Department of

MATERIALS SCIENCE AND ENGINEERING

Doctoral Written Exam

Day 1

Core Areas:

MATERIALS PHYSICS AND CHEMISTRY
ADVANCED MECHANICAL BEHAVIOR

Thursday, January 26, 2006

Department of Materials Science and Engineering

DOCTORAL WRITTEN EXAM – Day 1
January 26, 2006

Your exam packet for day I contains a total of six (6) questions from two (2) core areas, MATERIALS PHYSICS AND CHEMISTRY and ADVANCED MECHANICAL BEHAVIOR, plus 10 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.

MATERIALS PHYSICS AND CHEMISTRY:	ADVANCED MECHANICAL BEHAVIOR:
1. ____	4.____
2. ____	5.____
3. ____	6.____

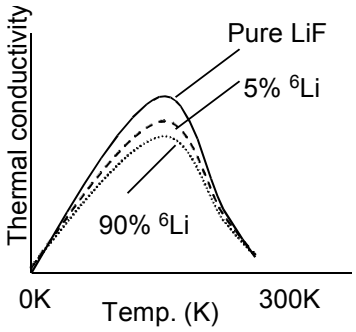
Day I – MATERIALS PHYSICS AND CHEMISTRY **CODE #_____**

1.

A qualitative plot of the thermal conductivity of LiF vs. temperature is shown schematically below for different proportions of the ^{7}Li and ^{6}Li isotopes. Answer the following questions:

a) Why does the thermal conductivity decrease for increasing concentration of ^{6}Li?

b) What would the trend in thermal conductivity be for increasing concentration of ^{7}Li?



Day I – MATERIALS PHYSICS AND CHEMISTRY **CODE #_____**

2.

Consider a Schottkey junction consisting of Tungsten and Silicon.

a) Draw the energy band diagram for this system.

b) If light were to shine on this junction and create electron-hole pairs, which way would the current flow within the devices when the junction is connected in a circuit? What is the maximum voltage that could be measured?

ϕ^{W}=4.5eV
ϕ^{Si}=4.0eV
χ^{Si}=3.7eV

Day I – MATERIALS PHYSICS AND CHEMISTRY **CODE #_____**

3.

A polymer (component 2) and solvent (component1) pair exhibit the following behavior:

Beaker A: Composition $v_2 = 0.1$ (volume fraction), homogeneous, clear solution at 500K. When stirred continuously and cooled slowly it turns milky-white at 400K.

Beaker B: Composition $v_2 = 0.6$, homogeneous, clear solution at 500K. When stirred continuously and cooled slowly it turns milky-white at 400K.

You should understand Flory-Huggins Theory to solve this problem.

$$\Delta G_m = RT[v_1 \ln v_1 + (v_2 / x) \ln v_2 + \chi v_1 v_2]$$

where, ΔG_m is the Gibbs free energy of mixing per mole of lattice sites, v_1 and v_2 are volume fraction, x is the molecular weight of the polymer, χ is the solubility parameter. Assume that the polymer is monodisperse, having the same molecular weight.

a) Explain these observations by sketching a T vs v_2 phase diagram.

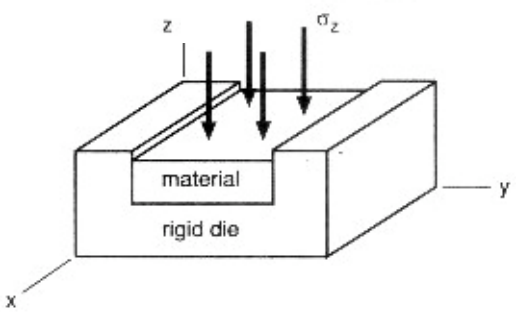
b) If the stirring is stopped, do you expect to be able to recover pure solvent from either of the beakers mentioned above? Explain your answer.

c) You are asked to estimate the degree of polymerization of the polypropylene. If you could have just one more data point on the left side ($v_2 < 0.5$) of the phase diagram, what data point would you ask for to achieve your goal of determining the degree of polymerization of the polymer? Explain.

Day I – ADVANCED MECHANICAL BEHAVIOR **CODE #_____**

4.

A sample of material is compressed in a completely rigid die as shown below.



a) The material is an isotropic, polycrystalline block with E = 200 GPa and ν=0.25. An applied compressive load along the "z" direction of 5kN is applied to the block, which measures 1 cm x 1cm in cross section. Determine σ_{yy} and $\varepsilon_{zz.}$ State your assumptions.

b) Write corresponding expressions for ε_{xx}, ε_{yy} and ε_{zz} that would apply if this were a single crystal with (001) type faces aligned with the "x" , "y" and "z" directions.

c) The load is increased until a block of the polycrystalline form of the same material just reaches the conditions for yielding. What relationship(s) between stress and strain would you use to describe deformation in this situation?

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5.

Below are the results of three creep experiments on a new, high-temperature, pressure-vessel material. Given the fact that no mechanism changes occur over the temperature and stress ranges appropriate for this question, answer the following questions based on this limited data set. You may assume that R = 8.3144 J/mol-K

Temperature (°C)	Stress (MPa)	Steady State Creep Rate (s^{-1})
700	350	3.3×10^{-8}
700	433	1.1×10^{-7}
750	350	3.4×10^{-7}

a) Determine the activation energy for creep.

b) Determine the creep stress exponent.

c) A thin-walled cylindrical pressure vessel with a diameter of 1 m, a length of 5 m, and a wall thickness of 3 mm must operate for 1 year at a pressure of 3 MPa and a temperature of 700°C with less than 1% effective creep strain. Will this material be adequate for the design? Assume negligible primary creep and justify your answer.

Day I – ADVANCED MECHANICAL BEHAVIOR **CODE #_____**

6.

A brittle matrix composite containing continuous ductile fibers is pulled axially in tension to a strain of 0.005 when the first matrix crack appears across the entire specimen. The elastic and plastic properties of the matrix and the fiber are given by:

$$\sigma_f = 700\ \varepsilon_f^{0.25} \text{MPa (fiber)}$$

$$\sigma_m = 260\ \varepsilon_m \text{ GPa (matrix)}$$

For a fiber volume fraction of 40%, determine the stress on the composite and whether the composite will fracture simultaneously. If not, what will be the tensile strength of the composite?