Homework Assignment #6

1. For a particular ferroelectric liquid crystal mixture the birefringence $\Delta n = 0.11$, and the tilt angle $\theta = 21^\circ$ (instead of the ideal $22.5^\circ$).
   a. How thick should a surface stabilized ferroelectric crystal cell be to form a half-wave plate for HeNe light (632.8 nm)?
   b. The graduate student who makes the cell is distracted by a fire alarm in the building and accidentally makes the cell 10% too thin. What is the maximum transmission of this cell when placed between crossed polarizers?
   c. Roughly how thick should a $90^\circ$ twisted nematic liquid crystal cell be for maximum transmission of HeNe light through crossed polarizers?
   d. The stupid fire alarm goes off again and she makes this cell 10% too thin also. What is the maximum transmission of this cell when placed between the crossed polarizers?
   e. What might one manufacturing advantage of TNLCs be over SSFLCs?

2. Consider a SmC* ferroelectric liquid crystal having a spontaneous polarization $P_s$ of 100 nC/cm$^2$ in a cell having electrically insulating alignment layers between the transparent conductors and the liquid crystal. The cell is driven by a single voltage pulse from a pulse generator, switching the liquid crystal fully to one state, with all the dipoles aligned. Immediately after the pulse, the pulse generator applies a voltage of zero (equivalent to shorting the leads to the cell).
   a. Immediately after an applied voltage of +5 volts is turned off, what is the voltage dropped across the liquid crystal? Assume the cell is 1 $\mu$m thick, the alignment layers are 30 nm thick each, and that $\varepsilon_{\infty} = 3$ for the alignment layers and the liquid crystal. What is the voltage across each alignment layer? Define positive as being in the direction parallel to the initial applied field.
   b. What would the voltage of part (a) across the cell be if $P_s$ were 5 nC/cm$^2$?
   c. What is the affect of this "depolarization" field of parts (a) & (b) across the liquid crystal?
   d. Consider a situation identical to that describe above, except assume the alignment layers are conductive. Does this change your answers to (a) and (b), and if so, how?
   e. If conductive alignment layers are not available, what other approaches could one take to mitigate the effect of the depolarization field?

3. a. You are asked to design a liquid crystal device that blocks light when no voltage is applied to it, and transmits greater than 50% of the light of all polarizations when a voltage is applied to it. How do you accomplish this? Describe the type of liquid crystal, the type of alignment, etc. It would be helpful if you drew a sketch of the on and off states. Hint: you cannot use any polarizers in the device because they always absorb at least 50% of the incident light, i.e., one polarization.
   b. You are asked to design a liquid crystal device that blocks light when a voltage is applied to it, and transmits greater than 50% of the light of all polarizations when no voltage is applied to it. How do you accomplish this? Hint: in addition to the approach you used in part (a), consider using a liquid having negative dielectric susceptibility.
4. Question 11.2, p. 253

5. Question 11.3, p. 253

6. Question 11.7, p. 254 (note: the formula given in (i) is not exactly correct)

7. Compare the voltage that would be required to achieve a $\pi$-phase shift for $\lambda = 1 \, \mu m$ in
   a. GaAs,
   b. KDP, and
   c. nitrobenzene
   for 100-μm, 1-mm and 1-cm thick material. Is this practical?
   d. For a non-twisted nematic liquid crystal in which $\Delta n = 0.15$ and $n_{avg} = 1.55$, an applied
      voltage (approximately 3 volts) causes the molecules to rotate from a homogeneous (parallel
      to substrate) state to a homeotropic (normal to substrate) state. For light polarized along the
      long axis of the molecules in the homogeneous state, what thickness of the liquid crystal cell
      is required for the same phase shift?