Physics 1
2017-2018

Unit 2:
= Kinematics

Name __________________
Period _____________
Introduction to Motion Lab: Using Motion Detectors to Make Distance vs. Time Graphs

**Purpose:** To see live motion represented on a Distance vs. Time graph

**Materials:** Computer with Logger Pro Software  
Motion Detector and LabPro interface  
Flat Board for reflecting sound waves

**Introduction:** In this investigation, you will use a motion detector to plot distance-time graphs of your motion. As you move forwards or backwards, the graph on the computer screen displays how far away from the detector you are.

- The motion detector is the **origin** from which distances are measured.
- The motion detector won't work at distances less than ~0.5 m.

**Procedure:**
1. Make sure the motion detector is plugged into the Labpro box into the Dig/Sonic 1socket, and the box is plugged into the wall.

2. Log onto the computer using **your name** as the User Name, and **your** password.

3. Open up **Logger Pro**. You will see a screen with a data table and 2 graphs.

4. Go to **Insert** and select **Graph**. A single graph is opened up. Grab the corners of this graph and enlarge it to make it take up the whole screen.

5. Double click in the center of the graph and a **Graph Options** box opens up. Select **Axes Options**.
   - For the **Y-axis**, select **Position (m)** -- only this box should be checked.
   - In the **Scaling Box**, select **Manual**. Type **5** in the **Top** box, and **0** in the **Bottom** box. Do not do anything for the Right Y-axis box.
   - For the **X-axis**, select **Manual** in the **Scaling** box. Type **0** in the **Left** box, and **10** in the **Right** box. Hit **Done**.

6. Go to **Experiment** and select **Data Collection**... Change the **Length** of the collection time to **10** seconds. Hit **Done**.

7. Grab a board and stand in front of the motion detector. Adjust the motion detector so that it points horizontally in the direction of a clear path. Stand about a meter from the detector. Hit the **Collect Button**. Walk back and forth to make sure your detector is working properly. If it is not, try adjusting the angle of the detector so that it stands as vertical as possible, and that there is nothing in the way that it might be picking up.

8. **Do not save** any graphs you have made during any part of the lab. If you are asked if you want to save a lab, click **No**.
1. Stand about 1/2 meter from the detector and make a distance/time graph by walking *slowly and steadily away* from the detector (origin). Sketch the graph.

2. Make a distance/time graph, walking *away* from the detector (origin) *medium fast and steady*. Sketch the graph.

3. Make a distance/time graph, walking *toward* the detector (origin) *slowly and steadily*. Sketch the graph.

4. Make a distance/time graph, walking *toward* the detector (origin) *medium fast and steady*. Sketch the graph.

5. Describe the difference between the graph you made by walking away slowly and the one made by walking away more quickly.

6. Describe the difference between the graph you made by walking toward the detector and the one made by walking away from the detector.
7. Predict the graph produced when a person starts at the 1 m mark, walks away from the detector slowly and steadily for 4 seconds, stops for 4 seconds, and then walks toward the detector quickly. Draw your prediction on the left graph.

**PREDICTION**

<table>
<thead>
<tr>
<th>Position (m)</th>
<th>Time (sec)</th>
</tr>
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</table>

**FINAL RESULT**

<table>
<thead>
<tr>
<th>Position (m)</th>
<th>Time (sec)</th>
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<tr>
<td></td>
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</table>

8. Now test your prediction by carefully following the directions given in question 7. Draw what you see on the FINAL RESULTS graph. Describe how the speed and direction at which you walk is displayed on the graph.

9. Graph Matching Exercise: Go to File and select Open...Do not save the graphs you have made so far. Open the Physics with Vernier folder, then open the file named **01c Graph Matching**. You will see a graph displayed. Stand 3 m away from the detector and hit Collect. Match your motion with the lines shown on the graph. You should keep repeating this procedure until you can match the graph very closely. Every member of your lab group should take turns until everyone can match the graph shown.

What was the difference in the way you moved to produce the two differently sloped parts of the graph when you were walking towards the detector?
Before continuing with the rest of the lab, go to **Insert** and select **Graph**. Enlarge the graph to fill the entire screen and make sure the axes set to the values you put in at the beginning of the lab.

10. Make the following curved distance-time graphs. **Describe** how you must move to produce each graph. Include the type and direction of motion. (Write on the graph).

11. Can you move so that your graph looks like the house in the picture below? Explain why it is very difficult for someone working alone to make a good house.

Explain how your group was able to make the house in the picture. Which was the most difficult part of the house to make and why?
Answer the following questions in the spaces provided.

1. What do you do to create a horizontal line on a distance-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 so the graph goes up steeply at first, and then continues up gradually?

5. How do you walk to create a U-shaped graph?
Sketch the distance (position)-time graph corresponding to each of the following descriptions of the motion of an object.

9. The object moves with a steady (constant) velocity away from the origin.

10. The object is standing still.

11. The object moves with a steady (constant) velocity toward the origin for 5 seconds and then stands still for 5 seconds.

12. The object moves with a steady velocity away from the origin for 5 seconds, then reverses direction and moves at the same speed toward the origin for 5 seconds.

13. The object moves away from the origin, starting slowly and speeding up.

Tools for Scientific Thinking
Homework—Introduction to Motion
Answer the following about two objects, A and B, whose motion produced the following distance (position) -time graphs.

6. a) Which object is moving faster—A or B?

b) What does the intersection mean?

7. a) Which object is moving faster?

8. a) Which object is moving faster?

b) Which starts ahead? Explain what you mean by "ahead."

Tools for Scientific Thinking
Homework—Introduction to Motion
Speed and Velocity Notes

Speed = \frac{\text{Change in } \text{distance}}{\text{Change in time}}

Speed does not depend on \text{distance}, so it is always \text{constant}.

What can you say about cars A and B in the graph to the right?

1. A and B are driving \text{constant speed}.
2. A and B are both going the \text{same direction}.

Velocity = \text{constant speed}

- Velocity does depend on \text{time}, so it can be \text{positive} or \text{negative}.
- Velocity is the \text{slope} of a position-time graph.
- You must choose which direction is positive, and which is negative.
- In the graph above, which direction is positive: South to Portland, or North to Seattle? \text{North to Portland}.

What can you say about Car A and Car B’s velocity in the graph above?

1. Car A and B have \text{constant speed} but \text{different} velocities.
2. Car A has a \text{negative} velocity. Car B has a \text{positive} velocity.

If you represent the distance from Seattle to Portland on a line graph, it would look like:

If Everett is 20 miles north of Seattle, what would its position be?
Average Speed and Average Velocity:

Average Speed = \( \frac{\text{Total Distance Traveled}}{\text{Total Time}} \)

Average Velocity = \( \frac{\text{Total Change in Position}}{\text{Total Time}} \)

Here is a different trip to Portland. I drive to Portland. It takes me 3 hours. I stay for one hour to have lunch with a friend. Then I drive back to Seattle. It takes me 3 hours to return home. Portland is about 180 miles from Seattle. Draw the journey on the position-time graph below.

Leg 1: Seattle to Portland:

Average Speed = 

Average Velocity =

Leg 2: Lunch in Portland:

Average Speed =

Average Velocity =

Leg 3: Portland to Seattle:

Average Speed =

Average Velocity =

Round Trip Seattle to Seattle:

Average Speed =

Average Velocity =
Speed Buggy Lab, Part 1: Determining the Speed of a uniform motion car

Purpose: You will determine the speed of a uniform motion buggy moving in one direction.

Buggy Name: ___________________ (You will need to use the same buggy for parts I and II).

MATERIALS: Electric Car  
 Meterstick  
 Stopwatch  
 Masking Tape

PROCEDURES:
1. Mark off 5 meters of floor, placing a labeled piece of masking tape at 0 m, 1m, 2m, 3m, 4m, and 5m.

2. Time how long it takes the buggy to go each of these distances. Do three trials for each distance.

3. Graph the motion of the buggy over 5 meters on a position-time graph. Use the best value of your trials for each distance. Be sure to put time on the x-axis and position on the y-axis.

4. Place a best-fit line through your data and find the slope. This slope will represent the speed of the buggy.

\[ \Delta v = \frac{\Delta p}{\Delta x} \quad \text{speed of the buggy in m/sec.} \]

\[ \frac{\Delta x}{\Delta t} \]

DATA: Position Versus Time for Electric Car Data Table

<table>
<thead>
<tr>
<th>Position (m)</th>
<th>Trial 1 time (sec)</th>
<th>Trial 2 time (sec)</th>
<th>Trial 3 time (sec)</th>
<th>Best Value (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>5</td>
<td></td>
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</tr>
</tbody>
</table>
GRAPH: Plot your best values for your trials above on a Position versus Time graph: (Position on Y-axis, Time on X-axis)

**Position Versus Time for the Speed Buggy**

**ANALYSIS:**
Description of potential sources of error:

Calculate the slope of your best-fit line (include the units for the slope). Circle the 2 points you use on your graph. This slope represents the speed of your buggy.

\[
\Delta v = \frac{\Delta p}{\Delta t} = \frac{p_2 - p_1}{t_2 - t_1}
\]
Speed Buggy Lab, Part 2: Graphing and Analyzing a Roundtrip Journey

The purpose of this lab is to make an accurate graph of the motion of an electric car that runs into the wall and returns. Start the car 2 m from the wall and have it return to the 2 m mark.

Questions:
1. What will the average speed and average velocity of an electric car be when it goes on a roundtrip?
2. How will this average speed compare to the average speed you found in part 1?
3. How will the average velocity be different from the average speed?

Average Speed found in Buggy Lab Part 1: ________________

Prediction: Sketch what you think the position vs. time graph of the car's roundtrip will look like.

Materials:

Procedure: Be sure to explain how you are going to accurately measure the round-trip of a buggy.
DATA: Create a data table below with your data for the three parts of the buggy's trip.

GRAPH: Plot your best values for your trials above on a Position versus Time graph: (Position on Y-axis, Time on X-axis)

Position Versus Time for the Speed Buggy's Round Trip
Data/Analysis:

1. Calculate the Speed Buggy's average speed and average velocity for its round trip journey. Show your work.

   Calculation of **Average Speed**: \[\text{Average Speed} = \frac{\text{Total Distance Traveled}}{\text{Total Time}}\]

   Calculation of **Average Velocity**: \[\text{Average Velocity} = \frac{\text{Total Change in Position}}{\text{Total Time}}\]

2. Description of **Reliability**: How consistent was your buggy during your trials? Use data to explain the reliability of your results.

3. Description of Potential Sources of Error:

**Conclusion**: Answer questions 2 and 3 posed at the beginning of the lab and explain why.

2. How is the average speed different than the average speed you found in part 1? Why is it different?

3. How is the average velocity different from the average speed? Why is it different?
Speed Buggy Lab, Part 3: Fast Car, Slow Car Race

**Purpose:** Using data for the fastest and slowest cars for 10 meters, students will graph the motion of each car, find the speed of each car, and predict the amount of time fast car will beat slow car in a 12 meter race.

**MATERIALS:**
- Fastest and Slowest Speed Buggies
- Meterstick
- Graph Paper
- Stopwatch
- Masking Tape
- Rulers

**Procedure:**
1. Measure 12 meters on the floor. Place a piece of masking tape at each meter, and label the tape 0m, 1m, 2m, etc., up to 12 meters.

2. Place a student with a stop watch at each meter up to 10 meters. Measure the time it takes slow car to go each meter and record in the data table. Repeat data collection for the fast car.

3. Make a graph of distance vs. time for fast car and slow car on the same piece of graph paper. Scale the distance to 12 meters. Scale time for at least 15 seconds beyond the largest time recorded in the data table.

4. Put a best-fit line through the slow car data, and a separate best-fit line through the fast car data. Extend the line through the 12 meter distance.

5. Calculate the slope of the line for fast car and slow car. These slopes represent the speed of each car.

6. Predict how many seconds fast car will beat slow car in a 12 meter race by looking at how long your best-fit lines show each car will take to reach 12 meters.

7. Calculate how long each car will take to get to 12 meters using the equation for slope of a line.

8. Test your predictions, and analyze how well your prediction matched your results.

**DATA: Fast Car and Slow Car Travel Times**

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Fast Car Time (sec)</th>
<th>Slow Car Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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<td>5</td>
<td></td>
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<td>6</td>
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<td>7</td>
<td></td>
<td></td>
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<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Graph: Graph the data for Fast Car and Slow Car on the graph paper below. Scale distance (y-axis) out to at least 12 meters. Scale time (x-axis) out at least 15 seconds beyond your largest time recorded in the data table.

Fast Car and Slow Car Distance-Time Graphs
ANALYSIS:

1. Find the speed of fast car and slow car by determining the slope of the best fit lines. **Circle the two points** on each line you use, **show your calculations**, and **label the appropriate units**.

   **Fast Car:**
   \[ \text{Speed} = \frac{\Delta p}{\Delta t} = \ \text{__________} = \]

   **Slow car:**
   \[ \text{Speed} = \frac{\Delta p}{\Delta t} = \ \text{__________} = \]

2. Predict what time each car will reach the 12 meter mark using the equation for slope of a line:

   \[ y = mx + b \]
   \[ y = \text{distance} = 12 \text{ m} \]
   \[ m = \text{slope you calculated} = \text{speed of the car} \]
   \[ b = y\text{-intercept} \text{ (for your two lines, } b = 0) \]
   \[ x = \text{time to go 12 m.} \]

   **Fast Car:**
   \[ 12 = (\text{speed})x + 0 \]

   \[ x = \ \text{__________} \text{ sec} \]

   **Slow Car:**
   \[ 12 = (\text{speed})x + 0 \]

   \[ x = \ \text{__________} \text{ sec} \]

   Subtract the time you calculated for Fast Car from the time calculated for Slow Car. This is your prediction:

   \[ \text{Time for slow car to go 12 m} - \text{Time for Fast Car to go 12 m} = \# \text{ of seconds by which Slow Car loses the race} \]

   \[ \text{__________} \text{ sec} - \text{__________} \text{ sec} = \text{__________} \text{ sec} \text{ (Prediction from slope calculations)} \]

3. Now look at the 12 meter distance on your graphs. By how many seconds will Fast Car beat Slow Car when they race to the 12 meter mark based on your graphs?

   **Prediction from Graph:** \[ \text{__________} \text{ sec} \]

4. Now conduct the Fast Car, Slow Car Race. Measure the **actual time difference** between Fast Car and Slow Car to go 12 m:

   \[ \text{Time difference between when Fast Car finishes and when Slow Car finishes the race} = \text{__________} \text{ sec}. \]

5. How close were your predictions in Questions 2 and 3 to the actual difference? What might account for any difference you observed?
Strobe Photos, Data Tables, and Graphs

1. 

Suppose the circles above represent the successive positions of an object moving from the left to the right as photographed stroboscopically. Did the object move with uniform speed, an increasing speed, or a decreasing speed? How do you know?

2. Draw a strobe photo series for an object which moves at constant speed for 4 intervals of time, and then slows down during 4 intervals of time.

3a. Based on the data table below, would you infer that the object has constant speed? Why or why not?

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Position (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>6</td>
<td>27</td>
</tr>
</tbody>
</table>

3b. From the data table, construct a position vs. time graph. What was the initial position of the object (i.e. where was the object when t = 0 sec)?
4. What is the constant speed of the object whose time and position are given in the data table below?

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Position (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>23</td>
</tr>
</tbody>
</table>

5. How is the object represented by the data table below moving? Be as specific as possible.

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Position (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

6. The graph below shows the position and time for an object over three intervals, A, B, and C. Describe how the object is moving for each of these three intervals.

7. Make a stroboscopic picture of the object whose position vs. time graph was given in problem 6. Assume the stroboscope flashes occur at 1 second intervals. A centimeter ruler is drawn below to help you place the object at each of the flashes.
For each of the position-time graphs below, create a strobe diagram. Use a 1 second flash interval for each graph. The scale is 1 square = 1m (vertical axes), 1 square = 1 sec (horizontal axes).

8.

[Position-time graph with time axis from 0 to 12 seconds and position axis from 0 to 10 meters.]

9.

[Position-time graph with time axis from 0 to 15 seconds and position axis from 0 to 7 meters.]

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How to Find Average Speed and Create Graphs from Word Problems

1. Read the problem all the way through. Count up how many different parts of the journey there are. Create a chart with distance, time, and velocity at the top of the chart with a row for each part of the journey. (Note: change in position and distance traveled are equivalent phrases).

2. Fill in the information you know into the chart.

3. Use the velocity equation to fill in the missing information in the chart.

4. Find the total distance traveled and the total time for the journey. Do not add up the speeds. There is no use for a "total speed."

5. Find the average speed by dividing the total distance traveled by the total time. Be sure to include the units in your answer.

Example:
A bicycle rider travels at 4 m/s for 100 seconds. She stops to rest for 20 sec. Then she travels at 2 m/s for 30 seconds. Then she moves at 7 m/s for 60 seconds. What is her average speed?

1. There are 4 different parts to her journey. Create a table with 4 rows for filling in information, one row for labels, and one row for the totals:

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Time (sec)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 s</td>
<td>4 m/s</td>
<td></td>
</tr>
<tr>
<td>20 s</td>
<td>0 m/s</td>
<td></td>
</tr>
<tr>
<td>30 s</td>
<td>2 m/s</td>
<td></td>
</tr>
<tr>
<td>60 s</td>
<td>7 m/s</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Fill in the information you were given.

3. You need to find the distances traveled for each part of the journey. Use the velocity equation:

\[ v = \frac{\Delta p}{\Delta t} \]

but rearrange to solve for change in position: \[ \Delta p = v \times \Delta t \]

These answers have been placed in the table in bold.

4. Add up the distances and the times to get the total distance traveled and the total time. These numbers are in bold and italics.

5. Find the average speed using the equation, and label your answer with the correct units:

\[ \text{Average speed} = \frac{\text{Total Distance Traveled}}{\text{Total Time}} = \frac{\text{m}}{\text{s}} = \]
How To Create a Graph From a Word Problem:

A bicycle rider travels at 4 m/s for 100 seconds. She stops to rest for 20 sec. Then she travels at 2 m/s for 30 seconds. Then she moves at 7 m/s for 60 seconds. Find the average speed, and make a position vs. time graph of her trip.

1. Fill in the chart for the missing information. Calculate average speed.

2. Use the chart, which shows the total distance traveled and the total time to scale your graph. Be sure to include the labels, units, and a title.

3. Fill in the different parts of the journey. **Be sure to add each distance on to the previous part(s) of the trip, and add each time on to the previous time(s) for the trip.** Your graph should end at the total distance and total time.

4. Draw lines connecting the parts of the trip where the motion was at a constant speed.

Example:

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Time (sec)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 s</td>
<td>4 m/s</td>
</tr>
<tr>
<td></td>
<td>20 s</td>
<td>0 m/s</td>
</tr>
<tr>
<td></td>
<td>30 s</td>
<td>2 m/s</td>
</tr>
<tr>
<td></td>
<td>60 s</td>
<td>7 m/s</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>210 s</strong></td>
<td></td>
</tr>
</tbody>
</table>

1. **Average Speed = Total Distance Traveled / Total Time**

2. Scale distance (y-axis) to __________ m, and time to 210 s (x-axis).

3. Fill in the parts of the journey, adding the times and the distances on to each previous part of the journey, for a cumulative trip of 210 s and __________ m.

4. Connect the points using straight lines.
Going from Descriptions of Motion to Graphs

1. Jim ran a 400 m race. He ran at 2 m/second for the first 200 m, 5 m/sec for the next 100 m, and at 7 m/sec for the last 100m.

1a. Fill in the distance time and velocity chart below for Jim’s race.

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Time (sec)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Total:</td>
<td></td>
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</tbody>
</table>

1b. Calculate the average speed for Jim’s race.

Average Speed = \(\frac{\text{Total Distance traveled}}{\text{Total Time}}\)

1c. Make a plot of distance vs. time for Jim’s race. Be sure to include a title, labels, units, and an appropriate scale.
2. Laura enters a straight highway and goes 100 km/hr for 0.75 hour. She stops to change a flat tire for 0.25 hour, then drives at 80 km/hr for 1 more hour.

2a. Fill in the distance, time and velocity chart below for Laura's trip.

<table>
<thead>
<tr>
<th>Distance (mi)</th>
<th>Time (min)</th>
<th>Vel. (mi/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>Total:</td>
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</tbody>
</table>

2b. Calculate the average speed for Laura's car trip.

\[
\text{Average Speed} = \frac{\text{Total Distance traveled}}{\text{Total Time}}
\]

2c. Make a plot of distance vs. time for Laura's trip. Be sure to include a title, labels, units, and an appropriate scale.
3. John walked 100 m in a straight line from the starting point to the ending point in 20 seconds, then 40 m back towards the starting point in 5 seconds. He waited for 5 seconds, then walked all the way back to the start in 10 seconds.

3a. Fill in the distance, time and velocity chart below for John’s trip.

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Time (sec)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

\[ \Delta p \]
\[ \nu \]
\[ \Delta t \]

Total distance and total time

3b. Calculate the average speed for John’s trip.

\[
\text{Average Speed} = \frac{\text{Total Distance traveled}}{\text{Total Time}}
\]

3c. Make a plot of distance vs. time for John’s trip. Be sure to include a title, labels, units, and an appropriate scale.
Steps to Solving Problems in Science

1. Draw a diagram if it helps to visualize the problem.

2. Write all the known quantities needed to solve the problem.

3. Write the unknown quantity or quantities that need solving.

4. Write the equation(s) needed to solve the problem (symbols with no numbers).

5. Substitute the known quantities into the equation (including the units).

6. Find the unknown answer. Be sure to include the units in your answer. Either circle or put a box around the answer.

7. Check your answer, asking yourself these two questions:
   A. Are the units accurate for the quantity you are trying to find?
   B. Is the answer reasonable given what you know about the situation?

Example: Carl measures that his car goes 40 miles in 2 hours. Calculate the velocity of Carl’s car.

1.

\[ \text{Distance} = 40 \text{ mi} \]

\[ \text{Time} = 2 \text{ hours} \]

2. Knowns: Distance = 40 mi (change in position)
   Time = 2 hours

3. Unknown: Velocity

4. Equation: \[ v = \frac{\Delta p}{\Delta t} \]
   Velocity = Change in position
   Change in time

5. \[ v = 40 \text{ mi/hr} \]
   2 hr.

6. \[ v = 20 \text{ mi/hr} \]

7A. Miles per hour are appropriate units for speed and velocity.
7B. 20 miles per hour is a reasonable answer for the speed of the car (i.e. 200 mi/hr would be noticeably too fast).
Kinematics Problem Set

Use the Steps to solving problems and the equation for velocity/speed to find the answers below.

\[ v = \frac{\Delta p}{\Delta t} \]  
(slowed can be substituted for velocity in word problems when the motion is in one direction)

<table>
<thead>
<tr>
<th>Problem</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A cart starting from rest travels a distance of 3.6 m in 1.8 sec. What is the speed of the cart?</td>
<td>[ v = \frac{\Delta p}{\Delta t} ]</td>
</tr>
<tr>
<td>Knowns:</td>
<td>Unknowns</td>
</tr>
<tr>
<td>Equation:</td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Answer with units:</td>
<td>Answer with units:</td>
</tr>
<tr>
<td>2. A car travels a distance of 98 m in 10 seconds. What is the average speed of the car during the 10 second interval?</td>
<td>Knowns:</td>
</tr>
<tr>
<td>Equation:</td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Answer with units:</td>
<td>Answer with units:</td>
</tr>
<tr>
<td>3. What is the distance traveled by an object that moves with an average speed of 6.0 m/sec for 8 seconds?</td>
<td>Knowns:</td>
</tr>
<tr>
<td>Equation:</td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Answer with units:</td>
<td>Answer with units:</td>
</tr>
<tr>
<td>4. The average speed of a plane was 600 km/hr. How long did it take the plane to travel 120 km?</td>
<td>Knowns:</td>
</tr>
<tr>
<td>Unknowns:</td>
<td>Unknowns</td>
</tr>
<tr>
<td>Equation:</td>
<td>Equation:</td>
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<tr>
<td>Equation with numbers:</td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Answer with units:</td>
<td>Answer with units:</td>
</tr>
<tr>
<td>5. The average speed of a runner in a 400 m race is 8.0 m/sec. How long did it take the runner to complete the race?</td>
<td>Knowns:</td>
</tr>
<tr>
<td>Unknowns:</td>
<td>Unknowns</td>
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<tr>
<td>Equation:</td>
<td>Equation:</td>
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<td>Equation with numbers:</td>
<td>Equation with numbers:</td>
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<tr>
<td>Answer with units:</td>
<td>Answer with units:</td>
</tr>
<tr>
<td>6. Your average speed is 44 m/sec. How far have you traveled after 15 sec?</td>
<td>Knowns:</td>
</tr>
<tr>
<td>Unknowns:</td>
<td>Unknowns</td>
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<tr>
<td>Equation:</td>
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<td>Equation with numbers:</td>
<td>Equation with numbers:</td>
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<td>Answer with units:</td>
<td>Answer with units:</td>
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<tr>
<td>Question</td>
<td>Calculation</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>7. You drive 240 miles in 6 hours. What is your average speed?</td>
<td></td>
</tr>
<tr>
<td>Knowns:</td>
<td></td>
</tr>
<tr>
<td>Unknown:</td>
<td></td>
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<tr>
<td>Equation:</td>
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<tr>
<td>Equation with numbers:</td>
<td></td>
</tr>
<tr>
<td>Answer with units:</td>
<td></td>
</tr>
<tr>
<td>8. You drive 240 miles in 6 hours. What is your position after 3 hours? (Use speed calculated in Question 7).</td>
<td></td>
</tr>
<tr>
<td>Knowns:</td>
<td></td>
</tr>
<tr>
<td>Unknown:</td>
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<tr>
<td>Equation:</td>
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<tr>
<td>Equation with numbers:</td>
<td></td>
</tr>
<tr>
<td>Answer with units:</td>
<td></td>
</tr>
<tr>
<td>9. How long does it take you to walk 400 m at a speed of 1.5 m/s?</td>
<td></td>
</tr>
<tr>
<td>Knowns:</td>
<td></td>
</tr>
<tr>
<td>Unknown:</td>
<td></td>
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<tr>
<td>Equation:</td>
<td></td>
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<tr>
<td>Equation with numbers:</td>
<td></td>
</tr>
<tr>
<td>Answer with units:</td>
<td></td>
</tr>
</tbody>
</table>

Use the directions on how to find average speed to answer questions 10-13.

Average Speed = \( \frac{\text{Total Distance Traveled}}{\text{Total Time}} \)

10. The graph to the right represents the trip of a turtle.

10a. Describe the turtle’s motion in words.

10b. Draw a stroboscopic picture of the turtle every minute, starting at 0 minutes.

10c. Find the average speed from \( t = 0 \) min to \( t = 3 \) min.

10d. Find the average speed from \( t = 3 \) min to \( t = 4 \) min.

10e. Find the average speed from \( t = 0 \) min to \( t = 4 \) min.
Phys1 Textbook Chapter 3: Kinematics, p. 70-75

1. If you saw 4 pictures of a ball rolling:
   A) How would you know it was moving?

   B) How would you know which direction it was moving?

   C) What would you see if it was moving at a constant speed? Make a picture to represent your description (compile all 4 pictures into one).

   D) What would you see if it was slowing down? Make a picture to represent your description.

2. Motion is relative and depends on your reference point. Explain this using an example of a person riding a bike.

3. If a football player catches a punt on the goal line and runs straight down the field for 10 yards then turn back and runs 3 yards and is then tackled.

   A) What is the football player’s total distance traveled?

   B) What is the football player’s displacement (change in position)?

If the football player took 4 seconds to run the 10 yards and 2 seconds to run back the 3 yards (show all work):

   C) What is the football player’s average speed?

   D) What is their average velocity?

4. What is the International System of Unit (SI) for speed? (Read page 15 for help if needed)_____________

5. Define instantaneous speed.

6. How is velocity different than speed?
7. If you walked 20 m, took a book from a library table, turned around and walked back to your seat, what is the
   a. distance traveled? ____________
   b. displacement? ____________

8. A cyclist leaves home and rides due east for a distance of 45 km. She returns home on the same bike path. The entire
   trip take 4 hours.
   a. What is her average speed?
   b. What is her displacement?
   c. What is her average velocity?

7. If a car is on a circular track and is moving at a constant speed of 50 miles per hour, is it moving at a constant velocity?
   Explain your answer.

8. Why is position always on the Y axis and time always on the X axis? (Hint: think of what the slope means).

9. On the blank graphs below, plot a graph to represent the motion of a car starting at position zero described:

   - Moves a constant speed in the positive direction.
   - Speeds up away from the origin, stops, turns around and speeds up back to the origin
   - Moves constant speed in positive direction, slows, then stops, then continues to move a constant speed away from the origin.
   - Moves away from origin at a constant speed, slows down and stops. Turns around and moves back towards to origin at a constant speed and stops behind the point at which it started.
11. What is your average speed in each of the cases below? Make a chart to help you find the answer.

11a. You run 100 m at a speed of 5.0 m/s and then you walk 100 m at a speed of 1.0 m/s.

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Time (s)</th>
<th>Speed (m/s)</th>
<th>Average Speed:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Equation: Avg. Speed = ( \frac{\text{Total Distance Traveled}}{\text{Total Time}} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td>Answer with units:</td>
</tr>
</tbody>
</table>

11b. You run 100 sec at a speed of 5.0 m/s, and then you walk for 100 sec at a speed of 1.0 m/s.

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Time (s)</th>
<th>Speed (m/s)</th>
<th>Average Speed:</th>
</tr>
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<tbody>
<tr>
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<td>Equation:</td>
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<td>Equation with numbers:</td>
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<tr>
<td>Total:</td>
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<td>Answer with units:</td>
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</tbody>
</table>

12. A train travels at 60 mi/hr for 0.52 hr, 30 mi/hr for the next 0.24 hr, and then 70 mi/hr for the next 0.71 hr. What is its average velocity?

<table>
<thead>
<tr>
<th>Distance (mi)</th>
<th>Time (hr)</th>
<th>Speed (mi/hr)</th>
<th>Average Speed:</th>
</tr>
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<tbody>
<tr>
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<td>Equation:</td>
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<td></td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td>Answer with units:</td>
</tr>
</tbody>
</table>

13. In a 20 mile bicycle race, Lois gave Sarah a head start of 15 minutes. Lois rode at an average speed of 22 mi/hr. Sarah rode at an average speed of 18 mi/hr. Who won the race? Show your work, and make a rough sketch of a distance vs. time graph of the race.
Making Velocity vs. Time Graphs Using Motion Detectors

**Purpose:** To observe how your motion appears on velocity vs time graphs, and to see the relationship between distance-time and velocity-time graphs.

**Materials:**  
- Computer with Logger Pro Software  
- Motion Detector and LabPro Interface  
- Flat Board for Reflecting Sound Waves

**Introduction:** In this investigation, you will use a motion detector to plot position-time and velocity-time graphs. Remember, the motion detector won’t work at distances less than ~0.5 m.

**Procedure:**
1. Make sure the motion detector is plugged into the Labpro box into the **Dig/Sonic 1** socket, and the box is plugged into the wall.

2. Log onto the computer using your name as the User Name, and your MIHS password.

3. Open up **Logger Pro**.

4. Double click in the center of the **Position vs. Time graph** and a **Graph Options** box opens up. Select **Axes Options**. For the Y-axis, in the **Scaling Box**, select **Manual**. Type 4 in the **Top** box, and 0 in the **Bottom** box.

5. Double click in the center of the **Velocity vs. Time graph** and a **Graph Options** box opens up. Select **Axes Options**. For the Y-axis, in the **Scaling Box**, select **Manual**. Type 2 in the **Top** box, and -2 in the **Bottom** box.

6. Adjust the motion detector so that it points horizontally in the direction of a clear path. Using a board, check to make sure the motion is working properly before starting the lab.

7. Follow the directions during the lab carefully. Change the settings on the graphs when requested. **Do not save** any graphs you have made during any part of the lab.
1. Walk away from the detector *slowly and steadily*. Sketch the position vs. time and velocity vs. time graphs that you see below.

![Graph](image1)

2. Walk away from the detector *steadily and medium fast*. Sketch the position vs. time and velocity vs. time graphs below.

![Graph](image2)

3. Compare the position vs. time graphs to the velocity vs. time graphs. How does constant motion appear on each graph?

4. Why do you think the velocity vs. time graphs look the way they do?

5. What is the most important difference between the velocity vs. time graph made by slowly walking away from the detector, and the one made by walking away more quickly?
6. Walk towards the detector slowly and steadily. Sketch the graphs.

7. Walk towards the detector medium fast steadily. Sketch the graphs.

8. How are position-time graphs different for motion away and motion towards the detector?

9. How are velocity-time graphs different for motion away and motion towards the detector? Why is this so?

10. How can you tell from a position-time graph that your motion is steady (constant velocity)?

11. How can you tell from a velocity-time graph that your motion is steady (constant velocity)?
12. Walk away from the motion detector with a speed that **steadily increases**. Sketch what you see.

13. Walk away from the motion detector with a speed that **steadily decreases**. Sketch what you see.

14. How can you tell if your speed is increasing on a **position-time** graph?

15. How can you tell if your speed is increasing on a **velocity-time** graph?

16. How can you tell if your speed is decreasing on a **position-time** graph?

17. How can you tell if your speed is decreasing on a **velocity-time** graph?

18. How is changing velocity (either increasing or decreasing speed) different than constant velocity on a **velocity-time** graph?
19. **Predicting Velocity-Time Graphs from Position-Time Graphs:** Study the distance-time graph shown below and predict the velocity-time graph that would result from the motion. Sketch your prediction using a **dotted line** on the velocity-time graph.

19a. Explain why you predicted what you did.

19b. Make the graph. Repeat until you have matched the position-time graph as closely as possible. Sketch the velocity-time graph you see using a **solid line**.

19c. Compare how standing still is represented on a position-time graph vs. the velocity-time graph. Why are they different?
20. **Predicting Position-Time Graphs from Velocity-Time Graphs:** Go to Experiment in the menu bar and select Data Collection... Change the Length of the collection time to 10 seconds. Check to make sure that your X-axes on both your graphs changed to 10 sec. If they don't, manually change them to 10 seconds.

20a. Study the velocity-time graph shown below and predict the position-time graph that would result from the motion. Sketch your prediction using a dotted line on the position-time graph.

Explain why you predicted what you did.

20b. Make the graph. Repeat until you have matched the velocity-time graph as closely as possible. Sketch the position-time graph you see using a solid line.

20c. How can you tell from a velocity-time graph that an object has changed direction?

20d. What is the velocity at the moment the direction changes? ________
21. **Graph Matching**: Go to File and select Open... Do not save the graphs you have made. Open the Physics with Vernier folder, then open the file named **01d Graph Matching**. You will see the graph below. Match your motion with the lines shown on the graph. Repeat this procedure until everyone in your group can match the graph very closely.

![Graph Matching](image)

21a. Describe how you moved to match each part of the graph (A-G). Write the type and direction of motion next to each letter on the graph above.

22. **Graph Matching**: Go to File and select Open... (without saving previous graphs). Open the Physics with Vernier folder, then open the file named **01e Graph Matching**. You will see the graph below. Every member of the group should now match their motion with the lines on this graph.

![Graph Matching](image)

22a. Describe what you have to do to match each part of the graph (A-D). Write the type and direction of motion next to each letter on the graph above.

22b. Is it possible for an object to move so that it produces an absolutely vertical line on a velocity-time graph? Why or why not?

23. Make a house on the position-time graph (without a chimney). Sketch below what the velocity-time graph looks like. What happens to the velocity when you make a nearly-vertical line on a position-time graph?
Velocity-Time Graphs

After studying the velocity-time graphs you have made, answer the following questions:

1. How do you move to create a horizontal line in the positive part of a velocity-time graph?

2. How do you move to create a straight-line velocity-time graph that slopes up from zero?

3. How do you move to create a straight-line velocity-time graph that slopes down?

4. How do you move to make a horizontal line in the negative part of a velocity-time graph?
5. The velocity-time graph of an object is shown below. Figure out the total distance traveled by the object. Show your work.

Distance = __________ meters.

6. Both of the velocity graphs below, 1 and 2, show the motion of two objects, A and B. Answer the following questions separately for 1 and for 2. Explain your answers when necessary.

   a) Is one faster than the other? If so, which one is faster? (A or B)
   b) What does the intersection mean?
   c) Can one tell which object is "ahead"? (define "ahead")
   d) Does either object A or B reverse direction? Explain.

   1
   
   VEL
   
   0
   TIME
   
   A
   B

   2
   
   VEL
   
   0
   TIME
   
   A
   B

   a) ______________________
   b) ______________________
   c) ______________________
   d) ______________________
Sketch velocity-time graphs corresponding to each of the following descriptions of the motion of an object.

7. The object is moving away from the origin at a steady (constant) velocity.

8. The object is standing still.

9. The object moves toward the origin at a steady (constant) velocity for 10 seconds, and then stands still for 10 seconds.

10. The object moves away from the origin at a steady (constant) velocity for 10 seconds, reverses direction and moves back toward the origin at the same speed for 10 seconds.
Ticker Tape Timer Lab: Changing Velocity

**Purpose:** To investigate the acceleration of a car rolling down a ramp. A "strobe" picture will be created using a ticker which ticks 60 times per second. This strobe picture will be used to make position vs. time and velocity vs. time graphs.

**The Experiment**
1. Take ~1.5 meters of ticker tape and tape it to the rear of your cart.

2. Put a disc of carbon paper on the pin in the timer (reuse them as much as you can). The carbon paper must be ink side up.

3. Feed the ticker tape through the staples and over the carbon paper.

4. Start the timer and let go of the car; have someone ensure the ticker tape feeds through the staples smoothly (so it doesn't slow the car down unnecessarily).

5. Catch the car before it rolls off the end of the ramp.

6. Remove the ticker tape and turn it over; you should see a series of blue dots.

**Collecting Data**
7. Mark every 6th dot. Since each dot represents one 60th of a second, every 6 dots represents one 10th of a second (0.1 sec). If the dots in the beginning are clumped together, feel free to choose the first clear dot as your starting point.

8. Measure the distance (in cm) from the first dot to each of your marked dots.

9. Record the times and distances in your table.

**Analysis**
1. Add two more columns to your table: a column for the change in position (from one marked dot to the next) and column for the average velocity between the dots.

**Example:**

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Position (cm)</th>
<th>Change in Position ((\Delta p))</th>
<th>Velocity ((\Delta p/\Delta t))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.1</td>
<td>1</td>
<td>1 cm</td>
<td>1/0.1 = 10 cm/sec</td>
</tr>
<tr>
<td>0.2</td>
<td>2.5</td>
<td>1.5 cm</td>
<td>1.5/0.1 = 15 cm/sec</td>
</tr>
<tr>
<td>0.3</td>
<td>4.5</td>
<td>2 cm</td>
<td>2/0.1 = 20 cm/sec</td>
</tr>
<tr>
<td>etc</td>
<td>etc</td>
<td>etc</td>
<td>etc</td>
</tr>
</tbody>
</table>

2. Using the lab template provided, or using a computer, create a table, a position-time graph, velocity-time graph, acceleration-time graph, and answer the questions embedded in the lab template. If you are using a computer, consult the template to see what those questions are.
### Position, Velocity and Acceleration Problems

**Equations:**  
\[ v = \frac{\Delta p}{\Delta t} \]  
\[ a = \frac{\Delta v}{\Delta t} \]

**Questions:**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Light travels at a constant speed of 300,000 km/sec. How far does light travel in 10 sec?</td>
<td><strong>2.</strong> What is the acceleration of light?</td>
<td><strong>3.</strong> Sound travels through 25°C air at 0.35 km/sec. How far does sound travel in 10 sec?</td>
</tr>
<tr>
<td>Knowns:</td>
<td>Knowns:</td>
<td>Knowns:</td>
</tr>
<tr>
<td>Unknown:</td>
<td>Unknown:</td>
<td>Unknown:</td>
</tr>
<tr>
<td>Equation:</td>
<td>Equation:</td>
<td>Equation:</td>
</tr>
<tr>
<td>Equation with numbers:</td>
<td>Equation with numbers:</td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Answer with units:</td>
<td>Answer with units:</td>
<td>Answer with units:</td>
</tr>
<tr>
<td>4. A car starting at rest accelerates to 25 m/sec in 10 sec. What is the acceleration of the car?</td>
<td>5. A bicycle moving at a speed of 2 m/sec accelerates by 3 m/sec/sec for 6 sec. How fast is the bicycle going at t = 6 sec?</td>
<td>6. A car accelerates from rest at 2 m/sec² until it is moving at a velocity of 20 m/sec. How long does it take the car to reach that speed?</td>
</tr>
<tr>
<td>Knobs:</td>
<td>Knobs:</td>
<td>Knobs:</td>
</tr>
<tr>
<td>Unknown:</td>
<td>Unknown:</td>
<td>Unknown:</td>
</tr>
<tr>
<td>Equation:</td>
<td>Equation:</td>
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<tr>
<td>Equation with numbers:</td>
<td>Equation with numbers:</td>
<td>Equation with numbers:</td>
</tr>
<tr>
<td>Answer with units:</td>
<td>Answer with units:</td>
<td>Answer with units:</td>
</tr>
</tbody>
</table>

| 7. A car moving at 1 mile/min slows to a stop in 0.25 min. What is the acceleration of the car? | 8. A bunny rabbit hops 60 m in 15 sec. What is the average velocity of the bunny? | 9. A wolf chases the bunny in Question 8. He starts from the same position as the bunny, but he leaves 10 seconds later. He runs at 8 m/sec. Where does he catch the bunny? (Assume the bunny keeps running after it passes the 60 m mark). A graph might help you. |
| Knowns: | Knowns: | Knowns: |
| Unknown: | Unknown: | Unknown: |
| Equation: | Equation: | Equation: |
| Equation with numbers: | Equation with numbers: | Equation with numbers: |
| Answer with units: | Answer with units: | Answer with units: |
Paradox: A seemingly contradictory statement that may nonetheless be true.

1. Why is it impossible to travel back in time through a black hole?

2. How could a worm hole help a person travel very great distances in very little time? (Hint: the comparison to a folded piece of paper might help you describe this).

3. How could a worm hole make time travel possible?

4. As you travel closer to the speed of light, what happens to time?

5. Describe the “Twin Paradox.” If one twin travels through space at a very high speed, does he/she age faster or slower than the twin left on Earth? Why is this a paradox?

6. Describe the “Grandfather Paradox.” Why could this be a problem for time travel into the past?

7. What is one possible solution to the Grandfather Paradox (i.e. why might it not be a paradox after all?)

8. Why is time travel into the past impossible today? (list more than one reason)
Study Guide for the Kinematics Test: Big Ideas and Equations

Position vs. Time graphs
- A straight line on a p vs t graph indicates constant speed (and velocity)
- An object at rest is indicated by a horizontal line
- The slope of a line on a p vs. t graph ($\Delta p/\Delta t$) = velocity of the object (steeper = faster)
- The main difference between speed and velocity is that velocity incorporates direction.
- Speed will always be positive but velocity can be positive or negative
- An object with continuously changing speed will be a curve. The slope of the line tangent to the curve at any location will give the instantaneous speed of the object.
- Positive vs. Negative slopes indicates the direction: + is away or upward-sloping, and - is toward the origin or downward sloping

Velocity vs Time graphs
- The velocity can be found by calculating the slope of a position-time graph
- The slope of a velocity vs. time graph ($\Delta v/\Delta t$) = the acceleration of the object

Equations:
Speed = Absolute value of velocity: $\frac{\Delta p}{\Delta t}$

Average Speed = Total Distance traveled (Direction does not matter) / Total Time

Velocity = $\frac{\Delta p}{\Delta t}$ (Direction matters: can be negative)

Average Velocity = Ending Position - Starting Position / Total Time

Acceleration = $\frac{\Delta v}{\Delta t}$ Units are distance per unit of time squared (i.e. m/s²)

Graphs: Look at the slope of one graph to determine what the next graph will look like:

An object speeding up away from the origin:
- Slope is increasing in positive direction
- Acceleration is constant and positive

[Diagram of p vs t graph with a curve]

[Diagram of v vs t graph with a straight line]

Strobe Diagrams:
- Another way to represent motion
- Gives position information, but not time information
- Time information can be determined with the flash interval
- Strobe diagrams can be created through placing a dot on a position line (ruler) each time the strobe flashes (i.e. one dot for each second if the time interval is one second)