Due Apr. 7, Thursday.

Problem 1 (20 points) 1.5 of Pierret. For the programming part, Matlab or Python is recommended. However, any language that you feel comfortable with is acceptable. Include your source code in your solutions.

Problem 2 (10 points) 1.6 of Pierret.

Problem 3 (10 points) 1.10 of Pierret.

Problem 4 (20 points) Quantum Strand: Introduction to Quantum Mechanics Activity at http://et.portal.concord.org/activities/. Note: (1) Please do "Intro and Admin: Activities: Survey" first. (2) As long as you complete the activities, you will get close to the perfect grade. You can revise your answers any time until the due date.

Problem 5 (20 points) Let us re-examine the hydrogen problem that we solved semi-classically ("Bohr method") (also see pages 735-736 of the book). However, consider the nucleus with charge Ze (not e =1.6e-19 C), and the electron with mass m^* (not equal to m_e, the free electron mass). Also, assume that the nucleus and the electron interact in a medium with a dielectric constant ε, instead of in vacuum. Each part of this problem is a continuation of the previous parts.

(a) Find the quantized energy level E_n in terms of the Rydberg constant ($R = 13.6$ eV), Z, m^*/m_e, and ε.

(b) In a typical semiconductor such as Si, m^* is indeed different from m_e. Let us take a typical number $m^* \sim m_e/10$. Also, $\varepsilon \sim 10$. Consider a P impurity in Si. This is the case of a "donor." P has five valence electrons, and thus can release ("donate") one electron to the Si crystal, as the tetrahedral covalent bonding requires only four valence electrons per atom. However, when the P atom releases one electron, it will be positively charged to become an ion. From now on, we shall consider this positive P ion as the "nucleus." What is the effective charge Ze of the P ion?

(c) The released electron may not go free but form a bound state with the P ion, just as an electron is bound to a positive nucleus charge in a hydrogen problem. What is the maximum binding energy $|E_1|$ of the electron in this case?

(d) What is the size of the orbit (r_1) corresponding to this binding energy?