Carleton University * Faculty of Engineering and Design

Mechanics I

ECOR 1101

Lecture 01

* General Principles
* Basic Concepts, Newton's Laws
* Fundamental Quantities

Section 1.1-1.6

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MECHANICS, UNITS, NUMERICAL CALCULATIONS & GENERAL PROCEDURE FOR ANALYSIS

Today's Objectives:

Students will be able to:

a) Identify what is mechanics / statics.
b) Work with two types of units.
c) Round the final answer appropriately.
d) Apply problem solving strategies.

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READING QUIZ

1. The subject of mechanics deals with what happens to a body when _____ is / are applied to it.

   A) magnetic field B) heat C) forces

   D) neutrons E) lasers

2. _____ still remains the basis of most of today's engineering sciences.

   A) Newtonian Mechanics B) Relativistic Mechanics

   C) Greek Mechanics C) Euclidean Mechanics

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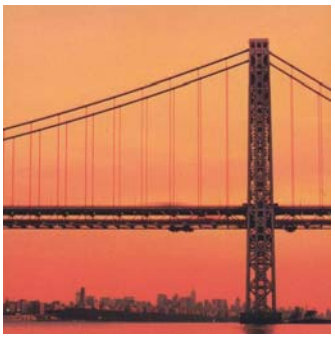
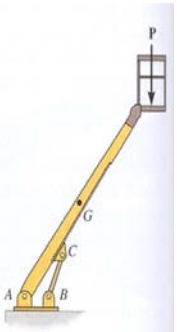
WHAT IS MECHANICS?

- Study of what happens to a "thing" (the technical name is "BODY") when FORCES are applied to it.
- Either the body or the forces could be large or small.





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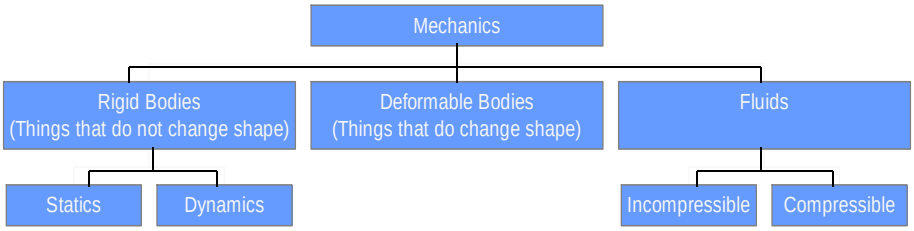
BRANCHES OF MECHANICS



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WHAT MAY HAPPEN IF STATICS IS NOT APPLIED PROPERLY?

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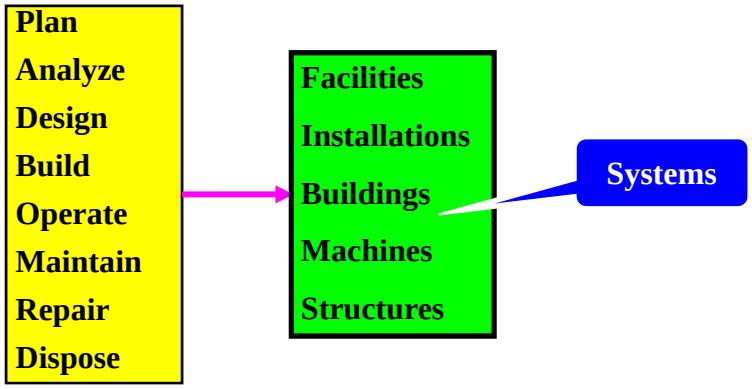
What do engineers do?



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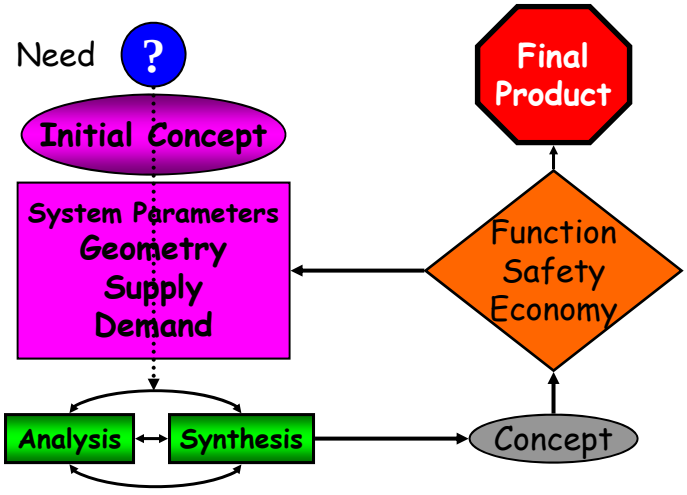
Engineering Design



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UNITS OF MEASUREMENT
(Section 1.3)

- **Four fundamental physical quantities.**
  - Length (Position, size)
  - Mass (Amount of matter, weight, inertia)
  - Time (motion, speed)
  - Force (push/pull between bodies)

- Newton's 2nd Law relates them: F = m * a
- We use this equation to develop systems of units.
- Units are arbitrary names we give to the physical quantities.

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UNIT SYSTEMS
Table 1-1 in the textbook summarizes these unit systems.

F=ma

Name	Length	Time	Mass	Force
International System of Units (SI)	meter (m)	second (s)	kilogram (kg)	newton* (N) $\left(\frac{kg \cdot m}{s^2}\right)$
U.S. Customary (FPS)	foot (ft)	second (s)	slug* $\left(\frac{lb \cdot s^2}{ft}\right)$	pound (lb)

*Derived unit.

- Force, mass and acceleration are called the base units.
- The fourth unit, time is derived from the acceleration term.
- We will work with two unit systems in statics:
  - International System (SI)
  - U.S. Customary (USCS)

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COMMON CONVERSION FACTORS

- Work problems in the units given unless otherwise instructed!
  - 1 ft = 0.3048 m
  - 1 lb = 4.4482 N
  - 1 slug = 14.5938 kg

- Example: Convert a torque value of 47 in • lb into SI units.

$$47\ \text{in.lb} = 47\text{in.lb}\ \text{x}\ \frac{0.3048\text{m}}{12in}.\frac{4.4482N}{lb} = 5.31026116\ \text{N} \bullet \text{m?}$$

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THE INTERNATIONAL SYSTEM OF UNITS
(Section 1.4)

- No Plurals (e.g., m = 5 kg not kgs)
- Separate Units with a • (e.g., meter second = m • s)
- Most symbols are in lowercase.
  - Some exceptions are **N (Newton)**, **Pa (Pascal), M** and **G.**
- Exponential powers apply to units, e.g., cm • cm = cm^2
- Other rules are given in your textbook.

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NUMERICAL CALCULATIONS
(Section 1.5)

- Must have dimensional "homogeneity." Dimensions have to be the same on both sides of the equal sign,
  - (e.g. distance = speed × time.)
- Use an appropriate number of significant figures (3 for answer, at least 4 for intermediate calculations). Why?
- Be consistent when rounding off.
  - greater than 5, round up (3528 → 3530)
  - smaller than 5, round down (0.03521 → 0.0352)
  - equal to 5, see your textbook.

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CONCEPT QUIZ

(continued)

2. Give the most appropriate reason for using three significant figures in reporting results of typical engineering calculations.

A) Historically slide rules could not handle more than three significant figures.

B) Three significant figures gives better than one-percent accuracy.

C) Telephone systems designed by engineers have area codes consisting of three figures.

D) Most of the original data used in engineering calculations do not have accuracy better than one percent.

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ATTENTION QUIZ

1. For a static's problem your calculations show the final answer as 12345.6 N. What will you write as your final answer?

   A) 12345.6 N B) 12.3456 kN C) 12 kN

   D) 12.3 kN E) 123 kN

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Example 1

Convert 2 km/h to m/s. How many ft/s is this?

SOLUTION

Since 1 km = 1000 m and 1 h = 3600 s, the factors of conversion are arranged in the following order, so that a cancellation of the units can be applied:

$$2\ \text{km/h} = \frac{2\ \cancel{\text{km}}}{\cancel{\text{h}}}\left(\frac{1000\ \text{m}}{\cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{h}}}{3600\ \text{s}}\right)$$

$$= \frac{2000\ \text{m}}{3600\ \text{s}} = 0.556\ \text{m/s} \qquad \textit{Ans.}$$

From Table 1–2, 1 ft = 0.3048 m. Thus

$$0.556\ \text{m/s} = \frac{0.556\ \cancel{\text{m}}}{\text{s}}\frac{1\ \text{ft}}{0.3048\ \cancel{\text{m}}}$$

$$= 1.82\ \text{ft/s} \qquad \textit{Ans.}$$

NOTE: Remember to round off the final answer to three significant figures.

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Example 2

Convert the quantities $300\ \text{lb}\cdot\text{s}$ and $52\ \text{slug/ft}^3$ to appropriate SI units.

SOLUTION

Using Table 1–2, $1\ \text{lb} = 4.448\ 2\ \text{N}$.

$$300\ \text{lb}\cdot\text{s} = 300\ \cancel{\text{lb}}\cdot\text{s}\left(\frac{4.448\ 2\ \text{N}}{\cancel{\text{lb}}}\right)$$
$$= 1334.5\ \text{N}\cdot\text{s} = 1.33\ \text{kN}\cdot\text{s} \qquad \textit{Ans.}$$

Also, $1\ \text{slug} = 14.593\ 8\ \text{kg}$ and $1\ \text{ft} = 0.304\ 8\ \text{m}$.

$$52\ \text{slug/ft}^3 = \frac{52\ \cancel{\text{slug}}}{\cancel{\text{ft}^3}}\left(\frac{14.593\ 8\ \text{kg}}{1\ \cancel{\text{slug}}}\right)\left(\frac{1\ \cancel{\text{ft}}}{0.304\ 8\ \text{m}}\right)^3$$
$$= 26.8(10^3)\ \text{kg/m}^3$$
$$= 26.8\ \text{Mg/m}^3 \qquad \textit{Ans.}$$

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Example 3

Evaluate each of the following and express with SI units having an appropriate prefix: (a) $(50\ \text{mN})(6\ \text{GN})$, (b) $(400\ \text{mm})(0.6\ \text{MN})^2$, (c) $45\ \text{MN}^3/900\ \text{Gg}$.

SOLUTION

First convert each number to base units, perform the indicated operations, then choose an appropriate prefix (see Rule 6 on p. 9).

Part (a)

$$(50\ \text{mN})(6\ \text{GN}) = [50(10^{-3})\ \text{N}][6(10^9)\ \text{N}]$$
$$= 300(10^6)\ \text{N}^2$$
$$= 300(10^6)\ \cancel{\text{N}^2}\left(\frac{1\ \text{kN}}{10^3\ \cancel{\text{N}}}\right)\left(\frac{1\ \text{kN}}{10^3\ \cancel{\text{N}}}\right)$$
$$= 300\ \text{kN}^2 \qquad \textit{Ans.}$$

NOTE: Keep in mind the convention $\text{kN}^2 = (\text{kN})^2 = 10^6\ \text{N}^2$ (Rule 4 on p. 9).

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Part (b)

$$(400\text{ mm})(0.6\text{ MN})^2 = [400(10^{-3})\text{ m}][0.6(10^6)\text{ N}]^2$$
$$= [400(10^{-3})\text{ m}][0.36(10^{12})\text{ N}^2]$$
$$= 144(10^9)\text{ m}\cdot\text{N}^2$$
$$= 144\text{ Gm}\cdot\text{N}^2 \quad \textit{Ans.}$$

We can also write

$$144(10^9)\text{ m}\cdot\text{N}^2 = 144(10^9)\text{ m}\cdot\cancel{\text{N}^2}\left(\frac{1\text{ MN}}{10^6\,\cancel{\text{N}}}\right)\left(\frac{1\text{ MN}}{10^6\,\cancel{\text{N}}}\right)$$
$$= 0.144\text{ m}\cdot\text{MN}^2$$

Part (c)

$$45\text{ MN}^3/900\text{ Gg} = \frac{45(10^6\text{ N})^3}{900(10^6)\text{ kg}}$$
$$= 0.05(10^{12})\text{ N}^3/\text{kg}$$
$$= 0.05(10^{12})\,\cancel{\text{N}^3}\left(\frac{1\text{ kN}}{10^3\,\cancel{\text{N}}}\right)^3\frac{1}{\text{kg}}$$
$$= 0.05(10^3)\text{ kN}^3/\text{kg}$$
$$= 50\text{ kN}^3/\text{kg} \quad \textit{Ans.}$$

NOTE: Here we have used Rules 4 and 8 on p. 9.

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PROBLEM SOLVING STRATEGY:
IPE, A 3 Step Approach

1. Interpret: Read carefully and determine what is given and what is to be found/ delivered. Ask, if not clear. If necessary, make assumptions and indicate them.

2. Plan: Think about major steps (or a road map) that you will take to solve a given problem. Think of alternative/creative solutions and choose the best one.

3. Execute: Carry out your steps. Use appropriate diagrams and equations. Estimate your answers. Avoid simple calculation mistakes. Reflect on / revise your work.

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