E106 Final Examination
15, 16, or 17 December 2004
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. To pass the class you must get five of the six essentially correct. The second section consists of two problems each worth 52 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. Quantitatively describe the microstructure of a mixture of 1.45 weight% carbon in iron that is slowly cooled from $1600°C$ to $800°C$. The Fe-C phase diagram is on page 396 of *Callister.*

2. Quantitatively describe the microstructure of a sample of 4340 steel that is heated to above $727°C$ for 100 hours, cooled rapidly to $650°C$, held there for $3\times10^4 s$ and then rapidly cooled to room tempreature. The relevant IT diagram is on page 441 of *Callister.*

3. Calculate the conductivity of the wire in a wirewound resistor with a total length of 20 m, a diamter of 0.511 mm, and a resistance of 10.6Ω.

4. Silicon is doped with 20.0 ppm (by atomic fraction, not mass fraction) of indium. At $400°C$ the material has a conductivity of $1140\ (\Omega m)^{-1}$. For reference the atomic weight of Si is 28.0855 g/g-atom, and the density is $2.33\ g/cm^3$. What is the carrier mobility at this temperature and dopant level?

5. Do Problem 15.8 (a) on page 664 of *Callister.*

6. Electrolytic tough pitch copper (C11000) has a density of $8.89\ g/cm^3$, a heat capacity of 385 J/kg K, and a thermal conductivity of 388 W/m K. A long copper rod is insulated along its length. The rod is initially at a uniform temperature. At the start of an experiment the temperature at the front surface of the rod is heated to a constant $100°C$. After 44.05 seconds, the temperature 106 mm from the end of the rod registers $46.66°C$. What is the thermal diffusivity of the copper and what was the initial temperature of the rod?

Section II – Long Question (52 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. Fill in as many values in the 3×3 compliance matrix as possible. Enter any unknowns as the appropriate variable names.
   c) Describe what experiments and measurements would have to be performed, and what calculations would have to be made in order to determine the values of the unknowns in the compliance matrix in part b.

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.
   a) 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.
   b) Determine the dopant element (austrium or lunicon) and quantity (in parts per million, ppm) required to form an n-type extrinsic semiconductor with a conductivity, $\sigma = 100\ (\Omega\text{m})^{-1}$ from indium antimonide, InSb. The ionic radii of indium and antimony are 0.092 nm and 0.090 nm respectively.