INTRODUCTION TO MECHANICAL ENGINEERING BMCG 2423

STATICS : GENERAL PRINCIPLES

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Lesson Outcome

At the end of lesson, students should be able to:

- use the basic quantities and SI unit system for statics problems
- know where to apply the Newton's Laws of Motion and Gravitation in statics problems.
- use the standard procedures in doing numerical calculations for statics analysis by following general guidelines that is given.

Chapter Outline

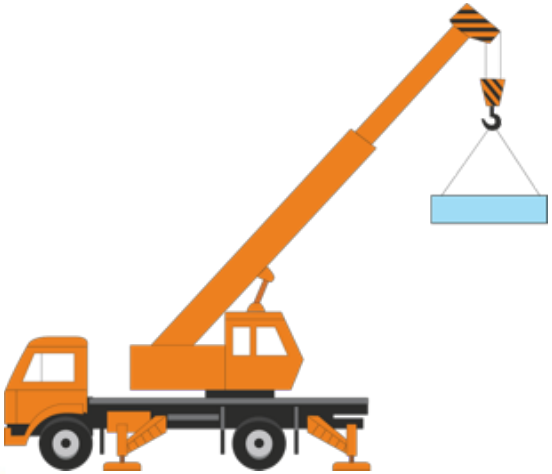
Mechanics and Fundamental Concepts

Units of Measurement and SI System

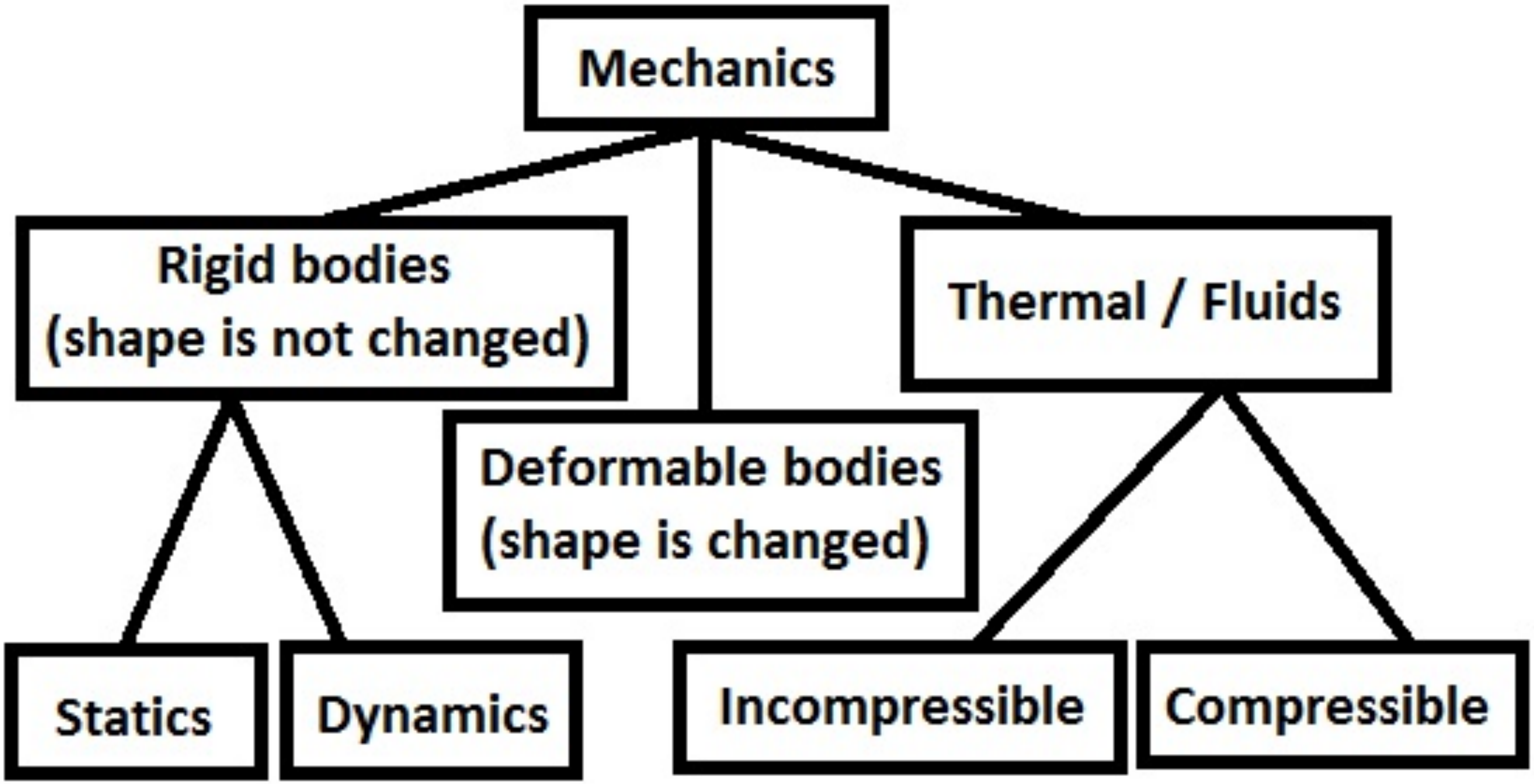
Numerical Calculations and General Procedure

What is Mechanics?

- A branch of applied mathematics to study the condition that can be happen to a “thing” (or technically called “**body**”) when it is subjected to motion and forces which produce motion.
- The body or the force can be in any value.



Branches of Mechanics



Basic subjects of Mechanics

- Statics: Deals with body at rest or moving at constant velocity.

- Dynamics: Deals with moving body with acceleration.

Fundamentals Concepts

Basic Quantities

- Length
  - – Indicates position and gives size of system.
  - – Measure distance and geometric properties.
- Mass
  - – Comparison of action of one body to another.
  - – Measure of resistance of matter due to a change in velocity.

Fundamentals Concepts

Basic Quantities

- Time
  - The succession of events.
- Force
  - "push" or "pull" given by one body on another.
  - Occur when there is direct contact between bodies. (Eg: Person pushing against a wall.)
  - Occur through a distance without direct contact. (Eg: Gravitational, electrical and magnetic forces.)

Fundamentals Concepts

Idealizations

- Particles
  - – Things with mass consideration but size is neglected.

  (Eg: Size of Earth is insignificant as compared to its' orbital size.)
- Rigid Body
  - – Combination of large number of particles.
  - – Material properties are neglected.

  (Eg: Deformations in structures, machines and mechanism.)

Fundamentals Concepts

Idealizations

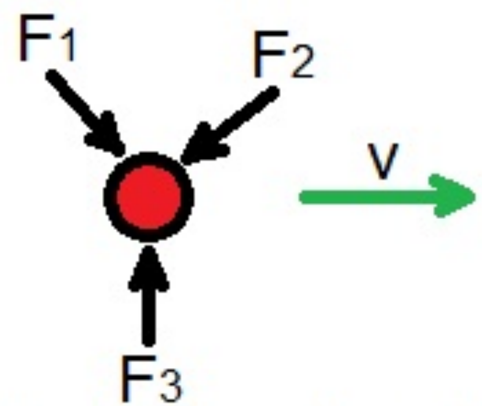
- Concentrated Force
  – Loading which is assumed to act at a point on a body.
  – Loading area is small as compared to overall size.
  (Eg: Contact force between wheel and ground.)

Fundamentals Concepts

Newton’s Three Laws of Motion

- First Law

“A particle originally at rest, or moving in a straight line with constant velocity, will remain in this state provided that the particle is not subjected to an unbalanced force” .



Equilibrium of particle

Fundamentals Concepts

Newton's Three Laws of Motion

- Second Law

"A particle acted upon by an *unbalanced force* **F** experiences an acceleration **a** that has the same direction as the force and a magnitude that is directly proportional to the force".

$$F = ma$$

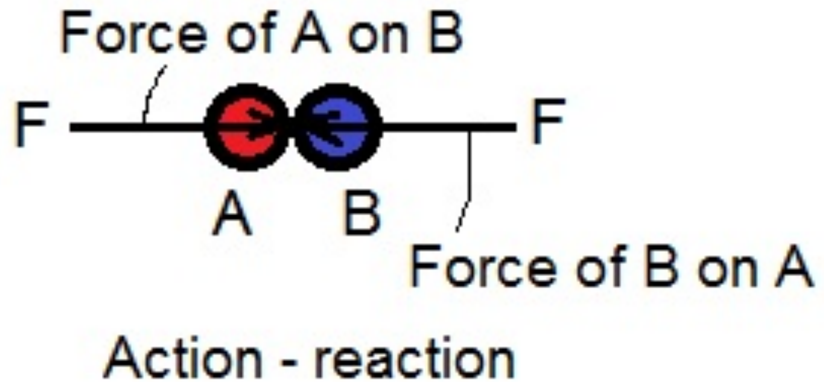
Accelerated motion

Fundamentals Concepts

Newton's Three Laws of Motion

- Third Law

"The mutual forces of action and reaction between two particles are equal and, opposite and collinear" .



Fundamentals Concepts

Newton's Law of Gravitational Attraction

$$F = G\frac{m_1 m_2}{r^2}$$

Weight, $W = G\dfrac{mM_e}{r^2}$

$$g = GM_e / r^2$$

$$W = mg$$

F = force of gravitation between two particles
G = universal constant of gravitation
m_1,m_2 = mass of each of the two particles
r = distance between the two particles

Fundamentals Concepts

- At a standard location,

  $g = 9.806\ 65\ m/s^2$

- For calculations, we use

  $g = 9.81\ m/s^2$

- Thus,

  $W = mg\ (g = 9.81 m/s^2)$

- Hence, a body of mass 1 kg has a weight of 9.81 N

Units for Measurement

International System of Units (SI) – for Static

Length	Time	Mass	Force
Meter (m)	Second (s)	Kilogram (kg)	Newton (N)
			$\left(\dfrac{kg.m}{s^2}\right)$

The International System of Units

Prefixes

- Used with units, especially for a very large or very small numerical quantity.
- Represent a multiple or sub-multiple of a unit.

Eg: *8,000,000 N = 8000 kN (kilo-newton)*

= 8 MN (mega- newton)

0.007 m = 7 mm (milli-meter)

The International System of Units

	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^{9}	Giga	G
1 000 000	10^{6}	Mega	M
1 000	10^{3}	Kilo	k
Sub-Multiple			
0.001	10^{-3}	Milli	m
0.000 001	10^{-6}	Micro	μ
0.000 000 001	10^{-9}	nano	n

The International System of Units

- No Plurals (*e.g., m = 3 kg not kgs*)
- Where possible, separate Units with a •

(*e.g., meter second = m • s*)

- Most symbols are in lowercase. (except in certain cases such as *N, Pa, M* and *G*).
- Exponential power is applied to units

(*e.g.,* $cm^2 = cm \bullet cm$ *)*

Numerical Calculations

- Must have dimensional "homogeneity." Dimensions have to be the same on both sides of equation, (*e.g. distance = speed* $\times$ *time.*)

- Use an appropriate number of significant figures (2 s.f. for answer, but at least 3 s.f. for intermediate calculations). Why?

- Be consistent when rounding off.

  - greater than 5, round up (5678 → 5670)

  - smaller than 5, round down (0.01231 → 0.0123)

Numerical Calculations

Example :

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

Solution :

First convert to base units, perform indicated operations and choose an appropriate prefix.

Numerical Calculations

Solution (a) :

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

Numerical Calculations

Solution (b) :

$$(400mm)(0.6MN)^2$$

$$= \left[400\left(10^{-3}\right)m\right]\left[0.6\left(10^{6}\right)N\right]^2$$

$$= \left[400\left(10^{-3}\right)m\right]\left[0.36\left(10^{12}\right)N^2\right]$$

$$= 144\left(10^{9}\right)m.N^2$$

$$= 144Gm.kN^2$$

Numerical Calculations

Solution (c) :

$$45MN^3 / 900Gg$$

$$= \frac{45\left(10^6 N\right)^3}{900\left(10^6\right)kg}$$

$$= 50\left(10^9\right)N^3 / kg$$

$$= 50\left(10^9\right)\cancel{N}^3\left(\frac{1kN}{10^3 \cancel{N}}\right)^3 \frac{1}{kg}$$

$$= 50kN^3 / kg$$

General Procedure for Analysis

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.

General Procedure for Analysis

Your analysis must be :

- NEAT
- IN ORDER / STEP BY STEP
- PRECISE / CORRECT

End of Lesson

Recall:

- What are the branches for field of mechanics?
- Can you remember all the Newton's Laws?
- What are the basic units of measurements?
- Can you recognize the SI symbols for prefixes?
- Why do we need to use at least three significant figures during calculation?

References

- Hibbeler, R.C. and Yap, K.B., 2013, **Mechanics for Engineers – Statics**, Thirteenth SI Edition, Pearson, Singapore.