Physics: Mechanics
Subject code: BSC-PHY-104G

Introduction of course

- applications of the laws of mechanics, the laws of motion in studying moving and stationary systems
- The idea of a force, a moment or a couple.
- The effect of internal forces and external forces on static systems. The generation of internal forces and internal force distributions in static systems, as well as understanding friction.

Future scope

- Mechanics begins by quantifying motion, and then explaining it in terms of forces, energy and momentum. This allows us to analyse the operation of many familiar phenomena around us, but also the mechanics of planets, stars and galaxies.
- The principles of mechanics have been applied to three general realms of phenomena. The motions of such celestial bodies as stars, planets, and satellites can be predicted with great accuracy thousands of years before they occur.

Syllabus

UNIT I: Vector Mechanics of Particles

Transformation of scalars and vectors under Rotation transformation; Forces in Nature; Newton’s laws and its completeness in describing particle motion; Form invariance of Newton’s Second Law; Solving Newton’s equations of motion in polar coordinates; Problems including constraints and friction; Extension to cylindrical and spherical coordinates.

UNIT II:Mechanics of Particles in Motion and Harmonic Motion

Potential energy function; F=-Grad V, equipotential surfaces and meaning of gradient; Conservative and non-conservative forces, curl of a force field; Central forces; Conservation of Angular Momentum; Energy equation and energy diagrams; Elliptical, parabolic and hyperbolic orbits; Kepler problem; Application: Satellite maneuvers.

Non-inertial frames of reference; Rotating coordinate system: Five-term acceleration formula. Centripetal and Coriolis accelerations; Applications: Weather systems, Foucault pendulum; Harmonic oscillator; Damped harmonic motion – over-damped, critically damped and lightly-damped oscillators; Forced oscillations and resonance.

UNIT III:Rigid Body Mechanics

Definition and motion of a rigid body in the plane; Rotation in the plane; Kinematics in a coordinate system rotating and translating in the plane; Angular momentum about a point of a rigid body in planar motion; Euler’s laws of motion, their independence from Newton’s laws, and their necessity in describing rigid body motion; Examples.

Introduction to three-dimensional rigid body motion—only need to highlight the distinction from two-dimensional motion in terms of (a) Angular velocity vector, and its rate of change and(b) Moment of inertia tensor; Three dimensional motion of a rigid body where in all points move in a coplanar manner: e.g. Rod exe cutting conical motion with center of mass fixed—only need to show that this motion looks two-dimensional but is threedimensional, and two-dimensional formulation fails.

UNIT IV: Statics of Solids

Free body diagrams with examples on modelling of typical supports and joints; Condition for equilibrium in three and two- dimensions; Friction: limiting and non-limiting cases; Force-displacement relationship; Geometric

compatibility for small deformations; Illustrations through simple problems on axially loaded members like trusses

Unit 1: Vector Mechanics of Particles

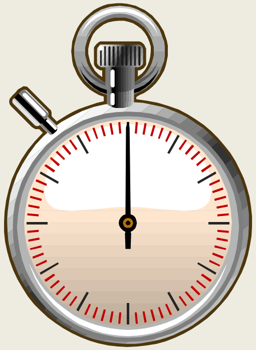
TABLE OF CONTENTS

Scalars

- A **scalar quantity** is a quantity that has magnitude only and has no direction in space

Examples of Scalar Quantities:

- Length
- Area
- Volume
- Time
- Mass

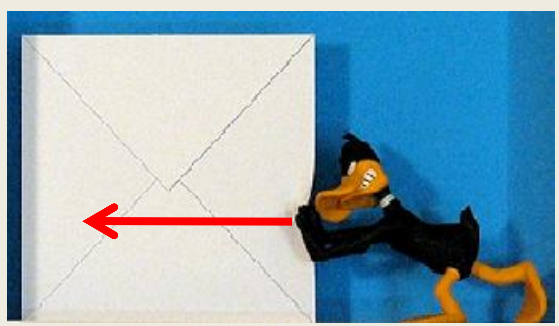


Vectors

- A **vector quantity** is a quantity that has both magnitude and a direction in space

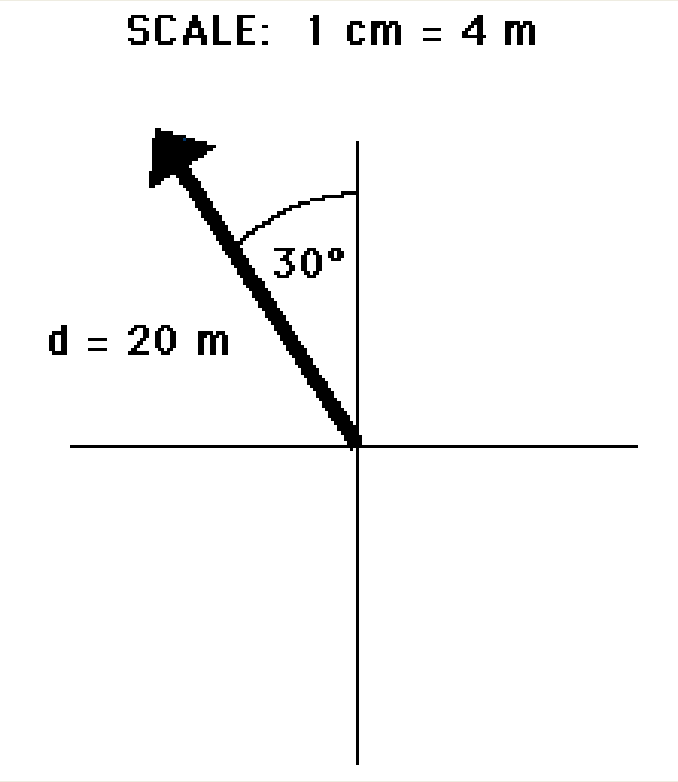
Examples of Vector Quantities:

- Displacement
- Velocity
- Acceleration
- Force



Vector Diagrams

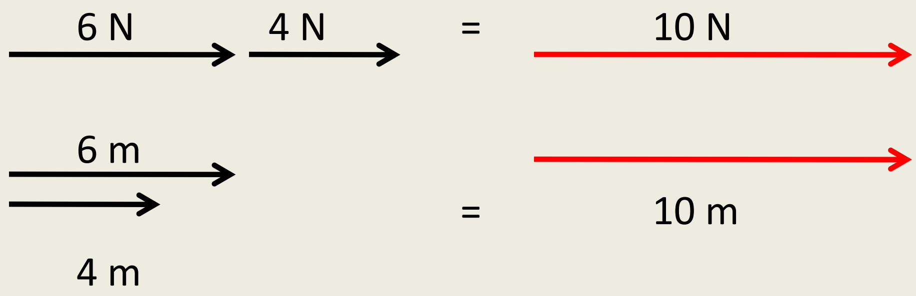
- Vector diagrams are shown using an arrow
- The length of the arrow represents its magnitude
- The direction of the arrow shows its direction



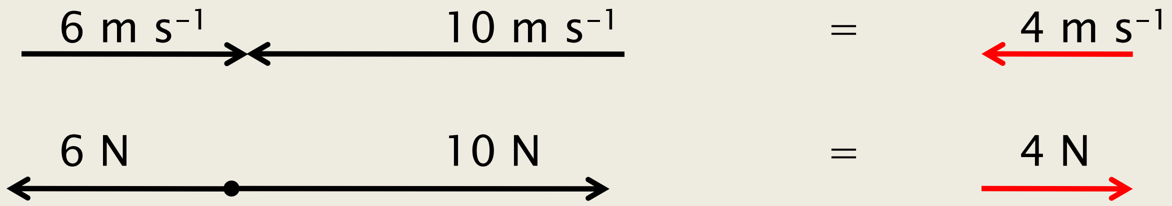
Resultant of Two Vectors

- The **resultant** is the sum or the **combined effect** of two vector quantities

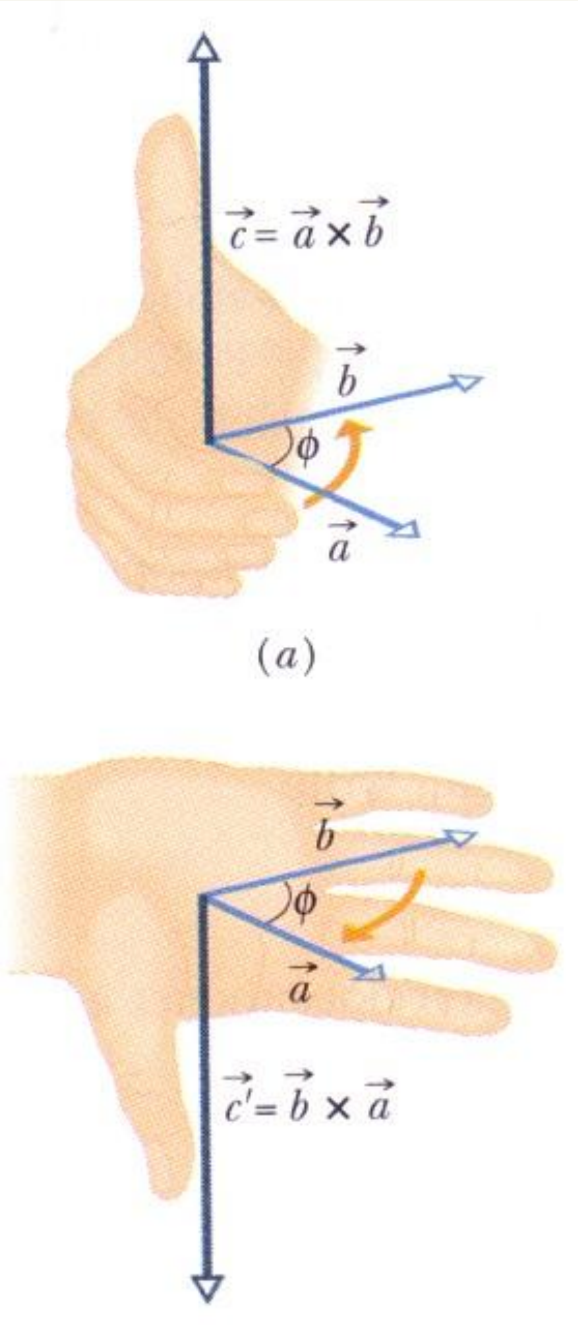
Vectors in the same direction:



Vectors in opposite directions:



The vector product, or cross product



$$\vec{a} \times \vec{b} = \vec{c}, \text{ where } c = ab \sin\phi$$

$$\vec{a} \times \vec{b} = -\left(\vec{b} \times \vec{a}\right)$$

Direction of $\vec{c} \perp$ to both $\vec{a}$ and $\vec{b}$

$$\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$$

$$\hat{i} \times \hat{j} = \hat{k} \qquad \hat{j} \times \hat{i} = -\hat{k}$$

$$\hat{j} \times \hat{k} = \hat{i} \qquad \hat{k} \times \hat{j} = -\hat{i}$$

$$\hat{k} \times \hat{i} = \hat{j} \qquad \hat{i} \times \hat{k} = -\hat{j}$$

What is a Force?

A force is a push or pull acting on an object that changes the motion of the object.

Types of Forces

- Contact Force – Forces that act through direct contact between two objects
  - Applied Forces, Friction
- Long Range Forces – Forces that can act over distances
  - Gravity, Electromagnetic Force (EMF)

Newton’s First Law of Motion (Law of Inertia)

- If no unbalanced forces act on a moving object, then the object will continue to move with a constant velocity (constant speed in a straight line). If an object is at rest it will stay at rest.
- Newton took his concept of forces and combined it with Galileo’s idea of inertia

Inertia

Inertia measures the tendency of an object to resist changes in motion.

- Galileo came up with the idea of inertia
- Objects do not want their motion to change
- Mass measures how much inertia an object has (More mass = More inertia)

Newton’s Second Law of Motion

- Newton discovered the idea of a Force
- He found the Force is proportional to the Acceleration of an object (more Force = more Acceleration)
- He found the Force is proportional to the mass of the object (more mass = more force needed).

Newton’s Second Law of Motion

- Moving objects accelerate when an unbalanced force (F) acts on them. The stronger the force, the greater the acceleration (a). Also, the greater the mass (m) the greater the force required to change the motion.
- Force = mass x acceleration
  - F = ma

Newton’s Second Law of Motion

- Force is a Vector Quantity and therefore has magnitude and direction.
- The direction of the force is the same as the direction of the acceleration.

S.I. Unit For Force

- The Unit for Force is a Newton (N)
  - 1N = 1kg m/s^2
  - A Newton (N) is defined as the amount of force required to accelerate 1 kg of mass at a rate of $1\ m/s^2$.

Net Force

- When Multiple forces are acting on an object. The Net Force is the amount of force that is left after adding all the forces on the object.

- Net force (F_{NET}) = Resultant Force (F_R)

Balanced Forces

Balanced Forces are forces that are equal and opposite so that they cancel out.

10 N East 10 N West

→ ←

Net Force = +10 N + -10 N = 0

Unbalanced Forces

Unbalanced Forces are forces that when added do not cancel out and cause a change in the motion of the object.

30 N East 10 N West

→ ← F_{net} =

+30 N + -10 N = +20 N East

Equilibrium

- First Condition for Equilibrium
  - If the Net Force acting on the object is zero

    $F_{NET} = 0 \quad a = 0$
  - The object is either stationary ($v = 0$) or traveling with a constant velocity (v = constant)

Future Scope and relevance to industry

- https://www.academia.edu/30300917/Vector_Mechanics_for_Engineers_Statics_and_Dynamics_10th_Edition_Beer

NPTEL/other online link

- https://nptel.ac.in/courses/122104014/
- https://nptel.ac.in/courses/115106090/15
- https://nptel.ac.in/courses/112106180/2