# Introduction to the Petrographic Microscope

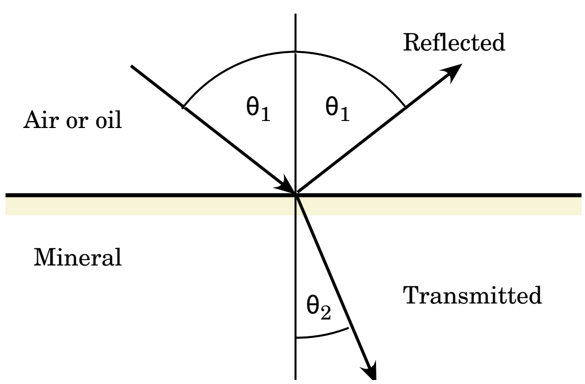
This lab begins our study of the optical properties of minerals. We divide all minerals into one of three groups according to their optical properties. Those are the isotropic minerals, uniaxial minerals, and biaxial minerals. Each group has distinct optical characteristics that distinguish its members. In the next three labs, we will look at each group individually.

This week you will become familiar with our principle tool, the petrographic microscope. There are several kinds of optical microscopes, each adapted for its particular purpose. All have one thing in common, they all magnify an image of an object; in our case this is a rock or mineral. An image of an object is created with the use of lenses, which are pieces of glass (in optical microscopes) with curved surfaces and which refract the light that passes through them.

There is a law that describes the paths taken by the transmitted light: the law of refraction or Snell's Law

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

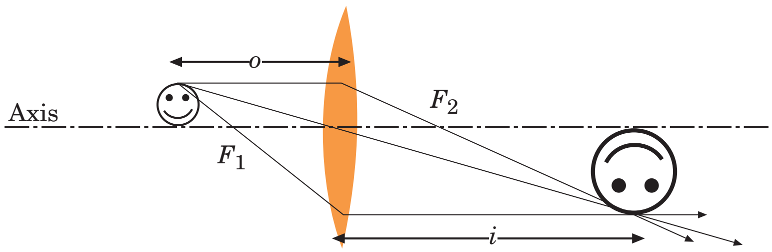
Here, $n$ stands for the index of refraction, which is defined as the speed of light in a vacuum divided by the speed of light in the medium, $c/v$. The angle $\theta$ is the angle between the light path (the "ray") and the normal to the interface between medium 1 and medium 2. The figure below shows an example of the law for light entering a mineral grain.



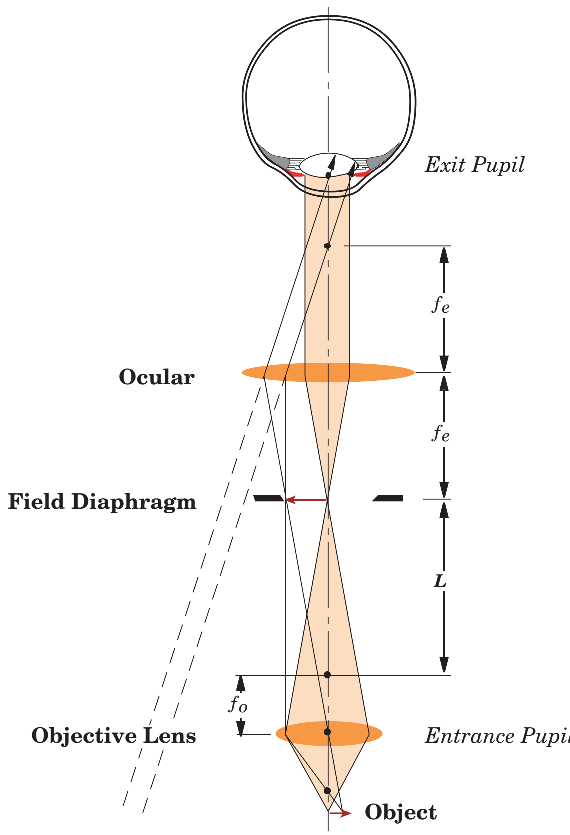

By adjusting the curvature of the lens, the refracted light from an object can be focused to form an image of the object. A simple spherical lens can magnify an object by virtue of having the two surfaces with different radii of curvature. The image distance for a thin lens is given by

$$\frac{1}{o} + \frac{1}{i} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

where $r$ is the radius of curvature of the front or back surface, $n$ is the index of refraction of the lens, and $o$ and $i$ are the object and image distances. The right side of the equation can used to define $1/f$, where $f$ is the focal length of the lens. The magnification is given by the ratio of the image distance to the object distance.




Microscopes use two lenses to form an image, the objective lens and the ocular. A sketch of a simple microscope is shown below.




Actually, the lenses in a microscope are compound to account for spherical aberration, in which a lens won't focus on a single point owing to the thickness of the glass, and for chromatic aberration, in which a lens forms separate images for each wavelength because of the dependence of $n$ on wavelength.

There are several features of a petrographic microscope that distinguish it from other microscopes. First, the condensing lens assembly, which transmits light through the sample, contains a piece of polarizing material. This results in plane-polarized light with a polarization direction oriented east-west (usually). Second is an analyzer, which is also a polarizing material but with its polarization direction oriented north-south. The analyzer is found between the objective lens and oculars. Third, the sample stage on a petrographic microscope can rotate about the axis of the microscope. This allows reorientation of the minerals with respect to the polarizer direction. Most petrographic microscopes also have a special lens called a Bertrand lens that allows the petrographer to view the focal plane of the objective lens directly. This lens is used in conjunction with a special substage condenser lens. The same effect is attained in other microscopes by removing the oculars. A photo of a petrographic microscope, similar to the ones we use, is shown below with the parts identified.


For this week's exercise, you will need a thin section of a rock that contains the mineral biotite. The rock is a schist or a gneiss and contains a variety of minerals such as quartz and plagioclase. A thin section is made by gluing a slice of a rock on a glass slide with epoxy. The rock slice is ground and polished until its thickness is 30 µm. Most minerals easily transmit light at this thickness, with the exception of conductors, which are opaque. The thin section can be examined under the microscope with polarized light to identify the minerals and to see the texture.

1. First find all the parts of the microscope shown in the picture above. Your instructor will tell you if there are some differences between the microscope in the picture and your microscope.

2. Remove the analyzer from the light path and look at the thin section. Find a brown grain of biotite and move it to the center of the field of view. Rotate the stage and observe the color change in the biotite. When the biotite is oriented east-west, parallel to the polarizer direction, the color should be dark brown. When the grain is oriented north-south, it should be light brown. The change in color with respect to the polarization direction of the light is called pleochroism. Note that biotite grains in some rocks have a green color, and in others

the color is a deep reddish brown. The color difference is related to the composition of the biotite.

3. Look at the other grains in the thin section. Quartz and feldspar are colorless. Now place the analyzer in the light path. You should see a variety of colors; quartz and feldspar should be gray and white, the biotite is bluish red, and other minerals can have different colors. Rotate the stage and you should see the minerals get light and dark. This phenomenon is called birefringence. The techniques of optical mineralogy allow you to use the pleochroism and birefringence and others features to identify minerals.