Fundamental Principles

Newton's First Law:

If the **resultant force** on a particle is **zero**, the particle will remain **at rest or continue** to move in a straight line.

First Law: A. body will remain at rest or continue to move with uniform velocity unless acted upon by an external force.

Newton's Second Law:

A particle will have an acceleration proportional to a non-zero resultant applied force.

- When a force acts on an object, the object accelerates in the direction of the force
- If the mass of an object is held constant, increasing force will increase acceleration.
- If the force on an object remains constant, increasing mass will decrease acceleration.

Second Law: If an external force acts upon a body, the rate of change of momentum is proportional to the force, and takes place in the direction of the force.

The second law applies to a body of mass m under the application of the motive force $\mathbf{F}$. Mathematically, the acceleration

$$\mathbf{a} \propto \mathbf{F}$$

or

$$\mathbf{F} = k\mathbf{a}$$

where k is a constant of proportionality. This constant, determined experimentally, equals the mass of the system.

Hence,

$$\boxed{\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{V}}{dt}} \tag{1.2a}$$

It is obvious that the force $\mathbf{F}$ and acceleration $\mathbf{a}$ must be collinear, vector $\mathbf{F}$ being m times vector $\mathbf{a}$. Further, the units of force are derived from the base units of mass and acceleration.

Mass	kg
Acceleration	m/s^2
Force	$kg \times m/s^2 = kg\ m/s^2 \equiv N$ or newton

Quantitatively, a force of 1 N causes an acceleration of 1 m/s^2 of a body of mass 1 kg.

The second law is not immediately applicable to the systems of variable mass. The law can, however, be reframed to cover the motion of constant-mass and variable-mass bodies by writing

$$\boxed{\mathbf{F} = \frac{d}{dt}(m\mathbf{V})} \qquad (1.2b)$$

The bracketed term ($m\mathbf{V}$) is the *momentum* of the body of mass m moving at a velocity $\mathbf{V}$. The second law, in other words, states:

The rate of change of momentum of a body equals the force impressed upon it.

In view of the fact that the first and third laws are contained in this law, only this law will be retained and henceforth referred to as *Newton's law.*

In order to appreciate that the first and third laws of motion due to Newton are substantially contained in the second law, we proceed as follows:

From the second law,

$$\mathbf{F} = m\mathbf{a} = m\frac{d\mathbf{V}}{dt}$$

If

$$\mathbf{F} = 0, \ \mathbf{a} = 0 = \frac{d\mathbf{V}}{dt}$$

whence $\mathbf{V}$ = zero or constant.

It follows that, in the absence of an external force, a body will continue to be in a state of rest or of uniform velocity. This is, in essence, the statement of the first law.

This reduction may also be seen graphically by plotting $\mathbf{F}$ *vs* $\mathbf{a}$ as shown in Fig. 1.10. The resulting straight line with slope m passes through the origin where,

for $\mathbf{F} = 0$, $\quad \mathbf{a} = 0$

Newton's Third Law:

The forces of action and reaction between two particles have the same magnitude and line of action with opposite sense.

Third Law: To every action there is a reaction equal in magnitude and opposite in direction

Sir Isaac Newton developed these laws in the late seventeenth century from a study of the motion of objects.

The application of these laws to engineering problems is the topic of Engineering Mechanics.

The first law deals with bodies in equilibrium and is the basis for the study of statics.

The second law is concerned with accelerating bodies and is the basis of the branch of mechanics known as ***Dynamics***

third law is fundamental to an understanding of the concept of force.

In engineering applications, ,the word ‘action’ may be taken to mean force and so, if a body exerts a force on a second body, the second body exerts an equal and opposite force on the first

Newton's Law of Gravitation:

Two particles are attracted with equal and opposite forces.

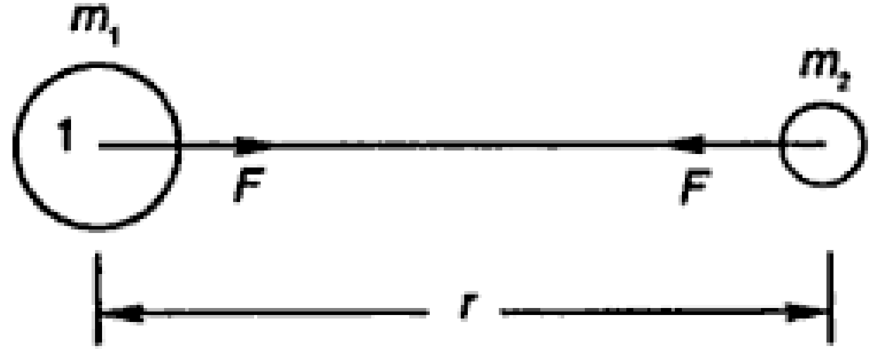
Every point mass in the universe attracts every other point mass with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

GM W = mg g = G = 6.67 x 10-11 Nm2/kg2 R2

Newton also propounded a Law of Gravitation, which together with his three Laws of Motion enabled him to explain the movement of the planets in the solar system. According to this law, any two bodies of mass m_1 and m_2 exert a force of attraction on each other. This gravitational force is proportional to the masses and inversely proportional to the square of the distance between their centres, d. That is:

$$F = G\frac{m_1 m_2}{d^2} \quad (1.1)$$

where G is a gravitational factor which according to Newton is constant throughout the universe.



The law of gravitation requires that the force of attraction between two particles of masses m_1 and m_2 separated by a distance r

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

The law of gravitation helps in defining the *weight* of a body. The weight of a body is the force exerted on it by the planet. For an earth-bound object of mass m, the weight is approximately given by

$$W = G\frac{M_e m}{r^2} \tag{1.6}$$

where M_e is the mass of the earth = 5.9761×10^{24} kg and r is the radial distance between the centres of the earth and the object.

It is customary to write

$$W = mg \tag{1.7}$$

where

$$g = \frac{GM_e}{R_e^2} = 9.806\ 65\ \text{m/s}^2 \tag{1.8}$$

and R_e = mean radius of the earth ≈ 6371 km.

Since g is a constant for a planet and, when multiplied by the mass of a body, it provides the force on the body, it is termed as acceleration due to gravity. It is indeed the acceleration acquired by a body falling freely, i.e., without resistance, in the gravitational field of the planet.

Si. no	MASS	WEIGHT
1	It is the quatity of matter contained in a body	It is the force with which the body is attracted towards the centre of the earth
2	It is constant for all places	It is not constant for all places
3	It resists motion in body	It provides motion in body
4	It is a Scalar Quantity	It is a Vector Quantity
5	It is never zero	It is zero at the centre of earth
6	It is measured in Kg, both MKS and SI Units	It is measured in Kg wt in MKS and Newton (N) inSI Units

Law of Parallelogram of Forces

If the two forces acting at a point be represented in magnitude and direction by the two adjacent sides of a parallelogram, then their resultant is represented in magnitude and direction by the diagonal of the parallelogram passing through that point. The magnitude of Resultant force R

- Parallelogram Law

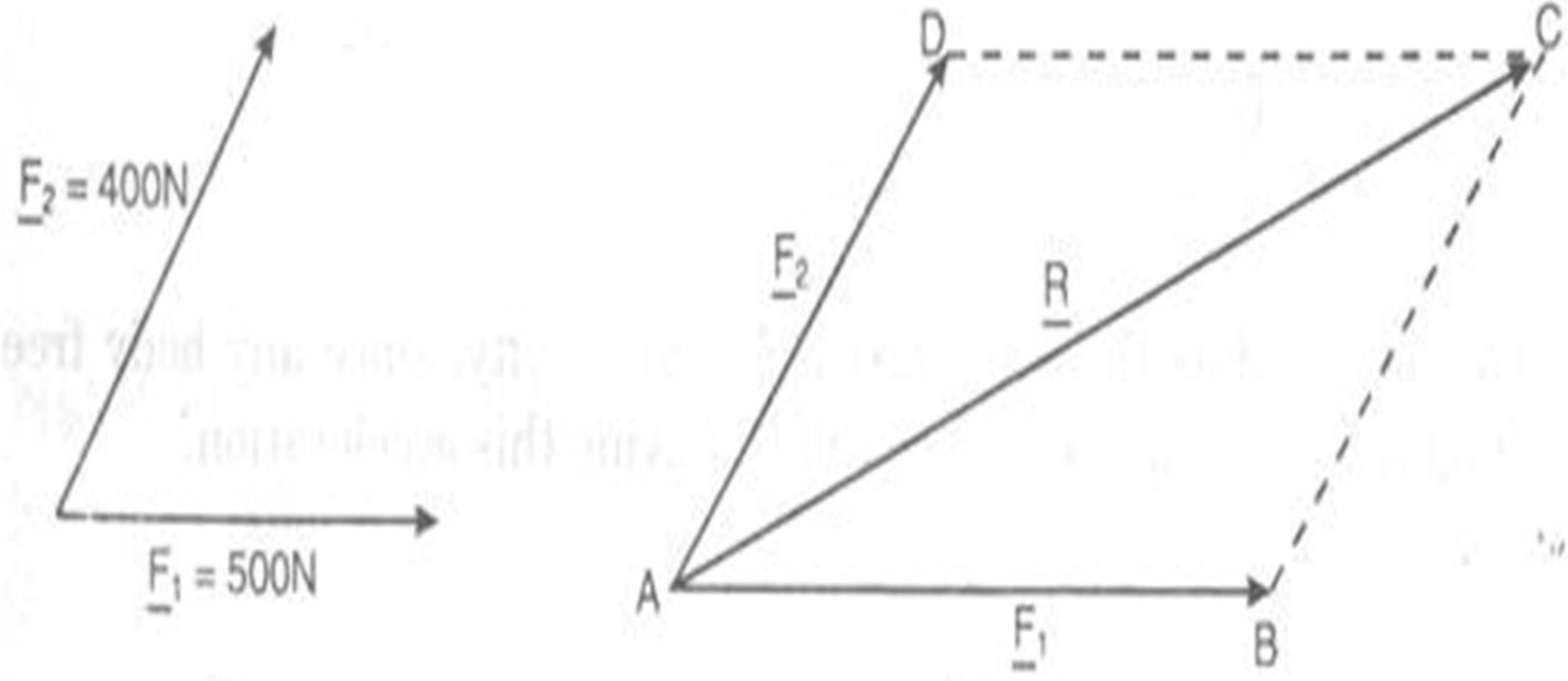
Parallelogram Law of Forces

This law was formulated based on experimental results.

Stevinus employed it in 1586,

the credit of presenting it as a law goes to Varignon and Newton (1687).

The Parallelogram law of forces enables us to replace the two forces acting at a point by a single force called the resultant force acting at that point without altering any effect on the body.



(a) (b)

It states that if **two forces acting simultaneously on a body at a point** are represented in magnitude and direction by the two adjacent "sides of a parallelogram,

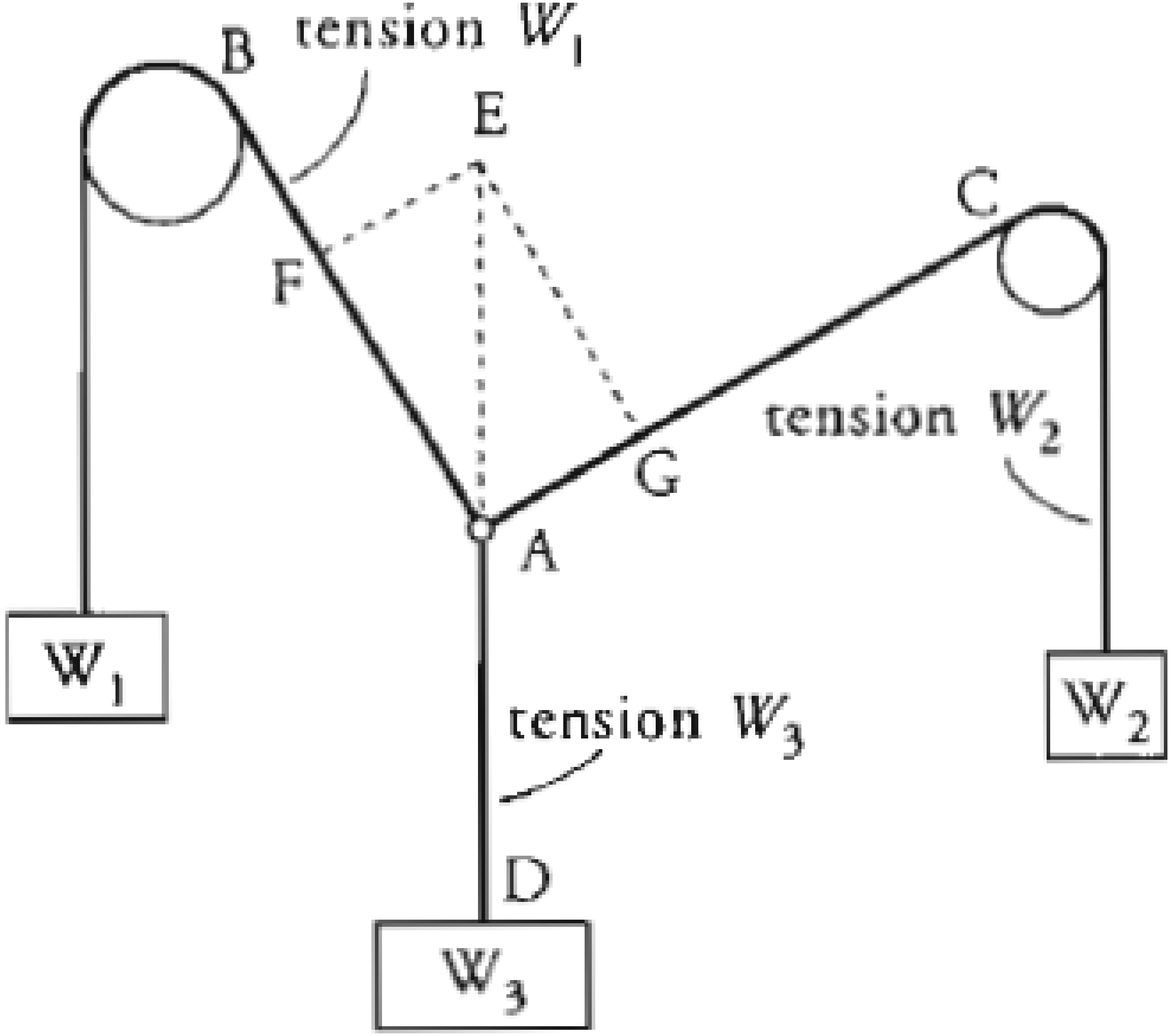
their resultant is represented in **magnitude and direction by the diagonal of the parallelogram** which passes through the point of intersection of the two sides representing the forces.

Fig. (a), **Two forces F_1= 500 N and F_2 = 400 N acting at point 'O' on a body, the angle between them being 60°**.

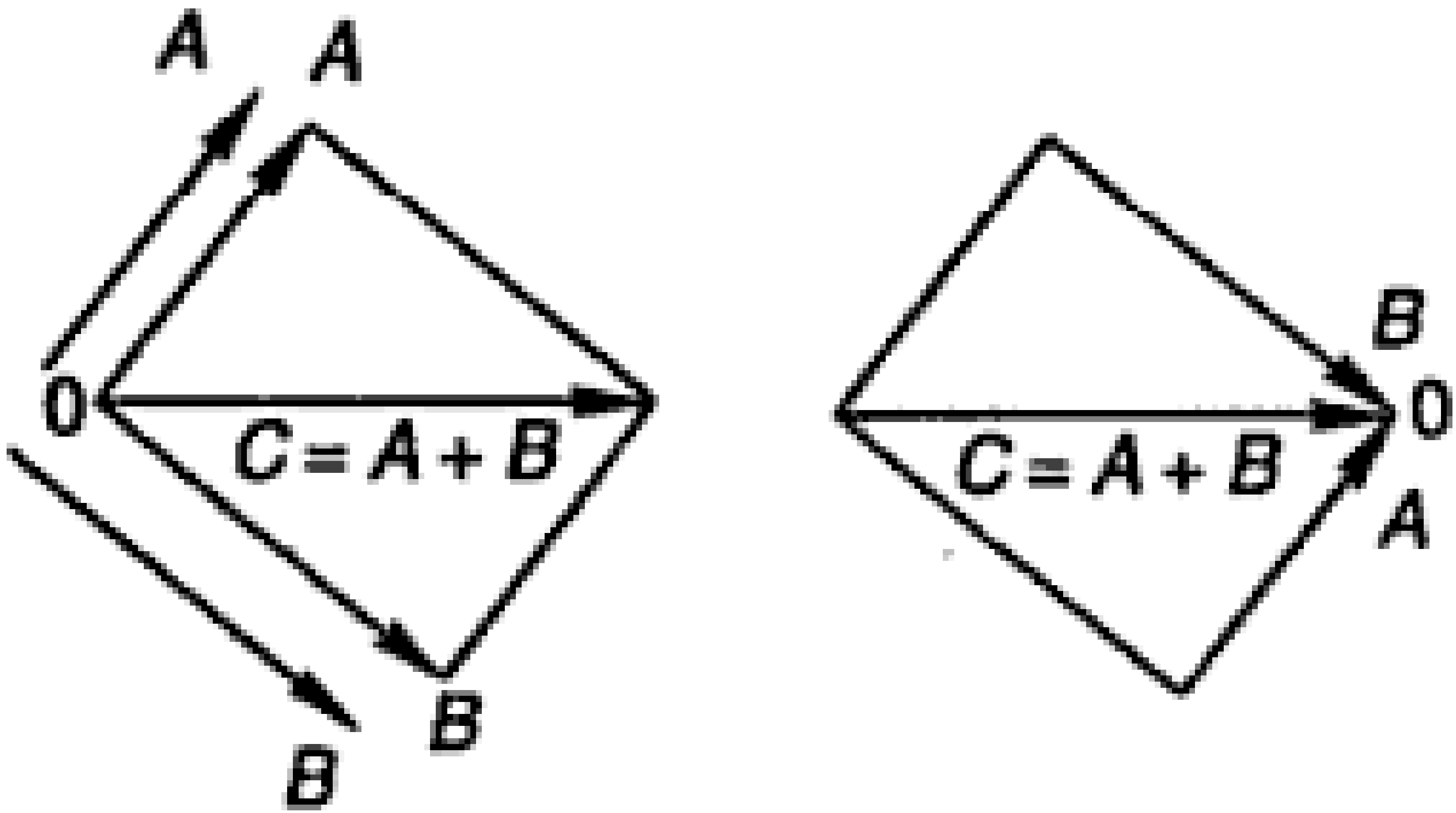
The parallelogram ABCD shown in Fig. (b) is constructed in such a way that the side **AB represents F_1 and side AD represents F_2 in magnitude (to the scale) and direction**.

Then, according to the parallelogram law of forces, the diagonal AC which passes through the intersection of AB and AD represents the resultant 'R' of the two forces F_1 and F_2 in magnitude and direction.

This force R is having the same effect as F_1 and F_2 had on the body.

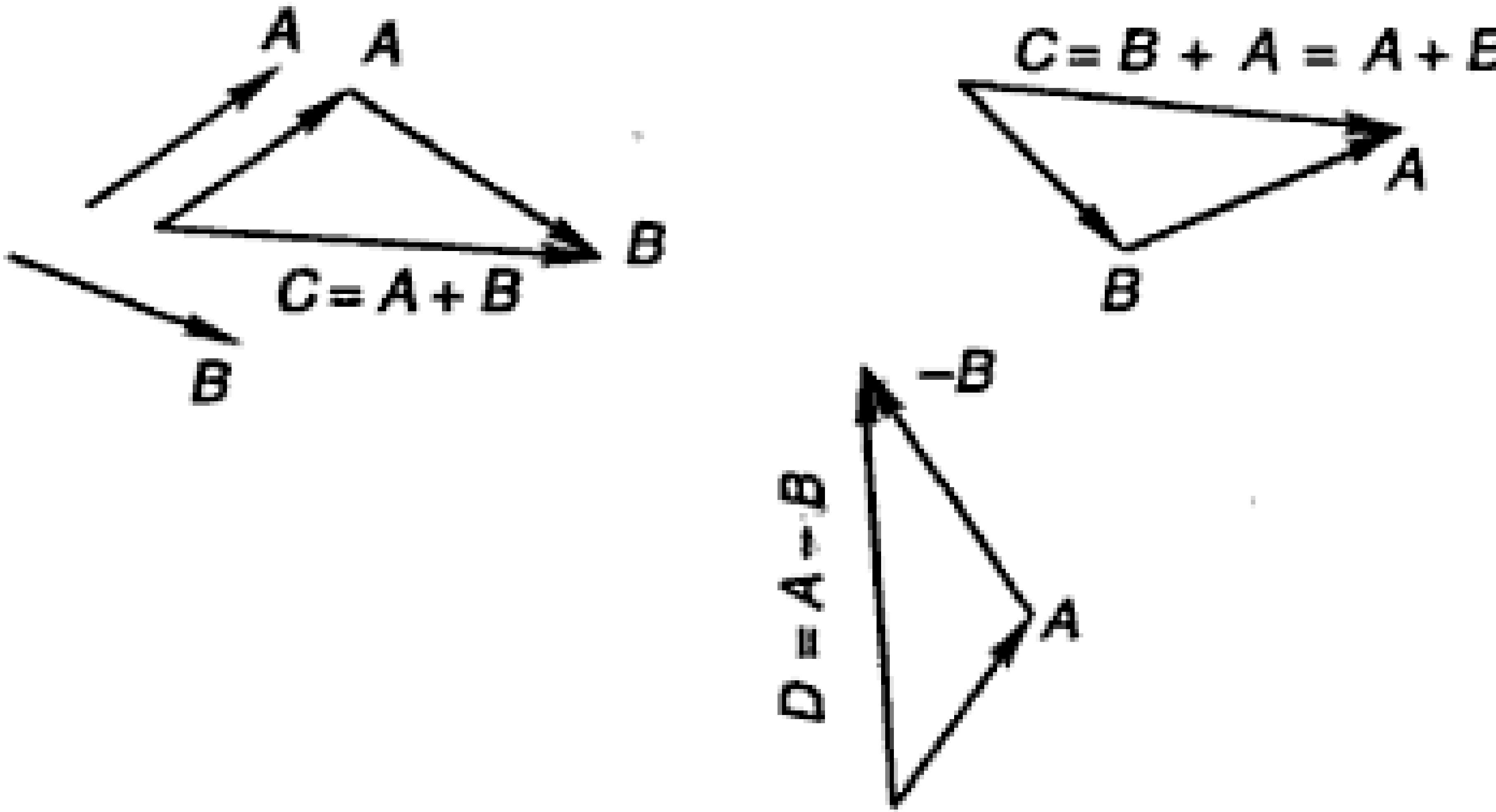

tension W_1
B
E
C
F
tension W_2
G
A
W_1
tension W_3
W_2
D
W_3

Parallelogram Law of Vectors



Law of Triangle of forces

"If the forces acting at a point be represented in magnitude and direction by the three sides of a triangle taken in order, they will be in equilibrium."



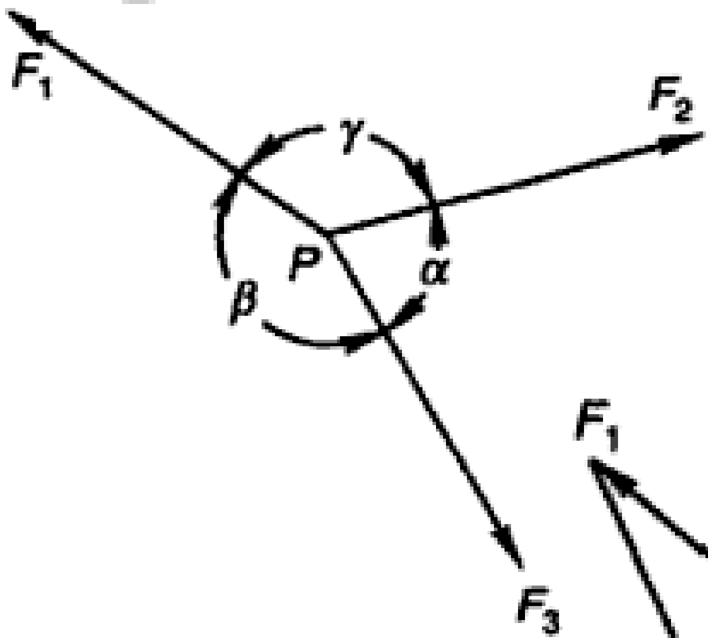
Triangle Law of Vectors

Lami's Theorem:

If three forces acting at a fixed point are in equilibrium, each force will be proportional to the sine of the angle between the other two forces."

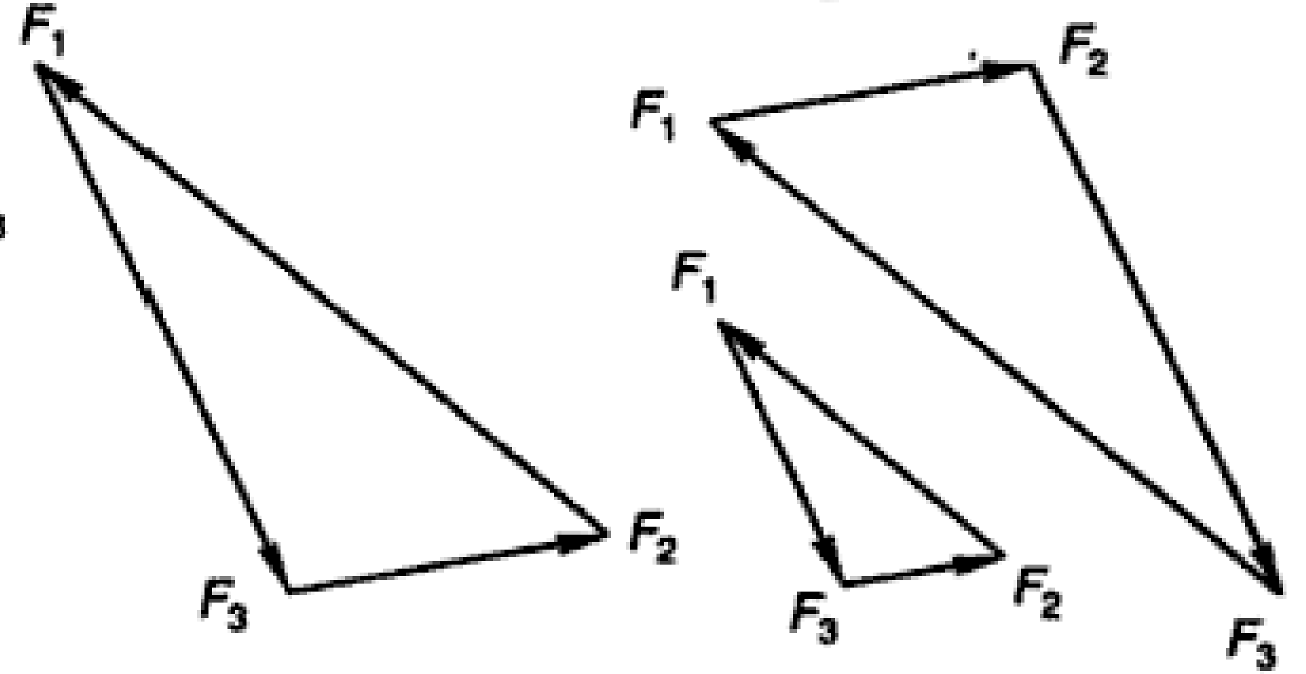
Lami's Theorem *If a particle is in equilibrium under the action of three forces, each force must bear the same proportionality with the sine of the angle between the other two forces.*

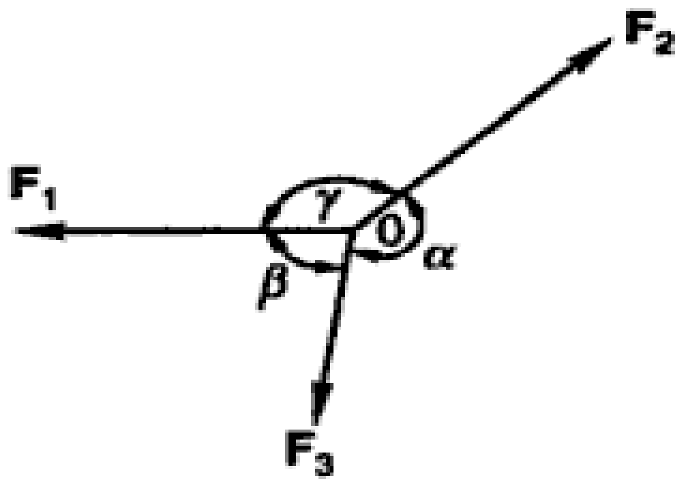
A Particle in Equilibrium

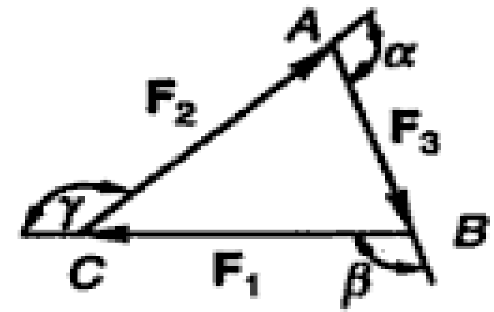


$$\frac{F_1}{\sin \alpha} = \frac{F_2}{\sin \beta} = \frac{F_3}{\sin \gamma}$$

Possible Triangles to Represent Force F_1 F_2 and F_3







Triangle of Forces

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

(c) Three Concurrent Forces

Fig. 3.5 ***Equilibrium of a Particle***

For the triangle ABC shown in Fig. 3.5(c) corresponding to the forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$, acting at a point O,

$$\angle CAB = 180° - \alpha$$

$$\angle ABC = 180° - \beta$$

$$\angle BCA = 180° - \gamma$$

From the sine rule for the triangle,

$$\frac{F_1}{\sin(180° - \alpha)} = \frac{F_2}{\sin(180° - \beta)} = \frac{F_3}{\sin(180° - \gamma)}$$

and from the fact that $\sin(180° - \alpha) = \sin\alpha$, etc., it reduces to the Lami's theorem

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

Principle of Transmissibility

Conditions of equilibrium or motion are not affected by transmitting a force along its line of action.

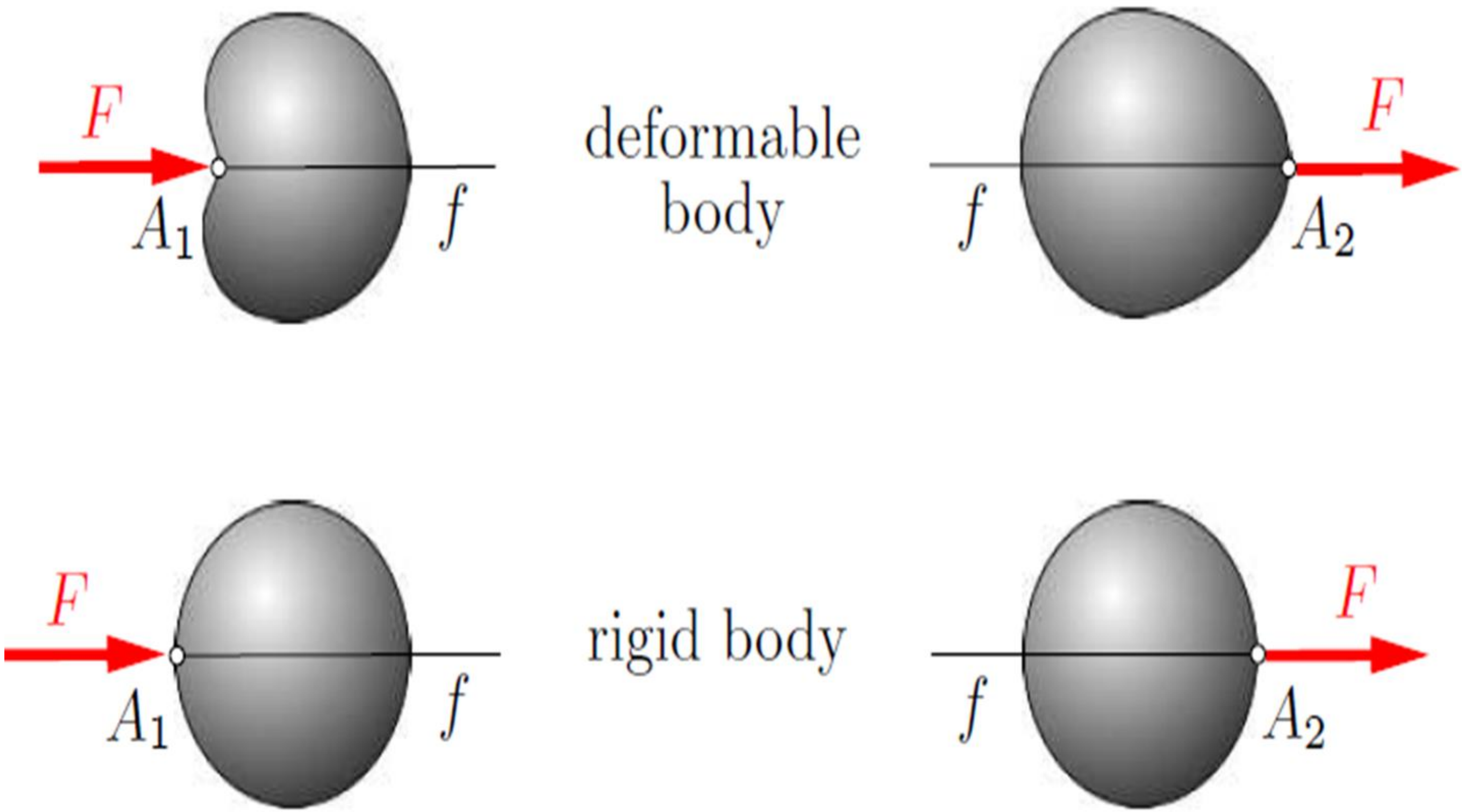
F and F' are equivalent forces.

Task Draw one simple mechanism to lift the body or water or weight.

Make the group of five students.

Principle of Transmissibility

States that a Force may be applied at any point on a given line of action without altering the resultant effects of the force exerted to the rigid on which it acts


F
A1
f
deformable
body
f
F
A2
F
A1
f
rigid body
f
F
A2