Department of
MATERIALS SCIENCE AND ENGINEERING

Doctoral Written Exam

Day 2

Core Areas covered:

MSE 532
MSE 535
MSE 560

Friday, January 28, 2005

Department of Materials Science and Engineering

DOCTORAL WRITTEN EXAM – Day 2
January 28, 2005

Your exam packet for day 2 contains a total of nine (9) questions from three (3) core areas, MSE 532 MSE 535, and MSE 560, plus 20 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 6 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 2:30 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 532:	MSE 535:	MSE 560:
1. ____	4.____	7.____
2. ____	5.____	8.____
3. ____	6.____	9.____

Day 2 – ADVANCED THERMODYNAMICS OF MATERIALS   CODE #________

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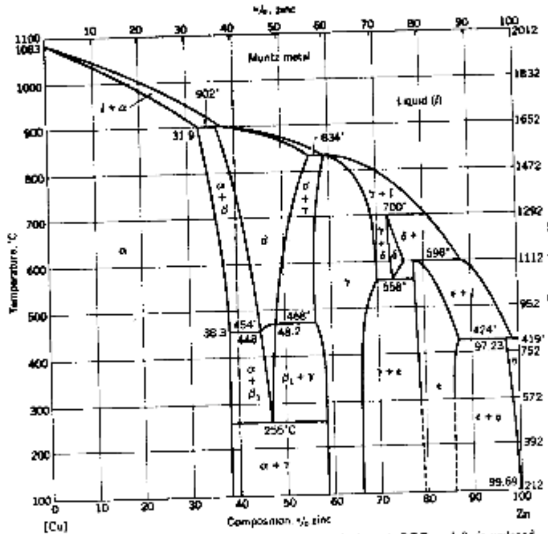
1.

The copper-zinc phase diagram is enclosed on the following page. Draw two neat, careful and qualitatively accurate plots, one plot with curves of (a) Gibbs free energy of mixing versus zinc composition, and a second plot with a curve of (b) zinc activity versus zinc concentration, for all stable phases in this system at 419^{o}C, the melting temperature of pure zinc. Identify clearly all one-phase, two-phase and three-phase regions in both plots, indicating the zero free energy of mixing in plot (a) and the standard state(s) with respect to which the calculations are based in plot (b).



The copper-zinc phase diagram. The β phase is BCC and β_1 is ordered and has the CsCl structure. The γ and δ phases have complex cubic structures; ϵ is HCP. (*Adapted from M. Hansen and K. Anderko, "Constitution of Binary Alloys," McGraw-Hill Book Co., New York, 1958.*)

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2.

Consider a system of two polymers mixed together that is known to follow well the Flory-Huggins free energy of mixing, given by:

$$\frac{\Delta G}{RT} = \frac{\phi_a}{N_a}\ln\phi_a + \frac{\phi_b}{N_b}\ln\phi_b + \chi\phi_a\phi_b$$

where ϕ_a, ϕ_b are the volume fractions of A and B, N_a and N_b are the degrees of polymerization, and χ is the Flory-Huggins interaction parameter. If the degree of polymerization of molecule A is 100, and that of molecule B is 10, then:

a) What is the value of ϕ_a at the critical point?

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

c) What is the value of χ at the critical point?

d) Draw the phase diagram of this system as a function of ϕ_a (x-axis) and χ (y-axis), showing the binodal and spinodal curves.

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3.

A cylinder of cross-sectional area A has a frictionless piston at the top. The cylinder contains a classical monatomic ideal gas. Initially the piston is held in place at height L_0, and the gas is in thermal equilibrium at temperature, T_0, and pressure, P_0. (The region surrounding the cylinder is evacuated.) Now, a mass M is placed, providing a weight, w=Mg, and the piston is released. After the system achieves equilibrium, what height, L, will the piston be located? Express L in terms of some or all of T_0, P_0, L_0, A, and w).

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4.

On New Years eve a balloon is dropped free fall from the Mutual of Omaha building in New York city 20 secs. before midnight so that it will hit the ground exactly at midnight to signal the beginning of the new year. The balloon is 2 meters in diameter and has a mass of 10 kg. (air density = 1.0 kg/m^3, air viscosity = 3x10^{-5}Pas, g = 9.8 m/sec^2)

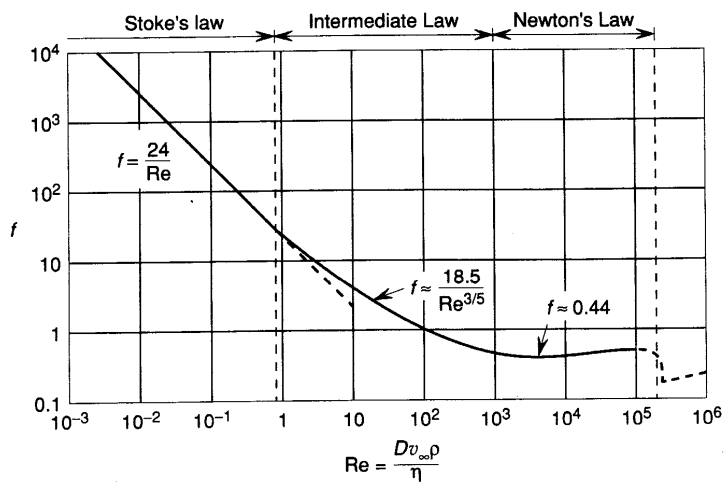

FIGURE 4.11 Variation of the friction factor with Reynolds number for fluid flow past sphere.

a) Can Stokes law be used to solve this problem? Show in detail.

b) Calculate and justify your choice of the value of the friction factor "f" that you will use. Show approximate calculations.

c) Using the "f" you determined above, calculate the terminal velocity of the balloon. (If you couldn't find f in part 2, use f = 1 and determine the answer)

d) Calculate the height of the building.

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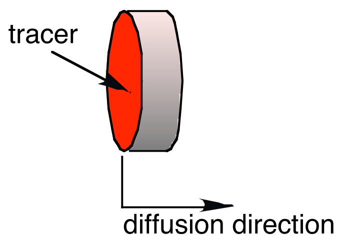
5.

In a tracer diffusion experiment a monolayer of radioisotope ^{60}Co is applied to the face of a Co_2SiO_4 (olivine) specimen (i.e., one of the flat surfaces of a cylindrical pellet). The specimen is then subject to heat treatment and the isotope diffuses into the specimen for an appropriate amount of time. The concentration profile of the isotope in direction perpendicular to the surface (axis of the cylinder) is determined by repeatedly abrading thin layer of material and then measuring the remaining radioactivity of the sample. Develop the appropriate formalisms that allow you, by using this procedure, to determine the diffusion coefficient of the radioisotope in the host material. Assume that the radioisotope emits γ-radiation, whose absorption by olivine is negligible.



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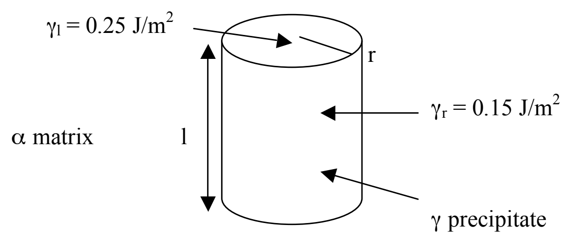
6.

A single-phase alloy undergoes a transformation from α solid to a mixture of α solid plus γ precipitates. The nucleation process produces rod-shaped precipitates of γ that can be modeled as cylinders, as shown below. In this system, embryos and nuclei form only with an aspect ratio (radius/length) that minimizes surface energy. As shown below, the surface energy is anisotropic. Calculate the size of a critical nucleus for an undercooling of 40K.

Data: Equilibrium transformation temperature = 400K, Enthalpy of transformation = 1.25×10^8 J/m^3, $\gamma_l = 0.25$ J/m^2, $\gamma_r = 0.15$ J/m^2



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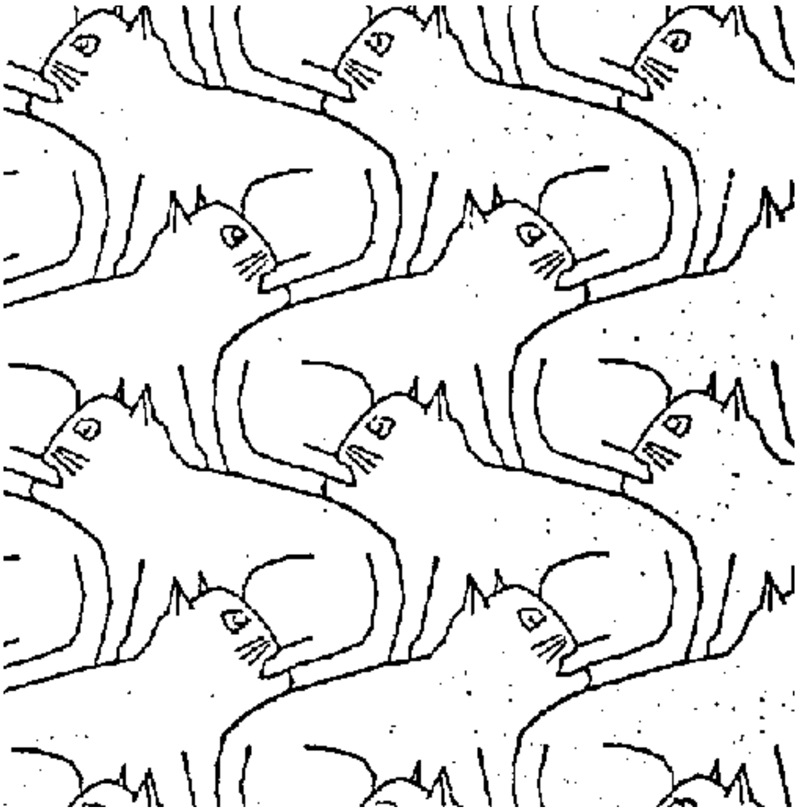
7.

Planar-Symmetry: Analyze the planar symmetry of the picture. Identify all mirror lines and centers of rotation. If there are translations and glide reflections which generate the pattern, identify those as well. [Note: ignore the black spots and assume eyes are all the same]:



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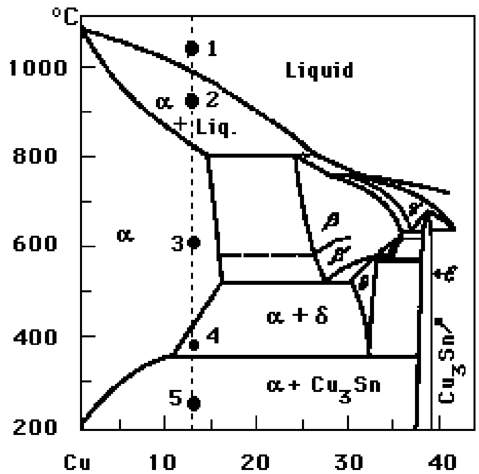
8.

Draw the x-ray diffraction patterns (I vs 2θ) for the microstructures at points 1 through 5 as indicated on the phase diagram below: (2 points each)



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9.

A crystal structure has a glide plane perpendicular to **b** (its normal is parallel to **b**) and has a translation vector ***a***/2 + ***c***/2. Does this create any special conditions (systematic absence) for reflections? If so, what are they?