

## Lecture 01

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

Section 1.1-1.6

# 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.



## READING QUIZ

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

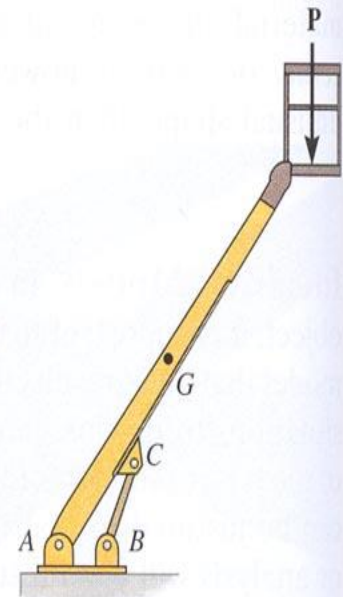
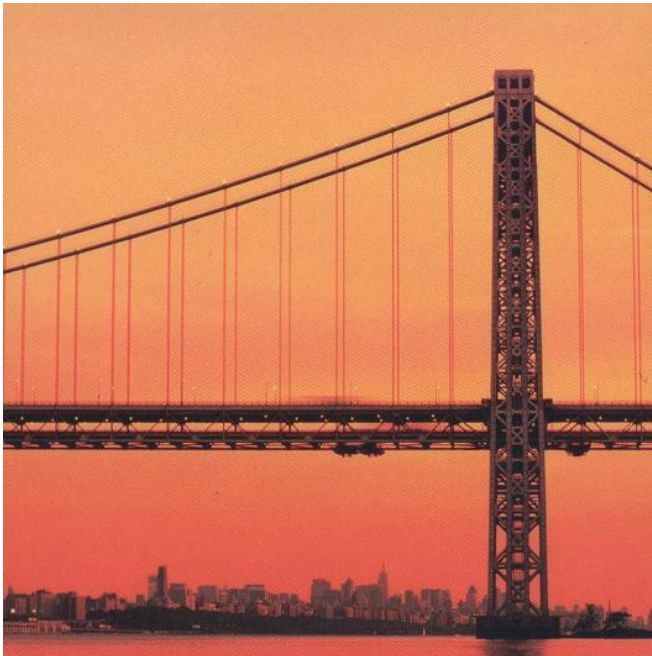
- A) magnetic field    B) heat    C) forces  
D) neutrons    E) lasers

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

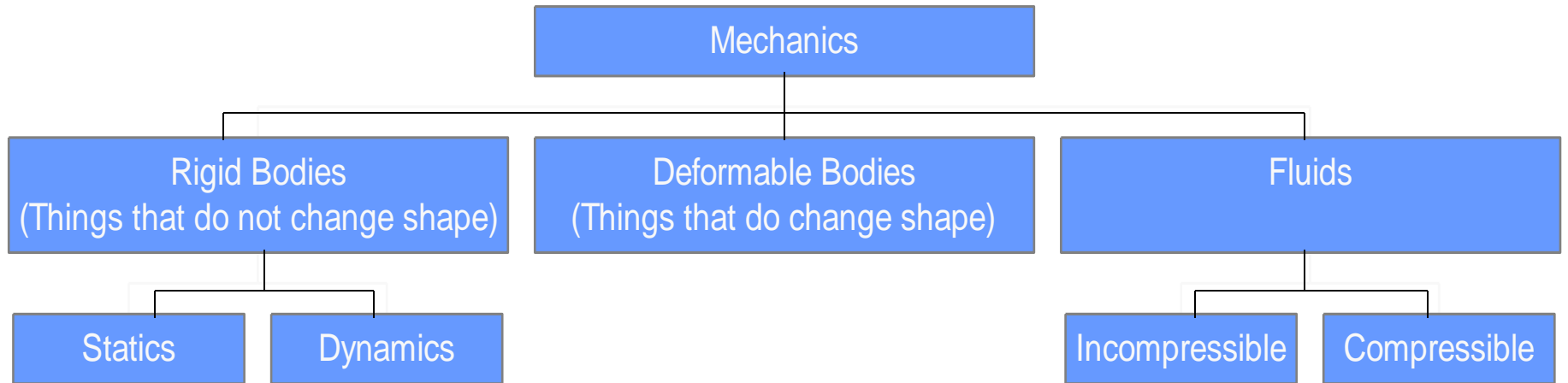
- A) Newtonian Mechanics    B) Relativistic Mechanics  
C) Greek Mechanics    C) Euclidean Mechanics

# 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.



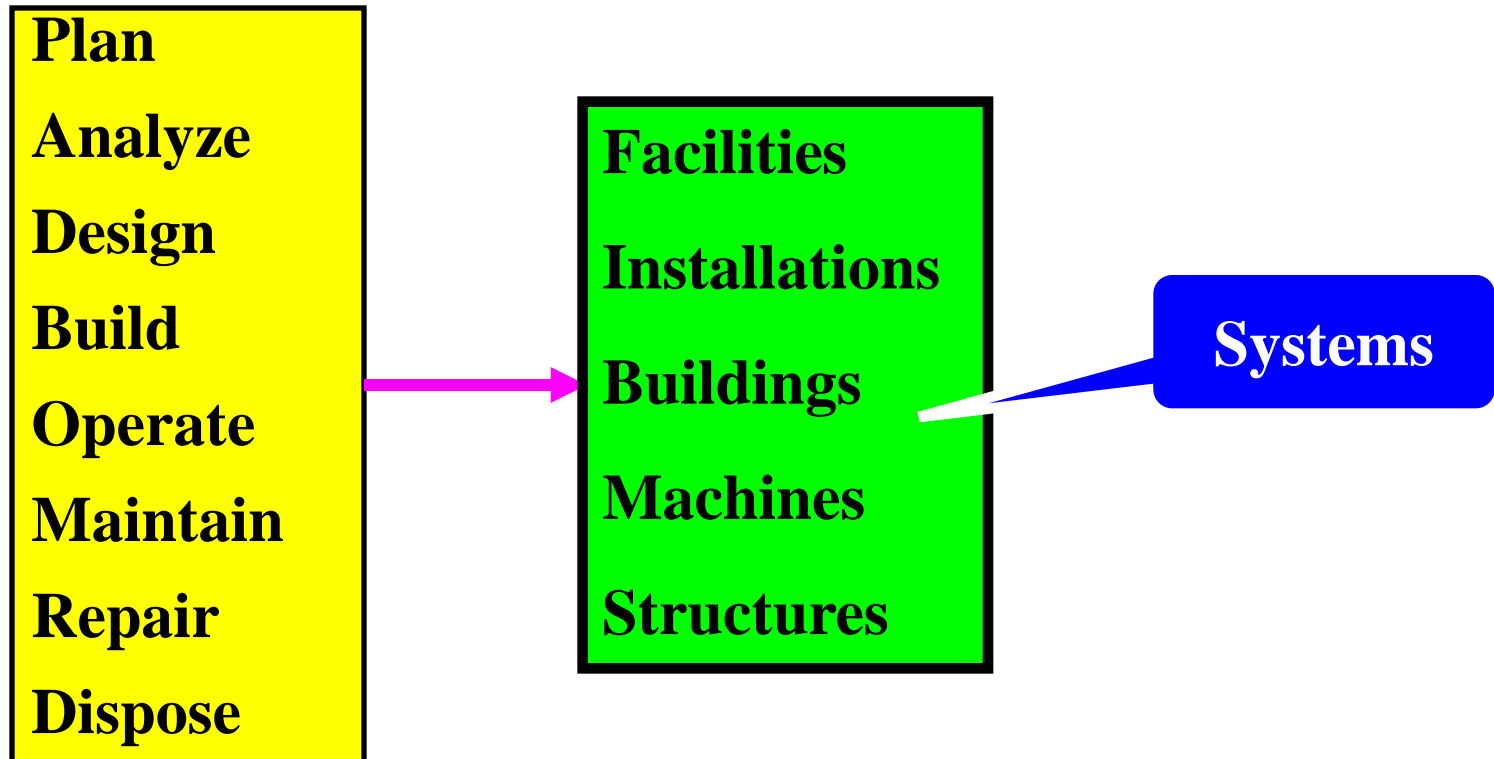
# BRANCHES OF MECHANICS



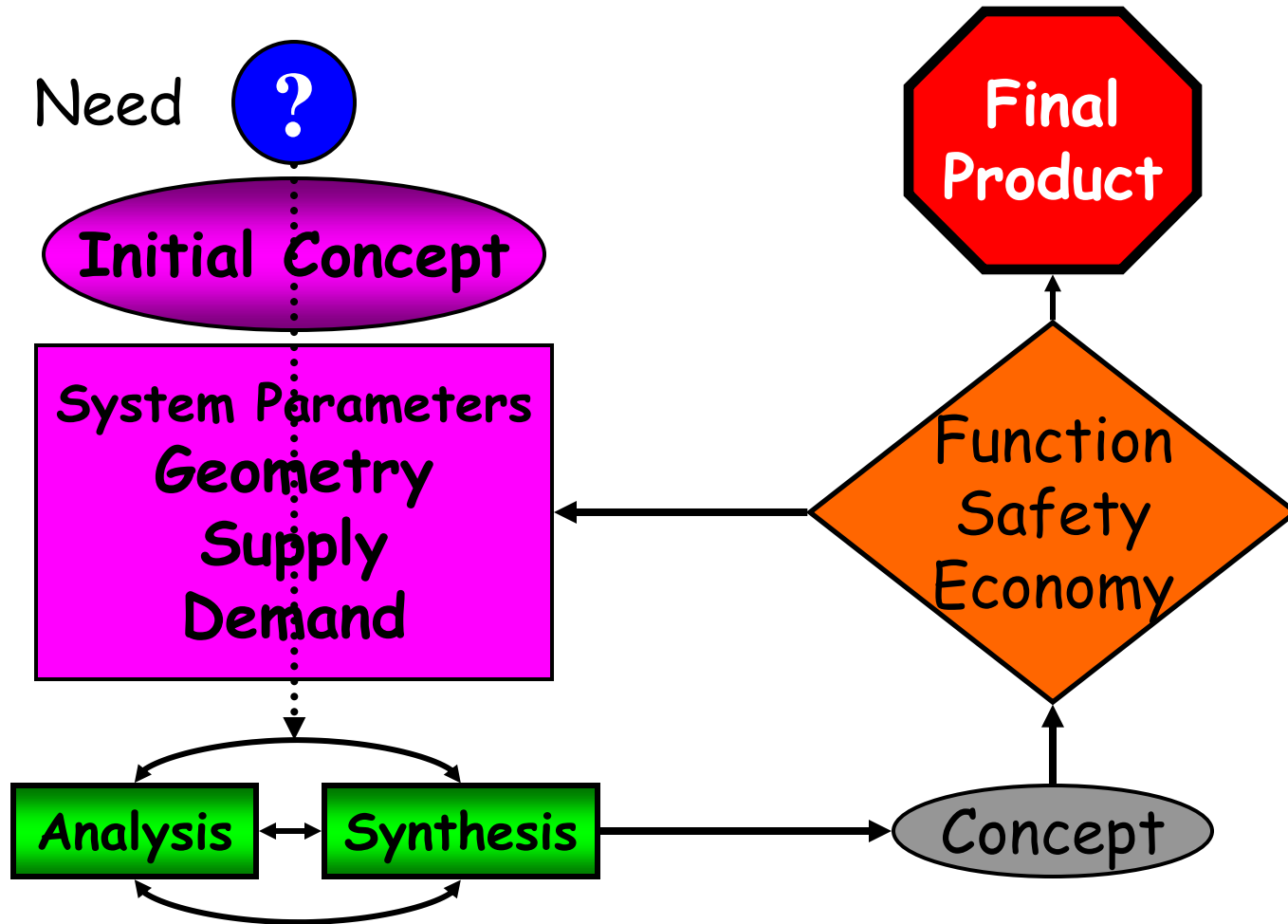
# WHAT MAY HAPPEN IF STATICS IS NOT APPLIED PROPERLY?



# What do engineers do?



# Engineering Design



# 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 2<sup>nd</sup> 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.

# UNIT SYSTEMS

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

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

$$F=ma$$

\*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)

## 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.

$$47 \text{ in}\cdot\text{lb} = 47 \text{ in}\cdot\text{lb} \times \frac{0.3048 \text{ m}}{12 \text{ in}} \cdot \frac{4.4482 \text{ N}}{\text{lb}} = 5.31026116 \text{ N}\cdot\text{m}?$$

# THE INTERNATIONAL SYSTEM OF UNITS

## (Section 1.4)

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

# 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  $\times$  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  $\rightarrow$  3530)
  - smaller than 5, round down (0.03521  $\rightarrow$  0.0352)
  - equal to 5, see your textbook.

# 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.

## 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

# 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:

$$\begin{aligned} 2 \text{ km/h} &= \frac{2 \text{ km}}{\text{h}} \left( \frac{1000 \text{ m}}{\text{km}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) \\ &= \frac{2000 \text{ m}}{3600 \text{ s}} = 0.556 \text{ m/s} \end{aligned} \quad \textit{Ans.}$$

From Table 1-2, 1 ft = 0.3048 m. Thus

$$\begin{aligned} 0.556 \text{ m/s} &= \frac{0.556 \text{ m}}{\text{s}} \frac{1 \text{ ft}}{0.3048 \text{ m}} \\ &= 1.82 \text{ ft/s} \end{aligned} \quad \textit{Ans.}$$

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

## Example 2

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

### SOLUTION

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

$$\begin{aligned} 300 \text{ lb} \cdot \text{s} &= 300 \cancel{\text{lb}} \cdot \text{s} \left( \frac{4.448 2 \text{ N}}{\cancel{\text{lb}}} \right) \\ &= 1334.5 \text{ N} \cdot \text{s} = 1.33 \text{ kN} \cdot \text{s} \end{aligned}$$

*Ans.*

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

$$\begin{aligned} 52 \text{ slug}/\text{ft}^3 &= \frac{52 \cancel{\text{slug}}}{\cancel{\text{ft}}^3} \left( \frac{14.593 8 \text{ kg}}{1 \cancel{\text{slug}}} \right) \left( \frac{1 \cancel{\text{ft}}}{0.304 8 \text{ m}} \right)^3 \\ &= 26.8(10^3) \text{ kg}/\text{m}^3 \\ &= 26.8 \text{ Mg}/\text{m}^3 \end{aligned}$$

*Ans.*

## 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)

$$\begin{aligned}(50 \text{ mN})(6 \text{ GN}) &= [50(10^{-3}) \text{ N}][6(10^9) \text{ N}] \\ &= 300(10^6) \text{ N}^2 \\ &= 300(10^6) \cancel{\text{N}}^2 \left( \frac{1 \text{ kN}}{10^3 \cancel{\text{N}}} \right) \left( \frac{1 \text{ kN}}{10^3 \cancel{\text{N}}} \right) \\ &= 300 \text{ kN}^2\end{aligned}$$

*Ans.*

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

### Part (b)

$$\begin{aligned}(400 \text{ mm})(0.6 \text{ MN})^2 &= [400(10^{-3}) \text{ m}][0.6(10^6) \text{ N}]^2 \\ &= [400(10^{-3}) \text{ m}][0.36(10^{12}) \text{ N}^2] \\ &= 144(10^9) \text{ m} \cdot \text{N}^2 \\ &= 144 \text{ Gm} \cdot \text{N}^2\end{aligned}$$

*Ans.*

We can also write

$$\begin{aligned}144(10^9) \text{ m} \cdot \text{N}^2 &= 144(10^9) \text{ m} \cdot \text{N}^2 \left(\frac{1 \text{ MN}}{10^6 \text{ N}}\right) \left(\frac{1 \text{ MN}}{10^6 \text{ N}}\right) \\ &= 0.144 \text{ m} \cdot \text{MN}^2\end{aligned}$$

### Part (c)

$$\begin{aligned}45 \text{ MN}^3/900 \text{ Gg} &= \frac{45(10^6 \text{ N})^3}{900(10^6) \text{ kg}} \\ &= 0.05(10^{12}) \text{ N}^3/\text{kg} \\ &= 0.05(10^{12}) \text{ N}^3 \left(\frac{1 \text{ kN}}{10^3 \text{ N}}\right)^3 \frac{1}{\text{kg}} \\ &= 0.05(10^3) \text{ kN}^3/\text{kg} \\ &= 50 \text{ kN}^3/\text{kg}\end{aligned}$$

*Ans.*

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

# 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.