SCIENCE DEPARTMENT
BGS

Year 9

Physics friend

Physics Skills

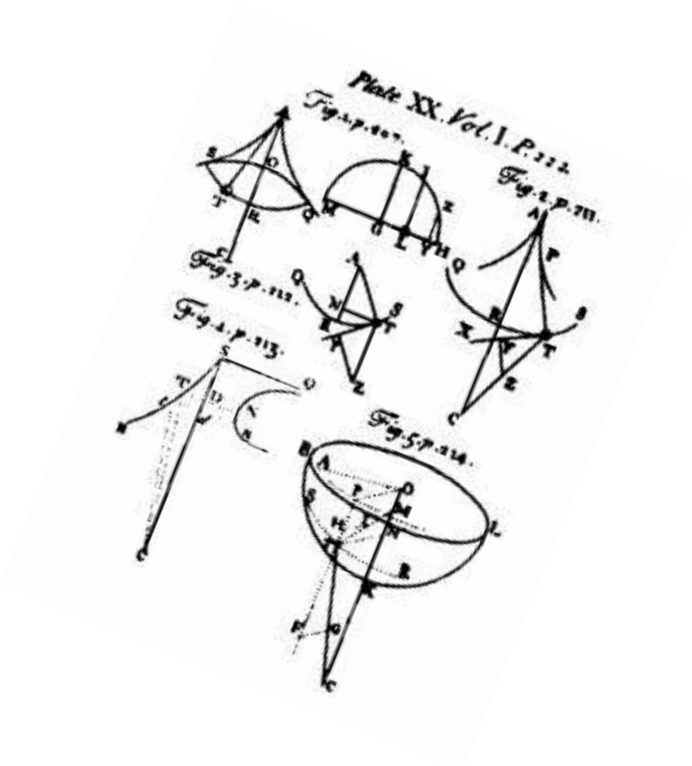
This booklet contains information to support your work in science lessons. You <u>must</u> bring it with you to all science lessons on the Physics Skills topic.

Replacement booklets must be paid for at a cost of £1.

Name:

Form:

Science Teacher:



Use this table to check your knowledge before the end-of-topic test.

I can…	Book page	Got it?
State the standard units for: mass, length, time, force and energy		
Understand how to use and convert units with a prefix such as kilo-		
Express large and small numbers in standard form		
Describe how to present answers to calculation questions		
Rearrange equations that are used in physics		
Describe three types of experimental error, with examples		
Calculate mean values and uncertainties in repeat measurements		
Explain how a graph is plotted		
Draw suitable lines of best fit		
Calculate the gradient of a straight line graph		
Calculate the area under a curve		
Explain how we can estimate the gradient of a curved graph at a point		
Describe and recognise direct proportionality		
Describe and recognise inverse proportionality		
Evaluate whether a set of data shows a special relationship		

Key words;

Quantity	Error	Uncertainty	Mean	Prefix
Kilogram	Metre	Second	Newton	Joule
Systematic error	Random error	Zero error	Anomalies	Gradient
	Directly proportional	Inversely proportional	Tangent	

The word search below contains the key words above

F	N	A	F	E	E	L	Y	H	R	J	J	E	D	Y	Y	H	E	Y	S
B	G	E	R	Q	O	S	X	J	L	J	U	R	A	O	A	Z	M	X	S
X	T	T	W	F	U	J	A	O	R	D	A	R	J	W	J	I	I	Y	C
K	E	T	O	T	F	J	S	U	I	O	I	O	N	X	T	K	S	G	R
M	L	L	X	X	O	C	G	L	R	S	R	R	I	N	I	T	C	W	S
S	Q	N	Q	E	J	N	J	E	U	S	G	R	E	H	E	F	J	Q	V
E	L	O	F	J	Q	I	A	H	S	Q	X	I	E	M	R	A	E	K	P
I	Y	A	M	W	Z	J	G	B	J	U	D	K	A	O	U	Y	Y	R	H
L	R	O	R	R	E	M	O	D	N	A	R	T	X	Q	R	G	N	O	P
A	O	Y	E	S	O	W	J	C	R	B	I	Y	N	E	J	E	H	N	A
M	N	M	I	F	O	S	E	G	X	C	S	E	R	P	Y	Z	Z	C	I
O	F	I	X	U	C	R	M	B	E	U	F	Q	T	A	N	G	E	N	T
N	S	X	X	Z	T	V	A	R	F	J	N	I	U	T	J	Q	R	I	M
A	W	M	E	A	P	G	R	M	G	X	Z	W	I	A	W	M	G	S	A
X	A	A	I	H	Q	O	G	C	R	E	T	J	A	Z	N	P	S	Y	T
X	T	N	B	O	R	E	O	S	Y	O	B	U	B	O	I	T	J	J	U
U	T	P	P	L	W	Q	L	E	Z	E	A	L	H	B	X	T	I	X	G
Y	H	Z	M	O	W	X	I	P	X	S	E	C	O	N	D	Q	U	T	S
J	G	N	L	Y	X	J	K	D	D	E	J	L	E	L	K	V	B	C	Y
G	F	H	T	G	V	Y	Q	W	F	N	A	E	M	Y	J	R	G	B	L

Note: Directly Proportional and Inversely Proportional are not in the word search.

Units, prefixes and standard form

Anything that can be measured and have value is a quantity. Science, especially Physics, uses measurements of quantities to determine relationships and to help us to understand the universe. Most quantities also have a specific unit. One example is the quantity of length. This can have units of inches, centimetres. furlongs, light years… (the list goes on).

There are some quantities that have standard units that most scientists agree to use. You need to know the following;

Quantity	Unit	Symbol of the unit
Mass	kilogram	kg
Length	metre	m
Time	second	s
Force	newton	N
Energy	joule	J

When dealing with very large, or very small, values of a quantity we sometimes use a prefix instead of writing lots of zeroes. For example, one billion newtons can be written as 1,000,000,000 N or 1 GN. The 'G' represents the prefix Giga and means 'one billion of…'.

You are expected to know the following prefixes, what values they represent, and how to convert from one to another:

Prefix name	Prefix symbol	Meaning
tera-	T	1,000,000,000,000 of
giga-	G	1,000,000,000 of
mega-	M	1,000,000 of
kilo	k	1,000 of

deci-	d	1/10 of
centi-	c	1/100 of

milli-	m	1/1000 of
micro-	μ	1/1,000,000 of
nano-	n	1/1,000,000,000 of

Worked example:
How many cm are there in 2 km?

2 km = 2000 m

If 1 m = 100 cm, then 2000 m = (2000 x 100) cm

So there are 200,000 cm in 2 km.

There are other ways to quickly represent very small or very large numbers. One of them is using standard form.

When writing numbers in standard form we write them in terms of the powers of ten. A number written in standard form will always be a number between 0 and 10, multiplied by a power of 10. So 2100 would be 2.1×10^3

Quantity	Unit	Symbol of the unit
10^1	10	10
10^2	10 x 10	100
10^3	10 x 10 x 10	1000
10^4	10 x 10 x 10 x 10	10,000

So 2100 would be 2.1×10^3 – which is the same as 2.1 x 10 x 10 x 10.

Worked example:
Express the number 15,000,000 in standard form.

1 million = 10 x 10 x 10 x 10 x10 x 10 = 10^6

So 15 million would be 15×10^6

But 15 is 1.5×10^1, so

$15 \times 10^6 = 1.5 \times 101 \times 10^6 = 1.5 \times 10^7$

Extension questions;

1. How many watts are there in 57 terawatts?

2. Express '4.7 GN' in standard form.

Calculations in physics

Calculations should be written in several steps:

- CONVERT: check for non-standard units and convert them into standard units
- SUBSTITUTE: show that you can replace symbols/words with the values from the question
- REARRANGE: make the value you need the subject of the equation
- EVALUATE: write down the correct answer with units. Round it if you're asked to.

Worked example:
How far would a car travel if it moved at a speed of 30 m/s for 1 hour? Use the equation 'distance = speed x time'.

CONVERT:
1 hour = 60 minutes. 60 minutes = 3600 seconds.

SUBSTITUTE:
Distance = 30 x 3600

EVALUATE:
Distance = 108,000 m

Sometimes you'll be asked to calculate a value for a quantity that isn't the subject of the equation you have available to you. You'll have to rearrange the equation to make the right quantity the subject.

Worked example:
Make time the subject of the equation "distance = speed x time".

Distance = speed x time

Notice that time is currently multiplied by speed. We need to 'undo' this by dividing both sides of the equation by 'speed':

$$\frac{\text{Distance}}{\text{Speed}} = \frac{\text{speed x time}}{\text{speed}}$$

Here on the right hand side I am both multiplying by speed AND dividing by speed. These operations cancel each other out:

$$\frac{\text{Distance}}{\text{Speed}} = \frac{\cancel{\text{speed}}\text{ x time}}{\cancel{\text{speed}}}$$

So I finish with:

$$\frac{\text{Distance}}{\text{Speed}} = \text{time}$$

Below is a more complicated exam question, where the use of two equations were required. Notice that the steps of working out are still the same.

These multi-equation questions usually require a preceding step of extracting useful numbers from the usually-quite-wordy question.

Worked example:

The charge that flows through the new shower in 300 seconds is 18 000 C.
The new electric shower has a power of 13.8 kW.

Calculate the resistance of the heating element in the new shower.

Write down any equations you use.

$Q = I \times t$
$P = V \times I$
$P = E/t$
$P = I^2 \times R$

Time = 300 s
Charge = 18,000 C
Power = 13.8 kW = 13,800 W
Resistance = ?
Current = 60 A

1. Extract numerical information from the question
2. Convert units
3. Write down relevant equations
4. Calculate whatever you can and add to your list
5. Check your equations and calculate anything new. Repeat if necessary

18,000 C = Current x 300 s

Current = 18,000 C / 300 s = 60 A

13,800 W = $(60\text{ A})^2$ x Resistance

Resistance = 13,800 W / $(60\text{ A})^2$ = 3.83 Ω

Extension question;

1. If an object with a mass of 100g has 2,000 J of kinetic energy, how fast must it be going?
   Use the equation $E_k = \frac{1}{2}mv^2$.

Errors and uncertainty

We have to take care when measuring quantities in investigations. Measurements are very rarely perfect, and neither are we. We are prone to making errors during measurements. The most common forms of errors fall into three categories:

Random errors: due to results varying in unpredictable ways.

Systematic errors: due to measurement results differing from the true value by a consistent amount each time.

Zero error: occurs when a piece of equipment has not been calibrated to zero before taking a measurement.

We can minimise the impact of random errors on our experiments by taking repeat readings. This allows us to spot any results that do not fit the pattern (results that are anomalous) and ignore them. We can then take a mean of the remaining values.

Worked example:
Calculate the mean values in the table below:

Mass of ammonium nitrate / g	Decrease in temperature / °C			
	1st	2nd	3rd	Mean
1	2.1	2.2	6.7	
2	4.6	7.8	4.1	
3	6.4	6.7	6.6	
4	5.9	7.4	7.8	
5	8.6	8.6	8.6	
6	9.3	8.9	9.6	

First we would check for anomalous results. We can see that 6.7 is an anomaly in the first row, 7.8 is in the second row and 5.9 is in the fourth row.

We can then calculate the means by ignoring the anomalies, summing up the number of remaining values, and dividing by the number of values.

Mass of ammonium nitrate / g	Decrease in temperature / °C			
	1st	2nd	3rd	Mean
1	2.1	2.2	(6.7)	2.2
2	4.6	(7.8)	4.1	4.4
3	6.4	6.7	6.6	6.6
4	(5.9)	7.4	7.8	7.6
5	8.6	8.6	8.6	8.6
6	9.3	8.9	9.6	9.3

All measurements have an inherent uncertainty. We can never be 100% sure of any value. There are many ways to quantify an uncertainty on a measurement but at GCSE we follow a simplified method.

Firstly, we take repeat measurements of a quantity.
Then we calculate the range of our repeats (the difference between the maximum and minimum value.
Finally, we divide this range by 2.

$$Uncertainty = \frac{Range}{2}$$

Where $Range = Maximum\ value - minimum\ value$.

Worked example:

Calculate the uncertainty in the decrease in temperature when 6g of ammonium nitrate were used in this investigation.

Mass of ammonium nitrate / g	Decrease in temperature / °C			
	1st	2nd	3rd	Mean
1	2.1	2.2	6.7	2.2
2	4.6	7.8	4.1	4.4
3	6.4	6.7	6.6	6.6
4	5.9	7.4	7.8	7.6
5	8.6	8.6	8.6	8.6
6	9.3	8.9	9.6	9.3

Range = 9.6-8.9
= 0.7

Uncertainty = 0.7/2
= 0.35

So the mean decrease in temperature when using 6g of ammonium nitrate is:

9.3 ± 0.35 °C.

Plotting Graphs

There are many different ways of presenting information. Below is a summary of the most common types and when they should be used. In science we use mainly line graphs and bar charts

Method of presentation	When used…
Table	• To show items in a certain order (e.g. numerical order, alphabetical order). This is useful if you want to show the best or worst thing in a list. The best thing appears at the top of the table and the worst appears at the bottom.
Bar charts	• to show how things compare • normally the independent variable is discontinuous and the dependent variable is quantitative
Frequency diagrams	• to compare numbers of things
Histograms	• a frequency diagram where the values for the independent variable are continuous but have been grouped into ranges
Line graphs	• to show how one variable changes as another (usually time) changes• used when you know that the two variables are linke
Scatter graphs	• to look for a link (relationship) between two variables• both variables are quantitative
Pie charts	• to show proportions of a total contributed by different items (e.g. the proportions of students who come to school by bus, car …)
Venn diagrams	• to show the amount by which groups of items are the same or different
Flow diagrams	• to show a sequence of information
Labelled drawings	• to describe objects and processe

Plotting rules

When plotting a line graph or scatter graph you must always follow the rules below:

- When choosing a scale, you should check the range of data you need to plot.
- Choose increments that are easily divisible by 2, 4, 5 or 10.
- Make sure each square along that axis has the same value (e.g. each small square is 0.2, so each big square is worth 2).
- The x-axis and y-axis do not have to have the same scale.
- Each axis should have a label and unit.
- Independent variable goes on x-axis and dependent variable goes on y-axis (unless told otherwise)

Gradients

A line graph will always feature a line of best fit. This helps us see how one variable changes with respect to another. We can quantify this relationship in terms of a gradient. This is a value that tells us how much one variable is changing with respect to the other.

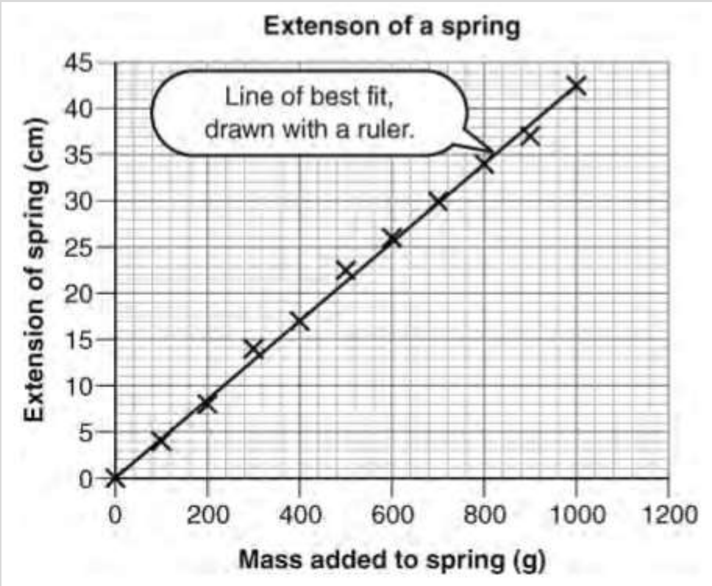
- Gradients can be positive or negative, but the bigger the gradient, the steeper the slope of the line and vice versa.
- To calculate the gradient, we pick two points from the line of best fit and write down their coordinates.
- We then find the difference in the y-values of the coordinates, and divide this by the difference in the x-coordinates.

$$Gradient = \frac{change\ in\ y}{change\ in\ x} = \frac{y\ of\ second\ point - y\ of\ first}{x\ of\ second\ point - x\ of\ first}$$

Worked example

Plot a graph of the following data, and calculate the gradient of the line of best fit.

Mass (g)	Extension of spring (cm)
0	0
100	4
200	8
300	14
400	17
500	22
600	26
700	30
800	34
900	37
1000	42



The points we'll pick are: (0,0) and (1000,42).

Gradient = (42-0)/(1000-0)
= 42/1000
=0.042 cm/g

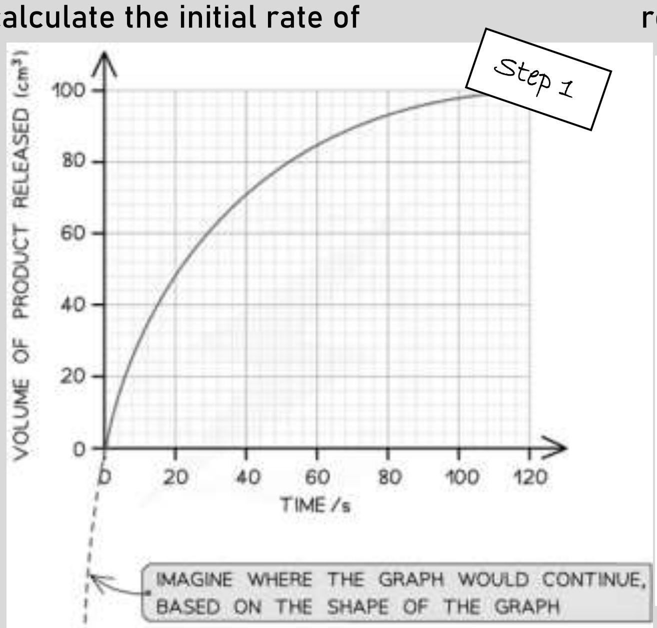
Note: the units from the gradient came from the units on the y-axis and the x-axis.

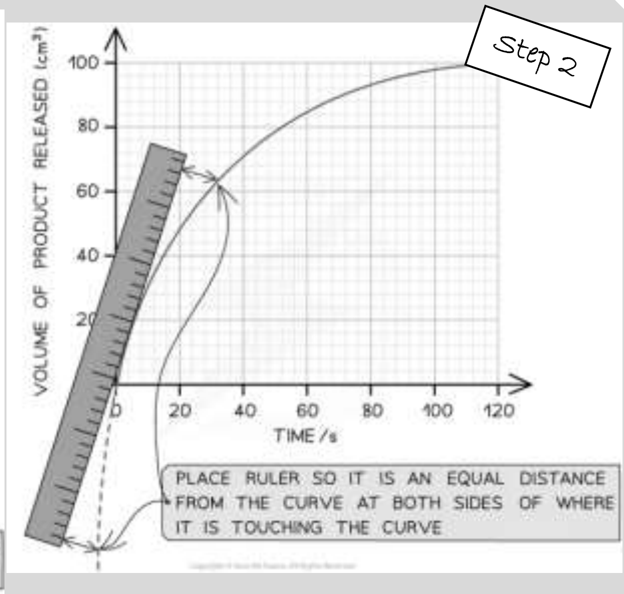
More graphs and relationships

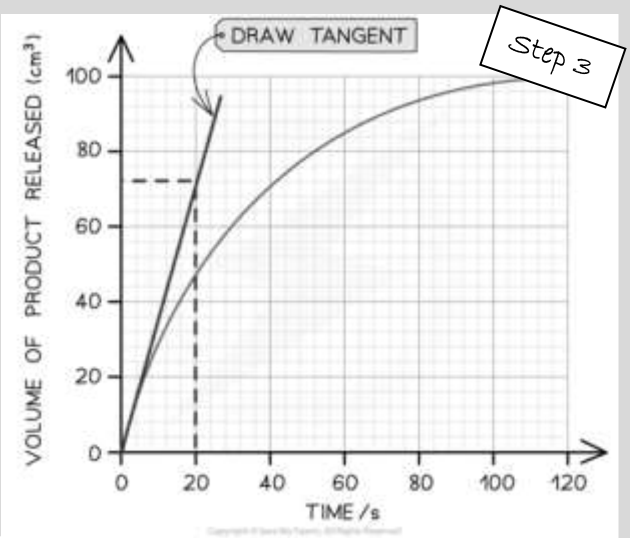
Many relationships between variables are non-linear and will have a curved line of best fit. This means the gradient of their line of best fit is constantly changing. Sometimes, it is useful to estimate the gradients of these curves. We do that by drawing a tangent to the curve. A tangent is a straight line that only touches the curve once at a particular point, and does not cross through the curve (unless there are multiple curves – this would not be tested at GCSE).

Worked example

The graph below shows the results of an enzyme rate reaction. Using this graph, calculate the initial rate of reaction.







Step 4

Gradient = (change in y-axis)/(change in x-axis)

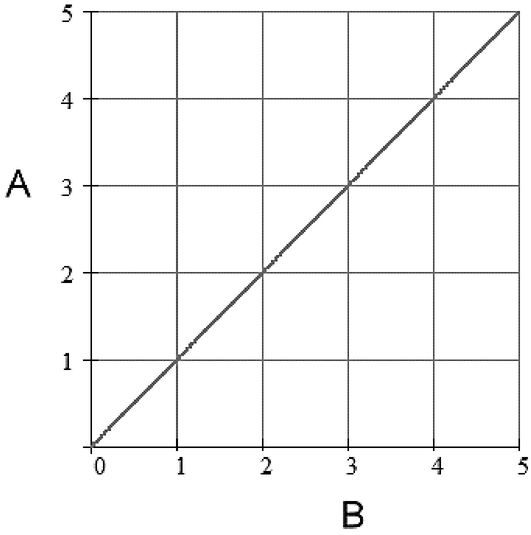
= 72/20

= 3.6 $cm^3\ s^{-1}$

Special relationships

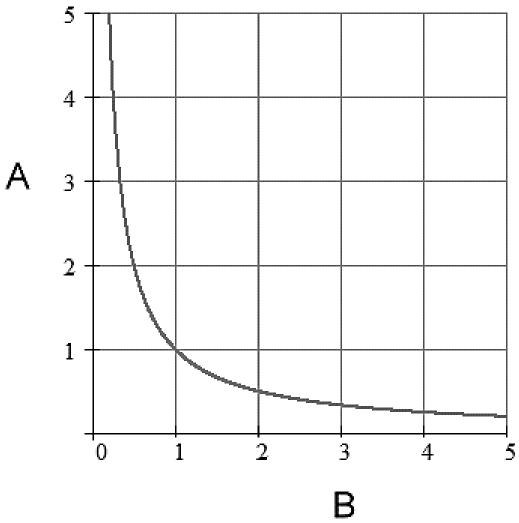
There are two special relationships between variables that you have to be able to recognise.

Here we would say that variable A is directly proportional to variable B.



- If the doubling of one variable means the other doubles too, and tripling means the other triples etc. then the variables are directly proportional.
- Graphs of direct proportionality always show a straight line through the origin.
- If variables are directly proportional, then dividing one by the other always gives the same value.

Here we would say that variable A is inversely proportional to variable B.



- If doubling one means halving the other, or tripling one will reduce the other by a factor of 3, then the variables are inversely proportional.
- If variables are inversely proportional, then multiplying one by the other always gives the same value.