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THAPAR INSTITUTE
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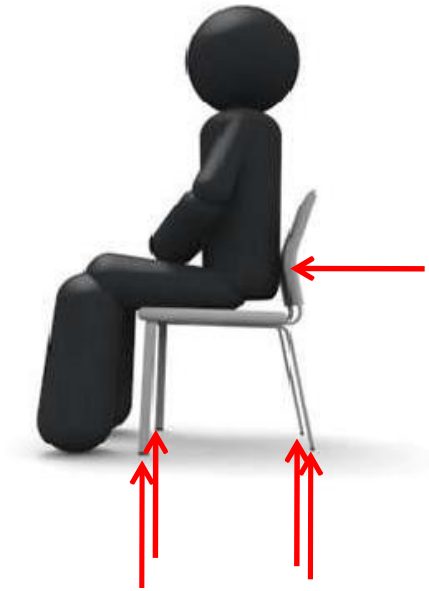
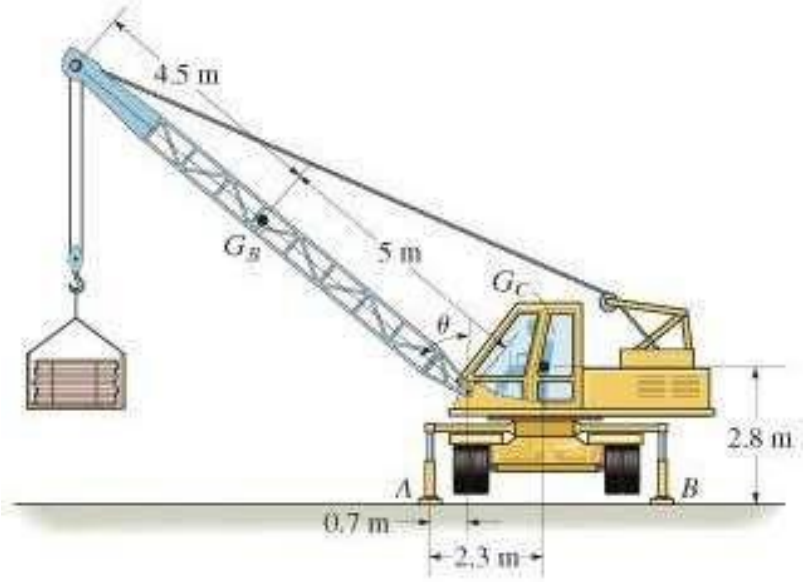
Engineering Mechanics

Rigid-body Mechanics

Statics: deals with equilibrium of bodies under action of forces (bodies may be either at rest or move with a constant velocity).

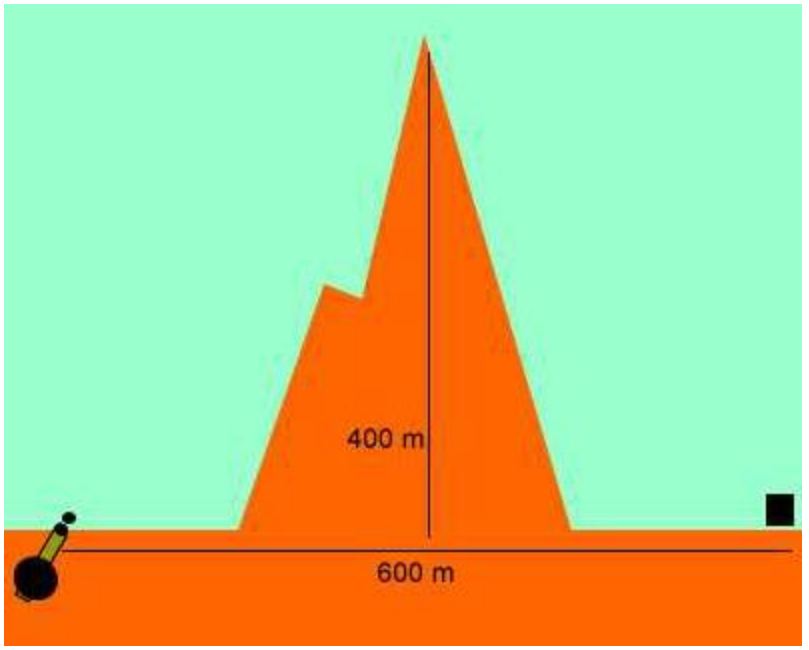




Engineering Mechanics

Rigid-body Mechanics

- Dynamics: deals with motion of bodies (accelerated motion)



Mechanics: Fundamental Concepts

Length (Space) : needed to locate position of a point in space, & describe size of the physical system :: Distances, Geometric Properties

Time: measure of succession of events :: basic quantity in Dynamics

Mass: quantity of matter in a body :: measure of inertia of a body (its resistance to change in velocity)

Force : represents the action of one body on another characterized by its magnitude, direction of its action, and its point of application

Force is a Vector quantity.

Mechanics: Fundamental Concepts

Newtonian Mechanics

Length, Time, and Mass are absolute concepts
independent of each other

Force is a derived concept
not independent of the other fundamental concepts.
Force acting on a body is related to the mass of the body and the variation of its velocity with time.

Force can also occur between bodies that are physically separated (Ex: gravitational, electrical, and magnetic forces)

Mechanics: Fundamental Concepts

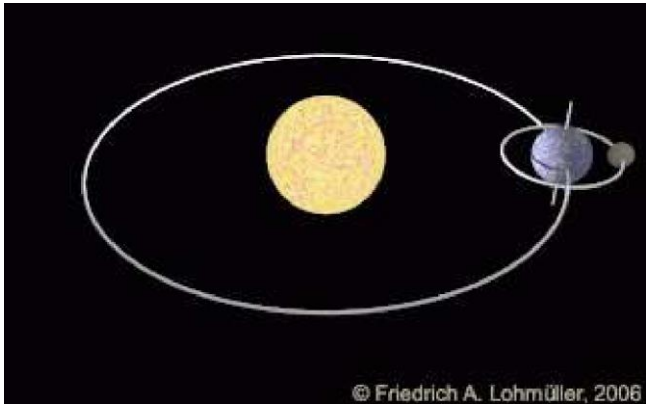
Remember:

- **Mass** is a property of matter that does not change from one location to another.
- **Weight** refers to the gravitational attraction of the earth on a body or quantity of mass. Its magnitude depends upon the elevation at which the mass is located
- Weight of a body is the gravitational force acting on it.

Mechanics: Idealizations

To simplify application of the theory

Particle : A body with mass but with dimensions that can be neglected



Size of earth is insignificant compared to the size of its orbit. Earth can be modeled as a particle when studying its orbital motion

Mechanics: Idealizations

Rigid Body : A combination of large number of particles in which all particles remain at a fixed distance (practically) from one another before and after applying a load.

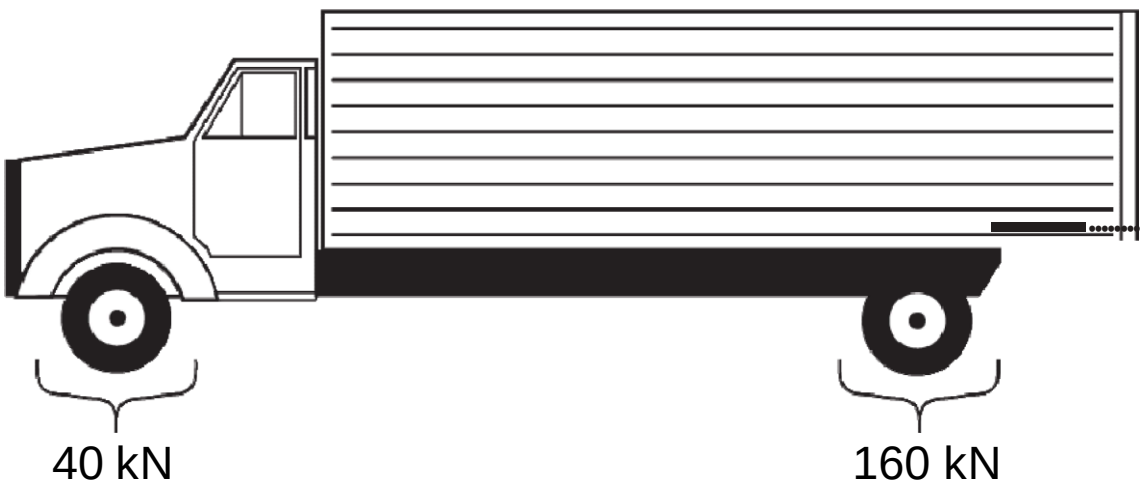
Material properties of a rigid body are not required to be considered when analyzing the forces acting on the body.

In most cases, actual deformations occurring in structures, machines, mechanisms, etc. are relatively small, and rigid body assumption is suitable for analysis

Mechanics: Idealizations

Concentrated Force: Effect of a loading which is assumed to act at a point (CG) on a body.

•Provided the area over which the load is applied is very small compared to the overall size of the body.



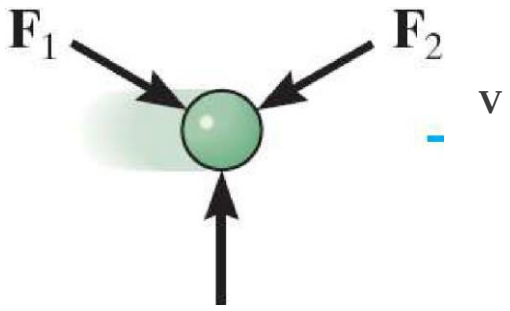
Ex: Contact Force between a wheel and ground.

Mechanics: Newton's Three Laws of Motion

Basis of formulation of rigid body mechanics.

First Law: A particle originally at rest, or moving in a straight line with constant velocity, tends to remain in this state provided the particle is not subjected to an unbalanced force.

First law contains the principle of the equilibrium of forces main topic of concern in Statics



Equilibrium

Mechanics: Newton's Three Laws of Motion

Second Law: A particle of mass "m" 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.

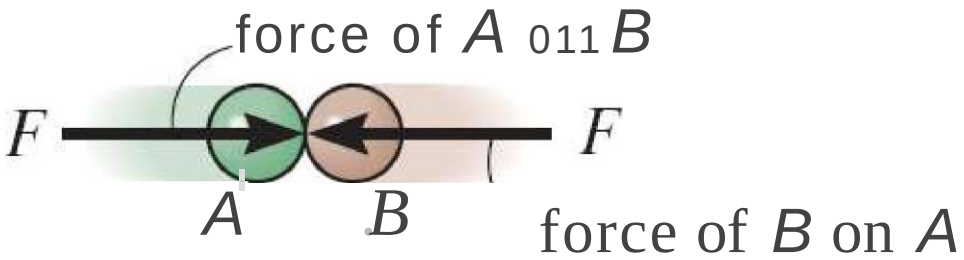
$F = ma$

Accelerated motion

Second Law forms the basis for most of the analysis in Dynamics

Mechanics: 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

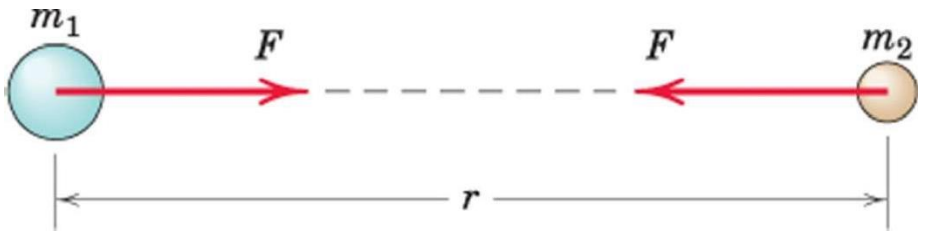
Third law is basic to our understanding of Force.

Force always occur in pairs of equal and opposite magnitude.

Mechanics: Newton's Law of Gravitational Attraction

Weight of a body (gravitational force acting on a body) is required to be computed in Statics as well as Dynamics.
This law governs the gravitational attraction between any two particles.

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



F = mutual force of attraction between two particles

G = universal constant of gravitation

Experiments → $G = 6.673 \times 10^{-11}\ m^3/(kg.s^2)$

Rotation of Earth is not taken into account

m_1, m_2 = masses of two particles

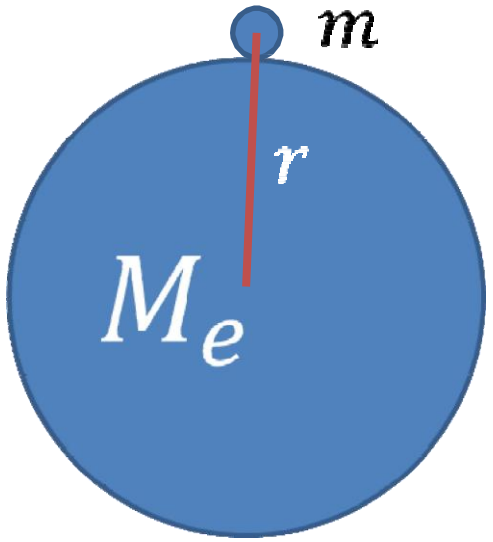
r = distance between two particles

Gravitational Attraction of the Earth

Weight of a Body: If a particle is located at or near the surface of the earth, the only significant gravitational force is that between the earth and the particle

Weight of a particle having mass $m_1 = m$:

Assuming earth to be a non-rotating sphere of constant density and having mass $m_2 = M_e$



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

r = distance between the earth's center and the particle

$$W = mg$$

Let $g = G\,M_e/r^2$ = acceleration due to gravity ($9.81 m/s^2$)

Mechanics: Units

Four Fundamental Quantities

Quantity	Dimensional Symbol	SI UNIT	
		Unit	Symbol
Mass	M	Kilogram	Kg
Length	L	Meter	M
Time	T	Second	s
Force	F	Newton	N

Basic Unit

$F = ma$ → N = kg.m/s^2

$W = mg$ → N = kg.m/s^2

1 Newton is the force required to give a mass of 1 kg an acceleration of 1 m/s^2

Mechanics: Units Prefixes

	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^{9}	g1ga	G
1000000	10^{6}	mega	M
1000	10^{3}	kilo	k
Submultiple			
0.001	10^{-3}	mllli	m
0.000 001	10^{-6}	micro	μ,
0.000 000 001	10^{-9}	nano	n.

Thank you