Summer task

Physics@EGS

Welcome brave soul and well done for choosing an excellent subject which will open doors you won't even imagine!

A-level Physics gives you the edge above millions of students, people are always impressed with a qualification in physics.

However, with every great triumph comes a lot of hard work. You need to be prepared for the year ahead. You also have to be aware that the jump from GCSE to A-level is massive and it will require a much bigger commitment.

In light of this, we expect all prospective A-Level Physics students complete the summer task. Well, it is more a booklet. The booklet will require more time than just ''oh I will do it the night before''.

Good luck and see you in September.

Physics@EGS

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Chapter 1: Introduction

One of things that many people find disconcerting when studying Physics is the idea of having to deal with lots of complicated equations. On first sight, it can be very daunting to see a page full of funny looking letters and symbols but with practice you will see that this really is just to save us having to write words out over and over again (physicists like to work efficiently).

The purpose of this introductory unit is to help you develop the core skills needed to solve numerical problems which will make your Year 12 Physics studies much more enjoyable and successful than they otherwise would be. Without these core skills solving problems becomes much more difficult if not impossible, a bit like trying to build a house with no wood or bricks. A bit of work before the course starts will pay huge dividends later and allow you to work and learn much more efficiently.

The key to success is to break numerical problems, where calculations are necessary, into smaller, simpler steps which can be followed every time.

The steps can be summarised as follows:-

Step 1: *Write down the values of everything you are given and put a question mark next to what you are asked to work out.*

Step 2: *Convert all the values into SI units i.e. time in seconds, distances in metres and so on.*

Step 3: *Pick an equation that contains the values we know and the quantity we are trying to work out.*

Step 4: *Re-arrange the equation so what we are trying to work out is the subject.*

Step 5: *Insert the values into the equation including the units.*

Step 6: *Type it into our calculator to get the answer and quote the answer to a reasonable number of significant figures and with units.*
Step 7: *Pause for one moment and think about if our answer is sensible.*

Chapters 2 and 3 will help you with Step 1

Chapters 4 and 5 will help you with Step 2

Chapter 6 will help with Steps 3 and 4

Chapters 7 and 8 will help with Step 6.

Chapter 9 will show a couple of examples to demonstrate how this all fits together.

With experience some of these steps can be done more quickly or in your head but you should always show your working. This is for several reasons:-

1. If you don’t show your working, you will needlessly lose many marks in the exam (probably enough to drop your score by one whole grade, i.e. from B → C).

2. It will help make the steps outlined above more apparent and easy to follow when tackling numerical problems.
3. It makes it easier for the teacher to see where you have gone wrong and therefore help you learn more quickly and effectively.

Chapter 2: Physical Quantities/Units

When we first look at numerical problem in Physics then we need to be able to recognise what quantities we are given in the question. This can be made a lot easier if we know what quantity corresponds to the units given in the question. For example, if a question says someone's speed changes at a rate of 5 ms^{-2}, you need to be able to recognise that ms^{-2} is the unit of acceleration and so we know that we have been given an acceleration (even though the word acceleration wasn't used in the question).

We can classify physical quantities as either

(a) Basic: These are **fundamental** which are **defined** as being independent

There are seven basic quantities defined by the Systeme International d'Unites (SI Units). They have been defined for convenience not through necessity (force could have been chosen instead of mass). Once defined we can make measurements using the correct unit and measure with direct comparison to that unit.

Basic quantity	Unit	
	Name	Symbol
Mass	Kilogram	kg
Length	Metre	m
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of a substance	Mole	mol
Luminous intensity	Candela	cd

NOTE: Base units are also referred to as dimensions.

(b) Derived: These are obtained by multiplication or division of the basic units **without** numerical factors. For example:

Derived quantity	Unit	
	Name	Symbols used
Volume	Cubic metre	m^3
Velocity	Metre per second	ms^{-1}
Density	Kilogram per cubic metre	kgm^{-3}

Some derived SI units are complicated and are given a simpler name with a unit defined in terms of the base units.

Farad (F) is given as $m^{-2}kg^{-1}s^4A^2$ **Watt** (W) is given as m^2kgs^{-3}

A table of quantities with their units is shown on the next page along with the most commonly used symbols for both the quantities and units.

Note that in GCSE we wrote units like metres per second in the format of m/s but in A-level it is written as ms^{-1}, and this is the standard way units are written at university level Physics.

Quantity	Quantity	SI Unit	Unit Symbol
Length	L or l	Metre	m
Distance	s	Metre	m
Height	h	Metre	m
Thickness (of a Wire)	d	Metre	m
Wavelength	λ	Metre	m
Mass	m or M	kilogram	kg
Time	t	second	s
Period	T	second	s
Temperature	T	Kelvin	K
Current	I	Ampere	A
Potential Difference	V	Volt	V
Area	A	Metres squared	m^2
Volume	V	Metres cubed	m^3
Density	ρ	Kilograms per metre cubed	$kg\ m^{-3}$
Force	F	Newton	N
Initial Velocity	u	Metres per second	ms^{-1}
Final Velocity	v	Metres per second	ms^{-1}
Energy	E	Joule	J
Kinetic Energy	E_K	Joule	J
Work Done	W	Joule	J
Power	P	Watt	W
Luminosity	L	Watt	W
Frequency	f	Hertz	Hz
Charge	Q	Coulomb	C
Resistance	R	Ohm	Ω
Electromotive Force	ε	Volt	V
Resistivity	ρ	Ohm Metre	Ωm
Work Function	ϕ	Joule	J
Momentum	p	kilogram metres per second	$kg\ ms^{-1}$
Specific Charge		Coulombs per kilogram	$C\ kg^{-1}$
Planck's Constant	h	Joule seconds	Js
Gravitational Field Strength	g	Newtons per kilogram	$N\ kg^{-1}$

This table needs to be memorised – once you know this it will significantly improve your ability to answer numerical questions. It is so important that we will test you on this very early on in Year 12.

Exercise

For each of the following questions write down the quantities you are trying to work out and write a question mark next to the quantity you are asked to find out with SI units shown. Note that you don't have to know any equations or any of the underlying physics to do this, it is a simply an exercise in recognising what you are being given in the question and what you are being asked to find out.

Example
Find the momentum of a 70 kg ball rolling at 2 ms^{-1}.
m=70 kg
v= 2 ms^{-1}
p= ? kg ms^{-1}

1. The resultant force on a body of mass 4.0 kg is 20 N. What is the acceleration of the body?
2. A particle which is moving in a straight line with a velocity of 15 ms^{-1} accelerates uniformly for 3.0s, increasing its velocity to 45 ms^{-1}. What distance does it travel whilst accelerating?
3. A car moving at 30 ms^{-1} is brought to rest with a constant retardation of 3.6 ms^{-2}. How far does it travel whilst coming to rest?
4. A man of mass 75 kg climbs 300 m in 30 minutes. At what rate is he working?
5. What is the maximum speed at which a car can travel along a level road when its engine is developing 24kW and there is a resistance to motion of 800 N?
6. Find the current in a circuit when a charge of 40 C passes in 5.0s.
7. What is the resistance of a copper cylinder of length 12 cm and cross-sectional area 0.40 cm^2 (Resistivity of copper = 1.7×10^{-8} Ωm)?
8. When a 12 V battery (i.e. a battery of EMF 12 V) is connected across a lamp with a resistance of 6.8 ohms, the potential difference across the lamp is 10.2 V. Find the current through the lamp.
9. Calculate the energy of a photon of wavelength 3.0×10^{-7} m.
10. Calculate the de Broglie wavelength of an electron moving at 3.0×10^{6} ms^{-1} (Planck's constant = 6.63×10^{-34} Js, mass of electron = 9.1×10^{-31} kg).

Chapter 3: Standard Form

You may well already be familiar with Standard Form from GCSE Maths, but just in case you aren't or could do with refreshing your memory then this chapter will explain what it is and why we use it.

Why use standard form? Standard form is used to make very large or very small numbers easier to read. Standard form also makes it easier to put large or small numbers in order of size.

In Physics, we often deal with quantities that are either really large, such as a parsec

1 pc = 30,900,000,000,000,000 m

Or really small like Planck's Constant:-

h= 0.000000000000000000000000000000000663 Js

Now, it would be tiresome to write out numbers like this over and over again and so we use a different notation known as standard form. Standard form shows the magnitude (size) of the number as powers of ten. We write a number between 1 and 10 and then show it multiplied by a power of 10.

For example

	1.234×10^{4}	1.234×10^{-4}
This means	1.234 x (10 x 10 x 10 x 10)	1.234 x(1 ÷ 10 ÷ 10 ÷ 10 ÷ 10)
Which is	12340	0.0001234

Let's see some more examples.

$0.523 = 5.23 \times 10^{-1}$ (note that $\times 10^{-1}$ means divide 5.23 by 10)

$52.3 = 5.23 \times 10^{1}$ (note that $\times 10^{1}$ means multiply 5.23 by 10)

$523 = 5.23 \times 10^{2}$ (note that $\times 10^{2}$ means multiply 5.23 by 100)

$5230 = 5.23 \times 10^{3}$ (note that $\times 10^{3}$ means multiply 5.23 by 1000)

$0.00523 = 5.23 \times 10^{-3}$ (note that $\times 10^{-3}$ means divide 5.23 by 1000)

Note that the sign (positive or negative) in the index tells you whether you are dividing or multiplying; a positive number means you are multiplying and a negative number means you are dividing. The number tells you how many times you are either dividing or multiplying by 10. So 1.60×10^{-19} means take the number 1.60 and divide it by 10 nineteen times (divide by 10^{19}) i.e. move the decimal point 19 places to the left.

And to go back to our examples from above:-

1 pc = 3.09×10^{16} m

h= 6.63×10^{-34} Js

So this is a much shorter way of writing these numbers!

To put a list of large numbers in order is difficult because it takes time to count the number of digits and hence determine the magnitude of the number.

1. Put these numbers in order of size,

5239824 , 25634897 , 5682147 , 86351473 , 1258964755
142586479, 648523154

But it is easier to order large numbers when they are written in standard form.

2. Put these numbers in order of size,

5.239×10^{6} , 2.563×10^{7} , 5.682×10^{6} , 8.635×10^{7} , 1.258×10^{9}
1.425×10^{8} , 6.485×10^{8}

You can see that it is easier to work with large numbers written in standard form. To do this we must be able to convert from one form into the other.

3. Convert these numbers into normal form.

a) 5.239×10^{3}
b) 4.543×10^{4} c) 9.382×10^{2} d) 6.665×10^{6}
e) 1.951×10^{2} f) 1.905×10^{5} g) 6.005×10^{3}

4. Convert these numbers into standard form.

a) 65345 (how many times do you multiply 6.5345 by 10 to get 65345 ?)
b) 28748 c) 548454 d) 486856
e) 70241 f) 65865758 g) 765

Standard form can also be used to write small numbers

e.g. 0.00056 = 5.6×10^{-4}

5. Convert these numbers into normal form.

a) 8.34×10^{-3} b) 2.541×10^{-8} c) 1.01×10^{-5}
d) 8.88×10^{-1} e) 9×10^{-2} f) 5.05×10^{-9}

6. Convert these numbers to standard form.

a) 0.000567 b) 0.987 c) 0.0052
d) 0.0000605 e) 0.008 f) 0.0040302

7. Calculate, giving answers in standard form,

a) $(3.45 \times 10^{-5} + 9.5 \times 10^{-6}) \div 0.0024$
b) $2.31 \times 10^{5} \times 3.98 \times 10^{-3} + 0.0013$

Chapter 4: Converting Units to SI Units

Some common non-SI units that you will encounter during Year 12 Physics:-

Quantity	Quantity	Alternative Unit	Unit Symbol	Value in SI Units
Energy	E	electron volt	eV	1.6×10^{-19} J
Charge	Q	charge on electron	e	1.6×10^{-19} C
Mass	m	atomic mass unit	u	1.67×10^{-27} J
Mass	m	tonne	t	10^{3} kg
Time	t	hour	hr	3,600 s
Time	t	year	yr	3.16×10^{7} s
Distance	d	miles	miles	1,609 m
Distance	d	astronomical unit	AU	3.09×10^{11} m
Distance	d	light year	ly	9.46×10^{15} m
Distance	d	parsec	pc	3.09×10^{16} m

It is essential that you recognise these units and also know how to change them to SI units and back again. A lot of marks can be lost if you are not absolutely competent doing this.

When you are converting from these units to SI units you need to multiply by the value in the right hand column. When you convert back the other way you need to divide.

Example

The nearest star (other than the Sun) to Earth is Proxima Centauri at a distance of 4.24 light years.

What is this distance expressed in metres?

4.24 light years = $4.24 \times 9.46 \times 10^{15}$ m = 4.01×10^{16} m

What is this distance expressed in parsecs?

4.01×10^{16} m = $4.01 \times 10^{16} / 3.09 \times 10^{16}$ m = 1.30 pc

Exercise

Convert the following quantities:-

1. What is 13.6 eV expressed in joules?
2. What is a charge of 6e expressed in coulombs?
3. An atom of Lead-208 has a mass of 207.9766521 u, convert this mass into kg.
4. What is 2.39 × 108 kg in tonnes?
5. It has been 44 years since England won the World Cup, how long is this in seconds?
6. An TV program lasts 2,560s, how many hours is this?
7. The semi-major axis of Pluto's orbit around the Sun is 5.91 × 1012 m, what is this distance in AU?

Converting Speeds

Things get a little more complicated when you have to convert speeds.   For example, if Usain Bolt runs at an average speed of 10.4 ms^{-1}, what is this speed in miles per hour?

First, we will change from ms^{-1} to miles s^{-1}:-

10.4 ms^{-1} = 10.4 /1609 miles s^{-1} = 6.46×10^{-3} miles s^{-1}

Now we have to change from miles s^{-1} to miles hr^{-1}

6.46×10^{-3} miles s^{-1} = $6.46 \times 10^{-3} \times 3{,}600$ miles hr^{-1} = 23.3 miles hr^{-1}

Notice that in last line we had to multiply by the number of seconds in an hour. This is because you would go further in an hour than you would in a second. If you find this hard to understand sometimes you can multiply by the conversion factor and divide by it and see which value is sensible. Let's see what would have happened if we had divided by 3,600:-

6.46×10^{-3} miles s^{-1} = 6.46×10^{-3} / 3,600 miles hr^{-1} = 1.80×10^{-6} miles hr^{-1}

Do you think Usain Bolt was running at a speed of about 2 millionths of a mile an hour? This is clearly wrong so we would have realised that we needed to multiply by 3,600.

Exercise

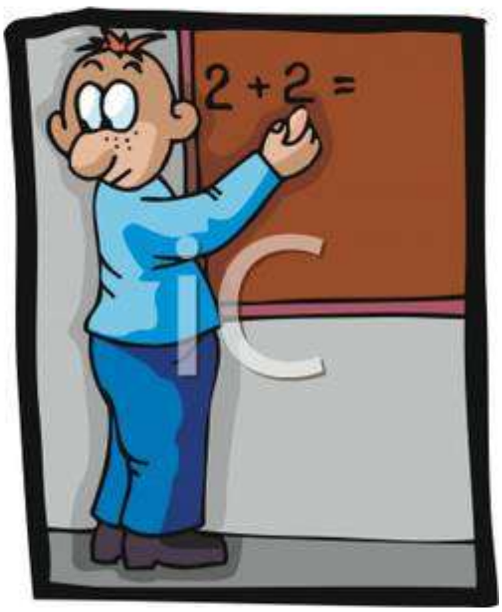
1. Convert 0.023 kms^{-1} into ms^{-1}.
2. Express 3456 m hr^{-1} into km hr^{-1}
3. What is 30 miles hr^{-1} in ms^{-1}?
4. What is 50 ms-1 in miles hr-1?
5. Convert 33 km hr-1 into ms-1.
6. Express 234 miles hr^{-1} in km hr^{-1}.

Chapter 5: Prefixes & Converting Unit Magnitudes

How to use and convert prefixes

Often in Physics, quantities are written using prefixes which is an even shorter way of writing numbers than standard form. For example instead of writing 2.95×10^{-9} m we can write 2.95 nm where n means nano and is a short way of writing $\times 10^{-9}$. Here is a table that shows all the prefixes you need to know in Year 12 Physics.

Prefix	Symbol	Name	Multiplier
femto	f	quadrillionth	10^{-15}
pico	p	trillionth	10^{-12}
nano	n	billionth	10^{-9}
micro	μ	millionth	10^{-6}
milli	m	thousandth	10^{-3}
centi	c	hundredth	10^{-2}
deci	d	tenth	10^{-1}
deka	da	ten	10^{1}
hecto	h	hundred	10^{2}
kilo	k	thousand	10^{3}
mega	M	million	10^{6}
giga	G	billion†	10^{9}
tera	T	trillion†	10^{12}
peta	P	quadrillion	10^{15}



Again, it is essential you know all of these to ensure that you don't lose easy marks when answering numerical problems.

When you are given a variable with a prefix you must convert it into its numerical equivalent in standard form before you use it in an equation.

FOLLOW THIS! Always start by replacing the prefix symbol with its equivalent multiplier.

For example: 0.16 μA = 0.16×10^{-6} A = 0.00000016A

3 km = 3000m = 3×10^{3} m

10 ns = 10×10^{-9} s = 0.00000001 s

DO NOT get tempted to follow this further (for example: 0.16×10^{-6} A = 1.6×10^{-7} A and also 10×10^{-9} s = 10^{-8} s) unless you are absolutely confident that you will do it correctly. It is always safer to stop at the first step (10×10^{-9} s) and type it like this into your calculator.

NOW TRY THIS!

1.4 kW =

24 cm =

46 pF =

52 Gbytes =

10 μC =

340 MW =

0.03 mA =

43 kΩ =

Converting between unit magnitudes for distances.

Convert the following: (Remember that milli = 10^{-3} and centi = 10^{-2})

1. 5.46m to cm
2. 65mm to m
3. 3cm to m
4. 0.98m to mm
5. 34cm to mm
6. 76mm to cm

Converting between unit magnitudes for areas and volumes

It’s really important that when we convert areas and volumes that we don’t forget to square or cube the unit.

Example

Let’s take the example of converting a sugar cube of volume 1 cm^3 into m^3.

If we just use the normal conversion, then 1 cm^3 = 1×10^{-2} m^3 ← **Wrong Answer!**

STOP! Let’s think about this one second:

Imagine in your head a box 1m by 1m by 1m, how many sugar cubes could you fit in there? A **lot** more than 100! That would only fill up one line along one of the bottom edges of the box! **So our answer must be wrong.**

What we have to do is do the conversion and then cube it, like this:-

$1\ cm^3 = 1\ (\times 10^{-2}\ m)^3 = 1 \times 10^{-6}\ m^3$.

So this means we could fit a million sugar cubes in the box, which is right.

Exercise

1. What is 5.2 mm^3 in m^3?
2. What is 24cm^2 in m^2?
3. What is 34 m^3 in μm^3?
4. What is 0.96×10^6 m^2 in km^2?
5. Convert 34 Mm^3 into pm^3.

Chapter 6: Re-arranging Equations

The first step in learning to manipulate an equation is your ability to see how it is done once and then repeat the process again and again until it becomes second nature to you.

In order to show the process once I will be using letters rather than physical concepts.

You can rearrange an equation $a = b \times c$ with

b as the subject $b = \frac{a}{c}$

or c as the subject $c = \frac{a}{b}$

Any of these three symbols a, b, c can be itself a summation, a subtraction, a multiplication, a division, or a combination of all. So, when you see a more complicated equation, try to identify its three individual parts a, b, c before you start rearranging it.

<u>Worked examples</u>

Equation	First Rearrangement	Second Rearrangement
$v = f \times \lambda$	$f = \frac{v}{\lambda}$	$\lambda = \frac{v}{f}$
$T = \frac{1}{f}$	$1 = T \times f$	$f = \frac{1}{T}$
$\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$	$1 = v \times \left(\frac{1}{u} + \frac{1}{f}\right)$	$v = \frac{1}{\frac{1}{u} + \frac{1}{f}}$

THINK! As you can see from the third worked example, not all rearrangements are useful. In fact, for the lens equation only the second rearrangement can be useful in problems. So, in order to improve your critical thinking and know which rearrangement is the most useful in every situation, you must practise with as many equations as you can.

NOW TRY THIS!

From now on the multiplication sign will not be shown, so $a = b \times c$ will be simply written as $a = bc$

Equation	First Rearrangement	Second Rearrangement
(Power of lens) $P = \frac{1}{f}$	$1 =$	$f =$
(Magnification of lens) $m = \frac{v}{u}$	$v =$	$u =$
(refractive index) $n = \frac{c}{v}$	$c =$	$v =$
(current) $I = \frac{\Delta Q}{\Delta t}$		
(electric potential) $V = \frac{\Delta E}{\Delta Q}$		
(power) $P = \frac{\Delta E}{\Delta t}$		
(power) $P = VI$		
(conductance) $G = \frac{I}{V}$		
(resistance) $R = \frac{V}{I}$		
(resistance) $R = \frac{1}{G}$		
(power) $P = I^2 R$		
(power) $P = \frac{V^2}{R}$		
(stress) $\sigma = \frac{F}{A}$	$F =$	$A =$
(strain) $\varepsilon = \frac{x}{l}$	$x =$	$l =$

Chapter 7: Significant Figures

You can lose a mark if you quote too many significant figures in an answer. It is not as bad a leaving off a unit when answering a question – but why lose marks needlessly when you don't have to?

The Rules

1. All non-zero digits are significant.

2. In a number without a decimal point, only zeros BETWEEN non-zero digits are significant. E.g. significant in 12001 but not in 12100

3. In a number with a decimal point, all zeros to the right of the right-most non-zero digit are significant. 12.100 → 5 s.f.

Examples

39.389 → 5 s.f.

120000000000000→ 2 s.f

3400.000 → 7 s.f.

34224000 → 5 s.f.

200000.0004 → 10 s.f.

Exercise:-

How many significant figures are the following numbers quoted to?

1. 224.4343
2. 0.00000000003244654
3. 3442.34
4. 200000
5. 43.0002
6. 24540000
7. 543325
8. 23.5454353
9. 4.0000000000
10. 4456001

Exercise II – For the numbers above that are quoted to more than 3 s.f., convert the number to standard form and quote to 3 s.f.

Using a Reasonable Number of S.F.

Try to use the same s.f. as those provided in the question or just one more.

Example:

Let's say we were faced with this question:

A man runs 110 metres in 13 seconds, calculate his average speed.

Distance = 110 m

Time = 13 s

Speed = Distance/Time = 110 metres / 13 seconds

=8.461538461538461538461538461538 m/s

This is a ridiculous number of significant figures!

=8.46 m/s seems acceptable (3 s.f.) because the figures we were given in the question we given to 2 s.f, so we've used just one more than that in our answer.

If in doubt quote answers to 3 s.f. in the exam – this is normally close enough to what they are looking for.