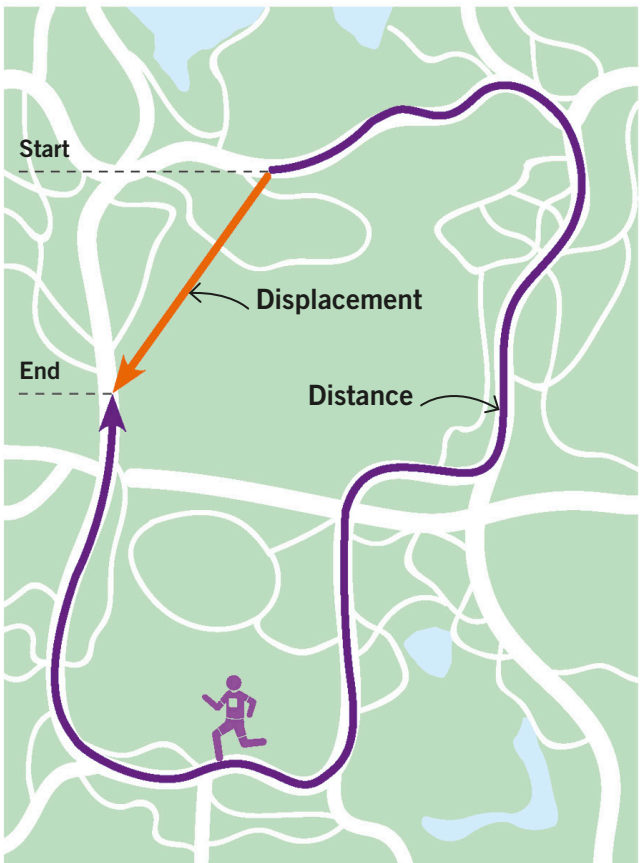
Scalars and vectors

Scientific measurements are either scalar quantities or vector quantities. Scalar quantities just have a magnitude (size), whereas vector quantities have magnitude and direction.

Distance and displacement

The map below shows the route a jogger takes around a park. How far has he traveled? One way to answer this is to measure the total distance of his winding path. This is a scalar quantity, as it has no particular direction. Another is to measure his displacement—his distance and direction in a straight line from his starting point. Displacement is a vector quantity because it has a direction as well as a magnitude.



Key facts

- ✓ **Scalar quantities have magnitude.**
- ✓ **Vector quantities have magnitude and direction.**
- ✓ **Distance is scalar; displacement is a vector.**

Vector quantities

Forces always have a direction, so all forces are vectors. Your weight is a force that acts downward toward Earth, so weight is a vector. In contrast, your mass (the amount of matter in your body) is a scalar quantity.

The velocity of an object is its speed in a particular direction. If a car is turning a corner at a steady 31 mph (50 km/h), its speed is constant but its direction is changing, so its velocity is changing, too.

Acceleration, in everyday language, means getting faster. However, the scientific meaning of acceleration is a change in velocity. Acceleration is a vector quantity and tells us if an object is getting faster, slower, or changing direction.

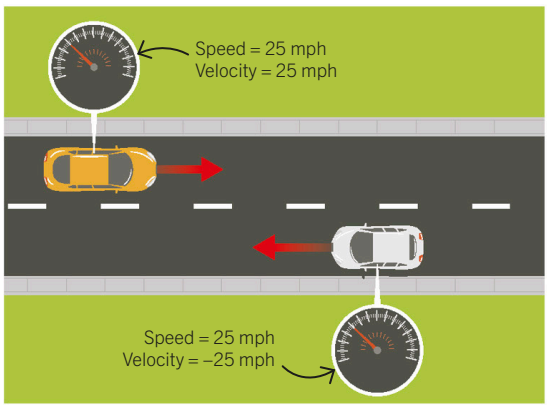
The momentum of an object is its mass multiplied by its velocity. Momentum is calculated from velocity and so is a vector quantity.

Velocity

Speed and velocity are not the same thing. Speed tells you how fast something is moving, but velocity is how fast something is moving in a particular direction. Unlike speed, which is a scalar quantity, velocity is a vector quantity—it has direction as well as magnitude.

Key facts

- ✓ **Velocity is the speed of a moving object in a particular direction.**
- ✓ **Velocity is a vector quantity—it has direction and magnitude.**
- ✓ **Speed is a scalar quantity—it has no direction.**



Speed and velocity
If two cars are traveling at the same speed but in opposite directions, they have different velocities. For example, the yellow car is traveling 25 mph (40 km/h) east, but the white car is traveling 25 mph (40 km/h) west. In physics, we can use a minus sign to show something is happening in the opposite direction. In this diagram, east is the positive direction, so the white car has a velocity of –25 mph (–40 km/h).

Changing velocity
When a car turns, its direction changes, which means that its velocity changes as well. The car here has driven at a constant speed all the way around a roundabout, but its velocity has been changing continually. Its average velocity going around the roundabout is 0 mph (km/h).

Frames of reference

Suppose you're standing on a train moving east at 50 m/s and you throw a ball forward at 10 m/s. What's the ball's velocity? The speed relative to you is 10 m/s, but for someone standing beside the track, the ball's velocity is 60 m/s. Likewise, if you throw the ball backward at 10 m/s, someone beside the track will see it moving forward at 40 m/s. All these quantities are correct, but each one depends on a different point of view. We call these different points of view "frames of reference."