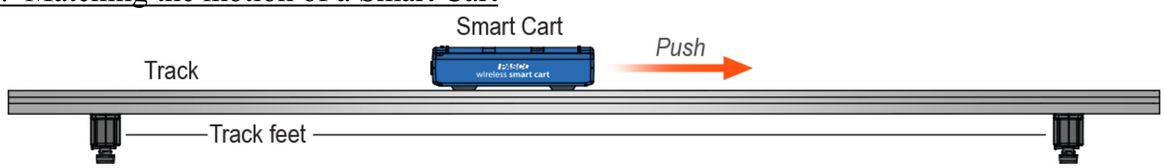
Investigation 3B: Motion graphs

Essential Question: How do we predict and object's position at a later time?

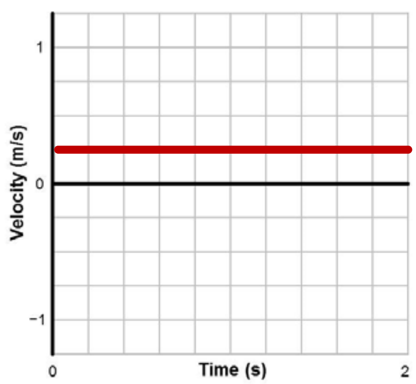
Graphs and equations are valuable methods for describing the motion of an object. Position versus time and velocity versus time graphs can describe where an object is located, how fast it is going, and which direction it is headed. In this activity, you will adjust the motion of a Smart Cart to match the velocity-time graphs below.

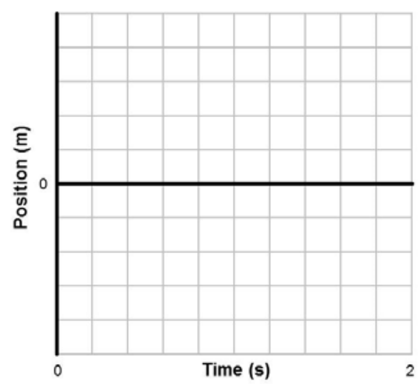
Part 1: Matching the motion of a Smart Cart



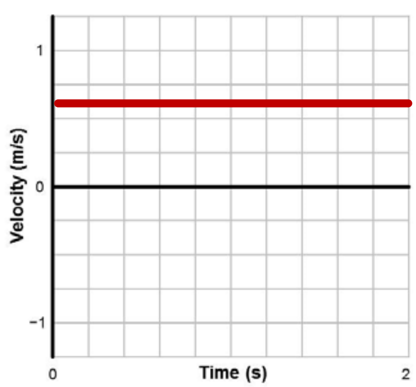
1. Set up your equipment like the picture.
2. Open the experiment file **03B_MotionGraphs**, and then power-on the Smart Cart and connect it wirelessly to the software.
3. Do the following for each velocity-time graph below:
   a. Sketch a *prediction* for the corresponding position-time graph. Label the prediction.
   b. Find the page in the experiment file with the corresponding velocity-time match graph. Hide any data so the position-time graph is blank and only the velocity-time match graph is shown.
   c. Place the cart on the track and record data as you push, pull, roll, or use your hand to move the cart so that its velocity-time data matches the velocity-time match graph.
   d. Sketch the *actual* position-time graph in the same graph as your prediction.

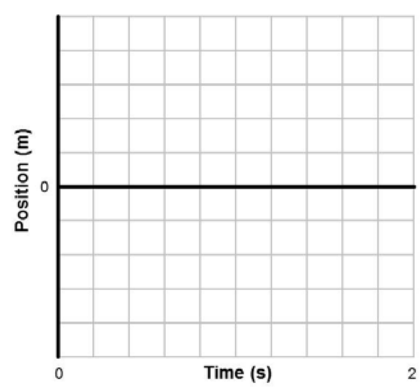
Moving forward at a slow speed (Ex. pg1)



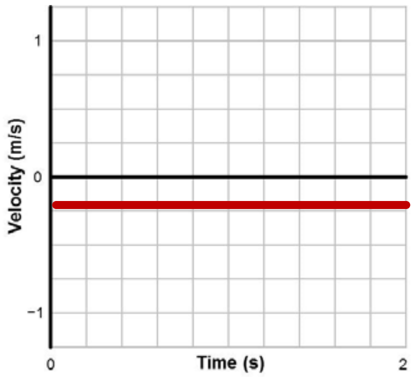


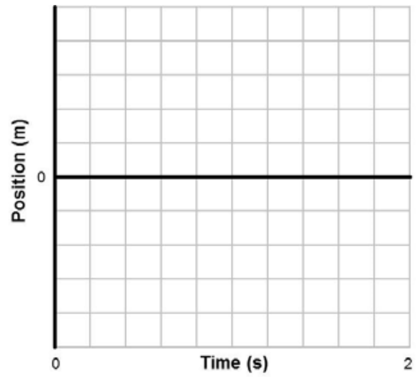
Moving forward at a fast speed (Ex. pg2)



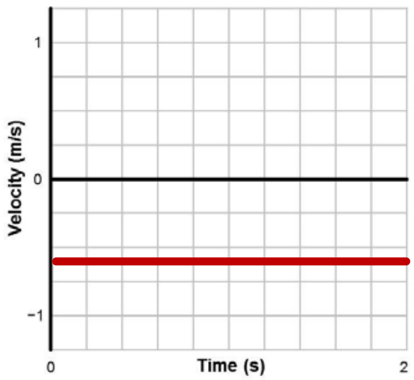


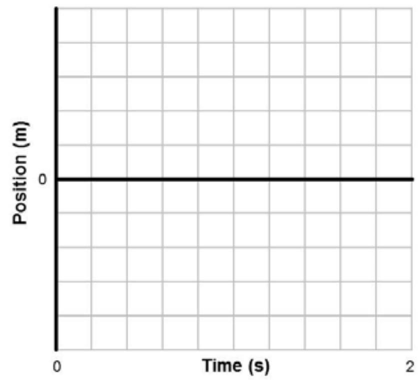
Moving backward at a slow speed (Ex. pg3)





Moving backward at a fast speed (Ex. pg4)





Questions

a. How does the position graph for a high positive velocity differ from a lower positive velocity?

b. How does the velocity graph for a high positive velocity differ from a lower positive velocity?

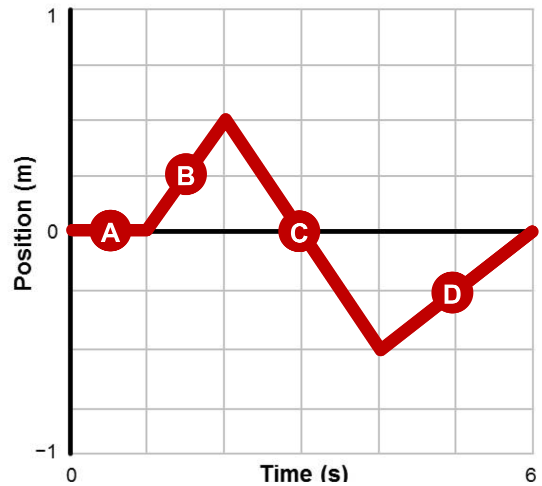
c. How does the position graph for a negative velocity differ from positive velocity?

d. How does the velocity graph for a negative velocity differ from a positive velocity?

e. Describe a situation for which the position versus time graph and the velocity versus time graph are both flat (zero slope) horizontal lines.

f. Go to page 5 in the experiment file and hide any data so the velocity-time graph is blank and only the position-time match graph is shown.

Record data to match the position-time graph, and then describe the motion of the cart during each section shown in the graph to the right. Use terms such as forward, backward, at rest, fast, and slow.



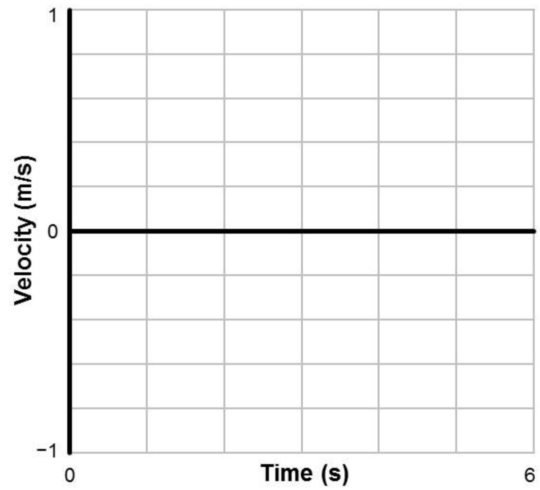
A:

B:

C:

D:

g. Draw the resulting velocity-time graph. Label each section corresponding to the letters in the position-time graph above.



h. Use the slope tool in your software to find the slope of the position-time graph in each section A, B, C, and D. Record the slopes below. How does the slope of the position time graph compare to the velocity recorded during the same period?

A:

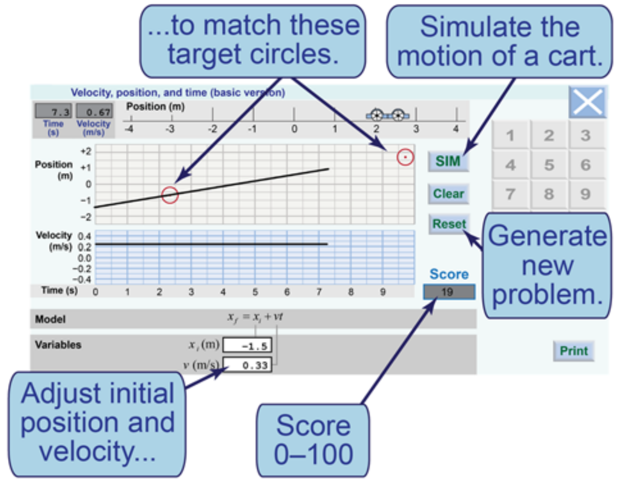
B:

C:

D:

Part 2: The constant velocity model for position vs. time

This interactive, graphical model shows position and velocity versus time graphs for the motion of a cart. Red circles on the position vs. time graph are "targets." Your goal is to adjust the initial parameters, x_i and v, so the line hits both targets.



1. [SIM] starts the simulation. [Stop] stops it without changing values. [Clear] resets all variables to zero. [Reset] resets all variables and sets new targets.
2. Enter values in the white boxes. Grey boxes are calculated and cannot be edited. The top score of 100 is achieved by crossing the center of each target circle.
3. Use the print button to print out a copy of your solution and score.

Questions

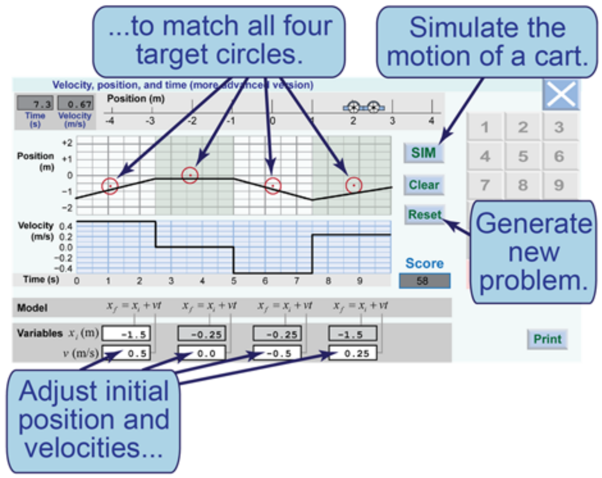
a. Describe the meaning of x_i and v in this model for the motion of a cart.

b. What velocity will move an object from +50 m to −50 m in 20 seconds? Show your work.

c. Find a solution yourself, then press [Clear] and have your partner find a solution. How well do your two solutions agree? Is one solution better than the other?

Part 3: A more complex model

1. This second interactive model contains four constant-speed segments.
2. Your goal is to adjust the values of x_i and v for all sections to hit the four targets.
3. Enter values in the white boxes. The top score of 100 is achieved by hitting the center of each target.
4. Simulate your model to view the graphs.



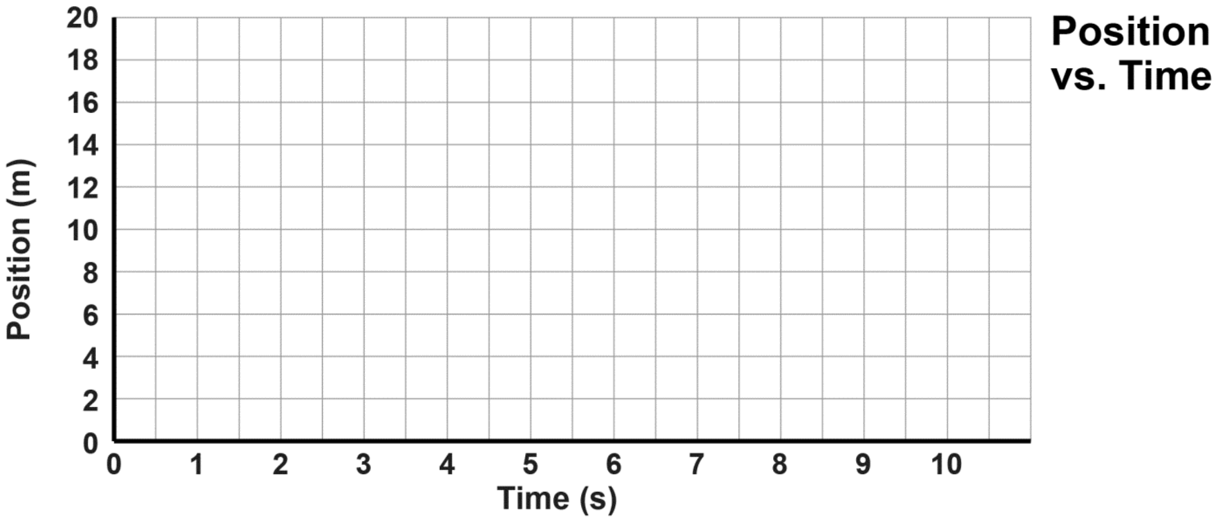
Questions

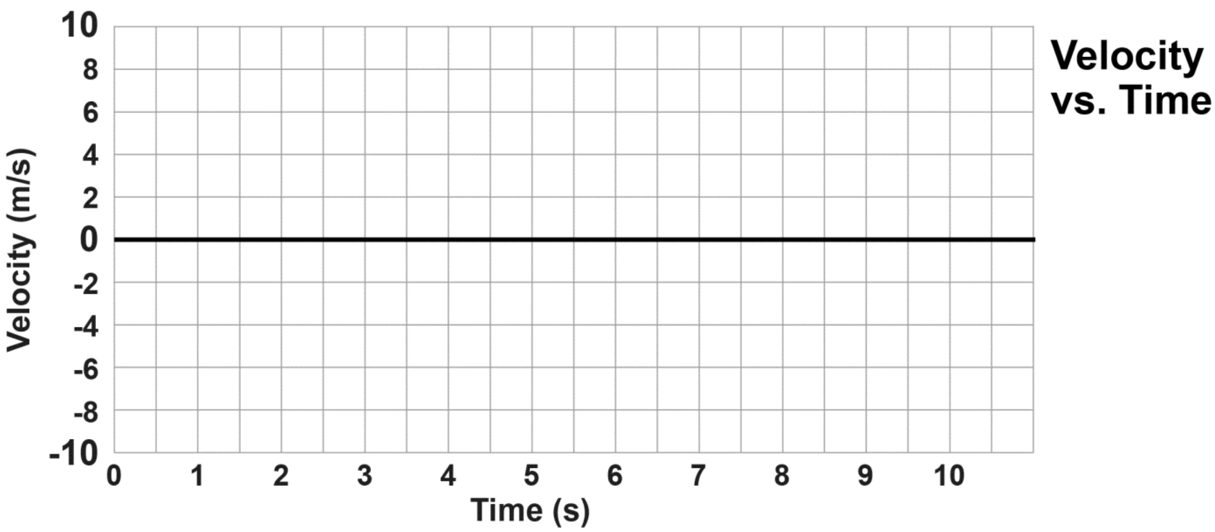
a. In this model for the motion of the cart, there are four values of x_i. Where do the three values of x_i in the grey boxes come from?

b. Describe how this model could be generalized to recreate any motion in one dimension.

Slide presentation graphs.

Plot the motion graphs used in the slide presentation along with your teacher. The object starts at the origin (0 meters) at $t = 0$ s. Use the slope equation shown below to calculate the velocities from the slope of the position verses time graph.





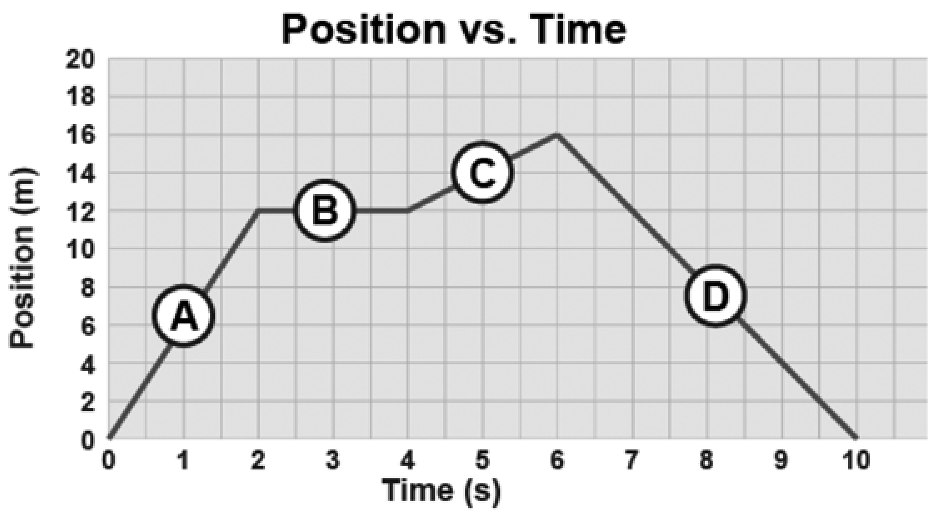
Velocity going out

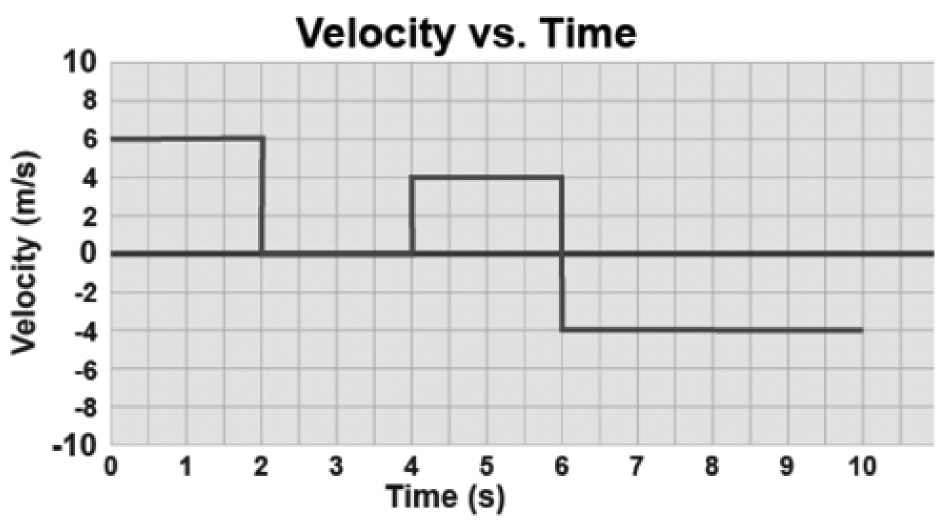
$$v = \frac{\Delta x}{\Delta t} = \frac{\square - \square}{\square} = \square$$

Velocity coming back

$$v = \frac{\Delta x}{\Delta t} = \frac{\square - \square}{\square} = \square$$

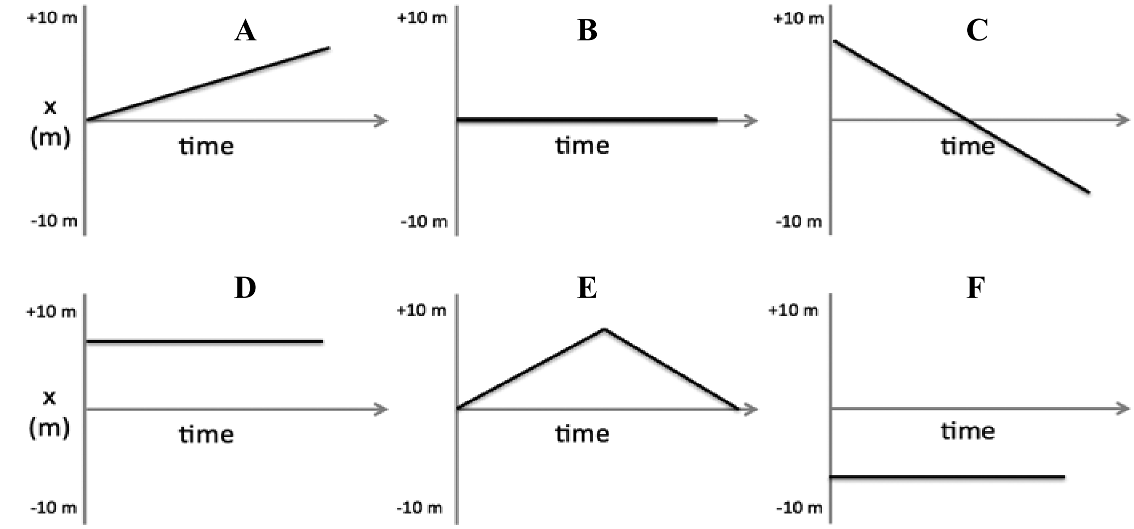
Sketch the changes to these graphs if the velocity at (A) and (C) is changed to 3 m/s.





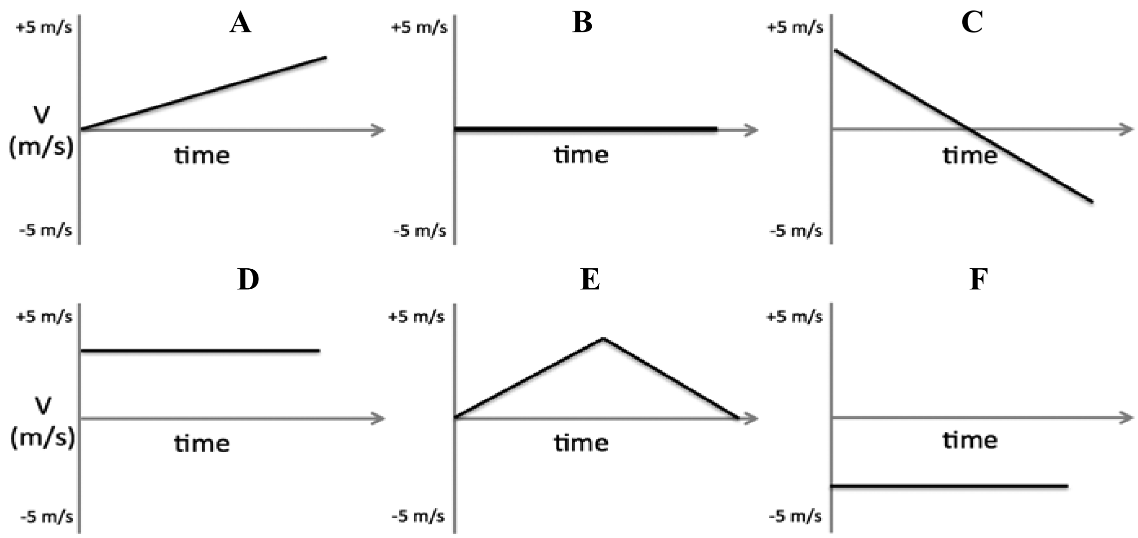
Applying new knowledge

Questions 1 – 4: Match each description of motion with the correct position versus time graph(s). There may be more than one correct answer.



1. The object is stopped. _______
2. The object is moving with constant positive velocity. _______
3. The object is moving with constant negative velocity. _______
4. The object turns around. _______

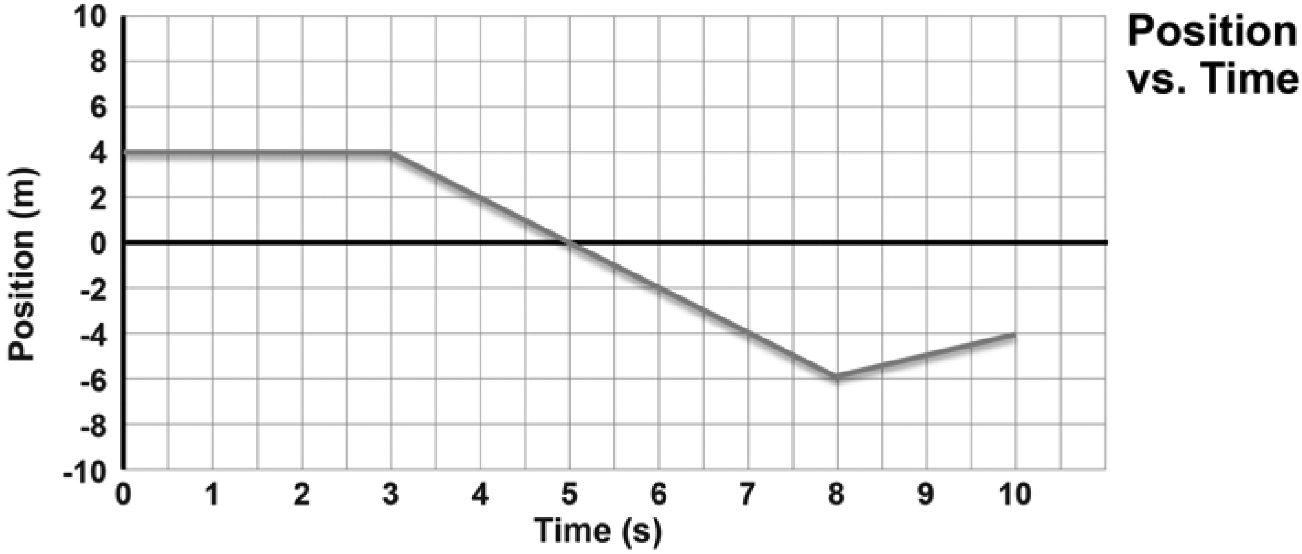
Questions 5 – 8: Match each description of motion with the correct velocity versus time graph(s). There may be more than one correct answer.



5. The object is stopped. _______
6. The object is moving with constant positive velocity. _______
7. The object is moving with constant negative velocity. _______
8. The object turns around. _______

Questions 9 – 11: The motion of a robotic car is shown on the position versus time graph below. Calculate the velocity during each time interval. (DO include signs!)

9. The velocity from 0 to 3 seconds: ____________
10. The velocity from 3 to 8 seconds: ____________
11. The velocity from 8 to 10 seconds: ____________



12. Create the velocity versus time graph for the robotic car.