Y7 PHYSICS

Physics is the study of everything that can be objectively studied.

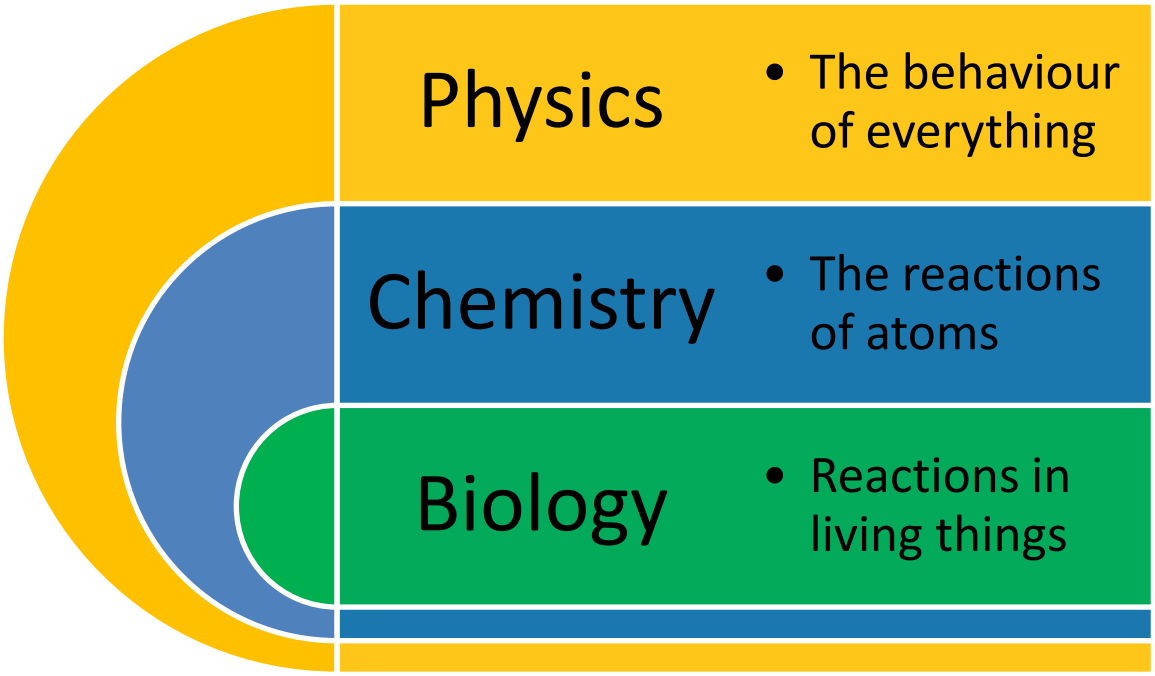
That is a big job. Physicists approach this task by making measurements and then testing to see if those measurements fit their theories. Theories are normally mathematical rules that connect different measurable factors.

If a theory survives all the tests we can throw at it, it will sometimes be upgraded to a law.

If repeated measurements do not fit the theory, the theory has to go.

$$E=mc^2$$

Energy equals mass change times the speed of light squared, Einstein's most famous equation is a consequence of his Theory of Special Relativity – just a theory!



USING THIS GUIDE

This set of notes does not contain anything that we do not cover in class and should not replace your own notes in your exercise book.

Details of experiments are not given here, but **will be required in your exams**.

The guide does contain examples of how to do the more difficult calculations, you might want to read these through, especially if you have not understood the calculations we did in class.

Information in red boxes will **not** be required in exams. Information in red is especially important for exams.

Exercises in this guide may be set for homework. You are expected to give the exercise reference (eg Exercise 1A), and write out workings and answers in your exercise books. You may work on computer, but you are still expected to show workings, and your work must be printed out and stuck into your book before the lesson.

CONTENTS

1. MEASUREMENT

To be a Physicist you need to be able to take measurements, apply mathematical rules and have the imagination to design new tests for theories, and even design whole new theories.

At school you will learn some of the accepted theories, how to make measurements, and some of the maths a physicist or engineer needs – the imagination you have to supply yourself.

1.1. UNITS

Measurements are only useful if every other physicist knows exactly which scale has been used. A widely agreed scale for any particular quantity is called a unit.

Scientists across the world use SI (Système International) units. The SI unit for anything you might want to measure can be traced back to an original scale set by the International Bureau of Weights and Measures in a laboratory outside Paris.

You have to learn the correct SI units for all common quantities. Failure to correctly include units will always cost marks.

Every unit is represented by one or two letters. Whether the first letter is a capital or not is *not* random. Only the short versions of units named after famous scientists have capitals. The unit of force is the newton, short version **N**. The unit of length is the metre, there was no Dr Metre, so the short version is **m**. Failure to correctly capitalise units will always cost marks.

For really big and small numbers it is easier to alter the unit than write out all the zeros. Units are modified by prefixes (short words on the beginning of another word) that tell you what to multiply the number by to turn it back into the original unit. The prefixes can also be shortened to single letters. Again the capitalisation is important, get it wrong and your milli becomes a Mega, a difference of a billion!

Prefix	conversion	Standard Form version	Shortens to
Terra	x1,000,000,000,000	$x10^{12}$	T
Giga	x1,000,000,000	$x10^{9}$	G
Mega	x1,000,000	$x10^{6}$	M
kilo	x1,000	$x10^{3}$	k
		$x10^{0}$	
milli	÷1,000	$x10^{-3}$	m
micro	÷1,000,000	$x10^{-6}$	µ
nano	÷1,000,000,000	$x10^{-9}$	n
pico	÷1,000,000,000,000	$x10^{-12}$	p

1.2. LENGTH

The base SI unit for length is the metre.

Most sizes that can be measured with a small ruler should be given using the milli prefix; millimetres. But you will be used to using the centi (hundredth) prefix; centimetres. If you can get into the habit of using millimetres, great, but centimetres are usually acceptable.

Miles are imperial, not SI, units and are not used in Physics. Physicists use kilometres.

1.2.1. CONVERSION EXAMPLES:

a) A4 paper is 297mm long and 210mm wide, what is this in metres?

In centimetres this is 29.7cm and 21.0cm (divide by 10)

To convert to metres the table above gives the conversion for the milli prefix as ÷1000 so:

$\frac{297}{1000} = 0.297\text{m}$ and $\frac{210}{1000} = 0.210\text{m}$

Counting Zeros

When there are lots of numbers in front of the decimal place (there are twelve zeros and a one in the number to convert from pico – above) it is easy to lose count. To try and help it is usual to add a comma every three numbers, counting forwards from the decimal place.

b) The average radius of the earth at the equator is 6378.15km what is this in metres?

To convert to metres the conversion is x1000 so:

6378.15x1000 = 6,378,150m

c) The average distance between earth and sun is 149,600,000,000m what is it in km and in Gm?

The average distance between the earth and sun is a unit. Not an SI one, but one used a lot by astronomers, 149.6Gm = 1AU. *The distance between the sun and Neptune is roughly* 40AU *or* 40 *times further away from the sun as the earth.*

The conversion of kilometres to metres is x1000, we need the opposite so ÷1000:

$\frac{149600000000}{1000}$ =149,600,000km

The conversion from Gigametres is x1,000,000,000, we need the opposite so ÷1,000,000,000

$\frac{149600000000}{1000000000}$ =149.6Gm

1.3. MASS

Physicists doing Physics must use language more carefully than we do when we are just talking generally. To a physicist mass and weight are different things. When you use the word "weight" in normal conversation you actually mean mass.

Weight to a physicist is the force of gravity acting on an object – an astronaut's weight is different on the moon because the moon's gravity is different from the earth's.

Mass to a physicist is a measure of how much stuff something is made of – essentially how many and what type of atoms something is made of. The mass of an astronaut on the earth and on the moon is the same.

Just to make things more complex the base SI unit of mass is the kilogram not the gram. The base unit is the one you use when performing calculations.

And one more complication, we do not use Megagrams, one thousand kilograms is a tonne. We can even extend this so that one million kilograms is a kilotonne and one billion kilograms is a megatonne. Although kilotonne and megatonne are usually only used to describe roughly how much ordinary explosive you would need to give the same bang as a nuclear bomb!

1.3.1. CONVERSION EXAMPLES:

a) A Range Rover has a Mass of 2360 kilograms what is this in tonnes (t) and grams?

The text above tells you there are 1000kg in a tonne so we need to ÷1000:

$$\frac{2360}{1000} = 2.360\text{t}$$

To convert from kilograms to grams you should know by now that there are 1000 grams in a kilogram so we do ×1000

2360×1000 = 2,360,000g

The size of the kilogram was originally chosen so that 1kg *had the same mass as one litre of pure water at* 4°C. *In 1889 this was replaced as the standard by a block of platinum & iridium alloy of the correct mass. Amazingly, although the kilogram is a French unit, the original platinum/iridium blocks were made by a firm in Britain, Johnson Matthey, who are still scientific precious metal suppliers today.*

Source: Wikipedia

b) A standard headache pill contains 200 milligrams of ibuprofen, what is this in grams and kilograms?

From the table to convert from milligrams to grams we ÷1000:

$$\frac{200}{1000} = 0.200\text{g}$$

And as there are also 1000 grams in a kilogram to go from grams to kilograms we do the same:

$$\frac{0.200}{1000} = 0.000200\text{kg}$$

Extra Zeros

You might have noticed that in the examples above zeros have been left on the end of numbers after the decimal place, 200mg *to* 0.000200kg. *If you try this on your calculator the extra zeros will disappear. This is because mathematically the extra zeros tell you nothing;* 0.000200kg *is the same size as* 0.0002kg. *In measurement, however, the extra zeros tell you the "precision" or "resolution", that is what scale the object has been measured to. 0.000200*kg *tells us that the ibuprofen has been measured to the nearest* mg.

At KS3 it is not vital to get this right. You will not usually lose marks for following your calculator and dropping the extra zeros, but leaving them on is a good habit to get into. If you use centimetres to record lengths measured with a ruler, then you have usually measured to the nearest millimetre. 11cm *means that you have only measured to the nearest centimetre,* 11.0cm *tells us that you have measured to the nearest* mm. *Not a problem if you used millimetres in the first place (*110mm*).*

1.4. TIME

The trouble with common units of time is that they come in difficult multiples:

Sixty seconds to a minute, sixty minutes to an hour, twenty four hours to a day, seven days to a week etc etc

As physicists we get around this by avoiding using anything except seconds and their prefixed versions milliseconds, microseconds, even gigaseconds.

This causes problems when carrying out measurements of time in an experiment because stopclocks usually measure in minutes, seconds and hundredths of a second (you would be correct to say centiseconds for hundredths of seconds, but we never do!).

You must convert what the stopclock says to seconds before writing it into your table.

The stopclock in the picture reads, nine minutes, three seconds and nineteen hundredths of a second, which could be written as 9:03.19. But in Physics that would be wrong, it must be converted to seconds:

$$9 \times 60 = 540$$

$$540 + 3.19 = 543.19\text{s}$$

543.19s would be the correct time in Physics.

1.4.1. WHAT THE COMMON UNITS OF TIME MEAN

You need to know what the physical meanings of some of the large common units are:

Day: The time it takes for the earth to turn completely on its axis and for the sun to be back in that same place in the sky.

Month: Roughly the time it takes for the moon to orbit the Earth.

Calendar Year: 365 days

Mean Sidereal **Year** (or just "year"): The time it takes for the Earth to orbit the sun once. A little more than 365 days.

Leap Year: A year containing an extra day to make up for the fact that the sidereal year is longer than 365 days.

1.4.2. MEASURING TIME

Before modern electronics were invented pendulums were the best way to measure time. This is because the time that a pendulum takes to swing once (its period) is almost entirely set by the distance between the pivot and the middle of the pendulum weight. In class you will perform an experiment to test the relationship between pendulum length and pendulum period. **You are required to be able to describe the method for performing this experiment**.

1.4.3. CONVERSION EXAMPLE:

a) How long is a year in megaseconds? (take a year to be 365.25 days)

There are 60×60 seconds in an hour, so there are 60×60×24 seconds in a day

60×60×24 = 86,400s per day

So there are 86,400×365.25 seconds in a year

86,400×365.25 = 31,557,600s per year

To convert megaseconds to seconds the table says we ×1,000,000 so here we do the opposite ÷1,000,000

$$\frac{31557600}{1000000} = 31.5576\text{Ms per year}$$

So the final answer is 31.558Ms (the final decimal place was rounded up so that there were five numbers [significant figures] in the answer to match the five significant figures in the number given in the question).

1.5. TEMPERATURE

The temperature scale that we use is degrees celsius (^{o}C).

Even though they do so in newspapers, books and on weather forecasts, do not leave out the degrees sign. A capital C on its own is the unit of charge (coulomb). Because the Celsius scale is based on the temperature scale invented by Anders Celsius the C is always a capital.

Any temperature scale has to have two set temperatures that are known with certainty and the gap in between the two has to be divided into a set number of divisions. For degrees celsius the two known temperatures are the freezing and boiling points of pure water at standard atmospheric pressure and there are a hundred divisions between the two.

1.5.1. IMPORTANT TEMPERATURES

There are some important temperatures that you need to know:

Absolute Zero: The lowest possible temperature -273°C

The boiling point of nitrogen at standard atmospheric pressure -196°C

The freezing point of water 0.0^{o}C

Normal Room Temperature 20-22°C

Record Air Temperature in Jersey 36.3^{o}C

Human Body Temperature 37.0^{o}C

Boiling point of water at standard atmospheric pressure 100.0^{o}C

Surface Temperature of the Sun 5500°C.

Absolute zero is the lowest temperature theoretically possible (-273.15^{o}C). It is possible to get within microdegrees of absolute zero, but not actually to get there.

It is the point where all movement stops and no energy exists. This makes absolute zero very important to Physics and Chemistry. Therefore at A level and beyond we use a different temperature scale; the Kelvin Scale. This uses absolute zero as its bottom set point so temperature is zero when energy is zero. This makes all calculations involving energy much easier to do.

1.6. AREA & VOLUME

Area is the first of our derived units. This means a unit that is calculated from other basic units.

Area is calculated from the product (in maths product means multiplied together) of two lengths. Since the SI unit of length is the metre, the unit of area is m×m which is usually written as m^2 – metres squared.

For rectangular shapes the formula for area is simple:

$$l \times w = A$$

Length (*l*) times width (*w*) equals area (*A*), for other shapes the formula is more complex.

The conversion between different areas can cause confusion. A metre squared can be drawn as a square a metre on each side, a centimetre squared is the same – a square a cm long each side. There are ten thousand centimetres squared in a square metre - the product of one hundred cms to a metre per side of the square.

There are one million square millimetres to a square metre – the product of one thousand millimetres per side of the square.

It is always easier to convert to the final unit that you want before you multiply the two lengths together than it is convert the square units afterwards.

Volume is the product of three lengths. Its SI unit is therefore m×m×m, written as m^3 – metres cubed.

The formula for the volume of what are called cuboids (rectangular blocks) is:

$$l \times w \times h = V$$

Length (*l*) times width (*w*), times height (*h*) equals volume (*V*). Multiplication is communicative, which means it does not matter what order you do the multiplication in:

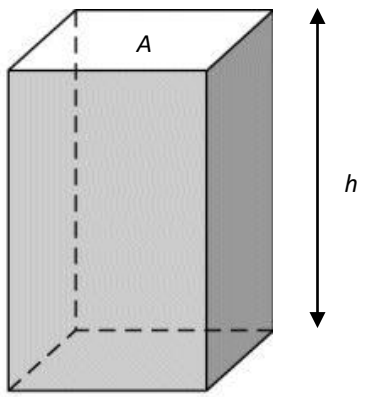
$$l \times w \times h = w \times l \times h = h \times w \times l = w \times h \times l = V$$

Which means that it does not matter which side you call width, which you call length and which you call height.

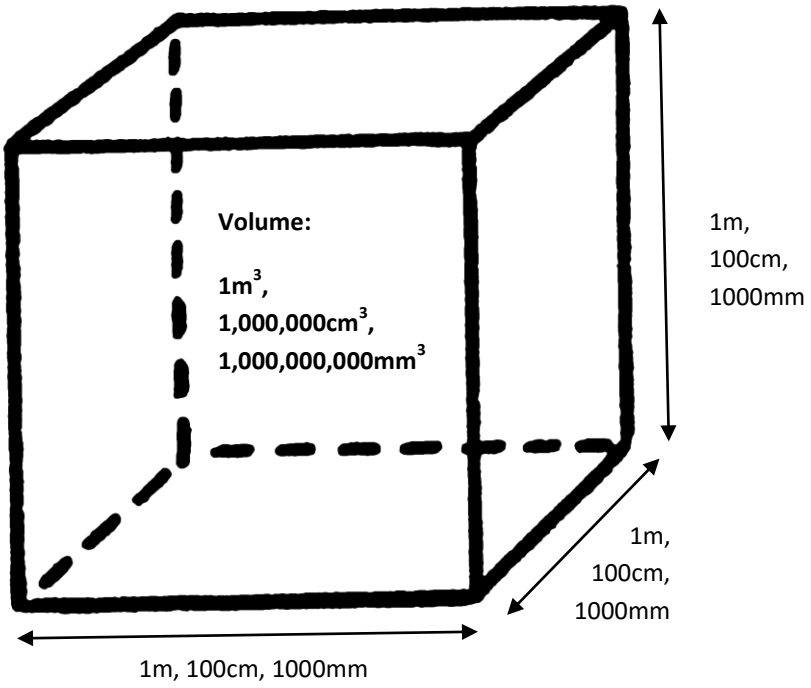
Comparing the formula for volume with the formula for area allows us to also write the volume formula as:

$$A \times h = V$$

The area of one side (*A*) times the height (*h*), measured away from that side, equals volume (*V*).



Volume has the same conversion problems as area, it is not obvious. One metre cubed is the same as one million centimetres cubed (100×100×100) and one billion millimetres cubed.



1.6.1. CONVERSION EXAMPLES:

a) Jersey is very roughly a rectangle 8km by 15km, what is its area in metres squared?

It is easier to convert to the final unit first, we want metres squared so we convert kilometres to metres before calculating the area.

8km by 15km is 8,000m by 15,000m

so the area is One metre cubed

$$8000 \times 15000 = 120{,}000{,}000\text{m}^2$$

(Wikipedia gives Jersey's area as 118,200,000m^2)

b) A large crystal of salt is a cube with each side 1.5mm long, what is its volume in metres cubed?

First convert 1.5mm to m by dividing by 1000:

$$\frac{1.5}{1000} = 0.0015\text{m}$$

Now calculate the volume by multiplying the three lengths together (in this case all three are the same length):

$$0.0015 \times 0.0015 \times 0.0015 = 0.000000003375\text{m}^3$$

The final volume is 0.0000000034m^3, where once again the answer has been rounded so that there are the same number of significant figures in the answer as the question.

c) The volume of the earth is roughly 1,000,000,000,000km^3 what is this is metres cubed?

This time we cannot convert the lengths first so we need to work out how many metres cubed there are in a kilometer cubed. There are 1000m in a km so:

$$1\text{km}^3 = 1000\times1000\times1000 = 1{,}000{,}000{,}000\text{m}^3$$

There are a billion metres cubed in a kilometer cubed so we need to multiply the volume of the earth in km^3 by one billion to get m^3:

$$1000000000000\times1000000000 = 1{,}000{,}000{,}000{,}000{,}000{,}000\text{m}^3$$

Notice that volumes and areas can end up being very large or very small numbers. You have to be very careful putting the numbers into your calculator, and then even more careful copying the answer out into your book.

1.6.2. CALCULATION EXAMPLES:

a) The area of one side of a rectangular block is 16cm^2, if the volume is 96cm^3 what is the block's height measured from this side?

Because we have been given an area we are going to use the second formula for volume:

$$A \times h = V$$

We need *h* so the formula has to be rearranged to make h the subject. The *A* needs to move to the other side, it is multiplying on the left so it will divide on the right:

$$h = \frac{V}{A}$$

Putting in our values:

$$h = \frac{96}{16} = 6\text{cm}$$

The height is 6.0cm.

b) Twenty four toy blocks 35.0mm by 72.0mm by 20.0mm fit into a box. The base of the box is 140mm by 144mm, what is the total volume of the box and what is the missing dimension?

There are two ways to answer this question, you could work out from the dimensions how the blocks fit into the base and then calculate how high they are stacked in the box. The more mathematical way is work out the total volume of blocks:

One block's volume is 35×72×20 = 50,400mm^3

Total volume is 24×50400 = 1,209,600mm^3

The total volume of the blocks must equal the volume of the box so we can use that in the volume formula to find the missing dimension *h*:

$$h \times l \times w = V$$

Rearranging to make h the subject:

$$h \times l = \frac{V}{w}$$

$$h = \frac{V}{l \times v}$$

and putting in the values we know:

$$h = \frac{1209600}{(140 \times 142)} = 60\text{mm}$$

The scientific calculators used in school allow you to put the values into your calculator so that they look just like the way they are written above ($\frac{1209600}{(140 \times 142)}$) - ask your maths teacher if you do not know how - then you can be certain that you will get the correct answer.

The answer is 60.0mm, meaning that the blocks must be stacked three deep in the box.

1.7. SPEED

Speed measures the distance that would be travelled in a given time. We are used to that given time being an hour, the speed limit in Jersey, for example, means that a car travelling at 40mph would travel 40 miles in one hour. But since physicists use neither miles nor hours, miles per hour is not an SI unit.

Two factors complicate this topic:

the proper unit for speed is ms^{-1}, but that involves maths that you have not yet done,

and both speed and distance travelled (displacement) tend to have directions (e.g. north to Trinity) making them vector quantities.

Things that have both a size and a direction are called vectors. Force, which we will do later, is always a vector because its direction is always as important as its size. In Physics velocity is the vector version of speed and displacement is the vector version of distance.

v (velocity) and s (spatium, the latin for displacement) are therefore the symbols for the vector quantities. We always use vectors in formulas.

Almost the only unit for speed that physicists use is metres per second. You might not think that anything would get very far in a second, but you walk at a bit over one metre per second and light travels at 300,000,000 metres per second. Metres per second is written as m/s where the slash stands for “divide” or “per”, **mps is never allowed**.

The word equation for speed is:

$$speed = \frac{distance\ travelled}{time\ taken}$$

The formula is:

$$v = \frac{s}{t}$$

Which is made difficult by the fact that we often use *v* for speed, or more properly velocity, and *s* for distance travelled (from the latin "spatium"), *t* is time.

In lessons you will perform different experiments to measure speed, using both stop clocks and light gates. You are required to be able to describe how to measure speed in an experiment.

1.7.1. CALCULATION EXAMPLES:

a) A trolley travelled 72.5cm down a runway in 3.21 seconds, what was its speed?

Speed or velocity is measured in metres per second so we need to convert cm to m

$$\frac{72.5}{100} = 0.725\text{m}$$

Using the formula:

$$v = \frac{s}{t} = \frac{0.725}{3.21} = 0.2258567\text{m/s}$$

The final answer is 0.226m/s, which as usual has been rounded to give the same number of significant figures as in the question.

b) Light travels the 5,600km between London and New York in 18.7ms, what is the speed of light?

The first thing to do is to make sure that both values are in the correct units, i.e. seconds and metres (remember that ms stands for milliseconds).

$$t = \frac{18.7}{1000} = 0.0187\text{s}$$

$$s = 5600 \times 1000 = 5{,}600{,}000\text{m}$$

Then we just put the values into our formula:

$$v = \frac{s}{t} = \frac{5600000}{0.0187} = 299{,}465{,}240\text{m/s}$$

The answer is 299,000,000m/s

c) A car travels along a French motorway at a constant 110km/h for three and a half hours, how far has it gone?

This question is a bit more of a maths question than a physics one because it uses kilometres per hour rather than m/s. The idea is the same, only the units are different.

Using the formula:

$$v = \frac{s}{t}$$

And rearranging to make distance (*s*) the subject:

$$v = \frac{s}{t}$$

$$v \times t = s$$

We now just put in the values, remembering to use the new units, hours and km/h

$$110 \times 3.5 = s = 385\text{km}$$

If we were to round this answer to 390km that would be correct, but so would 385km. This is because it is not obvious from the question whether two or three significant figures are being used. Besides, you are not usually marked wrong for giving an answer with one significant figure too many.

d) If a train travels at an average of 43m/s between London and Birmingham how long does the 165km journey take?

First we need the distance in metres:

$$165 \times 1000 = 165{,}000\text{m}$$

Then we need to rearrange the formula for speed to make *t* the subject which is a two step rearrangement:

$$v = \frac{s}{t}$$

First we need to move t off of the bottom, if it is dividing on the right it will multiply on the left:

$$v \times t = s$$

Then we need to move the v, it is multiplying on the left so will divide on the right:

$$t = \frac{s}{v}$$

Now we can insert the values and work out an answer:

$$t = \frac{s}{v} = \frac{165000}{43} = 3837.2\text{s}$$

The answer is 3830s (there are both 2 and three significant figures in the question so either would be OK in the answer). Only if you want to show off should you convert this to hours and minutes (just under one hour and four minutes).

1.8. MAKING MEASUREMENTS, UNCERTAINTY AND INSTRUMENT RESOLUTION

One aim when designing any experiment is to make sure that the uncertainty in the measurement is very much smaller than the value of the measurement.

The **resolution of a measuring instrument** is the smallest scale division that it can read to; one millimetre for a ruler, one hundredth of a second for a stop clock.

In Physics we say that the most certain we can be about a measurement is that the true value is somewhere within one scale division either side of the measured value. In other words the **measurement uncertainty** is plus or minus the instrument resolution. For a ruler ±1mm, for a stop clock ±0.01s, for a spring newton meter ±0.5N.

This why you **should always write down the instrument resolutions next to your results table**.

If we measure 196mm with a ruler, our uncertainty is ±1mm, that is fine, the uncertainty is tiny compared to the measurement. If we measure 5mm with a ruler the uncertainty is almost as big as the measurement – not good. If we try to measure the thickness of a sheet of paper with a ruler the uncertainty is much bigger than the measurement – no chance.

Remember within plus or minus the instrument resolution is the *most* certain we can be**. The instrument resolution is only the smallest possible uncertainty**. Sometimes uncertainties are much bigger. Think about an experiment that you will do, measuring the swing of a pendulum. You are using a stop clock, resolution 0.01s, to measure a swing of about 0.5s. Seems fine. But this experiment is relying on you pressing the buttons, you have to judge when the swing starts and stops and press the buttons at the right time. Seeing something, thinking about it and reacting can take 0.3s, add in the problem of judging the start and stop of the swing and your actual uncertainty could be just as large as the time you are measuring!

We can improve the 5mm and even the paper thickness problem by using a different measuring instrument and for the pendulum we could use electronic timing, but often you only have the kit provided, so you have to find a way around the uncertainty problem. **The solution is to measure lots and divide.**

If we measure a ream of paper with 500 sheets in it with a ruler, that is about 80mm, the uncertainty is therefore not a problem, and we can then divide that number by 500 to get the thickness of one sheet.

If we time ten swings of the pendulum, our uncertainty is still around ±0.3s, but we are now measuring for 5 seconds, not brilliant compared to the uncertainty, but much better than before. We then divide that time by ten to get the time for one swing.

An example that you might come across for homework is measuring the circumference of a tin can, a can of beans for example. The way to do this is to mark a piece of string wrapped around the can which can be laid out flat and measured. If you think about it, however, there are lots of uncertainties here. Is the end of the string a bit ragged, where does it actually end, how thick is the mark that you add, how tightly is the string wrapped around, what about the thickness of the string affecting the measurement? What can you do to reduce the size of the uncertainty compared to the size of the measurement? Hopefully you know the answer.

Uncertainty and not Lying about your Experiment

To understand this you have to understand what we mean by ***measurement uncertainty****. Think about measuring something with a ruler. The ruler can measure to the nearest millimetre, so we say that the* ***resolution of the measuring instrument*** *is* 1mm.

Measuring a length with a ruler you might get a value of 19.6cm *– is that the actual length? Absolutely certain?*

The first thing to do of course is to use the proper SI unit, so your length is probably 196mm

You could check by getting a couple of friends to measure the same length, if they get the same value, then we can say that the result is ***reproducible****, and so we are a little more certain that it is* 196mm

But what would happen if we could measure to tenths of a millimetre? Would it be 196.0.mm*? Or* 195.8mm*, or* 196.4mm*?*

If you think about how you do the measurement with the ruler, you make a judgment, is the length closer to the 6mm *mark than the* 5mm *mark or the* 7mm *mark? The length you are measuring rarely lines up with the mark exactly. Even if it does line up exactly, the* 6mm *mark itself has a thickness, where in the thickness of the mark is exactly* 6mm*, who knows ? The ruler designer perhaps knows, but we don't.*

All of which means your 19.6cm *could easily be* 0.5mm *larger or smaller, so we might write:*

196±0.5mm

Which says that we think it is 196mm*, but it could be* 0.5mm *larger or smaller. In other words we have a measurement uncertainty of* ±0.5mm *(plus or minus* 0.5mm*).*

This is method that is used in Maths when you meet measurement uncertainty – assume that the measurement could actually be half the instrument resolution bigger or half the instrument resolution smaller.

But what about the other end of the ruler? While you are concentrating on the 6mm *mark between* 19 *and* 20cm *is the zero still properly lined up with the other edge of your object? Are you sure?*

In Physics it is really important not to understate your uncertainties, because effectively that is lying about the quality of your experiment*. We tend to overestimate rather than risk underestimating uncertainty. So in Physics we do not say that the uncertainty is plus or minus half the resolution of the instrument, we say it is plus or minus the whole of the resolution of the instrument.*

In the case of the ruler it is easy to see why; we could easily be half a millimetre out at ***both*** *ends, meaning that there is a chance of being a whole millimetre out. So your measurement is actually:*

196±1mm

For other measuring instruments, why a whole resolution rather than half is less obvious. If you were a scientist in a university or a company laboratory you would work out the uncertainty properly for each instrument, but for school the "use the whole resolution of your instrument as the uncertainty" rule is easy, and is probably safely overestimating the uncertainty.

This "not lying about the quality of the experiment" is also why we only use the same number of significant figures in a calculated answer as there were to begin with. Just because your calculator says the speed is 13.333333333333333333333333333333333333333333333333333333m/s *does not mean that it actually is and we certainly could not measure it to that many significant figures even if that were its speed.*

1.9. MEASUREMENT HOMEWORK QUESTIONS

EXERCISE 1A

Estimate the length of each of the following objects and record it in a table like the one below. Then measure the length of the object and record it in your table in cm, mm and m. Do not forget to write down the resolution of your ruler or tape measure alongside your table.

Object	Estimate /cm	Measured Length /cm	Measured Length /mm	Measured Length /m
Length of an A4 sheet				
Width of a doorway				
Diagonal of a TV screen				
Height of a cereal box				
Span of an adult's hand				
Diameter of a tin can				
Length of a teaspoon				
Thickness of a telephone directory				
Thickness of a mobile phone				
Circumference of a tin can*				

*This problem is discussed in section 1.5

EXERCISE 1B

Use the fact that there are 1000 grams in a kilogram and 1000 kilograms in a tonne to convert the following:

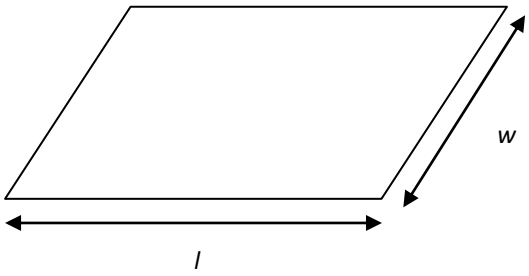
a) 1500g into kg
b) 750g into kg
c) 50g into kg
d) 6.4g into kg
e) 2.7kg into g
f) 119kg into g
g) 0.67kg into g
h) 98.2kg into g
i) 5300kg into t
j) 358kg into t
k) 2.1t into kg
l) 0.8t into kg
m) 7,300,000g into t
n) 0.55t into g

Write out the answers and any workings in your exercise book.

EXERCISE 1C

Use a calculator to work out the area of the following rectangles where you have been given the length (*l*) and width (*w*) for each. Each time write two answers into your exercise book, one in cm^2 and one in mm^2. It is easiest to convert the dimensions to the correct units before you multiply. Be careful to check what the starting units are before diving into the calculation.

a) *l* = 210mm *w* = 297mm
b) *l* = 2.4cm *w* = 21cm
c) *l* = 18mm *w* = 4200mm
d) *l* = 94mm *w* = 9.4cm
e) *l* = 18.0cm *w* = 433cm
f) *l* = 6.7m *w* = 2.0m
g) *l* = 0.21m *w* = 297mm
h) *l* = 12m *w* = 32cm



Do the same for the following cuboids (rectangular blocks). Give your answers in both cm^3 and mm^3.

i) *l* = 24mm *w* = 29mm *h* = 15mm
j) *l* = 330mm *w* = 82mm *h* = 82mm
k) *l* = 28cm *w* = 14cm *h* = 12cm
l) *l* = 340cm *w* = 120cm *h* = 18cm
m) *l* = 56mm *w* = 2.3cm *h* = 40mm
n) *l* = 0.32m *w* = 2.2m *h* = 1.0m
o) *l* = 90cm *w* = 38mm *h* = 0.14m
p) *l* = 1510mm *w* = 1.51m *h* = 151cm

EXERCISE 1D

HOME EXPERIMENT TO MEASURE THE VOLUME OF A STONE

Apparatus:

Collect the following items:

Empty Jersey Milk carton or similar cardboard drinks carton

A stone that fits inside the carton

Method:

Half fill the carton with water

Make a mark on the carton at the level of the water

Lower in the stone

Mark to new water level

Measure and record the difference in water levels

Measure and record the length and width of the carton

Calculate the volume of the stone from the volume of the displaced water.

Calculation:

Volume of displaced water = water level difference × length × width

In your exercise book draw a good diagram or diagrams clearly showing how this method works. (If you want to be creative you can draw the method out as a cartoon rather than using scientific diagrams).

Write down your results; length, width and level difference.

Write down your calculation.

Clearly write down the final volume of your stone.

EXERCISE 1E

All calculations should be performed using metres, seconds and metres per second – where necessary convert the units before attempting the calculation.

Write the calculations and answers in your exercise books, where necessary round your final answer to the same number of significant figures as are in the question, remember to include units.

a) Usain Bolt's 2009 world record time for the 100m was 9.58s.
   i. What was his average speed?

If his 200m world record the same year was 19.19s

   ii. What was his average speed in the 200m?
   iii. Suggest three reasons why we might expect Bolt to reach a higher top speed in the 100m than the 200m?

b) A baked bean can takes 2.34s to roll down a 1.00m ramp what is its average speed?

c) A model railway track has curved sections that are 24cm long and straights that are 18cm long. If there are six straights, eight curves and it takes the engine 19 seconds to do a circuit?

   i. What is the total track length?
   ii. How fast is the engine travelling?

d) A 12cm interrupt card on a trolley was timed to take 0.08s to pass through a light gate. What speed was the trolley travelling at?

e) A bullet travels the length of an 82cm rifle barrel in 3.4ms, what was its average speed?

f) A racing car moving at its top speed of 82m/s takes 4.7s to drive the length of a circuit's straight, how long is the straight?

g) A cannon is fired every day at Castle Cornet at exactly 12 noon, if an Elizabeth College student hears the bang at 4 seconds after 12, how far is he from the Castle (he needs a Victoria College student to do the maths for him – the speed of sound is 330m/s)?

h) Ex-Physics teacher Mr Simpson (who loves his model railways) decides to add four more straights to the track in question c). The engine is still travelling at the speed you calculated in c)ii. How long does it take to go around once now?

2. MATERIALS

2.1 ELECTRICITY

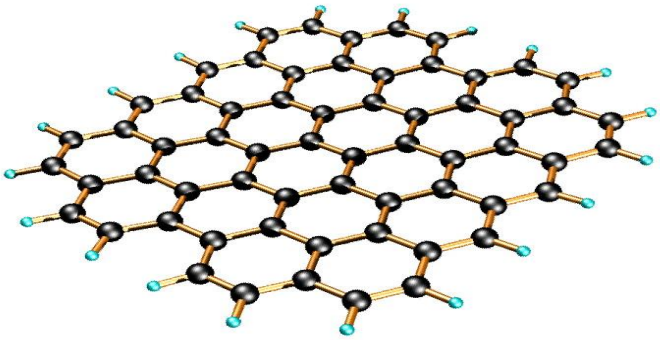
2.1.1 WHAT CONDUCTS?

In class you will test experimentally an idea that you probably know from Primary School; all metals conduct electricity and very few non-metals in their solid form do. The only common solid, non-metal that does conduct is graphite.

The reason for some materials conducting, and others not, is called "delocalisation". Electricity is the flow of charge; in solids this usually means the flow of electrons which are small particles with a charge. In most solids the electrons are confined to one place, one locality, they are localised, they can't move and electricity can't flow.

In metals, metallic bonding (you will learn more about bonding in Chemistry) works by sharing each atom's outer electrons with every other atom in the metal crystal. These electrons now belong to every atom so aren't locked in place, they are delocalised, they are free to move.

Every metal uses metallic bonding, so every metal can conduct electricity.



Graphite conducts electricity because of an unusual arrangement of atoms in its crystal.

In graphite the carbon atoms are arranged in sheets of repeating hexagons, meaning that each carbon has three others around it. Carbon atoms have four outer electrons, three of these form a different type of bond, covalent bonds, with the three surrounding carbon atoms and are localised in position between the carbon atoms. The fourth outer electron, very unusually for a non-metal, ends up free to roam, it is delocalised and so can conduct electricity.

In 2010 two physicists who work at the University of Manchester were awarded the Nobel Prize for discovering that single sheets, an atom thick, of graphite, called graphene, have very unusual electrical properties. The study of the properties and uses of graphene is now a big, cutting edge area of modern Physics

2.1.2 CIRCUITS

Electricity can only flow easily if:

- there is at least one complete loop of conductor (this allows all the electrons to smoothly move, there can be no build ups)
- there is an energy source included into the loop.

We call this combination a circuit. The motion of electrons around the circuit turns the energy of the source into other forms of energy, often heat (the principle of conservation of energy is a Year 8 topic).

Normal day to day physics – often called Newtonian Mechanics – does not allow electricity to flow without converting energy.

At the beginning of the twentieth century physicists discovered whole new types of physics. One of these new branches, Quantum Mechanics, allows superconductors to exist, but only at very low temperatures. These are materials that carry electricity without energy loss.

Superconductors were the subject of Dr Cooke's doctorate.

In Year 7 your energy source will normally be a **cell**. You probably want to call it a battery, but this is another example of physicists needing to be more careful with their language than normal people. A battery is a set of things grouped together, car batteries contain several cells linked together, but normal household "batteries" are actually just single electrochemical cells, so we call them cells. Cells have a **positive** and a **negative** end. We say that electricity flows from positive to negative.

Sometimes you might use the lab power packs as your source, these use mains electricity rather than a chemical reaction to drive them. The lab packs have positive (red) and negative (black) sockets.

Most of the circuit is made up of copper wires. In the labs these come as 20cm lengths with connectors on the ends and a coloured plastic coating. The colour of the plastic makes no difference. It is usual to use red coloured wires for the positive side of the circuit and black for the negative, try to get into this habit.

Copper is an excellent conductor. If the circuit, or a single loop of the circuit, is made from just copper wire the electricity will flow very easily and all of the energy of the cell is expended very quickly in heating up the wires. We call this a **short circuit**. At school this will damage the cell, at home, with mains electricity, a short circuit can overheat dangerously.

Usually we add other things into the circuit to control the flow, to convert the electrical energy in a controlled way, or both. We call these **circuit components**. In Year 7 the two circuit components you are most likely to use are **light bulbs (lamps)** and **switches**.

Circuits are drawn using an internationally agreed standard.

Wires are drawn as straight lines using a ruler

Cells as[1]:

Cell

The long line indicates the positive side, the short line being thicker is not compulsory.

Batteries:

Battery

Lamps:

Lamp

Switches:

Switch

Note that switches are normally drawn open, even if they have to be closed for the circuit to work.

In class you will experiment with **series** (just one loop in a circuit) and **parallel** (more than one loop) circuits, the use of switches to control circuits, and the effect of **short circuits**. You will need to make sure you understand these ideas for the final exam.

[1] Component images from BBC Bitesize

http://www.bbc.co.uk/bitesize/ks3/science/energy_electricity_forces/electric_current_voltage/revision/3/

2.1.3 MEASURING ELECTRICITY

There are two measures of circuit electricity; **current** (unit amperes, shortened to A) and **potential difference** – often called voltage – (unit volts, shortened to V).

Potential difference or voltage is the measure that most people have heard of, but is not straight forward and is often used incorrectly. We will leave potential difference until you are an older and more experienced physicist.

Current is an easier concept. It is a measure of the amount of charge, or number of electrons, passing through a point in a circuit every second. Some people compare it to measuring the volume of water passing through a pipe or along a river every second.

Ammeter

Current is measured using an Ammeter

In Year 7 current is discussed in terms of series and parallel circuits:

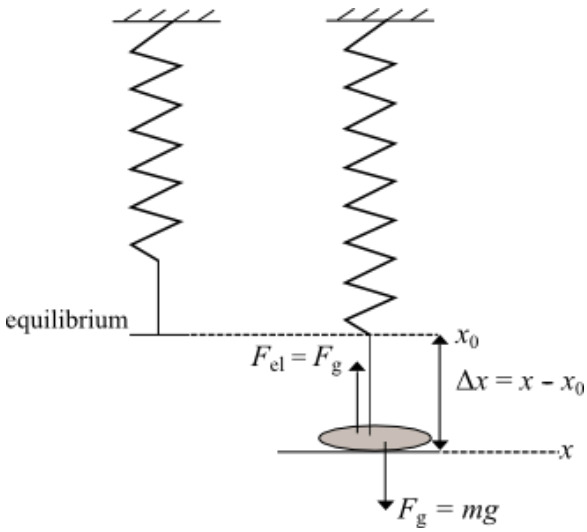
- The more components in a loop (series) the lower the current that flows.
- The more loops in a circuit (parallel) the higher the total current that is drawn from the cell.

2.2 ELASTICITY

2.2.1 SPRINGS

In class you will conduct an experiment to measure the behaviour of a spring as weight is added. You are required to be able to discuss details of this experiment.

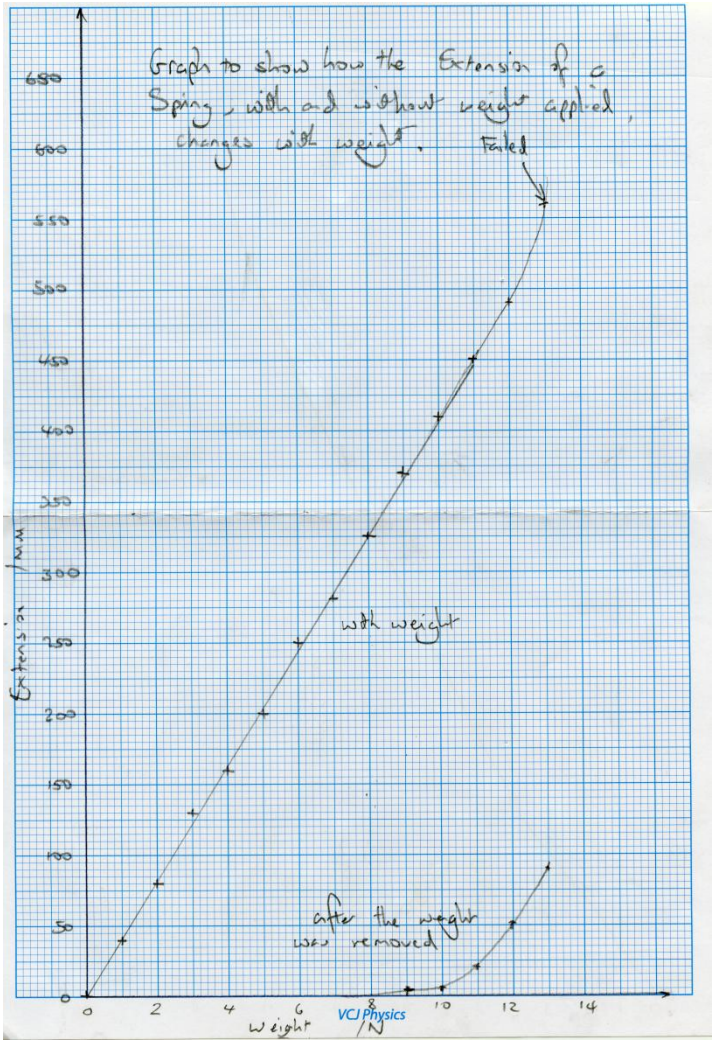
Note that in this situation “weight” and not “mass” is the correct word because we are using the masses hung from the spring to apply the force of gravity to the spring. In this case instead of measuring the applied weight in kilograms we measure it in newtons, the unit of force. The force of gravity acting on one hundred grams is taken to be one newton.



Note also that this experiment is to measure the change in length of the spring, properly called the **extension (*Δx* in the diagram)**, not the total length of the spring.

The details of this experiment are required for the end of year exam.

Your graph should resemble this one:



Drawing conclusions from graphs is one of the toughest skills in Physics, and is one that you will practice throughout your time doing Physics at school. There are several things that you can conclude from this graph, or rather this pair of graphs on one set of axes.

- The spring failed after 13 newtons.
- The main graph appears to be a straight line that passes through the origin, although there is a little bit of scatter of the points on either side of the line.
- This scatter is probably measurement error because it was not easy to keep the ruler straight against the spring. The uncertainty of the ruler used was ±1mm, but the difficulty of using the ruler with the hanging spring means that the uncertainty of the experiment was larger; the plotted points are up to 10mm either side of the line of best fit.
- The "without weight" graph shows that after about 8 newtons the spring no longer returns to its original length.
- Looking closely at the "with weight" graph after 8N shows that all the points are above the straight line and may curve away from the straight line.
- Therefore we can say that although the spring failed after 13N, it was actually damaged and no longer behaving as it had done after 8N.

If you managed to get half of those conclusions from your on graph by yourself you were doing very well.

This set of conclusions tell us that the spring obeyed **Hooke's Law**.

Hooke's Law says that:

The extension of a spring will be directly proportional to the force applied unless it exceeds its elastic limit

2.2.2 DIRECT PROPORTIONALITY

Directly Proportional is a very important idea in Physics, very many pairs of variables that we can measure and plot on a graph are directly proportional, and whether they are or not tells us a lot about the physics that connects them.

On a graph **direct proportionality shows up as a straight line that passes through the origin**.

The other way to tell whether a pair of variables is directly proportional is if one increases by a factor, the other should increase by the same factor. As a check the easiest factor to use is doubling.

If you look at our graph – redrawn on the next page - the value (read from the line of best fit, not the point) of extension at 3N is 122mm. Doubling 3N gives 6N, and the value for the extension at 6N is 243mm – *also double to within the uncertainty of the experiment*. Try the same exercise for 2N and 4N or 4N and 8N and you will get the same result.

If doubling your independent variable also leads to the dependent variable doubling (within the uncertainty of the experiment) **then your variables are directly proportional**

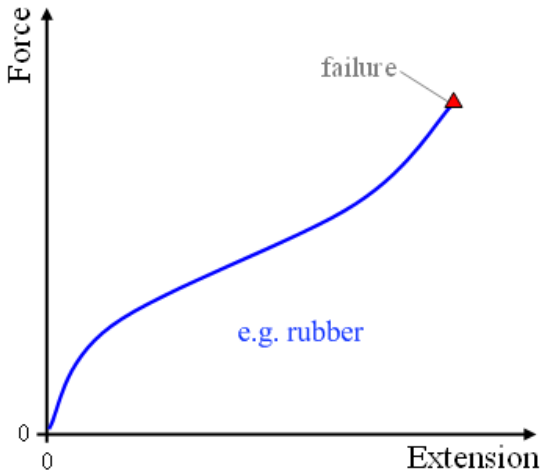
2.2.3 HOOKE'S LAW

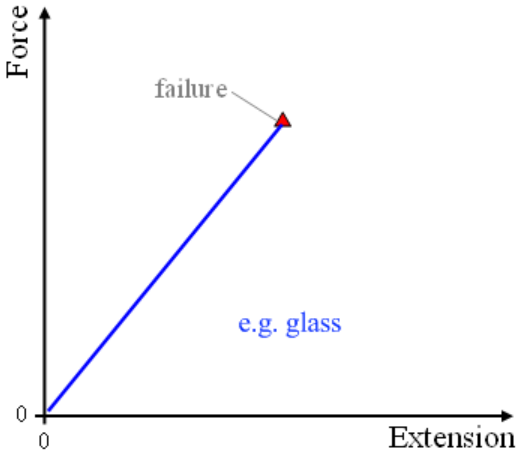
Returning to Hooke's Law, the graph for our spring is a straight line that goes through the origin up until 8N. So was can say that our spring obeys Hooke's Law (the extension and applied force – the weight – are directly proportional) up until 8N.

The point at which the line deviates from being straight is the same point at which the spring starts to permanently stretch. The spring no longer obeys Hooke's Law because the atoms within the crystals that make up the metal have started to slide over each other, changing the shape of the spring.

The point of deviation from direct proportionality can be called the "**Limit of Proportionality**". It is more often called the "**Elastic Limit**". This is because we call a material stretching and then returning to the same shape **Elastic Behaviour**. Stretching and not returning to the same shape is **Plastic Behaviour**. So the Elastic Limit is the point where elastic behaviour stops and plastic behaviour begins.

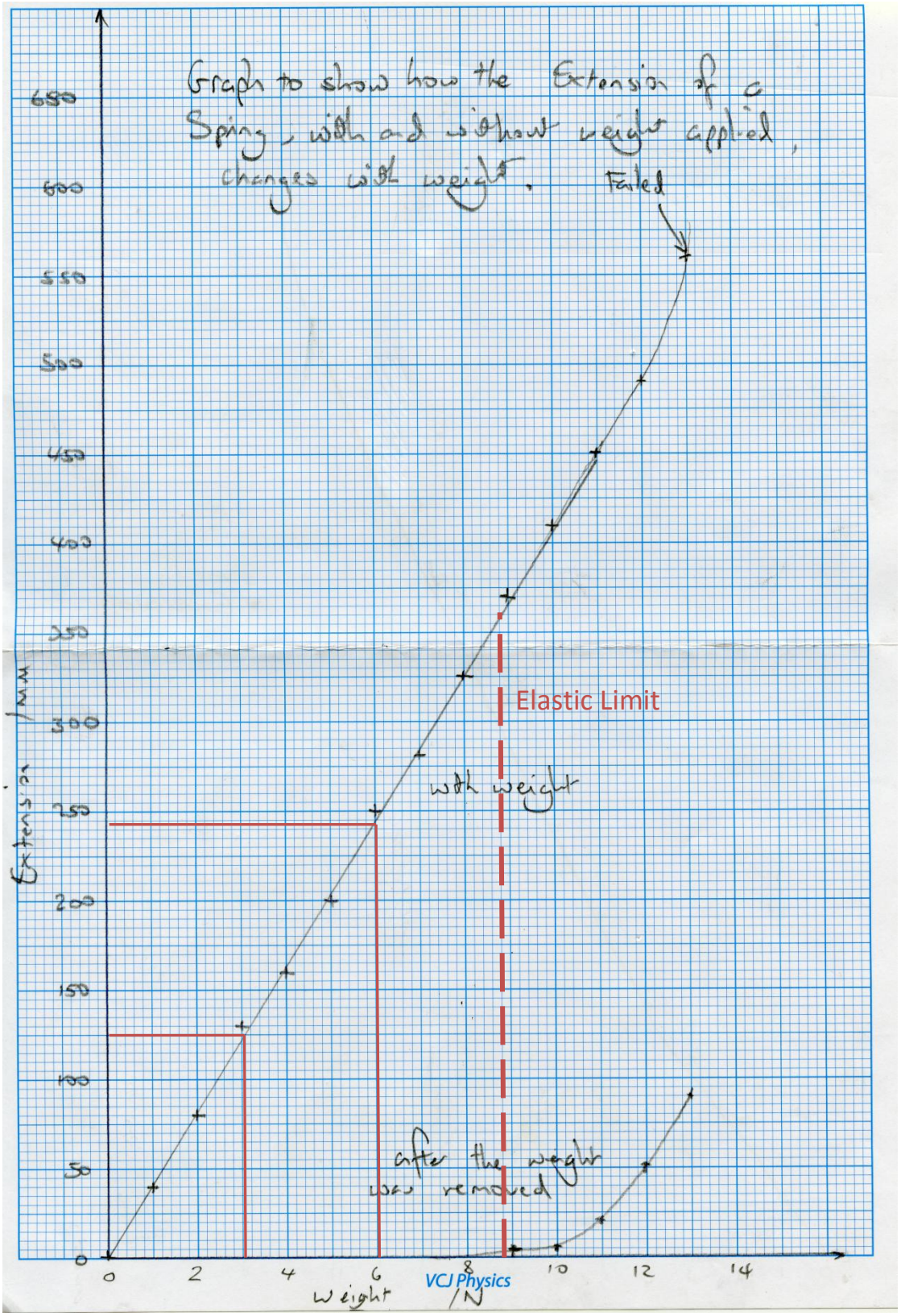
Most materials obey Hooke's Law to some extent. Some, like glass, snap before they show any plastic behaviour, others, like rubber bands, hardly need any force to exceed their elastic limit, and mostly show plastic behaviour.





Note that in these two images[2] the Force and Extension axes are the opposite way around to ours.

[2] http://www.diracdelta.co.uk/science/source/h/o/hookes%20law/source.html#.UsVnkNI7vAk



The Elastic Limit for our spring is somewhere between 8N and 9N, we are not sure exactly where, so we in our conclusion from the graph we can add a suggestion for further work:

"The Elastic Limit is between 8 and 9 newtons, if I were to repeat this experiment I would go up in smaller than 1 newton steps after about 6N so that I could find the spring's elastic limit more precisely."

2.2.4 QUESTION EXAMPLES

a. On the graph on the previous page find the extension of the spring when the applied weight is 6N

The way to answer this kind of question is to draw a line on the graph up that corresponds to a 6N weight (right hand vertical red line on graph) to see where this line crosses the line of best fit. Then draw a line across to the other axis to find out what value this corresponds to.

On the graph each small square up is 5mm so

Answer: *between 240 and 245mm, closer to 245mm*. **The extension is 245mm**

b. On the graph on the previous page find the weight needed for the spring to extend by 125mm

This is the same kind of problem except that we are starting on the vertical axis and reading down to the horizontal axis. Draw the lines on in the same way (see graph)

On the graph each small square across is 0.2N so

Answer: *Between 3.0 and 3.2N, closer to 3.0N*. **The weight is 3.0N**

It is vital when answering this kind of question to make sure that you draw the horizontal and vertical lines onto the graph. Failure to do so may cost you marks.

2.3 DENSITY

Density measures a material's mass per set volume, this allows us to compare the materials that different objects are made from even if the objects themselves are different shapes and sizes. Density is a very important quantity for architects, and civil and mechanical engineers.

The formula for density is:

$$\rho = \frac{m}{V}$$

The greek letter rho (ρ) is used as the symbol for density. So the formula reads; density (ρ) equals mass (m) divided by volume (V). We are dividing mass by volume so the unit for density is the mass unit per the volume unit – kg/m^3. Kilograms per metre cubed is the SI unit of density, but the non-SI unit grams per centimetre cubed is very widely used, so you have to be able to use both.

We know that there are 1,000 grams to a kilogram and we have seen already that there are 1,000,000 centimetres cubed to the metre cubed. One thousand divided by one million is one thousandth.

To convert from kg/m^3 to g/cm^3 divide by 1,000

To convert from g/cm^3 to kg/m^3 multiply by 1,000

You need to know that the density of air is roughly $1kg/m^3$ and that the density of water is $1g/cm^3$, in other words water is one thousand times denser than air.

In class we will look at methods for finding the volume and density of irregularly shaped solids, and for finding the density of liquids. We will also look at how average density affects an object's ability to float. You are required to know details of all of these things.

2.3.1 CALCULATION EXAMPLES:

a) A block of wood is a cuboid whose sides are 3.4cm, 12cm and 5.7cm, if its mass is 167g, what is its density in g/cm^3 and kg/m^3?

Because we have been given the units in cm and g it is easiest to work out the density in g/cm^3 and convert to kg/m^3 afterwards so:

The volume in cm^3 is:

$$V = l \times w \times h = 3.4 \times 12 \times 5.7 = 232.56\text{cm}^3$$

And

$$\rho = \frac{m}{V} = \frac{167}{232.56} = 0.71809\text{g/cm}^3$$

The answer is 0.72g/cm^3 (two significant figures in the question), which we convert to kg/m^3 by x1000:

$$\rho = 0.72 \times 1000 = 720\text{kg/m}^3$$

b) A steel girder has a volume of 0.35m^3. An engineer needs to know its mass, he looks up steel's density and finds it to be 7,800kg/m^3, what is the girder's mass?

The formula is:

$$\rho = \frac{m}{V}$$

Which we rearrange to make *m* the subject:

$$\rho \times V = m$$

And insert the values:

$$\rho \times V = 7800 \times 0.35 = m = 2730\text{kg}$$

The answer is 2700kg or 2.7t (two significant figures in the question)

c) A concrete sculpture has a mass of 3.23t, if the density of the concrete is 2,380kg/m^3 what is the mass of the sculpture?

We need to start by converting the units, we need the mass in kg so:

Chemistry is a more traditional subject than Physics and so sometimes uses units that are allowed in the metric system, but which are not true SI units. An example is litres, the litre is not an SI unit of volume we would say that a litre was 0.001m^3, 1,000,000mm^3 *or, sometimes* 1,000cm^3. *This makes a millilitre (a thousandth of a litre) equal to* 1cm^3.

Similarly chemists do calculations in grams, where a physicist would convert to the SI unit; kilograms.

This makes life harder for you because you have to work in both subjects at the same time.

Density is really important for chemists, and they tend to work in g/cm^3 *because they do their measurements in grams and millilitres (the conversion from millilitres to* cm^3 *is the easiest conversion possible).*

In lower school we are flexible in the units we use to accommodate the chemists – when you get to A level – SI units only please.

$$m = 3.23 \times 1000 = 3230\text{kg}$$

then we have to rearrange the density formula to make *V* the subject:

The first step is to move *V* off of the bottom (it is dividing on the right so must multiply on the left)

$$\rho = \frac{m}{V}$$

$$\rho \times V = m$$

Then we need to get *V* on its own by moving *ρ*, if it is multiplying on the left, it divides on the right, so:

$$V = \frac{m}{\rho}$$

We can then put in the values:

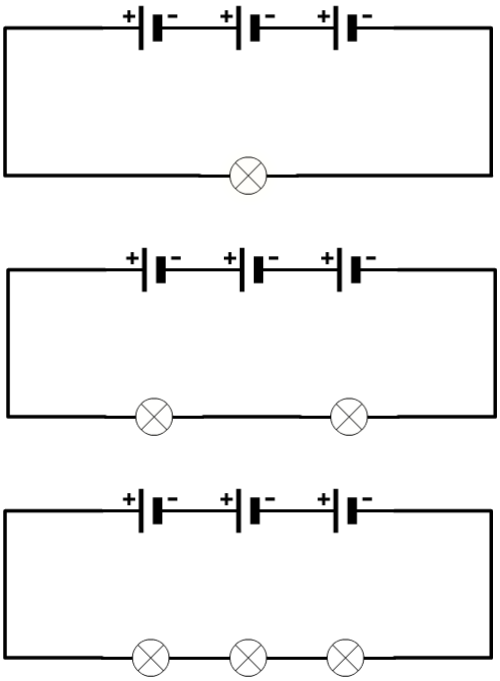
$$V = \frac{m}{\rho} = \frac{3230}{2380} = 1.3571\text{m}^3$$

The answer is 1.36m^3 (three significant figures in the question).

2.4 MATERIALS HOMEWORK QUESTIONS

EXERCISE 2A

Q1. Look at the following three circuits and answer the associated questions.



a) What do we call this type of circuit?

……

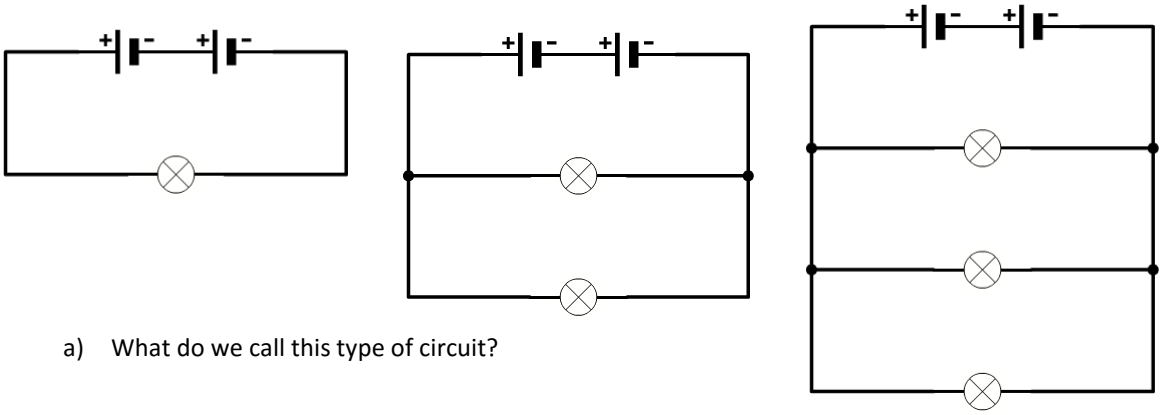
b) What would you notice about the brightness of the bulbs as each one is added?

……

c) What happens when you unscrew one of the bulbs?

……

Q2. Look at the following three circuits and answer the associated questions.



a) What do we call this type of circuit?

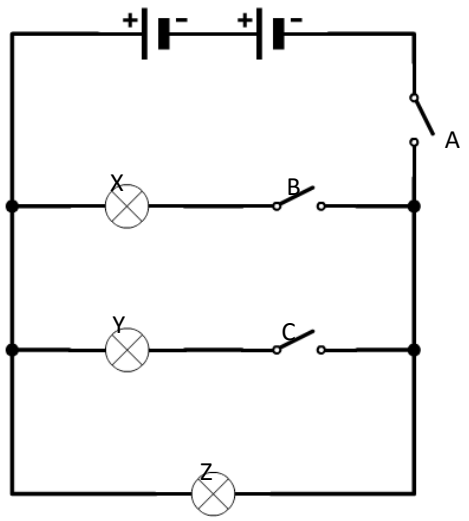
……

b) What would you expect to notice about the brightness of the bulbs as each one is added?

……

c) What happens when you unscrew one of the bulbs?

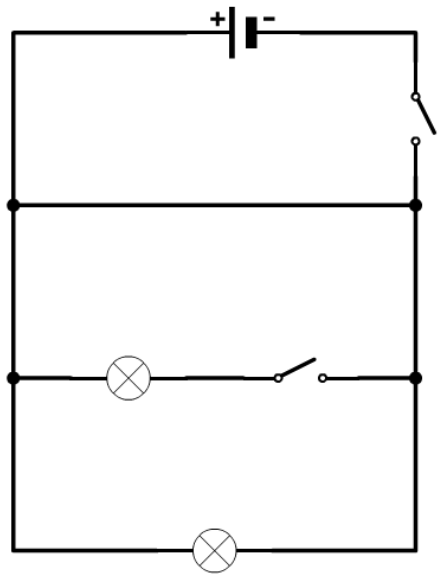
Q3. In the following circuit what would happen to each of the lights when the switches are in the positions specified? Complete the table, the first has been done for you.



	A	B	C
1	Closed	Closed	Closed
2	Open	Closed	Closed
3	Closed	Open	Closed
4	Closed	Closed	Open
5	Closed	Open	Open
6	Open	Open	Open

	X	Y	Z
1	On	On	On
2			
3			
4			
5			
6			

Q4. Look at the circuit below



a) Will any of the bulbs light?

……

b) Can you explain your answer?

……

c) What is this called?

……

EXERCISE 2B

For each item in the table below calculate the volume and density.

Write down the necessary calculation, the answer your calculator gives, and where necessary the final answer rounded to the correct number of significant figures – always include units. (The first question has been completed below the table as an example of what is expected.)

Material	Mass /g	Length /cm	Width /cm	Height /cm
Brick	10,600	20.0	15.0	10.0
Wood	10,600	50.0	30.2	8.0
Lead	1,560	6.1	4.9	4.0
Expanded Polystyrene	2,400	61	40	22
Aluminium	1,080	10.0	10.0	3.9
Stone	18,400	24.0	16.0	12.0
Ice	16	5.0	2.0	2.0
Gold	0.34	1.0	0.2	0.1
Plastic	560	27	10	10

Volume $= l \times w \times h$ Density $= \frac{m}{V}$

Brick:

Volume = 20×15×10 = <u>3,000cm^3</u>

Density = $\frac{10600}{3000}$ = 3.533333 = <u>3.53g/cm^3</u> to three sig figs

EXERCISE 2C

Answer in your exercise books, include all workings and do not forget units.

a) A concrete slab is 18.0cm long, 12.0cm wide and 8.2cm thick, it has a mass of 6910g.
   i. What is the concrete slab's volume?
   ii. What is the concrete slab's density?
   iii. What is the density to 3 significant figures?

b) 1000cm^3 of milk has a mass of 1150g. What is the density of milk?

c) Calculate and insert the missing values into the table:

Object	Mass / g	Volume / cm^3	Density / g/cm^3
A	40	20	
B		20	8.0
C	1300		2.6
D	136	17.0	

   i. Which object has the greatest mass?
   ii. Which object has the smallest volume?
   iii. Which objects are probably made from the same substance?

d) A stone of mass 32g is placed into a measuring cylinder containing some water. When the stone is completely immersed and the water level increases from 50cm^3 to 61cm^3. What is the density of the stone?

e) Wooden blocks are packed into a box. There are 1000 blocks and when stacked they measure 100cm by 24cm by 25cm.

   i. What is the volume of the stack?
   ii. What is the volume of one brick?

   If the density of the wood is 2.5g/cm^3,

   iii. What is the mass of the stack?

   If the box will take a maximum mass of 1.5kg,

   iv. what is the maximum number of blocks the box could take?

f) For yacht with a concrete hull (yes they do exist) to have a chance of floating the most its average density can be is 1000kg/m^3, if the hull weighs 4.3t what is the minimum total volume it can have?

3. FORCE

A force is a push or a pull.

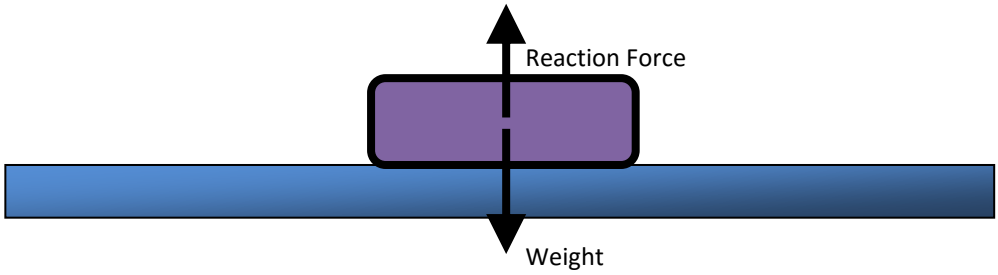
A force always has a direction; I push up, I pull towards me, gravity pulls downwards. For this reason a force is always marked on a diagram with an arrow, the length of the arrow should indicate the size of the force.

We call quantities which must have a direction as well as a size "vectors". Force is a vector quantity.

Force is measured in newtons, which is shortened to a capital N.

3.1 WEIGHT

There are always forces acting on objects, in particular gravity acting on an object's mass create a force which a Physicist calls "weight". An object's weight acts to pull the object towards the centre of the earth. If an object is not accelerating towards the centre of the earth then other forces must be opposing gravity. For an object sitting on a surface we call the force opposing gravity the "reaction force".



The reaction force is created by the atoms in the surface pushing back against the atoms of the object that are being forced against them by the action of gravity.

It is vital when doing Physics to distinguish between weight which is a force measured in newtons and mass which is measured in kilograms.

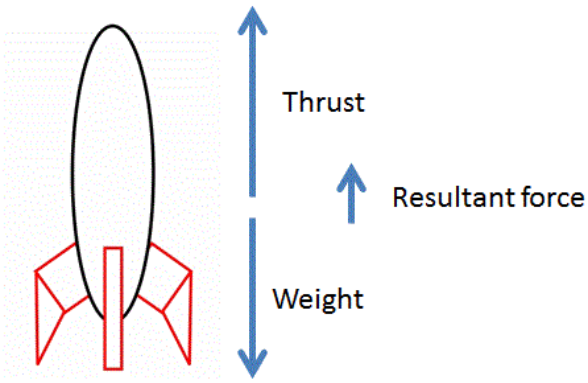
On earth the force of gravity acting on 1kg is approximately 10N, on the moon it would only be 1.6N.

On earth we calculate the force of gravity acting, the weight, of an object from its mass in kilograms by multiplying by 10. 10N/kg is the value of the gravitational field strength on earth.

Because 100g is 0.1kg, a 100g mass has a weight of 1N (0.1×10).

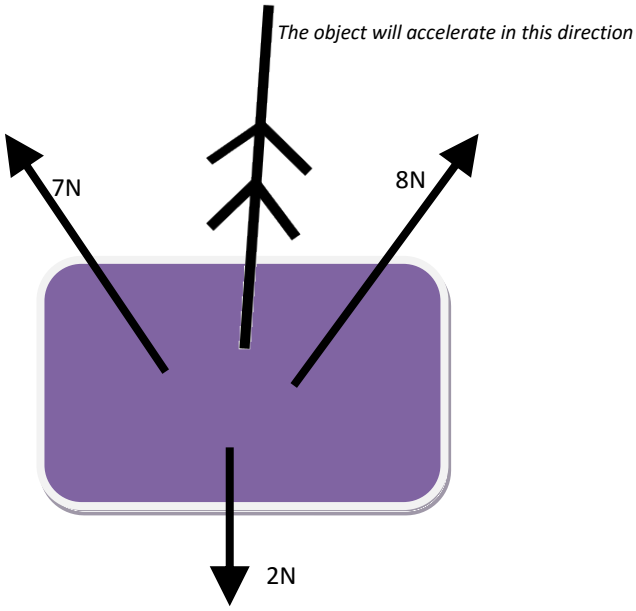
3.2 UNBALANCED FORCE AND ACCELERATION

The forces acting on an object sitting still on a table are balanced; the reaction force upwards is equal and opposite to the weight downwards. Things will change if forces are unbalanced. When forces are unbalanced the object accelerates. To a Physicist acceleration can be an object moving faster, moving slower or changing direction.



The rocket accelerates upwards because there is a resultant (unbalanced) force upwards.

Acceleration is also a vector quantity. To distinguish it from force acceleration is marked on diagrams using a double headed arrow in the centre of the line.



Aristotle was one of the great ancient greek philosophers and became tutor to Alexander, Prince of Macedonia in 356BC. As Alexander the Great, Aristotle's tutee conquered a huge swathe of the world from Egypt to India.

Aristotle developed a system of physics to try to explain all of the changes that happen in the world. In Aristotle's system if something is moving there must be a force acting on it.

Aristotle's idea was accepted for 2000 years because it matches our everyday experience; if we stop pushing the object stops moving.

It took two further greats, Galileo and Newton, to show that something different is actually happening. Aristotle was being fooled by the fact that on earth unseen forces like friction and air resistance are always acting to slow things down. We now know that an unbalanced force changes an object's motion; speeds it up, slows it down or changes its direction. Unchanging motion, however, does not need a force. This idea is known as Newton's First Law of Motion.

3.3 MOMENTS

A moment is the turning effect of a force.

A moment is the action of a force around a pivot. The force that the pivot can provide prevents the object from accelerating away, but the object can still rotate around the pivot if there is an unbalanced moment.

For an object to be balanced (for an object to be in equilibrium) the moments as well as the forces must be equal and opposite.

Moments are calculated by multiplying the force by its distance from the pivot:

$$moment = F \times d$$

The units of moments do not have their own name. So if we calculate the moment by multiplying newtons by metres we get Nm (newton metres), but equally we could calculate moments by multiplying newtons by centimeters then our moments units would be Ncm (newton centimeters).

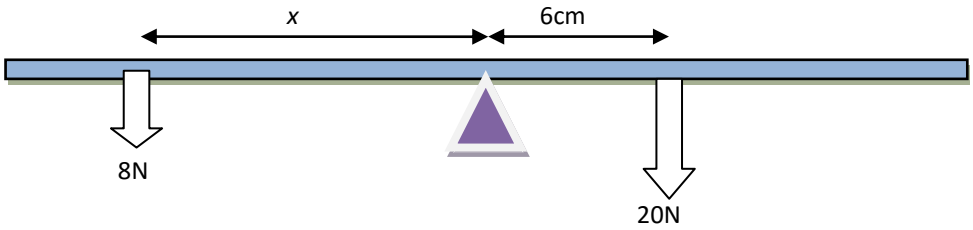
For a balanced object we have the rule that:

the total moments acting clockwise = the total moments anticlockwise

We test this rule experimentally in class, you are required to know the details of this experiment.

3.3.1 CALCULATION EXAMPLES

1.



A 20N force acts 8.0cm from a pivot, how far from the pivot (x) must an 8N force on the opposite side be for everything to balance?

The 20N force is acting to turn thing clockwise, so the clockwise moment is:

$$20 \times 6 = 120\text{Ncm}$$

The 8N force acts anticlockwise, so the anticlockwise moment is:

$$8 \times x = 8x$$

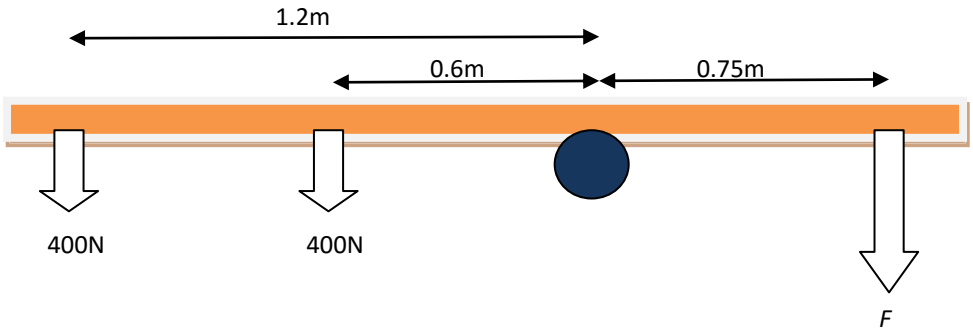
For balance the two must be equal:

$$8x = 120$$

Rearranging to make x the subject:

$$x = \frac{120}{8} = 15\text{cm}$$

2.



Two children, each weighing 400N, sit on one side of a see-saw, 1.2 and 0.60m from the pivot. If an adult sits 0.75m from the pivot on the other side the see- saw balances, what must the adult's weight (*F*) be?

The moments of the children both act anticlockwise, so the anticlockwise moment is:

$$400 \times 1.2 + 400 \times 0.6 = 720\text{Nm}$$

The adult moment acts clockwise and is written as 0.75*F*, equating the two and rearranging to make *F* the subject gives:

$$0.75F = 720$$

$$F = \frac{720}{0.75} = 960\text{N}$$

3.4 BUOYANCY

Buoyancy is the name we give to the upward force that an object in a fluid experiences.

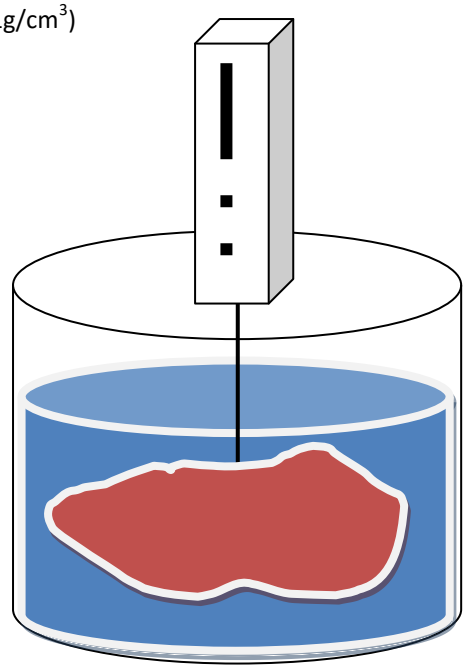
For an object that floats buoyancy equals weight. For objects that sink, the buoyancy force still exists but is not large enough to balance the object's weight and the object sinks.

You may have done an experiment in class to test buoyancy. As this is quite a complex experiment you are ***not*** expected to know the details of this experiment.

The **size of the buoyancy force is equal to the weight of the liquid displaced** (pushed out of the way) by the object.

3.4.1 CALCULATION EXAMPLE

A rock is hung from a newton meter, it weighs 4.5N. When the rock, still hanging on the newton meter, is lowered into water 110cm^3 of water is displaced. What does the newton meter read when the rock is in the water? (the density of water is 1g/cm^3)



The reading on the newton meter changes because of buoyancy.

The size of the buoyancy is given by the weight of the water displaced.

Because 1cm^3 of water has a mass of 1g, the mass of displaced water is 110g (mass = volume × density)

110g is 0.11kg, and we know that on Earth the gravitational field strength is 10N/kg so the weight of water displaced is:

$$0.11 \times 10 = 1.1\text{N}$$

The reading on the newton meter must therefore be:

$$4.5 - 1.1 = 3.4\text{N}$$

3.5 PRESSURE

The effect of a force can depend on its size, its distance from a pivot and also on the area that it is acting over. Accidentally stabbing yourself with the sharp end of a pencil is very different from hitting yourself with the blunt end, even if you use the same force. We call the measure of force per unit area Pressure.

The formula for pressure is:

$$\text{Pressure} = P = \frac{Force}{Area} = \frac{F}{A}$$

The units of pressure, like the units of moment can just represent what we have done; we have divided force in newtons by area in metres squared so the units are N/m^2 (newtons per metre squared). If we had divided by an area in centimetres squared our unit could be N/cm^2.

Because there are $10{,}000cm^2$ in $1m^2$, $1N/cm^2 = 10{,}000N/m^2$

Although N/m^2 is a perfectly good unit, talking about pressure is so common that the unit has also been given its own name, so a newton per metre squared can also be a pascal (shortened to Pa).

We normally measure the effect of gases and liquids as pressure not force, this is because gases and liquids at the same level push with the same pressure in every direction and over the whole area. The pressure of a liquid or gas is created by the particles of liquid or gas repeatedly bouncing off of a surface and so pushing on that surface.

Often the pressure of a liquid or gas is a measure of the weight of liquid or gas directly above. Air pressure is roughly 100,000Pa, this means that above every square metre, imagine laying four metre rulers down to make a square, there is 100,000N or 10 tonnes of air – that is a lot of air.

The variation of air pressure from place to place is measured by weather forecasters and input into their supercomputers so that they can model how the air, and the water that it carries, will move from day to day and make their predictions. In Britain low pressure is usually associated with bad weather whereas high pressure can mean clear skies and sunny days.

3.5.1 CALCULATION EXAMPLES

1. The extra pressure due to the water at the bottom of a fish tank is 4500Pa. If the bottom of the tank is 0.30m by 0.70m what is the total force that the water exerts on the bottom?

   The area of the bottom of the tank is $0.70 \times 0.30 = 0.21m^3$

   Using:

   $$P = \frac{F}{A}$$

   Rearranging to make *F* the subject and inserting the numbers:

   $$F = P \times A$$

   $$F = 4500 \times 0.21 = 945\text{N}$$

Rounding to two significant figures to match the significant figures in the question makes the final answer 950N

2. A steel block has a density of 7900kg/m^3, it is 20cm high, 35cm long and 12cm wide, what is the extra pressure exerted by the steel block on the ground?

   The volume of the block in metres cubed is 0.20×0.35×0.12 = 0.0084m^3

   Using the formula for density, rearranged to make mass the subject, find the mass of the block

$$m = \rho \times V = 7900 \times 0.0084 = 66.36\text{kg}$$

   In this case the force is the weight of the block, which is just the mass times ten, 663.6N

   The area of the base of the block pressing on the ground is 0.35×0.12 = 0.042m^2

   Substituting the numbers into the formula for pressure:

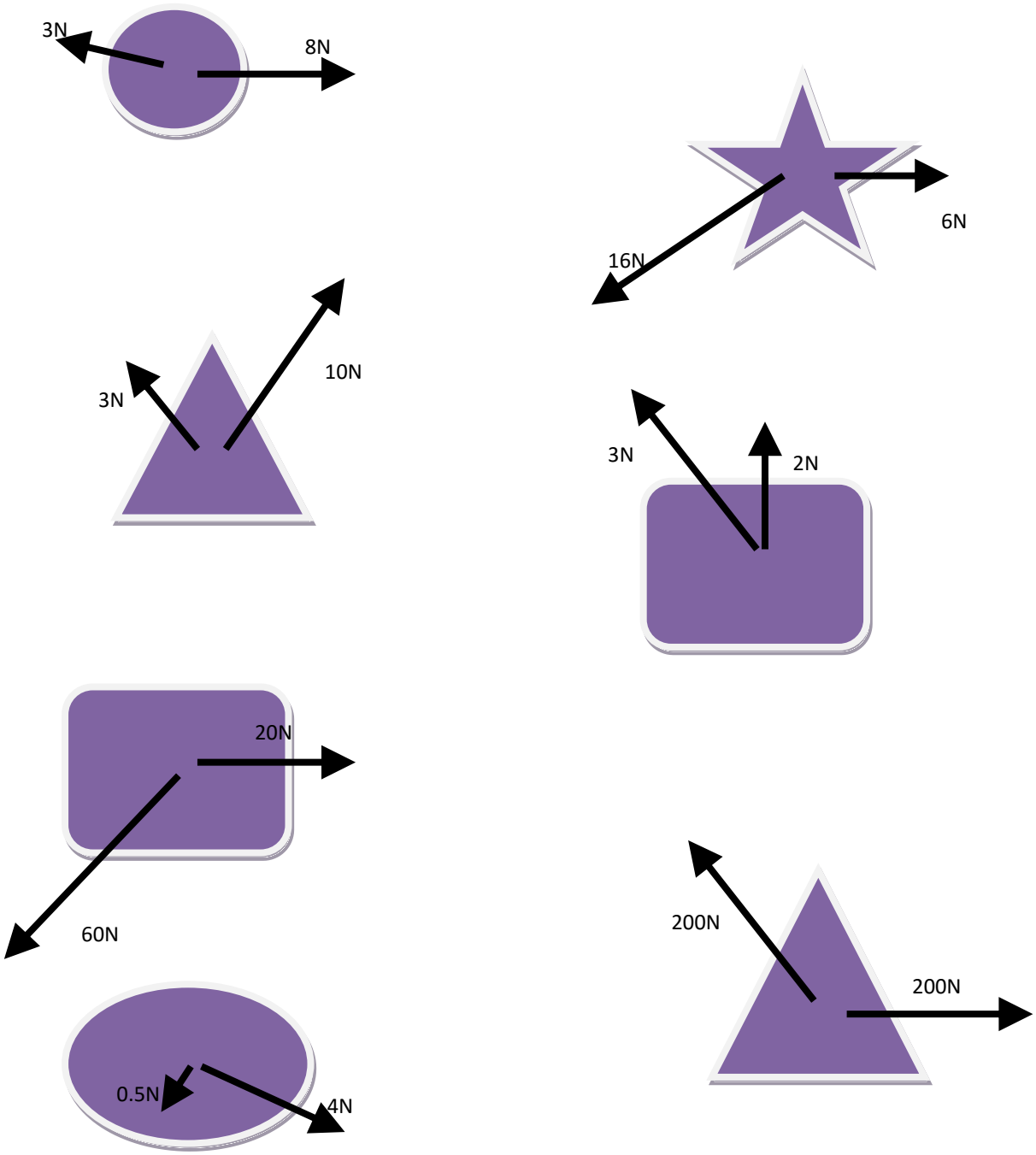
$$P = \frac{F}{A} = \frac{663.6}{0.042} = 15800\text{Pa}$$

   Rounding to give 2 significant figures to match the question gives the pressure to be 16,000Pa or 16kPa.

3.6 FORCES HOMEWORK QUESTIONS

EXERCISE 3A

Print and stick into your book, or copy out, the diagrams below and add the correct type of arrow to each showing the direction the object will accelerate in.

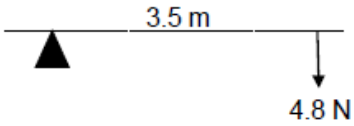


EXERCISE 3B

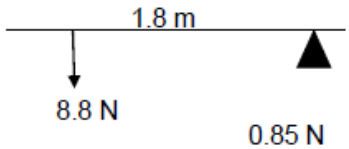
All work should be completed in your book **NOT ON THE SHEET**. Show **ALL** of your **WORKING** and **ALWAYS STATE A UNIT!** I recommend reading through the worked examples completed in class before starting.

1. Calculate the moments of the following forces.

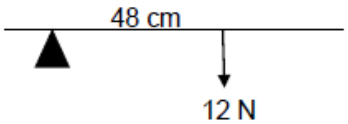
a)



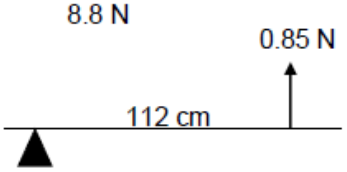
b)



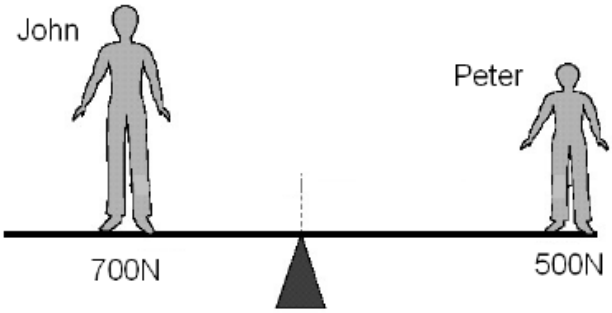
c)



d)



2. Are the following balanced or unbalanced when:



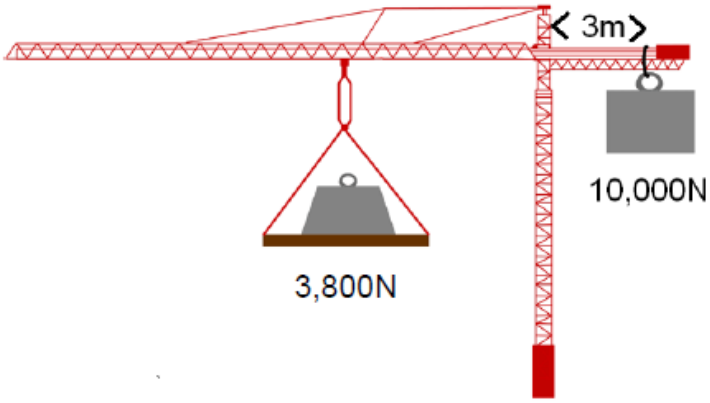
a) John is 0.5m from the pivot and Peter is 1.0m from the pivot?

b) John is 1.0m from the pivot and Peter is 1.4m from the pivot?

b) John is 0.40m from the pivot and Peter is 0.56m from the pivot?

d) John is 1.2m from the pivot and Peter is 1.0m from the pivot?

3. A counterweight is used to make a crane balance.



a) How far away from the pivot must the 3,800N load be in order for the crane to be balanced?

b) What weight can be lifted when the load is placed 9.5m from the pivot?

EXERCISE 3C

Remember to state a unit and to show **ALL** of your working.

Q1. Copy and complete the following sentences.

a) Pressure is the _____ per unit _____

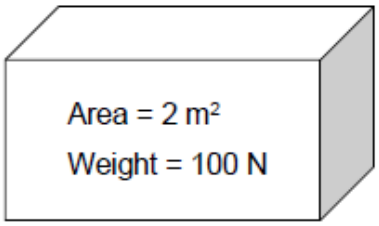
b) We measure Pressure in _____

c) 1 _____ = 1 N/m²

d) We can calculate pressure using the formula:

$$Pressure =$$

Q2. A box weighs 100N and its base has an area of 2m². Calculate the pressure exerted on the ground.

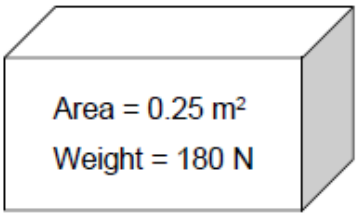


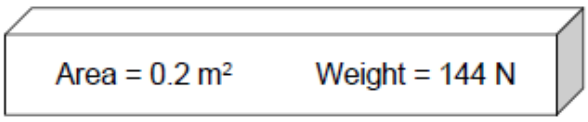
Q3. A car has a **mass** of 1000 Kg. The surface area of each wheel in contact with the ground is 0.1m². Calculate the pressure acting on the road.

Q4. A material requires a pressure of 50,000 Pa in order to be cut. If the surface area of a knife is 0.0001m², calculate the Force that needs to be exerted.

Q5. Paul exerts a pressure of 750 Pa on a surface. If he applies a force of 25N, calculate the area over which the force is exerted.

Q6. Which box below will exert a greater pressure on the ground?





4 SOLAR SYSTEM & THE EARTH IN SPACE

4.1 SOLAR SYSTEM

You are expected to know a fair bit about the solar system already; this unit of work is therefore dominated by a research and presentation project which will be issued to you by your teacher. There is, however, some knowledge that is required for the end of year examination:

- **You are required to know the order of the parts of the solar system[3], from the inside outwards:**

Named Object	Type
Sun	Yellow Dwarf Star
Mercury Venus Earth Mars	Rocky Planets
Ceres	Rocky Dwarf Planet in the Asteroid Belt
Jupiter Saturn	Gas Giant Planets
Uranus Neptune	Ice Giant Planets
Pluto Eris Makemake Haumea	Icy Dwarf Planets in the Kuiper Belt
	The Scattered Disk
	The Oort Cloud

[3] http://solarsystem.nasa.gov/planets/profile.cfm?Object=SolarSys

- **You are also required to know the following definitions:**

Word	Definition
Day	The time it takes for a solar system body to rotate once.
Orbital Path	The imaginary path in space taken by an object as it travels around the sun. For most major planets the orbital path is close to circular. For dwarf planets the orbit can be much more of an ellipse (squashed circle)
Year	The time is takes for a solar system body to complete one orbit; that is to follow the orbital path all the way around.

4.2 THE EARTH IN SPACE

It takes 24 hours for the earth to rotate once on its axis and have the sun return to the same position in the sky. It takes 365.242 days for it to complete one orbit around the sun. The extra 0.242 of a day is accounted for by the extra day each leap year, however, because it is not exactly 0.25, three out of four turns of the century are not leap years even though they are divisible by four, therefore 2100 will not be a leap year.

4.2.1 SEASONS

It is well known that the earth's axis of rotation (imagine a line from north to south poles through the centre of the earth) is not perpendicular to the orbital path, and that this 23.5^{o} tilt creates the seasons.

There are two contributing factors to the temperature change as the northern hemisphere tilts towards (summer) and away from (winter) the sun while the earth moves through its orbit – **day length** and **change in insolation** with change of angle

4.2.1.1 DAY LENGTH

Day length is relatively easy to understand especially if you have a play with this great simulation website http://science.sbcc.edu/physics/flash/LengthofDay.swf .

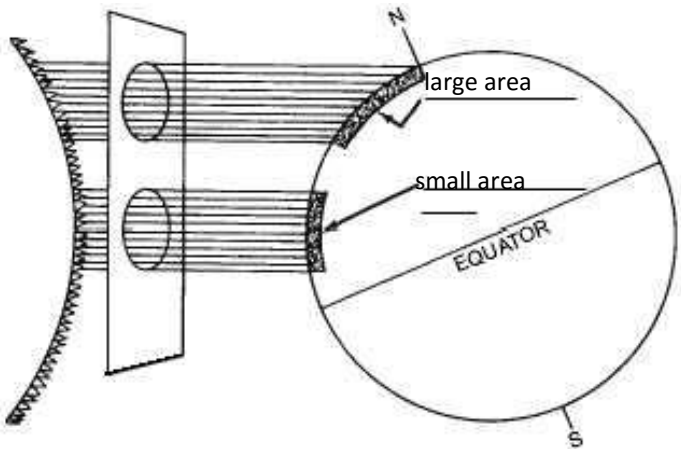
While using the simulator **make sure you understand these terms**:

Winter Solstice	Shortest day, usually December 21st
Spring (Vernal) Equinox	One of two days when the day and night lengths are equal, usually March 21st
Summer Solstice	Longest Day, usually June 21st
Autumn (Autumnal) Equinox	One of two days when the day and night lengths are equal, usually September 21st

In Jersey we have about eight hours of sunlight when the earth is titled away from the sun and close to 16 hours when it is tilted towards the sun. In general when the sun is up we are receiving heat from the sun, when it is down we are cooling down, no surprise then that the average temperatures in the summer are higher than in the winter.

4.2.1.2 INSOLATION

Insolation is the measure of how much energy a square metre of earth receives from the sun. It changes depending on latitude (how far from the equator you are, measured as an angle from the centre of the earth) and season. We live on a sphere and unless we live in the tropics we are angled away from the sun by the earth's curve. How big that angle is depends on latitude and season.



The same area of sunlight as it comes from the sun is spread out over different areas on the surface of the earth because of the earth's shape. The diagram shows the northern hemisphere summer[4].

In the summer we are tilted so that we are closer to 90° to the sun's rays and the sunlight is therefore spread across a smaller area, in the winter the opposite is true.

In Jersey we can receive a maximum of 1.03kW/m^2 of insolation on the summer solstice[5]. Whereas on the winter solstice that maximum falls to 0.60kW/m^2.

The combination of the day length and insolation angle effects means that, ignoring weather effects, the total energy that Jersey receives from the sun on June 21st is nearly four times the energy received on December 21st.

[4] http://meteorologytraining.tpub.com/14312/css/14312_19.htm

[5] http://www.pveducation.org/pvcdrom/properties-of-sunlight/calculation-of-solar-insolation

It is a common misconception that the seasons occur because the tilt of the earth means that we are closer to the sun in the summer.

On average the sun is 150 million kilometers away from the sun.

The earth is six and a half thousand kilometres in radius. The most that the tilt in the earth's rotation could move us towards the sun is about half that, three thousand kilometres. Three thousand in 150 million kilometers? There is no chance that this is responsible for the seasons.

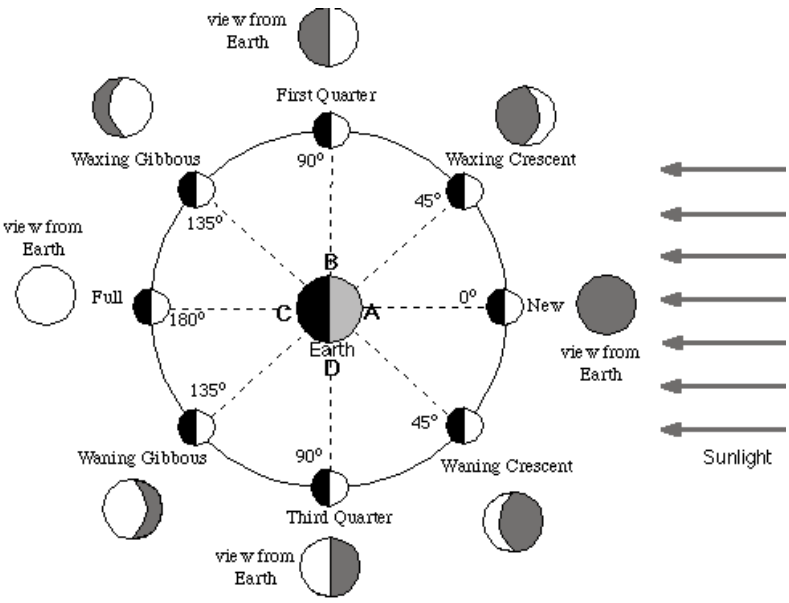
Another possibility is that the orbit, rather than the tilt that brings us closer to the sun. The orbital distance changes by ±2.5 million kilometers because the earth's orbit is not a perfect circle, still not much compared to 150 million. This orbital effect could just possibly be responsible for seasons, but then closest approach (perihelion) is in January – our winter – so clearly it isn't!

4.2.2 PHASES OF THE MOON

The moon orbits the earth every 27.3 days, but the phases of the moon only repeat every 29.5 days. This is because at the same time that the moon is going around the earth the earth is in motion around the sun and the extra two days is necessary for all three to come back into exactly the same relative positions.

The phases are created because, like the earth, half of the moon is always in sunshine and half in darkness, but the angle at which we see the moon from the earth changes, and so we see more or less of the lit side.

A diagram explaining the phases of the moon (like the one below) is covered in class, and understanding that diagram is necessary for the end of year exam.



The Sun-Moon angle is the angle defined by Sun->Earth->Moon with Earth (where *you* are) as the angle vertex. As the Sun-Moon angle increases we see more of the sunlit part of the Moon. Note that if this drawing were to scale, then the Moon would be half this size and its orbit would be about 22 **times** larger in diameter and the Sun would be about 389 **times** farther away than the Moon! [6]

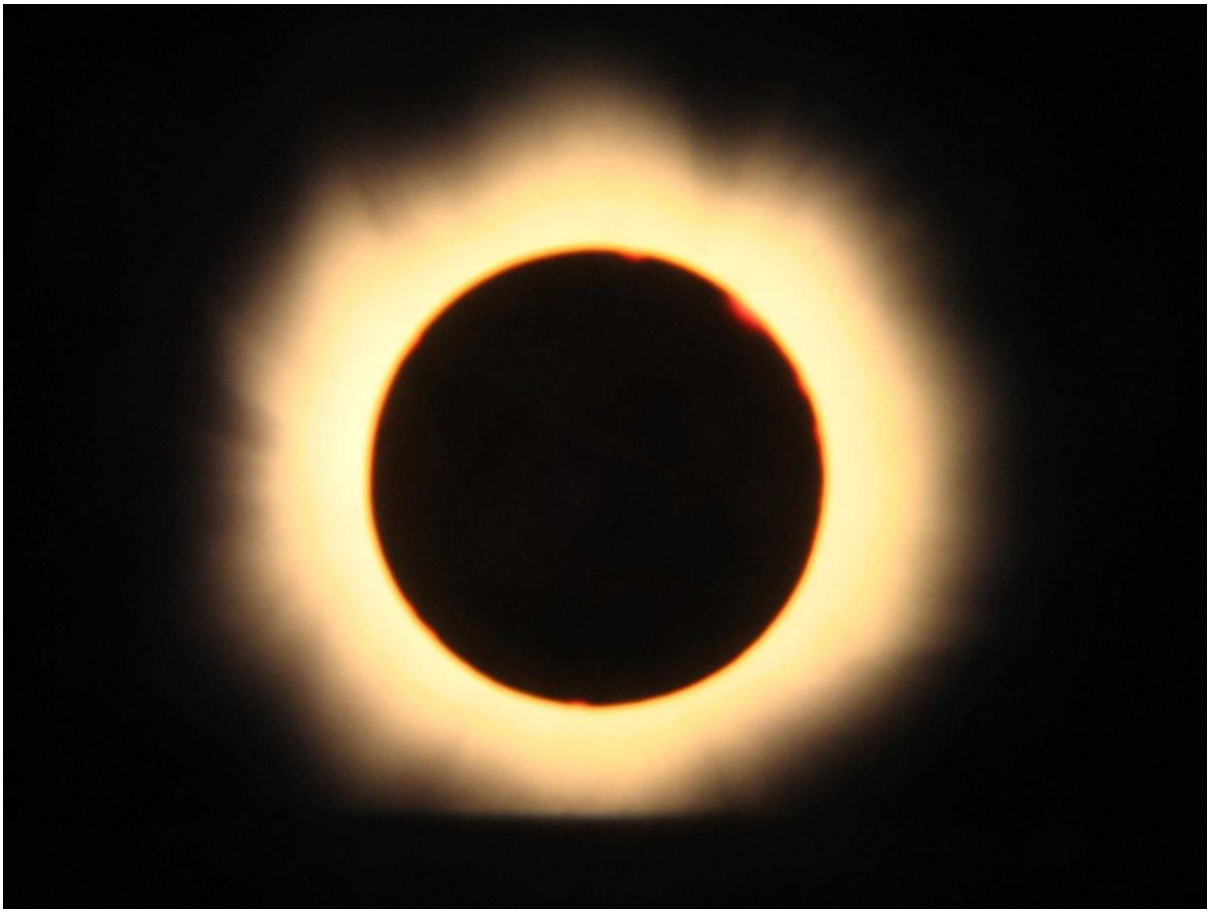
[6] http://www.moonphases.info/moon_phases.html

4.2.3 ECLIPSES

As is noted above the drawing is not to scale. If it were to scale a new moon would always cause a solar eclipse (the moon's shadows being cast onto the earth) and a full moon would always be a lunar eclipse (moon in the earth's shadow). However, the fact that the distances are very much larger than shown and the fact that the moon's orbit of the earth is at a five degree angle to the earth's orbit of the sun means that eclipses only happen twice a year.

4.2.3.1 SOLAR ECLIPSE

The full (umbral) shadow of the of the moon on the earth is so small that only a tiny portion of the earth gets to see the full eclipse and a hundred years can pass before a full eclipse once again passes through the same area (the last eclipse seen in the Channel Islands was in 1999 and there will not be one again in Britain until 2090 – although a partial solar eclipse, with a fair chunk of the sun obscured, will be visible in 2015).



The 1999 solar eclipse, photographed in France[7]

[7] http://www.green-witch.com/gweclipse.html

4.2.3.2 LUNAR ECLIPSE

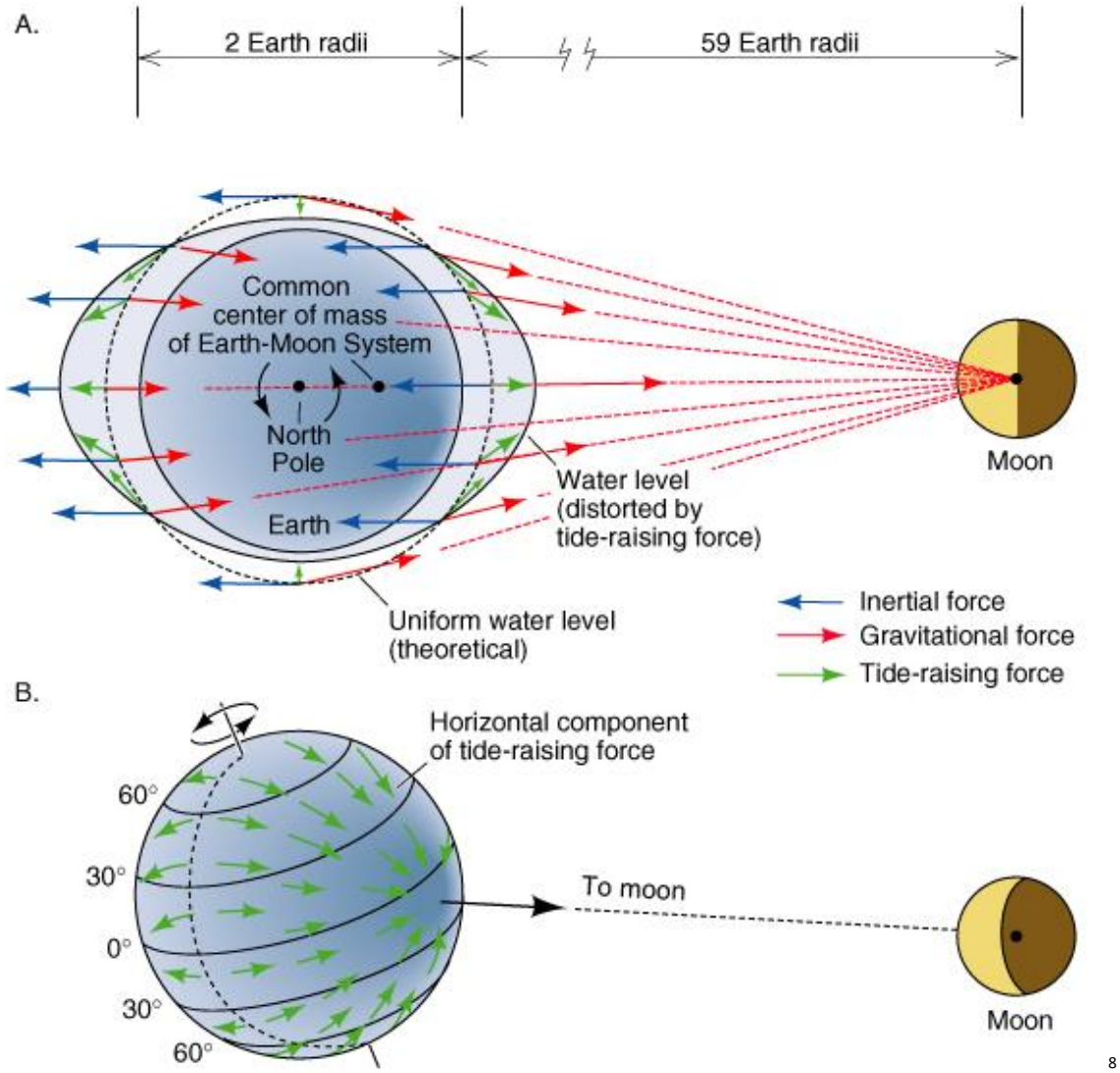
The moon is completely obscured by the earth's shadow and lunar eclipses are visible to the whole half of the earth turned that way at that moment, it is therefore much more common to see a lunar eclipse than a solar one. When in the shadow the moon does not go black, it goes red, this is because some red light from the sun is bent around the earth by our atmosphere and illuminates the moon a little.

4.2.4 TIDES

The moon is a long way away so the effect of its gravity is not large. In fact its effect only really shows up in the one set of really large, free to move things on the planet – the oceans. Because the oceans are so huge the small effect of the moon's gravity still produces a phenomenon we can observe, the tides.

There are several ways to explain the tides, but if you think the water is being lifted up by the moon's gravity you are wrong, the effect is nothing like big enough to achieve that.

One approach is to think of the moon and the earth as a single object – if we do that where would the balance point be? Where would the centre of mass or centre of gravity be, where is the point that the earth/moon system spins around? Well in turns out that this point is about 1,700km under the earth's surface directly below the moon, as shown on the diagram (common centre of mass).



[8]

The arrows on the diagram are to illustrate the explanation you were given in class for the bulges in the oceans that correspond to high tides. It is complicated to write out and you are not expected to be able to reproduce it.

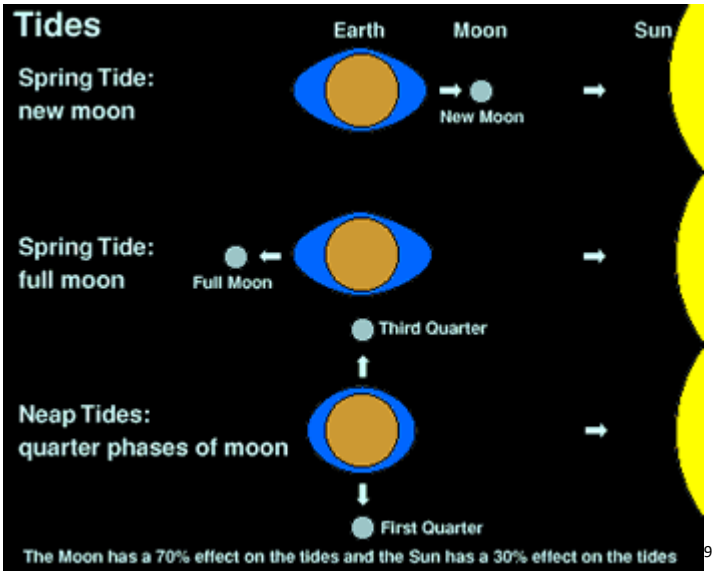
An alternative way to think of the tidal bulges is that the ocean water is likely to accumulate where the gravity that is trying to flatten it onto the surface of the earth is least. Where will that be? Well one point will be directly under the moon because here the earth's and moon's gravities are pulling in opposite directions, so the total gravity is slightly lower. A second point will be on the opposite side of the earth, because that is the furthest point from the common centre of mass (see top diagram), and gravity falls the further you are from the centre of mass of the object or objects creating the gravity.

However you think of it, two bulges form, one under the moon and one on the opposite side of the earth. As the earth rotates on its own axis we are rotated through first one bulge (high tide), a low area (low tide), on

[8] http://astronomyonline.org/ViewImage.asp?Cate=Home&SubCate=Introduction&SubCate2=SS00&Img=%2FSolarSystem%2FImages%2FEarth%5FMoon%2FTides%2Ejpg&Cpt=Tides

through the second bulge (high tide again), back through a low area and finally back to the first bulge. The consequence is that we get two high tides a day.

The sun also complicates things. When the sun, earth and moon are lined up the small tides created by the sun's gravity add to the lunar tides, increasing the size of the effect, creating big or "spring" tides. When the sun, earth and moon form a right angle, the solar and lunar tides are out of line and we get smaller, "neap" tides.



[9]

Tides are important to Jersey because we are on an island with some of the largest tides in the world. But because tides are complicated to explain you are unlikely to get questions about their formation in the end of year examination.

You are expected to know which phases of the moon have spring tides and which have neap tides.

[9] http://www.mesa.edu.au/friends/seashores/tidal_zone.html

4.3 SOLAR SYSTEM HOMEWORK QUESTIONS

EXERCISE 4A

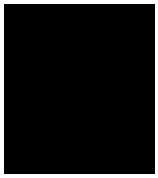
1. In two or three paragraphs describe what a space probe is likely to find in the gap between Mars and Jupiter. Give references for any web pages or books you have used to help.
2. Objects found in the Mars/Jupiter gap are similar so objects found in the Kuiper Belt. What is the main difference? Why?

EXERCISE 4B

1. Name and very briefly describe the two effects which mean that we receive less heat from the sun in winter than in summer. (You may use diagrams to help answer the question)
2. Draw and shade eight diagrams to show the phases of the moon as seen from the earth, in order starting with a New Moon and ending with a Waning Crescent
3. Look at these images[10] of phases of the moon as seen from earth. For each state whether you would be expecting a Spring, Neap or Intermediate tide.

a.  …….

b.  …….

c.  …….

d.  …….

e.  …….

4. Which phase must the moon be in for there to be a lunar eclipse? Why?

[10] http://static.uglyhedgehog.com/upload/2012/8/26/thumb-1346007426551-moon_phases.jpg