Concordia UNIVERSITY

DEPT. OF MECH. AND IND. ENG.

MECH 321 Properties and Failure of Materials

LECTURES: Wed-Fri H-531 from 10:15 to 11:30 am

FACULTY: Dr. Mamoun Medraj
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Dept. of Mech. Ind. & Aero. Eng.,
Room, EV12.185

Office Hours: **Wed. from 2:30 to 4:00 pm.**

TEXTBOOK:

W.D. Callister, Materials Science & Engineering: An Introduction 6th, 7th, 8th or 9th edition., J. Wiley.

Also, MECH 321 Coursepack from Bookstore.

References:

1. Mechanical Metallurgy, G.E. Dieter, McGraw-Hill, 3rd Edition, 1986
2. Deformation and Fracture Mechanics of Engineering Materials, RW. Hertzberg, Wiley, 4th Edition, 1995.

MECH 321 Properties and Failure of Materials

Handouts: are available at

www.me.concordia.ca/~mmedraj/mech321.html

Assessment:	
Lab	15%
In-Tutorial Exercises	10%
Exams:	
• Midterm	25 %
• Final	50 %

- Assignments will not be collected but the questions will be used as the basis for the In-Tutorial Assignment Problems.
- Also, some of the assignments problems (*or similar ones*) will be asked in the exams. The solutions will be discussed in the tutorial sessions.

The *In-Tutorial Assignment Problems* will take place **every second** tutorial. The first one will be on Friday January 25th.

The midterm exam is ***optional***. Students who write the midterm exam, however, will get the higher mark of the final exam plus the midterm or the final exam alone.

MECH 321 Properties and Failure of Materials

• Tutorial: Friday from 4:45-5:35 pm in MB-S2.401 *(XA)* and MB-S1.430 *(XB)*

TA's:

- Rizwan Shaik (*Tutor and Marker*), email: sra247@gmail.com
- Ajeesh S Nair (*Tutor and Marker*), email: ajeeshnair551@gmail.com
- Omid Aghababaei (*Labs*), email: omid.aghababaei@yahoo.com
- Rahul Chug (*Labs*), email: rahulchugmech@gmail.com
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- Parth Goyani (*Labs*), email: parth.goyani1993@gmail.com

✓ Peter Sakaris (*Laboratory Specialist*), email: sakaris@encs.concordia.ca

Properties and Failure of Materials Labs

Labs Topics:

- Tensile
- Fracture
- Impact test
- Heat treatment
- Flexural testing of ceramics
- Materials selection
  - *Cambridge Engineering Selector software*

- The timetable and explanation of each lab. experiment can be found in the Mech 321 lab Manual available on the course website or at the Digital Store.
- The labs are in H-1058 (*Tu and Th 11:45 to 1:35*).

✓ A short report is required for every lab.
✓ Lab attendance will be taken and is mandatory in order to receive a grade.
✓ The reports are to be submitted to the lab instructor.
✓ At least one lab related question on every exam.

Course Outline

- Introduction and Review (1 lecture)
- Plastic Deformation (3 lectures)
- Strengthening Mechanisms (3 lectures)
- Fracture: (12 lectures)
  - *Theory, design aspects…*
  - *Fatigue*
  - *Creep*
  - *Corrosion*
  - *Wear*
- Classes of Materials (2 lectures)
  - *Ferrous, non-ferrous alloys…*
- Materials Selection (3 lectures)
  - *Cambridge Engineering Selector*

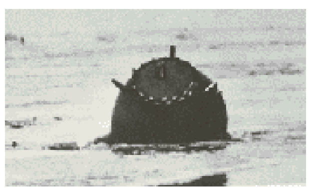
$\sum = 24 + 1$ Midterm $+ 1$ review $= 26$

Why Study Properties and Failure of Materials?

(1) Important to understand **capabilities** **and** **limitations of materials:**

- The following are just a few examples of catastrophic failure caused by a lack of fundamental understanding of *materials, their properties, and failure modes*.

Catastrophic Failure - *examples*



Liberty ships (WWII) → D-B-T in BCC Fe (metal)

Challenger (1986) → failure of an O-ring seal (polymer)

Catastrophic Failure - *examples*

Hyatt Regency (KC) walkway collapse (1981)

Death 114 people

Overstressed steel support rods *underdesigned*

Alaska MD-80 crash (1999)

Death 88 people

Excessive wear on stabilizer jackscrew

Catastrophic Failure - *examples*

- **Tacoma Narrows Bridge Collapse** (1940)

  poor design – insufficient crosswind stiffening

- **de Havilland Comet** (first commercial jet) (1954 – 55)

  metal fatigue, aggravated by high stresses around rivet holes near window openings

- **United DC-10** crash (Sioux City, IA) (1989)

  inclusion and cracking in primary #2 engine turbine blade

Why study Properties and Failure of Materials?

(2) An understanding of materials properties help us to **design better components, parts, devices**, etc.

- Why and how do materials *fail*?
- Can we prevent *failure*?
- How do we make metals *stronger*?
- Why do materials behave differently under dynamic loads compared to static loads?
- How do we select the right material for the job?

(3) It's *interesting* and helps to make you a more informed person

Classes of Materials

There are 3 major classes:

1. Metals

   Usually *alloys*, which are composed of two or more elements, at least one of which is metallic

   Two basic groups:

   a. Ferrous metals - based on iron, comprise ~ 75% of metal tonnage in the world:
      - *Steel = iron-carbon alloy with 0.02 to 2.11% C*
      - *Cast iron = alloy with 2% to 4% C*

   b. Nonferrous metals - all other metallic elements and their alloys: aluminum, copper, gold, magnesium, nickel, silver, tin, titanium, etc.

Classes of Materials

2. Polymers

   A compound formed of repeating structural units called *mers*, whose atoms share electrons to form very large molecules

   Three categories:

   1. *Thermoplastic polymers* - can be subjected to multiple heating and cooling cycles without altering their molecular structure
   2. *Thermosetting polymers* - molecules chemically transform (cure) into a rigid structure upon cooling from a heated plastic condition
   3. *Elastomers* - exhibit significant elastic behavior

Classes of Materials

3. Ceramics

- Molecules based on bonding between metallic and non-metallic elements (including oxides, nitrides, carbides)
- Typically insulating and refractory

Sub-Classes of Materials

Semiconductors (ceramics)
Intermediate electrical properties

Composites (all three classes)
Combinations

Bio Materials (all three major classes)
Materials compatible with body tissue

Factors Influencing Properties of Metals

- Structures
  - Atomic structure (electronic configuration.. etc)
  - Crystal structures: bcc, fcc, hcp
  - Microstructure
  - Slip: slip systems, anisotropy.. etc
- Imperfections
  - Line: dislocations (strain hardening)
  - Point: vacancy, interstitial (alloys, e.g. Fe-C), impurity (alloys, e.g., Al, Cu)
  - Volume: voids, inclusions (e.g. oxides, carbides, sulfides)
  - Planar: grain boundaries
- Grain boundaries
  - Properties depend on size, large grains lower the strength, hardness & ductility and produce rough surface after stretching

Factors Influencing Properties Polymerss

- Molecular Structures
  - Linear, branched, crosslinked or network polymers
- Molecular Weight
  - Melting / softening temperatures **increase** with molecular weight (up to ~ 100,000 g/mol)
  - At room temperature, short chain polymers (molar weight ~ 100 g/mol) are liquids or gases, intermediate length polymers (~ 1000 g/mol) are waxy solids, solid polymers have molecular weights of 10^4 - 10^7 g/mol
- Crystallinity
  - Linear polymers more easily form crystals because the molecules can orient themselves readily
  - Degree of Crystallinity ranges from 5 - 95%
  - The higher % Crystallinity → higher strength

Next time:

Mechanical Properties: *Plastic Deformation*