11. Motion Graphs

Follow the Leader

Driving Question

How do you know where you are going?

Materials and Equipment

For each student or group:

- ☐ Data collection system
- ☐ Motion sensor
- ☐ Reflector (optional)

Safety

Add these important safety precautions to your normal laboratory procedures:

- Make sure there is a clear path in front of the motion sensor.
- Do not allow obstacles to obstruct students' path or they may trip.

Thinking about the Question

Describing your location, or position, is based upon describing the distance between you and some fixed reference point. When you change your position, you experience motion.

If you have ever ridden a rollercoaster at an amusement park, you have probably used the ground as your fixed reference point. How did you know you were getting higher? If the rollercoaster went through loops or spirals, how could you tell if you were upside down? Sometimes people who are scared during the ride close their eyes. Do you think this might help? Why or why not? Regardless of whether the rollercoaster was fun or scary, the ride is eventually over. How would you know that the rollercoaster had stopped? Would it be possible to use a fixed reference point other than the ground?

Discuss with your lab group members how to compare where you are right now to where you live. How do you use a fixed reference point to help in this comparison? What does "frame of reference" mean? Do you need to use a direction and a distance? What is motion? How do you know if an object is in motion?

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Sequencing Challenge

☐ **The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.**

Determine how far away from the motion sensor 50 cm is, so the walker knows where to begin.	Make sure that each lab group member is aware of safety rules and procedures for this lab.	Determine the maximum distance away from the motion sensor the walker may move.	Start recording position versus time data.	Begin walking backward and forward when the clicking sound of the motion sensor becomes audible.

Investigating the Question

☐ **Note:** When you see the symbol "**[?]**" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Part 1 – Making predictions

1. ☐ The job of the "walker" in this activity is to walk back and forward in front of the motion sensor. The walker's position relative to the motion sensor will change throughout this activity. Write your predictions about the walker for the following:

   a. How will a graph of position versus time change when the walker moves closer to the fixed reference point (the motion sensor)?

   b. How will the graph of position versus time change when the walker moves away from the fixed reference point?

c. If the walker's distance from the fixed reference point does not change, how would this appear on the graph of position versus time?

2. ☐ Write your predictions for the following:

Suppose a walker begins two meters away from the reference point and walks slowly toward it until stopping at 0.5 meters away from it. Then a second walker takes the same walk, but walks much more quickly. How would the graphs of these two motions compare? How would they differ? You may sketch your predictions or describe them using words.

Part 2 – Follow the leader

3. ☐ Start a new experiment on the data collection system. (1.2)

4. ☐ Connect the motion sensor to the data collection system. (2.1)

5. ☐ Display Position on the y-axis of a graph with Time on the x-axis. (7.1.1)

6. ☐ Change the sampling rate to take position measurements 5 times per second (5 Hz). (5.1

7. ☐ Select one student to be the first walker. This person will be the leader for this part of the activity. The walker should stand in front of the motion sensor at a distance of 50 cm from the metal screen. Why is it important to choose one particular fixed object to measure the distance from?

8. ☐ Start data recording. (6.2)

9. ☐ The walker should now move as follows:

   a. Stand still for 2 seconds

   b. Back away from the motion sensor slowly for 6 seconds

   c. Stop and stand still for 2 seconds

10. ☐ Stop data recording. ◆(6.2)

11. ☐ If necessary, adjust the scale of the graph to show all data. ◆(7.1.2) The pattern on the graph shows the motion of the leader. The other members of your lab group will each try to match the position graph of the leader, walking the same distances in the same amounts of time.

12. ☐ Select a new walker to follow the leader. The new walker should stand in front of the motion sensor at a distance of 50 cm from the metal screen.

13. ☐ Start data recording. ◆(6.2)

14. ☐ The new walker should now move in such a way as to follow the motion of the leader, matching the leader's position graph as closely as possible.

15. ☐ At the end of the 10 seconds stop data recording. ◆(6.2)

16. ☐ Hide the last walker's data run so only the leader's graph shows. ◆(7.1.1)

17. ☐ Select the next walker to follow the leader. The next walker should stand in front of the motion sensor at a distance of 50 cm from the metal screen.

18. ☐ Start data recording. ◆(6.2)

19. ☐ The next walker should now move in such a way as to follow the motion of the leader, matching the leader's position graph as closely as possible.

20. ☐ At the end of the 10 seconds stop data recording. ◆(6.2)

21. ☐ Hide the last walker's data run so only the leader's graph shows. ◆(7.1.1)

22. ☐ Repeat the activity for each member of your lab group.

23. ☐ Save your experiment according to your teacher's instructions. ◆(11.1)

Part 3 – Matching position

24. ☐ Start a new experiment on the data collection system. ⁽¹.²⁾

25. ☐ Display Position on the y-axis of a graph with Time on the x-axis. ⁽⁷.¹.¹⁾

26. ☐ Change the sampling rate to take position measurements 5 times per second (5 Hz). ⁽⁵.¹

27. ☐ Select one student to be the first walker. This person will be the leader for this part of the activity.

28. ☐ The leader should stand in front of the motion sensor at a distance of his/her choice, but no closer than 15 cm from the metal screen.

29. ☐ Start data recording. ⁽⁶.²⁾

30. ☐ The leader should now begin moving slowly and steadily toward or away from the motion sensor, standing completely still at least once during the walk. The entire walk should take between 10 and 20 seconds.

31. ☐ Stop data recording. ⁽⁶.²⁾

32. ☐ Select a new walker to follow the leader. The new walker should stand in front of the motion sensor at the same initial distance from the motion sensor at which the leader began. For an added challenge, group member should not watch the "leader's" movement while they are making the graph.

33. ☐ Start data recording. ⁽⁶.²⁾

34. ☐ The new walker should now move in such a way as to follow the motion of the leader, matching the leader's position graph as closely as possible.

35. ☐ As soon as the new walker has matched the position graph of the leader, stop data recording. ⁽⁶.²⁾

36. ☐ Hide the last walker's data run so only the leader's graph shows. ⁽⁷.¹.¹⁾

37. ☐ Repeat the activity for each member of your lab group.

38. ☐ Save your experiment according to your teacher's instructions. ⁽¹¹.¹⁾

39. ☐ What did you observe about matching the leader's position graph? Write your observations in the space below.

Answering the Question

Analysis

1. How did your predictions from Part 1 compare to the results in Part 2?

2. What does the slope, or steepness, of the graph tell you about the walker's motion?

3. If you wanted to model a rollercoaster car coming to a stop at the end of the ride, the walker could represent the rollercoaster car, and the motion sensor could represent the boarding platform of the ride, where riders get on and off the rollercoaster. Describe or sketch the graph of the ride coming to a stop.

4. For Part 2, review your data carefully. Look at the position graph for the leader and each follower. (7.1.3) Compare the motion of each follower individually to the motion of the leader. Select a data run that you think is a good example of the follower matching the leader's motion well. How did you make your decision? Describe what characteristics of the graphs you looked at to decide how well the follower matched the leader's position over time.

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5. For Part 3, perform the same data analysis to compare each walker's motion to that of the leader. Choose one graph that you think is a good example of following the motion of the leader.

6. Get your teacher's permission to print out the example graph you have selected. (11.2)

7. Write a thorough, detailed description of the motion of the two walkers. You may write your description on the graph print-out, or in the space below. You may find it helpful to label important points along the motion graph in order to help you refer to them (for example, point A, point B, point C, et cetera).

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8. From which frame of reference is this motion observed?

_____

9. How could you have matched this position-time graph better?

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Multiple Choice

1. In the SI System of measurement, distance is measured in:

   A. Feet
   B. Meters
   C. Miles

2. A change in position relative to a fixed reference point is known as:

   A. Motion
   B. Distance
   C. Speed

3. Another term for how steep a line on a graph appears is:

   A. Slope
   B. Rise
   C. Run

4. In order to get information about their motion as they take off from the launch pad at Cape Canaveral, the astronauts on board the Space Shuttle compare their position to:

   A. The military and civilian aircraft flying nearby
   B. The ground beneath them
   C. The other astronauts in the cockpit with them

5. On a position versus time graph of motion, the fastest motion toward or away from the fixed reference point is where the graph:

   A. Remains flat and horizontal for a period of time
   B. Has the steepest slope
   C. Has the least steep non-zero slope

True or False

☐ **Enter a "T" if the statement is true or an "F" if it is false.**

_____ 1. In order to know if an object's position has changed, you must measure its distance to a fixed reference point.

_____ 2. If you are riding in a car that is traveling south at 60 km/h, your position is changing compared to the car.

_____ 3. If you are riding in a car that is traveling south at 60 km/h, your position is changing compared to the road.

_____ 4. To say that you are stopped means that your distance from some fixed reference point is not changing.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

distance	fixed frame of reference	motion	x-axis	y-axis

1. A measurement of _____is also a measurement of length.

2. On a graph of position versus time, position is plotted on the _____, while time is plotted on the _____.

3. An object whose position is changing relative to a fixed reference point is said to be in _____.

4. The round gold screen on the motion sensor serves as a _____ for determining motion.