



ENGINEERING MECHANICS I: SCALARS AND VECTORS

Compiled by: Solomon Getachew



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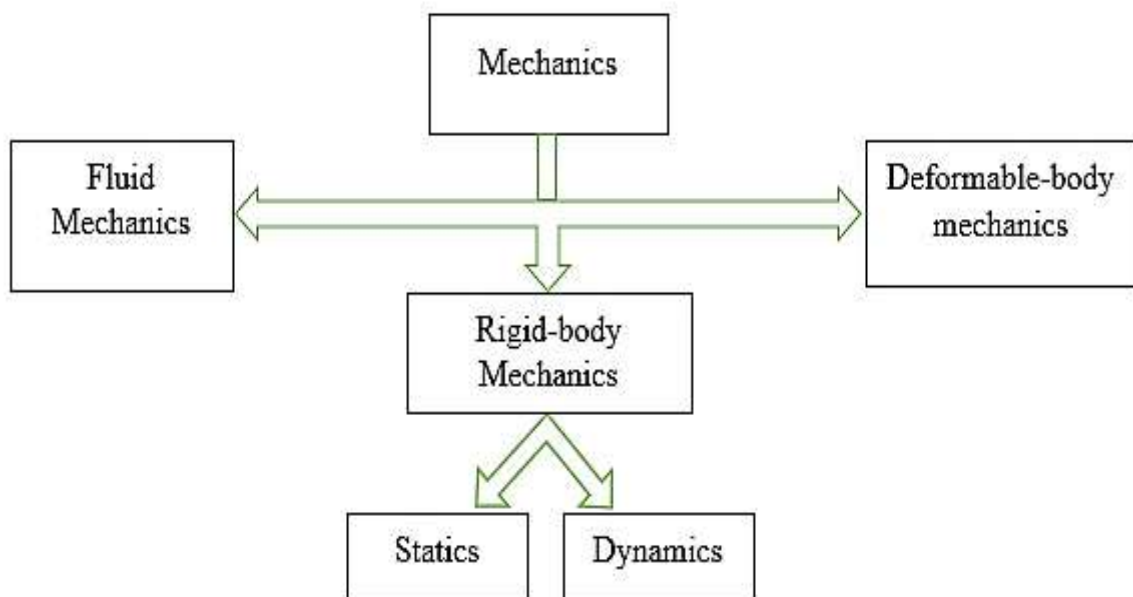
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DEBRE MARKOS, ETHIOPIA

Chapter One

Scalar and Vector

1.1. Introduction

- ✓ **Physics** is the science that relates the properties of matter and energy, excluding biological and chemical effects. Physics includes the study of mechanics, thermodynamics, electricity and magnetism, and nuclear physics.
- ✓ **Engineering** is the application of the mathematical and physical sciences (physics, chemistry, and biology) to the design and manufacture of items that benefit humanity.
- ✓ **Mechanics** is the branch of physics that considers the action of forces on bodies or fluids that are at rest or in motion.



- ✓ **Statics** deals with the equilibrium of bodies, that is, those that are either at rest or move with a constant velocity.

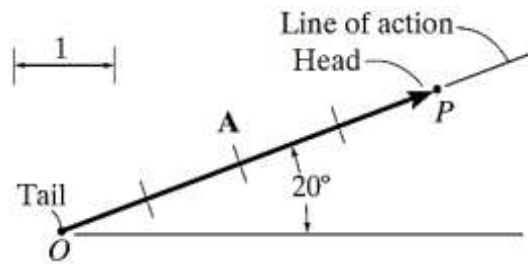
1.2. Scalars and Vectors

Many physical quantities in engineering mechanics are measured using either scalars or vectors.

A **scalar** is any positive or negative physical quantity that can be completely specified by its *magnitude*. Examples of scalar quantities include length, mass, and time.

A **vector** is any physical quantity that requires both a *magnitude* and a *direction* for its complete description. Examples of vectors encountered in statics are force, position, and moment. A vector is shown graphically by an arrow. The length of the arrow represents the *magnitude* of the vector, and the angle θ between the vector and a fixed axis defines the *direction of its line of action*. The head or tip of the arrow indicates the *sense of direction* of the vector.

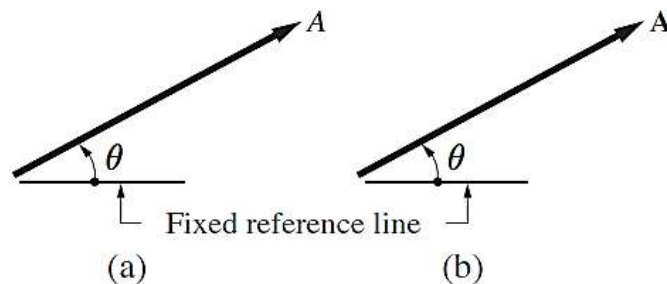
Vector quantities are represented by boldface letters such as **A**, and the magnitude of a vector is italicized, *A*. For handwritten work, it is often convenient to denote a vector quantity by simply drawing an arrow above it.



1.2.1. Properties of vectors

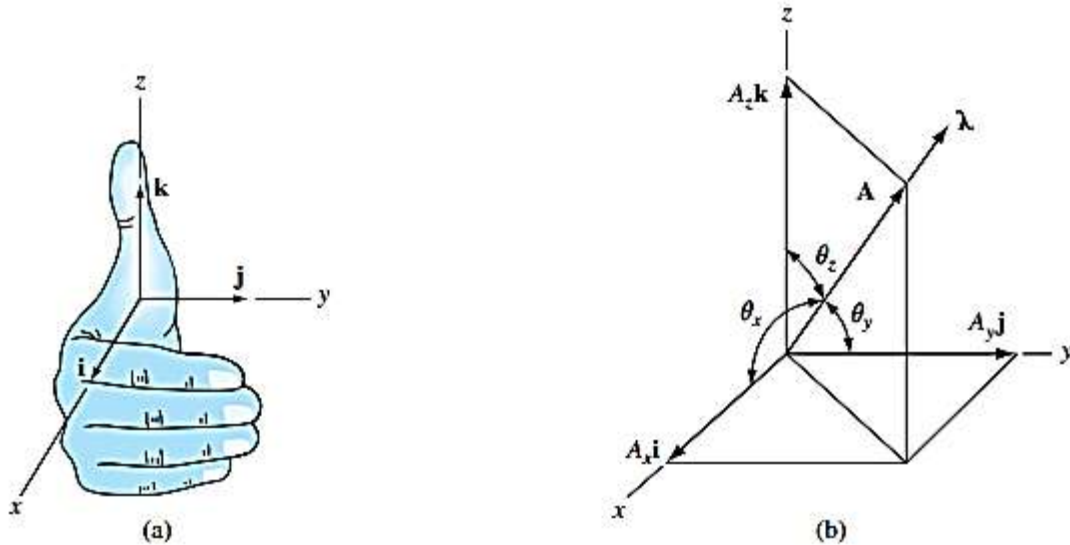
The following summarizes several important properties of vectors.

- a. Vectors as Directed Line Segments:** Any vector **A** can be represented geometrically as a directed line segment (an arrow), as shown in Fig. 1.2. The magnitude of **A** is denoted by $\hat{A}$, and the direction of **A** is specified by the sense of the arrow and the angle θ that it makes with a fixed reference line.



- b. Equality of Vectors:** Two vectors **A** and **B** are said to be equal, written as $\mathbf{A} = \mathbf{B}$,
If: - their magnitudes are equal that is, $A = B$, and
- they have the same direction.
- c. Scalar-Vector Multiplication:** The multiplication of a scalar m and a vector **A**, written as $m\mathbf{A}$ or as $\mathbf{A}m$, is defined as follows.
1. If m is positive, $m\mathbf{A}$ is the vector of magnitude mA that has the same direction as **A**.
 2. If m is negative, $m\mathbf{A}$ is the vector of magnitude $|m|A$ that is oppositely directed to **A**.
 3. If $m = 0$, $m\mathbf{A}$ (called the null or zero vector) is a vector of zero magnitude and arbitrary direction.
- d. Unit Vectors:** A unit vector is a dimensionless vector with magnitude 1. Therefore, if λ represents a unit vector ($|\lambda|=1$) with the same direction as **A**, we can write, $\mathbf{A} = A\lambda$. This representation of a vector often is useful because it separates the magnitude A and the direction λ of the vector.

1.2.2. Representation of Vector using rectangular components (Cartesian)



If a vector A is resolved into its rectangular components, as illustrated in the above figure, it can be written as

$$A = A_x i + A_y j + A_z k$$

where $A_x i$, $A_y j$, and $A_z k$ are the vector components of A .

The scalar components of A are

$$A_x = A \cos \theta_x \quad A_y = A \cos \theta_y \quad A_z = A \cos \theta_z$$

where θ_x , θ_y , and θ_z are the angles between A and the positive coordinate axes.

The scalar components can be positive or negative, depending upon whether the corresponding vector component points in the positive or negative coordinate direction.

The magnitude of A is related to its scalar components by

$$A = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

The direction of A customarily is specified by its direction cosines defined as

$$\lambda_x = \cos \theta_x \quad \lambda_y = \cos \theta_y \quad \lambda_z = \cos \theta_z$$

The scalar components of A are now become $A_x = A\lambda_x$, $A_y = A\lambda_y$, and $A_z = A\lambda_z$,

$$\text{so } A = A(\lambda_x i + \lambda_y j + \lambda_z k) = A\lambda$$

where

$$\lambda = \lambda_x i + \lambda_y j + \lambda_z k \text{ is a unit vector in the direction of } A.$$

Because the magnitude of λ is one, its components satisfy the identity

$$\lambda_x^2 + \lambda_y^2 + \lambda_z^2 = 1$$

Example 1

By considering figure (a), Determine

- the rectangular representation of the position vector A ; and
- the angles between A and each of the positive coordinate axes.

Solution:**Part 1.**

We first resolve A into two components as shown in Fig. (b): A_z along the z -axis and A_{xy} in the xy -plane. (Once again, we see that a carefully drawn sketch is an essential aid in performing vector resolution.) Because A , A_z , and A_{xy} lie in the same plane (a diagonal plane of the parallelepiped), we obtain by trigonometry

$$A_z = A \cos 30^\circ = 12 \cos 30^\circ = 10.392 \text{ m}$$

$$A_{xy} = A \sin 30^\circ = 12 \sin 30^\circ = 6 \text{ m}$$

The next step, illustrated in Fig. (c), is to resolve A_{xy} into the components along the coordinate axes:

$$A_x = A_{xy} \cos 40^\circ = 6 \cos 40^\circ = 4.596 \text{ m}$$

$$A_y = A_{xy} \sin 40^\circ = 6 \sin 40^\circ = 3.857 \text{ m}$$

Therefore, the rectangular representation of A is

$$A = A_x i + A_y j + A_z k = 4.60i + 3.86j + 10.39k \text{ m}$$

Part 2.

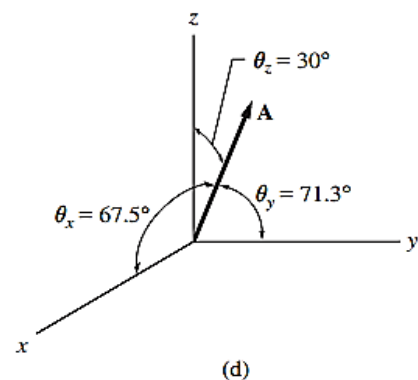
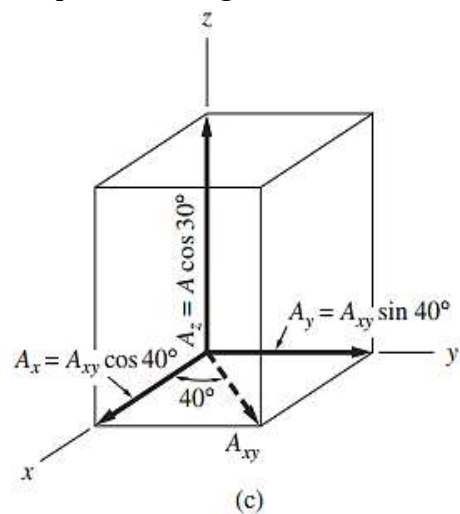
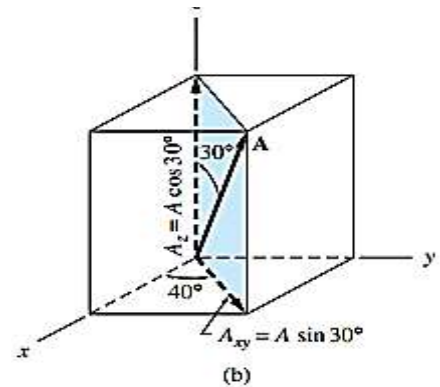
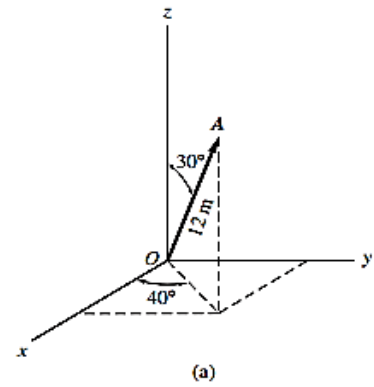
The angles between A and the coordinate axes can be computed as:

$$\theta_x = \cos^{-1} \frac{A_x}{A} = \cos^{-1} \frac{4.596}{12} = 67.5^\circ$$

$$\theta_y = \cos^{-1} \frac{A_y}{A} = \cos^{-1} \frac{3.857}{12} = 71.3^\circ$$

$$\theta_z = \cos^{-1} \frac{A_z}{A} = \cos^{-1} \frac{10.392}{12} = 30.0^\circ$$

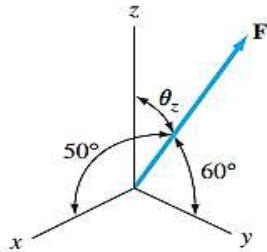
These angles are shown in Fig. (d). Note that it was not necessary to compute θ_z , because it was already given in Fig (a)



Exercise 1

If the magnitude of $F=120$ kN in the next figure

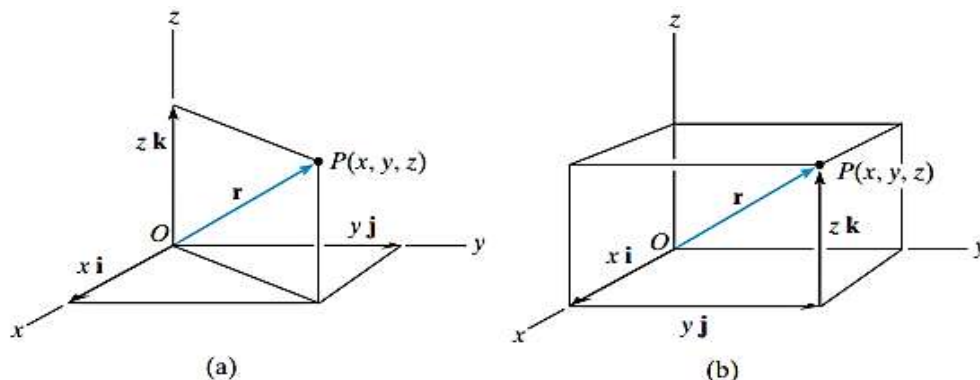
- Compute the angle θ_z between the force vector F and the z -axis.
- Determine the rectangular representation of F .

**1.2.3. Position Vector**

A position vector $\mathbf{r}$ is defined as a fixed vector which locates a point in space relative to another point. For example, if $\mathbf{r}$ extends from the origin of coordinates, O , to point $P(x, y, z)$, Fig a, then $\mathbf{r}$ can be expressed in Cartesian vector form as

$$\mathbf{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$$

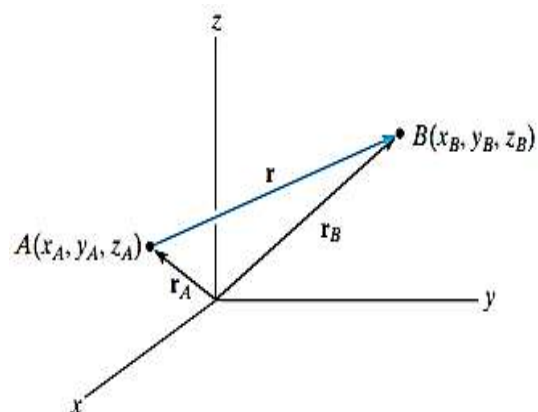
Note how the head-to-tail vector addition of the three components yields vector $\mathbf{r}$, Fig. 2–33b. Starting at the origin O , one “travels” x in the $+\mathbf{i}$ direction, then y in the $+\mathbf{j}$ direction, and finally z in the $+\mathbf{k}$ direction to arrive at point $P(x, y, z)$.



In the more general case, the position vector may be directed from point A to point B in space, figure below. This vector is also designated by the symbol $\mathbf{r}$.

As a matter of convention, we will sometimes refer to this vector with two subscripts to indicate from and to the point where it is directed. Thus, $\mathbf{r}$ can also be designated as $\mathbf{r}_{AB}$. Also, note that $\mathbf{r}_A$ and $\mathbf{r}_B$ in figure are referenced with only one subscript since they extend from the origin of coordinates.

From figure, by the head-to-tail vector addition, using the triangle rule, we require $\mathbf{r}_A + \mathbf{r} = \mathbf{r}_B$



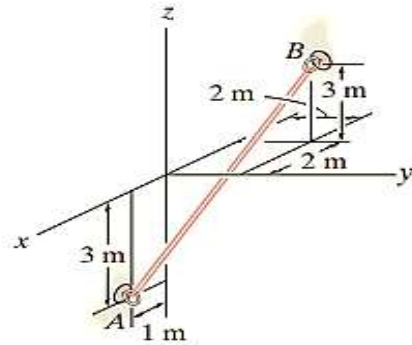
Solving for $\mathbf{r}$ and expressing $\mathbf{r}_A$ and $\mathbf{r}_B$ in Cartesian vector form yields

$$\mathbf{r} = \mathbf{r}_B - \mathbf{r}_A = (x_B \mathbf{i} + y_B \mathbf{j} + z_B \mathbf{k}) - (x_A \mathbf{i} + y_A \mathbf{j} + z_A \mathbf{k})$$

$$\text{or } \mathbf{r} = (x_B - x_A)\mathbf{i} + (y_B - y_A)\mathbf{j} + (z_B - z_A)\mathbf{k}$$

Example 2

An elastic rubber band is attached to points A and B as shown in figure. Determine its length and its direction measured from A toward B.

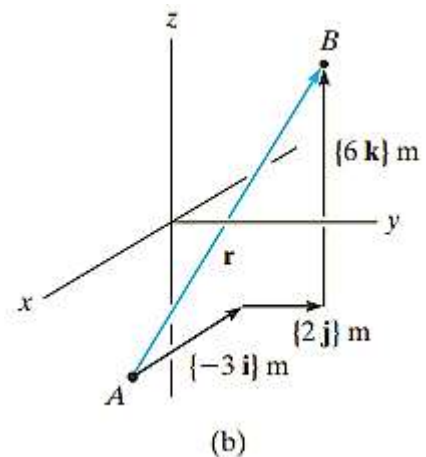


Solution:

We first establish a position vector from A to B, Fig b. In accordance with Equation, the coordinates of the tail A (1 m, 0, -3 m) are subtracted from the coordinates of the head B(-2 m, 2 m, 3 m), which yields

$$\begin{aligned} \mathbf{r} &= [-2 \text{ m} - 1 \text{ m}]\mathbf{i} + [2 \text{ m} - 0]\mathbf{j} + [3 \text{ m} - (-3 \text{ m})]\mathbf{k} \\ &= \{-3\mathbf{i} + 2\mathbf{j} + 6\mathbf{k}\} \text{ m} \end{aligned}$$

These components of $\mathbf{r}$ can also be determined directly by realizing that they represent the direction and distance one must travel along each axis in order to move from A to B, i.e., along the x axis $\{-3\mathbf{i}\}$ m, along the y axis $\{2\mathbf{j}\}$ m, and finally along the z axis $\{6\mathbf{k}\}$ m. The length of the rubber band is therefore



$$r = \sqrt{(-3 \text{ m})^2 + (2 \text{ m})^2 + (6 \text{ m})^2} = 7 \text{ m}$$

Formulating a unit vector in the direction of $\mathbf{r}$, we have

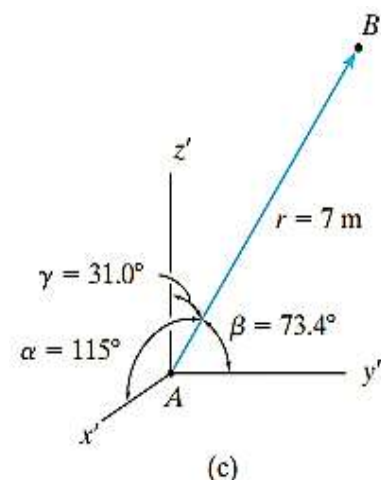
$$\lambda = \frac{\mathbf{r}}{r} = -\frac{3}{7}\mathbf{i} + \frac{2}{7}\mathbf{j} + \frac{6}{7}\mathbf{k}$$

The components of this unit vector give the coordinate direction angles

$$\alpha = \cos^{-1}\left(-\frac{3}{7}\right) = 115^\circ$$

$$\beta = \cos^{-1}\left(\frac{2}{7}\right) = 73.4^\circ$$

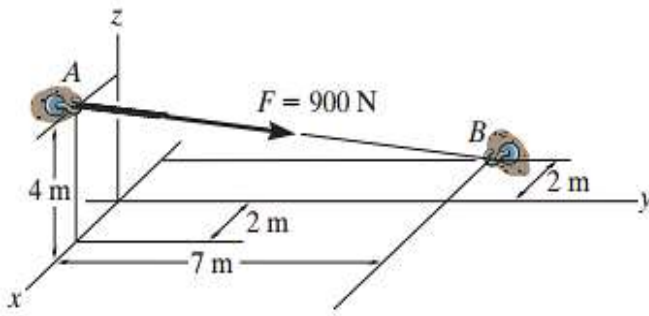
$$\gamma = \cos^{-1}\left(\frac{6}{7}\right) = 31.0^\circ$$



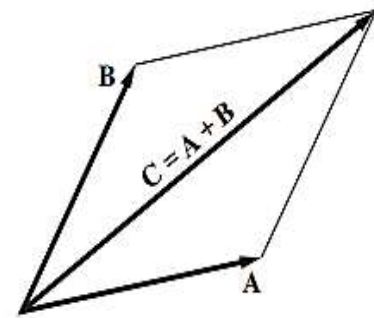
These angles are measured from the positive axes of a localized coordinate system placed at the tail of $\mathbf{r}$, as shown in Fig c.

Exercise 2

Express the force as a Cartesian vector.

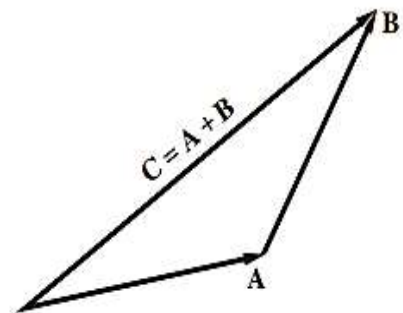
**1.3. Operations with Vectors****1.3.1. Vector Addition****a. The Parallelogram Law for Addition and the Triangle Law**

The addition of two vectors A and B is defined to be the vector C that results from the geometric construction shown in Fig (a). Observe that C is the diagonal of the parallelogram formed by A and B . The operation depicted in Fig (a), written as $A + B = C$, is called the parallelogram law for addition. The vectors A and B are referred to as components of C , and C is called the resultant of A and B . The process of replacing a resultant with its components is called resolution. For example, C in Fig (a) is resolved into its components A and B .



(a) Parallelogram law

An equivalent statement of the parallelogram law is the triangle law, which is shown in Fig (b). Here the tail of B is placed at the tip of A , and C is the vector that completes the triangle, drawn from the tail of A to the tip of B . The result is identical if the tail of A is placed at the tip of B and C is drawn from the tail of B to the tip of A . Letting E , F , and G represent any three vectors, we

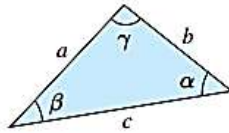


(b) Triangle law

have the following two important properties (each follows directly from the parallelogram law):

- ✓ Addition is commutative: $E + F = F + E$
- ✓ Addition is associative: $E + (F + G) = (E + F) + G$

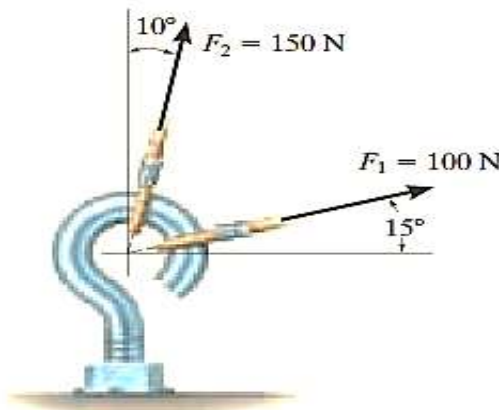
Because of the geometric nature of the parallelogram law and the triangle law, vector addition can be accomplished graphically. A second technique is to determine the relationships between the various magnitudes and angles analytically by applying the laws of sines and cosines to a sketch of the parallelogram (or the triangle)—see Table below.



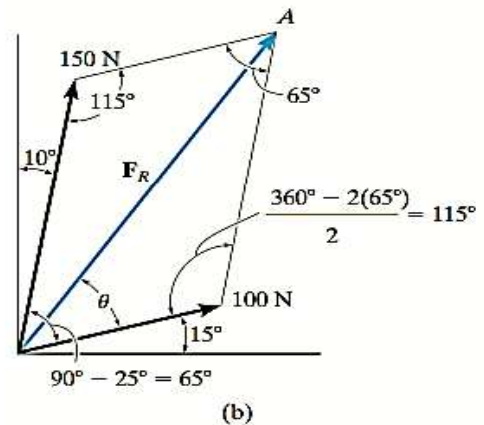
Law of sines	$\frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$
Law of cosines	$a^2 = b^2 + c^2 - 2bc \cos \alpha$ $b^2 = c^2 + a^2 - 2ca \cos \beta$ $c^2 = a^2 + b^2 - 2ab \cos \gamma$

Example 3

The screw eye in figure below is subjected to two forces, F_1 and F_2 . Determine the magnitude and direction of the resultant force.

**Solution:**

Parallelogram Law. The parallelogram is formed by drawing a line from the head of F_1 that is parallel to F_2 , and another line from the head of F_2 that is parallel to F_1 . The resultant force F_R extends to where these lines intersect at point A, fig b. The two unknowns are the magnitude of F_R and the angle θ (theta). Trigonometry. From the parallelogram, the vector triangle is constructed, Fig c. Using the law of cosines



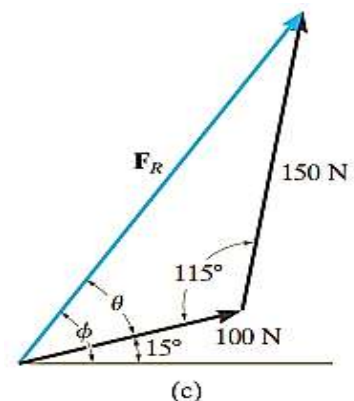
$$\begin{aligned}
 F_R &= \sqrt{(100 \text{ N})^2 + (150 \text{ N})^2 - 2(100 \text{ N})(150 \text{ N}) \cos 115^\circ} \\
 &= \sqrt{10\,000 + 22\,500 - 30\,000(-0.4226)} = 212.6 \text{ N} \\
 &= 213 \text{ N}
 \end{aligned}$$

Applying the law of sines to determine θ ,

$$\begin{aligned}
 \frac{150 \text{ N}}{\sin \theta} &= \frac{212.6 \text{ N}}{\sin 115^\circ} & \sin \theta &= \frac{150 \text{ N}}{212.6 \text{ N}} (\sin 115^\circ) \\
 \theta &= 39.8^\circ
 \end{aligned}$$

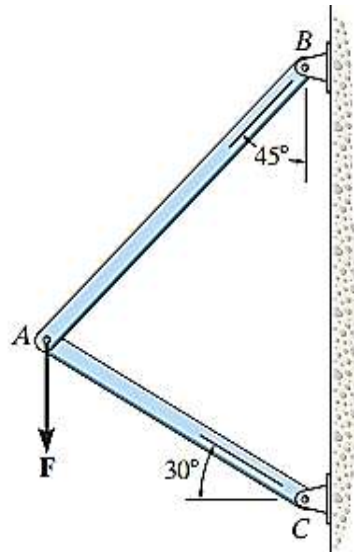
Thus, the direction ϕ (phi) of F_R , measured from the horizontal, is

$$\phi = 39.8^\circ + 15.0^\circ = 54.8^\circ$$



Exercise 3

By considering the following figure, determine the forces F_{AB} and F_{AC} , if the force $F=175$ N.

**b. Vector addition using rectangular components**

Consider the two vectors $A = A_x\mathbf{i} + A_y\mathbf{j} + A_z\mathbf{k}$ and $B = B_x\mathbf{i} + B_y\mathbf{j} + B_z\mathbf{k}$. Letting C be the sum of A and B , we have

$$C = A + B = (A_x\mathbf{i} + A_y\mathbf{j} + A_z\mathbf{k}) + (B_x\mathbf{i} + B_y\mathbf{j} + B_z\mathbf{k})$$

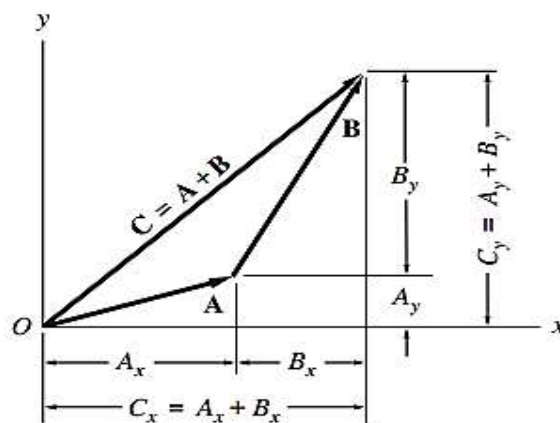
which can be written as

$$\begin{aligned} C &= C_x\mathbf{i} + C_y\mathbf{j} + C_z\mathbf{k} \\ &= (A_x + B_x)\mathbf{i} + (A_y + B_y)\mathbf{j} + (A_z + B_z)\mathbf{k} \end{aligned}$$

Equating like components, we find that the rectangular components of C are

$$C_x = A_x + B_x, C_y = A_y + B_y, C_z = A_z + B_z$$

This shows that each component of the sum equals the sum of the components. This result is depicted in figure below, where, for simplicity's sake, the xy -plane has been chosen as a plane that contains the vectors A and B . the above equations can, of course, be extended to include the sum of any number of vectors.



Example 4. Redo Example 3 using this method.

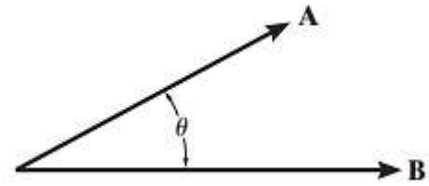
1.3.2. Vector Multiplication

a. Dot Product

The dot product of vectors A and B , written $A \cdot B$ and read “A dot B,” is defined as the product of the magnitudes of A and B and the cosine of the angle θ between their tails, Figure. Expressed in equation form,

$$A \cdot B = AB \cos \theta$$

where $0^\circ \leq \theta \leq 180^\circ$. The dot product is often referred to as the scalar product of vectors since the result is a scalar and not a vector.



Laws of Operation

1. Commutative law: $A \cdot B = B \cdot A$
2. Multiplication by a scalar: $a(A \cdot B) = (aA) \cdot B = A \cdot (aB)$
3. Distributive law: $A \cdot (B + D) = (A \cdot B) + (A \cdot D)$

Exercise 4. Proof those laws of operation using examples

Cartesian Vector Formulation. The above equation must be used to find the dot product for any two Cartesian unit vectors. If we want to find the dot product of two general vectors A and B that are expressed in Cartesian vector form, then we have

$$\begin{aligned} A \cdot B &= (A_x i + A_y j + A_z k) \cdot (B_x i + B_y j + B_z k) \\ &= A_x B_x (i \cdot i) + A_x B_y (i \cdot j) + A_x B_z (i \cdot k) + A_y B_x (j \cdot i) + A_y B_y (j \cdot j) + A_y B_z (j \cdot k) \\ &\quad + A_z B_x (k \cdot i) + A_z B_y (k \cdot j) + A_z B_z (k \cdot k) \end{aligned}$$

Carrying out the dot-product operations, the final result becomes

$$A \cdot B = A_x B_x + A_y B_y + A_z B_z$$

Thus, to determine the dot product of two Cartesian vectors, multiply their corresponding x , y , z components and sum these products algebraically. Note that the result will be either a positive or negative scalar, or it could be zero.

Applications

The following are two of the more important applications of the dot product.

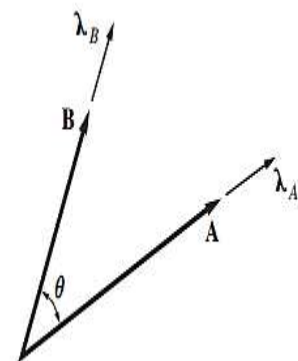
i. Finding the Angle Between Two Vectors

The angle θ between the two vectors A and B in figure can be found from the definition of the dot product in the above equation which can be rewritten

$$\cos \theta = \frac{A \cdot B}{AB} = \frac{A}{A} \cdot \frac{B}{B} \quad \text{as:}$$

Letting $\lambda_A = A/A$ and $\lambda_B = B/B$ be the unit vectors that have the same directions as A and B , as shown in figure, the last equation becomes

$$\cos \theta = \lambda_A \cdot \lambda_B$$



ii. Determining the Orthogonal Component of a Vector in a Given Direction

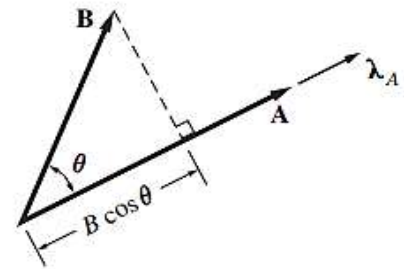
If we project B onto A as in figure, the projected length $B \cos \theta$ is called the orthogonal component of B in the direction of A. Because θ is the angle between A and B, the definition of the dot product, $A \cdot B = AB \cos \theta$, yields

$$B \cos \theta = \frac{A \cdot B}{A} = B \cdot \frac{A}{A}$$

Because $A/A = \lambda_A$ (the unit vector in the direction of A), as shown in figure, the last equation becomes

$$B \cos \theta = B \cdot \lambda_A$$

Therefore, The orthogonal component of B in the direction of A equals $B \cdot \lambda_A$.



b. Cross Product

The cross-product C of two vectors A and B, denoted by

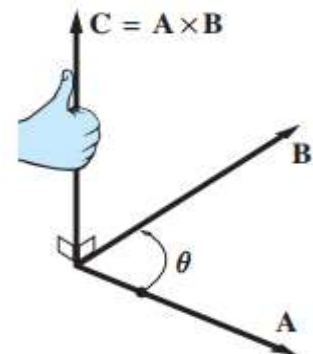
$$C = A \times B$$

has the following characteristics:

- The magnitude of C is $C = AB \sin \theta$ where θ ($0 \leq \theta \leq 180^\circ$) is the angle between the positive directions of A and B. (Note that C is always a positive number.)
- C is perpendicular to both A and B.
- The sense of C is determined by the right-hand rule, which states that when the fingers of your right hand are curled in the direction of the angle θ (directed from A toward B), your thumb points in the direction of C.
- From the properties of the cross product, we deduce that the base vectors of a rectangular coordinate system satisfy the following identities:

$$i \times i = 0 \quad j \times j = 0 \quad k \times k = 0$$

$$i \times j = k \quad j \times k = i \quad k \times i = j$$



When A and B are expressed in rectangular form, their cross product becomes

$$A \times B = (A_x i + A_y j + A_z k) \times (B_x i + B_y j + B_z k)$$

Using the distributive property of the cross product and Eqs. (1.26), this equation becomes

$$A \times B = (A_y B_z - A_z B_y)i - (A_x B_z - A_z B_x)j + (A_x B_y - A_y B_x)k$$

Laws of Operation

- Cross product is distributive; that is, $A \times (B + C) = (A \times B) + (A \times C)$
- Cross product is neither associative nor commutative. In other words,

$$\mathbf{A} \times (\mathbf{B} \times \mathbf{C}) \neq (\mathbf{A} \times \mathbf{B}) \times \mathbf{C}$$

$$\mathbf{A} \times \mathbf{B} \neq \mathbf{B} \times \mathbf{A}$$

- In fact, it can be deduced from the right-hand rule that $\mathbf{A} \times \mathbf{B} = -\mathbf{B} \times \mathbf{A}$.
- From the definition of the cross-product $\mathbf{C} = \mathbf{A} \times \mathbf{B}$, we see that
 - ✓ If $\mathbf{A}$ and $\mathbf{B}$ are perpendicular ($\theta = 90^\circ$), then $C = AB$; and
 - ✓ If $\mathbf{A}$ and $\mathbf{B}$ are parallel ($\theta = 0^\circ$ or 180°), then $C = 0$.

Applications

- Find the direction perpendicular to two given vectors.
- Determine if two vectors are orthogonal (checking for a dot product of 0 is likely faster though).
- “Multiply” two vectors when only perpendicular cross-terms make a contribution (such as finding torque).

Example 5

Given the vectors

$$\mathbf{A} = 8\mathbf{i} + 4\mathbf{j} - 2\mathbf{k} \text{ lb}$$

$$\mathbf{B} = 2\mathbf{j} + 6\mathbf{k} \text{ ft}$$

$$\mathbf{C} = 3\mathbf{i} - 2\mathbf{j} + 4\mathbf{k} \text{ ft}$$

calculate the following:

- $\mathbf{A} \cdot \mathbf{B}$;
- The orthogonal component of $\mathbf{B}$ in the direction of $\mathbf{C}$;
- The angle between $\mathbf{A}$ and $\mathbf{C}$;
- $\mathbf{A} \times \mathbf{B}$; and
- A unit vector λ that is perpendicular to both $\mathbf{A}$ and $\mathbf{B}$

Solution

- a. The dot product of $\mathbf{A}$ and $\mathbf{B}$ is

$$\begin{aligned}\mathbf{A} \cdot \mathbf{B} &= A_x B_x + A_y B_y + A_z B_z = 8(0) + 4(2) + (-2)(6) \\ &= -4 \text{ lb} \cdot \text{ft}\end{aligned}$$

The negative sign indicates that the angle between $\mathbf{A}$ and $\mathbf{B}$ is greater than 90° .

- b. Letting θ be the angle between $\mathbf{B}$ and $\mathbf{C}$

$$\begin{aligned}B \cos \theta &= \mathbf{B} \cdot \lambda_C = \mathbf{B} \cdot \frac{\mathbf{C}}{C} = (2\mathbf{j} + 6\mathbf{k}) \cdot \frac{3\mathbf{i} - 2\mathbf{j} + 4\mathbf{k}}{\sqrt{3^2 + (-2)^2 + 4^2}} \\ &= \frac{(0)(3) + (2)(-2) + (6)(4)}{\sqrt{29}} = 3.71 \text{ ft}\end{aligned}$$

c. Letting α be the angle between A and C,

$$\begin{aligned}\cos \alpha &= \lambda_A \cdot \lambda_C = \frac{\mathbf{A} \cdot \mathbf{C}}{A \cdot C} \\&= \frac{8\mathbf{i} + 4\mathbf{j} - 2\mathbf{k}}{\sqrt{8^2 + 4^2 + (-2)^2}} \cdot \frac{3\mathbf{i} - 2\mathbf{j} + 4\mathbf{k}}{\sqrt{3^2 + (-2)^2 + 4^2}} \\&= \frac{(8)(3) + (4)(-2) + (-2)(4)}{\sqrt{84}\sqrt{29}} = 0.16209 \\ \alpha &= 80.7^\circ\end{aligned}$$

d. The cross product of A and B is

$$\begin{aligned}\mathbf{A} \times \mathbf{B} &= \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ 8 & 4 & -2 \\ 0 & 2 & 6 \end{vmatrix} \\&= \mathbf{i} \begin{vmatrix} 4 & -2 \\ 2 & 6 \end{vmatrix} - \mathbf{j} \begin{vmatrix} 8 & -2 \\ 0 & 6 \end{vmatrix} + \mathbf{k} \begin{vmatrix} 8 & 4 \\ 0 & 2 \end{vmatrix} \\&= 28\mathbf{i} - 48\mathbf{j} + 16\mathbf{k} \text{ lb} \cdot \text{ft}\end{aligned}$$

e. The cross-product $\mathbf{A} \times \mathbf{B}$ is perpendicular to both A and B. Therefore, a unit vector in that direction is obtained by dividing $\mathbf{A} \times \mathbf{B}$, which was evaluated above, by its magnitude

$$\begin{aligned}\frac{\mathbf{A} \times \mathbf{B}}{|\mathbf{A} \times \mathbf{B}|} &= \frac{28\mathbf{i} - 48\mathbf{j} + 16\mathbf{k}}{\sqrt{28^2 + (-48)^2 + 16^2}} \\&= 0.484\mathbf{i} - 0.830\mathbf{j} + 0.277\mathbf{k}\end{aligned}$$

Because the negative of this vector is also a unit vector that is perpendicular to both A and B, we obtain

$$\lambda = \pm (0.484\mathbf{i} - 0.830\mathbf{j} + 0.277\mathbf{k})$$

Exercise 5

1. What is Scalar triple product? Illustrate using examples.
2. What are its properties and applications?

References

1. Andrew Pytel, Jaan Kiusalaas, *Engineering Mechanics: Statics (SI Edition)*, 3rd Edition, CEngage Learning, 2010
2. R. C. Hibbeler, *Engineering Mechanics: Statics*, 14th Edition, Prentice Hall; 2016