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

Fall 2018

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.: Amy Wat: email: *amy.wat@berkeley.edu*

WEB-PAGE: *https://bcourses.berkeley.edu/courses/1473955*

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 Tuesday, September 18; the second on Thursday, October 18. The final exam will be held from 8:00 to 11:00 am on Wednesday, December 12, 2018.

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, with10% 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, 5^{th} 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, 2^{nd} ed.)

2) Fracture Mechanics:

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

   D. Broek: *Elementary Engineering Fracture Mechanics* (Sijthoff & Noordhoff, 1982, 3^{rd} 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, 2^{nd} ed.)

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

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

3) Fatigue:

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

4) Environmentally-Influenced Failure:

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

5) Mechanical Testing:

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

6) Failure Analysis/Fractography:

   Metals Handbook, 9^{th} 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, 2^{nd} ed.)

*Advanced level text.

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MECHANICAL BEHAVIOR OF MATERIALS

Prof. R. O. Ritchie

Fall 2018

COURSE OUTLINE

				Reading Assignment (*Hertzberg et al*)
Aug.	Th	23	Introduction	Chapt. 11,12
	Tu	28	Continuum Deformation	Chapt. 1
	Th	30	Continuum Deformation	
Sept.	Tu	4	Elasticity	
	Th	6	Elasticity	
	Tu	11	Plasticity	Chapt. 2,3
	Th	13	Dislocations	
	Tu	18	**MID-TERM EXAM I**	Chapt. 2
	Th	20	Dislocations	
	Tu	25	Single Crystal Slip	Chapt. 3
	Th	27	Alloy Hardening: mechanisms	Chapt. 4
Oct.	Tu	2	Creep: mechanisms	
	Th	4	Creep: deformation	Chapt. 5
	Tu	9	Fracture: mechanisms	
	Th	11	Fracture Mechanics: introduction	Chapt. 6
	Tu	16	*Review*	Chapt. 6-7
	Th	18	**MID-TERM EXAM II**	
	Tu	23	Linear Elastic Fracture Mechanics: K fields & K_{Ic} testing	Chapt. 7
	Th	25	Linear Elastic Fracture Mechanics: resistance curves	Anderson
	Tu	30	Nonlinear Elastic Fracture Mechanics: J fields	Chapt. 7
Nov.	Th	1	Polymeric Materials (Prof. Lisa Pruitt)	
	Tu	6	Toughening Mechanisms: metals	Chapt. 7
	Th	8	Toughening Mechanisms: ceramics	
	Tu	13	Toughening Mechanisms: composites	Chapt. 8
	Th	15	Environmentally-Assisted Cracking	Chapt. 9,10
	Tu	20	*S/N* Fatigue	Chapt. 9
	Tu	27	*Review*	Chapt. 10
	Th	29	Damage-Tolerant Design: Fatigue-Crack Growth	
Dec.	W	12	**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/1473955*
- 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 (da/dN *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