Carre’s Grammar School

A-level Physics

Key information and summer transition work

Specification at a glance

We follow the OCR Advanced GCE Physics A course (code: H556). It is a two-year course with content from both Years 12 and 13 being examined at the end of Year 13.

Throughout both Years 12 and 13, you will study content relating to Modules 1 (Development of practical skills in physics) and 2 (Foundations of physics)

In Year 12, you will study Modules 3 and 4, and in Year 13 you will study Modules 5 and 6.

Module 3 – Forces and motion	**Module 4 – Electrons, waves and photons**	**Module 5 – The Newtonian World**	**Module 6 – Particles and medical physics**
• Kinematics • Dynamics • Work, energy and power • Materials • Newton's laws of motion and momentum	• Charge and current • Energy, power and resistance • Electrical circuits • Waves • Quantum physics	• Thermal physics • Circular motion • Oscillations • Gravitational fields • Astrophysics and cosmology	• Capacitors • Electric fields • Electromagnetism • Particle and nuclear physics • Medical imaging

At the end of Year 13, you will sit three exams covering content from both years.

Paper	**Modules**	**Duration and marks**	**Weighting**
H556/01 Modelling Physics	1, 2, 3 and 4	2 hours 15 minutes 100 marks	37% of A-level
H556/02 Exploring Physics	1, 2, 5 and 6	2 hours 15 minutes 100 marks	37% of A-level
H556/03 Unified Physics	All modules, including synoptic questions and practical methods.	1 hour 30 minutes 70 marks	26% of A-level

Alongside the A-level, you will also be carrying out PAGs which will be assessed for the purposes of the practical endorsement. This is not graded, it is can only be passed or failed, and is separate to the grading of the A-level (i.e. you can fail the practical endorsement but still get an A* in the A-level!). That being said, most science degree courses now require a pass in the practical endorsement as well as a good grade in the A-level so don't neglect this element of the course. It should also be noted that you could be examined on these practical techniques and skills in any of the exam.

SUMMER TRANSITION WORK

Over the next pages, there are notes and worksheets about key basic principles in physics that you will be required to understand throughout the course.

Over the holidays, you will need to read through each section (and you may wish to make your own notes as you go through them). Then you should complete the questions at the end of the booklet which will be collected in and marked at the beginning of Year 12.

If something does not make sense, then you should read around the subject material using other textbooks, revision guides or the internet to consolidate your understanding.

This work should not be left to the last minute, or taken lightly. It is important that you develop good independent study skills to ensure that you can cope with the demands of the A-level course.

To check that you have understood and learned the concepts covered, you will also be given a test at the beginning of Year 12 on the content of this booklet. A poor mark in this assessment will indicate that you are not prepared to study A-level physics and we will meet to discuss what needs to happen.

QUANTITIES AND UNITS

Powers of ten

When we want to give a rough estimate of a quantity in physics, we normally quote a power of ten. For example, a car has a mass of approximately 1000kg so we would write this as 10^3kg. This is particularly useful for very large quantities, such as the size of the Universe, and very small quantities, such as the mass of an electron (of the order 10^{-30}kg).

Standard form and significant figures

Powers of ten are useful for rough ideas, but we would normally quote quantities in standard form. This enables quick comparisons between different quantities, and is particularly useful for expressing very large and very small quantities. e.g.

Charge on a proton = +0.00000000000000000016C = $+1.6 \times 10^{-19}$C

It is also important in physics to quote data to an appropriate number of significant figures so as to indicate the level of precision in your measurements. It would be wrong to quote answers as fractions or surds because this indicates that there is no error in your measurements, something that is impossible!

In calculation questions, always quote your final answer to the same number of significant figures as the data given to you in the question. e.g.

Calculate the speed of a car that travels 13.3m in 2.13s

The data in the question is given to 3 significant figures, so your final answer needs to be to 3sf. i.e.

$$v = \frac{s}{t} = \frac{13.3}{2.13} = 6.24413\ldots = 6.24\ m\ s^{-1}\ (to\ 3s.f.)$$

Units

In physics, there are seven SI base units which are:

Quantity	Unit	Unit symbol
Length	metre	m
Time	second	s
Mass	kilogram	kg
Electrical current	ampere	A
Absolute temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

All other units are made from combinations of these seven units and are so-called derived units. For example, the newton is derived using $F = ma$

$$1N = 1kg \times 1\, m\, s^{-2} = 1kg\, m\, s^{-2}$$

You must always give quantities with the appropriate unit, though some quantities do not have a unit (such as strain and refractive index).

Prefixes

To reduce the amount of writing required (because scientists are lazy!), we sometimes add a prefix to units which add a power of ten to the unit. You will be most familiar with the prefix *kilo-* which means 10^3. There are many prefixes but the most important ones you need to know are:

Prefix	Symbol	Power of ten
femto-	f	10^{-15}
pico-	p	10^{-12}
nano-	n	10^{-9}
micro-	µ	10^{-6}
milli-	m	10^{-3}
centi-	c	10^{-2}
kilo-	k	10^{3}
mega-	M	10^{6}
giga-	G	10^{9}
tera-	T	10^{12}

QUANTITIES AND UNITS QUESTIONS

1) Write the following as powers of ten:
   a) 100
   b) 1 000 000
   c) 1/10
   d) 1/10 000

2) Write the following as numbers or fractions
   a) 10^3
   b) 10^5
   c) 10^{-3}
   d) 10^{-7}

3) Express the following in standard form:
   a) 156
   b) 21720
   c) 0.7327
   d) 0.0056

4) Evaluate
   a) $10^2 \times 10^3$
   b) $10^5/10^7$
   c) $5 \times 10^6 \times 3 \times 10^2$
   d) $2.8 \times 10^4 \times 7.0 \times 10^2$

5) Express the volt in base units (p.d. in V = work done ÷ charge).

6) A brass wire has diameter 2mm and length 2m. Calculate:
   a) its volume ($= \pi r^2$h)
   b) its mass (density of brass is 7800kg m^{-3}; mass = density x volume)

7) The circumference of the Earth is 40 000km to the nearest 1000km. The mass of the Earth is approximately$6 \times 10^{24} kg$. Calculate
   a) its radius in m, in standard form ($circumference = 2\pi r$),
   b) its volume in m^3 ($volume\ of\ a\ sphere = \frac{4\pi r^3}{3}$), and
   c) its average density.

8) Write out the units for each side of the equation in SI base units to show that the units match on both sides of the equation (this is called checking the homogeneity of the equation).
   a) $2as = v^2$
   b) $E_k = \frac{1}{2}mv^2$
   c) $P = I^2R$
   d) $F = \frac{mv^2}{r}$

9) Give things with quantities in the correct order of magnitude.
   a) What is 10^6 pence in £?
   b) What has a mass of approximately 10^2 kg?
   c) What is roughly 10^6m across?
   d) What has a mass of 10^{24}kg?
   e) How long is 10^6 s in days?

10) Just in powers of 10 and in SI units, roughly:
   a) How big is an atom?
   b) How big is a nucleus?
   c) How big is a lightwave?
   d) How heavy is a car?
   e) How long is a week?
   f) How heavy is a cubic metre of water?
   g) How far round is the Earth?

11) What powers of 10 do these multipliers represent? M m c k G

12) Give the prefix in words for: 10^6 10^{-6} 10^{-9} 10^{-12} 10^{12}

13) Express in standard form: 27MΩ 0.0054mA 19kPa 721nC 99GHz

14) Express using prefixes and numbers in the range 1-999
   a) 77 000Ω
   b) 101 300Pa (mean atmospheric pressure)
   c) 0.000 06V
   d) 2500g
   e) 0.076 kilo trombones

15) Convert:
   a) 1mm^3 to m^3
   b) 1cm^2 to m^2
   c) 25cm^2 to m^2

16) A sheet of paper measures $120cm \times 90cm$. Calculate its area in m^2. The packaging states that this is 80gsm (grams per square metre) paper, just like your printer uses! Find the mass of the sheet of paper in kilograms.

UNCERTAINTIES

When a value is measured, a lack of *precision* leads to measured values being scattered either side of the "true" value. An **uncertainty** is how much spread about the true value is caused by the limit of precision of the measuring device being used.

Determining absolute uncertainties in experimental work

To estimate the absolute uncertainty in your readings, you take the largest of either:

1. **half the range from the lowest to the highest value obtained**.
2. the **precision** of the instrument (**the smallest scale division**)

Exercise: Give the uncertainties of the following readings if no variation was seen between the results:

1. Length of a wire using a metre rule,
2. Diameter of a marble using a micrometre screw gauge,
3. Time of 10 oscillations of a pendulum using a stop watch,
4. Current using a digital multimeter,
5. Force using a newtonmeter with a maximum reading of 10N,
6. Angles between light ray traces using a simple protractor,
7. Temperature using a mercury thermometer in the range 0°C to 110°C,
8. Speed using a typical car speedometer.

Combining Absolute Uncertainties:

Adding and subtracting quantities

The maximum possible uncertainty in the result of two numbers added or subtracted is the *sum* of the individual uncertainties.

e.g. if the masses of three individual objects are 5.0 ± 0.1 kg, 6.2 ± 0.2 kg, and 3.1 ± 0.1 kg, the total mass can be expressed as 14.3 ± 0.4 kg.

Exercise:

1. An empty beaker has a mass of 100 ± 5g. The beaker with added water has a measured mass of 128 ± 5g. What is the mass of the water and what is the maximum uncertainty?
2. Three metal rods of length 9.4 ± 0.2 mm, 15.4 ± 0.2 mm, 4.3 ± 0.1 mm are laid end to end. What is the total length of the combination and the maximum possible uncertainty?
3. The ceiling is 2.30 ± 0.01m high. Dr Martin is 2.00 ± 0.05m tall (he bobs up and down while walking!) What is his clearance with the ceiling?

Note: ALWAYS quote errors to 1 significant figure, and then quote your value to the same number of decimal places as the error.

Percentage uncertainties

The **percentage uncertainty** is the uncertainty as a percentage of the measured value. It is calculated using:

$$Percentage\ uncertainty = \frac{Uncertainty}{Measured\ value} \times 100\%$$

Exercise: Find the percentage uncertainties of the following

1. Length of a pen measured using a ruler with a millimetre scale as 20.0cm,
2. Time for a ball bearing to reach the floor when dropped from rest measured as 12.11s using a stopclock,
3. Temperature of a beaker of water measured as 52°C using a mercury thermometer.

Multiplying and dividing quantities

When quantities are multiplied or divided, the **percentage uncertainties of each are added together**. E.g.

To find the area of a rectangle of length 5.0 ± 0.1cm and width 7.0 ± 0.1cm.
Percentage uncertainties are $\frac{0.1}{5.0} \times 100\% = 2.0\%$ and $\frac{0.1}{7.0} \times 100\% = 1.4\%$
Add the percentage uncertainties: 2.0% + 1.4% = 3.4%
Thus the area = 35.0 cm^2 ± 3.4% = 35.0 ± 1.2cm^2 (or just 35 ± 1cm^2)

Exercise: Find the result and the total uncertainty in the following examples:

1. Using $P = I^2R$, find P, where R = 22 ± 2 Ω, and I = 0.50 ± 0.02 A.
2. Using $V = \pi r^2 h$, find V, where h = 0.46 ± 0.01 m and r = 0.15 ± 0.01m.
3. Find the Young Modulus, E from: $E = \frac{FL}{A\Delta x}$, $A = \pi \left(\frac{d}{2}\right)^2$ where F = 90 ± 1 N, L = 1.5 ± 0.1 m, d = 0.75 ± 0.05mm, Δx = 3.5 ± 0.2 mm.
4. Find the centripetal force: $F = mr\omega^2$ where m = 0.5 ± 1%, r = 0.32 ± 0.02 m, $\omega = 0.62 \pm 0.03$ rad s^{-1}.
5. Find the acceleration due to gravity: g from the pendulum equation: $T = 2\pi\sqrt{\frac{l}{g}}$
   where T = 2.16 ± 0.01s and l = 1.150 ± 0.005 m.
6. **This equation gives the volume flow rate through a hypodermic needle:
   $$\frac{V}{t} = \frac{\pi r^4(p_1 - p_2)}{8\eta L}$$ (much harder!)
   where r (radius) = 0.43 ± 0.01 mm, L (length) = 5.5 ± 0.1 cm
   (pressures:) p_1= (1.150 ± 0.005) × 10^5 Pa, p_2= (1.000 ± 0.005) × 10^5 Pa
   V (volume) = 10.0 ± 0.1 cm^3, t (time) = 4.0 ± 0.1s,
   Calculate the constant, η, (which is called *viscosity*) and its uncertainty.

**Extremely difficult – you can skip this one if you like!

PRESENTING DATA IN TABLES

Here is some data for an experiment looking at how resistance of a variable resistor affects the current through the resistor.

R/Ω	**I/A**			**I_{mean}/A**
	1	**2**	**3**	
2.2	0.66	0.64	0.70	0.67
3.3	0.50	0.49	0.52	0.50
4.7	0.40	0.41	0.44	0.42
6.8	0.36	0.35	0.36	0.36
10.0	0.34	0.60	0.31	0.33
22.0	0.25	0.26	0.25	0.25
100.0	0.20	0.24	0.22	0.22

This table has been correctly laid out since:

- Each heading is complete with a quantity and its unit, separated by a /
- Within each column, the data is given to the same number of decimal places.
- No units appear in the body of the table, only in the headings.
- The anomaly has been highlighted (ideally this reading would be repeated and the anomaly not recorded at all).
- Means have been calculated and rounded to the same number of decimal places.
- The anomaly has not been included in the calculation of the mean for the 10.0Ω resistance.

Tasks

1) Estimate the uncertainty in each of sets of readings in the table.
2) Produce a similar table for the following data about the speed of a car for different times of its journey down a ramp.

1.42s: 6.2 m s^{-1}, 6.3 m s^{-1}

1.76s: 7.8 m s^{-1}, 7.6 m s^{-1}

2.34s: 9.9 m s^{-1}, 9.6 m s^{-1}

2.5s: 10.4 m s^{-1}, 10.7 m s^{-1}

3s: 12.5 m s^{-1}, 12.3 m s^{-1}

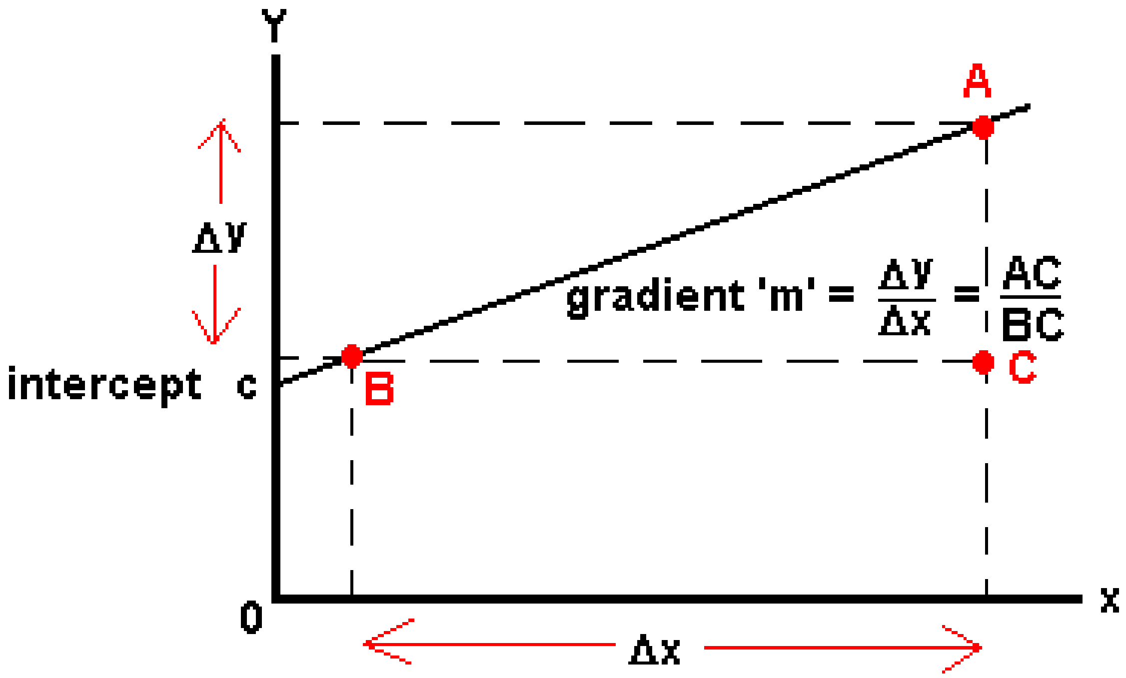
<u>Straight line graphs</u>

Relationships between physical quantities may take many algebraic forms, some of which can be hard to recognise and which certainly are hard to process in a quantitative way. Verifying the form of such relationships can enable us to check that the models we create are correct and we have our ideas right.

The easiest form both to recognise and manipulate is the straight line. You will be familiar with the generalised form of the straight line as:

$y = mx + c$ m is the gradient

c is the y-intercept (where the line crosses the y-axis)



We will use your algebra skills from GCSE to manipulate other graphical forms into linear ones. We can then extract information by measuring the gradient and the intercept. Some of this should become quite routine as a procedure, but there is also scope for some ingenuity.

As a simple example, you may have seen this before that for an object dropped from rest, the distance it will travel is given by the equation: $h = {gt^2}/{2}$

Clearly this is a quadratic function, so plotting h vs t will produce a parabola which is not very helpful if we want to calculate g. However, it should also be apparent that:

$$h \propto t^2$$

so plotting h vs t^2 will produce a straight line. Direct proportionality menas that the line passes through the origin (i.e. a zero intercept) and a gradient of ${g}/{2}$. Therefore determining the gradient and doubling it will yield a value for g.

Similarly, this equation tells us how the voltage output of an electrical power source varies when the current is drawn from it changes.

$\varepsilon = V + Ir$ where ε and r are both constants.

Here plotting V vs I will yield both ε, as the intercept, and r, as the (negative) gradient. This can be seen by rearranging the equation and comparing to the general equation for a straight line, $y = m\ x + c$

$$V = -r\,I\ + \varepsilon$$

Finally, before you get started on some uses of all this, don't forget about good practice when using graphical methods:

- Plot points as **X**, not just dots.
- Label axes and indicate units, e.g. R/Ω etc.
- Make graphs that fill **at least 50%** of the page – no postage stamps! In other words, if your scale could be doubled, all the points would no longer fit on the page. If that means not including the origin on your graph, that is fine.
- Big triangles to determine gradients (at least 8cm on the smallest side!)
- Draw smooth curves, not dot-to-dot or sketches.
- Beware false origins (i.e. not starting at least one of your axes at 0) – the gradient will be ok but the intercept will be wrong!

EXAMPLES

1) What combinations of variables might you plot to give a straight line if the expected relationships between them are as indicated by the equations below? What will the gradient and the y-intercept represent?

a) $P = {V^2}/{R}$ R fixed

b) $pV = k$ k fixed (Boyle)

c) $P = \sigma A T^4$ σ, A fixed (Stefan)

2) The time period for a mass, m, bouncing up and down on a spring is:

$$T = 2\pi\sqrt{{m}/{k}}$$ where k is the spring constant.

Given measurements of T and m, what graph might you plot to kind k and how would you then proceed?

3) The magnification of an image produced by a converging lens of focal length, f, is related to the image distance, v, by the equation:

$$M = \frac{v}{f} - 1$$

In an experiment, the following values are recorded:

v/cm	20.7	23.2	26.3	30.4	34.8	44.5	54
M	1.00	1.25	1.55	1.90	2.35	3.25	4.25

Use this information to plot a linear graph and hence determine the value of f.

(Why do you not need to bother about a true origin? Why are there no units for M?)

Checklist

I can…	✓
…give estimates of quantities using powers of ten.	
…quote quantities in standard form.	
…give quantities to an appropriate number of significant figures	
…recall the seven SI base quantities and units.	
…express derived units in terms of the SI base units.	
…recall and use the significant prefixes.	
…estimate the absolute uncertainty in a set of readings.	
…combine uncertainties when quantities are added or subtracted.	
…calculate percentage uncertainties.	
…combine uncertainties when quantities are multiplied or divided.	
…draw tables accurately.	
…plot graphs accurately.	
…determine the gradient and y-intercept of a straight-line graph.	
…use a given equation to suggest suitable variables to be plotted on the x- and y-axes to give a straight line graph.	
…give the physical significance of a gradient or y-intercept using a given equation.	