ENGINEERING MECHANICS INTRODUCTION

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19ME201	ENGINEERING MECHANICS	L	T	P	J	C
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UNIT I	BASICS & STATICS OF PARTICLES	9+3
Introduction – Units and Dimensions – Laws of Mechanics – Lami's theorem, Parallelogram and triangular Law of forces-Resolution of composition of forces – Vectorial representation of forces – Vector operations of forces – additions, subtraction, dot product, cross product – Equilibrium of a particle – Principle of transmissibility		

UNIT II	EQUILIBRIUM OF RIGID BODIES	9+3
Moment of a force -Varignon's theorem - Equivalent system of forces – Reduction of system of forces into single force and couple -Free body diagram and type of supports and reaction - Forces in space – Equilibrium of a particle in space -Equilibrium of rigid bodies in two dimensions		

UNIT III	FRICTION	6+3
Introduction, coefficient of friction, angle of friction, angle of repose; laws of dry (Coulomb) friction, Numerical problems on single and multibody system on horizontal planes and incline planes, Numerical problems on wedge friction, ladder friction, screw friction and belt friction.		

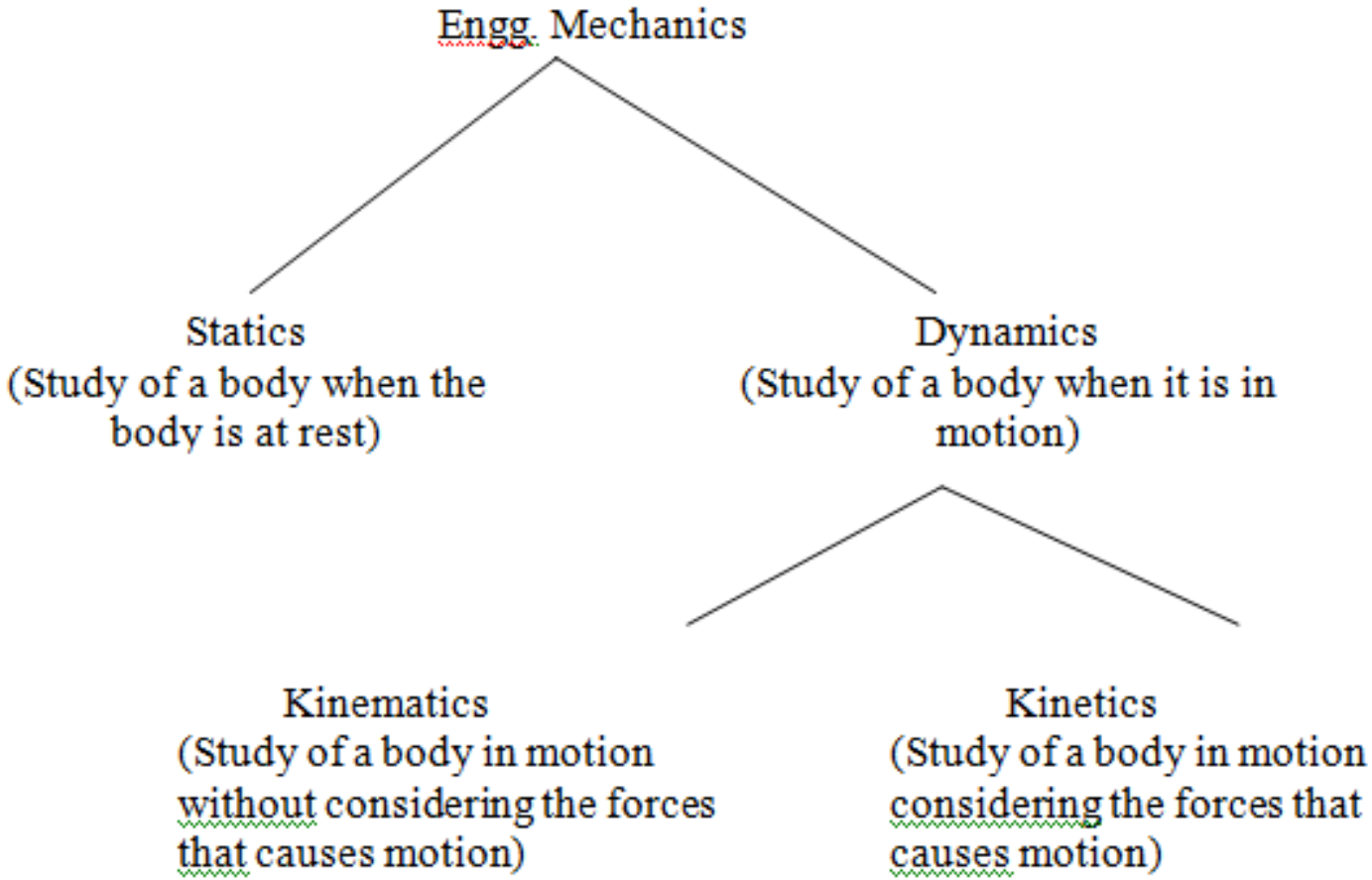
UNIT IV	DYNAMICS OF PARTICLES	12+3
Displacements, Velocity and acceleration, their relationship – Relative motion – Curvilinear motion Newton's laws of motion – Work Energy Equation– Impulse and Momentum Impact of elastic bodies.		

UNIT V	PROPERTIES OF SURFACES AND SOLIDS	9+3
Centroids and centre of mass – Centroids of lines and areas – Rectangular, circular, triangular areas by integration – T section, I section, – Angle section, Hollow section by using standard formula Theorems of Pappus – Area moments of inertia of plane areas – Rectangular, circular, triangular areas by integration – T section, I section, – Angle section, Hollow section by using Standard formula.		

TEXT BOOKS	
1.	Beer, F.P and Johnston Jr. E.R. "Vector Mechanics for Engineers", McGraw-Hill Education **11th Edition (India) Pvt Ltd. (2016).**
2.	Vela Murali, "Engineering Mechanics", Oxford University Press (2010)

Introduction

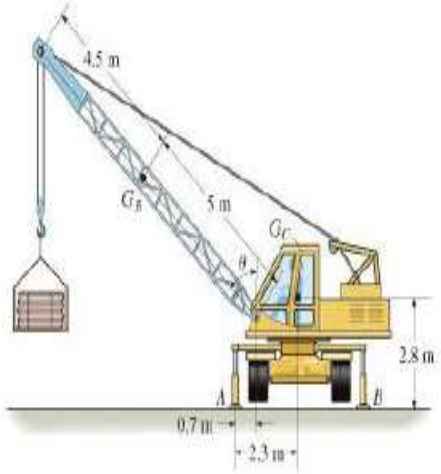
Engg. Mechanics is a branch of science which deals with the behavior of a body when the body is at rest or motion.



Introduction

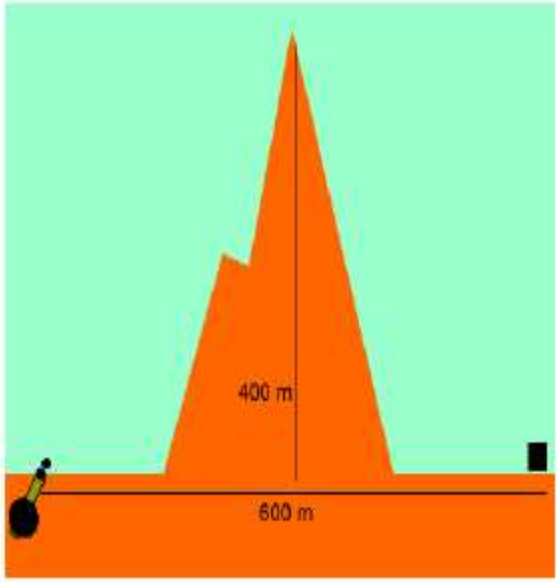
Rigid-body Mechanics

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



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

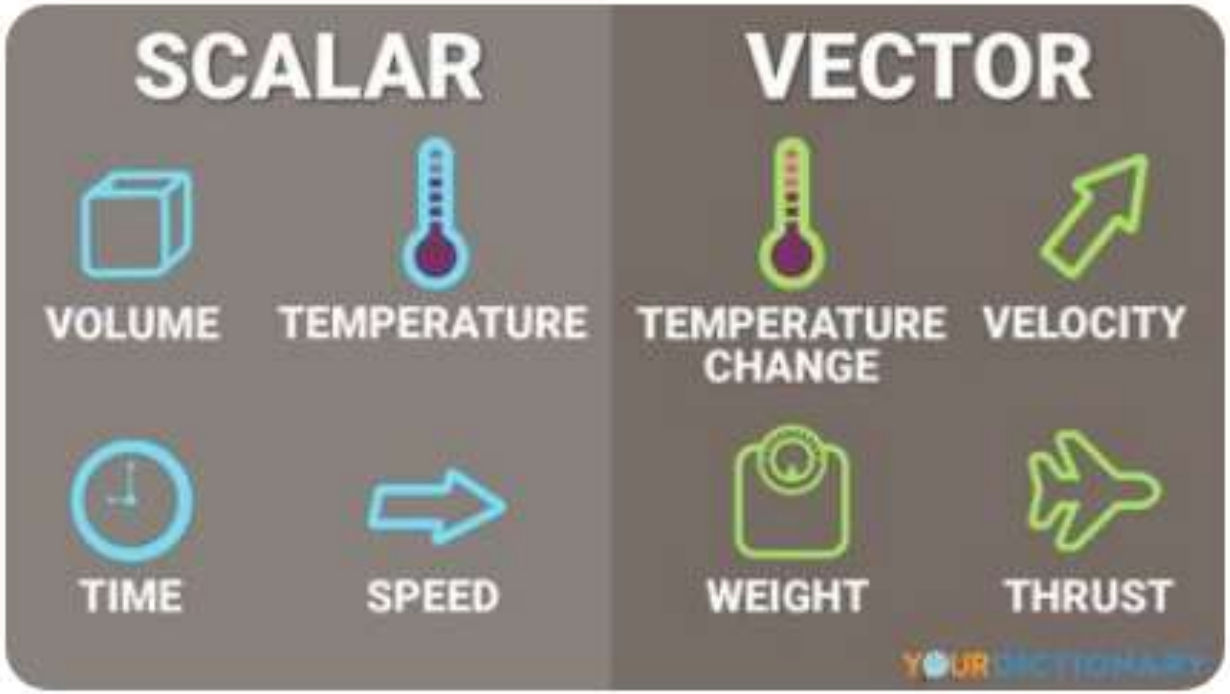
Time: measure of succession of events → basic quantity in Dynamics

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

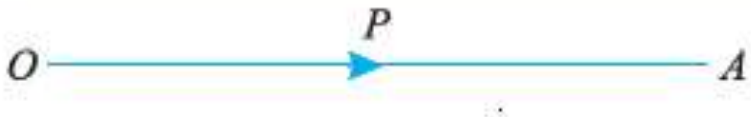
Force: represents the action of one body on another → characterized by its magnitude, direction of its action, and its point of application

→ Force is a Vector quantity.

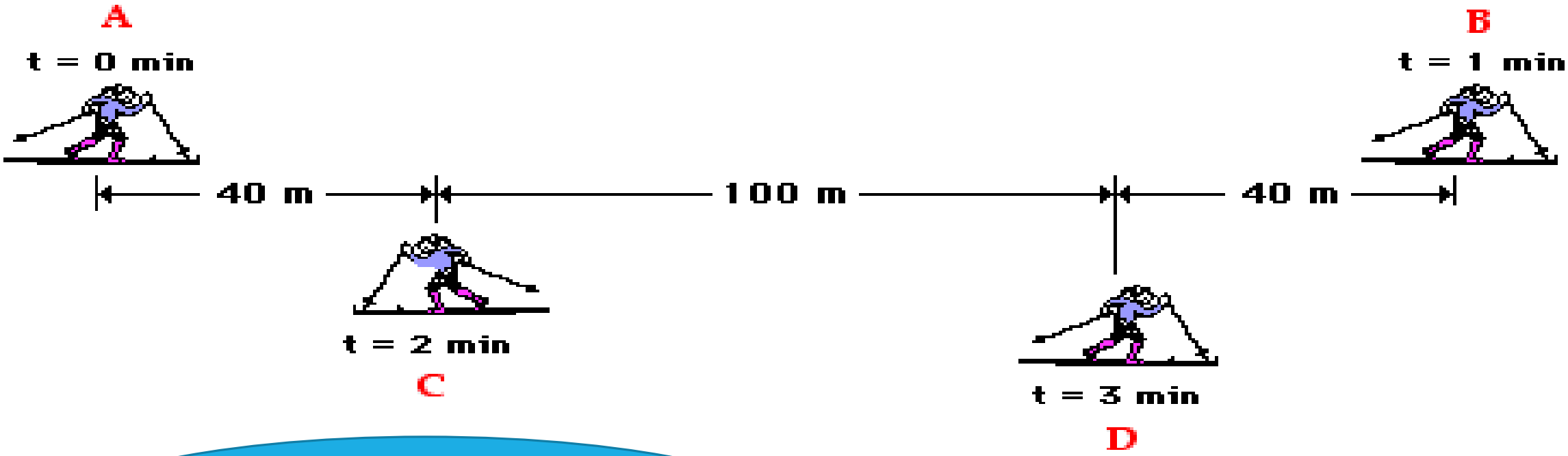
SCALAR & VECTOR



The velocity of this cyclist is an example of a vector quantity.



Use the diagram to determine the resulting displacement and the distance traveled by the skier during these three minutes.



The skier covers a distance of (180 m + 140 m + 100 m) = 420 m and has a displacement of 140 m, rightward.

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

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

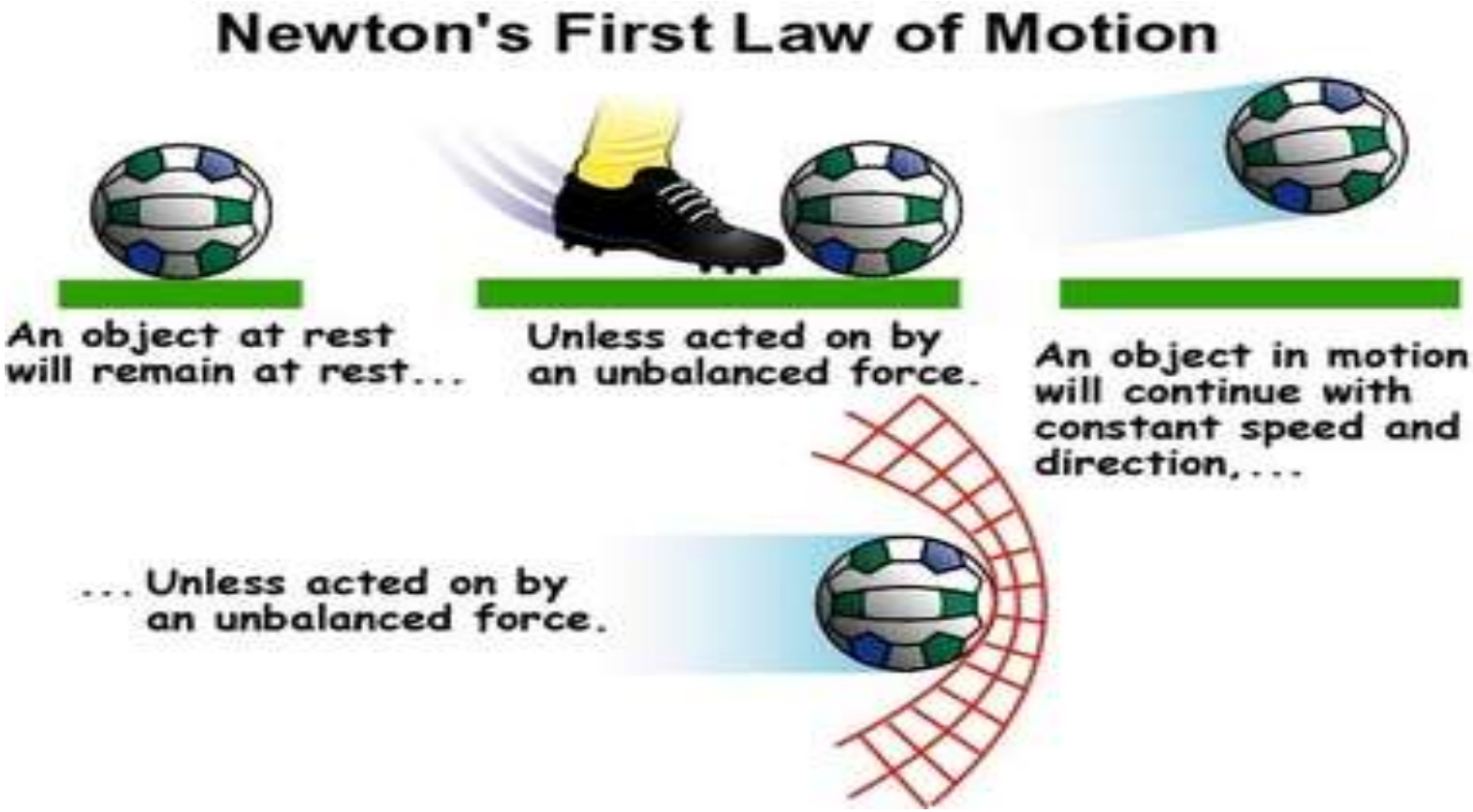
Concentrated Force: Effect of a loading which is assumed to act at a point (CG) on a body.

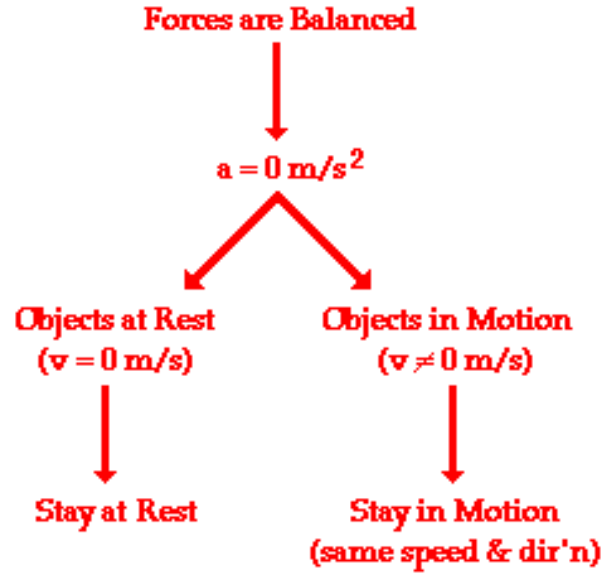
- Provided the area over which the load is applied is very small compared to the overall size of the body.

Ex: Contact Force between a wheel and ground.

LAWS OF MECHANICS

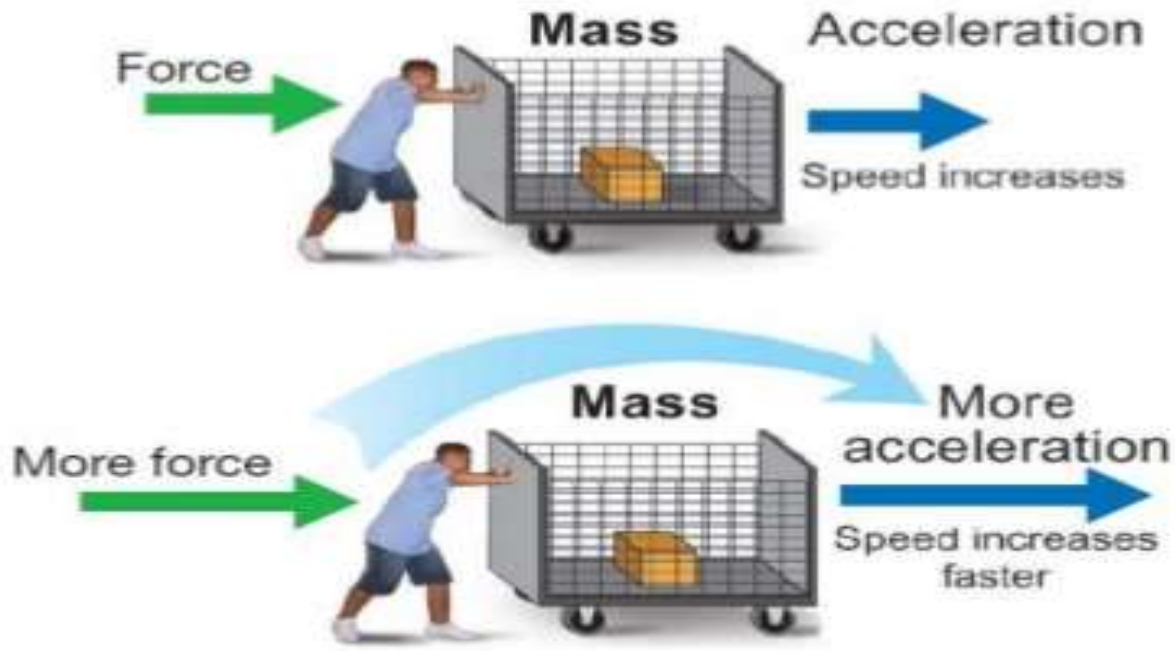
Newton's first law of motion:





LAWS OF MECHANICS

Newton's second law of motion:



Forces are Unbalanced

↓

There is an acceleration

↙ ↘

The acceleration depends directly upon the "net force"

The acceleration depends inversely upon the object's mass.

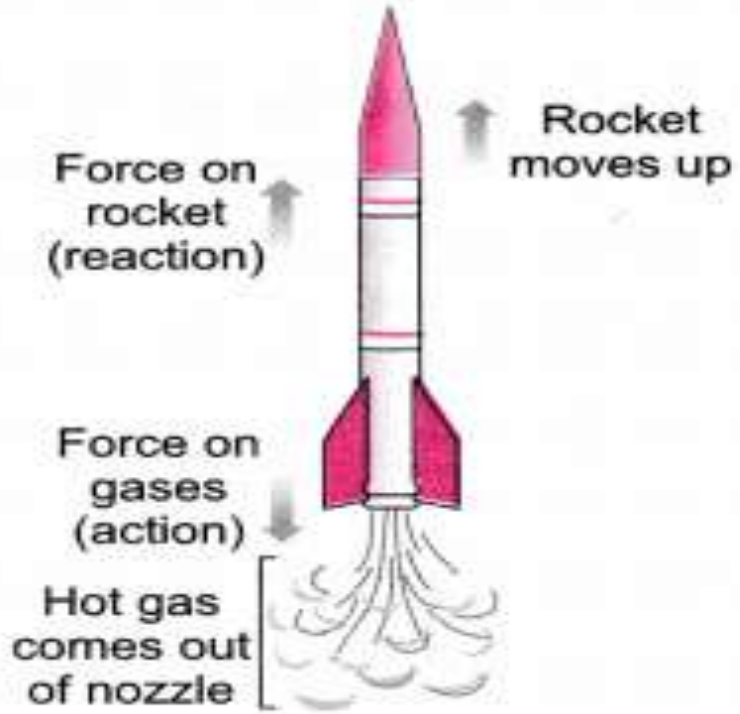
LAWS OF MECHANICS

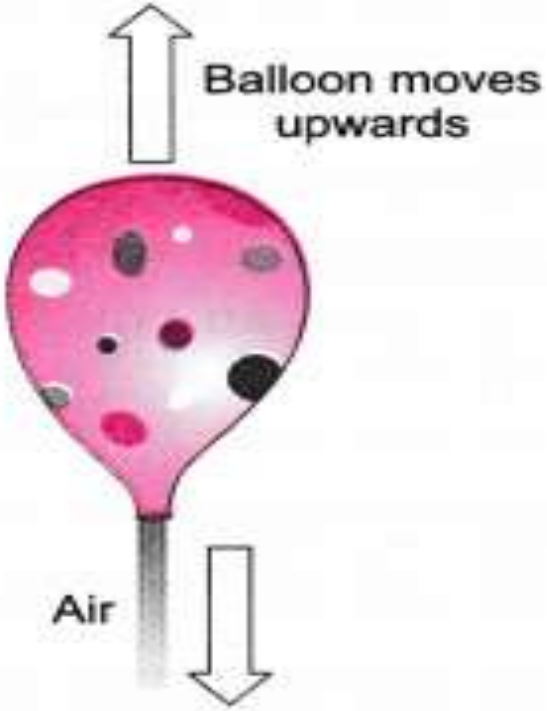
Newton's second law of motion:

	Net Force (N)	Mass (kg)	Acceleration (m/s/s)
1.	10	2	See Answer
2.	20	2	See Answer
3.	20	4	See Answer
4.	See Answer	2	5
5.	10	See Answer	10

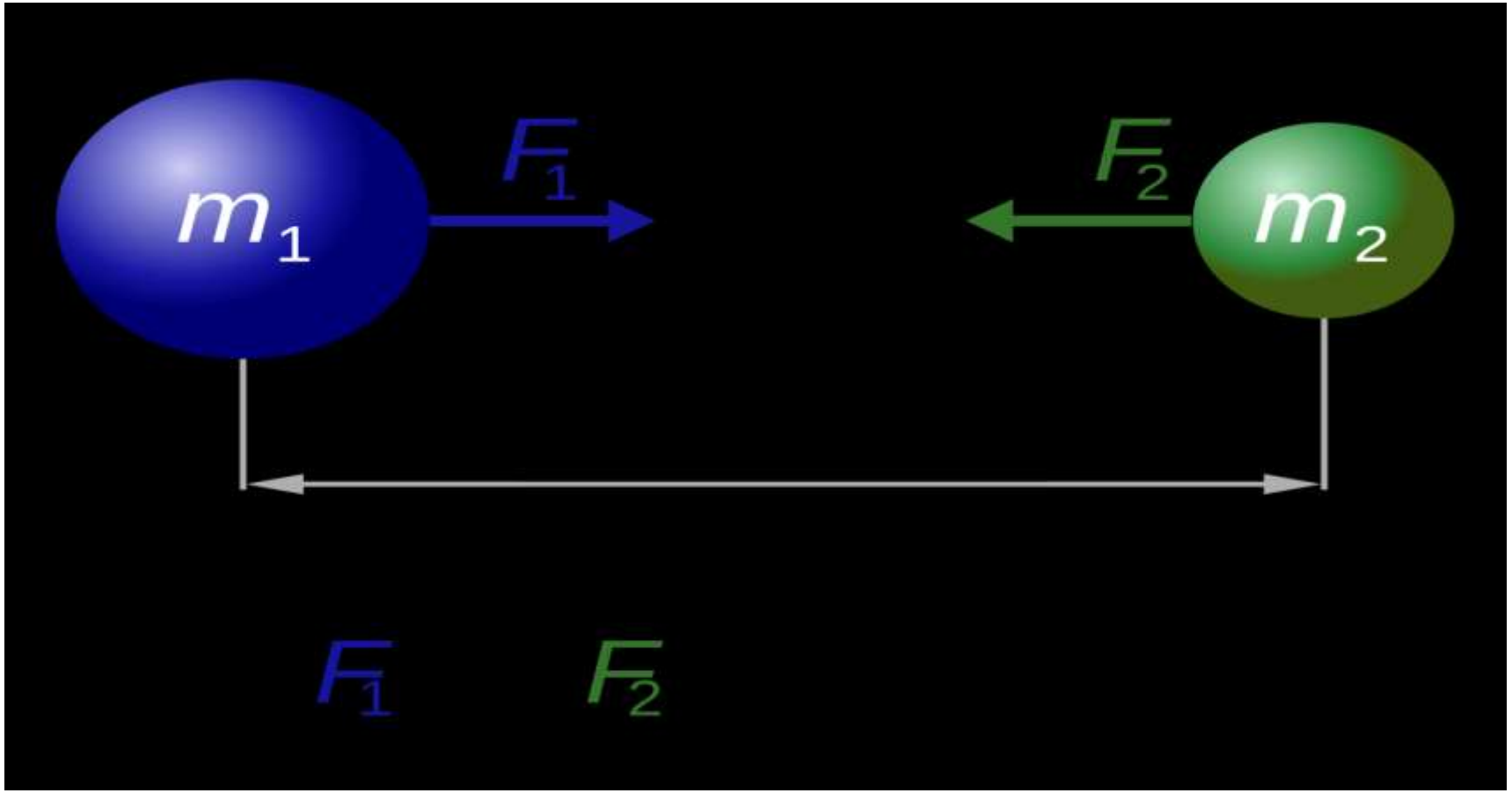
LAWS OF MECHANICS

Newton's third law of motion:





GRAVITATION LAW OF ATTRACTION



FORCE

DEFINITIONS:

- ✓ Force is a **push or pull**.
- ✓ Force is **the capacity to do work or cause Physical Change**.
- ✓ **Physical power or strength possessed** by a living being.

CHARACTERISTICS OF A FORCE

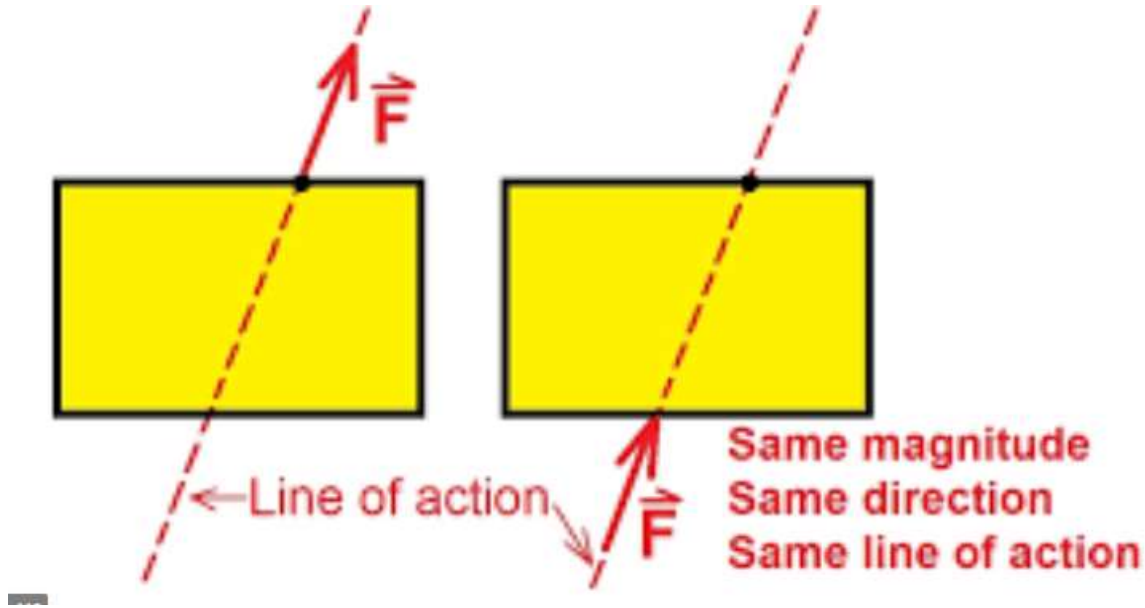
How Much…..?? – **Magnitude**

Where….???? - **Point of Application**

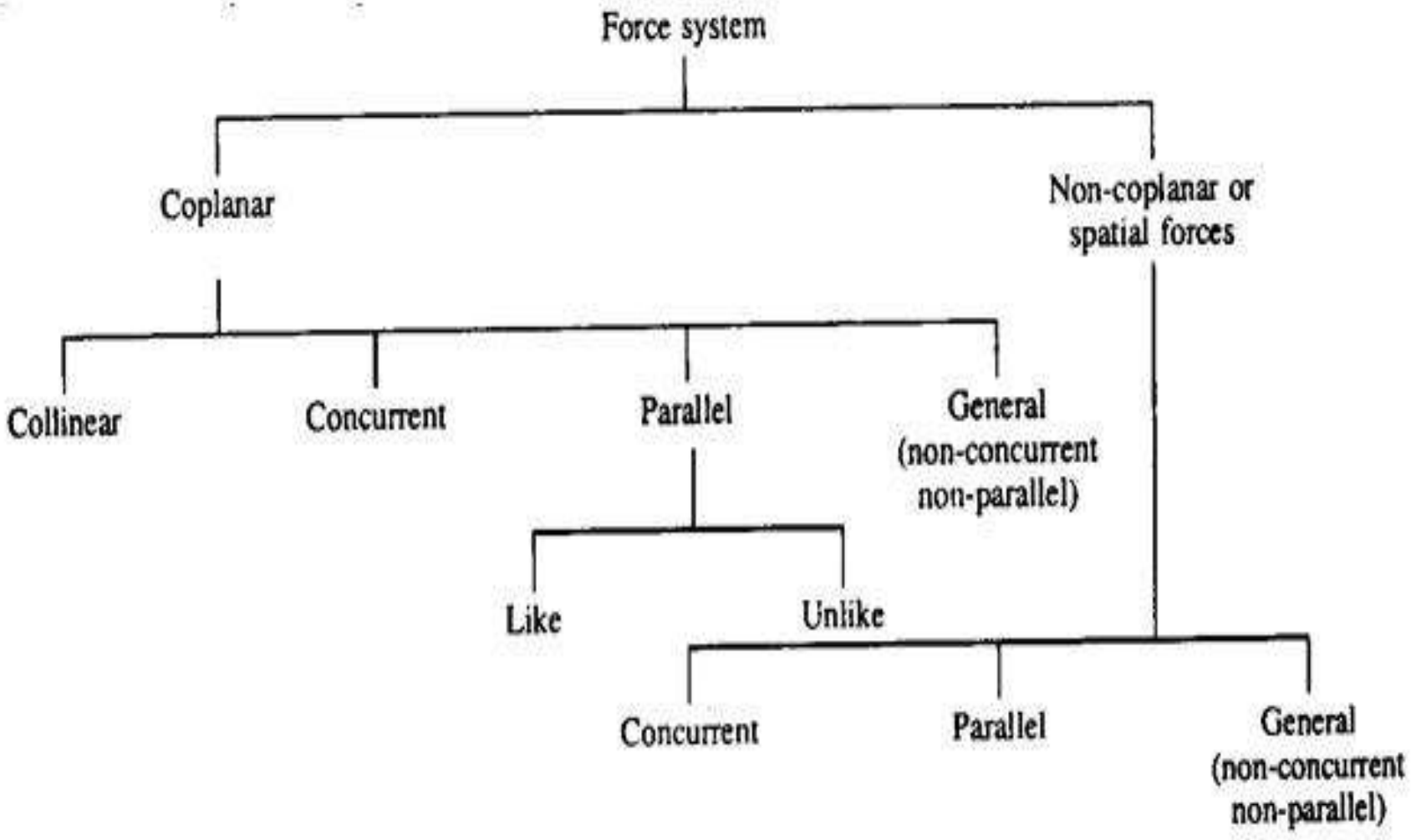
Path……!!!! - **Direction (or) Line of Action**

PRINCIPLE OF TRANSMISSIBILITY OF FORCES

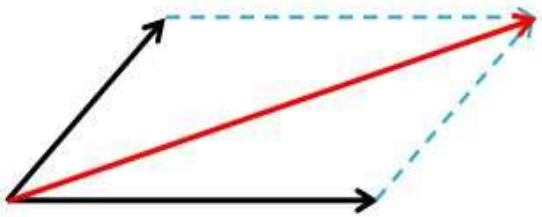
If a force acts at any point on a †rigid body, it may also be considered to act at any other point on its line of action, provided this point is rigidly connected with the body



SYSTEM OF FORCES

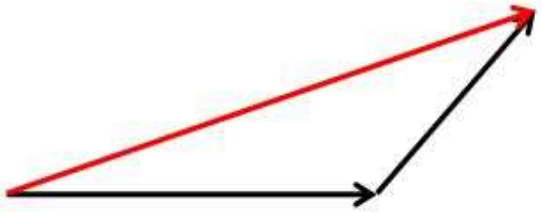


The Parallelogram Law



- When two vectors are joined tail to tail
- Complete the parallelogram
- The resultant is found by drawing the diagonal

The Triangle Law



- When two vectors are joined head to tail
- Draw the resultant vector by completing the triangle

PROBLEM-1

Two forces of 100 N and 150 N are acting simultaneously at a point. What is the resultant of these two forces, if the angle between them is 45°?

Solution. Given : First force (F_1) = 100 N; Second force (F_2) = 150 N and angle between F_1 and F_2 (θ) = 45°.

We know that the resultant force,

$$R = \sqrt{F_1^2 + F_2^2 + 2 F_1 F_2 \cos\theta}$$

$$= \sqrt{(100)^2 + (150)^2 + 2 \times 100 \times 150 \cos 45^\circ}\ \text{N}$$

$$= \sqrt{10\,000 + 22\,500 + (30\,000 \times 0.707)}\ \text{N}$$

$$= 232\ \text{N} \quad \textbf{Ans.}$$

PROBLEM -2

Two forces act at an angle of 120°. The bigger force is of 40 N and the resultant is perpendicular to the smaller one. Find the smaller force.

Solution. Given : Angle between the forces $\angle AOC = 120°$, Bigger force $(F_1) = 40$ N and angle between the resultant and F_2 $(\angle BOC) = 90°$;

Let F_2 = Smaller force in N

From the geometry of the figure, we find that $\angle AOB$.

$$\alpha = 120° - 90° = 30°$$

We know that

$$\tan\alpha = \frac{F_2 \sin\theta}{F_1 + F_2 \cos\theta}$$

$$\tan 30° = \frac{F_2 \sin 120°}{40 + F_2 \cos 120°} = \frac{F_2 \sin 60°}{40 + F_2 (-\cos 60°)}$$

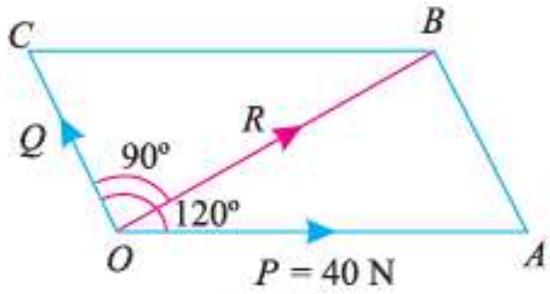


Fig. 2.1.

$$0.577 = \frac{F_2 \times 0.866}{40 - F_2 \times 0.5} = \frac{0.866 F_2}{40 - 0.5 F_2}$$

$$40 - 0.5 F_2 = \frac{0.866 F_2}{0.577} = 1.5 F_2$$

$$2F_2 = 40 \quad \text{or} \quad F_2 = 20 \quad \textbf{Ans.}$$

METHOD OF RESOLUTION FOR THE RESULTANT FORCE

1. Resolve all the forces horizontally and find the algebraic sum of all the horizontal components (*i.e., ΣH*).

2. Resolve all the forces vertically and find the algebraic sum of all the vertical components (*i.e., ΣV*).

3. The resultant *R of the given forces will be* given by the equation : $R = \sqrt{(\sum H)^2 + (\sum V)^2}$

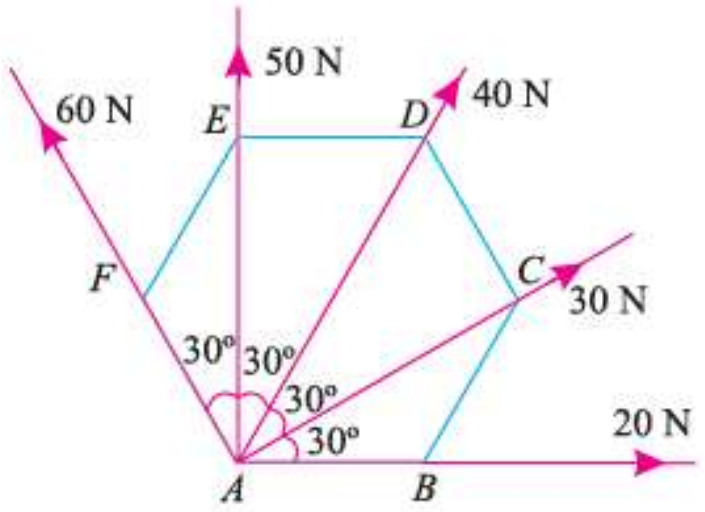
4. The resultant force will be inclined at an angle θ, with the horizontal, such that

$$\tan\theta = \frac{\sum V}{\sum H}$$

PROBLEM-3

The forces 20 N, 30 N, 40 N, 50 N and 60 N are acting at one of the angular points of a regular hexagon, towards the other five angular points, taken in order. Find the magnitude and direction of the resultant force.

The system of given forces is shown in Fig. 2.5



Magnitude of the resultant force

Resolving all the forces horizontally (*i.e.*, along *AB*),

$$\Sigma H = 20\cos 0° + 30\cos 30° + 40\cos 60° + 50\cos 90° + 60\cos 120° \text{ N}$$
$$= (20 \times 1) + (30 \times 0.866) + (40 \times 0.5) + (50 \times 0) + 60\,(-0.5) \text{ N}$$
$$= 36.0 \text{ N} \quad \ldots(i)$$

and now resolving the all forces vertically (*i.e.*, at right angles to *AB*),

$$\Sigma V = 20\sin 0° + 30\sin 30° + 40\sin 60° + 50\sin 90° + 60\sin 120° \text{ N}$$
$$= (20 \times 0) + (30 \times 0.5) + (40 \times 0.866) + (50 \times 1) + (60 \times 0.866) \text{ N}$$
$$= 151.6 \text{ N} \quad \ldots(ii)$$

We know that magnitude of the resultant force,

$$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2} = \sqrt{(36.0)^2 + (151.6)^2} = 155.8 \text{ N} \quad \textbf{Ans.}$$

Direction of the resultant force

Let θ = Angle, which the resultant force makes with the horizontal (*i.e.*, *AB*).

We know that

$$\tan\theta = \frac{\Sigma V}{\Sigma H} = \frac{151.6}{36.0} = 4.211 \quad \text{or} \quad \theta = 76.6° \quad \textbf{Ans.}$$

Note. Since both the values of ΣH and ΣV are positive, therefore actual angle of resultant force lies between 0° and 90°.

PRACTICE PROBLEM

The following forces act at a point :

(i) 20 N inclined at 30° towards North of East,

(ii) 25 N towards North,

(iii) 30 N towards North West, and

(iv) 35 N inclined at 40° towards South of West.

Find the magnitude and direction of the resultant force.