PHYSICS

Engineering Mechanics

Lecture 1

Introduction and Topics of Engineering mechanics

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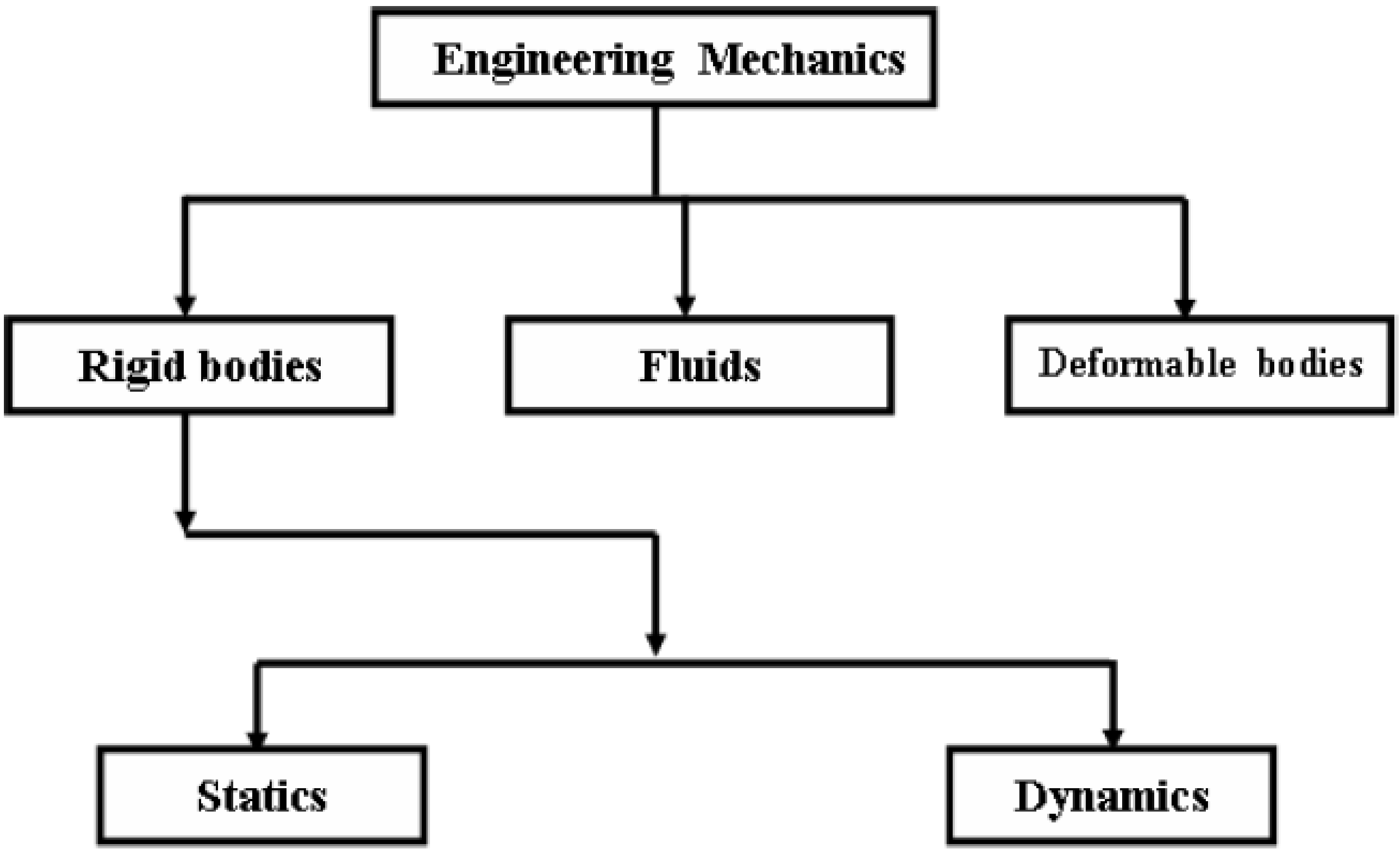
Engineering Mechanics : may be defined as a science which describes and predicts the condition of rest or motion of bodies under the action of forces.



- **Mechanics:** Is the physical science which deals with the effects of forces on objects.
- The subject of mechanics is logically divided into two parts:

1. **Statics**: Which concerns the equilibrium of bodies under action of forces.

2. **Dynamics**: Which concerns the motion of bodies.

BASIC CONCEPTS

- **Space:** Is the geometric region occupied by bodies whose positions are described by linear and angular measurements relative to a coordinate system.
- **Time:** Is the measure of the succession of events and is a basic quantity in dynamics.

- **Mass:** Is a measure of a quantity of matter.
- **Force:** Is the action of one body on another. The force tends to move a body in the direction of its action.
- **Particle:** Is 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.

Physical quantities :

Vector quantities: are the quantities which have magnitude and direction .such as:

Force , weight , distance , speed , displacement , acceleration ,velocity .

Scalar quantities : are the quantities which have only magnitude , such as :

Time , size , sound , density , light , volume .

Force : A "force" is an action that changes, or tends to change, the state of motion of the body upon which it acts. It is a vector quantity that can be represented either mathematically or graphically

A complete description of a force MUST include its:

1. Magnitude
2. Direction and sense
3. Point of action

WORKING WITH VECTORS

- The direction of the vector **V** may be measured by an angle θ from some known reference direction as shown in **Fig. 1/1.** The negative of **V** is a vector -**V** having the same magnitude as **V** but directed in the sense opposite to **V**, as shown in **Fig. 1/1.**

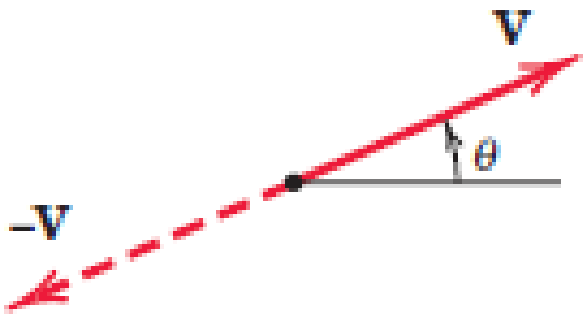


Figure 1/1

- **The vector sum** is represented by the vector equation:

$$\mathbf{V} = \mathbf{V1} + \mathbf{V2}$$

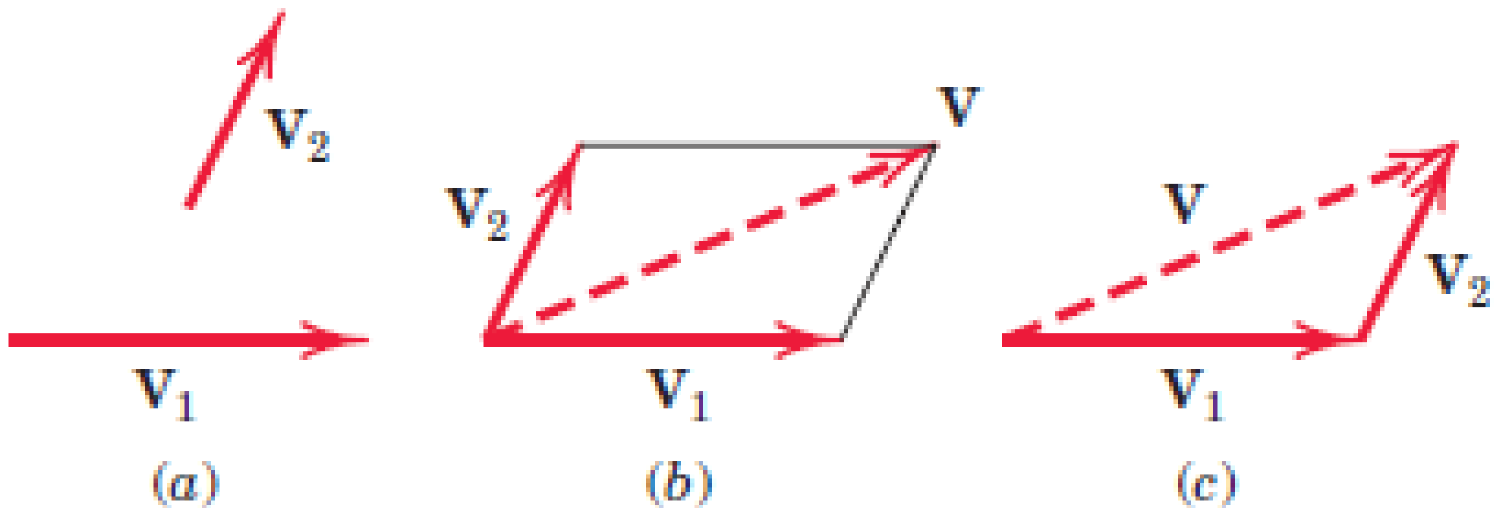


Figure 1/2

- **The scalar sum** of the magnitudes of the two vectors is written in the usual way as **V1 + V2**.
- The geometry of the parallelogram shows that $V \neq V1 + V2$.

Also $\mathbf{V1} + \mathbf{V2} = \mathbf{V2} + \mathbf{V1}$

- **The difference V1 - V2** between the two vectors is easily obtained by adding - **V2** to **V1** as shown in Fig. 1/3,

$$\mathbf{V'} = \mathbf{V1} - \mathbf{V2}$$

where the minus sign denotes ***vector subtraction*.**

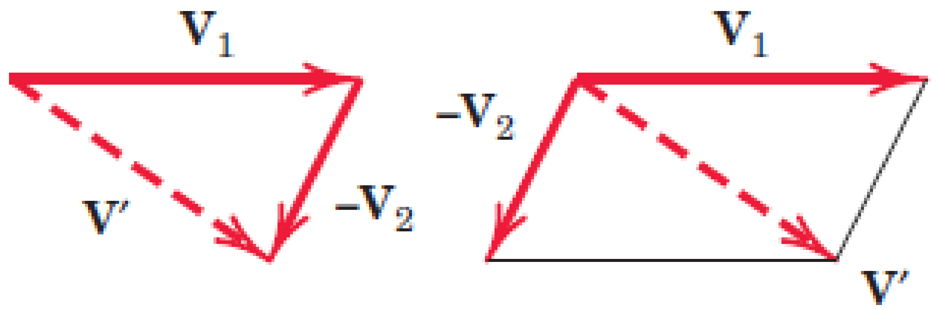


Figure 1/3

- Any two or more vectors whose sum equals a certain vector **V** are said to be the components of that vector.
- the vectors **V**1 and **V**2 in Fig. 1/4*a* are the components of **V** in the directions 1 and 2, respectively.

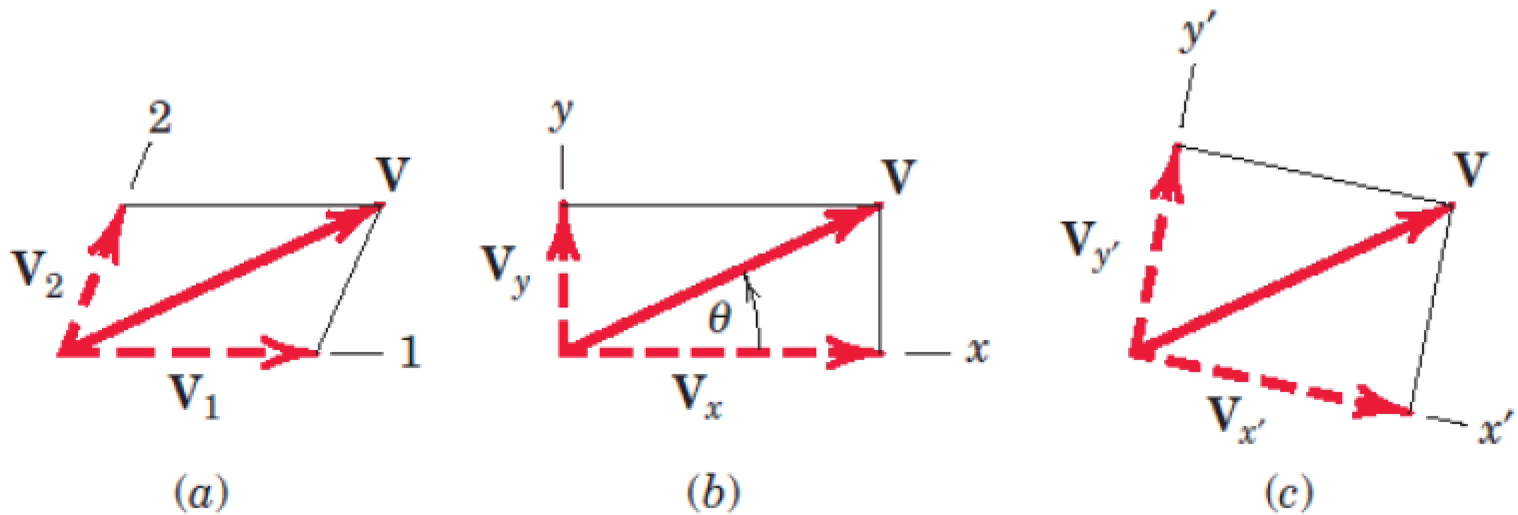


Figure 1/4

- Vectors **Vx** and **Vy** in **Fig. 1/4*b*** are the ***x* and *y*-components**, respectively, of **V**.

- Likewise, in **Fig. 1/4*c***, **V**x′ **and V**y′ **are the x and y components of V**.

- The vector components which are mutually perpendicular are called rectangular components.

- When expressed in rectangular components, the direction of the vector with respect to the *x*-axis is clearly specified by the angle θ, where

$$\theta = \tan^{-1}\frac{V_y}{V_x}$$

- In many problems, particularly three-dimensional ones, it is convenient to express the rectangular components of **V**, Fig. 1/5, in terms of unit vectors **i**, **j**, and **k**, which are vectors in the x, y, and z-directions, respectively.

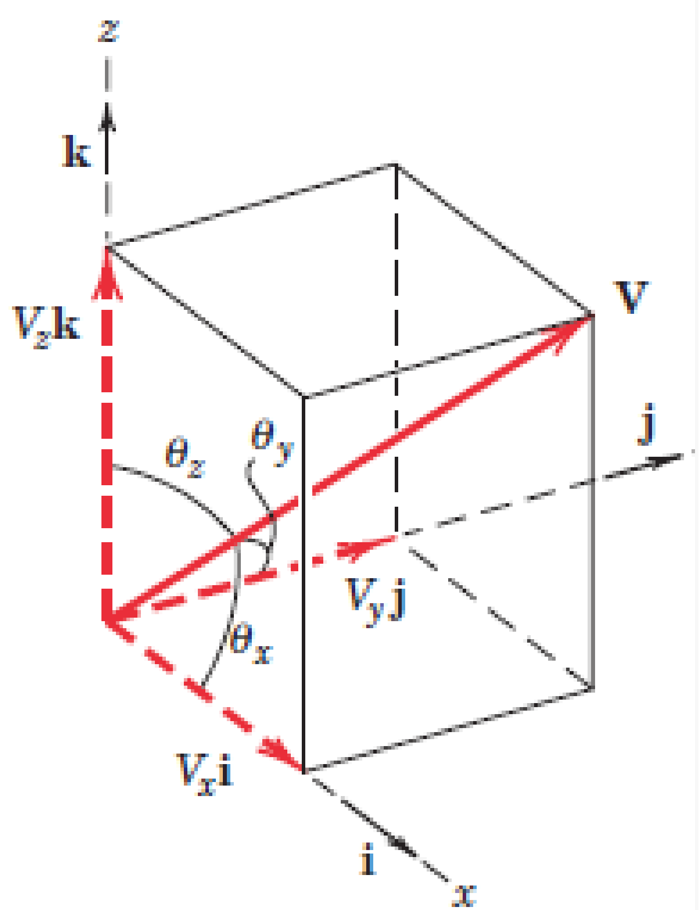


Figure 1/5

- the vector **V** is the vector sum of the components in the x, y, and z-directions.

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

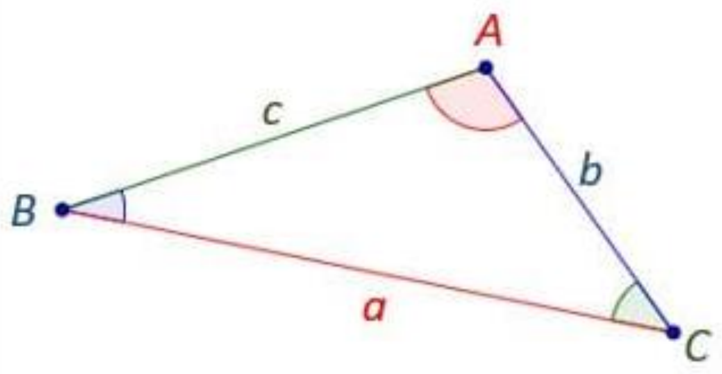
Where:

$$V_x = V\cos\theta_x \qquad V_y = V\cos\theta_y \qquad V_z = V\cos\theta_z$$

- The magnitude of vector V is:

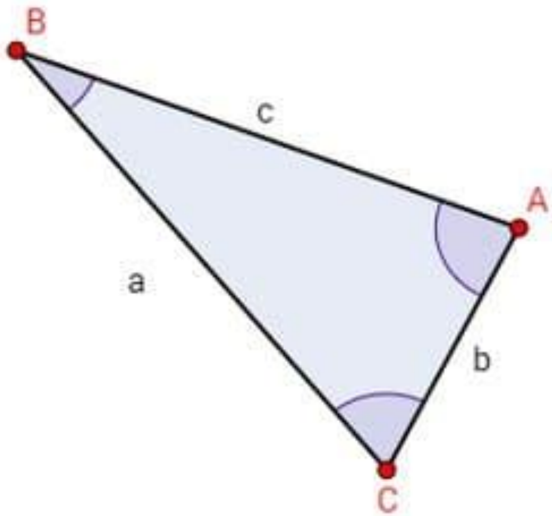
$$V^2 = {V_x}^2 + {V_y}^2 + {V_z}^2$$

Sine Rule or Law of Sines



$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

Law of Cosines



$$a^2 = b^2 + c^2 - 2bcCosA$$

$$b^2 = a^2 + c^2 - 2acCosB$$

$$c^2 = a^2 + b^2 - 2abCosC$$

Sample problem:

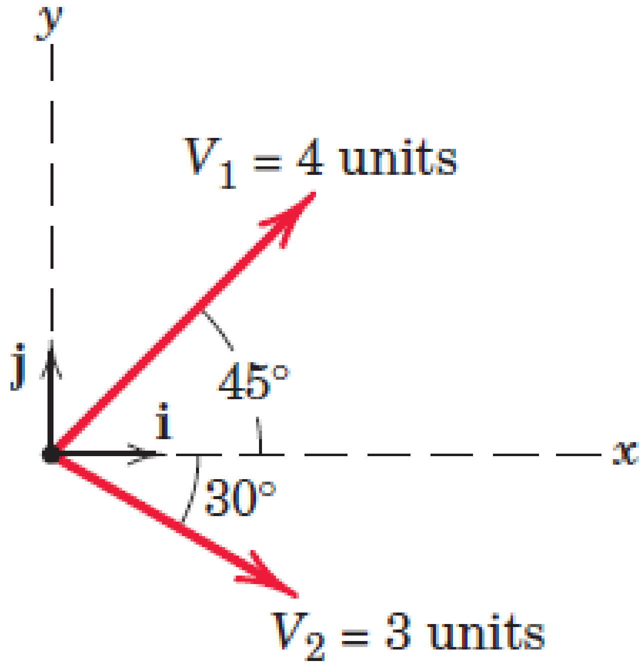
For the vectors **V**1 and **V**2 shown in the figure,

(*a*) determine the magnitude *S* of their vector sum **S** = **V**1 + **V**2

(*b*) determine the angle between **S** and the positive *x*-axis

(*c*) write **S** as a vector in terms of the unit vectors **i** and **j**

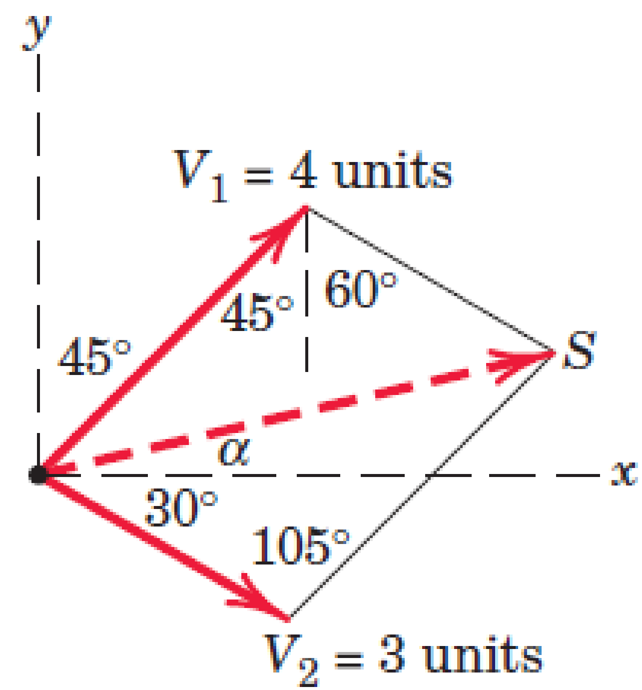
(*d*) determine the vector difference **D** = **V**1 - **V**2



Solution (*a*) We construct to scale the parallelogram shown in Fig. *a* for adding $\mathbf{V}_1$ and $\mathbf{V}_2$. Using the law of cosines, we have

$$S^2 = 3^2 + 4^2 - 2(3)(4)\cos 105°$$

$$S = 5.59 \text{ units} \qquad \textit{Ans.}$$



(*a*)

1 (*b*) Using the law of sines for the lower triangle, we have

$$\frac{\sin 105°}{5.59} = \frac{\sin(\alpha + 30°)}{4}$$

$$\sin(\alpha + 30°) = 0.692$$

$$(\alpha + 30°) = 43.8° \qquad \alpha = 13.76° \qquad \textit{Ans.}$$

(*c*) With knowledge of both S and α, we can write the vector **S** as

$$\mathbf{S} = S[\mathbf{i}\cos\alpha + \mathbf{j}\sin\alpha]$$

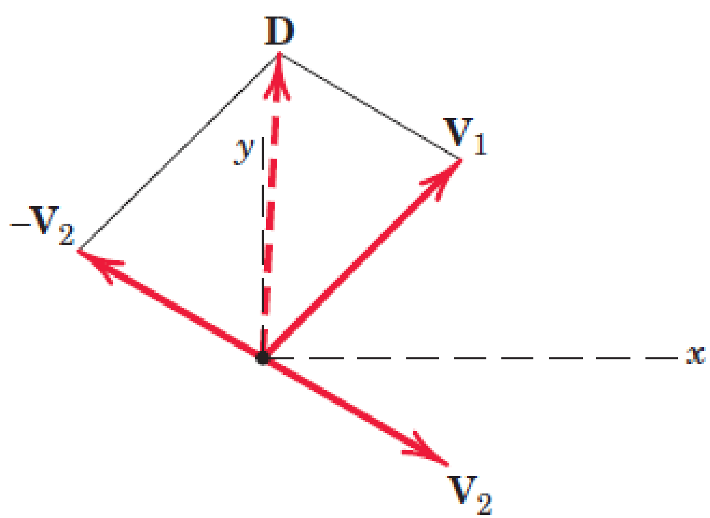
$$= 5.59[\mathbf{i}\cos 13.76° + \mathbf{j}\sin 13.76°] = 5.43\mathbf{i} + 1.328\mathbf{j} \text{ units} \qquad \textit{Ans.}$$

(*d*) The vector difference **D** is

$$\mathbf{D} = \mathbf{V}_1 - \mathbf{V}_2 = 4(\mathbf{i}\cos 45° + \mathbf{j}\sin 45°) - 3(\mathbf{i}\cos 30° - \mathbf{j}\sin 30°)$$

$$= 0.230\mathbf{i} + 4.33\mathbf{j} \text{ units} \qquad \textit{Ans.}$$

The vector **D** is shown in Fig. *b* as $\mathbf{D} = \mathbf{V}_1 + (-\mathbf{V}_2)$.



(*b*)