Department of

MATERIALS SCIENCE AND ENGINEERING

Doctoral Written Exam

Day 1

Core Areas covered:

MSE 500
MSE 520

Thursday, January 29, 2004

Department of Materials Science and Engineering

DOCTORAL WRITTEN EXAM – Day 1
January 29, 2004

Your exam packet for day I contains a total of six (6) questions from two (2) core areas, MSE 500 and MSE 520, plus 15 answer sheets. Each question is on a separate page. A copy of the Table of Constants is included for your reference. **You must submit 2 questions from each core area for grading**. You will have 4 hours to complete the questions. You can obtain extra answer sheets from the proctor, if needed. Please use the following procedure:

Write a four (4) digit code of your choice, and your name on the 3 X 5 card provided. Use this code in place of your name to identify all answer sheets you submit for both days of the exam. Renee will keep the code information, sealed in an envelope, until after the exams are graded.

For each answer, use the question sheet as the first page of your answer. If additional pages are required, use the blank answer sheets provided. At the end of the examination, staple each question sheet and corresponding answer sheets for each question separately, put this instruction sheet on top of the questions you are turning in, and place them in one side of your exam folder. Place all other exam pages in the other side of your folder, and return everything to the proctor, or Renee if you finish before 12:30 P.M.

Please be sure to complete the information required on each page.

GOOD LUCK!

CODE NUMBER ________________

CHECK THE 4 QUESTIONS YOU WISH TO HAVE GRADED.

MSE 500:	MSE 520:
1. ____	4.____
2. ____	5.____
3. ____	6.____

1.

A binary mixture of two molecules, A and B for which N_A and N_B are the number of monomer units in each polymer chain, is found to obey the Flory-Huggins free energy of mixing.

$$\frac{\Delta G_m}{RT} = \frac{\phi_A}{N_A}\ln\phi_A + \frac{\phi_B}{N_B}\ln\phi_B + \chi\phi_A\phi_B$$

where ΔG_m is the free energy of mixing per lattice site and ϕ_A is the volume fraction of component A.

a) What is the value of χ at the critical point where the system shows incipient phase separation?

b) What is the value of ϕ_A at the critical point?

c) What is a possible order parameter that could be used to describe the extent of phase separation in this system?

2.

Explain the dependence of pressure on the band gap of a solid using the standard Kronig-Penney model. Do semiconductors obey this behavior, if they do, why? If they don't, what accounts for the discrepancy?

3.

A strip of tin is 10 mm wide and 0.2 mm thick. When a current of 20 A is established in the strip and a uniform field of 0.25 T is oriented perpendicular to the plane of the strip, a Hall voltage of 2.20 μV is measured across the width of the strip.

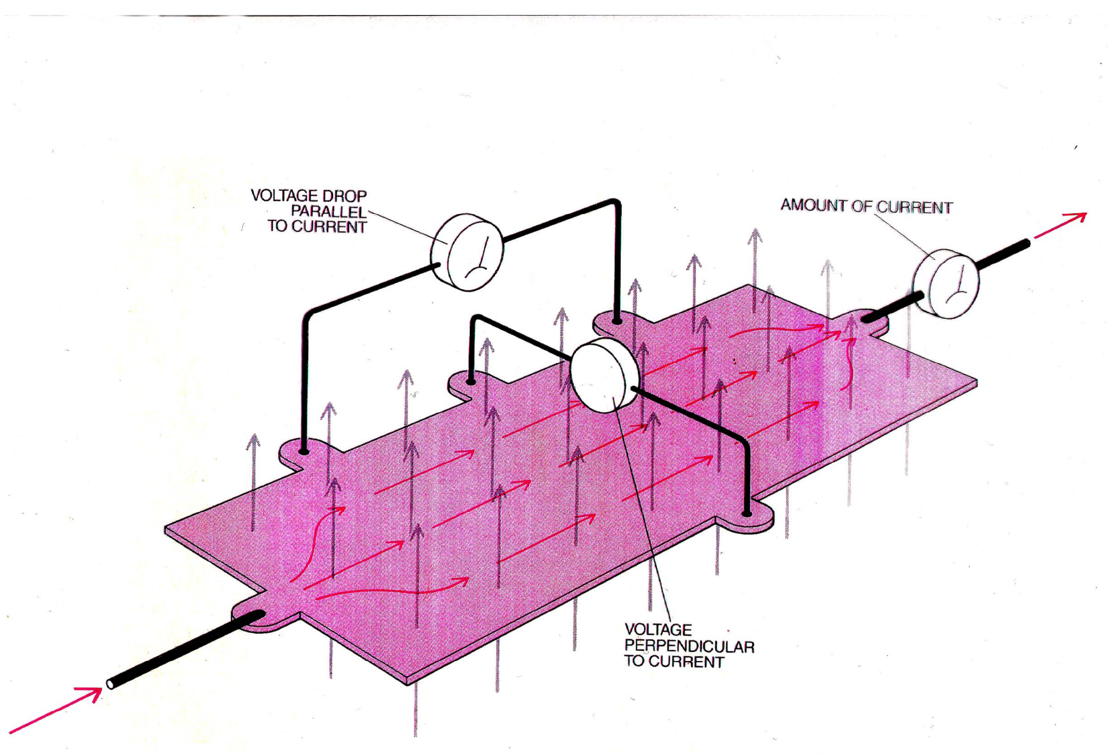
The density of tin is 5.75 x 10^3 kg/m^3 and its molar mass is 118.7 g/mole; the majority charge carriers in tin are holes.

a) Compute the charge carrier concentration (or "number density of charge carriers") in tin.

b) Using your answer in (a), compute the Fermi energy of tin, at 293K, in eV.

c) Compute the average number of charge carriers contributed by each tin atom.

d) In the diagram below, show the deflection of the charge carriers and indicate the proper sign for the Hall voltage:



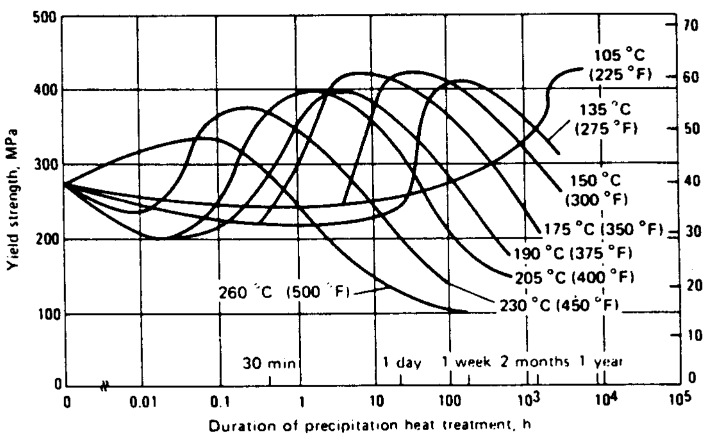
4.

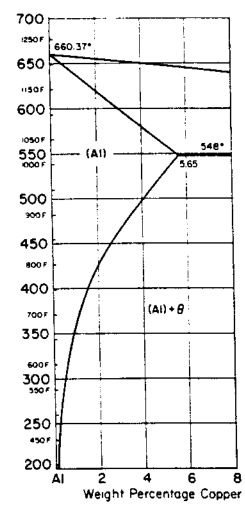
The curves below show how the yield strength of aluminum alloy 2014 which contains about 4.5% Cu changes with aging after quenching from a solution treatment at 500°C.

a) Estimate the slope, $d\sigma_y/dc$, of a plot of yield strength, σ_y, vs. atomic % copper, c, in solid solution. (Assume that after aging for 1 week at 260°C, all of the copper has precipitated and the dispersion strengthening is negligible. Also assume that immediately after quenching all of the copper is in solid solution.)

b) Consider the condition that gives a maximum yield strength (e.g. 1 day at 150°C). Determine the increase of yield strength, $\Delta\sigma_y$, attributable to the precipitate particles.

c) Assuming the Orowan mechanism for particle hardening by bowing of dislocations, estimate the distance between particles on the slip planes to achieve this strength increase.





5.

a) The plastic shear stress plastic shear strain curve of a single crystal is determined to be

$$\tau = 1.0 + 50\gamma^{1/2}$$

where τ and γ are the resolved shear stress and strain for the active slip system. Determine an approximate expression for the tensile stress-tensile strain curve for a polycrystalline form of this material, if this is the only information available. For a complete quantitative description of the tensile stress-tensile strain curve, state what additional information you might need. Would you expect different tensile stress-tensile strain curves for f.c.c. and b.c.c. metals? Explain why or why not.

b) The constitutive equation for a material is given by

$$\sigma = K\varepsilon^{1/2}e^{1/2}$$

where K is a constant, σ is the tensile stress, ε is the tensile strain and e is the tensile strain rate, $d\varepsilon/dt$ From this equation, determine the maximum stable strain (at maximum load) exhibited by such a material.

6.

Consider the Maxwell model (i.e. series model) for visco-elastic flow. For this case, schematically illustrate stress vs time and corresponding strain vs time plots for: (i) a creep test (where $\sigma = \sigma_{o,}$ a constant), and (ii) a constant strain rate tensile test (e = strain rate, which is constant and non-zero) followed by a stress-relaxation test (e = 0). Describe mathematically the forms of these plots by deriving them from assumed equations for the appropriate visco-elastic elements.