

Extension 1: Another type of motion diagram

Purpose

When scientists want to describe the motion of an object they find it useful to use diagrams that convey important information quickly and easily. In this activity you will examine one of the most common types of diagram, called a *motion diagram* (sometimes also called a *strobe diagram*).



How can we represent the motion of an object using a diagram showing its position?

What do we think?

On a hot day, you and a friend visit your local ice cream shop. You get served first and choose an ice cream cone. As you step outside, your ice cream begins to slowly melt and you notice that a drop of melted ice cream falls to the ground regularly, once every second as you walk away from the store along the sidewalk. After a few seconds your friend comes out of the store, catches up with you, and says.

"I see from the pattern of ice cream drips on the sidewalk that you walked away from the store at a constant speed."

Discuss with your neighbors how your friend could tell what your motion was like from the pattern of ice cream drips on the sidewalk



Draw what the pattern of drips would be like if you were indeed walking at a constant speed.



Explain carefully what it is about this pattern of drips that shows that the speed was constant.



Your teacher will lead a class discussion about how you can tell something about the motion of an object if you know what its position is at regular time intervals.

Motion Diagrams

You probably drew the pattern made by the dripping ice cream in the ‘What We Think’ section as a row of dots. Because the ice cream dripped regularly once each second, these dots show its location at each second in time. We call a pattern of dots like this a *motion diagram* (or sometimes a *strobe diagram*). It shows the position of an object at *equal time intervals* and we can use this type of diagram to show the motion of an object. In the rest of this lesson you will think about what a motion diagram would look like for different types of motion.

Activity 1: Motion diagrams for constant speed

You will need:

- Access to the **Motion and Force Simulator**

STEP 1: We will continue with the story of the dripping ice cream cone. Because your friend left the ice cream shop after you, and managed to catch up with you, your friend must have been moving at a faster speed than you. If your friend also moved at a constant speed, but faster than your speed, would a pattern of one-second ice cream drips from their cone look the same as, or different from yours?

The picture below shows two friends who have just left the ice cream shop with ice cream cones that will both drip once per second. The girl left first so she has already walked a short distance away from the store before the boy comes out. The girl will continue walking to the right at a **slow constant speed**. In order to catch up with her, the boy will also walk at a constant speed, but one that is **faster than the girl’s**.




Sketch what you think the pattern of drips will look like for these ice cream cones that are both moving at a **constant speed**, but with one moving faster than the other.




Briefly explain why you drew the two patterns of drips as you did. How do they show that the speeds of the two objects were both constant, but one had a higher speed than the other?


STEP 2: To check your thinking, open the first simulator setup for this lesson. This setup shows the situation described in STEP 1. When the simulator is played, both children will move to the right at different constant speeds. As they move, they will leave dots (just like the ice cream drips) that show their position every second.


Run the simulator now.

-  How did the motion diagrams provided by the simulator compare with your predictions? If they are very different, sketch the patterns of dots produced by the simulator below.



-  How do the patterns of drips show that both children's speed was constant? What is it about their motion that makes the pattern look like this?

-  How can you tell **from the patterns of drips** that the boy was walking faster than the girl? What is it about the boy's motion that makes his pattern of drips different from the girl's?

-  Your teacher will lead a class discussion about motion diagrams for objects that are moving at a constant speed.

Activity 2: Motion diagrams for changing speed

You will need:

- Access to the **Motion and Force Simulator**

STEP 1: After standing and talking to your friend for a short time you realize that your ice cream cone is still dripping. You want to get back to your house quickly, so you begin to run. In order not to knock the ice cream scoop loose from the cone, you increase your speed gradually over a period of ten seconds.



Sketch what you think the pattern of drips from your ice cream cone will look like while your speed is gradually increasing.



Briefly explain why you drew the patterns of drips as you did. How do they show that your speed was increasing?

STEP 2: To check your thinking, open the second simulator setup for this lesson. This setup shows one child who, when it is played, will move to the right at a gradually increasing speed.

Run the simulator now.



How did the motion diagram provided by the simulator compare with your prediction? If they are very different, sketch the pattern of dots produced by the simulator below.





How does the pattern of drips show that the child's speed was increasing? What is it about her motion that makes the pattern look like this?

STEP 3: After running as fast as you can almost all the way back home you get close to your house. Again, in order not to knock your ice cream scoop loose from the cone, you gradually decrease your speed over a period of ten seconds.



Sketch what you think the pattern of drips from your ice cream cone will look like while your speed is gradually decreasing.



Briefly explain why you drew the patterns of drips as you did. How do they show that your speed was decreasing?

STEP 4: To check your thinking, open the third simulator setup for this lesson. This setup shows one child who, when it is played, will move to the right at a gradually decreasing speed.

Run the simulator now.



How did the motion diagram provided by the simulator compare with your prediction? If they are very different, sketch the pattern of dots produced by the simulator below.





How does the pattern of drips show that the child's speed was decreasing? What is it about her motion that makes the pattern look like this?

Making Sense



Your teacher will lead a class discussion about motion diagrams. Write answers to the following questions after each one is discussed by the class.

- S1:** Draw a single motion diagram for the whole journey taken after you leave the ice cream shop. Your diagram should use a single line of dots to show the following steps in order.
- Walking at a slow constant speed
 - Starting to run with gradually increasing speed
 - Running at a fast constant speed
 - Ending your run with gradually decreasing speed

S2: The police are investigating a wreck in which a red car ran into the back of a blue car, while they were both driving along a straight, but narrow, country road. Both drivers agree that they were driving at the same constant speed for several miles and that what caused the wreck was that suddenly one of the cars changed its speed quickly, but they disagree on which car this was.

- The driver of the red car claims that he ran into the back of the blue car, because the blue car slowed very quickly with no warning while he continued at a constant speed.
- The driver of the blue car claims he was moving at a constant speed, and that the red car ran into the back of his car because it suddenly increased speed.

The police note a trail of oil drops on the road, leading to the site of the wreck, and establish that these must have come from the red car.

What would the pattern of drops look like if the driver of the red car was telling the truth? What if he were lying? Draw these two possible patterns of dots and explain how they would help you decide.

Extension 2: Showing speed with a line graph

Purpose

Graphs are a very useful way to show information and scientists often use them. When they want to show how some value is changing as time goes on, they often use line graphs because they provide a quick and easy way to show whether some value is increasing, decreasing, or staying constant. In this lesson you will first learn about line graphs and then think about how a line graph of an object's speed can show how it is behaving.

The key question for this lesson is:

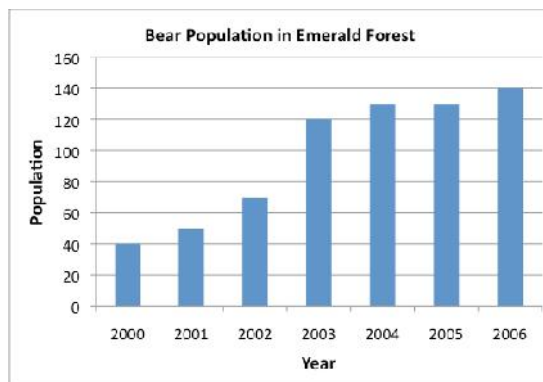


What do line graphs of speed versus time look like for different types of motion?

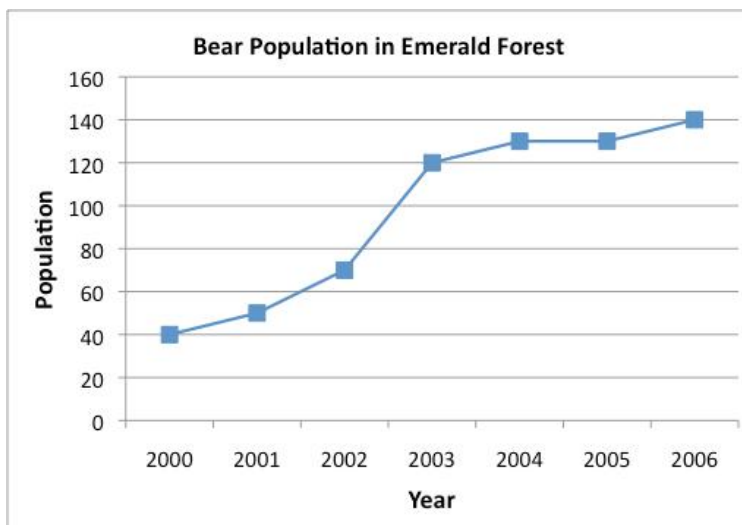
Bar Graphs and Line graphs

Suppose a scientist went into Emerald Forest on July 1st each year from 2000 to 2006, and counted the number of bears she saw. She could then use this information to draw a bar graph of the bear population in the forest over that period of years.

While this bar graph shows that the number of bears in the forest was increasing, suppose the researcher wanted to compare how quickly the population was increasing across different years. In this case, a line graph would be more useful.



To make a line graph, instead of drawing bars of different heights, the researcher plots points on the graph that correspond to the years and populations she recorded. *Notice that these points are at the exactly the same place that the center of the top of each bar in her bar graph would be.* She then joins the dots together by drawing lines between them. (Sometimes line graphs are even drawn without the dots, only the lines!)

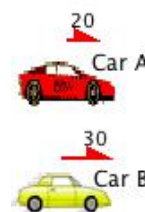


Looking at this line graph we can easily see that, although the line moves upward almost every year, it is steepest between 2002 and 2003. This tells the researcher that the bear population increased more quickly between July 1st 2002 and July 1st 2003 than during any other period shown on the graph.

It is in situations like this, where we want to see the overall trends and changes in values, that line graphs are most useful. In the rest of this lesson, you will think about what line graphs of the speed of an object would look like for the different types of motion you have already seen.

What do we think?

Two cars are driving down a two-lane highway. Car A is moving at a constant speed of 20 m/s. Car B is also moving at a constant speed, but at 30 m/s. Now suppose you wanted to draw line graphs for these two cars that show how their speed behaves over a ten second period. What would these graphs look like? The next few questions will help you think about this.



Recall that Car A is moving at a constant speed of 20 m/s, while Car B is moving at a constant speed of 30 m/s. Before drawing graphs it is useful to make a table of the values to be used. In this case we need a table of values for the speed of these two cars over the 10-second period of interest. In the table below the speed of the two cars at the beginning of the ten second period is already entered.



Complete the table by entering values for the speed of both cars at the other times given.

| Time | Speed of Car A | Speed of Car B |
|------|----------------|----------------|
| 0 s | 20 m/s | 30 m/s |
| 1 s | | |
| 2 s | | |
| 3 s | | |
| 4 s | | |
| 5 s | | |
| 6 s | | |
| 7 s | | |
| 8 s | | |
| 9 s | | |
| 10 s | | |



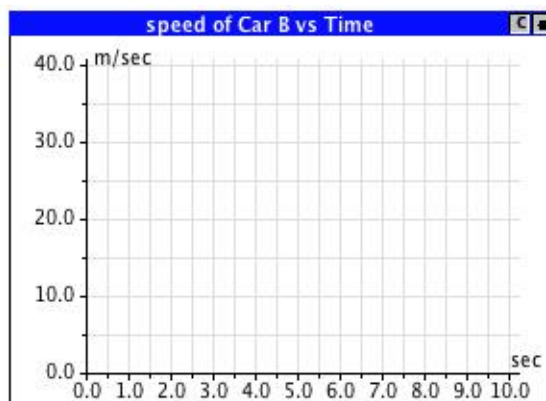
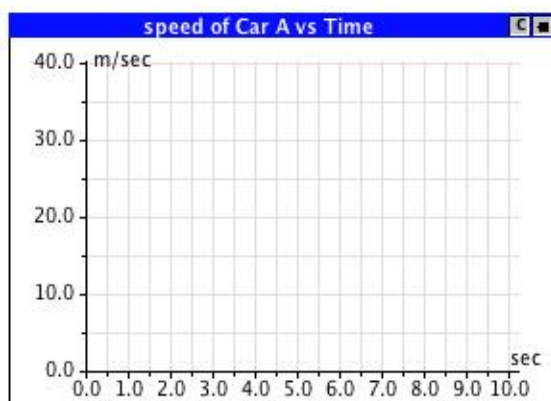
Explain how you determined what values to enter for the speed of both cars in each row of the table.



What do you think line graphs for the speed of these two cars will look like? Why do you think so?



Use the values you entered in the table to create line graphs for the speed of the two cars over the 10-second period. To do this, plot your points as small dots on the blank graphs below and then join the dots with straight lines.

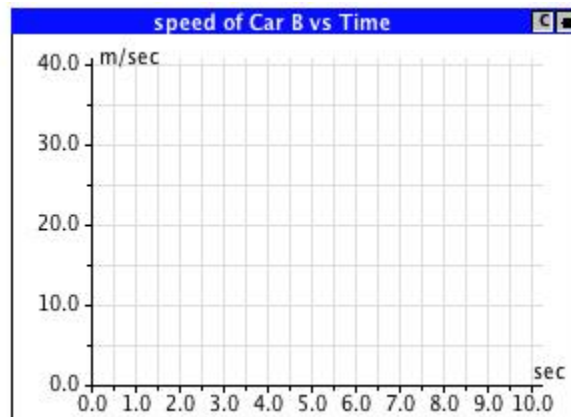
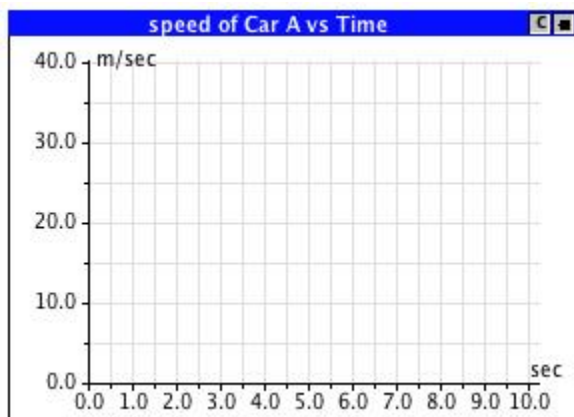


Your teacher will lead a class discussion about everyone's ideas about line graphs that show the speeds of the two cars.

Now run the first simulator setup for this lesson. It will show the two cars moving at constant speed and, as it runs, line graphs for the speed of each car will be generated.



Do the simulator line graphs look like those you drew above? If not, draw the simulator graphs below.



Activity 1: Line graphs for changing speed

STEP 1: When Car A first began moving, it started from rest (not moving) but as time went on its speed increased by 2 m/s every second for a total period of 10 seconds.



Use this information to complete the table below by entering values for the speed of Car A as its speed was increasing.

| Time | Speed of Car A |
|------|----------------|
| 0 s | 0 m/s |
| 1 s | 2 m/s |
| 2 s | |
| 3 s | |
| 4 s | |
| 5 s | |
| 6 s | |
| 7 s | |
| 8 s | |
| 9 s | |
| 10 s | |



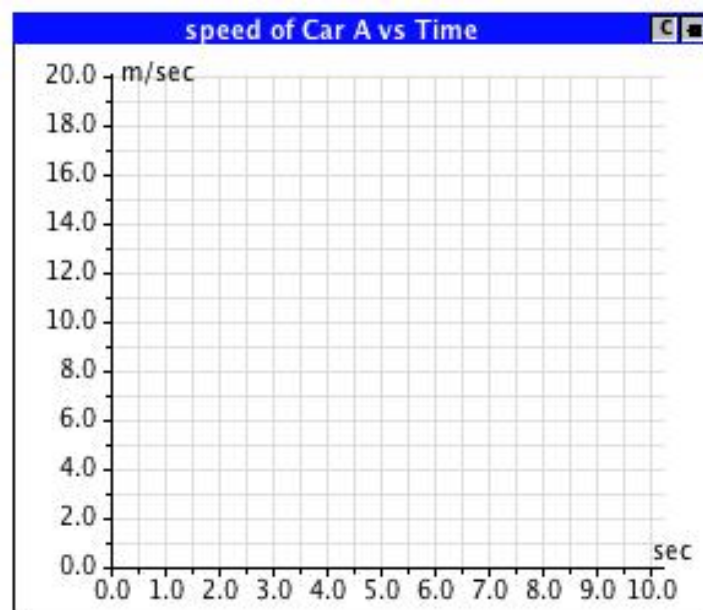
Explain how you determined what values to enter for the speed of Car A in each row of the table.



What do you think a line graph of the speed of Car A would look like while its speed was increasing? Why do you think so?



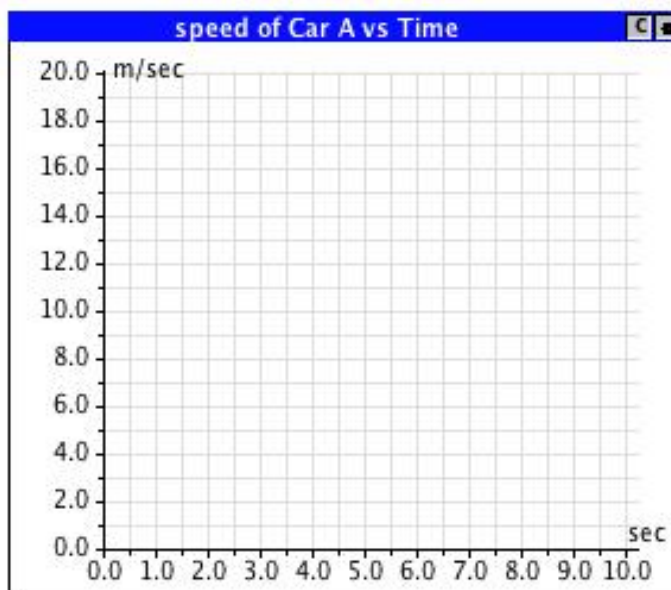
Use the values you entered in the table on the previous page to create a line graph for the speed of Car A over the 10-second period that its speed was increasing.



STEP 2: Now run the second simulator setup for this lesson. It will show Car A as its speed increases, and as it runs a line graph will be generated.



Does the simulator line graph look like the graph that you drew above? If not, draw the simulator graph here.



Your teacher will lead a class discussion about line graphs that show increasing speed.

STEP 3: When Car A was close to the end of its trip, it had a speed of 20 m/s but its speed then decreased by 2 m/s every second for the last 10 seconds.



Use this information to complete the table below by entering values for the speed of Car A as its speed was decreasing.

| Time | Speed of Car A |
|------|----------------|
| 0 s | 20 m/s |
| 1 s | 18 m/s |
| 2 s | |
| 3 s | |
| 4 s | |
| 5 s | |
| 6 s | |
| 7 s | |
| 8 s | |
| 9 s | |
| 10 s | |



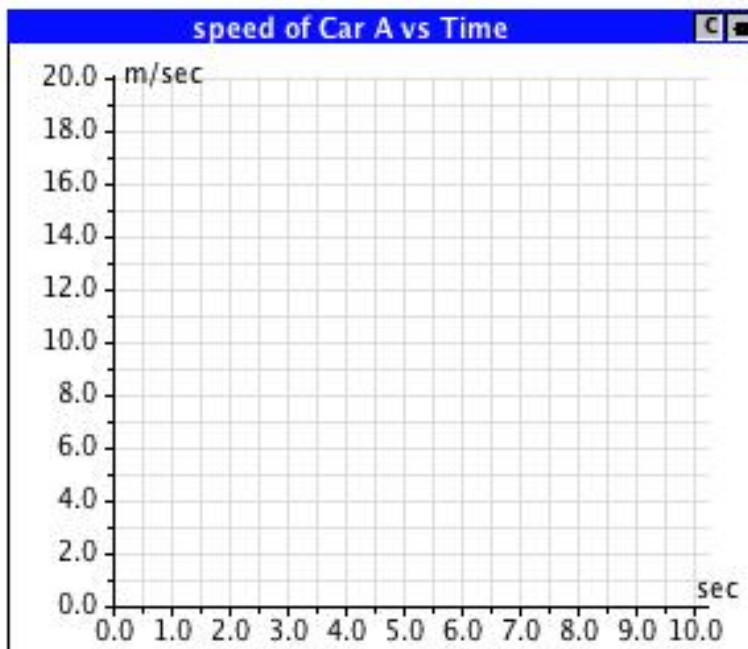
Explain how you determined what values to enter for the speed of Car A in each row of the table.



What do you think a line graph of the speed of Car A would look like while its speed was decreasing? Why do you think so?



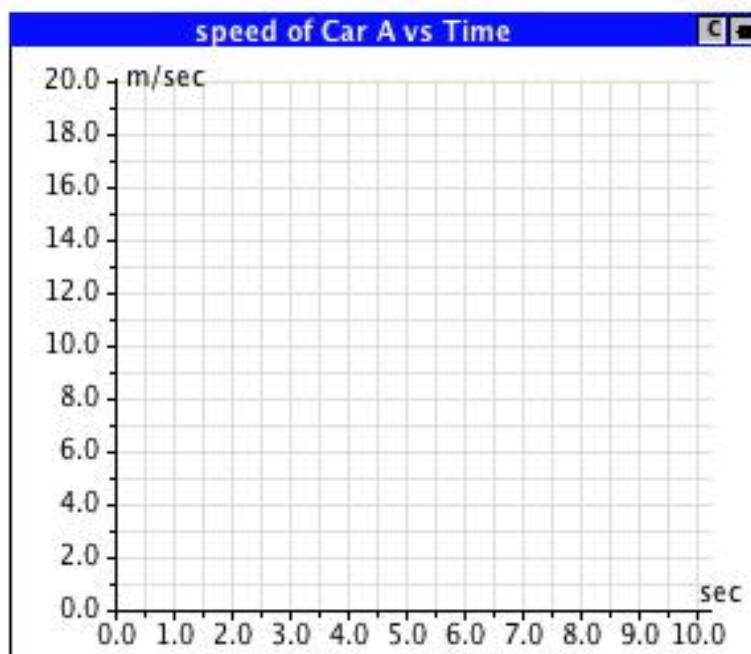
Use the values you entered in the table on the previous page to create a line graph for the speed of Car A over the 10-second period that its speed was decreasing.



STEP 4: Now run the third simulator setup for this lesson. It will show Car A as its speed decreases, and, as it runs, a line graph will be generated.



Does the simulator line graph look like the graph that you drew above? If not, draw the simulator graph here.



Your teacher will lead a class discussion about line graphs that show decreasing speed.

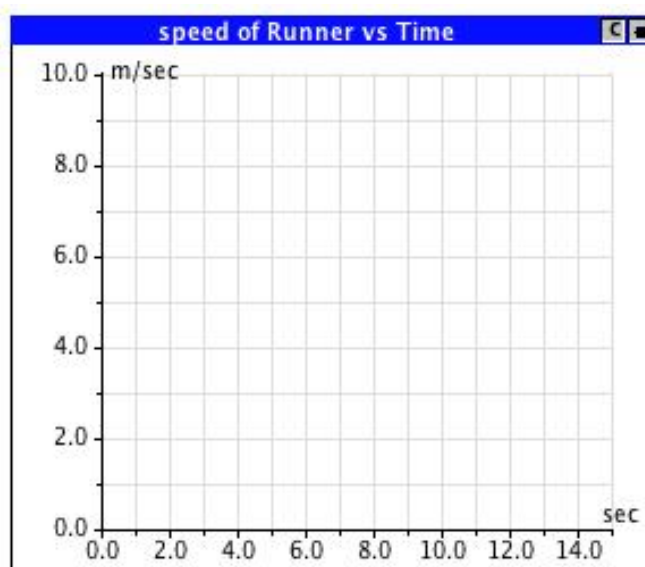
Making Sense



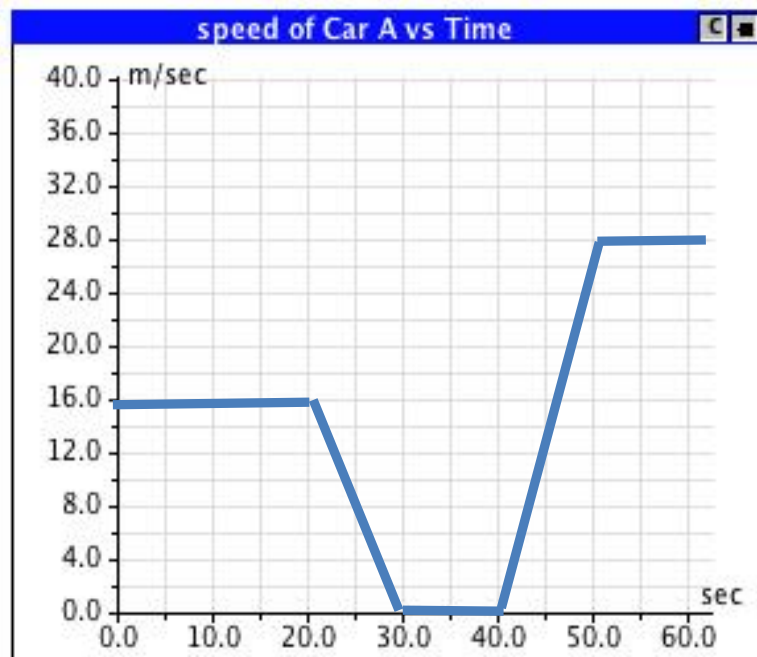
Your teacher will lead a class discussion about line graphs that show how the speed of an object behaves as time goes on. Write answers to the following questions after each one is discussed.

1. Imagine you run in a race along a straight track. In different parts of the race your speed behaves as described below:
 - At the start of the race you increase your speed from rest (not moving) to 4 m/s over the first 2 seconds.
 - Over the next 2 seconds you increase your speed to 6 m/s.
 - You then run at a constant speed of 6 m/s for the next eight seconds until you cross the finish line.
 - After crossing the finish line you decrease your speed by 3 m/s every second until you stop.

Draw a line graph that shows how your speed behaves over the period of time from when the race first starts, to when you stop after crossing the finish line.



2. Shown below is a line graph of the speed of a car during a short section of a much longer trip. Write a “story” about what happened to the car to make its speed behave in this way.



Extension 3: Showing distance moved with a line graph

Purpose

In the previous lesson you saw how a line graph of an object's speed is a useful way to show its motion. Another type of line graph that scientists often use to show motion is one that shows the distance an object has moved as time goes on.

The key question for this lesson is:



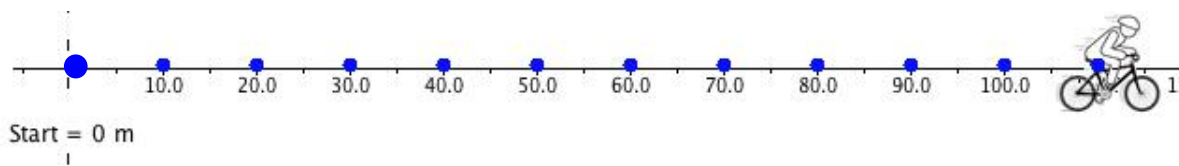
What do line graphs of distance versus time look like for different types of motion?

What do we think?

You will need:

- Access to the **Motion and Force Simulator**

Your friend is riding his bicycle along a straight road when he comes to a section where someone has made chalk marks every 10 meters. A motion diagram for his trip along this section of road is shown below. Each dot marks his position at every second after he passes the zero-meter starting point.



Was your friend's speed increasing, decreasing, or staying constant along this section of road? How do you know?



How far was your friend from the starting point at each second after he passed that point? To show this, complete the table below with his distance from the starting line at the times shown. Use the motion diagram on the previous page to help you.

| Time | Distance from starting line |
|------|-----------------------------|
| 0 s | 0 m |
| 1 s | 10 m |
| 2 s | |
| 3 s | |
| 4 s | |
| 5 s | |
| 6 s | |
| 7 s | |
| 8 s | |
| 9 s | |
| 10 s | |



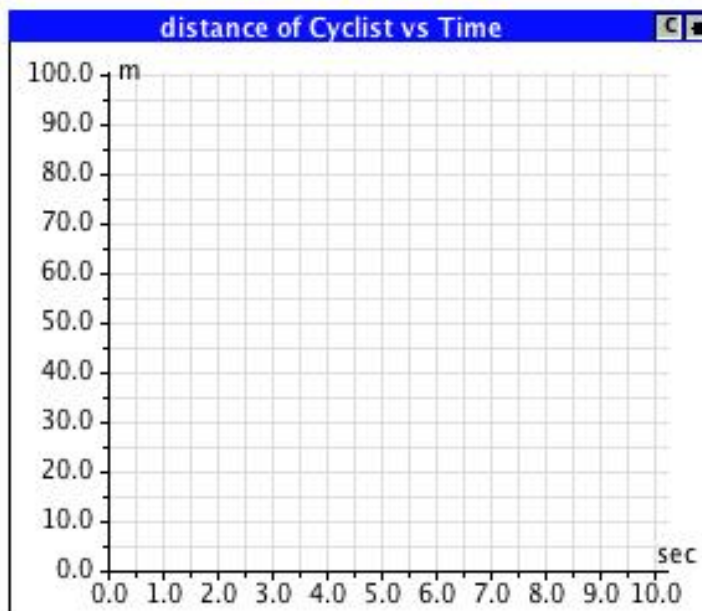
What was happening to your friend's distance from the starting line as time went on?



Suppose you were to make a line graph of your friend's distance from the starting line for the ten second period in the table, what do you think it would look like? Why do you think so?




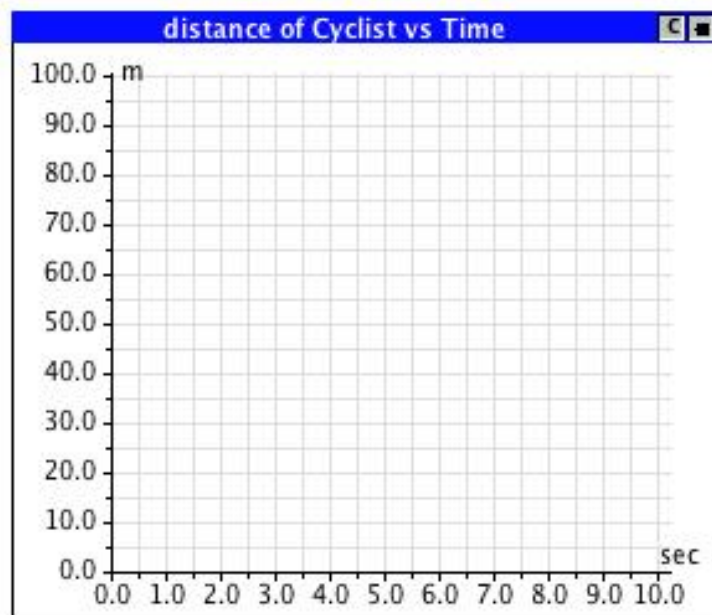
Use the values you entered in the table on the previous page to create a line graph for the distance of the cyclist from the starting line.




Your teacher will lead a class discussion about everyone's ideas about a line graph that shows the cyclist's distance from the starting line.

Now run the first simulator setup for this lesson. It will show the cyclist moving along the road and, as it runs, a line graph showing his distance from the starting line will be generated.

 Does the simulator line graph look like the graph you drew above? If not, draw the simulator graph here.



-  Your teacher will lead a class discussion about line graphs of distance versus time for objects that move at a constant speed.

Activity 1: Line graphs of distance versus time for changing speed

You will need:

- Access to the **Motion and Force Simulator**

STEP 1: In this part of the lesson you will think about line-graphs of distance-versus-time for changing speed. First, let's consider what is different between moving at a constant speed and moving with a speed that is changing.



Suppose you were running and moved a distance of 5 m in the first second. If your **speed was constant**, how far would you move in each second as time went on? Explain your reasoning.

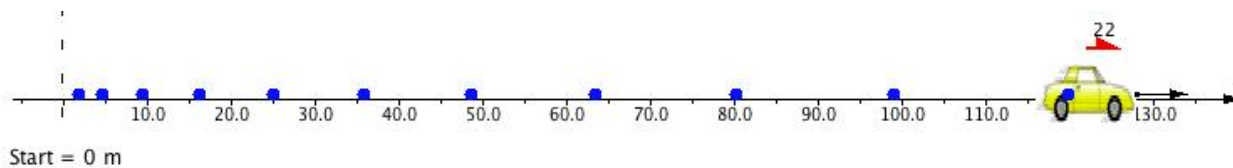


Now suppose instead that your **speed was increasing**, what would happen to the distance you moved in each second as time went on? Would it stay the same, or would it keep increasing, or keep decreasing? Why is this?



Finally, suppose instead that your **speed was decreasing**, what would happen to the distance you moved in each second as time went on? Would it stay the same, or would it keep increasing, or keep decreasing? Why is this?

STEP 2: Shown below is a motion diagram for a car driving down the same road as the cyclist in the 'What We Think' section. (The dots mark the position of the car every one second.)



What is happening to the speed of this car? Is it increasing, decreasing, or staying constant? How do you know?



The table below shows the approximate distance of the car from the starting point over the first 10 seconds.

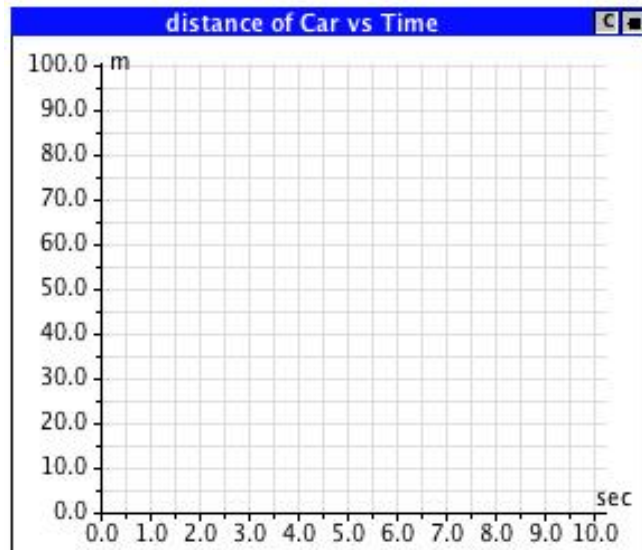
| Time | Distance from starting line |
|------|-----------------------------|
| 0 s | 0 m |
| 1 s | 2 m |
| 2 s | 5 m |
| 3 s | 9 m |
| 4 s | 16 m |
| 5 s | 25 m |
| 6 s | 36 m |
| 7 s | 48 m |
| 8 s | 63 m |
| 9 s | 80 m |
| 10 s | 98 m |



What shape do you think a line graph drawn using these points will be? Why do you think so?



Use the values from the table on the previous page to create a line graph for the distance of the car from the starting line.

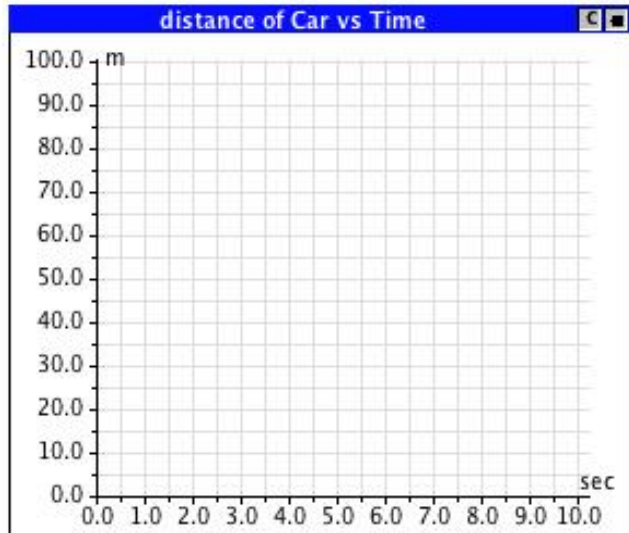


Your teacher will lead a class discussion about everyone's ideas about a line graph that shows the car's distance from the starting line.

Now run the second simulator setup for this lesson. It will show the car moving along the road, and as it runs a line graph showing its distance from the starting line will be generated.

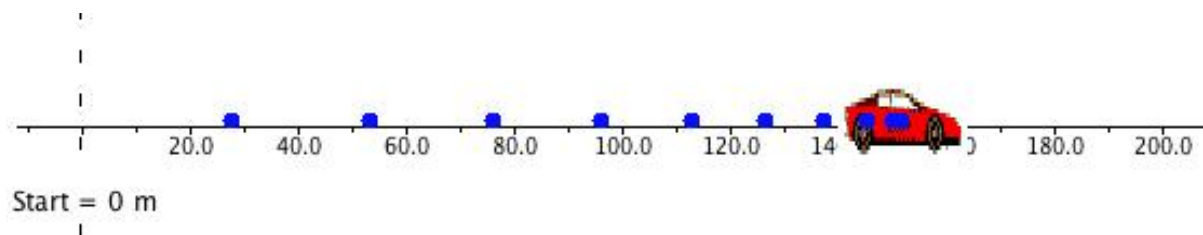


Does the simulator line graph look like the graph that you drew above? If not, draw the simulator graph here.



Your teacher will lead a class discussion about line graphs of distance versus time for objects that move with increasing speed.

STEP 3: Shown below is a motion diagram for a different car driving down the same road.





What is happening to the speed of this car? Is it increasing, decreasing, or staying constant? How do you know?



The table below shows the approximate distance of the car from the starting point over the first 10 seconds.

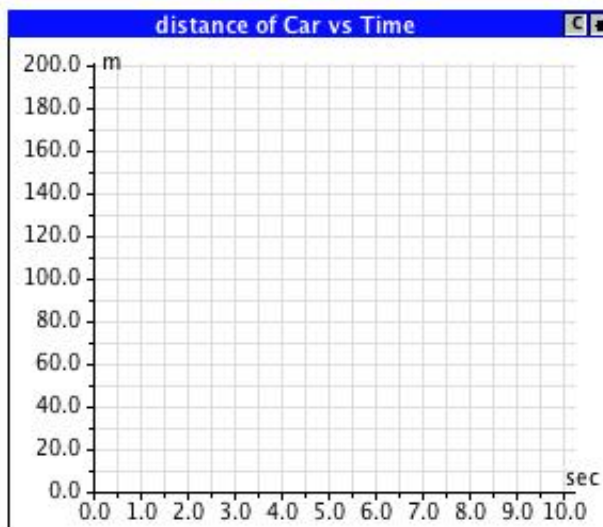
| Time | Distance from starting line |
|------|-----------------------------|
| 0 s | 0 m |
| 1 s | 28 m |
| 2 s | 53 m |
| 3 s | 76 m |
| 4 s | 95 m |
| 5 s | 112 m |
| 6 s | 127 m |
| 7 s | 136 m |
| 8 s | 143 m |
| 9 s | 148 m |
| 10 s | 150 m |



What shape do you think a line graph drawn using these points will be? Why do you think so?



Use the values from the table on the previous page to create a line graph for the distance of the car from the starting line.

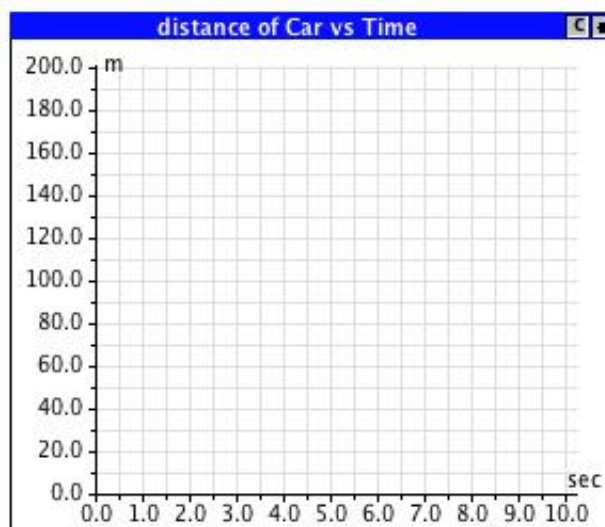


Your teacher will lead a class discussion about everyone's ideas about a line graph that shows the car's distance from the starting line.

Now run the third simulator setup for this lesson. It will show the car moving along the road, and as it runs a line graph showing its distance from the starting line will be generated.



Does the simulator line graph look like the graph that you drew above? If not, draw the simulator graph here.



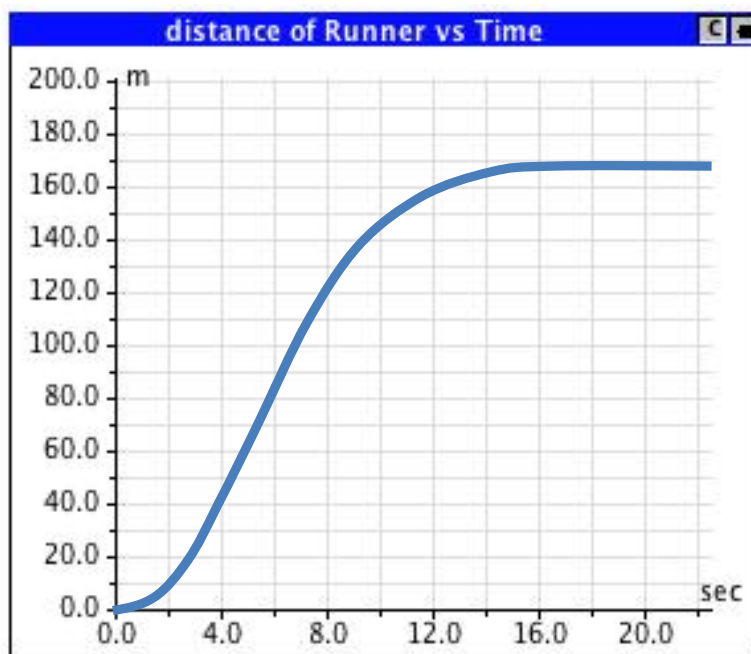
Your teacher will lead a class discussion about line graphs of distance versus time for objects that move with decreasing speed.

Making Sense



Your teacher will lead a class discussion about line graphs that show how the distance of an object from a starting point behaves as time goes on. Write answers to the following questions after each one is discussed.

1. Shown below is a graph that shows the distance of a runner from the starting line.



- a) Over approximately what time period was the runner not moving?
How do you know?
- b) Over approximately what time period was the runner's speed increasing? How do you know?
- c) Over approximately what time period was the runner's speed constant? How do you know?
- d) Over approximately what time period was the runner's speed decreasing? How do you know?