Engineering Mechanics: Statics

Chapter 1: General Principles

Chapter Outline

- Mechanics
- Fundamental Concepts
- Units of Measurement
- The International System of Units
- Numerical Calculations
- General Procedure for Analysis

1.1 Mechanics

- Mechanics can be divided into 3 branches:
  - Rigid-body Mechanics
  - Deformable-body Mechanics
  - Fluid Mechanics
- Rigid-body Mechanics deals with
  - Statics
  - Dynamics

1.1 Mechanics

- Statics – Equilibrium of bodies
  - At rest
  - Move with constant velocity
- Dynamics – Accelerated motion of bodies

1.2 Fundamentals Concepts

Basic Quantities

- Length
  - Locate position and describe size of physical system
  - Define distance and geometric properties of a body
- Mass
  - Comparison of action of one body against another
  - Measure of resistance of matter to a change in velocity

1.2 Fundamentals Concepts

Basic Quantities

- Time
  - Conceive as succession of events
- Force
  - "push" or "pull" exerted by one body on another
  - Occur due to direct contact between bodies

  Eg: Person pushing against the wall

  - Occur through a distance without direct contact

  Eg: Gravitational, electrical and magnetic forces

1.2 Fundamentals Concepts

Idealizations

- Particles
  - Consider mass but neglect size

  Eg: Size of Earth insignificant compared to its size of orbit
- Rigid Body
  - Combination of large number of particles
  - Neglect material properties

  Eg: Deformations in structures, machines and mechanism

1.2 Fundamentals Concepts

Idealizations

- Concentrated Force
  - Effect of loading, assumed to act at a point on a body
  - Represented by a concentrated force, provided loading area is small compared to overall size

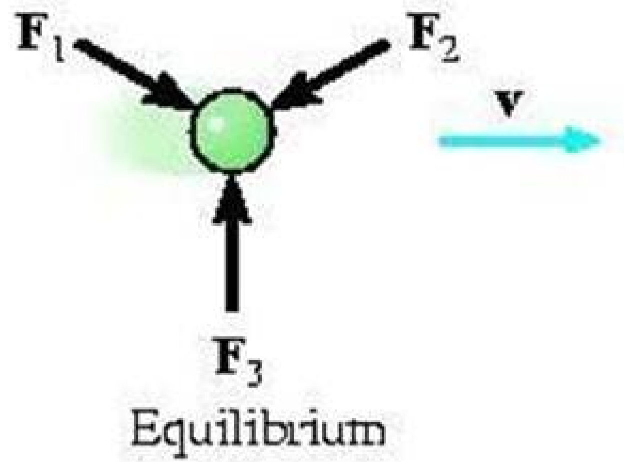
  Eg: Contact force between wheel and ground

1.2 Fundamentals Concepts

Newton's Three Laws of Motion

- First Law

  "A particle originally at rest, or moving in a straight line with constant velocity, <u>will remain in this state</u> provided that the particle is not subjected to an unbalanced force"



1.2 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"

$$F = ma$$

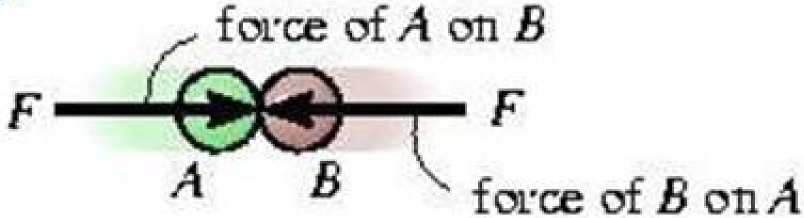
Accelerated motion

1.2 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"



Action – reaction

1.2 Fundamentals Concepts

Newton's Law of Gravitational Attraction

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

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

1.2 Fundamentals Concepts

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

Letting $g = GM_e / r^2$ yields

$$W = mg$$

1.2 Fundamentals Concepts

Comparing F = mg with F = ma

- g is the acceleration due to gravity
- Since g is dependent on r, weight of a body is not an absolute quantity
- Magnitude is determined from where the measurement is taken
- For most engineering calculations, g is determined at sea level and at a latitude of 45°

1.3 Units of Measurement

SI Units

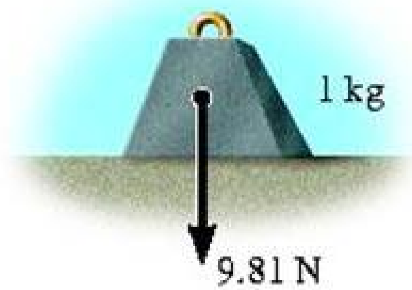
- Système International d'Unités
- F = ma is maintained only if
  - Three of the units, called *base units*, are *arbitrarily defined*
  - Fourth unit is derived from the equation
- SI system specifies: length in meters (m), time in seconds (s) and mass in kilograms (kg)
- Unit of force, called Newton (N) is derived from

$$F = ma$$

1.3 Units of Measurement

Name	Length	Time	Mass	Force
International Systems of Units (SI)	Meter (m)	Second (s)	Kilogram (kg)	Newton (N) $\left(\frac{kg.m}{s^2}\right)$

1.3 Units of Measurement

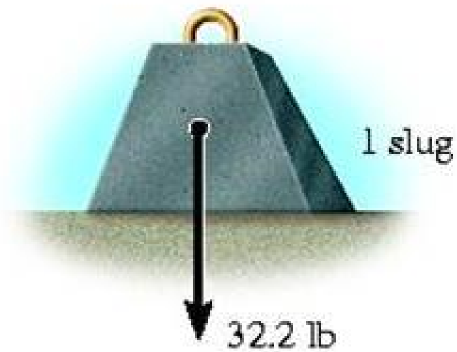


- At the standard location,

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

- For calculations, we use

  $g = 9.81\ m/s^2$



- Thus,

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

- Hence, a body of mass 1 kg has a weight of 9.81 N, a 2 kg body weighs 19.62 N

1.4 The International System of Units

Prefixes

- For a very large or very small numerical quantity, the units can be modified by using a prefix
- Each represent a multiple or sub-multiple of a unit

Eg: 4,000,000 N = 4000 kN (kilo-newton)

= 4 MN (mega- newton)

0.005m = 5 mm (milli-meter)

1.4 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

1.4 The International System of Units

Rules for Use

- Never write a symbol with a plural “s”. Easily confused with second (s)
- Symbols are always written in lowercase letters, except the 2 largest prefixes, mega (M) and giga (G)
- Symbols named after an individual are capitalized Eg: newton (N)

1.4 The International System of Units

Rules for Use

- Quantities defined by several units which are multiples, are separated by a dot

  Eg: $N = kg.m/s^2 = kg.m.s^{-2}$

- The exponential power represented for a unit having a prefix refer to both the unit and its prefix

  Eg: $\mu N^2 = (\mu N)^2 = \mu N.\ \mu N$

1.4 The International System of Units

Rules for Use

- Physical constants with several digits on either side should be written with a space between 3 digits rather than a comma

Eg: 73 569 . 213 427

1.5 Numerical Calculations

Significant Figures

- The accuracy of a number is specified by the number of significant figures it contains

- A significant figure is any digit including zero, provided it is not used to specify the location of the decimal point for the number

Eg: 5604 and 34.52 have four significant numbers

1.5 Numerical Calculations

Significant Figures

- When numbers begin or end with zero, we make use of prefixes to clarify the number of significant figures

Eg: 400 as one significant figure would be $0.4(10^3)$

2500 as three significant figures would be $2.50(10^3)$

1.5 Numerical Calculations

Rounding Off Numbers

For numerical calculations, the accuracy obtained from the solution of a problem would never be better than the accuracy of the problem data!

Often handheld calculators or computers involve more figures in the answer than the number of significant figures in the data.

1.5 Numerical Calculations

Rounding Off Numbers

Calculated results should always be "rounded off" to an appropriate number of significant figures.

1.5 Numerical Calculations

To ensure the accuracy of the final results, always give your answers 3 digits after the decimal point.

Eg:

45.703

101.007

1398.400

1.5 Numerical Calculations

For plane angles used in trigonometry, in this course, please give your answers in 4 digits after the decimal point both for the angles and their trigonometric equivalencies.

<u>Eg:</u> $\text{Sin } 35.0000^\circ = 0.5736$

$\text{Cos } 45.0380^\circ = 0.7066$

$\text{Tan}^{-1}\, 1.3459 = 53.3878^\circ$

1.6 General Procedure for Analysis

- Most efficient way of learning is to solve problems:

- To be successful at this, it is important to present the work in a logical and orderly way as suggested:

1) Read the problem carefully and try to correlate actual physical situation with theory;

2) Draw any necessary diagrams and tabulate the problem data;

1.6 General Procedure for Analysis

3) Apply relevant principles, generally in mathematical forms;

4) Solve the necessary equations, algebraically as far as practical, making sure that they are dimensionally homogenous, using a consistent set of units and complete the solution numerically;

1.6 General Procedure for Analysis

5) Report the answer with no more significance figures than accuracy of the given data;

6) Study the answer with technical judgment and common sense to determine whether or not it seems reasonable.