

# General Principles

*DYNAMICS, AGE-2320*

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# Definition

## **Mechanics:**

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

# ***Engineering Mechanics***

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graph TD; A[Engineering Mechanics] --> B[Solid Mechanics]; A --> C[Fluid Mechanics]; B --> D[Rigid Bodies]; B --> E[Deformable Bodies]; D --> F[Statics]; D --> G[Dynamics];
```

## ***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

# Basic Quantities

## Length

- meter
- foot

## 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.

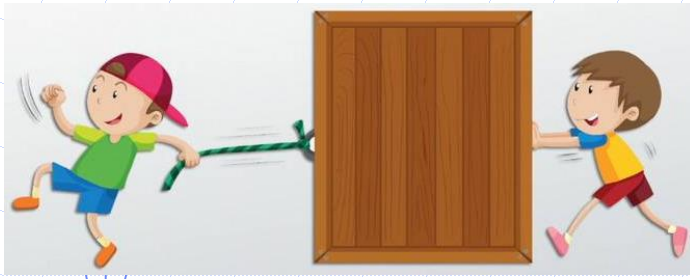
# Time

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



# Mass

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

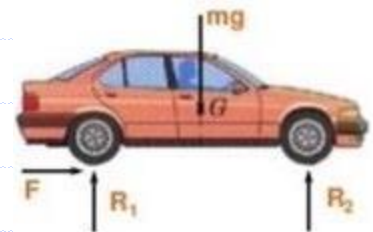
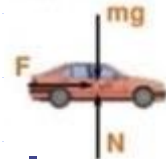


Generally considered as a push or a pull exerted by one body on another. Interaction occurs when there is direct contact between the bodies.

Gravitational, electrical and magnetic forces do not require direct contact. Force is characterized by magnitude, direction and point of application.

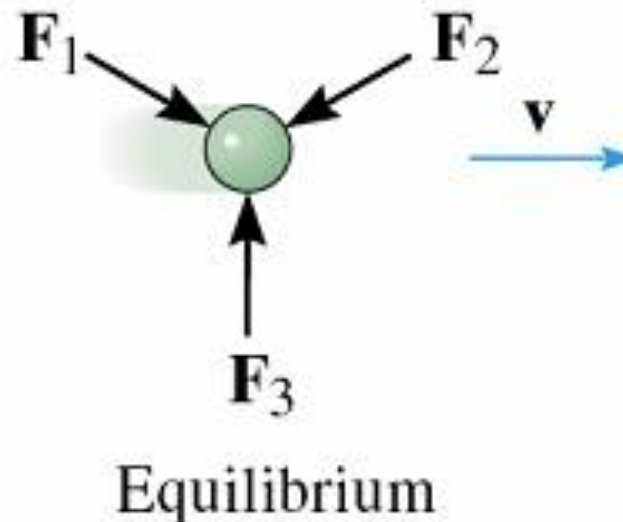
# Idealizations

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.



# 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.



# Newton's Three Laws of Motion

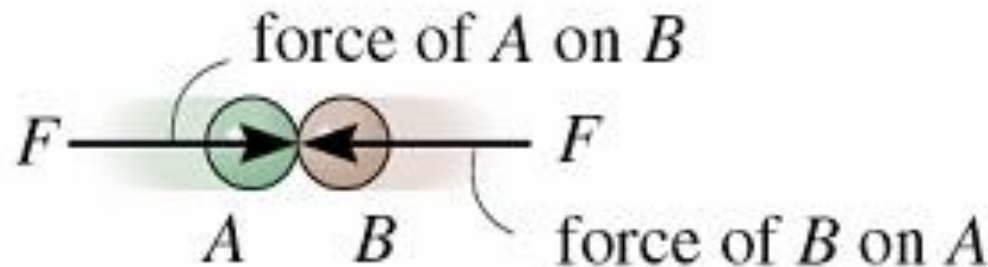
**Second Law**: A particle acted upon by an unbalanced force **F** experiences an acceleration **a** that has the same direction as the force and a magnitude that is directly proportional to the force. If **F** is applied to a particle of mass  $m$  then:  **$F = ma$** .



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 Laws of Gravitational Attraction

$$\mathbf{F} = \mathbf{G} \frac{\mathbf{m}_1 \mathbf{m}_2}{\mathbf{r}^2}$$

$$G = 6.67 \times 10^{-11} \text{ N.m}^2/\text{kg}^2$$

**Where:**

**F = force of gravitation**

**G = universal constant of gravitation**

**m<sub>1</sub>, m<sub>2</sub> = mass of two particles**

**r = distance between two particles**

# Weight

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

⇓

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

⇓

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

**m = mass of object**

**m<sub>2</sub> = mass of earth**

**r = distance from  
center of earth to  
particle**



# 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.

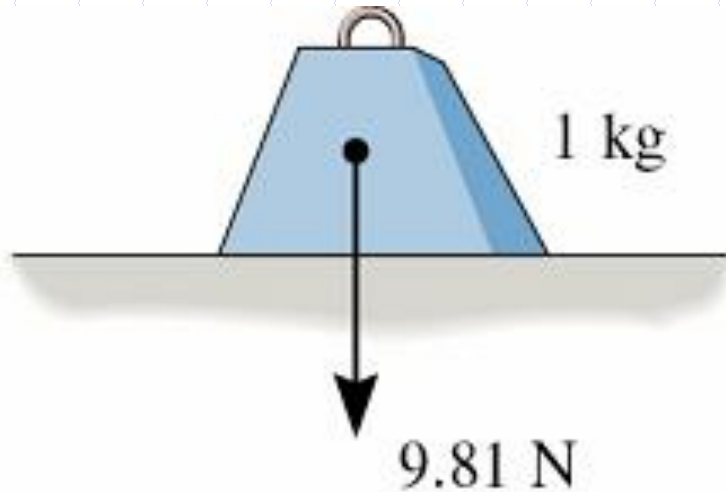
# SI Units

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**



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

$$F = ma$$

Diagram illustrating the units for the equation  $F = ma$ . Yellow arrows point from the units below to the corresponding variables in the equation:  $\text{N}$  points to  $F$ ,  $\text{kg}$  points to  $m$ , and  $\text{m/s}^2$  points to  $a$ .

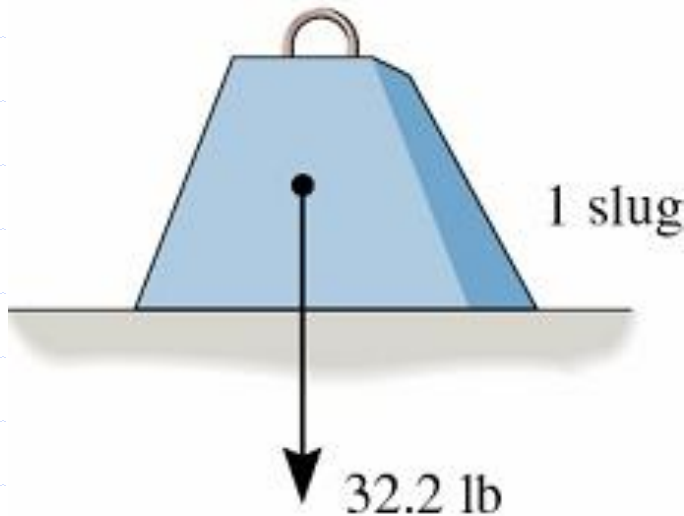
# U.S. Customary Units (fps)

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

$$\mathbf{g = 32.2 \frac{ft}{s^2}}$$

# U.S. Customary Units (fps)

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



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

$$m = F / a$$

Diagram illustrating the relationship between mass (m), force (F), and acceleration (a) in U.S. Customary Units:

- m** (mass) is labeled **slug** with a yellow arrow pointing to the variable.
- F** (force) is labeled **lb** with a yellow arrow pointing to the variable.
- a** (acceleration) is labeled **ft/s<sup>2</sup>** with a yellow arrow pointing to the variable.

# Systems of Units

Name	Length	Time	Mass	Force
<b>SI</b>	<b>meter (m)</b>	<b>second (s)</b>	<b>kilogram m (kg)</b>	<b>newton (N)</b>
<b>US Customary</b>	<b>foot (ft)</b>	<b>second (s)</b>	<b>slug (lb·s<sup>2</sup>/ft)</b>	<b>pound (lb)</b>

# 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
<b>Multiple</b>			
1,000,000,000	$10^9$	giga	G
1,000,000	$10^6$	mega	M
1,000	$10^3$	kilo	k
<b>Submultiple</b>			
0.001	$10^{-3}$	milli	m
0.000001	$10^{-6}$	micro	$\mu$
0.000000001	$10^{-9}$	nano	n



# Dimensional Homogeneity

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

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

**s** is position in meters

**v** is velocity in m/s

**a** is acceleration in m/s<sup>2</sup>

**t** is time in seconds

$$\text{m} = \text{m/s} \bullet \text{s} + \text{m/s}^2 \bullet \text{s}^2 = \text{m}$$

# 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

1. Newton's three laws of motion must be memorized!
2. Mass is a property of matter that does not change from one location to another
3. 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

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