

Engineering Mechanics I

Addis Ababa Science and Technology University

Bayelign H.

(BSc in Civil Eng'g & MSc in Structural Eng'g)

Course Outline

1. BASICS OF STATICS

- 1.1. Introduction
- 1.2. Basic Concepts in Mechanics
- 1.3. Scalars and Vectors
- 1.4. Operation with vectors

2. FORCE SYSTEMS

- 2.1. Introduction
- 2.2. Coplanar Force Systems (2-D)
 - 2.2.1. Resolution of a Force
 - 2.2.2. Moment, Couple & Force-Couple systems
 - 2.2.3. Resultants
- 2.3. Non-Coplanar Force Systems (3-D)
 - 2.3.1. Resolution of a Force
 - 2.3.2. Moment, Couple & Force-Couple systems
 - 2.3.3. Resultants

3. EQUILIBRIUM

- 3.1. Introduction
- 3.2. Equilibrium in Two-Dimensions
- 3.3. Equilibrium in Three-Dimensions

4. ANALYSIS OF STRUCTURES

- 4.1. Introduction
- 4.2. Trusses
 - 4.2.1. Plane Trusses
 - Method of Joints
 - Method of Sections
 - 4.2.2. Space Trusses
- 4.3. Pin-ended Multi-Force Structures
 - 4.3.1. Frames
 - 4.3.2. Simple Machines

Course Outline

5. INTERNAL ACTIONS IN BEAMS

- 5.1. Conventions and Classification of beams
- 5.2. Types of loads and reactions in beams
- 5.3. Shear Force and Bending Moment
- 5.4. Static Functions

6. CENTROIDS

- 6.1 Center of Gravity
- 6.2 Center of Lines, Areas, and Volumes
- 6.3 Centroids of Composite Bodies

7. AREA MOMENTS OF INERTIA

- 7.1 Introduction
- 7.2 Composite Areas
- 7.3. Product of Inertia
- 7.4. Transfer and Rotation of Axes

8. FRICTION

- 8.1. Introduction
- 8.2. Types of Friction
- 8.3. Dry Friction
- 8.4. Applications of Friction in Mechanics

Assessments/Requirement:

Assignments & continuous assessment ..50%

Quiz.....
10%

Test.....
20%

Chapter One

Basics of Statics

1.1 Introduction

- **Mechanics** is an area of science concerned with the behavior of physical bodies when subjected to forces or displacement.



Rotation



1.1 Introduction

- The major division of the mechanics discipline separates **classic mechanics** from **quantum mechanics**.
- **Quantum mechanics** is of a wider scope. It encompasses classical mechanics as a sub-discipline.
- Quantum mechanics has superiority over classic mechanics at the foundation level and is indispensable for explanation and prediction of process at molecular and subatomic level.

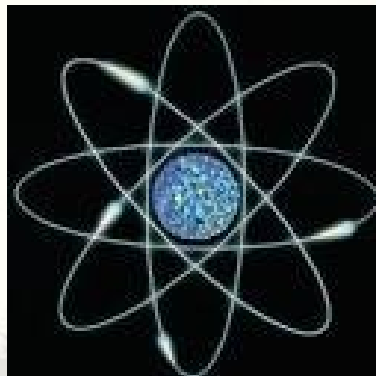


Figure of an
Atom

1.1 Introduction

➤ Parts of classical mechanics

- **Newtonian mechanics:** kinematics and dynamics
- **Analytical mechanics:** emphasizes on system energy
- **Solid mechanics:** elasticity, the properties of deformable bodies
- **Statics:** Rigid bodies in mechanical equilibrium
- **Fluid mechanics:** the motion of fluids
- **Soil mechanics:** mechanical behavior of soil
- **Hydraulics:** mechanical properties of liquids

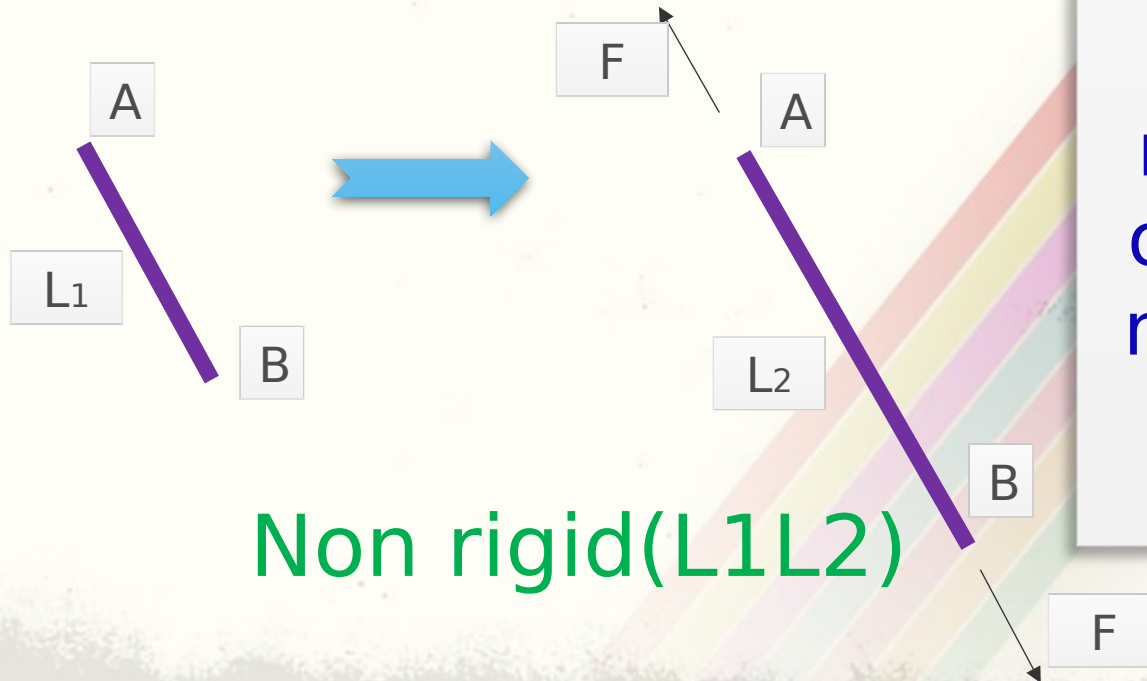
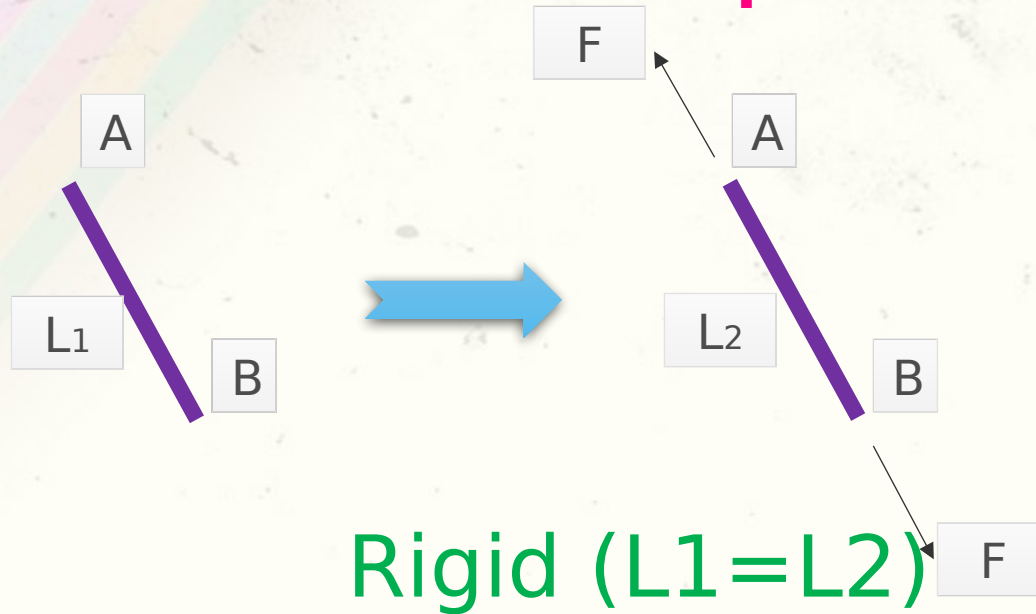
➤ Parts of quantum mechanics

- **Schrodinger wave mechanics:** used to describe the motion of the wave function of a single particle
- **Particle physics:** the motion, structure, and reaction of the particles
- **Nuclear physics:** the motion, structure, and reaction of the nuclei

1.2 Basic Concepts

- **The following definition and concepts are basic to the study of mechanics.**
- **Space:** geometric region occupied by bodies
- **Time:** the measure of the succession of events
- **Mass:** measure of inertia of a body. Mass can also be thought of as the quantity of matter in a body
- **Force:** the action of one body on other. It tends to move a body in its direction of action
- **Particle:** a body of negligible dimensions
- **Rigid body:** a body is considered rigid when the change in distance between any two of its points is negligible.

1.2 Basic Concepts



Diamond
is
considered
to be the
hardest
naturally
occurring
material

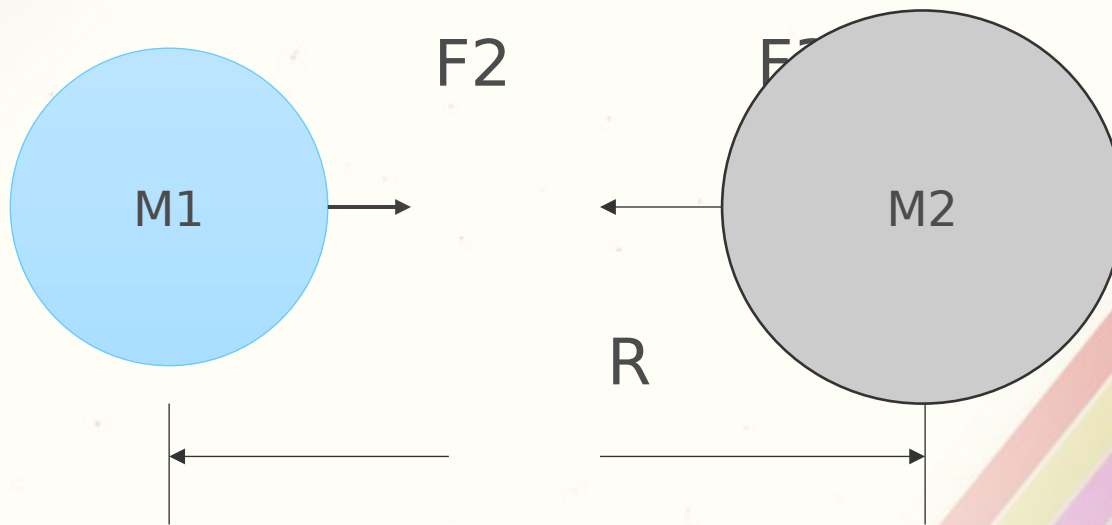


Fundamental Principles

- **The three laws of newton**
- **First law:** a particle remain at rest or continues to move in a straight line with a uniform velocity if there is no unbalanced force acting on it
- **Second law:** the acceleration of a particle is proportional to the resultant force acting on it and its in the direction of this resultant force
- **Third law:** the forces of action and reaction of interacting are equal in magnitude, opposite in direction and collinear

Fundamental principles

- Law of gravitation by Newton



Fundamental Principles

- **Example**

Using law of gravitation by newton, calculate the weight of a 60kg man given

- mass of earth = kg,
- constant of gravitation, $G =$
- Radius of earth = 6371km

Solution:

1.3 Scalars and Vectors

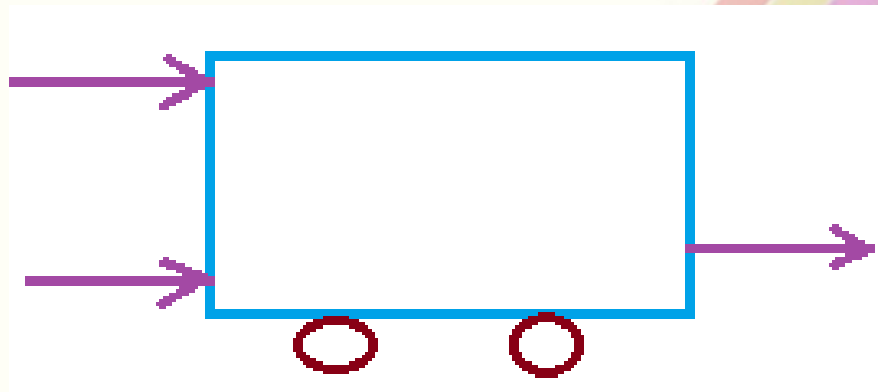
- **Scalar quantities:** are physical quantities that can be completely described (measured) by their **magnitude alone**.
- These quantities **do not need a direction** to point out their application (Just a value to quantify their measurability). They only need the magnitude and the unit of measurement to fully describe them.
- **E.g.** Time[s], Mass [Kg], Area [m²], Volume [m³], Density [Kg/m³],

1.3 Scalars and Vectors

- **Vector quantities:** Like Scalar quantities, Vector quantities **need a magnitude**. But in addition, they **have a direction**, and sometimes **point of application** for their complete description.
- Vectors are represented by short arrows on top of the letters designating them.
- **E.g.** Force [N, Kg.m/s²], Velocity [m/s], Acceleration [m/s²], Momentum [N.s, kg.m/s], etc.

Types of Vectors

- **Generally vectors fall into the following three basic classifications:**
- **Free Vectors:** are vectors whose action in space is **not confined or associated with a unique line** in space; hence they are 'free' in space.
- **E.g.** Displacement, Velocity, Acceleration, Couples, etc.



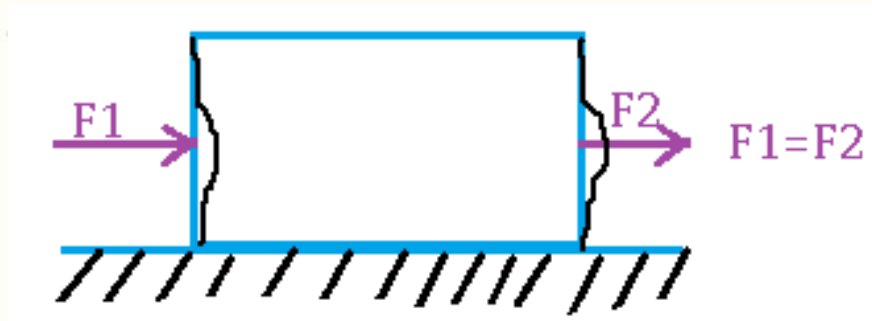
Types of Vector

- **Sliding Vectors**: are vectors for which a **unique line in space** along the action of the quantity must be maintained.
- **E.g.** Force acting on rigid bodies.



Types of Vector

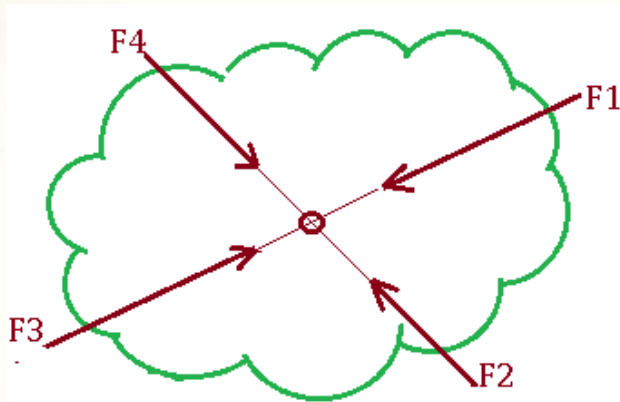
- **Fixed Vectors:** are vectors for which a **unique** and **well-defined point of application** is specified to have the same external effect.
- **E.g.** Force acting on non-rigid (deformable) bodies.



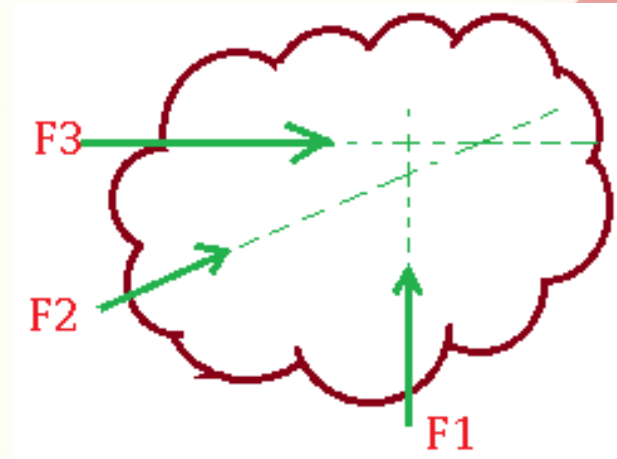
Classification of Vector

Based on coexistence of vector

➤ **Concurrent vector**:- the line of action of the vector meet at one point.



concurrent
concurrent



non

Classification of Vector

- **Collinear vectors**:- all of the line of actions of them are parallel.



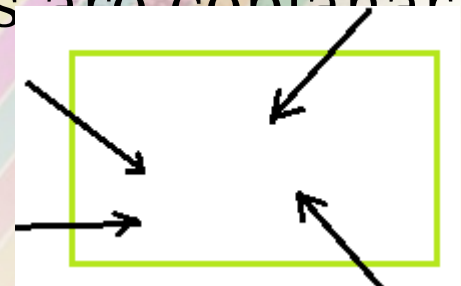
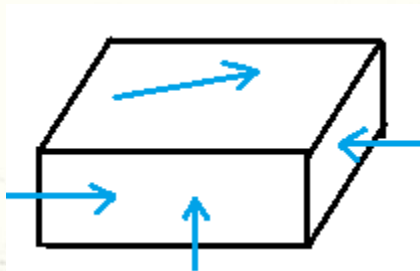
linear



non linear

- **Coplanar vectors**:- lines of action of the vectors lie on the same plane. Any two vectors are coplanar.

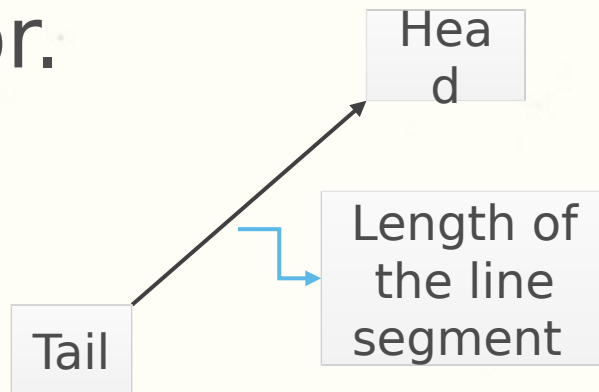
- **Space vectors**



Representation of Vector

A. Graphical representation

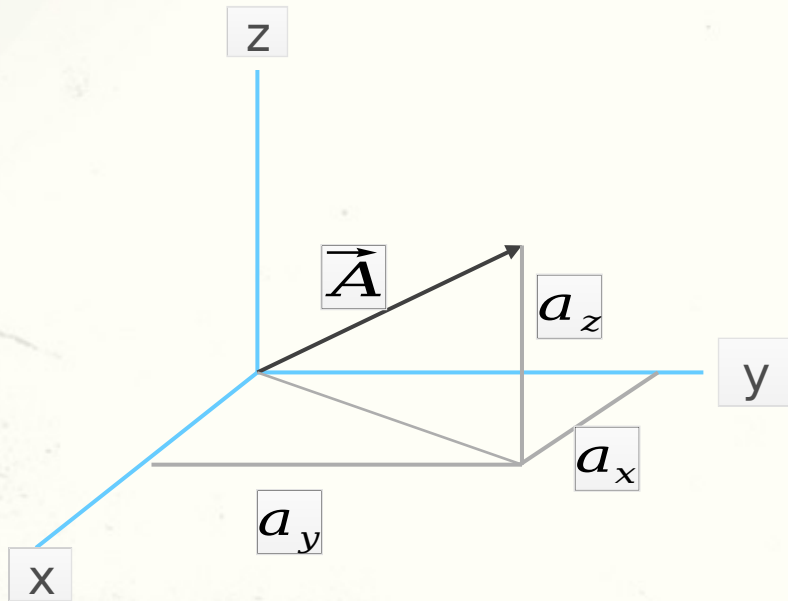
Graphically, a vector is **represented by a directed line segment** headed by an arrow. The length of the line segment is equal to the magnitude of the vector to some predetermined scale and the **arrow indicates the direction** of the vector.



Representation of Vector

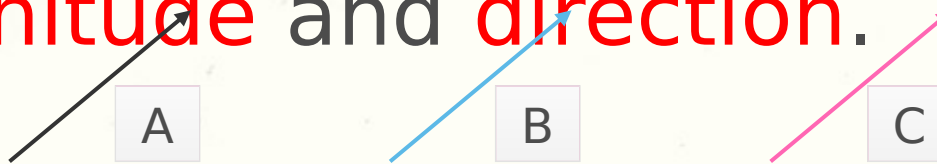
B. Algebraic (Arithmetic) representation

- Algebraically a vector is represented by the components of the vector along the three dimensions.



Properties of Vectors

- **Equality of vectors:** Two free vectors are said to be equal if and only if they have the **same magnitude** and **direction**.



$$\vec{A} = \vec{B} = \vec{C}$$

- **The Negative of a vector:** is a vector which has **equal magnitude** to a given vector but **opposite in direction**.



Properties of Vector

- **Null vector:** is a **vector of zero magnitude**. A null vector has an arbitrary direction.
- **Unit vector:** is any **vector whose magnitude is unity**.
- A unit vector along the direction of a certain vector, say vector A (denoted by u_A) can then be found by dividing vector A by its magnitude.

1.4 Operation With Vectors

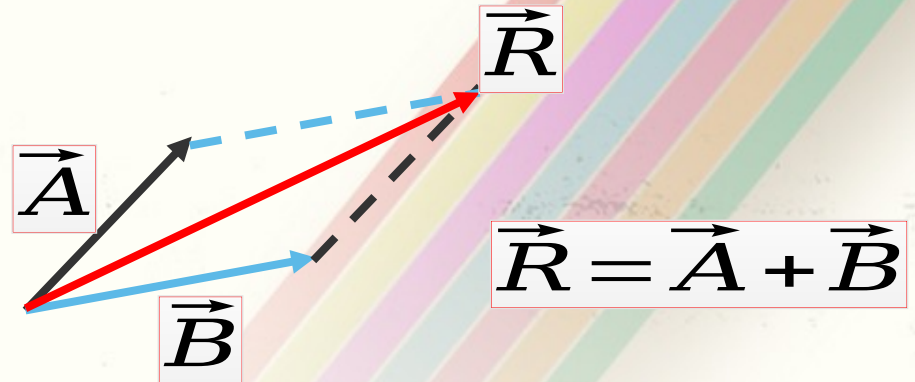
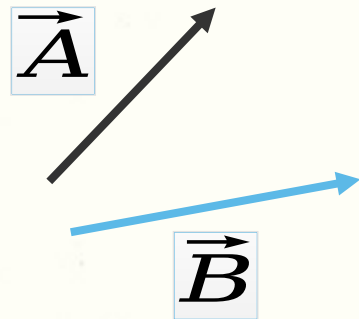
- **Vector Addition or Composition**
- **Composition** of vectors is the **process** of adding two or more vectors to get a single vector, a Resultant
- **Techniques of Adding Vectors**
 - A. Graphical Method
 - B. Analytical Method

1.4 Operation With Vectors

A. Graphical Method

I. The parallelogram law

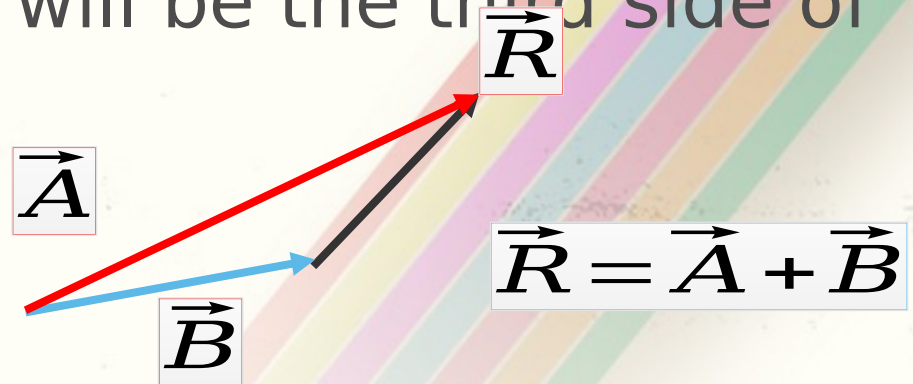
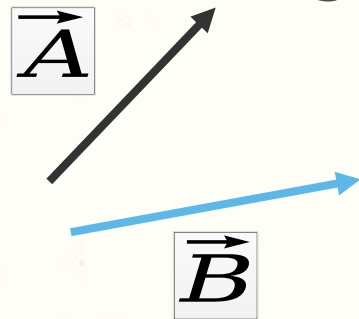
- Two free vectors drawn on scale, the resultant of the vectors can be found by drawing a parallelogram having sides of these vectors, and the resultant will be the diagonal



1.4 Operation With Vectors

II. The Triangle rule

- The Triangle rule is a corollary to the parallelogram axiom and it is fit to be applied to more than two vectors at once. It states “If the two vectors, which are drawn on scale, are placed tip (head) to tail, their resultant will be the third side of the triangle



1.4 Operation With Vectors

B. Analytic method

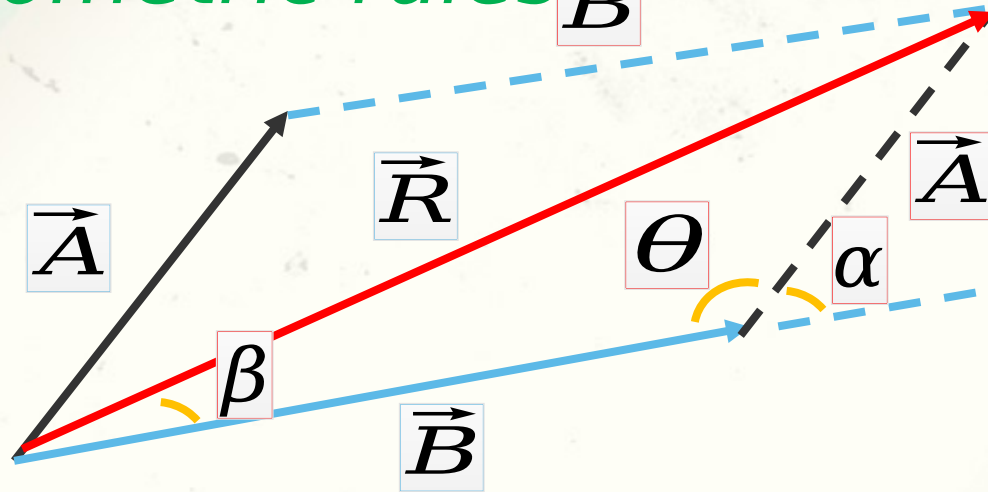
- The analytic methods are the direct applications of the above postulates and theorems in which the resultant is found mathematically

1. Trigonometric rules

The resultant of two vectors can be found analytically from the parallelogram rule by applying the cosine and the sine rules.

1.4 Operation With Vectors

I. Trigonometric rules



From Cosine law

..... magnitude

From Sine law

...direction



1.4 Operation With Vectors

II. Component Method of Vector Addition

- This is the most **efficient method of vector addition**, especially when the number of vectors to be added is large.
- In this method first the components of each vector along a convenient axis will be calculated.
- Then the **sum of the components** of each vector along each axis will be **equal to the components of their**

1.4 Operation With Vectors

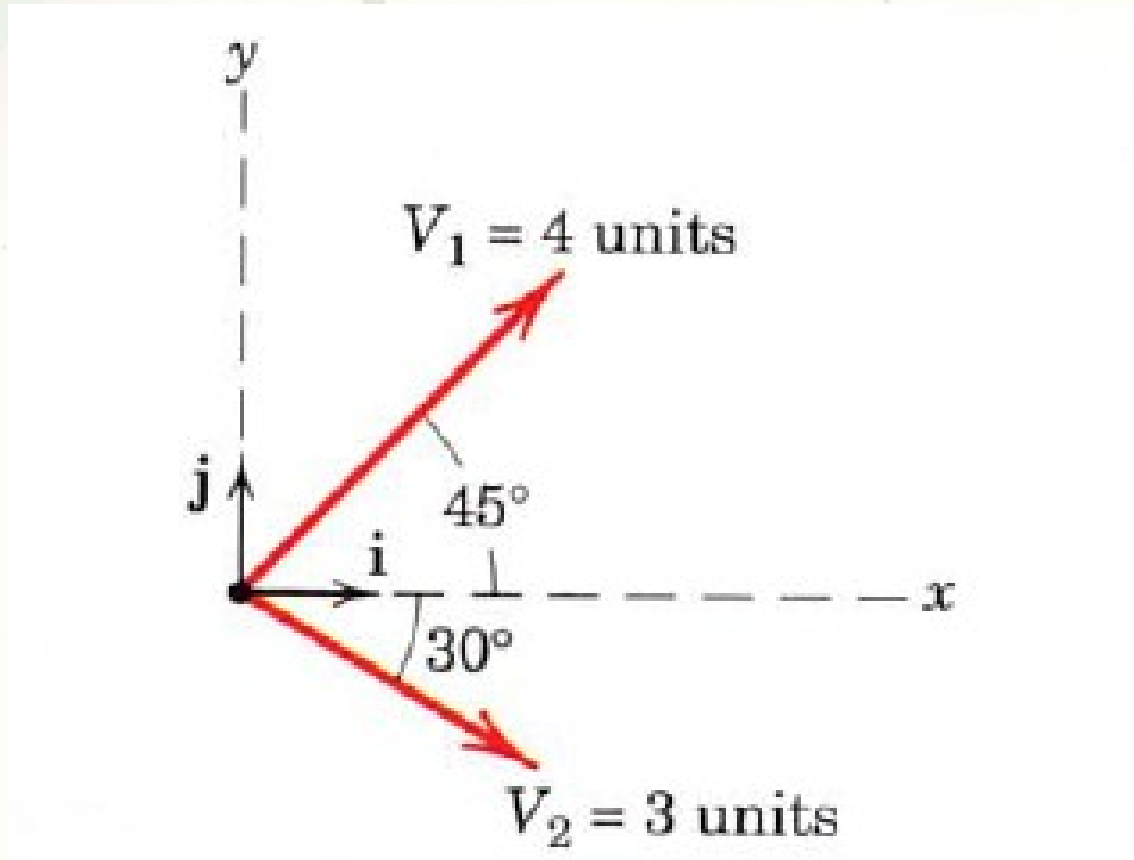
- Example

For vector V_1 and V_2 shown on the next slide

1. Determine the magnitude S of their vector sum $S = V_1 + V_2$
2. Determine the angle between S and the positive x -axis.
3. Write S as a vector in terms of unit vectors i and j and then write a unit along the vector sum S .
4. Determine the vector difference $D = V_1 - V_2$

1.4 Operation With Vectors

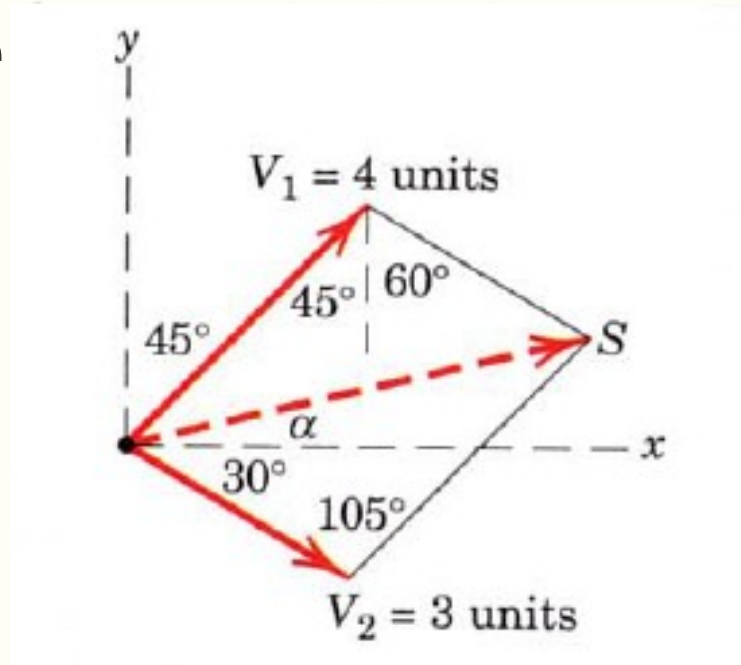
- Example cont..



1.4 Operation With Vectors

- Solution

1. We construct to scale the paralle



- Solution

Diagram illustrating the addition of two vectors V_1 and V_2 to find their resultant S using the triangle rule.

- Vector V_1 has a magnitude of 4 units and is directed at 45° to the positive x-axis.
- Vector V_2 has a magnitude of 3 units and is directed at 30° to the positive x-axis.
- The resultant vector S is the third side of the triangle formed by V_1 and V_2 .
- The angle between V_1 and V_2 is 105° .
- The angle between V_1 and S is 60° .
- The angle between V_2 and S is α .

1.4 Operation With Vectors

- Solution

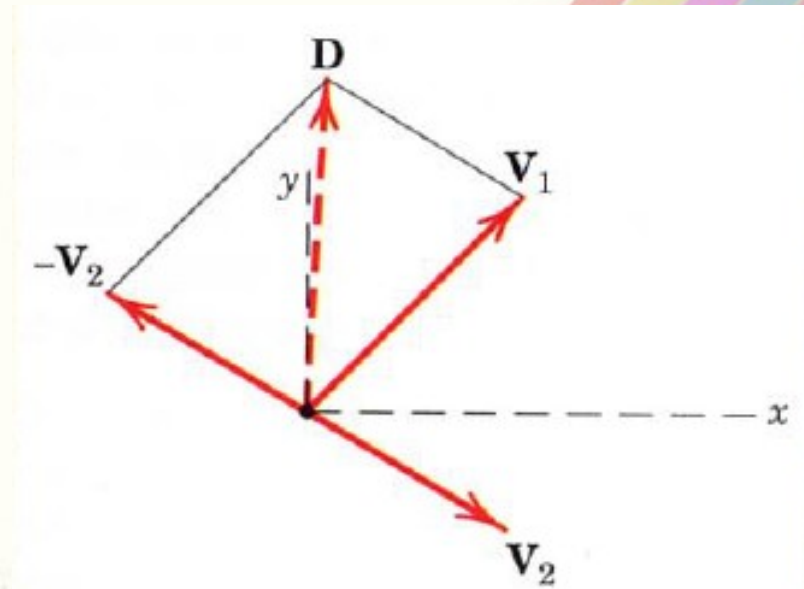
3. With knowledge of $\mathbf{S}$ and

Unit vector in the direction of $\mathbf{S}$

1.4 Operation With Vectors

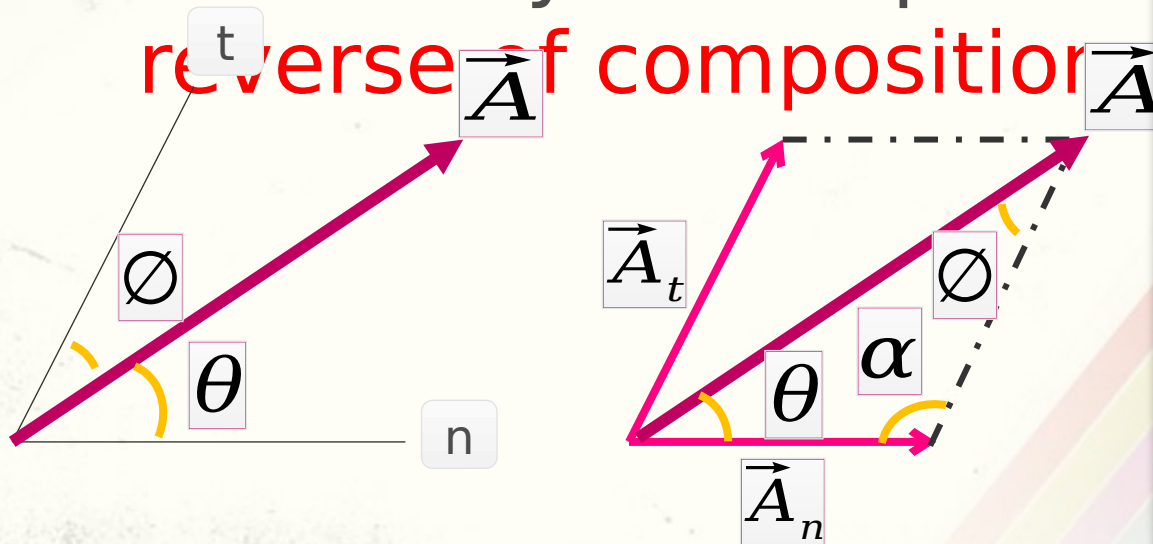
- Solution

3. The vector difference D



1.4 Operation With Vectors

- **Decomposition of vectors**
- **Decomposition** is the process of getting the **components** of a given vector along some other different axis.
- Practically decomposition is the **reverse of composition**



For rectangular coordinate system

1.4 Operation With Vectors

Vector Multiplication

1. Multiplication of vectors by scalars

2. Multiplication of vector by a vector

2.1 Dot Product: Scalar Product

2.2. Cross Product: Vector Product

1. Multiplication of vectors by scalars

Let n be a non-zero scalar and $\vec{a}$ be a vector, then multiplying $\vec{a}$ by n gives as a vector whose magnitude is $n|\vec{a}|$ and whose **direction is in the direction of $\vec{a}$ if n is positive or is in opposite direction to $\vec{a}$ if n is negative.**

1.4 Operation With Vectors

2. Multiplication of vector by a vector

2.1 Dot Product: Scalar Product

- The scalar product of two vectors A and B which are θ degrees inclined from each other denoted by $A \cdot B$ (A dot B) will result in a scalar of magnitude
i.e.
- If analytically expressed &

1.4 Operation With Vectors

2.2. Cross Product: Vector Product

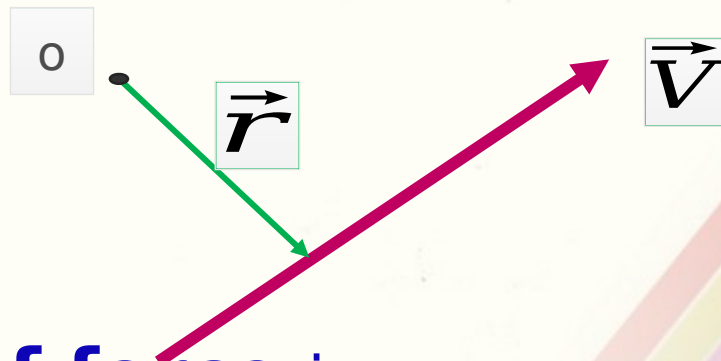
- The **vector product** of two vectors A and B that are θ degrees apart denoted by $A \times B$ (A cross B) **is a vector of magnitude**
- The direction is **perpendicular to the plane formed by the vectors A and B** . The sense of the resulting vector can be determined by the right-hand rule.

&

1.4 Operation With Vectors

- **Moment of a Vector**
- The moment of a vector V about any point O is given by

is a position vector from point O to any point on the line of action of the vector



Moment of force is a measure of a force's to produce torsion or rotation about an axis

The background of the slide is a light, textured grey. In the top-left and bottom-right corners, there are decorative elements consisting of several parallel diagonal stripes in a rainbow color palette (red, orange, yellow, green, blue, purple).

Thank You