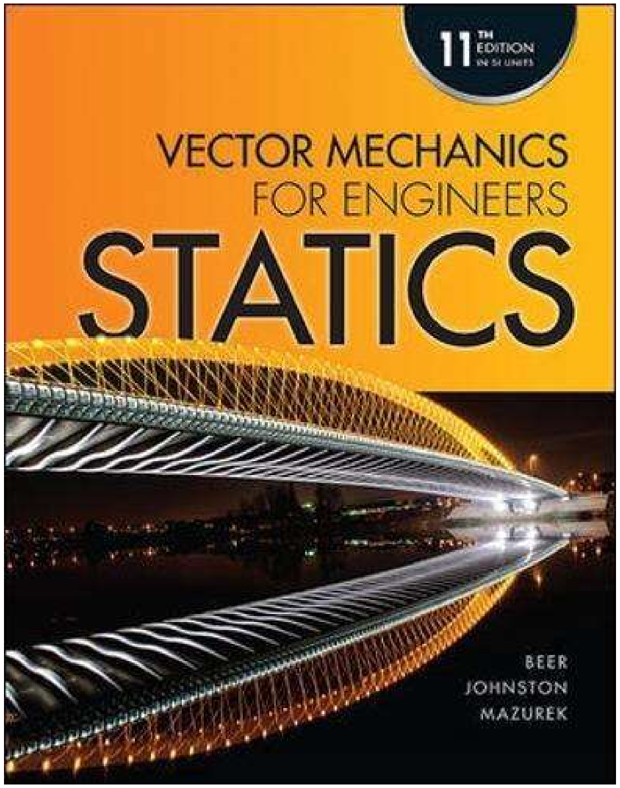
BIRZEIT UNIVERSITY

# STATICS

Instructor: Farhat Majadbeh

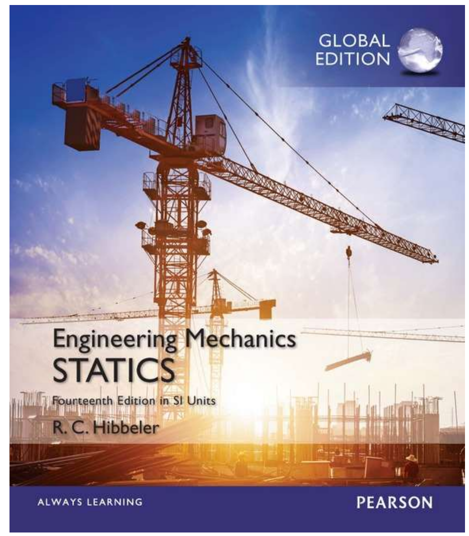
 

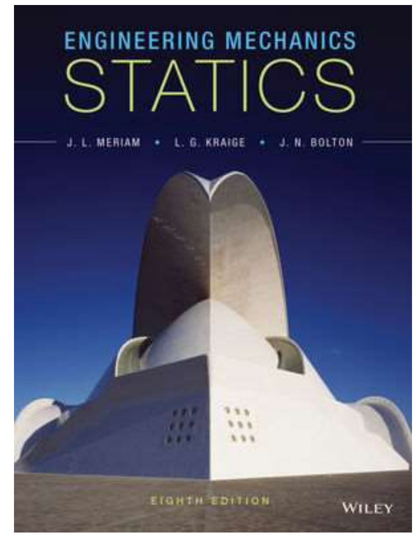
# Text book and references




**Text Book**

**References**



# Course outline

## Static of Particles – 2D and 3D

- Forces
- Equilibrium

## Static of Rigid Body – 2D and 3D

- Moments and Couples
- Equivalent Force Systems
- Equilibrium of Rigid Body
- Analysis of Structures

## Geometrical Properties of cross Sections

- Center of gravity
- Moment of Inertia

## Internal Forces

- Axial load, shear and moment diagrams.

# Introduction

Chapter 1

# What Engineers do?

- “Engineers create what never was”
- Engineers design structures, machines, processes, and much more for the benefit of humankind that should be:
  - Strong
  - Safe
  - Last long

# What Engineers do?

- Design requires
  - Understand loads, load paths, supports conditions, material properties throughout the life of the structure.
  - Have the ability to idealize structures with mathematical models

<u>Or thorough knowledge of science, mathematics, and computational tools.</u>

# What is STATICS?

Statics is the physics that study the equilibrium of objects under the action of forces that are applied to them.

# Fundamental Concepts and Principles

- The force
- Objects (particles & rigid bodies)
- The parallelogram law
- The principle of transmissibility
- Newton's laws of motion

# The concept of Force

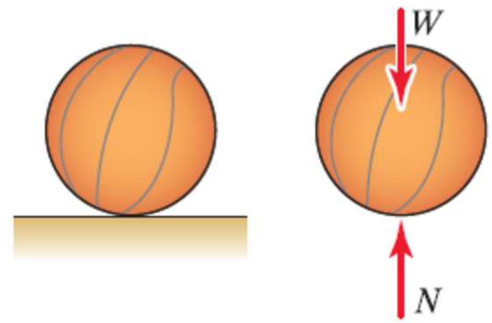
- A force is a phenomenon that causes or prevents either deformation or movement.


- Fundamental Forces of Nature are Gravity, Electromagnetic force and Strong and Weak nuclear forces.

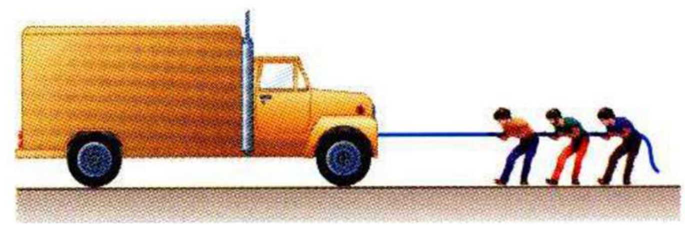
# Force categories

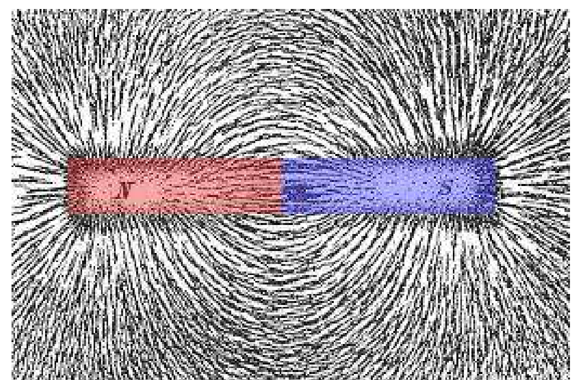
- All forces are produced from the interaction of two or more bodies which can take several forms such as:

1. **Contact force**. When two bodies touch, contact forces develop between them eighter a push or a pull




2. **Field force**. A force between bodies that acts through space. Examples of field forces include gravity and the force of attraction between a magnet and an iron object.





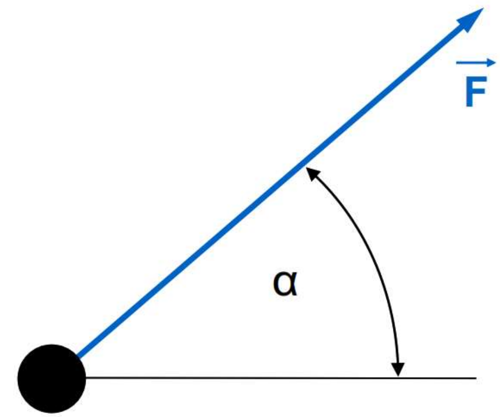
# Force categories

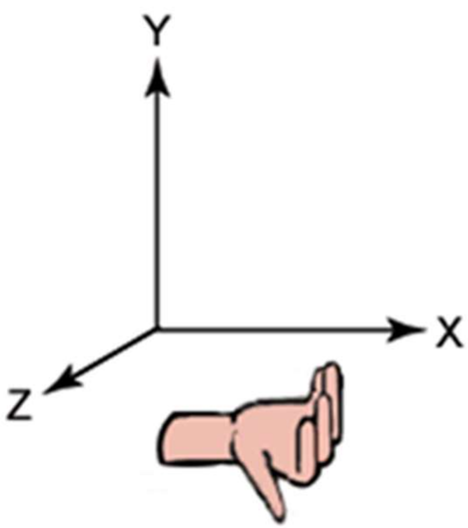
- In Mechanics different type of forces can be seen such as
  - Distributed force
  - Concentrated force or point load

# Force characteristics

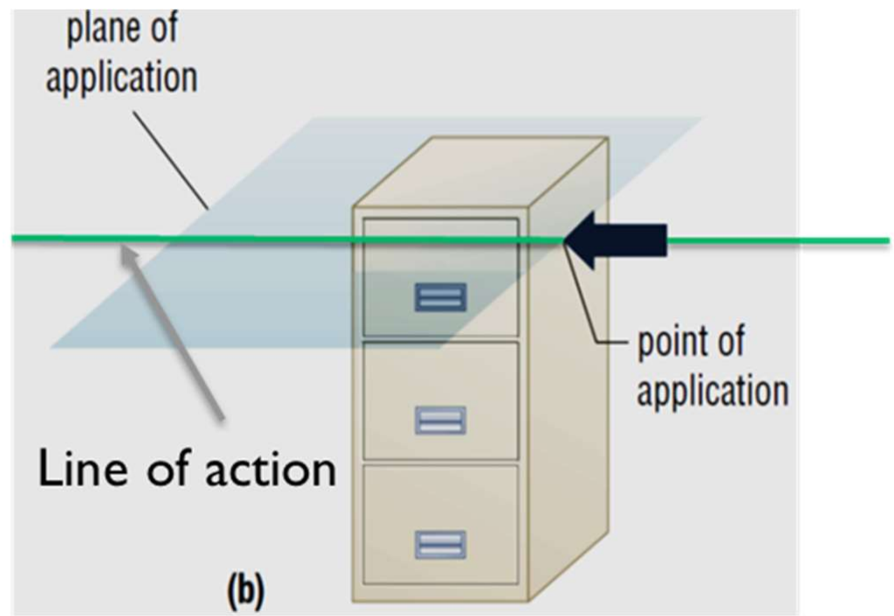
- **Force is a vector**

1. Point of application
2. Magnitude and
3. Direction → sense of the line of action



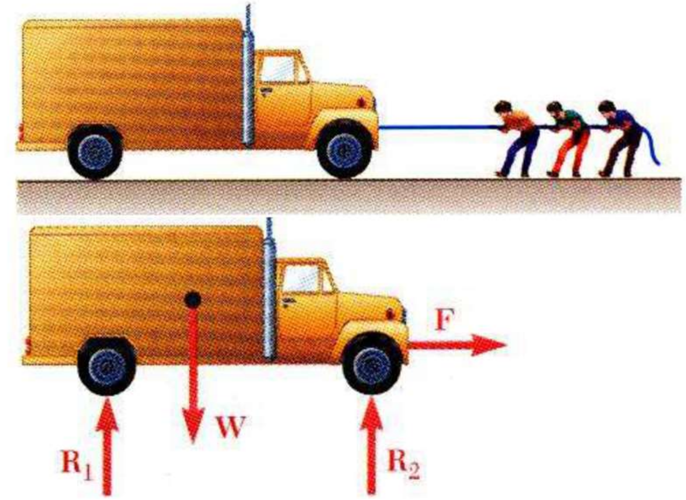




Right-handed
Cartesian Coordinates

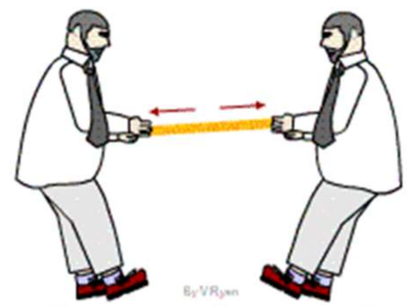


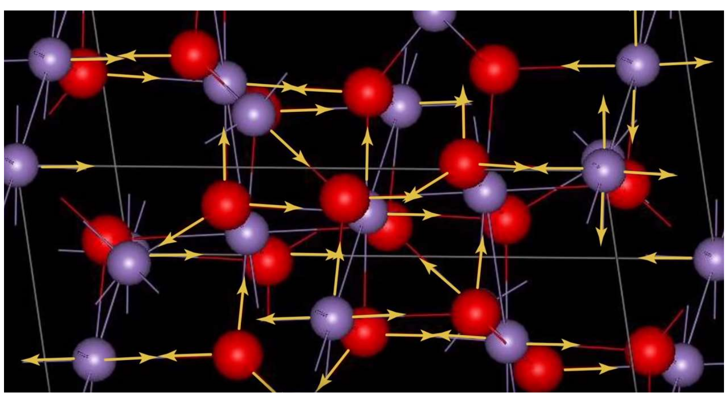
# External and Internal Forces

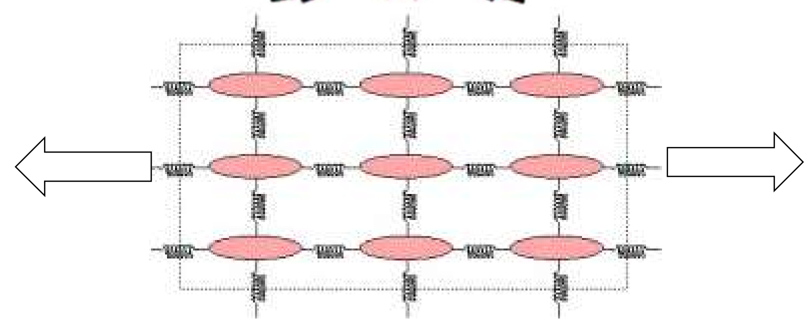
- **External forces:** are the forces applied from outside and can cause acceleration




- **Internal forces:** the forces that induced by external forces and keeps the body together

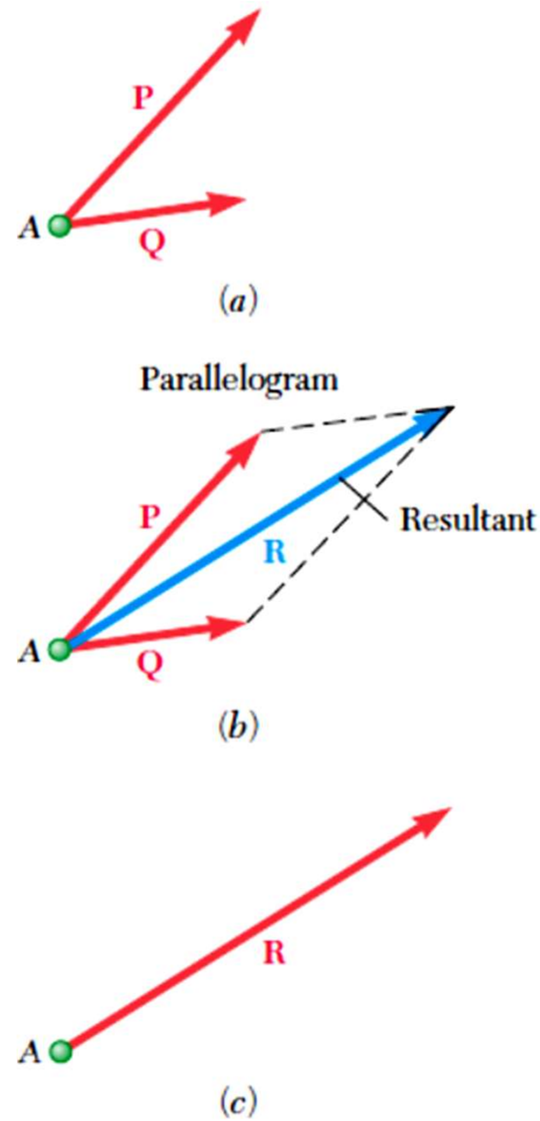


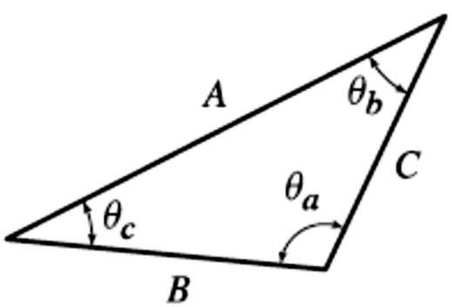




# The parallelogram law

- Two forces acting on a particle may be replaced by a single force, called their resultant, obtained by drawing the diagonal of the parallelogram which has sides equal to the given forces.
- We could add forces graphically but it is more precise and appropriate to use analytical methods.



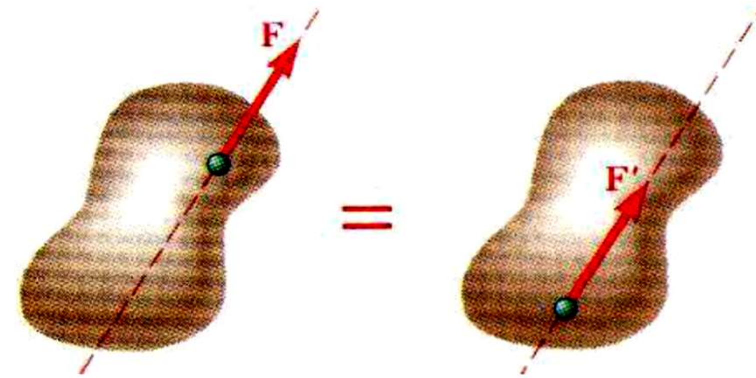



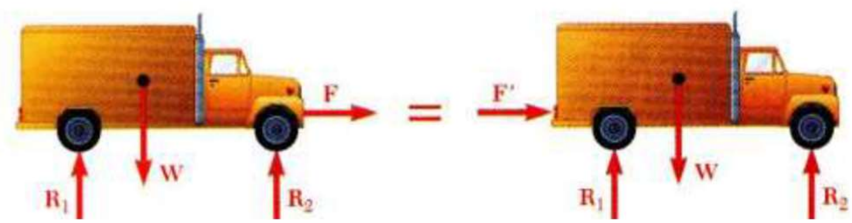

$$\frac{\sin\theta_a}{A} = \frac{\sin\theta_b}{B} = \frac{\sin\theta_c}{C} \qquad \text{law of sines,}$$

$$A = \sqrt{B^2 + C^2 - 2BC\cos\theta_a}$$
$$B = \sqrt{A^2 + C^2 - 2AC\cos\theta_b} \qquad \text{law of cosines.}$$
$$C = \sqrt{A^2 + B^2 - 2AB\cos\theta_c}$$

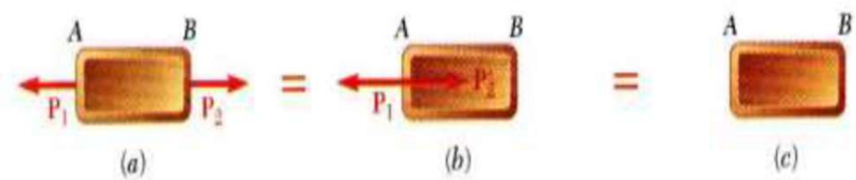
# The principle of transmissibility

- Conditions of equilibrium or motion of a rigid body are not affected by transmitting a force along its line of action. For example, moving the point of application of the force F to the rear bumper of the truck shown does not affect the motion or the other forces acting on the truck.



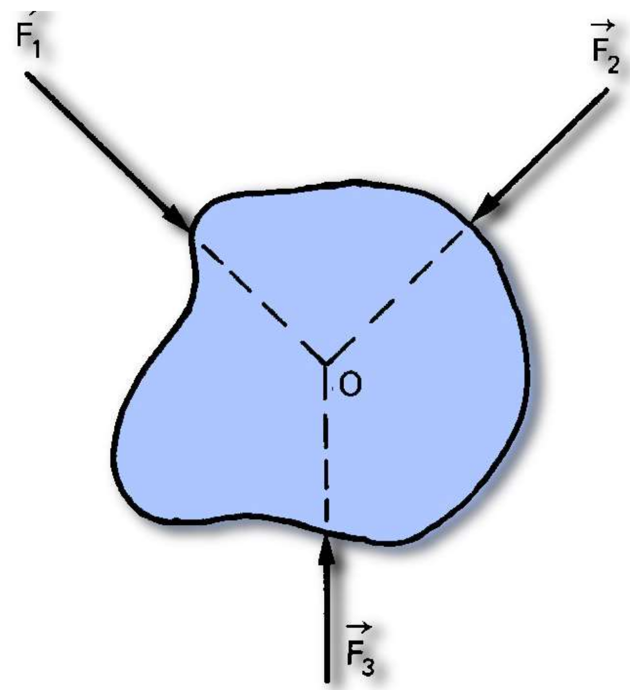




- Principle of transmissibility may not always be applied in determining internal forces and deformations.



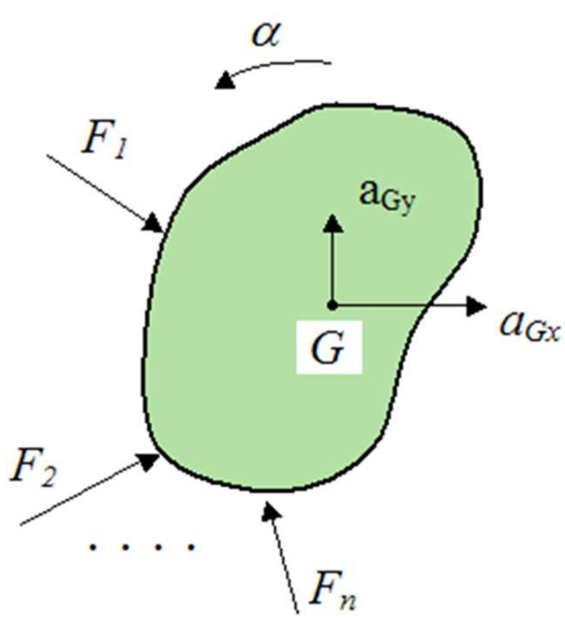
# Objects

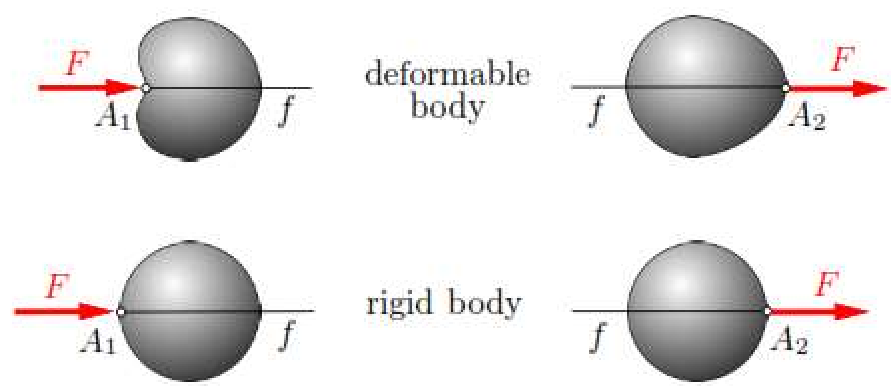
- Physical objects that will be considered in this course are particles and rigid bodies.
- **A particle** is an object whose mass is concentrated at a point, and it is said to have zero volume. In Mechanics any body which are subjected to concurrent forces as shown below can be idealized as Particle.
  - An important consequence of this definition is particle did not rotate, and size and shape of the bodies is not significant.
  - Clearly there are no true particles in nature, but it is possible to idealize real life objects as particles.



# Objects

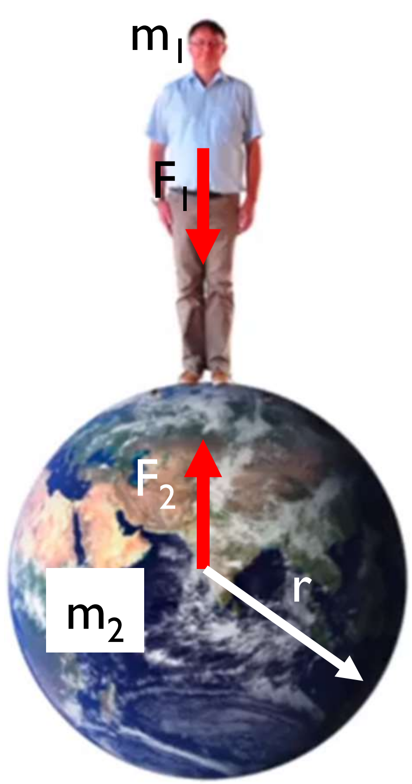
- **A body:** has mass and occupies a volume of space. When subjected to a force it can move and /or rotate.
- ***Rigid body*** is not deformable, and hence the distance between any two points in the body never changes. There are no true rigid bodies in nature, but very often we may idealize an object to be a rigid body.



# Newton’s laws

- **Newton’s laws of gravitation :** a particle attracts every other particle in the universe using a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.



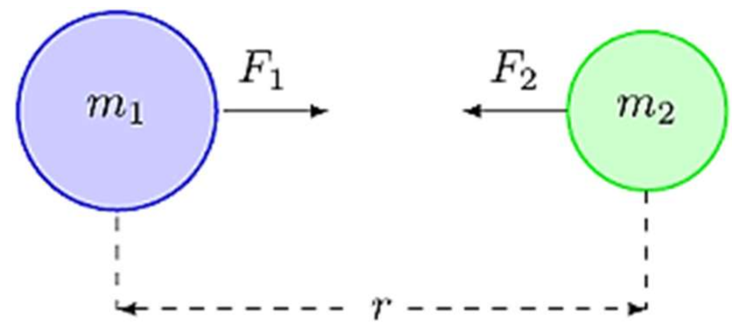

$$m_2 = 5.985 \cdot 10^{24}\ [\text{kg}]$$

$$r = 6'378'000\ [\text{m}]$$

$$G = 6.67 \cdot 10^{11} \left[\frac{\text{m}^3}{\text{kg} \cdot \text{s}^2}\right]$$

$$g = G\frac{m_2}{r^2} = 9.81\ {}^{m}/_{s^2}$$

$$F_1 = W = m_1 \times g$$




$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

F = The pull of gravity [N]
m1 = One object's mass [kg]
m2 = Other object's mass [kg]
r = distance between the object's
G = the universal constant(

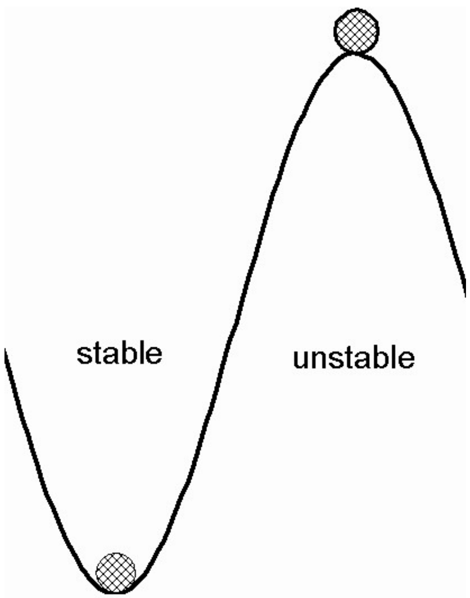
# Newton’s laws

- **Newton's first law**
  - The law states that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force.
  - In static objects are required to remine at rest then

$$\sum_{i=1}^{n} \overline{F}_i = 0$$

The state of static equilibrium

  - The static equilibrium may be stable or unstable. The difference comes from the reaction of the system on a small displacement from the state of equilibrium. Objective of design is to achieve Stable state of equilibrium.




states of static equilibrium

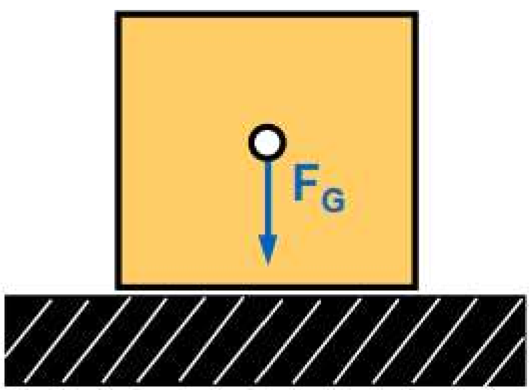
# Newton’s laws

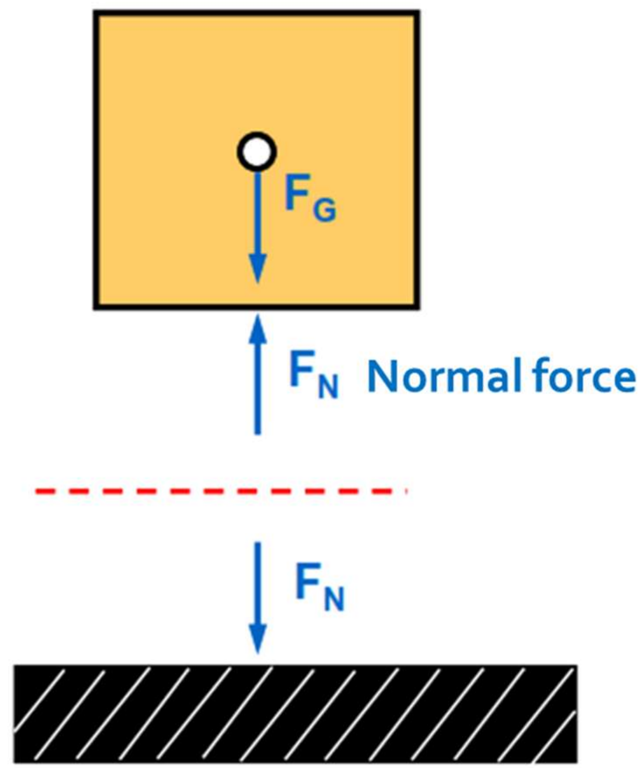
- **The second law**
  - The law explains how the velocity of an object changes when it is subjected to an external force. The law defines a force to be equal to change in momentum (mass times velocity) per change in time. Or for an object with a constant mass m, the second law states that the force F is the product of an object's mass and its acceleration a:

$$F = \frac{d}{dt}(mv). \qquad F = m\frac{dv}{dt} = ma.$$

# Newton’s laws

- **<u>The third law</u>** states that for every action (force) in nature there is an equal and opposite reaction. In other words, if object A exerts a force on object B, then object B also exerts an equal force on object A.



# Systems of Units

- International System of Units (SI)

The basic units

| Basic quantity | | Basic unit | |
|---|---|---|---|
| Name | Symbol | Name | Symbol |
| length | $\ell$ | metre | m |
| mass | $M$ | kilogram | kg |
| time | $T$ | second | s |
| electric current | $I$ | amp | A |
| thermodynamic temperature | $T$ | Kelvin | K |
| amount of material | $N$ | mol | mol |
| luminosity | $I$ | candela | cd |

Derived units.

| Derived quantity | Derived unit | |
|---|---|---|
| | Name | Symbol |
| area | square metre | $m^2$ |
| volume, content | cubic metre | $m^3$ |
| frequency | Hertz | $Hz = s^{-1}$ |
| force | Newton | $N = kgm/s^2$ |
| pressure, tension | Pascal | $Pa = N/m^2$ |
| work, energy, amount of warmth | Joule | $J = Nm$ |
| capacity, energy flow | Watt | $W = J/s$ |

Common SI prefixes.

| Prefix | Symbol | Factor |
|---|---|---|
| giga | G | $10^9$ |
| mega | M | $10^6$ |
| kilo | k | $10^3$ |
| milli | m | $10^{-3}$ |
| micro | $\mu$ | $10^{-6}$ |
| nano | n | $10^{-9}$ |

| Type of quantity | Definition | Dimension formula | SI unit |
|---|---|---|---|
| velocity | $v = du/dt$ | $LT^{-1}$ | m/s |
| force | $F = m \cdot a$ | $LMT^{-2}$ | $N = kgm/s^2$ |
| energy, work | $E = A = F \cdot \ell$ | $L^2MT^{-2}$ | $J = kgm^2/s^2$ |

Examples of derived units

# Systems of Units

- *U.S. Customary Units*:
  The basic units are length, time, and force which are arbitrarily defined as the foot (ft), second (s), and pound (lb). Mass is the derived

$$1 \text{ slug} = \frac{1 \text{ lb}}{1 \text{ ft/s}^2} = 1 \text{ lb}\cdot\text{s}^2/\text{ft}$$

**Table 1.3 U.S. Customary Units and Their SI Equivalents**

| Quantity | U.S. Customary Unit | SI Equivalent |
|---|---|---|
| Acceleration | $\text{ft/s}^2$ | $0.3048 \text{ m/s}^2$ |
| | $\text{in./s}^2$ | $0.0254 \text{ m/s}^2$ |
| Area | $\text{ft}^2$ | $0.0929 \text{ m}^2$ |
| | $\text{in}^2$ | $645.2 \text{ mm}^2$ |
| Energy | ft·lb | 1.356 J |
| Force | kip | 4.448 kN |
| | lb | 4.448 N |
| | oz | 0.2780 N |
| Impulse | lb·s | 4.448 N·s |
| Length | ft | 0.3048 m |
| | in. | 25.40 mm |
| | mi | 1.609 km |
| Mass | oz mass | 28.35 g |
| | lb mass | 0.4536 kg |
| | slug | 14.59 kg |
| | ton | 907.2 kg |
| Moment of a force | lb·ft | 1.356 N·m |
| | lb·in. | 0.1130 N·m |
| Moment of inertia | | |
| Of an area | $\text{in}^4$ | $0.4162 \times 10^6 \text{ mm}^4$ |
| Of a mass | $\text{lb}\cdot\text{ft}\cdot\text{s}^2$ | $1.356 \text{ kg}\cdot\text{m}^2$ |

# Systems of Units

- Common conversion factors from U.S. Customary Units to SI Units

| | U.S. Customary Unit | SI Equivalent |
|---|---|---|
| Length | 1 ft | 0.3048 m |
| | 1 in (12 in = 1 ft) | 25.4 mm |
| | 1 yd (1 yd = 3 ft) | 0.9144 m |
| | 1 mi | 1.609344 km |
| Force | 1 lb | 4.4482 N |
| Mass | 1 slug | 14.5939 kg |