The Lytro Camera
- the Physics and Informatics behind it

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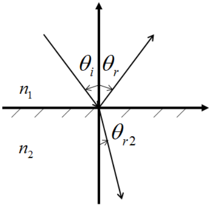
Geometrical Optics - Basics

Optical Instruments

The laws of Refraction

- - when a light ray arrives at a surface which separates two mediums
  - a part of the incident light is reflected
- - a part of it passes into the other medium;
- - if the angle of incidence is other than perpendicular
  - the ray is bent as it enters the new medium;
- - this bending of the ray in the second medium
  - is called refraction;



Physics & Informatics

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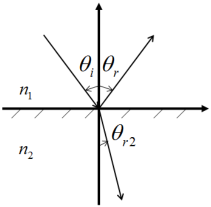

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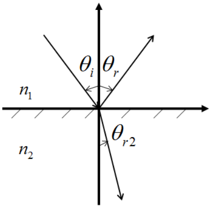

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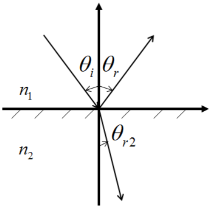

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- - let us consider a light ray incident on a refractive surface
- - which separarates two homogeneous media
  - of refractive indices n_1 and n_2;
- - the angle θ_i is the angle of incidence
  - and the angle θ_{r2} is the angle of refraction;
- - the angle of refraction depends on the speed of light in the two mediums and on the angle of incidence;
- - the relationship between them is given by Snell's law,
  - that is: $n_1 sin\theta_i = n_2 sin\theta_{r2}$;

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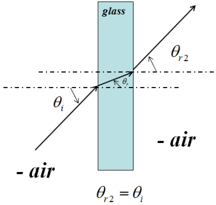
The Laws of Refraction

- from Snell's law it comes that
  - if $n_2 > n_1$, then $\theta_{r2} < \theta_i$
  - and vice versa;
- if we consider a flat piece of glass, as in the fig.,
  - the direction of the beam leaving the glass will be unchanged: $\theta_{r2} = \theta_i$;



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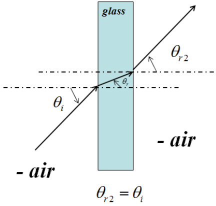

Total Internal Reflection

- - let us consider the case when $n_2 < n_1$;
  - from Snell's law we receive: $\theta_r > \theta_i$;
- - for a certain value of the angle of incidence θ_c, called critical angle, the angle of refraction will be 90°;
- - for any incident angle which is greater than θ_c,
  - there will be no refracted ray at all;
- - all the light arriving at the surface separating two homogeneous media of different optical properties will be reflected;
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Total Internal Reflection

- - total internal reflection can occur only
  - if the light strikes a boundary where the second medium has a lawer index of refraction;
- - there are many optical instruments which take advantage of the total internal reflection;
- - the principle behind fiber optics is:
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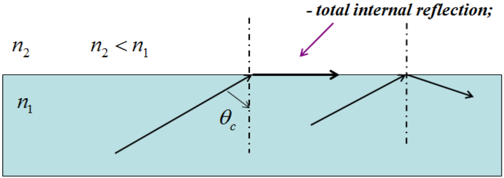

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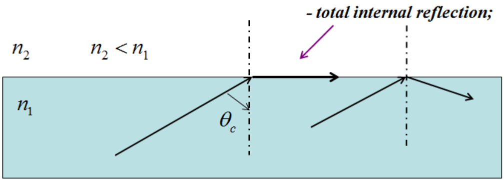

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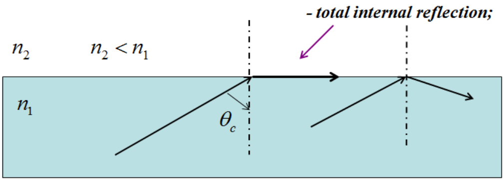

Total Internal Reflection

- - a bundle of tiny fibers, in which total internal reflection appears, is called a light pipe;
- - this is used in many areas, like:
- - decorative lamps to illuminate water streams in fountains;
- - to illuminate difficult places to be reached - like inside the human body;

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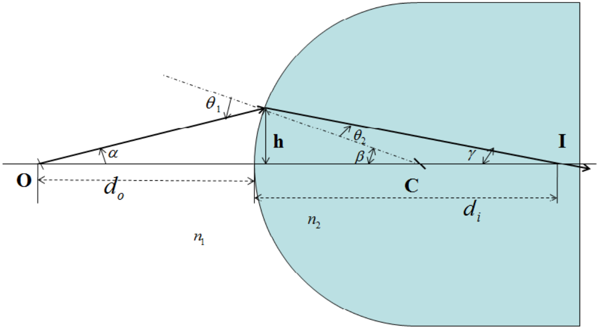
Refraction by Spherical Surfaces

- - let us consider a spherical surface
  - which separates the two mediums of refractive indices n_1 and n_2;



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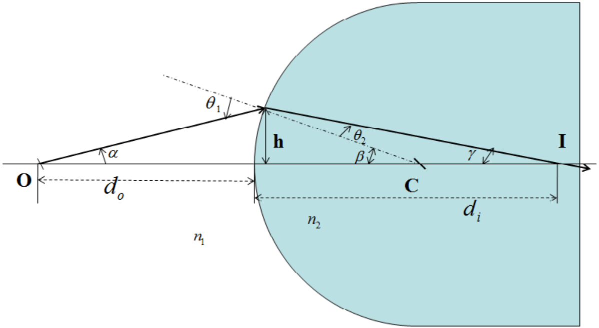

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Refraction by Spherical Surfaces

- - it follows that:

$$\alpha \approx \frac{h}{d_0} \quad (1)$$

$$\gamma \approx \frac{h}{d_i} \quad (2)$$

$$\beta \approx \frac{h}{R} \quad (3)$$

$$n_1\theta_1 \approx n_2\theta_2 \quad (4)$$

Refraction by Spherical Surfaces

- - besides:
  $\beta = \gamma + \theta_2$ and $\theta_1 = \alpha + \beta$;
- - from these:

$$\frac{h}{R} = \frac{h}{d_i} + \frac{n_1}{n_2}\left(\frac{h}{d_o} + \frac{h}{R}\right) \quad (5)$$

$$\frac{n_1}{d_o} + \frac{n_2}{d_i} = \frac{n_2 - n_1}{R} \quad (6)$$

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- \- if the surface is convex
  \- C is on the opposite side from which the light comes;
- \- R is considered to be positive;
- \- if the surface is concave
  \- C is on the same side and
  \- R is considered to be negative;
- \- the object distance is positive,
  \- if it is on the same side from which the litgh comes;
- \- the image distance is positive
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Geometrical Optics - Basics
The Laws of Reflection and Refraction
Refraction by Spherical Surfaces

Optical Instruments
Thin Lenses

Thin Lenses

- - the most important optical device is
  - the thin lens;
- - lenses form images of objects;
- - a lens is bounded by two spherical, or
  - a spherical and a plane surface,
  - having a refractive index of the material *n*;
- - a lens can be considered being a thin lens
  - if its thicknes is very small compared to its diameter;

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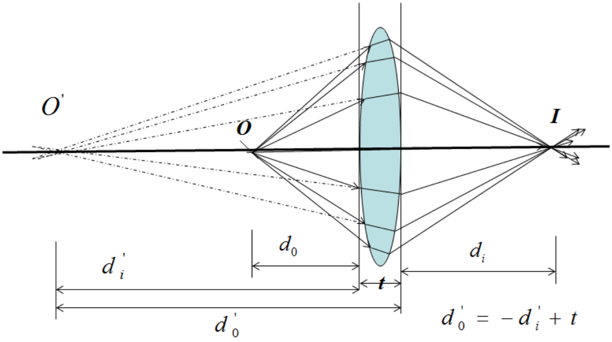
Thin Lenses

- \- if a lens having a index of refraction n
  \- is placed in air,
  \- for which the index of refraction is $n_1 = 1$,
  \- then, for the first spherical surface we get:

$$\frac{1}{d_o} + \frac{n}{d_i'} = \frac{n-1}{R_1}; \quad (7)$$



Thin Lenses

- \- where R_1 is the radius of curvature of the front surface of the lens;
- \- d_o and d_i' are the object and image distance respectively;
- \- for the second surface, we get a similar expression:

$$\frac{n}{-d_i' + t} + \frac{1}{d_i} = \frac{1-n}{R_2}; \tag{8}$$

- \- if the lens is very thin, we can consider t=0;
  \- and adding the two equations, it results:

$$\frac{1}{d_o} + \frac{1}{d_i} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right); \tag{9}$$

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- - the image will be formed
  - in the focal point, that is: $d_i = f$; where:

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