

Chemical Engineering 231
Principles of Engineering Materials
Spring 2009

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by appointment or almost any other time I'm in
required text: Callister, W.D, Jr. Fundamental of Material Science and Engineering: An Integrated Approach. 3rd ed., Wiley., 2008.

<u>Grade Breakdown</u>	<u>Grading Scale</u>			
use best 6 of 7 components	93.3 - 100	A	73.3 - 76.7	C
final exam (must be used)	90 - 93.3	A-	70 - 73.3	C-
pre-writing and in-class assignments	86.7 - 90	B+	66.7 - 70	D+
(3) closed book exams	83.3 - 86.7	B	63.3 - 66.7	D
(2) open-book exams	80 - 83.3	B-	60 - 63.3	D-
	76.7 - 80	C+	0 - 60	F

Appropriate scaling of the final course averages will be done at my discretion. Your grade will never be lower than that given on the above scale. Feel free to ask how you stand at any time.

Course Outcomes

- 1) Students will be able to communicate material science and engineering concepts in writing.
- 2) Students will be able to relate structure at the atomic and microscopic levels to physical properties such as melting point and density and mechanical behaviors such as strength, elasticity, and toughness for metals, ceramics, and polymers.
- 3) Students will be able to use binary equilibrium phase diagrams and phase transformation diagrams to determine phase composition, elemental composition, and microstructure.
- 4) Students will be able to identify the uses and properties of engineering materials including metals, ceramics, polymers, and composites.
- 5) Students will be able to solve problems requiring them to identify or represent directions and planes on a two-dimensional drawing of a three-dimensional cubical unit cell.
- 6) Students will be able to solve material science and engineering calculation problems requiring them to manipulate algebraic equations.

Daily Mechanics for the Course:

The list of closed-book questions and the rubric used to grade them is provided. These are the questions that the lectures will focus on, and are the questions that will appear on the closed-book exams.

Pre-writing assignments will be assigned on approximately half the class days for the following class period. Written responses will be required for one or two of the questions based on reading the chapter, before the material is presented in lecture. These responses will be submitted by email. The address is **che231@bobcat.ent.ohiou.edu**. They are due by 7 A.M. on the stated due date. They may be submitted anytime before then. Please don't send them to my personal email account. The subject line of your message should include your last name, and the question number. For example: E-mail Subject: Smith, Question 12. Only put one question per email message. Put the text directly in the email message. Don't use an attachment.

The pre-writing responses will be graded on a 0/3/6 scale. The expectation is far less rigorous than for the post-lecture, or exam responses. The objective is to prove to me that you have looked over the relevant material. A score of 6 is awarded for an answer that is predominantly correct, although it may be incomplete in some fashion. This doesn't mean that the same response will earn a 15 on an exam. A 6 can also be awarded if you clearly explain why you can't answer the question. This means a clear statement as to what is confusing you. For example, "Figure 10.3 seems to contradict the second paragraph on Page 543." This indicates you have reviewed the material, but are confused. An answer like, "I don't know where to look," won't earn the 6. A 3 is awarded for making a reasonable effort, but the response is incorrect and well off the mark.

The material will then be covered in lecture. An outline of the notes will be posted on the course webpage (<http://cheserver.ent.ohiou.edu/ChE231DR/>) approximately one week before the material is covered. You can also navigate to the page from the Chemical Engineering webpage. Click on "Current Students," then "Course Section Home Page." On some days a question from the current chapter will be assigned to be answered during the class. These will be graded using the 15 point scale. Possibly some of these will be answered in pairs, randomly assigned. Students will have about 5 minutes to review the notes and text and discuss the answer with other students, and then they will have 10-15 minutes to prepare a written response.

The Closed-Book Exams will consist of a series of questions pulled from the Question List. The typical number is four, but sometimes three or five have been given depending on the length of the responses. In most cases you will be given one more question than required (ie. "Answer 4 of 5). Certain question may be required. These are graded using the 15 point scale.

Quantitative calculation problems will also be included in the course. Examples will be covered in lecture, but graded homework will not be required. A list of both example and end-of-the-chapter problems useful in helping you learn the material is provided for each chapter. We will work a number of these, as well as other problems, in class. You are encouraged to work and study these together. You may, and are in fact encouraged, to submit any of these you wish at any time for review. Also some open-book calculation problems might be given as in-class quizzes, worth 10 or 15 points. This places the responsibility on you to keep up with the problems. Those who choose not to do the problems, or merely look at someone else's solutions before an exam, traditionally do poorly.

Academic Conduct

You are expected to act in a professional manner in this course, as you should in all professional activities. Copying or exchanging information on exams or quizzes is a violation of the standards set forth in this course and the *Student Handbook* in general. Appropriate penalties will be imposed, which could include a grade of F for the course and a referral to the Office of Judiciaries. Refer to the *Student Handbook* for descriptions of unethical behavior and the potential penalties.

Course Schedule

This is only an approximate schedule. The exams will be announced at least two class periods ahead of time.

<u>Week</u>	<u>Ch.</u>	<u>Topics and Notes</u>
1	1	Introduction
	2	Atomic Structure and Interatomic Bonding
2		no class
3	3	Structure of Metals and Ceramics
4	4	Polymer Structures
		Closed Book Exam #1
5	5	Imperfections in Solids
	6	Diffusion
		Open Book Exam #1
6	7	Mechanical Properties
7	8	Deformation and Strengthening Mechanisms
		Closed Book Exam #2
8	9	Failure
9	10	Phase Diagrams
	11	Phase Transformations
		Open Book Exam #2
10		Closed Book Exam #3
	11	Phase Transformations (cont.)
	20	Economic, Environmental and Societal Issues in Materials Science and Engineering
		Final Exam - Tuesday, June 9th, 8:00 A.M.

ChE 231 - Spring 2009 - Closed Book Question List

Chapter 1

- 1 Compare and contrast the typical physical properties of metals, ceramics, and polymers. (Generalization is expected; there will be specific exceptions to any statement you make.)
- 2 Briefly describe the different dimensional scales that are used to characterize the structure of a material.
- 3 Describe some common trade-offs in material properties.

Chapter 2

- 4 Explain the difference between a compound and a molecule.
- 5 Describe how and explain why atomic radius and electronegativity change with position in the periodic table.
- 6 Describe the different kinds of primary atomic bonds and how each type of primary atomic bond acts to fill the valence electron shells of individual atoms.
- 7 How can you tell what kind of primary atomic bonding is present by noting where the involved elements are located on the periodic table?
- 8 Describe how the electronegativity difference affects the ionic/covalent character of a bond.
- 9 Describe secondary atomic bonds including their cause and factors affecting their strength..
- 10 Explain why some covalently-bonded molecules have low boiling points and others have high boiling points.
- 11 Explain why covalent bonds are strong yet covalently-bonded polymers are weak.

Chapter 3

- 12 Compare the BCC, FCC, and HCP crystal structures. Consider the arrangement of atoms, coordination number, and packing density.
- 13 Explain is the structural difference between FCC and HCP structures.
- 14 Describe the factors which determine the crystal structure of crystalline ceramic materials.
- 15 Describe the difference in structure between crystalline and amorphous materials. Which way do metals, ceramics, and polymers generally behave?
- 16 Explain the relationship between the atomic structure and mechanical properties of the 2-dimensional (sheet) and 3-dimensional SiO_2 and carbon compounds.
- 17 How are grain boundaries of a metal caused by the solidification process? How will changes in the solidification process affect the grain size?
- 18 Explain how and why glass composition is varied. You don't have to remember specific formulations.

Chapter 4

- 19 Explain why it is important to know both the number-average and weight-average molecular weights of a polymer.
- 20 Describe the different ways that the configuration and structure of polymer molecules can vary. Consider the effects of monomer type, monomer functionality, branching and crosslinking, and the sequencing of monomer units in copolymers.
- 21 Explain the way that polymers are classified with respect to their response to elevated temperature. Relate the answer to the polymer structure and mer functionality.
- 22 Describe the crystalline structure of polymers and the factors which can affect the extent of crystallinity.

Chapter 5

- 23 Describe the different kinds of point defects that exist in solids. Include the specific differences that exist in ceramic crystal structures.
- 24 Define the term solution. Describe the two kinds of solid solutions and the kinds of atoms that are involved in each.
- 25 Describe edge and screw dislocations. Include the appearance of the dislocation and the orientation of the distortion relative to the dislocation.

Chapter 6

- 26 Describe the difference between kinetics and thermodynamics and explain the diffusion process in these terms.
- 27 Describe vacancy and interstitial diffusion. Include the types of elements involved, and their typical relative rates.
- 28 Explain the concepts of steady-state and nonsteady-state diffusion.

Chapter 7

- 29 Tell what you know about the different kinds of stress affecting solid parts and the ways to define and measure stress and strain.
- 30 Define elastic deformation and the terms used to characterize it.
- 31 How is the onset of plastic deformation defined and observed on a stress-strain diagram
- 32 Explain the difference between strength and toughness and how they are measured on a stress-strain diagram. When is strength important and when is toughness important?
- 33 Describe two different energy measurements that can be made using a stress-strain diagram.
- 34 Explain the significance of a decrease in engineering stress as strain increases.
- 35 Explain the influence of porosity on the mechanical properties of ceramics. Consider variability and stress concentration.
- 36 Describe three different typical stress-strain behaviors of polymers and relate this to temperature, crystallinity, and crosslinking.
- 37 Describe the possibilities for the strain response of a polymer subjected to a constant stress for a finite period of time, after which the stress is removed.
- 38 Describe the relationship between relaxation modulus and temperature and the effect of crystallinity and molecular weight.
- 39 Explain the difference between hardness and strength. Consider both the behavior that each term characterizes and the measurement technique.

Chapter 8

- 40 Describe the slip process and the importance of dislocations to slip. Include a description of how dislocations interact with each other during slip.
- 41 Why is slip easier in FCC than in either HCP or BCC crystal structures?
- 42 Explain why slip planes change direction when they cross grain boundaries.
- 43 Explain how and why a metal solution can have better mechanical properties than either pure metal.
- 44 Describe the process of strain hardening and how and why it changes a metal's properties.
- 45 Describe what happens to the grain structure of a cold-worked metal as it is held at an elevated temperature.
- 46 Explain how and why the typical mechanical properties of ceramics and metals differ. Consider plastic deformation.
- 47 Explain the mechanisms of plastic deformation for crystalline and non-crystalline ceramics.
- 48 Briefly describe the factors that affect the mechanical strength of semicrystalline polymers.
- 49 Explain the mechanical behavior of elastomers in terms of atomic-scale structures and processes.

Chapter 9

- 50 Describe and explain the relationship between temperature, toughness, and brittle vs. ductile failure modes in metals. Need to connect ideas of slip, ductility, and toughness.
- 51 Describe fatigue and some of the things that can be done to minimize it.
- 52 Define the term “fatigue limit” and explain why is it important?
- 53 Describe creep, compare it to slip, and describe the method and basis for predicting creep behavior in a short-duration test.

Chapter 10

- 54 Describe the changes in the equilibrium structure (atomic and microscopic scale) of a liquid mixture of nickel and copper as it's cooled and solidified. Other binary isomorphous systems could be substituted. The phase diagram will be provided..
- 55 Describe the possibilities for the solid atomic structure present when two dissimilar metals are mixed. Consider binary eutectic diagrams only.
- 56 Describe what happens (in terms of atomic and microscopic scale structure) to a liquid mixture of 20 wt% Ag in Cu as it is cooled to below 779 C. The phase diagram will be provided. Other materials and compositions could be substituted.
- 57 Describe what happens in an invariant reaction other than the eutectic reaction.
- 58 What do horizontal and vertical straight lines indicate on a two-component phase diagram?
- 59 Describe the origin and equilibrium microstructure of hypereutectoid and hypoeutectoid steel.

Chapter 11

- 60 Explain the shape of the isothermal phase transformation diagram for plain-carbon steel. Include both nucleation and diffusion concepts in your answer.
- 61 Describe the microstructure and cooling process followed to form the various two-phase mixtures which can be formed by cooling austenite.
- 62 Describe the mechanism by which martensite is formed. .
- 63 Compare the cooling programs needed to produce pearlite, bainite, and martensite.
- 64 Explain how alloy steels can be used to make larger parts made of martensite.
- 65 Explain how and why the strength of steel varies with carbon content and microstructure.
- 66 Compare constant cooling transformations and isothermal transformations. Consider both the ease and practical significance of the experiments.
- 67 Compare the strength and toughness of martensite, tempered martensite and bainite. Explain the reason for this. Consider the location of the carbon and the shape of any cementite particles.
- 68 Describe the process of precipitation hardening and explain why the hardness goes through a maximum value as aging time increases.
- 69 Describe the concept of the glass transition, and how it relates to the structure of polymers.
- 70 Describe the factors that affect the melt temperature and glass transition temperature of polymers.

Chapter 20

- 73 What are the three factors over which the engineer has control and which affect the final cost of a product? Which of these has this course been most concerned with?
- 74 (refers to Question 73) Thinking about the other two factors, give some examples where a particular material might be ideal for a given application, but it's not used. Why isn't it used?

Rubric for closed-book answers in CHE 231.

There are four main elements to a good answer. Weighting of the items is given below.

- 1 (4 points) All of the key technical elements (usually two to four items) of the required answer are identified. Usually some of the elements are given in the question.
- 2 (6 points) The technical elements which are present are correctly described along with their causal or sequential relationships to each other. The answer suggests that the student has a solid understanding of the material. Appropriate scientific or engineering terminology is used throughout. Pronouns are not used unless the noun they reference is clear. Colloquial or slang terms or phrases are not present.
- 3 (2 points) All of the text is grammatically correct and appears as sentences. Paragraphs, if needed, are effectively used to organize material. The first minor error, such as a missing article or incorrect capitalization are excused. Spelling, as long as it is reasonable, doesn't count.
- 4 (3 points) Overall, the answer is a well-structured, clear, concise statement. The answer doesn't ramble, the order of information is logical, all of the information present is either a part of an introduction to the answer or the answer to the question itself. Extraneous information, which does not address the question, is not present. Information is not repeated unnecessarily. This is the most subjective section.

ChE 231 - Spring 2009 - Open Book Question List

Chapter 3

- 1 Be able to calculate the coordination number, lattice constant, and atomic packing factor for FCC, BCC and HCP.
- 2 Be able to calculate the packing factor, density, for the cubic ionic crystal structures given in the text (NaCl structure, CsCl structure, zinc blende structure, perovskite structure).
- 3 Be able to calculate the density of a material based on the crystal structure, and atomic weight for crystalline metallic and ceramic structures.
- 4 Be able to determine the atomic positions, directions and Miller indices in cubic unit cells.
- 5 Be able to calculate planar, and linear densities in cubic unit cells.

Example Problems 1, 2, 3, 5, 6, 12, 13

End-of-Chapter Problems 1, 3, 7, 13, 14, 27, 28, 36, 37

Chapter 5

- 6 Be able to convert atomic percent to weight percent and vice-versa

Example Problems 4, 5

End-of-Chapter Problems 7, 9 (be able to do these calculations for materials with more than two components)

Chapter 6

- 7 Be able to apply the equation for Fick's first law, relating diffusion flux, diffusion coefficient and concentration gradient
- 8 Be able to apply the solution to Fick's second law for a semi-infinite solid fixed a fixed concentration at the surface (The solution given by Equation 5.5)
- 9 Be able to apply the concept of activation energy and the effect of temperature on diffusion

Example Problems 1, 2, 3, 4, 5, Design Example 1

End-of-Chapter Problems 4, 6, 7, 8, 11, 12, 16

Chapter 7

- 10 Be able to calculate engineering stress and strain, both tensile and shear.
- 11 Be able to apply the definitions of elastic modulus and shear modulus.
- 12 Know the definition of Poisson's ratio and how it is used to relate the elastic and shear moduli.
- 13 Be able to read the yield strength and tensile strength from a stress-strain diagram.

Example Problems 1, 2, 3

End-of-Chapter Problems 2, 4, 8, 12, 15

Chapter 8

- 13 Be able to calculate the resolved shear stress, given an applied force and a specified slip system
- 14 Be able to calculate the amount of cold work in a material
- 15 Be able to develop a cold work / heat treatment process to meet a specified set of properties

Example Problems 1, 2, Design Example 1

End-of-Chapter Problems 7, 14, D.3, D.4

Chapter 9

16 Be able to calculate the maximum stress in a crack

Example Problems 1

End-of-Chapter Problems 1, 2

Chapter 10

17 Be able to read a pure component phase diagram

18 Be able to use a binary isomorphous phase diagram

19 Be able to determine the phases present, the compositions and amounts of each phase present at a given temperature and overall composition (application of the lever rule)

20 Be able to calculate the amount of proeutectic and eutectic material for a given phase

21 Be able to write a eutectoid, peritectic and monotectic reaction

22 Be able to identify the phases present on the Fe-C phase diagram and their structure

23 Be able to apply the lever rule on the Fe-C phase diagram

24 Be able to calculate the amount of proeutectoid versus eutectoid material for both hypoeutectoid and hypereutectoid steels

25 Be able to identify the invariant reactions on the Fe-C phase diagrams

Example Problems 1, 2, 4

End-of-Chapter Problems 5, 6, 7, 17, 18, 25, 28, 29, 32

Chapter 11

26 Be able to describe how an isothermal transformation diagram is developed, and identify the phases present given a path or heat treatment

27 Be able to describe how a continuous cooling transformation (CCT) diagram is developed, and identify the phases present given a path or heat treatment

Example Problems 2

End-of-Chapter Problems 8, 11, 14, 20