Engineering Mechanics 1

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1/1 Mechanics

Mechanics is the physical science which deals with the effects of forces on objects

The subject of mechanics is divided into two parts:

1. **Statics**: equilibrium of bodies
2. **Dynamics**: motion of bodies

Applications

- Strength of machines and structures
- Vibrations (engine, building, bridge)
- Fluid mechanics (airplanes, fluid machinery)

1/2 Basic concepts

Space: the region occupied by bodies whose positions are described using coordinate system (meter)

Time: the measure of the succession of events (sec)
Used in dynamics

Mass: the body's resistance to change in velocity (kg)
the body's ability to generate attractive force between itself and another

Force: the action of one body to another (N)

Particle: a body of negligible dimensions (dimensions are not significant to the description of its position or forces applied to it) → concentrated mass

Rigid body: a body with negligible deformation

1/3 Scalars and vectors

Scalars: only *magnitude* is associated

Ex. mass, volume, density, speed, length, angle

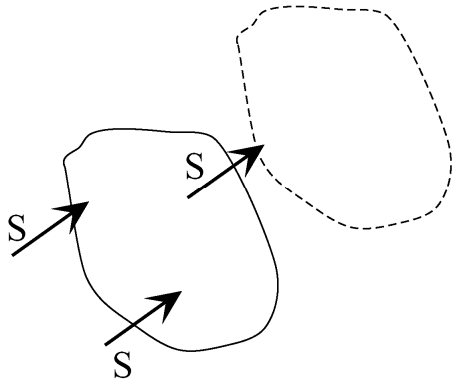
Vectors: *magnitude* and *direction* are important

Ex. Displacement, velocity, acceleration, force, moment

Vectors can be classified by the importance of their position

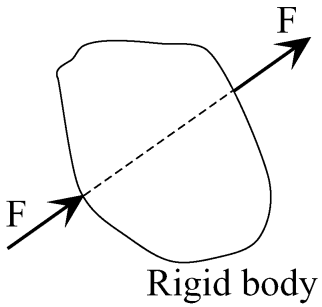
1. Free vector
2. Sliding vector
3. Fixed vector

1/3 Scalars and vectors



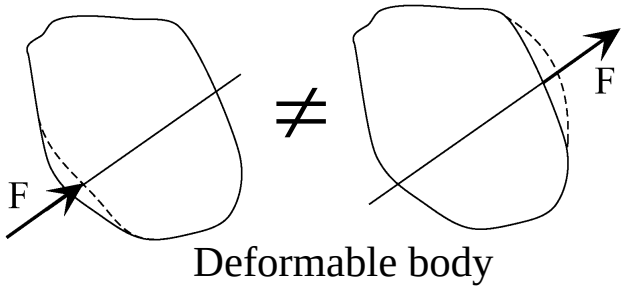
Free vector

Displacement of body moving without rotation



Sliding vector

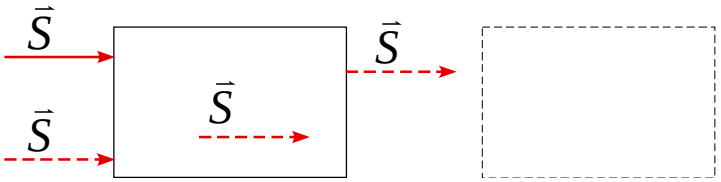
Force acting on a rigid body



Fixed vector

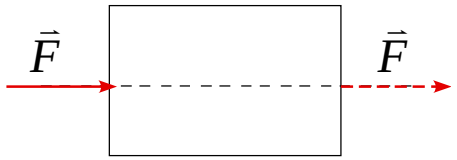
The action of force on a deformable body

1/3 Scalars and vectors



Free vector

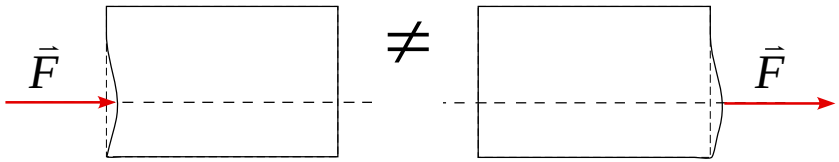
Displacement of body moving without rotation



Rigid body

Sliding vector

Force acting on a rigid body



Deformable body

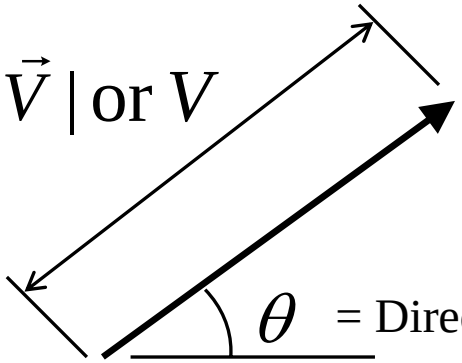
Fixed vector

The action of force on a deformable body

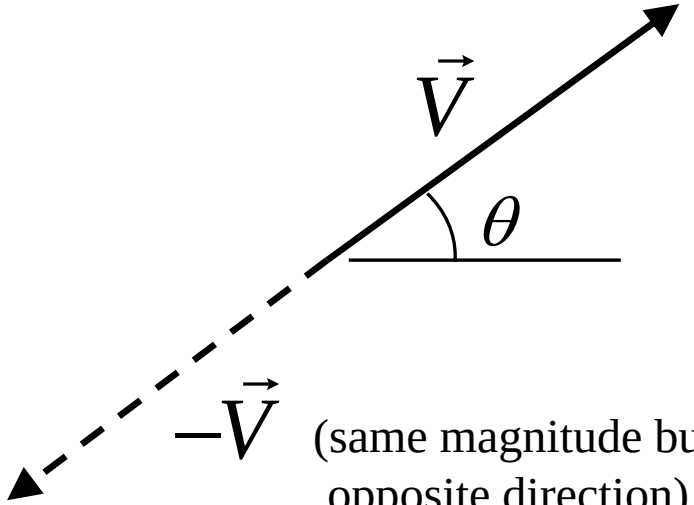
Vector basics (1)

- **Representation**

Magnitude = $|\vec{V}|$ or V

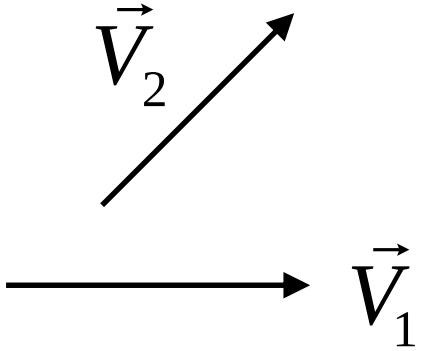


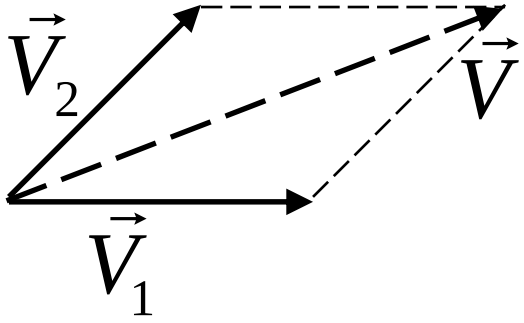
Vector = $\vec{V}$ or $\boldsymbol{V}$



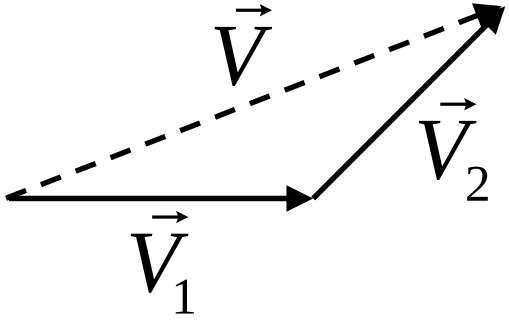
(same magnitude but opposite direction)

- **Addition (parallelogram law)**





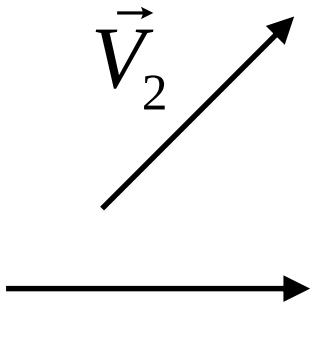
$$\vec{V} = \vec{V}_1 + \vec{V}_2$$



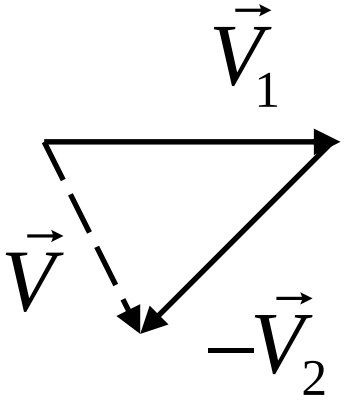
$$V \neq V_1 + V_2$$

Vector basics (2)

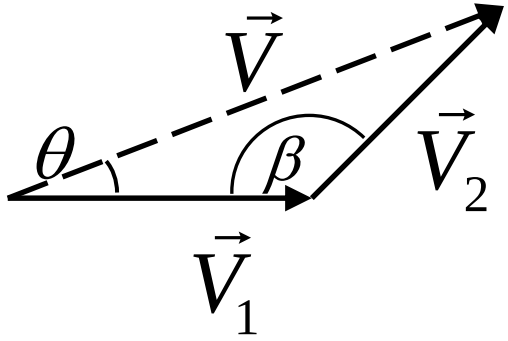
- **Subtraction**



$$\vec{V} = \vec{V}_1 - \vec{V}_2 = \vec{V}_1 + (-\vec{V}_2)$$



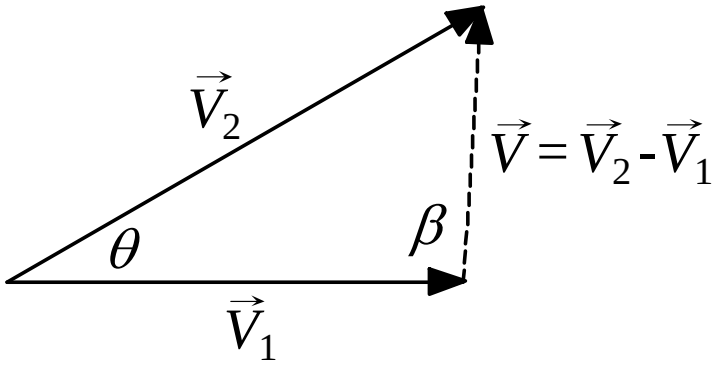
- **Basic relations**



$$V^2 = V_1^2 + V_2^2 - 2V_1V_2\cos(\beta)$$

$$\frac{V_2}{\sin(\theta)} = \frac{V}{\sin(\beta)}$$

Example (1)



Given: $V_2 = 12$, $V_1 = 10$

$\theta = 30$ deg

Find: V and β

cosine law $V^2 = V_1^2 + V_2^2 - 2V_1V_2\cos(\theta)$

$V^2 = 10^2 + 12^2 - 2(10)(12)\cos(30^\circ)$

$V = 6.013$

sine law $\dfrac{V_2}{\sin\beta} = \dfrac{V}{\sin\theta} \longrightarrow \dfrac{12}{\sin\beta} = \dfrac{6.013}{\sin 30^\circ}$

$\beta = 86.26^\circ, 93.74^\circ$

Example (2)

Check by cosine law

$\beta = 86.26^\circ$

cosine law $\quad 12^2 = 10^2 + 6.013^2 - 2(10)(6.013)\cos(86.26^\circ)$

$144 \neq 128$

$\beta = 93.74^\circ$

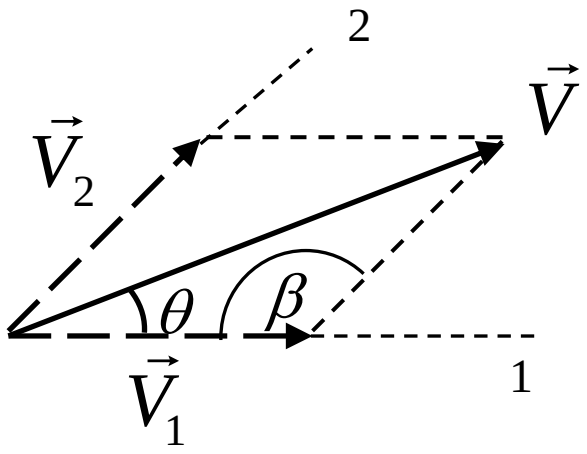
cosine law $\quad 12^2 = 10^2 + 6.013^2 - 2(10)(6.013)\cos(93.74^\circ)$

$144 = 144 \longrightarrow$ **OK**

$\therefore V = 6.013, \beta = 93.74^\circ \longrightarrow$ Ans

Vector basics (3)

- **Components**

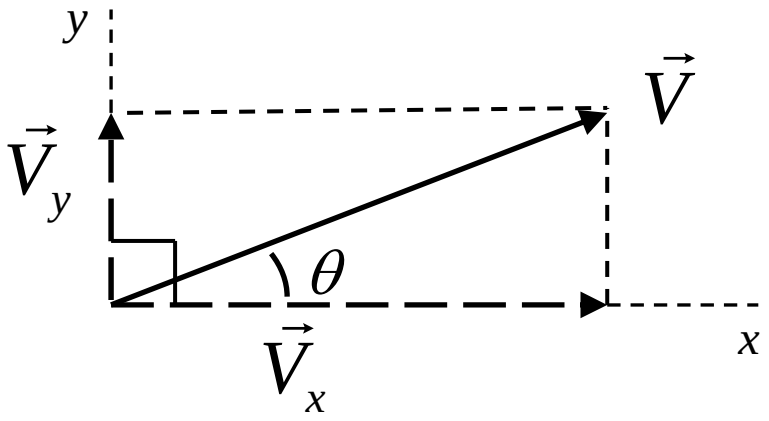


Given V, θ and β, we have

V_1 ⟶ Sine law

V_2 ⟶ Sine law

Rectangular Components



$$\boxed{\begin{aligned} V_x &= V\cos(\theta) \\ V_y &= V\sin(\theta) \end{aligned}}$$

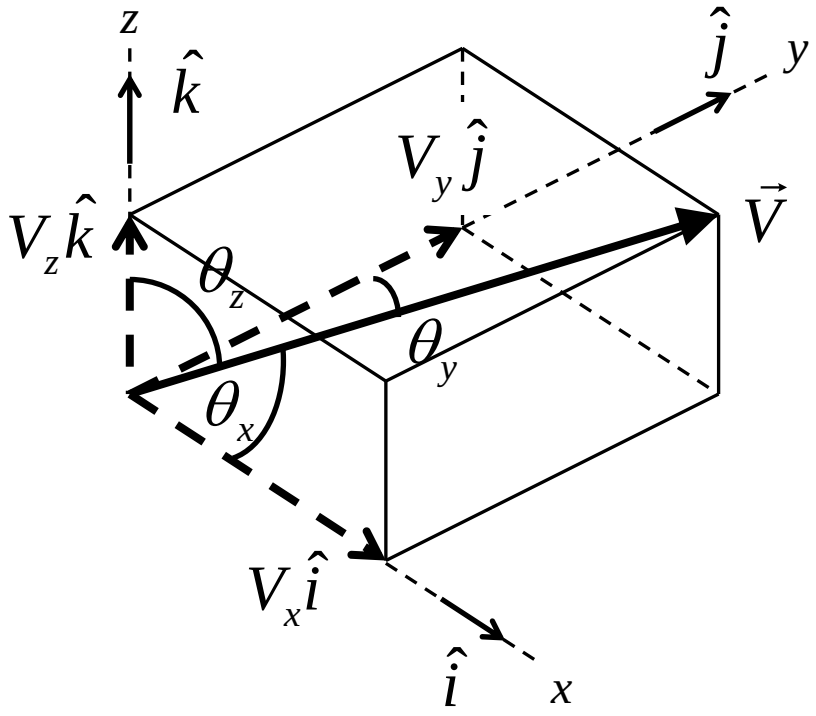
$$V = \sqrt{V_x^2 + V_y^2}$$

$$\theta = \tan^{-1}(V_y / V_x)$$

Vector basics (4)

Unit vector

$\vec{V} = V\hat{n}$, $\hat{n}$ = unit vector; (magnitude = 1, same direction as $\vec{V}$)



3D Rectangular component

$$\vec{V} = V_x\hat{i} + V_y\hat{j} + V_z\hat{k}$$

$$V_x = V\cos(\theta_x)$$

$$V_y = V\cos(\theta_y)$$

$$V_z = V\cos(\theta_z)$$

$$V^2 = V_x^2 + V_y^2 + V_z^2$$

$$1 = \cos^2(\theta_x) + \cos^2(\theta_y) + \cos^2(\theta_z)$$

Newton's Laws (1)

Law 1

"A particle remains at rest or continues to move in a straight line with a uniform velocity if there is no unbalanced force acting on it."

$$\vec{a} = 0 \quad \Leftrightarrow \quad \sum \vec{F} = 0$$

Law 2

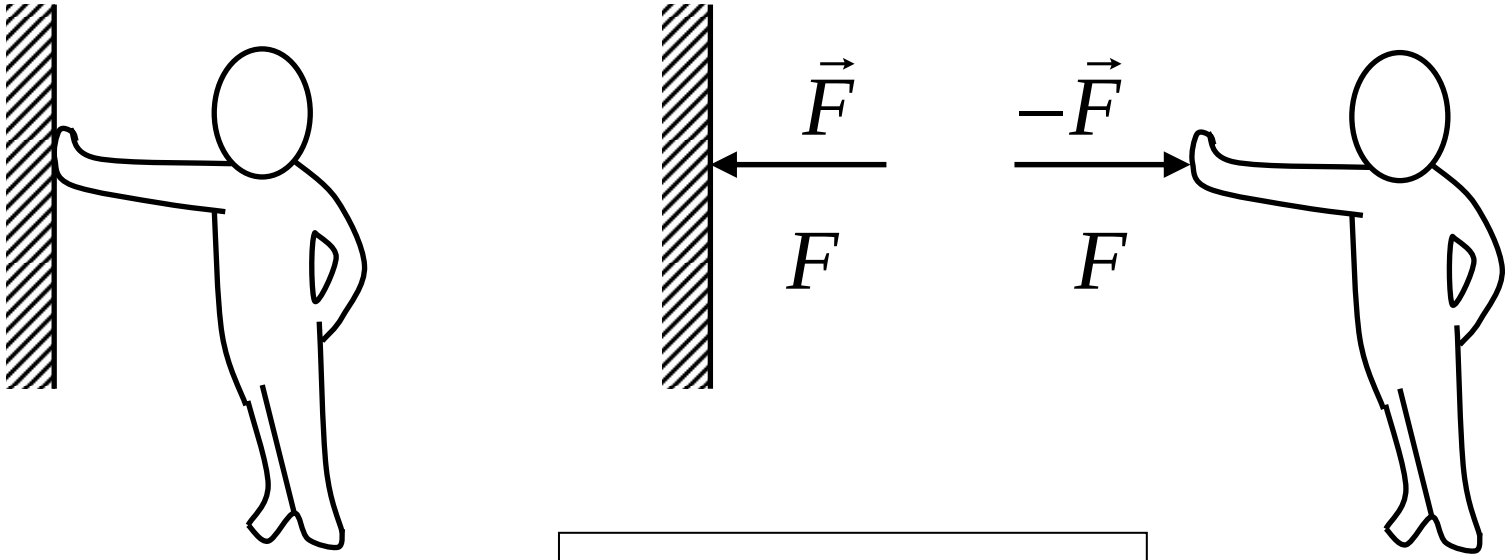
"The acceleration of a particle is proportional to the resultant force acting on it and is in the direction of this force."

$$\sum \vec{F} = m\vec{a}$$

Newton's Laws (2)

Law 3

"The force of action and reaction between interacting bodies are equal in magnitude, opposite in direction, and collinear."



Action = Reaction

* **Action and reaction are acting on different bodies.**