



Linear Kinetics



Parameters

- **Force**
 - Definition
 - Units
- **Inertia**
 - Mass
 - Weight
- **System**
 - Types of Forces
 - Internal
 - External
- **Linear Momentum (p)**



Sir Isaac Newton

- 1643 - 1727
- "Principia Mathematica Philosophiae Naturalis" in 1686.
- More [here](#).





Newton's Law of Gravitation

Any two bodies in the universe attract each other with a force varying directly as the product of the masses and inversely as the square of the distance between them.

$$F_G = \left(\frac{m_1 m_2}{d^2} \right) G$$

Where:

- m_1 = mass of body 1
- m_2 = mass of body 2
- d = distance between the two bodies
- G = gravitational constant



Newton's Law of Gravitation

- $G = 66.73 \times 10^{-12} \text{ m}^3/\text{kg s}^2$
- Circumference of the Earth is $\cong 24,855$ miles or $40 \times 10^6 \text{ m}$
- \therefore Radius of the Earth is $\cong 3,958$ miles or $6.37 \times 10^6 \text{ m}$
- Mass of the Earth is $\cong 5.97 \times 10^{24} \text{ kg}$

$$F_G = \left(\frac{m_1 m_2}{d^2} \right) G$$

- Where:
 - m_1 = mass of person on Earth
 - m_2 = mass of Earth
 - d = distance between the center of the Earth and the CM of a person
 - G = gravitational constant



Newton's Law of Gravitation

$$F_G = \left(\frac{m_{PERSON} m_{EARTH}}{d_{EARTH}^2} \right) G$$

$$F_G = mass_{PERSON} \times 9.81 \frac{m}{s^2}$$

$$W_{PERSON} = mass_{PERSON} \times 9.81 \frac{m}{s^2}$$



Center of Gravity (Mass)

- **The center of gravity is a geometric property of any object.**
- **The center of gravity is the average location of the weight of an object.**



Newton's First Law

The Law of Inertia

Every object will remain at rest ($v = 0$) or in uniform motion ($v = \text{constant}$) in a straight line unless compelled to change its state by the action of an external force exerted upon it.

If there is no net forces acting on an object (if all the external forces cancel each other out), then the object will maintain a constant velocity. If that velocity is zero, then the object remains at rest.

Law of Inertia may be viewed as a special case of the 2nd Law.



Newton's Second Law

The Law of Acceleration

The rate of change of linear momentum ($m\mathbf{v}$) of a body $[d(m\mathbf{v})/dt]$ is proportional to the net force causing it and the change takes place in the direction the net force acts.

$F_{NET} \equiv \Sigma F$ – Is the sum of all external forces acting upon the body

$$F_{NET} = \frac{d(mv)}{dt} = m \frac{dv}{dt} + \frac{dm}{dt} v$$

If the mass of the body is constant, ($dm/dt = 0$) &

$$F_{NET} = \frac{d(mv)}{dt} = m \frac{dv}{dt} + \frac{dm}{dt} v = m \frac{dv}{dt} = ma$$



Newton's Second Law

The Law of Acceleration

If an object has constant mass, we can state this Law as:

The acceleration of a body with constant mass is proportional to the net force causing it and the change takes place in the direction the net force acts.

$$\mathbf{F}_{NET} = ma$$

$$a = \mathbf{F}_{NET} / m$$



Newton's Second Law

The Law of Acceleration

$$F_{NET} = \frac{d(mv)}{dt}$$

$$F_{NET} dt = d(mv) = mdv$$

$$\int_{t_1}^{t_2} F_{NET} dt = \int_{v_1}^{v_2} mdv$$

Linear Impulse = Change in Linear Momentum

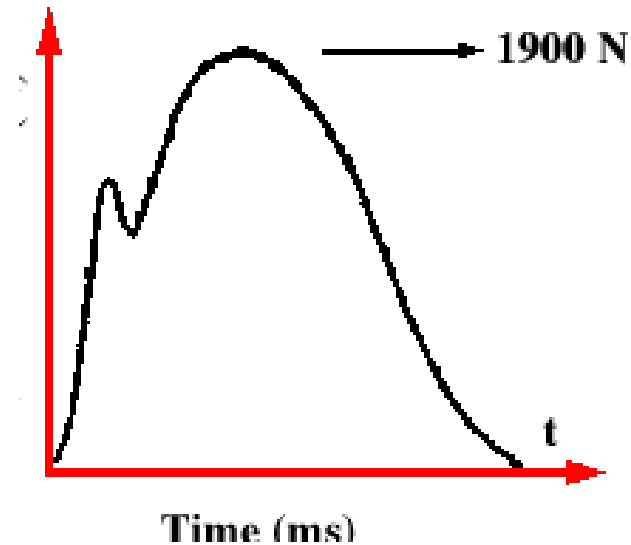
Newton's Second Law

The Law of Acceleration

Linear Impulse = Change in Linear Momentum

$$\int_{t_1}^{t_2} F_{NET} dt = \int_{v_1}^{v_2} m dv = m(v_2 - v_1) = m\Delta v_{1-2}$$

Area under the F_{NET} versus time graph between t_1 and t_2





Newton's Third Law Action & Reaction

For every action (force) in nature exerted by one body upon another, there is an equal and opposite reaction (force) exerted by the second body upon the first.

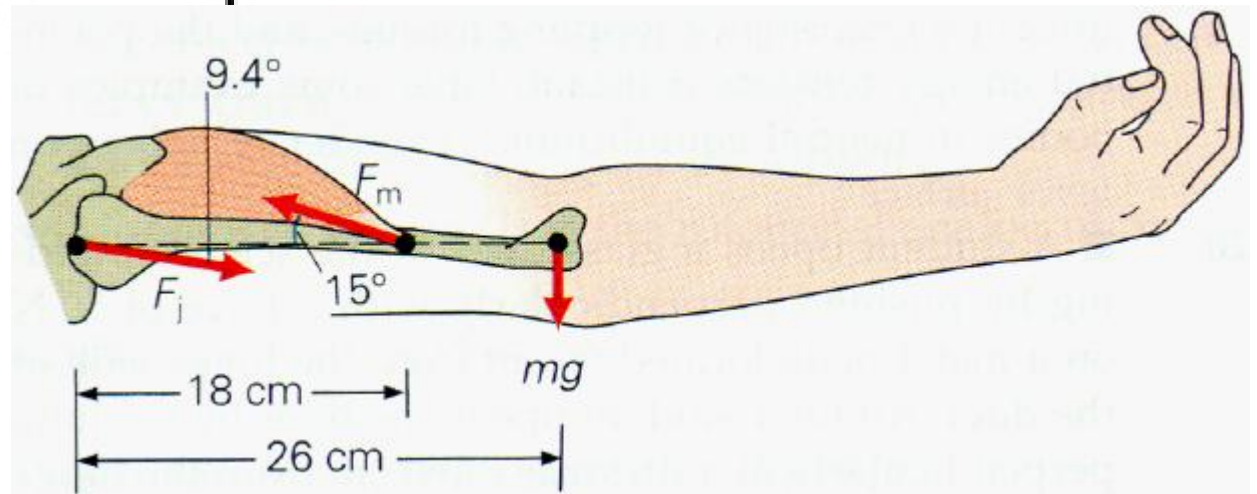
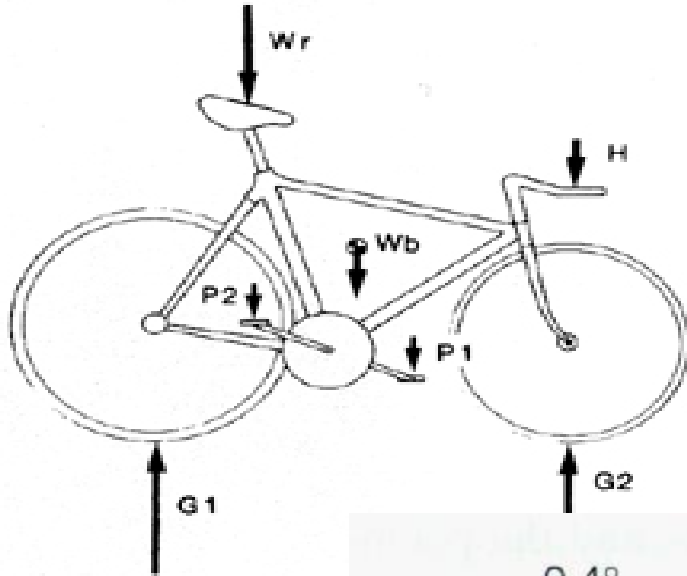
In other words, if object A exerts a force on object B, then object B also exerts an equal and opposite force on object A.



Free-Body Diagrams

- 1. Sketch the System estimating center of gravity location**
- 2. Sketch the Reference Frame**
- 3. Draw all External Forces**
 1. Weight at the center of gravity
 2. External forces at all points of contact
 3. Fluid forces
 4. Magnetic forces

Free-Body Diagram





Acceleration of System Center of Gravity

1. Obtain Sum of Forces (ΣF) in each direction (ΣF_x , ΣF_y & ΣF_z)
2. Divide each Sum of Force component by mass of the system ($\Sigma F/m$)
3. $a_x = \Sigma F_x/m$
 $a_y = \Sigma F_y/m$
 $a_z = \Sigma F_z/m$
4. Requires ability to directly measure forces and to determine the sum of forces acting on an object.



Sum of Forces Acting on a System

1. Videotape Movement
2. Define System
3. Digitize the motion of the System
4. Compute displacement of System CG versus time
5. Derivate s_{CG} versus t to obtain v_{CG} versus t
6. Derivate v_{CG} versus t to obtain a_{CG} versus t
7. Using known mass of the individual ($m = W/g$), obtain the Sum of Forces exerted on the System ($\Sigma F = ma$)
8. Depending on the FBD, may be able to solve for specific forces exerted upon the system



Frictional Forces

Review from Physics

1. Friction Force
2. Normal Force
3. Coefficient of Friction ($\mu = F_{\text{FRICTION}}/F_{\text{NORMAL}}$)
4. Relationship between μ_{STATIC} and μ_{DYNAMIC}

