Course Code: ESC106A
Course Title: Construction Materials and Engineering Mechanics

Lecture No. 6:

Fundamental Laws and Elements of Force

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Lecture Intended Learning Outcomes

At the end of this lecture, student will be able to:

- Define Newton's Laws and Law of Gravitation
- Describe Force and its elements
- Explain the laws of transmissibility, superposition and physical independence

Contents

Engineering Mechanics

- Laws of gravitation, Law of transmissibility, Principle of physical independence of forces, Principle of superposition of forces

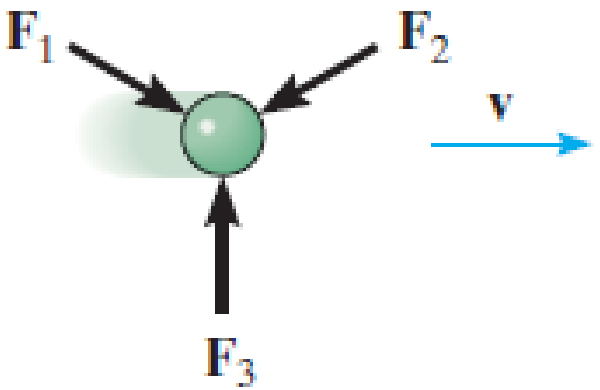
Newton's Three Laws of Motion

- Engineering mechanics is formulated on the basis of Newton's three laws of motion, the validity of which is based on experimental observation.

- These laws apply to the motion of a particle as measured from a nonaccelerating reference frame

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



Equilibrium

First Law

Ex: Applied to rocket lift off

Before firing:

Object in state of rest, airspeed zero.

Engine fired:

Thrust increases from zero.

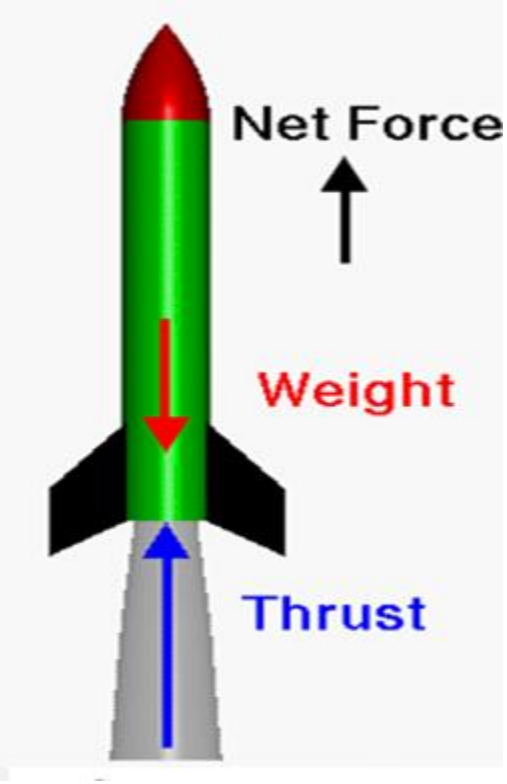
Weight decreases slightly as fuel burns.

When Thrust is greater than Weight:

Net force (Thrust – Weight) is positive upward.

Rocket accelerates upward

Velocity increases

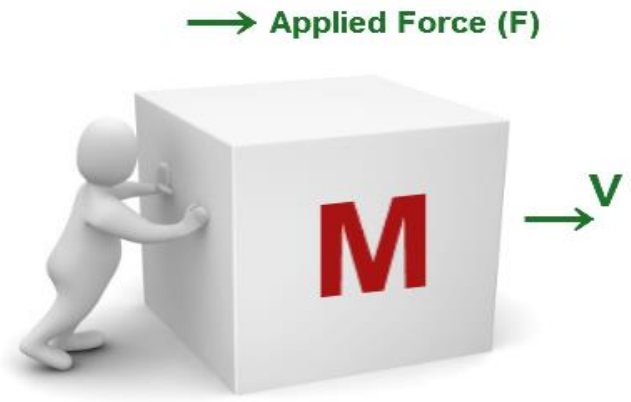


Applied to rocket lift off

Second Law

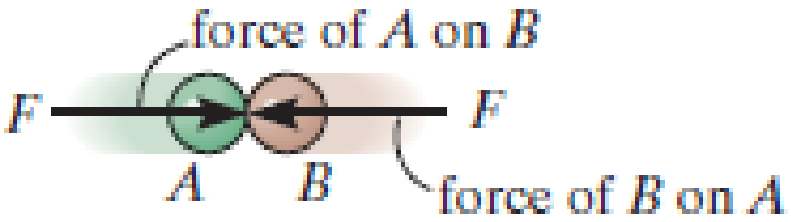
- A particle acted upon by an unbalanced force **F** experiences an acceleration **a** that has the same direction as the force and a magnitude that is directly proportional to the force
- If **F** is applied to a particle of mass m, this law may be expressed mathematically as

$$F=ma$$

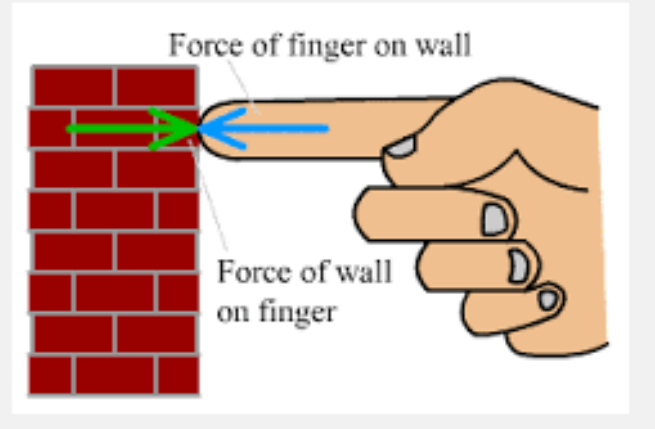


Third Law

- The mutual forces of action and reaction between two particles are equal, opposite and collinear



Action – reaction



Newton's Law of Gravitational attraction

- Newton postulated a law governing the gravitational attraction between any two particles.
- Stated mathematically

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

where

F = force of gravitation between the two particles

G = universal constant of gravitation; according to experimental evidence, $G = 66.73(10^{-12})\ \mathrm{m}^3/(\mathrm{kg}\cdot\mathrm{s}^2)$

m_1, m_2 = mass of each of the two particles

r = distance between the two particles

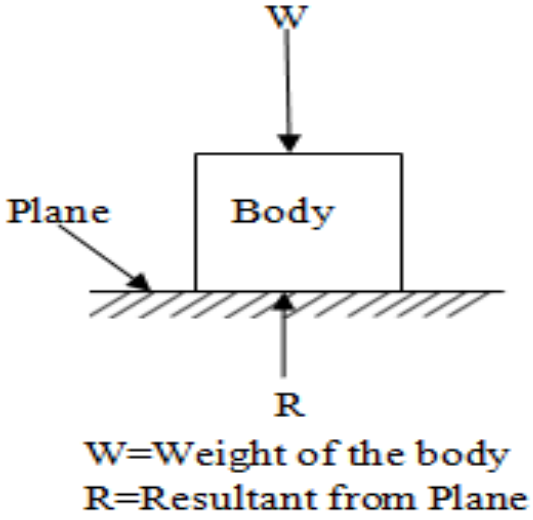
Force and its elements(Characteristics)

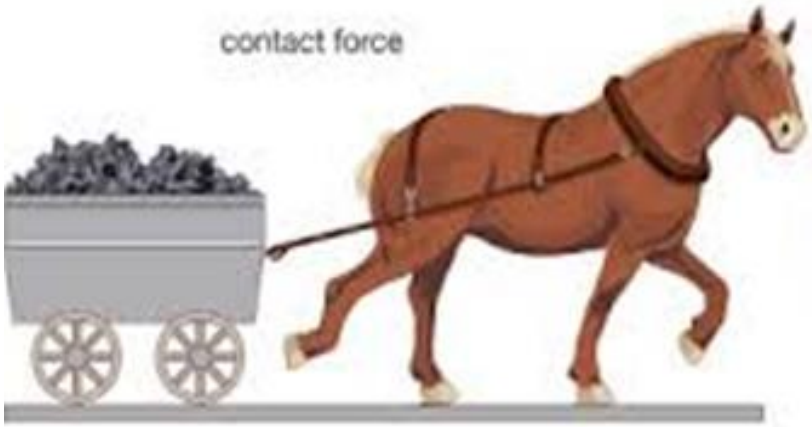
a. Magnitude

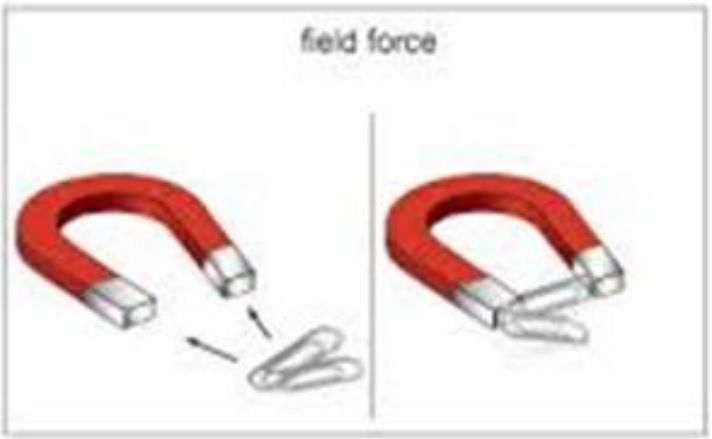
b. Direction

c. Line of action/Sense

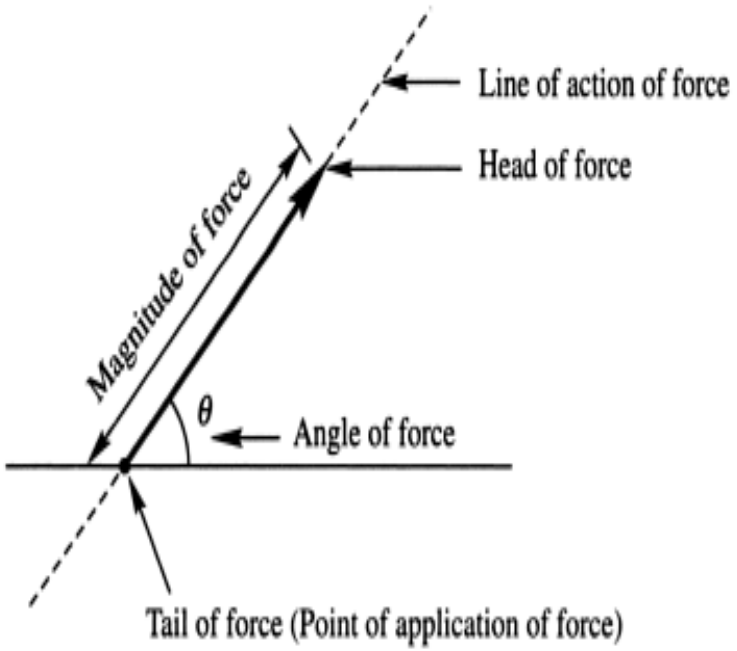
d. Point of action or application





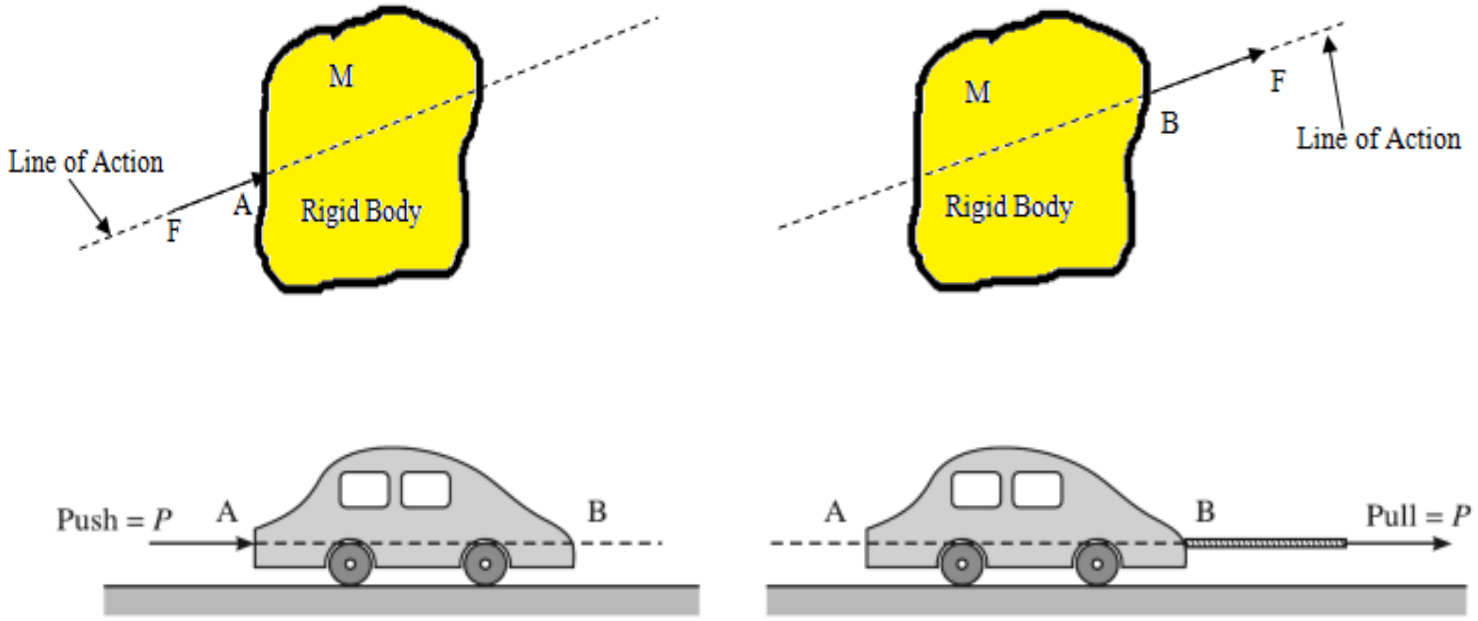


Graphical Representation of a force



Principle of transmissibility of forces:

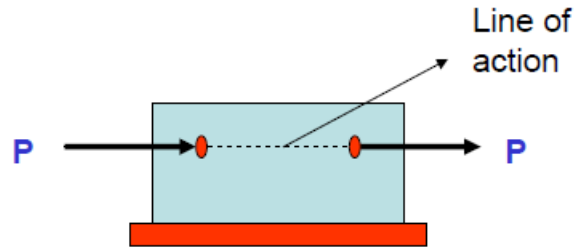
The external effect of a force on a rigid body will not change if we replace a force of the same characteristics but acting at a different point along the same line of action



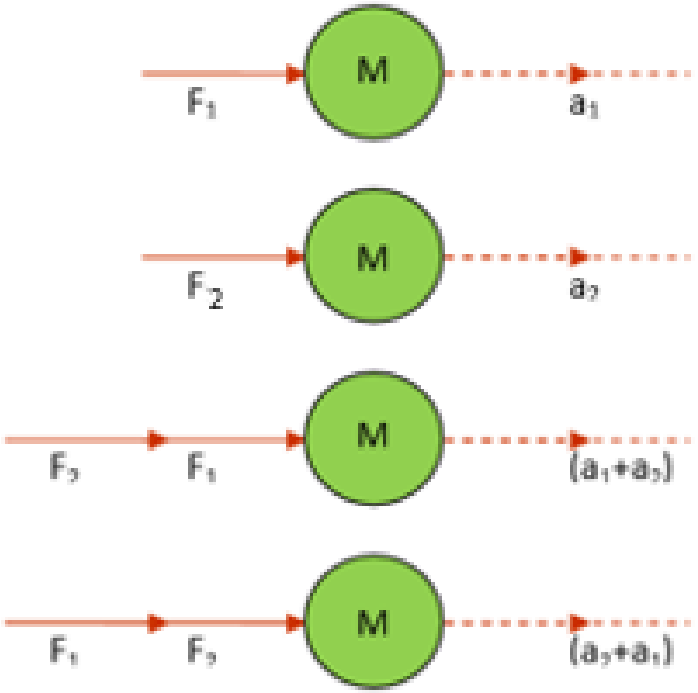
Limitations of Principle of Transmissibility

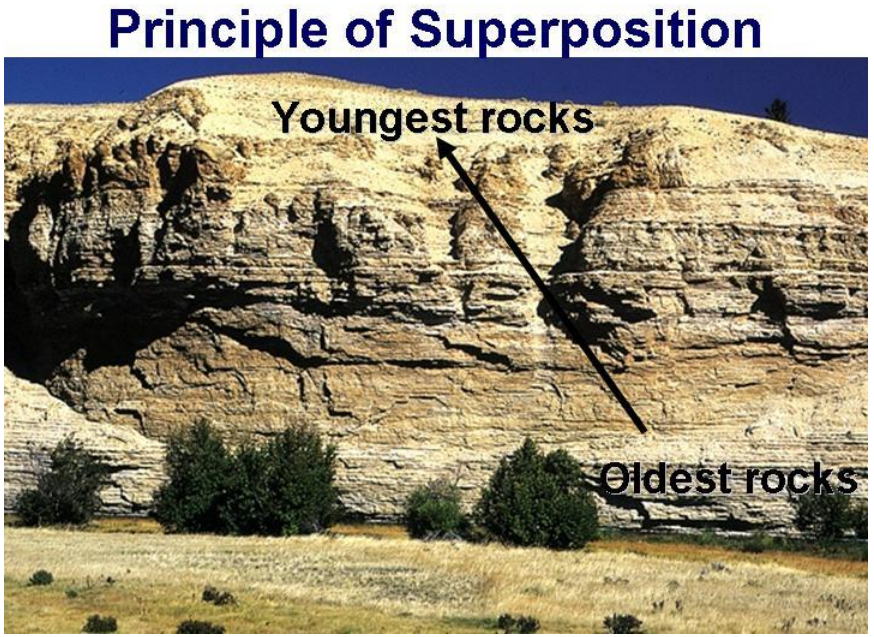
- Principle of transmissibility can be applied only for rigid bodies and cannot be used for deformable bodies
- It deals with the external effect of the force only

Magnitude, direction and line of action is important; not point of application



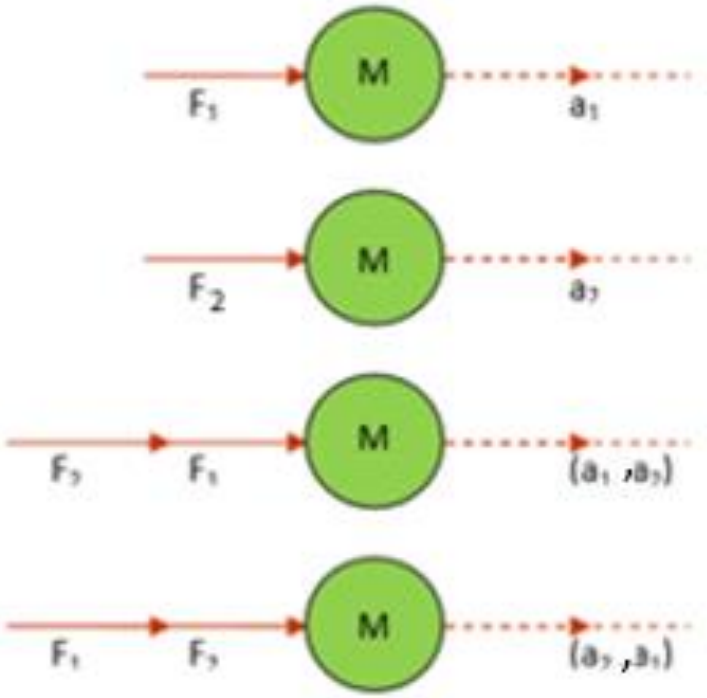
Principle of Superposition





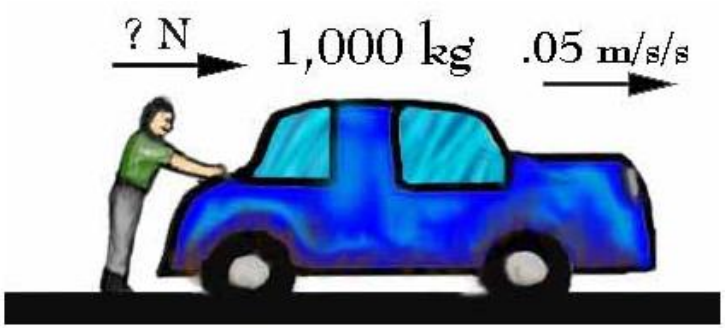
Net effect of forces applied in any sequence on a body is given by the algebraic sum of effect of individual forces on the body

Principle of Physical Independence of forces



Action of forces on bodies are independent, in other words the action of forces on a body is not influenced by the action of any other force on the body.

Problem



Mike's car, which weighs 1,000 kg, is out of gas. Mike is trying to push the car to a gas station, and he makes the car go 0.05 m/s/s. Using Newton's Second Law, you can compute how much force Mike is applying to the car.

Summary

- The basic elements of a force are magnitude, direction, line of action and point of application

- The principle of transmissibility states that the external effect of a force on a rigid body will not change if we replace a force of the same characteristics but acting at a different point along the same line of action

- Principle of superposition states that the net effect of forces applied in any sequence on a body is given by the algebraic sum of effect of individual forces on the body

- Principle physical independence of forces states that the action of forces on a body is not influenced by the action of any other force on the body