Handbook Self-Evaluation Exemplars

Purpose and Goals

The purpose of these exemplars is to help you develop the habit of thinking critically about the quality of their own work. The goal is that you will learn to work with the 4C criteria in mind and always think about how your work can be improved.

Instructions

(1) Read over the sample response for the question that has been selected from the day's investigation.

(2) Identify any improvements that can be made to your own work.

(3) Evaluate your response – give it a mark out of 5 based on the 4Cs criteria. Write the mark in the margin beside the question.

(4) Use the blue pens to improve your response based on the exemplar. Please note:

- There are **many excellent ways** of answering a question. Just because your response is written differently does not mean that it needs improvement.
- You must think carefully about what **meaningful** improvements could be made to **your** response. **Don't copy** the sample response unless you feel your response was really off track and can't be saved.
- If you are sure that your response can't be improved, give it a check mark and a 5/5 mark.
- Make sure your original work can still be read by your teacher.
- For this question of the investigation, you will be evaluated based on how thoughtfully you made your improvements.

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**
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.
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.
Concise	There are no extraneous or distracting statements which may or may not be correct.
Complete	No important parts of the explanation are missing. The evidence supporting the conclusion is mentioned along with the relevant definitions or laws.

0-2	3	4	5
Responses are missing, 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, but 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 12 student wrote this?"

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

In science we look for patterns hiding b… data. Based on your graph, does the dat… line pattern or a smooth curve pattern? … line or cu… **…ots! That does not highligh… .**

Axes have scale, labels, and units.

Start all calculations with symbols

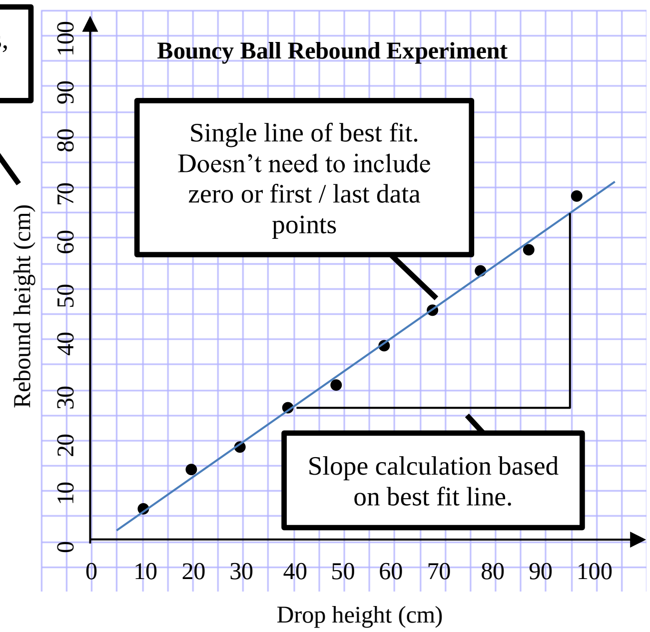
5. **Analyze**. Find the slope of a line of best fit for your data. Show your calculation below. Record the final result on your whiteboard.

$$Slope = \frac{y_2 - y_1}{x_2 - x_1} = \frac{61\ cm - 27\ cm}{95\ cm - 42\ cm} = \frac{34\ \not{cm}}{53\ \not{cm}} = 0.642$$

Every physics measurement should have a set of units

Show the units dividing away.

F… p members' slope calculations. ***Every time** a number is written it must have a unit – "Science!"*



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.

SPH3U: How to Answer a Question?

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

Reminder: After you sign up for your group work roles today, go back to yesterday's summary of your responsibilities and review them.

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.

Correct: It's all about a comparison of rebound height with drop height, not one of these quantities by itself.

Clear: no spelling or grammar issues, clear phrasing

2. 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.

The slope of the graph represents the "bounciness" of the ball, which is a ratio of the rebound height to the drop height. A larger slope or value means a greater rebound height for a given drop height, and a smaller value means a smaller rebound height.

Concise: No repetitions, simple and clear, does not attempt to explain why.

Complete: The response give the name of the slope, the meaning of the slope, and examples of what large and small values mean.

SPH3U: Measurement and Numbers

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

Measurements are the backbone of all science. Any scientific ideas, no matter how slick, are only as good as the measurements that have confirmed 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?

2. **Estimate** (*individually)* (**managers***: help organize this)***.** Without using the meter stick, make a reasonable guess (an estimation) for the height of your desk. Don't spend long doing this.

3. **Measure** (*individually)*. Use the metre stick to make a careful measurement of the height of your desk. If you can estimate a number between the smallest intervals marked on the meter stick, do so. Each member of the group should do this **without showing the results to one another**.

The term *significant digits* describes the digits in a number or measurement that are physically meaningful or reliable. 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** (*continue as a group now*)**.** How many significant digits are in the height measurement you just made? What is your instrumental uncertainty for this measurement?

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". We will call this *measurement notation*. All measurements should be recorded this way, even if we don't remind you!

5. **Record.** Write your height measurement using measurement notation.

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. **F**[illegible] the classroom. His t[illegible] d[illegible] in this display rea[illegible] v[illegible]

Correct: The decimal positions are correctly described. There is no need to use "milliseconds" here.

Clear: no spelling or grammar issues, clear phrasing

The digit "8" represents tenths of a second (0.1 s) and the digit "1" represents hundredths of a second (0.01 s). Another useful way of reading this is saying "81 hundredths of a second".

2. **Rec**[illegible] width of the unc[illegible] a decimal [illegible]

Complete: Each digit (aside from the "7") is explained. It is followed up with a helpful clarification to remind us that we are not reading milliseconds (which is a common guess).

Concise: Anything else would be repetitious. Short and simple.

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.

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, looking for patterns, and testing theories that help us to describe how our universe works.

A: The Gold Medal Race

A sixteen year-old swimmer from Toronto, Penny Oleksiak, won a gold medal in the women's 100m 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! Now imagine that you are a sports scientist. Your job is to analyze Penny's race and help her improve.

1. **Observe. (***individually***)**. Watch the video of her gold-medal winning race. Use your common, everyday understanding of motion to (a) list some ideas that you would measure to help analyze her motion or her swimming performance.

Manager: *When everyone is ready, help your group members take turns sharing ideas (one idea at a time) in the next step.*

2. **Discuss.** (*as a group*) Share your responses to the previous question and add to your lists above.

3. **Record.** On a whiteboard, record one motion idea you think is very important and one that you think other groups might not think of. (**Recorder**: Write large and only write a few words! Do this quickly.)

4. **Describe.** (*as a group*) Watch the video again. This time, think about Penny's speed, distance and time during two different parts of the race. Describe how your measurements might be different during the first 15 m of the race and in the middle sections of the pool. (**Speaker:** be prepared to share at any time)

First 15 m (diving, underwater)	**Middle** (regular strokes, not near a wall)

5. **Re**[...] on the middle part co[...] during the middle se[...]

Correct: There are lots of different possible answers to this question. Below is one example.

Clear: no spelling or grammar issues, clear phrasing

If Penny is slowing down too much, she might be getting tired or will be too far behind the leader to be able to catch up before the finish. If Penny is speeding up too much, she might get tired too early and not have enough energy near the end of the race to stay ahead of the others.

Complete: The response describes the concern for both speeding up too much and slowing down too much. It clearly describes how is might affect her race results.

Concise: Just enough detail to understand the concerns with each scenario. No need for a long story!

6. **Reas**[...]hether Pen[...]

9. **Represent and Calculate.** You are familiar ... symbols with physics symbols from this grap... is on the vertical axis instead. Use the physic... from the graph including their units. Comput...

Correct: Uses v, x, and t symbols. Uses 3 digits for final answer.

Complete: Shows three steps: symbols, substituted values with units, and a final result.

math class expression: $m = \frac{y_2 - y_1}{x_2 - x_1}$ physics graph expression: $v = \frac{x_2 - x_1}{t_2 - t_1} = \frac{175\ cm - 25\ cm}{3.51\ s - 0.42\ s} = 48.5\ cm/s$

Complete: This interpretation applies to this result only if the buggy travels at a constant speed, so this is an important assumption.

10. I... he motion of the buggy? For example, what does the buggy do every second?

Assume that the speed of the buggy does not change. If that's the case, the slope tells us that for every second that goes by the buggy moves forward 48.5 cm.

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

Correct: Response describes a change of position for every second.

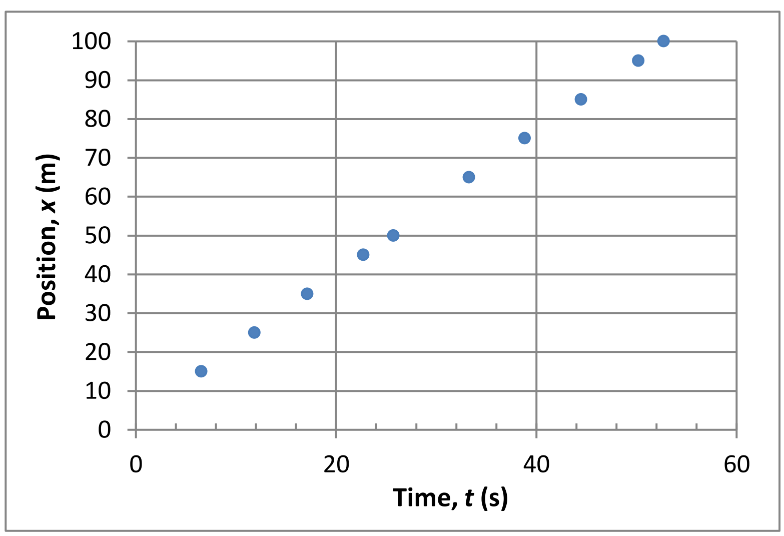
11. ... lts" how well do the advertised claims for the buggy hold up?

12. **Predict and Test.** Use your slope result as the speed of the buggy. Predict how much time it will take your buggy to travel 2.15 m. Follow the explanation process to show your work. *Call your teacher over to test your prediction.*

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.	

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.

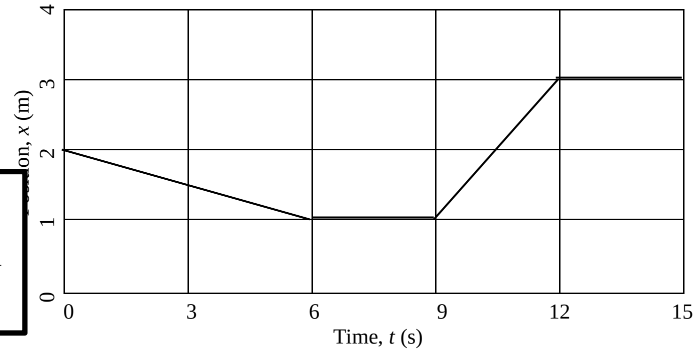
2. **Find a Pattern.** Draw a line of best fit that matches her data. Use physics symbols to construct an expression for the slope of the graph. Use this to calculate her velocity.

SPH3U: Interpreting Position Graphs

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

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

Complete: Each interpretation mentions the feature of the graph and gives the physical meaning. We don't focus on particular position values since they are easily read directly off the graph.

0-6 seconds: *The slope of the position graph is negative and small, so the student is moving slowly towards the detector.*

6-9 seconds: *The slope is zero, so the student is at rest.*

9-12 seconds: *The slope is large and positive, so the student is moving quickly towards the detector.*

12-15 seconds: *The slope is zero, so the student is at rest.*

Correct: Each characteristic of the slope matches the physical description of what is happening (the interpretation).

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	

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.

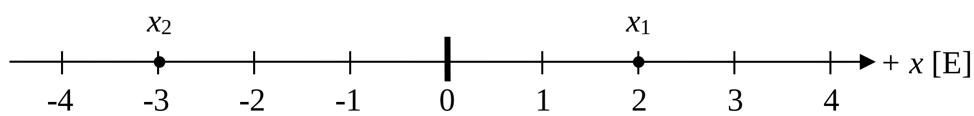
A: Events

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

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

B: Changes in Position - Displacement

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



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 = x_2 =

   words: x_1: x_2:

2. **Reason and Interpret.** What direction did Emmy move in? Use the sign convention and words to describe the direction. How far is the final position from the starting position? Use a ruler and draw an arrow (just above the axis) from the position x_1 to x_2 to represent this change.

The change in position of an object is called its *displacement* (Δx) and is found by subtracting the initial position from the final position: Δx … es a final value minus an initial value. The displac… *ector*, pointing from the initial to the final positio…

Complete: This response mentions the criteria for vectors: having a magnitude and direction. It reinforces this with an explanation of why the number part alone is not enough.

3. **Reason.** Is position a vector quantity? Explain. (Hint: to describe Emmy's position, do we need to mention a direction?)
   To describe Emmy's position, you need to say that she is 2 km east of the origin. This includes a magnitude (number part) and a direction, making position a vector quantity. If you only say "2 km" you don't know which side of the origin she is on.

4. **Reason.** In the example above with Emmy, which event is the "final" ev… event num… ich for the "i " in t… x_i)?

Correct: Position is a vector.

Concise: The second sentence is helpful since it provides another way to understand why position is a vector.

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

   Δx =

SPH3U: Velocity-Time Graphs

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

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)?

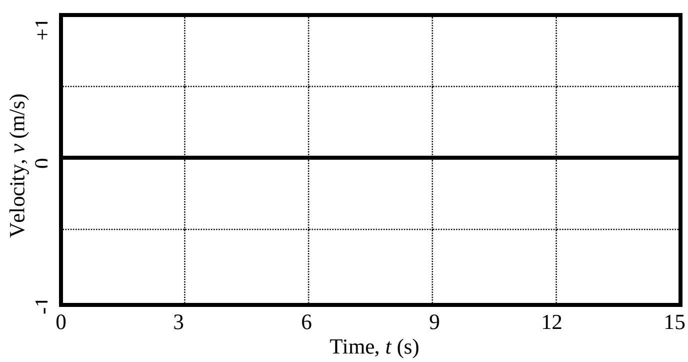
6. **Explain.** Based on your observations of the graphs above, how is direction represented on a velocity graph? (How can you tell if the object is moving in the positive or negative direction)?

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.

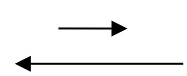


Velocity is a vector quantity since it has a magnitude (number) and direction. All vectors can be represented as arrows. In the case of velocity, the arrow does not show the initial and final positions of the object. Instead it shows the object's speed and direction.

Complete: This response interprets the appearance of each arrow and then matches them to the descriptions of motion.

2. **Represent.** Tw… 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?

The first arrow is short, which means a slower velocity, and points to the right. The second is longer, which means a faster velocity, and points to the left. Between moments 1 and 2 the person is moving slowly, which matches the top arrow. Between moments 4 and 4 the person is moving quickly in the opposite direction, which matches the bottom arrow.



Correct: Arrow length corresponds to speed. Arrow direction corresponds to velocity direction. The interpretation of each arrow matches the motion intervals.

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 a[…] o decide which quantity to put on the top and the bottom of the fraction. Explain h[…] the markings and units in the examples above.

Correct: The unwanted units must divide away.

The unit in the original quantity needs to divide away with the same unit in the conversion ratio. Set up the conversion ratio such that those units are on opposite sides of the fraction line. In the example, the original kg unit is in the numerator of a fraction, so the kg in the conversion ratio needs to be in the denominator.

Concise: No need to mention the ratio equals one.

Complete: This response explains the idea behind the decision and then explains how it is used in the example.

5. **Reason.** […] desc[…] e conversio[…] why it[…]

2. **Explain.** What is the important assumption that our model of this situation is based on? Do you think this assumption is 100% correct? Why might it be good enough for this situation? Explain.

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 solutio

Correct: The unwanted units must divide away.

3. **Interpret.** Our swimmer in this problem is swimmi e ways this is shown in the solution.
   (1) Equal spaced dots in motion diagram, (2) equal length arrows for velocity vectors, (3) position graph has straight non-zero slope, (4) velocity graph has horizontal line, (5) description in word prepresentation

4. **Interpr** elocity

Concise: No need to mention the ratio equals one.

Complete: This response explains the idea behind the decision and then explains how it is used in the example.

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 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!

5. **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)
   $v = \frac{\Delta x}{\Delta t}$

6. **Evaluate.** The evaluation step is a final check to help us decide whether our model, and its assumptions, seems reasonable. Suppose a friend of yours came up with an improvement of 13.1 s. Aside from an obvious math error, why is this result not reasonable in size?

B: Problems Unsolved

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

1. Usain Bolt ran the 200 m sprint at the 2012 Olympics in London in 19.32 s. What is his speed in km/h during the race? (37.3 km/h)

2. In February 2013, a meteorite streaked through the sky over Russia. A fragment broke off and fell downwards towards Earth with a speed of 12 000 km/h and struck the ground 10 s later. How far in kilometers did the fragment travel in this time? (33.3 km)

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

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

Exp **^** **EE**

SPH3U: Problem Solving

1. Usain Bolt ran the 200 m sprint at the 2012 Oly[mpics …] [i]s his speed (37.3 km/h)

> Subheadings are crossed out (or checked off)

> In this problem, the given units "agree" since there are no mixtures of m and km, h or s. As a result the conversion to km/h is easiest to do in Part D.

A: Pictorial Representation (of Model)

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

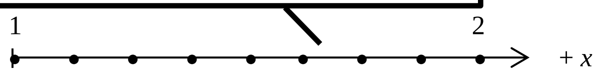
Event 1 = he starts the race   Event 2 = he reaches the finish

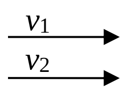
v = ?   Δx = 200m
Δt = 19.32 s

> Descriptions and quantities are attached to sketch in logical locations

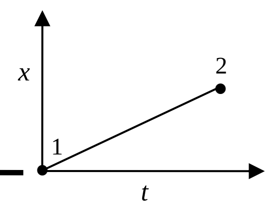
> Each representation correctly shows constant velocity: equal spaced dots, same length arrows, straight sloped position graph, slope zero velocity graph

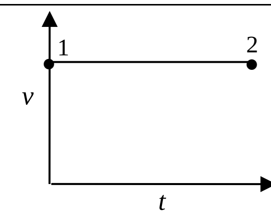
~~nts~~





> Event numbers are included with each representation





C: Word Representation (of Model)

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

He runs in the positive direction, starting at the origin. We assume that his velocity is constant throughout the race and he is running in a straight line. I estimate he will run at about 40 km/h, the speed of a slow car.

> - Describes position and velocity.
> - Simple estimation.

D: Mathematical Representation (of Model)

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

Find Usain's speed in the 200-m race:

$v = \Delta x/\Delta t$
$= (200\text{ m})/(19.32\text{ s})$
$= 10.35\text{ m/s}$

> - Begins with clear statement.
> - Equation shows symbols.
> - Substitution includes units.

Convert to km/h:

$$v = 10.35\frac{\cancel{m}}{\cancel{s}}\left(\frac{1\ km}{1000\ \cancel{m}}\right)\left(\frac{3600\ \cancel{s}}{1\ h}\right) = 37.26\text{ km/h}$$

> - Conversion starts with symbol.
> - Conversion ratio neatly shown.
> - Units crossed out.

According to this model, I predict his speed was 37.3 km/h.

> Final result stated as a prediction.

E: Evaluation (of Model)

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

His speed is similar to a slow car, which is a reasonable size for a very fast sprinter! The velocity is positive, meaning the forward direction. km/h are reasonable units for velocity.

> A simple explanation for why the size of the result seems reasonable.

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:

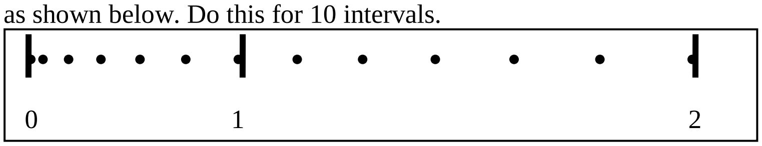
"The quantity $\Delta x/\Delta t$ tells us how far and in what direction the object travels every second. For example: -3m/s means that for every second that goes by, the object travels 3 metres in the negative direction."

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.

Complete: Agrees or disagrees. Explains the problem with Albert's explanation. Gives an improved explanation.

4. **Reason.** Albert m... entire dot pattern on the ticker tape. He says, "My resu... rt moves 53 cm in the positive direction." Do you agree or disagree with Albert? Explain.

I disagree with Albert. His statement would be correct if the cart continued moving with a constant velocity. However, the velocity of the cart is not constant and is speeding up instead. As a result, during the next second it will travel more than 53 cm, at least until it reaches the end of the incline.

Correct: Since the cart is speeding up, it will not travel the same distance each second.

When the velocity is noticeably chang... on of the ratio $\Delta x/\Delta t$. Instead, we call the ratio $\Delta x/\Delta t$ the *ave*... different *state of motion* than constant velocity. We nee... is 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.

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?

Complete: An interpretation describes what the number tells us about the motion of the object. The response also mentions the units.

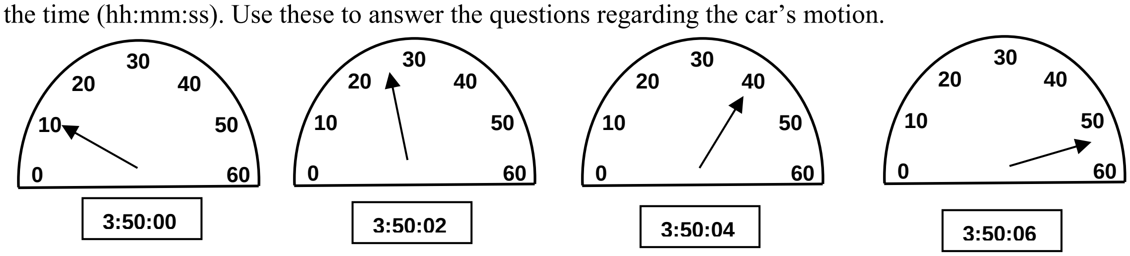
4. **Interpret.** Next, th ... umber 10? (Warning: don't use the word *acceleration* ... nits?)

The number 10 tells us that for every second that goes by, the velocity of the car changes by 10 km/h. The units of the number are (km/h)/s.

Correct: We want to use the expression "the velocity changes". The units are carefully shown

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?

Adapted from *Sense-Making Tutorials*, University of Maryland Physics Education Group

SPH3U: Calculating Acceleration

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

A: Defining Acceleration

The number calculated for the slope of the graph in part C of 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.

Part A:
Sketch shows the objects at the important moments in time.
Quantities are labeled with event numbers (v_2 not v_f).
Quantities are positioned near the appropriate events.
Note: Everyone's values will be a bit different!

Part B:
All representations have event numbers.
No units or values are shown.

... room. The ... otion dete... ty. ... om the gra... ou can ... of the vel...

A: Pictorial Representation

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

Event 1: cart begins moving

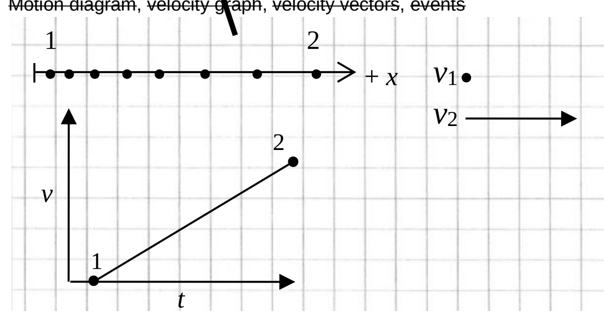
Event 2: just before it crashes

$v_1 = 0$
$t_1 = 0.45$ s

$v_2 = 0.45$ m/s
$t_2 = 4.4$ s

B: Physics Representation

~~Motion diagram~~, ~~velocity graph~~, ~~velocity vectors~~, ~~events~~



C: Word Representation

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

The cart starts from rest and speeds up with a positive acceleration. Assume the acceleration is constant. I estimate the acceleration will be around 0.1 m/s^2.

Part C:
Estimations can be tricky. Here are two approaches:
(1) Do a simplified mental calculation $a = (0.4\text{ m/s})/4\text{ s} = 0.1\text{ m/s}^2$
(2) Or just reason that its final speed is small, so the acceleration can't be very large and guess 0.5 m/s^2 or 0.1 m/s^2

D: Mathematical Representation

Describe physics of steps, complete equations, algebraically isolate, substitutions with units, final sta...

Find the acceleration of the cart as it speeds up along the track.

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{0.45\ m/s\ - 0}{4.4\ s - 0.45\ s} = 0.1139\ m/s^2$$

I predict the cart accelerated at 0.114 m/s^2 along the track.

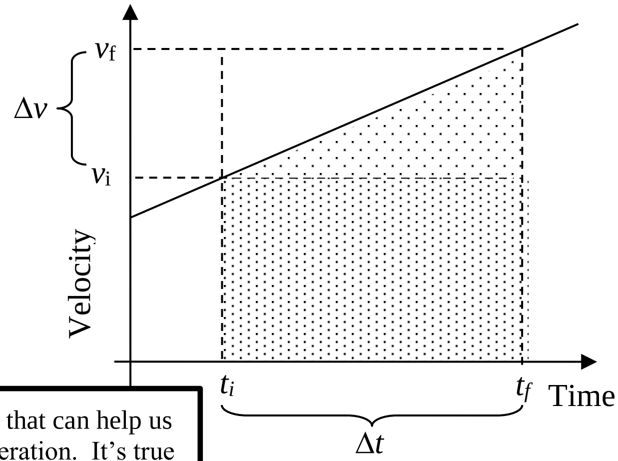
Part D:
The description should explain the purpose of the math you are about to do. Write the symbols using event numbers. Show all the values you substituted into the equation including their units. Give an answer with 4 sig. digs. The final statement has 3 sig. digs.

SPH3U: Area and Displacements

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
object if we

> We replace Δv with $a\Delta t$ because we want to create an equation that can help us find the object's displacement when we already know its acceleration. It's true that sometimes we don't know an object's acceleration. In that case, a different equation is needed to find the displacement! Coming soon!

3. **Repres** e: $\Delta v = a\Delta t$. Make a mathem le. Do a bit of algebra work to simplify your expression.

   area = $\frac{1}{2}\Delta v\Delta t = \frac{1}{2}(a\Delta t)\Delta t = \frac{1}{2}a\Delta t^2$

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

   area = $v_i\Delta t + \frac{1}{2}a\Delta t^2$

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.

   $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$

> 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 (2.51 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 x 10^6 m/s and then it slowed down at the rate of 1.25 x 10^{14} m/s^2 in 4 x 10^{-8} s. How far does it travel while slowing down? Hint: check the sign of each vector quantity in part A of your solution. (0.1 m)

SPH3U: The BIG Five

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

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.

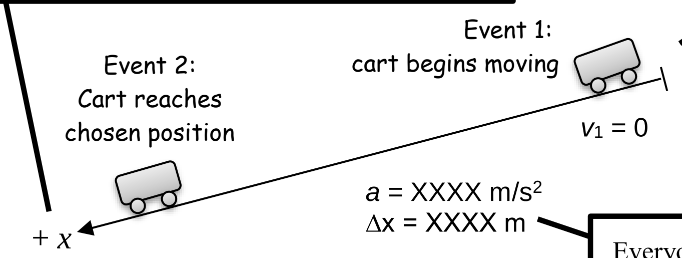
A: Pictorial Representation

s & unknowns with symbols,

Don't forget to label the positive *x*-direction.

The sketch should look like an incline!

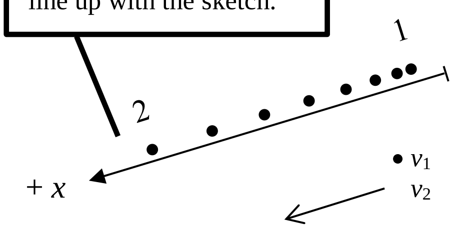
ers, the ... three to solve the problem. I'm stuck! Explain how to help Emmy.

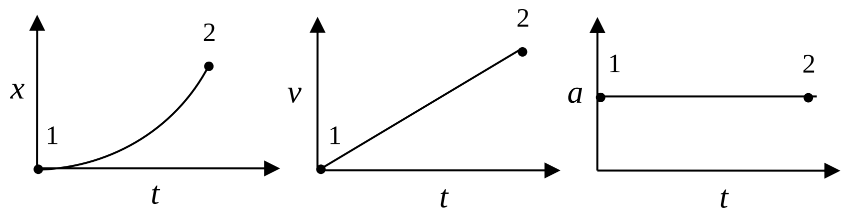


Everyone's values will be different!

The motion diagram and velocity vectors should line up with the sketch.

elocity vectors, events





D: Mathematical Representation

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

Find the velocity of the cart when it reaches our chosen position.

The description should be a full sentence that explains the purpose of the math you are about to do.

$v_2^2 = v_1^2 + 2a\Delta x$

$\therefore\ v_2 = \sqrt{2a\Delta x} = \sqrt{2(XXXX\ \frac{m}{s^2})(XXXX\ m)}$

$= X.XXX$ m/s

I predict the velocity of the cart at our chosen position will be X.XX m

Three significant digits for the final statement. Four digits for all the steps before it.

SPH3U: Force Problem Solving

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

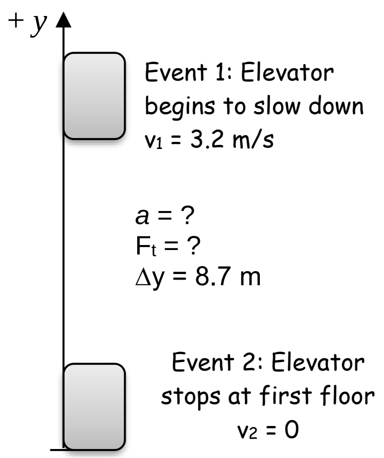
Forces help us to understand why things move the way they do. Newton's 2nd Law, $F_{net} = ma$, is the law of cause and effect: it relates the causes of motion (forces) with the effects (acceleration). As a result, any problem that involves both force and motion will likely use the 2nd law. To understand the force side of the equation we use force diagrams and calculate the net force. To understand the acceleration side we use motion graphs and the BIG 5 equations.

A: The Elevator

An elevator and its load have a combined mass of 1600 kg. It is initially moving downwards at 3.2 m/s. When the elevator passes the second floor, a motor attached to the cable supporting the elevator causes it to slow down through a distance of 8.7 m, allowing the people to get out on the first floor. Complete the parts of our solution process below.

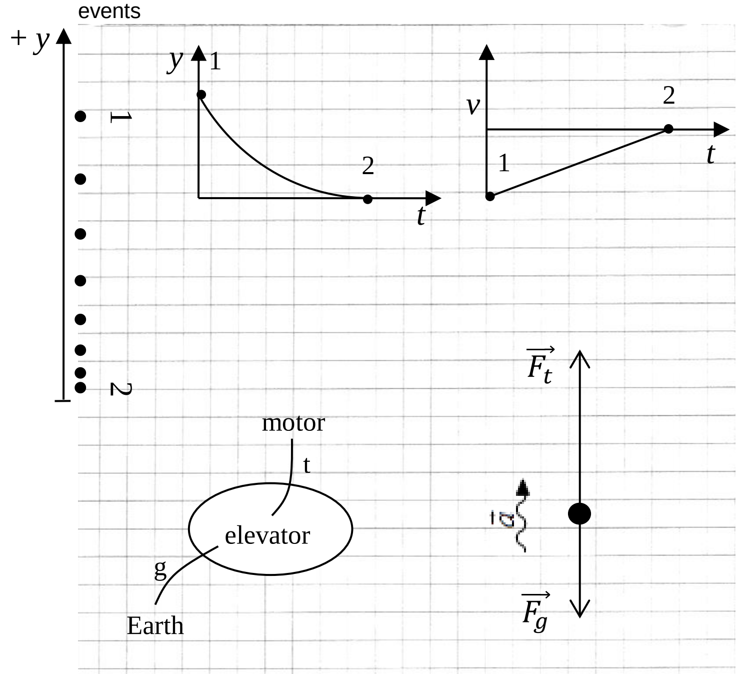
A: Pictorial Representation

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



B: Physics Representation

Motion diagram, motion graphs, interaction diagram, force diagram, events



1. **Explain.** How did you choose your key events?

2. **Describe.** While it is slowing down, what is the elevator interacting with?

C: Word Representation

Describe motion (no numbers), explain why, assumptions, prediction

Did you explain *why* it slows down?
What are we assuming about the acceleration?

The elevator is slowing down (negative velocity and positive acceleration) because the upwards force of tension is greater than the downwards force of gravity. Assume that the forces and acceleration are constant. I estimate the force will be bigger than F_g, around 17000 N.

D: Mathematical Representation

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

> Did you use your sign convention to write the F_{net} without using vector arrows? Did you use our guidelines for significant digits?

Find the acceleration of the elevator while it is slowing down:

$v_2^2 = v_1^2 + 2a\Delta y$

$\therefore\ a = v_2^2/2\Delta y = (3.2\ m/s)^2/(2\cdot 8.7\ m)$

$= 0.5885\ m/s^2$

Find the size of the force of tension:

$F_{net\ y} = ma_y$

$\therefore\ F_t - F_g = ma_y$

$\therefore\ F_t = ma_y + F_g$

$= ma_y + mg$

$= m(a_y + g)$

$= (1600\ kg)\ (0.5885\ m/s^2 + 9.8\ N/kg)$

$= 16620\ N$

The force of tension is 16600 N.

E: Evaluation

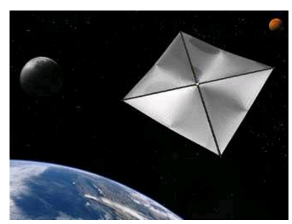
Answer has reasonable size, direction and units? Explain why.

> Is the size of the tension force reasonable? How can you tell compared with gravity?

The size is reasonable since F_t should be larger than F_g. The magnitude of the force is positive. N are a reasonable unit for forces.

B: Sample Problems

Use your solution sheets to answer the following questions.



2. Sunjamming. A "sun yacht" is a spacecraft with a large sail that is pushed by sunlight. Although such a push is tiny in everyday circumstances, it can be large enough to send the spacecraft outward from the Sun on a cost-free but slow trip. Your spacecraft has a mass of 900 kg and receives a steady push of 20 N from the sun. It starts its trip from rest. How far will it travel in 1.0 days and how fast will it then be moving?

3. Two People Pull. Two people are having a tug-of-war and pull on a 25 kg sled that starts at rest on frictionless ice. The forces suddenly change as one person tugs harder with a force of 92 N compared with the other person's force of 90 N. How quickly is the sled moving after 1.5 s?

4. Take Off. A Navy jet with a mass of 2.3×10^4 kg requires an airspeed of 85 m/s for liftoff. The engine develops a maximum force of 1.07×10^5 N, but that is insufficient for reaching takeoff speed in the 90 m runway available on an aircraft carrier. What minimum force (assumed constant) is needed from the catapult that is used to help launch the jet? Assume that the catapult and the jet's engine each exert a constant force over the 90 m distance used for takeoff.

Answers: (1) 8.29×10^7 m, 1.92×10^3 m/s, (2) 0.12 m/s, (3) 8.16×10^5 N

Adapted from Cummings, K., et al, *Understanding Physics*. Wiley, 2004

Conditions for Freefall.

The Air Resistance Assumption: In grades 11 and 12, the size of the force of air resistance (F_{air}) is almost always much smaller than the other forces involved. As a result, we will assume that the size of air resistance is zero. We will only include air resistance if the situation does not make sense without it (like a person with a parachute).

B: The Freefall Problem

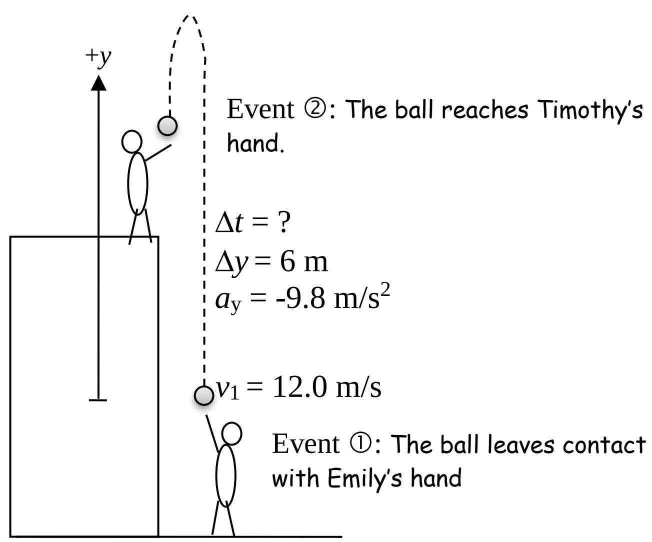
Timothy, a student no longer at our school, has climbed up on to the roof of our school. Emily is standing below and tosses a ball straight upwards to Timothy. The ball travels up past him, comes back down and he reaches out and catches it. Tim catches the ball 6.0 m above Emily's hands. The ball was travelling at 12.0 m/s upwards, the moment it left Emily's hand. We would like to know how much time this trip takes.

1. **Represent.** Complete part A below. Draw a coordinate system that shows the *y*-origin for position measurements and where upwards is positive. Only label the events that define the start and end moments of the problem.

2. **Represent.** Complete part B below. Make sure the two graphs line-up vertically. Draw a single dotted vertical line through the graphs indicating the moment when the ball is at its highest.

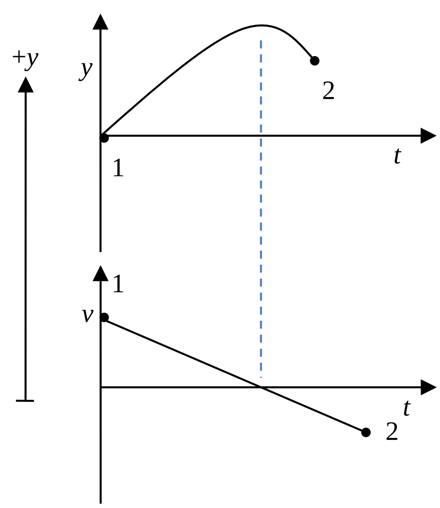
A: Pictorial Representation

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



B: Physics Representation

Motion diagram, ~~motion graphs~~, ~~key events~~



3. **Reason.** We would like to find the displacement of the ball while in freefall. Some students argue that we can't easily tell what the displacement is since we don't know how high the ball goes. Explain why it is possible and illustrate this displacement with an arrow on the sketch.

The total length of the path traveled by an object is the *distance*. The change in position, from one event to another is the *displacement*. Distance is a scalar quantity and displacement is a vector quantity. **For constant velocity only**, the magnitude of the displacement is the same as the distance.

4. **Reason.** The BIG 5 equations are valid for any interval during which the acceleration is constant. Does the ball accelerate uniformly between the two events you chose? Explain.

5. **Reason.** Isaac says, "I want to use an interval of time that ends when the ball comes to a stop in Tim's hand. Then we know that $v_2 = 0$." Why is Isaac incorrect? Explain.

6. **Solve.** Choose a BIG five equation to solve for the time. (Hint: one single BIG 5 equation will solve this problem). Note that you will need the quadratic formula to do this! $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ For convenience you may leave out the units for the quadratic step.

D: Mathematical Representation

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

Find the time for the ball to arrive in Timothy's hand.

$\Delta y = v_1\Delta t + \frac{1}{2}a\Delta t^2$

$6 = 12\Delta t + \frac{1}{2}(-9.8)\Delta t^2$

$\therefore -4.9\Delta t^2 + 12\Delta t - 6 = 0$

Use the quadratic formula:

$$\Delta t = \frac{-12 \pm \sqrt{12^2 - 4(-4.9)(-6)}}{2(-4.9)}$$

$\Delta t = 1.224 \pm 0.5242$ s

The ball reaches Timothy's hand at 1.75 s.

7. **Interpret.** Now we have an interesting result or *pair* of results! Why are there two solutions to this problem? How do we physically interpret this? Which one is the desired solution? Explain using a simple sketch.

The ball has a vertical displacement of 6 m above Emily at <u>two</u> different times, once on the way up and <u>again</u> on the way back down.

8. **Interpret.** State your final answer to the problem.

Homework: Freefalling

1. Isaac is practicing his volleyball skills by volleying a ball straight up and down, over and over again. His teammate Marie notices that after one volley, the ball rises 3.6 m above Isaac's hands. What is the speed with which the ball left Isaac's hand? (8.40 m/s)

2. With a terrific crack and the bases loaded, Albert hits a baseball directly upwards. The ball returns back down 4.1 s after the hit and is easily caught by the catcher, thus ending the ninth inning and Albert's chances to win the World Series. How high did the ball go? (20.6 m)

3. Emmy stands on a bridge and throws a rock at 7.5 m/s upwards. She throws a second identical rock with the same speed downwards. In each case, she releases the rock 10.3 m above a river that passes under the bridge. Which rock makes a bigger splash? (same)