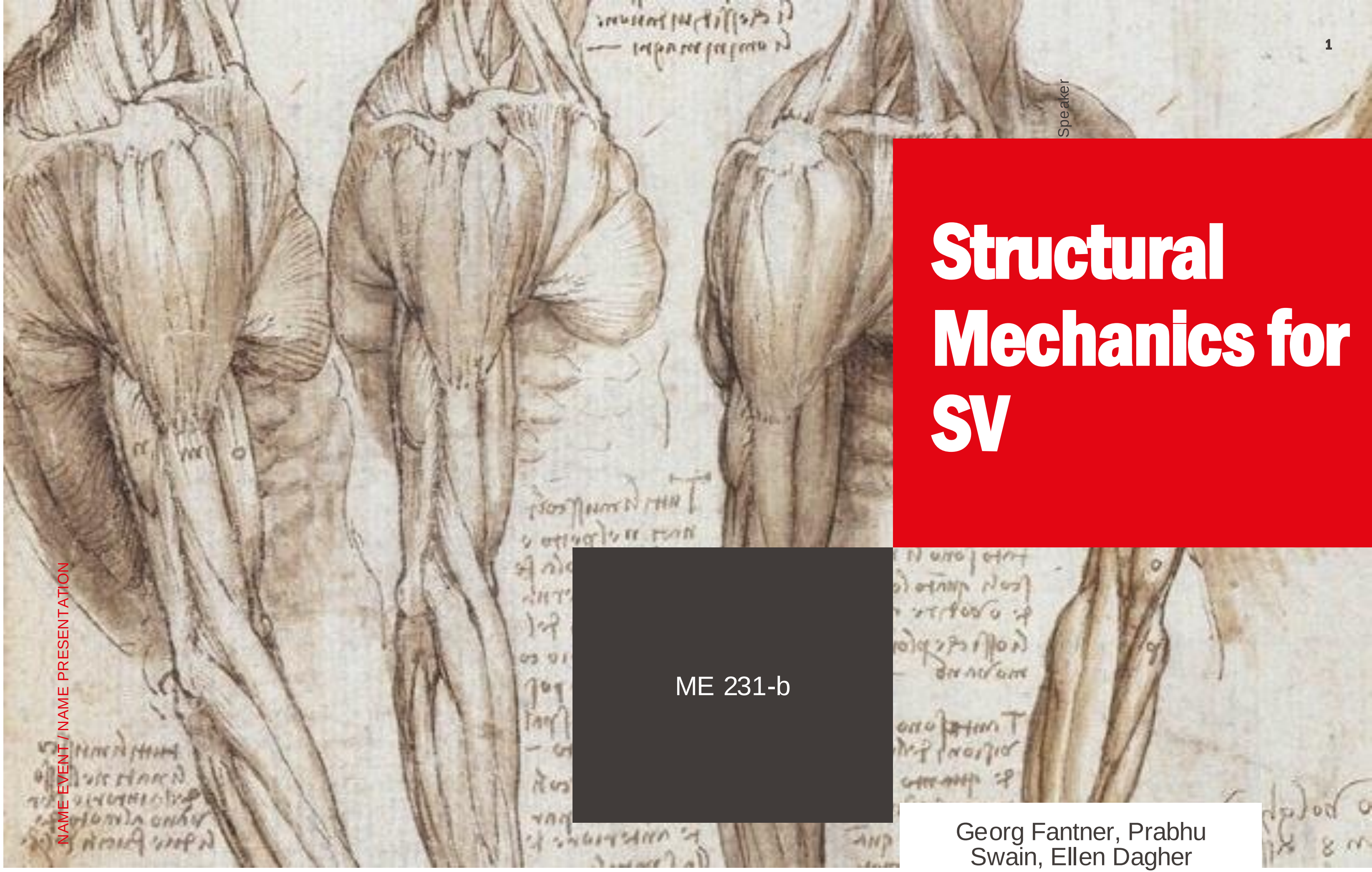


Speaker

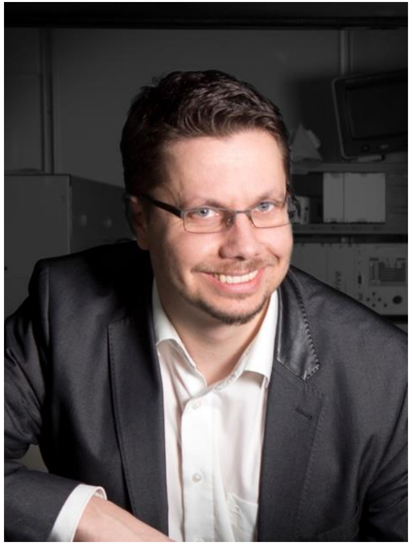
Structural Mechanics for SV

ME 231-b

Georg Fantner, Prabhu Swain, Ellen Dagher

NAME EVENT / NAME PRESENTATION

Welcome to ME 231-b!



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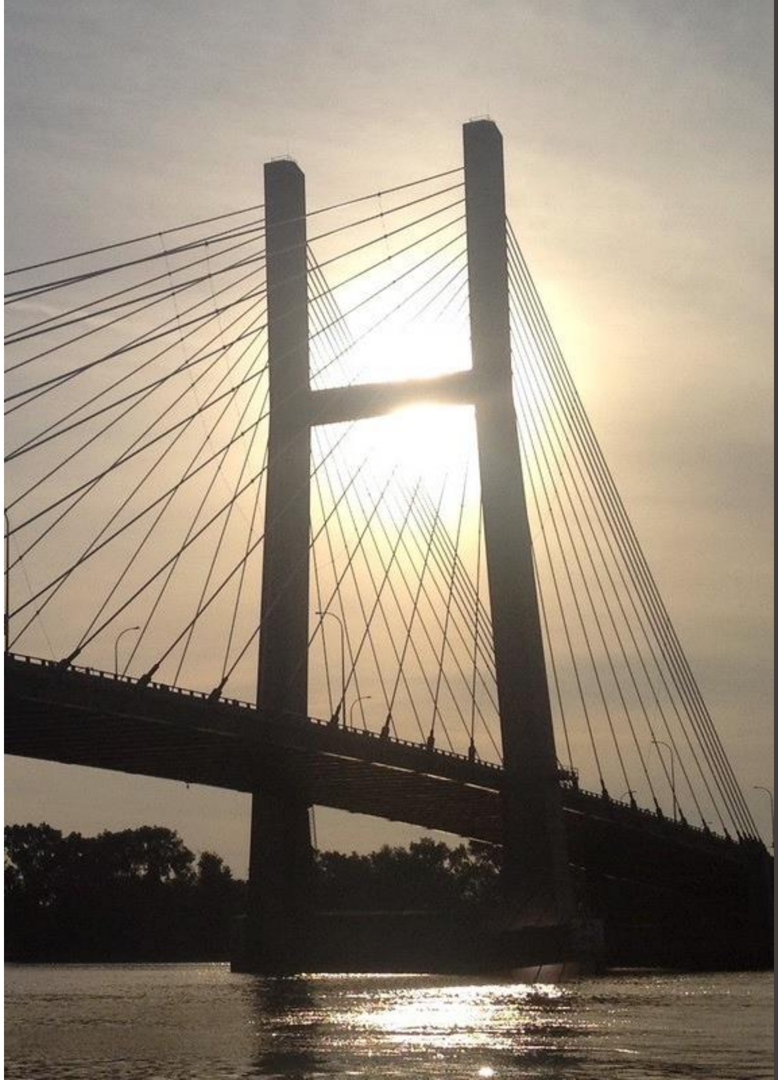
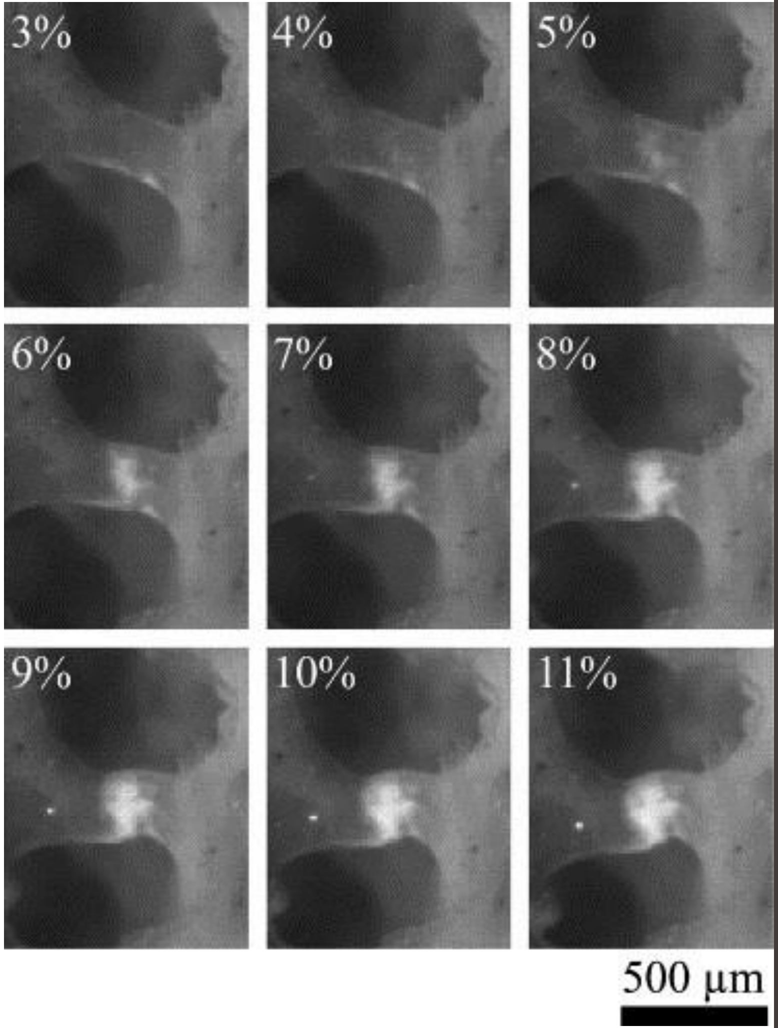


Purpose of structural mechanics:

Find out how structures react to loads considering both their geometry and materials properties

- how do structures bend
- what are the internal stresses and strains
- when will a structure break
- …



Fracture toughness of human trabecular bone

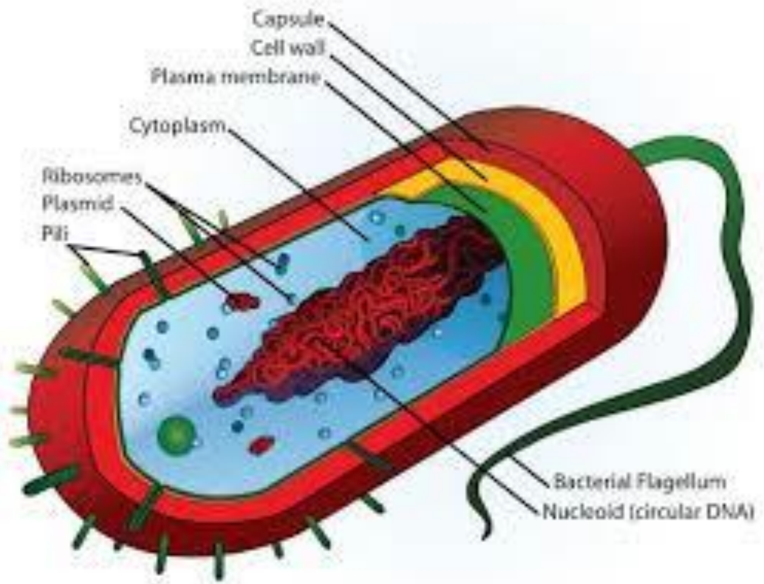
You study the fracture strength of trabecular bone in the vertebra of an osteoporotic patient. From a compression test, you see when damage occurs at global strain levels. You want to calculate what the local stresses are when the bone fails.

1. Analyze the geometry to calculate from global strain to local normal strains and shear strains
2. Use the elastic modulus for bone to calculate the normal stress and shear stress at the fracture point

Example: Robotic hand

You have a lever arm in the robotic hand you design, and you want to know what material you have to make the actuation rods out of so that under maximum load A) 99% of the displacement of the actuator is transmitted from your hydraulic actuators to the fingertips, and B) you have the optimal strength/mass ratio.

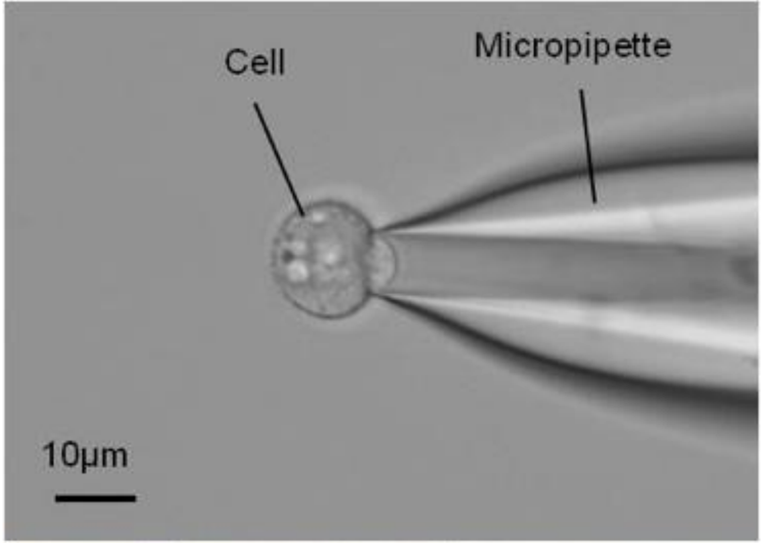
1. Calculate longitudinal stress and strain
2. use hooks law with the elastic modulus of the available materials (titanium, steel, aluminum,…) to determine the minimal thickness to keep the strain below 1%
3. calculate the mass the hand would have when it is made of the available materials
4. Choose the material that results in the lightest hand



Turgor-pressure

You want to measure the Turgor pressure in your favorite strain of bacteria through nanomechanical testing using an atomic force microscope (AFM).

- calculate the hoop stresses inside the bacterium
- determine from the applied force and size of your AFM tip the pressure you are exerting
- Subtract the pressure equivalent of the whoop stresses from the applied pressure to obtain only the Turgor pressure

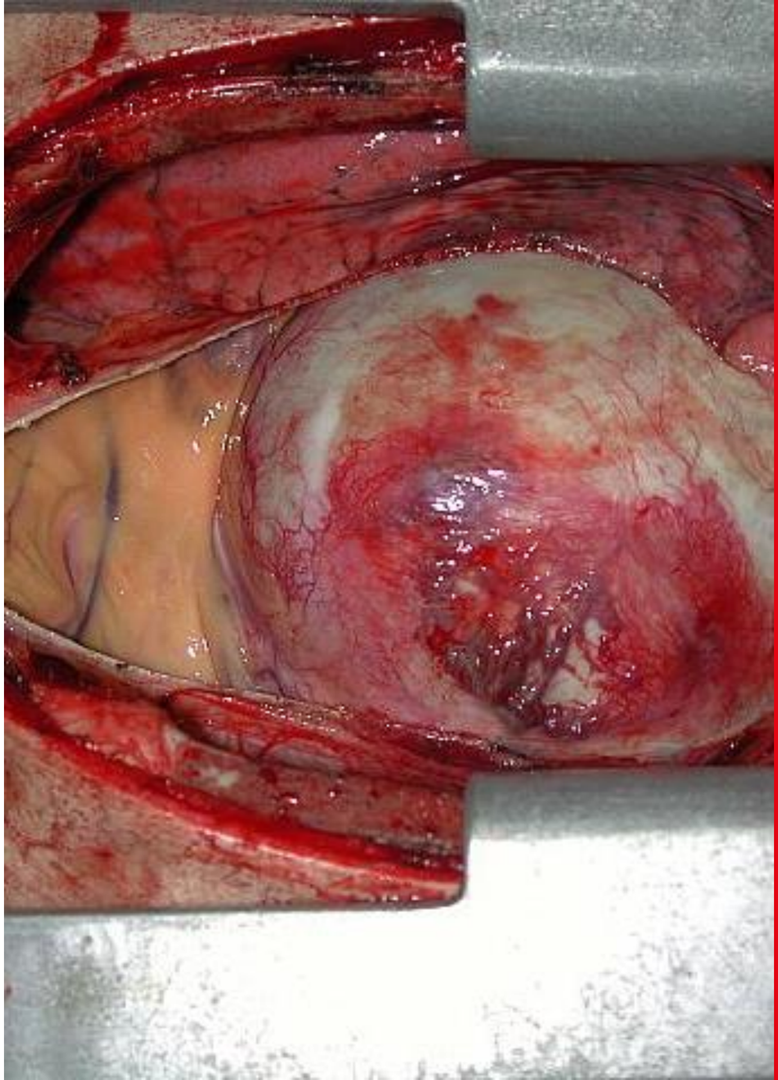


Micropipette aspiration

Lack of cholesterol in the membrane is known to increase membrane stiffness which could cause several changes in cell function.

You want to compare the effect of the anti cholesterol drug you have developed on the stiffness of the cell membrane.

You can do this by applying a known pressure to a micropipette and suck up a cell. Based on the amount that the cell membrane is pulled into the micropipette you can calculate the membrane stiffness.



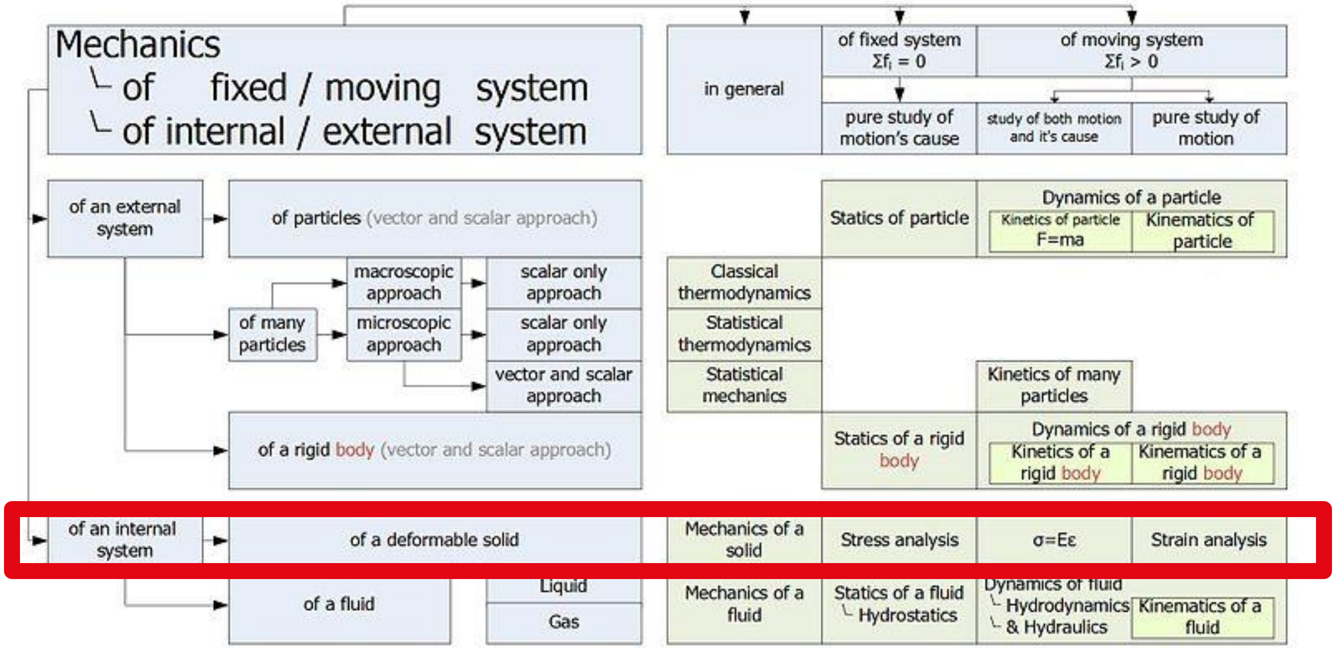
Aneurism

You monitor a phase II clinical trial about the benefits of a new surgical procedure to encase an aortic aneurysm with a polymer based medical device. You are asked to see if the rupture probability is directly correlated with the size of the aneurism.

Calculate the stresses in the arterial wall in radial and longitudinal direction for each aneurism in each patient

Perform a paired hypothesis test between the arterial stress values and the corresponding rupture data

Relationship to other branches of Mechanics



http://en.wikipedia.org/wiki/Mechanics

How I designed the course

The class is taught in English & we use a textbook that uses "simple" language

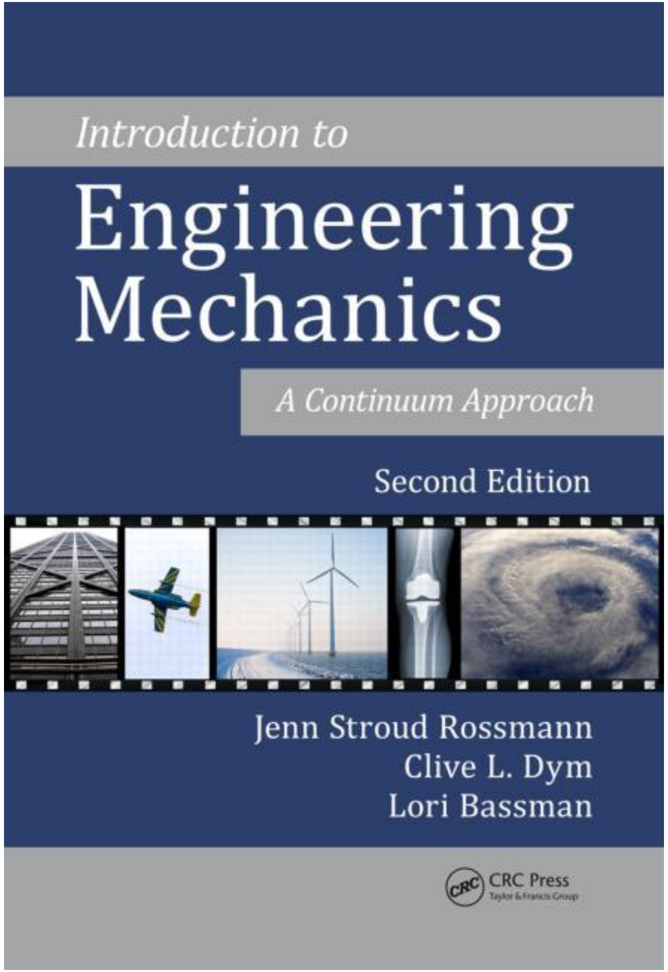
The course is built on the first edition
A second edition is now out!

There are no established "grade standards" from many previous years, so grading will be adapted

Proposed grading scheme:

one midterm counting 1/3 of your grade
one final counting 2/3 of your grade

The way the course is taught isn't "set in stone". So if you have suggestions on how we can best run this class, we can discuss it and make changes as we go along.



Textbook

Introduction to Engineering Mechanics – a continuum approach

Jenn Stroud Rossmann, Clive L. Dym and Lori Bassman

ISBN-10: 1420062719

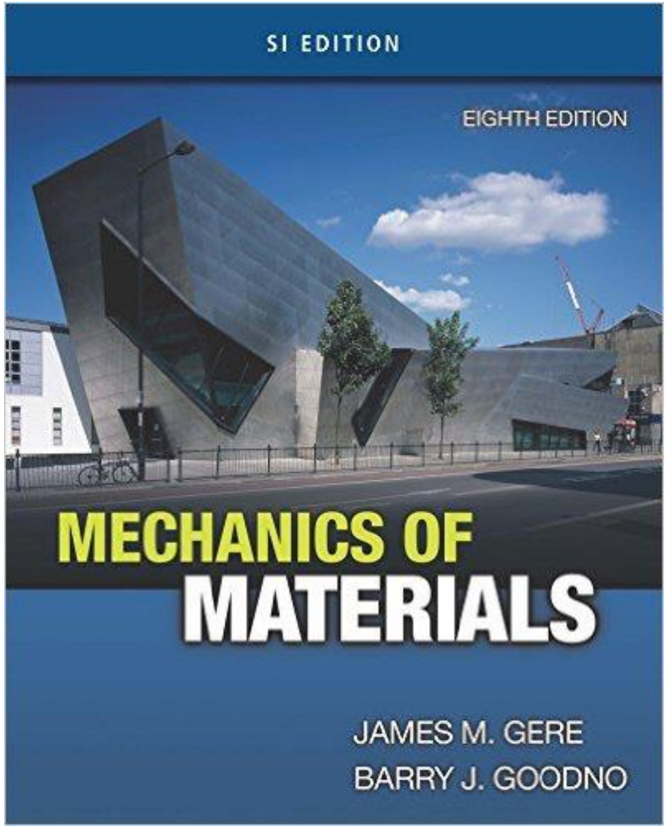
ISBN-13: 978-1420062717

- You can buy the book directly from the publisher (ca CHF 133):

https://www.crcpress.com/Introduction-to-Engineering-Mechanics-A-Continuum-Approach-Second-Edition/Rossmann-Dym-Bassman/9781482219487

- Also available as Kindle e-book for purchase (ca CHF110) or renting (ca CHF 40)
- The 1st edition is available amazon market place starting from ca CHF 20 to CHF30

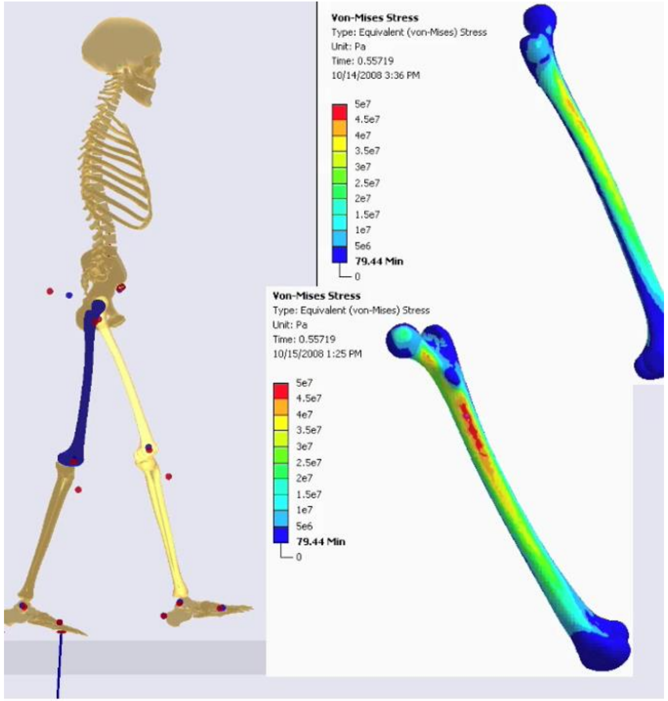
Additional reading material

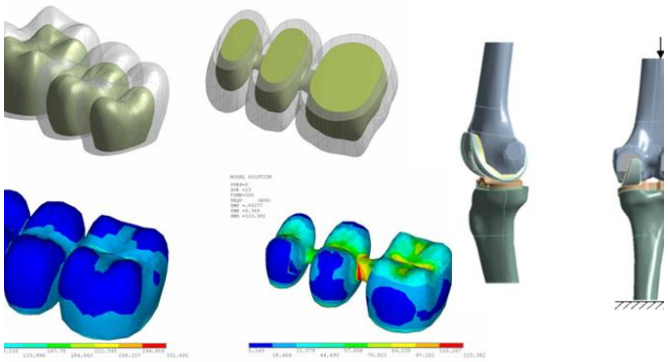


- **Mechanics of Materials 8th edition, SI Edition** by James M. Gere and Barry J. Goodno
- USD 137.67 new (used starting 34.56) at Amazon
- eTextbook (buy USD 63.49, rent ca USD42)
- From publisher: print: CHF 73.77, ebook CHF 49.82

Topics we will cover:

review of equilibrium ridged body mechanics	strain & stress in one dimension	strain & stress in higher dimensions
stress concentrations	torsion	transformation of stress and strain
stress and strain in beams (shear and bending moments)	beam bending	buckling





Why do I teach this course for SV?

PhD from Univ. California
Santa Barbara
Bone nanomechanics and molecular mechanics

University of California Santa Barbara · Let there be light

Post Doc. Massachusetts Institute of Technology
Virus nanowires and bacterial dynamics

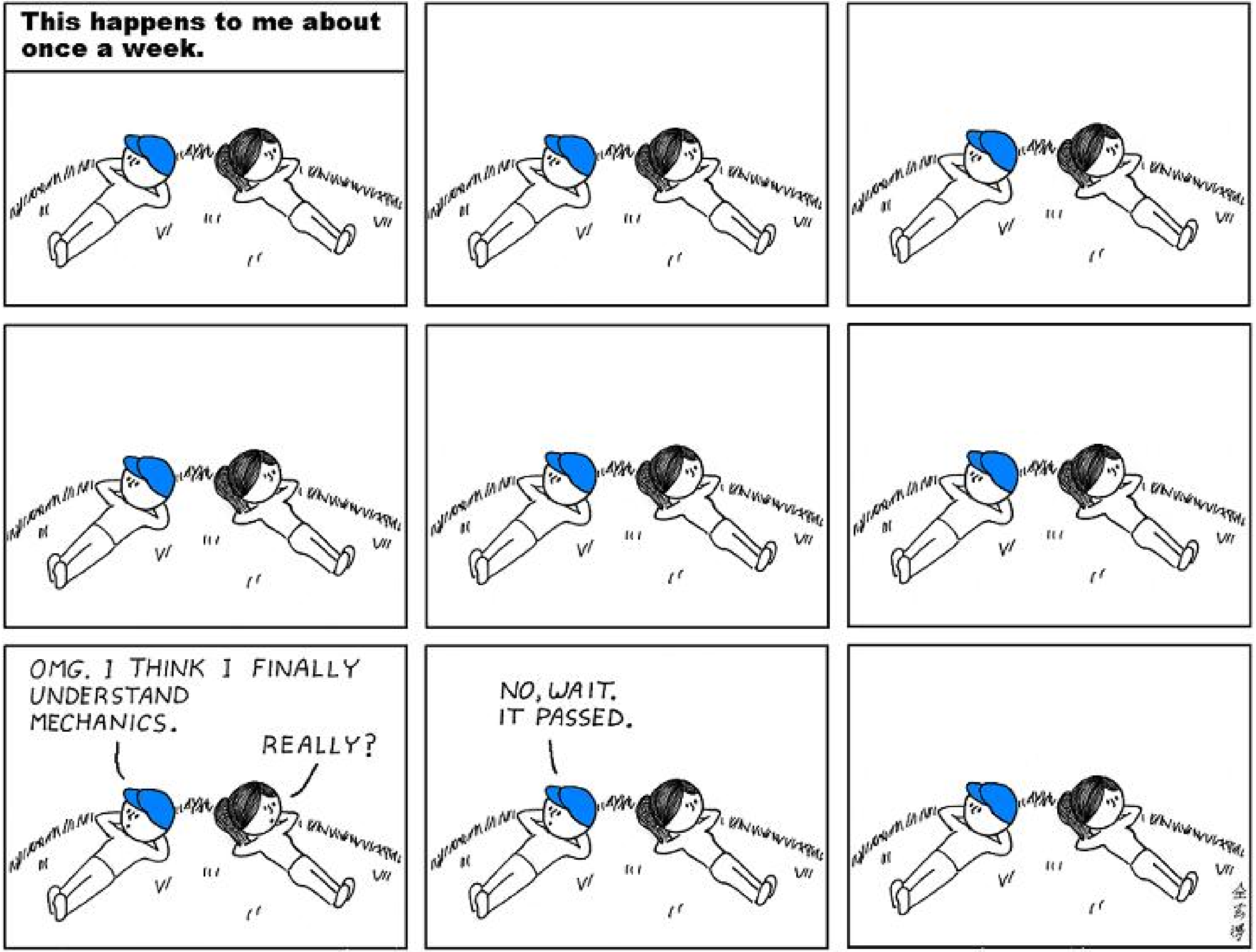
Massachusetts Institute of Technology

EPFL: Laboratory for Bio and Nano Instrumentation

Molecular and cellular mechanics

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Why do you want to take this course?


This happens to me about once a week.
OMG. I THINK I FINALLY UNDERSTAND MECHANICS.
REALLY?
NO, WAIT. IT PASSED.

Who knows what this is…

Newton's laws

Reactive forces and loads

Internal and external reaction forces and moments

Free body diagrams

Moment

Couple

Method of sections

Lecture 1:

1. Review of Newton's Laws
2. Review of vector math

Review of Newton's laws applied to continuum mechanics

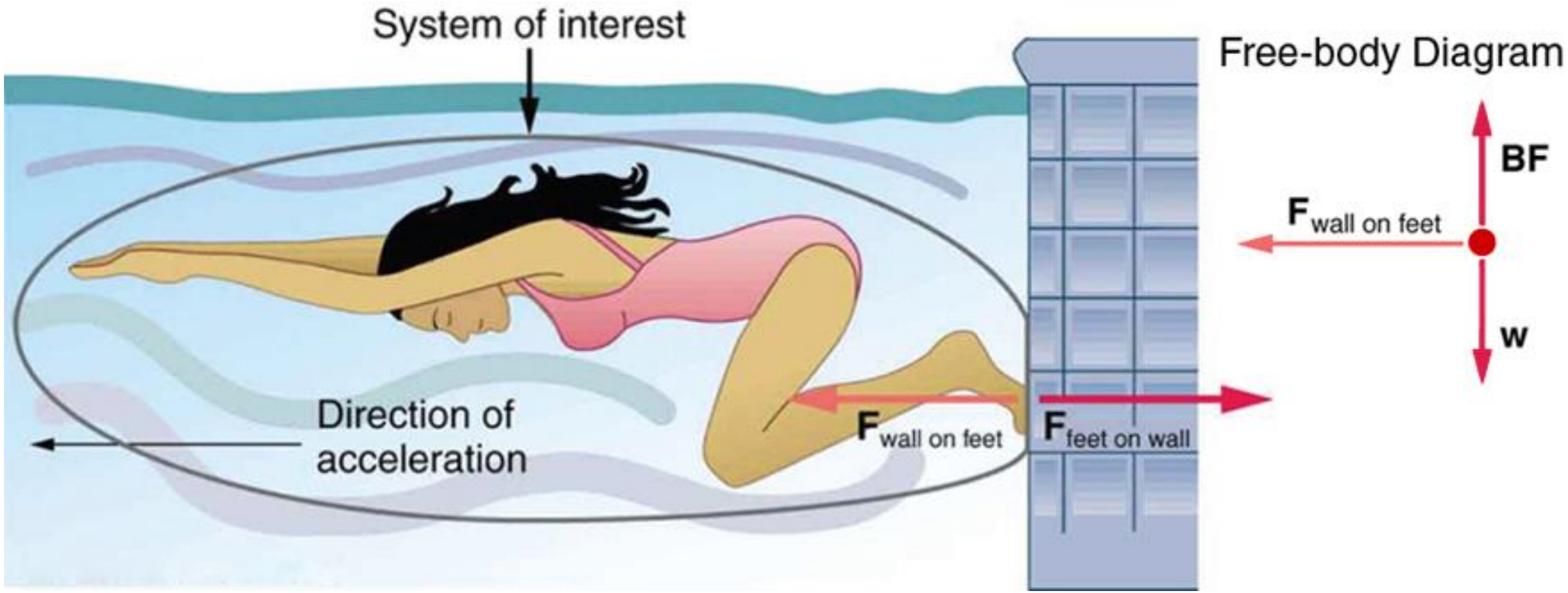
1. If no unbalanced forces act on the body, the body remains at rest or moves in a straight line

2. The sum of all forces is the change in mass and velocity

$$\sum F = \frac{d}{dt}(m * \vec{v})$$

3. to every force there is an equal and opposite reaction

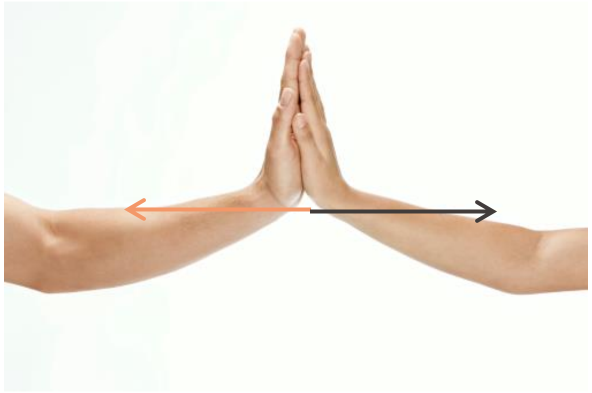
Reaction forces and loads



External forces vs. Internal forces

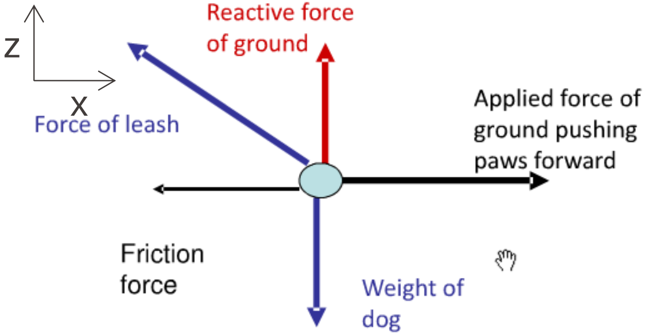
- Forces exerted by one part of an object on another part of the same object are called <u>internal forces</u>

- Forces between distinct, separate objects are called <u>external forces</u>

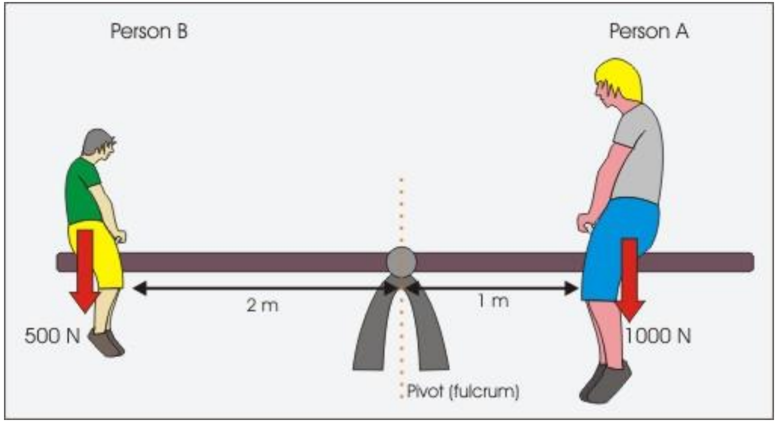


Free Body Diagram (FBD)

- A free body diagram shows all the forces that are acting on a body (both action and reaction forces as well as moments) in a very simplified manner
- A FBD should always have a coordinate system!



Moments

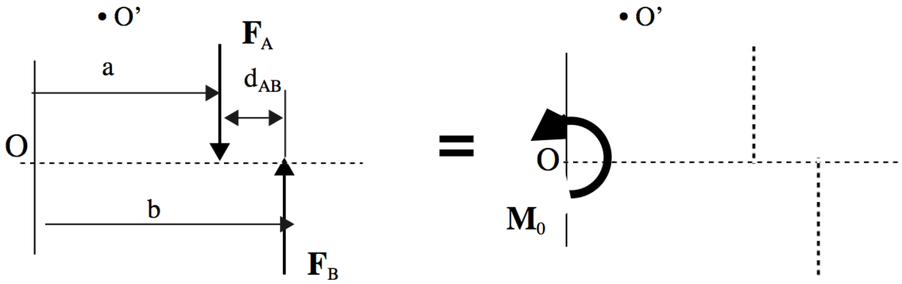


- In physics, moment is a <u>combination</u> of a <u>physical quantity</u> and a <u>distance</u>
- Moments are usually defined with respect to a fixed reference point
- The most common is the *moment of a force: M=F*d*

Georg Fantner

Couple

- Two equal and opposite forces that can be working at the same point or at a distance from each other



$$M_O = -a \cdot F_A + b \cdot F_B = (b - a) \cdot F_A = d_{AB} \cdot F_A$$

Equilibrium for static problems:

All of our problems in structural mechanics are STATIC

- From Newton's second law: in static equilibrium, the sum of all *forces* AND the sum of all *moments* have to be *zero*

$$\sum F_x = 0$$
$$\sum F_y = 0$$
$$\sum M_z = 0$$

For a 2D problem in the xy plane

The objective of structural mechanics

Characterize	characterize deformation due to loading
Calculate	calculate the internal loading
Relate	relate internal loading to deformation
Ensure	ensure equilibrium

Review of basic math

Scalars, Vectors and Tensors

- Scalar: has only a magnitude
- Vector: has a magnitude and a direction
- 2nd order Tensor: “represents a vector for each direction”

  “A tensor is a linear transformation of a vector to represent a quantity in the direction of the vector”

Stress tensor:

$$\overleftrightarrow{\tau} = \begin{pmatrix} \sigma_x & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z \end{pmatrix}$$

$$\vec{\tau}_n = \overleftrightarrow{\tau} \cdot \vec{n}$$

The stress tensor assigns a state of stress to each point on the plane defined by the normal vector n

Vector math

- representation of a vector: $\underline{v} = \vec{v} = v \cdot \vec{n} = v_x \cdot \vec{e}_x + v_y \cdot \vec{e}_y + v_z \cdot \vec{e}_z$
- magnitude of a vector: $|\vec{v}| = \sqrt{v_x^2 + v_y^2 + v_z^2}$

  with x,y,z referring to any set of orthogonal base vectors
- dot product: $\vec{u} \cdot \vec{v} = |\vec{u}| \cdot |\vec{v}| \cdot cos\theta = u_x v_x + u_y v_y + u_z v_z$
- cross product:

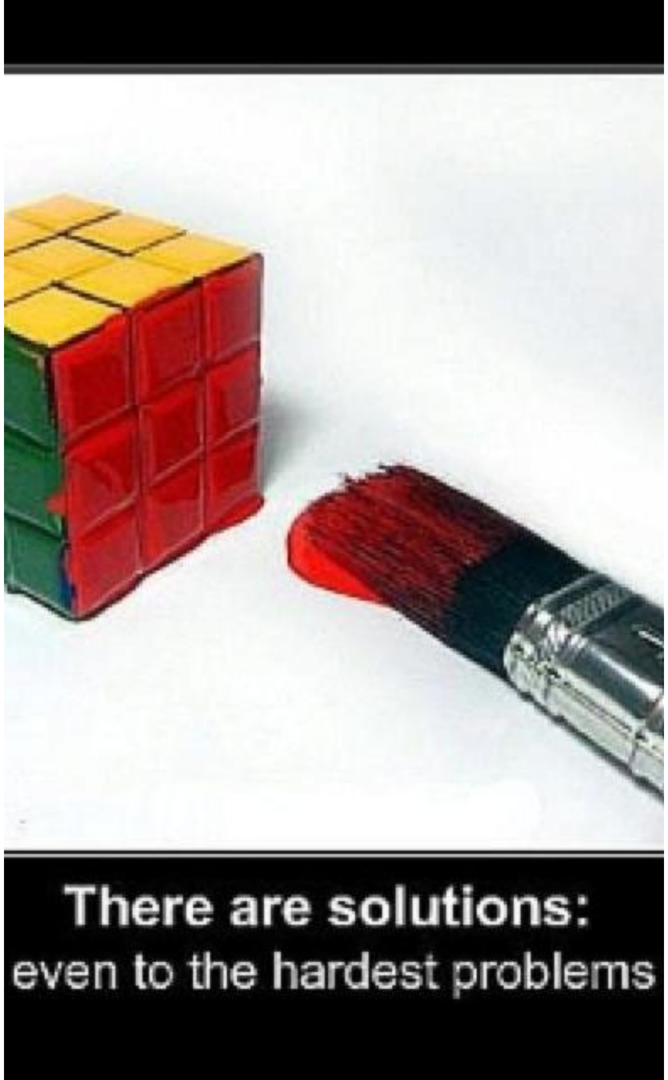
$$\vec{u} \times \vec{v} = det \begin{pmatrix} e_x & e_y & e_z \\ u_x & u_y & u_z \\ v_x & v_y & v_z \end{pmatrix} = \begin{vmatrix} e_x & e_y & e_z \\ u_x & u_y & u_z \\ v_x & v_y & v_z \end{vmatrix} = \begin{pmatrix} u_y v_z - u_z v_y \\ u_z v_x - u_x v_z \\ u_x v_y - u_y v_x \end{pmatrix}$$

- index notation: $x_i \quad i = 1, 2, \ldots, n$

- Summation convention: repetition of the index means summation over the index: $\vec{u} \cdot \vec{v} = u_i v_i$

Approach to problem solving

1. draw relevant sketches
2. what is given?
3. what is asked?
4. what is the governing principle: what are the equations that are required?
5. perform calculations in symbolic form
6. check your physical dimensions
7. do the calculations
8. state your answer + your conclusions: CHECK SIGNIFICANT DIGITS!



Lecture vs exercises

8:30-10:00

	Mo	Tu	We	Th	Fr	Sa
8h - 9h					Structural mechanics (for SV) BM5202 ME-231(b) Lecture	
9h - 10h					Structural mechanics (for SV) BM5202 ME-231(b) Exercises	
10h - 11h			Structural mechanics (for SV) AAC137 ME-231(b) Lecture			
11h - 12h			Structural mechanics (for SV) AAC137 ME-231(b) Lecture			
12h - 13h						
13h - 14h						
14h - 15h						
15h - 16h						
16h - 17h						
17h - 18h						
18h - 19h						

We can be flexible with the amount of lecture vs exercise. What do you prefer?