I. (20) Define the following terms:

A. Dispersion
   Index of refraction is a function of wavelength (color).

B. Indicatrix
   An ellipsoidal figure representing the indices of refraction for the various vibration directions for light in a crystal.

C. Diffraction
   The coherent scattering of a wave from a periodic array of scatterers.

D. Pleochroism
   Absorption of light is a function of direction in a crystal.

E. Liquidus
   The line on a temperature-composition phase diagram above which the system is completely liquid.
II. (15) I want to synthesize a sample of wadsleyite with a composition (formula) of Mg$_{1.70}$Fe$_{0.30}$SiO$_4$ by mixing together powdered oxide reagents of SiO$_2$, MgO, and FeO. (Oxide molecular weights are 60.086, 40.312, and 71.846 g, respectively as listed.) If I need a total of one gram (1000 mg) of starting material, how many milligrams of each oxide do I need to weigh out and mix together? (Hint: calculate weight percentages first.)

<table>
<thead>
<tr>
<th>Oxide</th>
<th>MolWt Oxide</th>
<th>Moles per form.</th>
<th>g/form</th>
<th>wt%</th>
<th>mg/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>60.086</td>
<td>1.000</td>
<td>60.086</td>
<td>40.012</td>
<td>400.12</td>
</tr>
<tr>
<td>MgO</td>
<td>40.312</td>
<td>1.700</td>
<td>68.530</td>
<td>45.635</td>
<td>456.35</td>
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<tr>
<td>FeO</td>
<td>71.846</td>
<td>0.300</td>
<td>21.554</td>
<td>14.353</td>
<td>143.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>150.170</td>
<td>100.00</td>
<td>1000.00</td>
</tr>
</tbody>
</table>

III. A. (10) Periclase (MgO), is a relatively rare metamorphic alteration product of dolomite, but is also believed to be a significant constituent of the lower mantle co-existing with bridgmanite. The crystal structure of periclase is cubic with a cell edge of 4.21Å and Z of 4 for pure MgO. MgO has a molecular weight of 40.3114g. Calculate the density of periclase.

\[ \rho = \frac{Z \times MW}{A \times V} \]

\[ \rho = 4 \times \frac{40.3114}{.6023 \times (4.21)^3} \]

\[ \rho = 3.588 \text{g/cm}^3 \]

III. B. (10) The index of refraction of periclase is 1.74. What is the speed of light in periclase?

\[ V = \frac{c}{i} \]
\[ V = \frac{3.0 \times 10^8}{1.74} \]
\[ V = 1.724 \times 10^8 \text{ m/s} \]
III. C. (10) Calculate the 2θ angle for Cu Kα radiation (λ = 1.5405Å) for the (2 0 0) and (111) X-ray diffraction peaks of periclase (a = 4.212 Å).

\[ d_{200} = \frac{a}{2} \]
\[ d_{200} = 2.106 \]

\[ 2\theta = 2 \sin^{-1} \frac{\lambda}{2d} \]
\[ 2\theta = \sin^{-1} \frac{1.5405}{4.212} \]
\[ 2\theta = 42.91° \]

\[ d_{111} = \frac{a}{1.732} \]
\[ d_{111} = 2.432 \]

\[ 2\theta = 2 \sin^{-1} \frac{1.5405}{4.864} \]
\[ 2\theta = 36.93° \]

IV. (15) Siderite, FeCO₃, is trigonal and uniaxial negative. Its two indices of refraction are 1.575 and 1.782.

A. A laser beam enters a siderite crystal propagating in the c-direction and vibrating in the a-b plane. Do you expect this light beam to experience strong birefringence?  
___ No ______________________

Why? ___ looking down the optic axis ___________

B. The laser beam enters the crystal propagating parallel to the a-axis and vibrating in the a-c plane. Do you expect this beam to experience strong birefringence?  
___ Yes ______________________

Why? ___ looking perpendicular to optic axis ___________

C. In this latter orientation (propagating parallel to a and vibrating in the a-c plane), do you expect to see strong pleochroism?  
___ Yes ______________________

Why? ___ Fe-bearing and looking perpendicular to optic axis ___________
V. (20) Below is a simplified melting (T-X) diagram for enstatite (Mg$_2$Si$_2$O$_6$) – diopside (CaMgSi$_2$O$_6$). There is limited crystalline solution between the end member. Starting with a liquid composition 80% enstatite and 20% 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? _______1450º_____________

B. How many phases are present at 1300ºC? __________2___________________

C. At what temperature does the last liquid disappear? _____1240º________________

D. What is the composition of the last liquid to crystallize? ___En50Di50______________

E. How many phases are present at 1100ºC?  ______2__________________

F. What is the composition of the enstatite phase at 1100ºC? __ __En90Di10____________________

G. What is the composition of the diopside phase at 1100ºC? ___ _En12Di88_______________