

3.E: Vectors (Exercises)

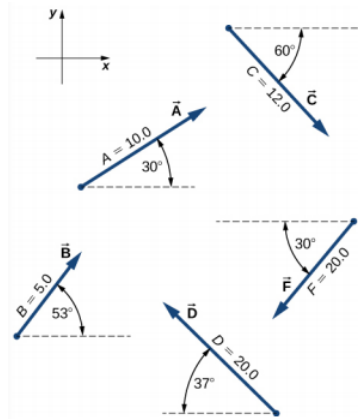
Conceptual Questions

1. A weather forecast states the temperature is predicted to be -5°C the following day. Is this temperature a vector or a scalar quantity? Explain.
2. Which of the following is a vector: a person's height, the altitude on Mt. Everest, the velocity of a fly, the age of Earth, the boiling point of water, the cost of a book, Earth's population, or the acceleration of gravity?
3. Give a specific example of a vector, stating its magnitude, units, and direction.
4. What do vectors and scalars have in common? How do they differ?
5. Suppose you add two vectors \vec{A} and \vec{B} . What relative direction between them produces the resultant with the greatest magnitude? What is the maximum magnitude? What relative direction between them produces the resultant with the smallest magnitude? What is the minimum magnitude?
6. Is it possible to add a scalar quantity to a vector quantity?
7. Is it possible for two vectors of different magnitudes to add to zero? Is it possible for three vectors of different magnitudes to add to zero? Explain.
8. Does the odometer in an automobile indicate a scalar or a vector quantity?
9. When a 10,000-m runner competing on a 400-m track crosses the finish line, what is the runner's net displacement? Can this displacement be zero? Explain.
10. A vector has zero magnitude. Is it necessary to specify its direction? Explain.
11. Can a magnitude of a vector be negative?
12. Can the magnitude of a particle's displacement be greater than the distance traveled?
13. If two vectors are equal, what can you say about their components? What can you say about their magnitudes? What can you say about their directions?
14. If three vectors sum up to zero, what geometric condition do they satisfy?
15. Give an example of a nonzero vector that has a component of zero.
16. Explain why a vector cannot have a component greater than its own magnitude.
17. If two vectors are equal, what can you say about their components?
18. If vectors \vec{A} and \vec{B} are orthogonal, what is the component of \vec{B} along the direction of \vec{A} ? What is the component of \vec{A} along the direction of \vec{B} ?
19. If one of the two components of a vector is not zero, can the magnitude of the other vector component of this vector be zero?
20. If two vectors have the same magnitude, do their components have to be the same?

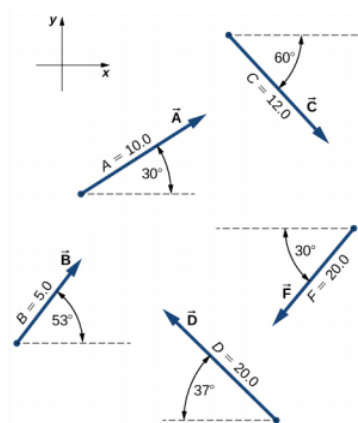
Problems

21. A scuba diver makes a slow descent into the depths of the ocean. His vertical position with respect to a boat on the surface changes several times. He makes the first stop 9.0 m from the boat but has a problem with equalizing the pressure, so he ascends 3.0 m and then continues descending for another 12.0 m to the second stop. From there, he ascends 4 m and then descends for 18.0 m, ascends again for 7 m and descends again for 24.0 m, where he makes a stop, waiting for his buddy. Assuming the positive direction up to the surface, express his net vertical displacement vector in terms of the unit vector. What is his distance to the boat?
22. Suppose you walk 18.0 m straight west and then 25.0 m straight north. How far are you from your starting point and what is the compass direction of a line connecting your starting point to your final position? Write your displacement as a column vector and compute its magnitude.
23. For the vectors given in the following figure, find the components of each lettered vector and find the following vectors:
 - a. $\vec{A} + \vec{B}$,
 - b. $\vec{C} + \vec{B}$,
 - c. $\vec{D} + \vec{F}$,
 - d. $\vec{A} - \vec{B}$,
 - e. $\vec{D} - \vec{F}$,
 - f. $\vec{A} + 2\vec{F}$,

g. $\vec{A} - 4\vec{D} + 2\vec{F}$.



28. A delivery man starts at the post office, drives 40 km north, then 20 km west, then 60 km northeast, and finally 50 km north to stop for lunch. What is the delivery man's displacement magnitude and direction from the post office?
29. An adventurous dog strays from home, runs three blocks east, two blocks north, one block east, one block north, and two blocks west. Assuming that each block is about 100 m, how far from home and in what direction is the dog?
30. In an attempt to escape a desert island, a castaway builds a raft and sets out to sea. The wind shifts a great deal during the day and he is blown along the following directions: 2.50 km and 45.0° north of west, then 4.70 km and 60.0° south of east, then 1.30 km and 25.0° south of west, then 5.10 km straight east, then 1.70 km and 5.00° east of north, then 7.20 km and 55.0° south of west, and finally 2.80 km and 10.0° north of east. Use a graphical method to find the castaway's final position relative to the island.
31. A small plane flies 40.0 km in a direction 60° north of east and then flies 30.0 km in a direction 15° north of east. Find the total distance the plane covers from the starting point and the direction of the path to the final position.
32. A surveyor measures the distance across a river that flows straight north by the following method. Starting directly across from a tree on the opposite bank, the surveyor walks 100 m along the river to establish a baseline. She then sights across to the tree and reads that the angle from the baseline to the tree is 35° . How wide is the river?
33. The magnitudes of two displacement vectors are $A = 20$ m and $B = 6$ m. What are the largest and the smallest values of the magnitude of the resultant $\vec{R} = \vec{A} + \vec{B}$?
34. Assuming the $+x$ -axis is horizontal and points to the right, resolve the vectors given in the following figure to their scalar components and express them in vector component form.



35. Suppose you walk 18.0 m straight west and then 25.0 m straight north. How far are you from your starting point? What is your displacement vector? What is the direction of your displacement? Assume the $+x$ -axis is to the east.
36. You drive 7.50 km in a straight line in a direction 15° east of north. (a) Find the distances you would have to drive straight east and then straight north to arrive at the same point. (b) Show that you still arrive at the same point if the east and north legs are reversed in order. Assume the $+x$ -axis is to the east.

37. A sledge is being pulled by two horses on a flat terrain. The net force on the sledge can be expressed in the Cartesian coordinate system as vector $\vec{F} = \begin{bmatrix} -2980.0 \\ 8200.0 \\ 0 \end{bmatrix}$ N. Find the magnitude and direction of the pull.
38. A fly enters through an open window and zooms around the room. In a Cartesian coordinate system with three axes along three edges of the room, the fly changes its position from point b(4.0 m, 1.5 m, 2.5 m) to point e(1.0 m, 4.5 m, 0.5 m). Find the scalar components of the fly's displacement vector and express its displacement vector in vector component form. What is its magnitude?
39. For vectors $\vec{B} = \begin{bmatrix} 1 \\ -4 \\ 0 \end{bmatrix}$ and $\vec{A} = \begin{bmatrix} -3 \\ -2 \\ 0 \end{bmatrix}$ (a) $\vec{A} + \vec{B}$ and its magnitude and direction angle, and (b) $\vec{A} - \vec{B}$ and its magnitude and direction angle.
40. A particle undergoes three consecutive displacements given by vectors $\vec{D}_1 = \begin{bmatrix} 3.0 \text{ mm} \\ -4.0 \text{ mm} \\ -2.0 \text{ mm} \end{bmatrix}$, $\vec{D}_2 = \begin{bmatrix} 4.0 \text{ mm} \\ -7.0 \text{ mm} \\ 4.0 \text{ mm} \end{bmatrix}$, and $\vec{D}_3 = \begin{bmatrix} -7.0 \text{ mm} \\ 4.0 \text{ mm} \\ 1.0 \text{ mm} \end{bmatrix}$. (a) Find the resultant displacement vector of the particle. (b) What is the magnitude of the resultant displacement? (c) If all displacements were along one line, how far would the particle travel?
41. Given two displacement vectors $\vec{A} = \begin{bmatrix} 3.0 \text{ m} \\ -4.0 \text{ m} \\ 4.0 \text{ m} \end{bmatrix}$ and $\vec{B} = \begin{bmatrix} 2.0 \text{ m} \\ 3.0 \text{ m} \\ -7.0 \text{ m} \end{bmatrix}$, find the displacements and their magnitudes for (a) $\vec{C} = \vec{A} + \vec{B}$ and (b) $\vec{D} = 2\vec{A} - \vec{B}$.
42. A small plane flies 40.0 km in a direction 60° north of east and then flies 30.0 km in a direction 15° north of east. Use the analytical method to find the total distance the plane covers from the starting point, and the geographic direction of its displacement vector. What is its displacement vector?
43. In an attempt to escape a desert island, a castaway builds a raft and sets out to sea. The wind shifts a great deal during the day, and she is blown along the following straight lines: 2.50 km and 45.0° north of west, then 4.70 km and 60.0° south of east, then 1.30 km and 25.0° south of west, then 5.10 km due east, then 1.70 km and 5.00° east of north, then 7.20 km and 55.0° south of west, and finally 2.80 km and 10.0° north of east. Use the analytical method to find the resultant vector of all her displacement vectors. What is its magnitude and direction?
44. A barge is pulled by the two tugboats shown in the following figure. One tugboat pulls on the barge with a force of magnitude 4000 units of force at 15° above the line AB (see the figure and the other tugboat pulls on the barge with a force of magnitude 5000 units of force at 12° below the line AB. Resolve the pulling forces to their scalar components and find the components of the resultant force pulling on the barge. What is the magnitude of the resultant pull? What is its direction relative to the line AB?
45. In the control tower at a regional airport, an air traffic controller monitors two aircraft as their positions change with respect to the control tower. One plane is a cargo carrier Boeing 747 and the other plane is a Douglas DC-3. The Boeing is at an altitude of 2500 m, climbing at 10° above the horizontal, and moving 30° north of west. The DC-3 is at an altitude of 3000 m, climbing at 5° above the horizontal, and cruising directly west. (a) Find the position vectors of the planes relative to the control tower. (b) What is the distance between the planes at the moment the air traffic controller makes a note about their positions?

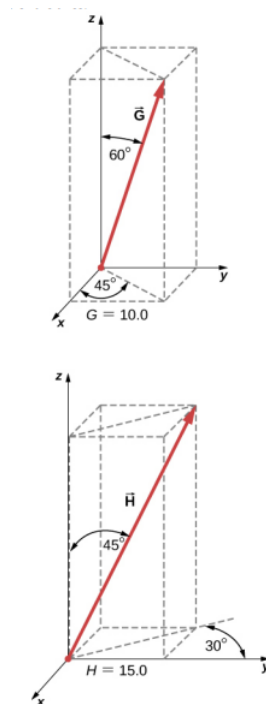
Additional Problems

46. You fly 32.0 km in a straight line in still air in the direction 35.0° south of west. (a) Find the distances you would have to fly due south and then due west to arrive at the same point. (b) Find the distances you would have to fly first in a direction 45.0° south of west and then in a direction 45.0° west of north. Note these are the components of the displacement along a different set of axes—namely, the one rotated by 45° with respect to the axes in (a).
47. An air traffic controller notices two signals from two planes on the radar monitor. One plane is at altitude 800 m and in a 19.2-km horizontal distance to the tower in a direction 25° south of west. The second plane is at altitude 1100 m and its horizontal distance is 17.6 km and 20° south of west. What is the distance between these planes?

48. Show that when $\vec{A} + \vec{B} = \vec{C}$, then $C^2 = A^2 + B^2 + 2AB \cos \varphi$, where φ is the angle between vectors \vec{A} and \vec{B} .
49. Four force vectors each have the same magnitude f . What is the largest magnitude the resultant force vector may have when these forces are added? What is the smallest magnitude of the resultant? Make a graph of both situations.
50. A stubborn dog is being walked on a leash by its owner. At one point, the dog encounters an interesting scent at some spot on the ground and wants to explore it in detail, but the owner gets impatient and pulls on the leash with force $\vec{F} = \begin{bmatrix} 98.0 \text{ N} \\ 132.0 \text{ N} \\ 32.0 \text{ N} \end{bmatrix}$ along the leash. (a) What is the magnitude of the pulling force? (b) What angle does the leash make with the vertical?
51. If the velocity vector of a polar bear is $\vec{u} = \begin{bmatrix} -18.0 \text{ km/h} \\ -13.0 \text{ km/h} \\ 0.0 \text{ km/h} \end{bmatrix}$, how fast and in what geographic direction is it heading?

Here, the positive x and y axes are directions to geographic east and north, respectively.

52. Find the scalar components of three-dimensional vectors \vec{G} and \vec{H} in the following figure and write the vectors in column vector form.



55. A diver explores a shallow reef off the coast of Belize. She initially swims 90.0 m north, makes a turn to the east and continues for 200.0 m, then follows a big grouper for 80.0 m in the direction 30° north of east. In the meantime, a local current displaces her by 150.0 m south. Assuming the current is no longer present, in what direction and how far should she now swim to come back to the point where she started?
56. A force vector \vec{A} has x- and y-components, respectively, of -8.80 units of force and 15.00 units of force. The x- and y-components of force vector \vec{B} are, respectively, 13.20 units of force and -6.60 units of force. Find the components of force vector \vec{C} that satisfies the vector equation $\vec{A} - \vec{B} + 3\vec{C} = 0$.

Challenge Problems

57. Vector \vec{B} is 5.0 cm long and vector \vec{A} is 4.0 cm long. Find the angle between these two vectors when $|\vec{A} + \vec{B}| = 3.0$ cm and $|\vec{A} - \vec{B}| = 3.0$ cm.

Contributors

Samuel J. Ling (Truman State University), Jeff Sanny (Loyola Marymount University), and Bill Moebs with many contributing authors. This work is licensed by OpenStax University Physics under a [Creative Commons Attribution License \(by 4.0\)](#).

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