Gr. 11 Physics Syllabus

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.

	Lesson	Homework
1	Welcome to Physics Course Introduction Group Work	Log on to course website. Homework sheet: *How Groups Work*
2	Group Work, *continued* How to Answer a Question	Handbook: *Learning About Your Brain*
3	Measurement	Handbook: *Measurement and Numbers*, pg. 10

Motion

1	Introduction to Motion	
2	Introduction to Motion, *continued*	Handbook: *Constant Speed*
3	Interpreting Position Graphs	Handbook: *Position Graphs*
4	Defining Velocity	Handbook: *Defining Velocity*
5	Velocity-Time Graphs	Handbook: *Velocity Graphs*
6	Conversions	Handbook: *Conversions*
7	Problem Solving	Handbook: *Problems Unsolved*
8	Changing Velocity	Handbook: *Representations of Motion*
9	Changing Velocity, *continued*	Handbook: *Changing Velocity*
10	Quiz: Representations of Motion The Idea of Acceleration	
11	Calculating Acceleration	Handbook: Finish investigation problems
12	Speeding Up or Slowing Down?	Handbook: *Speeding Up / Slowing Down*
13	Area and Displacement	Handbook: Finish investigation problems
14	Problem Solving Quiz	
15	The BIG Five	Handbook: Finish investigation problems
16	Review	
17	Test	

Forces

1	Interactions and Forces	Handbook: *Interactions*
2	What is the Effect of a Force?	
3	The Force-Motion Catalogue	Handbook: *The Net Force*
4	The Change of Force Principle	Handbook: *The Force-Change Principle*
5	The Force of Gravity Quiz: 1st Law + Net Force	Handbook: *Force of Gravity Homework*
6	Normal Force	Handbook: *Normal Forces Homework*
7	Force, Mass and Motion	
8	Force, Mass and Motion, *continued*	Handbook: *Force, Mass and Motion Homework*
9	Newton's Second Law Problem Solving	Problems: finish handbook questions
10	Freefall	
11	Freefall Acceleration	Handbook: *Freefalling*
12	Interaction Forces	
13	Newton's 3rd law	Handbook: *Newton's Third Law Homework*
14	Friction	
15	Friction	Problem: The Kobe question (E#8) on a solution sheet.
16	Review	
17	Test	

Energy

1	Tracking Energy – part 1	
2	Tracking Energy – part 2	Handbook: *Tracking Energy Homework*
3	Doing Work!	Handbook: *Doing Work Homework*
4	Measuring Energy	Handbook: *Measuring Energy Homework*

5	Changes in Gravitational Energy	Handbook: *Changes in Gravitational Energy*
6	The Conservation of Energy	Handbook: *Conservation of Energy Homework*
7	Power	Handbook: *C:He's Got the Power*
8	Energy Challenge	Handbook: *Energy Challenge*
9	Quiz on Energy	
10-15	Green Vehicle Project	

Electricity and Magnetism

1	The Flow of Electricity	Handbook: *The Flow of Electricity*
2	Models of Current Flow	Handbook: *Electric Circuits and Voltage Homework*
3	Electric Energy	Handbook: *Electric Energy*
4	Current and Voltage Laws	Handbook: *Current and Voltage Laws*
5	Resistance and Ohm's Law	Handbook: Resistance and *Ohm's Law*
6	Equivalent Resistance	Handbook: *Equivalent Resistance Homework*
7	Circuit Analysis	Handbook: Complete lesson problems
8	Electricity Quiz	
9	Magnetic Interactions	Handbook: *Magnetic Interactions Homework*
10	Electromagnetism	Handbook: *Electromagnetism Homework*
11	The Domain Theory of Magnetism	
12	The Strong Field Mystery	
13	The Magnetic Field of Loops and Coils	Handbook: *Loops and Coils Homework*
14	The Motor Principle	Handbook: *Motor Principle Homework*
15	Quiz on magnetism, start waves	

Waves and Sound

1	Good Vibrations	
2	Good Vibrations, *continued*	Handbook: *Good Vibrations Homework*
3	Making Waves	Handbook: *Making Waves Homework*
4	Interference	Handbook: *Interference Homework*
5	The Speed of Waves	Handbook: *Speed of Waves Homework*
6	Standing Waves	Handbook: *Standing Waves Homework*
7	Resonance	Handbook: *Resonance Homework*
8	Sound Waves	Handbook: *Sound Waves Homework*
9	The Propagation of Sound	Handbook: *Propagation of Sound Homework*
10	Resonance in Air Columns	Handbook: *Resonance in Air Columns Homework*
11	Resonance in Air Columns, *continued*	

Test Preparation Strategies

Warning! 90% of preparing for a test is the work you do every day in class and at home. "Studying" for a test the night before or even for a few days before only refreshes your memory – it won't build your understanding or skills by any great amount. Only long-term, careful practice builds them. In our physics course, we test for deep understanding and fluent skills.

(1) **Focus.** Start your test preparation by reviewing each lesson and focusing on the key ideas (often found in handy boxes!)
(2) **Explain.** Explain the key ideas to an imaginary friend by referring to a concrete example (don't just recite a definition).
(3) **Apply.** Prove to yourself that you can apply (use) the key ideas. Find questions from the homework or the investigations that use the ideas. Repeat steps 1-3 for each lesson of the unit.
(4) **Test.** Create a practice test based on questions from the investigations or the homework of the whole unit. Give yourself a time limit. Do not look at your notes, except for a list of equations. Complete the test.
(5) **Evaluate.** Based on your practice test, identify any ideas or skills that you need to improve.
(6=1) **Focus.** Repeat this process with a focus on the areas that need improvement.

Course Website

We now use Google classroom for the grade 11 physics course. Login into Google Classroom with your TDSB account: firstname.lastname@student.tdsb.on.ca

Write down the class code here:

See your teacher to reset your password if needed. Your new password will be SSSSDDMM@Tdsb, where SSSS is first four digit of your student ID, DD is your birth day, MM is birth month.

References

Many excellent resources were adapted to develop the physics lessons in this document. Many other resources inspired ideas here and there. Listing them all would take pages, but here are a few of the most influential ones:

Laws, Priscilla W., and Robert J. Boyle. *Workshop physics activity guide*. New York: Wiley, 1997.

McDermott, Lillian C. *Physics by Inquiry*, Wiley-VCH, August 1995.

Van Heuvelen, Alan, and Eugenia Etkina. *The physics active learning guide*. Pearson/Addison-Wesley, 2006.

O'Kuma, Thomas L., David P. Maloney, and Curtis J. Hieggelke, eds. *Ranking task exercises in physics*. Vol. 26. Upper Saddle River, NJ: Prentice Hall, 2000.

Etkina, E. *Physics Union Mathematics*. http://pum.rutgers.edu/

Knight, Randall D., and Juan R. Burciaga. "Five easy lessons: Strategies for successful physics teaching." *American Journal of Physics* 72.3 (2004): 414-414.

Redish, Edward F., and Juan R. Burciaga. "Teaching Physics with the Physics Suite." *American Journal of Physics* 72.3 (2004): 414-414.

Laws, Priscilla W., et al. *Understanding physics*. New York, NY, USA: Wiley, 2004.

Knight, Randall, and R. Knight. *Physics for Scientists and Engineers: A Strategic Approach with Modern Physics [and Mastering Physics TM]*. Pearson Educaiton., 2007.

Arons, Arnold. *A guide to Introductory Physics Teaching*. New York, NY, USA: Wiley, 1990.

And many, many individual research articles that can be found at: http://journals.aps.org/prstper/

SPH3U: Grade 11 Physics
University Preparation

An Inquiry-Based Course
Welcome to the wonderful world of physics! SPH3U is an introduction to the world of physics and a prerequisite for the grade 12 course, SPH4U. This course is designed according to the principles of Physics Education Research which clearly demonstrate the power of learning through inquiry in a collaborative group format. Major Canadian and American universities (U of T, McGill, McMaster, MIT, Harvard, Stanford and more) are transforming their introductory physics courses by reducing or eliminating traditional lectures and replacing them with engaging activities that have a deep conceptual and practical focus.

Homework
The majority of the class time will be spent doing activities and discussing physics with your colleagues. At home you will be responsible for solving problems using our solution format. You should expect about 30 minutes of physics homework per day on average. Homework problems will be randomly submitted for assessment. Optional textbook readings, online lessons and resources are listed in the syllabus for each lesson.

Assessment and Evaluation
Due to the central role of group work in this course, the work you do in class will account for an important portion of your mark. Daily work will be randomly handed-in and assessed. To help ensure that individual students are pulling their weight in groups, there will be regular quizzes and tests. There is a final exam that covers the entire course material and a major project that will be announced halfway through the course.

Mark Breakdown
The categories of *Knowledge and Understanding* (K/U), *Thinking and Inquiry* (T/I), *Communication* (C), and *Application* (A) are a component of most of the assessments used in this course – however some focus on certain categories more than others. The basic mark breakdown for the course is 70% term work and 30% final examination. The term mark is composed as shown in the chart to the right.

K/U	28%	Tests (usually 3 tests)
T/I	14%	Daily work (7%) (3-4 collected) Regular quizzes (7%) (3-4 quizzes)
C	14%	Tests (8%) (usually 3 tests) Homework Assignments (6%) (7-10 collected)
A	14%	Project(s)

Attendance and Punctuality
Students who are absent are responsible for determining what was missed and making sure that they are caught up *before* the following class. If possible, please speak to your teacher in advance.

Missed Tests
If you miss a test you **must**:
- Let your teacher know in advance if it is due to a pre-arranged reason (i.e. appointment for surgery)
- Call in to the school so your name goes on the daily "Absent List" in the main office.
- Find your teacher immediately after setting foot in the school upon your return.
- Do not discuss the test by any means with your colleagues.
- Be prepared to write the test immediately, at your teacher's discretion.

Please Read This Document!
Please sign below signifying that you have read this course description.

_______________________________________ _____________________________________

Signature of parent, or student if 18 and over Print name

SPH3U: How Groups Work

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

A: Welcome to Your Group!

1. **Choose Roles.** Each group member will choose the role they will perform at the start of every class. Every day, you will choose a different role. Record each group member's name in the box to the right showing who is performing what role**.** If there are four people in a group, the fourth person can write their name on top of the box: that person is the motivator. **Circle your name.**

Manager*: Ask the speaker to read out loud the instructions and the following questions.*

Working well in a group is a like acting in a play: we all have roles to perform and we can learn perform them well with regular, careful practice. Most colleges, universities, and businesses consider the ability to work well in a group a top skill, so let's start practicing now! In physics class, group work encourages students to discuss and explain their ideas, which is the best way for most people to learn physics.

B: The Bouncy Ball Challenge

Each group will soon have a small bouncy ball (to be acquired later!). Your group's task is **to create a scientific model that will allow you to predict the rebound height of the ball when you are given a drop height**.

Manager: For the following question (B#1), a*sk your group members for their ideas. Always encourage many different ideas (this is important).*
Speaker: *Ask your group about their ideas for each question. You need to be able to confidently explain them to the class. At any time during a lesson, you should be ready to present your group's ideas to the class.*
Motivator*: Provide encouragement and praise for your group: use humour, keep them energized, and keep on doing this!*

1. **Design.** To create your model, you need to collect data that will help you predict the ball's rebound height if you are given any drop height. Draw a simple sketch that shows how you will collect your data. Include a few short explanations.

2. **Record.** On a whiteboard, record <u>one</u> idea that might help make your measurements and data more reliable.

Recorder: *Place the whiteboard flat on your table so everyone can see it. Record on the white board* ***only*** *what your other group members say. Write* ***large*** *so that students far away in the classroom can read it. Be* ***brief:*** *write just a few words. Use different colours where appropriate.*

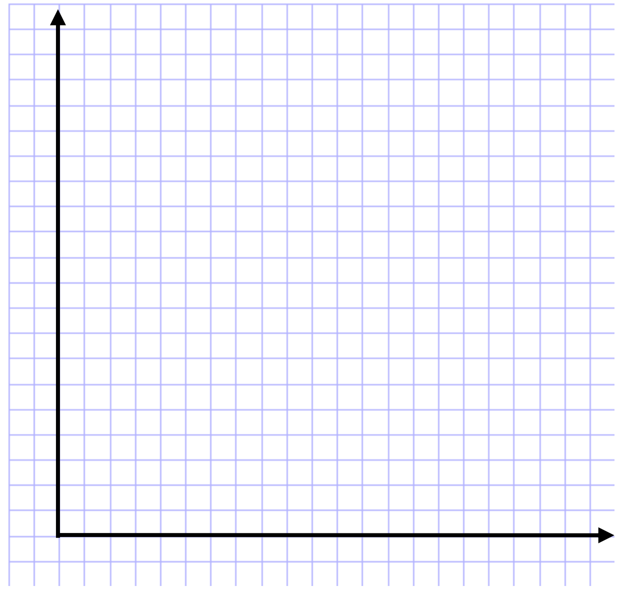
3. **Observe**. Gather the materials you will need and conduct your experiment. Label and record your results here. Make sure a person reading your results below would understand the information.

Recorder: *Check that everyone recorded the data above using labels and the appropriate units.*

In an experiment, we carefully change one quantity to see how it affects another. The quantity that we carefully change is the *independent variable*. The quantity we want to explore as a result of the changes is the *dependent variable*. Typically**,** we record the dependent variable on the vertical axis of a graph.

4. **Represent.** To help analyze the data, represent it graphically on the grid on the next page. Which quantity should be on which axis? Explain.

Scientists look for patterns in data. Does the data in your graph suggest a straight-line pattern or a smooth, curving pattern? Draw an appropriate line or curve. **Never connect the dots! That does not highlight any underlying pattern.**



5. **Analyze**. Draw a line of best fit for your data. Find the slope of your line. Show your calculation below. Record the final result on your whiteboard (don't show the math).

Recorder: *Check your group members' slope calculations.* ***Every time*** *a number is written it must have a unit, e.g.* 15 cm

6. **Interpret.** We need to decide what the slope result **means**. It is not just a number, it tells us something useful about the ball. What would be physically different about a bouncy ball that had a larger slope result? What about a smaller result? Give this quantity a name that helps us understand what it tells us about the ball. Record this name on your whiteboard.

7. **Predict.** You have created a scientific model that describes the ball's bouncy properties! Congratulations! Bring your graph to your teacher and ask for a drop height. Use the slope value from your model to predict a rebound height for your ball. Show your work here.

8. **Test.** Ask your teacher to observe the test of your prediction. A good test result should agree with your prediction to within ± 5 cm. Was your model successful? If not, what could you improve about it?

Manager: *Lead the group through the last question. Focus the group's attention on one role at a time. Encourage many ideas.*
Speaker: *Ask your group questions to help clarify the group's ideas. Imagine what questions a curious student from a non-physics class might ask about these roles. Be prepared to speak to the class about any of them.*

9. **Summarize.** In the chart below, summarize the responsibilities of each role in the group.

Manager	Recorder	Speaker

Recorder: *Clean off the whiteboard at the end of class.*

SPH3U: Homework – How Groups Work	Name:

On the course website are two videos which chronicle the exploits of a dysfunction physics group and a well-functioning physics group. Begin by viewing the video of the dysfunctional group (https://youtu.be/vgF_lmPqbOA).

A: Dysfunctional Group

1. **Observe.** Watch the video and note in the chart below any actions or behaviours of Sam, Robert or Mike that contribute to the poor functioning of the group.

Sam	Robert	Mike

2. **Reflect**. The video is something of an exaggeration, but it does help us to think about our own behaviours. Which individual(s) do you think you share the most habits with? (Of course you won't be as extreme as these guys, but maybe you have a tendency to do some of the same things? Be honest!) Explain.

3. **Reason.** Imagine you were a well-function member of this group. Describe some actions you would have taken to help the group work better (i.e. to help smooth over some of the problems you mentioned above).

B: The Well-Functioning Group

1. **Observe.** Watch the video of the functional group (https://youtu.be/xAJKxNUbjf8). Record in the chart below the positive behaviors of Sam, Robert and Mike which help the group to function well.

Sam	Robert	Mike

2. **Reflect.** Which of the behaviours that you mentioned in the previous question do you think you share with Sam, Robert or Mike? Explain.

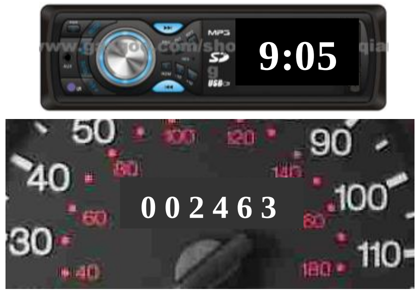
3. **Reflect.** Which of the behaviours that you noted in question B#1 would you like to encourage more of in yourself? How can you do this?

4. **Evaluate.** Use the chart on the right to evaluate the quality of the work you have done on this page. 5 = excellent, 1 = poor

Quality Work Criteria	Mark
My responses use thoughtful, complete sentences and are very easy to read.	
I took time and care with all parts.	

SPH3U: Measurement and Numbers Homework   Name:

You decide to take a trip to with a friend to watch a concert. When you begin driving, you glance at the clock in your car and at the car's odometer, which measures how far the car has traveled in kilometres. As you pull in to the concert parking lot, you look at the clock and the odometer a second time.



1. **Reason.** What is the instrumental uncertainty of the clock and the odometer?

2. **Record.** How much time did the trip take in **minutes**? How far did you travel? Record the results using measurement notation.

3. **Estimate.** What was your speed during this car ride? (don't use your calculator!) Don't change any units: use units of kilometers per minute.

4. **Calculate.** Find your speed. Carefully go through the explanation process for calculations and cross out each sub-heading that is listed for you as you complete that part. (For example: ~~Describe purpose~~)

Explanation process

Describe purpose, complete equations, substitutions with units, calculate result, final statement

5. **Interpret.** Explain what the speed result means. For example, how far does this result suggest you are traveling during every minute of the trip?

6. **Evaluate.** Do you think your interpretation of the speed result is 100% correct? Why?

7. **Evaluate.** Use the chart to the right to help evaluate the quality of your work. Give each criteria a mark out of five (5 = excellent, 1 = missing or poorly done)

Quality Work Criteria	Mark
My responses use thoughtful, complete sentences and are very easy to read.	
I carefully showed and crossed out all steps in the explanation process (Q#4).	
I wrote numbers with units and an appropriate number of significant digits.	
I took time and care with all parts.	
This work would be useful for **any** student to study from in the future.	

SPH3U: How to Answer a Question?

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

Manager: After everyone signs up for group roles today, ask them to go back to yesterday's summary of your responsibilities and review them.

Manager: Ask you group how they would like to go through the new information below. The group can choose to have the speaker read it out loud, or everyone can read it silently.

A major focus of Gr. 11 physics is the careful explanation of our observations and ideas. Every question you encounter should be carefully explained using complete sentences and correct English. Even if the question doesn't actually say "explain", you must still justify your answers and outline your reasoning.

High quality responses to any physics question must be **correct**, **clear**, **concise** and **complete**. We will routinely use these terms and the notation explained below for the evaluation of your daily written work.

Criteria	Description	Notation
Correct	The physics is correctly stated. Conclusions follow logically from the stated evidence and refer to key definitions or laws. Technical details are all present and correct.	Incorrect sections are underlined and given an "__X__". Correct ideas are checked " √ "
Clear	The explanation is precisely stated with a good choice of physics vocabulary. The explanation is straight forward with no awkward or unclear phrases. Spelling and grammar are correct.	Unclear sections are underlined with a wiggly line and given a "?" A poor word choice is indicated by a wiggly line. Spelling errors are cirlced.
Concise	There are no extraneous or distracting statements which may or may not be correct.	Phrases that are not relevant are crossed out. ~~Like this~~.
Complete	No important parts of the explanation are missing. The evidence supporting the conclusion is mentioned along with the relevant definitions or laws.	Where an explanation is missing or incomplete we will write ". . . ." or "and …" or "more …" or give a clear hint at what is missing: "force?"

Your daily work in physics will be marked based on the four C's criteria for high quality responses. An overall mark will be assigned on a scale of 0 to 5 depending on how your responses meet the four criteria according to the rubric below.

0-2 "Poor"	3 "OK"	4 "Good"	5 "Awesome!"
Responses are missing important parts, fundamentally incorrect, or challenging to understand. A "yes or no" answer is given.	Response is basically correct, but contains problems or omissions.	Response is correct. Only minor details could be improved or clarified.	Response is thoughtful, clear and complete. If another physics teacher saw it they would say, "Wow! A grade 11 student wrote this?"

A: Mark Up These Responses!

1. **Evaluate.** Below you will find five student responses to question B#6 from yesterday's activity.
   (a) Mark up each response according to the four C's criteria **using the notation shown above**.
   (b) Use this rubric below each response to evaluate it after you have marked it up. **Circle** any key words in the rubric's description to highlight you rationale and then circle the mark on the rubric.

> **6. Interpret.** We need to decide what the slope result **means**. It is not just a number; it tells us something useful about the ball. What would be different about a bouncy ball that had a larger result? What about a smaller result? Give this quantity a name that helps us understand what it tells us about the ball. Record this name on your whiteboard.

__Response1__: **It means the bounciness of the ball.**

0-2	3	4	5
Responses are missing important parts, fundamentally incorrect, or challenging to understand. A "yes or no" answer is given.	Response is basically correct, but contains problems or omissions.	Response is correct. Only minor details could be improved or clarified.	Response is thoughtful, clear and complete. If another physics teacher saw it they would say, "Wow! A grade 11 student wrote this?"

Response 2: **The interperetation of the slope of the line helps us to know how it bounces. Bigger slops means a bigger bounce. Smaller slops is less bounce.**

Response 2

0-2	3	4	5
Responses are missing important parts, fundamentally incorrect, or challenging to understand. A "yes or no" answer is given.	Response is basically correct, but contains problems or omissions.	Response is correct. Only minor details could be improved or clarified.	Response is thoughtful, clear and complete. If another physics teacher saw it they would say, "Wow! A grade 11 student wrote this?"

Response 3: **We can interpret the slope of the line to mean the "bounciness" of the ball, which compares the bounce height with the drop height. It is the bounciness of the ball depending on the drop height. A bigger value is bouncier, a smaller is less.**

Response 3

0-2	3	4	5
Responses are missing important parts, fundamentally incorrect, or challenging to understand. A "yes or no" answer is given.	Response is basically correct, but contains problems or omissions.	Response is correct. Only minor details could be improved or clarified.	Response is thoughtful, clear and complete. If another physics teacher saw it they would say, "Wow! A grade 11 student wrote this?"

Response 4: **Slope is the rebound. A larger slope value means the ball will bounce back closer to its drop height. A smaller slope value means it will bounce back to less of its drop height.**

Response 4

0-2	3	4	5
Responses are missing important parts, fundamentally incorrect, or challenging to understand. A "yes or no" answer is given.	Response is basically correct, but contains problems or omissions.	Response is correct. Only minor details could be improved or clarified.	Response is thoughtful, clear and complete. If another physics teacher saw it they would say, "Wow! A grade 11 student wrote this?"

Response 5: **We call it "rebound". It rebounds more when its bigger and it rebounds less when its smaller. It helps us to know how much rebound the ball has.**

Response 5

0-2	3	4	5
Responses are missing important parts, fundamentally incorrect, or challenging to understand. A "yes or no" answer is given.	Response is basically correct, but contains problems or omissions.	Response is correct. Only minor details could be improved or clarified.	Response is thoughtful, clear and complete. If another physics teacher saw it they would say, "Wow! A grade 11 student wrote this?"

2. **Reason.** You may have noticed that none of the responses earned a 5. Use the best ideas from the different student examples to create a 5/5 response based on the 4 C's. Call your teacher over to check your awesome response.

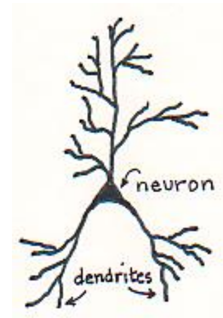
SPH3U Homework: Learning About Your Brain! Name:

How Your Brain Learns and Remembers

Part 1: What Happens Inside Your Brain When You Learn Something New?

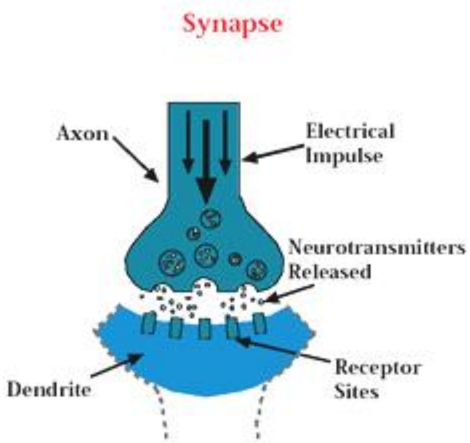
Meet Your Brain

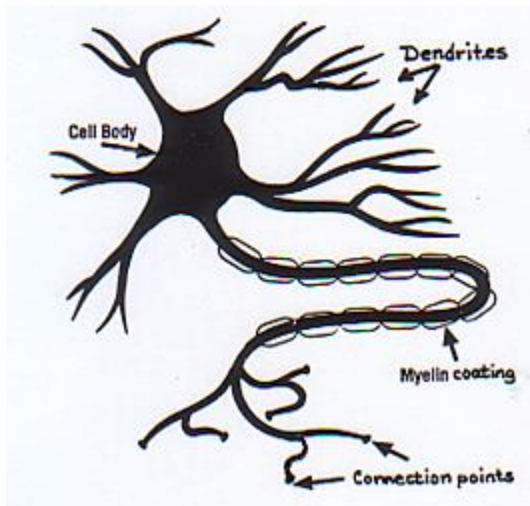
Brain cells are called neurons. You are born with at least 100 billion neurons. Dendrites (fibers) grow out of the neurons when you listen to/write about/talk about/ practice something. Learning is natural. Neurons know how to grow dendrites, just like a stomach knows how to digest food. Learning is growth of dendrites. New dendrites take time to grow; it takes a lot of practice for them to grow.

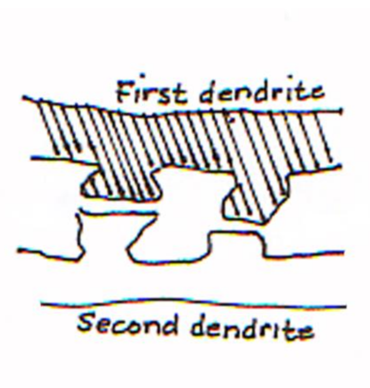


Connections Form between Neurons

When two dendrites grow close together, a contact point is formed. A small gap at the contact point is called the synapse. Messages are sent from one neuron to another as electrical signals travel across the synapse.







Practice Improves Connections

Special chemicals called neurotransmitters carry the electrical signals across the synapse. When you practice something, it gets easier for the signals to cross the synapse. That's because the contact area becomes wider and more neuro-transmitters are stored there. When you practice something, the dendrites grow thicker with a fatty coating of myelin. The thicker the dendrites, the faster the signals travel. The myelin coating also reduces interference. With enough practice, the dendrites build a double connection. Faster, stronger, double connections last a very long time. You remember what you learned!

Short-term memory is VERY short!

If you learn something new and do it only once or twice, the dendrite connection is very fragile and can disappear within hours. Within 20 minutes, you remember only 60%. Within 24 hours, you remember only 30%. But if you practice within 24 hours, and then practice again later, you remember 80%.

Make the Most of Practice Time…

You grow dendrites for exactly the same thing you are practicing. If you listen or watch while math problems are solved, you grow dendrites for listening or for watching. If you read over your notes, you build dendrites for reading. If you actually solve the problems yourself, you grow dendrites for solving.

Part 2: Brain Friendly Ways to Learn Better

A: Grow Your Intelligence

You can grow your intelligence, because your brain knows how to grow dendrites just like your stomach knows how to digest food. Think about a baby who learns to speak in its native language without any special classes or training!

B: Do Something Active to Learn

You must do something active to learn, like explaining, solving, drawing, or writing. That's because dendrites grow ONLY when you are actively doing something. No one else can grow dendrites for you!

C: Grow Off of What You Know

Dendrites cannot grow in a void. New dendrites can only grow off of what is already there. New skills must connect to, and grow off of, previously learned skills. If you do not have the necessary dendrites in place, new material will seem to go "right over your head".

D: Give It Time and Practice

Learning takes time, because it takes a lot of practice for dendrites to grow. This is why you do homework. This is why trying to cram everything into your brain the night before a test doesn't work.

E: Mistakes Are Essential

Making mistakes, and getting feedback so you can correct them, allows you to check the accuracy of the connections in your brain. Be sure to get feedback quickly so you don't practice the wrong thing and build a strong, but wrong, connection!

F: Emotions Affect Learning and Memory

Anxiety floods your body with adrenaline ("fight or flight").Adrenaline makes it hard for the neurotransmitters to carry messages across the synapses in your brain. That causes "blanking out" on a test.

G: How can emotions help you?

Endorphins make you feel calm. Your body produces endorphins when you relax, exercise, laugh, or learn new things. If you practice producing calming hormones, it will help when you are under stress.

Part 3: What Does All This Mean For Me?

Use your understanding from this article to answer the following questions. (Remember to give a 5/5 response!)

1. **Explain.** Marie says, "I listen carefully in class and everything makes sense. But when I get home and start on the homework, I am lost. What's going on?" Explain to Marie why.

2. **Explain.** Isaac says, "I attend class, do all the homework, and feel like I understand everything. Then why do I just 'blank out' on the test and can't do anything?" Help Isaac understand why.

3. **Explain.** Emmy says, "Why should I show all the steps in this homework? It's so much extra work." Respond to Emmy.

4. **Explain.** Albert says, "I've haven't done homework for a week and there's a test tomorrow, but I'll be fine if I do it all tonight." Explain why Albert is in trouble.

5. **Evaluate.** In class you learned how your written work in physics will be marked and evaluated. Use the rubric below to evaluate your responses to the homework questions above. **Circle** the mark on the rubric below and circle any key words in the rubric's description to highlight your rationale.

0-2 "Poor"	3 "OK"	4 "Good"	5 "Awesome!"
Responses are missing important parts, fundamentally incorrect, or challenging to understand. A "yes or no" answer is given.	Response is basically correct, but contains problems or omissions.	Response is correct. Only minor details could be improved or clarified.	Response is thoughtful, clear and complete. If another physics teacher saw it they would say, "Wow! A grade 11 student wrote this?"

SPH3U: Measurement and Numbers

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

Measurements are the backbone of all science. All scientific ideas and models, no matter how slick, are only as good as the measurements that support them. Without careful measurements, science is mostly guess work and hunches – suspicions and rumours!

A: The Meter Stick

Our most basic scientific tool is the meter stick. But, do you know how to use it? Please get one meter stick for your group.

1. **Describe.** Examine the markings on the meter stick. What is the size of the smallest interval **marked** on it? What fraction of a metre is this interval?

Estimating is a strategy to quickly come up with a value or result **without** doing a careful measurement or calculation. We can estimate a measurement by "eyeballing" the situation, imagining using the measuring tool, reflecting on your personal experiences, or making a skilled guess. We understand that an estimated result is not quite right, but is hopefully close enough that it helps us to think about the situation.

2. **Estimate** (*individually).* Without using the meter stick, estimate the height of your desk in units of centimetres. Do this quickly and don't worry about being "right".

3. **Measure** (*as a group).* Use the metre stick to carefully measure the height of your desk. If you can estimate a number between the smallest intervals marked on the meter stick, do so.

Significant digits are the digits in a number or measurement that are reliable or trustworthy. You would be pretty confident that the value of a significant digit was very close to the *actual value*. The *instrumental uncertainty* of a measuring device is the smallest interval **you** personally can distinguish from the device. The instrumental uncertainty gives a rough guide for deciding on the last significant digit in a measurement.

4. **Explain.** Emmy used a regular metre stick to measure the height of her desk. She says to her group, "My measurement is 75.35 cm, which has three significant digits and an uncertainty of 0.1 cm." Do you agree with Marie? Explain.

The number we read from a measurement device is the *indicated value*. When you record a measurement, **always** record it with the indicated value, the instrumental uncertainty, and a unit like this: "75.3 ± 0.1 cm". This notation means that we think the actual value is somewhere between 75.4 cm and 75.2 cm. We will call this *measurement notation*. All measurements should be recorded this way, even if we don't remind you!

5. **Interpret.** Write your height measurement using measurement notation. What range of values does your notation mean?

B: The Stopwatch

Now we will examine another common measuring device. You will need a stop watch (you can use a smartphone if you like).

1. **Reason.** Albert measures the time for Marie to walk across the classroom. His timer reads $\boxed{00{:}07.81}$. The "7" in this display reading means "7 seconds". Explain what each digit in this display reading means. (This is a review of place values for the decimal system!)

2. **Record.** Measure the time for one group member to walk the length or width of the classroom. What is the instrumental uncertainty of your stopwatch? Write the result from your stopwatch as a decimal number using measurement notation.

C: Calculating a Result

1. **Estimate** (*individually)***.** How far did your group member travel during the time interval you measured? Don't share your estimations.

2. **Measure.** Use a long measuring tape to measure the distance. Use measurement notation.

Recorder: *always check that your group continues measurement notation from today onwards!*

The *speed* of an object is the distance it travels in each unit of time: *speed = distance / time interval*. To *estimate a calculation*, change the values to simple numbers and make a quick mental calculation. Don't write down any work. Simple numbers are ones that add, subtract, multiply, or divide easily. For example, a speed calculation: 71 m ÷ 32 s = 2.219 m/s becomes 80 m ÷ 40 s = 2 m/s

3. **Estimate.** What is the speed of your group member? Don't use a calculator!

4. **Calculate.** When we perform calculations in science we always carefully explain our process. Complete any missing parts of the following steps using your group's measurements.

Explanation Process for Calculations	Student Work
(1) Describe the purpose of the math you are going to do.	*Find the walking speed of my group member.*
(2) Write the complete equation using symbols (or words).	$speed = \dfrac{distance}{time\ interval}$
(3) Substitute the values. **Always** include a unit with each number. Do not use measurement notation during calculations!	$speed = \dfrac{\qquad}{\qquad}$
(4) Calculate a result. Write the result with four significant digits. No measurement notation!	*speed* =
(5) Write a final statement that interprets your calculated result. Use three significant digits. No "±" needed!	*Our group member …*

Guidelines for Writing Numbers	
Measured numbers	• use the instrumental uncertainty to determine the last significant digit, write using measurement notation: 3.752 m ± 0.001 m • write "round" numbers according to the uncertainty: e.g. 2.000 m if the uncertainty is 0.001 m
Calculated numbers or Numbers from problems	• for <u>final statements</u>, use three significant digits to avoid too much rounding error • for <u>calculations</u>, keep an extra (a fourth) digit as a *guard digit* to help reduce the amount of rounding error. • use scientific notation **only** when it is convenient (for really small or really big) numbers • write "round" numbers in a simple way: 2 instead of 2.0 or 2.00
Estimated numbers	• estimations are always very rough results. Only use **one** significant digit.
These are very **rough** guidelines. In grade 12 we will improve on these and in university you will learn the real rules!	

Guidelines for Significant Digits	
Numbers greater than one	• Count three or four significant digits starting with the leftmost digit For example, your calculator reads: 1 056 428, you write: 1 060 000 m or 1.06×10^{6} m For example, your calculator reads: 1.001 356, you write: 1 kg or 1.00 kg
Numbers less than one	• Count three or four significant digits starting with the first non-zero digit right of the decimal point For example, your calculator reads: 0.01075, you write: 0.0108 s or 1.08×10^{-2} s

5. **Apply.** After completing a variety of calculations, your calculator displays the following results. Write the result in an appropriate way for a <u>final statement</u>. Use our new guidelines!

1.438947 m/s →	0.127485 m →	5 938 454 km →
5.00001 s →	9.46379 days →	0.000383 s →

SPH3U: Introduction to Motion

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

Welcome to the study of physics! As young scientists you will be making measurements and observations, building theories, and testing models that help us to describe how our world works.

A: The Gold Medal Race

A sixteen year-old swimmer from Toronto, Penny Oleksiak, won a gold medal in the women's 100-m freestyle swimming competition at the 2016 Rio Summer Olympics. Your teacher will show you the video of this exciting race. A team of sports scientists and coaches have helped Penny reach this extraordinary level of performance. And since Penny was only 16 years old when she won, they expect her to get even better! You are now a sports scientist and your job is to analyze Penny's race performance and help her improve. Thanks to Ryan Atkison from the Canadian Sports Institute, Ontario for the data from Penny Oleksiak's race.

1. **Describe.** Watch the video of her gold-medal winning race. After watching, Isaac says, "I want to make some distance and time measurements for her motion, but I don't know how. Her arms are moving, her legs are moving … it all seems very complicated!" Are there any *simple* measurements you could help Isaac make? Describe those measurements.

Our world is too complex for any one person to understand everything: there is just too much going on! To deal with this, scientists make *models* that are simplified scientific pictures of a part of our complex world. Every model is built out of assumptions. A *system* is an object or group of objects that we want to study. An *assumption* is a statement about the system that is not quite 100% correct, but is probably pretty close. A *reliable* assumption is one that helps us create a model that will make predictions about the system that closely match our measurements.

2. **Explain.** Albert says, "I have an idea to simplify things. Let's assume Penny is just a blob moving through the water. No arms, no legs." In what ways is Albert's idea crazy? In what ways is it both reasonable and helpful?

It is often helpful to use the *point particle assumption* when we create a scientific model. With this assumption, we model the system as a small blob of matter. This is a reliable assumption if the details of the object's size or its shape don't have a noticeable effect on the predictions of the model.

3. **Describe.** Watch the video again. Discuss how she swims or moves differently during different parts of the race. Break up the race into different intervals where she is swimming or moving differently. Name and describe these intervals

Interval	Description

A scientific model is more reliable (it will give better predictions) when it focuses on a specific interval of time.

4. **Reason.** During which interval of the race would it be easiest to make distance, time, or speed measurements? Why?

5. **Reason.** As a sport scientist, you want to focus your attention on the longest interval of Penny's race. You are concerned that she might be speeding up or slowing down too much during this interval. Why are you concerned?

6. **Reason.** How could you use distance and time measurements to verify whether Penny is moving at steady rate?

7. **Define.** *(as a class)* We need a definition that will allow us to test whether Penny, or any other object, moves with a constant speed.

Definition: Constant Speed

8. **Explain.** Below are two sets of data from two different swimming races. Use our new definition to *explain* which set is an example of constant speed. (One of these is from Penny's race!)

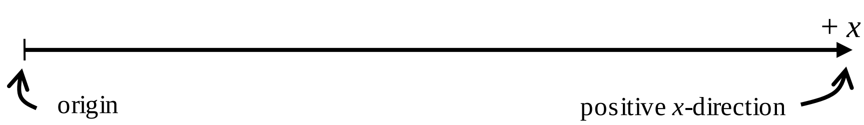
Position in Pool	15 m	25 m	35 m	45 m
Time	6.52 s	11.83 s	17.10 s	22.69 s

Position in Pool	15 m	25 m	35 m	45 m
Time	6.52 s	11.83 s	17.14 s	22.45 s

B: Testing a Claim – Constant Speed

It's time to test your understanding and an advertising claim. A motorized car, which we affectionately call the physics buggy, is sold with this description: "Equally appealing to students of all ages, this simple but powerful toy provides a visible source of uniform speed." Your task is to design an experiment that will test the claim that the toy moves with a *constant* speed.

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 what direction it is in. One direction along the line is chosen to be the positive *x*-direction and the other negative. This choice is the *sign convention*. Choose your sign convention such that the position measurements you make today will be positive.



1. **Plan.** Your group will use one physics buggy, a large measuring tape (share if necessary) and a stopwatch (or your smartphone with lap timer!).
   (a) Describe a simple experiment using **position** and **time** measurements that will allow you to decide whether the buggy moves with a constant speed.
   (b) Draw a simple picture of the experiment, including the origin, and illustrate the quantities you will measure.

***** *Check your plan with your teacher****

2. **Measure.** Find your equipment and conduct your experiment. Record your data below. Record your buggy number:__________. Note: we would like to use the time values for the buggy to travel from the **origin** to each position.

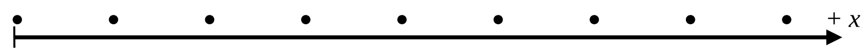
Position, *x* (m)								
Time, *t* (s)								

3. **Reason.** When you made your position measurements, what do you think **your** instrumental uncertainty was? What about your time measurements? Write down one sample measurement for each using measurement notation.

4. **Reason.** Is the speed of your buggy constant? Describe how you can decide just by looking at the measurements in your chart (remember that there are uncertainties!).

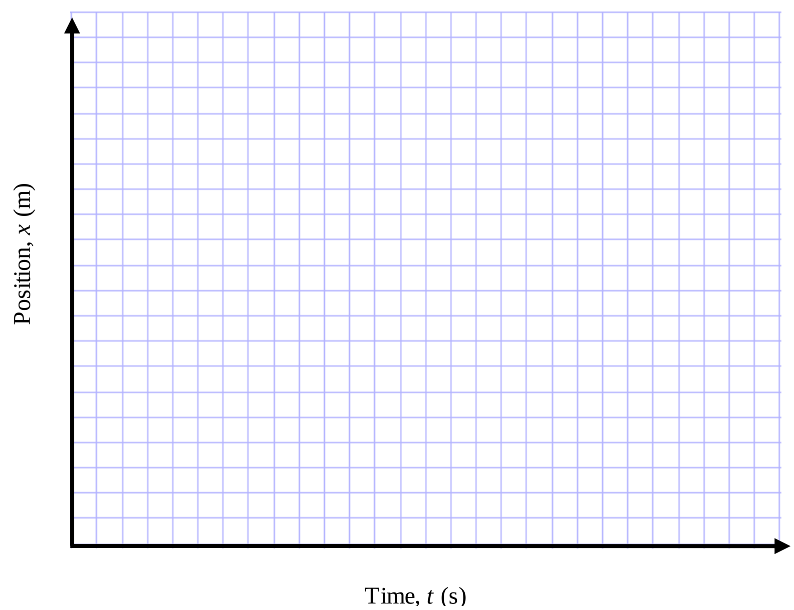
A *motion diagram* is a sequence of dots that represents the motion of an object. Imagine that the object produces dots while it moves after equal intervals of time. We draw these dots along an axis that shows the positive direction and use a small vertical line to indicate the origin. The scale of your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

5. **Interpret.** Below is a motion diagram for one student's buggy. Explain how you can tell whether the speed of this buggy was constant.



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, symbol 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 uncertainties that 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 data points. As a result, we **never** connect the dots in our graphs of data.



6. **Represent.** We want to look for patterns in the position of the buggy. Plot your data on a graph with position on the vertical axis.

7. **Find a pattern.** To create a model of the motion of the buggy, we need to look for a pattern in the data. Do you believe your data is best modelled by a curving pattern or a straight-line pattern? How well does your data fit a straight-line pattern?

8. **Reason.** Imagine an experiment with a second buggy that produces a similar graph, but with a steeper line of best fit. What is different about the movement of the second buggy? Explain.

9. **Represent and Calculate.** You are familiar with the expression for slope from your math class. Replace the math class symbols with physics symbols from this graph. For example, on this graph there are no "*y*" symbols, the *x*-axis position is on the vertical axis instead. Use the physics symbol "*v*" to replace the math symbol "*m*". Next, substitute the values from the graph <u>including their units</u>. Compute the final result.

math class expression: $m = \frac{y_2 - y_1}{x_2 - x_1}$ physics graph expression:

10. **Interpret.** What does the slope of your line tells us about the motion of the buggy? For example, what does the buggy do every second?

The slope of a position graph gives the object's *velocity*. In the study of physics, velocity has a very special meaning that makes it different from speed.

11. **Evaluate.** Based on your experimental results how well do the advertised claims for the buggy hold up?

12. **Predict and Test.** Use your model (the slope result) to predict how much time it will take your buggy to travel 2.15 m. Follow the explanation process below to show your work.

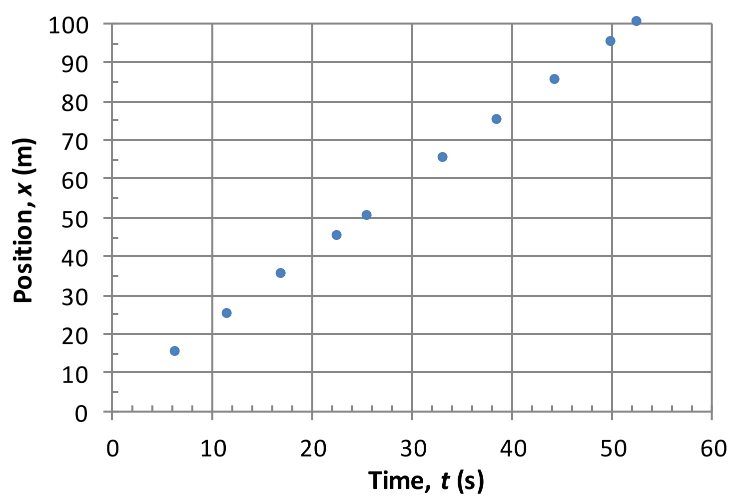
Explanation Process for Calculations	**Your Work**
(1) Describe the purpose of the math you are going to do.	
(2) Write the complete equation using symbols (or words).	
(3) Substitute the values. Always include a unit with each number. Do not use measurement notation for calculations.	
(4) Calculate a result. Write the result with four significant digits.	
(5) Write a final statement that interprets your calculated result. Use three significant digits.	

*** *Set up your buggy and call your teacher over to test your prediction.* ***

C: Penny's Gold Medal Race

Now back to our regularly scheduled program. The graph below shows the position and time data for Penny during her gold-medal race. Note that the data begins a short while after the start of the race.

1. **Interpret.** According to the data in the graph, is her speed constant? Explain how you decide.



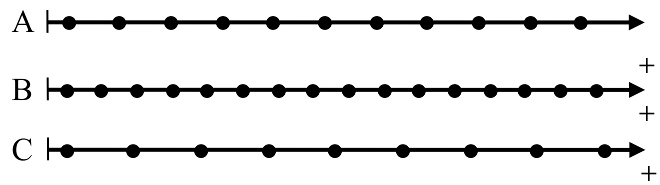
2. **Find a Pattern.** Draw a line of best fit that matches her data. Use physics symbols to construct an expression for the slope of the graph. Use this to calculate her velocity.

3. **Summarize.** In how many different ways was motion represented in this investigation? Explain.

SPH3U Homework: Constant Speed Name:

1. The image below shows the International Space Station as it travels between the moon and Earth on February 4, 2017, as photographed by astral photographer Thierry Legault. The camera took photos after equal intervals of time. Is the speed of the ISS constant or changing? Explain.

2. Three different physics buggies produce the motion diagrams shown to the right.
   (a) Reason. Rank the speed of the three buggies from fastest to slowest. Explain your reasoning.



3. **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	
Position (cm)	Time (s)	Position (cm)	Time (s)
0	0	0	0
15	1	2	5
30	2	6	10
45	3	12	15
60	4	20	20

4. Canadian swimmer Penny Oleksiak completed the first 50 m of her gold medal race in a time of 25.7 s.
   (a) **Estimate.** Without using a calculator, estimate her speed during the first 50 m of her race. This time, please show your thinking.

   (b) **Solve.** Find Penny's speed. Carefully go through the explanation process for calculations and cross out each sub-heading when you have completed that part of the process. (For example: ~~Describe purpose~~, ~~complete equations~~, ...)

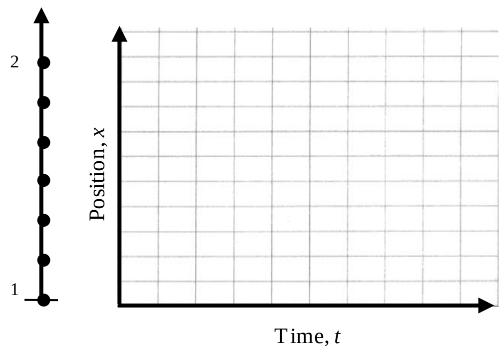
Explanation process

Describe purpose, complete equations, substitutions with units, calculate result, final statement

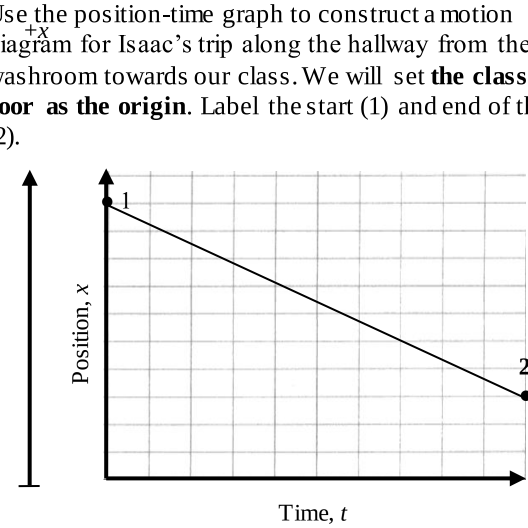
Quality Work Criteria	**Mark /5**
My responses use thoughtful, complete sentences and are very easy to read.	
I carefully showed and crossed out all steps in the explanation process (Q#4).	
I wrote numbers with units and an appropriate number of significant digits.	
I took time and care with all parts.	
This work would be useful for **any** student to study from in the future.	

SPH3U Homework: Position Graphs Name:

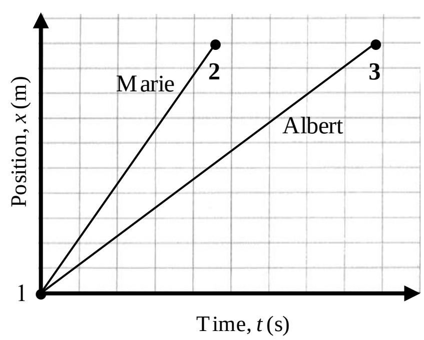
1. Emmy walks along an aisle in our physics classroom. A motion diagram shows her changing position. Two events, her starting position (1) and her final position (2) are labeled. Use the motion diagram sketch the position graph. (A sketch doesn't worry about exact values.)



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.
   (a) 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 or 3). Hint: think about their initial and final positions!



Pretend you are talking to a friend who has **never** seen a position graph before. **Explain** to your friend the answer the following questions.

(b) Who leaves the starting point first?

(c) Who travels faster?

(d) Who reaches the cafeteria first?

Quality Work Criteria	Mark /5
My responses use thoughtful, complete sentences and are very easy to read.	
My graphs are carefully sketched and use event numbers	
My motions diagrams are neat and include event numbers	
I took time and care with all parts.	
This work would be useful for **any** student to study from in the future.	

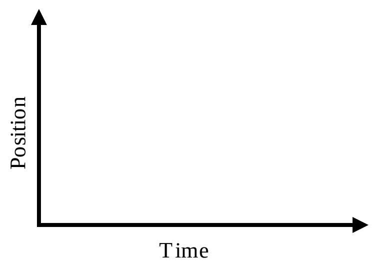
SPH3U: Interpreting Position Graphs

Today you will learn how to draw and interpret position-time graphs.

A: Interpreting Position Graphs

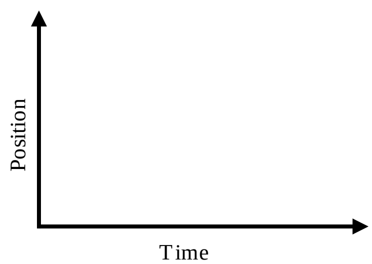
1. **Observe and Interpret** (*as a class*)**.** A student will move in front of the motion detector according to the descriptions below. The origin is at the sensor and the direction away from the sensor is chosen as the positive direction. We will call the line along which the student moves the *x*-axis. After observing each result from the computer, interpret the meaning of the graph.

(a) Standing still, close to the sensor



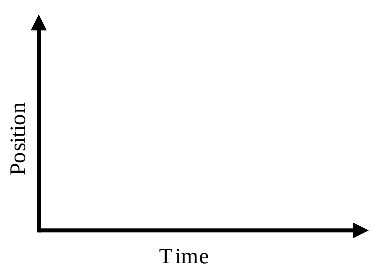
Feature	Value	Meaning
Type of graph		
Starting position		
Size of slope		

(b) Standing still, far from the sensor



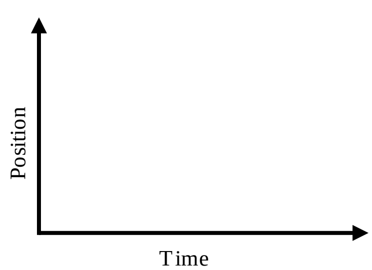
Feature	Value	Meaning
Type of graph		
Starting position		
Size of slope		

(c) Walking slowly away from the sensor at a steady rate.



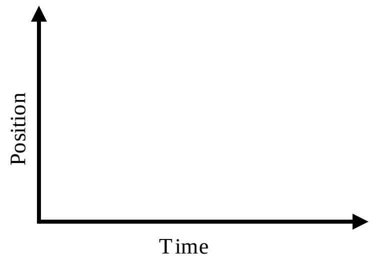
Feature	Value	Meaning
Type of graph		
Starting position		
Shape of graph		
Size of slope		
Sign of slope		

(d) Walking quickly away from the sensor at a steady rate.



Feature	Value	Meaning
Type of graph		
Starting position		
Shape of graph		
Size of slope		
Sign of slope		

(e) Walking slowly towards the sensor at a steady rate



Interpret

Feature	Value	Meaning
Type of graph		
Starting position		
Shape of graph		
Size of slope		
Sign of slope		

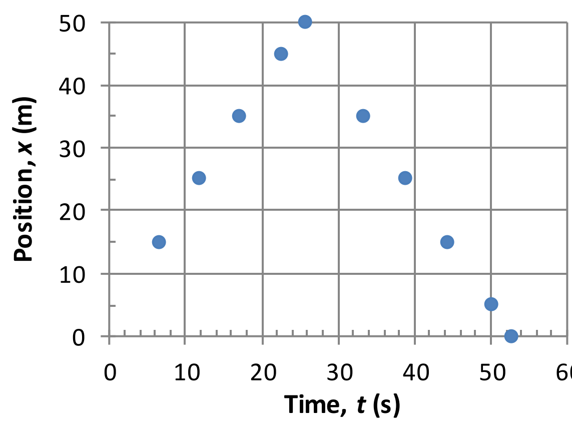
2. **Find a Pattern.** Describe the difference between the position graphs made by walking slowly and quickly.

3. **Find a Pattern.** Describe the difference between the position graphs made by walking towards and away from the sensor.

4. **Interpret.** The position graph from Penny's gold medal race actually looks more like the one to the right (we cheated a bit in the previous lesson – maybe you can figure out why). Identify the two important intervals of time in her race. Interpret the meaning of the position graph for each interval.

(1):

(2):

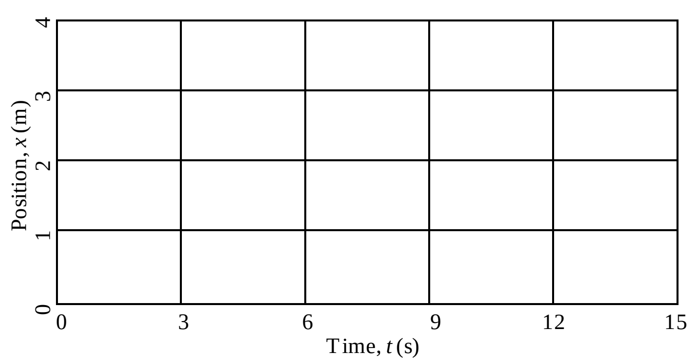


B: The Position Prediction Challenge

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.

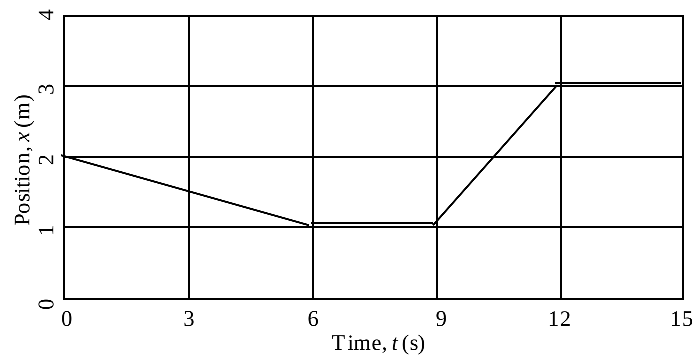
1. **Predict.** (*individually*) Use a dashed line to sketch your prediction for the position-time graph for this set of motions.



2. **Test and Explain.** Use the computer and motion detector to test your predictions. Call out instructions to your group member who is walking. Compare the computer results with your prediction. Explain any important differences between your personal prediction and the computer 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. **Interpret.** (*individually*) Study the graph to the right and write down a list of instructions that describe 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.

   0-6 seconds:

   6-9 seconds:

   9-12 seconds:

   12-15 seconds:

2. **Test.** (*as a class*) Observe the results from the computer. Explain any important differences between your predictions and the ones which worked for our "walker".

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	

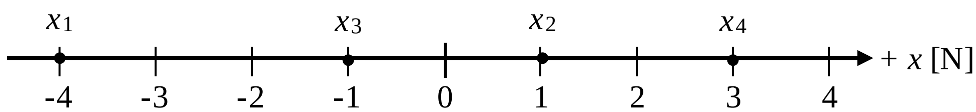
2. What, in addition to the speed, does the slope of a position-time graph tell us about the motion on an object?

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:

Albert walks along York Mills Rd. on his way to school. Four important events take place. The $+x$ direction is north.

Event 1: At 8:07 Albert leaves his home.
Event 2: At 8:28 Albert realized he has dropped his phone somewhere along the way and immediately turns around.
Event 3: At 8:43 Albert finds his phone on the ground with its screen cracked (no insurance).
Event 4: At 8:52 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	$\Delta x_{12} =$		
Direction of movement			
Time interval result	$\Delta t_{12} =$		
Velocity	$v_{12} = \frac{\Delta x_{12}}{\Delta t_{12}} =$		

3. **Reason.** Why do you think the magnitude of his velocity (the number part) is so different in each interval of his trip? What's happening in each?

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**.

Quality Work Criteria	Mark /5
My responses use thoughtful, complete sentences and are very easy to read.	
The symbols I use have proper event numbers	
I always include units with every physics quantity I write.	
I took time and care with all parts.	
This work would be useful for **any** student to study from in the future.	

SPH3U: Defining Velocity

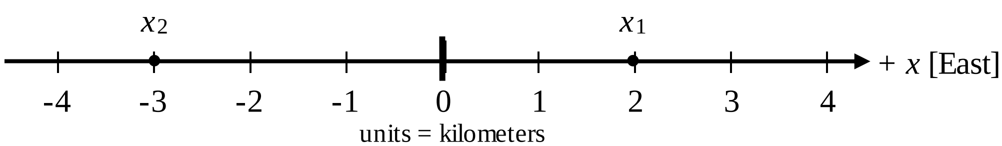
Recorder: ____________________
Manager: ____________________
Speaker: ____________________
0 1 2 3 4 5

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.

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 an event number (x_2 or t_3).

A: 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.



1. **Interpret.** What is the position of x_1 and x_2 relative to the origin? Write your answer two ways: mathematically, using a sign convention, and in words describing the direction.

   math: x_1 = 2 m $\qquad$ x_2 =

   words: x_1: 2 metres <u>east</u> of the origin $\qquad$ x_2:

2. **Reason and Interpret.** In what direction did Emmy move? Describe this mathematically and in words. Use a ruler and draw an arrow (just above the axis) from the position x_1 to x_2 to represent this change.

   math: $\qquad$ words:

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. In your work, you will always replace the subscripts "*f*" and "*i*" with the appropriate event number. The displacement can be visually represented by an arrow, called the *displacement vector*, pointing from the initial to the final position. Any quantity in physics that requires a direction to describe it is called a *vector* quantity.

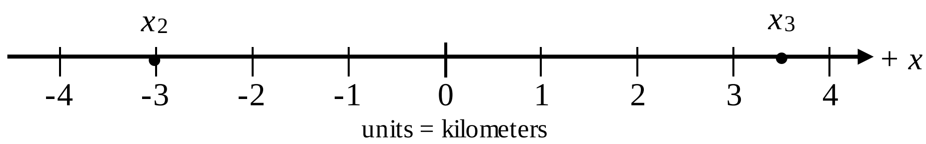
3. **Reason.** Is position a vector quantity? Explain. (Hint: to describe Emmy's position, do we need to mention a direction?)

4. **Reason.** 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 ($\Delta x = x_f - x_i$)?

5. **Calculate and Interpret.** Calculate the displacement for Emmy's trip. What is the interpretation of the result? Be sure to mention the number part and the sign of the result. A sample is provided below.

   Sample using different values: $\Delta x = x_2 - x_1$ = 6 km – (-2 km) = 8 km, Emmy moved 8 km to the east of her start

6. **Calculate and Represent.** Emmy continues her trip. Calculate the displacement for the following example. Draw a displacement vector that represents the change in position.



B: 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.

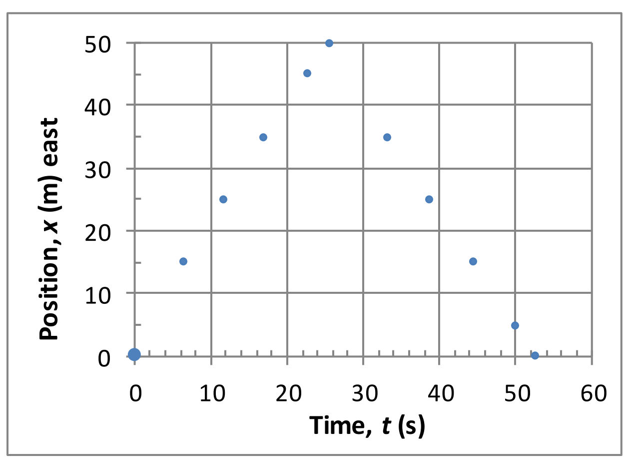
1. **Reason.** Write an algebraic equation for the velocity in terms of v, x, Δx, t and/or Δt. (Note: some of these quantities may not be necessary.)

2. **Calculate.** Consider the example with Emmy between events 1 and 2. What was her displacement? What was the interval of time? Now find her velocity. Provide an interpretation for the result (don't forget the sign!).

> 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**, 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**, the distance is the magnitude of the displacement: distance = |displacement|.

C: Velocity and Speed

Your last challenge is to find the velocity of Penny from her position-time graph. The positive direction is east. Event 1 is the start of the race, event 2 is when she turns around, and event 3 is when she touches the wall to finish.



1. **Calculate.** What is Penny's displacement during each half of the race? Use the appropriate symbols!

2. **Calculate.** Find her velocity during each half of her race.

3. **Calculate.** Find her speed during each half of the race.

SPH3U: Velocity-Time Graphs

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

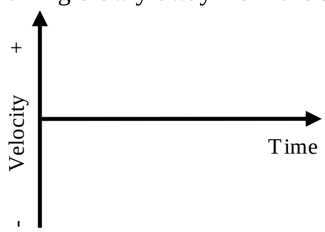
We have had a careful introduction to the idea of velocity. Now it's time to look at its graphical representation.

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.

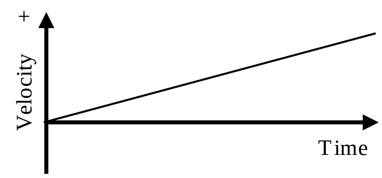
1. **Observe and Interpret.** (*as a class*) A student walks slowly away from the sensor with a constant velocity. Observe a student and record the results from the computer. You may smooth out the jiggly data from the computer.

Walking slowly away from the sensor



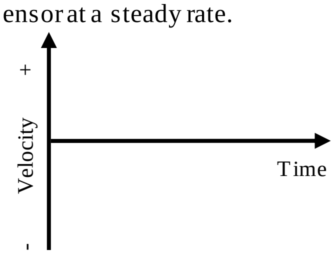
Feature	Value	Meaning
Type of graph		
Sign of velocity values		
Size of velocity values		
Slope of graph		

2. **Explain.** Isaac was asked to predict the shape of the previous velocity graph. He drew the graph to the right. Explain what he was thinking when making this prediction.



3. **Predict.** (*individually*) Sketch your prediction for the four velocity-time graphs that corresponds to each situation described in the chart below and continued on the next page. Use a dashed line for your predictions.

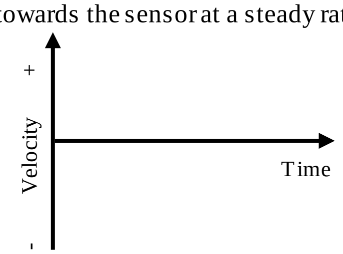
(a) Walking **quickly** away from the sensor at a steady rate.



Interpret

Feature	Value	Meaning
Type of graph		
Sign of velocity values		
Size of velocity values		
Slope of graph		

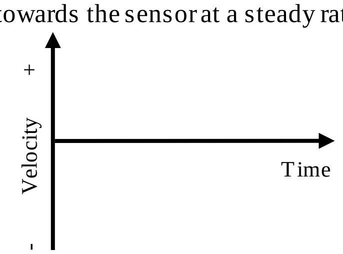
(b) Start 3 m away and walk quickly towards the sensor at a steady rate.



Interpret

Feature	Value	Meaning
Type of graph		
Sign of velocity values		
Size of velocity values		
Slope of graph		

(c) Start 3 m away and walk slowly towards the sensor at a steady rate.



Interpret

Feature	Value	Meaning
Type of graph		
Sign of velocity values		
Size of velocity values		
Slope of graph		

(d) Start 1.5 m away and walk slowly **towards** the sensor at a steady rate.

Interpret Feature	Value	Meaning
Type of graph		
Sign of velocity values		
Size of velocity values		
Slope of graph		

4. **Observe and Interpret.** (*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. Complete the interpretation part of the chart.

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

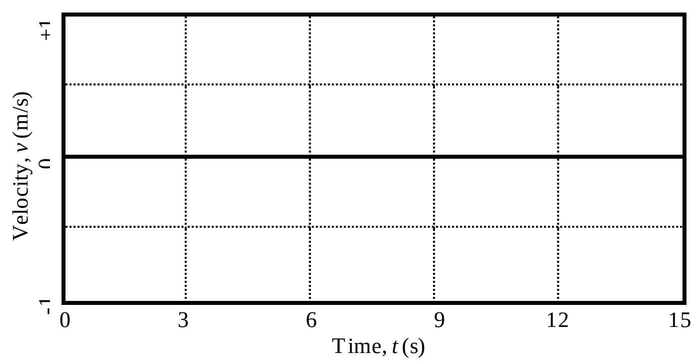
6. **Explain.** Based on your observations of the graphs above, how is direction represented on a velocity graph? (How can you tell if the object is moving in the positive or negative direction)?

7. **Explain.** If everything else is the same, what effect does the starting position have on a velocity graph?

B: The Main Event!

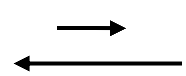
A person moves in front of a sensor. There are four events: (1) The person starts to walk slowly away from the sensor, (2) at 6 seconds the person stops, (3) at 9 seconds the person walks towards the sensor twice as fast as before, (4) at 12 seconds the person stops.

1. **Predict.** (*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.



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.

2. **Represent.** Two vector arrows are drawn below representing the velocity of the person in the graph above. One represents her velocity between moments 1 and 2, the other between moments 3 and 4. How can you tell which is which?



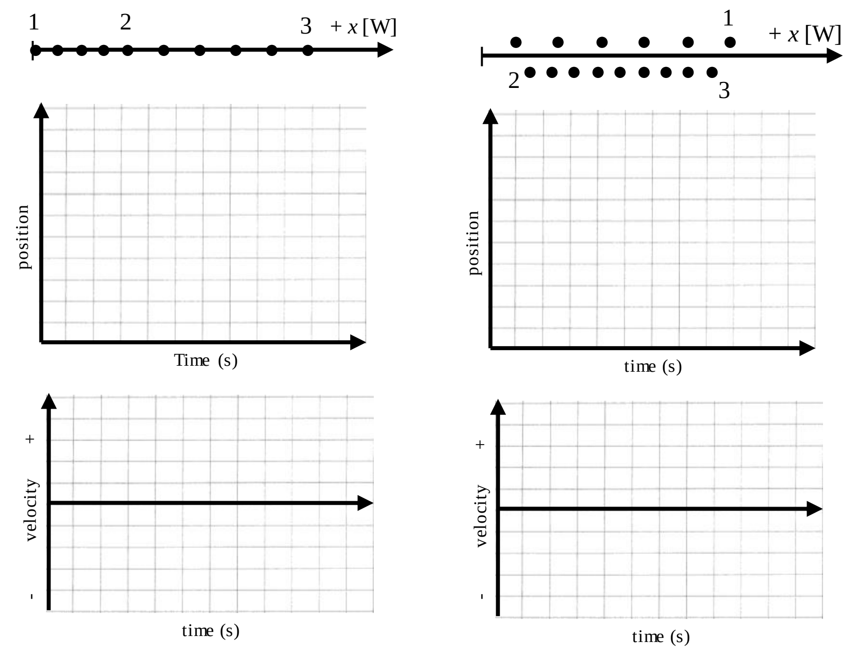
SPH3U Homework: Velocity Graphs Name:

1. Two motion diagrams track the movement of a student walking in a straight line.

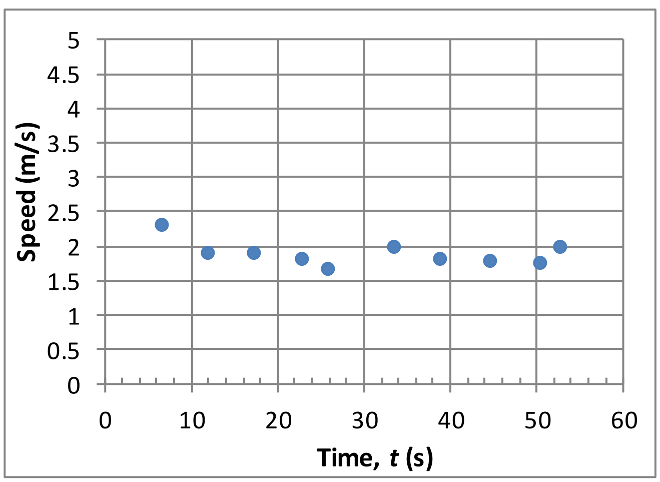
   (a) **Represent.** Sketch a position-time graph for each motion diagram. The scale along the position axis is not important. Use one grid line = 1 second for the time axis.

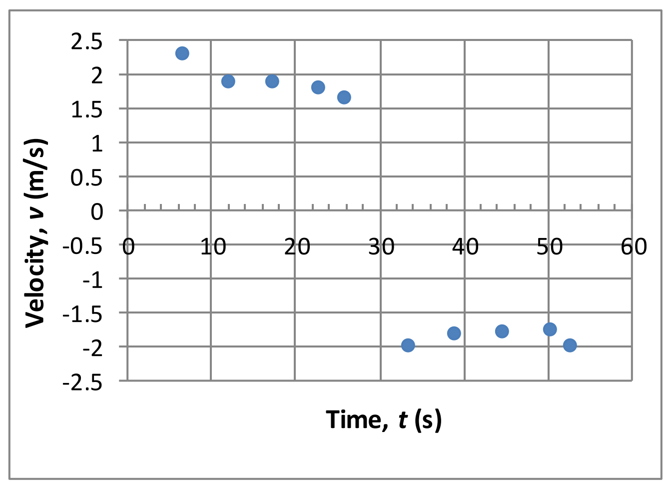
   (b) **Represent.** Sketch a velocity-time graph for each motion diagram. The scale along the velocity axis is not important.

   (c) **Interpret.** Label each section of each representation as "fast" or "slow". Is each set consistent?



2. The two graphs below show data from Penny Oleksiak's 100-m gold-medal race.





   (a) **Read.** What is Penny's speed at 22 s? What is her velocity at 22 s?

   (b) **Read.** What is Penny's speed at 33 s? What is her velocity at 33 s?

   (c) **Interpret.** Is Penny's speed constant? What about her velocity? What is your evidence?

Quality Work Criteria	Mark /5
My responses use thoughtful, complete sentences and are very easy to read.	
I took time and care with all parts.	
This work would be useful for **any** student to study from in the future.	

SPH3U Homework: Conversions

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. You convert a time interval from hours into years. Do you expect the number part to be a larger or smaller value? Explain.

Quality Work Criteria	Mark /5
My responses use thoughtful, complete sentences and are very easy to read.	
I assigned a symbol to each quantity I converted.	
I used a conversion ratio in each response.	
I carefully showed how the units divide away in each response.	
This work would be useful for **any** student to study from in the future.	

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".

$$m = 0.454\ \cancel{\text{kg}}\left(\frac{2.204\ lbs}{1.00\ \cancel{kg}}\right) = 1.00\ \text{lbs or } 1\ \text{lb} \qquad v = 65\ \frac{km}{\cancel{h}}\left(\frac{1.000\ \cancel{h}}{3600\ s}\right) = 0.0180\ \text{km/s}$$

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
Δt = 12.5 minutes $\left(\frac{\quad}{\quad}\right) =$	Δx = 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
m = 138 lbs $\left(\frac{\quad}{\quad}\right) =$	Δt = 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 Penny's finishing race speed to km/h
$v = 105\ \frac{km}{h}\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right) =$	$v = 1.98\ \frac{m}{s}\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right) =$

6. **Conversion Challenge.** Choose an interesting object that belongs to your group. Your teacher has a collection of small weights. Your challenge is to assemble a group of weights that has the same mass as your interesting object. The trick is, the collection of weights are all measured in grams, and the digital balance scale only measures in ounces! (1 pound = 16 ounces) Go! When you are ready, test your result for your teacher. A good result will agree with the original measurement to within ± 0.1 oz.

SPH3U: Modeling Solutions to Problems

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

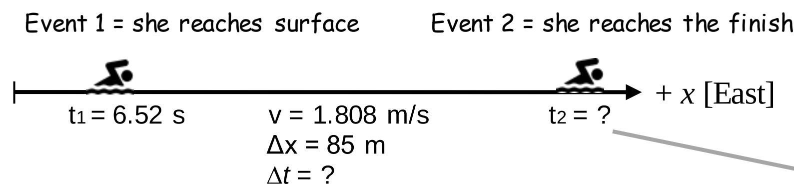
Creating a model of a system and using it to make predictions requires thought and care. In our physics course, we do this using a five-part process. Let's return to Penny`s gold-medal race and explore an example of this process.

Manager: Help your group read carefully through this example. Members can take turns reading. Don't skip anything!

Problem: Penny dives into the pool and reaches the surface after swimming under water for 6.52 s. Then she swims the remaining 85 m of the race with a steady speed of 1.808 m/s. According to this model, what is her time for the entire race?

A: Pictorial Representation (of Model)

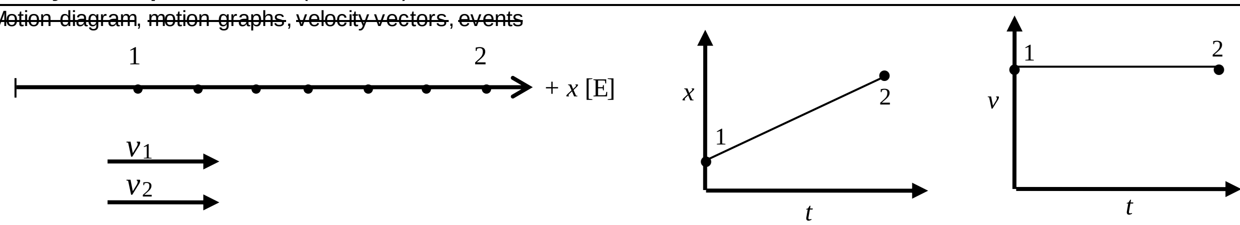
~~Sketch showing events~~, ~~describe events~~, ~~coordinate system~~, ~~label givens & unknowns with symbols~~, ~~conversions~~



Notice how each quantity has a symbol assigned to it and is attached to the appropriate part of the sketch.

B: Physics Representation (of Model)

~~Motion diagram~~, ~~motion graphs~~, ~~velocity vectors~~, ~~events~~



C: Word Representation (of Model)

~~Describe motion (no numbers)~~, ~~assumptions~~, ~~estimated result (no calculations)~~

She swims east (the positive direction). We assume Penny is a point particle and has a constant velocity. I estimate it will take her about 40 seconds to swim this distance.

D: Mathematical Representation (of Model)

~~Describe physics of steps~~, ~~complete equations~~, ~~algebraically isolate~~, ~~substitutions with units~~, ~~final statement of prediction~~

Find Penny's time to swim the remaining distance:

$v = \Delta x/\Delta t$

$\therefore \Delta t = \Delta x / v$

$= (85\ \cancel{m})/(1.808\ \cancel{m}/s) = 47.01\ s$

A good description mentions what is happening (swimming the rest of the distance), the object (Penny), and what you want to find (time) without using symbols.

Find the time for her entire race:

$\Delta t = t_2 - t_1$

$\therefore\ t_2 = t_1 + \Delta t$

$= 6.52\ s + 47.01\ s$

$= 53.53\ s$

Always isolate the unknown variable you want to find <u>before</u> you substitute any values into your equation. The list of steps under part D above is meant to be done in that order.

According to this model, I predict her race time will be 53.5 s.

A physics calculation based on a model is always a <u>prediction</u>. It tells us what the model predicts will happen. The reliability of this prediction depends on the assumptions of our model and the quality of the data.

E: Evaluation (of Prediction)

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

The size of her time is reasonable: since she is moving slowly, it will take her a while to finish the race. Time does not have a direction. Seconds are reasonable units for a short interval of time.

1. **Explain.** Why do the given and unknown quantities have these positions in the sketch of this example?

2. **Reason.** Imagine you could only see part A of the solution. How could you decide if any conversions are necessary for the solution? Explain.

3. **Describe.** Event 1 in this problem does not occur at the origin for position measurements. There are three ways that this is shown in the solution. Describe these three ways.

When we solve a problem 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. If the object is moving in the positive direction, we should see that reflected in many parts. Always check to see that the important physics ideas are properly reflected in all parts of the solution.

4. **Interpret.** Our swimmer in this problem is swimming in the positive direction. List all the ways this is shown in the solution.

5. **Interpret.** Penny swims with a constant velocity. List all the ways this is shown in the solution.

A new step in the explanation process for calculations (what we are now calling the *Mathematical Representation*) is the step "*algebraically isolate*". Before we substitute any numbers into an equation, we will isolate the unknown variable on one side of the equation using symbols. Exercise those algebra skills you have worked so hard on in math class!

6. **Explain.** Carefully show all the mathematical steps used to rearrange the velocity equation to solve for time. Make sure you show how quantities divide away. (Note: the work shown in the sample solution is all you need to do in the future)
$$v = \frac{\Delta x}{\Delta t}$$

7. **Explain.** Why can it be helpful to do the work isolating a quantity (like t_2 or Δt in the example above) using only symbols and waiting until <u>after</u> that is done before substituting any values into the equation?

8. **Evaluate.** The evaluation step is a final check to help us decide whether our model and its assumptions seem reasonable. Suppose a friend of yours came up with a final time of 8.9 s. Aside from an obvious math error, why is this result not reasonable in size?

B: Problems Unsolved

Use the new process to model a solution for 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.

1. In a record-breaking race, Usain Bolt took 50 m to reach his top speed. After that, he ran the next 150 m of his race in 13.59 s. What is his speed in km/h during the last past of his race?

The next problem involves <u>vertical</u> motion. Draw your sketch vertically and use the symbol y instead of x for the position. For this problem, choose upwards as the $+y$ direction and the ground as the origin.

2. In February 2013, a meteorite streaked through the sky over Russia. A fragment broke off 35 km above the surface of the earth and traveled downwards with a velocity of -12 000 km/h. It exploded 10 s after breaking off. How far above the earth was the meteorite when it exploded? (Hint: set y_1 = 35 km and watch for the negative velocity!)

Answers: (1) 39.7 km/h, (2) 1.67 km

Motion Solution Sheet	Name:	Problem:

A: Pictorial Representation

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

B: Physics Representation

Motion diagram, motion graphs, velocity vectors, events

C: Word Representation

Describe motion (no numbers), assumptions, estimated result (no calculations)

D: Mathematical Representation

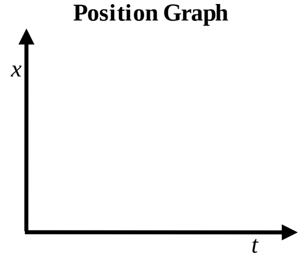
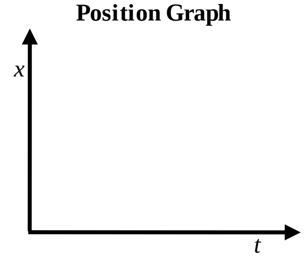
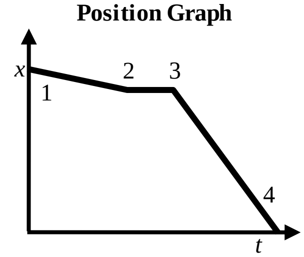
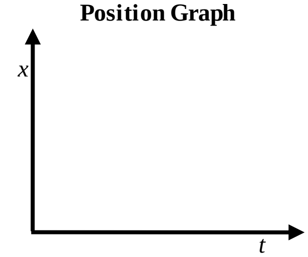
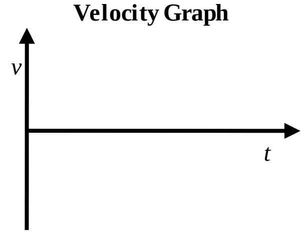
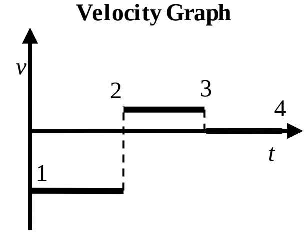
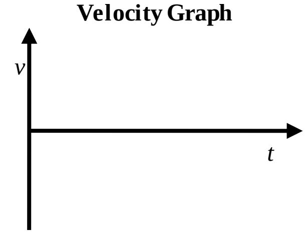
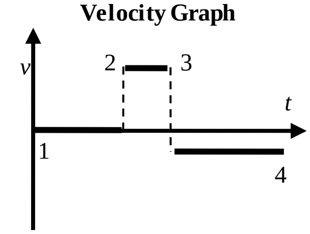
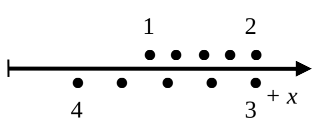
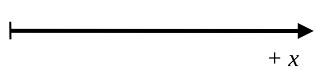
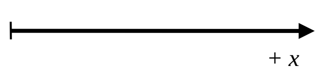
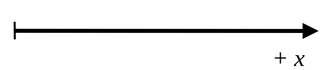
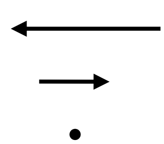
Describe physics of steps, complete equations, algebraically isolate, substitutions with units, final statement of prediction

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. Here are some hints for the **motion diagrams**: (a) If the object remains at rest, the two events will be located at the same position on a motion diagram (see situation 1), (b) if it changes direction, shift the dots just above or below the axis (see situation 1), (c) remember that the origin is marked by a small vertical line. There is at least one completed example of each type of representation that you can use as a guide. The positive *x*-direction is east.

Situation 1	Situation 2	Situation 3	Situation 4
Description 1-2: 2-3: 3-4:	**Description** 1-2: 2-3: 3-4:	**Description** 1-2: 2-3: 3-4:	**Description** 1-2: It starts at the origin and remains at rest for a while. 2-3: It moves quickly in the positive direction (east) with a constant velocity 3-4: It moves slowly in the negative direction (west) with a constant velocity.
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 during each interval) 1-2: 2-3: 3-4:	**Velocity Vectors** (velocity during each interval) 1-2: 2-3: 3-4: 	**Velocity Vectors** (velocity during each interval) 1-2: 2-3: 3-4:	**Velocity Vectors** (velocity during each interval) 1-2: 2-3: 3-4:

SPH3U: Changing Velocity

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

We have explored the idea of velocity and now we are ready to test it carefully and see how far this idea goes. As you work through this investigation remember how we have interpreted the velocity ratio $\Delta x/\Delta t$ so far:

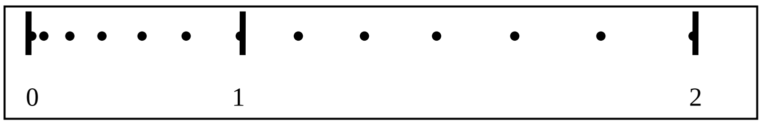
"The quantity $\Delta x/\Delta t$ tells us how far and in what direction the object travels every second.
For example: -3m/s means that for every second that goes by, the object travels 3 metres in the negative direction."

A: Motion with Changing Velocity

Your teacher has a tickertape timer, a cart and an incline set-up. Turn on the timer and then release the cart to run down the incline. Bring the tickertape back to your table to analyze.

1. **Observe**. Examine the pattern of dots on your tickertape. How can you tell whether or not the velocity of the cart was constant?

2. **Find a Pattern.** From the **first dot** on your tickertape, draw lines that divide the dot pattern into intervals of six *spaces* as shown below. Do this for 10 intervals.



3. **Reason.** The timer is constructed so that it hits the tape 60 times every second. How much time does each six-space interval take? Explain your reasoning.

4. **Reason.** Albert makes a calculation of the velocity ratio $\Delta x/\Delta t$ for the interval of his entire dot pattern on the ticker tape. He says, "My result is 53 cm/s. This means that for every second that goes by, the cart moves 53 cm in the positive direction." Do you agree or disagree with Albert? Explain.

When the velocity is noticeably changing during a time interval Δt, we cannot use our simple interpretation of the ratio $\Delta x/\Delta t$. Instead, we call the ratio $\Delta x/\Delta t$ the *average velocity*. This is our first hint that changing velocity is a very different *state of motion* than constant velocity. We need to develop a more powerful interpretation for the ratio $\Delta x/\Delta t$ in this new state of motion.

B: Analyzing Motion with Changing Velocity

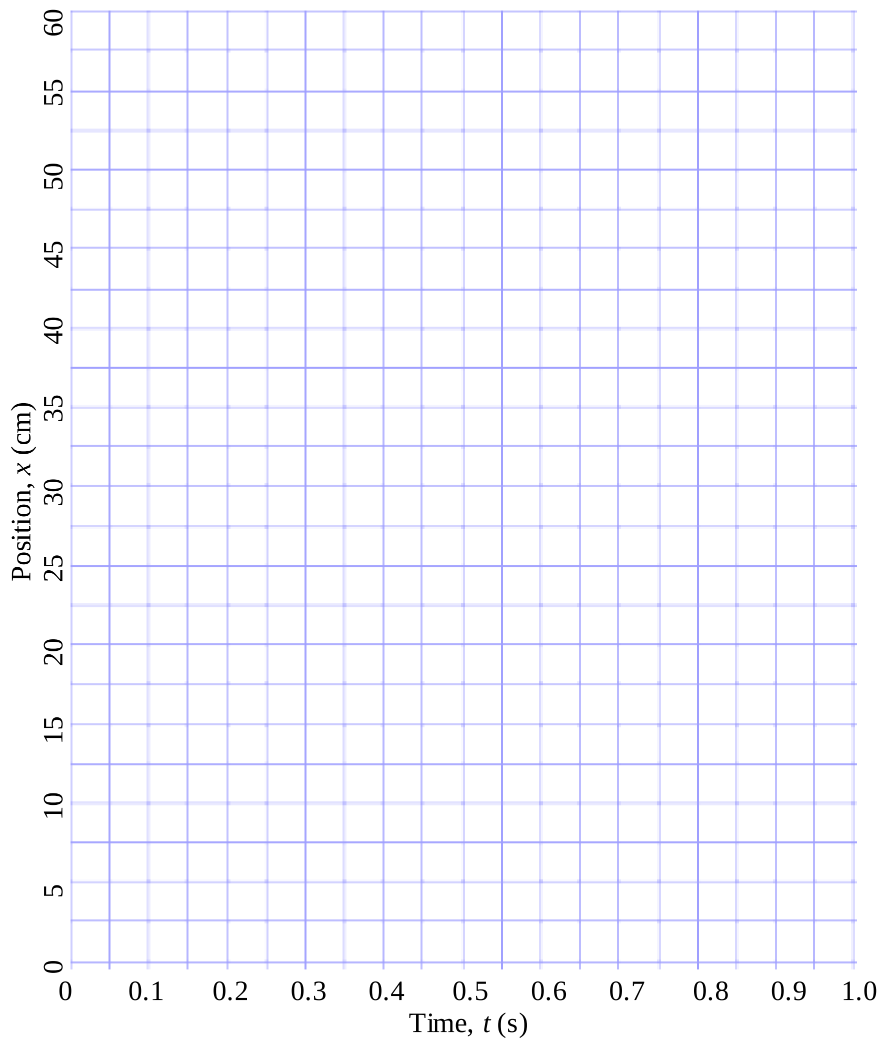
On the next page are a chart for your position-time data and a grid for your graph. Follow the instructions below.

1. **Measure.** Collect a complete set of position and time data from your tickertape. **Each** position measurement should start from the first mark "0" you make. Record your data in the chart on the next page.

2. **Reason.** What is the uncertainty in your position measurements?

3. **Find a Pattern.** Plot the data in a graph of position vs. time. Does the data seem to follow a straight-line pattern or a curve? Explain.

Time, t (s)	Position, x (cm)
0	
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	
0.8	
0.9	
1.0	



Smooth Curve. When data follows a curving pattern, we draw a smooth curve to fit the data. Just like with lines of best-fit, we do not want to connect the dots and create a zig-zag pattern. Draw a smooth curve through most of the data points, but don't try to connect points that do not fit into your smooth curve.

4. **Explain.** We will focus on the time interval from 0 to 1.0 seconds. During this time interval:
   (a) How do the spaces between the ticker tape dots show that the velocity is changing?

   (b) How does the position data in the chart above show that the velocity is changing?

   (c) Draw a straight line on your position graph that connects with your smooth curve at 0 and 1.0 s (or your last data point). How can you tell that the velocity during this time interval is not constant?

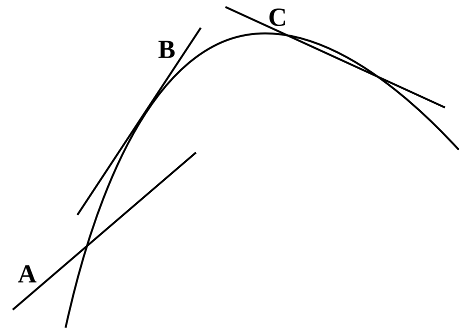
5. **Explain.** We will focus on a smaller interval of time, near the middle of your set of data, for example from 0.4 to 0.6 s. Highlight this on your ticker tape. Imagine these are all the dots all you can see.
   (a) When you examine the ticker-tape dots, is it easier or harder to decide if the velocity is changing? Why?

   (b) Draw a straight line on your position graph that connects with your smooth curve at 0.4 and 0.6 seconds. Is it easier or harder to decide if the velocity is changing during this interval? Why?

6. **Explain.** Now let's explore a very small interval, starting one single dot before 0.5 s and one single dot after 0.5 s. Highlight this on your tickertape. Imagine these are all the dots you can see. How hard is it now to decide if the velocity is constant?

As the time interval becomes smaller, the velocity within that interval appears more and more like constant velocity. We can always make the time interval smaller and smaller, and when we do that something remarkable happens: the line we have been drawing on our graph no longer appears to connect with the graph at two separate points. So we say that the line now touches the graph at one point. This type of line is called a *tangent*: a straight line that touches a curve at only one point without crossing over the curve.

7. **Apply.** Use the new definition of a tangent to explain which lines are tangent to the curve shown to the right and which are not.



8. **Represent and Reason.** Draw a tangent to your smooth curve such that it touches the curve at 0.5 s.
   (a) Now hold your ruler against your curve as if you were going to draw another tangent at 0.4s (don't draw it!). How does the slope of the tangent at 0.4 s compare with the one at 0.5 s?

   (b) Do the same for 0.6 s. How does this slope compare with 0.5 s?

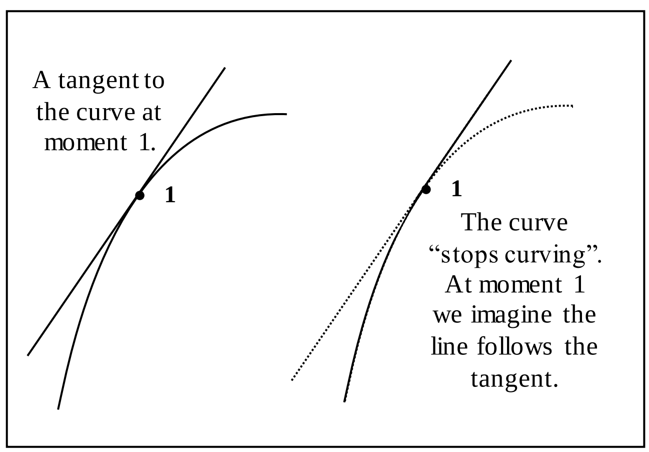
   (c) What quantity or characteristic of the cart's motion is changing each at every moment in time? (Hint: what does the slope of a position-time graph represent?)

The slope of the tangent to a curving position-time graph give the object's *instantaneous velocity*, meaning it's velocity at one moment (or instant) in time. This new type of velocity will be our focus for most of our work in physics. Since instantaneous velocities are different at different moments in time, it is helpful to label them with a subscript number that corresponds to the event. For example: $v_1 = 12$ m/s means the instantaneous velocity at moment 1 (the time of event 1).

9. **Calculate.** Label the point on your curve at 0.5 s event "1". Find the slope of the tangent to your curve. Hint: when you find the slope of any line, you will get a more reliable result (with less uncertainty) if you choose two points on the line that are **far apart**. Be sure to use physics symbols and show your units when you substitute the values.

The slope of a tangent is the same as the slope of the curve *at that point along the curve*. It might seem strange to think of a curve as having a slope, since it has no section that is straight. But we use a trick: the tangent allows us to imagine what the graph might look like if the curve stopped curving! So, the slope of the tangent equals the slope of the curve at that point along the curve.

This provides an important clue to help us interpret the meaning of the ratio $\Delta x/\Delta t$ for an instantaneous velocity: it tells how the object would move *if* the velocity stopped changing. For example: $v_1 = +2$ m/s means "At 0.5 seconds (the time of event 1), the object would travel 2 m in the positive direction every second if its velocity stopped changing."



10. **Interpret.** Use the description above to interpret the slope result for your tangent.

C: Summary of Velocity Ideas

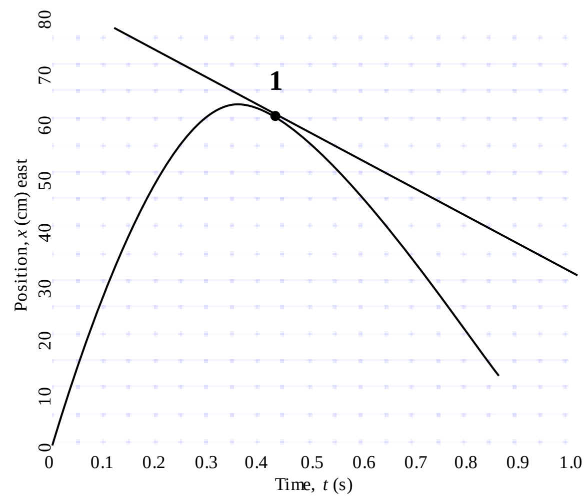
We started this lesson with a simple idea of velocity. After exploring motion with changing velocity, we learned that we need to *refine* our velocity ideas in order to properly interpret the velocity ratio $\Delta x/\Delta t$ in this new situation. Here is a summary of what we have figured out.

The Meaning of the Velocity Ratio $\Delta x/\Delta t$			
State of Motion	**Time Interval**	**Interpretation of Ratio**	**Label for Ratio**
Constant Velocity	large	"*for every time interval Δt, the object **will** travel through a displacement Δx*"	velocity, v
Changing Velocity	large	When the velocity noticeably changes: "*during the time interval Δt, the object travels through a displacement Δx*"	average velocity, v_{avg}
	small (or just one moment in time)	When the velocity appears constant: "*for every time interval Δt, the object **would** travel through a displacement Δx **if** its velocity stopped changing*"	instantaneous velocity, v_1, v_2, etc.

The Language of Velocity. In the future, most of our physics work will focus on situations with changing velocity. As a result, we tend to get lazy and just say "velocity" when we really mean instantaneous velocity. You can always decide which velocity we mean by thinking about the state of motion and the time interval involved.

The magnitude (the number part without the direction) of the instantaneous velocity is the *instantaneous speed*. We will often use the word *speed* to refer to the size of the instantaneous velocity.

SPH3U: Changing Velocity Homework – Do This Now!



1. **Calculate.** Find the slope of the tangent to the curve at moment 1. This represents the instantaneous velocity at what moment in time?

2. **Interpret.** Draw three other tangents at different places on the graph.
   (a) Label them "faster" or "slower" compared with the tangent that was drawn for you.
   (b) Label the directions represented by the slopes of your tangents "east" or "west".

3. **Explain.** Is it possible to draw a tangent to this graph that represents an instantaneous velocity of zero? Explain and, if possible, draw.

4. **Explain.** At the beginning of her race, Penny Oleksiak dove into the water and swam underwater for a 10-m distance. During this time, she was slowing down and at one moment had a velocity of 1.99 m/s. Explain how to use the summary chart above to decide what type of velocity this is.

5. **Interpret.** Google Maps told you that your drive trip to school involved traveling 3 km north and took 5 minutes. You use these values in a calculation of the velocity ratio. Explain how to use the summary chart above to decide what type of velocity this is.

SPH3U: The Idea of Acceleration

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

A: The Idea of Acceleration

Interpretations are powerful tools for making sense of calculations. Please answer the following questions by **thinking and explaining** your reasoning to your group, rather than by plugging into equations. Consider the situation described below:

A car was traveling with a constant velocity 20 km/h south. The driver presses the gas pedal and the car begins to speed up at a steady rate. The driver notices that it takes 3 seconds to speed up from 20 km/h to 50 km/h.

1. **Reason.** How fast is the car going 2 seconds after starting to speed up? Explain.

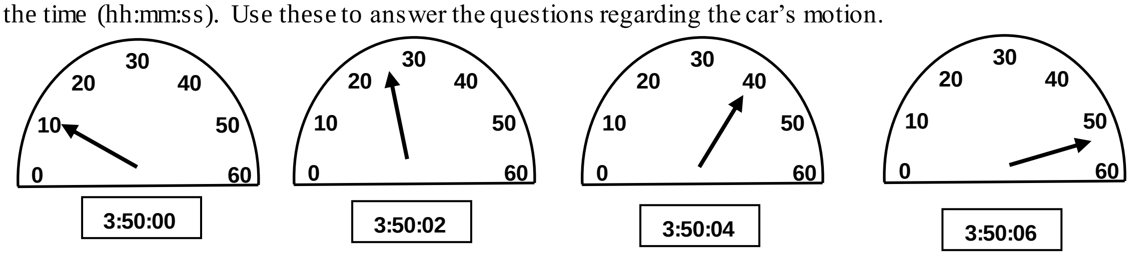
2. **Reason.** How much time would it take to go from 20 km/h to 80 km/h? Explain.

3. **Interpret.** A student who is studying this motion subtracts 50 – 20, obtaining 30. How would you interpret the number 30? What are its units?

4. **Interpret.** Next, the student divides 30 by 3 to get 10. How would you interpret the number 10? (Warning: don't use the word *acceleration*, instead explain what the 10 describes a change in. What are the units?)

B: Watch Your Speed!

Shown below are a series of images of a speedometer in a car showing speeds in km/h. Along with each is a clock showing the time (hh:mm:ss). Use these to answer the questions regarding the car's motion.



1. **Reason.** What type of velocity (or speed) is shown on a speedometer – average or instantaneous? Explain.

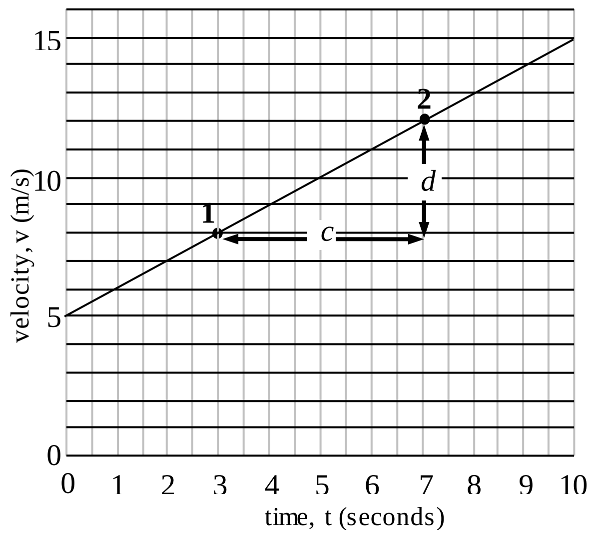
2. **Explain.** Is the car speeding up or slowing down? Is the change in speed steady?

3. **Explain and Calculate.** Explain how you could find the acceleration of the car. Calculate this value and write the units as (km/h)/s.

4. **Interpret.** Albert exclaims, "In our previous result, why are there two different time units: hours and seconds? This is strange!" Explain to Albert the significance of the hours unit and the seconds unit. The brackets provide a hint.

C: Interpreting Velocity Graphs

To the right is the velocity versus time graph for a particular object. Two moments, 1 and 2, are indicated on the graph.



1. **Interpret.** What does the graph tell us about the object at moments 1 and 2?

2. **Interpret.** Give an interpretation of the interval labelled c. What symbol should be used to represent this?

3. **Interpret.** Give an interpretation of the interval labelled d. What symbol should be used to represent this?

4. **Interpret.** Give an interpretation of the ratio d/c. How is this related to our discussion in part A?

5. **Calculate.** Calculate the ratio d/c including units. Write the units in a similar way to question B#3.

6. **Explain.** Use your grade 8 knowledge of fractions to explain how the units of (m/s)/s are simplified.

$$(m/s)/s = \frac{m}{s} \div s = \frac{m}{s} \div \frac{s}{1} = \frac{m}{s} \times \frac{1}{s} = {}^{m}\!/\!{}_{s^2}$$

SPH3U: Calculating Acceleration

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

A: Defining Acceleration

The quantity calculated from the slope of the velocity graph in last class's investigation is called the *acceleration*. The motions shown in parts A, B and C of that investigation all have the characteristic that the velocity of the object changed by the same amount in equal time intervals. When an object's motion has this characteristic, we say that the object has *constant acceleration*. We can therefore interpret the number $\Delta v/\Delta t$ as the *change* in velocity occurring in each unit of time. The number, $\Delta v/\Delta t$, is called the *acceleration* and is represented by the symbol, a.

$$a = \Delta v/\Delta t = \frac{v_f - v_i}{t_f - t_i}\text{, if the acceleration is constant}$$

In Gr. 11 physics, we will focus on situations in which the acceleration is constant (sometimes called *uniform acceleration*). Acceleration can mean speeding up, slowing down, or a change in an object's direction - any change in the velocity qualifies! In the equation above, we wrote v_f and v_i for the final and initial velocities during some interval of time. If your time interval is defined by events 2 and 3, you would write v_3 and v_2 for your final and initial velocities.

1. **Explain.** We mentioned earlier that the "Δ" symbol is a short form. In this case, explain carefully what Δv represents using both words and symbols.

B: You've Got Problems!

1. Your teacher has a cart set up on a track at the front of the room. The cart is equipped with a fan that causes it to accelerate. Your teacher will release the cart and use the motion detector to measure to display a graph of its velocity. You may choose what moments in time and what values from the graph to use. **What is the cart's acceleration?** (You can check your answer by using the computer to find the slope of the velocity graph.)

A: Pictorial Representation

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

B: Physics Representation

Motion diagram, velocity graph, velocity vectors, events

C: Word Representation

Describe motion (no numbers), assumptions, estimated result (no calculations)

D: Mathematical Representation

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

In the previous example, if you did your work carefully you should have found units of m/s^2 for the acceleration. It is important to understand that the two units of time in (m/s)/s (m/s^2 is shorthand) play different roles. The *second* in m/s is just part of the unit for velocity (like *hour* in km/h). The other *second* is the unit of time we use when describing how much the velocity changes in one unit of time.

For convenience, our new equation for acceleration is often written as: $v_f = v_i + a\Delta t$

2. **Explain.** Show the algebraic steps that start from the equation $a = \Delta v/\Delta t$ and lead to $v_f = v_i + a\Delta t$.

3. **Hit the Gas!** You are driving west along the 401 and want to pass a large truck. You floor the gas pedal and begin to speed up. You start at 102 km/h, accelerate at a steady rate of 2.9 (km/h)/s (obviously not a sports car). What is your velocity after 5.3 seconds when you finally pass the truck?

A: Pictorial Representation

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

Check: did you replace "i" and "f" in your symbols with event numbers?

B: Physics Representation

Motion diagram, velocity graph, velocity vectors, events

C: Word Representation

Describe motion (no numbers), assumptions, estimated result (no calculations)

D: Mathematical Representation

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

E: Evaluation

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

4. **The Rocket** A rocket is travelling upwards. A second engine begins to fire causing it to speed up at a rate of 21 m/s^2. After 4.3 seconds it reaches a velocity of 413 km/h and the engine turns off. What was the velocity of the rocket when the second engine began to fire?

> To describe motion in the vertical direction, use the symbol *y* for the *vertical* position. All other symbols remain the same. In physics, the symbol *x* will only be used for *horizontal* position. The sketch for the situation should show the vertical motion and the coordinate system should show which vertical direction is the +*y*-direction. The motion diagram and the velocity vectors should point vertically.

A: Pictorial Representation

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

B: Physics Representation

Motion diagram, velocity graph, velocity vectors, events

C: Word Representation

Describe motion (no numbers), assumptions, estimated result (no calculations)

D: Mathematical Representation

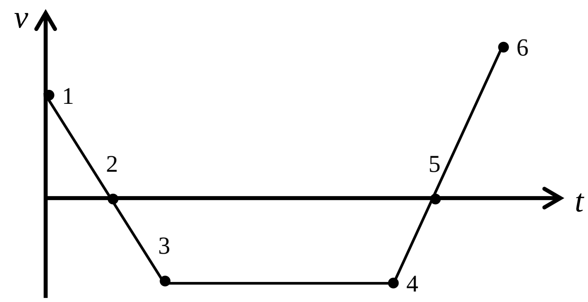
Describe physics of steps, complete equations, algebraically isolate, substitutions with units, final statement of prediction

E: Evaluation

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

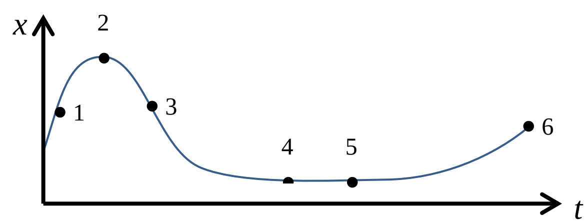
Homework: Speeding Up and Slowing Down

1. **Interpret and Explain.** A person walks back and forth in front of a motion detector producing the velocity graph shown to the right. Six events have been labelled on the graph. The chart below lists different examples of motion. Find the appropriate interval(s) of time in the graph that correspond to that type of motion and **provide evidence from the graph** supporting your choice**.**



Type of motion	**Interval(s)**	**Evidence**
positive acceleration		
negative acceleration and a positive velocity		
acceleration of zero		
speeding up		
slowing down		
at rest (reminder: at rest means not moving for an **interval** of time)		
Change of acceleration	Moments:	

2. **Interpret and Explain.** In a different experiment, a person walks back and forth in front of a motion detector and produces the position graph shown to the right. The chart below lists different examples of motion. Find the appropriate interval(s) of time or events in the graph that correspond to that type of motion and **provide evidence from the graph** supporting your choice**.**



Type of motion	**Intervals or Events**	**Evidence**
Zero velocity		
Speeding up		
Slowing down		
Turning around		

Quality Work Criteria	**Mark /5**
My responses use thoughtful, complete sentences and are very easy to read.	
For each response, I mentioned specific features of the graphs as my evidence	
This work would be useful for **any** student to study from in the future.	

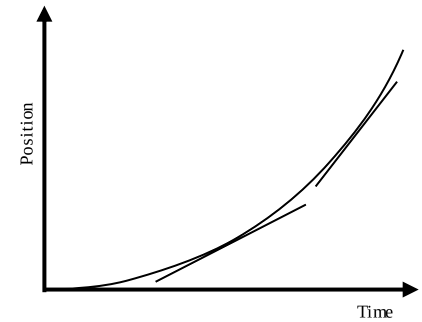
SPH3U: Speeding Up or Slowing Down?

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

There is one mystery concerning acceleration remaining to be solved. Our definition of acceleration, $\Delta v/\Delta t$, allows the result to be either positive or negative, but what does that mean? Today we will get to the bottom of this.

A: Acceleration in Graphs

Your teacher has set-up a cart with a fan on a dynamics track and a motion detector to help create position-time and velocity-time graphs. Let's begin with a position graph before we observe the motion. The cart is initially moving forward. The fan is on and gives the cart a steady, gentle push which causes the cart to accelerate.



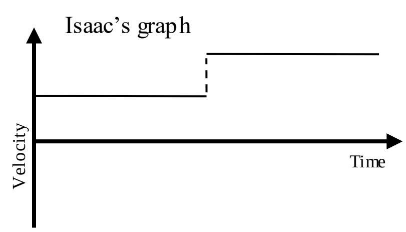
1. **Reminder.** What does the slope of a tangent to any position-time graph represent?

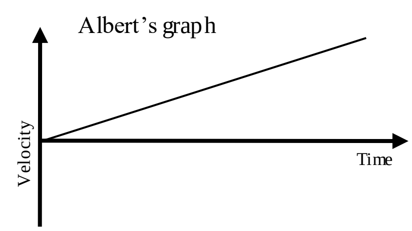
2. **Interpret.** Is the cart speeding up or slowing down? Use the two tangents to the graph to help explain.

To help interpret position graphs, we will use the *tangent trick*. Use a ruler or pencil as the tangent line to a position graph. Interpret the slope of the tangent. Then move the tangent to a new spot along the graph and interpret. Decide if the object is speeding up or slowing down. This trick can also be used decide how to sketch a position graph.

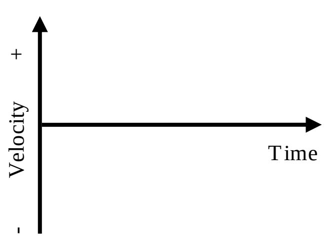
3. **Reason.** Is the change in velocity positive or negative? What does this tell us about the acceleration?

4. **Reason.** Two students draw a velocity graph based on the position graph above. Which graph do you think best matches the position graph? Explain.





5. **Test and interpret.** *(as a class)* Observe the velocity-time graph produced by the computer for this situation. Interpret the motion shown in the velocity graph. **In all the following examples, east is the positive direction.**

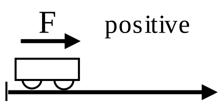
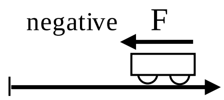
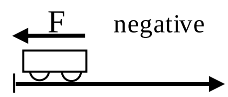
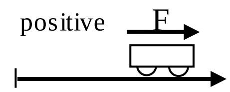
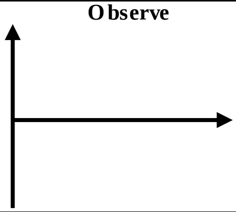
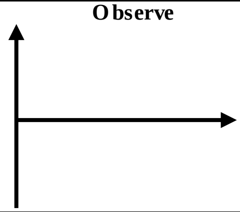
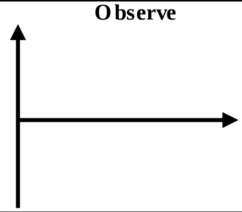
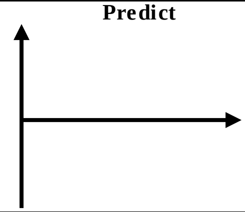
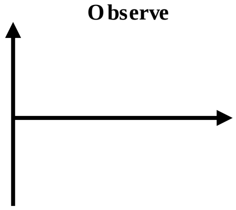
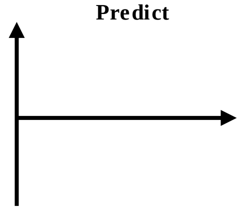
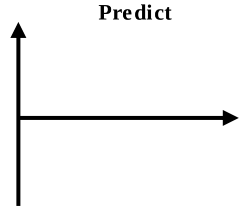
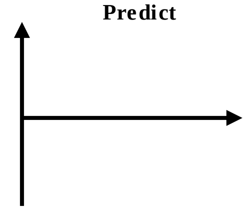
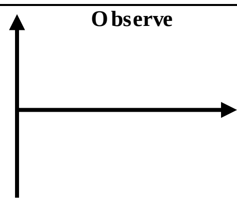
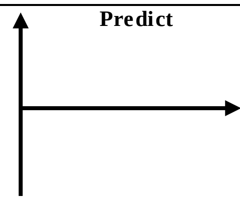
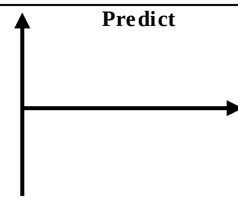
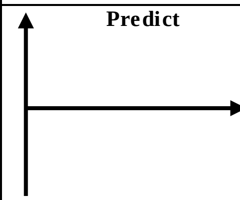


Feature	Value	Meaning
Type of graph		
Sign of velocity values		
Size of velocity values		
Shape of graph		
Slope of graph		

B: The Sign of the Acceleration

Your teacher has a cart with a fan set up on a track.

1. **Observe, Predict and Interpret.** *(as a class)* Your teacher will lead you through four different situations involving the cart. You will make observations, make prediction and interpret the results using the chart on the next page.

Situation	**1**	**2**	**3**	**4**
Description	The cart is released from rest near the motion detector. The fan exerts a force on the cart pointing **away** from the detector.	The cart is released from rest far from the detector. The fan exerts a force on the cart **towards** the detector.	The cart is moving away from the detector. The fan exerts a force on the cart **towards** the detector.	The cart is moving towards the detector. The fan exerts a force on the cart **away** from the detector.
Sketch with Force				
Position graph	**Observe** 	**Observe** 	**Observe** 	**Predict** 
Velocity graph	**Observe** 	**Predict** 	**Predict** 	**Predict** 
Acceleration graph	**Observe** 	**Predict** 	**Predict** 	**Predict** 
Slowing down or speeding up?				
Sign of Velocity				
Sign of Acceleration				

2. **Reason.** Emmy says, "We can see from these results that when the acceleration is positive, the object always speeds up." Do you agree with Emmy? Marie says, "No. There's more to it than that." Who do you agree with? Explain.

3. **Reason.** What conditions for the acceleration and velocity must be true for an object to be speeding up? To be slowing down?

4. **Reason.** The sign of the acceleration **always** matches the sign of what other quantity in our chart?

Always compare the magnitudes of the velocities (the speeds) using the terms *faster* or *slower*. Describe the motion of accelerating objects as *speeding up* or *slowing down* and state whether it is moving in the positive of negative direction. Other ways of describing velocity often lead to ambiguity and trouble! **Never** use the d-word (*deceleration*) - yikes! Note that we will always assume the acceleration is uniform (constant) unless there is a good reason to believe otherwise.

5. **Reason.** In situation #4, why might it be confusing to interpret the velocity graph by saying, "the velocity is increasing"? What might be better to say?

SPH3U: Area and Displacements

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

A graph is more than just a line or a curve. We will discover a very handy new property of graphs which has been right under our noses (and graphs) all this time!

A: Looking Under the Graph

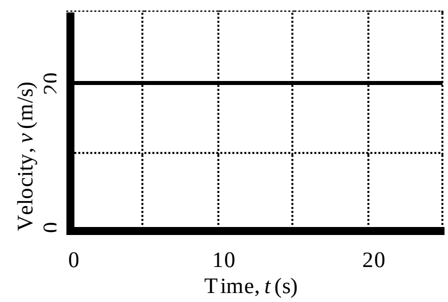
A car drives south along a straight road at 20 m/s. After 5 s the car passes a streetlight and at 20 s the car passes a stop sign.

1. **Describe.** Based on what you have learned so far in physics, how can we calculate the displacement of the car between the streetlight and the stop sign?

2. **Reason.** Suppose instead that the car's starting velocity was 20 m/s and at 0 s the car began to speed up. In the same 15-s time interval, would the car's displacement be larger or smaller? Explain.

3. **Sketch.** Now we will think about this calculation in a new way. Draw and shade a rectangle on the graph that fills in the area between the line of the graph and the time axis, for the time interval of 5 to 20 seconds.

4. **Describe.** In math class, how would you calculate the area of the rectangle?



5. **Interpret.** Calculate the area of the rectangle. Note that the length and width have a meaning in physics, so the final result is not a physical area. Use the proper physics units that correspond to the height and the width of the rectangle. What physics quantity does the final result represent?

The *area* under a velocity-time graph for an interval of motion gives the *displacement* during that interval. Both velocity and displacement are vector quantities and can be positive or negative depending on their directions. According to our usual sign convention, areas above the time axis are positive and areas below the time axis are negative.

B: Applying Our New Tool

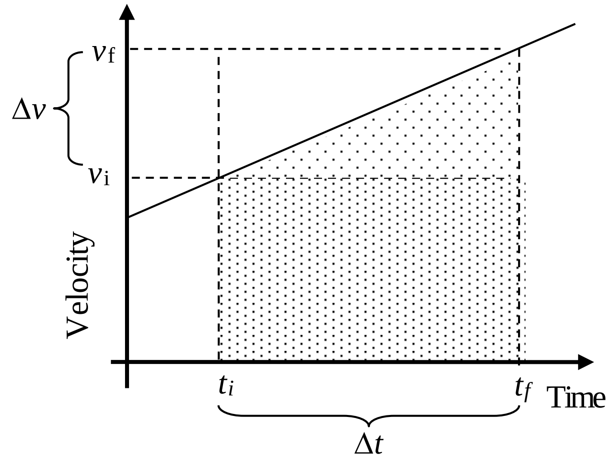
Our new tool for finding displacements will help us find the answer to a sticky problem: how can we find the displacement of an accelerating object?

Consider the graph on the next page that shows the velocity of an object that is speeding up. We want to use this graph to find the displacement of the object between the times t_i and t_f. The area under this graph has an unusual shape, but we can split up the area into two simpler shapes.

1. **Represent.** How do we find the area of any rectangle? Write an expression for the area the way you would write it in math class. How can we find the area of the rectangle under this graph? Write a new expression for the area using physics symbols from this graph.

    math class expression: area =

    physics graph expression: area =



2. **Represent.** Write an expression for the area of the triangle in two different ways..

    math class expression: area =

    physics graph expression: area =

Our goal is to create an equation that lets us find the displacement of the object if we know its acceleration. To do that, we need to do a math trick.

3. **Represent.** Remember our definition of acceleration: $a = \Delta v/\Delta t$. If we rearrange it, we have: $\Delta v = a\Delta t$. Make a mathematical substitution for Δv in your physics graph expression for the area of the triangle. Do a bit of algebra work to simplify your expression.

    area =

4. **Represent.** Create one expression that describes the *total* area underneath the graph.

    area =

5. **Interpret.** We understand that the area under the graph between those moments in time represents the displacement of the object. Write a final version of your equation. Replace the word "area" with the appropriate physics symbol.

** call your teacher over to check your equation **

The equation you have just constructed is one of the five equations for constant acceleration (affectionately known as the BIG five). Together they help relate different combinations of the five variables of motion: Δx, a, v_i, v_f and Δt. You have encountered one other BIG five so far, (in a disguised form) the definition of acceleration: $a = \Delta v/\Delta t$. Recall that this equation was also constructed by analyzing a graph showing changing velocity! Awesome!

6. Evaluate. Would the new equation produce a result that agrees with your response for question A#2? Explain.

Displacement Problems!

Use the full solution format to solve these problems. Hint: when choosing an equation (you have a choice of two), think about which quantities you know and which you are trying to find out.

1. **Taking Off.** A jumbo jet takes flight while travelling down a 1.80 km runway. It barely makes it off the ground after it reaches the end of the runway, taking 37.9 s of time. What is the acceleration of this jet? Give your answer in m/s^2

2. **Stopping a Muon.** A muon (a subatomic particle) moving in a straight line enters a detector with a speed of 5×10^6 m/s and then it slowed down at the rate of 1.25×10^{14} m/s^2 in 4×10^{-8} s. How far does it travel while slowing down? (Hint: to slow down, one of your vector quantities will need to be negative. Which one?)

Answers: (1) 2.51 m/s^2, (2) 0.1 m

SPH3U: The BIG Five

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

Last class we found three equations to help represent motion with constant acceleration. A bit more work along those lines would allow us to find two more equations which give us a complete set of equations for the five kinematic quantities.

A: The BIG Five – Revealed!

Here are the BIG five equations for uniformly accelerating motion (the acceleration is constant).

The **BIG** Five	v_i	v_f	Δx	a	Δt
$v_f = v_i + a\Delta t$					
$\Delta x = v_i\Delta t + ½a\Delta t^2$					
$\Delta x = v_f\Delta t - ½a\Delta t^2$					
$\Delta x = ½(v_i + v_f)\Delta t$					
$v_f^2 = v_i^2 + 2a\Delta x$					

1. **Observe.** Fill in the chart with √ and × indicating whether or not a kinematic quantity is found in that equation.

2. **Find a Pattern.** How many quantities are related in each equation?

3. **Reason.** If you wanted to use the first equation to calculate the acceleration, how many other quantities would you need to know?

4. **Describe.** Define carefully each of the kinematic quantities in the chart below.

v_i	
v_f	
Δx	
a	
Δt	

5. **Reason.** What condition must hold true (mentioned in the previous investigation) for these equations to give reasonable or realistic results?

B: As Easy as 3-4-5

Solving a problem involving uniformly accelerated motion is as easy as 3-4-5. As soon as you know **three** quantities, you can always find a **fourth** using a BIG **five**! Write your solutions carefully using our solution process. Use the chart to help you choose a BIG five. Here are some sample problems that we will use the BIG five to help solve. Note that we are focusing on certain steps in our work here – in your homework, make sure you complete all the steps!

1. **Solve.** Your teacher has an inclined track set up at the front of the room. Your teacher will release a cart from rest at the top of the track. Your group must choose a position along the track. Label this position with a sticky-note that includes your group number and the displacement of the cart when it reaches that position. Your challenge is to predict the cart's speed at that position. Your teacher will give you the cart's acceleration. When you are finished, add your prediction to your sticky-note.

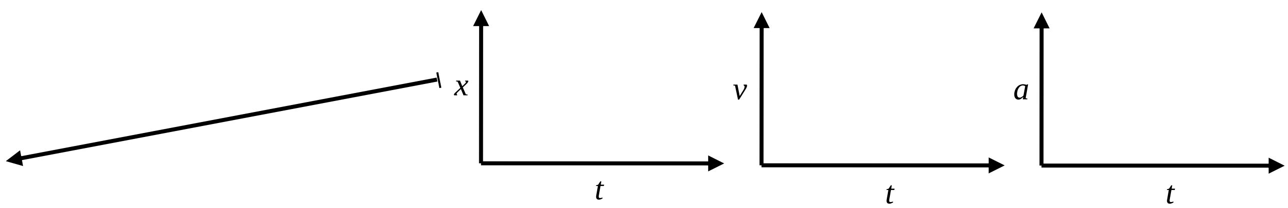
A: Pictorial Representation

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

Emmy says, "I know only two numbers, the acceleration and displacement. I need three to solve the problem. I'm stuck!" Explain how to help Emmy.

B: Physics Representation

Motion diagram, motion graphs, velocity vectors, events



D: Mathematical Representation

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

C: You've Got Problems: Complete these problems on a separate solution sheet

(1) **Crash Test.** An automobile safety laboratory performs crash tests of vehicles to ensure their safety in high-speed collisions. The engineers set up a head-on crash test for a Smart Car which collides with a solid barrier. The engineers know the car initially travels south at 100 km/h and the crash test dummy moves 0.78 m south during the collision. The engineers have a couple of questions: How much time does the collision take? What is the passenger's acceleration during the collision?

(2) **Microscopic physics.** All cell biology works according to the laws of physics! A sodium ion (3.817×10^{-26} kg) arrives near an opening in a cell. You may assume it is initially at rest. Electric forces cause it to speed up and travel towards the cell opening. As a result, it travels 1.48×10^{-7} m in 0.512 s. What is the acceleration of the sodium ion?

(3) **Off the Wall.** An important part of Penny's swim race is when she turns around while pushing on the swimming pool wall. When she makes contact with the wall, she is travelling at 1.66 m/s east. After pushing against the wall for 0.3 s, she leaves contact with it and is travelling at 1.98 m/s west. What is her acceleration during this time?

(4) **The Track.** A cart is placed at the bottom of an inclined track. It uses a spring to launch itself up the incline with a speed of 0.79 m/s. While travelling up and down the incline, the cart has an acceleration of 0.54 m/s^2. How much time does it take to make the complete trip up and back down to its starting position? (Hint: this is a one step problem)

Answers: (1) 0.0562 s, -495 m/s^2, (2) 1.13×10^{-6} m/s^2, (3) 12.1 m/s^2 west, (4) 2.93s