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Your Name Goes On This Line

E106 Final Examination
6, 9, 10, or 12 May 2005
Exam Time: 3 hours.

In this examination you may use the class texts and *any notes* that you have taken in class or made in preparation for the exam. You may also use your homework and quizzes, and my homework solutions. There are two sections to the exam. The first section consists of six short problems, each worth 16 points. They are designed to be answered quickly, without a great deal of derivation or calculation. The second section consists of three problems each worth 35 or 34 points. The total possible for the exam is 200 points. Within each section, the problems are of equal weight but *not* of equal difficulty. There is partial credit. Please write neatly and ***on one side*** of your paper only. You may work on your problems in any order, but please assemble your completed exam with the problems in the correct order and in the correct section. For safety, you may want to write your name on every page.

Section I – Skills Questions (16 Points Each)

1. The energetics of the ionic bond in CaF_2 are adequately described by

   $$E_N = -\frac{C}{r} + D\exp\left(-\frac{r}{\rho}\right) \quad ,$$

   where $D = 67.14$ eV , $\rho = 0.08704$ nm , the bond length is 0.233 nm, and E_N is in electron volts. What is the theoretical elastic modulus for CaF_2? Be sure to include units.

2. A 3/8-inch diameter piece of chalk with a failure strength of 29 psi (yes, psi) fails in a three-point bending test at a load of 0.200 lb. What is the length of the piece of chalk?

3. Germanium is doped with 0.612 ppm (by atomic fraction, not mass fraction) of indium. At 400 K the material has a conductivity of $3893\ (\Omega m)^{-1}$. For reference the atomic weight of Ge is 72.6100 g/g-atom , and the density is $5.323\ g/cm^3$. What is the carrier mobility at this temperature and dopant level?

4. A flat-plate capacitor has a capacitance of $47\mu F$, a length of 7 m, a width of 2 m, and a plate separation of 0.010 mm. What is the dielectric constant of the dielectric in the capacitor?

5. Do Problem 15.12 (b) on page 664 of *Callister*. The volume fraction of fibers in the composite is 0.418.

6. A sample of a polymer with a linear coefficient of thermal expansion of $122\times10^{-6}(°C)^{-1}$ is rigidly attached to two immovable walls and then heated from $25°C$ to $100°C$ where it experiences an compressive stress of 21.8 MPa . What is the elastic modulus of the polymer?

Section II – Long Question (35 or 34 Points Each)

1. A carbon-fiber reinforced epoxy is desired with high-modulus fibers (data in Table 15.6 on page 650) Parallel cylindrical fibers (all of equal diameter) are to be laid in the longitudinal direction.
   a) What is the maximum volume fraction possible for the fibers? An answer of 1.00 or 100% will result in a score of 0 for this problem so don't be tempted.
   b) Assume that the actual volume fraction will be 80 percent of the maximum. Again, an answer that uses $V_f \approx 0.8$ will result in a score of 0 for the problem. Calculate the values of E_{cl} and E_{ct} for this composite.

2. Austrium and lunicon are fictitious Group IV elements used to dope III-V compound semiconductors. Data on III-V semiconductors is found on page 488 of *Callister*. Austrium always replaces the Group III element and lunicon always replaces the Group V element. Determine the dopant element (austrium or lunicon) and quantity (in parts per million, ppm) required to form a p-type extrinsic semiconductor with a conductivity, $\sigma = 100\ (\Omega\text{m})^{-1}$ from gallium phosphide, GaP. The Ga-P bond distance is 0.236 nm.

3. The exterior wall of a rather unusual house consists of a 1/2-inch thick layer of nylon 6,6 on the inside and a 1-inch thick layer of Douglas fir on the outside. The grain of the wood runs vertically in the wall. The wall is 8 feet high and 12 feet wide. On a Summer day, the temperature in the room (and on the inside surface of the wall) is $78°\text{F}$ and the temperature outside (and on the outside surface of the wall) is $100°\text{F}$.
   a) Will a 7000 BTU/hr room air conditioner be sufficient to keep the room at $78°\text{F}$?
   b) What is the temperature at the nylon-wood interface?