

## ***Extension 1: Another type of motion diagram***

### **LESSON TARGET IDEAS**

The motion of an object can be represented using a diagram that shows its position at regular time intervals by a succession of dots. (We call this a strobe diagram.) A constant spacing between successive positions indicates constant speed. An increasing spacing indicates increasing speed. A decreasing spacing indicates decreasing speed.

### **COMMON MISCONCEPTIONS**

- *The spacing between dots represents the time interval to travel a fixed distance (rather than the distance traveled in a fixed amount of time).*
- *Objects that move faster leave dots at a faster rate (i.e., closer together).*

### **WHAT TO FOCUS ON**

In this activity, students are introduced to strobe diagrams and how to interpret/draw patterns of dots that represent an object's motion. (A similar type of diagram may have emerged from the class in earlier activities. If so, the teacher can refer back to it during this activity. If not, it is not important.) Emphasizing that a consistent amount of time (in this activity, 1 second) passes between each dot is likely to be helpful as students become familiar with strobe diagrams. Following the introduction, students draw predictions for patterns of dots (from children carrying melting ice cream cones) in strobe diagrams for a series of scenarios: slow constant speed, fast constant speed, increasing speed and decreasing speed. Each prediction is then checked by examining the results of a corresponding computer simulation. When viewing the simulations, students should focus on how the movement of children holding ice cream cones is reflected in the spacing of dots in the strobe diagram. For example, it is important to match increasing speed of the child with increasing space between dots rather than an increasing rate of dot appearance that students might expect to see. Students should also focus on the spacing of dots when comparing their predictions to the simulations. From these observations and comparisons, students should see that knowing the position of an object at successive time intervals also gives information about the speed of the object and whether the speed is constant, increases, or decreases.


Students may become focused on the exact spacing between dots in their diagrams. However, the important aspect is the pattern of the dots: more space between the dots indicates greater speed; increasing space indicates increasing speed, and decreasing space indicates decreasing speed.


**MATERIALS NEEDED FOR THIS LESSON**


<b>Material</b>	<b>Quantity</b>
Motion and Force Simulator ( <a href="http://149.149.136.29/~cpusims/horizonPD/">http://149.149.136.29/~cpusims/horizonPD/</a> )	1 per class



## What do we think?

 This scenario is meant to provoke discussion around how the position of an object would change if its speed is constant.

 Some students will likely draw a set of regularly-spaced dots. Others may draw a more random pattern, not realizing the importance of the regular time intervals between drips.

 We are aiming for students to express the idea that the distance between successive dots is constant, showing that the same distance was moved every second, which means the speed was constant. Even students who drew a regularly spaced set of dots may have difficulty expressing this idea, so the teacher should be prepared to prompt the class to think in these terms

## ***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.


 The teacher will likely have to emphasize the importance of the idea that the position is given at regular time intervals, and that students need to focus on the distance moved in those time intervals. Help students realize that by using both pieces of information (distance moved and time interval), they can tell something about the object's motion.

Combine this discussion with an explanation of the next paragraph.

## Activity 1

 The idea of a motion diagram for constant speed was already discussed in the previous section of the lesson. This activity allows the teacher to check that students understand this idea, while also extending it to comparing the speeds of two different objects.

### Activity 1: Step 1

 The teacher should explain the scenario, emphasizing that both children move at a constant speed, but that one is moving faster than the other. If possible, project the picture below and explain that both start from their shown positions (i.e., different starting points), but will end up together at the same place, a few seconds later.



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**.



Allow students to work together to make predictions without input from the teacher. If speed arrows are unfamiliar to students, explain that a longer arrow indicates a greater speed.



Student ideas are likely to fall into one of three groups.

1. The spacing of dots will be the same for both children. Those drawing their diagrams like this probably hold the idea that the spacing reflects the same time intervals for both, rather than the different distance moved in those time intervals.
2. The spacing for the boy's dots will be smaller than those for the girl. Those drawing their diagrams like this probably think that a faster speed for the boy is reflected in dots being drawn at a higher frequency.
3. The spacing for the boy's dots will be larger than those for the girl. Those drawing their diagrams like this probably hold the appropriate idea that the spacing reflects the idea that the boy's higher speed means he moved a greater distance in each second than the girl.

## Activity 1: Step 2



An index of simulator setups can be found at:

<http://149.149.136.29/~cpusims/horizonPD/>

The teacher may wish to project these and run them as demonstrations. However, if possible, it is a good opportunity for students to use the technology themselves.






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.*


 Monitor students to make sure they attend to the important aspects of these motion diagrams: namely, that both patterns have evenly spaced dots, but that the spacing is greater for the boy than the girl. (The exact spacing and number of dots is not important, providing these aspects are included.)

Give students time to make sense of what they are seeing. The teacher may wish to have students who understand explain to those who are trying to make sense of what they are seeing.


 By this point most students should realize that even spacing indicates constant speed, because at a constant speed the child would move the same distance every second. The teacher should be prepared to prompt students to think in this way if it is not apparent.


 Again, by now most students should realize that the larger spacing of the boy's dots indicates that he moved a greater distance in each second than the girl did. Thus, his speed was faster than hers.


 At this point the teacher should lead a class discussion to review the characteristics of motion diagrams, and in particular how the spacing is an indication of an object's speed (i.e., the greater the spacing, the greater the speed). This idea will be important for the rest of the lesson.

-  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: Step 1



Allow students to work together to make predictions without input from the teacher.



Hopefully, students will associate increasing speed with increasing distance moved in each successive time interval. If not, however, the teacher should not tell students. If they have not yet figured it out, they will see it in a simulation.

## Activity 2: Step 2



Monitor students to make sure they attend to the important aspects of this motion diagram: namely, that the spacing between successive dots increases as time goes on. (The exact spacing and number of dots is not important, providing this aspect is included.)

Give students time to make sense of what they are seeing. The teacher may wish to have students who understand explain to those who are trying to make sense of what they are seeing.

## 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.





The teacher should monitor groups and be prepared to prompt students to think about increasing speed in terms of distance moved in successive equal time intervals.

### Activity 2: Step 3



Again, allow students to work together to make predictions without input from the teacher.



By now students should be comfortable with the link between speed and distance moved in successive time intervals. They should therefore conclude that decreasing speed will mean shorter distances moved and so the spacing between dots will decrease as time goes on.



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.





Monitor students to make sure they attend to the important aspects of this motion diagram: namely, that the spacing between successive dots decreases as time goes on. (The exact spacing and number of dots is not important, providing this aspect is included.)

Give students time to make sense of what they are seeing. The teacher may wish to have students who understand explain to those who are trying to make sense of what they are seeing.



### **Making Sense Questions**

Question S1: Students may initially be uncomfortable with this question because it involves combining different types of motion in one diagram. If so, the teacher should inform them that they can just join the diagrams they know about from their work in this activity together into one. A suitable diagram, with the necessary features, is shown below



Some students may not worry about “continuity,” in that, for example, their period of speeding up may seem to begin from a speed of zero, rather than the constant speed already established. If this issue arises, the teacher should initiate discussion of these points and prompt students to consider what their diagram actually seems to show and whether it matches the diagram provided.





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



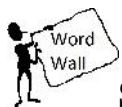
Your teacher will lead a class discussion about motion diagrams. Write answers to the following questions after each one is discussed by the class.

- 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

Question S2: This is a complicated scenario, so the teacher may wish to break it down for the students into two parts.

- 1) If the driver of the red car was telling the truth the pattern should show a constant speed for the red car right up until the point of the wreck.
- 2) If the driver of the blue car was telling the truth, the pattern should show an increasing speed for the red car before the wreck.

It may also be helpful to ask students to recall what the dot patterns looked like when the child carrying the ice cream cone had a constant or increasing speed.



## Science Vocabulary

The only new vocabulary term in this lesson is “**strobe diagram.**” It is not necessary to add this term to the word wall.

**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***

### **LESSON TARGET IDEAS**

The motion of an object can be represented using a line graph that shows how its speed behaves over a certain time period. On such a graph, increasing speed is shown by a line segment that slopes upward, constant speed is shown by a flat horizontal line segment, and decreasing speed is shown by a line segment that slopes downward.

### **COMMON MISCONCEPTIONS**

- *Sloped lines on any graph show that an object is moving up or down a hill.*
- *All constant speeds are represented with a horizontal line at the same y-axis value.*
- *An object that is not moving cannot be shown on a speed-time graph.*
- *A diagonal line is not a straight line.*


### **WHAT TO FOCUS ON**

Speed-time line graphs are a very useful way to show the motion of an object. It is possible that they were proposed by students earlier in the Unit and, if so, the teacher can remind the class of this, saying that now we will examine that idea further. In this activity, students create line graphs that show constant speed, increasing speed and decreasing speed. For each case, students first infer the speeds of two cars at regular time intervals from the scenarios provided. Speed values are recorded in tables and supply the data that are used to create the graphs. Students should be focused on using these data as the source for graphing rather than indicating a general line shape based on the scenario. However, it is also important that students relate the shape of each graph to the description of motion (i.e., constant, increasing or decreasing speed), rather than simply transferring data as a mechanical exercise. Each scenario is also shown in a simulation, which allows students to compare the lines they plotted to those generated in the simulations. Students should compare the lines produced for two cars travelling at different constant speeds to see that not all constant speeds are represented with a horizontal line at the same y-axis value. In responding to the making sense questions, students should find that a description of an object's speed, (which may include multiple changes), can be represented using a speed-time line-graph. They should also see that a story describing an object's speed(s) over time can be created from an existing speed-time line-graph. The teacher should point out that the period of time when the car is not moving is illustrated by the graph.

### **MATERIALS NEEDED FOR THIS LESSON**

<b>Material</b>	<b>Quantity</b>
None	

## **Purpose**

 The next section is intended to provide a brief introduction to line graphs. The teacher should feel free to extend or replace this section, depending on prior student exposure.

## ***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:

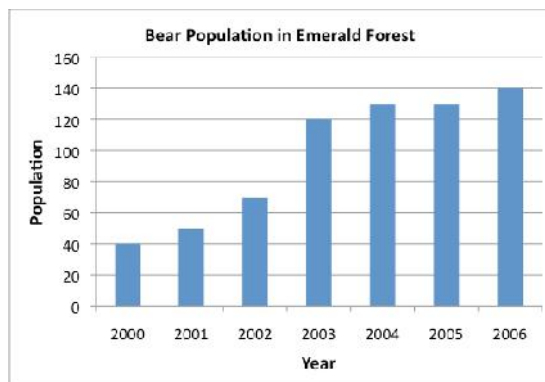


*What do line graphs of speed versus time look like for different types of motion?*


### **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!)

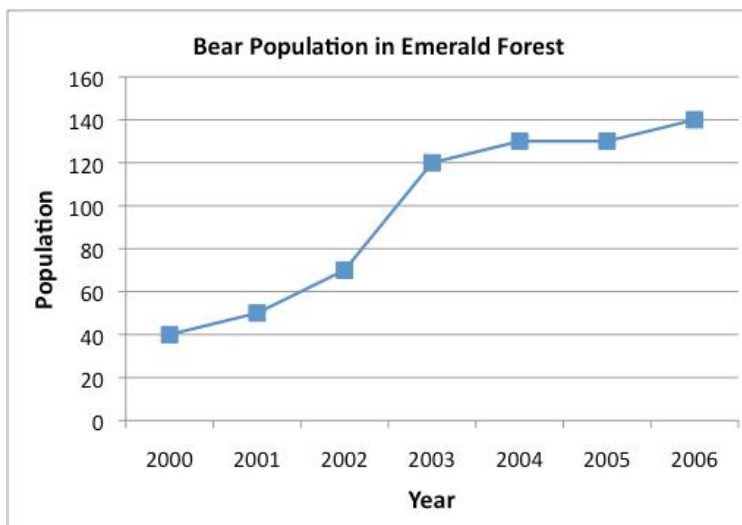
 The line graphs drawn by the simulators do not plot data points, they just show the lines. Therefore, it is important that the teacher lets students know that sometimes it is OK to leave the dots off. However, when students generate their own line graphs, they should include a dot for each data point, so that the teacher can see whether the plotted data are accurate.

### **What do we think?**

 This scenario is meant to give students a “gentle” introduction to line graphs of speed. The teacher should explain it and make sure to emphasize that the speed of the two cars is different, but both are constant at those different values.

 The teacher should explain that making a table of values is often useful before drawing a graph. In this case the students will be completing a table that has already been started for them.



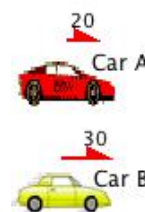


Looking at this line graph we can easily see that, although the line moves upward almost every year, it is steepest between 2002 and 2003. This tells the researcher that the bear population increased more quickly between July 1<sup>st</sup> 2002 and July 1<sup>st</sup> 2003 than during any other period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





For some, this step may seem trivial. However, it is good practice for what is coming later. Because the speed is staying constant, the value for each car will be the same in each row.



Make sure students can explain why the value for each car is the same in each row of the table (i.e., the speed remains constant).



We are looking for a brief description here in term of what the lines will look like. Will they slope upward or downward, or will they be horizontal? How will the lines for the two cars compare?

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?



If students have completed the table appropriately, they should draw their points in a horizontal line at the appropriate value on each graph. Some students may be sloppy when drawing their lines to join the points and end up with a “wiggly” line.



If possible, the teacher should find some way to display some student graphs and discuss them. Some issues to include in the discussion are:

- Why are all the points plotted at the same value?
- Should the overall shape of the graphs be flat and horizontal, or “wiggly,” and why?
- Why is the line higher on the graph for Car B than for Car A?
- In general, if an object is moving at a constant speed, what would a line graph of its speed look like? (We are looking for “flat and horizontal” at a particular value.)
- What would the graph look like if an object is not moving?

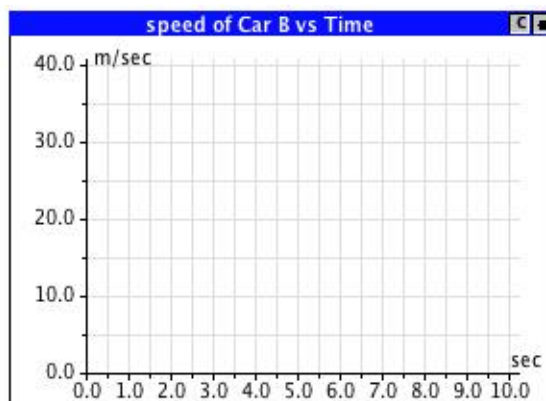
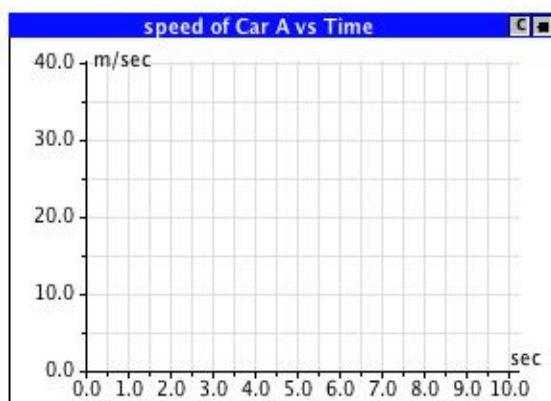


If computers are available, the teacher may choose to let students run the simulator themselves. If not, the teacher can project it in some way and run it as a demonstration. An index of simulator setups can be found at:

<http://149.149.136.29/~cpusims/horizonPD/>




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.

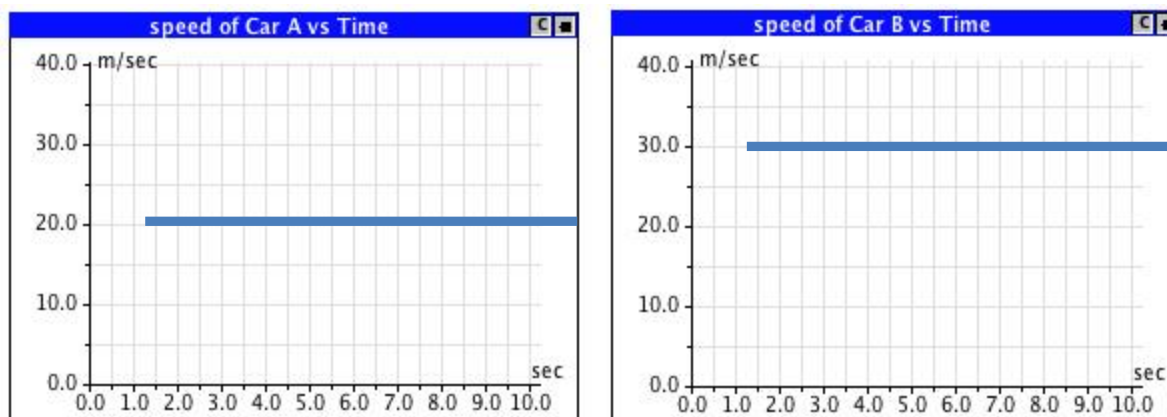


Your teacher will lead a class discussion about everyone's ideas about line graphs that show the speeds of the two cars.

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.

 The general shape of the graphs should come as no surprise to students at this point. Some may be concerned that no “points” are plotted, only lines. The teacher can tell them that the simulator “measures” the speed of the cars much more often than once a second and so the points are not shown because they would cover up the line.


Make sure students copy the simulator graphs if their predictions were different in any significant way (sloped lines, wrong values, “wiggly lines”). (Because the whole graph seems to be a straight line, it is OK to use a ruler to help draw it.)



The teacher should introduce the next activity by telling students that now that they know what a line graph looks like for constant speed, we will now think about what a graph would look like if the speed were changing.

A motivating question might be whether they think it will still be a flat horizontal line or not, and why?

### Activity 1: Step 1

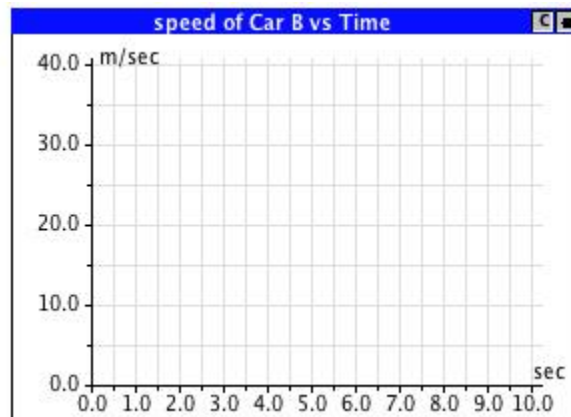
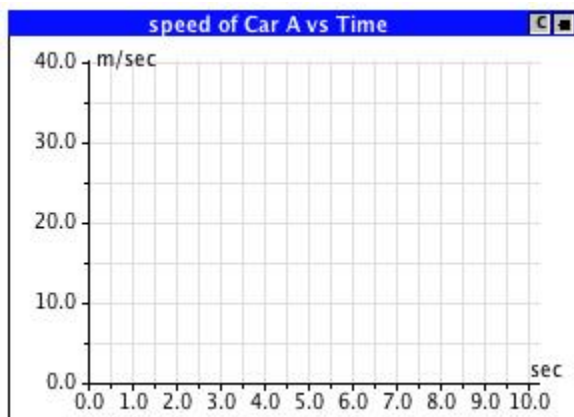
 The first scenario we will examine is that of a steadily increasing speed. For this we will go back to the time when Car A first started moving. Emphasize that this is not the same 10 seconds as in the ‘What We Think’ section and occurred earlier in time. Once we chose a period of time to examine, we often let the beginning of that period be “zero” because we start counting forward from then.

The first two entries in the table are already provided to give a “hint” to students. Let them discuss together how to proceed from there.

Some students may be concerned about the first value being zero m/s. The teacher should ask them about the speed of an object that is not moving.



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	



Students should add 2 m/s to the speed for each second that passes, and most students should be comfortable with doing this. Some may want to put the same value for every blank entry, because that is what they did previously.



If they have completed the table appropriately, students should be able to say that the line will slope upward, though they may say it in various different ways. They will be less likely to realize that it will be a straight diagonal line, but they will be more likely to see that when they plot their graph or see the simulator.



Do not discuss student graphs at this point, but monitor groups for possible issues in drawing them.

Some students may be concerned that the speed scale does not go up in “ones.” Assure them that the odd values are still indicated by tick marks, but not labeled because it would be too “cluttered.” Many students will not be careful when joining their dots with short lines and so produce a “wiggly” line.





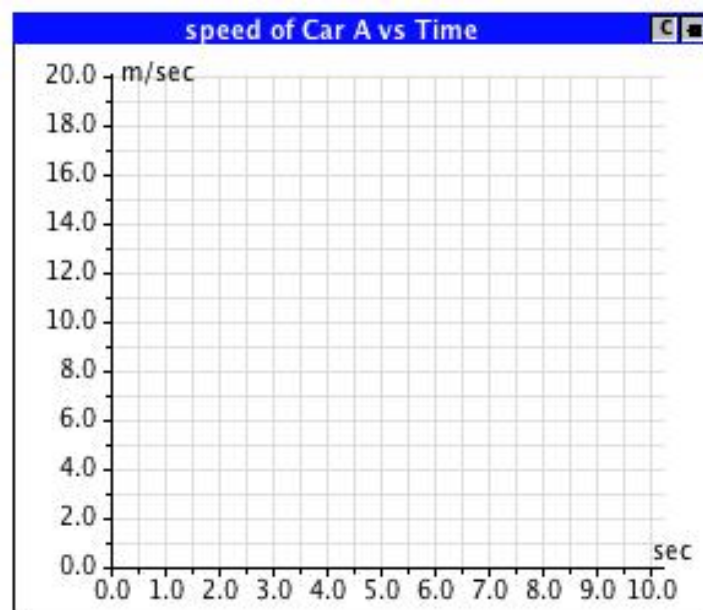
Explain how you determined what values to enter for the speed of Car A in each row of the table.



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.

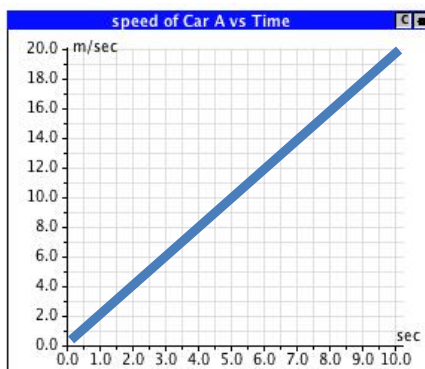


## Activity 1: Step 2

⚠ If computers are available, the teacher may choose to let students run the simulator themselves. If not, the teacher can project it in some way and run it as a demonstration.

🔍 The general shape of the graph (shown below) will likely be no surprise to students at this point. Some may again be concerned that no “points” are plotted, only lines.

Make sure students copy the simulator graphs if their predictions were different in any significant way (non-sloped lines, wrong values, “wiggly lines”).



🗣 Some issues to include in the discussion are:

- Why do the plotted points increase in value?
- Should the overall shape of the graph be straight, or “wiggly,” and why?
- How fast was the car moving at the end of the period shown?
- In general, if an object’s speed is increasing by the same amount every second, what would a line graph of its speed look like? (We are looking for “straight and diagonal upward” or “constantly sloping upward.”.)

If the misconception that “a *diagonal line is not a straight line*” arises, this graph can be used to show that a line can be both diagonal and straight. It may be helpful to draw a horizontal (or vertical) line on a sheet of paper and rotate the sheet such that the line resembles the diagonal line in the above graph to demonstrate that horizontal and diagonal lines share the same (straight) line shape.

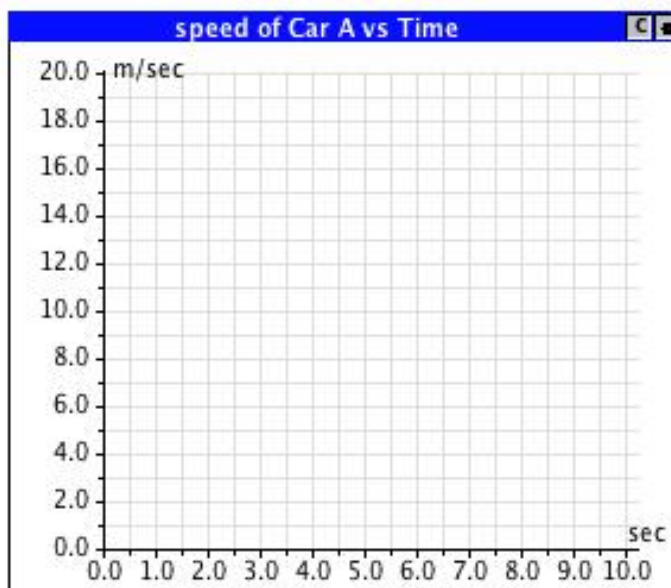
**Extension:** If the teacher feels comfortable, at this point the class could investigate how the graph would be different if the speed increased at a faster or slower rate, say 1 m/s or 4 m/s every second. (This is its rate of acceleration!) How would this affect how many seconds it takes to reach 20 m/s?

⚠ The second scenario we will examine is that of a steadily decreasing speed. For this we will go forward in time to the last 10 seconds of Car A’s trip. Emphasize again that this is yet another different 10 seconds than before, but that we will again let the beginning of this period be “zero” and then start counting forward from that point.

**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.

### Activity 1: Step 3



The first two entries in the table are already provided to give a “hint” to students. Let them discuss together how to proceed from there.

Some students may be concerned about the last value being zero m/s. The teacher should ask them what this means.



Students should subtract 2 m/s to the speed for each second that passes, and most students should be comfortable with doing this.



If they have completed the table appropriately, students should be able to say that the line will slope downward, though they may say it in various different ways. They will be less likely to realize that it will be a straight diagonal line, but they will be more likely to see that when they plot their graph or see the simulator.

**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?



Do not discuss student graphs at this point, but monitor groups for possible issues in drawing them. Some of the same issues as before may emerge.

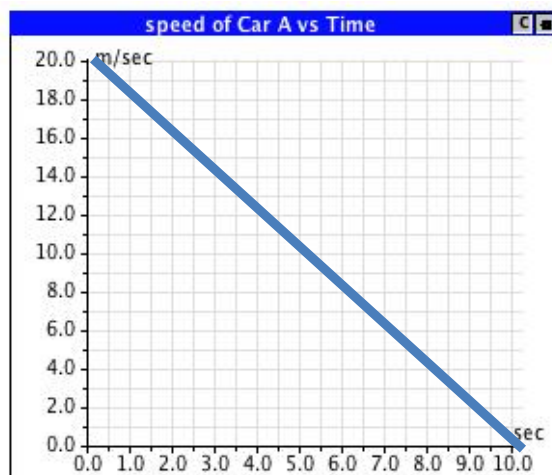
### Activity 1: Step 4



If computers are available, the teacher may choose to let students run the simulator themselves. If not, the teacher can project it in some way and run it as a demonstration.



The general shape of the graph (shown below) will likely be no surprise to students at this point. Make sure students copy the simulator graphs if their predictions were different in any significant way (non-sloped lines, wrong values, “wiggly lines”).



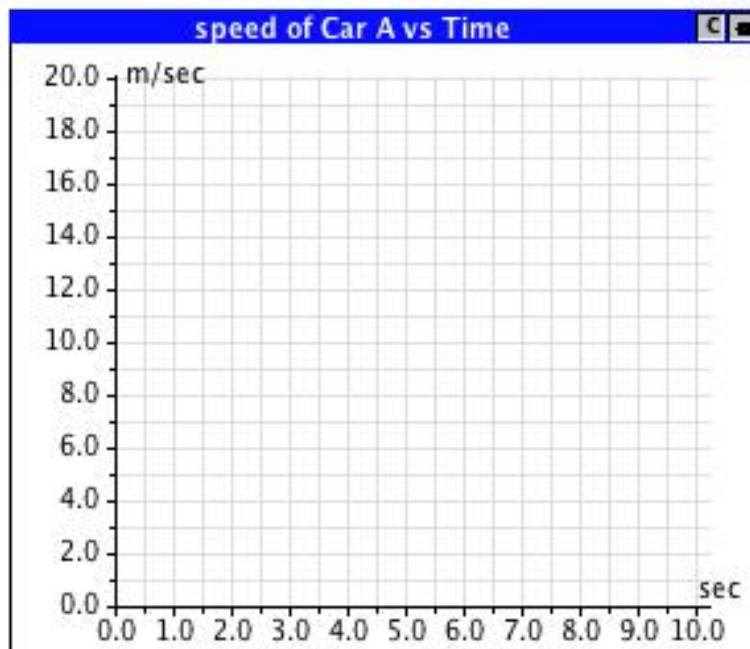
Some issues to include in the discussion are:

- Why do the plotted points decrease in value?
- Should the overall shape of the graph be straight, or “wiggly,” and why?
- How fast was the car moving at the end of the period shown and what does this mean? (0 m/s means it stopped!)
- In general, if an object’s speed is decreasing by the same amount every second, what would a line graph of its speed look like? (We are looking for “straight and diagonal downward” or “constantly sloping downward.”)

**Extension:** If the teacher feels comfortable, at this point the class could investigate how the graph would be different if the speed decreased at a different rate. How would this affect how many second it takes to stop?



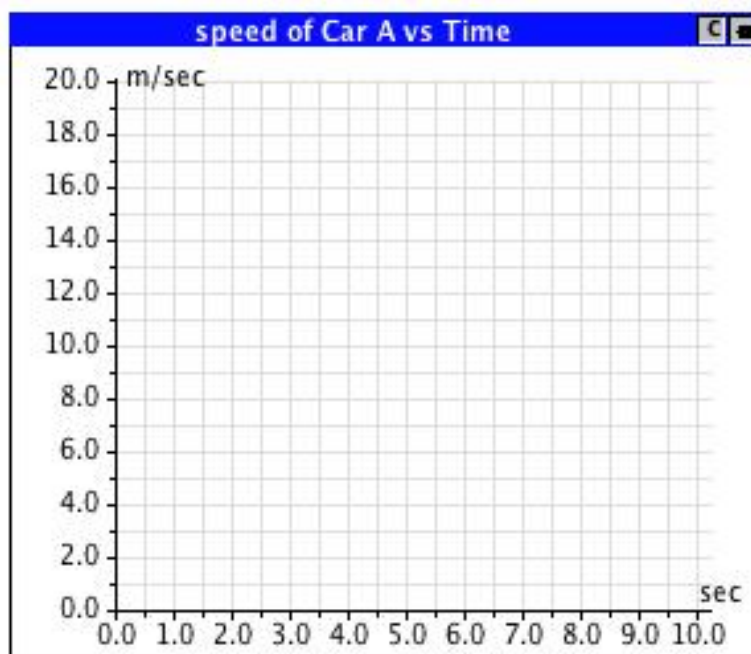
Use the values you entered in the table on the previous page to create a line graph for the speed of Car A over the 10-second period that its speed was decreasing.



**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.

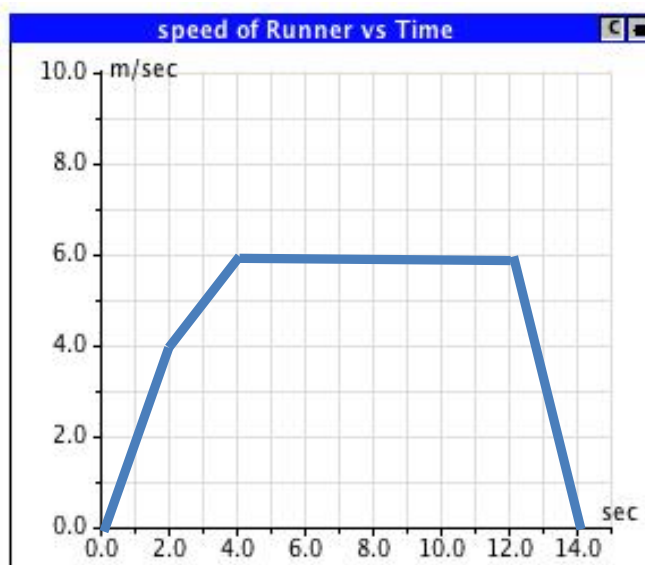
## Making Sense Questions

Question 1: Allow groups of students to work on this question together. Encourage them to make a table like those completed earlier in this activity to help them. There are likely to be several issues with which students may need help.

- There are two different rates of increasing speed at the beginning. 2 m/s per second for two seconds, then 1 m/s per second for another two seconds.
- The second rate of increasing speed is not given. Instead the final speed and the time period are given. Students may not realize the runner already has a speed of 4 m/s at the beginning of this period.
- Students are not told how long it takes for the runner to stop. They may need help recognizing that this occurs when the speed reaches 0 m/s.
- The blank graph given has only even values of speed and time shown. Odd values are indicated only with tick marks.

Monitor groups as they are working and determine what needs to be discussed. If there are major differences, have groups draw their graphs on display boards, or otherwise project them. Then discuss significant differences and try to resolve them.

The graph should look like:



Note: The misconception that “*sloped lines on any graph show that an object is moving up or down a hill*” is not explicitly addressed in this lesson. However, question 1 would allow this if the teacher specifies that the track is flat. In this case, the misconception is countered here because sloped lines are generated when considering motion on a flat track.



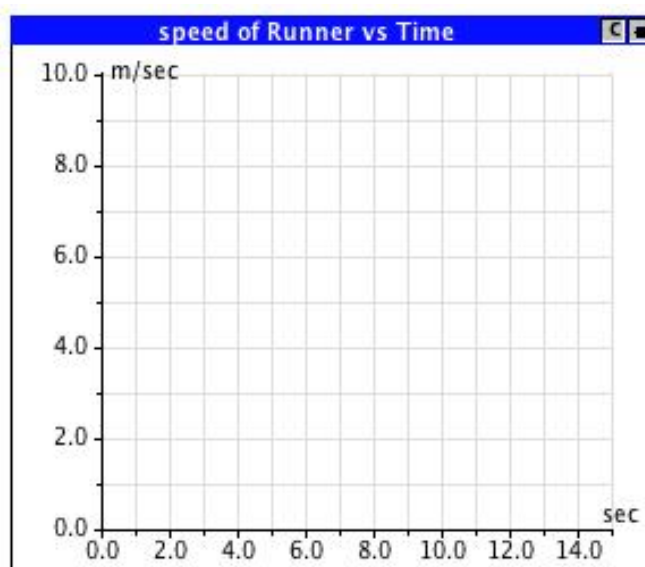
## Making Sense



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.

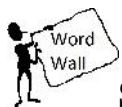
Draw a line graph that shows how your speed behaves over the period of time from when the race first starts, to when you stop after crossing the finish line.



Question 2: Allow students to invent their own stories. One issue they may have is that the car is already moving at the beginning of the graph. This is because we are taking a section out of the middle of the trip.

Correct stories should include:

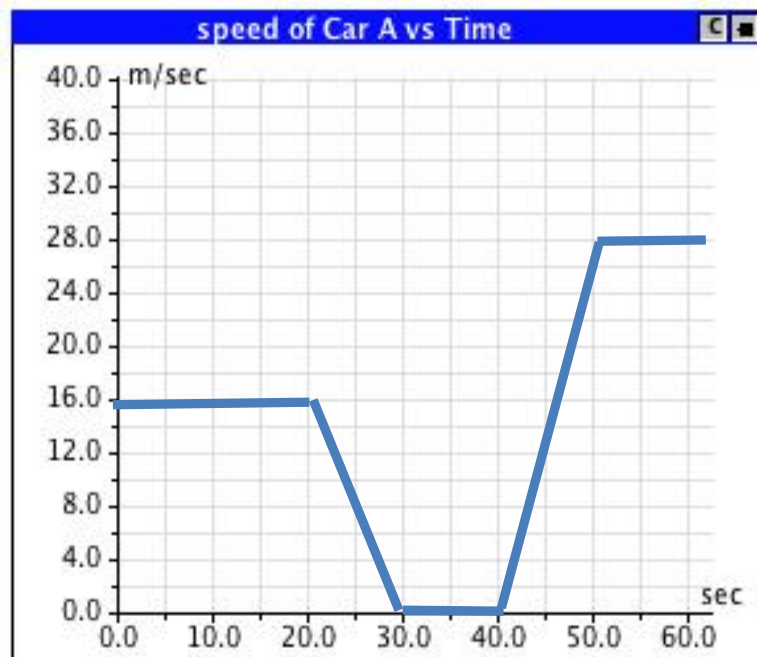
- Car is moving at a constant speed of 16 m/s from time = 0 to time = 20 s
- Car's speed decreased from 16 m/s to 0 m/s (stopped) from time = 20 s and time = 30 s
- Car's speed was constant at 0 m/s (or car was stopped) from time = 30 s to time = 40 s
- Car's speed increased from 0 m/s to 28 m/s from time = 40 s to time = 50 s
- Car's speed remained constant at 28 m/s from time = 50 s to time = 60 s



## Science Vocabulary

There are no new vocabulary terms in this lesson.

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***

### **LESSON TARGET IDEAS**

The motion of an object can be represented using a line graph that shows how its distance from some starting point changes over a certain time period. On such a graph, increasing speed is shown by a line segment that becomes steeper and steeper, constant speed is shown by a straight diagonal line segment, and decreasing speed is shown by a line segment that gets less and less steep.

### **COMMON MISCONCEPTIONS**

- *Sloped lines on any graph show that an object is moving up or down a hill.* (This would actually be true for a distance-time graph, if the object were moving vertically, but is not generally true!)
- *A horizontal line on a distance-time graph means constant speed.* (It is true that it means a constant speed of zero, but any other constant speed is represented by a straight diagonal line.)
- *A line that is moving upward or downward on a distance-time graph means the speed is increasing or decreasing.* (This could be, but is not necessarily true. A straight diagonal line actually indicates constant speed.)
- *An object that is not moving must be at a distance of zero.* (It could be at any position, as long as its distance is not changing.)

### **WHAT TO FOCUS ON**

It is widely accepted that distance-time line graphs are more difficult to understand than speed-time graphs, probably because to really understand them you need to truly understand the connection between distance moved and speed. An attempt to strengthen this link is made in this lesson using motion diagrams and guiding questions. Having engaged with drawing speed-time line graphs in the previous lesson, students will likely struggle with using a new representation (distance-time) to show the same types of motion. It is important that the teacher make it clear to students that they will be focusing on the *distance* an object travels over time instead of the *speed* of the object.

In this activity, students create distance-time line graphs that show constant speed, increasing speed, and decreasing speed. For the constant speed scenario, students fill in a table with distance data from a strobe diagram and then use those data to create a distance-time line graph. For the increasing and decreasing speed scenarios the data tables are already provided for students to use to create their line graphs. Each scenario is also illustrated in a simulation that students can use to compare to their own graphs.

Students may be quick to draw distance-time line graphs that represent increasing speed and decreasing speed as straight diagonal lines because of the pattern they found with speed-time line graphs in the previous activity. The teacher should make sure

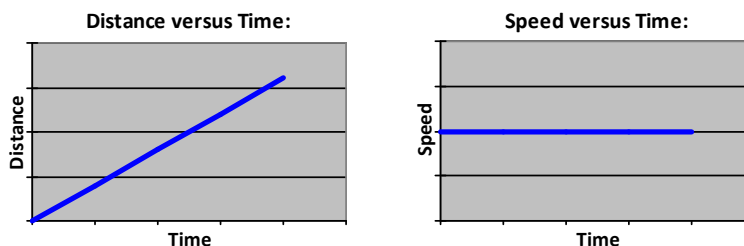
students plot the entire set of values from the data table before making assumptions about the shape of the line graph.

When considering what the shape of the distance-time line graph represents, the teacher should focus students on how the steepness (slope) of particular sections of the line graph compares with the distance the object has travelled in a set amount of time. For example, sections of a distance-time line graph with the same steepness show that an object covers the same distance per unit of time (e.g., 5 meters every 1 second). Furthermore, sections of a line graph that are less steep will cover less distance per unit of time (e.g., 2 meters in 1 second) than a section of the graph that is steeper (e.g., 7 meters in 1 second). From this analysis students should see that for a distance-time line graph:

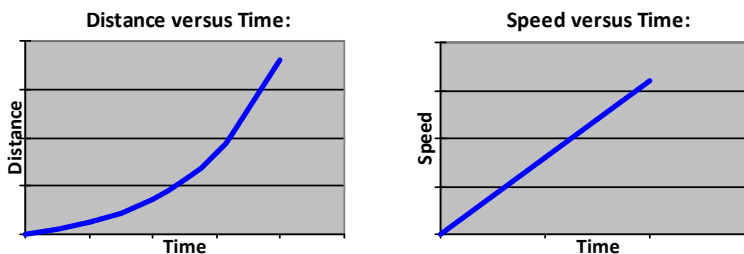
- steepness that does not change represents constant speed;
- steepness that increases represents increasing speed; and
- steepness that decreases represents decreasing speed.

The following figures show distance-time and speed-time graphs side-by-side for each type of motion.

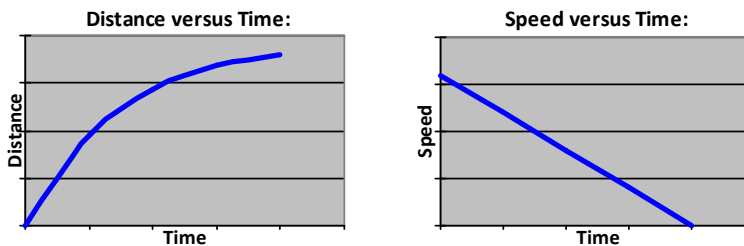
### Constant Speed



### Increasing Speed




### Decreasing Speed




**MATERIALS NEEDED FOR THIS LESSON**

<b>Material</b>	<b>Quantity</b>
Motion and Force Simulator ( <a href="http://149.149.136.29/~cpusims/horizonPD/">http://149.149.136.29/~cpusims/horizonPD/</a> )	1 per class

## Purpose

 This scenario is meant to give students a “gentle” introduction to line graphs of distance versus time via a scenario of constant speed. However, the teacher should not explain the graphs until students have established for themselves that these graphs represent distance versus time for an object moving at constant speed.

## What do we think?

 Students should recognize this motion diagram as indicating constant speed. Hopefully they will justify this shape of the graph by saying the cyclist moves the same distance in every second, but they may simply rely on pattern recognition from the earlier lesson on motion diagrams. If the “equal distances” idea does not come up yet, the teacher should not introduce it, as there is a chance for it to come up again soon.



## ***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:



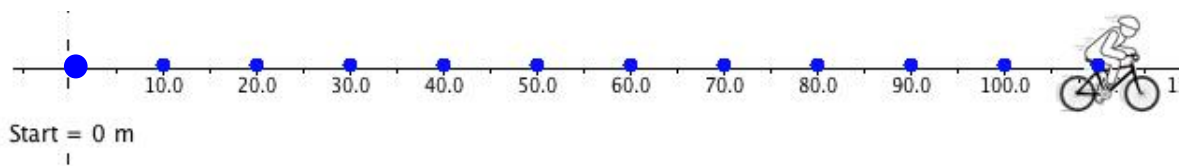
*What do line graphs of distance versus time look like for different types of motion?*

### **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?



Completing the table should be easy for students as they simply have to read off the values from the scale on the diagram. Keeping track of time may be an issue. If so, encourage students to label the dots, starting at 0 seconds.



Some students will simply say the distance was increasing. Others may add that the distance was increasing by the same amount (10 m) every second.



Students may need some guidance as to what is being asked. We are really looking for some suggestion of what the general shape of the line will be like. Will it be horizontal, diagonal, curved, or “wiggly”? The teacher should prompt students to give reasons for their answers.

The teacher should monitor the groups to make sure the plotting is being done in a reasonable manner.

If students have completed the table appropriately, they should draw their points in a diagonal line. Some students may be sloppy when drawing their lines to join the points and end up with a “wiggly” diagonal line.



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?



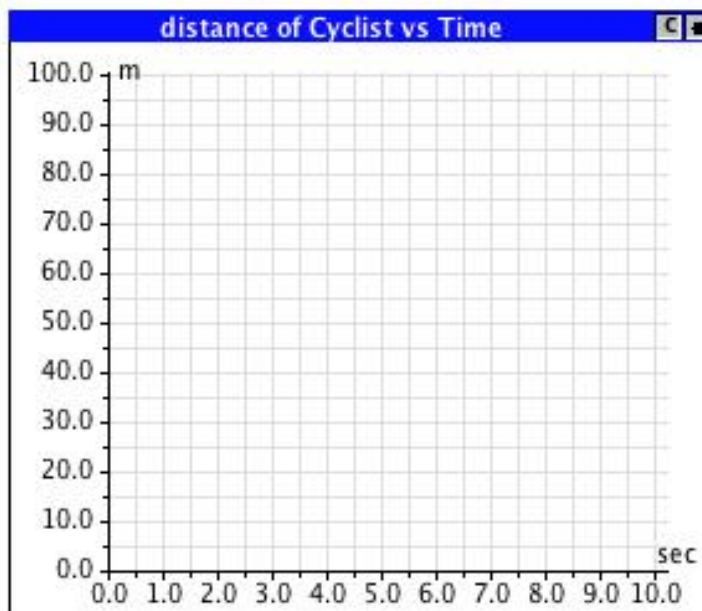
Suppose you were to make a line graph of your friend's distance from the starting line for the ten second period in the table, what do you think it would look like? Why do you think so?

 If possible, the teacher should find some way to display some student graphs and discuss them. Some issues to include in the discussion are:

- Why are all the points plotted in a diagonal pattern?
- Should the overall shape of the graphs straight or “wiggly,” and why?
- In general, if an object is moving at a constant speed, what would a line graph of its distance look like? (We are looking for “straight diagonal” as the distance increases by the same amount each second.)
- What would the graph look like if an object were not moving?



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.



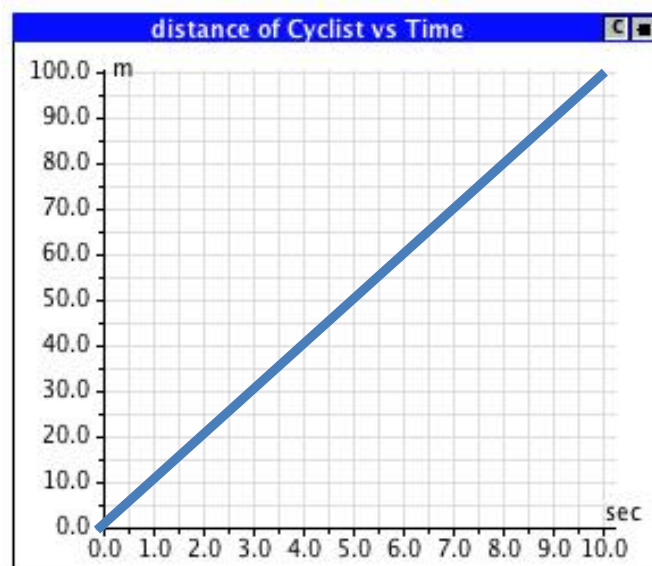
Your teacher will lead a class discussion about everyone's ideas about a line graph that shows the cyclist's distance from the starting line.

⚠ If computers are available, the teacher may choose to let students run the simulator themselves. If not the teacher can project it in some way and run it as a demonstration. An index of simulator setups can be found at:

<http://149.149.136.29/~cpusims/horizonPD/>

🔍 The general shape of the graph should come as no surprise to students at this point.

Make sure students copy the simulator graph if their predictions were different in any significant way (curved lines, wrong values, “wiggly lines”). (Because the whole graph seems to be a straight line, it is OK to use a ruler to help draw it.)




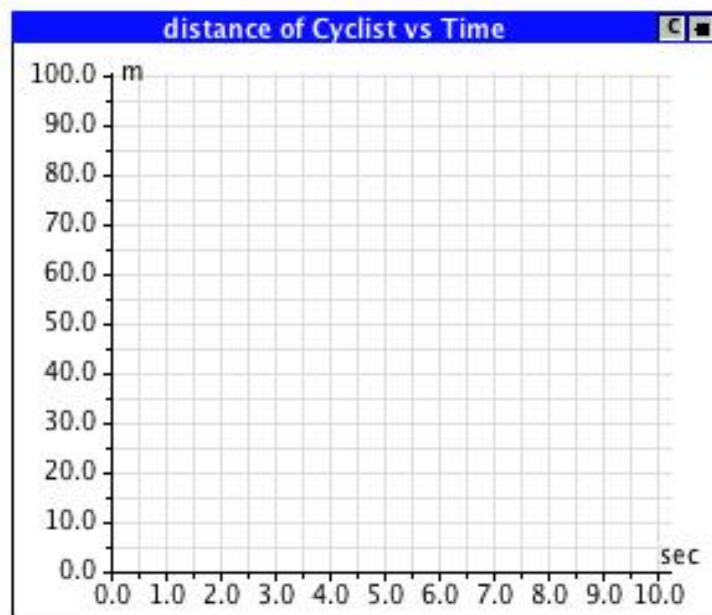
Note: The misconception that “*sloped lines on any graph show that an object is moving up or down a hill*” is not explicitly addressed in this lesson. However, it can be addressed in this scenario if the teacher specifies that the road is flat. In this case, the misconception is countered here because a sloped line is generated when considering motion on a flat road.


🗣 The teacher should introduce the next activity by telling students that now they know what a line graph of distance versus time looks like for constant speed, we will now think about what a graph would look like if the speed were changing.

A motivating question might be whether they think it will still be a straight diagonal line or not, and why?


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

 The first part of this activity is intended to get students thinking about the link between speed and distance moved in successive seconds.

### Activity 1: Step 1

 Students should be comfortable with the idea that you would move 5 meters in each second. The teacher should also establish that this constant speed is 5 m/s.

 This question may be difficult for some students. The teacher may want to give some values for the speed to help students think about it. For example, if the speed were 5 m/s in the first second, suppose it were 7 m/s over the next second, and 9 m/s for the next, etc. The goal is to establish that the amount of distance moved in each successive second will keep increasing.

 This question should be easier, given the discussion on the previous question. Still, the teacher may want to give some values for the speed to help students think about it. For example, if the speed were 5 m/s in the first second, suppose it were 4 m/s over the next second, and 3 m/s for the next etc. We are trying to establish that the amount of distance moved in each successive second will keep decreasing.

The teacher may want to extend this discussion down until the speed becomes zero and discuss what a speed value of zero means.



## 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?

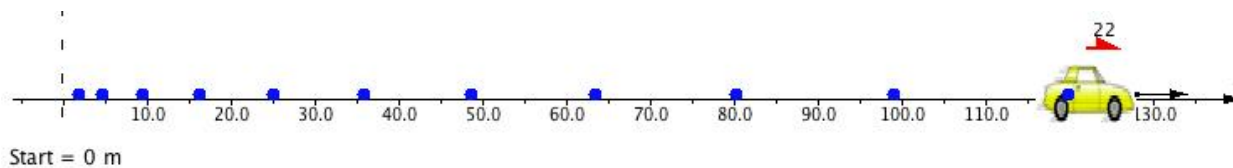
## Activity 1: Step 2

 Having thought about distances moved, now we try to firm up the connection using a motion diagram.

 Students should identify that the representation shows increasing speed and, hopefully, justify it using the increasing distance between successive dots.

 It would be difficult and time-consuming to have students try to read distances from the diagram, so reasonable values are given.

**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



Students will likely simply say that the line will move upward. Some may say diagonal, but is unlikely any will realize that the slope will be steadily increasing. For now, the teacher should not expect students to identify that the slope will be steadily increasing.



The teacher should monitor the groups to make sure the plotting is being done in a reasonable manner. Students should produce a graph that curves upward with a steadily increasing slope.



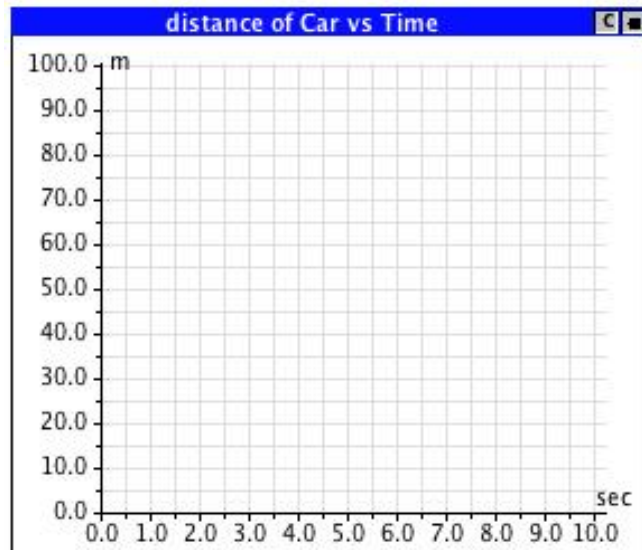
Students may be uncomfortable that the graph is seemingly not straight. The teacher should encourage them to think about what this might mean in terms of distance moved, but the teacher should not confirm the shape of the graph yet.



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.

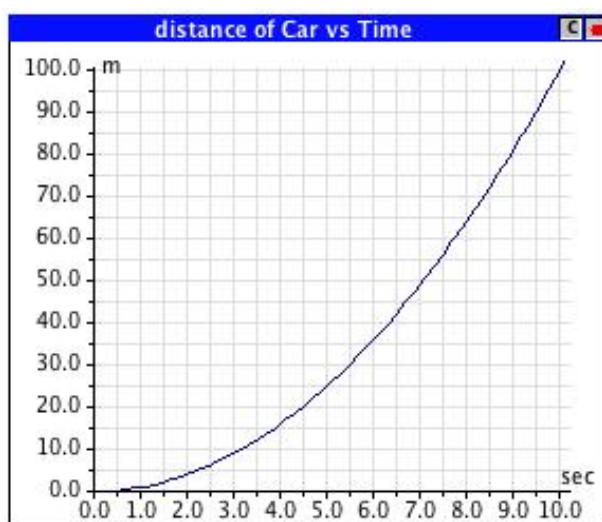


Your teacher will lead a class discussion about everyone's ideas about a line graph that shows the car's distance from the starting line.

! If computers are available, the teacher may choose to let students run the simulator themselves. If not, the teacher can project the simulation in some way and run it as a demonstration.

🔍 The general shape of the graph may still be a surprise to students at this point. Some may be concerned that their graph shows a series of short straight lines whereas the simulator shows a smoother curve. The teacher can tell students that the simulator measures the distance much more often than once a second and so the straight lines it draws between points blend into a curve.

Make sure students copy the simulator graphs if their predictions were different in any significant way (non-curved lines, wrong values, “wiggly lines”).



🗨️ Some issues to include in the discussion are:

- Why do the plotted points increase in value?
- Why is the line not a straight diagonal line?
- In general, if an object's speed is increasing what would a line graph of its distance versus time look like? (We are looking for “curving upward” or “getting steeper and steeper.”)

**Extension:** If the teacher feels comfortable, at this point the class could investigate how the graph would be different if the speed increased at a faster or slower rate. (The curve would be more or less pronounced.)

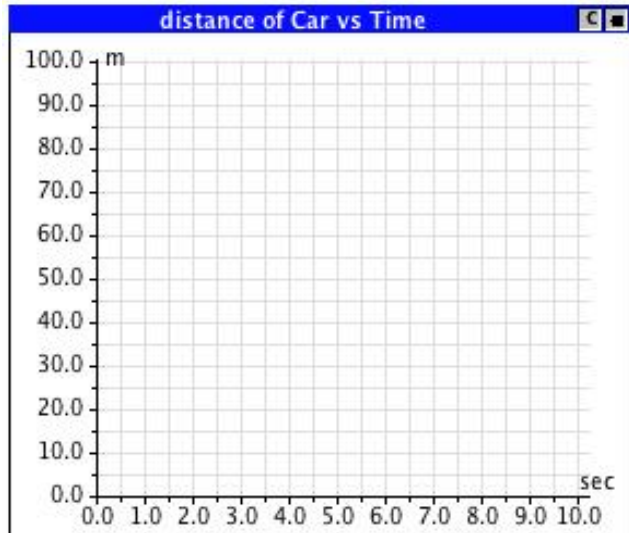
### Activity 1: Step 3

! Now we move on to thinking about decreasing speed. We again start with a motion diagram.

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.

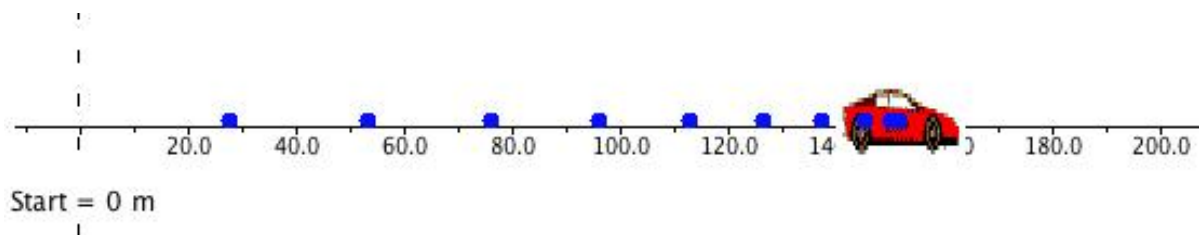



Does the simulator line graph look like the graph that you drew above? If not, draw the simulator graph here.





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.



 Students should identify that the representation shows decreasing speed and, hopefully, justify it using the decreasing distance between successive dots.

 Again, it would be difficult and time-consuming to have students try to read distances from the diagram, so reasonable values are given.

 Some students will likely say that the line will move upward. Some may say diagonal, but is unlikely any will realize that the slope will be steadily decreasing. Encourage students to share the reasons for their answers.

Without realizing that the data in the table contradict them, some may say that the line will move downward on the graph. In this case, these students are likely thinking more in terms of a speed-time graph.





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



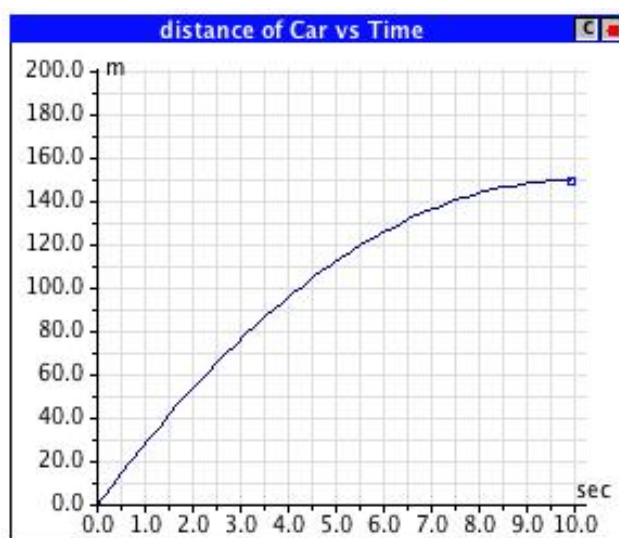
What shape do you think a line graph drawn using these points will be? Why do you think so?

 Students may be uncomfortable that the graph is seemingly not straight. The teacher should encourage them to think about what this might mean in terms of distance moved, but the teacher should not confirm the shape of the graph yet.

 If computers are available, the teacher may choose to let students run the simulator themselves. If not the teacher can project the simulation in some way and run it as a demonstration.

The general shape of the graph may still be a surprise to students at this point. Again, some may be concerned that their graph shows a series of short straight lines whereas the simulator shows a smoother curve. The teacher can tell students that the simulator measures the distance much more often than once a second and so the straight lines it draws between points blend into a curve.

Make sure students copy the simulator graphs if their predictions were different in any significant way (non-curved lines, wrong values, “wiggly lines”).



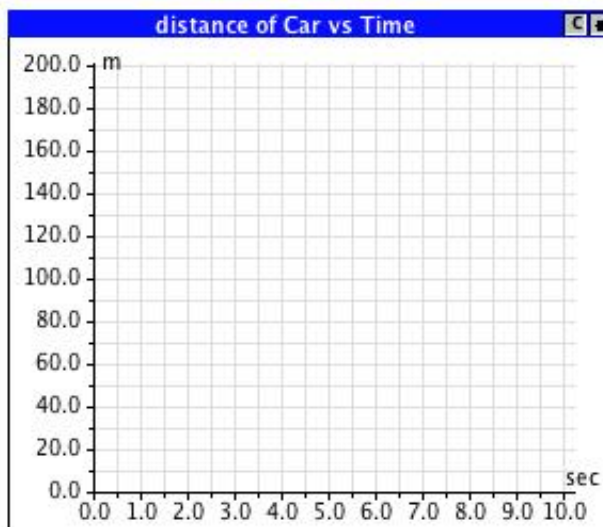
 Some issues to include in the discussion are:

- Why do the plotted points increase in value?
- Why is the line not a straight diagonal line?
- In general, if an object's speed is decreasing what would a line graph of its distance look like? (We are looking for “increasing but getting less and less steep.” Some students may wish to say “curve downward,” but this is not strictly true as the graph keeps moving upward.)

**Extension:** If the teacher feels comfortable, at this point the class could investigate how the graph would be different if the speed decreased at a faster or slower rate. (The curve would be more or less pronounced.)



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.

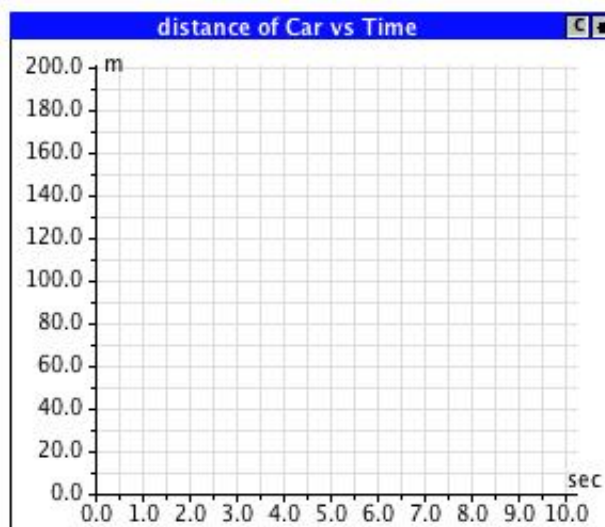


Your teacher will lead a class discussion about everyone's ideas about a line graph that shows the car's distance from the starting line.

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 Questions**

 Having students draw their own distance-time graphs for anything other than constant speed would be time consuming and so we simply have students interpret a graph that we give them.

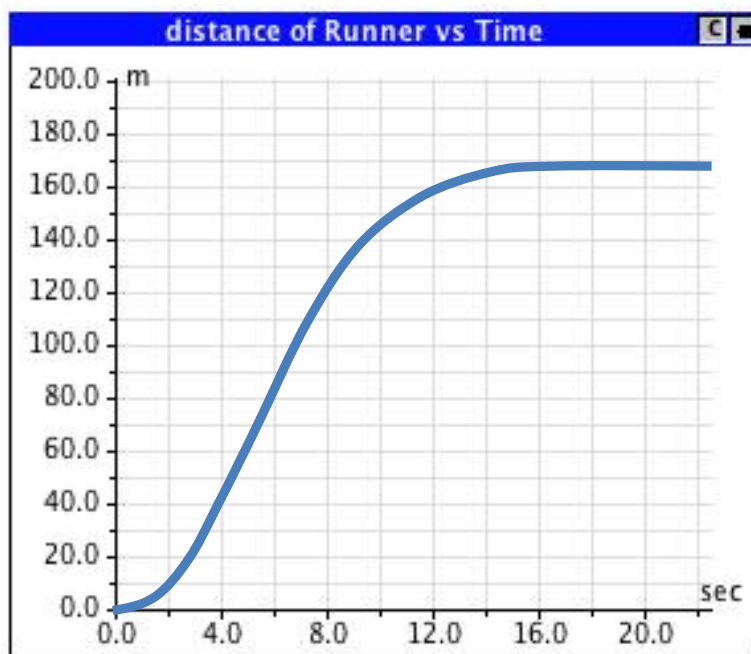
Students may need some help interpreting the graph in segments that have different characteristics.

## 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.



Question 1a: The runner is not moving from approximately time = 16 seconds onward. We can tell this because according to the graph, his distance from the starting point is not changing.

 The issue of constant position was not addressed explicitly in the lesson up to now and so may require substantial discussion. Some students may express the idea that not moving must correspond to a distance of zero. If so, the teacher should act out a scenario in which s/he moves away from a starting point and then stands still.

Question 1b: The runner's speed is increasing over about the first four seconds. We can tell this because the graph is curving upward over this period. It may be helpful to direct students back to the distance-time graphs they drew during STEP 2 as an example of increasing speed.

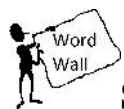
The teacher may take this opportunity to review why the graph is curving upward.

Question 1c: The runner's speed is constant from time = 4 seconds to time = 8 seconds. We can tell this because the graph is a straight diagonal over this period. Students may point out that the runner's speed is also constant (not moving is a constant speed of 0 m/s) from time = 16 seconds to time = 22 seconds, as the graph is straight and horizontal over this period. It may be helpful to direct students back to the distance-time graphs they drew during the "What do we think" activity as an example of constant speed.

The teacher may take this opportunity to review why the graph is a straight diagonal.

Question 1d: The runner's speed is decreasing from time = 8 seconds to time = 15 seconds. We can tell this because the graph is getting less and less steep over this period. It may be helpful to direct students back to the distance-time graphs they drew during STEP 3 as an example of decreasing speed.

The teacher may take this opportunity to review why the graph is curving then flattening.



## Science Vocabulary

There are no new vocabulary terms in this lesson.

- 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?