Objective: Re-familiarize yourself with the optical properties of minerals and concepts like, anisotropy/isotropy, refractive index, relief, extinction angle, sign of elongation, pleochroism, maximum birefringence, and optic sign, all of which aid in mineral identification.

Microscope Adjustments

A. Focus the oculars – Focus on a thin section, close your left eye, then focus the crosshair in right ocular by twisting the top part while holding the cylinder. Then refocus on the thin section, then refocus the cross hair. Keep doing this iteration until both the thin section and the cross hair are focused. Then focus on the thin section with the non-cross hair ocular.

B. Center the objectives - Focus on a thin section and center a point object on the cross hair. Turn the stage 360° and note the circle traced by the point. If the point traces a circle greater than a couple intervals on the cross hair scale, the object should be recentered. To do this, insert the two small Allen screwdrivers (stored on the back of the microscope) into the holes on the objective ring on both sides of the objective to be recentered. Turn the screws such that the cross hair center moves to the centerpoint of the circle. Rotate the stage again and keep adjusting the objective until the point stays approximately centered. Do this for each objective.

C. Determine the field of view for each objective - Place a transparent metric ruler on the stage and determine the approximate width of the total field of view for each objective and calculate the length of each crosshair subdivision. For the high power objectives, use the class micrometer slide (scale is 2mm wide with 0.1mm subdivisions). Write these values in a place where you can easily retrieve them.

Exercise: View the thin sections indicated below and answer the related questions

1) Tremolite (Optic Plane, 010) section; determine the sign of elongation (length fast or length slow) and extinction angle (1 pt)
   
   Sign of Elongation     Extinction Angle
   length ___________     ______º

2) Tremolite Bxo section. What type of extinction angle does this display relative to the 120° cleavage?

   ______________________________________________________________________________ (1 pt)

3) Beryl ⊥ C section; obtain an optic figure (2 pts)
   
   What type of optic figure is this?________________________________________
   
   What is the optic sign? __________
   
   Is the uniaxial indicatrix oblate (pancake-shape) or prolate (cigar-shaped)? ______________
   
   What is the approximate shape of the indicatrix section represented by this mineral slice ___________

4) Beryl || C section; obtain an optic figure (2 pts)
   
   What type of optic figure is this?________________________________________
   
   How many degrees of rotation does the optic figure remain in view? ____________

This mineral slice should yield the greatest ellipticity of the indicatrix section and thus this alignment should show the highest interference colors. Assuming the section is 30\(\mu\)m thick, what is the approximate maximum birefringence of beryl \(\text{_______________}\) (remember to turn the Bertrand lens off).

Draw the shape of the crystal you are viewing and the orientation of the \(\omega\) and \(\varepsilon\) vibration directions in the circle below.

\[
\begin{array}{c}
\text{\includegraphics[width=0.3\textwidth]{crystal_shape}}
\end{array}
\]

5) Calcite \(\parallel\) C section; view under med to low power and X-polar illumination (1 pt)

The mineral appears to have white interference colors. How can you tell if this is very high interference colors producing white light or it is first order white colors? (Hint –what do you notice when you insert the gypsum plate)

_____________________________________________________________________________________

6) Calcite \(\perp\) C section; obtain an optic figure. (1 pt)

What type of optic figure is this? \(\text{______________________________}\)
What is the optic sign? \(\text{____________}\)

7) Calcite rhombohedral section; obtain an optic figure. (1 pt)

What type of optic figure is this? \(\text{______________________________}\)
How many cycles of color orders are evident in the isochromes of this optic figure? \(\text{________________}\)

8) Optic signs slide with the Phlogopite mineral; Obtain an optic figure for this biaxial phase. (2 pts)

What type of figure is it? \(\text{______________________________}\)
What is the optic sign? \(\text{____}\)
What is the approximate 2V angle based on separation of the isogyres \(\text{____}\)
What vibration axis are you looking down with this mineral orientation? \(\text{____}\)

9) Andalusite Bxo and Bxa figures slide: Obtain an optic figure for each orientation. (1 pt)

What optic sign do you get from the Bxa figure? \(\text{____}\)
What optic sign do you get from the Bxo figure? \(\text{____}\)
They should be different; which is the correct one? \(\text{____}\)
This exercise demonstrates that when the 2V angle gets close to 90° a Bxa is difficult to distinguish from a Bxo figure and therefore optic signs can be erroneous if the wrong figure is used.

10) **Sanidine Bxa**: Obtain an optic figure for this phase. (1 pt)
   What is the optic sign? _______
   What is the approximate 2V angle based on separation of the isogyres? _______

11) **Topaz ⊥ One Optic Axis**: Obtain an optic figure. (2pts)
   What is the approximate 2V angle based on isogyre curvature? _______
   Draw a picture of the isogyre curvature and the change in isochrome colors that indicate the optic sign

12) **Olivine Gabbro sample (GKS-16)**. There are two high relief translucent minerals in the section* that are often difficult to distinguish in gabbroic rocks. **Augite** has a slightly brownish tint, locally shows some cleavage, and may contain biotite or opaque inclusions. **Olivine** is clearer than augite, lacks cleavage, but is often fractured, and has slightly higher relief. They also have different maximum birefringences. Determine the maximum birefringence of these minerals; compare your answer with the reported range in birefringence. (3 pts)
   **Augite**
   Highest interference color _______________ \( \delta_{\text{max}} \text{ estimated } \) _______ \( \delta_{\text{max}} \text{ reported } \) _______

   **Olivine**
   Highest interference color _______________ \( \delta_{\text{max}} \text{ estimated } \) _______ \( \delta_{\text{max}} \text{ reported } \) _______
   Why do these phases have a range in interference colors? __________________________________________

* the other minerals in the section are twinned plagioclase, opaque magnetite rimmed by minor biotite, and inverted pigeonite (low birefringence with pronounced exsolution lamellae).
13) **Granite sample (D-37).** This sample contains the main minerals commonly found in felsic igneous rocks – sodic plagioclase, alkali feldspar, quartz, mica (biotite), amphibole (hornblende) and minor amounts of Fe-oxide, apatite, and zircon. Be sure that you can positively identify each phase and then answer the questions below. (5 pts)

A. Sodic plagioclase, alkali feldspar and quartz are all colorless, low birefringent minerals; how can quartz be readily distinguished from the two feldspars? _____________________________________________
   ____________________________________________________________________________
   ____________________________________________________________________________

B. How can sodic plagioclase feldspar and alkali feldspar be distinguished? __________________________
   ____________________________________________________________________________
   ____________________________________________________________________________

C. Name two criteria by which biotite be distinguished from hornblende
   i) ___________________________________________________________________________
   ii) __________________________________________________________________________

D. How can sodic plagioclase feldspar and alkali feldspar be distinguished? __________________________
   ____________________________________________________________________________
   ____________________________________________________________________________

E. Get an optic axis figure on quartz and sketch what you see in the circle. Show how you can determine the optic sign from this figure?

14) View the “glaucophane” section. Note that it has three segments where the prisms of this blue pleochroic amphibole mineral are oriented in different directions. The figure below shows the optical information for glaucophane from Deer, Howie and Zussman (DHZ). (4 pts)

A) Notice that glaucophane can have a wide range of birefringence (.008-.020). From the maximum interference colors shown in the center section, what is the approximate birefringence of this glaucophane? __________________________
B) What two vibration directions are dominant in the crystals in this center section? _______ & __________

C) In the section that shows the lowest interference colors, use the two dominant pleochroic colors to determine which two vibration directions are in this section _______ & __________

D) The section also includes jadeite (Na pyroxene) and garnet, which both are colorless with high relief. How can we tell them apart?

________________________________________________________________________

________________________________________________________________________

15) Garnet-staurolite-kyanite-muscovite-quartz-biotite schist sections (3355). List the optical attributes of the minerals in this section and estimate their mode. (9 pts)

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Color/ Pleochroism</th>
<th>Maximum Birefring. (TS-30μm)</th>
<th>Isotropic, Uniaxial, or Biaxial?</th>
<th>Mode (vol%)</th>
<th>Other Notable Features</th>
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<tbody>
<tr>
<td>Quartz</td>
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<td>Staurolite</td>
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<td>Biotite</td>
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