I. (20) Define the following terms and give an example of how each might be used to distinguish various minerals:

   A. Refraction
   The bending of light due to a change in the velocity of light between two media. In thin section high-index mineral appear to have high relief which can be used to distinguish quartz from orthopyroxene.

   B. Dispersion
   The index of refraction is a function of wavelength.

   C. Pleochroism
   The absorption of light is a function of direction in an anisotropic medium.

   D. Diffraction
   The coherent scattering of a wave by a periodic array of scatterers.

   E. Birefringence
   The index of refraction in an anisotropic medium is a function of direction so that light is refracted into two separate rays traveling at different velocities in the medium.
II. A. (10) Cuprite, Cu$_2$O, is a minor ore of copper and one of two hemi-oxide minerals. (The other one is ice.) The crystal structure of cuprite is cubic with a cell edge of 4.27Å and Z of 2. Cu$_2$O has a molecular weight of 143.09 g. Calculate the density of cuprite.

$$\rho = \frac{Z \cdot MW}{AV}$$

$$\rho = \frac{2 \times 143.09}{0.6023 \times 4.27^3}$$

$$\rho = 6.103 \text{ g/cm}^3$$

II. B. (10) The index of refraction of cuprite is 2.85, nearly the highest of any mineral and higher than diamond. What is the speed of light in cuprite?

$$V = \frac{c}{n}$$

$$1.05 \times 10^8 \text{ m/s}$$

III. (10) Calculate the 2$\theta$ angle for Cu K$\alpha$ radiation ($\lambda = 1.5405$Å) for the (110) and (211) X-ray diffraction peaks of cuprite.

$$D_{110} = \frac{a}{2^{0.5}}$$

$$2\theta = 2 \sin^{-1} \left( \frac{\lambda}{2d} \right)$$

$$D_{110} = \frac{4.27}{1.414} = 3.020$$

$$2\theta = 29.55^\circ$$

$$D_{211} = \frac{4.27}{2.449} = 1.743$$

$$2\theta = \sin^{-1} \left( \frac{1.5405}{3.486} \right) = 52.44^\circ$$
Below is a melting (T-X) diagram for diopside (CaMgSi$_2$O$_6$) – anorthite (CaAl$_2$Si$_2$O$_8$). Diopside is a pyroxene and anorthite is a feldspar so there is no solid solution between them. Starting with a liquid of composition 70% anorthite and 30% diopside at 1600°C (dot) answer the following questions based on the diagram assuming perfect equilibrium between crystals and solid:

A. At what temperature do the first crystals form? ______ 1460º

B. How many phases are present at 1300ºC? __________ 2

C. At what temperature does the last liquid disappear? ____ 1200º

D. What is the composition of the last liquid to crystallize? __________ An$_{40}$Di$_{60}$