

Name: \_\_\_\_\_

## Physics Induction Task: Mathematical skills

There are several areas in which students sometimes struggle:

- Use of symbols;
- Use of SI units;
- Use of a calculator;
- Use of formulae;
- Presentation of data;
- Plotting of the data in a graph;
- Interpretation of graphical data.

These notes and activities are to help you to become more confident with these basic skills before you begin the course. The physics data sheet is at the back of this pack. **You may need to use the internet or books as well as the information in this pack.**

### Using Symbols

An **equation** is a mathematical model that sums up how a system behaves. For example, we know that, if we have a current flowing through a wire and double the voltage, the current will double as well. We know that the quantities of current and voltage are related by the simple rule:

$$V = IR$$

In physics problems we are given certain quantities and use them to find an unknown quantity with an equation. At AS level you will never be expected to tackle a problem with two or more unknowns. That said you may need to look up some quantities from the data sheet.

1. Write down three equations that you can remember from GCSE (not $V=IR!$ )	(3)

### Symbols

In GCSE you were often given equations in words:

$$\text{Distance (m)} = \text{speed (m/s)} \times \text{time (s)}$$

In A level, you will normally use symbols to make your working clearer. Some symbols are easy;  $V$  stands for voltage. Some are not so easy.  $I$  for current comes from the French *intensité du courant*, since it was a French physicist who first worked on it.

2. What are the meanings for these symbols? (7)
$a$
$A$
$F$
$M$
$I$
$P$
$Q$

You will come across symbols written in Greek letters. The normal (Latin) alphabet has 26 characters. The Greek Alphabet is this:

<i>Greek</i>	<i>Name</i>		<i>Greek</i>	<i>Name</i>
$\alpha$	alpha		$\nu$	nu
$\beta$	beta		$\xi$	xi
$\gamma$	gamma		$\omicron$	omicron
$\delta (\Delta)$	delta		$\pi$	pi
$\epsilon$	epsilon		$\rho$	rho
$\zeta$	zeta		$\sigma (\Sigma)$	sigma
$\eta$	eta		$\tau$	tau
$\theta$	theta		$\upsilon$	upsilon
$\iota$	iota		$\phi (\Phi)$	phi
$\kappa$	kappa		$\chi$	chi
$\lambda (\Lambda)$	lambda		$\psi (\Psi)$	psi
$\mu$	mu		$\omega (\Omega)$	omega

The ones in grey are the ones you won't generally come across in A-level. You will come across the others in the context of:

- Particles – many particles are given Greek letters, e.g.  $\pi$  meson.
- Physics symbols, e.g.  $c = f\lambda$

3 The wave equation is $c = f\lambda$ . What do the symbols refer to? (3)
$c$
$f$
$\lambda$

The most common uses of Greek letters are:

- $\alpha$  – as in alpha particle;
- $\beta$  – as in beta particle;
- $\gamma$  – as in gamma ray;
- $\Delta$  – change in ( $\Delta t$  is time interval);
- $\theta$  – angle;
- $\pi$  – 3.1415...;
- $\Sigma$  – sum of.

4 Find two other formulae that use Greek letters (2)

## Units

Physics formulae use **SI** (Système International) **units** based on seven **base units**:

- **Distance** – metre (m);
- **Mass** – kilogram (kg);
- **Time** – second (s);
- **Temperature** – Kelvin (K);
- **Current** – ampere (A);
- **Amount of substance** – mole (mol);
- **Intensity of light** – candela (cd) [which you will not come across at A-level.]

Many physics formulae will give you the right answer **ONLY** if you put the quantities in SI units. This means that you have to convert. You will often find units that are prefixed, for example kilometre. The table below shows you the most common prefixes and what they mean:

<i>Prefix</i>	<i>Symbol</i>	<i>Meaning</i>	<i>Example</i>
pico	p	$\times 10^{-12}$	1 pF
nano	n	$\times 10^{-9}$	1 nF
micro	$\mu$	$\times 10^{-6}$	1 $\mu$ g
milli	m	$\times 10^{-3}$	1 mm
centi	c	$\times 10^{-2}$	1 cm
kilo	k	$\times 10^3$	1 km
Mega	M	$\times 10^6$	1 M $\Omega$
Giga	G	$\times 10^9$	1 GWh

When converting, it is perfectly acceptable to write the number and the conversion factor. For example:

$$250 \text{ nm} = 250 \times 10^{-9} \text{ m} = 2.5 \times 10^{-7} \text{ m}$$

5 Convert the following quantities to SI units: (5)	
15 cm	
500 g	
3 km	
35 mV	
220 nF	

When you write out your answer, you must always put the correct **unit** at the end. The number 2500 on its own is meaningless; 2500 J gives it a meaning.



**Failure to put units in loses marks in the exam.**

This little character is about to walk into a common bear trap by failing to convert into SI units.

Converting areas and volumes causes a lot of problems.

$$1 \text{ m}^2 \neq 100 \text{ cm}^2.$$

$$1 \text{ m}^2 = 100 \text{ cm} \times 100 \text{ cm} = 10\,000 \text{ cm}^2 = 10^4 \text{ cm}^2$$

6 Convert the following: (4)	
$1 \text{ m}^2 =$	$\text{mm}^2$
$0.45 \text{ mm}^2 =$	$\text{m}^2$
$1 \text{ cm}^3 =$	$\text{m}^3$
$22.4 \text{ dm}^3 =$	$\text{m}^3$

## Standard Form

**Standard form** consists of a number between 1 and 10 multiplied by a **power** of 10. For big numbers and very small numbers standard form is very useful.

7. Comment on what happens if you try to put the following numbers into a calculator as they are. Can you do any calculations on them?

(a) 3200

(b) 5 600 000

(c) 2 800 000 000 000

(d) 0.0000000000000341

(2)

You should have found that very small numbers entered into a calculator are read as 0, unless they are entered as standard form. The following number is shown in standard form:

$$\begin{aligned} & \mathbf{3.28 \times 10^5} \\ & = 3.28 \times 100\,000 = 328\,000 \end{aligned}$$

Look at this number:

4 505 000 000 000 000 000



Start counting from here to get the power of 10.

We find that there are 18 digits after the first digit, so we can write the number in standard form as:

$$4.505 \times 10^{18}$$

For fractions we count how far back the first digit is from the decimal point:

0.00000342

In this case it is six places from the decimal point, so it is:

$$3.42 \times 10^{-6}$$

A negative power of ten (negative index) means that the number is a fraction, i.e. between 0 and 1.

8. Convert these numbers to standard form:	(7)
86	
381	
45300	
1 500 000 000	
0.03	
0.00045	
0.0000000782	

There is no hard and fast rule as to when to use standard form in an answer. Basically if your calculator presents an answer in standard form, then use it. I generally use standard form for:

- numbers greater than 100 000
- numbers less than 0.001

When doing a **conversion** from one unit to another, for example from millimetres to metres, I consider it perfectly acceptable to write:

$$15 \text{ mm} = 15 \times 10^{-3} \text{ m}$$

## Using a Calculator

A **scientific calculator** is an essential tool in Physics, and you should always **bring a calculator to every lesson**.

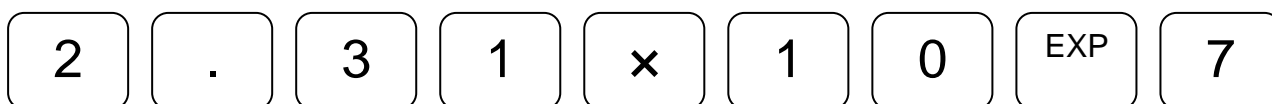
There are a couple of common mistakes made when using calculators :

Misuse of the EXP key:

Suppose we have a number like  $2.31 \times 10^7$ . You key it in like this:



Do NOT key it in like this:



This will give you  $2.31 \times 10^8$ . Misuse of the calculator will always cost marks.

Too Many Significant Figures

Consider this calculation:

$$V_{\text{rms}} = \frac{13.6}{\sqrt{2}}$$

Your calculator will give the answer as  $V_{\text{rms}} = 9.6166526 \text{ V}$

There is no reason at all in A-level Physics to write any answer to any more than 3 significant figures. Three significant figures is claiming accuracy to about one part in 1000. Blindly writing your calculator answer is claiming that you can be accurate to one part in 100 million, which is absurd.

During the course you will learn to judge exactly how many significant figures are appropriate:

$$V_{\text{rms}} = 9.62 \text{ V (3 s.f.)}$$

$$V_{\text{rms}} = 9.6 \text{ V (2 s.f.)}$$

Do any **rounding** up or down at the end of a calculation. If you do any rounding up or down in the middle, you could end up with rounding errors.

9. Use your calculator to do the following calculations. Write your answers to no more than three significant figures. (10)	
	<i>ANSWER</i>
(a) $\frac{3.4 \times 10^{-3} \times 6.0 \times 10^{23}}{235}$	
(b) $\frac{27.3^2 - 24.8^2}{\sqrt{38}}$	
(c) $1.4509^3$	
(d) $\sin 56.4$	
(e) $\cos^{-1} 0.4231$	
(f) $\tan^{-1} 2.143$	
(g) $\sin^{-1} 0.00052$	
(h) Reciprocal of $2.34 \times 10^5$	
(i) $\log_{10} 200$	
(j) $45 \sin 10$	

Some other tips on use of calculators:

- On most calculators the number is keyed in before the function (sin, cos, log)
- Take one step at a time and write intermediate results.
- It is easy to make a mistake such as pressing the  $\times$  key rather than the  $\div$  key. It is a good idea to do the calculation again as a check.
- As you get more experienced, you will get a feel for what is a reasonable answer. 1000 N is a reasonable force that a car would use to accelerate;  $2 \times 10^{-10}$  N is most certainly not.



## Rearranging Formulae

The **rearrangement** of formulae is a skill that is essential for successful study of Physics. A wrong formula will lose all the marks available in that part of the question. (However, if you use your incorrect answer correctly in subsequent parts, your error will be carried forward and you will gain the credit.)

Some students find rearrangement very difficult and it hampers their progress and enjoyment of the subject. They try to get round it by learning all the variants of a formula, which is a waste of brain power.

It is far better to get into the habit of rearranging formulae from the start. The best thing to do is to practise.

Key Points:

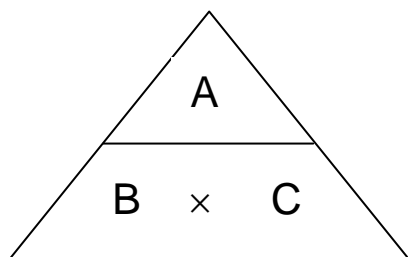
- What you do on one side you have to do on the other side. It applies whether you are working with numbers, symbols, or both.
- Don't try to do too many steps at once.

### Rearranging Simple Formulae

Simple formulae are those that consist of three quantities, taking the form  $A = BC$ . A typical example is  $V = IR$

10. Write down two other formulae of this kind.	(2)

A simple trick is to use the **formula triangle**, although this only works for three term equations.



You put your finger over the term you want to be **subject** of the formula (what you want to find) and then the rest follows:  
 $B = A/C$

However it is better that you follow a more orthodox method. Suppose we are using the equation  $V = IR$  and wanted to know  $I$ . We want to get rid of the  $R$  on the RHS so that  $I$  is left on its own.

So we divide both sides by  $R$  which gives us:

$$\frac{V}{R} = \frac{IR}{R}$$

The  $R$ s on the RHS cancel out because  $R/R = 1$ . So we are left with:

$$\frac{V}{R} = I$$

It does not matter which way the equation ends up, as long as it is rearranged properly.

11. Rearrange these equations: (4)		
<i>Equation</i>	<i>Subject</i>	<i>Answer</i>
$V = IR$	$R$	
$p = mv$	$v$	
$\rho = \frac{m}{V}$	$m$	
$Q = CV$	$C$	

#### Formulae with Four Terms

Triangle methods will not work with these. Do the same method as above. Consider this formula:

$$R = \frac{\rho l}{A}$$

Make  $\rho$  the subject.

Get rid of the  $l$  by dividing the whole equation by  $l$ .

$$\frac{R}{l} = \frac{\rho l}{Al}$$

The  $l$  terms cancel to give:

$$\frac{R}{l} = \frac{\rho}{A}$$

To get rid of the  $A$  downstairs we need to multiply both sides by  $A$ :

$$\frac{AR}{l} = \frac{A\rho}{A}$$

The  $A$  terms cancel to give us our final result:

$$\rho = \frac{AR}{l}$$

12. Rearrange these equations: (4)		
<i>Equation</i>	<i>Subject</i>	<i>Answer</i>
$pV = nRT$	$V$	
$Ep = mg\Delta h$	$\Delta h$ ( $\Delta h$ is a single term)	
$V = -\frac{GM}{r}$	$G$	
$\lambda = \frac{ws}{D}$	$D$	

Equations with + or -

If there are terms which are added or subtracted, we need to progress like this:

$$Ek = hf - \Phi$$

We want to find  $h$ .

To get rid of the  $\Phi$  term we need to add it to both sides of the equation:

$$\begin{aligned} Ek + \Phi &= hf - \Phi + \Phi \\ Ek + \Phi &= hf \end{aligned}$$

Now we can get rid of the  $f$  on the RHS by dividing the whole equation by  $f$ :

$$\frac{(Ek + \Phi)}{f} = \frac{hf}{f}$$

Which gives us our final result of:

$$h = \frac{(Ek + \Phi)}{f}$$

13. Rearrange these equations: (2)		
<i>Equation</i>	<i>Subject</i>	<i>Answer</i>
$v = u + at$	$t$	
$E = V + Ir$	$r$	

Dealing with Squares and Square Roots

If we have a square root, we get rid of it by squaring. If there is a square, we get rid of it by taking the square root.

Consider this formula:

$$T = 2\pi \sqrt{\frac{l}{g}}$$

Suppose we want to find  $g$ .

Get rid of the square root by squaring the whole equation:

$$T^2 = 4\pi^2 \frac{l}{g}$$

Now bring  $g$  upstairs by multiplying the equation on both sides and cancelling:

$$gT^2 = 4\pi^2 l$$

Now get rid of the  $T^2$  by dividing the whole equation by  $T^2$  and cancelling.

$$g = \frac{4\pi^2 l}{T^2}$$

14. Rearrange these equations: (6)		
<i>Equation</i>	<i>Subject</i>	<i>Answer</i>
$Ek = \frac{1}{2}mv^2$	$v$	
$T = 2\pi\sqrt{\frac{m}{k}}$	$k$	
$f = \frac{1}{2\pi\sqrt{LC}}$	$C$	

What I did well:	
What I need to work on:	

## Tips for Calculations

1. Write down a formula or equation using standard symbols if possible.

$$s = ut + \frac{1}{2}at^2$$

2. You may wish to write a "shopping list" for the quantities in the formula/equation.

$$s = 4.5\text{m}$$

$$u = 0$$

$$v =$$

$$a =$$

$$t = 0.90\text{s}$$

3. Substitute values into the formula/equation **without rearranging first** (unless you know you won't make daft mistakes).

$$4.5 = 0 + \frac{1}{2}a \times 0.90^2$$

4. Rearrange and calculate your final answer.

$$4.5 = 0.405a$$

5. Write the answer using sensible **significant figures** and, if necessary, standard form. Add the proper **units**.

$$a = \frac{4.5}{0.405}$$

$$\underline{a = 11.1 \text{ m s}^{-2}}$$

*Check that you have answered what the question actually asked for.*

**If you have done all this** underline your answer.