Experimental Physics 3 - Em-Waves,Optics, Quantum mechanics

Lecture 1

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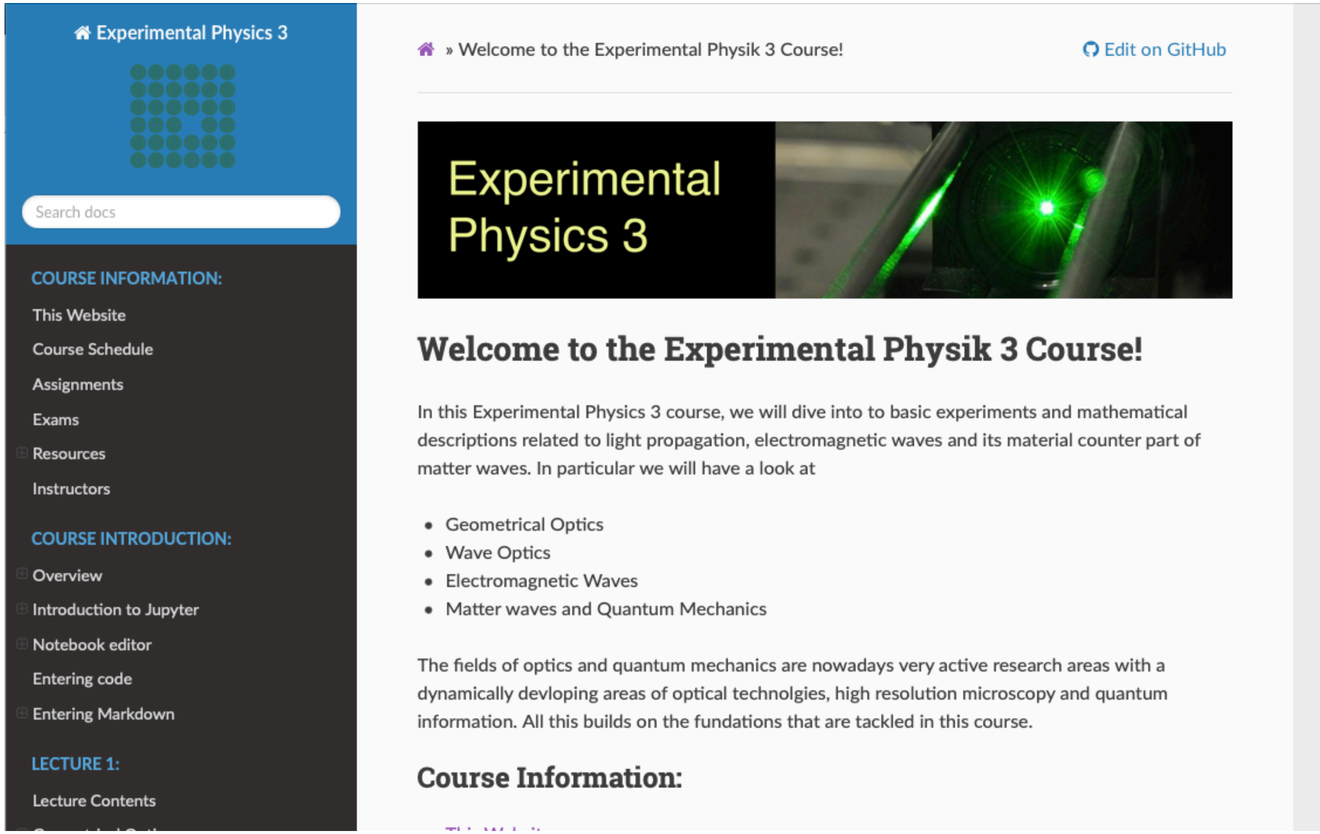
WS 2020/21

fcichos.github.io/exp3



1. Geometrical Optics

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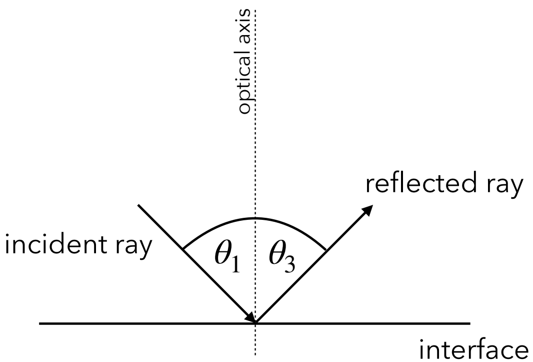
Geometrical optics is an approximate description of light propagation in the limit of infinitely small wavelength, where all wave phenomena like diffraction can be neglected.

Geometrical Optics - Assumptions

- light rays emerge from a light source
- light rays are detected by a detector

- light matter interaction is characterized by a refractive index n
- rays may be reflected and refracted at interfaces between media
- light propagates in straight line path (rays) in a homogeneous medium
- light bends to a curved path in inhomogeneous media $n(\vec{r})$
- the speed of light is $c = c_0/n$

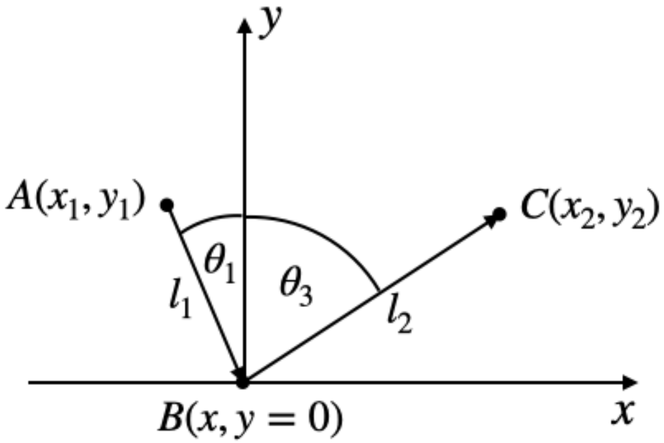
1.1 Reflection

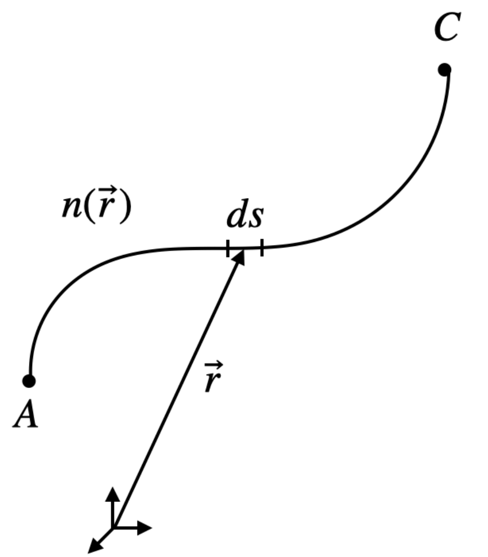


- light is reflected at interfaces

$$\theta_1 = \theta_3$$

Fermat's principle



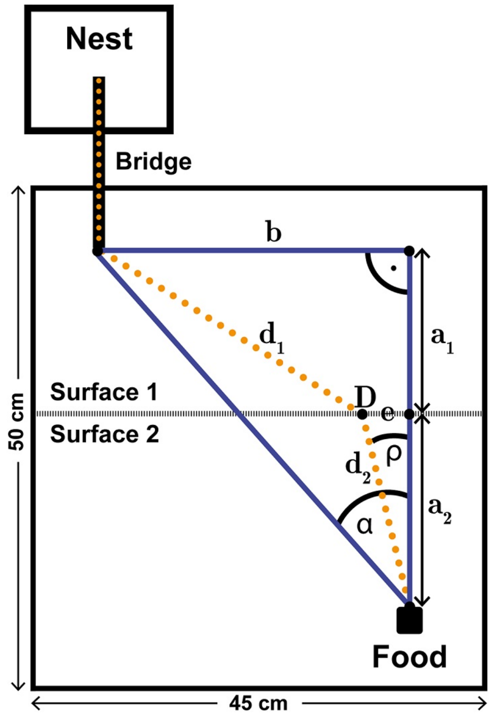


Light takes the path of shortest time.

A ray going in a certain particular path has the property that if we make a small change in the ray in any manner whatever, say in the location at which it comes to the mirror, or the shape of the curve, or anything, there will be no first-order change in the time; there will be only a second-order change in the time

$$\delta \int_A^C n(\vec{r})ds = 0$$

Funny Fact



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Fermat's Principle of Least Time Predicts Refraction of Ant Trails at Substrate Borders

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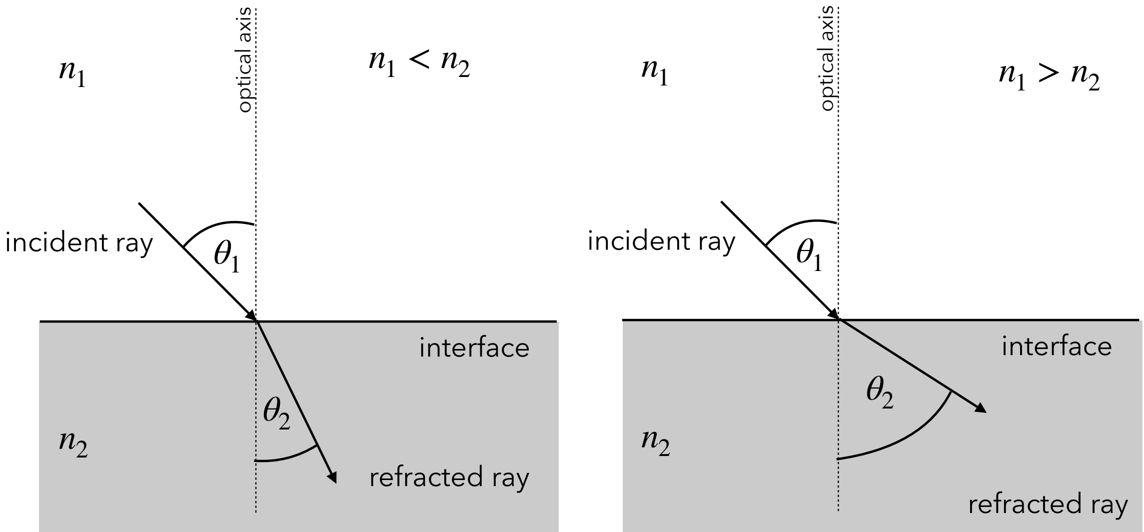
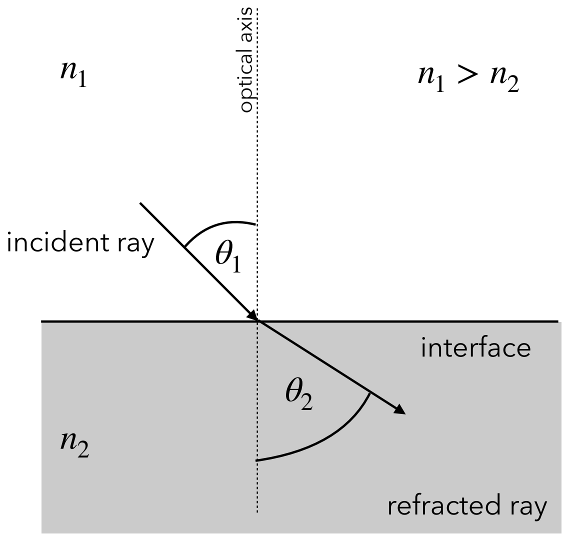
1.2 Refraction



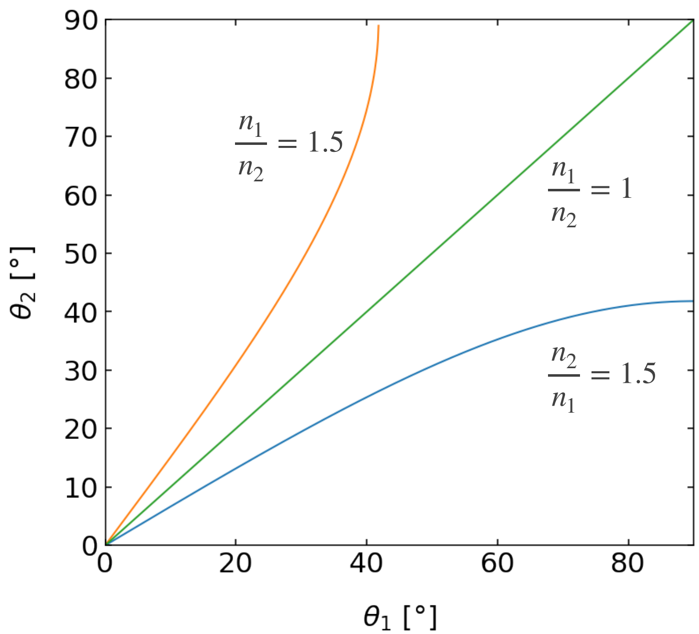
- light is refracted at interfaces

Snell's law $\quad n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

1.2 Refraction - Total Internal Reflection (TIR)



$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \qquad \theta_2 = \frac{\pi}{2}$$

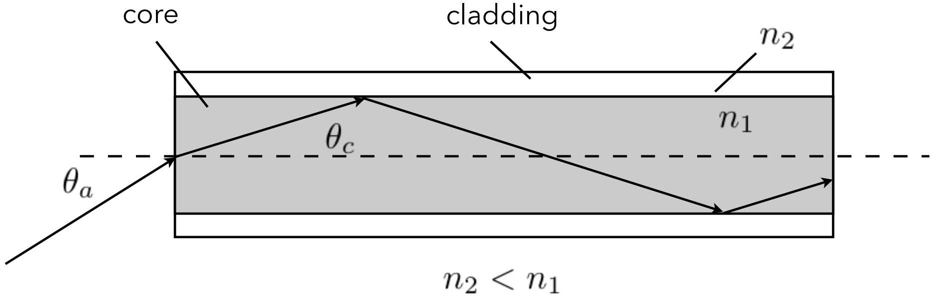


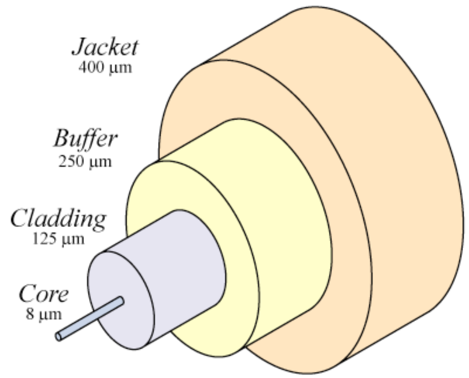
When going from an optical thick to and optical thin medium, total internal reflection occurs for

$$\theta_1 > \arcsin\left(\frac{n_2}{n_1}\right)$$

1.2 Refraction - Applications of TIR

glass fiber for optical communications





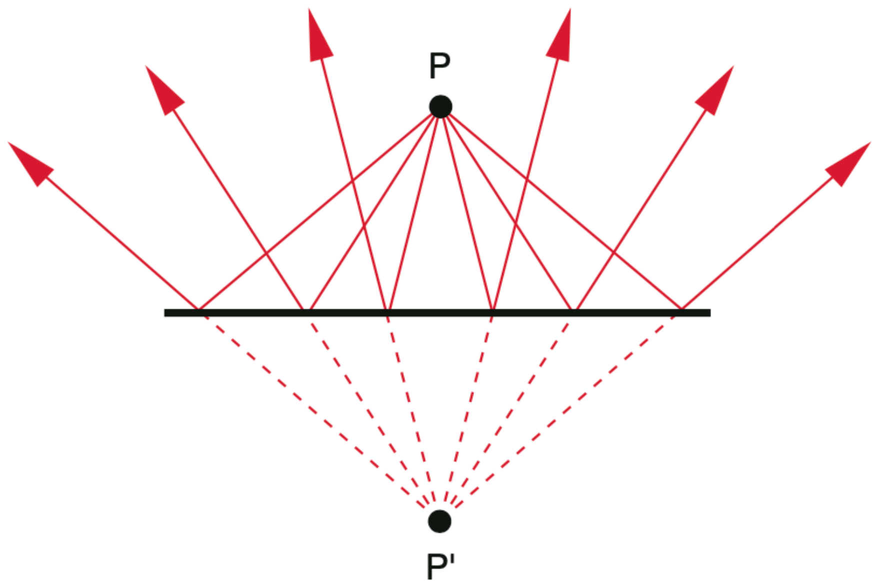
θ_a acceptance angle

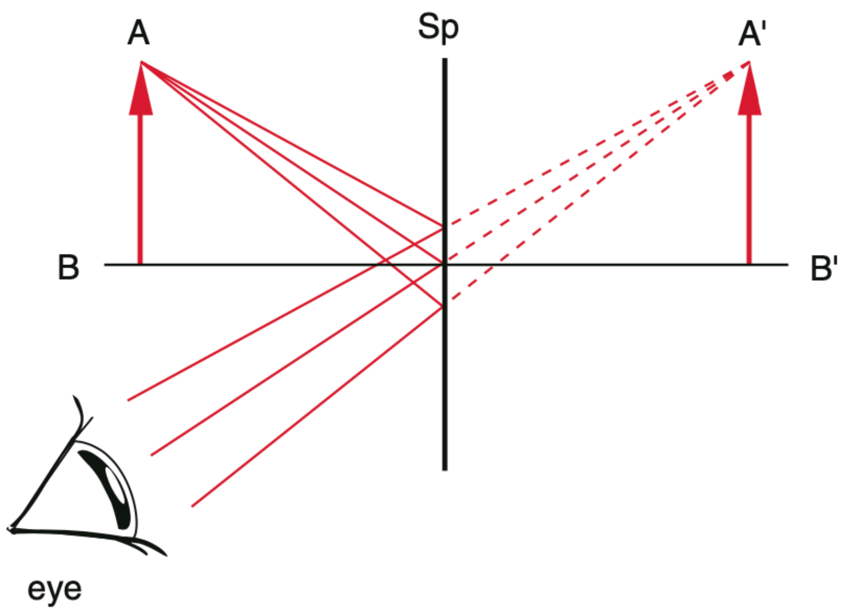
numerical aperture: $NA = \sin\theta_a = \sqrt{(n_1^2 - n_2^2)}$

typical value: $NA \approx 0.2 \quad n_1 = 1.475,\ n_2 = 1.46$

1.3 Mirrors, Prisms, Lenses - Mirrors

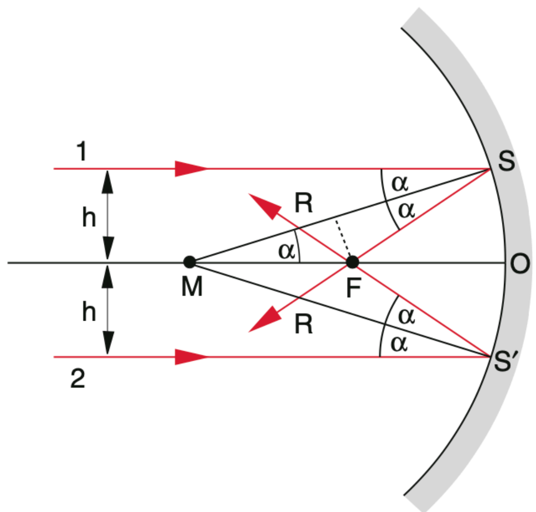
Plane Mirrors

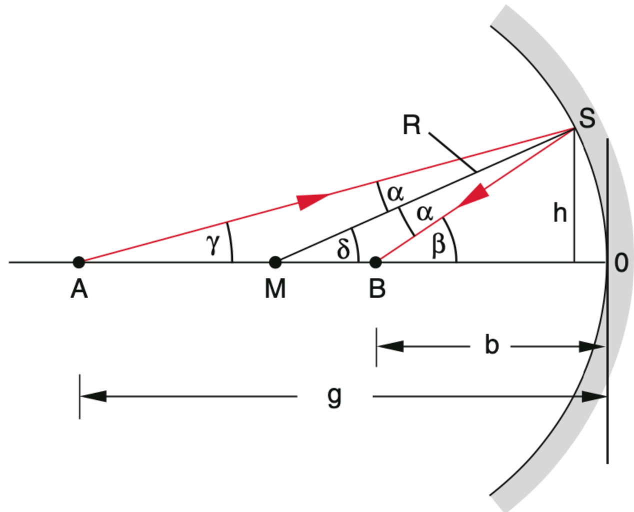




1.3 Mirrors, Prisms, Lenses - Mirrors

Concave (spherical) Mirrors





Focal distance

$$f = OF = R(1 - 1/(2\cos(\alpha))$$

$$f = R\left(1 - \frac{R}{2\sqrt{R^2 - h^2}}\right)$$

Imaging equation

$$\frac{1}{g} + \frac{1}{b} \approx \frac{2}{R} \approx \frac{1}{f}$$