

2

Vectors and Projectiles

2-1 Vectors and Scalars

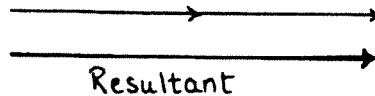
Vocabulary **Vector:** A quantity with magnitude (size) and direction.

Some examples of vectors are displacement, velocity, acceleration, and force.

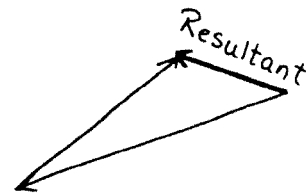
Vocabulary **Scalar:** A quantity with magnitude only.

Some examples of scalars are distance, speed, mass, time, and volume.

Vectors are represented by arrows. They can be added by placing the arrows head to tail. The arrow that extends from the tail of the first vector to the head of the last vector is called the **resultant**. It indicates both the magnitude and direction of the vector sum.

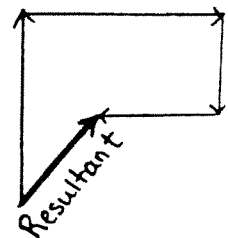


Remember, vectors don't always have to be in a straight line but may be oriented at angles to each other, such as

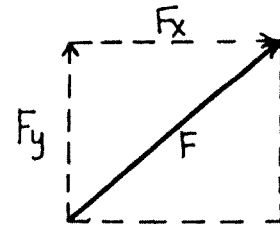


Resultant vectors can be determined by a number of different methods. Here you will solve vector addition exercises both **graphically** and with **vector components**.

Graphical addition of vectors: Using a ruler, draw all vectors to scale and connect them head to tail. The **resultant** is the vector that connects the tail of the first vector with the head of the last. (Hint: Using graph paper makes this method even easier!)



Vector Components: Because a vector has both magnitude and direction, you can separate it into horizontal (or x) and vertical (or y) components. To do this, draw a rectangle with horizontal and vertical sides and a diagonal equal to the vector. Draw arrow heads on one horizontal and one vertical side to make the original vector the resultant of the horizontal and vertical components.



After you have drawn the components, you can find their lengths by using simple trigonometry. If you are not familiar with trigonometry or need a quick refresher, refer to Appendix A.

Solved Examples

Example 1: Every March, the swallows return to San Juan Capistrano, California after their winter in the south. If the swallows fly due north and cover 200 km on the first day, 300 km on the second day, and 250 km on the third day, draw a vector diagram of their trip and find their total displacement for the three-day journey.

Example 2: In the record books, there are men who claim that they have such strong teeth that they can even use them to move cars, trains, and helicopters. Joe Ponder of Love Valley, North Carolina is one such man. Suppose a car pulling forward with a force of 20 000 N was pulled back by a rope that Joe held in his teeth. Joe pulled the car with a force of 25 000 N. Draw a vector diagram of the situation and find the resultant force.

Example 3: If St. Louis Cardinals homerun king, Mark McGwire, hit a baseball due west with a speed of 50.0 m/s , and the ball encountered a wind that blew it north at 5.00 m/s , what was the resultant velocity of the baseball?

Example 4: The Maton family begins a vacation trip by driving 700 km west. Then the family drives 600 km south, 300 km east, and 400 km north. Where will the Matons end up in relation to their starting point? Solve graphically.

Example 5: Ralph is mowing the back yard with a push mower that he pushes downward with a force of 20.0 N at an angle of 30.0° to the horizontal. What are the horizontal and vertical components of the force exerted by Ralph?

Practice Exercises

Exercise 1: Some Antarctic explorers heading due south toward the pole travel 50. km during the first day. A sudden snow storm slows their progress and they move only 30. km on the second day. With plenty of rest they travel the final 65 km the last day and reach the pole. What was the explorers' displacement?

Answer: _____

Exercise 2: Erica and Tory are out fishing on the lake on a hot summer day when they both decide to go for a swim. Erica dives off the front of the boat with a force of 45 N, while Tory dives off the back with a force of 60. N. a) Draw a vector diagram of the situation. b) Find the resultant force on the boat.

Answer: b. _____

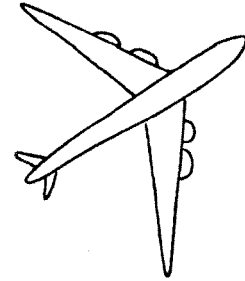
Exercise 3: Young thoroughbreds are sometimes reluctant to enter the starting gate for their first race. Astro Turf is one such horse, and it takes two strong men to get him set for the race. Derek pulls Astro Turf's bridle from the front with a force of 200. N and Dan pushes him from behind with a force of 150. N, while the horse pushes back against the ground with a force of 300. N. a) Draw a vector diagram of the situation. b) What is the resultant force on Astro Turf?

Answer: b. _____

Exercise 4: Shareen finds that when she drives her motorboat upstream she can travel with a speed of only 8 m/s, while she moves with a speed of 12 m/s when she heads downstream. What is the current of the river on which Shareen is traveling?

Answer: _____

Exercise 5: Rochelle is flying to New York for her big Broadway debut. If the plane heads out of Los Angeles with a velocity of 220. m/s in a northeast direction, relative to the ground, and encounters a wind blowing head-on at 45 m/s, what is the resultant velocity of the plane, relative to the ground?



Answer: _____

Exercise 6: While Dexter is on a camping trip with his boy scout troop, the scout leader hands each boy a compass and map. The directions on Dexter's map read as follows: "Walk 500.0 m north, 200.0 m east, 300.0 m south, and 400.0 m west." If he follows the map, what is Dexter's displacement? Solve graphically.

Answer: _____

Exercise 7: Amit flies due east from San Francisco to Washington, D.C., a displacement of 5600. km. He then flies from Washington to Boston, a displacement of 900. km at an angle of 55.0° east of north. What is Amit's total displacement?

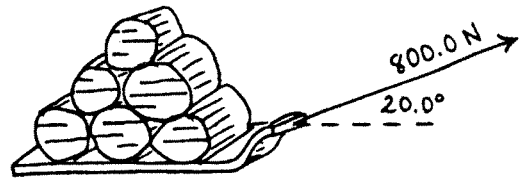
Answer: _____

Exercise 8: Marcie shovels snow after a storm by exerting a force of 30.0 N on her shovel at an angle of 60.0° to the vertical. What are the horizontal and vertical components of the force exerted by Marcie?

Answer: _____

Answer: _____

Exercise 9: Ivan pulls a sled loaded with logs to his cabin in the woods. If Ivan pulls with a force of 800. N in a direction 20.0° above the horizontal, what are the horizontal and vertical components of the force exerted by Ivan?



Answer: _____

Answer: _____

Additional Exercises

- A-1:** A flock of Canada geese is flying south for the winter. On the first day the geese fly due south a distance of 800. km. On the second day they fly back north 100. km and pause for a couple of days to graze on a sod farm. The last day the geese continue their journey due south, covering a distance of 750. km. a) Draw a vector diagram of the journey and find the total displacement of the geese during this time. b) How does this value differ from the total distance traveled?
- A-2:** A seal swims toward an inlet with a speed of 5.0 m/s as a current of 1.0 m/s flows in the opposite direction. How long will it take the seal to swim 100. m?
- A-3:** In Moncton, New Brunswick, each high tide in the Bay of Fundy produces a large surge of water known as a tidal bore. If a riverbed fills with this flowing water that travels north with a speed of 1.0 m/s, what is the resultant velocity of a puffin who tries to swim east across the tidal bore with a speed of 4.0 m/s?
- A-4:** Lynn is driving home from work and finds that there is road construction being done on her favorite route, so she must take a detour. Lynn travels 5 km north, 6 km east, 3 km south, 4 km west, and 2 km south. a) Draw a vector diagram of the situation. b) What is her displacement? Solve graphically. c) What total distance has Lynn covered?
- A-5:** Avery sees a UFO out her bedroom window and calls to report it to the police. She says, "The UFO moved 20.0 m east, 10.0 m north, and 30.0 m west before it disappeared." What was the displacement of the UFO while Avery was watching? Solve graphically.
- A-6:** Eli finds a map for a buried treasure. It tells him to begin at the old oak and walk 21 paces due west, 41 paces at an angle 45° south of west, 69 paces due north, 20 paces due east, and 50 paces at an angle of 53° south of east. How far from the oak tree is the buried treasure? Solve graphically.
- A-7:** Dwight pulls his sister in her wagon with a force of 65 N at an angle of 50.0° to the vertical. What are the horizontal and vertical components of the force exerted by Dwight?
- A-8:** Esther dives off the 3-m springboard and initially bounces up with a velocity of 8.0 m/s at an angle of $80.^\circ$ to the horizontal. What are the horizontal and vertical components of her velocity?
- A-9:** In many locations, old abandoned stone quarries have become filled with water once excavating has been completed. While standing on a 10.0-m-high quarry wall, Clarence tosses a piece of granite into the water below. If Clarence throws the rock horizontally with a velocity of 3.0 m/s, how far out from the edge of the cliff will it hit the water?