Bridging the Gap from GCSE Physics and Preparing for A-Level Physics

June 2021

Physics is Challenging

It is said time and time again, by people that should know better, that physics is a hard subject. But physics is like any other area of human endeavour. It is challenging because it is worth while.

Physics is challenging and it should be. Education should be a mental gymnasium where you perspire, ache and then grow. Anyone will be able to succeed in a challenging field if they commit to working hard and are prepared to ask for advice and help.

This booklet will hopefully prepare in part for the challenges ahead. It is strongly advised that you work through this booklet **and** revise the physics components from your GCSEs. A levels, in all subjects, are more challenging and rigorous than GCSEs so make sure you give ourself the best opportunity to succeed!

Measuring and Estimating

Measuring techniques and being able to estimate quantities play a very important part in the A level Physics course. So here are a few tasks to do over the summer break. Be prepared to bring this work in and talk about it at the start of next term.

1. Using objects you can find in the kitchen, measure the density of water.
2. Explain how you did this and show all working.
3. Measure as accurately as you can the thickness of a yellow page from the YellowPages. Again explain how you did this and show all working.
4. Estimate the height of your house. Explain how you did this.
5. Work out how long your average foot step is using Google maps
6. Try to calculate the height of your house using trigonometry- do not measure it!

Practice Mathematics

Many students worry about the mathematical content of physics A-level. It is true that the mathematical component of this course can be demanding yet there is no way to circumvent this. This challenge needs to be taken head on. "Practice makes perfect" should be the motto that is inscribed into your work ethic.

Below you will find five areas that need to be mastered for any student to succeed in A-level physics. Ideally, each section should be completed and understood by the time you start in September.

1. Physical Quantities

Maths and Physics have an important but overlooked distinction by students. Numbers in Physics have meaning – they are the size of physical quantities which exist. To give numbers meaning we suffix them with units. There are two types of units:

Base units These are the seven fundamental quantities defined by the Système international d'Unités (SI units). Once defined, we can make measurements using the correct unit and make comparisons between values.

Basic quantity	Unit	
	Name	Symbol
Mass	kilogram	kg
Length	metre	m
Time	second	s
Current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Derived units These are obtained by multiplying or dividing base units. Some derived units are complicated and are given simpler names, such as the unit of power Watt (W) which in SI units would be m^2kgs^{-3}.

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

Notice that at A-Level we use the equivalent notation ms^{-1} rather than m/s.

Do not become confused between the symbol we give to the quantity itself, and the symbol we give to the unit. For some examples, see the table on the right.

Quantity	Quantity symbol	Unit name	Unit symbols
Length	L or l or h or d or s	metre	m
Wavelength	λ	metre	m
Mass	m or M	kilogram	kg
Time	t	second	s
Temperature	T	kelvin	K
Charge	Q	coulomb	C
Momentum	p	kilogram metres per second	kg ms^{-1}

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}
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}

Often the value of the quantity we are interested in is very big or small. To save space and simplify these numbers, we prefix the units with a set of symbols.

Knowledge of standard form and how to input it into your calculator is essential.

For example: 245×10^{-12} m = 245 pm
2.45×10^{3} m = 2.45 km

We may need to convert units to make comparisons.

For example: Which is bigger, 0.167 GW or 1500 MW?
0.167 GW = 0.167×10^{9} W
= 167×10^{6} W
= 167 MW < 1500 MW

Physical Quantities - Questions

1) The unit of energy is the joule. Find out what this unit is expressed in terms of the base SI units.

2) 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}

3) Convert these quantities into standard form:

    a) 65345 N
    b) 765 s
    c) 486856 W
    d) 0.987 cm^2
    e) 0.000567 F
    f) 0.0000605 C
    g) 0.03000045 J

4) Write down the solutions to these problems, giving your answer in standard form:

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

5) Calculate the following:

    a) 20mm in metres
    b) 3.5kg in grams
    c) 589000 µm in metres
    d) 1m^2 in cm^2 (careful)
    e) 38 cm^2 in m^2

6) Find the following:

    a) 365 days in seconds, written in standard form
    b) 3.0×10^{4} g written in kg
    c) 2.1×10^{6} Ω written in MΩ
    d) 5.9×10^{-7} m written in µm
    e) Which is bigger? 1452 pF or 0.234 nF

Mark = /27

2. Significant Figures

Number in Physics also show us how certain we are of a value. How sure are you that the width of this page is 210.30145 mm across? Using a ruler you could not be this precise. You would be more correct to state it as being 210 mm across, since a ruler can measure to the nearest millimetre.

To show the precision of a value we will quote it to the correct number of significant figures. But how can you tell which figures are significant?

The Rules

1. All non-zero digits are significant.
2. In a number with a decimal point, all zeros to the right of the right-most non-zero digit are significant.
3. In a number without a decimal point, trailing zeros may or may not be significant, you can only tell from the context.

Examples

Value	# of S.F.	Hints
23	2	There are two digits and both are non-zero, so are both significant
123.654	6	All digits are significant – this number has high precision
123.000	6	Trailing zeros after decimal are significant and claim the same high precision
0.000654	3	Leading zeros are only placeholders
100.32	5	Middle zeros are always significant
5400	2, 3 or 4	Are the zeros placeholders? You would have to check how the number was obtained

When taking many measurements with the same piece of measuring apparatus, all your data should have the same number of significant figures.

For example, measuring the width of my thumb in three different places with a micrometer:

20.91×10^{-3} m 21.22×10^{-3} m 21.00×10^{-3}m   all to 4 s.f

Significant Figures in Calculations

We must also show that calculated values recognise the precision of the values we put into a formula. We do this by giving our answer to the same number of significant figures as the least precise piece of data we use.

There is no way we can state the runners speed this precisely.

For example: A man runs 110 m in 13 s. Calculate his average speed.

Speed = Distance / Time = 110 m / 13 s = 8.461538461538461538461538461538 m/s

= 8.5 m/s to 2 s.f.

This is the same number of sig figs as the time, which is less precise than the distance.

Significant Figures - Questions

1) Write the following lengths to the stated number of significant figures:
   a) 5.0319 m to 3 s.f.
   b) 500.00 m to 2 s.f.
   c) 0.9567892159 m to 2 s.f.
   d) 0.000568 m to 1 s.f.

2) How many significant figures are the following numbers quoted to?
   a) 224.4343
   b) 0.000000000003244654
   c) 344012.34
   d) 456
   e) 4315.0002
   f) 200000 stars in a small galaxy
   g) 4.0

3) 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. ↑

4) Calculate the following and write your answer to the correct number of significant figures:
   a) 2.65 m x 3.015 m
   b) 22.37 cm x 3.10 cm
   c) 0.16 m x 0.02 m
   d) $\frac{54.401\ m^3}{4\ m}$

Mark = /19

3. Using Equations

You are expected to be able to manipulate formulae correctly and confidently. You must practise rearranging and substituting equations until it becomes second nature. We shall be using quantity symbols, and not words, to make the process easier.

Key points

- Whatever mathematical operation you apply to one side of an equation must be applied to the other.
- Don't try and tackle too many steps at once.

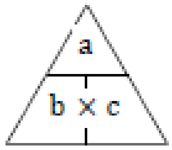
Simple formulae

The most straightforward formulae are of the form $a = b \times c$ (or more correctly $= bc$).

Rearrange to set b as the subject: Divide both sides through by c $\frac{a}{c} = \frac{b \times c}{c}$ therefore $\frac{a}{c} = b$

Rearrange to set c as the subject: Divide both sides through by b $\frac{a}{b} = \frac{b \times c}{b}$ therefore $\frac{a}{b} = a$

Alternatively you can use the formula triangle method. From the formula you know put the quantities into the triangle and then cover up the quantity you need to reveal the relationship between the other two quantities. This method only works for simple formulae, it doesn't work for some of the more complex relationships, so you must learn to rearrange.



More complex formulae

Formulae with more than 3 terms		Formulae with additions or subtractions		Formulae with squares or square roots	
Find ρ	$R = \frac{\rho l}{A}$	Find h	$Ek = hf - \Phi$	Find g	$T = 2\pi\sqrt{\frac{l}{g}}$
Divide by l	$\frac{R}{l} = \frac{\rho l}{Al}$	Add Φ	$Ek + \Phi = hf - \Phi + \Phi$	Square	$T^2 = 4\pi^2 \frac{l}{g}$
Cancel l	$\frac{R}{l} = \frac{\rho l}{Al}$	Cancel Φ	$Ek + \Phi = hf$	Multiply by g	$gT^2 = 4\pi^2 l$
Multiply by A	$\frac{R}{l} = \frac{\rho l}{Al}$	Divide by f	$\frac{Ek+\Phi}{f} = \frac{hf}{f}$	Divide by T^2	$g = \frac{4\pi^2 l}{T^2}$
Cancel A	$\frac{R}{l} = \frac{\rho l}{Al}$	Cancel f	$\frac{Ek+\Phi}{f} = h$		

Symbols on quantities

Sometimes the symbol for a quantity may be combined with some other identifying symbol to give more detail about that quantity. Here are some examples.

Symbol	Meaning
Δx	A change in x (difference between two values of x)
$\Delta x/\Delta t$	A rate of change of x
$\langle x \rangle$ or $\bar{x}$	Mean value of x
$\vec{x}$	Quantity x is a vector
x_1 x_2	Subscripts distinguish between same types of quantity

Using Equations - Questions

1) Make t the subject of each of the following equations:

   a) $V = u + at$

   b) $S = ½ at^2$

   c) $Y = k (t - t_0)$

   d) $F = \frac{mv}{t}$

   e) $Y = \frac{k}{t^2}$

   f) $Y = 2t^{1/2}$

   g) $v = \frac{\Delta s}{\Delta t}$

2) Solve each of the following equations to find the value of *t*:

   a) $30 = 3t - 3$

   b) $4(t + 5) = 28$

   c) $\frac{5}{t^2} = 10$

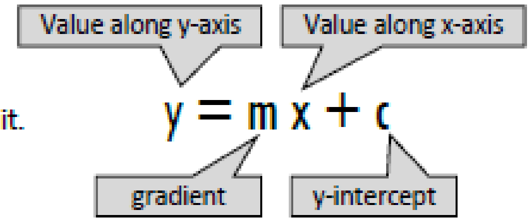
   d) $3t^2 = 36$

   e) $t^{-1/2} = 6$

   f) $t^{1/3} = 3$

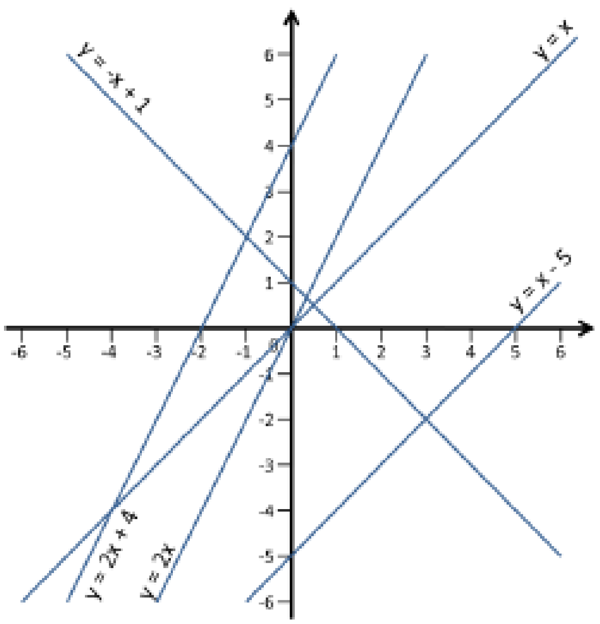
Mark = /13

4. Straight Line Graphs



If a graph is a straight line, then there is a formula that will describe it.

Here are some examples:



y = x	A positive line through the origin Gradient, m = 1 y-intercept, c = 0
y = x – 5	Parallel to y = x but transposed by -5. Gradient, m = 1 y-intercept, c = -5
y = 2x	A positive line through the origin Gradient, m = 2 y-intercept, c = 0
y = 2x + 4	Parallel to y = 2x ,transposed by 4. Gradient, m = 2 y-intercept, c = 4
y = -x + 1	A negative line, parallel to y = -x Gradient, m = -1 y-intercept, c = 1

DIRECTLY PROPORTIONAL describes any straight line through the origin. Both y α x and Δy α Δx

LINEAR describes any other straight line. Only Δy α Δx.

Using Straight Line Graphs in Physics

If asked to plot a graph of experimental data at GCSE, you would plot the *independent variable* along the x-axis and the *dependent variable* up the y-axis. Then you might be able to say something about how the two variables are related.

At A-Level, we need to be cleverer about our choice of axes. Often we will need to find a value which is not easy to measure. We take a relationship and manipulate it into the form y = mx + c to make this possible.

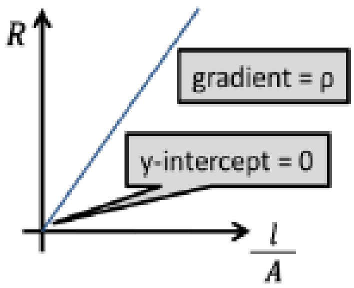
Example: $R = \frac{\rho l}{A}$ is the relationship between the resistance R of a conductor, the resistivity ρ of the material which it is made of, its length l, and its area A.

We do an experiment to find R, l and A, which are all easy to measure.
We want to find the resistivity ρ, which is harder.

This example doesn't need rearranging, just rewriting $R = \frac{\rho l}{A}$ into the shape y = mx + c:

R	$=$	ρ	$\frac{l}{A}$	
y		m	x	+ c

So it is found that by plotting R on the y-axis and l/A on the x-axis, the resitivity ρ will be the gradient of the graph.



Straight Line Graphs - Questions

1) For each of the following equations that represent straight line graphs, write down the gradient and the y intercept:

   a) $y = 5x + 6$

   b) $y = -8x + 2$

   c) $y = 7 - x$

   d) $2y = 8x - 3$

   e) $y + 4x = 10$

   f) $3x = 5(1-y)$

   g) $5x - 3 = 8y$

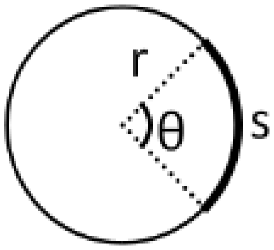
Mark = /14

5. Trigonometry

When dealing with vector quantities or systems involving circles, it will be necessary to use simple trigonometric relationships.

Angles and Arcs

There are two measurements of angles used in Physics.



- **Degrees** There are 360° in a circle
- **Radians** There are 2π radians in a circle

Whichever you use, make sure your calculator is in the correct mode!

To swap from one to the other you need to find what fraction of a circle you are interested in, and then multiply it by the number of degrees or radians in a circle.

$$\theta_{\text{radians}} = \frac{\theta_{\text{degrees}}}{360} \times 2\pi \quad \text{or} \quad \theta_{\text{degrees}} = \frac{\theta_{\text{radians}}}{2\pi} \times 360$$

For example: To convert 90° into radians: $\theta_{\text{radians}} = \frac{\theta_{\text{degrees}}}{360} \times 2\pi = \frac{90}{360} \times 2\pi = \frac{1}{4} \times 2\pi = \frac{\pi}{2}$ radians
(We tend to leave answers in radians as fractions of π)

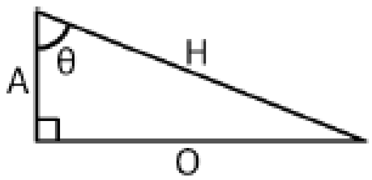
To find the length of an arc, use $s = \theta r$. The angle must be in radians. What would the relationship be if you wanted the entire circumference? Compare to this formula.

Sine, Cosine, Tangent

Recall from your GCSE studies the relationships between the lengths of the sides and the angles of right-angled triangles.

Using SOHCHATOA:

$\sin\theta = \frac{O}{H}$ $\cos\theta = \frac{A}{H}$ $\tan\theta = \frac{O}{A}$



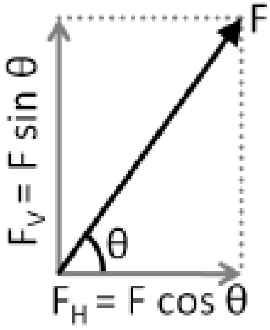
Vector Rules

A vector is a quantity which has two parts: SIZE and DIRECTION
(e.g. force, velocity, acceleration)

A scalar is a quantity which just has SIZE
(e.g. temperature, length, time, speed)

We represent vectors on diagrams with arrows.

To simplify problems in mechanics we will separate a vector into horizontal and vertical components. This is done using the trigonometry rules.



Trigonometry - Questions

1) Calculate:

   a) The circumference of a circle of radius 0.450 m

   b) the length of the arc of a circle of radius 0.450m for the following angles between the arc and the centre of the circle:

      i. 340°

      ii. 170°

      iii. 30°

2) For the triangle ABC shown, calculate:

   a) Angle θ if AB = 30cm and BC = 40cm

   b) Angle θ if AC = 80cm and AB = 35cm

   c) AB if $\theta = 36^\circ$ and BC = 50 mm

   d) BC if $\theta = 65^\circ$ and AC = 15 km

3) Calculate the horizontal component A and the vertical component B of a 65 N force at 40° above the horizontal.

Mark = /10

Mathematical Requirements

A summary of the mathematical requirements appears below. Once you have mastered a concept you can place a tick next to that part of the mathematical content. This will serve as a visual check on what you need to work on and what to ask the teaching staff for advice on.

1. Arithmetic and numerical computation

(a) recognise and use expressions in decimal and standard form

(b) use ratios, fractions and percentages

(c) use calculators to find and use power, exponential and logarithmic functions

(d) use calculators to handle $\sin x$, $\cos x$, $\tan x$ when x is expressed in degrees or radians

2. Handling data

(a) use appropriate number of significant figures

(b) find arithmetic means

(c) make order of magnitude calculations

3. Algebra

(a) understand and use the symbols $= < > \approx$

(b) change the subject of an equation

(c) substitute numerical values into algebraic equations using appropriate units for physical quantities

(d) solve simple algebraic equations

4. Graphs

(a) translate information between graphical, numerical and algebraic forms

(b) plot two variables from experimental or other data

(c) understand that $y = mx + c$ represents a linear relationship

(d) determine the slope and intercept of a linear graph

(e) draw and use the slope of a tangent to a curve as a measure of rate of change

(f) understand the possible physical significance of the area between a curve and the x axis and be able to calculate it or measure it by counting squares as appropriate

(g) use logarithmic plots to test exponential and power law variations

(h) sketch simple functions including $y = k/x$; $y = kx^2$; $y = sin x$; $y = cos x$; $y = e^{-x}$

5. Geometry and trigonometry

(a) calculate areas of triangles, circumferences and ares of circles, surface areas and volumes of rectangular blocks, cylinders and spheres

(b) use Pythagoras' theorem, and the angle sum of a triangle

(c) use sin, cos and tan in physical problems

(d) understand the relationship between degrees and radians and translate from one to the other

(e) use relationship for triangles: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$