Motion

What are some words and/or concepts we use when describing motion?

Look at an object. Close your eyes. In a few seconds, open them again. Can you tell that motion has occurred?

How?

Distance and Displacement

Distance is a scalar representing the length of some path.

Displacement is a vector representing a change in position. Its magnitude is the straight-line distance between the start and end points, while its direction is the direction of the straight line from the start point to the end point.

If you start at an initial position $\vec{x}_i$ and move to a final position $\vec{x}_f$, your displacement $\Delta\vec{x}$ is defined as:

$$\Delta\vec{x} = \vec{x}_f - \vec{x}_i$$

Example Problem

If you move 5 meters north, $\Delta\vec{x} = +5$ meters north.

Now go the other direction, with a displacement of 3 m south.

What is the total distance traveled?

What is your net displacement?

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If you move 5 meters north, $\Delta\vec{x} = +$ 5 meters north.

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1. 2 m
2. 8 m

Example problem

If you move 5 meters north, $\Delta\vec{x} =$ + 5 meters north.

Now go the other direction, with a displacement of 3 m south.

What is your net displacement?

1. 2 m
2. 8 m
3. Neither of these

Solving the Problem

For multiple displacements, the total distance traveled is the sum of the distances for the individual displacements.

The total distance traveled is 5 m + 3 m = 8 m.

The net displacement is the vector sum of the individual displacements.

Define north to be the positive direction.

$\Delta\vec{x}_1 = +5$ m north.

$\Delta\vec{x}_2 = +3$ m south = -3 m north.

$$\Delta\vec{x}_{net} = \Delta\vec{x}_1 + \Delta\vec{x}_2 = +5 \text{ m north} - 3 \text{ m north} = +2 \text{ m north} .$$

Worksheet, part 1

Pick a partner to work with. You will take turns describing, without speaking, a motion that one of you sees to the other.

Multiple Representations

There are many ways to represent motion. Four are shown in the simulation. We can also simply describe the motion in words.

Description in words: An object drifts to the right with constant speed.

A motion diagram records the position of an object at regular time intervals.

Speed and Velocity

Speed is …….

Velocity is …….

Sometimes we want to know the average values (averaged over time) of the speed or velocity.

$$\text{average speed} = \frac{?}{\text{total time}}$$

$$\text{average velocity} = \frac{?}{\text{total time}} \text{ , or, } \bar{v} = \frac{?}{\Delta t}$$

Speed and Velocity

Speed is a scalar representing how fast an object is traveling.

Velocity is a vector combining the speed with the direction of motion. We can also define velocity as the rate of change of position.

Sometimes we want to know the average values (averaged over time) of the speed or velocity.

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$\text{average velocity} = \frac{\text{net displacement}}{\text{total time}} \text{ , or, } \quad \bar{v} = \frac{\Delta \vec{x}}{\Delta t}$$

A Question about a round trip

On your way to class one morning, you leave home and walk at 3.0 m/s east towards campus. After exactly one minute, you realize that you've left your physics assignment at home, so you turn around and run, at 6.0 m/s, back to get it. You're running twice as fast as you walked, so it takes half as long (30 seconds) to get home again.

Note that you covered 180 m before turning around.

What is your average speed for the round trip?

1. zero
2. 2.0 m/s
3. 4.0 m/s
4. 4.5 m/s
5. 5.0 m/s

Average Speed

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{360\ \text{m}}{90\ \text{s}} = 4.0\ \text{m/s}$$

Why can’t you just average the 3.0 m/s and the 6.0 m/s, to get 4.5 m/s?

Average Speed

Alternate approach:

You can't just average the 3.0 m/s and the 6.0 m/s, because of the different times involved. You can do a weighted average, however, counting the 3.0 m/s twice because the speed was 3.0 m/s for twice as long as the speed was 6.0 m/s.

$$\frac{3.0\text{ m/s} + 3.0\text{ m/s} + 6.0\text{ m/s}}{3} = \frac{12.0\text{ m/s}}{3} = 4.0\text{ m/s}$$

Another question about a round trip

On your way to class one morning, you leave home and walk at 3.0 m/s east towards campus. After exactly one minute, you realize that you've left your physics assignment at home, so you turn around and run, at 6.0 m/s, back to get it. You're running twice as fast as you walked, so it takes half as long (30 seconds) to get home again.

Note that you covered 180 m before turning around.

What is your average velocity for the round trip?

1. zero
2. 1.5 m/s west
3. 4.0 m/s west
4. 4.5 m/s west
5. None of these

Average Velocity

$$\text{average velocity} = \frac{\text{net displacement}}{\text{total time}} = \frac{0\ \text{m}}{90\ \text{s}} = 0$$

Why can’t you just average the +3.0 m/s and the -6.0 m/s, to get -1.5 m/s?

Average Velocity

Alternate approach:
We could do a weighted average again, counting the +3.0 m/s twice because the velocity was +3.0 m/s for twice as long as the velocity was -6.0 m/s.

$$\frac{+3.0\text{ m/s} + (+3.0\text{ m/s}) + (-6.0\text{ m/s})}{3} = \frac{0}{3} = 0$$

Instantaneous vs. average

When you pass the state trooper on the Mass Pike, is the trooper interested in your average speed or your instantaneous speed?

1. Your average speed
2. Your instantaneous speed

Instantaneous values

Sometimes we are interested in instantaneous speed or instantaneous velocity, the values of the speed or velocity at a particular instant.

When driving, what, in your car, would you use to find your instantaneous speed?

If you drive from Boston to New York City, what, in your car, would you use to find your average speed for the trip?

When you pass the state trooper on the Mass Pike, is the trooper interested in your average speed or your instantaneous speed?

Instantaneous values

Sometimes we are interested in instantaneous speed or instantaneous velocity, the values of the speed or velocity at a particular instant.

When driving, what, in your car, would you use to find your instantaneous speed? The speedometer.

If you drive from Boston to New York City, what, in your car, would you use to find your average speed for the trip?

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If you drive from Boston to New York City, what, in your car, would you use to find your average speed for the trip?

The odometer and the clock.

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When you pass the state trooper on the Mass Pike, is the trooper interested in your average speed or your instantaneous speed? Your instantaneous speed.

Instantaneous velocity

$$\text{average velocity} = \frac{\text{net displacement}}{\text{total time}}, \text{ or, } \bar{v} = \frac{\Delta \vec{x}}{\Delta t}$$

$$\text{instantaneous velocity} = \vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{x}}{\Delta t}$$

This is an intimidating definition. It's often easier, and more intuitive, to find instantaneous velocity from a graph.

Worksheet, part 2

Answer the five questions about the graph at the bottom of side 1 of the worksheet.

Worksheet, part 2

1. The instantaneous velocity at t = 10 s is:

$$\vec{v} = \frac{\Delta \vec{x}}{\Delta t} = \frac{+100 \text{ m} - (+50 \text{ m})}{20 \text{ s}} \hat{x} = +\left(2.5 \text{ m/s}\right) \hat{x}$$

Worksheet, part 2

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$$\vec{v} = \frac{\Delta \vec{x}}{\Delta t} = \frac{+100 \text{ m} - (+50 \text{ m})}{20 \text{ s}} \hat{x} = +\left(2.5 \text{ m/s}\right) \hat{x}$$

2. The instantaneous velocity at t = 25 s is zero.

Worksheet, part 2

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2. The instantaneous velocity at t = 25 s is zero.
3. The displacement for that interval is zero.

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2. The instantaneous velocity at t = 25 s is zero.
3. The displacement for that interval is zero.
4. The average velocity for the 50 s interval is:

$$\bar{v} = \frac{\Delta\vec{x}}{\Delta t} = \frac{(0\text{ m} - 50\text{ m})}{50\text{ s}}\hat{x} = -\left(1.0\text{ m/s}\right)\hat{x}$$

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5. The average speed is:

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{150\text{ m}}{50\text{ s}} = 3.0\text{ m/s}$$

Worksheet, part 3

Turn the worksheet over, and we'll draw graphs of three motions. Two we saw earlier, and the third represents the motion of me, standing still at the finish line.

Making use of the motion graphs

Complete the following sentences.

The instantaneous velocity is the ______ at a particular instant on a position-versus-time graph.

The displacement is the ____________________ for a particular time interval on a velocity-versus time graph.

Making use of the motion graphs

Complete the following sentences.

The instantaneous velocity is the slope at a particular instant on a position-versus-time graph.

The displacement is the ____________________ for a particular time interval on a velocity-versus time graph.

Making use of the motion graphs

Complete the following sentences.

The instantaneous velocity is the slope at a particular instant on a position-versus-time graph.

The displacement is the area under the curve for a particular time interval on a velocity-versus time graph.