# Introduction to Motion: Distance vs. Time and Velocity vs. Time Graphs

(completion time: approx. 2 hr.) (1/6/17)

## *Introduction*

In this lab you will use a "motion sensor" to generate graphical representations of position and motion. The motion sensor emits sound pulses and detects their echoes (i.e. reflections) off of an object. The computer measures the time from emission of each pulse to detection of its echo. Using the speed of sound in air, the computer calculates and records distances from the detector to the object as a function of time. You will practice making and interpreting position (i.e. distance from sensor) vs. time and velocity vs. time graphs for motions along a straight-line path.

## *Equipment*

- motion sensor
- masking tape
- PASCO Capstone Software
- Computer with PASCO interface*
- 2-meter stick

* The Capstone Starter Manual is online at: www.pasco.com.

## *Procedure*

**Setting up the motion sensor and Data Studio program**

1)Launch PASCO Capstone (click Start; or launch from the desktop)
2)On the Tools Palette (Left Margin), click **Hardware Setup**
3)Capstone will automatically detect and connect to the PASCO interface. If you see a yellow caution symbol, check to be sure USB and power connections are complete.
4)Plug in the Motion Sensor by placing the **gold and black plugs in channels 1 and 2 respectively**.
5)Double click the image of the channel 1 plug and select the Motion Sensor from the drop menu.
6)Drag and drop a Graph from the Display Palette (Right Margin)
7)Select the Type of Measurement Position/Velocity as required within the lab exercise.
8)Press the **RECORD** button to collect data and **STOP** at the end of each run.
9)To clear the data from previous runs, press **DELETE LAST RUN.**

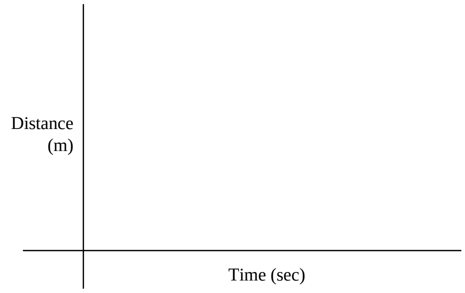
If needed, view a brief tutorial for using Capstone: **http://tinyurl.com/zpykfwo**

Practice with the detector until you understand the reading. Sound is emitted in a cone that spreads out from the motion sensor. If the sound is reflected by a fixed object (such as the ceiling), a straight line will appear on the graph, since distance to the ceiling is not changing as a function of time. Position your sensor so it does not hit any fixed objects and you are able to walk back and forth in front of it on a clear path approximately 3 meters long. Move back and forth in front of the sensor and watch the distance graph change.

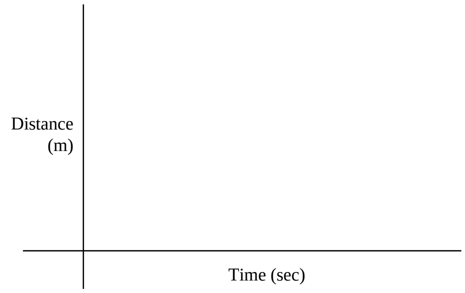
Stand 0.5 meter, then 1 meter, then 2 meters from the sensor, using a 2-meter stick to check that the distances recorded correspond to your position. Clear the data from your graph.

**Activity 1: Making distance vs. time graphs for different walking speeds and directions**

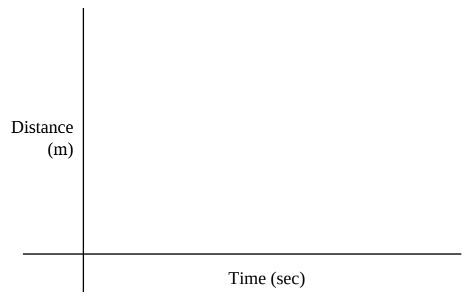
Start at the ½ meter mark and make a distance versus time graph, walking *away from* the sensor *slowly and steadily* (at constant speed). Sketch your graph on the axes to the right. Label different parts of your graph to make clear which data represent the specified actions.



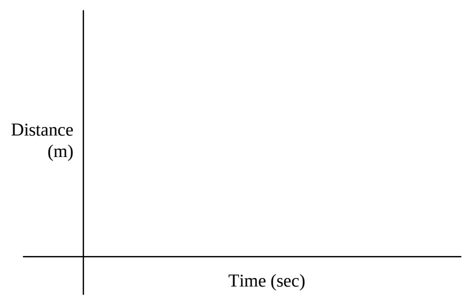

Make a distance-time graph walking *away from* the detector *medium fast and steadily*. Sketch and label your graph.




Make a distance-time graph walking *toward* the detector *slowly and steadily*. Sketch and label graph.




Make a distance time graph walking *toward* the detector *fast and steadily.* Sketch the graph.




### a) Questions:

Answer the following using complete sentences. Consider using these words or phrases (as well as your own): up, down, steeper, less steep, rising, falling, increasing, decreasing, faster, slower.

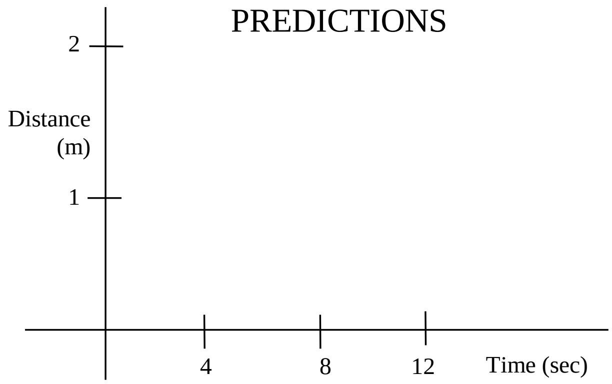
How is distance changing as a function of time when you walk *away* from the sensor?
When you walk *toward* the sensor?

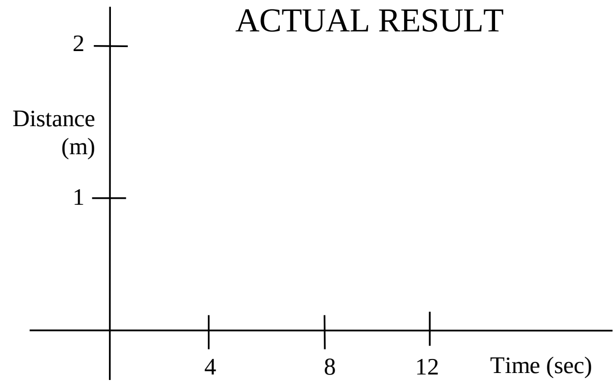
How does your graph show whether you are moving away from the sensor or toward it?

How does your graph show whether you are moving quickly or slowly?

## Activity 2: Prediction

Using a dotted line, sketch your prediction of how a distance vs. time graph would look for a person starting at the 1 meter mark, walking *away slowly and steadily* for 4 seconds, stopping for 4 seconds, then walking *toward* the sensor *more quickly*. Compare predictions within your group and discuss them. Arrive at a consensus prediction and draw it with a solid line (do not erase your original prediction).




Now, do the experiment. Move in the way described above and graph your motion. When you are satisfied that your graph represents the specified activities, draw your groups' final result above.

**Questions**

Was your initial prediction essentially the same as the actual result?
If not, why was your prediction incorrect?

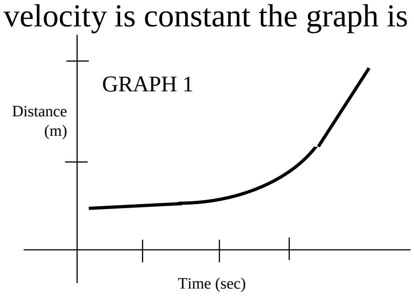
How does the graph show when you are moving away from or closer to the sensor?

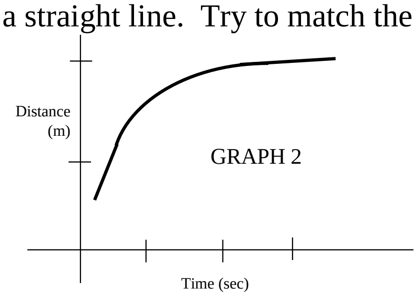
How does it show the speed of motion?
(Note: Speed, as used in physics, is the absolute magnitude of velocity, without regard to direction.)

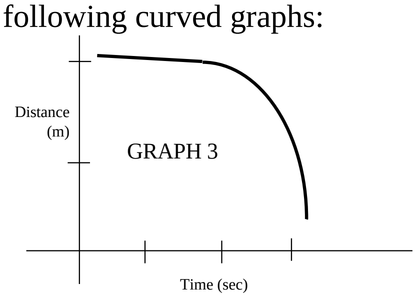
How does it show no motion (i.e. "stationary motion")?

## Activity 3: Moving at non-constant speed

For straight-line motion, the *slope* of the distance vs. time graph represents the velocity. When velocity is constant the graph is a straight line. Try to match the following curved graphs:




For each graph carefully describe how you had to move to match the graph. Use words like faster, slower, going toward, going away, increasing speed, decreasing speed, steeper, less steep.

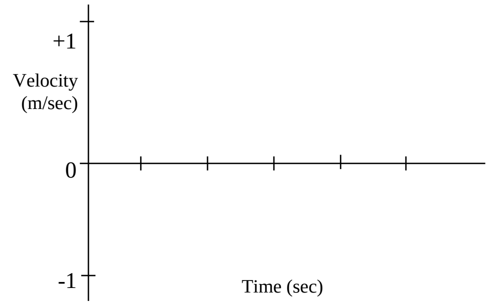
Graph 1:
Graph 2:
Graph 3:

How does a graph where the speed is changing differ from a graph where you are moving *steadily*?

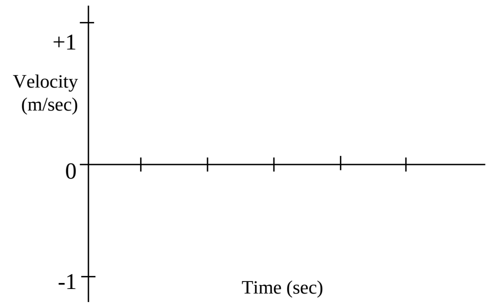
**Activity 4: Velocity-time graphs**

Set up the program to display **Velocity**. Double click on **Distance** on the vertical axis of the graph and select **Velocity** in the dialog box. Set the range from -1 to +1 meters/sec. (You can do this by putting the cursor on a number on the velocity axis, clicking on and stretching/contracting the axis.)

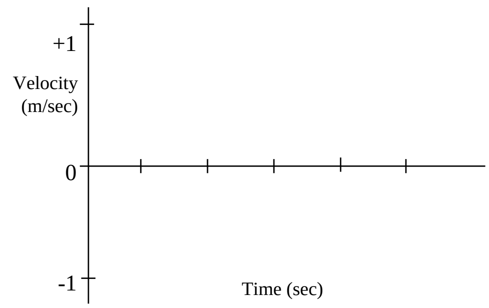
Make a velocity vs. time graph, walking *away from* the sensor *slowly and steadily*. Sketch and label the graph.



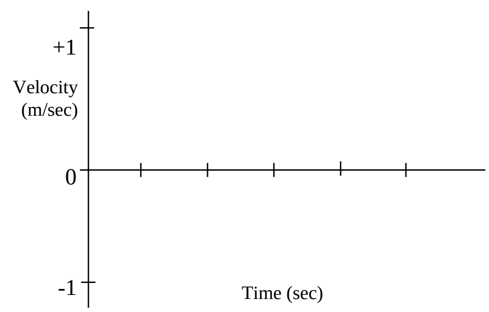

Make a velocity versus time graph walking *toward* the detector *medium fast and steadily*. Sketch and label the graph.




Make a velocity versus time graph by first walking *fast and steadily away from the detector,* then *pausing* for about a second, then walking *slowly toward the detector*. Sketch and label this graph.




Make a velocity graph first standing still for 1 second, then walking *toward* the detector first slowly and then with increasing speed. Sketch and label the graph.



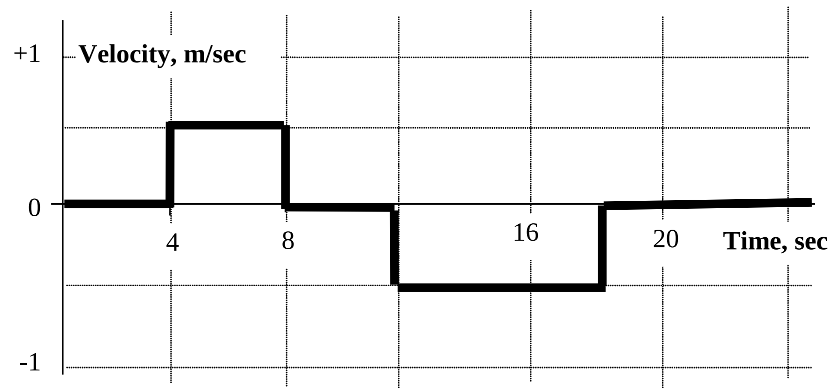

**Questions**

How does the plus and minus sign of the velocity reflect the *direction* of motion?

Does the sign of the velocity show whether the distance is *increasing* or *decreasing*? Explain.

**Activity 5: Matching a velocity graph**

Try to create a matching graph. You may need to try a number of times. Work as a team and plan your movements so as to match the times and velocities.



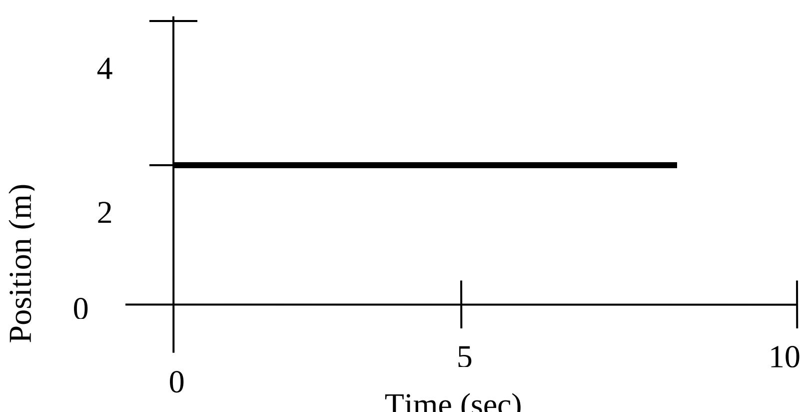

Sketch your graph using a dotted line. Label the different parts of the graph, describing your corresponding motions.

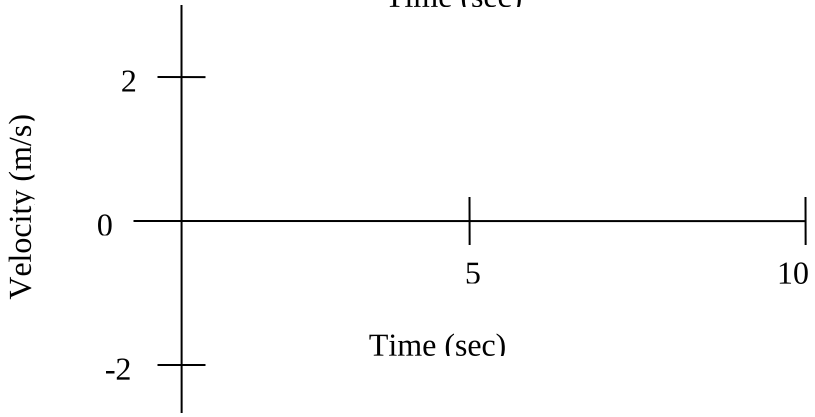
Is it possible to move so as to create a perfectly vertical line on the velocity graph? Explain.

**Activity 6: The relationship between velocity vs. time and position vs. time graphs**

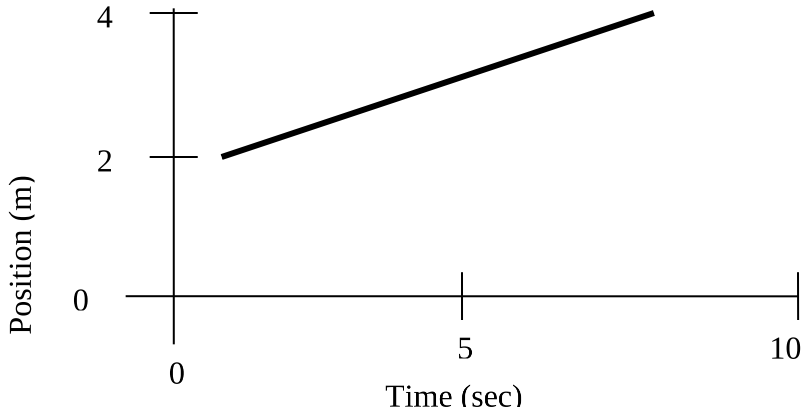
Following is a series of paired position vs. time and velocity vs. time graphs for various motions. One graph in each pair has been completed. Use a *dotted* line to indicate what you predict the corresponding graph must be based on the motion described by the completed graph. Then, use the motion sensor to check your answers. For example, if a graph of position vs. time is given, use your motion sensor to generate a similar graph as well as the corresponding velocity vs. time graph. When you are satisfied that you have reproduced the completed graph reasonably well, record your results on the appropriate graphs using *solid* lines.

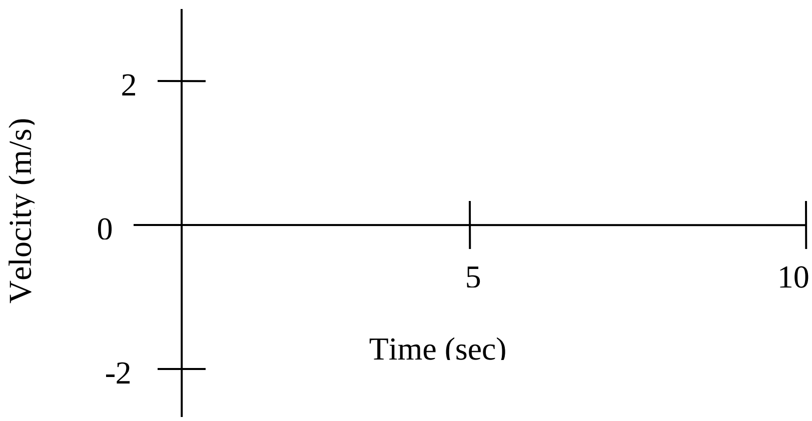
**Set A:**



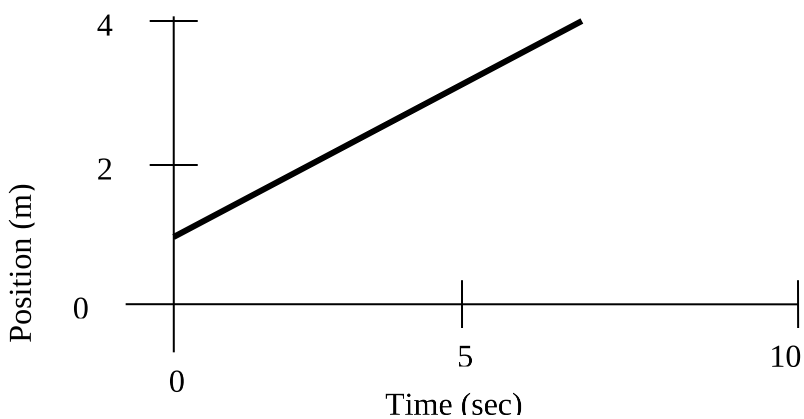



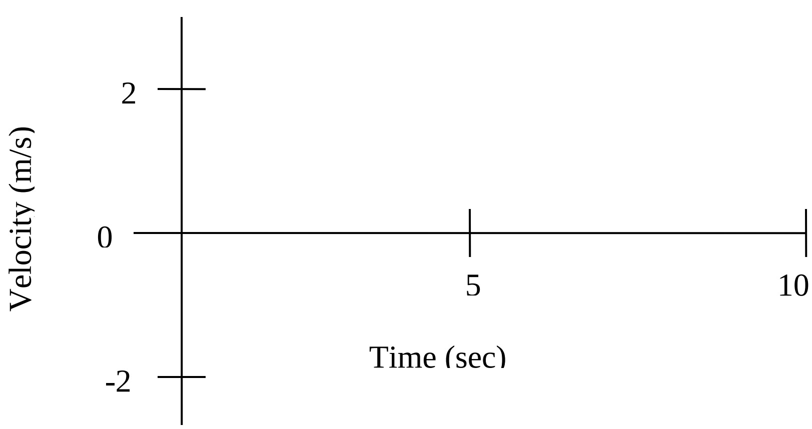
**Set B:**


4
2
0
Position (m)
0
5
10
Time (sec)

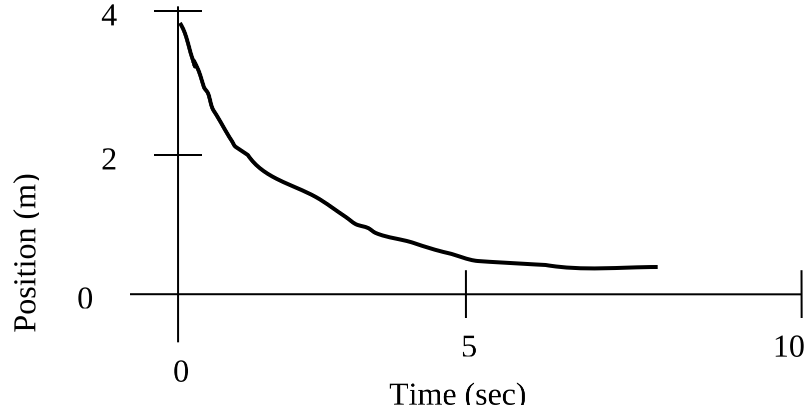

2
0
-2
Velocity (m/s)
5
10
Time (sec)

**Set C:**

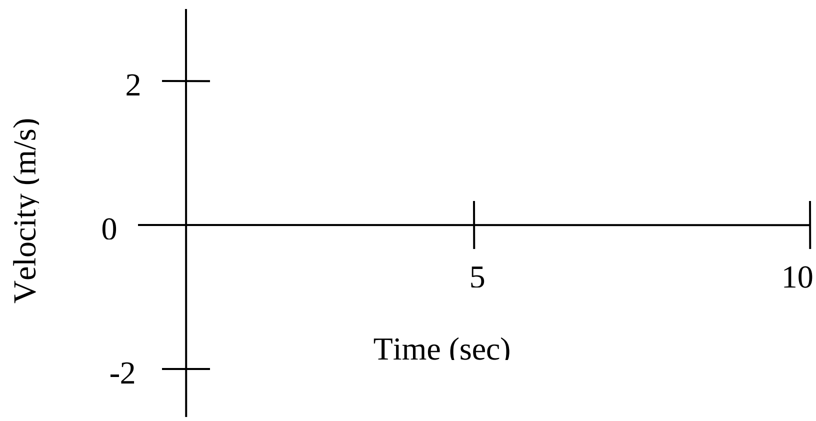

4
2
0
Position (m)
0
5
10
Time (sec)


2
0
-2
Velocity (m/s)
5
10
Time (sec)

**Set D:**

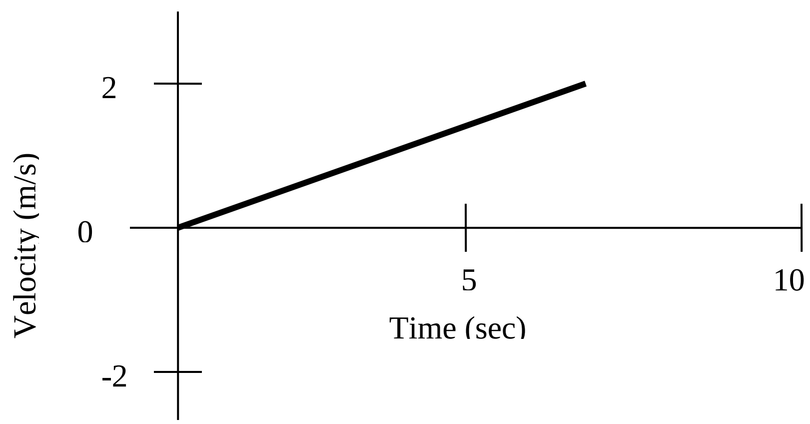


4
2
0
Position (m)
0
5
10
Time (sec)

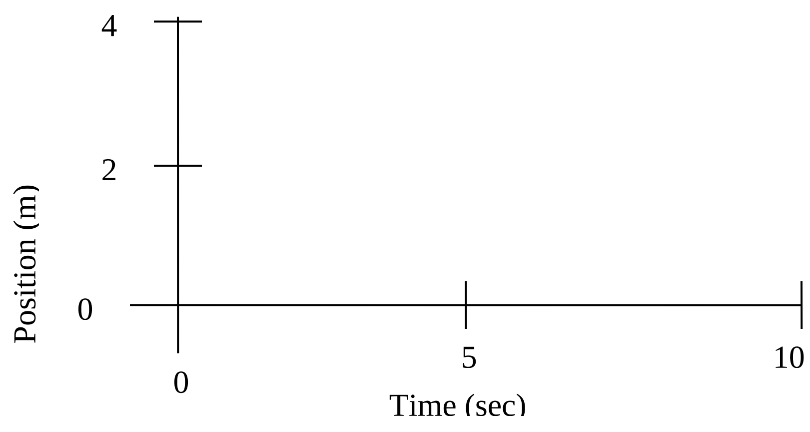



2
0
-2
Velocity (m/s)
5
10
Time (sec)


**Set E:**

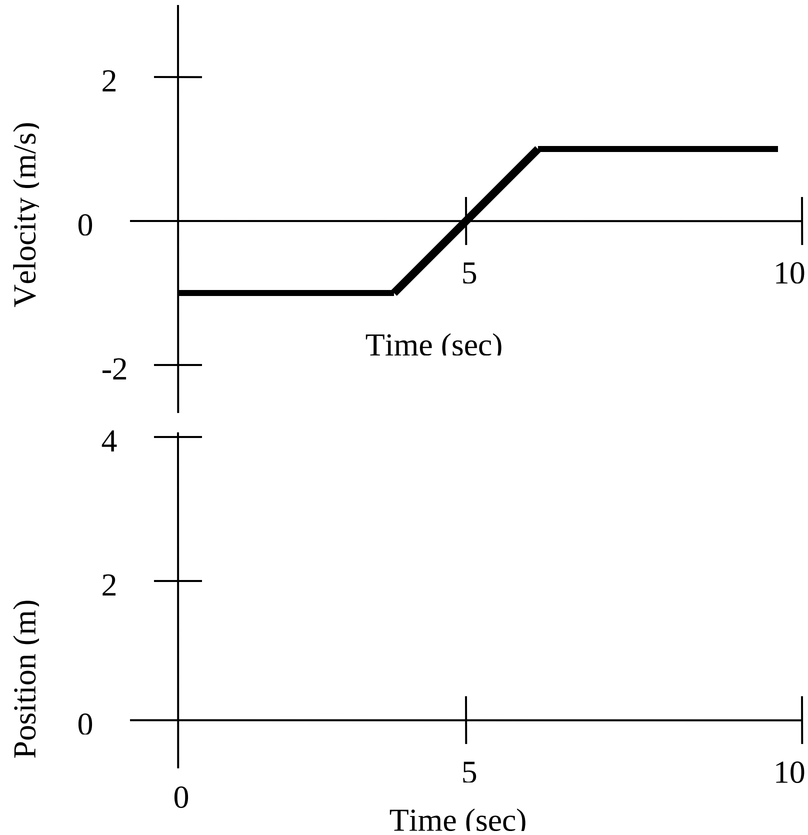


2
0
-2
Velocity (m/s)
5
10
Time (sec)

4
2
0
Position (m)
0
5
10
Time (sec)

**Set F:**




## Questions

For Set F, which part(s) of the position graph correspond to a horizontal line on the velocity graph? Label and describe them.

In general, which parts of a velocity graph correspond to increasing distance (i.e. position)?

What does the *slope* of the position graph look like in this case?
(Refer to the sets of graphs and your results for examples.)

In general, which parts of a velocity graph correspond to decreasing distance (position)?

What does the *slope* of the position graph look like in this case?
(Refer to the sets of graphs and your results.)

What units does the slope of a position vs. time graph have?

What does the slope of a position vs. time graph represent?

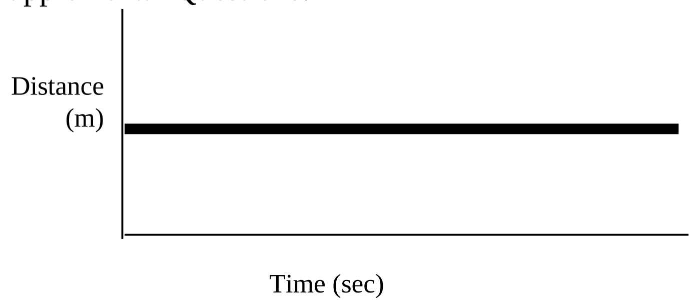
Qualitatively, what's the difference between the types of motion represented in Set C and Set D?

How does this difference change the way we graph the motion on a position vs. time graph?

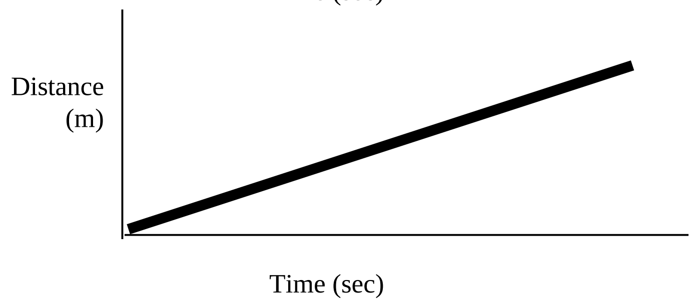
Explain the concepts of velocity and position and how they are related graphically.

## Supplemental Questions:

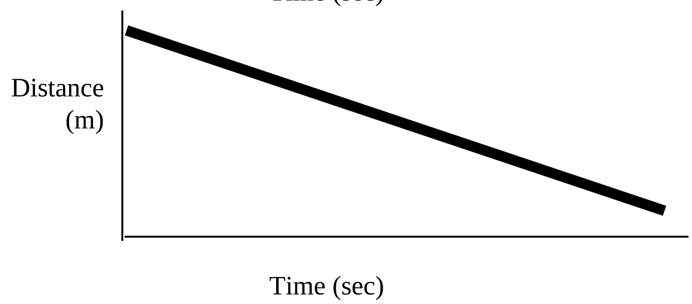
1. How do you move to create a horizontal line on a distance versus time graph?



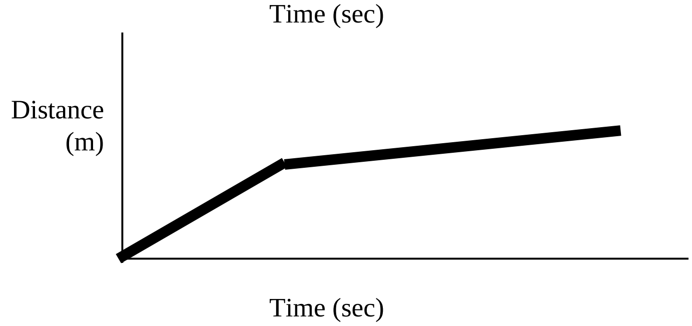

2. How do you walk to create a straight line that slopes up?



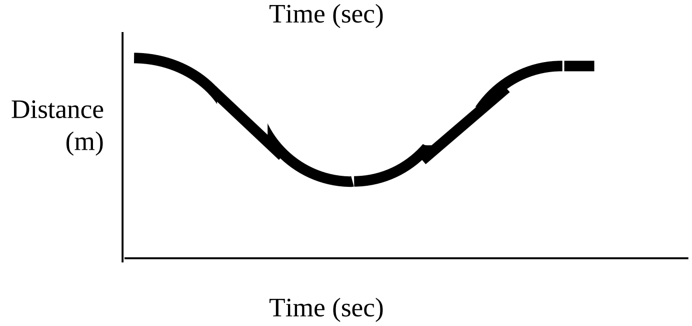

3. How do you walk to create a straight line that slopes down?




4. How do you move to create a line that goes up steeply at first, then goes up less steeply?

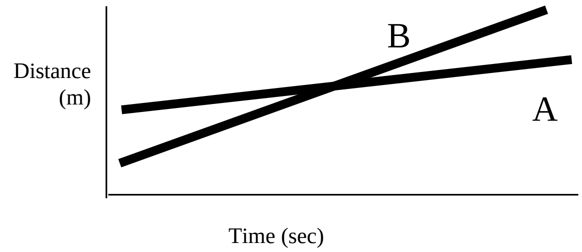



5. How would you move to create a U-shaped graph?




6. For which parts of the U-shaped graph is the velocity zero? (label them)

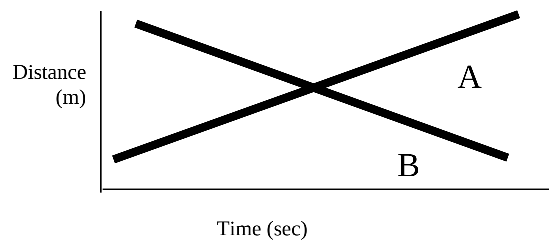
7. Which object is moving faster, A or B?




8. Which starts in front? Which finishes in front?

9. What happens at the intersection of the two lines?

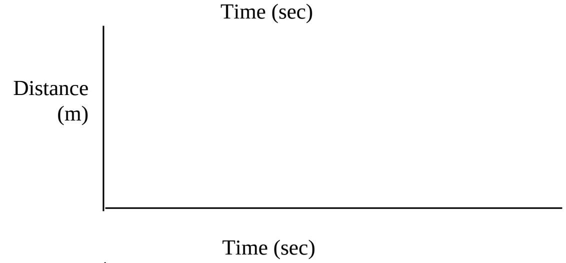
10. Which object is moving faster (can you tell?)



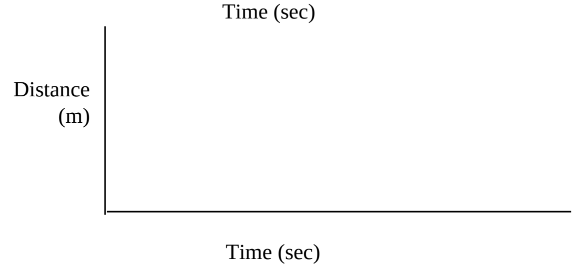

11. Which is moving towards the detector? Which away?

12. Sketch a graph for an object moving steadily away from the detector.


13. Sketch a graph for an object that is standing still.




14. Sketch a graph for an object that moves quickly toward the detector then slows down and stops.




DISCUSS YOUR RESPONSES TO 1-14 WITH YOUR TEAMMATES AND TRY TO REACH AGREEMENT.

**REMOVE ALL TAPE FROM FLOOR WHEN FINISHED!**