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Academy Shoreditch



Sixth
Form

Summer Assignment

Complete this booklet and bring it in to show your teachers on your return to Y12. You will be tested on the contents.

Physics

So you are considering A Level Physics?

This pack contains a programme of activities and resources to prepare you to start an A level in Physics in September. It is aimed to be used as a bridging resources from the topics you have covered in GCSE physics, throughout the remainder of the Summer term and over the Summer Holidays to ensure you are ready to start your course in September. Read it a couple of pages a time, do the tasks. Look up ideas that you find difficult, or just ask on Teams.

Introduction

AQA GCE Physics (7408) – a content-led approach. You will study physics in a range of different contents, conveying the excitement of contemporary physics. The course provides a distinctive structure within which you will learn about fundamental physical concepts and about physics in everyday and technological settings. Practical skills are embedded within the specification and you are expected to carry out practical work in preparation for a written examination that will specifically test these skills.

The specification has been developed with subject and teaching experts, working in close consultation with teachers and representatives from Higher Education (HE) with the aim of including up-to-date relevant content within a framework that is interesting to learn.

The specification can be downloads from here: <https://www.aqa.org.uk/subjects/science/as-and-a-level/physics-7407-7408>

Contents of A Level in Physics (7408)

The first year of the specification content is divided into five teaching modules. Each module is introduced with a summary of the physics it contains and each topic is also introduced with a short summary text.

A summary of the content for the first year of the course is as follows:

Module 3.1 – Measurements and their errors

Module 3.2 – Particles and radiation

3.2.1 Particles

3.2.2 Electromagnetic radiation and quantum phenomena

Module 3.3 – Waves

3.3.1 Progressive and stationary waves

3.3.2 Refraction, diffraction and interference

Module 3.4 – Mechanics and materials

3.4.1 Force, energy and momentum

3.4.2 Materials

Module 3.5 – Electricity

3.5.1 Current electricity

3.5.2 Materials

Contents of A Level in Physics (7408)

The A Level in Physics (7408) specification content is divided into nine teaching modules – the 5 modules covered in year 1 and 4 additional modules in year 2. Each module is introduced with a summary of the physics it contains and each topic is also introduced with a short summary text.

A summary of the additional content for the A level course is as follows:

Module 3.6 – Further mechanics and thermal physics

3.6.1 Periodic motion

3.6.2 Thermal physics

Module 3.7 – Field and their consequences

Contents of A Level in Physics (7408) (continued)

3.7.1 Fields

3.7.2 Gravitational fields

3.7.3 Electric fields

3.7.4 Capacitance

3.7.5 Magnetic fields

Module 3.8 – Nuclear physics

3.8.1 Radioactivity

Module 3.9 – Astrophysics (option unit)

3.9.1 Telescopes

3.9.2 Classification of stars

3.9.3 Cosmology

A summary of the assessment for the A level course is as follows:

Paper 1 – Sections 1 – 5 and 6.1

Written paper, 2 hour, 85 marks, 34% of total A level

Paper 2 – Sections 6.2, 7 and 8 (02)

Written paper, 2 hour, 85 marks, 34% of total A level

Paper 3 – Practical skills and option unit

Written paper, 2 hours, 80 marks, 32% of total A level

Practical endorsement in physics (04)

Non exam assessment throughout 2 years – reported separately on A level

Teaching program

The teaching program for the first year of this course is provided through a 9 lesson every two week timetable.

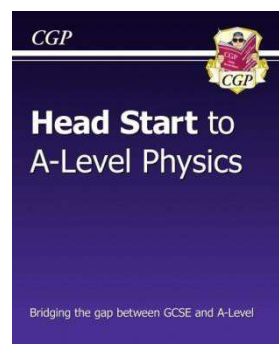
The classes will explore the application of physics to modern day applications, through taught theory, demonstrations, and student practicals within the physics teaching rooms.

With transition from KS4 to KS5 there is a clear expectation that all students will consolidate their learning both after each class and through home learning – homework will be set by both teachers at least once per week.

Students will be provided with access to the online learning resource Kerboodle which has an online course text book.

Students are encouraged to make the transition from KS4 to KS5 by purchasing the following CGP transition book:

- Head Start to A-level Physics
- Paperback
- By [CGP Books](#) (Author, Editor)
- **ISBN-13:** 978-1782942818
- Price £4.95

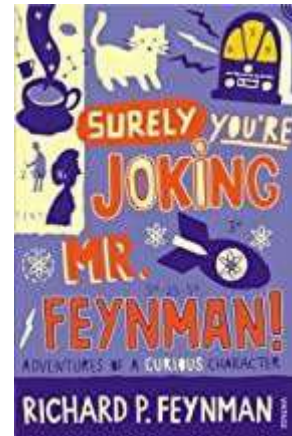


Book Recommendations

Below is a selection of books that should appeal to a physicist – someone with an enquiring mind who wants to understand the universe around us. None of the selections are textbooks full of equation work (there will be plenty of time for that!) instead each provides insight to either an application of physics or a new area of study that you will be meeting at A Level for the first time.

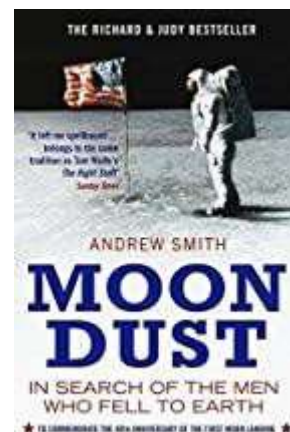
1. Surely You're Joking Mr Feynman: Adventures of a Curious Character

ISBN - 009917331X - Richard Feynman was a Nobel Prize winning Physicist. In my opinion he epitomises what a Physicist is. By reading this books you will get insight into his life's work including the creation of the first atomic bomb and his bongo playing adventures and his work in the field of particle physics



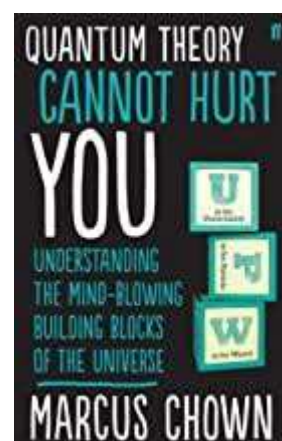
2. Moondust: In Search of the Men Who Fell to Earth

ISBN – 1408802384 - One of the greatest scientific achievements of all time was putting mankind on the surface of the moon. Only 12 men made the trip to the surface, at the time of writing the book only 9 are still with us. The book does an excellent job of using the personal accounts of the 9 remaining astronauts and many others involved in the space program at looking at the whole space-race era, with hopefully a new era of space flight about to begin as we push on to put mankind on Mars in the next couple of decades.



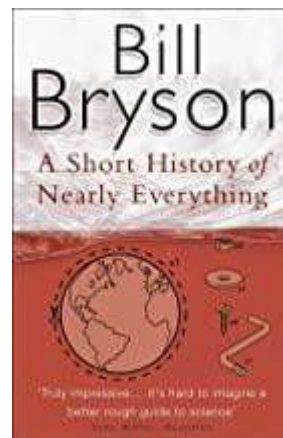
3. Quantum Theory Cannot Hurt You: Understanding the Mind-Blowing Building Blocks of the Universe

ISBN - 057131502X - Any Physics book by Marcus Chown is an excellent insight into some of the more exotic areas of Physics that require no prior knowledge. In your first year of A-Level study you will meet the quantum world for the first time. This book will fill you with interesting facts and handy analogies to whip out to impress your peers!



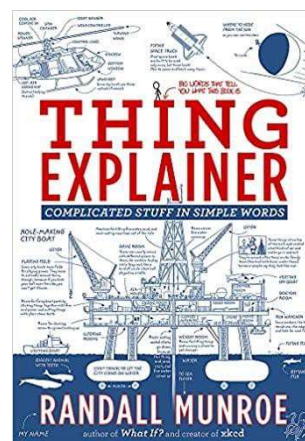
4. A Short History of Nearly Everything

ISBN – 0552997048 - A modern classic. Popular science writing at its best. A Short History of Nearly Everything Bill Bryson's quest to find out everything that has happened from the Big Bang to the rise of civilization - how we got from there, being nothing at all, to here, being us. Hopefully by reading it you will gain an awe-inspiring feeling of how everything in the universe is connected by some fundamental laws.



5. Thing Explainer: Complicated Stuff in Simple Words

ISBN – 9781473637313 - This final recommendation is a bit of a wild-card – a book of illustrated cartoon diagrams that should appeal to the scientific side of everyone. Written by the creator of online comic XTCD (a great source of science humour) is a book of blueprints from everyday objects such as a biro to the Saturn V rocket and an atom bomb, each one meticulously explained BUT only with the most common 1000 words in the English Language. This would be an excellent coffee table book in the home of every scientist.



Video Clip / Movie Recommendations

Hopefully you'll get the opportunity to soak up some of the Sun's rays over the summer – synthesising some important Vitamin-D – but if you do get a few rainy days where you're stuck indoors, here are some ideas for films to watch or clips to find online.

Science Fiction Films with some real physics:

- *Moon* (2009)
- *Gravity* (2013)
- *Interstellar* (2014)
- *The Imitation Game* (2015)
- *The Prestige* (2006)

▪ **Online Clips / Series:**

- **Minute Physics** – Variety of Physics questions explained simply (in felt tip) in a couple of minutes. Addictive viewing that will have you watching clip after clip – a particular favourite of mine is “Why is the Sky Dark at Night?”
<https://www.youtube.com/user/minutephysics>
- **Wonders of the Universe / Wonders of the Solar System** – Brian Cox explains the Cosmos using some excellent analogies and wonderful imagery.

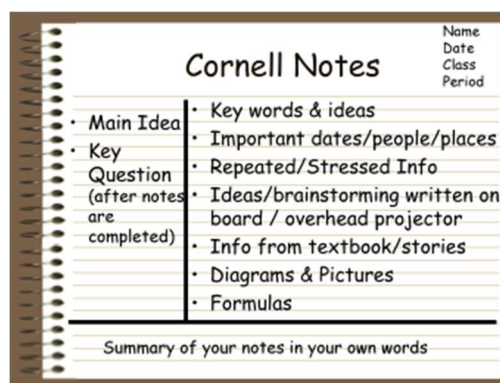
- **Shock and Awe, The Story of Electricity** – A 3 part BBC documentary that is essential viewing if you want to see how our lives have been transformed by the ideas of a few great scientists a little over 100 years ago.
- **NASA TV** – Online coverage of launches, missions, testing and the ISS. Plenty of clips and links to explore to find out more about applications of Physics in Space technology. <http://www.nasa.gov/multimedia/nasatv/>
- **The Fantastic Mr. Feynman** – I recommended the book earlier, I also cannot recommend this 1 hour documentary highly enough. See the life's work of the “great explainer”, a fantastic mind that created mischief in all areas of modern Physics.

Research activity

To get the best grades in A Level Physics you will have to get good at completing independent research and making your own notes on difficult topics. Below are links to 5 websites that cover some interesting Physics topics.

Using the Cornell notes system:

<http://coe.jmu.edu/learningtoolbox/cornellnotes.html> make 1 page of notes **from one of the sites** covering a topic of your choice.



- <http://home.cern/about>
 - CERN encompasses the Large Hadron Collider (LHC) and is the largest collaborative science experiment ever undertaken. Find out about it here and make a page of suitable notes on the accelerator.
- http://joshworth.com/dev/pixelspace/pixelspace_solarsystem.html
 - The solar system is massive and its scale is hard to comprehend. Have a look at this award winning website and make a page of suitable notes.
- <https://phet.colorado.edu/en/simulations/category/html>
 - PhET create online Physics simulations when you can complete some simple experiments online. Open up the resistance of a wire html5 simulation. Conduct a simple experiment and make a one page summary of the experiment and your findings.
- <http://climate.nasa.gov/>
 - NASA's Jet Propulsion Laboratory has lots of information on Climate Change and Engineering Solutions to combat it. Have a look and make notes on an article of your choice.
- <http://www.livescience.com/46558-laws-of-motion.html>
 - Newton's Laws of Motion are fundamental laws for the motion of all the objects we can see around us. Use this website and the suggested further reading links on the webpage to make your own 1 page of notes on the topics

Pre-Knowledge Topics

Moving from GCSE Science to A Level can be a daunting leap. You'll be expected to remember a lot more facts, equations, and definitions, and you will need to learn new maths skills and develop confidence in applying what you already know to unfamiliar situations.

This remainder of this bridging workbook aims to give you a head start by helping you:

- to pre-learn some useful knowledge from the first chapters of your A Level course
- understand and practice of some of the maths skills you'll need.

Learning objectives

After completing the bridging workbook you should be able to:

- define practical science key terms
- recall the answers to the retrieval questions
- perform maths skills including:
 - unit conversions
 - uncertainties
 - using standard form and significant figures
 - resolving vectors
 - rearranging equations
 - equations of work, power, and efficiency

Retrieval questions

You need to be confident about the definitions of terms that describe measurements and results in A Level Physics.

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

Practical science key terms

When is a measurement valid?	when it measures what it is supposed to be measuring
When is a result accurate?	when it is close to the true value
What are precise results?	when repeat measurements are consistent/agree closely with each other
What is repeatability?	how precise repeated measurements are when they are taken by the <i>same</i> person, using the <i>same</i> equipment, under the <i>same</i> conditions
What is reproducibility?	how precise repeated measurements are when they are taken by <i>different</i> people, using <i>different</i> equipment
What is the uncertainty of a measurement?	the interval within which the true value is expected to lie
Define measurement error	the difference between a measured value and the true value
What type of error is caused by results varying around the true value in an unpredictable way?	random error
What is a systematic error?	a consistent difference between the measured values and true values
What does zero error mean?	a measuring instrument gives a false reading when the true value should be zero
Which variable is changed or selected by the investigator?	independent variable
What is a dependent variable?	a variable that is measured every time the independent variable is changed
Define a fair test	a test in which only the independent variable is allowed to affect the dependent variable
What are control variables?	variables that should be kept constant to avoid them affecting the dependent variable

Matter and radiation

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many answers as you can. Check and repeat.

What is an atom made up of?	a positively charged nucleus containing protons and neutrons, surrounded by electrons
Define a <i>nucleon</i>	a proton or a neutron in the nucleus
What are the absolute charges of protons, neutrons, and electrons?	$e = 1.60 \times 10^{-19}$, 0, and -1.60×10^{-19} coulombs (C) respectively.
What are the relative charges of protons, neutrons, and electrons?	1, 0, and -1 respectively (charge relative to proton)
What is the mass, in kilograms, of a proton, a neutron, and an electron?	1.67×10^{-27} , 1.67×10^{-27} , and 9.11×10^{-31} kg respectively
What are the relative masses of protons, neutrons, and electrons?	1, 1, and 0.0005 respectively (mass relative to proton)
What is the atomic number of an element?	the number of protons
Define an isotope	isotopes are atoms with the same number of protons and different numbers of neutrons
Write what A, Z and X stand for in isotope notation (${}^A_Z X$)?	A: the number of nucleons (protons + neutrons) Z: the number of protons X: the chemical symbol
Which term is used for each type of nucleus?	nuclide
How do you calculate specific charge?	charge divided by mass (for a charged particle)
What is the specific charge of a proton and an electron?	9.58×10^7 and 1.76×10^{11} C kg ⁻¹ respectively
Name the force that holds nuclei together	strong nuclear force
What is the range of the strong nuclear force?	from 0.5 to 3.4 femtometres (fm)
Name the three kinds of radiation	alpha, beta, and gamma
What particle is released in alpha radiation?	an alpha particle, which comprises two protons and two neutrons
Write the symbol of an alpha particle	${}^4_2 \alpha$
What particle is released in beta radiation?	a fast-moving electron (a beta particle)
Write the symbol for a beta particle	${}^0_{-1} \beta$
Define <i>gamma radiation</i>	electromagnetic radiation emitted by an unstable nucleus
What particles make up everything in the universe?	matter and antimatter
Name the antimatter particles for electrons, protons, neutrons, and neutrinos	positron, antiproton, antineutron, and antineutrino respectively
What happens when corresponding matter and antimatter particles meet?	they annihilate (destroy each other)
List the seven main parts of the electromagnetic spectrum from longest wavelength to shortest	radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays
Write the equation for calculating the wavelength of electromagnetic radiation	wavelength $\lambda = \frac{\text{speed of light } (c)}{\text{frequency } (f)}$
Define a <i>photon</i>	a packet of electromagnetic waves
What is the speed of light?	3.00×10^8 m s ⁻¹
Write the equation for calculating photon energy	photon energy (E) = Planck constant (h) \times frequency (f)
Name the four fundamental interactions	gravity, electromagnetic, weak nuclear, strong nuclear

Maths skills

1 Measurements

1.1 Base and derived SI units

Units are defined so that, for example, every scientist who measures a mass in kilograms uses the same size for the kilogram and gets the same value for the mass. Scientific measurement depends on standard units – most are *Système International (SI)* units. Every measurement must give the unit to have any meaning. You should know the correct unit for physical quantities.

Base units

Physical quantity	Unit	Symbol
length	metre	m
mass	kilogram	kg
time	second	s

Physical quantity	Unit	Symbol
electric current	ampere	A
temperature difference	Kelvin	K
amount of substance	mole	mol

Derived units

Example:

$$speed = \frac{\text{distance travelled}}{\text{time taken}}$$

If a car travels 2 metres in 2 seconds:

$$speed = \frac{2 \text{ metres}}{2 \text{ seconds}} = 1 \frac{m}{s} = 1ms^{-1}$$

This defines the SI unit of speed to be 1 metre per second (m/s), or 1 m s^{-1} ($s^{-1} = 1/s$)

Practice questions

1 Complete this table by filling in the missing units and symbols.

Physical quantity	Equation used to derive unit	Unit	Symbol and name (if there is one)
frequency	period ⁻¹	s ⁻¹	Hz, hertz
volume	length ³		–
density	mass ÷ volume		–
acceleration	velocity ÷ time		–
force	mass × acceleration		
work and energy	force × distance		

1.2 Significant figures

When you use a calculator to work out a numerical answer, you know that this often results in a large number of decimal places and, in most cases, the final few digits are 'not significant'. It is important to record your data and your answers to calculations to a reasonable number of significant figures. Too many and your answer is claiming an accuracy that it does not have, too few and you are not showing the precision and care required in scientific analysis.

Numbers to 3 significant figures (3 s.f.): 3.62 25.4 271 0.0147 0.245 39400

(notice that the zeros before the figures and after the figures are *not* significant – they just show you how large the number is by the position of the decimal point).

Numbers to 3 significant figures where the zeros *are* significant:

207 4050 1.01 (any zeros between the other significant figures *are* significant).

Standard form numbers with 3 significant figures:

9.42×10^{-5} 1.56×10^8

If the value you wanted to write to 3.s.f. was 590, then to show the zero was significant you would have to write:

590 (to 3.s.f.) or 5.90×10^2

Practice questions

2 Give these measurements to 2 significant figures:

a 19.47 m **b** 21.0 s **c** 1.673×10^{-27} kg **d** 5 s

3 Use the equation:

$$\text{resistance} = \frac{\text{potential difference}}{\text{current}}$$

to calculate the resistance of a circuit when the potential difference is 12 V and the current is 1.8 mA.
Write your answer in k Ω to 3 s.f.

1.3 Uncertainties

When a physical quantity is measured there will always be a small difference between the measured value and the true value. How important the difference is will depend on the size of the measurement and the size of the uncertainty, so it is important to know this information when using data.

There are several possible reasons for uncertainty in measurements, including the difficulty of taking the measurement and the resolution of the measuring instrument (i.e. the size of the scale divisions).

For example, a length of 6.5 m measured with great care using a 10 m tape measure marked in mm would have an uncertainty of 2 mm and would be recorded as 6.500 ± 0.002 m.

It is useful to quote these uncertainties as percentages. For the above length, for example,

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{measurement}} \times 100$$

$$\text{percentage uncertainty} = \frac{0.002 \times 100}{6.500} = 0.03\%. \text{ The measurement is } 6.500 \text{ m} \pm 0.03\%.$$

Values may also be quoted with absolute error rather than percentage uncertainty, for example, if the 6.5 m length is measured with a 5% error,

the absolute error = $5/100 \times 6.5 \text{ m} = \pm 0.325 \text{ m}$.

Practice questions

- 4** Give these measurements with the uncertainty shown as a percentage (to 1 significant figure):
a $5.7 \pm 0.1 \text{ cm}$ **b** $450 \pm 2 \text{ kg}$ **c** $10.60 \pm 0.05 \text{ s}$ **d** $366\,000 \pm 1000 \text{ J}$
- 5** Give these measurements with the error shown as an absolute value:
a $1200 \text{ W} \pm 10\%$ **b** $330\,000 \Omega \pm 0.5\%$
- 6** Identify the measurement with the smallest percentage error. Show your working.
A $9 \pm 5 \text{ mm}$ **B** $26 \pm 5 \text{ mm}$ **C** $516 \pm 5 \text{ mm}$ **D** $1400 \pm 5 \text{ mm}$

2 Standard form and prefixes

When describing the structure of the Universe you have to use very large numbers. There are billions of galaxies and their average separation is about a million light years (ly). The Big Bang theory says that the Universe began expanding about 14 billion years ago. The Sun formed about 5 billion years ago. These numbers and larger numbers can be expressed in standard form and by using prefixes.

2.1 Standard form for large numbers

In standard form, the number is written with one digit in front of the decimal point and multiplied by the appropriate power of 10. For example:

The diameter of the Earth, for example, is 13 000 km.

$$13\,000\text{ km} = 1.3 \times 10\,000\text{ km} = 1.3 \times 10^4\text{ km}.$$

The distance to the Andromeda galaxy is 2 200 000 light years = $2.2 \times 1\,000\,000\text{ ly}$
= $2.2 \times 10^6\text{ ly}$.

2.2 Prefixes for large numbers

Prefixes are used with SI units (see Topic 1.1) when the value is very large or very small. They can be used instead of writing the number in standard form. For example:

A kilowatt (1 kW) is a thousand watts, that is 1000 W or 10^3 W .

A megawatt (1 MW) is a million watts, that is 1 000 000 W or 10^6 W . A

gigawatt (1 GW) is a billion watts, that is 1 000 000 000 W or 10^9 W .

Prefix	Symbol	Value
kilo	k	10^3
mega	M	10^6

Prefix	Symbol	Value
giga	G	10^9
tera	T	10^{12}

For example, Gansu Wind Farm in China has an output of $6.8 \times 10^9\text{ W}$. This can be written as 6800 MW or 6.8 GW.

Practice questions

- Give these measurements in standard form:
a 1350 W b 130 000 Pa c $696 \times 10^6\text{ s}$ d $0.176 \times 10^{12}\text{ C kg}^{-1}$
- The latent heat of vaporisation of water is 2 260 000 J/kg. Write this in:
a J/g b kJ/kg c MJ/kg

2.3 Standard form and prefixes for small numbers

At the other end of the scale, the diameter of an atom is about a tenth of a billionth of a metre. The particles that make up an atomic nucleus are much smaller. These measurements are represented using negative powers of ten and more prefixes. For example:

The charge on an electron = $1.6 \times 10^{-19}\text{ C}$.

The mass of a neutron = $0.016\,75 \times 10^{-25}\text{ kg} = 1.675 \times 10^{-27}\text{ kg}$ (the decimal point has moved 2 places to the right).

There are a billion nanometres in a metre, that is 1 000 000 000 nm = 1 m. There are a million micrometres in a metre, that is 1 000 000 $\mu\text{m} = 1\text{ m}$.

Prefix	Symbol	Value
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}

Prefix	Symbol	Value
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}

Practice questions

- 3 Give these measurements in standard form:
 a 0.0025 m b $160 \times 10^{-17} \text{ m}$ c $0.01 \times 10^{-6} \text{ J}$ d $0.005 \times 10^6 \text{ m}$ e $0.00062 \times 10^3 \text{ N}$
- 4 Write the measurements for question 3a, c, and d above using suitable prefixes.
- 5 Write the following measurements using suitable prefixes.
 a a microwave wavelength = 0.009 m
 b a wavelength of infrared = $1 \times 10^{-5} \text{ m}$
 c a wavelength of blue light = $4.7 \times 10^{-7} \text{ m}$

2.4 Powers of ten

When multiplying powers of ten, you must *add* the indices.

So $100 \times 1000 = 100\,000$ is the same as $10^2 \times 10^3 = 10^{2+3} = 10^5$

When dividing powers of ten, you must *subtract* the indices.

So $\frac{100}{1000} = \frac{1}{10} = 10^{-1}$ is the same as $\frac{10^2}{10^3} = 10^{2-3} = 10^{-1}$

But you can only do this when **the numbers with the indices**, called the bases, are the same. So $10^2 \times 2^3 = 100 \times 8 = 800$

And you can't do this when adding or subtracting. $10^2 + 10^3 = 100 + 1000 = 1100$

$10^2 - 10^3 = 100 - 1000 = -900$

Remember: You can only add and subtract the indices when you are multiplying or dividing the numbers, not adding or subtracting them.

Practice questions

- 6 Calculate the following values – read the questions very carefully!
 a $20^6 + 10^{-3}$
 b $10^2 - 10^{-2}$
 c $2^3 \times 10^2$
 d $10^5 \div 10^2$
- 7 The speed of light is $3.0 \times 10^8 \text{ m s}^{-1}$. Use the equation $v = f\lambda$ (where λ is wavelength) to calculate the frequency of:
 a ultraviolet, wavelength $3.0 \times 10^{-7} \text{ m}$ b radio waves, wavelength 1000 m c X-rays, wavelength $1.0 \times 10^{-10} \text{ m}$.

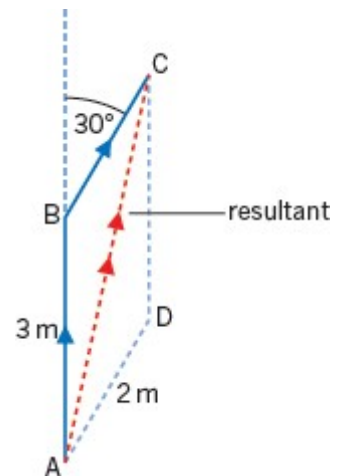
3 Resolving vectors

3.1 Vectors and scalars Vectors have a magnitude (size) and a direction. Directions can be given as points of the compass, angles or words such as forwards, left or right. For example, 30 mph east and 50 km/h north-west are velocities.

Scalars have a magnitude, but no direction. For example, 10 m/s is a speed.

Practice questions

- 1 State whether each of these terms is a vector quantity or a scalar quantity: density, temperature, electrical resistance, energy, field strength, force, friction, frequency, mass, momentum, power, voltage, volume, weight, work done.
- 2 For the following data, state whether each is a vector or a scalar: 3 ms^{-1} , $+20 \text{ ms}^{-1}$, 100 m NE, 50 km, -5 cm , 10 km S 30° W, $3 \times 10^8 \text{ ms}^{-1}$ upwards, 273°C , 50 kg, 3 A.



3.2 Drawing vectors

Vectors are shown on drawings by a straight arrow. The arrow starts from the point where the vector is acting and shows its direction. The length of the vector represents the magnitude.

When you add vectors, for example two velocities or three forces, you must take the direction into account.

The combined effect of the vectors is called the resultant.

This diagram shows that walking 3 m from A to B and then turning through 30° and walking 2 m to C has the same effect as walking directly from A to C. AC is the resultant vector, denoted by the double arrowhead.

A careful drawing of a scale diagram allows us to measure these. Notice that if the vectors are combined by drawing them in the opposite order, AD and DC, these are the other two sides of the parallelogram and give the same resultant.

Practice question

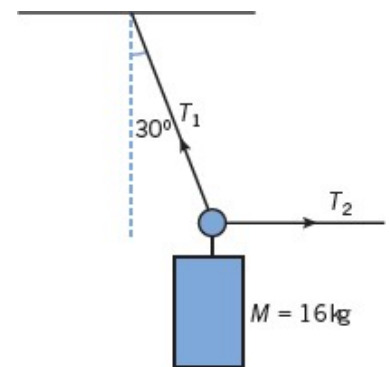
- 3 Two tractors are pulling a log across a field. Tractor 1 is pulling north with force 1 = 5 kN and tractor 2 is pulling east with force 2 = 12 kN. By scale drawing, determine the resultant force.

3.3 Free body force diagrams

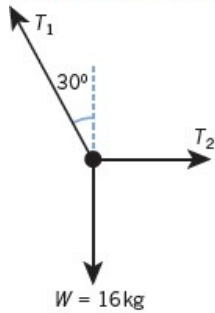
To combine forces, you can draw a similar diagram to the one above, where the lengths of the sides represent the magnitude of the force (e.g., 30 N and 20 N). The third side of the triangle shows us the magnitude and direction of the resultant force.

When solving problems, start by drawing a free body force diagram. The object is a small dot and the forces are shown as arrows that start on the dot and are drawn in the direction of the force. They don't have to be to scale, but it helps if the larger forces are shown to be larger. Look at this example.

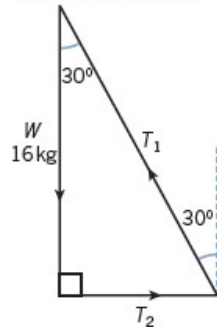
A 16 kg mass is suspended from a hook in the ceiling and pulled to one side with a rope, as shown on the right. Sketch a free body force diagram for the mass and draw a triangle of forces.



Free body force diagram



Triangle of forces



Notice that each force starts from where the previous one ended and they join up to form a triangle with no resultant because the mass is in equilibrium (balanced).

Practice questions

- 4 Sketch a free body force diagram for the lamp (Figure 1, below) and draw a triangle of forces.
- 5 There are three forces on the jib of a tower crane (Figure 2, below). The tension in the cable T , the weight W , and a third force P acting at X . The crane is in equilibrium. Sketch the triangle of forces.

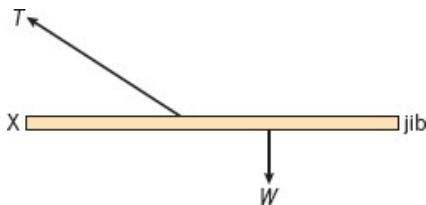
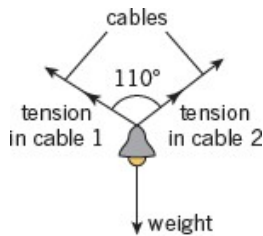


Figure 1

Figure 2

3.4 Calculating resultants

When two forces are acting at right angles, the resultant can be calculated using Pythagoras's theorem and the trig functions: sine, cosine, and tangent.

For a right-angled triangle as shown:

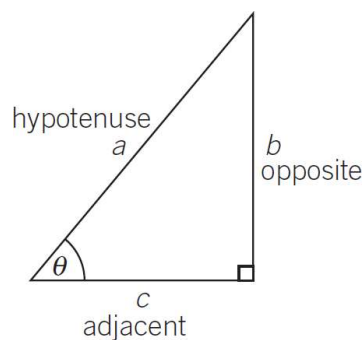
$$h^2 = o^2 + a^2$$

$$\sin \vartheta = \frac{o}{h}$$

$$\cos \vartheta = \frac{a}{h}$$

$$\tan \vartheta = \frac{o}{a}$$

(soh-cah-toa).

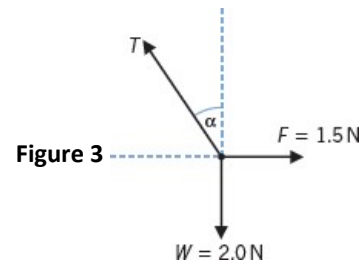


Practice questions

- 6 Figure 3 shows three forces in equilibrium. Draw a triangle of forces to find T and α .

7 Find the resultant force for the following pairs of forces at right angles to each other:

- a 3.0 N and 4.0 N b 5.0 N and 12.0 N



4 Rearranging equations

Sometimes you will need to rearrange an equation to calculate the answer to a question. For example, if you want to calculate the resistance R , the equation:

potential difference (V) = current (A) \times resistance (Ω) or $V = IR$

must be rearranged to make R the subject of the equation:

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

When you are solving a problem:

- Write down the values you know and the ones you want to calculate.
- you can rearrange the equation first, and then substitute the values
or
- substitute the values and then rearrange the equation

4.1 Substitute and rearrange

A student throws a ball vertically upwards at 5 m s^{-1} . When it comes down, she catches it at the same point. Calculate how high it goes.

step 1: Known values are:

initial velocity $u = 5.0 \text{ m s}^{-1}$

final velocity $v = 0$ (you know this because as it rises it will slow down, until it comes to a stop, and then it will start falling downwards)

acceleration $a = g = -9.81 \text{ m s}^{-2}$

distance $s = ?$

Step 2: Equation:

(final velocity) 2 – (initial velocity) $^2 = 2 \times$ acceleration \times distance or

$$v^2 - u^2 = 2 \times g \times s$$

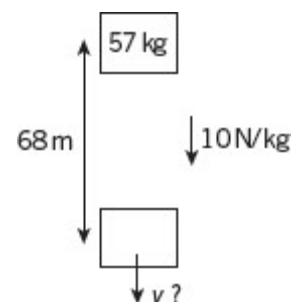
Substituting: $(0)^2 - (5.0 \text{ m s}^{-1})^2 = 2 \times -9.81 \text{ m s}^{-2} \times s$

$$0 - 25 = 2 \times -9.81 \times s$$

Step 3: Rearranging:

$$-19.62 s = -25$$

$$s = \frac{25}{19.62} = 1.27 \text{ m} = 1.3 \text{ m (2 s.f.)}$$



Practice questions

8 The potential difference across a resistor is 12 V and the current through it is 0.25 A. Calculate its resistance.

9 Red light has a wavelength of 650 nm. Calculate its frequency. Write your answer in standard form.

(Speed of light = $3.0 \times 10^8 \text{ m s}^{-1}$)

4.2 Rearrange and substitute

A 57 kg block falls from a height of 68 m. By considering the energy transferred, calculate its speed when it reaches the ground.

(Gravitational field strength = 10 N kg^{-1})

Step 1: $m = 57 \text{ kg}$ $h = 68 \text{ m}$ $g = 10 \text{ N kg}^{-1}$ $v = ?$

Step 2: There are three equations:

$$PE = m g h \quad KE \text{ gained} = PE \text{ lost} \quad KE = 0.5 m v^2$$

Step 3: Rearrange the equations before substituting into it.

$$\text{As KE gained} = PE \text{ lost, } m g h = 0.5 m v^2$$

You want to find v . Divide both sides of the equation by $0.5 m$:

$$\frac{mgh}{0.5m} = \frac{0.5mv^2}{0.5m}$$

$$2 g h = v^2$$

$$\text{To get } v, \text{ take the square root of both sides: } v = \sqrt{2gh}$$

Step 4: Substitute into the equation:

$$v = \sqrt{2 \times 10 \times 68}$$

$$v = \sqrt{1360} = 37 \text{ m s}^{-1}$$

Practice question

10 Calculate the specific latent heat of fusion for water from this data:

$4.03 \times 10^4 \text{ J}$ of energy melted 120 g of ice.

Use the equation:

$$\text{thermal energy for a change in state (J)} = \text{mass (kg)} \times \text{specific latent heat (J kg}^{-1}\text{)}$$

Give your answer in J kg^{-1} in standard form.

5 Work done, power, and efficiency

5.1 Work done

Work is done when energy is transferred. Work is done when a force makes something move. If work is done *by* an object its energy decreases and if work is done *on* an object its energy increases.

$$\text{work done} = \text{energy transferred} = \text{force} \times \text{distance}$$

Work and energy are measured in joules (J) and are scalar quantities (see Topic 3.1).

Practice question

11 Calculate the work done when the resultant force on a car is 22 kN and it travels 2.0 km .

12 Calculate the distance travelled when 62.5 kJ of work is done applying a force of 500 N to an object.

5.2 Power

Power is the rate of work done.

It is measured in watts (W) where $1 \text{ watt} = 1 \text{ joule per second}$.

$$\text{power} = \frac{\text{energy transferred}}{\text{time taken}} \quad \text{or} \quad \text{power} = \frac{\text{work done}}{\text{time taken}}$$

$$P = \Delta W / \Delta t$$

Δ is the symbol 'delta' and is used to mean a 'change in'

Look at this worked example, which uses the equation for potential energy gained. A motor lifts a mass m of 12 kg through a height Δh of 25 m in 6.0 s.

Gravitational potential energy gained:

$$\Delta PE = mg\Delta h = (12 \text{ kg}) \times (9.81 \text{ m s}^{-2}) \times (25 \text{ m}) = 2943 \text{ J}$$

$$\text{Power} = \frac{2943 \text{ J}}{6.0 \text{ s}} = 490 \text{ W (2 s.f.)}$$

Practice questions

- 13** Calculate the power of a crane motor that lifts a weight of 260 000 N through 25 m in 48 s.
- 14** A motor rated at 8.0 kW lifts a 2500 N load 15 m in 5.0 s. Calculate the output power.

5.3 Efficiency

Whenever work is done, energy is transferred and some energy is transferred to other forms, for example, heat or sound. The efficiency is a measure of how much of the energy is transferred usefully.

Efficiency is a ratio and is given as a decimal fraction between 0 (all the energy is wasted) and 1 (all the energy is usefully transferred) or as a percentage between 0 and 100%. It is not possible for anything to be 100% efficient: some energy is always lost to the surroundings.

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \quad \text{or} \quad \text{Efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

(multiply by 100% for a percentage)

Look at this worked example.

A thermal power station uses 11 600 kWh of energy from fuel to generate electricity. A total of 4500 kWh of energy is output as electricity. Calculate the percentage of energy 'wasted' (dissipated in heating the surroundings).

You must calculate the energy wasted using the value for useful energy output:

$$\text{percentage energy wasted} = \frac{(\text{total energy input} - \text{energy output as electricity})}{\text{energy input}} \times 100 \text{ total}$$

$$\text{percentage energy wasted} = \frac{(11600 - 4500)}{11600} \times 100 = 61.2\% = 61\% \text{ (2 s.f.)}$$

Practice questions

- 15** Calculate the percentage efficiency of a motor that does 8400 J of work to lift a load. The electrical energy supplied is 11 200 J.
- 16** An 850 W microwave oven has a power consumption of 1.2 kW. Calculate the efficiency, as a percentage.
- 17** Use your answer to question 4 above to calculate the percentage efficiency of the motor. (The motor, rated at 8.0 kW, lifts a 2500 N load 15 m in 5.0 s.)
- 18** Determine the time it takes for a 92% efficient 55 W electric motor to lift a 15 N weight 2.5 m.