SECTION 3.1

Introduction to Vectors

KEY TERMS

scalar
vector
resultant

Scalars and Vectors

Previously you explored motion in one dimension. You know that direction can be indicated by a positive or negative sign if motion is only forward and back.

Vectors indicate direction. Scalars do not.

Each of the physical quantities described in this book has a magnitude. Magnitude is a property that can be described by a real number. Some quantities also have a direction. Direction often matters when you analyze motion.

A **scalar** is a quantity that has a magnitude but no direction. An example is volume. Mass and perimeter also have magnitude but no direction. A **vector** is a quantity that has both direction and magnitude. Examples include velocity and acceleration.

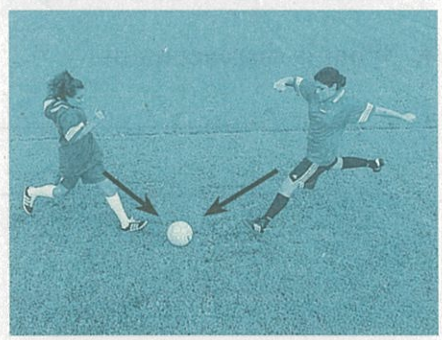
READING CHECK

1. Give another example of a scalar. Give another example of a vector.

Vectors are represented by boldface symbols.

This book uses **boldface** to indicate vector quantities. Scalar quantities will be in *italics*. An example is speed. Speed might be written $v = 3.5$ m/s and velocity as $\mathbf{v} = 3.5$ m/s to the left. Vectors can also be indicated by an arrow over the variable.

One way to represent vectors is to use diagrams. The quantity is represented by an arrow in the direction of the vector. The length of each arrow is proportional to the magnitude of each vector.



The player on the right is running faster than the player on the left. She is also running at a different angle. The arrows show the velocity of each player. The start of the arrow shows where the motion starts. The direction of the arrow shows the direction of the motion. The length of the arrow shows the magnitude of the motion.

A resultant vector represents the sum of two or more vectors.

Vectors can be combined. This is easy to see in one-dimensional motion. Here is an example. A 2 cm displacement right plus a 3 cm displacement right results in a 5 cm displacement right. A 2 cm displacement right plus a 3 cm displacement left would result in a net displacement of $2 + (-3) = -1$. This can be written as 1 cm left. In this example, right is positive and left is negative. The sum of two or more vectors is the **resultant** vector.

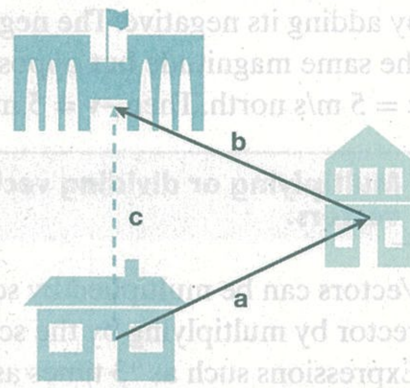
Sometimes you will need to add vectors. First check that they measure the same quantity. The quantity might be velocity. You cannot add meters to meters/second. Also make sure that the two quantities are in the same units. You must convert one if they are not.

Vectors can be added graphically.

You can add vectors by drawing the problem on paper. Choose a scale for the vectors that is easy to work with. Suppose distances are 1200 m and 1500 m. Use 1 cm = 300 m. The vector representing 1200 m will be 4 cm long. The vector representing 1500 m will be 5 cm long.

You want to add **a** + **b**. Draw **a**. Then draw **b**. Start with the tail of **b** at the head of **a**. This also works when combining two velocities or two accelerations.

The resultant vector **c** is then drawn from the tail of **a** to the head of **b**. The tail of **c** is against the open tail in the chain of vectors. The head of **c** is against the open head in the chain. The resultant's magnitude and angle can be measured with a ruler and protractor. This technique works to combine any number of vectors at any angle.



A student walks from his house to his friend's house. His displacement is shown by vector **a.** He then walks from his friend's house to school. This second displacement is shown by vector **b.** The resultant displacement is found by a vector along path **c.**

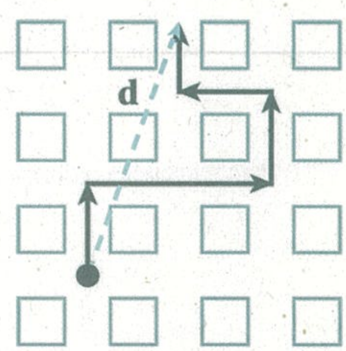
Properties of Vectors

Graphic vector addition is not limited to displacement. It can be used to combine all the vectors of any single quantity acting on the same object.

Vectors can be moved parallel to themselves in a diagram.

Suppose a moving walkway at an airport moves forward at 1.5 m/s. You walk along it in the forward direction at 1 m/s. Your resultant velocity is 2.5 m/s forward. This is relative to the unmoving floor beside the walkway.

Draw both velocity vectors. One is for you as you walk. The other is for the walkway as it moves. You want to combine them graphically. Shift one to start at the head of the other. Keep each vector parallel to itself and pointing in the same direction. Then you can move it anywhere in the diagram.



Five displacement vectors are arranged in one path through a map. Start at the same position each time. The five vectors are 1 up, 2 right, 1 up, 1 left, and 1 up. These can be combined in any order. Your net displacement at **d** will be the same no matter how you combine the moves. You can try this with a piece of graph paper.

Vectors can be added in any order.

Vectors can be added in any order. So 1.5 m/s forward plus 1 m/s forward will give the same results as 1 m/s forward plus 1.5 m/s forward.

To subtract a vector, add its opposite.

You know that $1 - 3 = 1 + (-3)$. You can also subtract a vector by adding its negative. The negative of a vector is a vector with the same magnitude but opposite in direction. Suppose $\mathbf{v}$ = 5 m/s north. Then $-\mathbf{v}$ = 5 m/s south.

Multiplying or dividing vectors by scalars results in vectors.

Vectors can be multiplied by scalars. Finding the negative of a vector by multiplying by the scalar –1 is one example. Expressions such as "3 times as fast" and "half as far" also work.

If $\mathbf{v}$ = 4 m/s up, then $3\mathbf{v}$ = 12 m/s up.

If $\mathbf{d}$ = 18 cm left, then $\frac{1}{2}\mathbf{d}$ = 9 cm left.

Did YOU Know?

The word *vector* is also used by airline pilots and navigators. They use a vector for the path an object follows. It is given as a compass heading.

READING CHECK

2. Apply "twice as fast in the other direction" to $\mathbf{v}$ = 3 cm/s.

SECTION 3.1 REVIEW

REVIEWING MAIN IDEAS

1. Which of the following are scalars? Which are vectors?

a. the acceleration of a plane as it takes off ______________________________

b. the number of passengers on the plane ______________________________

c. the duration of the flight ______________________________

d. the displacement of the flight ______________________________

e. the amount of fuel required for the flight ______________________________

2. A roller-coaster car moves 85 m horizontally. It then travels 45 m at an upward angle of 30.0° above the horizontal. Use graphic addition to find the displacement of the car from its starting point.

Critical Thinking

3. The water used in many sprinkler systems is recycled. Suppose a single water particle in a sprinkler system travels 85 m and then returns to its starting point. What is the displacement of this water particle after one cycle?

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