Questions for Solid State Physics, set 4:

Defects, amorphous materials:

1. If you have a *1*cm^3 sample of aluminum, how many vacancies would it contain at *250K* if the energy needed to create the vacancy is *0.75*eV and there are 10^{22} atomic sites in every cubic centimeter of the sample?
2. Impurities can exist in all types of crystals, such as metals and insulators. In the special case of an n-doped semiconductor, how would you model one of these impurities if you where interested in quantities such as the binding energy? What if the semiconductor was p-doped?
3. Which of the following types of order is present in an *amorphous* solid? (1) short range order (2) long range order or (3) both short and long range order?
4. Which of the following types of order is present in a *crystalline* solid? (1) short range order (2) long range order or (3) both short and long range order?

Dielectrics

1. What are the physical mechanisms which can lead to a dielectric polarization of solids?
2. Name three places dielectrics can be found in electronics components?
3. Estimate the static dielectric constant of NaCl. Use that NaCl has a density of $\rho=2170$ kg/m^3, a lattice constant of $a=5.6$ Å and a Young's modulus of $Y=40$ GPa. The optical ε is *2.34* (Hofmann Table 9.2) and the result can be compared to the static ε of *6.1* (also Hofmann).
4. What is the magnitude of the dipole moment of a pair of point charges 6nm apart from one another if one charge has the value +4fC and the other -4fC?

Semiconductors

1. (a) Is the depletion region in a p-n junction largest when the junction is under (I) no bias, (II) reverse bias, or (III) forward bias? (b) When a p-n junction is under the condition given in your answer to question (a), do the drift currents or diffusion currents dominate?
2. (a) How many regions of differently doped semiconductor make up a bipolar junction transistor? (b) How are these regions arranged?
3. What is the difference between a 'unipolar' and a 'bipolar' device?
4. What is the significance of the gate threshold voltage, V_{GT}, in a MOSFET?
5. (a) Name the three basic processes that can occur between a photon and an electron in a solid.(b) Which of these processes forms the basis for laser operation?
6. (a) Calculate the effective density of states N^C_{Eff} for the conduction band of Silicon at $T=150$ K and $T=300$ K. (b) For a chemical potential in the middle of the gap, calculate the electron density in the conduction band.
7. (a) Name the three most widely used techniques for growing "perfect" semiconductor crystals? (b) What is the purpose of a seed crystal, and which of these processes uses one?
8. Name two important steps (there are more) in device manufacturing and suggest which techniques can be used to perform these steps.
9. A simple solarcell *pn*-junction configuration has a very highly doped *n* segment and a low doped *p* segment. We have made such a solarcell with the material InP. The acceptor doping is $N_A=10^{16}/cm^3$ while the donor doping N_D is not quite known, but it is orders of magnitudes larger. The potential difference across the *pn*-junction (the built-in-potential) is $\Delta U=0.8\text{V}$ at $T=300\text{K}$ and $\varepsilon_{InP}=12.4$. The intrinsic carrier concentration is $n_i=p_i=1.0\cdot 10^{14}\,cm^3$ at this temperature. We assume a sharp transition between the depletion region and the non-depletion region. Draw the charge density in the depletion zone. Derive expressions for and draw the electric field distribution and potential distribution within the depletion zone. Find the potential difference over the junction. Calculate the depletion width and the donor doping level. Assume that the donors and acceptors are fully ionized.