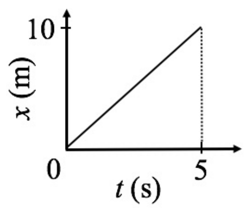
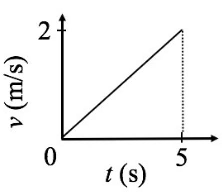
Lab 2. Understanding Motion

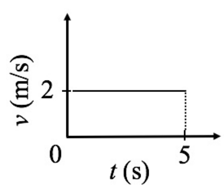
Warm-up Questions

1. Use graph-reading skills to decide which of the four graphs below makes sense as the velocity-time graph for an object with a displacement-time graph like this:

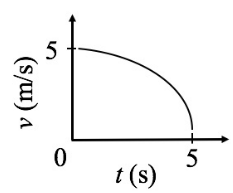




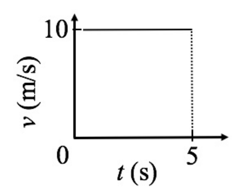
(a)



(b)

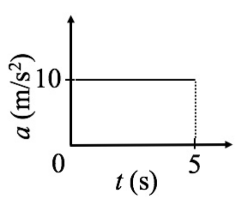


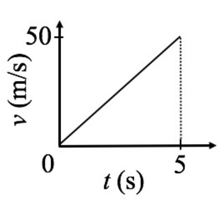
(c)



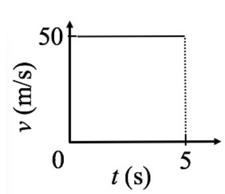
(d)

2. Use graph-reading skills to decide which of the four graphs below makes sense as the velocity-time graph for an object with a acceleration-time graph like this:

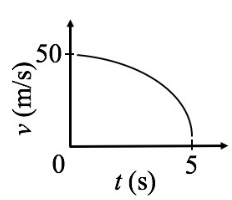




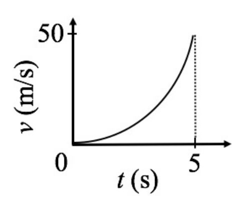
(a)



(b)



(c)



(d)

Instructor Initials:________

Purpose

To understand motion by creating position- and velocity- versus time graphs and identifying the key features (e.g., shape, slope, intercepts, etc...) that describe the relationship between the different quantities of motion.

Equipment

- Vernier Go Direct Motion Detector
- Wooden board
- Vernier Graphical Analysis (software)

2.1 Graph Analysis

The skills we learn or practice in lab are very important for the course and will be strongly represented on examinations. We begin by looking at graphs of motion. You will also translate between graphical and verbal descriptions of motion.

General instructions for running the motion sensor (and most bluetooth devices in future labs):

1. Power on motion sensor (red light will begin to blink)
2. Open *Vernier Graphical Analysis* software on the desktop
3. Click "Sensor Data Collection" at the top
4. Find your sensor (e.g., GDX-MD 0B2007L3) from the list and click to connect
5. Once connected the sensor will begin clicking periodically
6. Orient the detector so there is plenty of room to move around (try not to cross another group's path)
7. Hit "collect" to start data collection
8. Do NOT save when done

Each group member should familiarize themselves with this software as it will be used throughout the semester. Explicit directions won't always be provided for procedures covered in a previous lab!

2.1.1 Try Something and Cross your Fingers

The computer is now set to make the first type of graph of your motion. Make a graph by having another group member click the "collect" button for you and then move toward and away from the detector (using the wooden board as a flat surface to reflect the sound waves from the detector). You need to be facing the computer monitor and the detector, so you can see the graph you produce as you walk. **Each person should make at least one graph.**

Hint: Your data will be better if you are at least 40 cm from the detector.

(Individually) Determine through experimentation which direction is the positive x-axis and explain how you know.

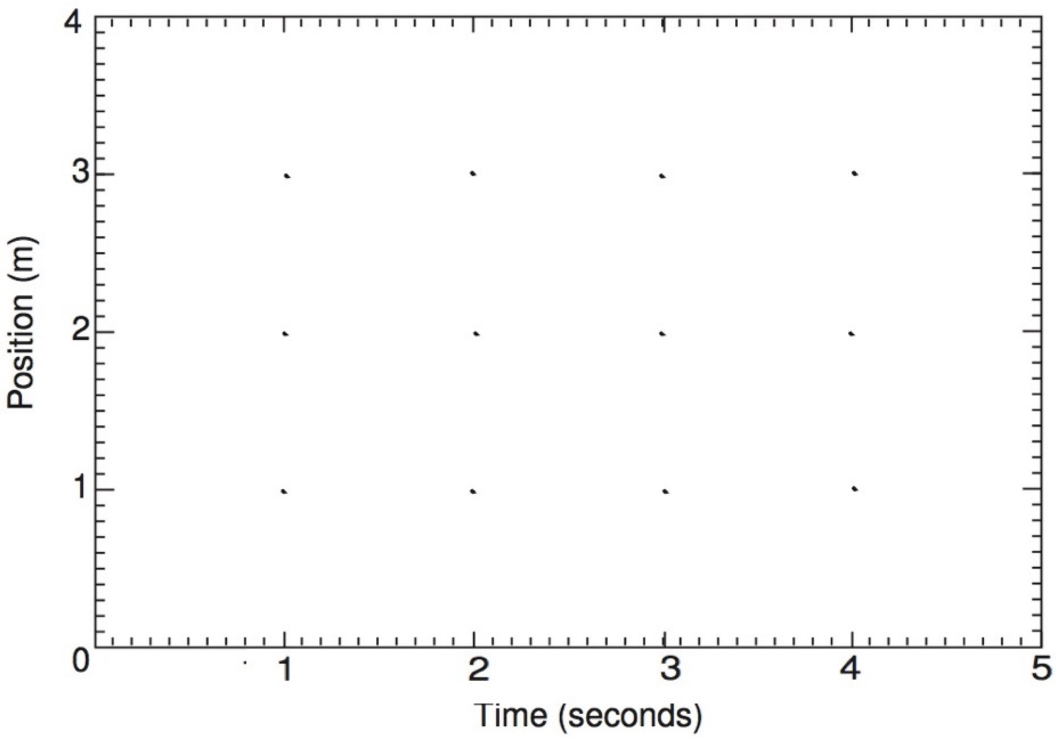
Compare notes with your lab partners.

Were their descriptions different than yours? If everyone agreed, write NA here and move on. If not, discuss why each of you wrote what you did in order to come to a group consensus as to which direction is the positive x-axis. Write down what the group agreed on here.

STOP! Check in with your TA before moving on.

Using what you have seen so far, on the axes below...

1. Draw what you think the graph will look like for a steady, slow motion, away from the detector. Label this line "slow away".
2. Draw what you think the graph will look like for a steady, fast motion, away from the detector. Label this line "fast away".
3. Draw what you think the graph will look like for a steady, slow motion, toward the detector. Label this line "slow to".
4. Draw what you think the graph will look like for a steady, fast motion, toward the detector. Label this line "fast to".



(Individually) Explain why you think the graphs will look like this.

What is the primary difference between the lines for faster and slower motions on a position-time graph?

What is the primary difference between the lines for motions toward and away on a position-time graph?

Compare with your lab partners. If they have drawn their lines differently, add those lines to your graph and identify each by who made it. In the space below, write the reasoning behind their predictions.

Now confirm your prediction. Note the ways in which these graphs do and do not match the predictions you and your group have made. (It may be useful to click the *Autoscale* button on the graphs.)

- First, have each member of the group move *slowly and steadily away* from the detector, while facing the detector and the computer screen. Sketch this on the same graph with a dashed line labelled "slow me away".
- Next, have each member of the group move *faster* than before, *but still steadily away* from the detector, while facing the detector and the computer screen. Sketch this on the same graph with a dashed line labelled "fast me away".
- Next, have each member of the group move *slowly* and *steadily toward* the detector, while facing the detector and the computer screen. Sketch this on the same graph with a dashed line labelled "slow me to".
- Next, have each member of the group move *faster* and *steadily toward* the detector, while facing the detector and the computer screen. Sketch this on the same graph with a dashed line labelled "fast me to".

What appears to be the difference between slower and faster motions on these position-time graphs? Does this agree with your prediction? If so, you do not have to rewrite your answer.

If there were predictions that did not match the actual graphs, discuss them with your group and see if you can come up with something which might explain the discrepancy. Record the ideas your group considers below as you discuss this issue.

2.1.2 Put it to the test.

From the bottom left "graph options," add "graph match" for position.

Based on what you observed with the graphs so far, reproduce the graph with your own motion in front of the motion detector. *Everyone should try this.* Feel free to compete for who does it best!

Answer the following question yourself and then discuss your answers with your lab partners. Write down any new ideas you get from your partners.

Carefully describe the motion in the graph you matched.

STOP! Check in with your TA before moving on.

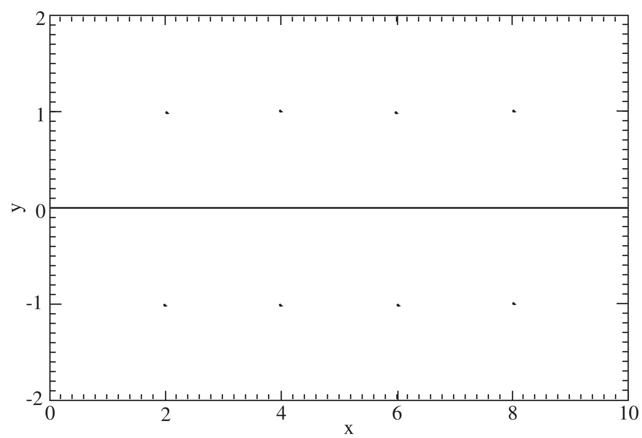
2.1.3 A New Kind of Graph

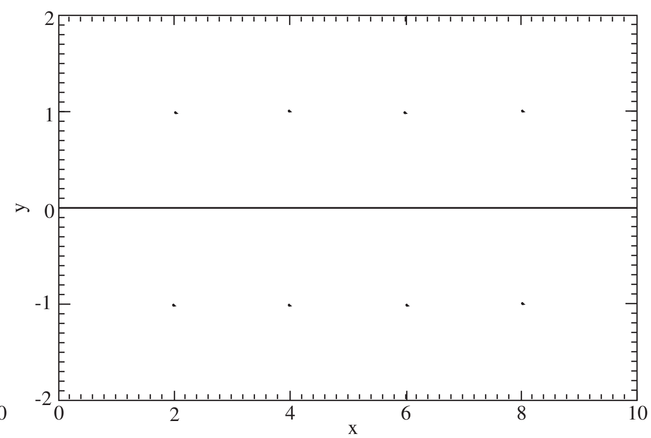
Let's continue to examine our own ideas about motion, but with a new type of graph. To understand what aspects of motion are illustrated in this second type of graph, we will use our own experiences in moving as we make these new graphs. You have two options to display a different graph:

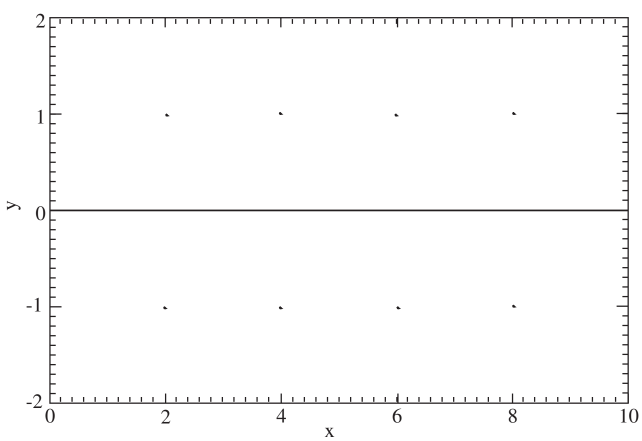
1. In the top right corner select "view options" and display 2 graphs, or

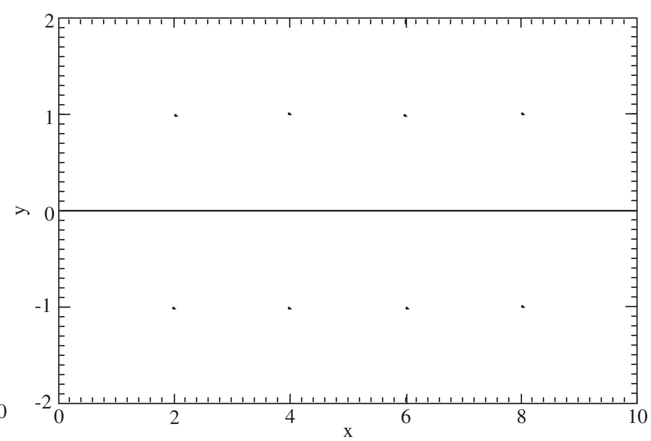
2. Click on the y-axis label and select "velocity" instead of position

Each group member should make some motions in front of the detector. Make these motions calm and steady, but do them at different speeds. Record your results on the axes below.









(Individually) Is the positive x-axis direction you determined for the first type of graph consistent with this new graph? Explain how you know.

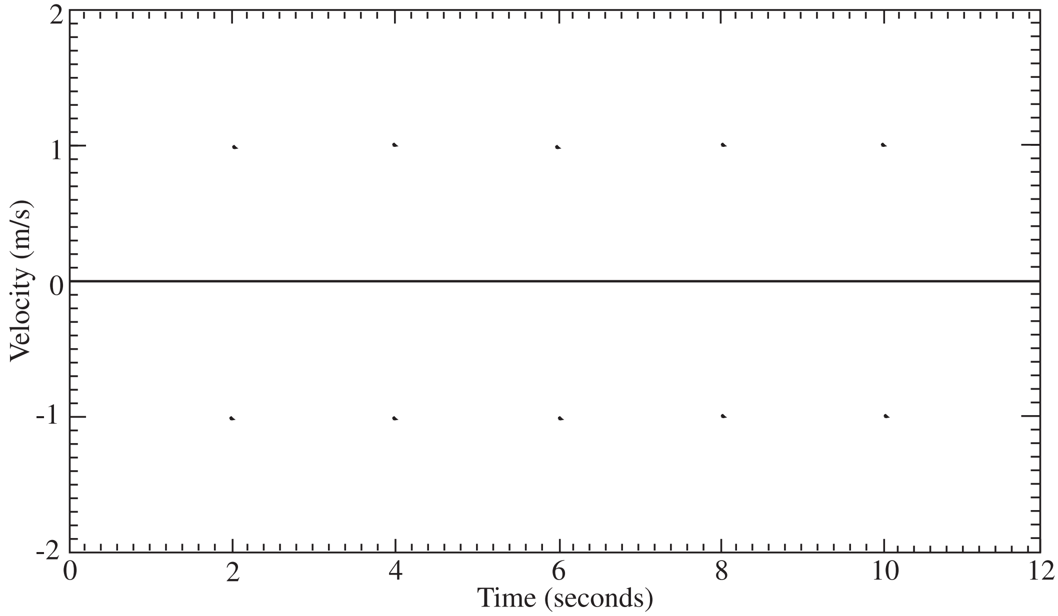
Compare notes with your lab partners. Were their explanations different than yours? If so, record them. If not, write NA here and move on.

Before creating your own graphs, make sure you have an expectation (i.e., a prediction) of what you think the data will look like.

Using what you have seen so far, on the axes below...

1. Draw what you think the graph will look like for a *steady slow* motion, *away* from the detector. Label this line “slow away”.
2. Draw what you think the graph will look like for a *steady fast* motion, *away* from the detector. Label this line “fast away”.
3. Draw what you think the graph will look like for a *steady slow* motion, *toward* the detector. Label this line “slow to”.
4. Draw what you think the graph will look like for a *steady fast* motion, *toward* the detector. Label this line “fast to”.

STOP! Check in with your TA before moving on.



In the space below, explain why you think the graphs will look like this.

Now confirm your predictions and note the ways in which these graphs do and do not match the predictions you and your group have made.

- Now have each member of the group move *slowly* and *steadily away* from the detector while facing the detector and the computer screen. Sketch this on the same graph with a dashed line labelled "slow me away."
- Next, have each member of the group move *faster* than before, but still *steadily away* from the detector, while facing the detector and the computer screen. Sketch this on the same graph with a dashed line labelled "fast me away."
- Next, have each member of the group move *slowly* and *steadily toward* the detector, while facing the detector and the computer screen. Sketch this on the same graph with a dashed line labelled "slow me to."
- Next, have each member of the group move *faster* and *steadily toward* the detector, while facing the detector and computer screen. Sketch this on the same graph with a dashed line labelled "fast me to."

What appears to be the difference between slower and faster motions on these velocity-time graphs? Does this agree with your prediction? If so, you do not have to rewrite your answer.

What appears to be the difference between toward and away motions on these velocity-time graphs? Does this agree with your prediction? If so, you do not have to rewrite your answer.

If there were predictions that did not match the actual graphs, discuss them with your group and see if you can come up with something which might explain the discrepancy. Record the ideas your group considers below as you discuss this issue.

What do you think is the essential difference between the lines for these steady motions away from the detector on the *position-time* graph and the lines on the *velocity-time* graph?

What is the definition of "steady" as we have been using it? You will be responsible for understanding what it means in problems on homework and tests.

2.1.4 Put it to the test.

Add "graph match" for velocity from the bottom left "graph options."

Based on what you have observed with the graphs so far, reproduce the graph with your own motion in front of the motion detector. Everyone should try this. Feel free to compete for who does it best!

Answer the following questions yourself and then discuss your answers with your lab partners. Write down any new ideas you get from your partners.

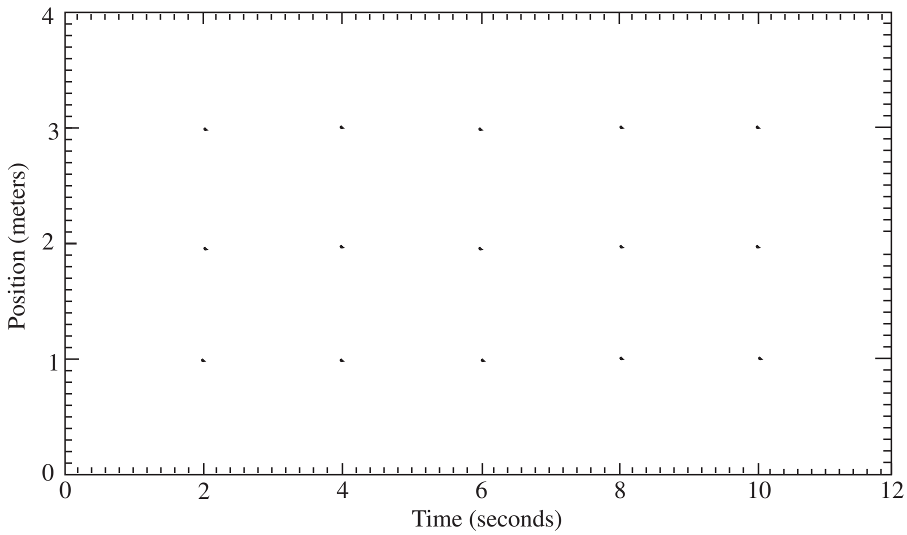
Carefully describe, in words, the motion you used to match the graph.

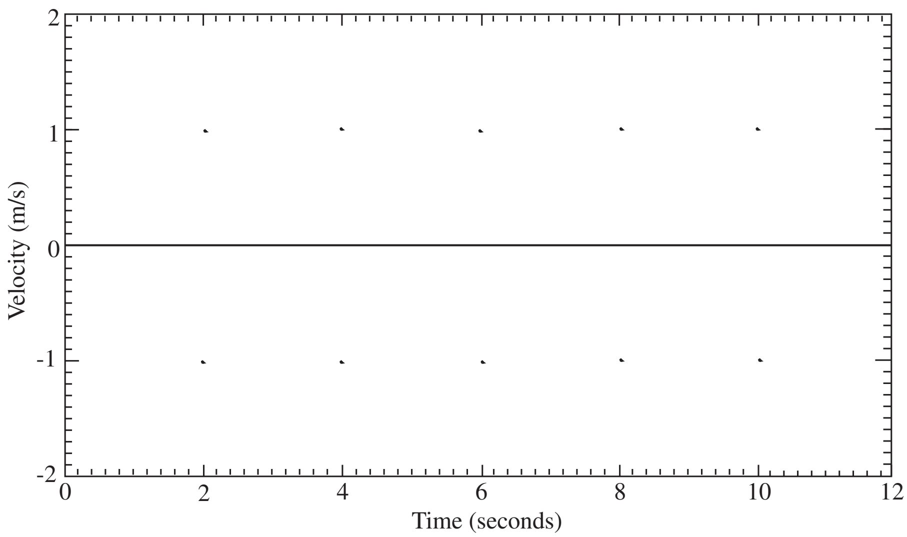
2.1.5 Work it backwards

For the following described motion, you will draw both a position-time and a velocity-time graph on the following graph paper. DO NOT use the motion detector for this part!

1. Standing still at the 0.6 meter position for 1 second.
2. Walking away from the detector slowly and steadily for 3 seconds.
3. Standing still for 1 second.
4. Walking steadily toward the detector, somewhat faster than in step 2.
5. Stopping just before the 0.6 meter position.

Draw the position-time graph of the motion on the first graph. Normally, I will expect you to do this on your own, but, since this is the first quantitative graph, I have asked you to draw I will warn you to be very careful to use the graph paper well (don't crowd it near one edge; choose your scale to make the best use of your paper) in the future. However, I drew the scale in for you this time. In the future I won't, but if you want full credit, you will remember this note. ALWAYS carefully demonstrate all the important features of any graph you are asked to draw. In other words, I should not have to guess if something is a straight line or not, if it is horizontal, or where it crosses zero...etc.. If you can tell what a value should be, I should be able to read it from your graph.





Draw the velocity-time graph of the motion. Make sure the two graphs are consistent, and that all the important features are present.

STOP! Check in with your TA before moving on.

2.2 Group problems

Purpose

To practice some problem solving within a group. Work together to reach solutions to the following problems.

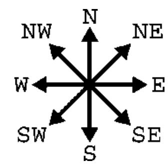
2.2.1 It's a sunny Sunday afternoon, about 65° F, and you are walking around Lake Calhoun enjoying the last of the autumn color. The sidewalk is crowded with runners and walkers. You notice a runner approaching you wearing a tee-shirt with writing on it. You read the first two lines, but are unable to read the third and final line before he passes. You wonder, "Hmm, if he continues around the lake, I bet I'll see him again, but I should anticipate the time when we'll pass again." You look at your watch and it is 3:07 p.m. You recall the lake is 3.4 miles in circumference. You estimate your walking speed at 3 miles per hour and the runner's speed to be about 7 miles per hour. (Credit: University of Minnesota Physics Education Research and Development Group.)

Vector Addition Problem

A State Forest Park in West Virginia has four main attractions; an old mine, a valley, a lake and a group of waterfalls. All these locations are connected to the visitor's center by different trails. In the following parts, work with vector component decomposition and vector addition to find the solutions.

PART A:

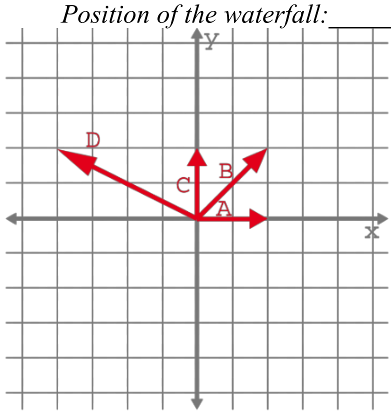
The different trails are represented by the following figures. For each figure, combine the vectors as indicated and determine the direction of the resultant vector. Then select from the rosette at the right, the closest direction of the attraction from the visitor's center.



i. Maple Waterfalls

U = A+B+C+D

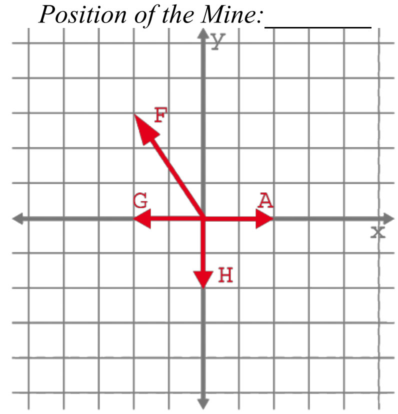
*Position of the waterfall:*_______



ii. Old Coal Mine

V = A+F+G+H

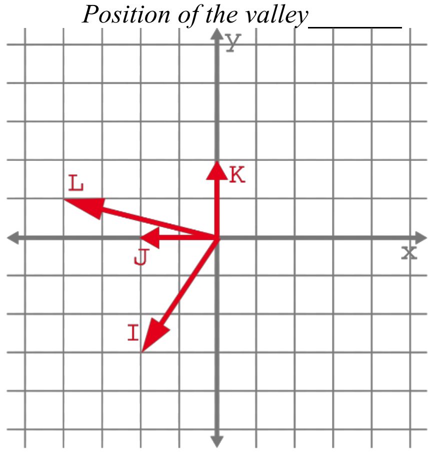
*Position of the Mine:*________



iii. Rhododendron Valley

R = I+J+K+L

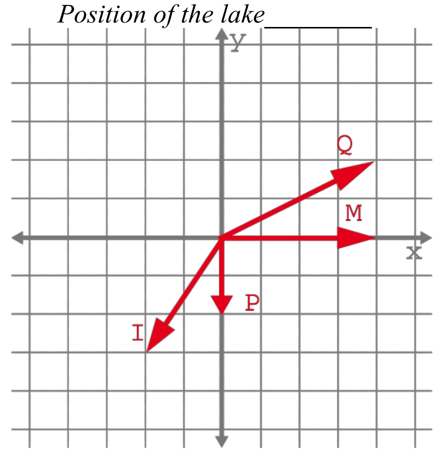
*Position of the valley*_______



iv. Brook Lake

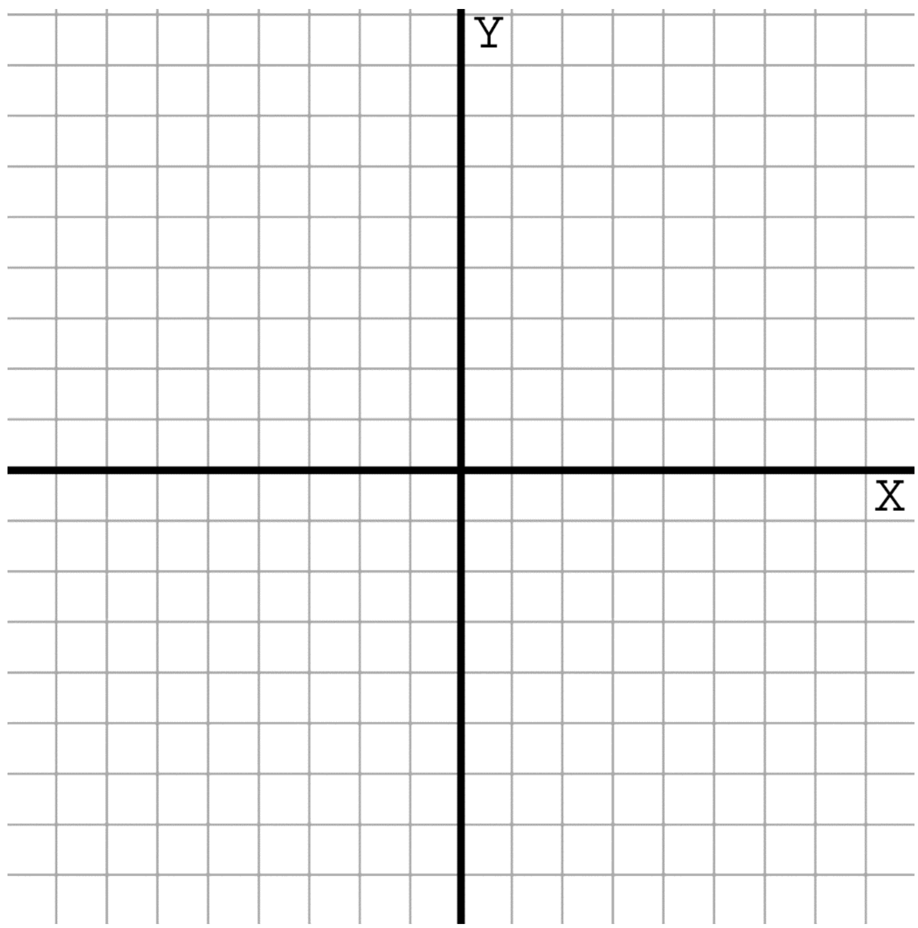
T = I+M+P+Q

*Position of the lake*________



PART B:

Using the previous information, draw a map of the State Park based on the magnitude and direction of the vectors represented in the previous part. Use the point (0, 0) as the visitor's center position. Then find the positions of each attraction.



Maple Waterfalls (____,____) Old Coal Mine (____,____) Rhododendron Valley (____,____) Brook Lake (____,____)

PART C:

Identify the x and y components of all the vectors and complete the chart.

Displacement Vector	x-component (Km.)	y-component (Km.)
A		
B		
C		
D		
F		
G		
H		
I		
J		
K		
L		
M		
P		
Q		

PART D:

i. List all vectors that have a zero x-component

ii. List all vectors that have a zero y-component

iii. List all vectors that have a positive x-component

iv. List all vectors that have a positive y-component

STOP! Check in with your TA to make sure you understand the practice problems.

(Credit for the previous vector problems: Cae Gutierrez Quintanilla and Newtonian Tasks Inspired by Physics Education Research, Hiegglelke, Maloney, and Kamin.)