Georgia Tech
College of
Engineering

COE 3001

MECHANICS OF DEFORMABLE BODIES

Lecture 1 – Introduction

Yazhuo Liu
Georgia Institute of Technology

Jan. 12, 2026

General Information

Course Materials

- All lecture notes, assignments, and solutions will be available at **Canvas**

Office Hours

- In-person: MW 12:30 – 1:30 pm, MRDC 4114A (next to the meeting room)
- Online: Zoom meeting based on appointment

Prerequisite

- COE 2001 or CEE 2020 or ME 2211 or AE 2120 (**Statics**)
- MATH 2403 or MATH 2552 or MATH 2413 (**Differential equations**)

General Information

Textbook

✓ Mechanics of Materials, by James M. Gere & Barry J. Goodno, 9th Ed, Cengage Learning.

Note:

✧ Homework may be taken from the textbook but will provide full context.

✧ Reading recommendations are based on the textbook.

✧ Different editions are **ACCEPTABLE**.

General Information

Grading

- (Bonus) Attendance: 6 pts.
- Homework: 5 × 6 pts. + 4 pts. bonus
- Midterm Exam: 30 pts.
- Final Exam: 40 pts.

Points	Letter grade
90 ~ 100	A
80 ~ 89	B
70 ~ 79	C
60 ~ 69	D
0 ~ 59	F

➢ 3 attendance check (bonus points)

- ✓ 1 present – 1 pt.
- ✓ 2 presents – 3 pts.
- ✓ 3 presents – 6 pts.

General Information

Grading

- (Bonus) Attendance: 6 pts.
- Homework: 5×6 pts. + 4 pts. bonus
- Midterm Exam: 30 pts.
- Final Exam: 40 pts.

Points	Letter grade
90 ~ 100	A
80 ~ 89	B
70 ~ 79	C
60 ~ 69	D
0 ~ 59	F

6 assignments: 6 pts each

- Lowest grade assignment will be dropped.
- Typed assignments have 1 bonus pt each time (maximum total: 4 pts)

General Information

Grading

- (Bonus) Attendance: 6 pts.
- Homework: 5×6 pts. + 4 pts. bonus
- Midterm Exam: 30 pts.
- Final Exam: 40 pts.

Points	Letter grade
90 ~ 100	A
80 ~ 89	B
70 ~ 79	C
60 ~ 69	D
0 ~ 59	F

Exam:

- Exam info will be announced separately.
- In class and close book
- 1 page (2 sides) equation sheet allowed
- Copy homework solutions on equation sheet prohibited

General Information

Using GenAI Responsibly – Key Guidelines

- Permitted Use:
- Clarify concepts, review material, explore alternative explanations
- Support learning—not replace understanding
- Critical Evaluation Required:
- Verify all AI-generated content with authoritative sources (lectures, readings, course materials)
- Strictly Prohibited:
- Using GenAI to complete assignments, homework, projects, or exams
- Submitting AI-generated work as your own = academic misconduct
- Important Reminders:
- Over-reliance without comprehension may result in penalties
- Always adhere to Georgia Tech's Academic Integrity Policy
- Learn more: https://oit.gatech.edu/ai/guidance

Gemini

ChatGPT

Claude

Copilot

. . .

General Information

Course Principles

1. Discussions on homework and lecture notes are encouraged. However, exchange of written information in completing assignments is **NOT** permitted.
2. Unless approval is granted, late assignments will receive a 30% late penalty. Assignments submitted after the solutions have been posted will not be accepted, except for delays due to serious illness or other documented difficulties.
3. Unless approval is granted, **NO** make-up exams will be given, except for serious illness or other documented difficulties.

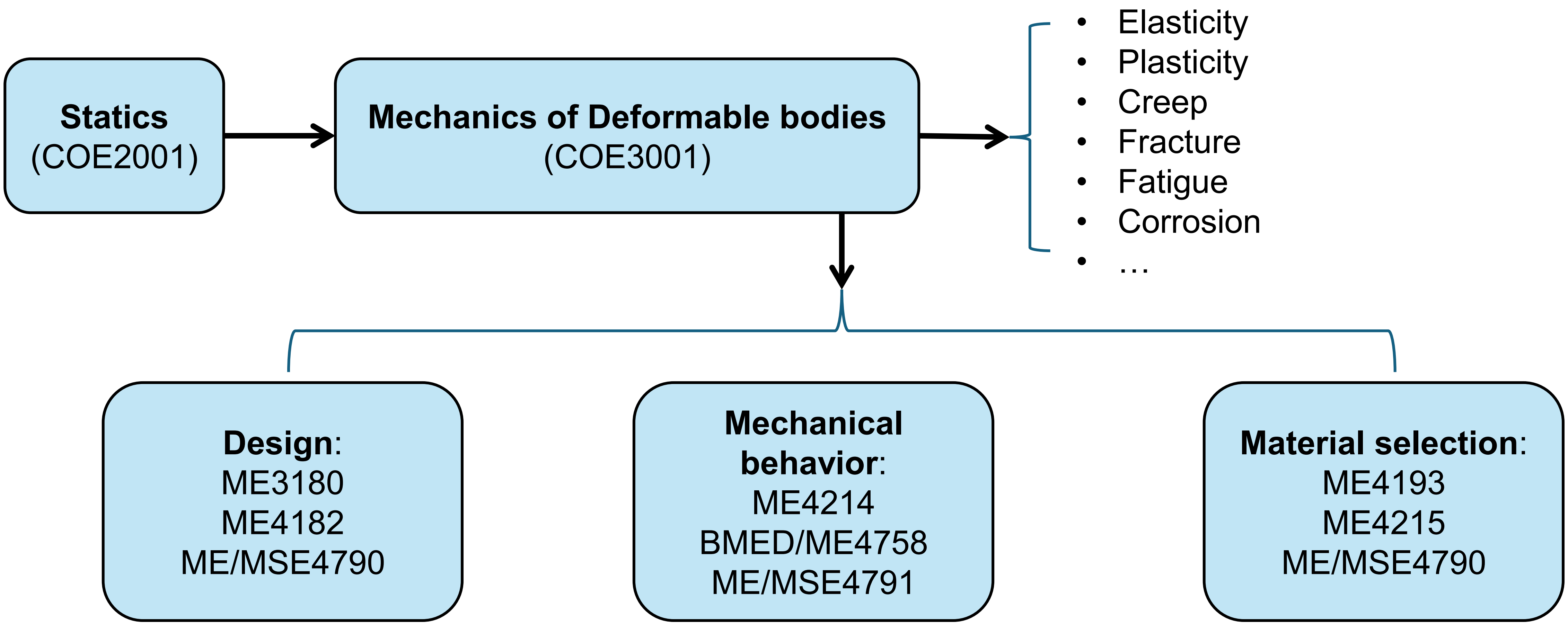
Learning Objectives

By the end of this course, students will be able to:

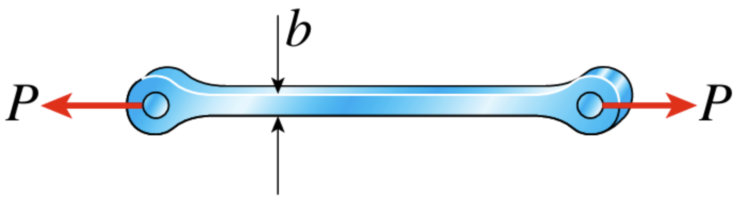
- Analyze the strength, stiffness, and stability of structural components.
- Solve real-world engineering problems — such as designing lightweight bridges
- Understand the mechanical behavior of materials in practical applications.
- Build a solid foundation for advanced courses in *machine design* , *structural mechanics* , and *mechanical systems*.

This course bridges everyday experience with engineering principles, helping students develop the analytical tools needed to design and evaluate safe, efficient, and reliable structures and systems.

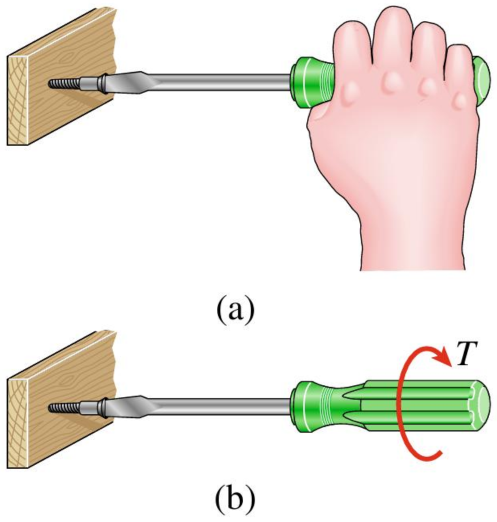
Relation to other courses



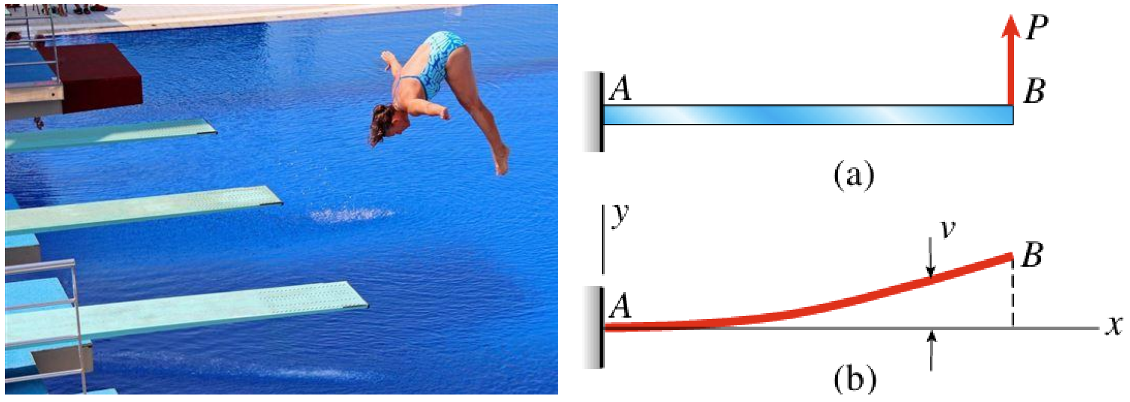
Topics



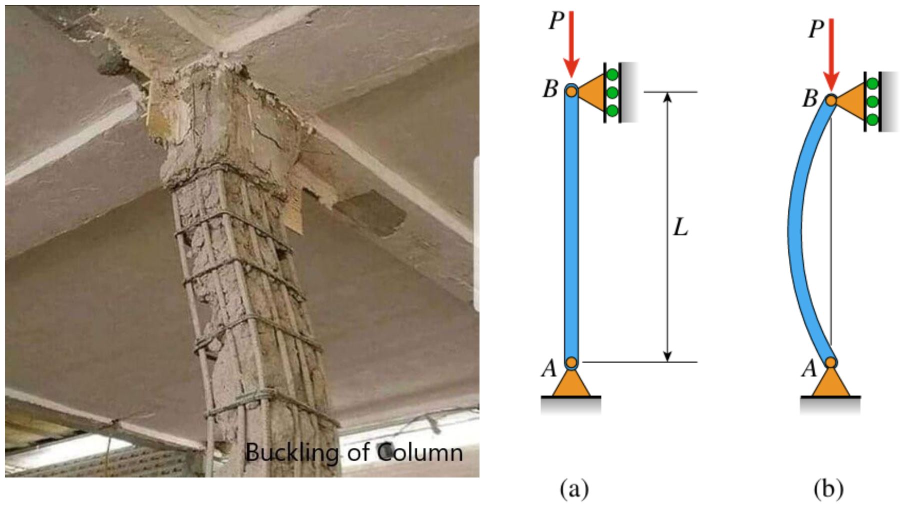
Bars: tension/compression



Shafts: torsion



Beams: bending



Columns: buckling

Road map

It's okay if you don't understand it now. You'll gain a much better understanding when you revisit it later in the course.

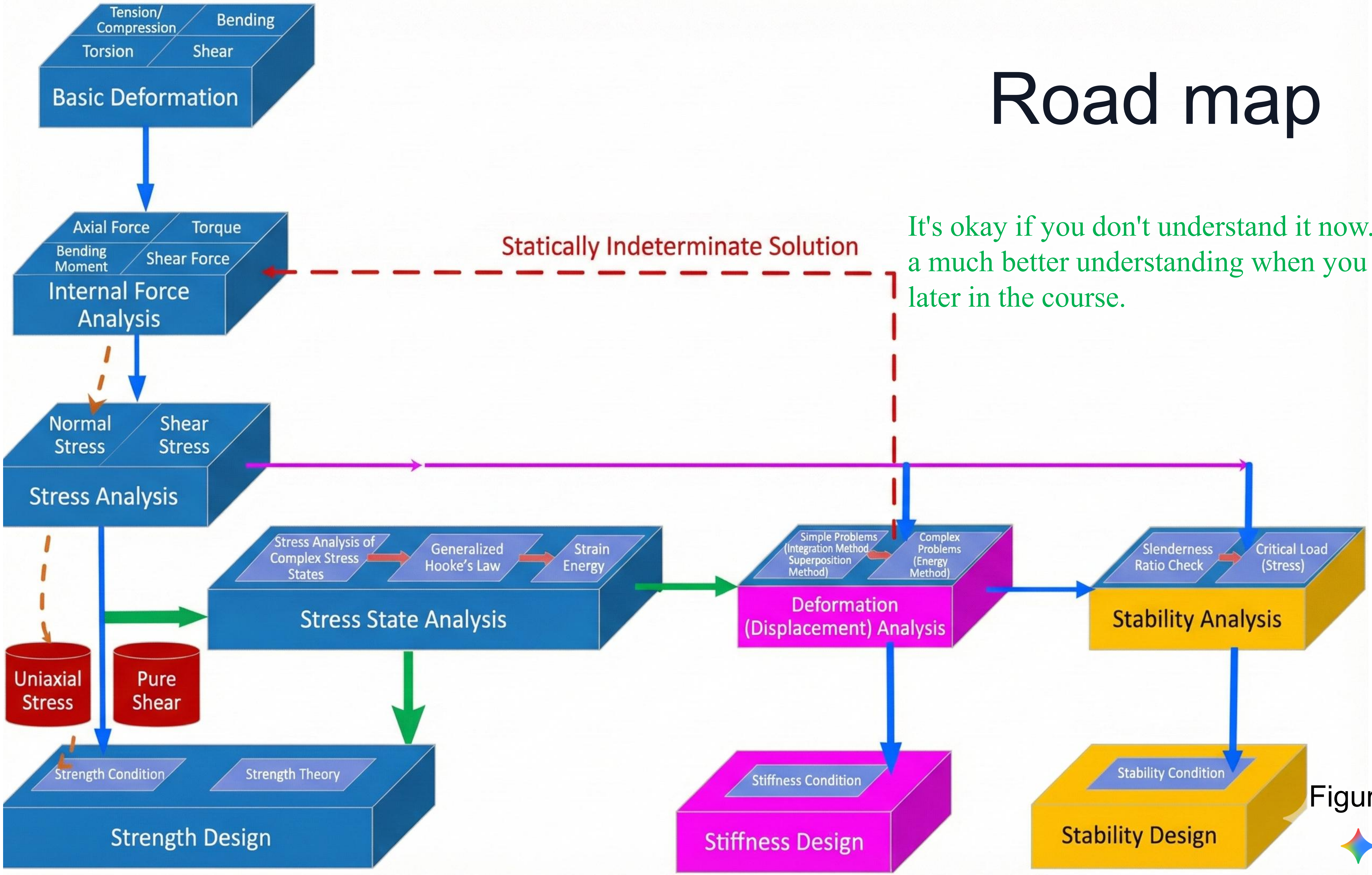
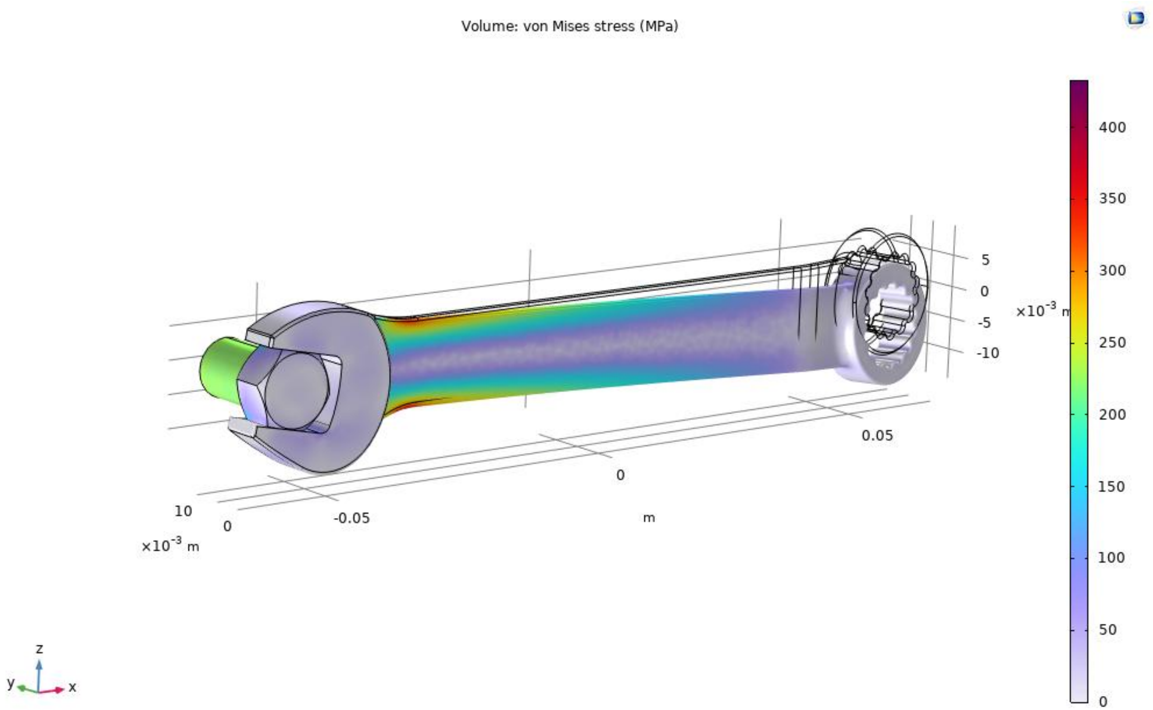
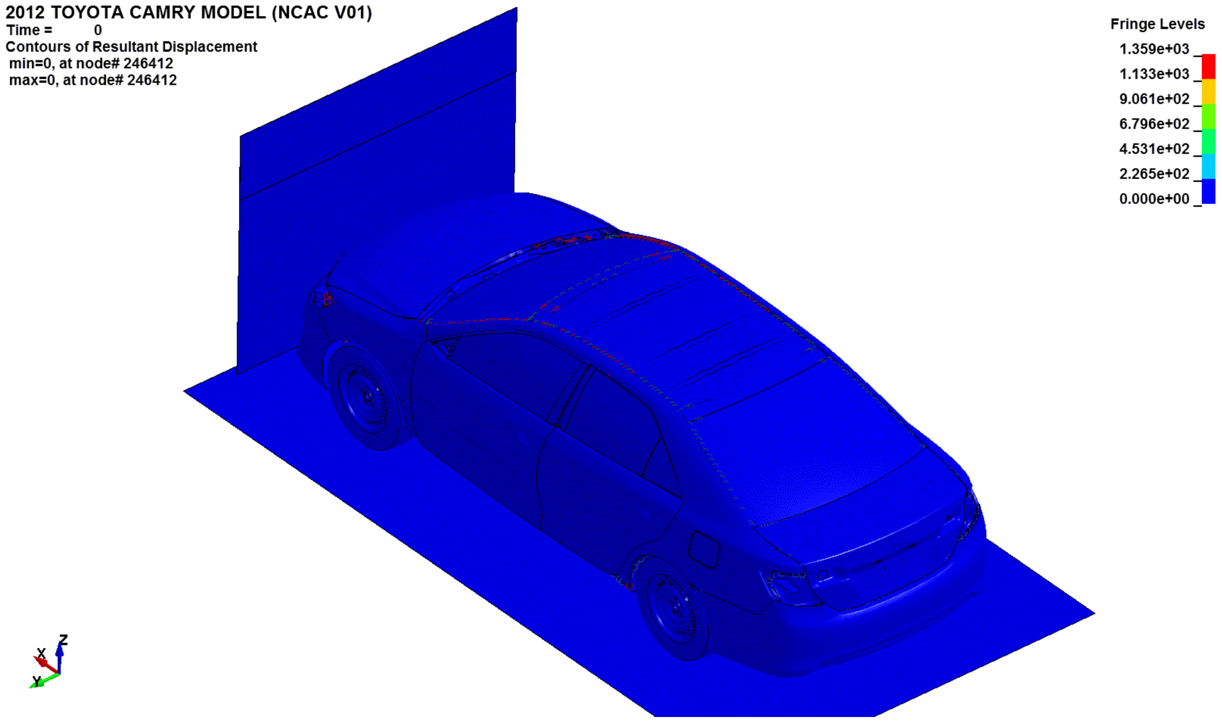


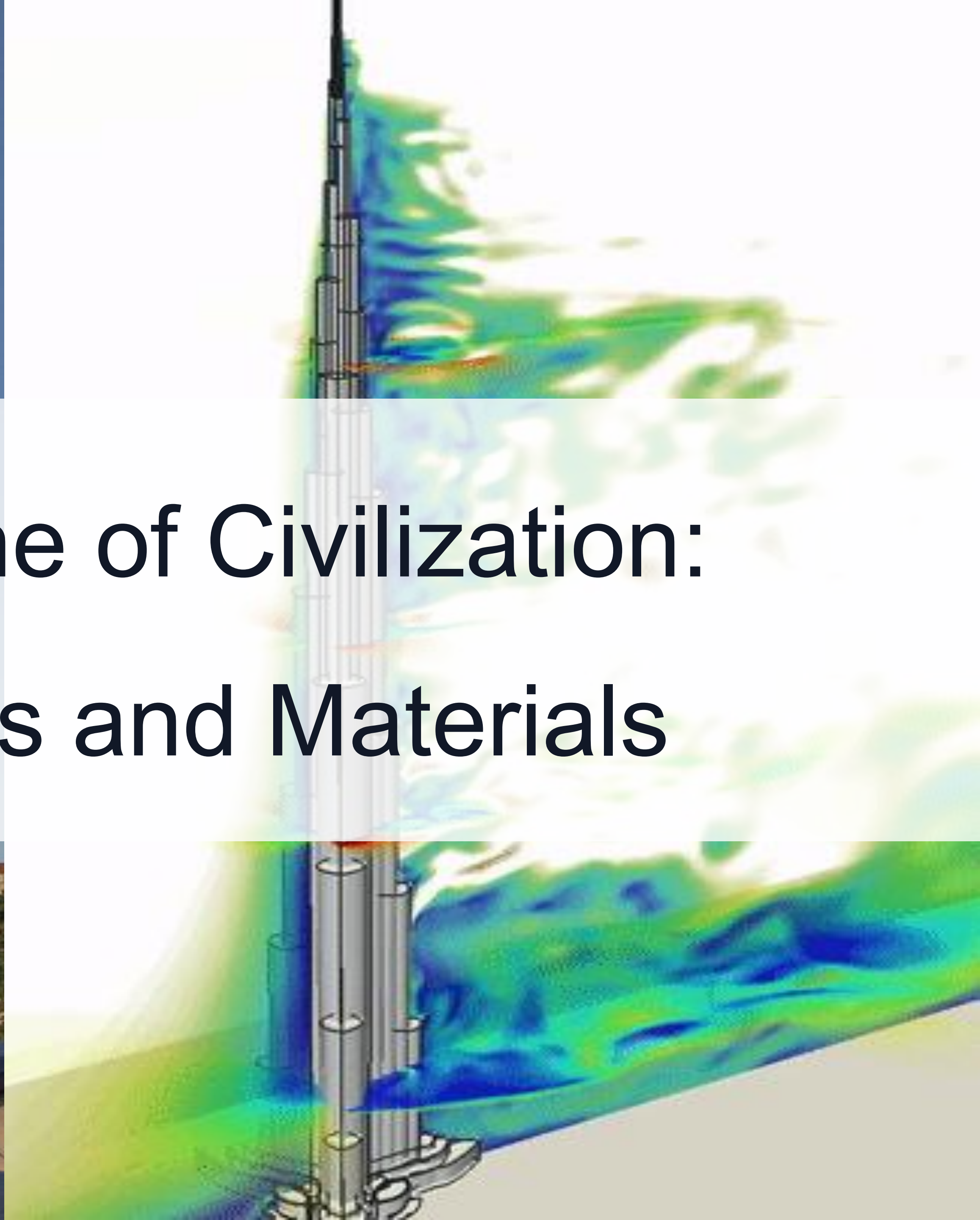
Figure plotted by Gemini

Mechanics of life



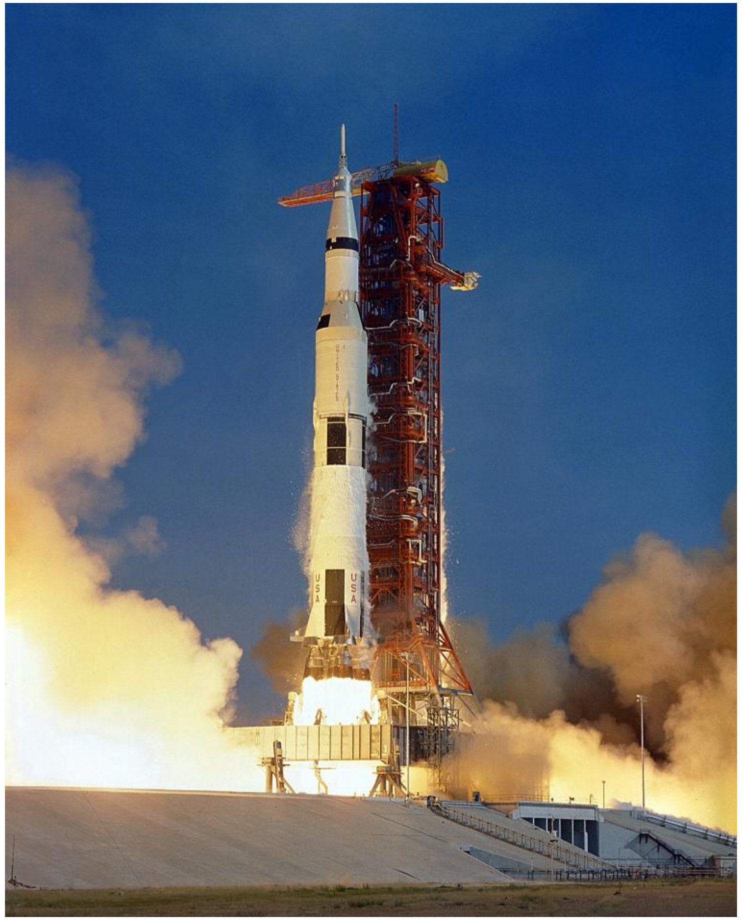


The Hidden Backbone of Civilization: Stories of Mechanics and Materials



Saturn V – Reaching for the Moon

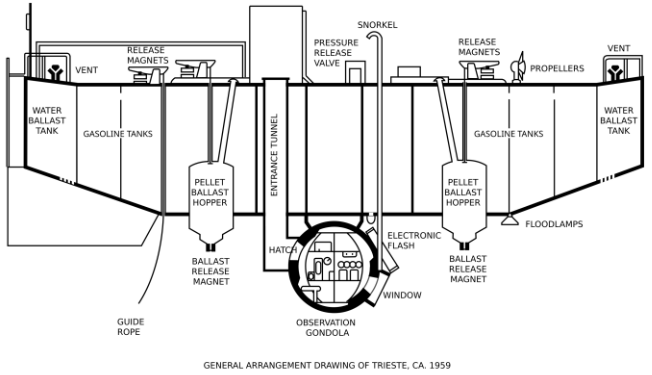
- Materials: Aluminum alloys, titanium alloys, etc.
  - *Honeycomb sandwich structures — lightweight yet strong enough to defy Earth's gravity.*
- Engine thrust and its immense weight:
  - *Compression/Tension*
- Aerodynamic forces:
  - *Bending*
- Roll control thrusters:
  - *Torsion*

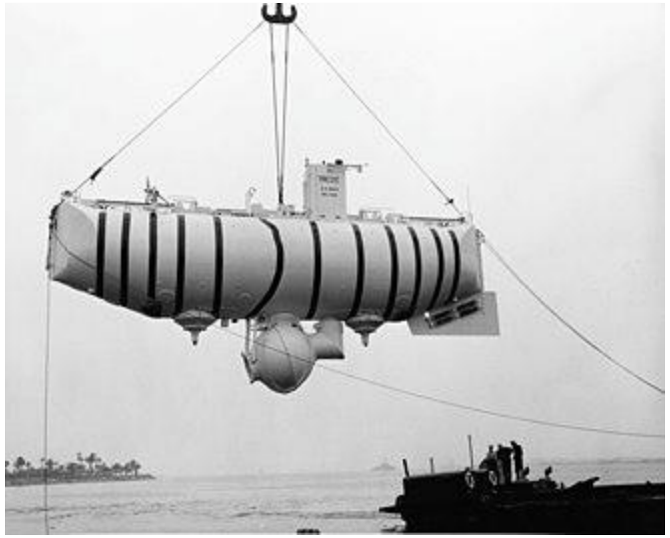


The launch of the historic Apollo 11 mission on Saturn V SA-506, July 16, 1969

Bathyscaphe Trieste – Into the Abyss

- Materials: Steel spherical pressure hull
  - *Designed to withstand ~110 MPa external pressure.*
- External water pressure:
  - *Compression (uniform on hull)*
- Supporting cables & mounts:
  - *Tension*
- Deployment forces at ports or during mooring:
  - *Bending / Torsion*

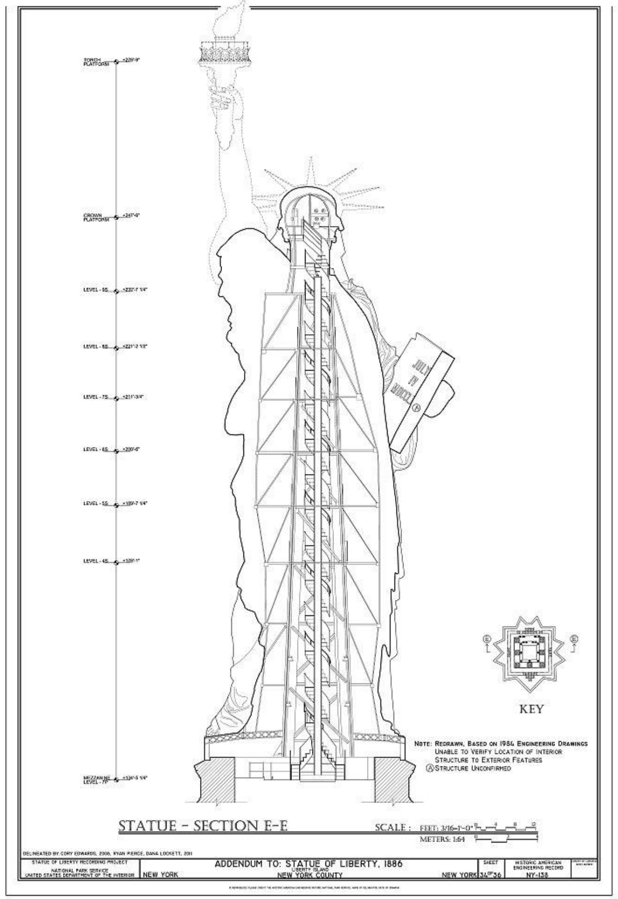




Bathyscaphe Trieste — In 1960, it became the first crewed vessel to reach the bottom of Challenger Deep in the Mariana Trench.

Statue of Liberty – Engineering Aesthetics

- Materials: Wrought iron frame, copper skin
  - *Copper shell expands/contracts with temperature; iron framework resists deformation.*
- Central pylon:
  - *Compression (supports vertical load)*
- Armature bars:
  - *Tension (prevents collapse from wind or weight)*
- Wind loads (especially on torch arm):
  - *Bending / Torsion*

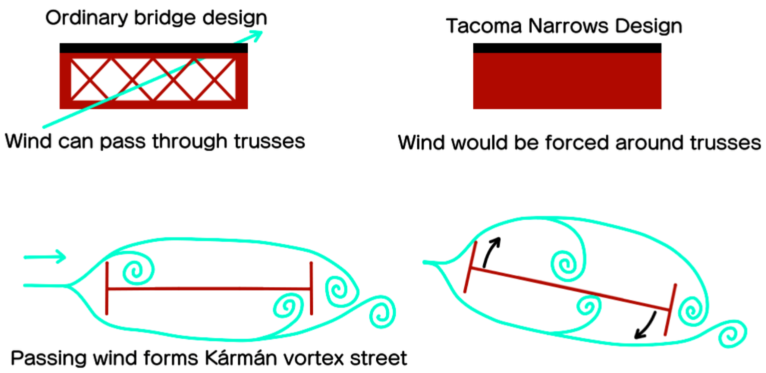


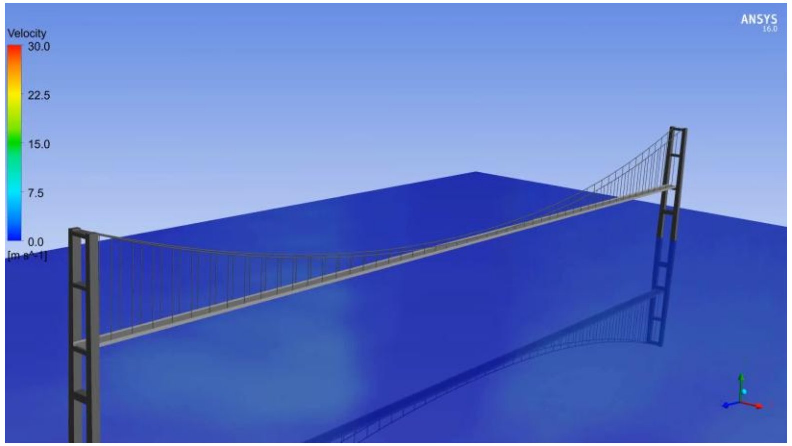
A massive iron pylon and secondary skeletal framework allows the Statue's copper skin to move independently yet stand upright.

Mechanics Design is Important ...

Tacoma Narrows Bridge,
Nov. 7, 1940, Washington

- The longest suspension bridge of its time.
- It opened to traffic on Jul. 1, 1940, and dramatically collapsed into Puget Sound on Nov. 7 of the same year.
- Due to **design faults**.
- The violent swaying and eventual collapse resulted in the death of a cocker spaniel named "*Tubby*".





Understanding Mechanics is Important ...

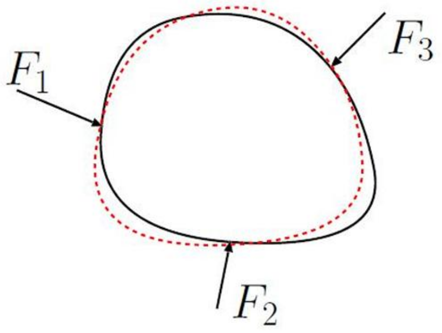
Aloha Airlines Flight 243, Boeing 737-200,
Apr. 28, 1988

- The flight suffered extensive damage after an explosive decompression in flight.
- A large section of the roof had torn off, consisting of the entire top half of the aircraft skin extending from just behind the cockpit to the fore-wing area.
- Due to **fatigue cracks and poor maintenance.**
- The one fatality, flight attendant *Clarabelle "C.B." Lansing*, was ejected from the airplane. 65 passengers and crew were injured.

COE 3001 is important !!!

Mechanics of Deformable bodies is foundational in biomedical, mechanical, civil, and aerospace engineering. It explores how materials respond to external forces — addressing the central question:

How do materials resist or fail under external load?



deformable body

- **Strength:**

  capacity of a structure to resist loads (max load)

- **Stiffness:**

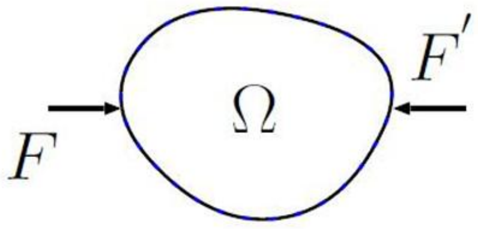
  ability to resist changes in shape (allowable deformation)

- **Stability:**

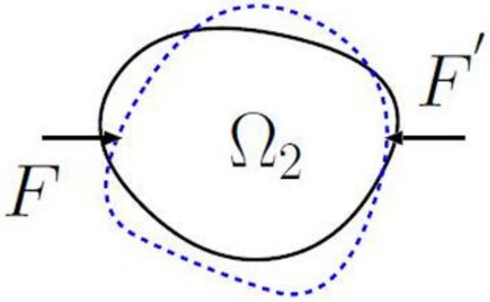
  ability to resist buckling under compressive stresses (stable or not while in service)

Rigid/deformable bodies

Rigid bodies	Deformable bodies
can sustain unbounded load	upper bound exists
NO shape and size changes	with shape and size changes
idealized model	more realistic
cares only the overall load carrying, kinematics, dynamics, etc.	cares more about the shape and size changes due to loads
usually used in COE 2001	usually used in COE 3001



A rigid body



A deformable body

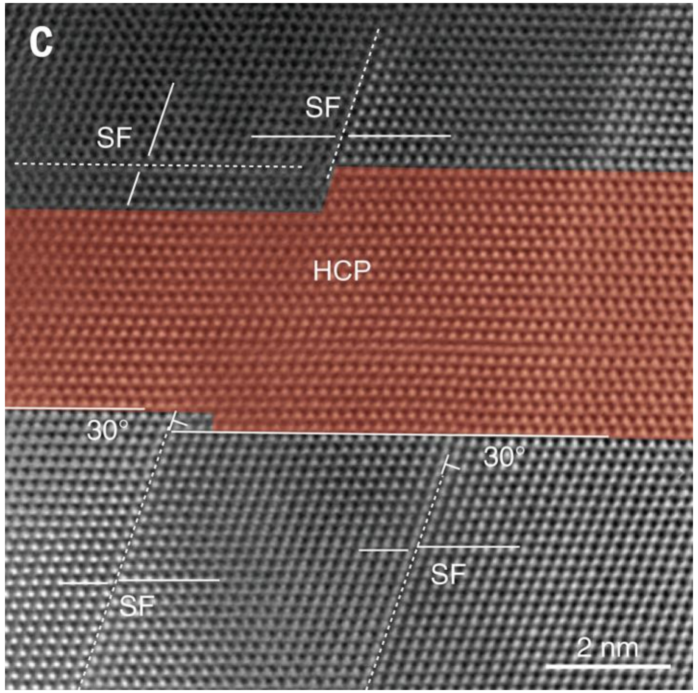
Idealizations for deformable bodies

Assumptions that work well on macro-scales:

1. continuous (no voids, cracks, defects, etc.)
2. homogeneous (uniform in material properties)
3. isotropic (behaving identically in all directions)

Steel Highway Guardrail-Roller Barrier

Think about the size scale you are interested



Magnified HAADF-STEM image for Stainless Steel
Pan, et al., Science 2025

Isotropic

- In the study of mechanical properties of materials, isotropic means having identical values of a property in all directions.
- Isotropic materials: metals, glass, etc.
- Anisotropic materials: composites, etc.

isotropic

anisotropic

Units

SI units are used in this course.

Quantity	SI Units	USC Units
Length	meter (m)	Foot (ft)
Mass	kilogram (kg)	slug
Force	Newton (N)	pound (lb)
Moment	Newton-meter (N*m)	foot-pound (lb*ft)
Energy	Joule (J)	foot-pound (lb*ft)
etc.		

Quantity	Metric (SI) Units of Measure	US Customary (USC) Units of Measure	Conversion Factors (SI) to (USC)
Time	second (s) 1 minute (min) = 60 seconds 1 hour (hr) = 60 minutes 1 day = 24 hours	second (s) 1 minute (min) = 60 seconds 1 hour (hr) = 60 minutes 1 day = 24 hours	--
Length	meter (m) 1000 millimeters (mm) = 1 m 1 kilometer (km) = 1000 m	foot (ft) 12 inches (in) = 1 ft 1 mile (mi) = 5280 ft	1 m = 3.281 ft
Area	square meter (m^2)	square foot (ft^2)	1 m^2 = 10.764 ft^2
Volume	cubic meter (m^3) Liter (L) = .001 m^3	cubic foot (ft^3) Gallon (gal) = .1337 ft^3	1 m^3 = 31.315 ft^3 3.785 L = 1 gal
Mass	kilogram (kg) metric ton / tonne (t) = 1000 kg	slug = $1\left(\frac{lb*s^2}{ft}\right)$	14.59 kg = 1 slug
Force	newton (N) = $1\left(\frac{kg*m}{s^2}\right)$ kilonewton (kN) = 1000 N	pound (lb) 16 ounces (oz) = 1 lb 1 kilo pound (kip) = 1000 lbs 1 ton = 2000 lbs	4.448 N = 1 lb
Velocity (Linear)	meter per second (m/s) 3.6 kilometers per hour (kph) = 1 m/s	feet per second (ft/s) mile per hour (mph) = 1.467 $\frac{\mathrm{ft}}{\mathrm{s}}$	$1\ \frac{\mathrm{m}}{\mathrm{s}} = 3.281\ \frac{\mathrm{ft}}{\mathrm{s}}$
Acceleration (Linear)	meter per second squared $\left(\frac{\mathrm{m}}{s^2}\right)$	foot per second squared $\left(\frac{\mathrm{ft}}{s^2}\right)$	$1\ \frac{\mathrm{m}}{\mathrm{s}^2} = 3.281\ \frac{\mathrm{ft}}{\mathrm{s}^2}$
Velocity (Angular)	radian per second $\left(\frac{\mathrm{rad}}{s}\right)$ 1 rotation per minute (rpm) $= \frac{2\pi}{60}\frac{\mathrm{rad}}{s}$	radian per second $\left(\frac{\mathrm{rad}}{s}\right)$ 1 rotation per minute (rpm) $= \frac{2\pi}{60}\frac{\mathrm{rad}}{s}$	--
Acceleration (Angular)	radian per second squared $\left(\frac{\mathrm{rad}}{s^2}\right)$	radian per second squared $\left(\frac{\mathrm{rad}}{s^2}\right)$	--
Moment of a Force; Torque	Newton-meter (N*m)	Foot-pound (lb*ft) Inch pound (lb*in)	1.356 N*m = 1 lb*ft
Area Moment of Inertia	meter^4 (m^4) 1 milimeter^4 (mm^4) = $10^{-12} * \mathrm{m}^4$	foot^4 (ft^4) 20736 inches^4 (in^4) = 1 ft^4	8.6x10^{-3} m^4 = 1ft^4
Mass Moment of Inertia	kilogram meter^2 $(\mathrm{kg} * \mathrm{m}^2)$	slug foot^2 $(\mathrm{slug} * \mathrm{ft}^2)$	1 kg*m^2 =1.356 lb*ft^2
Work and Energy	joule (J) = 1 $(N * m)$	foot-pound (ft lb)	1.356 J = 1 ft lb
Power	watt (W) = 1 (J/s) = $1\left(\frac{\mathrm{kg*m}}{s^2}\right)$ kilowatt (kW) = 1000 W	foot pound per second $\left(\frac{\mathrm{ft*lb}}{\mathrm{s}}\right)$ horsepower (hp) = 550 $\left(\frac{\mathrm{ft*lb}}{\mathrm{s}}\right)$	$1.356\ \mathrm{W} = 1\ \frac{\mathrm{ft\ lb}}{\mathrm{s}}$ 1 kW = 1.341 hp
Pressure or Stress	pascal (Pa) = 1 N/m^2 kilopascal (kPa) = 1000 Pa megapascal (MPa) = 10^6 Pa gigapascal (MPa) = 10^9 Pa	pounds per square inch (psi) = 1 (lb/in^2) kilo-pounds per square inch (ksi) = 1000 psi	6894.76 Pa = 1 psi

Prefixes

In the SI, designations of multiples and subdivision of any unit may be arrived at by combining with the name of the unit the prefixes

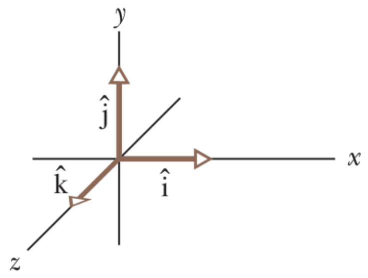
Name	Symbol	Meaning
giga	G	10^9
mega	M	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
etc.		

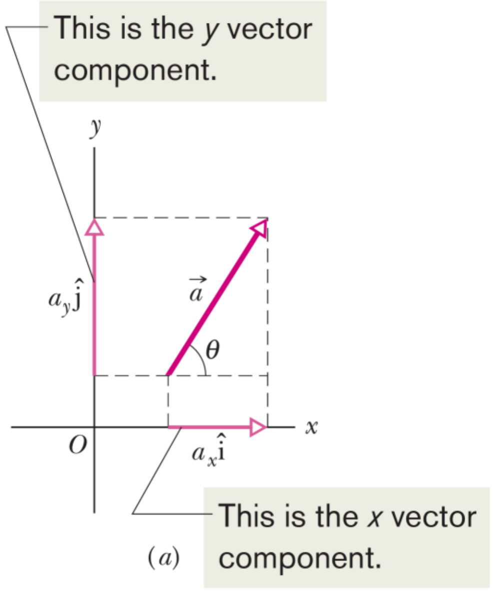
e.g.,

200 GPa = $200 * 10^9$ Pa

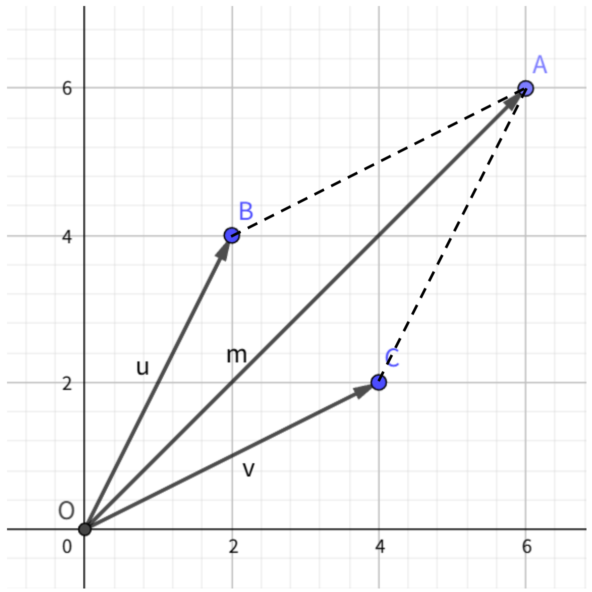
100 MPa = $100 * 10^6$ Pa

Scalars vs. Vectors





- Scalar: A quantity that has **magnitude only**
  - Examples: mass, time, temperature, energy
- Vector: A quantity that has both **magnitude** and **direction**
  - Examples: force, velocity, displacement, acceleration

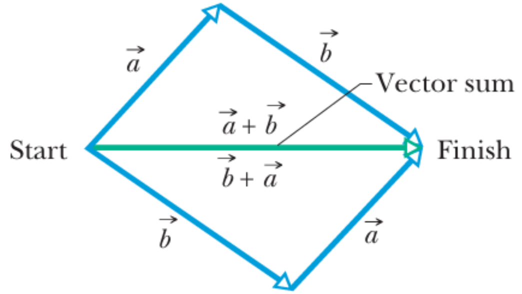


$$\boldsymbol{u} = 2\boldsymbol{i} + 4\boldsymbol{j} = \begin{pmatrix} 2 \\ 4 \end{pmatrix}$$

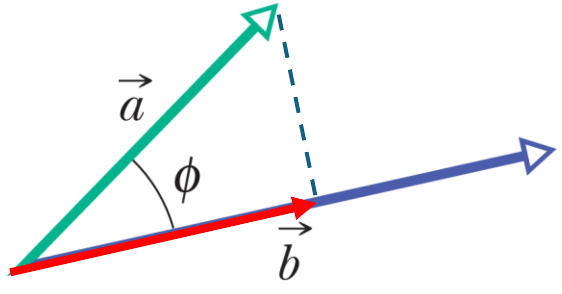
$$\boldsymbol{v} = 4\boldsymbol{i} + 2\boldsymbol{j} = \begin{pmatrix} 4 \\ 2 \end{pmatrix}$$

$$\boldsymbol{m} = \boldsymbol{u} + \boldsymbol{v} = (2\boldsymbol{i} + 4\boldsymbol{j}) + (4\boldsymbol{i} + 2\boldsymbol{j}) = \begin{pmatrix} 2 \\ 4 \end{pmatrix} + \begin{pmatrix} 4 \\ 2 \end{pmatrix}$$

$$\boldsymbol{m} = 6\boldsymbol{i} + 6\boldsymbol{j} = \begin{pmatrix} 6 \\ 6 \end{pmatrix}$$



Multiplying Vectors



Component of $\boldsymbol{a}$ along direction of $\boldsymbol{b}$ is $a\cos\phi$

- Dot product:

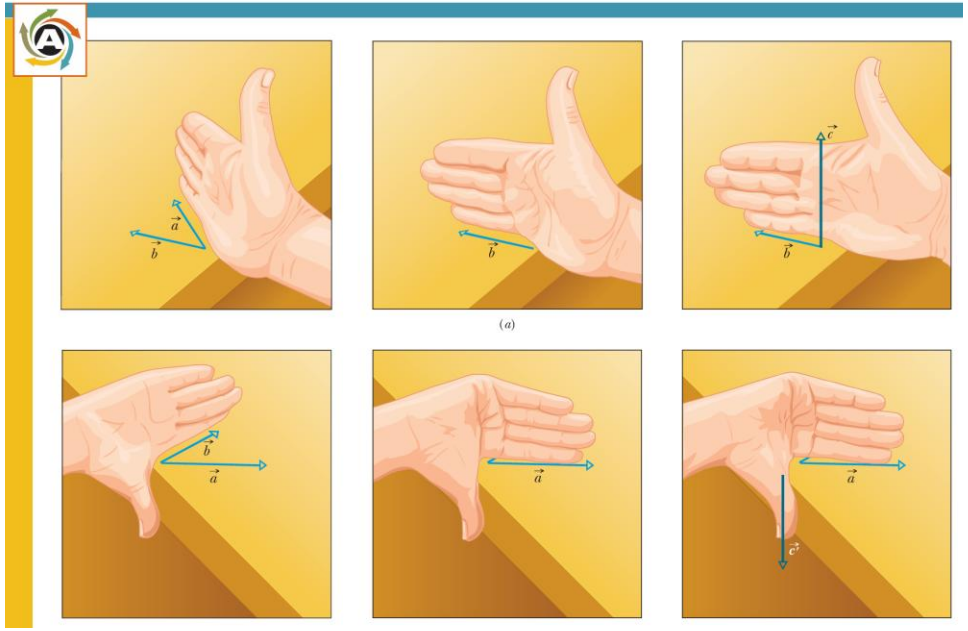
$$\boldsymbol{a}\cdot\boldsymbol{b} = ab\cos\phi = (a\cos\phi)\, b$$

$$\boldsymbol{a}\cdot\boldsymbol{b} = \left(a_x\boldsymbol{i} + a_y\boldsymbol{j} + a_z\boldsymbol{k}\right)\cdot\left(b_x\boldsymbol{i} + b_y\boldsymbol{j} + b_z\boldsymbol{k}\right) = a_xb_x + a_yb_y + a_zb_z$$

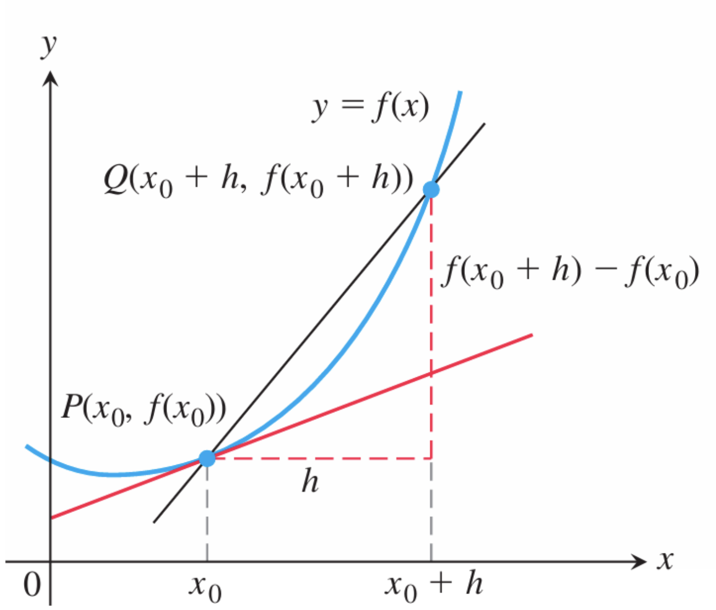
- Cross product:

$$\boldsymbol{a}\times\boldsymbol{b} = \begin{vmatrix} \boldsymbol{i} & \boldsymbol{j} & \boldsymbol{k} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

  - Magnitude: $|\boldsymbol{a}\times\boldsymbol{b}| = ab\sin\phi$
  - Direction: Right-hand rule



Derivatives and Differential Equations



DEFINITION The **derivative of a function f at a point x_0**, denoted $f'(x_0)$, is

$$f'(x_0) = \lim_{h \to 0} \frac{f(x_0 + h) - f(x_0)}{h}$$

provided this limit exists.

DEFINITION The **derivative** of the function $f(x)$ with respect to the variable x is the function f' whose value at x is

$$f'(x) = \lim_{h \to 0} \frac{f(x + h) - f(x)}{h},$$

provided the limit exists.

DIFFERENTIATION RULES

General Formulas

Assume u and v are differentiable functions of x.

Constant: $\frac{d}{dx}(c) = 0$

Sum: $\frac{d}{dx}(u + v) = \frac{du}{dx} + \frac{dv}{dx}$

Difference: $\frac{d}{dx}(u - v) = \frac{du}{dx} - \frac{dv}{dx}$

Constant Multiple: $\frac{d}{dx}(cu) = c\frac{du}{dx}$

Product: $\frac{d}{dx}(uv) = u\frac{dv}{dx} + v\frac{du}{dx}$

Quotient: $\frac{d}{dx}\left(\frac{u}{v}\right) = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$

Power: $\frac{d}{dx}x^n = nx^{n-1}$

Chain Rule: $\frac{d}{dx}(f(g(x)) = f'(g(x)) \cdot g'(x)$

Trigonometric Functions

$\frac{d}{dx}(\sin x) = \cos x$ $\qquad \frac{d}{dx}(\cos x) = -\sin x$

$\frac{d}{dx}(\tan x) = \sec^2 x$ $\qquad \frac{d}{dx}(\sec x) = \sec x \tan x$

$\frac{d}{dx}(\cot x) = -\csc^2 x$ $\qquad \frac{d}{dx}(\csc x) = -\csc x \cot x$

Exponential and Logarithmic Functions

$\frac{d}{dx}e^x = e^x$ $\qquad \frac{d}{dx}\ln x = \frac{1}{x}$

$\frac{d}{dx}a^x = a^x \ln a$ $\qquad \frac{d}{dx}(\log_a x) = \frac{1}{x \ln a}$

Inverse Trigonometric Functions

$\frac{d}{dx}(\sin^{-1} x) = \frac{1}{\sqrt{1 - x^2}}$ $\qquad \frac{d}{dx}(\cos^{-1} x) = -\frac{1}{\sqrt{1 - x^2}}$

$\frac{d}{dx}(\tan^{-1} x) = \frac{1}{1 + x^2}$ $\qquad \frac{d}{dx}(\sec^{-1} x) = \frac{1}{|x|\sqrt{x^2 - 1}}$

$\frac{d}{dx}(\cot^{-1} x) = -\frac{1}{1 + x^2}$ $\qquad \frac{d}{dx}(\csc^{-1} x) = -\frac{1}{|x|\sqrt{x^2 - 1}}$

Hyperbolic Functions

$\frac{d}{dx}(\sinh x) = \cosh x$ $\qquad \frac{d}{dx}(\cosh x) = \sinh x$

$\frac{d}{dx}(\tanh x) = \operatorname{sech}^2 x$ $\qquad \frac{d}{dx}(\operatorname{sech} x) = -\operatorname{sech} x \tanh x$

$\frac{d}{dx}(\coth x) = -\operatorname{csch}^2 x$ $\qquad \frac{d}{dx}(\operatorname{csch} x) = -\operatorname{csch} x \coth x$

Inverse Hyperbolic Functions

$\frac{d}{dx}(\sinh^{-1} x) = \frac{1}{\sqrt{1 + x^2}}$ $\qquad \frac{d}{dx}(\cosh^{-1} x) = \frac{1}{\sqrt{x^2 - 1}}$

$\frac{d}{dx}(\tanh^{-1} x) = \frac{1}{1 - x^2}$ $\qquad \frac{d}{dx}(\operatorname{sech}^{-1} x) = -\frac{1}{x\sqrt{1 - x^2}}$

$\frac{d}{dx}(\coth^{-1} x) = \frac{1}{1 - x^2}$ $\qquad \frac{d}{dx}(\operatorname{csch}^{-1} x) = -\frac{1}{|x|\sqrt{1 + x^2}}$

Parametric Equations

If $x = f(t)$ and $y = g(t)$ are differentiable, then

$$y' = \frac{dy}{dx} = \frac{dy/dt}{dx/dt} \quad \text{and} \quad \frac{d^2y}{dx^2} = \frac{dy'/dt}{dx/dt}.$$

Derivatives and Differential Equations

A **first-order differential equation** is an equation

$$\frac{dy}{dx} = f(x, y) \tag{1}$$

in which $f(x, y)$ is a function of two variables defined on a region in the xy-plane. The equation is of *first order* because it involves only the first derivative dy/dx (and not higher-order derivatives). We point out that the equations

$$y' = f(x, y) \qquad \text{and} \qquad \frac{d}{dx}y = f(x, y)$$

are equivalent to Equation (1) and all three forms will be used interchangeably in the text.

In this course, most likely:

$$\frac{dy}{dx} = f(x)$$

$$\Longrightarrow y = \int f(x)\, dx$$