10, 11

## B: Problems Unsolved

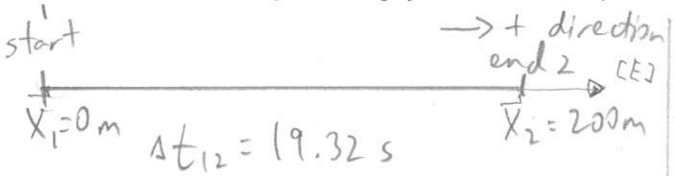
Use the new process to solve the following problems. To conserve paper, some people divide each page down the centre and do two problems on one page.

1. Usain Bolt ran the 200 m sprint at the 2012 Olympics in London in 19.32 s. Assuming he was moving with a constant velocity, what is his speed in km/h during the race? (37.3 km/h)
2. In February 2013, a meteorite streaked through the sky over Russia. A fragment broke off and fell downwards towards Earth with a speed of 12 000 km/h. The fragment was first spotted just as it entered our atmosphere at a position of 127 km above Earth. What was its position above Earth 10.0 seconds later? (93.7 km)

### A: Pictorial Representation

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

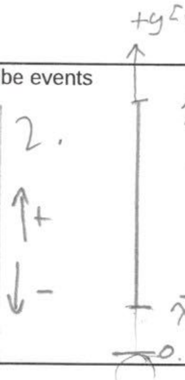
1\.




$\Delta t_{12} = 19.32$ s

$\vec{v} = ?$

2\.




$\vec{x}_1 = 127$ km  $\vec{v}_1 = -12000$ km/h

$\Delta t = 10$ s

$\vec{x}_2 = ?$  $\vec{v}_2 = -12000$ km/h

### B: Word Representation

Describe motion (no numbers), assumptions

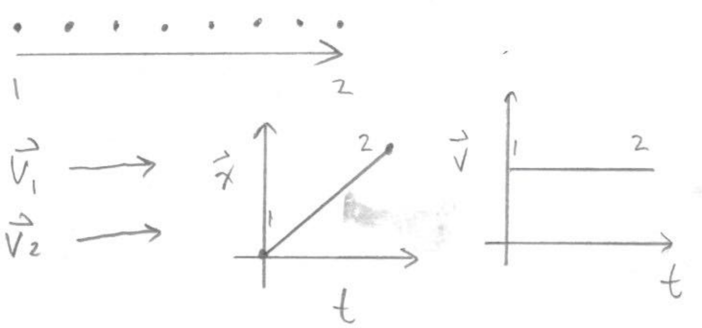
1\. running along track at constant velocity

2\.
- meteorite falling downwards (negative direction)
- constant velocity

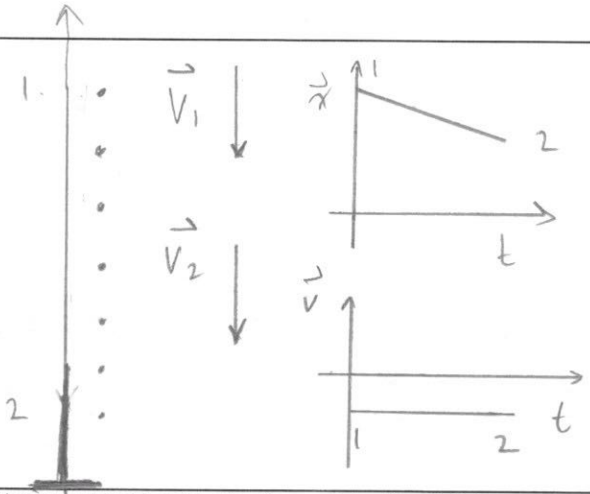
### C: Physics Representation

Motion diagram, motion graphs, velocity vectors, events

1\.




2\.




### D: Mathematical Representation

Number and describe steps, complete equations, substitutions with units, final statement with units, direction and significant digits

**Problem 1**

$\Delta \vec{x}_{12} = 200$ m  $\Delta t = 19{,}32$ s

Find velocity

$$\vec{v} = \frac{\Delta \vec{x}_{12}}{\Delta t} = \frac{200 \text{ m}}{19.32 \text{ s}} = 10{,}35 \text{ m/s}$$

Convert to km/h

$$\vec{v} = 10.35 \text{ m/s}\left(\frac{1 \text{ km}}{1000 \text{ m}}\right) = 0.01035 \text{ km/s}$$

$$= 0.01035 \text{ km/s}\left(\frac{3600 \text{ s}}{1 \text{ h}}\right)$$

$$= 37.3 \text{ km/h}$$

**Problem 2**

$\Delta \vec{x}_{12} = ?$  $\vec{v} = -12000$ km/h  $\Delta t = 10$ s

1. Convert time to h

$$\Delta t = 10 \text{ s}\left(\frac{1 \text{ h}}{3600 \text{ s}}\right) = 0.002\dot{7} \text{ h}$$

2. Find $\Delta \vec{x}_{12}$

$$\vec{v} = \frac{\Delta x}{\Delta t}$$

$$-12000 = \frac{\Delta x}{0.0027}$$

$$(-12000)(0.0027) = \Delta x$$

$$\Delta x = -33.3 \text{ km}$$

3. Find $\vec{x}_2$

$$\Delta \vec{x}_{12} = \vec{x}_2 - \vec{x}_1$$

$$-33.3 = \vec{x}_2 - 127$$

$$+127 \qquad +127$$

$$\boxed{93.7 \text{ km} = \vec{x}_2}$$

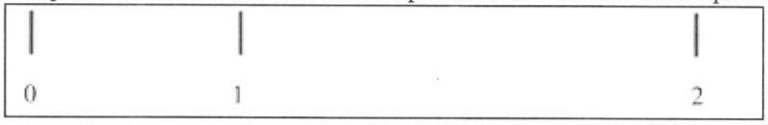
# SPH3U: Changing Velocity

We have explored the idea of changing velocity, average velocity and instantaneous velocity and the differences between them.

**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. **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.



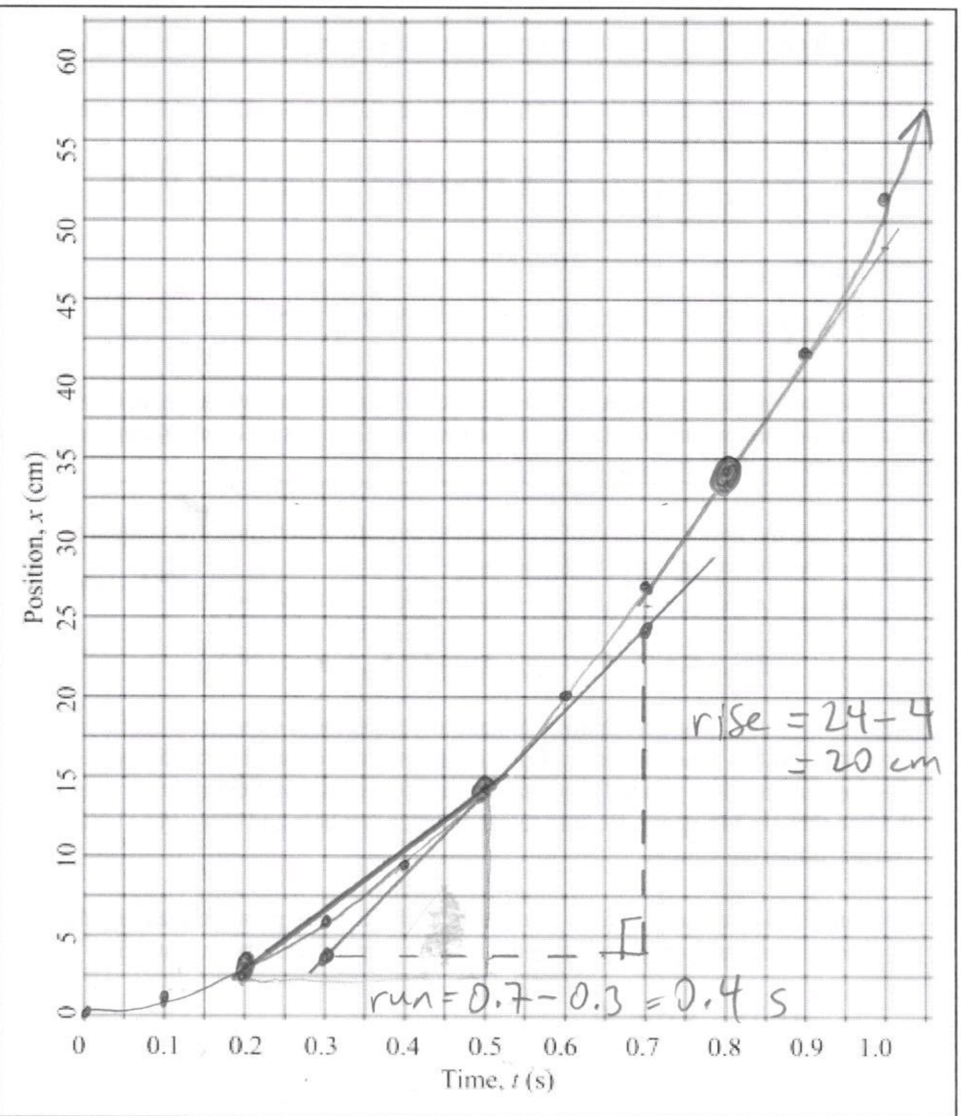

2. **Reason.** The timer is constructed so that it hits the tape 60 times every second. How much time does each six-space interval take? Explain your reasoning. Each dot represents $\frac{1}{60}$ s. So 6 dots is $6 \times \left(\frac{1}{60}\right)$ $= 0.1$ s

3. **Measure.** Collect a complete set of position and time data from your tickertape. **Each** position measurement should start from the first mark: "0".

| Time, *t* (s) | Position, *x* (cm) |
|---|---|
| 0 | 0 |
| 0.1 | 1 |
| 0.2 | 3 |
| 0.3 | 6 |
| 0.4 | 9 |
| 0.5 | 14 |
| 0.6 | 20 |
| 0.7 | 27 |
| 0.8 | 34 |
| 0.9 | 42 |
| 1.0 | 52 |

4. **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. curve - vertical distances seem to be increasing

5. **Represent**. 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.




~~23~~ 12 $\vec{v}_5 = \frac{\Delta x}{\Delta t} = \frac{20 \text{ cm}}{0.4 \text{ s}} = 50$ cm/s

6. **Explain.** During the time interval from 0 to 1.0 seconds, how can you tell if the velocity is changing:

a) from the ticker tape? b) from the table of values? c) from the position-time graph?

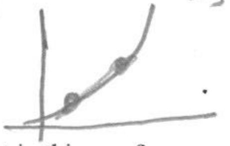
position values go up by bigger amounts ⟺ distance between points increases. is curved

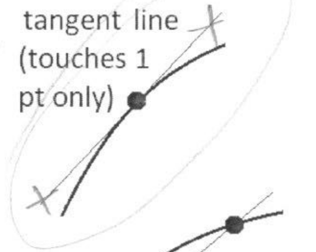
7. **Draw & Calculate**. Draw a secant line on your graph connecting the position at 0.2 s with the position at 0.5 s, and then determine the slope of that line.

rise = 14 − 3 = 11 cm

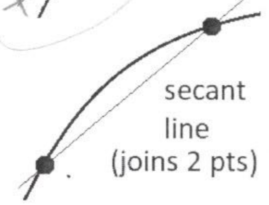
run = 0.5 − 0.2 = 0.3 s

$m = \frac{11\text{ cm}}{0.3\text{ s}} = 36.7\text{ cm/s}$






8. **Interpret.** What does the slope of this secant line represent in this case?




The velocity (average) between 0.2 and 0.5 s.

| The slope of the secant line on a curving position-time graph gives the object's *average velocity* over that time interval |
|---|

9. **Draw & Calculate**. Draw a tangent line on your graph at 0.8 s. Determine the slope of that line.

(1.0, 48)

(0.7, 26)

$m = \frac{48-26}{1.0-0.7} = \frac{22\text{ cm}}{0.3\text{ s}} = 73.3\text{ cm/s}$

10. **Interpret.** What does the slope of this tangent line represent in this case?

The velocity at 0.8 s (instantaneous)

| The slope of the tangent to a curving position-time graph give the object's *instantaneous velocity* |
|---|

11. **Reason.** Is it possible for the average velocity over a given interval to be the same as the instantaneous velocity at some specific time during that interval? Consider a diagram to help explain.

Yes

↳ slope of secant and slope of tangent are the same.

12. **Reason.** A student claims that during any time interval there must be an instantaneous velocity that is the same as the average velocity over that interval. Do you agree? Consider diagrams to help explain.

Seems to be true. Can always draw a tangent with same slope as secant.

10, 11

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## A: Pictorial Representation

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

1. start → + direction [E]; end 2

$X_1 = 0\,m$ $\quad \Delta t_{12} = 19.32\,s$ $\quad X_2 = 200\,m$

$\vec{v} = ?$

2. $+y$ [up]; ↑+ ↓−

$\vec{x}_1 = 127\,km$ $\quad \vec{v}_1 = -12000\,km/h$

$\Delta t = 10\,s$

$\vec{x}_2 = ?$ $\quad \vec{v}_2 = -12000\,km/h$

0

## B: Word Representation

Describe motion (no numbers), assumptions

running along track at constant velocity

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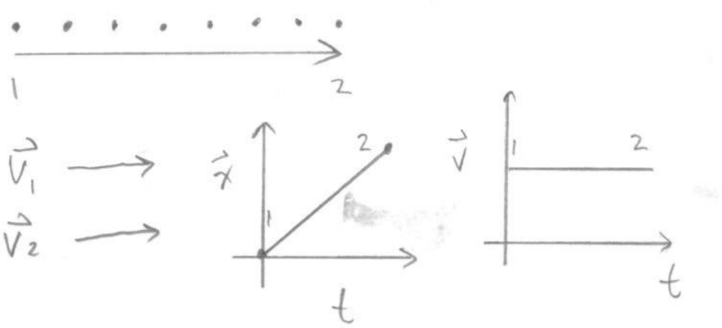
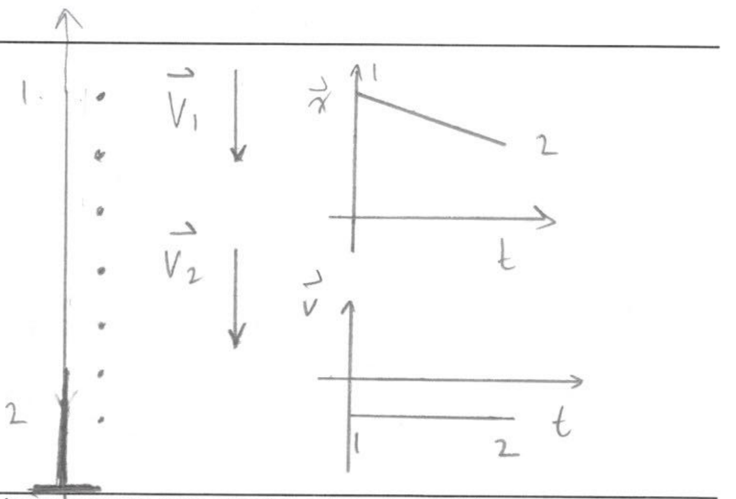
- constant velocity

## C: Physics Representation

Motion diagram, motion graphs, velocity vectors, events





## D: Mathematical Representation

Number and describe steps, complete equations, substitutions with units, final statement with units, direction and significant digits

$\Delta \vec{x}_{12} = 200\,m$ $\quad \Delta t = 19.32\,s$

Find velocity

$\vec{v} = \frac{\Delta \vec{x}_{12}}{\Delta t} = \frac{200\,m}{19.32\,s} = 10.35\,m/s$

Convert to km/h

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$\Delta \vec{x}_{12} = ?$ $\quad \vec{v} = -12000\,km/h$ $\quad \Delta t = 10\,s$

1. Convert time to h

$\Delta t = 10\,s\left(\frac{1\,h}{3600\,s}\right) = 0.002\dot{7}\,h$

2. Find $\Delta \vec{x}_{12}$

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$-33.3 = \vec{x}_2 - 127$

$+127 \quad\quad +127$

$\boxed{93.7\,km = \vec{x}_2}$

# SPH3U: The Idea of Acceleration

## A: The Idea of Acceleration

Interpretations are powerful tools for making 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. 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.

   Every second the car gains 10 km/h. So in 2 seconds it gains 20 km/h. So velocity is 20+20=40 km/h

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

   6 seconds → needs to gain 80-20=60 km/h, and gains 10 km/h every second.

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?

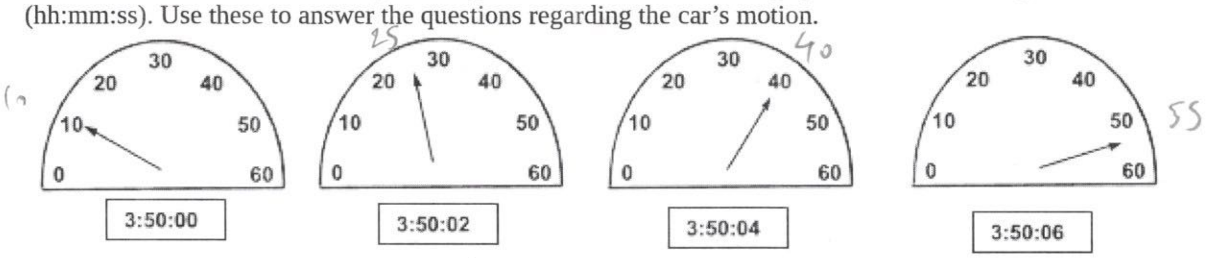
   30 km/h – this is the increase in speed between beginning and end of increase

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?)

   $\frac{30\text{ km/h}}{3\text{ s}} = 10$ km/h per second. Every second the speed increases by 10 km/h

## 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.

   Instantaneous – a speedometer only shows speed the car is currently travelling

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

   Speeding up steadily – gaining 15 km/h every 2 seconds. (or 7.5 km/h every second)

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

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.

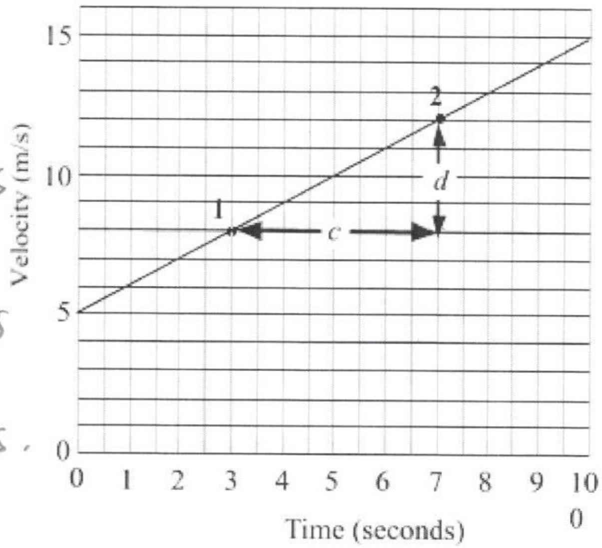
Divide the change in velocity $\Delta v$ by the change in time $\Delta t$ $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ $\frac{km/h}{s}$

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

Hours unit is grouped with km as km/h, representing velocity
Seconds unit shows how much $\vec{v}$ is changing every second.

## 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?

Moment 1: at 3 s, velocity is 8 m/s
Moment 3: at 7 s, velocity is 12 m/s

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

It's the time interval between 3 s and 7 s.
$\Delta t_{12}$

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

It's the change in velocity that occurs between moments 1 and 2.

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

$\frac{\text{change in velocity}}{\text{change in time}}$ } how much velocity is changing per second

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

$\Delta \vec{v} = d = 12 - 8 = 4\,m/s$ $\quad \frac{d}{c} = \frac{4\,m/s}{4\,s} = 1\,\frac{m/s}{s}$

$\Delta t = c = 7 - 3 = 4\,s$

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

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



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