bending Light
- Intro
- show intensity of reflected.

Demo: Fiber Optic Demo.

Lenses

A lens is a piece of transparent material with curved sides. Generically there are two types of curved surfaces

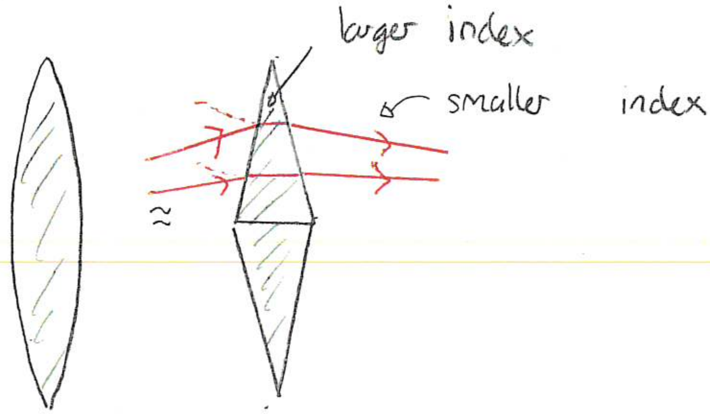
convex lens concave lens

Demo: BB optics - show curved sections

Lenses operate by refraction of light. Each ray is refracted twice

- once as it enters the lens
- a second time as it leaves the lens.

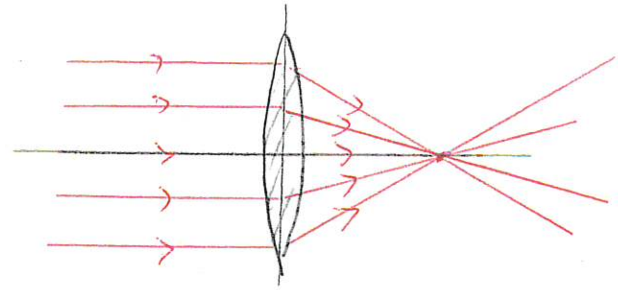
This can be illustrated by approximating the lens as a pair of prisms.



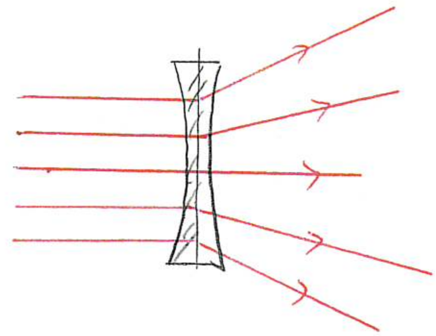
If the lens is relatively thin and has a curved surface which is a section of a spherical surface then it becomes possible to analyze the totality of the light rays that pass through the lens.

Generally:

1) convex lenses tend to produce converging light rays



2) concave lenses tend to produce diverging light rays



The extent to which such lenses do this depends on:

1) the curvature of their surfaces

2) the index of refraction of the lens material and also of the surrounding material.

Quiz 3 80% - 100%