# Chapter 1: General Principles

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**Textbook:** R.C. Hibbeler, *Engineering Mechanics: Statics*, 14th Edition, Pearson Prentice Hall, ISBN 978-981-06-8134-0, 2010

# Plan

- Mechanics
- Fundamental concepts
- Units of measurement
- The international system of units
- Numerical calculations

# Mechanics

Mechanics can be divided in three main branches:

- **Rigid-body mechanics**
- Deformable-body mechanics
- Fluid mechanics

Rigid-body mechanics deals with:

- Statics: Equilibrium of bodies: at rest or moving with constant velocity
- Dynamics: Accelerated motion of bodies

# Fundamental concepts

## **Basic Quantities**:

- Length: locate the position of a point in a space
- Time: succession of events
- Mass: measure of a quantity of matter
- Force: “push” or “pull” exerted by a body on another

# Fundamental concepts

**Idealizations**:

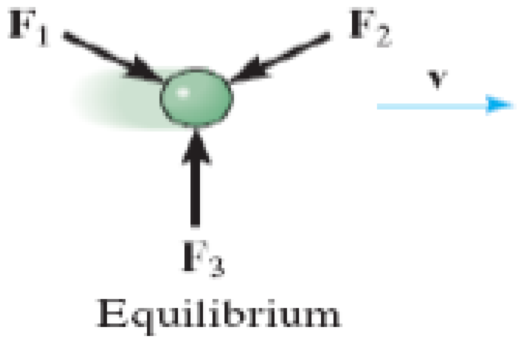
- Particle: has a mass but neglected size
- Rigid body: combination of a large number of particles
- Concentrated force: effect of a loading, assumed to act at a point on a body.

# Fundamental concepts

## **Newton’s 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*.



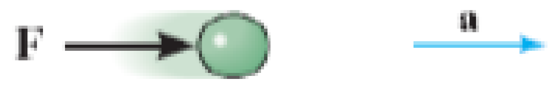
# Fundamental concepts

## **Newton's 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****=m**a***



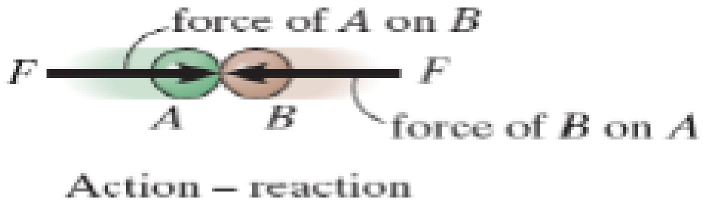
Accelerated motion

# Fundamental concepts

## **Newton's Laws of Motion**:

- Third Law:

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



# Fundamental concepts

## **Newton's Laws of Gravitational Attraction**:

The gravitation attraction between any two particles:

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

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

# Fundamental concepts

## Weight:

The weight of a particle having a mass m:

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

With Me: mass of earth,

Acceleration due to gravity $g = \frac{GM_e}{r^2} \Rightarrow$

$$\boldsymbol{W = mg}$$

Generally, g is determined at sea level and at a latitude of 45°, considered the “standard location”

# Units of measurement

## **SI Units**: International System of Units

- 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

$$\Rightarrow N = \frac{kg.m}{s^2}$$

- At the standard location, g=9.80665 m/$s^2$
- For calculations, g=9.81 m/$s^2$ $\Rightarrow$ W=mg (g=9.81 m/$s^2$)

# Units of measurement

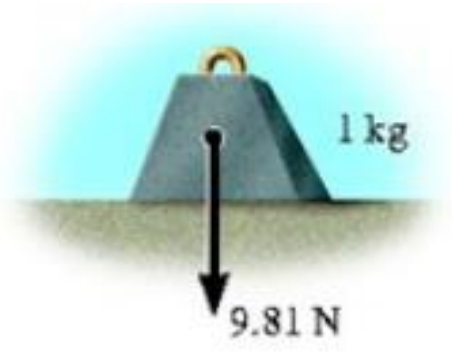
## **U.S Customary**:

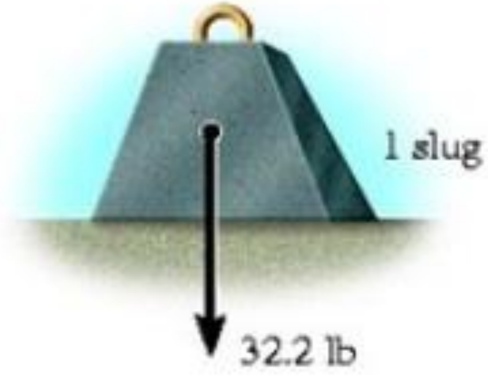
- U.S system specifies Length in feet (ft), time in seconds (s), and force in pounds (lb) ⇒ mass in slug (slug=lb.$s^2$/ft)

- At standard location g=32.2 ft/$s^2$ ⇒ $m = \frac{W}{g}$ (g=32.2 ft/$s^2$)

# Units of measurement

- At the standard location, $g=9.80665\ m/s^2$
- For calculations, we use $g=9.81\ m/s^2$
- $W=mg$ ($g=9.81\ m/s^2$)
- A body of mass 1 kg has a weight of 9.81 N, a 2 kg weighs 19.62 N



# Units of measurement

## Systems of Units

| Name | Length | Time | Mass | Force |
|---|---|---|---|---|
| International System of Units SI | Meter (m) | Second (s) | Kilogram (Kg) | Newton ($N=kg.m/s^2$) |
| U.S. Customary FPS | Foot (ft) | Second (s) | Slug ($lb.s^2/ft$) | Pound (lb) |

## Conversion of units

| Quantity | Unit of measurement (FPS) | Unit of measurement (SI) |
|---|---|---|
| Force | lb | 4.448 N |
| Mass | slug | 14.59 Kg |
| Length | ft | 0.3048 m |

In FPS system:

1 ft=12 in (inches), 5280 ft=1 mi (mile), 1000 lb=1 kip (kilo-pound), 2000 lb=1 ton

# International System of Units

## Prefixes:

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

e.g. 4,000,000 N=4000 KN (kilo-newton)

=4 MN (mega-newton)

0.005 m=5 mm (milli-meter)

# International System of Units

## Prefixes:

| | 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 |
| Submultiple | | | |
| 0.001 | $10^{-3}$ | milli | m |
| 0.000 001 | $10^{-6}$ | micro | µ |
| **0.000 000 001** | $\mathbf{10^{-9}}$ | **nano** | **n** |

# International System of Units

## Rules for use:

- Except the two largest prefixes, mega (M) and giga (G), symbols are always written in lowercase letters.
- Symbols named after an individual are capitalized e.g. Newton (N)
- Separate quantities, defined by several units which are multiples, by a dot e.g. N=Kg.m/$s^2$=kg.m.$s^{-2}$
- Exponential power represented for a unit having a prefix refer to both the unit and its prefix e.g. $\mu N^2 = (\mu N)^2 = \mu N.\mu N$
- Represent numbers, when performing calculations, in terms of their base or derived units by converting all prefixes to powers of 10.
- Avoid the use of a prefix in the denominator of composite units.

# Numerical Calculations

## **Dimensional Homogeneity**:

- The terms of any equation used to describe a physical process must be dimensionally homogeneous $\Rightarrow$ each term must be expressed in the same units.

- All terms of an equation can be replaced by a consistent set of units, that can be used as a partial check for algebraic manipulations of an equation.

# Numerical Calculations

## **Significant Figures**:

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

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

# Numerical Calculations

## **Rounding Off Numbers**:

- Calculated results should be rounded off to an appropriate number of significant figures.
- If n+1 digit is less than 5, the n+1 digit and others following it are dropped.
- If n+1 digit is equal to 5 with zero following it, round nth digit to an even number.
- If n+1 digit is greater than 5 or equal to 5 with non-zero digits following it, increase the nth digit by 1 and drop the n+1 digits and the others following it

# Numerical Calculations

## **Calculations**:

- Retain a greater number of digits than the problem data to ensure better accuracy.

- In engineering, generally round off final answers to three significant figures.

# Problems

1. Round off the following numbers to the three significant figures: (a) 4.65735 m, (b) 55.578 s , (c) 4555N and (d) 2768 Kg
2. A rocket has a mass $3.529(10^6)$ kg on earth. Specify (a) its mass in SI units and (b) its weight in SI units. If the rocket is on the moon, where the acceleration due to gravity is $g=1.61\ m/s^2$, determine to three significant figures (c) its weight in SI units and (d) its mass in SI units.
3. Evaluate each of the following to the three significant figures and express each answer in SI units, using an appropriate prefix: (a) $(200\ KN)^2$, (b) $(0.005\ mm)^2$, and (c) $(400\ m)^3$