Gr. 11 Physics Kinematics – Constant Velocity

This chart contains a complete list of the lessons and homework for Gr. 11 Physics. Please complete all the worksheets and problems listed under "Homework" before the next class. A set of optional online resources, lessons and videos is also listed under "Homework" and can easily be accessed through the links on the Syllabus found on the course webpage. You may want to bookmark or download the syllabus for frequent use.

The textbook reading are divided up into small parts (often a single paragraph) and don't follow the order in the class very closely. You may want to take notes from these sections, but this is not necessary since all the content is in your handbook or is discussed in class.

Some of the video lessons listed are from the website "Khan Academy", www.khanacademy.org which has many math and physics lessons. Another excellent source of online lessons comes from the physics teachers at Earl Haig S. S. http://www.physicseh.com/. **One warning**: Sometimes the notation used in the online lessons is different from what we use in class. Please be sure to use our notation. The Physics Classroom (http://www.physicsclassroom.com) is another excellent website, but does include more advanced material as well.

Kinematics

1	Introduction to Motion	Constant speed, position, time, d-t graphs, slope of d-t, sign convention	Video: The Known Universe
2	Introduction to Motion, *continued*		Handbook : *Constant Speed pg. 5* Read: pg. 12, "*Position*" Read: pg. 14,15, "Graphing Uniform Motion" Problems: pg. 15 #10,12,13 Lesson: Slope of d-t Graph
3	Interpreting Position Graphs	Position graphs for uniform / nonuniform motion	Handbook: *Position Graphs pg. 6* Lesson: Describing d-t Graphs
4	Defining Velocity	Displacement, velocity vs. speed, when is v changing?	Handbook: *Defining Velocity pg. 10* Read : pg 12, "*Displacement*" Lesson: Speed Calculation
5	Velocity-Time Graphs	Velocity graphs for uniform motion, vectors	Handbook: *Velocity Graphs pg. 15* Read: pg. 6, "*Scalars*", pg 12 *"vectors"* Read: pg. 14, *"Graphing Uniform Motion"* Lesson: Vectors and Scalars
6	Conversions	units and conversions	Handbook: *Conversions pg. 16* Lesson: Unit Conversion
7	Problem Solving	Problem solving,	Handbook: *Problems Unsolved pg. 20* Video: Peregrine Falcon
8	Representations of Motion		Handbook: *Representations of Motion pg. 22*
9	Vectors in Two Dimensions	Displacement vectors in 2-D, scale vector diagrams, distance vs. displacement, speed vs. velocity	Read: pg. 18-21, *"Two Dimensional Motion"* Handbook: *Vector Practice pg. 26,27* Lesson: Writing Vectors Lesson: Adding Vectors
10	Two Dimensional Motion	Displacement vectors in 2-D, scale vector diagrams, distance vs. displacement, speed vs. velocity	Read : pg. 22-23 *"Relative Motion"* Lesson: Relative Velocities 1 Lesson: Relative Velocities 2 Video: Shooting Soccer Ball Video: Tennis Ball Launcher
11	The Vector Adventure	Adding vectors	Video: Test Anxiety?
12	Review		Review: pg. 49 #1,2, 3, 4, 5a,b, 7, 10a,b, 13a, 19a
13	Test		

SPH3U: Introduction to Motion

Recorder: ___________________
Manager: ___________________
Speaker: ___________________
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Welcome to the study of physics! As young physicists you will be making measurements and observations, looking for patterns, and developing theories that help us to describe how our universe works. The simplest measurements to make are *position* and *time* measurements which form the basis for the study of motion.

A: Constant Speed?

You will need a motorized physics buggy, a pull-back car.

1. **Observe.** Which object moves in the steadiest manner: the buggy or the pull-back car? Describe what you observe and explain how you decide.

2. **Reason.** Excitedly, you show the buggy to a friend and mention how its motion is very steady or uniform. Your friend, for some reason, is unsure. Describe how you could use some simple position and time measurements (don't do them!) which would convince your friend that the motion of the buggy is indeed very steady.

3. **Define.** The buggy moves with *constant speed*. Use your ideas from the previous question to help write a definition for constant speed. (Danger! Do not use the words *speed* or *velocity* in your definition!) When you're done, write this on your whiteboard – show your teacher - you will share this later.

Definition: Constant Speed

B: Testing a Hypothesis – Constant Speed

You have a hunch that the buggy moves with a constant speed. Now it is time to test this hypothesis. Use a physics buggy, large measuring tape and stopwatch (or your smartphone with lap timer!). We will make use of a new idea called *position.*

To describe the *position* of an object along a line we need to know the distance of the object from a reference point, or origin, on that line and which direction it is in. Usually the position of an object along a line is positive along one side of the origin and negative if it lies on the other – but this *sign convention* is really a matter of choice. Choose your sign convention such that the position measurements you make today will be positive.

1. **Plan.** Discuss with your group a process that will allow you test the hypothesis mentioned above using the idea of position. Draw a simple picture, including the origin, and illustrate the quantities to be measured. Describe this process as the procedure for your experiment. *Check this with your teacher.*

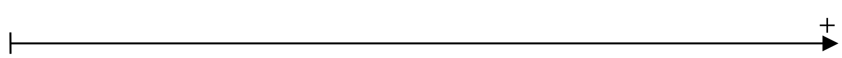
2. **Measure.** Push in your stools and conduct your experiment. Record your data below. Record your buggy number: _____

Position (m)								
Time (s)								

3. **Reason.** Explain how you can tell whether the speed is constant just by looking at the data.

A *motion diagram* is a sequence of dots that represents the motion of an object. We imagine that the object produces a dot as it moves after equal intervals of time. We draw these dots along an axis which shows the positive direction and use a small vertical line to indicate the origin. The scale of your diagram is not important, as long as it shows the right ideas.

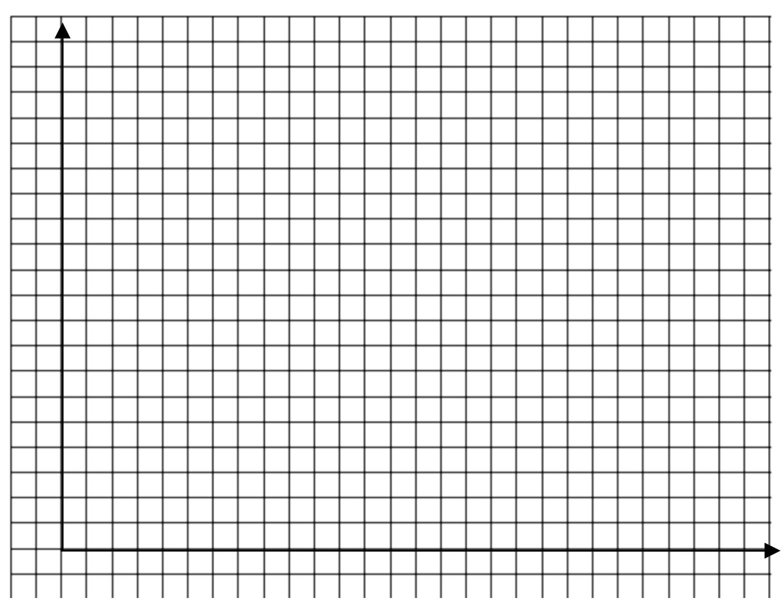
4. **Represent.** Draw a motion diagram for your buggy during one trip of your experiment. **Explain** why your pattern of dots correctly represents constant speed.



Graphing. Choose a convenient scale for your physics graphs that uses most of the graph area. The scale should increase by simple increments. Label each axis with a name and units.

Line of Best-Fit. The purpose of a line of best fit is to highlight a pattern that we believe exists in the data. Real data always contains errors which lead to *scatter* (wiggle) amongst the data points. A best-fit line helps to average out this scatter and uncertainty. Any useful calculations made from a graph should be based on the best-fit line and **not** on the data chart or individual points. As a result, we **never** connect the dots in our graphs of data.

5. **Represent.** Now plot your data on a graph. Make the following plot: position (vertical) versus time (horizontal).



6. **Find a pattern.** When analyzing data, we need to decide what type of pattern the data best fits. Do you believe the data follows a curving pattern or a straight-line pattern? Why do you think the data does not form a perfectly straight line? Explain.

7. **Reason.** Imagine an experiment with a different buggy that produced a similar graph, but with a steeper line of best fit. What does this tell us about that buggy? Explain.

8. **Calculate and Interpret.** Calculate the slope of the graph (using the best-fit line, don't forget the units). Interpret the meaning of the slope of a position-time graph. (What does this quantity tell us about the object?) *Reminder: slope = rise / run.*

9. **Explain.** Explain how you could predict (without using a graph) where would the buggy would be found 2.0 s after your last measurement.

C: The Buggy Challenge

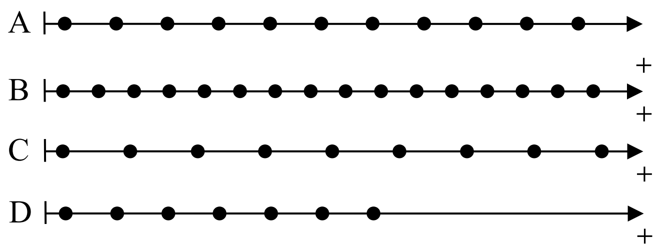
1. **Predict.** Your challenge is to use your knowledge of motion and predict how much time it will take for your buggy to travel a 2.3 m distance. Explain your prediction carefully.

2. **Test and Explain.** Set up your buggy to travel the predicted distance and have your stopwatch ready. Record your results and explain whether your measurements confirm your prediction.

SPH3U Homework: Constant Speed Name:

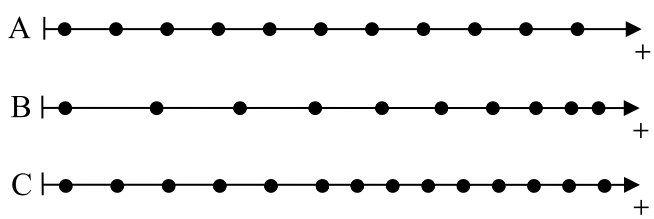
1. **Reason.** A good physics definition provides the criteria, or the test, necessary to decide whether something has a certain property. For example, a student is a "Trojan" (a FHCI student) if he or she has a timetable for classes at Forest Heights. What is a test that can be used to decide whether an object is moving with a constant speed?

2. Consider the four motion diagrams shown below.
   (a) Reason. Rank the four motion diagrams shown below according to the speed (fastest to slowest) of the object that produced them. Explain your reasoning.



   (b) Reason. Which object took the most time to reach the right end of the position axis? Explain.

3. **Reason**. Examine the motion diagrams shown below. Explain whether or not each one was produced by an object moving at a constant speed.

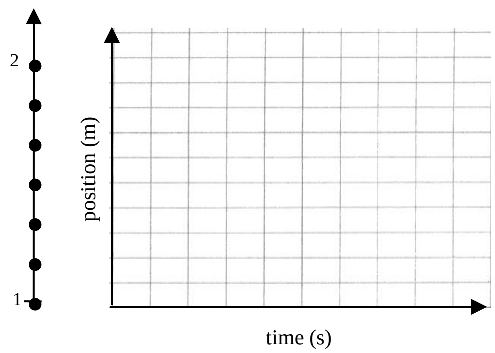


4. **Reason.** Different student groups collect data tracking the motion of different toy cars. Study the charts of data below. Which charts represent the motion of a car with constant speed? Explain how you can tell.

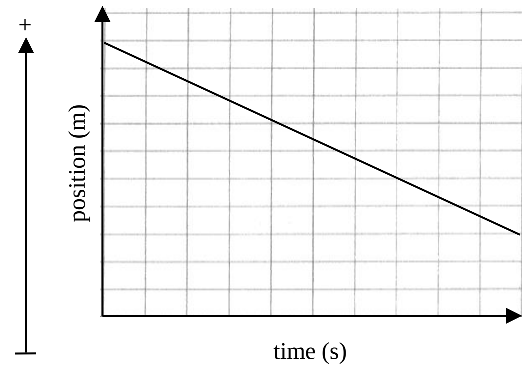
A		B		C		D	
Distance (cm)	Time (s)	Distance (cm)	Time (s)	Distance (cm)	Time (s)	Distance (cm)	Time (s)
0	0	0	0	0	0	7	0
15	1	2	5	1.2	0.1	15	2
30	2	6	10	2.4	0.2	24	4
45	3	12	15	3.6	0.3	34	6
60	4	20	20	4.8	0.4	45	8

SPH3U Homework: Position Graphs Name:

1. Emmy walks along an aisle in our physics classroom. A motion diagram records her position once every second. Two events, her starting position (1) and her final position (2) are labeled. Use the motion diagram to construct a position time graph – you may use the same scale for the motion diagram as the position axis. Draw a line of best-fit.



2. Use the position-time graph to construct a motion diagram for Isaac's trip along the hallway from the washroom towards our class. We will set **the classroom door as the origin**. Label the start (1) and end of the trip (2).

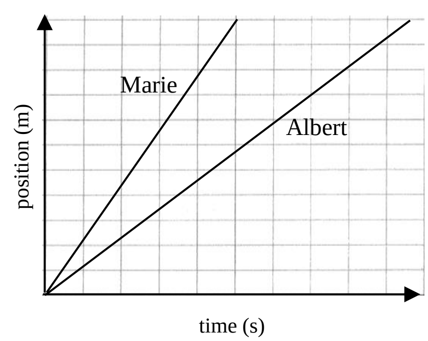


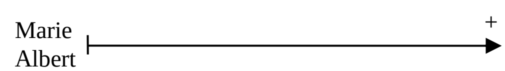
3. Albert and Marie both go for a stroll from the classroom to the cafeteria as shown in the position-time graph to the right. **Explain** your answer the following questions according to this graph.
   (a) Who leaves the starting point first?

   (b) Who travels faster?

   (c) Who reaches the cafeteria first?

   (d) Draw a motion diagram for both Albert and Marie. Draw the dots for Marie above the line and the dots for Albert below. Label their starting position (1) and their final position (2). Hint: think about their initial and final positions!





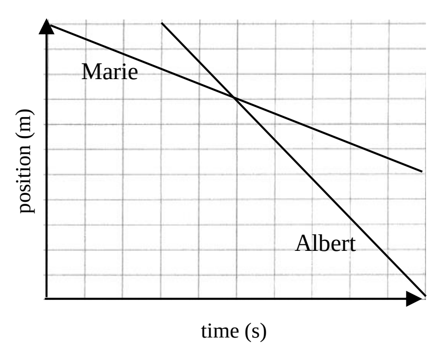
4. Albert and Marie return from the cafeteria as shown in the graph to the right. **Explain** your answer the following questions according to this graph.
   (a) Who leaves the cafeteria first?

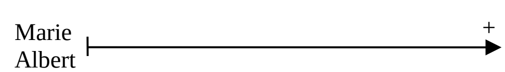
   (b) Who is travelling faster?

   (c) What happens at the moment the lines cross?

   (d) Who returns to the classroom?

   (e) Draw a motion diagram for both Albert and Marie. Label their starting position (1) and their final position (2).





SPH3U: Interpreting Position Graphs

Recorder: ___________________
Manager: ___________________
Speaker: ___________________
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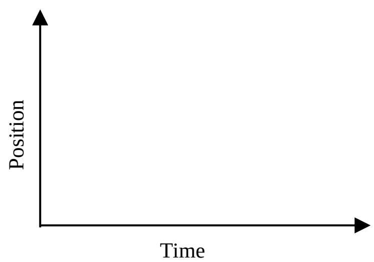
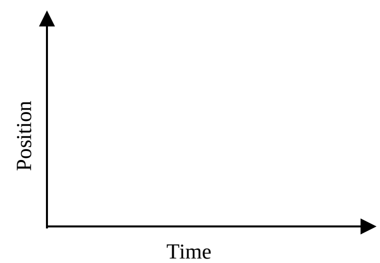
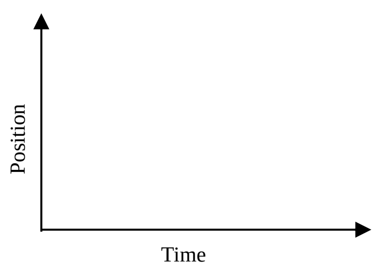
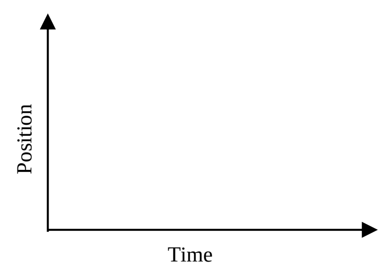
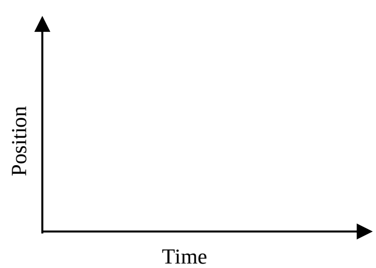
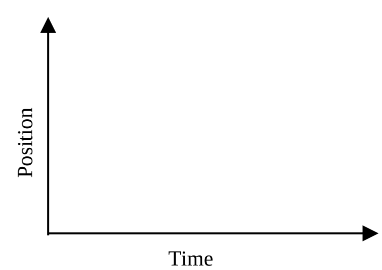
Today you will learn how to relate position-time graphs to the motion they represent. We will do this using a computerized motion sensor. The origin is at the sensor and the direction away from the face of the sensor is set as the positive direction. The line along which the detector measures one-dimensional horizontal motion will be called the *x*-axis.

A: Interpreting Position Graphs

1. (*work individually*) For each description of a person's motion listed below, sketch your prediction for what you think the position-time graph would look like. Use a dashed line for your predictions. Note that in a sketch of a graph we don't worry about exact values, just the correct general shape. Try not to look at your neighbours predictions, but if you're not sure how to get started, ask a group member for some help.

(a) Standing still, close to the sensor		(b) Standing still, far from the sensor	
(c) Walking slowly away from the sensor at a steady rate.		(d) Walking quickly away from the sensor at a steady rate.	
(e) Walking slowly towards the sensor at a steady rate		(f) Walking quickly towards the sensor at a steady rate.	

2. (as a group) Compare your predictions with your group members and discuss any differences. Make any changes you feel necessary.

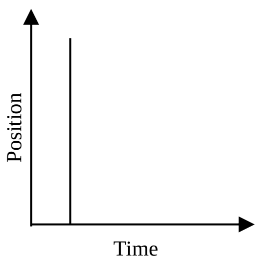
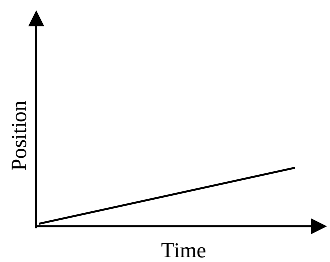
3. (as *a class*) Your group’s speaker is the official “walker”. The computer will display its results for each situation. Record the computer results on the graphs above using a solid line. Note that we want to smooth out the bumps and jiggles in the computer data which are a result of lumpy clothing, swinging arms, and the natural way our speed changes during our walking stride.

4. (as *a class)* Interpret the physical meaning of the mathematical features of each graph. Write these in the box below each description above.

5. (as *a group*) Describe the difference between the two graphs made by walking away slowly and quickly.

6. Describe the difference between the two graphs made by walking towards and away from the sensor.

7. Explain the errors in the following predictions.

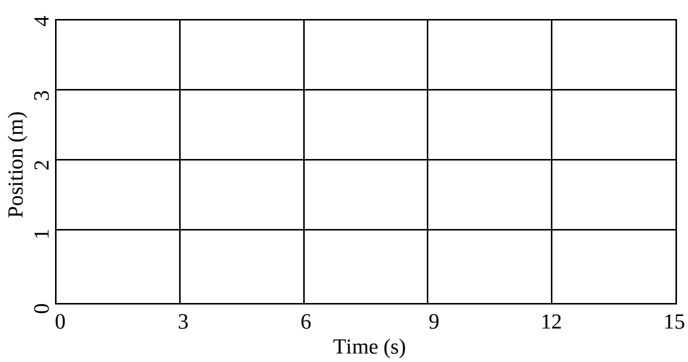
For situation (a) a student predicts: 	For situation (d) the student says: “Look how long the line is – she travels far in a small amount of time. That means she is going fast.” 

B: The Position Prediction Challenge

Now for a challenge! From the description of a set of motions, can you predict a more complicated graph?

A person starts 1.0 m in front of the sensor and walks away from the sensor slowly and steadily for 6 seconds, stops for 3 seconds, and then walks towards the sensor quickly for 6 seconds.

1. (*work individually*) Use a dashed line to sketch your prediction for the position-time graph for this set of motions.

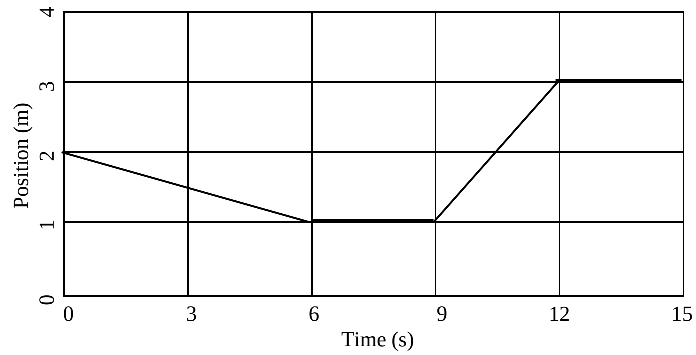


2. (*as a group*) Compare your predictions. Discuss any differences. Don’t make any changes to your prediction.

3. (*as a class*) Compare the computer results with your group’s prediction. Explain any important differences between your personal prediction and the results.

C: Graph Matching

Now for the reverse! To the right is a position-time graph and your challenge is to determine the set of motions which created it.



1. (*Work individually*) Carefully study the graph above and write down a list of instructions that could describe to someone how to move like the motion in this graph. Use words like *fast, slow, towards, away, steady, and standing still*. If there are any helpful quantities you can determine, include them.

2. (*as a group*) Share the set of instructions each member has produced. Do not make any changes to your own instructions. Put together a best attempt from the group to describe this motion.

D: Summary

1. Summarize what you have learned about interpreting position-time graphs.

Interpretation of Position-Time Graphs	
Graphical Feature	Physical Meaning
steep slope	
shallow slope	
zero slope	
positive slope	
negative slope	

2. What, in addition to the speed, does the slope of a position-time graph tell us about the motion on an object?

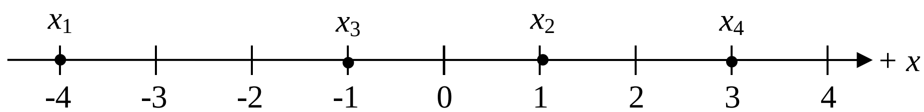
We have made a very important observation. The slope of the position-time graph is telling us more than just a number (how fast). We can learn another important property of an object's motion that speed does not tell us. This is such an important idea that we give the slope of a position-time graph a special, technical name – the **velocity** of an object. The velocity is much more than just the speed of an object as we shall see in our next lesson! Aren't you glad you did all that slope work in gr. 9?!

SPH3U Homework: Defining Velocity Name:

A: Where's My Phone?

Albert walks along Fischer-Hallman Rd. on his way to school. Four important events take place. The $+x$ direction is east.

Event 1: At 8:00 Albert leaves his home.
Event 2: At 8:13 Albert realizes he has dropped his phone somewhere along the way. He immediately turns around.
Event 3: At 8:22 Albert finds his phone on the ground with its screen cracked (no insurance).
Event 4: At 8:26 Albert arrives at school.



units = kilometers

1. **Represent**. Draw a vector arrow that represents the displacement for each interval of Albert's trip and label them Δx_{12}, Δx_{23}, Δx_{34}.

2. **Calculate.** Complete the chart below to describe the details of his motion in each interval of his trip.

Interval	1-2	2-3	3-4
Displacement expression	$\Delta x_{12} = x_2 - x_1$		
Time interval expression	$\Delta t_{12} = t_2 - t_1$		
Displacement result (km)			
Interpret direction			
Time interval result (min)			
Velocity (km/min)			

3. **Reason.** Why do you think the size of his velocity is so different in each interval of his trip? Explain.

4. **Explain.** Why is the sign of the velocity different in each interval of his trip?

5. **Calculate.** What is his displacement for the **entire trip**? (Hint: which events are the initial and final events for his whole trip?)

6. **Interpret**. Explain in words what the result of your previous calculation **means**.

SPH3U: Defining Velocity

Recorder: ___________________
Manager: ___________________
Speaker: ___________________
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To help us describe motion carefully we have been measuring positions at different moments in time. Now we will put this together and come up with an important new physics idea.

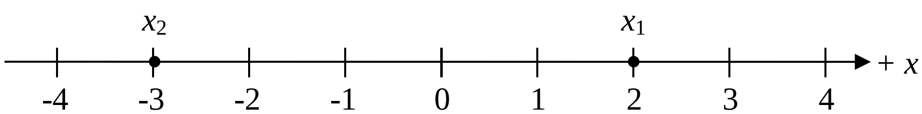
A: Events

When we do physics (that is, study the world around us) we try to keep track of things when interesting events happen. For example when a starting gun is fired, or an athlete crosses a finish line. These are two examples of **events**.

An *event* is something that happens at a certain place and at a certain time. We can locate an event by describing *where* and *when* that event happens. At our level of physics, we will use one quantity, the position (x) to describe where something happens and one quantity time (t) to describe when. Often, there is more than one event that we are interested in so we label the position and time values with a subscript number (x_2 or t_3). In physics we will exclusively use subscript numbers to label events.

B: Changes in Position - Displacement

Our trusty friend Emmy is using a smartphone app that records the events during her trip to school. Event 1 is at 8:23 when she leaves her home and event 2 is at 8:47 when she arrives at school. We can track her motion along a straight line that we will call the x-axis, we can note the positions of the two events with the symbols x_1, for the initial position and x_2, for the final position.



units = kilometers

1. What is the position of x_1 and x_2 relative to the origin? Don't forget the sign convention and units!
   x_1 = x_2 =

2. Did Emmy move in the positive or negative direction? How far is the final position from the starting position? Use a ruler and draw an arrow (just above the axis) from the point x_1 to x_2 to represent this change.

The change in position of an object is called its *displacement* (Δx) and is found by subtracting the initial position from the final position: $\Delta x = x_f - x_i$. The Greek letter Δ ("delta") means "change in" and always describes a final value minus an initial value. The displacement can be represented graphically by an arrow, called the *displacement vector*, pointing from the initial to the final position. Any quantity in physics that includes a direction is a *vector*.

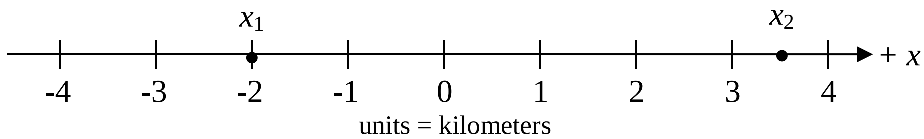
3. In the example above with Emmy, which event is the "final" event and which event is the "initial"? Which event number should we substitute for the "f" and which for the "i" in the expression for the displacement ($\Delta x = x_f - x_i$)?

4. Calculate the displacement for Emmy's trip. What is the interpretation of the number part of the result of your calculation? What is the interpretation of the sign of the result?

   Δx =

5. Displacement is a vector quantity. Is position a vector quantity? Explain.

6. Calculate the displacement for the following example. Draw a displacement vector that represents the change in position.



C: Changes in Position and Time

In a previous investigation, we have compared the position of the physics buggy with the amount of time taken. These two quantities can create an important ratio.

When the velocity is constant (constant speed and direction), the *velocity* of an object is the ratio of the displacement between a pair of events and the time interval. In equal intervals of time, the object is displaced by equal amounts.

1. Write an algebraic equation for the velocity in terms of v, x, Δx, t and Δt. (Note: some of these quantities may not be necessary.)

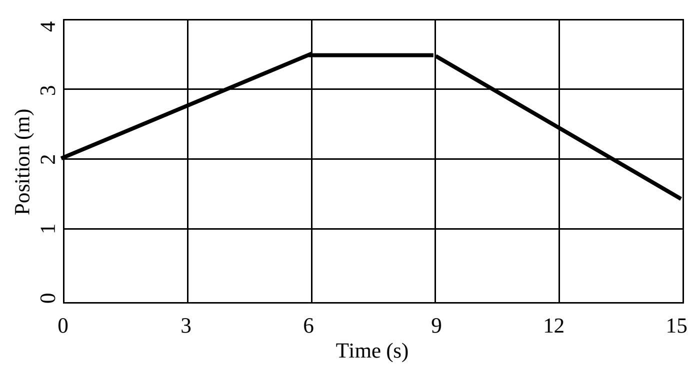
2. Consider the example with Emmy once again. What was her displacement? What was the interval of time? Now find her velocity in km/min. Provide an interpretation for the sign of the result.

In physics, there is an important distinction between *velocity* and *speed*. Velocity includes a direction while speed does not. Velocity can be positive or negative, speed is always positive. For **constant velocity only**, the speed is the magnitude (the number part) of the velocity: speed = |velocity|. There is also a similar distinction between *displacement* and *distance*. Displacement includes a direction while distance does not. A displacement can be positive or negative, while distance is always positive. For **constant velocity only**, the distance is the magnitude of the displacement: distance = |displacement|.

D: Velocity and Position-Time Graphs

Your last challenge is to find the velocity of a person from a position-time graph.

1. Explain how finding the velocity is different from simply finding the speed.



2. Calculate the following:

Speed between the following given times:	Velocity between the following given times:
a) 0 and 6 seconds:	b) 0 and 6 seconds:
c) 6 and 9 seconds:	d) 0 and 9 seconds:
e) 9 and 15 seconds:	f) 0 and 15 seconds:

SPH3U: Velocity-Time Graphs

Recorder: ___________________
Manager: ___________________
Speaker: __________________
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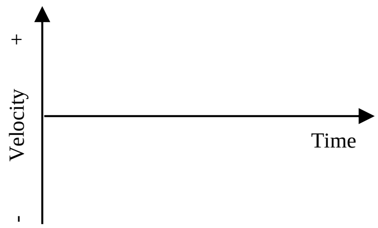
We have had a careful introduction to the idea of velocity. Now it's time to look at its graphical representation.

A: The Velocity-Time Graph

A velocity-time graph uses a sign convention to indicate the direction of motion. We will make some predictions and investigate the results using the motion sensor. Remember that the positive direction is away from the face of the sensor.

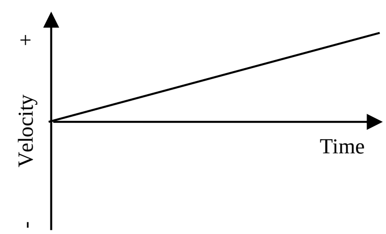
1. **Predict**. (*work individually*) A student walks slowly away from the sensor with a constant velocity. Predict what the velocity-time graph will look like. You may assume that the student is already moving when the sensor starts collecting data.



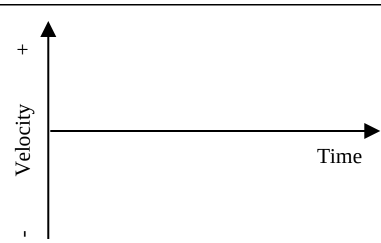
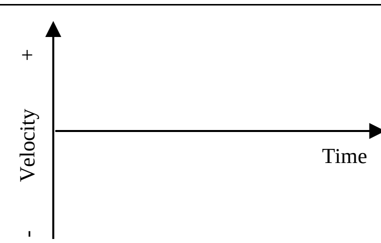
2. **Observe.** (*as a class*) Observe a student and record the results from the computer. You may smooth out the jiggly data from the computer.

Interpret:

3. **Explain.** Most students predict a graph for the previous example that looks like the one to the right. Explain what the student was thinking when making this prediction.



4. **Predict.** (*Work individually*) Sketch your prediction for the velocity-time graph that corresponds to each situation described in the chart below. Use a dashed line for your predictions.

Walking **quickly** away from the sensor at a steady rate.		Start 2 m away and walk slowly towards the sensor at a steady rate.	
Start 4 m away and walk slowly towards the sensor at a steady rate.		Start 4 m away and walk quickly towards the sensor at a steady rate.	

5. **Discuss.** (*Work together*) Compare your predictions with your group members and discuss any differences. Don't worry about making changes.

6. **Observe.** (*As a class*) The computer will display its results for each situation. Draw the results with a solid line on the graphs above. Remember that we want to smooth out the bumps and jiggles from the data.

7. **Explain.** Explain to your group members any important differences between your personal prediction and the results.

8. **Explain.** Based on your observations of the graphs above, how is speed represented on a velocity-time graph? (How can you tell if the object is moving fast or slow)?

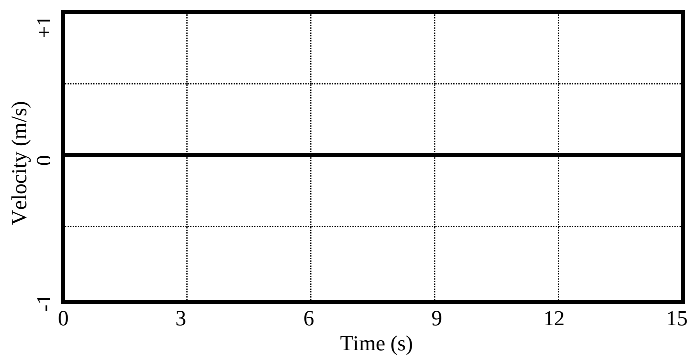
9. **Explain.** Based on your observations of the graphs above, how is direction represented on a velocity-time graph? (How can you tell if the object is moving in the positive or negative direction)?

10. **Explain.** If everything else is the same, what effect does the starting position have on a v-t graph?

B: Prediction Time!

A person moves in front of a sensor. There are four events: (1) The person starts to walk slowly away from the sensor, (2) at 6 seconds the person stops, (3) at 9 seconds the person walks towards the sensor twice as fast as before, (4) at 12 seconds the person stops.

1. **Predict.** (*Work individually*) Use a dashed line to draw your prediction for the shape of the velocity-time graph for the motion described above. Label the events.



2. **Discuss.** (*Work together*) Compare your predictions with your group and see if you can all agree.

3. **Observe.** (*As a class*) Compare the computer results with your group's prediction. Explain to your group members any important differences between your personal prediction and the results. Record your explanations here.

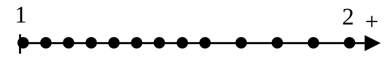
Velocity is a vector quantity since it has a magnitude (number) and direction. All vectors can be represented as arrows. In the case of velocity, the arrow does not show the initial and final positions of the object. Instead it shows the object's speed and direction. We can use a scale to draw a velocity vector, for example: 1.0 cm (length on paper) = 1.0 m/s (real-world speed)

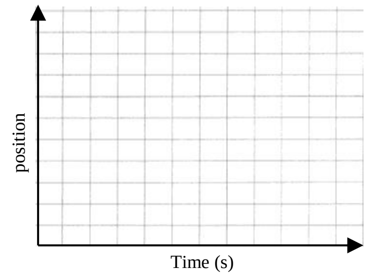
4. **Represent.** Refer to the graph above. Sketch two vector arrows to represent the velocity of our walker at 4 seconds and at 11 seconds. Label them v_1 and v_2.

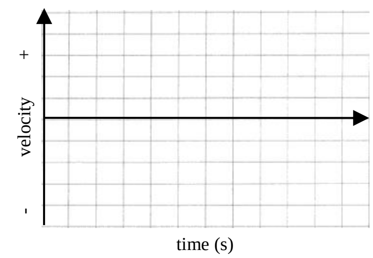
$\longrightarrow + x$

SPH3U Homework: Velocity Graph Name:

1. A motion diagram tracks the movement of a remote control car. The car is able to move back and forth along a straight track and produces one dot every second.







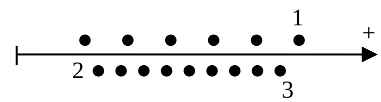
   (a) Is the velocity of the car constant during the entire trip? Explain what happens and how you can tell.

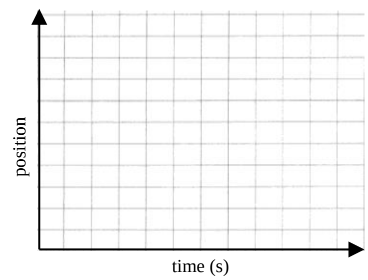
   (b) At what time does the motion change? Explain.

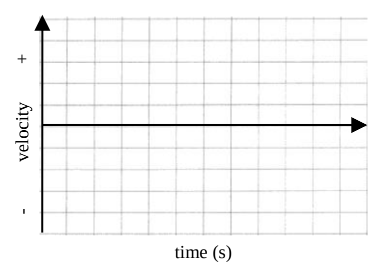
   (c) Sketch a position-time graph for the car. The scale along the position axis is not important. Use one grid line = 1 second for the time axis. Explain how the slopes of the two sections compare.

   (d) Sketch a velocity-time graph for the car. The scale along the velocity axis is not important. Use one grid line = 1 second for the time axis.

2. In a second experiment we track the same car and create a new motion diagram showing the car suddenly **turning around**. We begin tracking at event 1 and finish at event 3.







   (a) Is the velocity of the car constant during the entire trip? Explain what happens and how you can tell.

   (b) Does the car spend more time traveling fast or slow? Explain how you can tell.

   (c) Sketch a position-time graph for the car. The scale along the position axis is not important. Use one grid line = 1 second for the time axis. Explain how the slopes of the two sections compare.

   (d) Sketch a velocity-time graph for the car. The scale along the velocity axis is not important. Use one grid line = 1 second for the time axis. Explain how you chose to draw each section of the velocity-time graph.

   (e) According any velocity-time graph, how can you tell what direction an object is moving in?

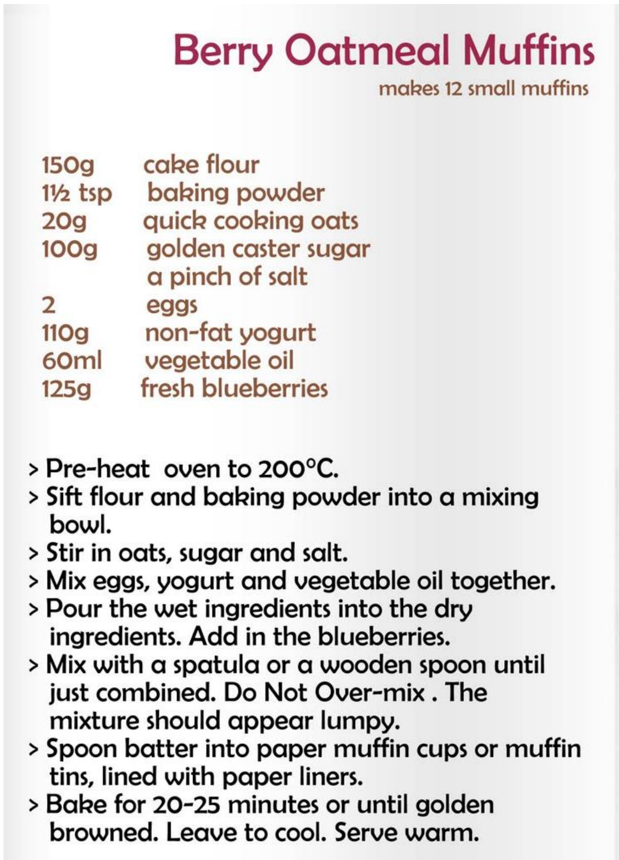
SPH3U Homework: Conversions

For all the questions below, be sure to show your conversion ratios!

1. You are driving in the United States where the speed limits are marked in strange, foreign units. One sign reads 65 mph which should technically be written as 65 mi/h. You look at the speedometer of your Canadian car which reads 107 km/h. Are you breaking the speed limit? (1 mi = 1.60934 km)

2. You step into an elevator and notice the sign describing the weight limit for the device. What is the typical weight of a person in pounds according to the elevator engineers?

3. You are working on a nice muffin recipe only to discover, halfway through your work, that the quantity of oil is listed in mL. You only have teaspoons and tablespoons to use (1 tsp = 4.92 mL, 1 tbsp = 14.79 mL). Which measure is best to use and how many?



4. Your kitchen scale has broken down just as you were trying to measure the cake flour for your muffin recipe. Now all you have is your measuring cup. You quickly look up that 1 kg of flour has a volume of 8.005 cups. How many cups should you put in your recipe?

5. Atoms are very small. So small, we often use special units to describe their mass, *atomic mass units* (u). One uranium atom has a mass of 238 u. Through careful experiments we believe 1 u = $1.6605402 \times 10^{-27}$ kg. What is the mass of one uranium atom in kg?

SPH3U: Conversions

Recorder: __________________
Manager: __________________
Speaker: __________________
0 1 2 3 4 5

In our daily life we often encounter different units that describe the same thing – speed is a good example of this. Imagine we measure a car's speed and our radar gun says "100 km/h" or "62.5 miles per hour". The numbers (100 compared with 62.5) might be different, but the measurements still describe the same amount of some quantity, which in this case, is speed.

A: The Meaning of Conversions

When we say that something is 3 m long, what do we really mean?

1. **Explain.** "3 metres" or "3 m" is a shorthand way of describing a quantity using a mathematical calculation. You may not have thought about this before, but there is a mathematical operation (+, -, ×, ÷) between the "3" and the "m". Which one is it? Explain.

Physics uses a standard set of units, called S. I. (Système internationale) units, which are not always the ones used in day-to-day life. The S. I. units for distance and time are *metres* (*m*) and *seconds* (*s*). It is an important skill to be able to change between commonly used units and S.I. units. (Or you might lose your Mars Climate Orbiter like NASA did! Google it.)

2. **Reason.** Albert measures a weight to be 0.454 kg. He does a conversion calculation and finds a result of 1.00 lbs. He places a 0.454 kg weight on one side of a balance scale and a 1.00 lb weight on the other side. What will happen to the balance when it is released? Explain what this tells us physically about the two quantities 0.454 kg and 1.00 lbs.

3. **Reason.** There is one number we can multiply a measurement by without changing the size of the physical quantity it represents. What is that number?

The process of conversion between two sets of units leaves the physical quantity unchanged – the number and unit parts of the measurement will both change, but the result is always the same physical quantity (the same amount of stuff), just described in a different way. To make sure we don't change the actual physical quantity when converting, we only ever multiply the measurement by "1". We multiply the quantity by a *conversion ratio* which must always equal "1".

$$0.454 \text{ kg} = 0.454\ \cancel{\text{kg}} \left(\frac{2.204\ \ lbs}{1.00\ \ \cancel{kg}} \right) = 1.00 \text{ lbs} \qquad 65\ \frac{km}{h} = 65\ \frac{km}{\cancel{h}} \left(\frac{1.000\ \cancel{h}}{3600\ \ s} \right) = 1.8 \times 10^{-2} \text{ km/s}$$

The ratio in the brackets is the conversion ratio. Note that the numerator and denominator are equal, making the ratio equal to "1". It is usually helpful to complete your conversions in the first step of your problem solving.

4. **Explain.** Examine the conversion ratios in the example above. When converting, you need to decide which quantity to put on the top and the bottom of the fraction. Explain how to decide this. A hint comes from the markings and units in the examples above.

5. **Reason.** You are trying to convert a quantity described using minutes into one described using seconds. Construct the conversion ratio you would use and explain why it will work.

B: The Practice of Conversions

1. **Solve**. Convert the following quantities. Carefully show your conversion ratios and how the units divide out. Remember to use our guidelines for significant digits!

Convert to seconds	Convert to kilometres
12.5 minutes $\left(\frac{\quad}{\quad}\right) =$	4.5 m $\left(\frac{\quad}{\quad}\right) =$

2. **Reason.** In the previous question, you converted from minutes to seconds. Explain in a simple way why it makes sense that the quantity measured in seconds is a bigger number.

3. **Reason.** You are converting a quantity from kilograms into pounds. Do you expect the number part to get larger or smaller? Explain.

4. **Solve**. Convert the following quantities. Carefully show your conversion ratios and how the units divide out. Don't forget those sig. dig. guidelines!

Convert to kilograms	Convert to seconds
138 lbs $\left(\frac{\quad}{\quad}\right) =$	3.0 days $\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right) =$

5. **Reason.** You are converting a quantity from km/h into m/s. How many conversion ratios will you need to use? Explain.

Convert to m/s	Convert to km/h
$105\ \frac{km}{h}\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right) =$	$87\ \frac{m}{s}\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right) =$

SPH3U: Problem Solving

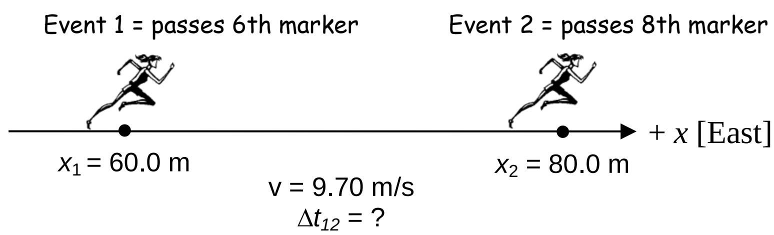
Recorder: ____________________
Manager: ____________________
Speaker: ____________________
0 1 2 3 4 5

A: Problem Solved

We can build a deep understanding of physics by learning to think carefully about each problem we solve. Our goal will be to do a small number of problems really well and to learn as much as possible from each one. To help do this, we will use a special process shown below to carefully describe or represent a problem in many different ways. Read through the solution below, which is presented without showing the original problem.

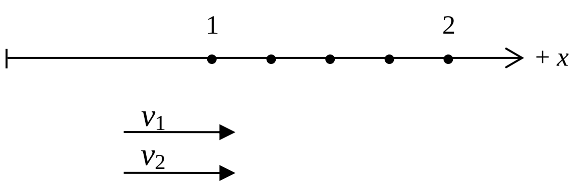
A: Pictorial Representation

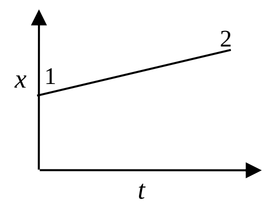
Sketch, coordinate system, label givens & unknowns with symbols, conversions, describe events

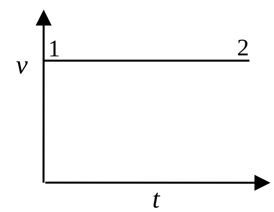


B: Physics Representation

Motion diagram, motion graphs, velocity vectors, events







C: Word Representation

Describe motion (no numbers), explain why, assumptions

The runner travels east (the positive direction) along a track. We assume she runs with a constant velocity since she has reached her top speed.

D: Mathematical Representation

Describe steps, complete equations, algebraically isolate, substitutions with units, final statement

Find the displacement:
$\Delta x = x_2 - x_1 = 80.0\text{ m} - 60.0\text{ m} = 20.0\text{ m}$

Solve for time:
$v = \Delta x/\Delta t$
$\therefore \Delta t = \Delta x/v$
$= (20.0\ \cancel{\text{m}})/(9.70\ \cancel{\text{m}}/\text{s}) = 2.062\text{ s}$

The runner took 2.06 s to run the distance.

E: Evaluation

Answer has reasonable size, direction and units? Explain why.

A small time interval is reasonable since she is running quickly and travels through a short distance. Time does not have a direction. *Seconds* are reasonable units for a short interval of time.

1. **Explain.** Is the athlete in this problem running in the positive or negative direction? In how many ways is this shown in the solution?

2. **Reason.** By looking at the information presented in part A of the solution, can you decide if any conversions are necessary for the solution? Explain.

3. **Calculate.** Just out of curiosity, is the runner travelling as fast as a car on a residential street (40 km/h)?

4. **Interpret.** In part C we state that we are assuming the runner travels with a constant velocity. Did we use this assumption in part B? Describe and explain all the examples of the use of this assumption that you find in part B.

When we solve a problem in a rich way using this solution process, we can check the quality of our solution by looking for *consistency*. For example, if the object is moving with a constant velocity we should see that reflected in many parts of the solution – check these parts. If the object is moving in the positive direction, we should see that reflected in many parts. Always check that the important physics ideas properly reflected in all parts of the solution.

5. **Explain.** Did part D of the solution follow our guidelines for significant digits? Explain.

6. **Evaluate.** The evaluation step encourages you to decide whether your final answer seems reasonable. Suppose a friend of yours came up with a final answer of 21 s. Aside from an obvious math error, why is this result not reasonable in size?

B: Problems Unsolved

Use the new process to solve the following problems. Use the blank solution sheet on the next page. To conserve paper, some people divide each page down the centre and do two problems on one page. Use the subheadings for each part as a checklist while you create your solutions. Don't forget to use our guidelines for significant digits!

1. Usain Bolt ran the 200 m sprint at the 2012 Olympics in London in 19.32 s. Assuming he was moving with a constant velocity, what is his speed in km/h during the race? (37.3 km/h)

2. In February 2013, a meteorite streaked through the sky over Russia. A fragment broke off and fell downwards towards Earth with a speed of 12 000 km/h. The fragment was first spotted just as it entered our atmosphere at a position of 127 km above Earth. What was its position above Earth 10.0 seconds later? (93.7 km)

3. Imagine the Sun suddenly dies out! The last ray of light would travel 1.5×10^{11} m to Earth with a speed of 3.0×10^{8} m/s. How many minutes would elapse between the Sun dying and the inhabitants of Earth seeing things go dark? (8.33 min)

C: Calculation Skills

Make sure you can correctly use your calculator! Scientific notation is entered using buttons that look like the examples to the right.

Exp	^	EE

Motion Solution Sheet	**Name:**	**Problem:**

A: Pictorial Representation

Sketch, coordinate system, label givens & unknowns using symbols, conversions, describe events

B: Physics Representation

Motion diagram, motion graphs, velocity vectors, events

C: Word Representation

Describe motion (no numbers), explain why, assumptions

D: Mathematical Representation

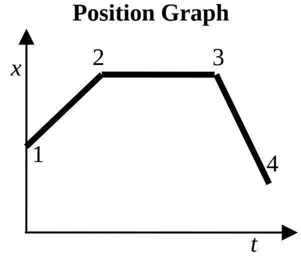
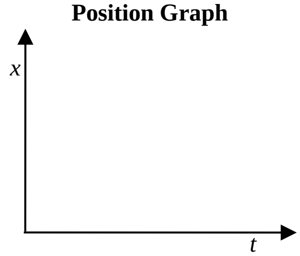
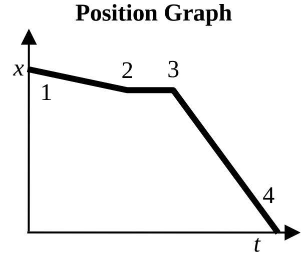
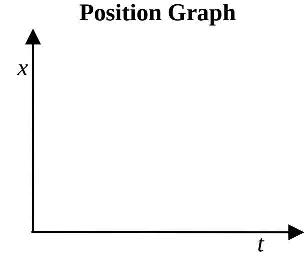
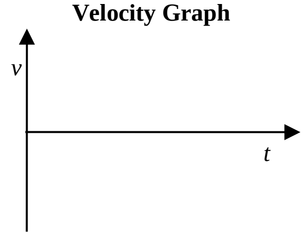
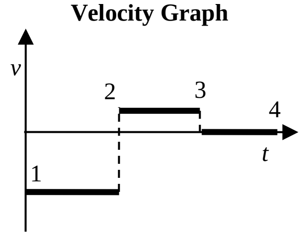
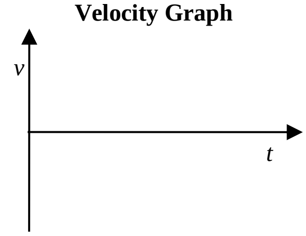
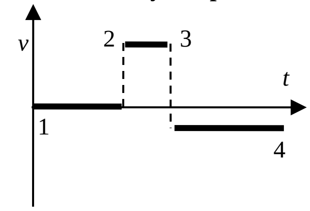
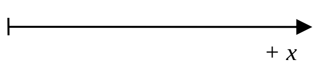
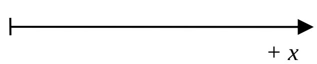
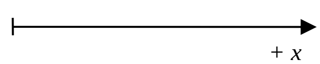
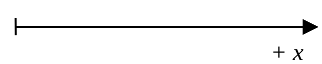
Describe steps, complete equations, algebraically isolate, substitutions with units, final statement

E: Evaluation

Answer has reasonable size, direction and units? Explain why.

Homework: Representations of Motion

Each column in the chart below shows five representations of one motion. The small numbers represent the events. Remember that the motion diagram is a dot pattern. If the object remains at rest, simply "pile up" the dots. If it changes direction, use a separate line just above or below the first. Remember that in the motion diagrams the origin is marked by a small vertical line.

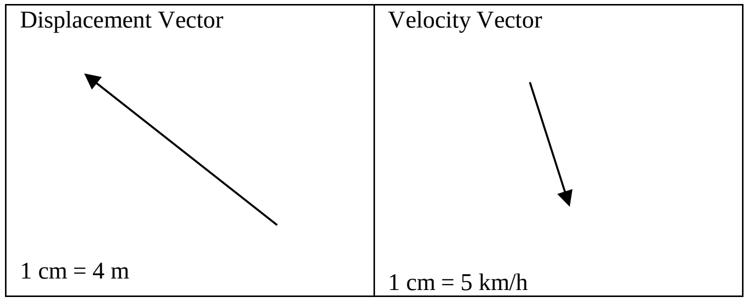
Situation 1	**Situation 2**	**Situation 3**	**Situation 4**
Description	**Description**	**Description**	**Description**
Position Graph 	**Position Graph** 	**Position Graph** 	**Position Graph** 
Velocity Graph 	**Velocity Graph** 	**Velocity Graph** 	**Velocity Graph** 
Motion Diagram 	**Motion Diagram** 	**Motion Diagram** 	**Motion Diagram** 
Velocity Vectors (velocity just after each event) v_{12} v_{23} v_{34}	**Velocity Vectors** (velocity just after each event) v_{12} ← v_{23} → v_{34} •	**Velocity Vectors** (velocity just after each event) v_{12} v_{23} v_{34}	**Velocity Vectors** (velocity just after each event) v_{12} v_{23} v_{34}

SPH3U: Vectors in Two-Dimensions

The main model of motion we have developed so far is constant velocity in a straight line. But the real world can be much more complex than this! When we walk, bike or drive, we change directions, hang a left, or go west. These are examples of two dimensional motion or motion in a plane.

A: Representing a Two-Dimensional Vector

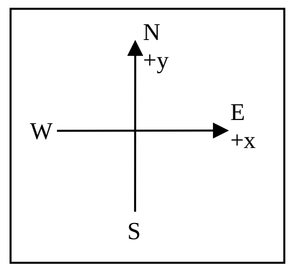
We visually represent vectors by drawing an arrow. We have done this with displacement and velocity vectors earlier in our study of motion. When an object moves in two-dimensions these vectors do not necessarily line up with our *x*- or *y*-directions any more.



1. **Interpret.** What does the length of a displacement vector describe? What does the length of velocity vector describe?

2. **Interpret.** Use a ruler to find the magnitude of the displacement and velocity vectors. Explain how you do this.

To help describe the direction of a vector we need a coordinate system. With vectors in a straight line, we used positive or negative *x* or *y* to show directions. In two-dimensions we will use both of these. Sometimes we add extra labels to help describe the directions, such as: N, S, E, W or Up, Down, Left, Right. A complete coordinate system is shown to the right.



3. **Measure.** Use a ruler to draw a coordinate system for each vector above. Line-up the coordinate system such that the *tail* of each vector is at the centre of the coordinate system. Use a protractor to measure an angle formed between the tail of each vector and the coordinate system you drew.

To label vectors in two-dimensions with 2-D vector notation, imagine someone travels 3.5 m in a direction north and 60^o to the west. We will record this by writing: $\Delta\vec{d} = 3.5\ m\ [N60^o W]$. The symbol $\Delta\vec{d}$ with an arrow signifies a displacement (a change in the position vector). The number part, 3.5 m, is called the magnitude of the vector. The angle that is used is always between zero and 90^o and is measured at the tail of the vector.

4. **Represent.** Use 2-D vector notation to label the two vectors $\Delta\vec{d}$ and $\vec{v}$ shown above. Be sure to use the square bracket notation for the direction.

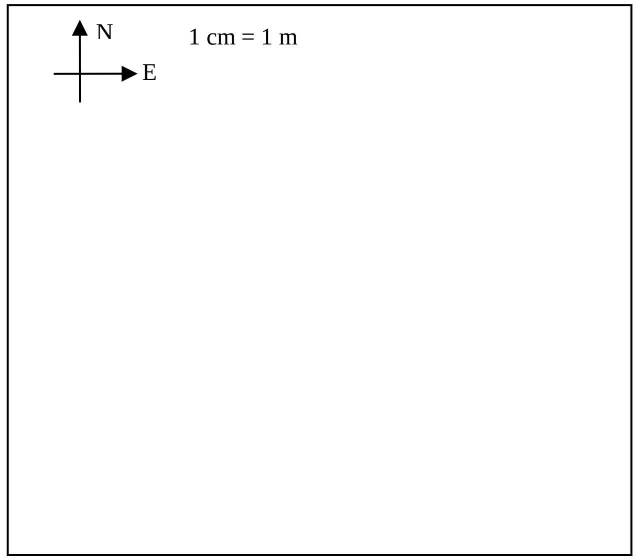
5. **Reason.** Albert wrote his direction for the displacement vector as [N 50^o W]. Isaac wrote his direction for the same vector as [W40^o N]. Who has recorded the direction correctly? (Don't worry about small errors due to the measurements.)

6. **Represent**. On your coordinate systems above, draw a vector that represents a displacement $\Delta\vec{d}_2 = 12$ m [S 30^o W] and a velocity $\vec{v}_2 = 17.5$ km/h [N60^{o}E] (Don't worry if it leaves the box!)

7. **Interpret.** How does the magnitude of the two displacement vectors compare? Which velocity is slower? How can you tell?

B: Let’s Take a Walk

You and a friend take a stroll through a forest. You travel 7 m [E 35^o S] and then 5 m [W 20^o S].



1. **Represent.** Draw the two displacement vectors one after the other (tip to tail).

2. **Interpret.** After travelling through the two displacements, how far are you from your starting point? In what direction? Explain how you find these quantities from your diagram.

3. **Represent.** Draw a single vector arrow which represents the total displacement for your friend’s entire trip. Use a double line for this vector.

4. **Represent.** Label the three vectors in your diagram as $\Delta\vec{d}_1,\ \Delta\vec{d}_{2,}$ *and* $\Delta\vec{d}_t$ following the example described above including the magnitude, unit and direction.

The vector diagram we have drawn above is actually a picture of an equation where two quantities are added in a new and special way are equal to a third quantity, the total: $\Delta\vec{d}_1 + \Delta\vec{d}_2 = \Delta\vec{d}_t$. Technically, we should use a different symbol than “+” in this equation since this is a new kind of math operation called **vector addition** that works in a different way than traditional addition. But out of convenience we just write “+” and must remember that the addition of vectors is special. Note that whenever vectors are added together to give a total, they are drawn *tip to tail*, just as you have done above.

C: Adding Vectors

A vector is a different kind of mathematical quantity than a regular number (a scalar). It behaves differently when we do math with it. When our vectors point do not point along a straight line, we must be especially careful to remember these difference and our new techniques.

1. **Reason.** Marie says, “Why can’t we just add up the number part in the previous question? Should the displacement be 7 + 5 = 12 m?” Help Marie understand what she has overlooked.

2. **Reason.** Suppose you walk for 1 m and then for another 2 m. You get to choose the directions of these two displacements. What is the smallest total displacement that could result? What is the largest? Draw a vector diagram illustrating each.

3. **Summarize.** When working with vectors, does 1 + 2 always equal 3? Explain.

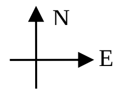
SPH3U: Two-Dimensional Motion

Recorder: ___________________
Manager: ___________________
Speaker: ___________________
0 1 2 3 4 5

We now have the tools to track motion in two-dimensions! Let's take a trip.

A: Vectors vs. Scalars, Fight!

1. **Represent.** You are about to enter the classroom when you realize you forgot your homework in your locker. You travel 12 m [S], 7 m [W], and then 3 m [N] to get to your locker. Draw this series of displacements and find your total displacement from the classroom door. Label these quantities in your vector diagram.
You do not need tostart your vector diagram on your coordiante system. Choose a starting point such that your entire trip can be represented in the space given.



1 cm = 3 m

2. **Reason.** Once you reach your locker, how far are you from the classroom door? How far did you travel from the classroom door to your locker? Why are these quantities different?

3. **Reason.** There is only one situation in which the magnitude of your displacement will be the same as the distance you travel. Explain what situation this might be.

4. **Reason.** You time your trip from the classroom to your locker. You calculate the ratio of your displacement over your time, what quantity have you found? Explain and be specific!

The ideas behind average velocity work for any kind of motion: 1-D, 2-D and beyond. The average velocity is always the ratio of the displacement divided by the time interval: $\vec{v} = \Delta\vec{d}/\Delta t$. Now that we are analysing motion in two dimensions, we have new techniques to find and describe the vectors in this equation.

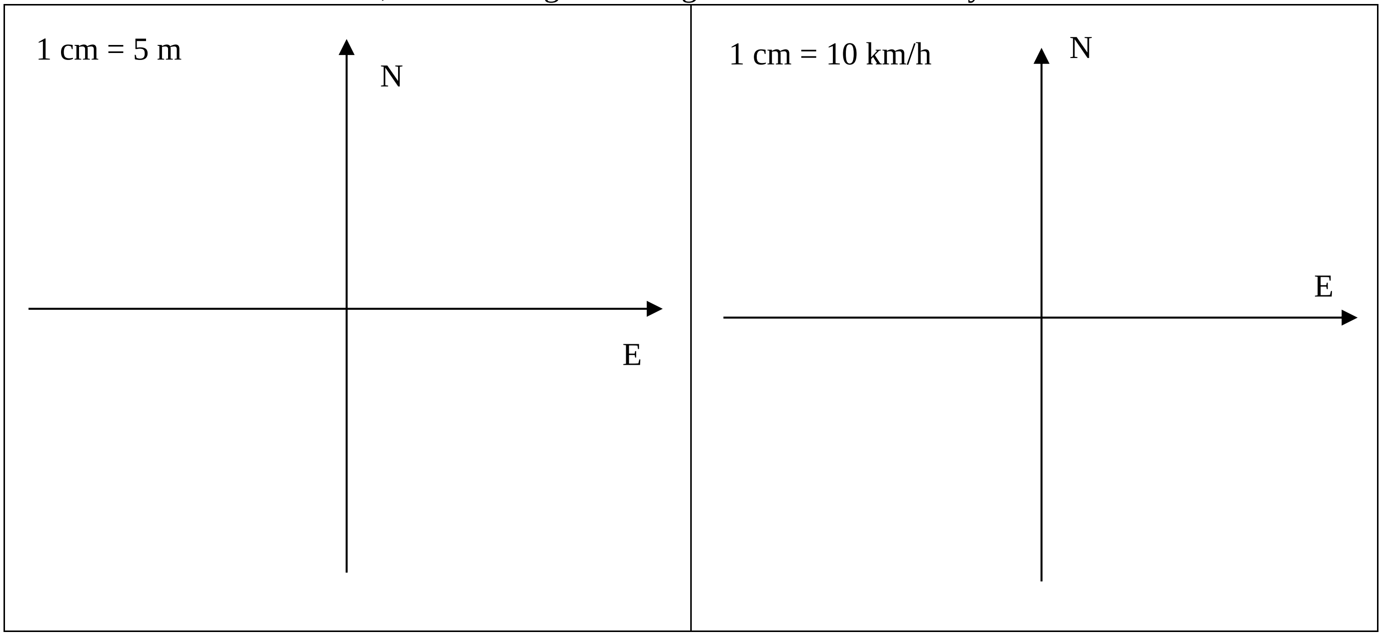
5. **Calculate.** It took you 23 s to travel to your locker. What is your average velocity for your trip from the classroom to your locker? Be sure to use your square bracket vector notation!

6. **Reason.** You now have your homework and continue moving. When will your total displacement be zero? What is your total distance traveled at that same time?

7. **Reason.** When you return to the classroom your teacher impatiently informs you that it took 47 s for you to return. Compare the magnitude of your average velocity with your average speed for the whole trip.

SPH3U: Vector Practice

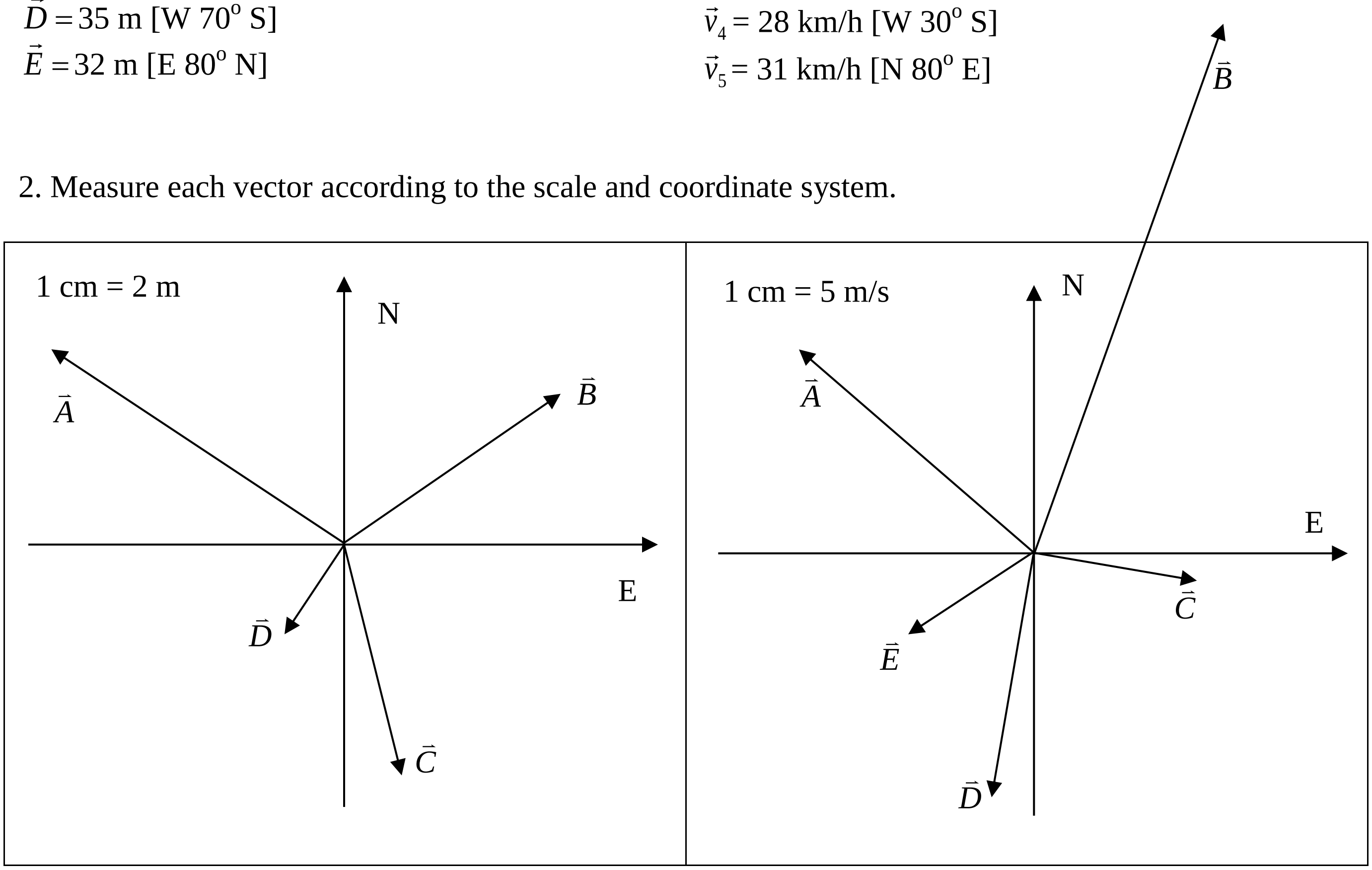
1. Draw each vector to scale, each starting at the origin of the coordinate system.



$\vec{A} = 10$ m [E]
$\vec{B} = 25$ m [N 30^{o}W]
$\vec{C} = 42$ m [S 10^o E]
$\vec{D} = 35$ m [W 70^o S]
$\vec{E} = 32$ m [E 80^o N]

$\vec{v}_1 = 15$ km/h [S]
$\vec{v}_2 = 20$ km/h [N 45^o W]
$\vec{v}_3 = 50$ km/h [E 15^o N]
$\vec{v}_4 = 28$ km/h [W 30^o S]
$\vec{v}_5 = 31$ km/h [N 80^o E]

2. Measure each vector according to the scale and coordinate system.



1. Find the total displacement for each trip by adding the two displacement vectors together tip-to-tail. Complete the chart assuming the whole trip took 2.0 h. Use the scale 1 cm = 10 km. Don't worry if your vectors go outside the boxes!

Vectors	Diagram	Total Displ.	Total Dist.	Avg. Velocity	Avg. Speed
40 km [E] 30 km [E]					
40 km [E] 30 km [N]					
40 km [E] 30 km [W]					
40 km [E] 30 km [E30^{o}N]					
40 km [E] 30 km [S50^{o}W]					

SPH3U: The Vector Adventure

Mission
Your mission, should you choose to accept it (and you do), is to find the displacement and time for a trip from the threshold of the classroom to each location marked on the map.

Proof
As proof **you** must construct a scale diagram for each path leading to the goal.

- Draw all paths on one sheet of graph paper, starting at the classroom doors.
- Make sure your final destination will fit on the paper.
- Clearly show your coordinate system and scale (in metres).
- Each vector in the path must be accurately labeled.
- The total displacement should be drawn in a different colour, measured carefully and labeled.
- Time your walk back to the start.
- Create a chart on your diagram giving the total distance, displacement, time, average speed and average velocity.

Destination	Δd	$\Delta\vec{d}$	Δt	v_{avg}	$\vec{v}_{avg}$

Tricks

- To simplify distance measurements, you may use the floor tiles as a standard unit. Each tile is 1.10 m square. Make sure you convert your measurements to metres when constructing your diagrams and labeling them.
- You may assume that corridor 6 is aligned due North. Sometimes there is more than one way to reach a certain destination, one being easy the other hard. Choose the easy one.
- This mission is all about accuracy. Make careful measurements. Draw your scale diagrams accurately.

The options for your destinations are below. Each group must have a different location.

A. Boys potty in corridor 3
B. Girls potty in corridor 5
C. Co-op office in corridor 1
D. Boys potty in corridor 9
E. Center of the intersection of corridor 4 & 5
F. Center of the intersection of corridor 9 & 4
G. Main office
H. Geography office

Forest Heights C.I. Floorplan – 1st Floor