Criteria for evaluating an optical imaging system

- **Criteria for obtaining a perfect image of a point light source**
  
  To develop such formalism, let’s start from the simpler to the more complicated cases of imaging. The simplest thing to image is a point light source, for example the point P shown in the figure below. Thus,

  We would like to get the image of the point light source P through a refractive surface $S$ (a boundary that divides two regions of different indices of refraction.)

  ![Image of a point light source and a refractive surface](image)

  What would constitute a perfect image of P?

  We impose that the image of the point P should be another point (P’, for example, as shown in the figure below.)

  To obtain a perfect image of P, then, all the rays emanating from P should arrive to P’. 
Notice, however, that in general not all the rays leaving the point P will arrive at P’, unless the interface S has the proper shape.

Thus, our task of obtaining a perfect image is equivalent to find the proper geometrical shape of the surface S such that all the rays leaving from P and hitting the surface deviates towards P’.

On the other hand, keeping into account that light indeed has a wave nature, we impose the additional requirement that all the rays that emanate from P arrive at P’ at the same time (otherwise, they could interfere destructively and thus spoil the image formation.)

These requirement will be included in the context of the Fermat’s principle of least time or, more generally, the variational principle.

**The Fermat’s Principle of Least Time**

It turn out, time ago in 1650, Fermat enunciated the principle that light, when going from one point to
another, follows the particular path for which the time of flight is minimum (compare to the time it would take if another path were taken.) This principle will be described in more detail in the following sections.

We will adopt this principle given its generality and power for making perditions. In particular we will use it here as a tool to guide us in the design of devices that produce perfect images. Indeed, using this principle:

a) we will be able to find the path followed by the light when it crosses interfaces (i.e. Snell’s law); and

b) we will be able to find the shape of the interface $S$ (alluded in the previous section) necessary for obtaining a perfect image.
Outline for the next lecture

Imaging through perfect surfaces

In Lecture-10 we will describe the Fermat principle in some detail, and use it first to derive the laws that govern how rays are refracted and reflected at interfaces (Snell’s law.) The Fermat principle will be described in the context of the “Variational Principle,” which has far more reaching consequences (even beyond the filed of Optics.)

In Lecture-11, we will invoke the Fermat’s principle in order to find the actual shape an interface $S$ must have in order to obtain the perfect image of a point.

Non perfect imaging surfaces

Anticipating that perfect imaging surfaces may be too difficult to fabricate, simpler surfaces, such as spherical surfaces, will be considered. The imaging through spherical surfaces will be covered in Lecture-12.

As a consequence of using spherical boundary surfaces, the rays going from P to P’ will not arrive at the same time. The time delay between two particular rays will provide a measurement of the “imperfection” of the spherical imaging surface. It is in that sense that the Fermat principle is considered our standard theoretical principle to evaluate the quality of an imaging system.