SYLLABUS, GEO 3460

Crystal Optics

Review of basic optics.

- Sinusoidal wave motion – definitions of wavelength, amplitude, period, and frequency.
- Light as an oscillating electric vector. Constancy of velocity in a vacuum.
- Units of wavelength – the Angstrom and nanometer. Wavelengths of visible spectrum.
- Concept of wave fronts and rays.
- Law of reflection of light. Definition of the normal to a surface.
- Law of refraction – Snell's law deduced from the glass block, pins, and board experiment. Nature of refractive index being a ration of velocities.
- Definition of absolute refractive index.
- Dispersion of refractive index.

Measurement of Refractive Index

- Apparent depth method
- Minimum deviation of a prism method
- Immersion oil method
- Relief of grain
- The Becke line

Behavior of Light in Crystals.

- Concept of isotropy and anisotropy
- Concept of polarization of a wave
- Anisotropy in crystals shown by the double refraction of calcite
- The apperant failure of Snell's law. The ordinary and the extraordinary rays.
- Path of extraordinary ray predicted by Poynting's vector.
- Snell's law redefined in terms of the wave normals. Proof that refractive index varies as inverse of wave velocity.
- Some ray paths in calcite by Huygens construction:
  i) along c-axis
  ii) normal to c-axis
  iii) random

The Uniaxial Indicatrix

- Refractive index and polarization direction combined into a single vector leading to representation of unpolarised light as a circle and the polarized waves in a crystal as an ellipse. The circle and the ellipse shown to be sections through an ellipsoid of revolution. Proof that this ellipsoid and the extraordinary ray velocity surface are identical on shape.
- Definition of positive (prolate) and negative (oblate) indicatrices. Definitions of circular, principal and random sections.
- Birefringence and its dependence on orientation.

Origin of Interference Colors.

- Interference of waves. Conditions for reinforcement and annihilation.
- Interference of white light. Origin of color of soap film. Newton's rings.

- The design of the polarizing microscope. The polariser and the analyzer.
- Review of vector resolution. Resolution of plane polarized light into two waves of differing amplitude on entering crystal.
- Retardation. Proof retardation equals thickness times birefringence.
- Recombination by analyzer of light into two wave trains of equal emplitude polarized in the same plane but retarded with respect to one another.
- Production of light and dark bands by quartz wedge inserted into sodium light.
- Effect of retardation by mineral on white light. Equal retardation removes some wavelengths from spectrum, reinforces others. Result production of interference colors.
- Order of an interference color.

Examination of Uniaxial Minerals.

- Nicols uncrossed – pleochroism
- Nicols crossed – Extinction 4 times a revolution.
- Interference colors – Contours of equal retardation.
- Significance of minerals that remain dark on rotation of stage.
- Interference figures. Origin of isogyres and isochromes.
- The off-axis interference figure.
- Determination of sign – the gypsum plate.
- Orientation – length fast and length slow.

Examination of Biaxial Minerals.

- Biaxial indicatrix as a triaxial ellipsoid whose principal axes are parallel to the polarization directions of those three waves that travel with constant velocity in those planes and whose lengths are equal to the refractive indices of those same waves.
- Definitions of principal planes, circular sections optic axes, 2V, acute and obtuse bisectrices, optic plane.
- Definition of optic sign. The uniaxial indicatrix as a special case of the biaxial.
- Some polarsition directions and ray paths for different planes of incidence.
    i) light incident on a principal section
    ii) on a plane containing a principal axis
    iii) a random section
    iv) a circular section. External conical refraction

The Biaxial Interference Figure.

- The Biot-Fresnel law. Use of law to deduce form of biaxial figure with optic plane east-west and in 45^{o} position. Origin of isochromes.
- Optic axis and optic normal figures.
- Effect of 2V on acute nisectrix figure.
- Estimation of 2V. From separation of isogyres. Effect of n_{β} 2V vs. 2E. Oil immersion objective. Wright's method.

Extinction Angles.

- Significance of straight extinction.
- Inclined extinction. Distinguishing aegirine and aegirine-angite.
- The extinction angles of the plagioclases.

How to Use Optical Descriptions in a Handbook.

- Review of terms: Color, Form, Cleavage, Relief, Birefringence, Extinction, Orientation, Interference Figure, Distinguishing Features, Related Minerals, Occurrence.

Review of principal rock forming minerals

- Crystal chemistry
- Crystal structure
- Exsolution, phase relationships where appropriate.

Laboratory Exercises

- Huygens construction
- Becke Line
- Fast and slow directions
- Finding interference figures

<u>Minerals in Thin Section.</u>

- Birefringence, cleavage habit.
- Properties in thin section of:
    + The potash felspars
    + The plagioclases
    + The Olivines
    + The orthopyroxenes
    + The clinopyroxenes
    + The amphiboles
    +The spinels
    + The micas
    + Epidote, zoisite and clinozoisite
    + Andalusite, kyanite and sillimanite
    + Cordierite
    + Idocrase
    + Zircon
    + Allanite
    + Monazite