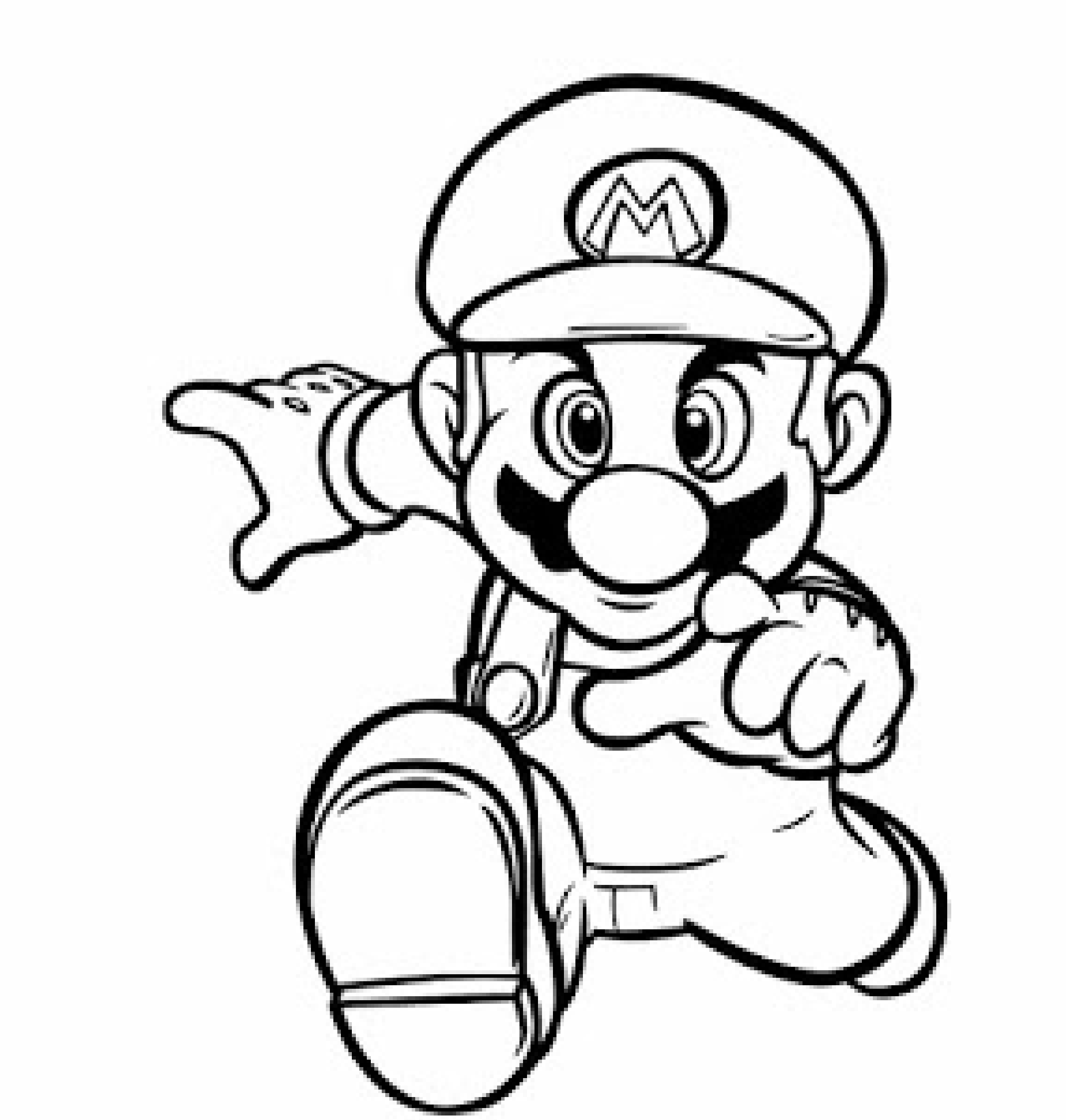
Unit 3

Motion



Just How Fast Were They?

Average speed is defined as:

So just how fast were these athletes on race day?

Case 1: Rio 2016 Olympics: Penny Oleksiak Wins Gold, Sets Olympic Record

YouTube link: https://www.youtube.com/watch?v=Yej6QDEoZzk

Event: ____

Distance Travelled: __________________

Time of Penny Oleksiak's Gold / Olympic Record Performance: __________________

Question:

What was Penny Oleksiak's speed in units of:

(a) metres-per-second, "m/s"?

(b) kilometres-per-hour, km/h"?

Case 2: Rio 2016: Usain Bolt Wins Gold, Andre De Grasse Wins Bronze in Men's 100M

YouTube link: https://www.youtube.com/watch?v=z2tXiPOgX80&t=259s

Event: ____

Distance Travelled: __________________

Time of Usain Bolt's gold medal Performance: __________________

Time of Andre De Grasse's bronze medal Performance: __________________

Questions:

1. What was **Usain Bolt's** speed in units of:
    (a) metres-per-second, "m/s"?

    (b) kilometres-per-hour, "km/h"?

2. What was **Andre De Grasse's** speed in units of:
   (a) metres-per-second, "m/s"?

   (b) kilometres-per-hour, "km/h"?

Case 3: Rio 2016: Penny Oleksiak's Silver Medal Race in Women's 100m Butterfly

YouTube link: https://www.youtube.com/watch?v=3-5D43TeAMM

Event: ____

Distance Travelled: ________________

Time of Penny's silver medal performance: ________________

Question:

What was Penny Oleksiak's speed in units of:
(a) metres-per-second, "m/s"?

(b) kilometres-per-hour, "km/h"?

Practice Problems

1. For each case below, quote the speed of the athlete or athletes in units of:
   (i) metres-per second, "m/s"   (ii) kilometres-per-hour, "km/h"

(a) Rio 2016: Canada's Bronze Medal Race in Women's Swimming 4x200M Freestyle Final
YouTube link: https://www.youtube.com/watch?v=ZWl0pWpZ1JM

(b) Rio 2016: Canada's Silver Medal Race in Women's Rowing Lightweight Double Sculls
YouTube link: https://www.youtube.com/watch?v=qitS-zDHGyU

(c) Atlanta 1996: Canada's Donovan Bailey sets a World Record and Gold in 100m Final
YouTube link: https://www.youtube.com/watch?v=_Z64K8kznYs

2. Compare Donovan Bailey's 1996 gold medal speed to Usain Bolt's 2016 gold medal speed. Beyond human ability, what may have changed since 1996 to lead to a faster speed for a runner?

Units and Unit Conversions

This "physics" unit will commonly make measurements regarding the ***motion*** of an object.

With any measurement in science, there are two important parts:

1)

2)

*Each part is of equal importance! Get used to quoting **BOTH PARTS** as we work through these studies of motion.*

Quite often, we make a measurement in one unit, yet will wish to ***convert the value to another unit***.

Length Measurements

For length (and distance) measurements, we need to know the SI prefixes which convert from the ***base unit*** of ***metres, "m"*** to a ***derived unit*** such as kilometres, km.

The list of prefixes are below, with their full ***names***, their ***prefix symbol***, and the **factor of 10** that they represent.

name:	Mega	kilo	hecta	deca	(Base Unit)	deci	centi	milli	micro
prefix:	M	k	h	da	(Base Unit)	d	c	m	µ
factor of 10:	10^6	10^3	10^2	10^1	(Base Unit)	10^{-1}	10^{-2}	10^{-3}	10^{-6}
i.e.	1000000	1000	100	10		0.1	0.01	0.001	0.000001

We can remember the prefixes using the memory device:

Quite often we will be given a value, with its given units. We will want new units, which will have a new value. The new units is our goal, our "target" units.

To convert between one unit and another:

Method 1: Unit factors

Idea:
1. Given a value, with its "given" units.
2. Note the "target" or new units, that we want.
3. Set up a conversion factor, using the "factors of 10". Important: In our conversion factor, the new "target" units (that we ***want***) ***go on the top*** (***numerator***). The "given" units (***which must cancel***) ***go on the bottom*** (***denominator***).

Sample Problem 1

Convert 2.15m to centimetres, cm.

Sample Problem 2

Convert 3500mm (millimetres) to kilometres, km. (*Note: Do this in two steps - or the next method!)*

Method 2: Moving the decimal place

Idea:
1. Given a value, with its "given" units.
2. Note the "target" or new units, that we want.
3. Move the decimal as many places as required, according to the "factors of 10" between the two units. Important: Make sure you move the decimal in the correct direction. If the target "want" unit is a larger unit than the "given" unit, move the decimal to the left. If the target "want" unit is a smaller unit than the "given" unit, move the decimal to the right.

IMPORTANT: Note the "JUMPS" for the decimal place:

Name:	Mega	kilo	hecta	deca	(Base Unit)	deci	centi	milli	micro
prefix:	M	k	h	da	(Base Unit)	d	c	m	μ
factor of 10:	10^6	10^3	10^2	10^1	(Base Unit)	10^{-1}	10^{-2}	10^{-3}	10^{-6}
i.e.	1000000	1000	100	10		0.1	0.01	0.001	0.000001

Sample Problem 1

Convert 2.15m to centimetres, cm.

Sample Problem 2

Convert 3500mm (millimetres) to kilometres, km.

Practice Problems: (Answers are at the bottom of the page.)

1. Use either Method 1 or Method 2 above to convert each of the following given values to the new value that corresponds to the new units.
   (a) 1241m to km

   (b) 86cm to hm

   (c) 1.45km to mm

   (d) 5.54km to m

   (e) 13.5mm to cm

   (f) 45dam to dm

2. For each of the following converted values, determine the unit which goes in the blank.

   (a) 14.6cm = 0.146___

   (b) 4643mm = 0.004643___

   (c) 243m = 0.243___

   (d) 243m = 0.243___

ANSWERS

1. (a) 1.241km (b) 0.0086hm (c) 1450000mm (d) 5540m (e) 1.35cm (f) 4500dm
2. (a) m (b) km (c) km (d) km

Time Unit Conversions

Converting between the various units of time is an important skill in the study of motion. Remember these "time unit facts":

1 minute = _____ seconds 1 hour = _____ minutes

To convert between values using different units of time, the unit factor method is useful.
Also note that if a time unit is given as a decimal, the conversion is a little different than if a time value is given as a "mixture of two time units" (compare ***Sample Problem 1*** to ***Sample Problem 2*** below).

Sample Problem 1
Convert 3.5minutes to seconds.

Sample Problem 2
Convert 2 minutes and 14 seconds to seconds only.

Sample Problem 3
Convert 2.1 hours to seconds.

Instead of using the conversion factor method above, we may wish to use the "time unit facts" above to convert between time units. Consider:

1 minute = ____ seconds. So: For minutes to seconds, ________________ by ____

For seconds to minutes, ________________ by ____.

1 hour = ______ minutes. So: For hours to minutes, _________________ by ____

For minutes to hours, _________________ by ____.

1 hour = ______ seconds. So: For hours to seconds, _________________ by ____

For seconds to hours, _________________ by ____.

* Note that for each of the conversions above, to go to the ***smaller time unit*** we ***multiply.***
To go to the ***bigger time unit*** we ***divide***.

Practice Problems

1. Convert each of the following time measurements to the new units.
   (a) 17.3 minutes to seconds.

   (b) 17 minutes and 3 seconds to minutes.

   (c) 2.2 hours to minutes.

   (d) 2.2 hours to seconds.

kilometres-per-hour (km/h) **versus** ***metres-per-second (m/s)***

Quite often, we want to convert between "km/h" and "m/s". In this case, both a distance unit and a time unit are involved. We can use the unit factor method to determine a quick conversion factor rule for converting between these units.

For "km/h" converted to "m/s":

So: For km/h ***to*** m/s, we ________________________________.

For "m/s" converted to "km/h":

So: For m/s ***to*** km/h, we ________________________________.

Sample Problem

Complete each conversion..

(a) 50.0km/h to m/s

(b) 12m/s to km/h

Scientific Notation

Scientific Notation converts regular (decimal) notation for a reported value to a ***base*** and a ***power of 10.***

This means: 0.0034m = 3.4 x 10^{-3} m

The ***base*** is found by ***moving the decimal place until a number between 1 and 10 is obtained.*** (In our example above, we had to move the decimal ***3*** times ***to the left*** to get "***3.4***", which is a number between one and ten.)

The ***power of ten*** is just "10^x" where "***x***" is the number of times you move the decimal.

NOTE: When going FROM regular notation TO scientific notation:
- moving the decimal to the LEFT means "***x***" is ***positive***;
- moving the decimal to the RIGHT means "***x***" is ***negative***.

This means that ***very large numbers AND very small numbers can be conveniently quoted with scientific notation.***

Problems:

1. Convert the following into scientific notation.

(a) 300 000 000 m/s = ______________________________

(b) 0.0003634 km/h = ______________________________

(c) 7543 mm = ______________________

2. Convert the following from scientific notation to decimal notation.

(a) 2.75 x 10^{-4} m = ____

(b) \$2 x 10^{6} = ____

(c) 1.602 x 10^{-19} J = ____

Scientific Notation and Math Operations

Make sure that you know how to enter scientific notation in to your calculator, and be able to add, subtract, multiply and divide these values.

Problems:

Calculate each of the following. Quote your final answer in scientific notation.

(a) 3.85 cm - $2.1\text{x}10^{-1}$ cm

(b) $\dfrac{3.0\text{x}10^{2}\text{ m}}{15.4\text{ s}}$

Worksheet Unit Conversions and Scientific Notation

1. Convert each of the following distance values.
    - (a) 2.45km to m
    - (b) 5.4km to cm
    - (c) 185cm to m
    - (d) 185cm to km
    - (e) 756mm to km
    - (f) 44.2km to m
    - (g) 165m to km
    - (h) 3.28m to km

2. Convert each of the following time values.
    - (a) 3.45min to seconds
    - (b) 3 minutes and 45 seconds to seconds only
    - (c) 5.20 hours to minutes
    - (d) 5465seconds to minutes
    - (e) 6463seconds to hours
    - (f) 7.15 hours to seconds
    - (g) 7 hours and 15 minutes to seconds only

3. Convert each of the following to scientific notation.
    - (a) 454.3m
    - (b) 0.00034m
    - (c) 0.851 seconds
    - (d) 305km
    - (e) 0.000009m
    - (f) 8000000000mm

4. Convert each of the following to decimal form.
    - (a) 3.5 x 10^{-4}m
    - (b) 2.6 x 10^{3}m
    - (c) 1.8 x 10^{-2}m
    - (d) 7.4 x 10^{5}m

5. Calculate the following values. Quote your final answer in scientific notation, with correct units.
    - (a) 2.340 x 10^{2}m + 1.000 x 10^{3}m
    - (b) 51.20km + 3.2 x 10^{-1}km
    - (c) (2.45h)·(1.10 x 10^{2}km/h)
    - (d) $\dfrac{7.7\text{m}}{2.1 \text{ x } 10^{-2}\text{ s}}$

Answers:

1. (a) 2450m
    - (b) 540000cm
    - (c) 1.85m
    - (d) 0.00185km
    - (e) 0.000756km
    - (f) 44200m
    - (g) 0.165km
    - (h) 0.00328km

2. (a) 207s
    - (b) 225s
    - (c) 312min
    - (d) 91.08min
    - (e) 1.795h
    - (f) 25740s
    - (g) 26100s

3. (a) 4.543 x 10^{2}m
    - (b) 3.4 x 10^{-4}m
    - (c) 8.51 x 10^{-1}s
    - (d) 3.05 x 10^{2}km
    - (e) 9 x 10^{-6}m
    - (f) 8 x 10^{9}mm

4. (a) 0.00035m
    - (b) 2600m
    - (c) 0.018m
    - (d) 740000m

5. (a) 1.234 x 10^{3}m
    - (b) 51.52m = 5.152 x 10^{1}km
    - (c) 269.5km = 2.695 x 10^{2}km
    - (d) 3.7 x 10^{2}m/s

Measurement and Significant Figures

Quick Activity: Making Measurements

Purpose: To perform length measurements using various methods of measurement.

Materials: timing device (watch, stopwatch, cellphone app)
Various rulers, measuring tapes, and metre sticks

Procedure:

For the time measurement:

1. Have your measurement device ready. Measure the time it takes for a person to walk across the classroom.

For the distance measurements:

1. Choose a measuring device from those available and measure the length of the object.
2. Report the measurement length, including the measured value **and** units. Report the device used to measure the object.

Observations:

Time Measurement:

Time to walk across the classroom: ________________________

Distance Measurements:

Item / distance measured:

1.__________________________ Length:___________ Device used:___________________

2.__________________________ Length:___________ Device used:___________________

3.__________________________ Length:___________ Device used:___________________

Analysis:

1. For the time measurement, what would be implied if we did not quote the decimal places with our time measurement?

2. For the distance measurements, was there a particular item / distance measured that you feel was measured with lesser accuracy than most others? Briefly explain why this is the case.

3. Was there a particular item / distance measured that you feel was measured with greater accuracy than most others? Briefly explain why this is the case.

4. When it comes to measuring a distance accurately, what can be done to achieve an accurate measurement?

Significant Figures

The use of **significant figures** reflect the ***accuracy of a measurement***. In general, if a measured value is quoted with many significant figures, it is an accurately measured value compared to a value quoted with few significant figures.

To count the significant figures in a value, it is important that we know **how to deal with non-zero values and zero values.**

Guidelines: For a decimal number *or* the leading part of a scientific notation value

1. Non-zero values are counted as significant.
2. Zeroes to the **left** of non-zero values are **not significant**, regardless of where the decimal place is found.
3. Zeroes to the **right** of non-zero values **are significant**. **IMPORTANT:** If no decimal places are shown in the value, the zeros to the right are not significant. (See (d) below.)
4. Zeroes which are "sandwiched" between non-zero values **are significant**.

Sample Problem 1

Count the number of significant figures in each measured value.

(a) 0.102cm: ________________________

(b) 3.60km: __________________________

(c) 0.05060m: ________________________

(d) 230km: __________________________

Sample Problem 2

Round each value to the given number of significant figures.

(a) 0.01850m to two significant figures: __________________________

(b) 0.41 seconds to one significant figure: __________________________

(c) 6.83 x 10^{-2}g to one significant figure: __________________________

Significant Figures and Mathematical Operations

When we perform mathematical operations (i.e. multiplying and dividing), we must take in to account the significant figures which **go in to making the result** and **quote the correct significant figures in the final result**.

Rule: Addition and Subtraction

Report the final result to have the **least decimal places** as the values which went in to producing that result.

Rule: Multiplication and Division

Report the final result to have the **least total significant figures** as the values which went in to producing that result.

Rounding: When rounding, for five (5) and above, round up. For values below 5, round down.

Sample Problem 3

Report each final value with correct units and significant figures.

(a) 12.5cm - 3.12cm

(b) 0.80m + 0.221m

(c) 3.5m / 2.06s

(d) 9cm^2 x 9.34cm

Worksheet *Significant Figures*

1. Write the number of significant figures in the blank.

(a) 760 km ___
(b) 310.0 s ___
(c) 35070 mm ___
(d) 105040 atoms ___
(e) 3.890 m ___
(f) 1001.10 kg ___
(g) 0.0025 m ___
(h) 21.0400 L ___
(i) 0.250 s ___
(j) 890.010 g ___

2. Complete the operations below and report your final answer with the correct number of significant figures.

(a) 145 s + 7.8 s = ____________
(b) 1.25 km + 65 km = _____________
(c) 12.5 g + 0.05 g = ____________
(d) 75 s - 20 s = ____________
(e) 34.0454 km - 32.022 km = ____________
(f) 235 g + 12.1 g = ____________
(g) 1025 m + 1010 m = ___________
(h) 1.0025 m - 0.250 m = ___________
(i) 8500.0 g - 650.00 g = ___________
(j) 175.68 m - 95.5 m = ___________

3. Complete the operations below and report your final answer with the correct number of significant figures.

(a) 3.894 x 2.16 = ____________
(b) 2.46 x 2 = ____________
(c) 13.7 x 2.5 = ____________
(d) 0.00003 x 727 = ____________
(e) (8.9 x 10^{-1}) / 9 = ____________
(f) 485 ÷ 9.231= ____________
(g) (5.12 x 10^{4}) x (6.8726 x 10^{-9}) = ____________
(h) 21.0 x 3.58 = ____________
(i) 5003 / 3.781 = ____________
(j) 5100 / 55 = ____________

4. Complete, with correct significant figures:
(a) 2500 m - 2400.50 m = ____________
(b) 3000m / 16s = ____________

Answers

1. (a) 2
(b) 4
(c) 4
(d) 5
(e) 4
(f) 6
(g) 2
(h) 6
(i) 3
(j) 6

2. (a) 153s
(b) 66km
(c) 12.6g
(d) 55s
(e) 2.023km
(f) 247g
(g) 2035m
(h) 0.753m
(i) 7850.0g
(j) 80.2m

3. (a) 8.41
(b) 5
(c) 34
(d) 0.02
(e) 0.1 or 1x10^{-1}
(f) 52.5
(g) 3.52 x 10^{-4}
(h) 75.2
(i) 1323
(j) 93

4. (a) 1.0 x 10^{2}m
(b) 2 x 10^{2} m/s

Speed, Distance, and Time

We have seen: $speed = \frac{distance}{time}$

In symbols: $v = \frac{d}{t}$

Given any two of the three, we will wish to calculate the third quantity.
IMPORTANT: Watch the ***units***! ***Always*** include units with ***every*** value, and ***cancel*** units as you go along. Lastly, ***always quote the final units*** with the final answer.

If we choose to rearrange this formula, we get:

for distance, d: $d = vt$

for time, t: $t = \frac{d}{v}$

Sample Problems

1. Zeke runs 18m in 3.4 seconds. What's Zeke's average speed?
2. Jerry hikes 4.4 hours at a speed of 2.6km/h. What distance does Jerry hike?
3. How long does it take to cycle 21.5km at a speed of 23.5km/h?

Worksheet Speed, Distance, and Time

(Answers at the end of next page)

1. If David throws a football 49 meters in 2.3 seconds, what is the average speed of the football?

2. When playing soccer, it takes Ashley 2.85 seconds to run from her place on the field at an average speed of 6.4m/s to get to the ball. What is the distance does she cover in that time?

3. Darrell ran 5845 meters in a local road race at an average speed of 6.1 m/s. What was his race time?

4. If Brian races his pickup down Route 10 for 24100 meters in 815 seconds, what is his average speed?

5. If Mike rides his motorcycle at an average speed of 21 m/s for 524 seconds, how far did he ride?

6. If Sarah backstrokes at an average speed of 4.3 m/s, how long will it take her to complete a race of 200.0 meters length?

7. A spider was able to cover 20 centimeters in 5 seconds. What was the average speed of the spider?

8. Zoe kayaks at a speed of 9.7km/h. What time will it take her to cross a 3.4km pond in units of:
   (a) hours (b) minutes

9. A car travels from Corner Brook to Mount Pearl, a distance of 681km. The average speed of the car is 102km/h. What time will it take to do the trip, expressed in units of:
   (a) hours (b) hours and minutes

10. Use your mobile device to look up the distance between where you are now and an ideal getaway destination. Then, choose a mode of transportation, and look up the average speed for that mode of transportation. Use this data to determine the travel time to your destination, using your chosen mode of transportation.

ANSWERS

1. 21m/s 2. 18m 3. 958s → $9.5\text{x}10^2$s (2 significant figures) 4. 29.6m/s
5. 11004m → $1.1\text{x}10^4$m or 11km (2 significant figures) 6. 47s 7. 4cm/s
8. (a) 0.35h (b) 21 minutes 9. (a) 6.68h (b) 6 hours, 41 minutes

Uniform Motion and Graphs

Consider: A sports team gets on a bus, and leaves the school heading across the highway. A table of data for the distance the bus has travelled is given below:

time (hours)	Distance Travelled (km)
1	91
2	210
3	303
4	387
5	509

1. Estimate the speed of the bus. Briefly explain your reasoning.

2. Graph the data below using a line graph. Use a line of best fit when drawing the line of the graph. Fully label the graph.

3. Use a slope calculation to find the average speed of the bus. Show your workings.

Scalar and Vector Quantities

Textbook pages 198 onward

Scalar quantities: have a ____________________ (i.e. size and units), but ***<u>NO direction</u>*** is given.

Examples: ***distance***, ***d***, as in "12 m" or "5km"
time, as in "60 minutes" or "3600s"
speed, as in 25km/h or 6.7m/s

Vector quantities: have a ***<u>magnitude</u>*** ***<u>AND</u>*** a given ***<u>direction</u>***.

Two of the vector quantities that we will study are ***DISPLACEMENT*** and ***VELOCITY***.

<u>DISPLACEMENT:</u>

displacement, $\vec{\Delta d}$**:** the change in an object's *final position* relative to it's (1)____________________ position.

Example: Tom is 20km[N] of his home on his neighbourhood path.
Note the magnitude (20km) and the direction ([N], for "north").

Also notice the "→" above the "$\vec{\Delta d}$". This indicates that we are referring to displacement, which is a (2) __________________ . This is ***<u>not</u>*** the same as distance, *"d"*, which is a scalar.

If we compare **distance** to **displacement**, we see that:

- ***distance, d,*** keeps track of ***total length*** traveled;
- ***displacement,*** $\vec{\Delta d}$, gives you the "Point A to Point B" straight line length from your starting point position to your final position. Consider:

$$\vec{\Delta d} = \vec{d}_2 - \vec{d}_1$$

where: $\vec{\Delta d}$ ≡ *displacement*;

$\vec{d}_1$ ≡ *starting position;* $\vec{d}_2$ = *final position*

- ***distance***: scalar, *<u>no direction</u>* given. ***displacement***: vector, *<u>has direction</u>*.

<u>DEFINING DIRECTION for DISPLACEMENT VALUES</u>

We will only be studying motion along <u>one direction</u> in Science 1206.
This means, problems may use the following terminology to define direction:

North [N] / South [S], and West [W] / East [E] ***<u>or</u>*** up / down, and, left / right.

<u>IMPORTANT:</u> When we consider graphs:
"***moving to the right", [N] or [E]*** is "***<u>positive</u>***" (or "+") displacement;
"***moving to the left", [S] or [W]*** is "***<u>negative</u>***" (or "-") displacement.

When solving problems involving distance and displacement, ***number lines*** are very useful.

Using Scalar and Vector Quantities to Describe Motion Textbook pages 200 onward

Sample Problem 1
Tom rides his bike 5.0 km east to get to school, then back 3.0 km west to hang out at Jerry's after school. When Tom is at Jerry's:
(a) what is his distance traveled?
(b) what is his displacement?

Solution, Sample Problem 1:

Sample Problem 2
Tom walks 5.5m to the right, then 3.1m to the left. He then walks 1.1m to the right. Lastly, he moves 3.5 to the left. What is Jack's: (a) total distance, and (b) displacement?

Solution, Sample Problem 2:

Worksheet Scalars, Vectors and Displacement

Scalars and Vectors

1. Classify each measurement as being either *scalar* or *vector*.
    - (a) 43.5m[W]
    - (b) 43.5m
    - (c) 12.6s
    - (d) 3.4km[right]
    - (e) 87km/h
    - (f) 78km/h[N]
    - (g) 1.54min
    - (h) 2.2×10^3km[down]

2. Does a car's speedometer indicate a scalar quantity, a vector quantity, or both? Explain.

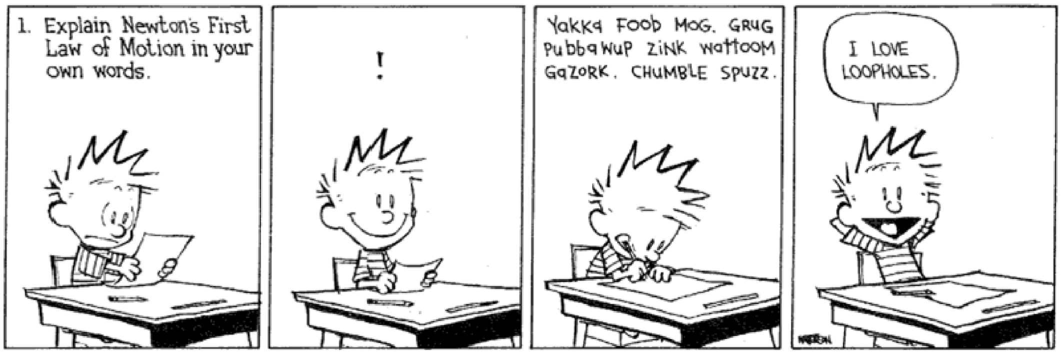
3. Can the displacement of an object from its original position ever exceed the total distance moved? Explain.

4. A jogger runs 725m[N], then encounters a mad dog. He then turns around and runs back 812m[S].
    - (a) What is the distance travelled?
    - (b) What is the runner's displacement?

5. A ball rolls 15m to the right, then hits a wall and rolls 8m to the left. What is the
    - (a) distance travelled by the ball?
    - (b) ball's displacement?

6. A frog hops 12m[W], then 14m[E], then another 6m[E]. What is the:
    - (a) frog's distance travelled?
    - (b) frog's displacement?

7. A ball makes two moves. First, the ball rolls 65m[right]. Its final displacement is 14m[left].
    - (a) What was the ball's second move?
    - (b) What is the ball's total distance travelled?



Answers

1. (a) vector (b) scalar (c) scalar (d) vector (e) scalar (f) vector (g) scalar (h) vector
2. Scalar. The speed is measured, but no direction.
3. No. The displacement is the straight-line (shortest) distance from the starting position to the final position. That may equal the distance travelled in some instances, but displacement will never be greater than the distance travelled.
4. (a) 1537m (b) 87m[S]
5. (a) 23m (b) 7m[right] or +7m (with "right" defined as "+")
6. (a) 32m (c) 8m[E]
7. (a) 79m[left] (b) 144m

Speed and Velocity

Textbook pages 208 onward; pages 256 to 258.

In terms of ***scalar*** measurements, ***speed*** is what we get when we look at ***distance traveled over a certain time period.***

speed, v : the total ***distance traveled*** over time: $$v = \frac{d}{t}$$

In terms of ***vector*** measurements, we have ***velocity***.

velocity, $\vec{v}$ ***:*** the rate at which ***displacement*** changes over time: $$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$

The above formula applies to ***uniform motion*** (i.e. ***no acceleration***), and refers to the average velocity of the object. Later, when we consider non-uniform motion (i.e. acceleration occurs) we will look at instantaneous velocity.

Sample Problem 1:
A cart is pushed 25.5m west for 7.0seconds. It then turns, and goes 16.5m east in 4.0 seconds. For the cart, what is the:

(a) distance traveled?
(b) displacement?
(c) average speed?
(d) average velocity?

Sample Problem 2:

A bus drives at 55km/h north for 1.8hours. It then drives at 75km/h south for 1.1hours. Determine the:

(a) distance traveled by the bus
(b) displacement of the bus
(c) average speed
(d) average velocity

Worksheet Velocity and Speed Calculations

1. A skateboarder cruises 65m to the left in 22 seconds. She then turns instantly, and moves 34m to the right in 11 seconds.
    (a) Determine the total distance traveled by the skateboarder and her average speed.
    (b) Determine the displacement of the skateboarder and her velocity.

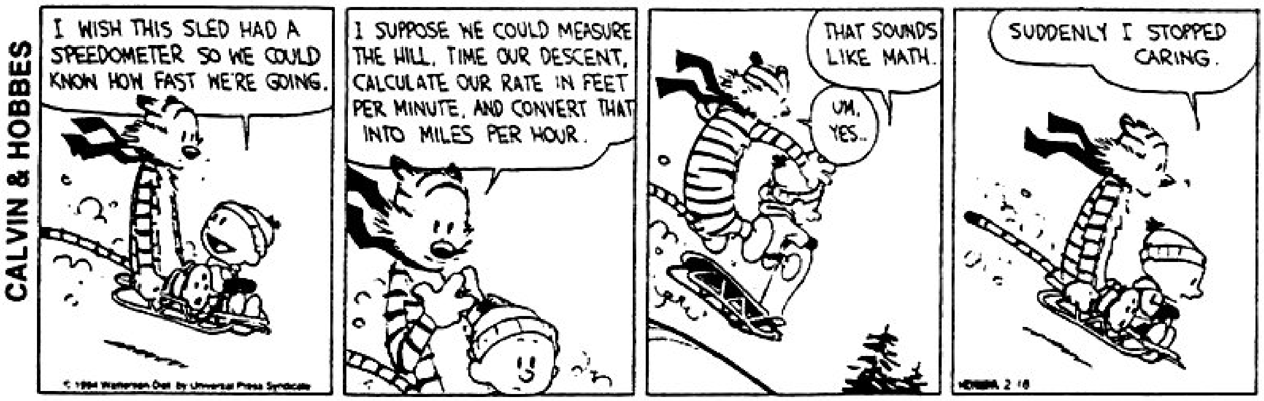
2. (a) Determine the final displacement of a spider which moves 15cm north in 5.0s, 12cm south in 2.0s and 21cm north in 4.5s on his web.
    (b) State the total distance for the spider's journey.
    (c) Calculate the spider's average speed.
    (d) Calculate the time it would take for the spider to travel a total distance of 52cm at this average speed.
    (e) Calculate the spider's velocity.

3. A toy rocket at take-off has a velocity of 15m/s [N] for 5.0s. The engine suddenly stops, and the rocket starts falling toward the earth at a velocity of 12m/s [S] for 3.0s. Determine the rocket's:
    (a) total distance
    (b) displacement
    (c) average velocity
    (d) average speed

4. A ball rolls at 44cm/min to the right for 0.50minutes. It then rolls at a velocity of 25cm/min left for 0.75minutes. What is the ball's:
    (a) displacement
    (b) total distance
    (c) average velocity
    (d) average speed

ANSWERS *(Detailed answers, with workings, are on the Science 1206 webpage)*

1. (a) 3.0m/s (b) -31m or 31m[left] for displacement; -0.94m/s or 0.94m/s[left] for velocity.
2. (a) +24cm or 24cm[N] (b) 48cm (c) 4.2cm/s (d) 12s (e) +2.1cm/s or 2.1cm/s[N]
3. (a) 111m (b) +39m or 39m[up] (c) first, time=8.0s; then +4.9m/s or 4.9m/s[up] for velocity
   (d) 14m/s
4. (a) +3cm or 3cm[right] (b) 41cm (c) first, time=1.25min; then 2.4cm/min[right] (d) 33cm/min



Physics Review 1

Terms:

1. SI prefixes (Mega to micro)
2. base unit
3. derived unit
4. scientific notation
5. significant figures
6. counted value
7. defined value
8. speed
9. distance
10. uniform motion
11. distance-time graph
12. slope
13. scalar
14. vector
15. displacement
16. velocity

Matching Terms Review

Match the above terms to the statements below. Not all terms will be used. No term is used twice.

(a) The distance traveled in a given amount of time.
(b) The change in displacement in a given amount of time.
(c) A SI unit that is obtained by placing a prefix upon the base unit.
(d) Motion which involves constant speed (no acceleration).
(e) A means of communicating the accuracy of a measurement based upon the number of digits in a value.
(f) A means of communicating a value; particularly useful when the value is an extremely large or extremely small value.
(g) A plot which shows a straight line for uniform motion.
(h) The product of "speed multiplied by time".
(i) A quantity which has a magnitude and unit, but no direction.
(j) The straight line measurement (including direction) from an object's starting position to its final position.
(k) This is a measurement of an object's speed using a distance-time graph.

Questions to Answer

1. Convert each given amount to the amount in the wanted unit.
   (a) 8395m to km
   (b) 45.33cm to mm
   (c) 2.33km to m
   (d) 3.50min to s
   (e) 3min 50s to seconds only
   (f) 234s to min
   (g) 2.3h to s
   (h) 5344s to h
   (i) 55km/h to m/s
   (j) 4.5m/s to km/h

2. State each value as scientific notation.
   (a) 0.0046
   (b) 4002
   (c) 0.00000056
   (d) 987654
   (e) 0.033
   (f) 33

3. State each value as decimal form.
   (a) 4.6 x 10^{-3}
   (b) 3.3 x 10^{2}
   (c) 1.66 x 10^{4}
   (d) 8.4 x 10^{-2}

4. Count the number of significant figures in each value.
   (a) 0.03020m
   (b) 2.00 x 10^{-4}m
   (c) 5.50 seconds
   (d) 1.0 x 10^{4}m
   (e) 0.0060km
   (f) 3400s

5. Round each value to the number of significant figures stated.
   - (a) 3.42km to 2 significant figures
   - (b) 3.45km to 2 significant figures
   - (c) 8.94cm to 1 significant figure
   - (d) 4.002cm to 3 significant figures
   - (e) 586m to 2 significant figures

6. Complete each calculation, quoting the final answer with correct units and significant figures.
   - (a) 4.08cm - 2.3cm
   - (b) 6.73km + 2km
   - (c) (24m/s)·(3.30s)
   - (d) 145.1km/1.55h

7. What is the *purpose* of using significant figures in scientific measurements and calculations?

8. Consider the following information and answer the questions below.
   - (1) The speed of light is 3.00×10^8 m/s.
   - (2) There are 28 students in Homeroom 203.
   - (3) There are 1000m in 1km.
   - (4) The distance from Foxtrap to Portugal Cove is 33km.
   - (5) The length of a certain computer screen is 0.4m

   (a) Which is a defined value?
   (b) Which is a counted value?
   (c) Which value has two significant digits?
   (d) Which value has at least one leading zero?
   (e) Which value has three significant digits?
   (f) What is the speed of light written in regular notation instead of scientific notation?
   (g) What is the length of the computer screen written in scientific notation?

9. Rearrange the formula: v = d/t for: (a) d = ? (b) t = ?

10. What is the speed of a motorcycle, in "km/h", which travels 65km in 45min?

11. What is the distance travelled by a bus which has an average speed of 96.0km/h for 1.50h?

12. What time will it take to drive to Clarenville to St.John's (189km) at an average speed of 102km/h?

13. The following data were obtained for Jack and George on their race bikes: Jack travelled 24.5km in 42 minutes, while George travelled 26.2km in 33 minutes.
   - (a) Convert the time travelled for each cyclist into hours.
   - (b) Calculate the average speed of each cyclist in km/h.
   - (c) (i) At his speed above, how long would it take Jack to travel 33.4km?
     - (ii) Convert the above time (in (i)) from a decimal value to "hours and minutes"
   - (d) Calculate the distance George can travel in 1 hour and 30 minutes.
   - (e) How many *seconds* would it take Jack to travel 50.0km?

14. The following data were measured for a rollerblader at Bowring Park

time (s)	distance (m)
0	0
2	9.8
4	19.2
6	29.3
8	38.6
10	48.5

(a) Plot a fully labeled distance-time graph for the data, using a line of best fit.
(b) Is the rollerblader moving with uniform motion? Briefly explain your choice.
(c) Using your graph, what is the distance traveled by the rollerblader in: (i) 5 seconds; (ii) 9 seconds
(d) Using your graph, determine the average speed of the rollerblader. Include the units in your answer.
(e) What is the speed of the rollerblader converted to "km/h"?
(f) At this average speed, how long would it take the rollerblader to travel the approximate length of the park, which is 4.8km?

15. A toy train is moving with uniform motion at an average speed of 0.15m/s for 30.0 seconds around a circular-shaped track which has a total length of 4.5m.
   (a) What distance is travelled during this time?
   (b) How many times around the track has the train gone during this time?
   (c) What is the displacement of the train when it goes around the whole track once? *Briefly explain* your response.
   (d) Consider your answers to (a) and (c). Should your answers be equal? *Briefly* explain your choice.

16. A boy and his toy tiger in a wagon travels 72m[E] in 12s. They stop, turn, and immediately travel 125m[W] in 17s. What is the boy's:
   (a) total distance travelled?
   (b) displacement?
   (c) average speed?
   (d) average velocity?

17. A ball runs along a track at a track at 105cm/s to the right for 8.20s. It then bounces off a wall and rebounds, moving 103cm/s to the left for 4.80s. What is the ball's:
   (a) total distance travelled?
   (b) displacement?
   (c) average speed?
   (d) average velocity?

Answers - Physics Review 1

Matching Terms Review

(a) 8 (d) 10 (g) 11 (j) 15
(b) 16 (e) 5 (h) 9 (k) 12
(c) 3 (f) 4 (i) 13

Questions to Answer

1. (a) 8.395km (f) 3.9min *or* 3 min 54 seconds
(b) 453.3mm (g) 8280s
(c) 2330m (h) 1.484h
(d) 210s (i) 15m/s
(e) 230s (j) 16km/h

2. (a) 4.6×10^{-3} (c) 5.6×10^{-7} (e) 3.3×10^{-2}
(b) 4.002×10^{3} (d) 9.87654×10^{5} (f) 3.3×10^{1}

3. (a) 0.0046 (b) 330 (c) 16600 (d) 0.084

4. (a) 4 (c) 3 (e) 2
(b) 3 (d) 2 (f) 2

5. (a) 3.4km (d) 4.000cm
(b) 3.5km (e) We can switch to "km", then round to two significant figures: 0.59km
(c) 9cm *or* we can use scientific notation: 5.9×10^{2}m.
It is not recommended to say "590m". This is considered to be ambiguous.

6. (a) 1.8cm (b) 9km (c) 79m (d) 93.6km/h

7. Significant figures indicate the accuracy of a measurement. In general, the more significant figures reported in a value, the more accurately measured the value. For example, 2.10m has three significant figures, and conveys the idea of a more accurately measured value than 2.1m, with two significant figures.

8. (a) 3 (b) 2 (c) 4 (d) 5 (e)1 (f) 300000000m/s (g) 4×10^{-1}m

9. (a) $d = v \cdot t$ (b) $t = d/v$

10. First convert minutes to hours: $45\text{min} \cdot (1\text{h}/60\text{min}) = 0.75\text{h}$

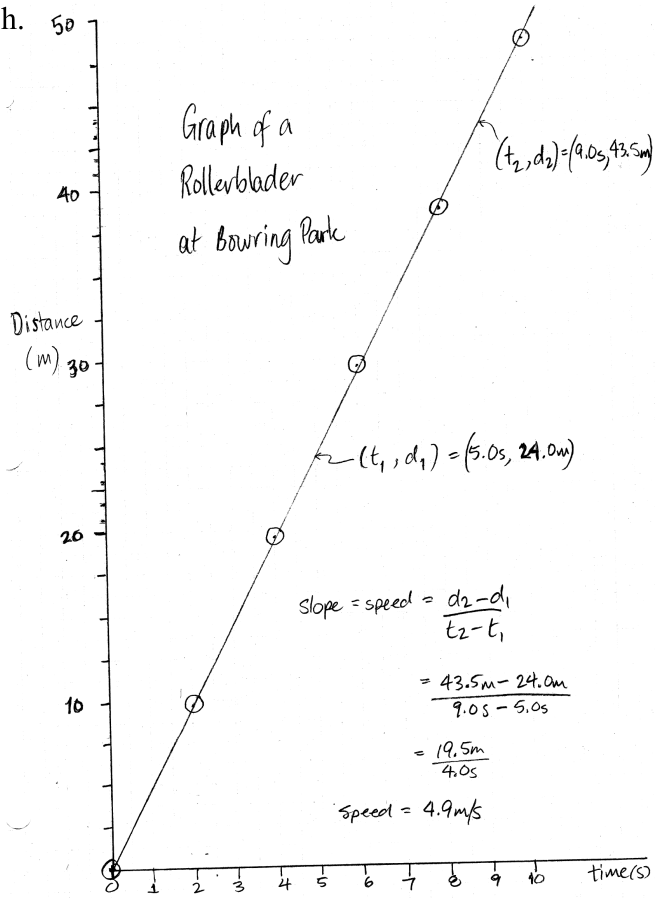
Then: $$v = \frac{d}{t} = \frac{65\text{km}}{0.75\text{h}} = 87\text{km/h}$$

11. $d = v \cdot t = (96.0\text{km/h}) \cdot (1.50\text{h}) = 144\text{km}$

12. $$t = \frac{d}{v} = \frac{189\text{km}}{102\text{km/h}} = 1.85\text{h}$$

13. (a) Jack: 0.70h George: 0.55h
    (b) Jack: 35km/h George: 48km/h
    (c) (i) 0.95h (ii) 0 hours, 57minutes
    (d) First convert time to hours only: 1 hours 30 minutes = 1.5hours. Distance:71km
    (e) 1.428h = 5142s = 5.1 x 10^3s (using two significant digits)

14. (a) See graph.

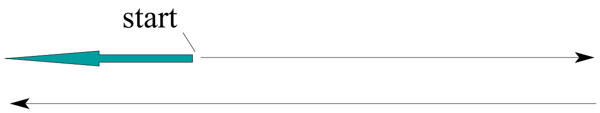


(b) Yes, the rollerblader is moving with uniform motion (constant speed). Reason: The distance-time graph is a straight line.
(c) See graph. (i) At t=5.0s, distance d= 24.0m (ii) At t=9.0s, distance d=43.5m
(d) See graph for the slope calculation. Slope=speed. Average speed = 4.9m/s.
(e) 18km/h (17.64km/h rounded to two significant figures.)
(f) 0.27h or 16 minutes.

15. (a) $d = v \cdot t = (0.15m/s) \cdot (30.0s) = 4.5m$
    (b) It works out that since the track is 4.5m, the train has gone around the track exactly once.
    (c) The displacement would be zero, since displacement is the straight-line distance between the final position and the starting position. So, since the final position is back at the start of the circular track, the displacement is zero.
    (d) The distance is the total length travelled, 4.5m. The displacement is zero and is not the same, since displacement is the straight line distance between the final position and the starting position.

16. (a) distance = 72m + 125m = 197m

(b) Note the start point indicated below. The bold arrow is the displacement arrow.
Also: [E] is the positive (+) direction; [W] is the negative (-) direction.
So:



72m[E] = +72m
125m[W] = -125m

displacement: $\Delta\vec{d} = \vec{d}_1 + \vec{d}_2 = (+72m) + (-125m) = -53m = 53m[W]$

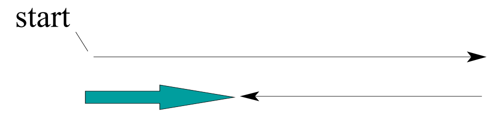
(c) First: total time, t = 12s + 17s = 29s

average speed: $$v = \frac{d}{t} = \frac{197m}{29s} = 6.8m/s$$

(d) average velocity: $$\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{53m[W]}{29s} = 1.8m/s\ [W]$$

17. (a) First use $d=v \cdot t$ to determine the distance for each of moving to the right, then to the left:
<u>To the right:</u> $d=v \cdot t = (105cm/s) \cdot (8.20s) = 861cm$ to the right
<u>To the left:</u> $d=v \cdot t = (103cm/s) \cdot (4.80s) = 494cm$ to the left
Total distance travelled: d = 861cm + 494cm = 1355cm

(b) Note the start point indicated below. The bold arrow is the displacement arrow.
Also: "right" is the positive (+) direction; "left" is the negative (-) direction.
So:



861cm to the right = +861cm
494cm to the left = -494cm

displacement: $\Delta\vec{d} = \vec{d}_1 + \vec{d}_2 = (+861cm) + (-494cm) = +367cm = 367cm$ to the right.

(c) First: total time, t = 8.20s + 4.80s = 13.00s (Note the significant figures :)

average speed: $$v = \frac{d}{t} = \frac{1355cm}{13.00s} = 1.042 \times 10^2\ cm/s$$

(d) average velocity: $$\Delta\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{+367cm}{13.00s} = +28.2cm/s$$ *or* 28.2cm/s to the right

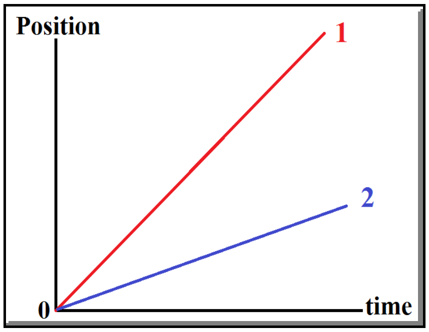
Intro to Position-Time Graphs

Textbook pages 218 onward

Position-Time Graphs

The graphs below give several examples on how to describe an object's position over time.

Sample Graph 1

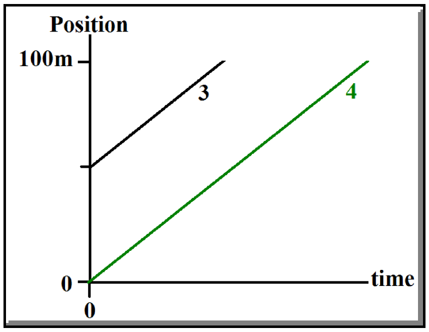


Time = 0 defines the object's ________________________ (1) position. Since Object 1 and Object 2 are starting at the zero mark on the y-axis, the position axis, they are starting at "the origin" or position zero.

Notice the slope of each line. A positive slope means that the object is moving in the direction of "to the _________________ (2)" from its starting point.

Given that we are now referring to position and displacement, the slope of the position-time graph equals the object's ___________________(3). The faster the object is moving, the steeper the slope. Above, Object 1 is moving ______________(4) than Object 2.

Sample Graph 2



In this graph, look to t=0, the start time.

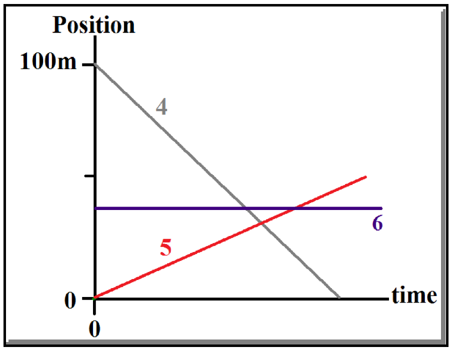
Object 4 is *initially* positioned at 0m, or "at the ________________ (5)."

Object 3 is *initially* at a position of _______ (6) to the ____________ (7) of the origin.

The final position is the same for each object. Each object is found at the position of ____________(8) to the _____________ (9) of the origin.

Regarding the velocity of each object, note that the slope is the same for each. This means that the velocity is the ______________ (10) for each.

Sample Graph 3

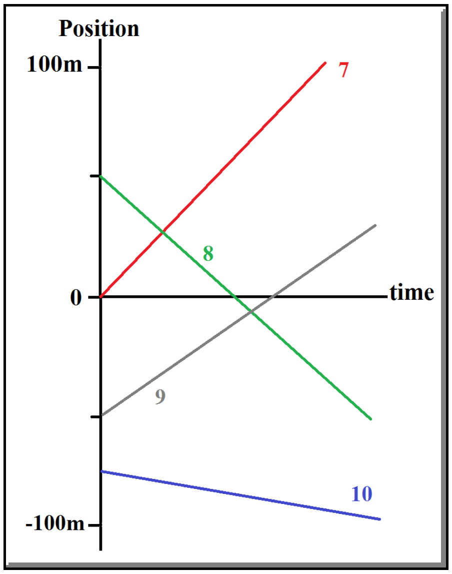


On this graph, object 4 starts at the __________ (11) position, to the right of the origin. Note the negative slope: it is moving in the direction of "to the ____________ (12)." Object 4 finishes at the position of ___________(13).

Object 5 starts at the _____________(14) and moves in the direction of "to the ___________(15)." Object 5 has a final position of ______ (16).

Object 6 has no change in its position over time. In other words, object 6 has _______________ (17). Note that it has a <u>horizontal (i.e. flat)</u> line, with <u>zero slope</u> for its position-time line.

Sample Graph 4 (Note: Your teacher may assign some of these graph analyses to be done as exercises.)



Note: The time axis has units of "*s*"

Notice the axes on this graph: The origin, 0, has objects starting in many different places, including to the right side (+) and to left side (-) of the origin.

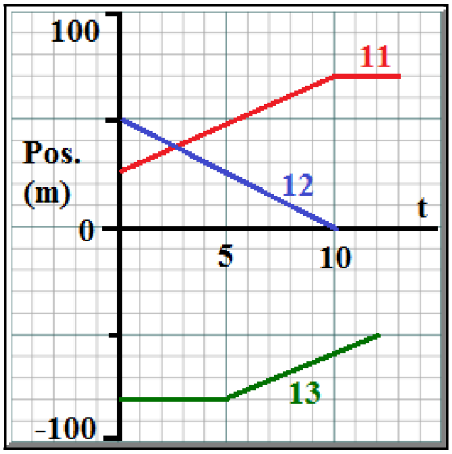
Object 7 starts at the ____________________ (18). It moves to the _______________ (19), and finishes at the _______________(20) position.

Object 8 starts at ____________________ (21). It moves to the _______________ (22), and finishes at the _______________(23) position.

Object 9 starts at ____________________ (24). It moves to the _______________ (25), and finishes at the _______________(26) position.

Object 10 starts at ____________________ (27). It moves to the _______________ (28), and finishes at the _______________(29) position.

Sample Graph 5



Note that with this graph, the time scale is shown in detail; we will focus on both position and time measurements in ths example.

Object 11 starts at ________ (30). It moves to the ___________ (31), until the time of __________ (32). It is located at the position of _________ (33). It is stopped at this position.

Object 12 starts at ________ (34). It moves to the ____________ (35) until the time of __________ (36). Its final position shown is at _____________ (37) at the time of ___________ (38).

Object 13 starts at ________ (39). It is stopped until the time of __________ (40). It then moves to the final position of _______ (41) at the time of ____________ (42).

For the graph above, we can calculate the slope to determine the velocity of the objects over a given time frame. Determine the velocity of:

Object 11, from t=0 to t=10.0s

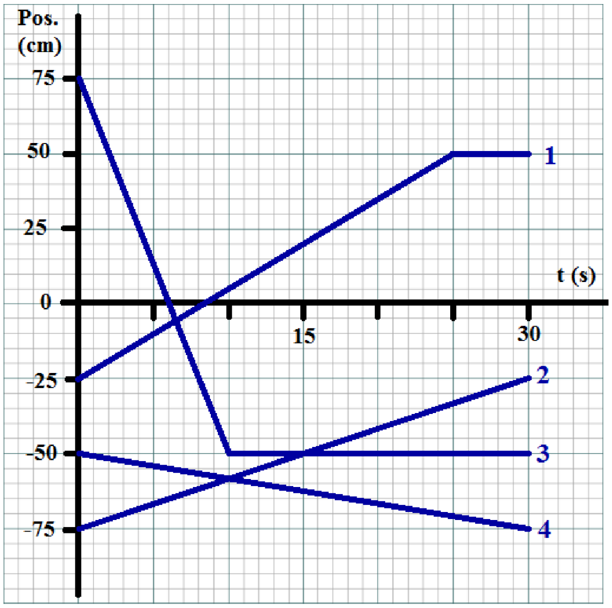
Object 12, from t=0 to t=10.0s

Object 13, from t=0 to t=5.0s.

Worksheet Intro to Position-Time Graphs

The answers to this worksheet are found on page 157.

Provide information for each position-time graph by filling in the blanks / spaces provided.



1. State the starting position of each object.
   Object 1: ______ Object 2: ______ Object 3: ______ Object 4: ______

2. Which objects are moving: (a) to the left at some point? ___________________________
   (b) to the right at some point? ___________________________

3. Which object stops at: (a) 10s? ________________ (b) 25s? _______________

4. What is the position of: (a) Object 1 at 15s? __________ (c) Object 2 at 27s? __________
   (b) Object 4 at 5s? ___________ (d) Object 3 at 2s? ___________

5. What is the velocity of:
   (a) Object 1 from 15.0s to 25.0s?

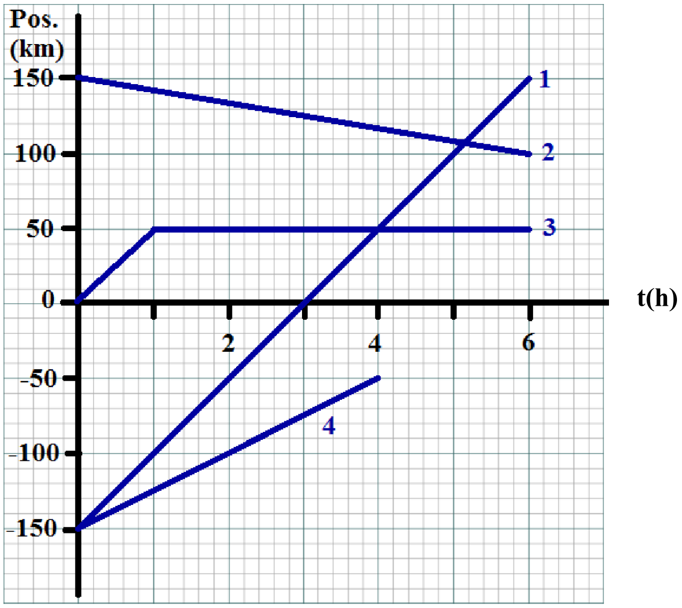
   (b) Object 1 from 25.0s to 30.0s?
   (c) Object 2?

   (d) Object 3 from 0.0s to 10.0s?

   (e) Object 4?

Worksheet (continued) *The answers to this worksheet are found on page 157.*

Provide information for each position-time graph by filling in the blanks / spaces provided.



1. State the starting position of each object.
   Object 1: ______ Object 2: ______ Object 3: ______ Object 4: ______

2. Which objects are moving: (a) to the left at some point? ________________________
   (b) to the right at some point? ________________________

3. Which object stops at the 1h mark? _________ What is its position at this time? _________

4. What is the position of: (a) Object 1 at 4h? __________ (c) Object 2 at 4h? __________
   (b) Object 3 at 4h? __________ (d) Object 4 at 4h? __________

5. What is the velocity of:
   (a) Object 1?

   (b) Object 2?

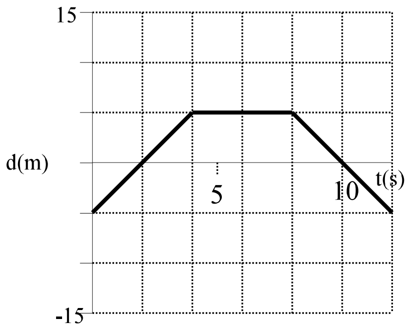
   (c) Object 3 when it is not stopped?

   (d) Object 4?

Worksheet More Position-Time Graphs for Uniform Motion

The answers to this worksheet are found on page 157.

1.

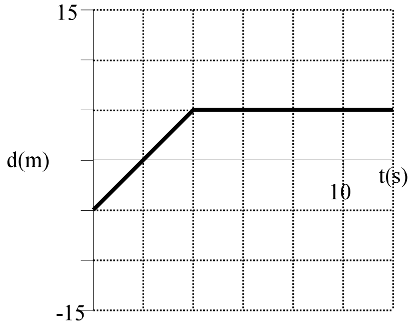


a) What is the position of the object at 10 s?

b) When is the object stopped?

c) Describe the motion of the object.

2.



a) What is the starting position of the object?

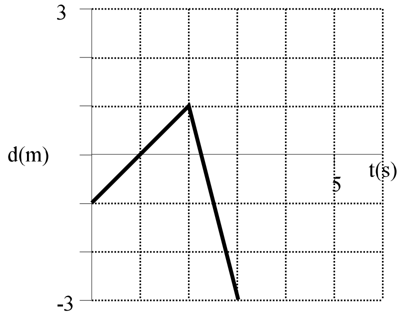
b) What is the position of the object at 6.0 s?

c) At what time does the object stop moving?

d) What is the velocity of the object at t=2.0s?

e) Describe the motion of the object.

3.



a) What is the starting position of the object?

b) What is the position of the object at 3.0 s?

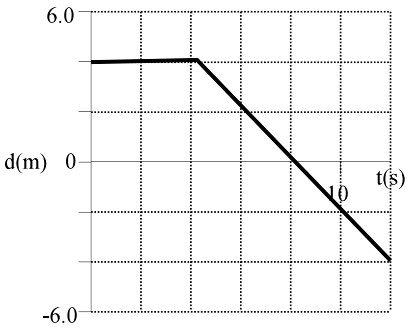
c) What is the velocity of the object at t=1.0s?

d) What is the velocity of the object at t=2.5s?

e) Describe the motion of the object.

Worksheet (continued) *The answers to this worksheet are found on page 157.*

4.



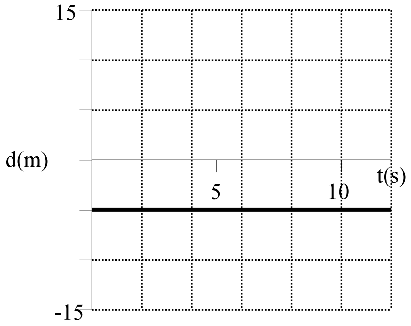
a) What is the starting position of the object?

b) For what duration is the object stopped?

c) What is the velocity of the object at t = 8.0 s?

d) Describe the motion of the object.

5.

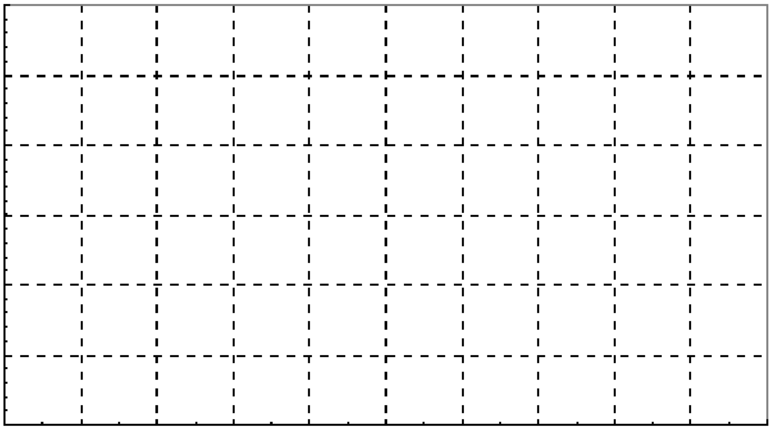


a) What is the velocity of the object at t = 1.0 s?

b) What is the position of the object at 5.0 s?

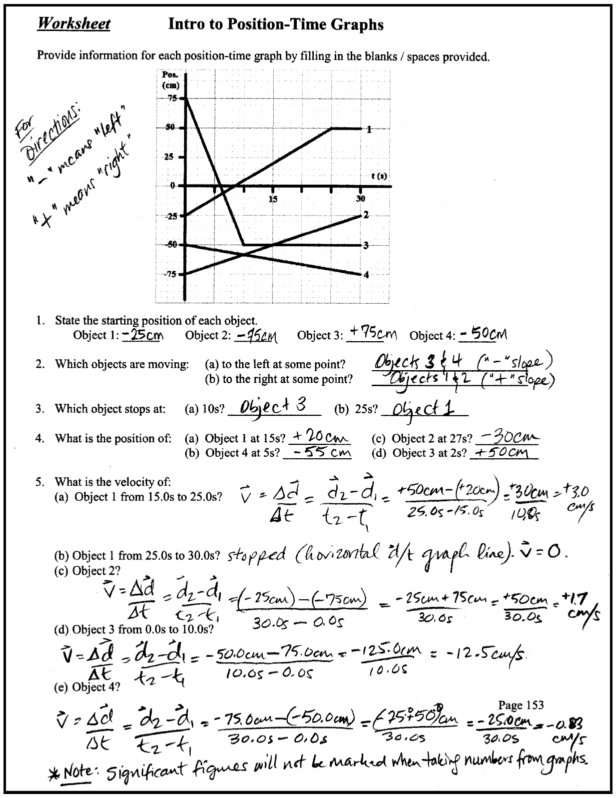
c) Describe the motion of the object.

6. (a) Draw a position time graph for an object which starts at 4m[left] of the origin. It moves to the left until t=5s and reaches 10m[left]. It stops until t=7s. Then it moves to the right and reaches the position 10m[right] at t=10s.



(b) Calculate the velocity of the object in (a) at:
(i) t=3s (ii) t=8s

Answers to Worksheets, pages 153 to 156



Worksheet **Intro to Position-Time Graphs**

Provide information for each position-time graph by filling in the blanks / spaces provided.

1. State the starting position of each object.
   Object 1: −25cm Object 2: −75cm Object 3: +75cm Object 4: −50cm
2. Which objects are moving: (a) to the left at some point? Objects 3 & 4 ("−" slope)
   (b) to the right at some point? Objects 1 & 2 ("+" slope)
3. Which object stops at: (a) 10s? Object 3 (b) 25s? Object 1
4. What is the position of: (a) Object 1 at 15s? +20cm (c) Object 2 at 27s? −30cm
   (b) Object 4 at 5s? −55 cm (d) Object 3 at 2s? +50cm
5. What is the velocity of:
   (a) Object 1 from 15.0s to 25.0s? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{+50cm-(+20cm)}{25.0s-15.0s} = \frac{+30cm}{10.0s} = +3.0\ cm/s$

   (b) Object 1 from 25.0s to 30.0s? stopped (horizontal d/t graph line). $\vec{v} = 0$.
   (c) Object 2? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{(-25cm)-(-75cm)}{30.0s - 0.0s} = \frac{-25cm+75cm}{30.0s} = \frac{+50cm}{30.0s} = +1.7\ cm/s$
   (d) Object 3 from 0.0s to 10.0s? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{-50.0cm-75.0cm}{10.0s-0.0s} = \frac{-125.0cm}{10.0s} = -12.5cm/s.$
   (e) Object 4? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{-75.0cm-(-50.0cm)}{30.0s-0.0s} = \frac{(-75+50.0)cm}{30.0s} = \frac{-25.0cm}{30.0s} = -0.83\ cm/s$

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* **Note**: Significant figures will not be marked when taking numbers from graphs.

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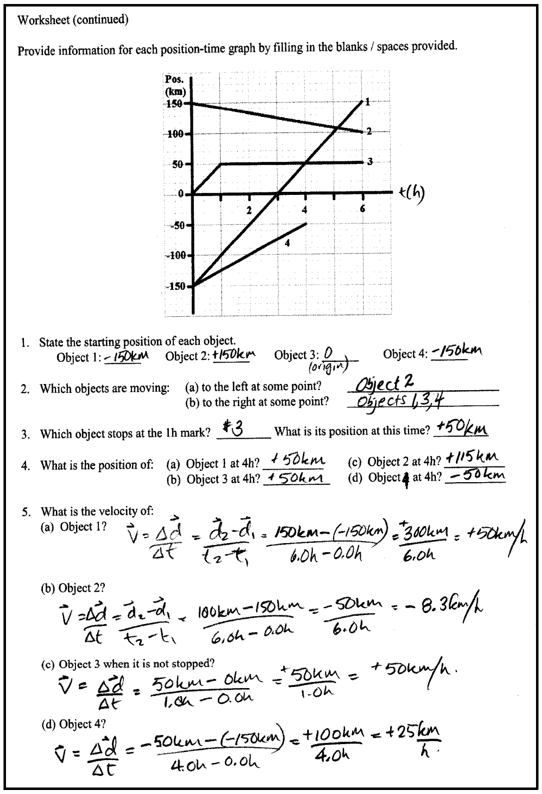

Worksheet (continued)

Provide information for each position-time graph by filling in the blanks / spaces provided.

1. State the starting position of each object.
   Object 1: −150km Object 2: +150km Object 3: 0 (origin) Object 4: −150km
2. Which objects are moving: (a) to the left at some point? Object 2
   (b) to the right at some point? Objects 1,3,4
3. Which object stops at the 1h mark? #3 What is its position at this time? +50km
4. What is the position of: (a) Object 1 at 4h? +50km (c) Object 2 at 4h? +115km
   (b) Object 3 at 4h? +50km (d) Object 4 at 4h? −50km
5. What is the velocity of:
   (a) Object 1? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{150km-(-150km)}{6.0h-0.0h} = \frac{+300km}{6.0h} = +50km/h$

   (b) Object 2? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{100km-150km}{6.0h-0.0h} = \frac{-50km}{6.0h} = -8.3km/h$

   (c) Object 3 when it is not stopped? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{50km-0km}{1.0h-0.0h} = \frac{+50km}{1.0h} = +50km/h.$

   (d) Object 4? $\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{-50km-(-150km)}{4.0h-0.0h} = \frac{+100km}{4.0h} = +25\frac{km}{h}.$

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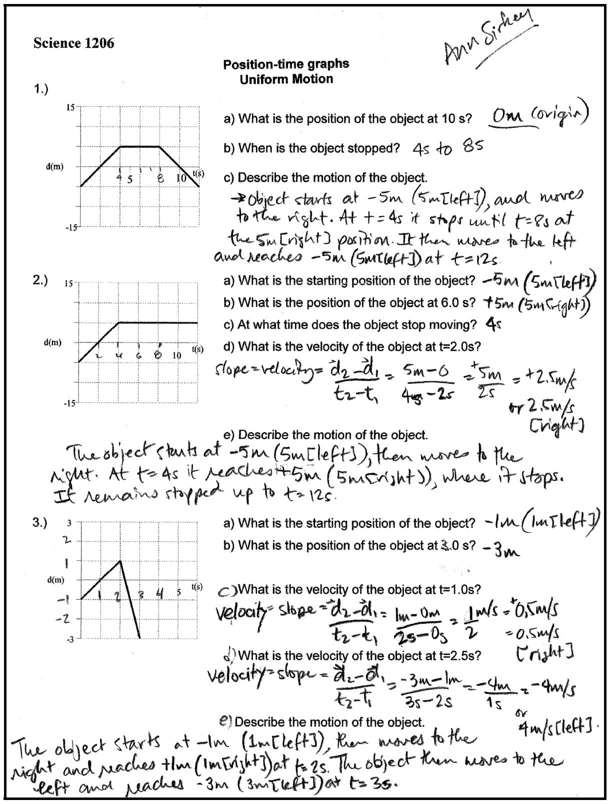

Science 1206

Ann Sirhey

Position-time graphs
Uniform Motion

1.)
a) What is the position of the object at 10 s? 0m (origin)
b) When is the object stopped? 4s to 8s
c) Describe the motion of the object.
→ Object starts at −5m (5m[left]), and moves to the right. At t=4s it stops until t=8s at the 5m[right] position. It then moves to the left and reaches −5m (5m[left]) at t=12s.

2.)
a) What is the starting position of the object? −5m (5m[left])
b) What is the position of the object at 6.0 s? +5m (5m[right])
c) At what time does the object stop moving? 4s
d) What is the velocity of the object at t=2.0s?
slope = velocity = $\frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{5m-0}{4s-2s} = \frac{+5m}{2s} = +2.5m/s$ or 2.5m/s [right]
e) Describe the motion of the object.
The object starts at −5m (5m[left]), then moves to the right. At t=4s it reaches +5m (5m[right]), where it stops. It remains stopped up to t=12s.

3.)
a) What is the starting position of the object? −1m (1m[left])
b) What is the position of the object at 3.0 s? −3m
c) What is the velocity of the object at t=1.0s?
velocity = slope = $\frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{1m-0m}{2s-0s} = \frac{1m/s}{2} = +0.5m/s$ = 0.5m/s [right]
d) What is the velocity of the object at t=2.5s?
velocity = slope = $\frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{-3m-1m}{3s-2s} = \frac{-4m}{1s} = -4m/s$ or 4m/s[left].
e) Describe the motion of the object.
The object starts at −1m (1m[left]), then moves to the right and reaches +1m (1m[right]) at t=2s. The object then moves to the left and reaches −3m (3m[left]) at t=3s.

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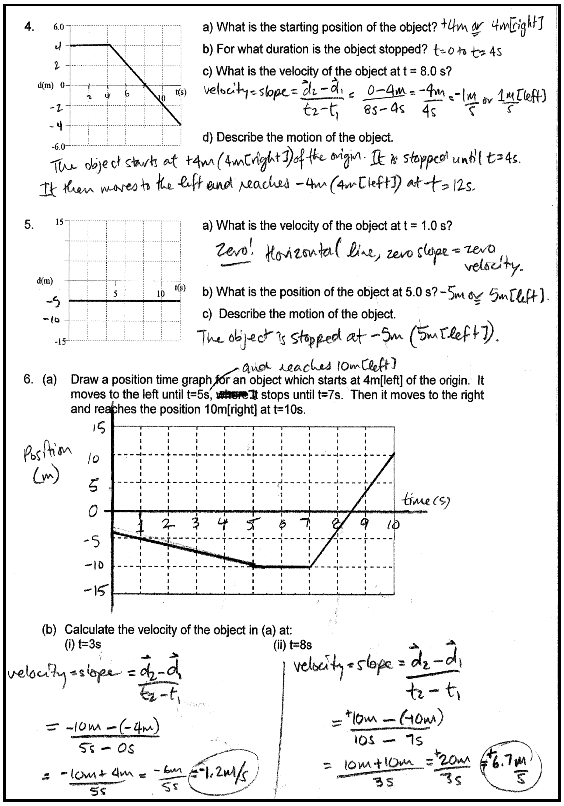

4.
a) What is the starting position of the object? +4m or 4m[right]
b) For what duration is the object stopped? t=0 to t=4s
c) What is the velocity of the object at t = 8.0 s?
velocity = slope = $\frac{\vec{d}_2-\vec{d}_1}{t_2-t_1} = \frac{0-4m}{8s-4s} = \frac{-4m}{4s} = -1\frac{m}{s}$ or $1\frac{m}{s}$[left]
d) Describe the motion of the object.
The object starts at +4m (4m[right]) of the origin. It is stopped until t=4s. It then moves to the left and reaches −4m (4m[left]) at t=12s.

5.
a) What is the velocity of the object at t = 1.0 s?
Zero! Horizontal line, zero slope = zero velocity.
b) What is the position of the object at 5.0 s? −5m or 5m[left].
c) Describe the motion of the object.
The object is stopped at −5m (5m[left]).

6. (a) Draw a position time graph for an object which starts at 4m[left] of the origin. It moves to the left until t=5s, and reaches 10m[left] ~~where~~ It stops until t=7s. Then it moves to the right and reaches the position 10m[right] at t=10s.

(b) Calculate the velocity of the object in (a) at:
(i) t=3s
velocity = slope = $\frac{\vec{d}_2-\vec{d}_1}{t_2-t_1}$
$= \frac{-10m-(-4m)}{5s-0s}$
$= \frac{-10m+4m}{5s} = \frac{-6m}{5s} = \boxed{-1.2m/s}$

(ii) t=8s
velocity = slope = $\frac{\vec{d}_2-\vec{d}_1}{t_2-t_1}$
$= \frac{+10m-(-10m)}{10s-7s}$
$= \frac{10m+10m}{3s} = \frac{+20m}{3s} = \boxed{+6.7\frac{m}{s}}$

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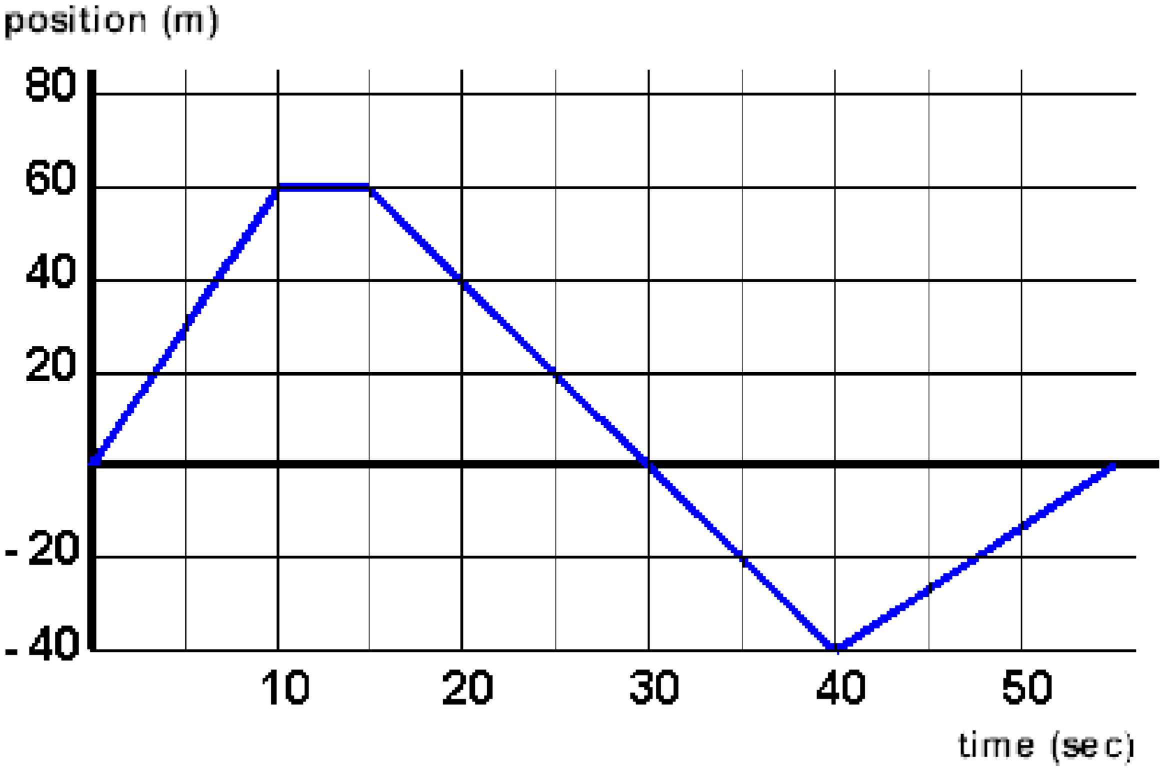
Position-Time Graphs, Continued

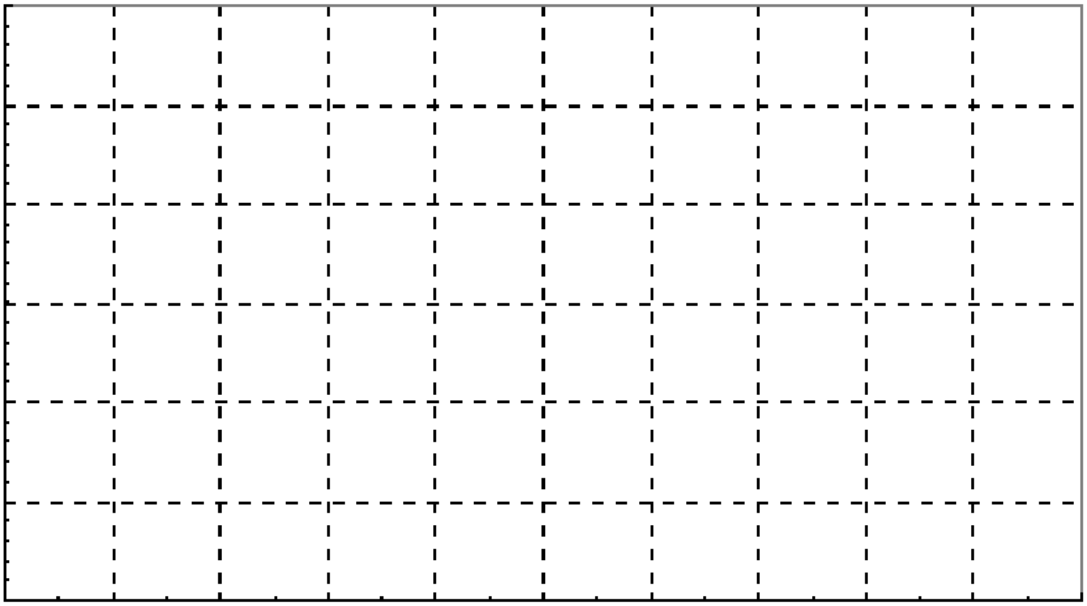
For the graph below:



1. What is the position:
   (a) initially?
   (b) at t=5.0s?
   (c) at t=35.0s?

2. What is the velocity at:
   (a) t=5.0s?
   (b) t=12.0s?
   (c) t=30.0s?

2. (a) Draw a position time graph for an object which starts at 6m[right] of the origin. It moves to the left until t=3s, where it has reached 1m[right]. The object then stops there until t=6s. Lastly, it moves to the left and reaches the position 8m[left] at t=9s.



(b) Calculate the velocity of the object in (a) at:
(i) t=2s (ii) t=8s

Looking for more graph problems? Check out:
http://tinyurl.com/n2o6lue

Velocity-Time Graphs

Textbook pages 233 onwards

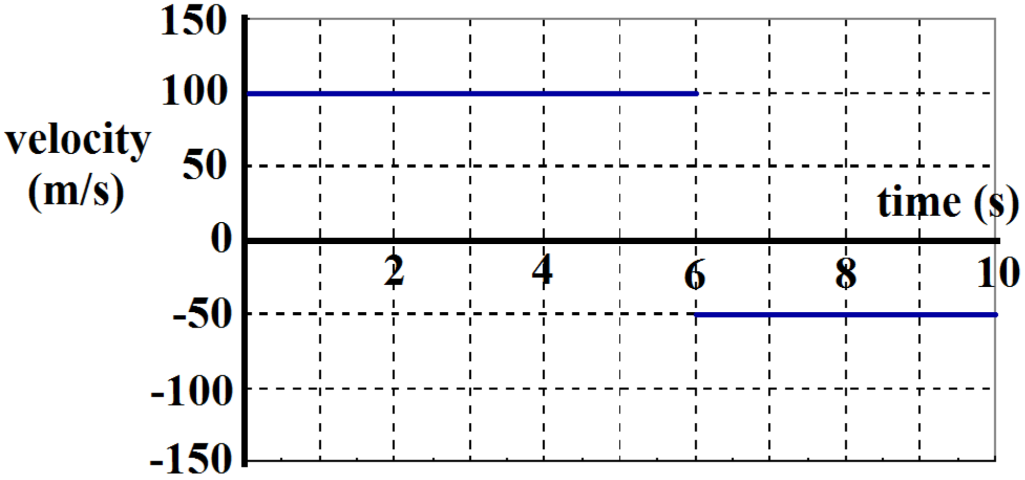
When given a graph, first ***read the axes labels.*** A velocity-time graph is different from a position time graph.

Remember: Uniform motion means constant speed or ___________________(1). This means that a velocity time graph for an object moving with uniform motion will have _____________________(2) lines, indicating the constant velocity.

Also remember that *displacement = velocity· time.* This means that the **area** between the velocity line and the time axes gives the _________________________(3) for the object over that time frame.

Sample Problem 1

Given the velocity-time graph below:



(a) What is the velocity at: (i) 0s to 6.0s? *Answer:* _________________________

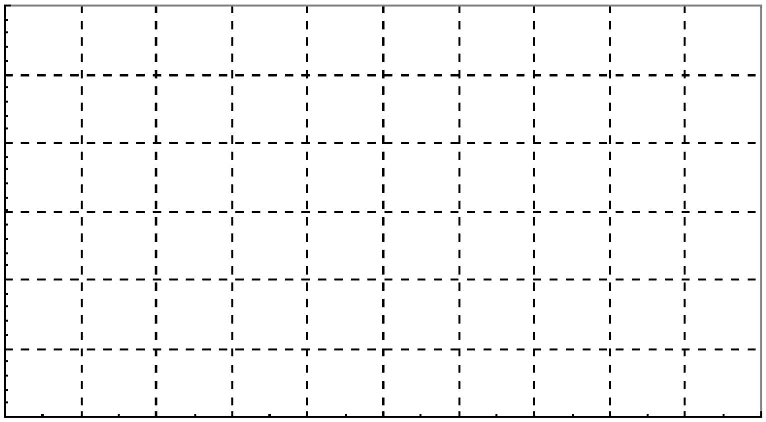
(ii) 6.0s to 10.0s? *Answer:* _________________________

(b) Determine the object's displacement from 0s to 6.0s. *Careful with units!* Is the object moving to the left or right?

(b) Determine the object's displacement from 6.0s to 10.0s. *Careful with units!* Is the object moving to the left or right?

Sample Problem 2

6. (a) Draw the velocity-time graph for an object which travels at 40.0km/h[left] for 2.0h, then stops from 2.0h to 4.0h. Lastly, the object travels at 50.0km/h[left] from 4.0h to 9.0h



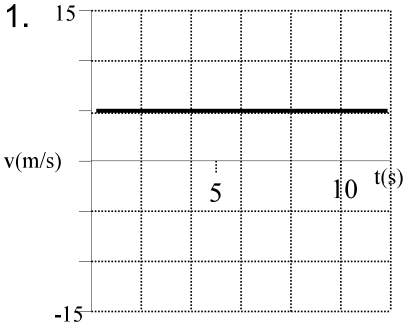
(b) Calculate the displacement of the object from 0.0h to 2.0h.

(c) Calculate the displacement of the object from 2.0h to 4.0h.

(d) Calculate the displacement of the object from 4.0h to 9.0h.

Worksheet Velocity-Time Graphs for Uniform Motion

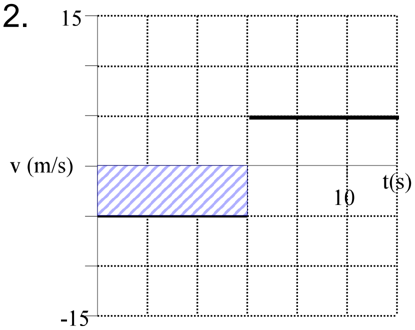
1.



a) What is the velocity of the object at 10 s?

b) Which way is the object going?

2.



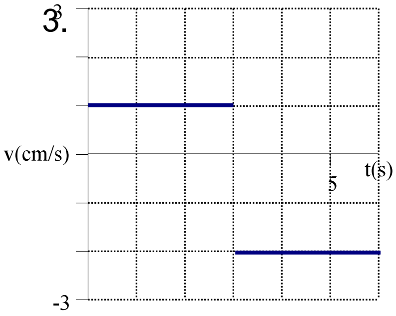
a) Describe the motion of the object.

b) What is the displacement of the object from 0 to 6.0s?

(Calculate the area of the shaded rectangle...is it moving left or right?)

c) What is the displacement of the object from 6.0s to 12.0s?

3.



a) What is the velocity of the object at:

(i) t = 2.0s (ii) t=5.0s

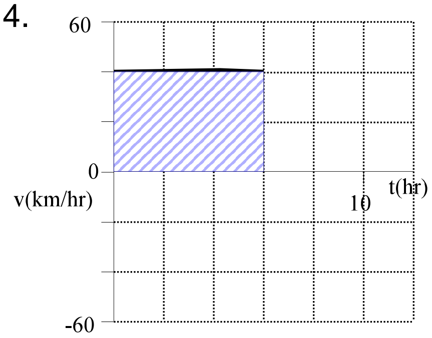
b) Shade the rectangle that represents the displacement of the object from 0 to 3 s, and from 3 to 6 seconds.

c) Calculate the displacement using each rectangle.

(Careful, what will the unit of measurement be? m? cm? km?)

Worksheet, continued

4.



a) What is the velocity of the object at t = 2.0 hr?

b) Describe the motion of the object.

c) How far has the object traveled in 6.0 hr?

5. (a) Draw the velocity-time graph for an object which travels at 4.0m/s[N] for 6.0s, then 5.0m/s[S] from 6.0s to 10.0s.

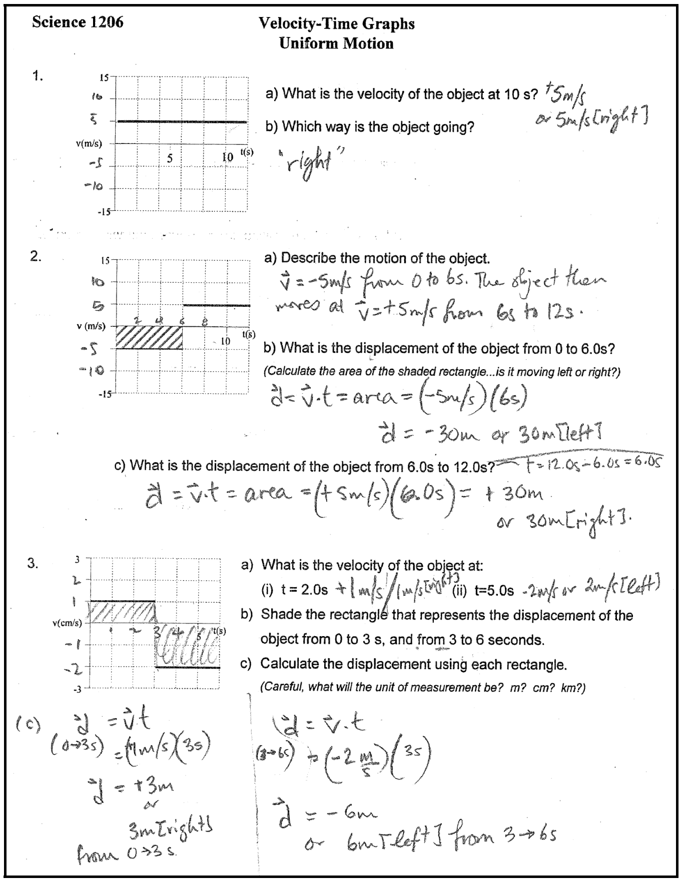
(b) Calculate the displacement of the object from 0.0s to 6.0s.

(c) Calculate the displacement of the object from 6.0s to 10.0s.

6. (a) Draw the velocity-time graph for an object which travels at 110km/h[right] for 1.5h, then stops from 1.5h to 3h. Lastly, the object travels at 75km/h[left] from 3h to 4h.

(b) Calculate the displacement of the object from 0.0h to 1.5h.

Answers to Worksheet, page 162 - 163



Science 1206

Velocity-Time Graphs
Uniform Motion

1\. a) What is the velocity of the object at 10 s? +5m/s or 5m/s[right]

b) Which way is the object going?

"right"

2\. a) Describe the motion of the object.

$\vec{v} = -5$m/s from 0 to 6s. The object then moves at $\vec{v} = +5$m/s from 6s to 12s.

b) What is the displacement of the object from 0 to 6.0s?

(Calculate the area of the shaded rectangle...is it moving left or right?)

$\vec{d} = \vec{v} \cdot t = \text{area} = (-5\text{m/s})(6\text{s})$

$\vec{d} = -30\text{m}$ or 30m[left]

c) What is the displacement of the object from 6.0s to 12.0s? $t = 12.0\text{s} - 6.0\text{s} = 6.0\text{s}$

$\vec{d} = \vec{v} \cdot t = \text{area} = (+5\text{m/s})(6.0\text{s}) = +30\text{m}$ or 30m[right].

3\. a) What is the velocity of the object at:

(i) t = 2.0s +1m/s / 1m/s[right] (ii) t=5.0s -2m/s or 2m/s[left]

b) Shade the rectangle that represents the displacement of the object from 0 to 3 s, and from 3 to 6 seconds.

c) Calculate the displacement using each rectangle.

(Careful, what will the unit of measurement be? m? cm? km?)

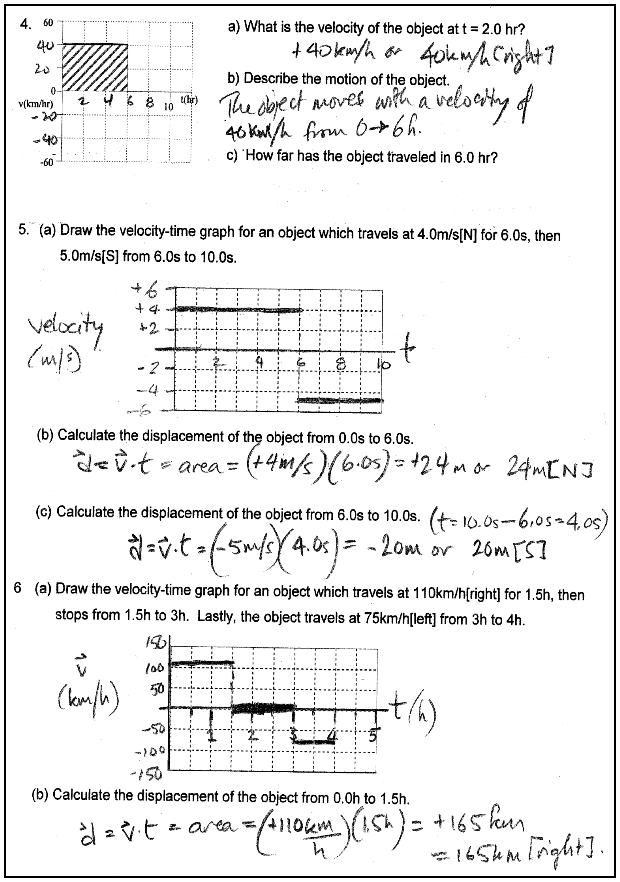
(c) $\vec{d}_{(0\to3s)} = \vec{v}t = (+1\text{m/s})(3\text{s})$

$\vec{d} = +3\text{m}$ or 3m[right] from 0→3 s.

$\vec{d}_{(3\to6s)} = \vec{v} \cdot t = (-2\frac{\text{m}}{\text{s}})(3\text{s})$

$\vec{d} = -6\text{m}$ or 6m[left] from 3→6s

page 162



4\. a) What is the velocity of the object at t = 2.0 hr?

+40km/h or 40km/h[right]

b) Describe the motion of the object.

The object moves with a velocity of 40km/h from 0→6h.

c) How far has the object traveled in 6.0 hr?

5\. (a) Draw the velocity-time graph for an object which travels at 4.0m/s[N] for 6.0s, then 5.0m/s[S] from 6.0s to 10.0s.

(b) Calculate the displacement of the object from 0.0s to 6.0s.

$\vec{d} = \vec{v} \cdot t = \text{area} = (+4\text{m/s})(6.0\text{s}) = +24\text{m}$ or 24m[N]

(c) Calculate the displacement of the object from 6.0s to 10.0s. $(t = 10.0\text{s} - 6.0\text{s} = 4.0\text{s})$

$\vec{d} = \vec{v} \cdot t = (-5\text{m/s})(4.0\text{s}) = -20\text{m}$ or 20m[S]

6 (a) Draw the velocity-time graph for an object which travels at 110km/h[right] for 1.5h, then stops from 1.5h to 3h. Lastly, the object travels at 75km/h[left] from 3h to 4h.

(b) Calculate the displacement of the object from 0.0h to 1.5h.

$\vec{d} = \vec{v} \cdot t = \text{area} = (+110\frac{\text{km}}{\text{h}})(1.5\text{h}) = +165\text{km} = 165\text{km [right]}.$

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ACCELERATION

Textbook pages 232 onward

Acceleration is defined as the change in **velocity** divided by the change in **time**. It is a **vector**. When an object accelerates, it does not keep a constant velocity. This means that we will ***not*** refer to accelerating objects under the heading of "uniform motion". Accelerating objects have "non-uniform motion".

Units and Acceleration

Consider: An object accelerates at +2.0 m/s/s. (We read "2.0 metres per second, per second".) This means that the velocity changes by +2.0 m/s, as *each second* goes by. Note that the unit "m/s/s" is awkward. Instead, we write the unit as "m/s^2".

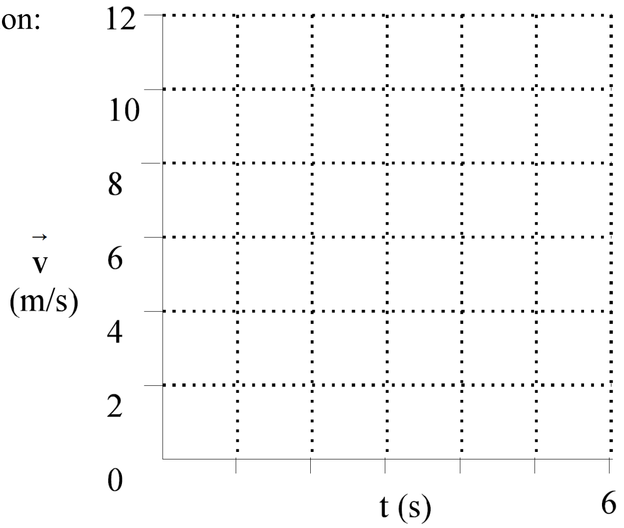
Sample Problem

If you start from rest, $\vec{v}$ **= 0 m/s,** with acceleration of **+2.0 m/s^2** then my **velocity**:

after 1.0 second is _________ ... after 2.0 seconds is _________ ... after 3.0 seconds is _________

after 4.0 seconds is ________ ... after 5.0 seconds is _________ ... after 6.0 seconds is _________ .

1. Graph this motion:



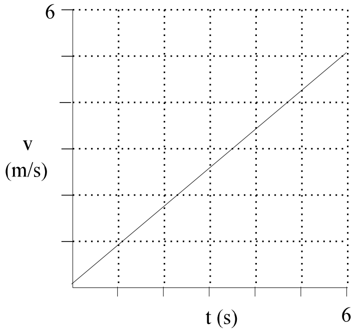
2. Is this motion uniform? How can you tell?____________________________________
3. From the graph, What is the **instantaneous velocity** at:

   1.0 s = ___________ 3.0 s = ___________ 6.0 s = ______________

4. ***IMPORTANT:*** The **slope of the line** from a **velocity-time** graph tells me the **acceleration**. What is the acceleration of this object? _______________________ (*Don't forget the unit.*)
5. Describe the motion of this object. Is it moving to the right or left? Is it speeding up or slowing down? ____
6. Regardless of whether the motion is uniform motion (no acceleration) or non-uniform motion (acceleration), the **area** of a **velocity-time graph** has the same meaning. What does the **area** of a $\vec{v}$-t graph tell us? __________________.

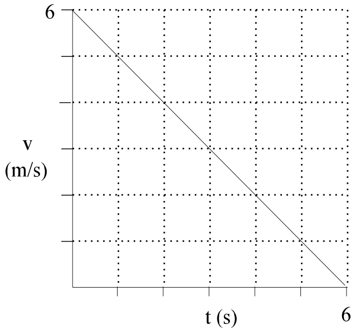
7. Remember, the **area under a velocity-time graph** tells us the **displacement**. Calculate the displacement under each $\vec{v}$ -t graph. *Don't forget your unit in each case. Remember that the area of a triangle is determined from the equation ½ x base x height, and in some cases, you may need to break the area under the graph into both a rectangle and a triangle.*

Graph A



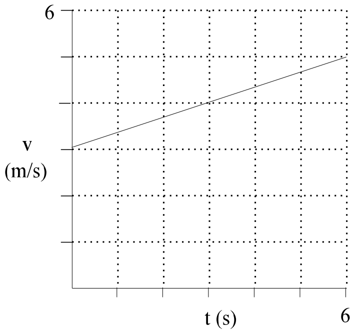
$\vec{d}$: ______________

Graph B



$\vec{d}$: ______________

Graph C



*hint: triangle + rectangle

$\vec{d}$: ____________

8. The **slope** of a $\vec{v}$ -t graph means **acceleration**. What is the acceleration for each of the objects above? A. $\vec{a}$ = ________ B. $\vec{a}$ = ________ C. $\vec{a}$ = ________

9. The **initial velocity** is the velocity at time zero (t = 0.0 seconds). You get this from the y-intercept of the $\vec{v}$ -t graph. What is the initial velocity for each of the objects above?

A. $\vec{v}$ = ________ B. $\vec{v}$ = ________ C. $\vec{v}$ = ________

10. *Question*: How do you know if the object is speeding up or slowing down?
Answer: Check to see if the velocity becomes bigger or smaller over time.
For each of the graphs above describe its motion. (State "Speeding up" or "slowing down")

A. ____________________ B.________________________ C.________________________

11. *Question*: How do you tell if the object is moving right or left?
Answer: The velocity will tell you. Remember:

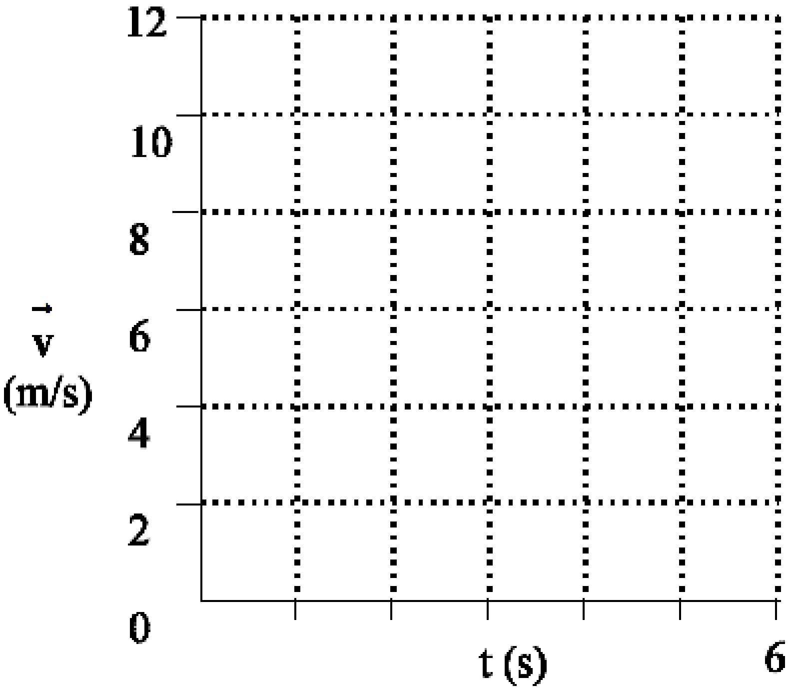
$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$

Positive velocities are positive displacements, to the right,
negative velocities are negative displacements, to the left.
Which way is each object moving above? (State: "Moving left" or "Moving right")

A. ____________________ B.________________________ C.________________________

12. Now we can bring all our knowledge together. Graph the $\vec{v}$ -t graph for the motion given below.

t (s)	$\vec{v}$ (m/s)
0	12
1	11
2	10
3	9
4	8
5	7
6	6



(a) What is the **acceleration** of the object? (Slope) __________ (remember the unit and sign)

(b) What is the **displacement** of the object from 0-6 seconds? (Area) ______________

(c) What is the **initial velocity** of the object? (y-intercept) ___________________

(d) What is the **instantaneous velocity** at t = 4.0 seconds? ____________________

(e) Is this object speeding up or slowing down? _____________________

(f) Is this object moving to the right or to the left? ___________________

Acceleration Calculations

Textbook pages 259 to 262.

Vector acceleration is the change in velocity over time. We can write the math formula below:

where: the vector acceleration is: _________

the ***change*** in ***velocity*** is: _________

Note: where the final velocity is __________ and

the initial (start) velocity is __________.

the ***change*** in ***time*** is: _________

Note: where the final time is __________ and

the initial (start) time is __________.

Our mathematical problems will give us two out of the three variables in the acceleration formula at the top of the page, and we will solve for the missing variable.

Some students wish to translate the formula in to "the triangle":

POINTERS: Solving acceleration problems

- Practice will help rearranging the formula. If the triangle helps you, then use it... ***just make sure that you get the triangle correct to begin with!***
- Watch the ***units!*** The "time" units mus match through the problem. Remember:
  1 minute = 60 seconds
  60 minutes = 1 hour
  ... so 1 hour = 3600 seconds
- ***Useful trick*** for converting between "m/s" and "km/h:

  From "m/s" *to* "km/h", we _______________________by 3.6

  From "km/h" *to* "m/s", we _______________________ by 3.6
- Sometimes we need to do $\Delta t = t_f - t_i$ ***FIRST or*** _________________________
  before doing the acceleration formula,

Sample Problem 1
A ball is dropped from rest, from a second floor window. If its velocity is 4.9m/s [down] after 0.50 seconds, calculate the acceleration due to gravity.

Solved:

Sample Problem 2
A cyclist is moving at 6.0m/s and slows to 1.5m/s in a time of 2.0s. What is the cyclist's acceleration?

Solved:

Sample Problem 3
A car travelling at 120 km/h comes to a stop in 2.4 seconds. What is the acceleration of the car?

Solved:

Sample Problem 4
How long does it take for a car to accelerate from zero to 115km/h at an acceleration of $2.6 m/s^2$?

Solved:

Sample Problem 5

A rocket has just launched, and has been flying for some time. If it is accelerating at 575m/s^2 [up] for a time frame of 1.50s, what is the:

(a) velocity change over this time frame?

(b) initial velocity at the start of the time frame, if its velocity at the end of the time frame is 988m/s [up]?

Solved:

Additional Acceleration Problems

1. A current Mercedes McLaren Formula 1 race car can accelerate from rest to 300.0km/h in 8.4s. What is the acceleration for the race car?

2. A skydiver is falling at 9.9m/s[down]. He opens his parachute, and in 3.0s, has slowed to 1.1m/s[down]. What is the acceleration of the sky diver?

3. A cyclist applies the brakes on her bike, causing her speed to drop from 35.5km/h to 15.5km/h in 2.0s. What is the cyclist's acceleration?

Worksheet ***Acceleration***

(Answers are at the end of the worksheet.)

1. A car has a constant acceleration of 4.0 m/s^2[E], starting from rest. How fast is it travelling after 3.0 seconds?

2. An object travels with uniform motion at 20.0 m/s for 5.0 s. What is the acceleration? [*Think!* ☺]

3. A running football player has a change in velocity of 9.80 m/s [N] in 1.4 s. What is his average acceleration?

4. An object accelerates at 1.2 m/s^2 [N]. How long will it take to reach a velocity of 5.0 m/s [N] if it is starting from rest?

5. If a car accelerates from 3.0 m/s to 12.0 m/s in 3.0 seconds, what the average acceleration?

6. A baseball is travelling 65 km/h [E] and is caught by a player. The ball is brought to rest in 0.50 s. What is the acceleration of the ball? (*Note the units on this question.*)

7. Dexter is travelling on his bike, 4.0 m/s [S]. If he accelerates at a rate of 1.5 m/s^2 [S] for 2.0 seconds, what is his final velocity?

8. A car increases its speed from 9.6 m/s to 11.2 m/s in 4.0 s. What is the average acceleration of the car during this 4.0 s interval?

9. An object accelerates at 2.2 m/s^2 for 3.0 s. If the final velocity of the object is 15.0 m/s, what was the initial velocity?

10. A motorcycle travelling on a straight stretch of highway accelerates at 4.7 m/s^2 from a speed of 6.0 m/s. How fast would it be travelling after 2.0 s?

11. A car comes up to a construction zone. Calculate the acceleration of the car after the driver gently applies the brakes, changing the speed from 108km/h to 29km/h in 12 seconds.

12. A shark, moving at 7.2km/h accelerates at 4.3 m/s^2 to a final speed of 54.0km/h. What is the elapsed time during the acceleration?

Answers:
(1.) 12 m/s [E] (2.) 0 m/s^2! (3.) 7.0 m/s^2 [N] (4.) 4.2 s (5.) 3.0 m/s^2
(6.) -36m/s^2 [E], or, 36 m/s^2 [W] (7.) 7.0m/s [S] (8.) 0.40 m/s^2 (9.) 8.4 m/s
(10.) 15.4 m/s (11.) -1.8 m/s^2 (12.) 3.0 s

Position-Time Graphs for Accelerated Motion

Textbook pages 247 onward

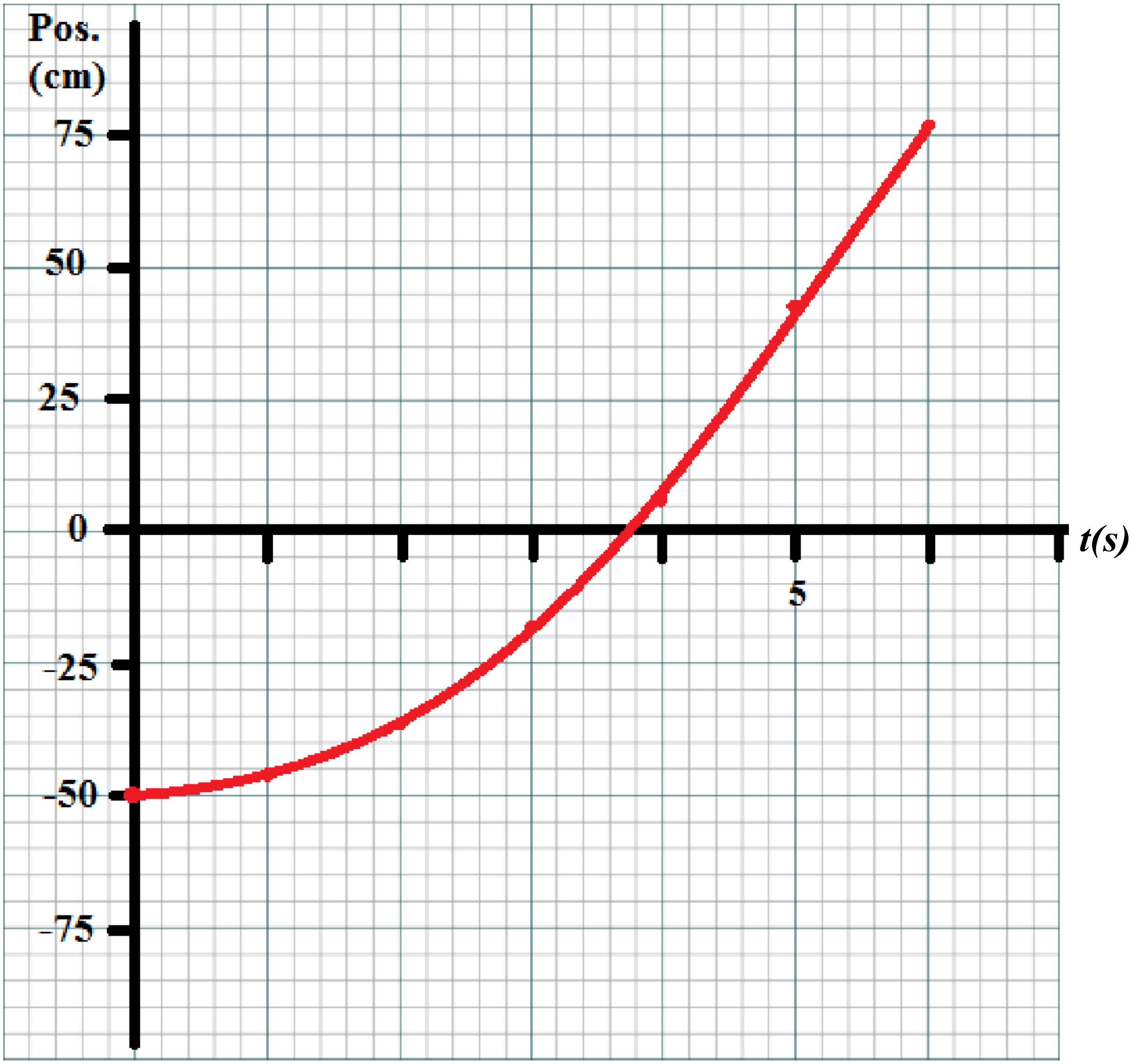
Determining Instantaneous Velocity using Tangents

When an object undergoes acceleration (non-uniform motion), its position-time graph will be *curved*. The *instantaneous velocity* for any "instant" or given time is equal to the *slope of the tangent line at that instant in time.*

Sample Problem

For the graph below, make note of the times t = 0.0, 1.0, 3.0 and 5.0 s:

(a) draw a tangent line for t = 1.0, 3.0 and 5.0 s (Assume that the object is starting from rest.)
(b) get the slope of the tangent line (slope of tangent = instantaneous velocity, $\vec{v}$, at that point in time)
(c) describe the motion of the object.



Solved

(a) Draw tangents.

(b) Slopes:

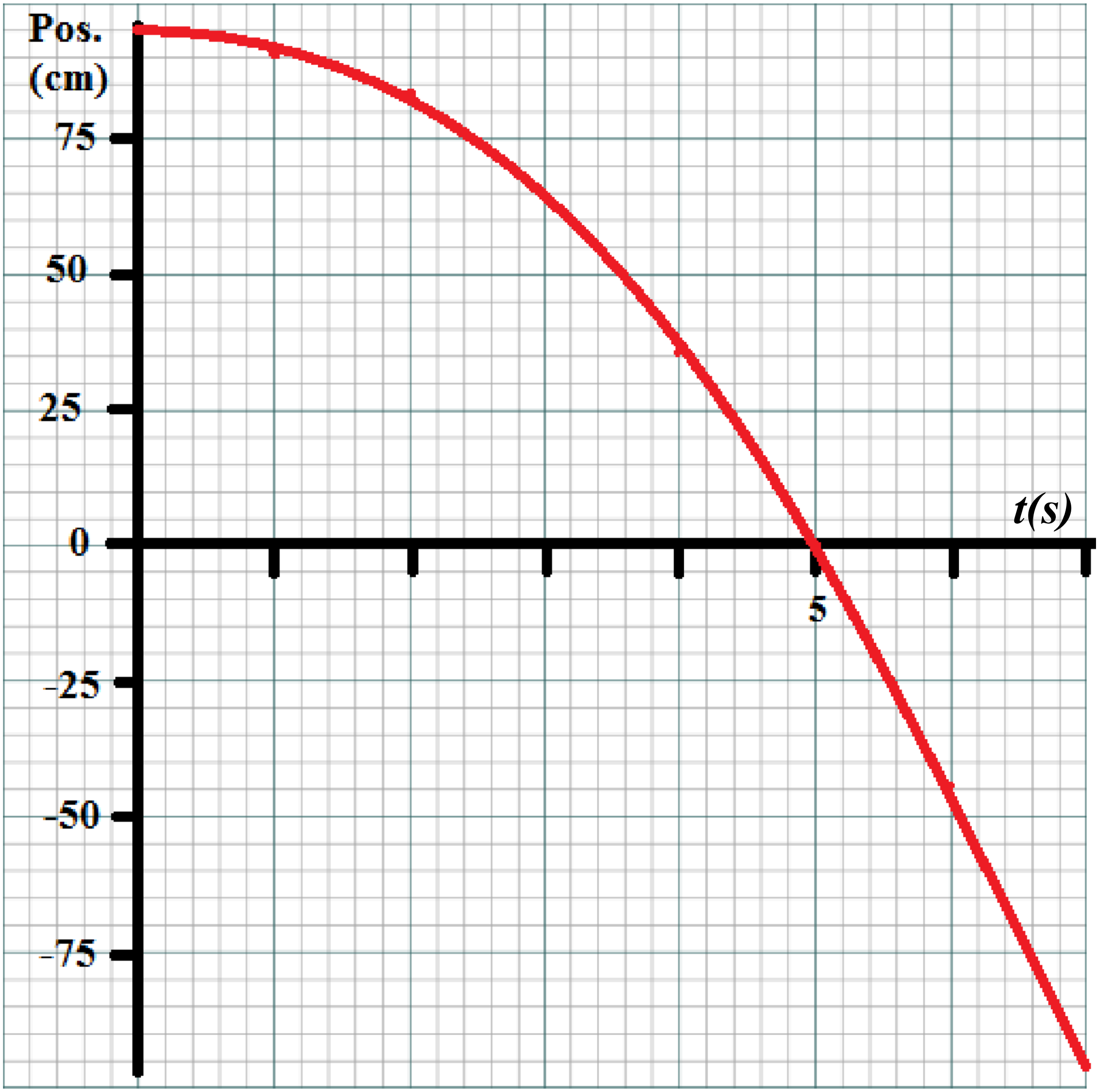
Summary:		
t (s)	$\vec{d}$ (cm)	$\vec{v}$ (cm/s)
0	-50	0
1		
3		
5		

(c) Description of the motion:

Practice Problem (Completed detailed answer at the end of the problem.)

For the graph below, make note of the times t = 0.0, 1.0, 3.5 and 6.0 s:

- draw a tangent line for t = 1.0, 3.5 and 6.0 s (Assume that the object is starting from rest.)
- get the slope of the tangent line (slope of tangent = instantaneous velocity, $\vec{v}$, at that point in time)
- describe the motion of the object.



Solved:

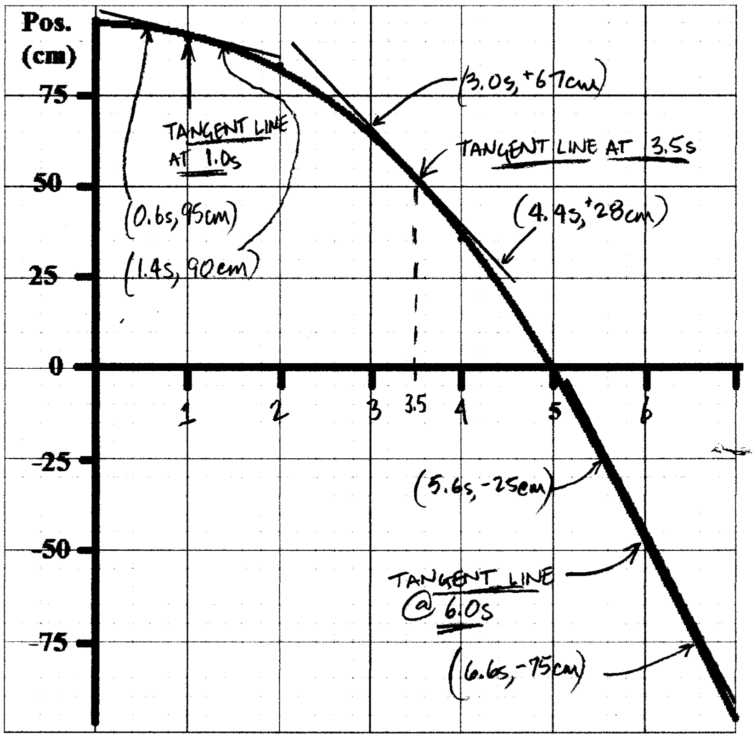
Summary:		
t (s)	$\vec{d}$ (cm)	$\vec{v}$ (cm/s)
0		0
1		
3.5		
6		

Answer to practice problem, page 178-179:

Practice Problem

For the graph below, make note of the times t = 0.0, 1.0, 3.5 and 6.0 s:

- draw a tangent line for t = 1.0, 3.5 and 6.0 s (Assume that the object is starting from rest.)
- get the slope of the tangent line (slope of tangent = instantaneous velocity, $\vec{v}$, at that point in time)
- describe the motion of the object



Solved:

@ t = 1.0   Point 1: (0.6s; 95cm)   Point 2: (1.4s, 90.cm)

$$\text{velocity} = \text{slope} = \frac{d_2 - d_1}{t_2 - t_1} = \frac{90.\text{cm} - 95\text{ cm}}{1.4\text{s} - 0.6\text{s}} = \frac{-5\text{cm}}{0.8\text{s}} = \boxed{-6\text{cm/s} \quad @\ t = 1.0\text{s}} \quad \vec{v} @ 1.0\text{s}$$

@ t = 3.5s   Point 1: (3.0s, +67cm)   Point 2: (4.4s, +28cm)

$$\text{velocity} = \text{slope} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1} = \frac{28\text{cm} - 67\text{cm}}{4.4\text{s} - 3.0\text{s}} = \frac{-39\text{cm}}{1.4\text{ s}} = \boxed{\frac{-28\text{cm}}{\text{s}}} \quad \vec{v} @ 3.5\text{s}$$

@ t = 6.0s   Point 1: (5.6s, -25cm)   Point 2: (6.6s, -75cm)

$$\text{velocity} = \text{slope} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1} = \frac{-75\text{cm} - (-25\text{cm})}{6.6\text{s} - 5.6\text{s}} = \frac{-50\text{cm}}{1.0\text{s}} = \boxed{-50.\frac{\text{cm}}{\text{s}}} \quad \vec{v} @ t = 6.0\text{s}$$

DESCRIPTION OF MOTION

The object starts @ +80cm position. It moves to the left, speeding up in its motion to the left (increase in "−" velocity) as it moves along.

Summary:

t (s)	$\vec{d}$ (cm)	$\vec{v}$ (cm/s)
0.0	+80	0
1.0	+92	-6
3.5	+52	-28
6.0	-47	-50.

READ GRAPH POINT   SLOPE OF TANGENT

Summary: Graphs for Uniform Motion Compared to Accelerated Motion

For ***uniform motion***:

- Objects move at a **constant speed or velocity**: there is **no acceleration**.
- Position-time graphs are not curved; all segments are straight lines
- The slope of the line position-time graph gives the velocity of the object.
- Velocity-time graphs have horizontal lines indicating constant velocity and uniform motion.
- The area between the velocity-time graph and the time axis indicates the displacement of the object.

Sample Problem 1

Sketch a **position-time** graph for an object:

(a) starting at the origin and moving with uniform motion to the left
(b) starting at the origin and moving with uniform motion to the right
(c) stopped to the left of the origin
(d) stopped to the right of the origin

Sample Problem 2

Sketch a **velocity-time** graph for an object:

(a) moving with uniform motion to the left
(b) moving with uniform motion to the right
(c) stopped to the left of the origin
(d) stopped to the right of the origin

For **accelerated motion**

- Objects ***do NOT*** move at a constant speed or velocity: there is **acceleration**, as **objects are speeding up or slowing down**.
- **Position-time graphs are curved**, and the instantaneous velocity for some point in time can be found by getting the slope of the tangent line for that point in time.
- Velocity-time graphs are sloped for accelerated motion, indicating that objects are speeding up or slowing down.

Sample Problem 1

Sketch a **position-time** graph and a **velocity-time graph** for an object:

(a) starting at the origin, moving to the left and moving faster to the left.
(b) starting at the origin, moving to the left and moving slower to the left.
(c) starting at the origin, moving to the right and speeding up as it moves to the right.
(d) starting to the right of the origin, moving to the left and slowing down as it moves to the left.

Strategy for drawing the position-time graph

- Put in the start and finish points on your graph first
- determine the curve of your graph by "speeding up" (steeper tangents as time goes on) or "slowing down" (less steep tangents as time goes on).
- Draw the line!

Strategy for drawing the velocity-time graph

- Use the position-time graph as your guide (along with the description in the question)

Identifying the Type of Motion from a Given Graph

As we go to describe the motion in each graph which follows:

Step 1: Look at the *axes labels*. Ask yourself: Is it a position-time graph or a velocity-time graph?

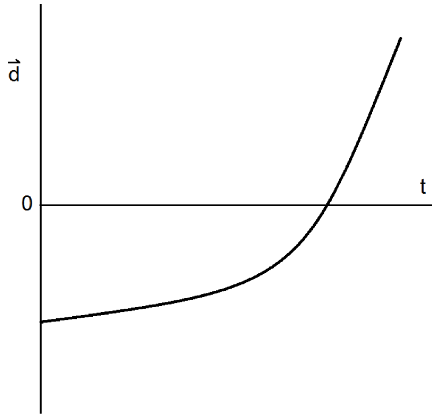
Step 2: If it is a:

- **position-time graph**, ask yourself: is it curved (accelerated motion) or having straight-line segments (uniform motion)?
  Remember: For accelerated motion, imagine tangent lines at various points on the position-time graph. A positive slopes on these tangents means "speeding up"; negative slopes means "slowing down". The greater the slope, the greater the velocity.
  Remember: For uniform motion, the slope of the straight-line segment is the velocity.

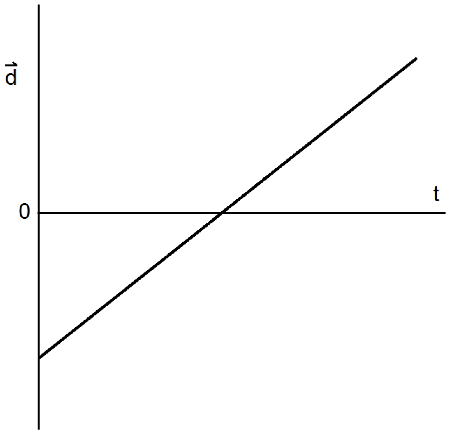
- **velocity-time graph**, ask yourself: is it a horizontal line (zero slope, as seen in uniform motion) or is it a sloped line graph (accelerating object)?
  Remember: The area between the velocity-time graph and the time axis gives the change in displacement for the object.

Identify the type of motion in each graph:

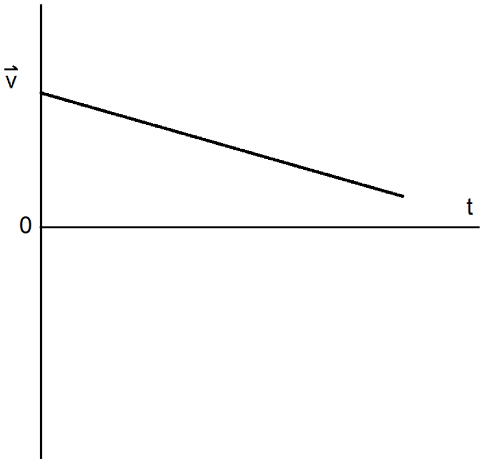
(a)



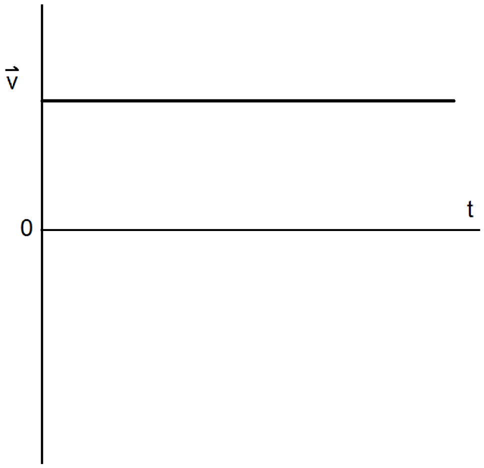
(b)



(c)



(d)



Physics Review 2

Terms

1. position-time graph
2. velocity-time graph
3. uniform motion
4. acceleration
5. tangent
6. instantaneous velocity
7. "at rest"

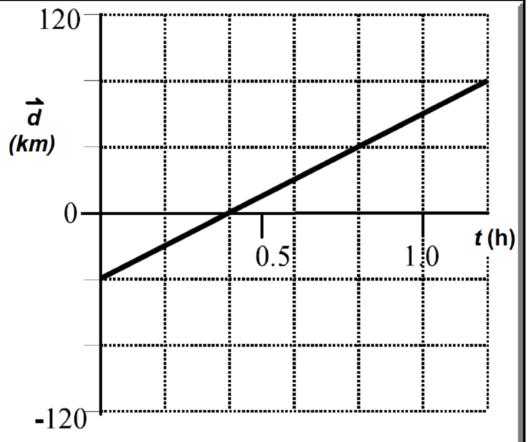
Matching Terms Review

Match the above terms to the statements below. Not all terms will be used. No term is used twice.

(a) Motion which involves an object is speeding up or slowing down.
(b) Motion which involves and object moving at constant velocity.
(c) A graph which, for uniform motion, has straight horizontal line segments.
(d) A graph which is curved for accelerated motion, such as a cart rolling down a ramp.
(e) The velocity of a moving object for a single moment in time; this term is often used when speaking about the velocity of an accelerating object.
(f) Another way of stating that an object is stopped.
(g) A line which is drawn at a point in time on a position-time graph for accelerated motion, used to get the instantaneous velocity for the object at that point in time.

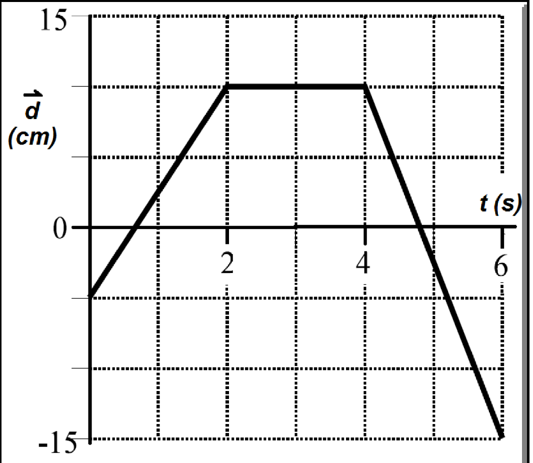
Review Questions

1. Use the position-time graph at right for Question 1.
   (a) What is the starting position of the object?
   (b) What is the final position of the object?
   (c) What is the velocity of the object at t = 0.60 h?
   (d) Describe the motion of the object.



For Question 1

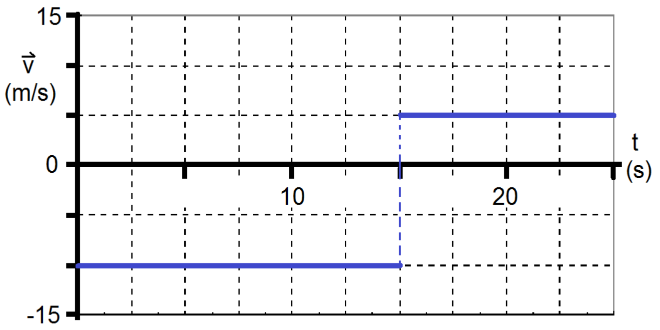
2. Use the position-time graph at right for Question 2.
   (a) What is the starting position of the object?
   (b) What is the final position of the object?
   (c) What is the velocity of the object at t = 1.0 s?
   (e) What is the velocity of the object at t = 3.0 s?
   (f) What is the velocity of the object at t = 5.0 s?
   (g) Describe the motion of the object.



For Question 2

3. (a) Draw a position-time graph for an object which starts 1.0km[left] of the origin. It moves to the 5.0km[left] position at t = 1.5h, where it stops until the 3.0 hour point in time. The object then moves to the right and reaches the 4.0km[right] position at t=5.0h.
   (b) Calculate the velocity of the object at: (i) t = 1.0h (ii) t = 2.0h (iii) t = 4.5h

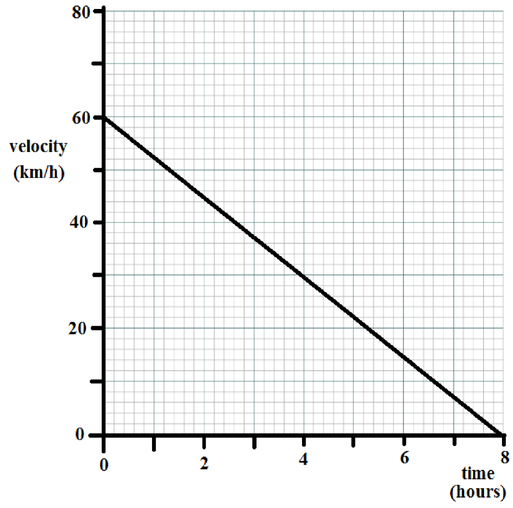
4. Use the <u>velocity-time</u> graph at right for Question 4.
   (a) What is the velocity of the object at t = 5.0s?
   (b) What is the velocity of the object at t = 20.0s?
   (c) Determine the object's displacement from t = 0.0s to t = 15.0s.
   (d) Determine the object's displacement from t = 15.0s to t = 25.0s.
   (e) Describe the motion of the object.



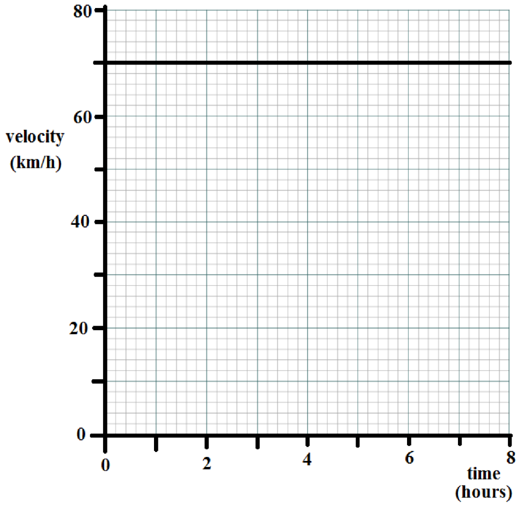
For Question 4

5. (a) Draw the velocity-time graph for a cyclist which travels at 20.0km/h[E] for 2.0h, then stops from 2.0h to 3.0h. The cyclist then travels at 25.0km/h[W] from 3.0h to 4.5h.
   (b) Calculate the change in displacement of the cyclist from:
   (i) 0.0h to 2.0h (ii) 2.0h to 3.0h (iii) 3.0h to 4.5h

6. (a) Which graph below shows uniform motion, and which shows acceleration? Briefly explain your choice.



Graph #1



Graph #2

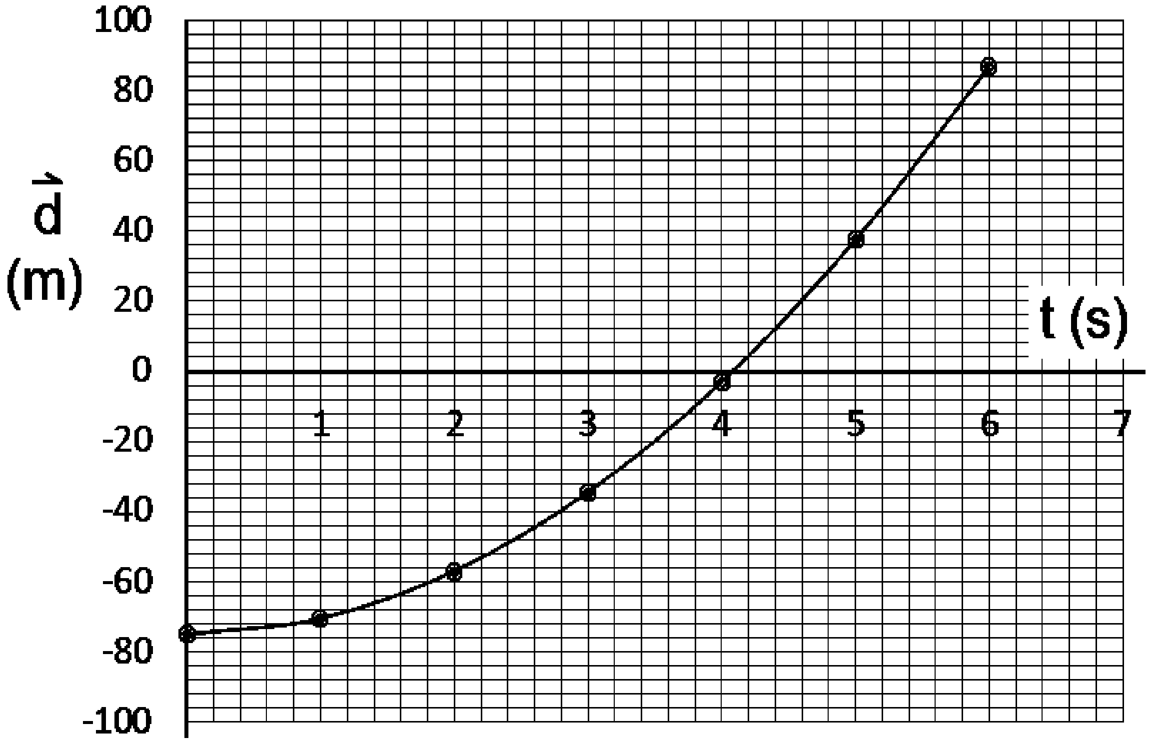
   (b) For the t=0 to t=8.0h time frame, determine the <u>*displacement*</u> for the object in:
   (i) Graph #1 (ii) Graph #2.
   (c) For the t=0 to t=8.0h time frame, determine the <u>*acceleration*</u> for the object in:
   (i) Graph #1 (ii) Graph #2.

7. How long will it take a speedskater, accelerating at 4.6m/s^2, to accelerate from 1.0m/s to 9.8m/s?

8. What is the acceleration of a ball rolling down a long ramp if its velocity changes from 1.50cm/s [down] to 17.8cm/s [down] in 4.4 seconds?

9. (a) A car has a constant acceleration of -5.50m/s^2 for 3.60s. What is the car's change in velocity?
   (b) If the car was initially moving at a velocity of 115km/h[forward] (i.e."+115km/h"), what was the final velocity of the car? (Careful with the units here.)

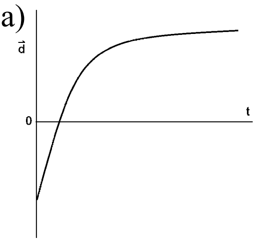
10. Refer to the position-time graph below to answer the questions which follow.
    (a) Is the object moving with uniform motion or is it accelerating?
    (b) Describe the motion of the object, referring to its starting and final position, and whether it is moving to the left or right of the reference point.
    (c) Calculate the instantaneous velocity of the object at t=1.0s.
    (d) Calculate the instantaneous velocity of the object at t=4.0s



For Question 10

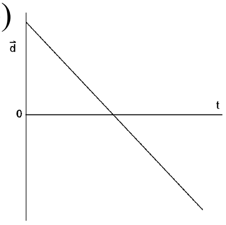
11. For each graph:
    - identify the starting position of the object (for a position-time graph only);
    - state whether the object is moving to the left or right;
    - state where the object is moving with uniform motion (constant speed) or speeding up/slowing down.

(a)



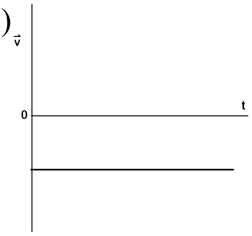
(Note: position-time)

(b)



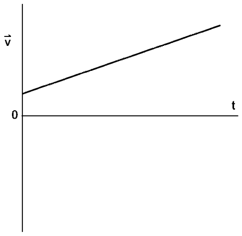
(Note: position-time)

(c)



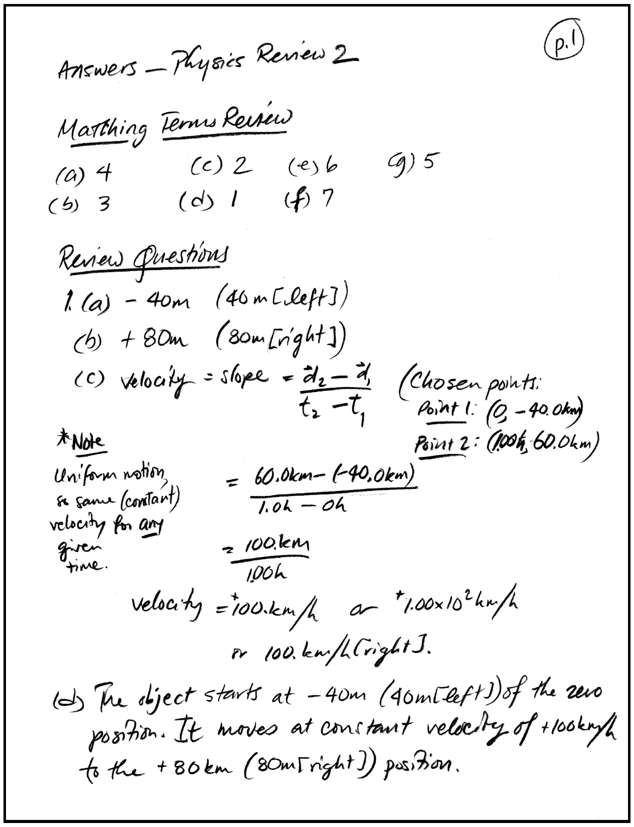
(Note: velocity-time)

(d)



(Note: velocity-time)

Answers: Physics Review 2



(p.1)

Answers — Physics Review 2

Matching Terms Review

(a) 4 (c) 2 (e) 6 (g) 5

(b) 3 (d) 1 (f) 7

Review Questions

1. (a) − 40m (40m[left])

(b) + 80m (80m[right])

(c) velocity = slope = $\frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$ (Chosen points:
Point 1: (0, −40.0km)
Point 2: (1.00h, 60.0km)

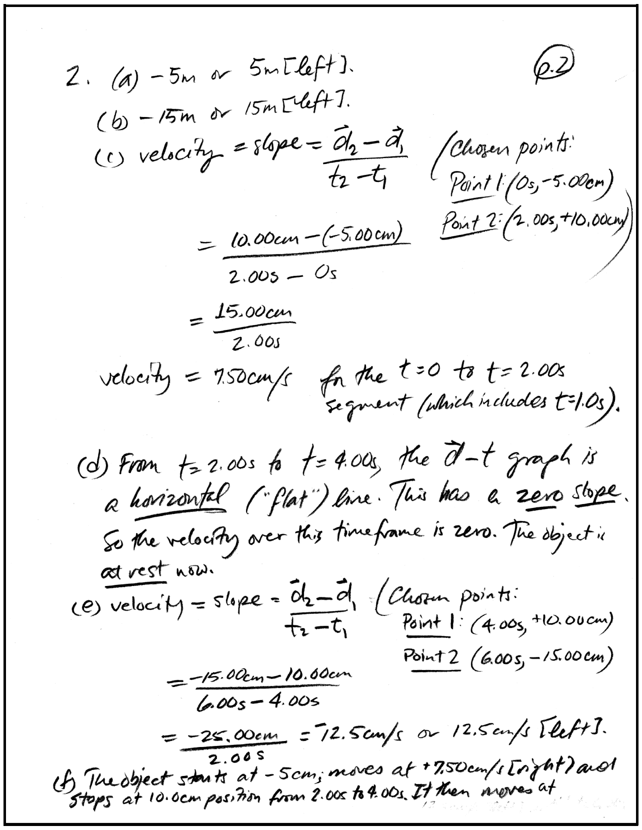
$= \frac{60.0km - (-40.0km)}{1.0h - 0h}$

$= \frac{100.km}{1.00h}$

*Note
Uniform motion, so same (constant) velocity for any given time.

velocity = $^+$100.km/h or $^+1.00 \times 10^2$ km/h or 100. km/h [right].

(d) The object starts at −40m (40m[left]) of the zero position. It moves at constant velocity of +100km/h to the +80km (80m[right]) position.



(p.2)

2. (a) −5m or 5m[left].

(b) −15m or 15m[left].

(c) velocity = slope = $\frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$ (Chosen points:
Point 1: (0s, −5.00cm)
Point 2: (2.00s, +10.00cm))

$= \frac{10.00cm - (-5.00cm)}{2.00s - 0s}$

$= \frac{15.00cm}{2.00s}$

velocity = 7.50cm/s for the t=0 to t=2.00s segment (which includes t=1.0s).

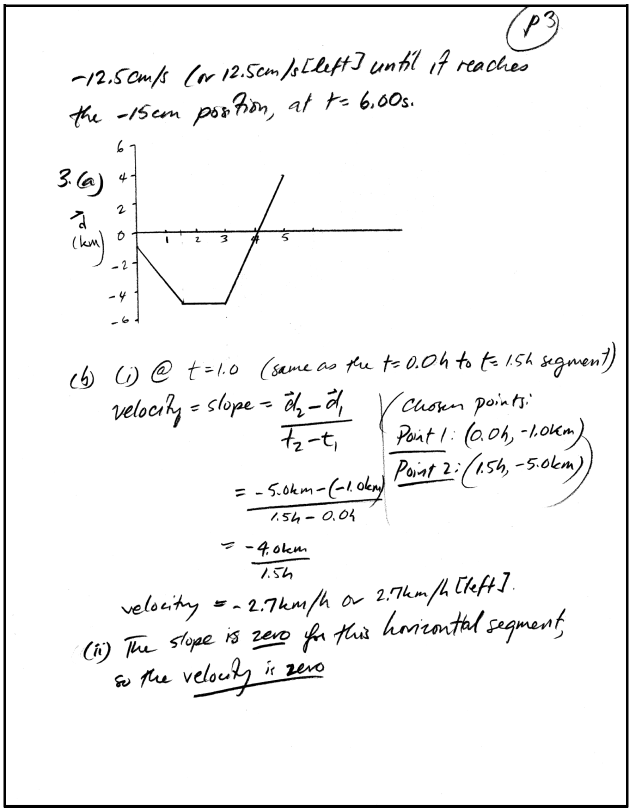
(d) From t=2.00s to t=4.00s, the $\vec{d}$−t graph is a horizontal ("flat") line. This has a zero slope. So the velocity over this timeframe is zero. The object is at rest now.

(e) velocity = slope = $\frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$ (Chosen points:
Point 1: (4.00s, +10.00cm)
Point 2 (6.00s, −15.00cm))

$= \frac{-15.00cm - 10.00cm}{6.00s - 4.00s}$

$= \frac{-25.00cm}{2.00s}$ = $^-$12.5cm/s or 12.5cm/s [left].

(f) The object starts at −5cm; moves at +7.50cm/s [right] and stops at 10.0cm position from 2.00s to 4.00s. It then moves at



(p3)

−12.5cm/s (or 12.5cm/s[left] until it reaches the −15cm position, at t=6.00s.

3. (a)

(b) (i) @ t=1.0 (same as the t=0.0h to t=1.5h segment)

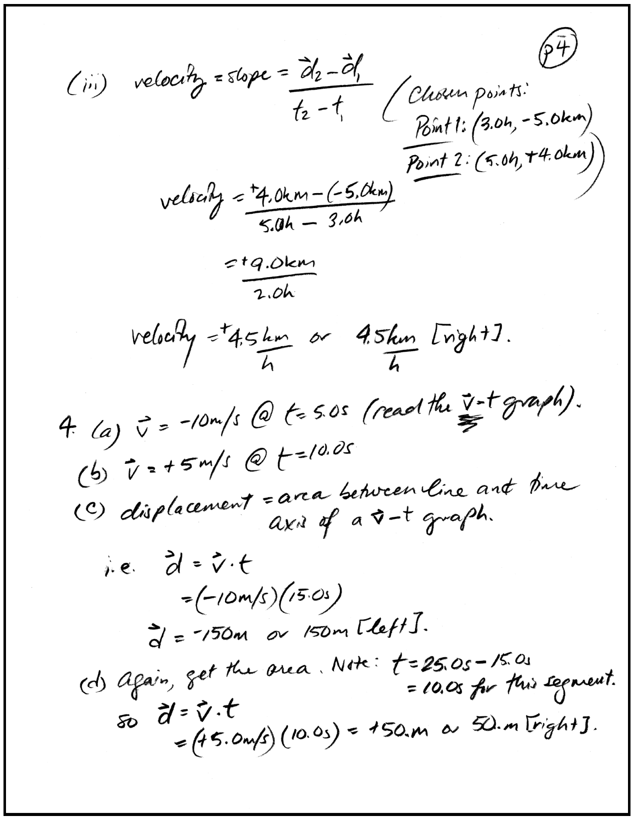
velocity = slope = $\frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$ (Chosen points:
Point 1: (0.0h, −1.0km)
Point 2: (1.5h, −5.0km))

$= \frac{-5.0km - (-1.0km)}{1.5h - 0.0h}$

$= \frac{-4.0km}{1.5h}$

velocity = −2.7km/h or 2.7km/h [left].

(ii) The slope is zero for this horizontal segment, so the velocity is zero



(p4)

(iii) velocity = slope = $\frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$ (Chosen points:
Point 1: (3.0h, −5.0km)
Point 2: (5.0h, +4.0km))

velocity = $\frac{^+4.0km - (-5.0km)}{5.0h - 3.0h}$

$= \frac{+9.0km}{2.0h}$

velocity = $^+4.5 \frac{km}{h}$ or $4.5 \frac{km}{h}$ [right].

4. (a) $\vec{v}$ = −10m/s @ t=5.0s (read the $\vec{v}$−t graph).

(b) $\vec{v}$ = +5m/s @ t=10.0s

(c) displacement = area between line and time axis of a $\vec{v}$−t graph.

i.e. $\vec{d} = \vec{v} \cdot t$

$= (-10m/s)(15.0s)$

$\vec{d}$ = $^-$150m or 150m [left].

(d) again, get the area. Note: t = 25.0s − 15.0s = 10.0s for this segment.

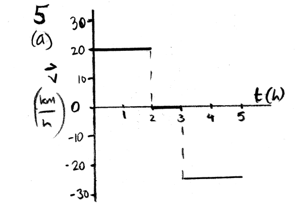
so $\vec{d} = \vec{v} \cdot t$

= (+5.0m/s)(10.0s) = +50.m or 50.m [right].

(p5)

(e) The object moves at -10m/s (10m/s [left]) for 15.0s. During this time its displacement changes by 150 m [left]. Then the object moves 5.0m/s [right] from 15.0s to 25.0s. During this time its displacement changes by 50.m [right].

5 (a)



(b) Change in displacement = area between the $\vec{v}$-t graph and time axis.

$\vec{d}$ = area = $\vec{v} \cdot t$
= (20.0km/h [E])(2.0h) = 40. km [E]

(b) The cyclist is at rest. No change in displacement.

(c) From 3.0h to 4.5h, the time change is: $t = 4.5h - 3.0h$
$t = 1.5h$

so $\vec{d}$ = area = $\vec{v} \cdot t$
$= \left(25.0\frac{km}{h}[W]\right)(1.5h)$
$\vec{d}$ = 38km [W]

(p6)

6 (a) Note that each graph is a $\vec{v}$-t graph.
For uniform motion, velocity is constant.
For accelerated motion, velocity changes.
Graph #1 is accelerated motion (velocity changes from +60km/h to zero)
Graph #2 is uniform motion, as velocity is constant at +70km/h.

(b) Displacement = area of $\vec{v}$-t graph

(i) $\vec{d}$ = area = $\underset{\text{triangle}}{\frac{1}{2}bh} = \frac{1}{2}(8.0h)\left(60\frac{km}{h}\right) = \underline{\underline{+240km}}$

(ii) $\vec{d}$ = area = $\underset{\substack{(b\cdot h)\\ \text{(rectangle)}}}{\vec{v} \cdot t} = \left(\frac{70km}{h}\right)(8.0h) = \underline{\underline{{}^{+}560km}}$

(c) Acceleration is the slope of the velocity-time graph

so: (i) $\vec{a} = \dfrac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$ (Chosen points:
Point 1: (0.0h, 60.0km/h)
Point 2: (8.0h, 0.0km/h))

$= \dfrac{0.0km/h - 60.0km/h}{8.0h - 0.0h}$

$\vec{a} = \dfrac{-60km/h}{8.0h}$

$\vec{a} = -7.5km/h^2$

Note units, and "–" sign. The object is slowing down (–) at 7.5km/h, per hour.

(p.7)

(ii) The slope is zero (horizontal line), so the acceleration is zero.

7. $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t}$

Aside: $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$
$= 9.8m/s - 1.0m/s$
$\Delta\vec{v} = 8.8m/s$

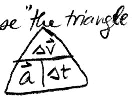
so $\Delta t = \dfrac{\Delta\vec{v}}{\vec{a}}$

$\Delta t = \dfrac{8.8m/s}{4.6m/s^2}$

$\underline{\underline{\Delta t = 1.9s}}$

* Note: can use "the triangle"

$\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t}$ ≡



just make sure you get the triangle correct!

8. $\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t}$

Aside:
$\Delta\vec{v} = \vec{v}_f - \vec{v}_i = 17.8\frac{cm}{s}[down] - 1.50\frac{cm}{s}[down]$
$\Delta\vec{v} = 16.3\frac{cm}{s}[down]$

so
$\vec{a} = \dfrac{16.3cm/s\,[down]}{4.4s}$

$\underline{\underline{\vec{a} = 3.7cm/s^2\,[down]}}$.

(p8)

9. (a) Given: $\vec{a} = -5.50m/s^2$
$t = 3.60s$

$\vec{a} = \dfrac{\Delta\vec{v}}{\Delta t} \Rightarrow \Delta\vec{v} = \vec{a} \cdot \Delta t$
$= \left(-5.50\frac{m}{s^2}\right)(3.60s)$
$\Delta\vec{v} = -19.8m/s$

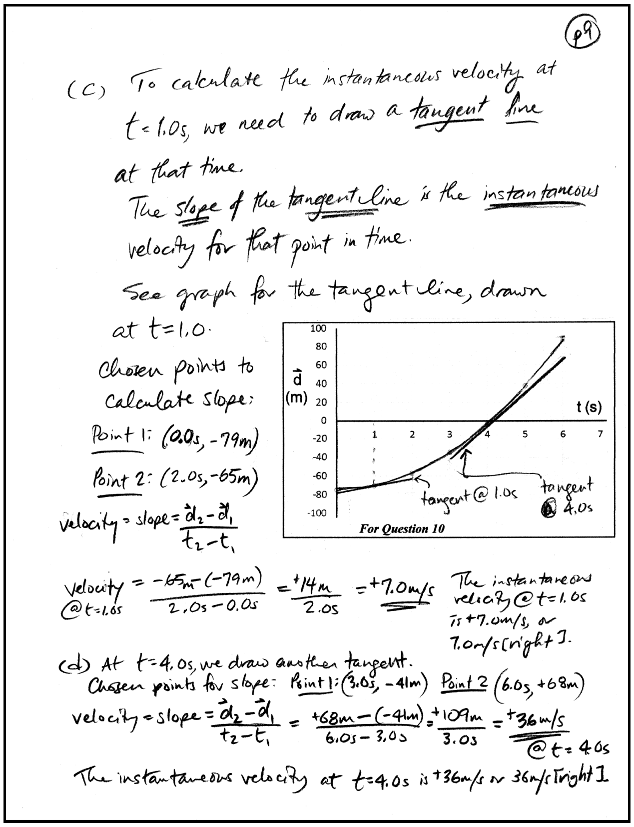
(b) First convert "km/h" to "m/s":

$\dfrac{+115\frac{km}{h}}{3.6} = {}^{+}31.9m/s$, initially so $\vec{v}_i = +31.9m/s$

so $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$

or $\vec{v}_f = \Delta\vec{v} + \vec{v}_i$ ($\Delta\vec{v} = {}^{-}19.8m/s$, from part (a))
$= -19.8m/s + 31.9m/s$
$\vec{v}_f = 12.4m/s$ The final velocity is +12.4m/s or 12.4m/s [forward].

10. (a) It is accelerating. The position-time graph is curved.
(b) The object starts at -75m (or 75m [left] of zero) and accelerates as it moves to the right. Its final position is +85m (or 85m [right] of zero).



(c) To calculate the instantaneous velocity at $t = 1.0s$, we need to draw a **tangent line** at that time.

The **slope** of the **tangent line** is the **instantaneous** velocity for that point in time.

See graph for the tangent line, drawn at $t=1.0$.

For Question 10

Chosen points to calculate slope:

Point 1: (0.0s, -79m)

Point 2: (2.0s, -65m)

$$\text{velocity} = \text{slope} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1}$$

$$\underset{@t=1.0s}{\text{velocity}} = \frac{-65m-(-79m)}{2.0s-0.0s} = \frac{^{+}14m}{2.0s} = \underline{\underline{^{+}7.0m/s}}$$

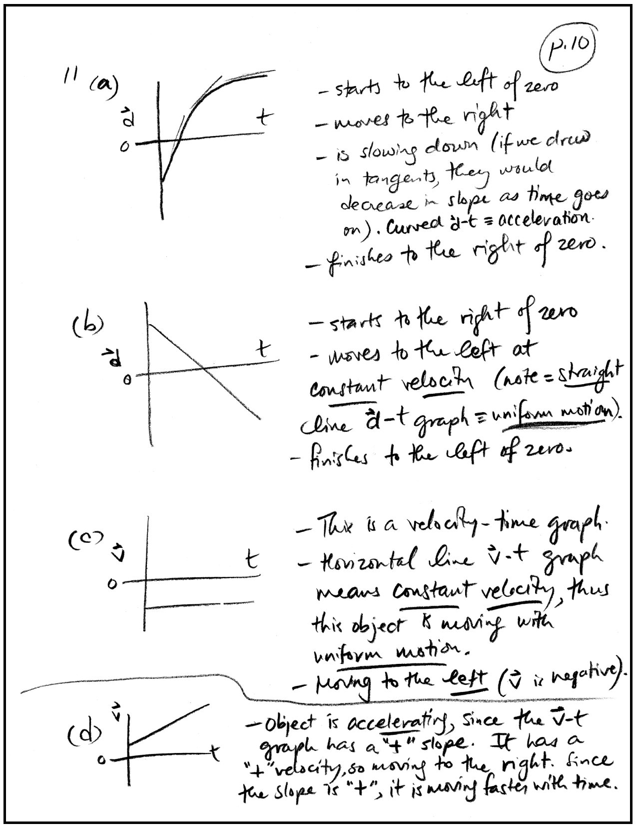
The instantaneous velocity @ $t=1.0s$ is $^{+}7.0m/s$, or $7.0m/s$ [right].

(d) At $t=4.0s$, we draw another tangent.

Chosen points for slope: Point 1: (3.0s, -41m) Point 2 (6.0s, +68m)

$$\text{velocity} = \text{slope} = \frac{\vec{d}_2 - \vec{d}_1}{t_2 - t_1} = \frac{+68m-(-41m)}{6.0s-3.0s} = \frac{^{+}109m}{3.0s} = \underline{\underline{^{+}36m/s}}\ @t=4.0s$$

The instantaneous velocity at $t=4.0s$ is $^{+}36m/s$ or $36m/s$ [right]



11 (a)

- starts to the left of zero
- moves to the right
- is slowing down (if we drew in tangents, they would decrease in slope as time goes on). Curved $\vec{d}$-t ≡ acceleration.
- finishes to the right of zero.

(b)

- starts to the right of zero
- moves to the left at constant velocity (note = straight line $\vec{d}$-t graph ≡ uniform motion).
- finishes to the left of zero.

(c)

- This is a velocity-time graph.
- Horizontal line $\vec{v}$-t graph means constant velocity, thus this object is moving with uniform motion.
- Moving to the left ($\vec{v}$ is negative).

(d)

- Object is accelerating, since the $\vec{v}$-t graph has a "+" slope. It has a "+" velocity, so moving to the right. Since the slope is "+", it is moving faster with time.