A LEVEL PHYSICS
GCSE TO A LEVEL TRANSITION BOOK
STUDENT BOOK

NAME	
FORM	
SUBJECT TEACHER	

Complete Sections 4 and 5 for summer work.

This will be collected in at the **end of the first teaching week** in 2019-2020.

SECTIONS

SECTION 0: COURSE INFORMATION

SECTION 1: MATHS GUIDE

SECTION 2: PRACTICAL GUIDE

SECTION 3: PHYSICS GUIDE

SECTION 4: THEORETICAL PROBLEM SOLVING

SECTION 5: PRACTICAL PROBLEM SOLVING

INSTRUCTIONS

The following transition booklet is a resource to help you understand and adapt to the demands of the A-Level Physics course.

This booklet, in sections 0-3, will provide essential information and key skills on how to solve the questions posed on this course. In addition, the booklet will explain the key concepts covered on the course and how you will be assessed. **You should highlight the key information in these sections.** There are several revision questions throughout the section, these questions are **optional** but you may feel the benefit of attempting them.

Finally, in sections 4 and 5, there are several problem-solving tasks. **These tasks are similar to the style of questioning faced in your A-Level examinations.**
Please complete Section 4 and 5 for the first week of the course starting in September. Completing these tasks will allow you to see the demand you face on the course.

Once completed, please place this transition booklet into your Physics Assessment Folder.
This will be a useful resource in preparation for your A-Level exams.

Thank you for reading this booklet and good luck!

SECTION 0: COURSE INFORMATION

This section contains information on the structure of the A-Level Physics course.

In this section, it is advised you read the information and highlight the key information.

Course Overview

To successfully achieve a qualification in A-Level Physics students must carry out two years of studies (Year 12 and Year 13) and carry out 3 assessments at the end of the course based on the specification below.

In addition, students must carry out a list of 12 required practical activities that they must carry out.

Exam questions will be based on these practicals. 6 practicals will be carried out in Year 12 and 6 practicals will be carried out in Year 13. If successful, students will receive a practical endorsement along with their A-Level Physics qualification.

First year of A-level (Year 12)

1. Measurements and their errors, including use of SI units and their prefixes, limitations of physical measurement, estimation of physical quantities

2. Particles and radiation, including constituents of the atom, particle interactions, collisions of electrons with atoms.

3. Waves, including progressive waves, interference, diffraction.

4. Mechanics and energy, including projectile motion, Newton's laws of motion.

5. Electricity, including current/ voltage characteristics, circuits, electromotive force and internal resistance.

Second year of A-level (Year 13)

6. Further mechanics and thermal physics, including periodic motion, thermal energy transfer, and molecular kinetic theory model.

This is completed in Year 12 at St. Mary's.

7. Fields, including Newton's law of gravitation, orbits of planets and satellites, magnetic flux density.

8. Nuclear physics, including evidence for the nucleus, radioactive decay, nuclear instability.

In addition, one option from:

- Astrophysics, including classification of stars by luminosity, Doppler Effect, detection of exoplanets.
- Medical physics, including physics of vision, ECG machines, x-ray imaging.
- Engineering physics, including rotational dynamics, thermodynamics and engines.
- Turning points in physics, including discovery of the electron, Einstein's theory of special relativity.
- Electronics, including discrete semiconductor devices, data communication systems.

Students will be awarded with a practical endorsement qualification if students complete all 12 required practical to the required competency standard of the exam board.

The required practicals will be completed during lesson time where appropriate with the specification.

Examinations

To gain a qualification in A Level Physics – you must sit three examinations. The course content is split over the examinations as following…

Paper 1	+	Paper 2	+	Paper 3
Content • Topics 1 – 5 • and periodic motion		**Content** • Topics 6 – 8		**Content** • Practical skills • Data analysis • Optional topic
Assessment • Written exam: 2 hours • 85 marks • 34% of A-level		**Assessment** • Written exam: 2 hours • 85 marks • 34% of A-level		**Assessment** • Written exam: 2 hours • 80 marks • 32% of A-level
Questions • 60 marks: a mixture of short and long answer questions • 25 marks: multiple choice questions		**Questions** • 60 marks: a mixture of short and long answer questions • 25 marks: multiple choice questions		**Questions** • 45 marks: questions on practical experiments and data analysis • 35 marks: questions on optional topic

The marks awarded on the papers will be scaled to meet the weighting of the components. Students' final marks will be calculated by adding together the scaled marks for each component. Grade boundaries will be set using this total scaled mark. The scaling and total scaled marks are shown in the table below.

Component	Maximum raw mark	Scaling factor	Maximum scaled mark
Paper 1	85	x1	85
Paper 2	85	x1	85
Paper 3: Section A	45	x1	45
Paper 3: Section B (Astrophysics – option)	35	x1	35
Paper 3: Section B (Medical physics – option)	35	x1	35
Paper 3: Section B (Engineering physics – option)	35	x1	35
Paper 3: Section B (Turning points in physics – option)	35	x1	35
Paper 3: Section B (Electronics – option)	35	x1	35
		Total scaled mark:	250

The recommended option choice for the course is Astrophysics.

Specification Links

There is a great deal of overlap between A-Level Physics and the GCSE Physics qualification you have completed in Year 11.

The A-Level specification builds and extends the concepts covered at GCSE Physics.

The chart below shows the concepts covered at GCSE Physics which are shared content with the A-Level Physics.
This will provide you will an understanding on the base knowledge required for the A-Level modules.

Module 1: Waves

Properties of waves

Wave speed

Transverse and longitudinal waves

Reflection

Refraction

Ultrasound (GCSE Physics **only**)

Sound Waves (GCSE Physics **only**)

Module 2: Particles

Energy levels

Models of the atom

Isotopes

Mass number

Atomic number

Module 3: Mechanics and Materials

Hooke's Law

Energy Stores

Work Done

Power

Momentum

Impulse (GCSE Physics **only**)

Moments (GCSE Physics **only**)

Vectors and scalars

Vector addition

Motion graphs

Acceleration and velocity

Newton's laws

Equations of motion (SUVAT)

Module 4: Electricity

Current

Potential difference

I-V graphs

Resistance in series and parallel

Semi-conductors

Electrical work done

Module 5: Periodic Motion

Circular motion (GCSE Physics only)

Energy conservation

Module 6: Gravitational Fields

Orbits (GCSE Physics **only**)

Non-contact forces

Module 7: Electric Fields

Electric field lines (GCSE Physics **only**)

Static charge (GCSE Physics **only)**

Non-contact forces

Module 7: Capacitors

Electric charge

Module 8: Thermal Physics

Specific latent heat

Specific heat capacity

Internal energy

Particle model of matter

Gas motion

Gas pressure

Changes in gas pressure (GCSE Physics **only**)

Module 9: Magnetic Fields

Magnets

Magnetic fields

Electromagnetism

Motor effect

Lorentz force

Induction

Alternating current

Generator (GCSE Physics **only**)

Dynamo (GCSE Physics **only**)

Transformer (GCSE Physics **only**)

Module 10: Nuclear Physics

Nuclear decay

Instability

Half life

Uses of radioactive isotopes

Alpha, beta and gamma decay

Nuclear contamination

Nuclear fission (GCSE Physics **only**)

Nuclear fusion (GCSE Physics **only**)

Background radiation (GCSE Physics **only**)

SECTION 1: MATHS GUIDE

In this section, it is advised you read through the information and highlight the key information.

If needed attempt the practice questions found in this section.

Congratulations on choosing A level physics!

You will probably have heard that it is challenging or that there's 'lots of maths' in it. You might even know that the syllabus changed in 2015 and there is now 'even more maths' in it.

Many physics students are very competent at and interested in maths but, if that's not you, don't worry: it's true that there are several number-related skills to master to be good at physics (indeed, that's one of the reasons why physics graduates are in demand for all the best jobs) but you won't need most of the topics you studied for your maths GCSE.

Physics is about real-life, practical, useful things. We've discovered that many things in nature follow the same kinds of patterns: for example, you might have learned about electricity using an analogy about water flow or about radioactivity by rolling dice.

We use maths in physics because it's good for describing patterns clearly and because it lets us put a number on things: rather than just saying something increases we'd like to be able to say by how much.

So we tend to look at equations a bit differently than your maths teachers. We see our equations as pictures: pictures of the real life situation that the maths is describing.

The other thing that makes our equations different is that, unlike the maths department, we almost never mean them to be exact. Nature is complex so most situations don't quite perfectly fit the patterns we have discovered and in any case, we can never measure things perfectly.

So, all our equations are approximate to some extent, or only work in certain situations.

Maths in Physics

Here is a guideline to the mathematical skills required for A-Level Physics

Mathematical Skills Needed at A-Level Year 1	Mathematical Skills Needed at A-Level Year 2
Using formulae (Including squared terms and square root terms). Re-arranging formulae (Including squared terms and square root terms). Tabulating data. Rounding data to correct decimal places and significant figures. Plotting linear graphs. Drawing lines of best fit on simple graphs. Calculating gradients of lines and tangents. Using ratios to derive simple terms. Simple trigonometry. Calculating means and ranges. Calculating percentage and percentage difference values. Proving linear relationships. Using 'y = mx + c' for straight-line graphs. **All mathematical skills will be taught to students during the A-Level Physics course where appropriate.** **A-Level Mathematics is NOT essential for A-Level Physics.** However, the subjects complement each other. All the mathematical skills required for A-Level Physics will also appear in A-Level Mathematics.	Using formulae (Including squared terms, square root terms, ln terms and e terms). Re-arranging formulae (Including squared terms, square root terms, ln terms and e terms). Tabulating data. Rounding data to correct decimal places and significant figures. Plotting linear graphs. Plotting log graphs. Drawing lines of best fit on simple graphs. Drawing lines of best fit on complex graphs. Calculating gradients of lines and tangents. Using ratios to derive simple terms. Using ratios to derive complex terms (terms with mathematical functions such as squares). Simple trigonometry. Calculating means and ranges. Calculating percentage and percentage difference values. Proving linear relationships. Proving exponential relationships. Using 'y = mx + c' for straight-line graphs. Using 'y = mx + c' for straight-line log graphs.

The only difference between A-Level Physics and GCSE Maths is the use of logarithms and exponentials. This will be taught explicitly in lessons. Do not worry.

Using Maths in Physics

The better you can visualise the patterns and understand the limits of equations in physics, the easier you will find it.

This booklet aims to give you some pointers to, and some practice, in those bits of maths that come up a lot in A level physics. It also shows you the calculation skills you need to practise so that you can find answers quickly and check they are reasonable. They might seem daunting at first but don't be put off: **like anything else that is worth doing, you will only get good at them through practice.**

Standard Form, Units, Prefixes and Significant Figures

You will probably be familiar with these ideas from GCSE maths and science but you will meet more challenging examples at A level such as:

- Conversion of complex units such as those for density, for example from g cm^{-3} to kg m^{-3}
- Using more unit prefixes e.g. nano-, giga- and micro-
- Learning more about measurements and significant figures (sf).

Unit Prefixes

In Physics, you must able to recognise prefixes and convert values into base quantities.

Such as……

k = x 10^3 m = x 10^{-3} n = x 10^{-9} μ = x 10^{-6} M = x 10^6

G = x 10^9

This is shown in the following example….

Worked example

An ultrasound pulse travels through a metal bar and reflects off a defect inside the bar. The time for the pulse echo to be detected is 12 μs. The speed of ultrasound in the bar is 1.1 km s^{-1}. Calculate the distance between the defect and the bar's surface in mm.

Answer

$d = vt$

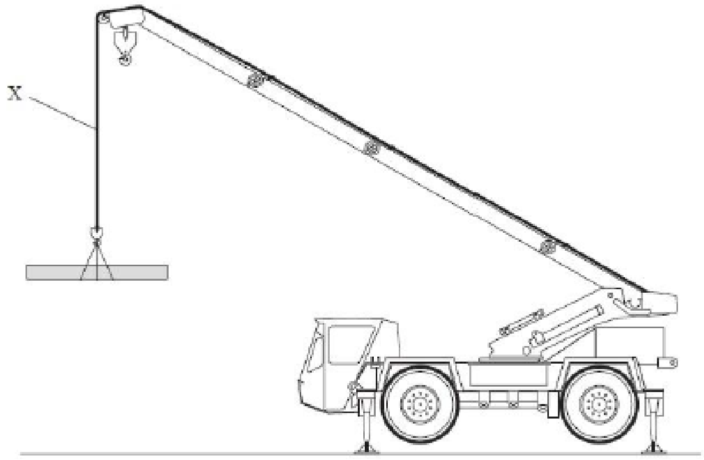
$= 1.1 \times 10^3 \times (½ \times 12 \times 10^{-6})$

$= 6.6 \times 10^{-3}$ m

$= 6.6$ mm

Practice question 1

The diagram shows a crane lifting a concrete beam.



Weight of beam = 13 kN diameter of steel cable = 1.1 cm

Show that the stress in the cable at point X is about 0.1 GPa.

Tip

Stress = Force / Cross Sectional Area

Cross Sectional Area = π (Diameter/2)^2

Tip

Remember to convert the prefixes.

Deriving Base Units

Considering the units of quantities will help both in certain exam questions such as the example below but also in problem solving where the units of the answer can show you how to get started with the problem.

In the following example, we can use mathematical equations to derive the units of quantities.

Tip: think of the **number of** electrons, photons etc. like a unit – that way electrons and anything else that is **per electron** will cancel. Never write them as if they are a unit however because they are not part of SI and therefore technically not correct as units.

Worked example

The current I in a length of aluminium of cross-sectional area A is given by the formula

$$I = nevA$$

where e is the charge on an electron.

Show that the units on the left-hand side of the equation are consistent with those on the right-hand side.

Answer

Write out the units for each quantity. In this example we're thinking of the ones as being electrons (but not writing it this way).

$$nevA = \frac{\cancel{1}}{\cancel{m^3}} \quad \frac{C}{\cancel{1}} \quad \frac{\cancel{m}}{s} \quad \cancel{m^2}$$

$$= C\,s^{-1}$$

$$= A$$

This derivation of the units of quantities can be used to prove an equation is correct.
This derivation allows you to understand what the units of a quantity is.

When converting unfamiliar units, it might help you to think of a conversion factor having two units: for example, there are 1000 m per km so it's 1000 m km^{-1}.

Then when you multiply km by km^{-1} (or if you divide m by m) they cancel.

Cancelling out units can be shortcut to finding answers in Physics problems.

Worked example

The specific heat capacity of aluminium is 900 J kg^{-1} K^{-1}.

Convert this to kJ mol^{-1} K^{-1} (M_r aluminium is 27 g mol^{-1}).

Answer

M_r is 27 g mol^{-1} = 27 $\cancel{g}$ mol^{-1} ÷ 1000 $\cancel{g}$ kg^{-1} = 0.027 kg mol^{-1}

For kJ the conversion is 1000 J kJ^{-1}

Specific heat capacity = 900 J kg^{-1} K^{-1}

= (900 $\cancel{J}$ $\cancel{kg}^{-1}$ K^{-1} ÷ 1000 $\cancel{J}$ kJ^{-1}) × 0.027 $\cancel{kg}$ mol^{-1}

= 0.0243 kJ mol^{-1} K^{-1}

Practice question 2

A submarine has a volume of 7100 m^3. Calculate the upthrust force.

Density of sea water = 1.03 g cm^{-3}

Tip

Upthrust = Density x Volume x Gravitational Field Strength

Estimations

It is always advised in Physics to roughly estimate answers to check that your solutions to difficult problems could be correct.

It is useful to be able to do a sum roughly in your head to make sure the answer is sensible and that you did not make a calculator error.

You will find this hard at first, but keep practising: your physics teacher is probably very good at it following many years of practice! Using standard form, do all the numbers roughly first, then work out the powers separately: finally change the answer to standard form.

For example:

$$\frac{1.60\times10^{-19}}{9.11\times10^{-31}}\approx\frac{2}{10}\times10^{(-19--31)}=0.2\times10^{12}=2\times10^{11}$$

This shows your answer to the solution should be in the approximate region of ~ x 10^{11}.

This should only be a quick activity to allow you to guide to your correct answer.

If you do not get this answer, you may wish to check your working out.

Transformation of Formulae

In maths, this is called 'changing the subject of a formula'.

You might have used the 'magic triangle' approach before, but for A level you will meet more complex formulae and you will need to learn the 'proper' maths technique now.
It can be difficult at first, but practice makes perfect!

Tip: when a new formula is introduced, practise transposing it to make each variable the subject

One situation you might find confusing is if you have a fraction on the bottom of a fraction. For example:

$$\frac{14.6}{\frac{7.3}{2}}$$

In this situation just move the bottom of the bottom to the top – in other words:

$$\frac{2 \times 14.6}{7.3}$$

Practice question

Calculate the angular velocity of a satellite that makes 8 complete orbits in 3 days.

Tip

Angular Displacement = Angular Velocity x Time

This can be difficult skill to master, but it is very useful in the long run.

Estimation

Examination questions might ask you to estimate the value of a familiar quantity such as the volume of a house.
This kind of question can be daunting at first but you will find it becomes easier with practice and it can be fun to make up questions of your own.

To become good at estimating you need to be able to make assumptions to simplify the problem, to have a rough idea of the sizes of some everyday things (at least the nearest factor of 10) and to be able to combine those using physics ideas.

For example, to estimate the weight of the air in an average house we might use.

$$\text{mass} = \text{density} \times \text{volume}$$

Mass = 1 x 130 = 130 kg
Weight = 130 x 10 = 1300N

A useful number to know is the density of air: about 1 kg m^{-3} (it's 1.2 but that doesn't matter). What about the volume? If we assume the house is a cube we know it's bigger than 1 m on a side but probably not as much as 10 m on a side. Assuming it's a 5 m cube is near enough; so the volume is 125 m^3.

So the answer to the question is probably about 1300 N (did you remember we wanted weight?).

Practice question

Estimate:

- the number of photocopies made in your school in a year
- the sea level rise caused if the entire world's population went swimming
- the rate at which rubber wears off the tyres of a family car (in $mm^3\,s^{-1}$).

Tip

This is a difficult skill to do at first.

There is not one correct answer for these questions – rather it is an approximate estimation.

Proportion, Percentage Change and Uncertainty

Proportional reasoning is a skill we use as physicists all the time: when this thing doubles, this other thing doubles (or halves, or quadruples…). It saves time in recalculating if we can see the answer using a pattern. This skill appears often in A level questions but rarely at GCSE so it is worth practising.

Questions can be set using numbers: in these questions, you can just recalculate with the new value, but this is much slower than using proportion.

Worked example

The current through a bulb connected to a 6 V cell is 2 A. The bulb is replaced with one of half the original resistance. Calculate the new current.

The long way (by calculation)

Resistance of original bulb, using Ohm's law, $R = \frac{V}{I} = \frac{6}{2} = 3\ \Omega$.

Therefore new bulb has resistance 1.5 Ω.

New current, using Ohm's law, $I = \frac{V}{R} = \frac{6}{1.5} = 4$ A.

Using proportion

Ohm's law tells us $I \propto \frac{1}{R}$ (if V constant) so if R halves then I doubles.

So the answer is 4 A.

Practice question 1

A football has a diameter of 22.5 cm. It contains air at a temperature of 20°C and a pressure of 1.65×10^5 Pa. When the football is left in direct sunlight, the temperature of the air in the football increases to 40°C.

Show that the new pressure exerted by the air in the football is about 2×10^5 Pa. Assume that the volume of the football remains constant.

Tip

Pressure x Volume is proportional to Temperature

Calculating by proportion is much faster and quicker way of problem solving.

Questions can also be set with letters (algebraic symbols) rather than values: in this case you can only use proportion.

Practice question 2

Two protons, separated by a distance x, experience a repulsive force F.

If the separation is reduced to $\frac{x}{3}$ the force between the protons will be:

A $\frac{F}{9}$ **B** $\frac{F}{3}$ **C** $3F$ **D** $9F$

Tip

Force is directly proportional to $1/x^2$

Another common question type asks you to check whether some experimental results are in direct or inverse proportion (or sometimes inverse square or exponential relationships).

These can be tested by checking that the data values multiply or divide to give a constant.

If two things are proportional, y α x,
Then y = constant × x
So x/ y is constant.

y/cm	1.2	2.9	3.4	4.6
x/V	0.245	0.579	0.684	0.922
$\frac{y}{x}$	4.90	5.01	4.97	4.99

Calculate x /y for each pair of values (as shown above).

This gives the same answer (to within the uncertainty in your experiment) so we conclude that y α x.

This is used in experimental technique questions to derive relationships between factors.

Practice question 3

A wire carries a constant current. A Hall probe is used to investigate how the magnetic flux density produced by the wire varies with distance from the wire.

r/cm	V/V
1.0	0.725
1.5	0.483
2.0	0.363
2.5	0.29
3.0	0.242
3.5	0.21

The potential difference V was recorded for a range of distances r.

It is suggested that V and r are related by the equation

$$V = \frac{k}{r}$$

where k is a constant.

Determine by calculation whether this suggestion is valid.

You may also be asked to look at calculating the percentage change in a value from calculations.

Remember that if the value has a power function attached to it, then the percentage value must multiply by the power factor.

Worked example

A 1 m length of wire of cross-section 1.00×10^{-2} mm² has resistance 2.00 Ω.

a Calculate the resistivity of the material.

b What is the effect on the resistance of a 2% increase in diameter?

Answer

a $\rho = \frac{RA}{l} = \frac{2 \times 1 \times 10^{-2} \times 10^{-6}}{1} = 2 \times 10^{-8}\ \Omega\,\text{m}$

b

Expert teacher solution

$R \propto \frac{1}{d^2}$ so increasing d by 2% makes R decrease by 4%.

So the answer is 96% of 2 Ω which is 1.92 Ω to 3 sf.

Transitioning student's solution

$R = \frac{\rho l}{A} = \frac{2 \times 10^{-8} \times 1}{A}$

$A = \pi(\frac{d}{2})^2$ so $d = 2\sqrt{\frac{A}{\pi}} = 0.113$ mm

So new $d = 0.115$ mm, $A = 1.04 \times 10^{-2}$ mm²

So $R = \frac{2 \times 10^{-8} \times 1}{1.04 \times 10^{-2}} = 1.92\ \Omega$ (3 sf)

Vectors

Physics makes use of the idea of a vector to show direction. Lots of quantities in physics have an associated direction (quantities like time or mass that don't have direction are called scalars.)

You will also be familiar with writing column vectors from maths but, for A level physics, the idea of writing a vector in this column notation is not so important.

It is more important to be able to add two vectors (at right angles) and carry out the reverse process (to split a single vector into two components at right angles).

You will remember that to do this you need to use Pythagoras' theorem and a bit of trigonometry.

Although this is the same as the ideas you've met in maths, students often say that it doesn't look the same when you first meet it in physics, as we write them out differently to maths.

Practice question 1

Which set of quantities is all scalar?

A acceleration, displacement, velocity

B energy, mass, power

C extension, force, gravitational potential energy

D weight, kinetic energy, work

Note
This is GCSE revision

Practice question 2

A model boat is crossing a stream. The stream is travelling east at a speed of 1.5 m s^{-1}.

The boat is heading north at a speed of 0.5 m s^{-1}.

The magnitude of the resultant velocity is:

A $(1.5 + 0.5)$ m s^{-1}

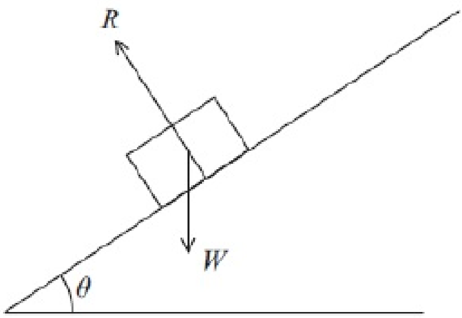
B $(1.5^2 + 0.5^2)$ m s^{-1}

C $\sqrt{1.5 + 0.5}$ m s^{-1}

D $\sqrt{(1.5^2 + 0.5)^2}$ m s^{-1}

Note
This is GCSE revision

Practice question 3



The diagram shows an object on an inclined surface.

The component of the weight *W* parallel to the surface is

A 0

B 1

C $W \cos \theta$

D $W \sin \theta$

Practice question 4

Films made to be watched in three dimensions (3D) are produced by projecting two slightly different images on to the screen, one to be seen by each eye.

In one technique the images are polarised. The viewers wear special glasses where the lenses are replaced by two separate plane polarising filters.

The light from the screen reaching each eye passes through a different filter so each eye sees a different image. The filter for one eye has a plane of polarisation of 45° and the filter for the other eye has a plane of polarisation of 135°.

Explain this choice of angles.

Note
This is a difficult question.

Rate

The idea of rate occurs in several places in physics as well as in the other subjects you are probably studying.

Examples: reaction rate in chemistry, photosynthesis rate in biology, GDP growth in economics, attrition rate in a psychological study.

Rate tells us how quickly something is changing compared to another, which is related to the gradient of a graph (and to ideas in calculus [differentiation and integration] if you study this in maths).

For example, acceleration tells us how much the speed is changing in each time; or absorption rate tells us how the number of beta particles changes as they pass through different thicknesses of absorbing material.

It is very rare to have a question specifically about rate but many questions expect you to be able to recognise it and understand that we are really talking about the gradient of a graph.

This can be tricky when the word rate does not appear: for example, acceleration and power both have the idea of rate built in to their definition.

This leads to a common calculation mistake we see in exams, confusing power in watts and energy in joules.

Problem Solving

It is quite hard to define what we mean by problem solving. Sometimes it is hard to see how to connect what you know with the way the examiner has phrased the question.

How do you get from what you know to what they want? That's a good enough definition of problem solving as far as it applies to A level physics.

There are two general tips you can use to tackle these questions.

Tip: draw a detailed diagram with all the information on it.

This puts all the information into a visual form and sometimes helps you to see which part of physics the question is about. Then read through the information of the question, and underline the important values/properties displayed in the question.

This might lead you to a plan of attack or at least to a principle you need to use, such as the principle of moments or the laws of energy conservation.

Tip: start with what you need and work backwards.

The above tip means look for the keywords of the questions and recognise what principles need to be discussed.

Usually the problem will only require two steps (maybe using two formulae or a principle that isn't given to you in the question, like energy conservation).

That means there's probably only 'one degree of separation' between what you know and what's required so you just need to find that missing link.

Here is an example of how to problem solve a situation in Physics.

Worked example

A bulb of resistance 12 Ω is connected to a 6 V battery. Calculate the charge passing through the bulb in 1 minute.

Answer

The current would tell us how much charge passes in given time ($Q = It$).

We can find current from the information we have using Ohm's law ($V = IR$).

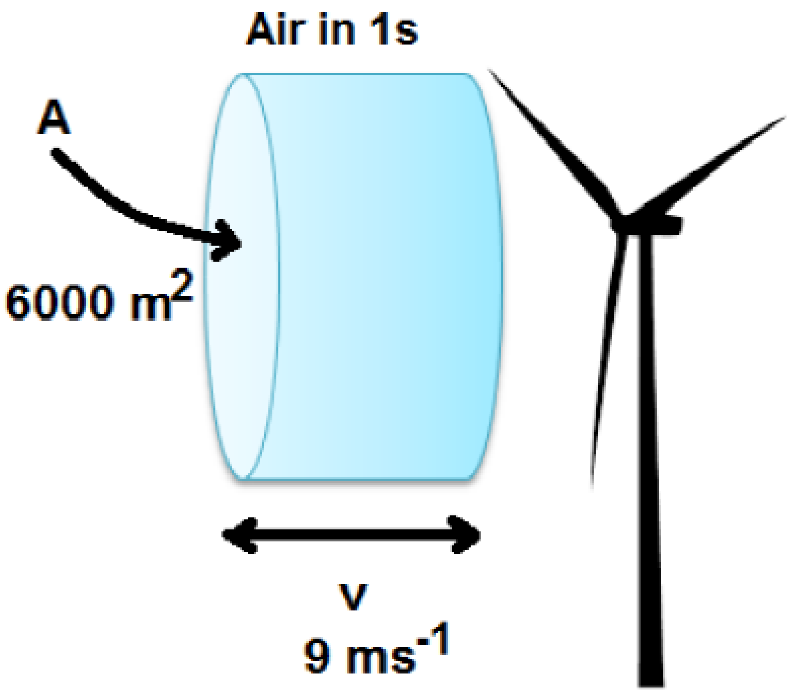
$I = \frac{6}{12} = 0.5\text{ A}$

$Q = 0.5 \times 60 = 30\text{ C}$

Here is another example of how to problem solve a situation in Physics.

Worked example

Kinetic energy of wind is transferred to electrical energy by a wind turbine as the blades rotate.



The area swept out by one blade, as it turns through 360°, is 6000 m^2. Wind at a speed of 9 m s^{-1} passes the turbine.

Calculate the maximum power available to the wind turbine.

density of air = 1.2 kg m^{-3}

Answer

We need to find power. $P = \frac{E}{t}$

The energy transfer is from the wind's KE to the turbine's.

So we need the KE available from the wind in 1 s. $KE = \frac{1}{2}mv^2$

We don't know *m* but we know how much wind passes through the turbine in 1 s from our diagram: it is $A\rho x$. x is the distance the wind goes in 1 s so that's v.

So the power is the wind's KE available in 1 s which is $\frac{1}{2}(A\rho v)v^2$.

So the answer is 2.62 MW.

Practice question 1

The heating element of an electric shower has a power of 6.0 kW.

Water enters the shower at a temperature of 7.5°C.

Calculate the water flow rate required to give an output temperature of 37.5°C.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}

Note
This is a difficult question.

Practice question 2

A CCD sensor of area 1 mm^2 is illuminated with light of wavelength 700 nm and intensity 2.84 mW m^{-2}. The quantum efficiency of the CCD is 70%. Find the rate at which electrons are released in the sensor.

Note
This is a difficult question.

SECTION 2: PRACTICAL GUIDE

In this section, it is advised you read through the information and highlight the key information.

If needed attempt the practice questions found in this section.

Physics is a practical subject, which means that whatever anybody thinks – hypothesis – it is only by testing the idea – carrying out an investigation – that we can come to conclusion about whether the idea might be a reasonable explanation of the universe around us.

Practical skills are central to the work of a physicist and the A level course is built around the development of those skills.

At GCSE you might have seen a Geiger counter measuring the emissions from a radioactive source, by putting different materials between source and detector you were able to tell whether the radiation was alpha, beta or gamma. All the ideas and principles in physics have been tested like this and this early investigation of the nucleus led, over a hundred years, to the investigations at CERN.

It is really important to remember that the term 'practical skills' covers a very wide range of requirements at A level. It does not mean just the ability to handle equipment in a school laboratory or know how to use some particular piece of apparatus. It ranges from using mathematics in a practical context to understanding how scientists investigate ideas, how they analyse their data and how they use that data when drawing conclusions. This guide will explain each of these in more detail.

By carrying out a programme of practical work you will develop the skills that a student must have if he or she is to be regarded as a competent practical physicist. You will have to be able to work safely in the laboratory and to manage your time so as to complete your work in the time allowed. Normally you will be given written instructions so you must be able to follow these carefully.

Over the two years of your A level course your teacher will assess your competence as a practical physicist by letting you carry out core practicals. At the end of the course your teacher will list the practical work you have carried out and decide if you have passed as a competent practical physicist. If you pass, then this will be recorded on your A Level certificate.

How is this different from GCSE?

First of all you will be doing most of the practical work; occasionally working with one or more other people you will develop a wide range of skills.

You will need to keep asking 'How do we know that?' You will also realise that, even at A level, you will only have part of the story and that science is constantly changing. It is not a pile of 'facts' it is just the best model we have at the present, in as far as we can test it.

By the end of the course you will have a mastery of practical work which means you will be consistently and routinely competent and therefore happy to have a go at a huge range of physics in the laboratory.

Developing independent thinking
An investigation is more than simply finding a value for something or verifying the behaviour of a system. In the same way, a practical mastery is more than the sum of the parts, more than all the practical skills lumped together. The 'extra ingredient' is independent thinking.
For example knowing which instruments to use and knowing how to use them is a key part of planning, using them correctly and being able to get accurate and precise readings is carrying out your investigation.

Completing the work is to present your data and your conclusions supported by some analysis. Thinking independently means being able to make the right decisions about what you know and making them at the right time. Perhaps there is more to an investigation, there is the 'I wonder...', 'what would happen if I did this?' and 'how do we know that?' – an enquiring mind.

All of this makes a good physicist but physicists seldom work alone. Modern projects such as CERN or the Very Large Telescope in Atacama require literally thousands of highly trained specialists to make them work. Therefore, although the spark of an idea starts in one head – think of Peter Higgs and his boson – the investigation is usually a collaboration.

Physics is about describing the world around us, perhaps predicting what it might do next but not really explaining it, that is left for the philosophers. Creating models and then testing them is the way physicists do this and the models evolve all the time. Communicating that spreading understanding is then another aspect of the work.

Finally, physicists are very careful about claiming to have proved something and they are more likely to talk of developing the current model.

Thinking independently is about the creativity of the individual working within the framework of the subject and its other skilled practitioners.

Over the A-Level course, you will carry out several practicals on the course, and you will carry out the required practicals of the course. The required practicals will be recorded in a special assessment book to detail your different skills in experimental work.
The required practicals will be examined in Paper 3 of the course, and you must have a clear understanding on how each practical works.

Writing Investigations

Some of the required practicals offer you the opportunity to go beyond simply learning a technique by applying your knowledge to the design of an investigation.

You will have met some of the requirements at GCSE level but during the two years of your A level course you will be expected to gain a deeper understanding of the details.

You might start as follows.

- **Is the hypothesis clear?**
- **Exactly what is to be measured? Is this the correct dependent variable, does it match the hypothesis and how can it be measured as accurately as possible?**
- **Are there any other variables that I need to control? What can I do about ones I cannot control?**
- **How much data will be needed to come to some meaningful conclusions?**

For example in a required practical, you will investigate the effect of length, tension and mass per unit length on the frequency of vibration of a string or wire. You might think of a guitar, adjusting the frequency means tuning it or playing it – and each of the six strings has a different composition. How will you plan your investigation?

You must start with your own hypothesis and run through the questions above. You will need a framework for you practical investigation. You can probably add questions to the list – but do not make it too complicated, you are aiming to test your hypothesis.

Instruments

You will choose which instruments you are going to use for each of your measurements and explain why they are appropriate; this is probably due to their resolution – smallest measuring division – but also their range. If the instruments are electrical then it is the range that you must specify, for example a voltmeter on its 20 V range. You should also detail any additional apparatus you will need such as retort stands, beakers or perhaps a bench pulley.

It is a really good idea to draw a diagram of how you will set up your apparatus. This should be labelled, large and drawn with a pencil and ruler. This process will help you think more clearly about what you are about to do. Key dimensions should be indicated on your diagram, these are lengths you will measure.

Question A

You are given two samples of a metal and told that they might both be aluminium. One is in the form of a sheet of kitchen foil and one is a cylindrical block with a mass of approximately 1 kg. In order to test the suggestion you decide to measure the density of the metal of each. What instruments would you use? Justify your choices.

You justify instruments in Physics by calculating or estimating a sample percentage uncertainty in the results due to the resolution – if this is a small value, it is a suitable instrument to use.

You must always justify the instruments you use.

Method

This can be bullet points but should include everything you will need to do including a risk analysis of your activity; this should include the equipment and other people in the room.
You should discuss repeat readings and the intervals and range you are expecting to cover.

Techniques

You should also describe any techniques you will employ to improve accuracy. For example, a timing marker if the experiment concerns oscillations or zero errors on almost any instrument. This helps you to think more clearly about what you will actually do.

You might think about holding your head perpendicular to the scale to get a more accurate reading, on a thermometer for instance.

In A-Level Physics, you will encounter new and more accurate measuring devices such as Vernier Scale callipers and screw gauge micrometers.

Question B

Describe how you would use the micrometer in Question A to measure the thickness of the foil with as good a resolution as possible.

Planning should be detailed but concise, in an investigation it is to help you test the right thing in the right way.

Recording

When recording your data you should always use a table with headings, which include the quantity and its unit, write the unit that you read from the instrument. You might read a metre rule in centimetres, so head the column of length L say as L/cm, you should also record the resolution of the instrument as ±0.1 cm in the case of the rule.

Use the number of significant figures (SF) that the instrument gives, so a small length might be 6.4 cm and a longer one 25.6 cm.
Recording to the resolution of the instrument is more important than having the same number of SF.

Be careful that your recorded figure represents what you think you measured. For example if you record values for mass and write down M = 1.00 kg you are recording the mass to the nearest 10 g, the resolution is much nearer 1 g so you should write M = 1.000 kg.

When you record the period of 10 oscillations using a timer with a resolution of 0.01 s you might record 10T = 14.52 s, this gives you T = 1.452 s and the resolution of your measurement has improved because you recorded a longer time interval.

Make sure you record enough data and not too much. Keep your eye on the dependent variable and if it is changing slowly increase the increments in the independent variable.
You should be flexible and not stick rigidly to your plan if nothing much is changing. Physicists can change their experimental methods if it is not working correctly.

Write your readings straight into your table and record everything you measure.

In investigations, you must be able to calculate mean averages, absolute uncertainties, percentage uncertainties and percentage differences.
This forms the basis of your data analysis.

Question C

A student records the following values for the diameter of a piece of wire

d/mm	0.27, 0.29, 0.27, 0.77, 0.26

Calculate a mean value for the diameter and explain your choice.

Graphs

Almost every physics experiment will display data in graphical form and physicists always use a form of their data that produces a straight line – if all goes well with the data.
There is usually a mathematical model for the data and it is this that can be manipulated to give a straight line on the graph. This will happen when the model has been manipulated to be similar to y = mx + c.
Here you can use the equation of y = mx + c to determine values of different factors.

Some examples are shown in the table.

Mathematical Model	*x*-axis	*y*-axis	gradient	intercept
$V = IR$	I	V	R	Zero
$v^2 = u^2 + 2as$	s	v^2	$2a$	u^2
$I = I_0 \exp^{\left(\frac{-t}{RC}\right)}$	t	$\ln I$	$\frac{-1}{RC}$	$\ln I_0$
$T = kx^p$	$\ln x$	$\ln T$	p	$\ln k$
$I = I_0 \exp^{\left(\frac{b}{T}\right)}$				
$T = f^2\lambda^2 \mu$				

Question D

Complete the bottom two lines in order to determine a value for *b* in the first one where the variables are *I* and *T* and a value for *μ* in the bottom line where the variables are *T* and *f*.

The axes of graphs should be labelled with a unit such as s/m or ln (T/s) – in this way the plots have no units.
The scale should stretch the plots over at last half the graph paper in each direction but should not be difficult to read i.e. multiples of 7s or 3s – take care when plotting time in seconds.
The plots should be accurate to 1 mm and the line of best fit should have plots above it and below.
Always tabulate the numbers you are going to use for your graph alongside your data. A graph in physics is always a scatter graph with a line of best fit shown.

You should plot error bars on your data and these should come from the spread in your repeated readings – it is usual to use half the spread as the size of the error bar – or the percentage uncertainty calculated.
This will enable you to draw different lines of fit and hence estimate the uncertainty in your gradient, which is usually a key aspect of the investigation.

Analysing
Investigations might be to verify the behaviour of a system or to calculate a value for some aspect of it. In the first case, you will be commenting on the goodness of fit of your best fit line. In the second you will be doing further numerical analysis. In both cases, you should record what was easy and what was difficult about your practical work, if your method was easy to carry out you might expect plots close to a straight line whereas difficulties might explain a spread of readings.

If you were expecting a straight line but got a curve there might be a reason for that too.
For example if you are measuring the period of a pendulum and varying the length then plotting T^2 against l should give a straight line from

$$T = 2\pi\left(\frac{l}{g}\right)^{\frac{1}{2}}$$

But if your oscillations are too large so that this is not the correct mathematical model then that explains the curve you might get on your graph.

In the practical to determine a value for g and if your experimental value turns out to be 9.25 N kg^{-1} then you can use a percentage difference to gauge the error.
Percentage difference = 100 × (your value – accepted value) ÷ accepted value
Here that gives %D = 100 × (9.81 – 9.25) ÷ 9.81 = 5.7% – not a bad result.
Any percentage difference below 10% is considered a good result.

A properly plotted graph can tell you a very great deal about your experiment and always you to calculate many different values.

Question E

You measure a value for Young modulus of copper and obtain a value of 1.32×10^{11} Pa. The accepted value is 1.17×10^{11} Pa. Calculate the percentage difference between the two values.

Extension

Do you think this is a good experimental result? Why is this?

Use of Mathematics

Nearly all the mathematical requirements needed at A-Level are the same as those of GCSE Maths at Higher Level, but you have to get GCSE Maths right when you use it. Although this might sound worrying, you should find that as you practice over the course and keep ticking over with the maths you improve, just as you do with everything else.

The only difference between A-Level Physics and GCSE Maths is the use of logarithms and exponentials. This will be taught explicitly in lessons. Do not worry.

Evaluating Uncertainties

Uncertainties give you a degree of confidence in your recorded value so that if your uncertainties are large, say 25%, then you might find little confidence in your conclusion but if they are small, say 2%, then you might think your results are valid i.e. you have measured what you were supposed to be measuring.

In your investigation you will want to derive an uncertainty in your final value, this will depend on the difficulty you experienced taking the readings, the spread in your repeated readings and other factors too.

In some experiments, you will be comparing your final value to an accepted value. Your value for g was 5.7% different from he accepted value; if your uncertainty was 9% then your result might be valid because the percentage difference can be explained by the percentage uncertainty.
If your percentage uncertainty was 3% then the difference is not explained by the uncertainty and your experiment was flawed in some way.

When evaluating the result of your investigation as well as considering percentages, as above, you should consider your graph and the readings it shows as well as the difficulties you felt you had in taking accurate readings. As part of this you might consider whether a different method would produce a better result.

You can calculate your percentage uncertainty with the following….

Percentage Uncertainty = [(Absolute Uncertainty) / Recorded Value] x 100

The absolute uncertainty can be considered to be half the spread of results (or from mean to max value) or the resolution of the device.

Your report should end with a conclusion supported by numbers and an evaluation based on the evidence you have assembled.

Question F

A wave crosses a tray, reflects off the far side and returns after a time *t*. A student measures the distance *d* across the tray as 33.4 cm with an uncertainty of 0.2 cm.

She then measures *t* = 0.92 s with an uncertainty of 0.03 s.

(i) Use these measurements to calculate *v*, the velocity of the wave.

(ii) Estimate the percentage uncertainty in your value for *v*.

Question G

A student records measurements of a metre rule. She repeats these from several positions along the rule.

Width/mm 28.2, 29.3, 28.9, 29.0, 29.1

Thickness/mm 6.04, 5.94, 5.97, 6.01, 5.99

Mass/g = 106.4

(i) Use these measurements to calculate a value for the density of the rule.

(ii) Calculate the uncertainty in your value for the density.

Question H

A student takes measurements to determine the resistivity of constantan in the form of a wire. He measures the diameter and the resistance of a length of wire. He records:

Diameter = 0.559 mm ±0.010 mm

Resistance 1.15 Ω ±0.02 Ω

Length = 0.600 m ±0.003 m

Note

This is a difficult question.

Ii) Calculate the resistivity of the constantan.

(ii) Calculate the percentage uncertainty in your value for the resistivity

(iii) The accepted value for the resistivity of constantan is 4.9×10^{-7} Ω m. Comment on the result of using the student's measurements.

SECTION 3: PHYSICS GUIDE

AQA A-level Physics is a natural progression from the GCSE course and there are many familiar topics that are taken a stage further from previous teachings.

Some topics, such as electricity, are studied in greater detail while others, such as energy transfer, broaden the GCSE experience and include a greater use of mathematics so that the qualitative understanding becomes quantitative.

A substantial change at A-level is the inclusion of optional topics, all of which build on familiar topics from GCSE and give students the chance to study in areas they have a specific interest in, such as astrophysics, medical physics or engineering, and is the first step towards specialising towards a career.

In the following section, you can see how the knowledge learnt at GCSE is used at A-Level and how it is built upon.

Content

Kinetic theory

GCSE specification reference: 1.1.2

A-level specification reference: 6.2.2 (Ideal gases) and 6.2.3 (Molecular kinetic theory model).

There is no numerical work at GCSE, just an appreciation of the basic model of constantly moving atoms, molecules and particles, as well as the different energy states of solid, liquid and gases.

The kinetic theory at A-level is described by assumptions and mathematical interpretation linking micro and macro to generate, for gases, $PV = nRT$(as well as $pV = NkT$) , moles, work done, Avogadro constant, NA, Boltzmann's constant k and absolute temperature, (T).
The link between $(KE)_{av}$ and T is also covered at A-level.

Energy transfer by heating

GCSE specification reference: 1.1.3

A-level specification reference: 6.2.1 (Thermal energy transfer).

There is use of $Q = mc\Delta T$ in both the GCSE and A-level specifications. Definition of c and measurement as well as ideas about cooling by evaporation also appear in both.

A-level also deals with quantitative appreciation of latent heat and $Q = mL$ for fusion and evaporation.

Energy and efficiency

GCSE specification reference: 1.2.1

A-level specification reference: 4.1.8 (Conservation of energy).

Both GCSE and A-level have definitions of efficiency and assumed principles of conservation of energy.

Transferring electrical energy

GCSE specification reference: 1.3.1

A-level specification reference: 5.1.4 (Circuits).

GCSE and A-level have common equations for power and energy. At GCSE the equation is restricted to P=IV, and knowledge of kW, kWh.

At A-level the power equation is broadened to be defined as $P=I^2R$ and $P= V^2/R$.

Generating electricity/The National Grid

GCSE specification reference: 1.4.1 and 1.4.2

A-level specification reference: 5 (Electricity) and 7.4 (Magnetic fields).

Knowledge of National Grid and use of transformers is assumed at A-level and the transmission of energy by power lines is common to both GCSE and A-level.

A-level develops an equation for generating of an AC voltage (rotating coil), includes the transformer and deals quantitatively with power loss in transmission lines.

Wave Properties

GCSE specification reference: 1.5.1

A-level specification reference: 3 (Waves)

Both GCSE and A-level require a basic knowledge of longitudinal and transverse waves, their nature and properties, including speed of electromagnetic waves in a vacuum. Also common are the wave equations (using different symbols for velocity) i.e. $v = f\lambda$ and $c = f\lambda$.

At A-level, the oscillation of particles in a medium and the idea of phase difference is introduced with a formal definition of frequency ($f=1/T$), and polarisation.

Refraction of waves at an interface and diffraction are treated qualitatively at GCSE.
At A-level refractive index/Snell's law and total internal reflection (critical angle) are treated numerically and their application in fibre optics is introduced.

At A-level single slit diffraction, Young's slits and the diffraction grating are explained mathematically through superposition and interference.

Sound

GCSE specification reference: 1.5.3

A-level specification reference: 3.1.1 (Progressive waves) to 3.2.1 (Interference).

Implied knowledge of longitudinal nature and the requirement of a medium is included in both GCSE and A-level specifications.

At A-level, the concept of stationary waves, superposition, interference and the determination of the speed of sound is included.

Resultant forces

GCSE specification reference: 2.1.1

A-level specification reference: 4.1.1 (Scalars and vectors).

The outcome of resultant forces and the concept of equilibrium (resultant force=zero) is common to both GCSE and A-level for parallel forces, including acceleration in the direction of the resultant force.

At A-level, the calculation of the resultant of two forces at 90° and resolution of forces are treated mathematically.

Forces and motion

GCSE specification reference: 2.1.2

A-level specification reference: 4.1.3 (Motion along a straight line), 4.1.4 (Projectile motion), 4.1.5 (Newton's laws of motion) and 4.1.6 (Momentum).

Both GCSE and A-level assume knowledge of F = ma, but at A-level all three of Newton's laws are required. GCSE content is restricted to motion in a straight line and definitions of velocity and acceleration, including graphical representation for uniform straight line motion to determine acceleration and distance travelled.

At A-level, all SUVAT equations and displacement are defined and the use of Δ for changes in $V=\Delta s/\Delta t$ is introduced, including non-uniform acceleration. The acceleration due to gravity (g) and its measurement is an A-level requirement. Projectile motion is analysed mathematically taking account of air resistance.

Forces and Terminal velocity

GCSE specification reference: 2.1.4

A-level specification reference: 4.1.4 (Projectile motion).

This builds on the idea of equilibrium (balanced forces). Both GCSE and A-level require a knowledge of why there is a terminal speed (velocity), that fluid resistance depends on speed and how drag forces can be useful. Interpretation of u-t graphs for objects falling under gravity with drag forces present is also included.

Lift forces are considered only at A-level.

Forces and elasticity

GCSE specification reference: 2.1.5

A-level specification reference: 4.2.1 (Bulk properties of solids) and 4.2.2 (The Young modulus).

Both GCSE and A-level include an understanding of Hooke's law and expressions in terms of a spring constant, k. Mathematical expressions of force and extension: $F=ke$ (GCSE) and $F=k\Delta L$ (A-level) including elastic, strain and potential energy stored are also included.

At A-level the concept of elastic limit, plastic behaviour, breaking stress, fracture and brittle behaviour are included with the use of stress and strain graphs. The area under a force-extension graph is equated to energy stored as $E=F\Delta L$ and also the transformation of energy in a mass and spring system between KE and PE. Use of stress and strain curves to determine the Young modulus and its measurement is at A-level only.

Momentum

GCSE specification reference: 2.2.2

A-level specification reference: 4.1.6 (Momentum).

Both GCSE and A-level define momentum and conservation of momentum, including the concept of a 'closed system', for collisions and explosions.

At A-level, linear momentum in one dimension is specified and involves the understanding that force results from a momentum change per second. The idea of impulse ('force × time') including an appreciation of impact forces and contact times is introduced and for constant and variable forces, the area under a force-time graph is used for momentum change. There is also consideration at A-level for both elastic (conservation of KE) and inelastic collisions, with calculations.

Electrical circuits

GCSE specification reference: 2.3.2

A-level specification reference: 5 (Electricity).

Both GCSE and A-level include circuit symbols; the terms, I, Q, V; and the definitions of current, voltage (PD), and work done in a circuit. The concept of resistance (R=VI), and I-V characteristics for ohmic and non ohmic components, and series/parallel circuits is common to both.

At A-level, the potential divider/potentiometer is introduced as a control mechanism, as are cells in series and parallel. Conservation of charge and energy in a DC circuit and the equation for resistors in parallel are considered only at A-level, as is resistivity and superconductors.

Atomic structure

GCSE specification reference: 2.5.1

A-level specification reference: 2 (Particles and radiation), 8 (Nuclear physics).

Simple 'Bohr model' of an atom in terms of protons, neutrons, electrons, and the relative masses of these particles is common to both GCSE and A-level. The idea of neutrality (number of electrons = number of protons) and ions and isotopes is also discussed. 'Atomic number' is used at GCSE and 'proton number, Z' is used at A-level. 'Mass number' is referred to in GCSE and 'nucleon number' in A-level.

For A-level only, evidence for the nucleus (Rutherford) and specific charge of nuclei, ions and protons/electrons and the concept of a nuclide with symbolic representation.

Atoms and radiation

GCSE specification reference: 2.5.2

A-level specification reference: 2 (Particles and radiation), 8 (Nuclear physics) and 9.2.3 (Classification by temperature, black body radiation-Astrophysics option).

A general appreciation of radioactive substances, the three types of radiation and their properties, safety, hazards, background and half-life is assumed at A-level. At GCSE, only the nuclear equation for α–decay is required. At A-level, the equation for β–decay (including the neutrino) is also required. A-level requires more detail about the reasons for instability, including the N against Z curve, and the forces involved in decay such as the strong nuclear force and short range attractive.

The experimental investigation of evidence for α, β and γ is required at A-level, along with the inverse square law for γ. Count rate (elimination of background), mathematical definition of half-life and manipulation of exponential decay equations are all required at A-level, along with knowledge of natural logs.

Nuclear fission and Nuclear fusion

GCSE specification reference: 2.6.1 and 2

A-level specification reference: 8.1.6 (Mass and energy) and 8.1.7 (Induced fission).

Knowledge of the fissile substances used in thermal reactors and that the process involves the nucleus and neutrons is common to both GCSE and A-level, as is the fact that fusion involves nuclei 'joining' at high temperatures.

At A-level, the concepts of binding energy and use of $E = mc^2$ for calculations of mass difference and energy are required. An understanding of critical mass, moderator, control rods and coolant in a thermal reactor is necessary for A-Level.

Applications of Light

GCSE specification reference: 3.1.5

A-level specification reference: 3.2.3 (Refraction at a plane surface).

An appreciation of total internal reflection, optical fibres and lasers is assumed from GCSE.

At A-level the critical angle is related to refractive index by Sin θ_c = ratio of two refractive indices. A-level deals in slightly more detail for optical fibres with a step index.

Centre of mass

GCSE specification reference: 3.2.1

A-level specification reference: 4.1.2 (Moments) and 6.1.2 (Simple harmonic motion).

The definition of centre of mass and stability in general is assumed as are the general properties of a simple pendulum as this is covered at GCSE.

At A-level there is analysis of the simple pendulum time period equation.

Moments

GCSE specification reference: 3.2.2

A-level specification reference: 4.1.2 (Moments).

Both GCSE and A-level specifications require the definition of a moment and the principle of moments, including the idea of equilibrium/stability.

A-level introduces the concept of parallel opposite forces forming a couple.

Circular motion

GCSE specification reference: 3.2.4

A-level specification reference: 6.1.1 (Circular motion).

Both GCSE and A-level require knowledge of centripetal forces, their origins and how these forces depend on mass, speed and radius.

The equation for centripetal forces $F = mv^2/r$ and the link $v = \omega r$ are only required at A-level.

The motor effect

GCSE specification reference: 3.3.1

A-level specification reference: 7.4 (Magnetic fields).

An understanding of how current-carrying conductors react in magnetic fields is included for both GCSE and A-Level. In particular, Fleming's left hand rule is required for currents and fields at 90°.

A-level considers the concept of B (flux density) and moving charges with equations for F used to explain how a current balance works and the circular motion of particles, e.g. in a cyclotron.

Transformers

GCSE specification reference: 3.3.2

A-level specification reference: 7.4.6 (The operation of a transformer).

The concept of electrical induction, including simple experiments, is expected at both GCSE and A-level, as is the structure of a transformer, its turns ratio and power ratio for an ideal transformer.

A-level requires an understanding of Lenz's and Faraday's laws for induction, flux and flux linkage, leading to an appreciation of energy losses in a transformer – Eddy currents/laminations.
Calculations are included at A-level on transformers with efficiency below 100%.

In the following section, there are practice A-Level questions on key concepts in physics which you can attempt to familiarise yourself with the A Level Physics course.

These questions are problems posed on content covered at GCSE in an A-Level format.

You can use these questions to understand how they will present questions in a problem-solving format.

These questions are optional.

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

1. Vectors and Scalars

1 Which of the following is a scalar quantity?

Place a cross (☒) in the box next to your answer.

A acceleration ☐

B displacement ☐

C force ☐

D work ☐

(1 mark)

2 A cyclist travelling at a speed of 4.2 m s^{-1} accelerates at 1.1 m s^{-2}. In a time of 7.4 s what is the distance travelled?

Place a cross (☒) in the box next to your answer.

A 30 m ☐

B 35 m ☐

C 61 m ☐

D 91 m ☐

(1 mark)

3 Complete the sentence by putting a cross (☒) in the box next to your answer.

A building has 5 floors. The windows on successive floors are separated by the same vertical distance.

A brick is dropped from a window on each floor at the same time. The bricks should hit the ground at…

A decreasing time intervals ☐

B equal time intervals ☐

C increasing time intervals ☐

D the same time ☐

(1 mark)

4 **a** Explain the difference between scalar and vector quantities.

(1 mark)

Answers for these questions can be found later in the document.

Answers for these questions can be found later in the document.

b When asked to run one complete lap around a track, a student says, 'However fast I run, my average velocity for the lap will be zero.'

Comment on his statement.

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

(3 marks)

5 This photograph shows an athlete performing a long jump.

At take-off his horizontal speed is 8.0 m s^{-1} and his vertical speed is 2.8 m s^{-1}.

a Show that the total time the athlete spends in the air is about 0.6 s.

Assume that his centre of gravity is at the same height at take-off and landing.

(3 marks)

Answers for these questions can be found later in the document.

b Calculate the horizontal distance jumped by the athlete.

(2 marks)

c In reality, when the athlete lands his centre of gravity is 50 cm lower than its position at take-off.

Calculate the extra horizontal distance this enables the athlete to jump.

(4 marks)

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

2. Motion Graphs

Answers for these questions can be found later in the document.

1 Complete the sentence by putting a cross (☒) in the box next to your answer.

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

Distance travelled can be found from the...

A area under a velocity-time graph ☐

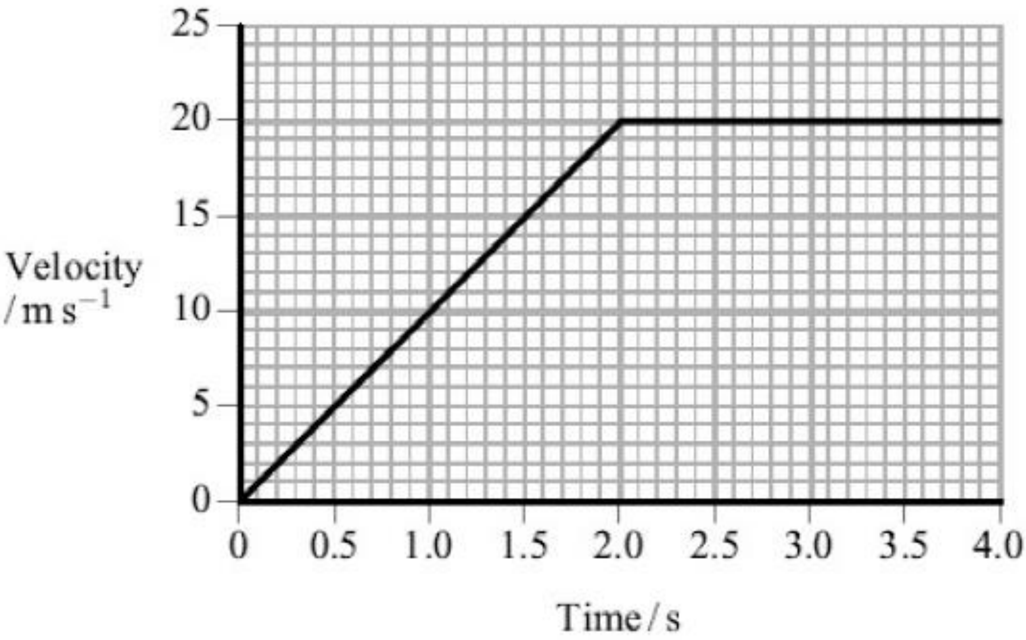
B area under an acceleration-time graph ☐

C gradient of a force-time graph ☐

D gradient of a velocity-time graph ☐

(1 mark)

2 Complete the sentence by putting a cross (☒) in the box next to your answer.



The graph shows how velocity varies with time for an object.

The acceleration at 3 s is...

A 10 m s^{-2} ☐

B 7 m s^{-2} ☐

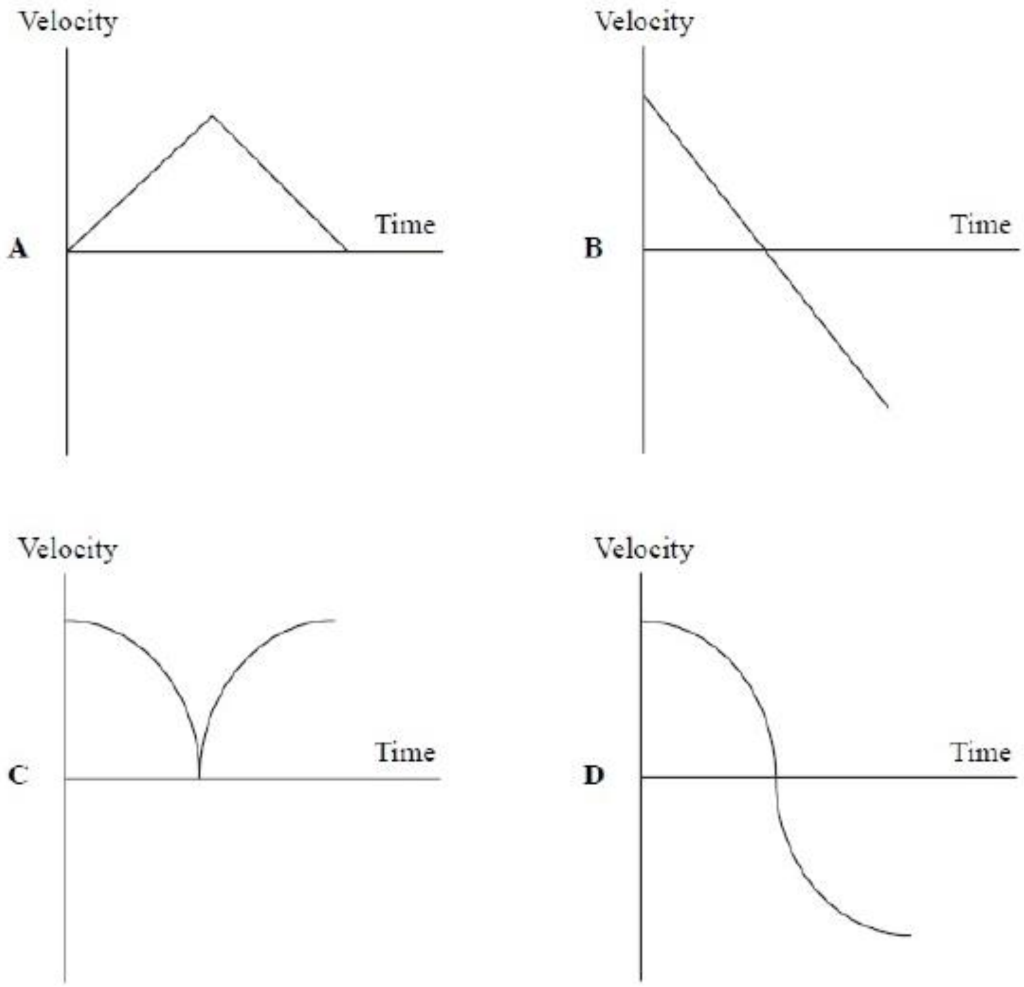
C 5 m s^{-2} ☐

D 0 m s^{-2} ☐

(1 mark)

Answers for these questions can be found later in the document.

3 A ball is thrown straight up in the air and caught when it comes down. Which graph best shows the velocity of the ball from the moment it is released until just before it is caught?



Select one answer from A to D and put a cross in the box (☒).

A ☐

B ☐

C ☐

D ☐

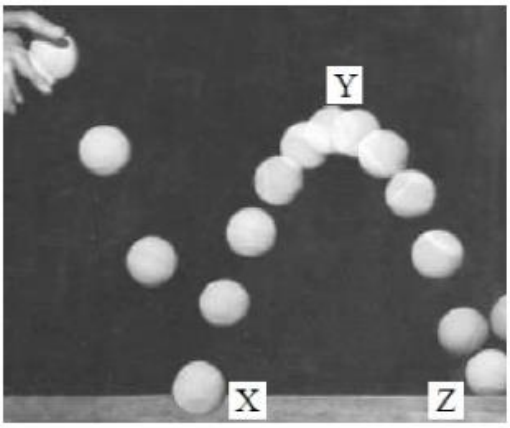
(1 mark)

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

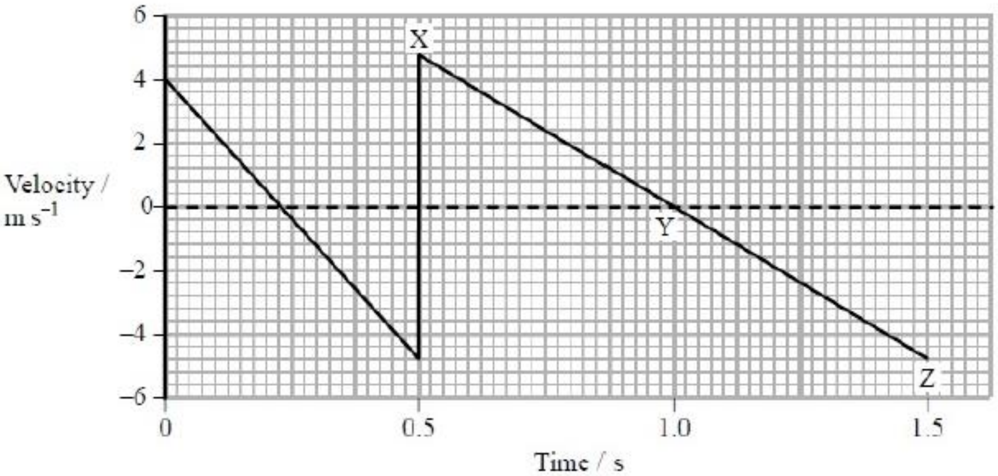
Answers for these questions can be found later in the document.

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

4 The photograph shows a sequence of images of a bouncing tennis ball.



A student plots the following graph and claims that it shows the vertical motion of the ball in the photograph.



a Without carrying out any calculations describe how the following can be found from the graph:

i the vertical distance travelled by the ball between 0.5 s and 1.0 s

ii the acceleration at Y.

(2 marks)

Answers for these questions can be found later in the document.

b The graph contains several errors in its representation of the motion of the ball. Explain two of these errors.

Error 1

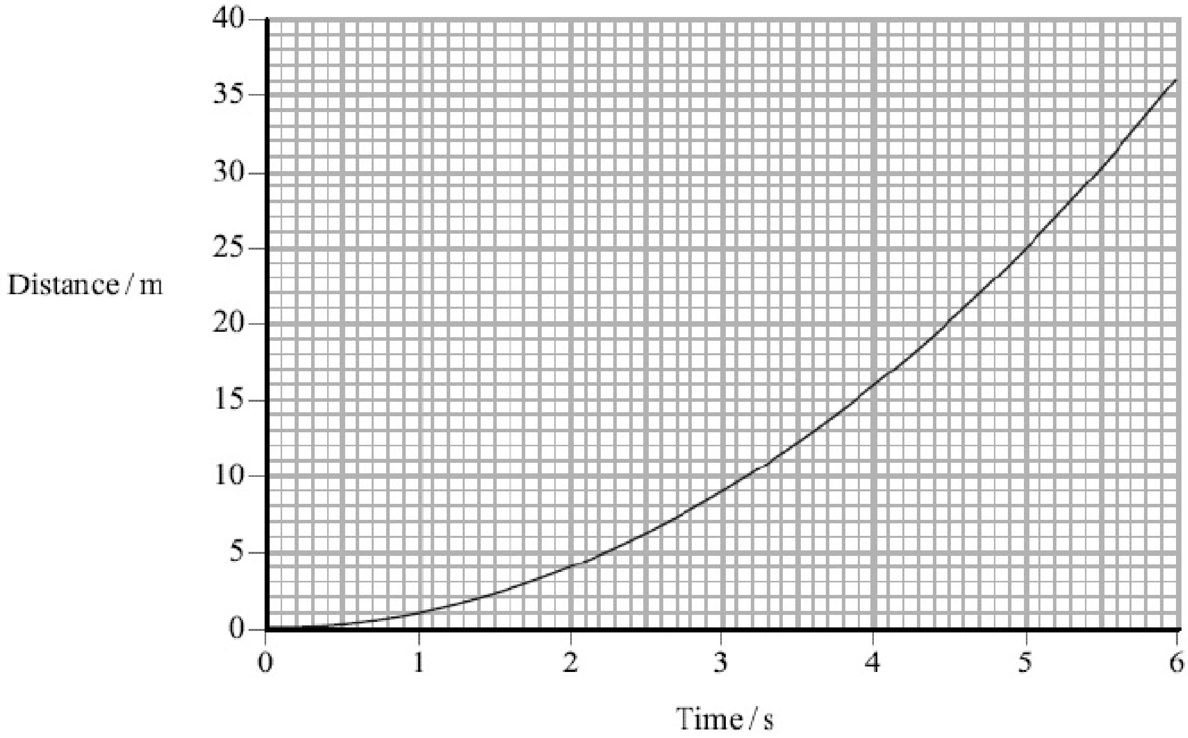
Error 2

(4 marks)

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

Answers for these questions can be found later in the document.

5 The graph shows how displacement varies with time for an object which starts from rest with constant acceleration.



a Use the distance-time graph to determine the speed of the object at a time of 4.0 s.

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

(3 marks)

b Calculate the acceleration.

(2 marks)

3. Weight and Mass

Answers for these questions can be found later in the document.

1 Complete the sentence by putting a cross (☒) in the box next to your answer.

On a newly discovered planet, an object of mass 8.0 kg has a weight of 60 N.

The gravitational field strength on this planet is...

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

A 0.13 N kg^{-1} ☐

B 7.5 N kg^{-1} ☐

C 9.8 N kg^{-1} ☐

D 480 N kg^{-1} ☐

(1 mark)

2 A person weighing 100 N stands on some bathroom scales in a lift. If the scales show a reading of 110 N, which answer could describe the motion of the lift?

Select one answer from A to D and put a cross in the box (☒).

A Moving downwards and decelerating. ☐

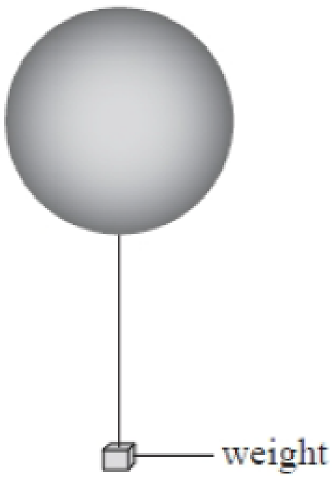
B Moving downwards with a constant velocity. ☐

C Moving upwards and decelerating. ☐

D Moving upwards with a constant velocity. ☐

(1 mark)

3 A student is asked to calculate the magnitude of a weight required to keep a spherical helium filled balloon stationary in the air.



The only measurement taken is the diameter d of the balloon. The student is given the values of the density of air ρ_a, the density of helium ρ_h and gravitational field strength g.

Answers for these questions can be found later in the document.

a Using the symbols given, write an expression for:

i the volume V of the balloon

(1 mark)

ii the mass of the helium inside the balloon

(1 mark)

iii the mass of the air displaced by the balloon

(1 mark)

iv the upthrust on the balloon.

(1 mark)

b Assuming the weight of the balloon and string are negligible, write an expression for the magnitude of the required weight.

(1 mark)

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

Answers for these questions can be found later in the document.

4 You are asked to determine the acceleration of free fall at the surface of the Earth, g, using a free fall method in the laboratory.

a Describe the apparatus you would use, the measurements you would take and explain how you would use them to determine g.

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

(6 marks)

b Give **one** precaution you would take to ensure the accuracy of your measurements.

(1 mark)

4. Series Circuit

Answers for these questions can be found later in the document.

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

1 Complete the sentence by putting a cross (☒) in the box next to your answer.

The unit of potential difference can be expressed as…

A $C\ s^{-1}$ ☐

B $J\ C^{-1}$ ☐

C $A\ \Omega^{-1}$ ☐

D $J\ A^{-1}$ ☐

(1 mark)

2 Complete the sentence by putting a cross (☒) in the box next to your answer.

A rechargeable cell stores a maximum energy of 4200 J. The cell has an e.m.f. of 1.5 V and after 2.0 hours use the cell is completely discharged.

Assuming the e.m.f. stays constant, the charge passing through the cell during this time is…

A 1400 C ☐

B 2800 C ☐

C 5600 C ☐

D 6300 C ☐

(1 mark)

3 An electric torch uses two 1.5 V cells. The torch bulb is marked 2.4 V, 270 mA.

What is the resistance of the torch bulb?

Put a cross (☒) in the box next to your answer.

A 0.81 Ω ☐

B 0.65 Ω ☐

C 8.9 Ω ☐

D 11 Ω ☐

(1 mark)

Answers for these questions can be found later in the document.

4 A student is taking measurements in order to determine the resistance of a component in a circuit. He connects a voltmeter in parallel with the component and an ammeter in series with the component.

Explain why the voltmeter should have a very high resistance.

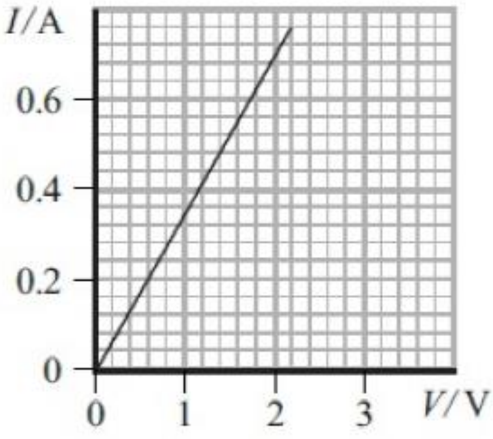
Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

(2 marks)

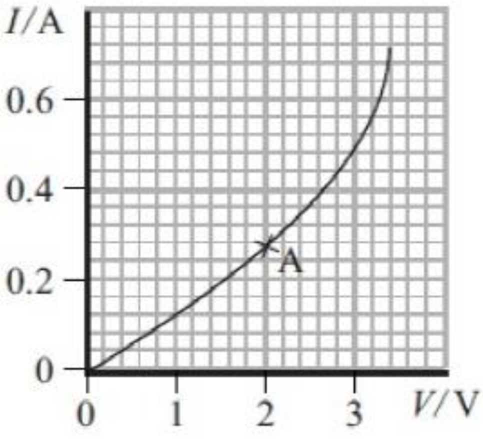
5 a Show how the ohm is derived.

(1 mark)

b The graphs show the current-potential difference (I-V) characteristics for a metal conductor and for a thermistor.



Metal conductor



Thermistor

i Calculate the resistance of the thermistor at point A.

(2 marks)

Answers for these questions can be found later in the document.

ii Use the graphs to describe how the resistance varies with potential difference for each component.

(2 marks)

iii Explain, in terms of electrons, why the thermistor behaves in this way.

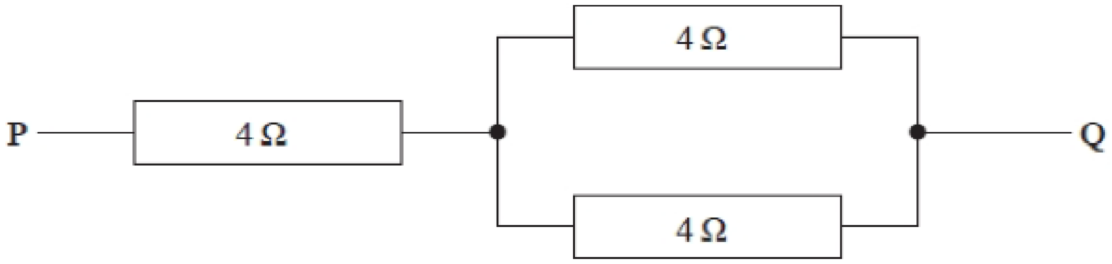
(2 marks)

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

5. Parallel Circuits

Answers for these questions can be found later in the document.

1 The diagram shows a combination of three identical resistors.



What is the combined resistance between P and Q?

Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

Put a cross (☒) in the box next to your answer.

A 4 Ω ☐

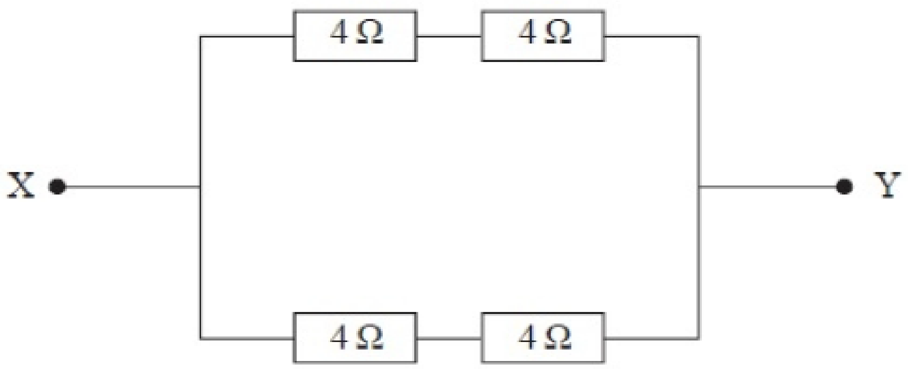
B 6 Ω ☐

C 8 Ω ☐

D 12 Ω ☐

(1 mark)

2 The diagram shows a resistor network.



Complete the sentence by putting a cross (☒) in the box next to your answer.

The total resistance between points X and Y is...

A 0.25 Ω ☐

B 1.0 Ω ☐

C 4.0 Ω ☐

D 16 Ω ☐

(1 mark)

Answers for these questions can be found later in the document.

3 Complete the sentence by putting a cross (☒) in the box next to your answer.

Two identical resistors connected in series have a total resistance of 8 Ω.
The same two resistors when connected in parallel have a total resistance of...

A 0.5 Ω ☒

B 2 Ω ☒

C 4 Ω ☒

D 8 Ω ☒

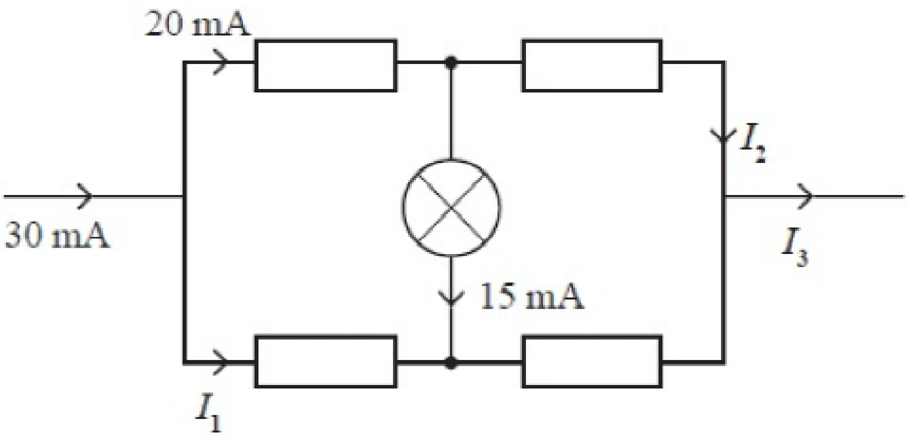
Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

(1 mark)

4 **a** What is the coulomb in base units?

(1 mark)

b The diagram shows part of an electrical circuit.



Determine the magnitudes of the currents I_1, I_2 and I_3.

I_1 =

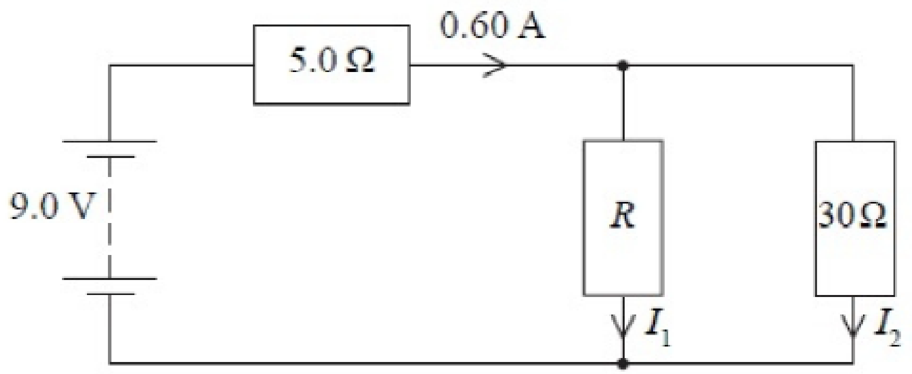
I_2 =

I_3 =

(3 marks)

Answers for these questions can be found later in the document.

5 The circuit diagram shows a battery of negligible internal resistance connected to three resistors.



Do not worry if you find these questions challenging – the A-Level format takes some time to adjust to.

a Calculate the potential difference across the 5 Ω resistor.

(2 marks)

b Calculate the current I_2.

(2 marks)

c Calculate the resistance R.

(2 marks)

ANSWERS

Section 1

Here are the answers to the problems given previously.

Use this information to mark your work **or** to see how to solve various problems in Physics.

The problems are challenging, you are not expected to answer all questions correctly at this stage.

1 **D** work (1 mark)

2 **C** 61 m (1 mark)

3 **A** decreasing time intervals (1 mark)

4 **a** Answer must mention direction or give an e.g. with direction. [Vectors have direction (1 mark) *or* scalars don't have direction (1 mark).]

Scalar – magnitude/size only but vector – magnitude/size and direction (1 mark).

Accept vector has direction but scalar doesn't.

b (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate.)

Velocity is: a vector/speed in a given direction/= displacement/time = (total distance in a particular direction)/time [accept references to velocity being positive and negative/changing direction] (1 mark)

End and start at the same place/distance in any direction is zero/displacement = 0 (1 mark)

So its true (average) velocity = zero (1 mark) (consequential on 2nd mark)

5 **a** Use of an equation of motion involving $a = g$ *or* $-g$ (1 mark).

$v = u + at$ with v or $u = 0$ and double t

Or

Use of $s = ut + ½at^2$ with $s = 0$

Or

Use of $a = \frac{v - u}{t}$ with $v = -u$

Or

Find max $s = 0.40$ m then use $s = ½(v + u)t$ and double t (1 mark)

Do not award if 8 m s^{-1} used.

Time = 0.57 or 0.58(s) (1 mark)

Do not award if negatives have been ignored.

Example of calculation using $a = \frac{v - u}{t}$.

$t = \frac{0 - 2.8\text{ms}^{-1}}{-9.81\text{ms}^{-2}}$ = 02.85 s to reach top of jump

$t = 0.57$ (s)

b Use of distance = 8 m s^{-1} × time (either their time or 0.6 s) (1 mark)

Distance = 4.6 m (ecf (a)) (1 mark)

If show that value of 0.6 s used then d = 4.8 m.

Example of calculation

Distance = 8.0 m s^{-1} × 0.57 s

Distance = 4.6 m

c Attempt to calculate total/extra time using correct equations with correct vertical values (1 mark).

t = 0.14 s or $\frac{1}{7}$ s extra time for additional drop assuming u = 2.8 m s^{-1}

t = 0.43 s or $\frac{3}{7}$ s time from calculation of maximum height using u = 0

t = 0.71 s or $\frac{5}{7}$ s time for whole trajectory using s = – 0.5 m (1 mark)

Distance = 8.0 m s^{-1} × time (1 mark)

Extra horizontal distance travelled = 1.1 m to 1.2 m (1 mark)

Example of calculation

$v^2 = (2.8 \text{ m s}^{-1})^2 + (2 \times 9.81 \text{ m s}^{-2} \times 0.50 \text{ m})$

$v = 4.2 \text{ m s}^{-1}$

$$t = \frac{4.2\text{ms}^{-1} - 2.8\text{ms}^{-1}}{-9.81\text{ms}^{-2}}$$

t = 0.14 s

Distance = 8.0^{-1} × 0.14 s

Distance = 1.1 m

Section 2

1 **A** area under a velocity-time graph (1 mark)

2 **D** 0 m s^{-2} (1 mark)

3 **B** (1 mark)

4 **a** **i** Area under graph between 0.5 and 1.0 s/X and Y/these points/use average velocity between these points × time (1 mark).

Accept correct working with or without units i.e. $0.5 \times 4.8 \times 0.5$.

Accept 4.4 instead of 4.8.

ii Gradient of line at Y/of XY/of XZ/of YZ/at 1.0 s (1 mark)

Accept correct working with ot without units i.e. $(-)4.8 \div 0.5$ or $9.6 \div 1$.

Accept 4.4 instead of 4.8 or 8.8 instead of 9.6.

If candidates answer **i** 'area under graph'/'average velocity' and **ii** 'gradient of graph' without specifying where on graph allow 1 mark in total.

b (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate to be eligible for 4 marks.)

Maximum 2 per error, maximum 2 errors.

- Lines not parallel (1 mark).
  Acceleration should be the same/both should have the same gradient (1 mark).
- Maximum +ve and –ve speeds (from 0.5 s) all the same (1 mark).
  There will be some energy losses (bounce, air resistance) so maximum should have smaller magnitude each time (1 mark).
- Velocity at X/Z greater than at start (1 mark).
  Ball cannot gain energy (1 mark).
- Starts with a positive velocity (1 mark).
  But initial movement is down (1 mark).
- Starts with non-zero velocity/graph starts in wrong place (1 mark).
  From photo, it is dropped from rest (1 mark).
- There is a vertical line (1 mark).
  Bounce must take some time/acceleration can't be infinite etc. (1 mark).
- The graph shows a change in direction of velocity between 0 and 0.5 s/ release and striking the ground (1 mark).
  It is travelling in one direction/down this whole time (1 mark).
- Graph shows an initial deceleration (1 mark).
  It is actually accelerating downwards (1 mark).

Allow an independent mark for second point in a pair if the context is not ambiguous e.g. can't just say 'it is travelling downwards' without saying when.

5 Draw a tangent (accuracy marked in final part) or state use gradient (1 mark).

Use of speed = distance ÷ time for values from graph (i.e. on gradient or curve) (1 mark).

Correct answer [8.0 +/1 0.5 m s^{-1}] (1 mark) (No ecf for values taken.)

Possible alternative – state or use $s = (u + v)t \div 2$ (1 mark), correct substitution (1 mark), correct answer (1 mark). Speed from curve values then × 2 gains all 3 marks.

Example of calculation

$a = (v - u) \div t$

$= (8.0\ \text{m s}^{-1} - 0) \div 4\ \text{s}$

$= 2\ \text{m s}^{-1}$

Section 3

1 **B** 7.5 N kg^{-1} (1 mark)

2 **A** Moving downwards and decelerating. (1 mark)

3 a i $(V =)\ \frac{4}{3}\pi(d \div 2)^3$ *or* $(V =)\ \frac{1}{6}\pi d^3$ (1 mark)

To get this mark, the symbol d must be used.

ii (Mass of helium in the balloon =) $V\rho_h$

Or $\frac{4}{3}\pi(d \div 2)^3\rho_h$

Or $\pi d^3\rho_h \div 6$ (1 mark)

(ecf for volume from part **a i**)

iii (Mass of displaced air =) $V\rho_a$

Or $\frac{4}{3}\pi(d \div 2)^3\rho_a$

Or $\pi d^3\rho_h \div 6$ (1 mark)

(ecf for volume from part **a i**)

iv (Upthrust acting on the balloon =) $V\rho_a g$

Or $\frac{4}{3}\pi(d \div 2)^3\rho_a g$

Or $\pi d^3\rho_a g \div 6$ (1 mark)

(ecf for volume from part **a i** and mass of displaced air from **a iii** and accept $m_a g$)

b (Weight =) Upthrust (− weight of helium)

Or (weight =) $\frac{4}{3}\pi(d \div 2)^3 \rho_a g$ (− $\frac{4}{3}\pi(d \div 2)^3 \rho_h g$)

Or (weight =) $V\rho_a g - (V\rho_h g)$ (1 mark)

(ecf from parts **a i–a iv**)

4 a (QWC – Work must be clear and organised in a logical manner using technical wording where appropriate.)

1 mark each from the following list, maximum 6 marks

- State sufficient quantities to be measured (e.g. *s* and *t or v*, *u* and *t* or *u*, *v* and *s*).
- Relevant apparatus (includes ruler and timer/data logger/light gates).
- Describe how a distance is measured.
- Describe how a speed or time is measured.
- Further detail of measurement of speed or time.
- Vary for described quantities and plot appropriate graph.
- State how result calculated.
- Repeat and mean (1 mark maximum for any relevant quantity/result).

b Any precaution relating to experimental procedure (1 mark).

Section 4

1 B J C^{-1} (1 mark)

2 B 2800 C (1 mark)

3 C 8.9 Ω (1 mark)

4 (High resistance) so very little/negligible/zero current in the voltmeter.

Or because otherwise a current would pass through he voltmeter.

Or so the total resistance of the parallel circuit isn't changed.

Or because otherwise total resistance of parallel combination would be reduced (1 mark).

Because that would change/increase the current in the ammeter.

Or because that would mean the current through the ammeter was different to (larger than) the current through the component (1 mark).

5 a (Ω =) V A^{-1} *or* (Ω =) $\frac{\text{V}}{\text{A}}$ *or* $R = \frac{V}{I}$ [*or* volt in alternative equivalent units divided by ampere in alternative equivalent units, as long as Ω isn't part of it] (1 mark).

Units and quantities must not be mixed.

b **i** Use of $R = \frac{V}{I}$ with values feasibly from the graph (1 mark).

R = 6.8 Ω to 8.0 Ω (1 mark)

Marks not awarded if using a gradient.

ii Resistance of metal remains constant (1 mark).

Resistance of thermistor decreased (as p.d. increases) (1 mark).

iii (Increasing) current leads to temperature increase/leads to thermistor 'heating up' (1 mark).

More conduction electrons/more electrons released/more free electrons/more charge carriers/charge carrier density increased/n increases (1 mark).

Section 5

1 **B** 6 Ω (1 mark)

2 **C** 4.0 Ω (1 mark)

3 B 2 Ω (1 mark)

4 **a** A coulomb is an Amp second or As (1 mark).

Do not credit current × time.

b I_1 = 10 mA (1 mark)

I_2 = 5 mA (1 mark)

I_3 = 30 mA (1 mark)

5 **a** Use of $V = IR$ (1 mark)

V = 3.0 V (1 mark)

b p.d. across 30 Ω resistor = 6.0 V ecf their answer (1 mark)

I_2 = 6.0 ÷ 30 = 0.20 A (1 mark)

c I_1 = 0.60 – 0.20 = 0.40 A (1 mark)

R = 15 Ω full ecf for their answer for I_2 and their V across 30 Ω (1 mark)

SECTION 4: THEORETICAL PROBLEM SOLVING

To familiarise yourself with the physics problem-solving side of the course, **please complete the following questions for the first week of the course in 2019-2020.**
You will find these questions hard, as answering these types of problems is an untaught and unfamiliar skill to you, however the more practice you have on these types of questions, they better you will become.
In many questions, there is less structure than what you are used from GCSE examinations. Look for the key ideas in the questions and work from there.
You do not need to be explicitly aware of the concept to answer these questions.

A1. What volume of asphalt is needed to resurface 1km length of road to an average depth of 20mm if the width of the road is 5m? Give your answer is kilograms per metre^3.

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Tip

You can use the equation book on **pages 73-77**.

This is given to you in your A-Level examinations.

Equations do not need to be memorised at A-Level.

A2. How far does a rocket move in 1μs if its speed is 10km/s? Give your answer in metres.

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Tip

You can use the equation book on **pages 73-77**.

This is given to you in your A-Level examinations.

Equations do not need to be memorised at A-Level.

A3. What volume of liquid will fill a 50cm length of capillary tube if the cross sectional area of the tube is $1mm^2$? Give your answer is kilograms per $metre^3$.

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Tip

You can use the equation book on **pages 73-77**.

This is given to you in your A-Level examinations.

Equations do not need to be memorised at A-Level.

A4. What mass of air, density $1kg/m^3$, is contained in a cube of side 10cm? Give your answers in kilograms.

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Tip

You can use the equation book on **pages 73-77**.

This is given to you in your A-Level examinations.

Equations do not need to be memorised at A-Level.

A5. Which is the longer time, a kilosecond or a microcentury?

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Tip

Use your knowledge of prefixes to answer this question

A6. At a recent British International drag festival, one of the cars covered the standing start quarter mile (400m) in 8.3 seconds.
A6.1 What uniform acceleration would enable it to do this?
A6.2 What is the percentage difference between the answer in 6.1 and the acceleration due to gravity on Earth?
A6.3 What would the final speed of the car be?

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Tip

You can use the equation book on **pages 73-77**.

This is given to you in your A-Level examinations.

Equations do not need to be memorised at A-Level.

THIS IS A HARD QUESTION
A7. One of the first estimates of the age of the Earth was made by Edmund Halley in 1715. He assumed that all the salt now in the oceans has been brought there by the rivers that drain into them. Knowing the rate at which the rivers bring the salt down, he calculated how long it would have taken for the salt concentration in the oceans to build up from nothing to its current level. This method is very rough.
From present day data, use this method to calculate the age of the Earth.
Total area of the oceans = 4×10^8 km^2
Mean depth = 4000 m
Mean salinity = 3% by weight
Rate of addition of salt by rivers = 1×10^4 kg/s (In one year there are 3×10^7 seconds)

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Tip

You can use the equation book on **pages 73-77**.

This is given to you in your A-Level examinations.

Equations do not need to be memorised at A-Level.

Reference: Inquiring into Physics Book 1; A.W Wilson

SECTION 5: PRACTICAL PROBLEM SOLVING

To familiarise yourself with the practical problem-solving side of the course, **please complete the following questions for the first week of the course in 2019-2020.**
You will find these questions hard as this is an untaught and unfamiliar skill to you, however the more practice you have on these types of questions, they better you will become.

You do not need to be explicitly aware of the practical to answer these questions.

2 A student performs an experiment to find the acceleration due to gravity. The student measures the time t for a spherical object to fall freely through measured vertical distances s. The time is measured electronically. The results are shown in **Table 1** below.

Use the equation…
$s = ut + ½ at^2$

Table 1

s/m	t_1/s	t_2/s	t_3/s	**mean time** t_m/s	t_m^2/s^2
0.300	0.245	0.246	0.244	0.245	0.0600
0.400	0.285	0.286	0.286	0.286	0.0818
0.500	0.319	0.321	0.318	0.319	0.102
0.600	0.349	0.351	0.348	0.349	0.122
0.700	0.378	0.380	0.378	0.379	0.144
0.800	0.403	0.406	0.404		
0.900	0.428	0.428	0.430		

2 (a) Complete **Table 1** by entering the missing values for t_m and t_m^2.

[1 mark]

2 (b) Complete the graph in **Figure 2** by plotting the remaining two points and draw a line of best fit.

[2 marks]

HINT

The larger the gradient triangle the better.

2 (c) Determine the gradient of the graph.

[3 marks]

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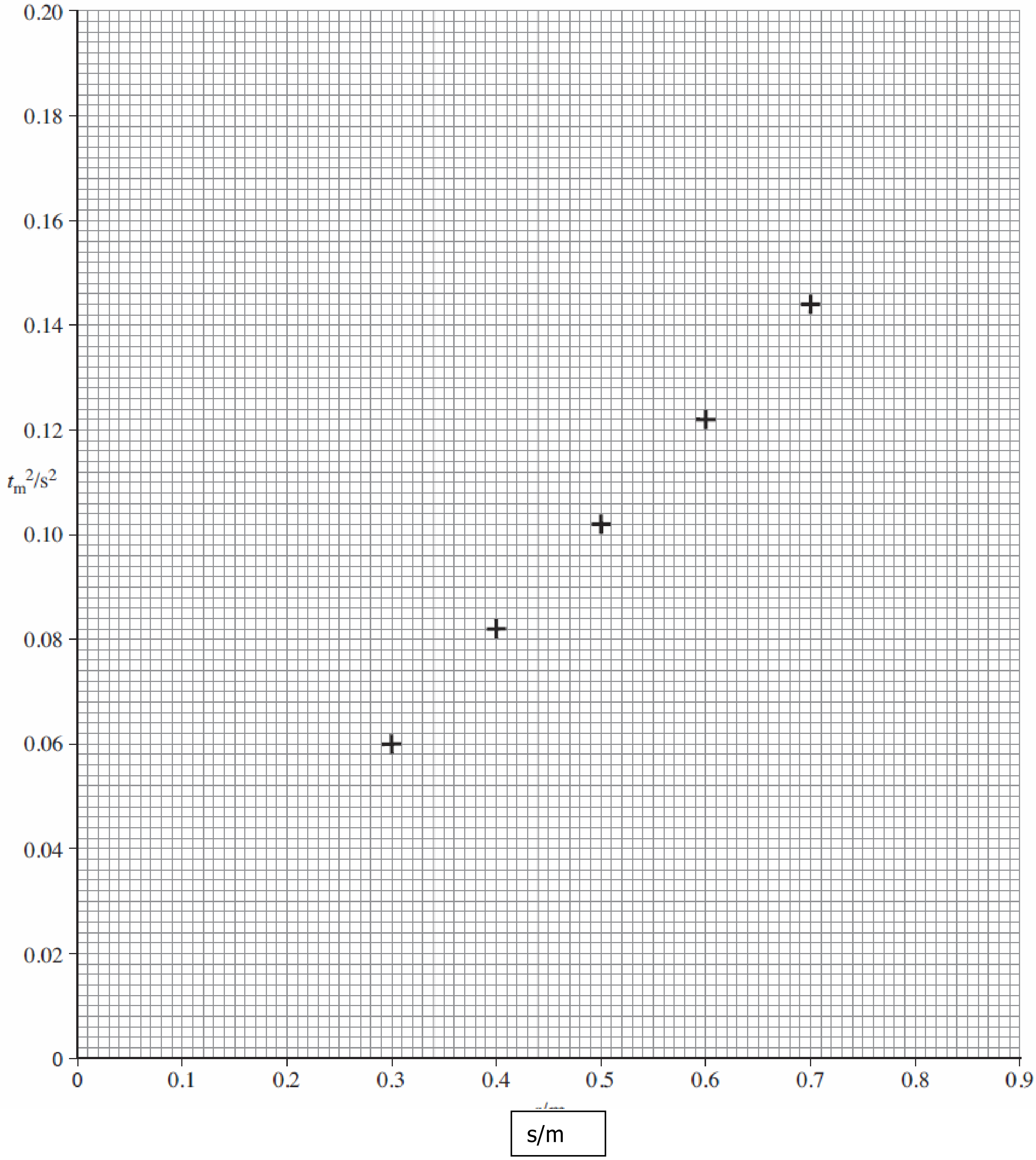
WARNING: These questions are difficult, as you have not been taught the practical skills yet.

These questions are found on A-Level Physics Paper 3 examinations.

Figure 2


0.20
0.18
0.16
0.14
0.12
t_m^2/s^2
0.10
0.08
0.06
0.04
0.02
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
s/m

2 (d) Theory suggests that the equation for the line is $t^2 = \frac{2s}{g}$ where g is the acceleration due to gravity.

Calculate a value for g using the above equation and the gradient of your graph in **Figure 2**.

[1 mark]

2 (e) Calculate the percentage difference between your value for g and the accepted value of $9.81\ \mathrm{m\ s^{-2}}$.

[1 mark]

Use the equation…
Percentage Difference = <u>Difference in Values</u> x 100
Accepted Value

$$\text{Percentage Difference} = \frac{\text{Difference in Values}}{\text{Accepted Value}} \times 100$$

Reference: AQA A-Level Physics ISA Section P 2016 Examination

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(a) Calculate the uncertainty in the smallest value of t_m.

The uncertainty is half the spread of results in the different repeated values.

[1 mark]

(b) Calculate the value of g which would be given from the smallest value of t_m and the corresponding value of s.

[3 marks]

(c) The uncertainty in each value of s is ± 0.001 m.

Calculate the uncertainty in the value of g you calculated in 3(b).
You will need to use the uncertainty for t_m you calculated in 3(a).

[3 marks]

$$\text{Percentage Uncertainty} = \frac{\text{Absolute Uncertainty}}{\text{Value}} \times 100$$

WARNING: These questions are difficult, as you have not been taught the practical skills yet.

These questions are found on A-Level Physics Paper 3 examinations.

Reference: AQA A-Level Physics ISA Section P 2016 Examination

A student wishes to investigate the effect of changing the mass of the spherical object on the acceleration of free fall.

Explain how you would modify the experiment in Question 2.

[3 marks]

WARNING: These questions are difficult, as you have not been taught the practical skills yet.

These questions are found on A-Level Physics Paper 3 examinations.

Reference: AQA A-Level Physics ISA Section P 2016 Examination

DATASHEET

DATA – FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\ s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\ m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\ m^{2}\ kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\ m^{-2}\ K^{-4}}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	$\mathrm{C\ kg^{-1}}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^{7}	$\mathrm{C\ kg^{-1}}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$\mathrm{N\ kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\ s^{-2}}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.97×10^{24}	6.37×10^{6}

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
curved surface area of cylinder	$= 2\pi rh$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

		Lepton number
Particles:	$e^-, \nu_e; \mu^-, \nu_\mu$	$+1$
Antiparticles:	$e^+, \overline{\nu_e}, \mu^+, \overline{\nu_\mu}$	-1

Photons and energy levels

photon energy $E = hf = hc/\lambda$

photoelectricity $hf = \phi + E_{k\,(max)}$

energy levels $hf = E_1 - E_2$

de Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

Waves

wave speed $c = f\lambda$ *period* $f = \frac{1}{T}$

first harmonic $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

fringe spacing $w = \frac{\lambda D}{s}$ *diffraction grating* $d \sin\theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 *and* n_2,

law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

critical angle $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

moments moment $= Fd$

velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

equations of motion $v = u + at$ $s = \left(\frac{u+v}{2}\right)t$

$v^2 = u^2 + 2as$ $s = ut + \frac{at^2}{2}$

force $F = ma$

force $F = \frac{\Delta(mv)}{\Delta t}$

impulse $F\,\Delta t = \Delta(mv)$

work, energy and power $W = F\,s\cos\theta$

$E_k = \frac{1}{2}m\,v^2$ $\Delta E_p = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

$efficiency = \frac{useful\ output\ power}{input\ power}$

Materials

density $\rho = \frac{m}{V}$ *Hooke's law* $F = k\,\Delta L$

Young modulus $= \frac{tensile\ stress}{tensile\ strain}$ *tensile stress* $= \frac{F}{A}$ *tensile strain* $= \frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

Electricity

current and pd $I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$ $R = \frac{V}{I}$

resistivity $\rho = \frac{RA}{L}$

resistors in series $R_T = R_1 + R_2 + R_3 + \ldots$

resistors in parallel $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

power $P = VI = I^2R = \frac{V^2}{R}$

emf $\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$

Circular motion

magnitude of angular speed $\omega = \frac{v}{r}$

$\omega = 2\pi f$

centripetal acceleration $a = \frac{v^2}{r} = \omega^2 r$

centripetal force $F = \frac{mv^2}{r} = m\omega^2 r$

Simple harmonic motion

acceleration $a = -\omega^2 x$

displacement $x = A\cos(\omega t)$

speed $v = \pm\omega\sqrt{(A^2 - x^2)}$

maximum speed $v_{max} = \omega A$

maximum acceleration $a_{max} = \omega^2 A$

for a mass-spring system $T = 2\pi\sqrt{\frac{m}{k}}$

for a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

Thermal physics

energy to change temperature $Q = mc\Delta\theta$

energy to change state $Q = m\,l$

gas law $pV = nRT$

$pV = NkT$

kinetic theory model $pV = \frac{1}{3}N\,m\,(c_{\text{rms}})^2$

kinetic energy of gas molecule $\frac{1}{2}m\,(c_{\text{rms}})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$

Gravitational fields

force between two masses $F = \frac{Gm_1m_2}{r^2}$

gravitational field strength $g = \frac{F}{m}$

magnitude of gravitational field strength in a radial field $g = \frac{GM}{r^2}$

work done $\Delta W = m\Delta V$

gravitational potential $V = -\frac{GM}{r}$

$g = -\frac{\Delta V}{\Delta r}$

Electric fields and capacitors

force between two point charges $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$

force on a charge $F = EQ$

field strength for a uniform field $E = \frac{V}{d}$

work done $\Delta W = Q\Delta V$

field strength for a radial field $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

electric potential $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$

$E = \frac{\Delta V}{\Delta r}$

capacitance $C = \frac{Q}{V}$

$C = \frac{A\varepsilon_0\varepsilon_r}{d}$

capacitor energy stored $E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

capacitor charging $Q = Q_0(1 - e^{-t/RC})$

decay of charge $Q = Q_0e^{-t/RC}$

time constant RC

Magnetic fields

force on a current	$F = BIl$
force on a moving charge	$F = BQv$
magnetic flux	$\Phi = BA$
magnetic flux linkage	$N\Phi = BAN\cos\theta$
magnitude of induced emf	$\varepsilon = N\dfrac{\Delta\Phi}{\Delta t}$
	$N\Phi = BAN\cos\theta$
emf induced in a rotating coil	$\varepsilon = BAN\omega\sin\omega t$
alternating current	$I_{rms} = \dfrac{I_0}{\sqrt{2}} \quad V_{rms} = \dfrac{V_0}{\sqrt{2}}$
transformer equations	$\dfrac{N_s}{N_p} = \dfrac{V_s}{V_p}$
	$efficiency = \dfrac{I_s V_s}{I_p V_p}$

Nuclear physics

the inverse square law for γ radiation	$I = \dfrac{k}{x^2}$
radioactive decay	$\dfrac{\Delta N}{\Delta t} = -\lambda N,\ N = N_0 e^{-\lambda t}$
activity	$A = \lambda N$
half-life	$T_{½} = \dfrac{\ln 2}{\lambda}$
nuclear radius	$R = R_0 A^{1/3}$
energy-mass equation	$E = mc^2$

OPTIONS

Astrophysics

1 astronomical unit = 1.50×10^{11} m

1 light year = 9.46×10^{15} m

1 parsec = 206265 AU = 3.08×10^{16} m
= 3.26 light year

Hubble constant, H = 65 km s^{-1} Mpc^{-1}

$$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$$

in normal adjustment	$M = \dfrac{f_o}{f_e}$
Rayleigh criterion	$\theta \approx \dfrac{\lambda}{D}$
magnitude equation	$m - M = 5\log\dfrac{d}{10}$
Wien's law	$\lambda_{max} T = 2.9 \times 10^{-3}$ m K
Stefan's law	$P = \sigma A T^4$
Schwarzschild radius	$R_s \approx \dfrac{2GM}{c^2}$
Doppler shift for v << c	$\dfrac{\Delta f}{f} = -\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$
red shift	$z = -\dfrac{v}{c}$
Hubble's law	$v = Hd$

Medical physics

lens equations	$P = \dfrac{1}{f}$
	$m = \dfrac{v}{u}$
	$\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$
threshold of hearing	$I_0 = 1.0 \times 10^{-12}$ W m^{-2}
intensity level	$intensity\ level = 10\log\dfrac{I}{I_0}$
absorption	$I = I_0 e^{-\mu x}$
	$\mu_m = \dfrac{\mu}{\rho}$
ultrasound imaging	$Z = \rho c$
	$\dfrac{I_r}{I_i} = \left(\dfrac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$
half-lives	$\dfrac{1}{T_E} = \dfrac{1}{T_B} + \dfrac{1}{T_P}$

Engineering physics

moment of inertia $I = \Sigma mr^2$

angular kinetic energy $E_k = \frac{1}{2}I\omega^2$

equations of angular motion

$$\omega_2 = \omega_1 + \alpha t$$

$$\omega_2{}^2 = \omega_1{}^2 + 2\alpha\theta$$

$$\theta = \omega_1 t + \frac{\alpha t^2}{2}$$

$$\theta = \frac{(\omega_1 + \omega_2)\,t}{2}$$

torque $T = I\,\alpha$

$T = F\,r$

angular momentum $\text{angular momentum} = I\omega$

angular impulse $T\Delta t = \Delta(I\omega)$

work done $W = T\theta$

power $P = T\omega$

thermodynamics $Q = \Delta U + W$

$W = p\Delta V$

adiabatic change $pV^{\gamma} = \text{constant}$

isothermal change $pV = \text{constant}$

heat engines

$$\text{efficiency} = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

$$\text{maximum theoretical efficiency} = \frac{T_H - T_C}{T_H}$$

work done per cycle = area of loop

input power = calorific value × fuel flow rate

$$\text{indicated power} = (\text{area of } p - V \text{ loop}) \times (\text{number of cycles per second}) \times (\text{number of cylinders})$$

output or brake power $P = T\omega$

friction power = indicated power – brake power

heat pumps and refrigerators

refrigerator: $COP_{\text{ref}} = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C}$

heat pump: $COP_{\text{hp}} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C}$

Turning points in physics

electrons in fields

$$F = \frac{eV}{d}$$

$$F = Bev$$

$$r = \frac{mv}{Be}$$

$$\tfrac{1}{2} mv^2 = eV$$

Millikan's experiment

$$\frac{QV}{d} = mg$$

$$F = 6\pi\eta rv$$

Maxwell's formula

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$$

special relativity

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$l = l_0\sqrt{1 - \frac{v^2}{c^2}}$$

$$E = mc^2 = \frac{m_0c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Electronics

resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$

Q-factor $Q = \frac{f_0}{f_B}$

operational amplifiers: open loop $V_{\text{out}} = A_{\text{OL}}(V_+ - V_-)$

inverting amplifier $\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_f}{R_{\text{in}}}$

non-inverting amplifier $\frac{V_{\text{out}}}{V_{\text{in}}} = 1 + \frac{R_f}{R_1}$

summing amplifier $V_{\text{out}} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \cdots\right)$

difference amplifier $V_{\text{out}} = (V_+ - V_-)\frac{R_f}{R_1}$

Bandwidth requirement:

for AM $\text{bandwidth} = 2f_M$

for FM $\text{bandwidth} = 2(\Delta f + f_M)$

Acknowledgements

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