General Principles

- Introduction
- Basic Quantities
- Laws of Motion
- Units
- Procedure for Analysis

STATICS, AGE-1330

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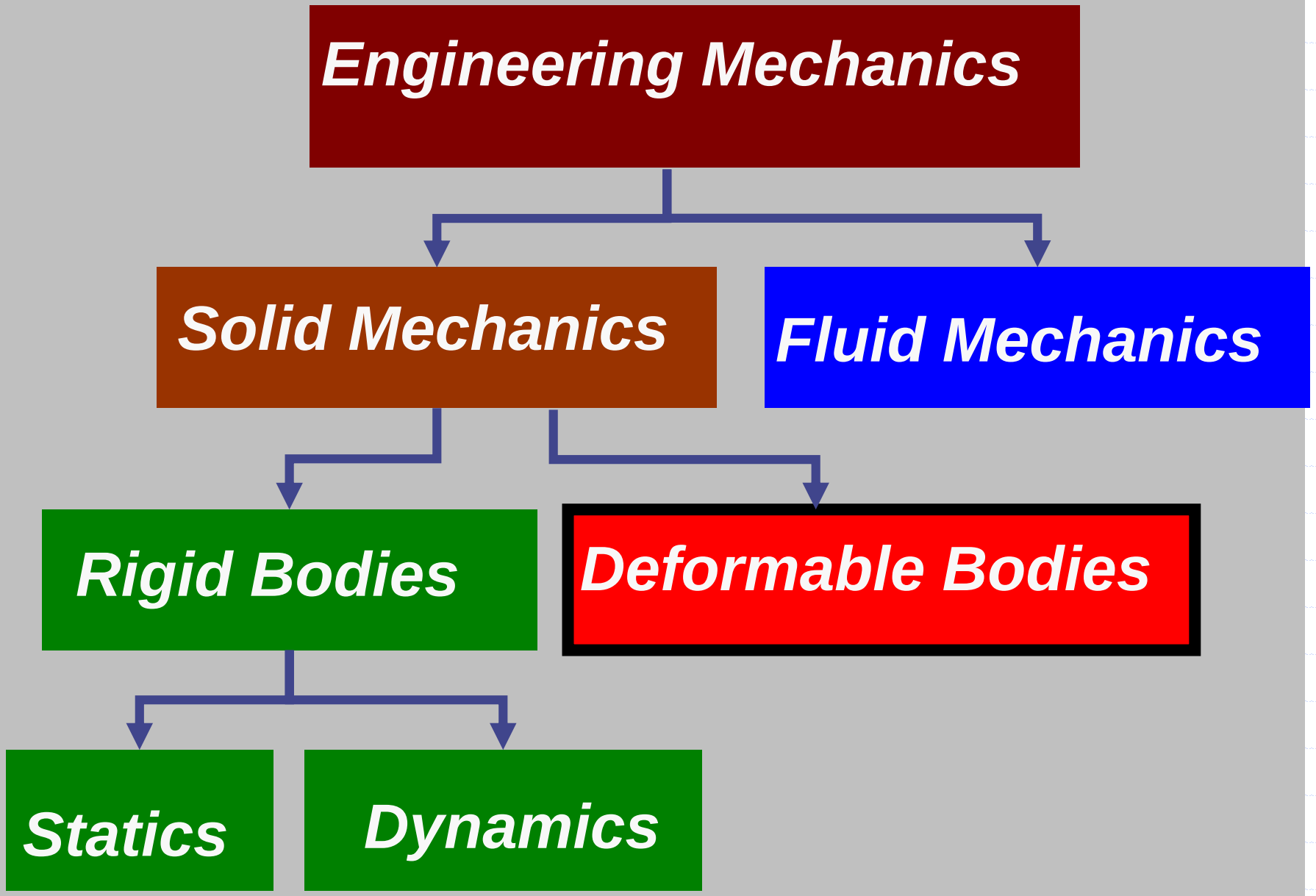
1. Introduction

Definition

Mechanics:

Branch of physical sciences concerned with the state of rest or motion of bodies subjected to forces.


Engineering Mechanics
Solid Mechanics
Fluid Mechanics
Rigid Bodies
Deformable Bodies
Statics
Dynamics

Rigid Body Mechanics

- **Statics – Bodies at rest**
- **Dynamics – Accelerated motion of bodies**

Statics

- Depends on geometry and forces

Dynamics

- Accurate measurement of time

2. Basic Quantities

Basic Quantities

Length
- meter (SI)
- foot (US)

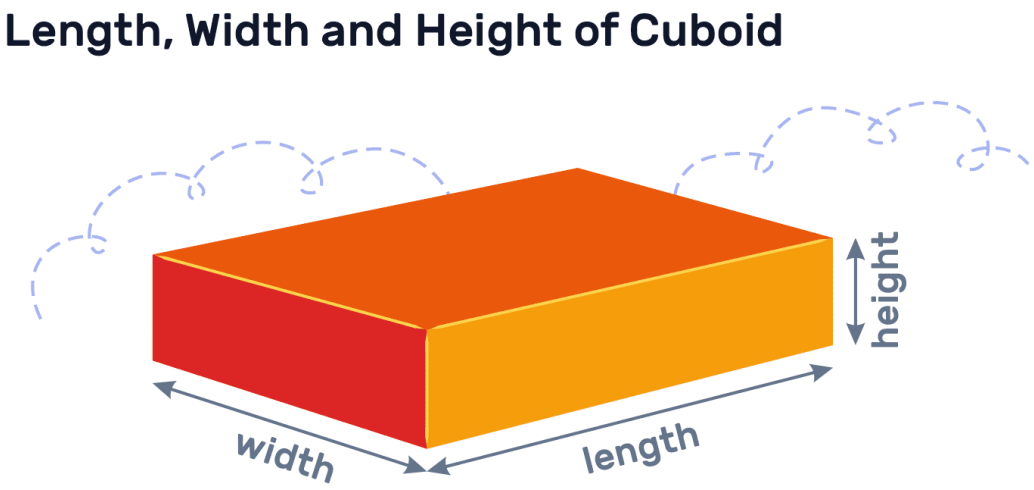
Time
- second

Mass
- kilogram
- slug

Force
- newton
- pound

Length

Needed to locate the position of a point in space and describe the size of a physical system

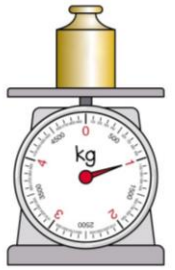


Time

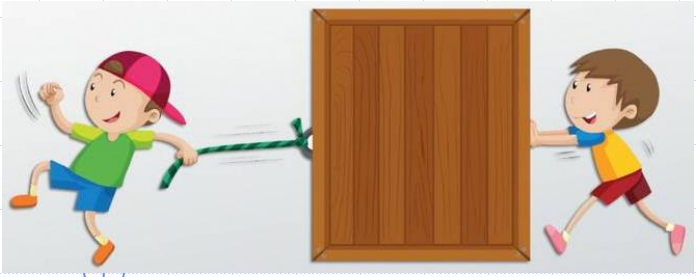
Conceived as a succession of events
Concepts of STATICS are time independent

mass → kg

Mass



A property of matter by which we can compare the action of one body to another. This property manifests itself as a gravitational attraction between two bodies and provide a qualitative measure of the resistance of matter to a change in velocity.

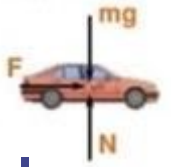


Force

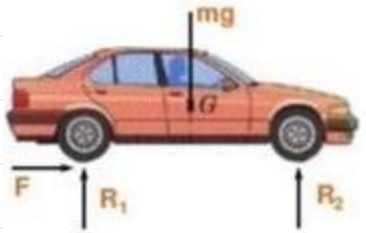
Generally considered as a push or a pull exerted by one body on another. Interaction occurs when there is direct contact between the bodies. Gravitational, electrical and magnetic forces do not require direct contact. Force is characterized by magnitude, direction and point of application.

Idealizations

1. Particle - an object having mass but the size is neglected.



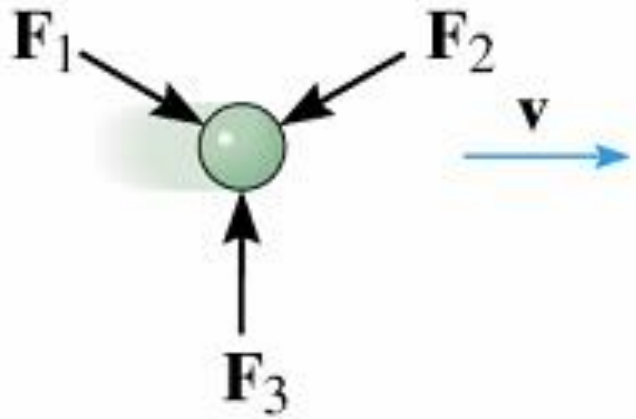
2. Rigid Body - a combination of a large number of particles which remain in a fixed position relative to each other, both before and after the application of a force.



3. Laws of Motion

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 the particle is ***not*** subjected to unbalanced forces.



Equilibrium

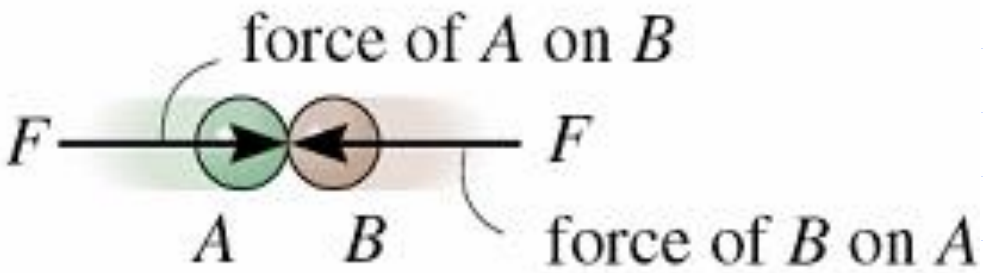
Newton's Three Laws of Motion

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. If **F** is applied to a particle of mass *m* then: **F** = *m***a**.

Accelerated motion

Newton's Three Laws of Motion

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

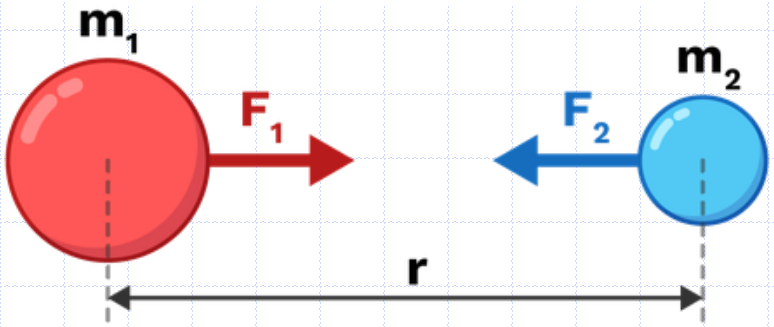


Action – reaction

Newton's Law of Gravitational Attraction

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

$G = 6.67\times10^{-11}\ N.m^2/kg^2$



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

Where:

F = force of gravitation

G = universal constant of gravitation

m_1,m_2 = mass of two particles

r = distance between two particles

Weight

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

$$\Downarrow$$

$$W = G\frac{m m_2}{r^2}$$

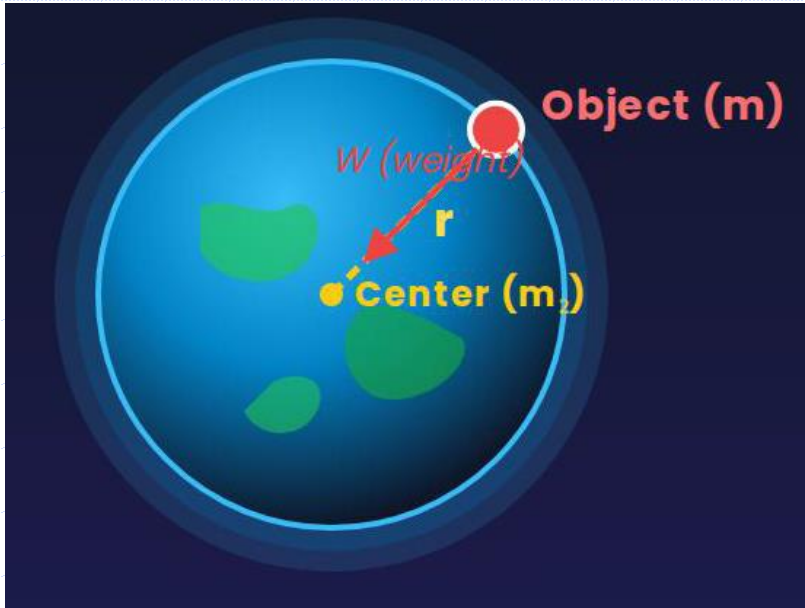
$$\Downarrow$$

$$W = mG\frac{m_2}{r^2}$$

m = mass of object

m_2 = mass of earth

r = distance from center of earth to particle



4. Units

Units

1. Basic quantities (force, mass, length, time) are related by Newton's second law.
2. Units used to measure quantities are not all independent.
3. Three of four units, called ***base*** units, are arbitrarily defined and the fourth is derived.

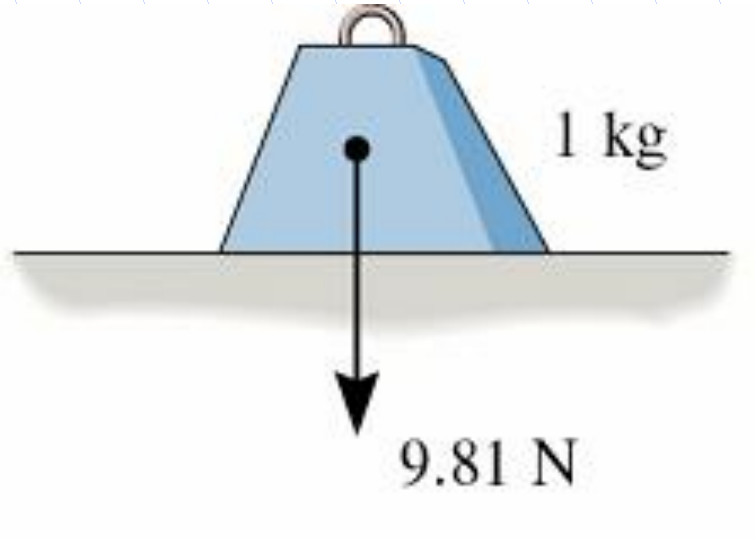
SI Units

1. Modern version of metric system.
2. Base units are length, time and mass, meter (m), second (s), and kilogram (kg)
3. Acceleration of gravity:

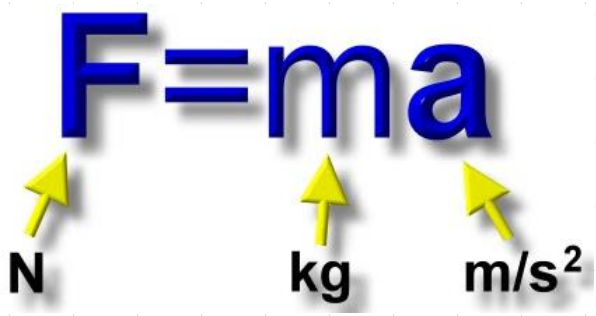
$$\mathbf{g = 9.81\ \frac{m}{s^2}}$$

SI Units

4. Force is derived quantity measured in unit called a **newton**



$$1\,\mathrm{N} = 1\,\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}$$



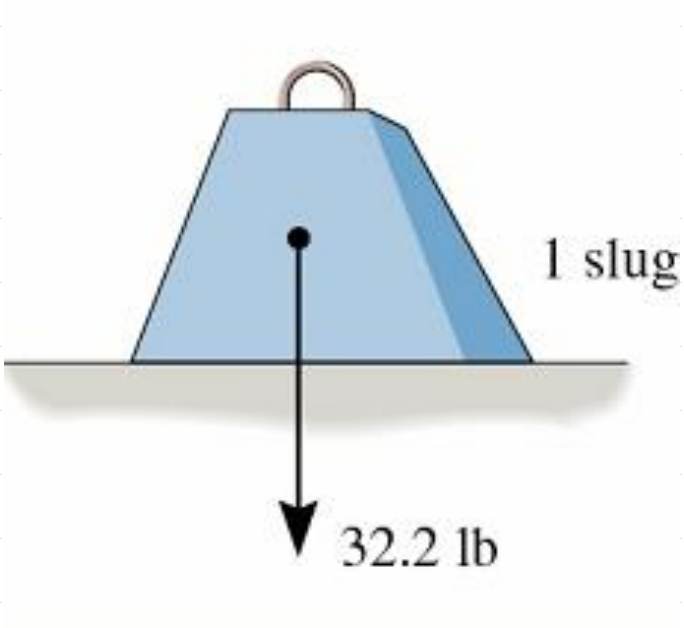
U.S. Customary Units (fps)

1. Base units are length, time and force.
2. feet (ft), second (s), and pound (lb)
3. Acceleration of gravity:

$$g = 32.2 \ \mathrm{ft/s^2}$$

U.S. Customary Units (fps)

4. Mass is derived quantity measured in a unit called a **slug:**



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

$$m = F / a$$

slug lb ft/s²

Systems of Units

Name	Length	Time	Mass	Force
SI	meter (m)	second (s)	kilogram (kg)	newton (N)
US Customary	foot (ft)	second (s)	slug ($lb \cdot s^2/ft$)	pound (lb)

Unit Conversions

Force : 1 lb = 4.4482 N

Mass : 1 slug = 14.5938 kg

Length : 1 ft = 0.3048 m

Note, 1 slug = 32.2 lbm

Prefixes for SI 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**
Submultiple			
0.001	10^{-3}	**milli**	**m**
0.000001	10^{-6}	**micro**	**μ**
0.00000001	10^{-9}	**nano**	**n**

Dimensional Homogeneity

Each of the terms of an equation must be expressed in the same units.

$\boldsymbol{s = v\,t + 1/2\,a\,t^2}$

s is position in meters

v is velocity in m/s

a is acceleration in m/s^2

t is time in seconds

$m = m/s \bullet s + m/s^2 \bullet s^2 = m$

5. Procedure for Analysis

Procedure for Analysis

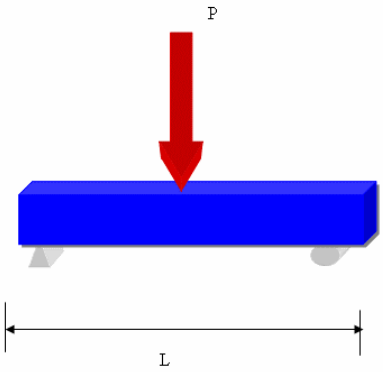
1. Read the problem carefully and correlate the actual physical situation with the theory studied
2. Draw necessary diagrams and tables
3. Apply relevant principles, generally in mathematical form

Procedure for Analysis

4. Solve the equations algebraically (without numbers) as far as possible, then obtain a numerical answer
5. Be sure to use a consistent set of units
6. Report the answer with no more significant figures than the accuracy of the given data
7. Decide if answer seems reasonable
8. Think about what the problem taught you!

Important Points

1. Statics is the study of bodies at rest or moving with constant velocity
2. A particle has mass but a size that can be neglected
3. A rigid body does not deform under load
4. Concentrated forces are assumed to act at a point on a body



Important Points

5. Newton's three laws of motion must be memorized!
6. Mass is a property of matter that does not change from one location to another
7. Weight is the gravitational attraction of the earth on a body or quantity of mass. Its magnitude depends on the location of the mass

Important Points

8. In the SI system the unit of force is the newton. It is a derived quantity. Mass, length and time are the base quantities
9. In the SI system prefixes are used to denote large or small numerical quantities of a unit
10. Perform numerical calculation to several significant figures and report answers to three significant figures
11. Be sure that all equations are dimensionally homogeneous