COURSE: MSE 113

TITLE: Mechanical Behavior of Materials

UNITS: 3

LECTURES: Tu,Th 11-12:30, Room 348 Hearst Memorial Mining Building

LECTURER: Professor R. O. Ritchie, 324 Hearst Memorial Mining Bldg.,
           or Bldg. 62, Rm. 239, Materials Sciences Division, LBNL
           tel: 486-5798; e-mail: *roritchie@lbl.gov*

T.A.:   Jon Ell: email: *jonell@berkeley.edu*

WEB-PAGE: https://bcourses.berkeley.edu/courses/1464243

BRIEF COURSE DESCRIPTION:

A presentation is given of deformation and fracture in engineering and some
biological materials, including elastic and plastic deformation from simple
continuum mechanics and microscopic viewpoints, dislocation theory, alloy
hardening and creep deformation, fracture mechanisms, linear elastic and
nonlinear elastic fracture mechanics, toughening of metals, ceramics and
composites, environmentally-assisted cracking, fatigue failure, subcritical
crack growth, stress/life and damage-tolerant design approaches.

PREREQUISITES: E 45, ME c85/CEE c30, or equivalent

GRADING: Homeworks: 15%
            Mid-Term I: 20%
            Mid-Term II: 20%
            Final: 45%

NOTE:

The first few lectures involve a review of simple continuum mechanics and
elasticity, as taught in "strength of materials" courses such as ME c85/CEE
c30. Students are strongly advised to consult the reference texts on this topic,
listed overleaf, if they have some deficiency in this topic. Unless otherwise
announced, the first mid-term exam will be held on Thursday, September 21;
the second on Thursday, October 26. The final exam will be held from 8:00 to
11:00 am on Thursday, December 14, 2017.

Homework will be due one week after it is set (unless otherwise stated). Late
homework will only be allowed for two days after the stated due date, with 10%
lost credit per day.

REQUIRED TEXT:

R. W. Hertzberg, R. P. Vinci and J. L. Hertzberg: *Deformation and Fracture Mechanics of Engineering Materials* (Wiley, 2012, 5th ed.)

REFERENCE TEXTS:

1) Mechanical Behavior of Materials:

    F. A. McClintock and A. S. Argon: *Mechanical Behavior of Materials* (Addison-Wesley, 1966)*

    W. F. Hosford, *Mechanical Behavior of Materials*, (Cambridge Univ. Press, 2005)

    M. A. Meyers and K. K. Chawla: *Mechanical Behavior of Materials* (Cambridge Univ. Press, 2009, 2nd ed.)

2) Fracture Mechanics:

    T. L. Anderson: *Fracture Mechanics: Fundamentals and Applications* (CRC Press, 1991, 2nd ed.)* (or 3rd or 4th ed., although 2nd ed. is better!)

    D. Broek: *Elementary Engineering Fracture Mechanics* (Sijthoff & Noordhoff, 1982, 3rd ed.)

    J. F. Knott: *Fundamentals of Fracture Mechanics* (Halstead Press, 1973)*

    S. T. Rolfe and J. M. Barson: *Fracture and Fatigue Control in Structures* (Prentice-Hall, 1987, 2nd ed.)

    H. L. Ewalds and R. J. Wanhill: *Fracture Mechanics* (Arnold, 1984)*

    B. R. Lawn: *Fracture of Brittle Solids* (Cambridge Univ. Press, 1993, 2nd ed.)

3) Fatigue:

    S. Suresh: *Fatigue of Materials* (Cambridge Univ. Press, 1998, 2nd ed.)*

4) Environmentally-Influenced Failure:

    J. C. Scully: *Fundamentals of Corrosion* (Pergamon, 1975, 2nd ed.)

5) Mechanical Testing:

    Metals Handbook, 9th ed., vol. 8 (American Society for Metals)

6) Failure Analysis/Fractography:

    Metals Handbook, 9th ed., vol. 12 (American Society for Metals)

7) Continuum Mechanics/Elasticity:

    E. P. Popov: *Introduction to Mechanics of Solids* (Prentice-Hall, 1968)

    S. H. Crandall, N. C. Dahl and T. J. Lardner: *An Introduction to the Mechanics of Solids* (McGraw-Hill, 1978, 2nd ed.)

*Advanced level text.

UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Materials Science and Engineering

MSE 113   **MECHANICAL BEHAVIOR**   Prof. R. O. Ritchie
Tu,Th 11-12:30   **OF MATERIALS**
Room 348 HMMB

Fall 2017

COURSE OUTLINE

				Reading Assignment (*Hertzberg et al*)
Aug.	Th	24	Introduction	Chapt. 11,12
	Tu	29	Continuum Deformation	Chapt. 1
	Th	31	Continuum Deformation	
Sept.	Tu	5	Elasticity	
	Th	7	Elasticity	
	Tu	12	Plasticity	Chapt. 2,3
	Th	14	Dislocations	
	Tu	19	Dislocations	Chapt. 2
	Th	21	**MID-TERM EXAM I**	
	Tu	26	Single Crystal Slip	Chapt. 3
	Th	28	Alloy Hardening: mechanisms	Chapt. 4
Oct.	Tu	3	Creep: mechanisms	
	Th	5	Creep: deformation	Chapt. 5
	Tu	10	Fracture: mechanisms	
	Th	12	Fracture Mechanics: introduction	Chapt. 6
	Tu	17	Linear Elastic Fracture Mechanics: K fields	Chapt. 6-7
	Th	19	Linear Elastic Fracture Mechanics: K_{Ic} testing	
	Tu	24	Linear Elastic Fracture Mechanics: resistance curves	Chapt. 7
	Th	26	**MID-TERM EXAM II**	Anderson
	Tu	31	Nonlinear Elastic Fracture Mechanics: J fields	Chapt. 7
Nov.	Th	2	Toughening Mechanisms: metals	
	Tu	7	Toughening Mechanisms: ceramics	Chapt. 7
	Th	9	Toughening Mechanisms: composites	
	Tu	14	Environmentally-Assisted Cracking	Chapt. 8
	Th	16	*S/N* Fatigue	Chapt. 9,10
	Tu	21	Fatigue-Crack Propagation	Chapt. 9
	Tu	28	Polymeric Materials	Chapt. 10
	Th	30	Damage-Tolerant Design: lifetime calculations	
Dec.	Th	14	**FINAL EXAMINATION (8:00 – 11:00 am)**	

*for additional reading on these topics, which are not covered too well in Hertzberg *et al*.'s book, see Meyers & Chawla's or Anderson's book.

MSE 113: MECHANICAL BEHAVIOR OF MATERIALS

ONLINE RESOURCES

- Course website *https://bcourses.berkeley.edu/courses/1464243*
- Instructor: Robert O. Ritchie

CATALOG DESCRIPTION

A presentation is given of deformation and fracture in engineering materials, including elastic and plastic deformation from simple continuum mechanics and microscopic viewpoints, dislocation theory, alloy hardening and creep deformation, fracture mechanisms, linear elastic and nonlinear elastic fracture mechanics, toughening of metals, ceramics and composites, environmentally-assisted cracking, fatigue failure, subcritical crack growth, stress/life and damage-tolerant design approaches.

COURSE PREREQUISITES
E 45, ME c85/CEE c30, or equivalent

PREREQUISITE KNOWLEDGE AND/OR SKILLS TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Required text: R. W. Hertzberg, R. P. Vinci and J. L. Hertzberg: *Deformation and Fracture Mechanics of Engineering Materials* (Wiley, 2012, 5th ed.)

COURSE OBJECTIVES

- provide an understanding of the mechanics and micro-mechanisms of elastic and plastic deformation, creep, fracture, and fatigue failure, as applied to metals, ceramics, composites, thin film and biological materials.
- provide a thorough introduction to the principles of fracture mechanics.
- provide practical examples of the application of fracture mechanics to design and life prediction methods and reporting.
- provide a basis for the use of fractography as a diagnostic tool for structural failures.

DESIRED COURSE OUTCOMES

The successful student will learn:

- Ability to use of both mathematical modeling with lab-based experimentation to define and characterize the limiting conditions for the future of engineering materials.
- Ability to use simple continuum mechanics and elasticity to determine the stresses, strains and displacements in a loaded structure.

- Understanding and mathematical modeling of the elements of plastic deformation, with respect to continuum and microscopic mechanisms.
- Understanding how micro-structural design can influence the mechanical properties of materials.
- Use of fracture mechanics to quantitatively estimate failure criteria for both elastic and plastically deforming structure.
- Use of fracture mechanics in design of life prediction strategies and for fracture control plans, with examples from the automotive, aerospace, medical, and other industries.
- Understanding of fatigue failure, how this affects structural lifetimes of components.
- Design of metals, ceramics, composites, and biological materials for optimal failure and fatigue analysis.

TOPICS COVERED

Simple continuum mechanics and elasticity; stress, strain, stress concentrations; elastic deformation, Hooke's law; plastic deformation, stress-strain curves/constitutive behavior, plastic instability, concept of a dislocation, simple dislocation theory, application to plastic deformation, grain boundaries, hardening mechanisms in metals, single-crystal slip; creep deformation, creep mechanisms in metals and ceramics, creep constitutive laws, life prediction; Griffith and Orowan theories of ideally brittle fracture, fracture in ductile and brittle materials, fractography, linear-elastic fracture mechanics, concept of fracture toughness, resistance-curves, introduction to nonlinear-elastic fracture mechanics, application to design; toughening mechanisms in metals, ceramics, polymers, composites and biological materials (*e.g*., bone and teeth); environmentally-assisted cracking, mechanisms, fracture mechanics description (*v-K* curves); fatigue failure, mechanisms of fatigue in metals, ceramics and biological materials, stress-strain/life description (*S/N* curves, endurance strengths/fatigue limits, Goodman relationship, Neuber's and Miner's rules, fatigue strength reduction factors), application of fracture mechanics to fatigue-crack growth ($\mathrm{d}a/\mathrm{d}N$ *vs*. ΔK curves), mechanisms, effect of overloads, environment, etc., damage-tolerant life predictions, design against fatigue, fatigue thresholds, crack closure, small crack fracture mechanics; other mechanisms of failure, *e.g*., elastic buckling and wear, as time permits.

CLASS SCHEDULE

Lectures: Tu, Th, 11:00 - 12:30   348 Hearst Memorial Mining Building

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

The course presents major components of mechanics and nano-/micro-structural phenomena essential to the understanding of the failure processes in solids.

RELATIONSHIP OF THE COURSE TO UNDERGRADUATE DEGREE PROGRAM OBJECTIVES

All materials engineering and material science students must be conversant with the basis aspects of the mechanical behavior of materials, from both a mechanics and materials science perspective. This course fulfills that objective.

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

- 9 homework sets
- 2 mid-term exams
- 1 final exam

PERSON(S) WHO PREPARED THIS DESCRIPTION

Robert O. Ritchie