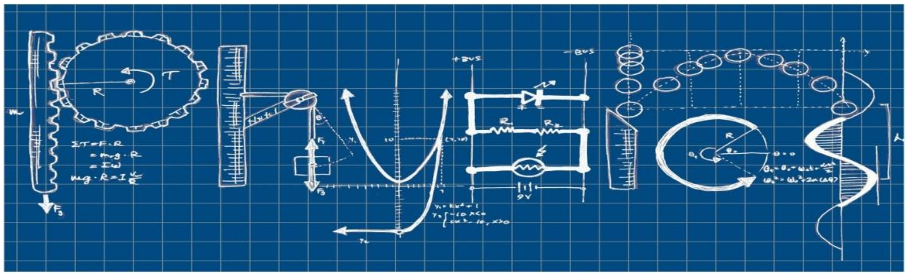


By studying physics at school or college you're opening the door to a wide variety of rewarding careers. As well as learning about how the universe works, you'll gain a broad training in skills that all employers value: an ability to grasp concepts quickly and a determination to find coherent answers; problem-solving, analytical, mathematical and IT skills. Even if you don't end up working in a physics-related industry, these skills are still highly regarded. Studying physics is a good way of keeping your options open and earning a good salary.

In order to succeed at anything, it is imperative you commit your time. Physics A-level is no different. Attendance and attainment are closely linked, so turning up to class is important. Physics is a huge subject and we'll only be covering a tiny aspect of it in class. To help with your understanding you must also read around the subject. The reading you do doesn't have to be purely about what we're studying at the time. Physics is incredible, as are all the sciences. If you don't read or find out about what is happening in the world of science, you'll miss the fantastic and sometimes mind blowing things that are happening or have happened in our world. Fact is definitely stranger than fiction!

In summary, do your best, work hard and enjoy it – it's as simple as that.

Below are a few careers that studying physics can lead to:

Architecture

Astronomy

Engineering

Education

Finance

Further Education

Material development

Medicine

Meteorology and climate change

Nanotechnology

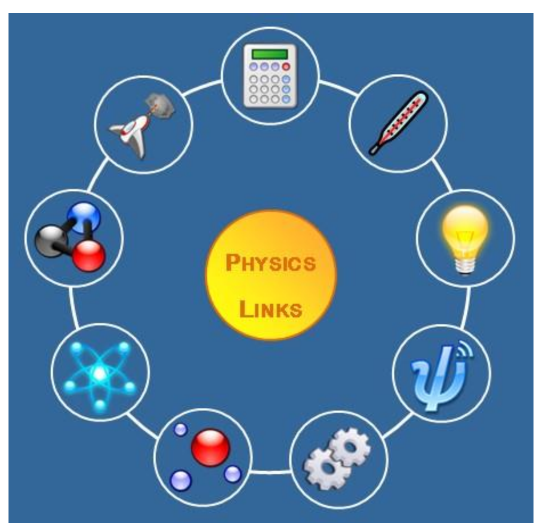
Oil and gas

Renewable energy

Scientific research

Space exploration industries

Telecommunications



Please follow the link to find all the AQA specification and course content.

There is no course work. Your practical skills are monitored and assessed throughout the year and questions in the exams are based on set practicals you would have completed.

Students are expected to buy course books and required practical lab books which we will be selling, through the school, at a considerable discount. If eligible for the post 16 bursary, materials for the course can be ordered by the school on your behalf via bursary funding. Please ask in the sixth form office for details.

What independent learning looks like in…

Physics

1. Before each lesson

- see your teacher in advance to get any work you may be missing
- ensure you have completed preparation work / homework
- read ahead in the book or on kerboodle
- have a knowledge or understanding / definition of key words, terms and equations

2. After each lesson

- review your lesson notes and highlight any aspects you don't understand so you can ask about them next lesson
- locate relevant material in your book, online or in the library in order to help you with anything you're not sure about
- ensure you have noted down any deadlines in your diary
- use the module check sheet on kerboodle to tick off what has been covered so you know where you are in terms of the syllabus

3. Regularly

- use recommended books and websites to read around the subject and further your understanding (see below for a suggested wider reading list)
- practice exam questions from past papers, these are all available at http://www.physicsandmathstutor.com/
- use YouTube to help with any difficult concepts or equations
- read around the subject; watch the news, read articles, to see where physics is relevant in the real world
- use the library resources, especially Physics Review

4. Before tasks / homework

- ensure you understand the work set – ask your teacher if you are unsure
- read about the topic, start form the ground up before if you find the subject tricky
- meet with other students and work together
- find examples and model answers

5. Before tests

- use your check sheet to break the topic down into manageable revision sections
- practice past exam questions
- use the online activities on kerboodle to show you how to break down questions with many stages to them and how to interpret command words
- use the AQA website to see what you are expected to know

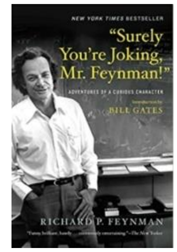
Physics Wider Reading List

These books have been selected to help you delve beyond the specification into the world of physics.

1) **Surely You’re Joking Mr Feynman**

   Richard Feynman

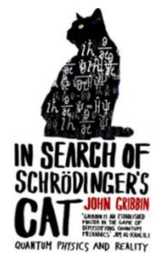
   Richard Feynman (1918-1988), winner of the Nobel Prize in physics, thrived on outrageous adventures. Here he recounts in his inimitable voice his experience trading ideas on atomic physics with Einstein and Bohr; cracking the uncrackable safes guarding the most deeply held nuclear secrets and much else of an eyebrow-raising nature.



2) **In Search of Schrödinger's Cat: Quantum Physics and Reality**

   John Gribbin

   It is so shocking that Einstein could not bring himself to accept it. It is so important that it provides the fundamental underpinning of all modern sciences. Without it, we'd have no nuclear power or nuclear bombs, no lasers, no TV, no computers, no science of molecular biology, no understanding of DNA, no genetic engineering—at all. John Gribbin tells the complete story of quantum mechanics, a truth far stranger than any fiction.



3) **The Martian**

   Andy Weir

   Six days ago, astronaut Mark Watney became one of the first people to walk on Mars. Now, he’s sure he’ll be the first person to die there. Drawing on his ingenuity, his engineering skills — and a relentless, dogged refusal to quit — he steadfastly confronts one seemingly insurmountable obstacle after the next. Will his resourcefulness be enough to overcome the impossible odds against him?

4) **The Physics of Superheroes**

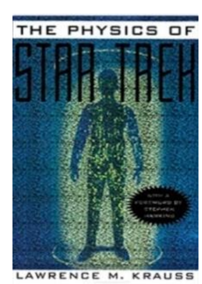
   James Kakalios

   James Kakalios explores the scientific plausibility of the powers and feats of the most famous superheroes and discovers that in many cases the comic writers got their science surprisingly right. Along the way he provides an engaging and witty commentary while introducing the lay reader to both classic and cutting-edge concepts in physics.

5) **The Physics of Star Trek**

   Lawrence M. Krauss

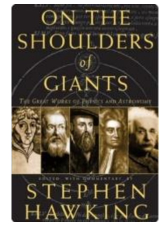
   Lawrence M. Krauss, an internationally known theoretical physicist and educator, has written the quintessential physics book for Trekkers and non-Trekkers alike. Anyone who has ever wondered, "Could this really happen?" will gain useful insights into the "Star Trek" universe (and, incidentally, the real universe) in this charming and accessible volume.



6) On the Shoulders of Giants: the Great Works of Physics and Astronomy

Stephen Hawking (editor), Isaac Newton, Nicolaus Copernicus, Albert Einstein, Johannes Kepler, Galileo Galilei

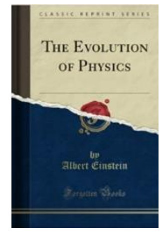
Stephen Hawking brings together the greatest works by Copernicus, Galileo, Kepler, Newton and Einstein, showing how their pioneering discoveries changed the way we see the world.



7) The Evolution of Physics: From Early Concepts to Relativity and Quanta

Albert Einstein, Leopold Infeld

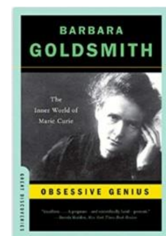
Clear and concise explanations of the development of theories explaining physical phenomena.



8) Obsessive Genius: the Inner World of Marie Curie

Barbara Goldsmith

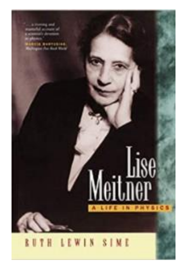
Through family interviews, diaries, letters, and workbooks that had been sealed for over sixty years, Barbara Goldsmith reveals the Marie Curie behind the myth—an all-too-human woman struggling to balance a spectacular scientific career, a demanding family, the prejudice of society, and her own passionate nature



9) Lise Meitner: A Life in Physics

Ruth Lewin Sime

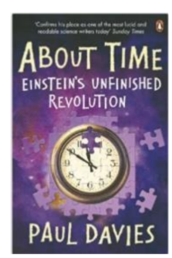
Lise Meitner (1878-1968) was a pioneer of nuclear physics and co-discoverer, with Otto Hahn and Fritz Strassmann, of nuclear fission. Braving the sexism of the scientific world, she joined the prestigious Kaiser Wilhelm Institute for Chemistry and became a prominent member of the international physics community.



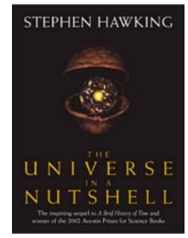
10) About Time: Einstein's Unfinished Revolution

Paul Davies

An elegant, witty, and engaging exploration of the riddle of time, which examines the consequences of Einstein's theory of relativity and offers startling suggestions about what recent research may reveal.



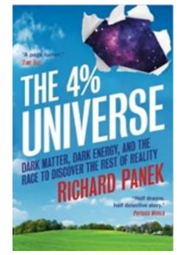
11) The Universe in a Nut Shell



Stephen Hawking

Seeking to uncover the holy grail of science, the elusive Theory of Everything that lies at the heart of the cosmos, Professor Stephen Hawking takes us to the cutting edge of theoretical physics. In a realm where truth is often stranger than fiction, he explains in layman's terms the principles that control our universe.

12) The 4 Percent Universe



Richard Panek

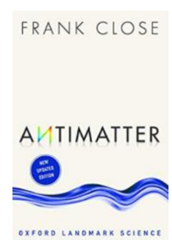
In recent years, a handful of scientists has been racing to explain a disturbing aspect of our universe: only 4 percent of it consists of the matter that makes up you, me, and every star and planet. The rest is completely unknown. Richard Panek tells the dramatic story of how scientists reached this cosmos-shattering conclusion.

13) Neutrino

Frank Close

An account of the discovery of neutrinos and our growing understanding of their significance, also touching on some speculative ideas concerning the possible uses of neutrinos and their role in the early universe.

14) Antimatter



Frank Close

Antimatter *explores a strange mirror world, where particles have identical yet opposite properties to those that make up the familiar matter we encounter everyday; where left becomes right, positive becomes negative; and where, should matter and antimatter meet, the two annihilate in a blinding flash of energy that makes even thermonuclear explosions look feeble by comparison.*

Induction Day Tasks

Before starting A-level physics, you need to do a bit of revision, a little work, some research and a web quest. Please complete the tasks below and bring to the July induction day.

1. Research the importance of the work of Rutherford's alpha particle scattering experiment and how it changed our ideas of the atom.

2. For each of these famous physicists, write a short paragraph about their contribution to science and how it is still relative today.

   Niels Bohr
   Louis de Broglie
   Albert Einstein
   Michael Faraday
   Max Planck
   Wolfgang Ernst Pauli
   Richard Phillips Feynman

3. The **Web Quest** on the pages below.

4. The **Retrieval Questions** and **Maths Skills Questions** on the pages below

   [from Oxford A-Level Sciences © Oxford University Press 2019
   The resource sheet may have been changed from the original]

Web Quest

Follow the instructions below and use the web sources provided to complete this task. It is essential you do so as this work is part of, and will contribute towards, your A-level course.

Introduction to superconductors

Superconductivity is an astonishing property of certain materials for which, below a critical temperature, the electrical resistance suddenly drops to zero. It was discovered in 1911 by Heike Kamerlingh Omes but, until 1986, it was essentially inaccessible due to the very low temperatures required.

Superconductivity can produce incredibly strong magnetic fields and has significant potential to advance technology and improve quality of life in areas such as communication, transport and medicine.

In this Web Quest, you will research superconductivity and its applications. You'll come to understand how it works, the history of its development, its modern uses (such as in magnetic resonance image (MRI) scanning), and the risks associated with it.

Task

Your task is to create a research report about superconductivity and the MRI (Magnetic Resonance Imaging) scanner. For each section of your report you should provide a summary of the most significant and relevant pieces of information contained within the main body of your text. Your report should cover the following points:

- the history of superconductivity's discovery
- the challenges facing superconductivity before 1986 and how they were overcome
- some of the applications of superconductivity
- what a MRI scanner is and its benefits
- the risks associated with MRI scanners

Process

Step 1 research: what is superconductivity?

- find out what superconductivity is and how it was discovered.

Step 2 research: what happened in 1986?

- summarise the main events of the 1986 discovery and their implications for society.

Step 3 research: applications of superconductivity

- compile a list of the current applications of superconductivity. For each one briefly summarise the application and its implications on society. Look out for the 'squids'!
- focus on the MRI scanner. Find out how it works and the risks associated with it.

Step 4 prepare your report

- gather all the information you have found and prepare your report on superconductivity
- give your report the following sections for its structure:
  1. What is superconductivity?
  2. What happened in 1986?
  3. Applications of superconductivity
  4. The MRI scanner

Step 5 Create section summaries

- summarise the most important information from each section of your report. Include these at the beginning of each section.

Possible Sources

What is superconductivity?

CERN Teacher Programmes

Physics Central: superconductors

Magnet Man: superconductors

What happened in 1986? History of superconductors

The Naked Scientists

HyperPhysics

SuperConductors: history of superconductors

Applications of superconductivity

Superconductors: uses for superconductors

The MRI scanner

Physics Central: MRI Magic

HowStuffWorks: MRI

Conclusion

In this Web Quest you will have learned:

- how superconductivity works
- what happened in 1986 that made superconductivity more useful
- some of the applications of superconductivity
- what an MRI scanner is
- the risks and benefits of superconductivity

The future of superconductivity depends mostly on the ability to develop superconductors that can operate at higher temperatures.

Currently cost is the primary factor limiting their advancement, rather than the risks associated with them. However, as the technology improves and the costs come down, society will have to weigh the benefits and risks of using such strong magnetic fields.

Transition from GCSE to A-Level

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 worksheet 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 worksheet 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 *same* person, using the *same* equipment, under the *same* conditions
What is reproducibility?	how precise repeated measurements are when they are taken by *different* people, using *different* 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 *nucleon*	a proton or a neutron in the nucleus
What are the absolute charges of protons, neutrons, and electrons?	$+1.60\times10^{-19}$, 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 gamma radiation	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 $(\lambda) = \dfrac{\text{speed of light } (c)}{\text{frequency } (f)}$
Define a photon	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:

$$\text{speed} = \frac{\text{distancetravelled}}{\text{timetaken}}$$

If a car travels 2 metres in 2 seconds:

$$\text{speed} = \frac{2\text{metres}}{2\text{seconds}} = \frac{1\text{m}}{1\text{s}} = 1\text{m/s}$$

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

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 39 400

(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 kΩ 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 depends 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:

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

$$\text{percentageuncertainty} = \frac{0.002}{6.500} \times 100\% = 0.03\%.$$ The measurement is 6.500 m ± 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 × 6.5 m = ± 0.325 m.

Practice questions

4. Give these measurements with the uncertainty shown as a percentage (to 1 significant figure):

a 5.7 ± 0.1 cm **b** 450 ± 2 kg **c** 10.60 ± 0.05 s **d** 366 000 ± 1000 J

5. Give these measurements with the error shown as an absolute value:

a 1200 W ± 10% **b** 330 000 Ω ± 0.5%

6. Identify the measurement with the smallest percentage error. Show your working.

a 9 ± 5 mm **b** 26 ± 5 mm **c** 516 ± 5 mm **d** 1400 ± 5 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 km = 1.3 × 10 000 km = 1.3×10^4 km.
- The distance to the Andromeda galaxy is 2 200 000 light years
  2.2 × 1 000 000 ly = 2.2×10^6 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 6.8×10^9 W. This can be written as 6800 MW or 6.8 GW.

Practice questions

1. Give these measurements in standard form:
   a 1350 W **b** 130 000 Pa **c** 696×10^6 s **d** 0.176×10^{12} C kg^{-1}

2. 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 = 1.6×10^{-19} C.
- The mass of a neutron = $0.016\,75 \times 10^{-25}$ kg = 1.675×10^{-27} 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 µm = 1 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** 160×10^{-17} m **c** 0.01×10^{-6} J **d** 0.005×10^6 m **e** 0.00062×10^3 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 = 1×10^{-5} m
   c a wavelength of blue light = 4.7×10^{-7} 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 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 3.0×108 m s−1. Use the equation v = f λ (where λ is wavelength) to calculate the frequency of:
a ultraviolet, wavelength 3.0×10^{-7} m
b radio waves, wavelength 1000 m
c X-rays, wavelength 1.0×10^{-10} 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 ms^{-1}, 100 m NE, 50 km, −5 cm, 10 km S 30° W, 3 × 10^8 ms−1 upwards, 273 °C, 50 kg, 3 A

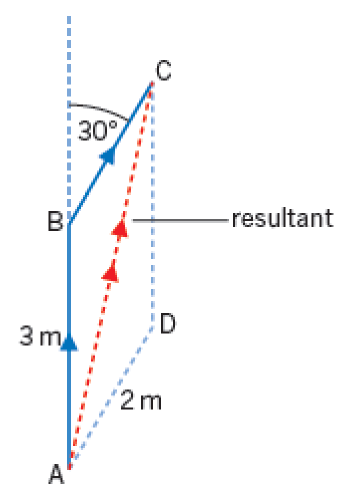
3.2 Drawing vectors

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

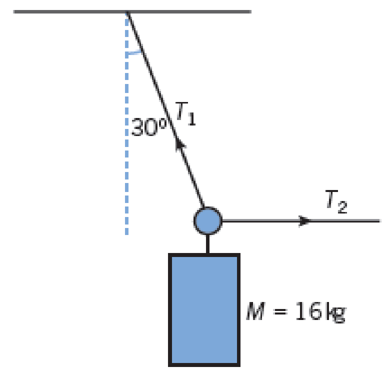
3. Two tractors are pulling a log across a field. Tractor 1 is pulling north with force 1 = 5 kN and tractor 2 is pulling east with force 2 = 12 kN. By scale drawing, determine the resultant force.

3.3 Free body force diagrams

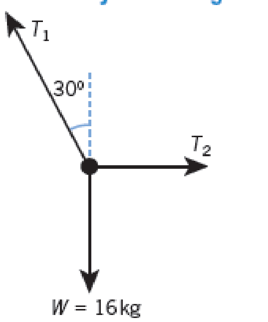
To combine forces, you can draw a similar diagram to the one above, where the lengths of the sides represent the magnitude of the force (e.g. 30 N and 20 N). The third side of the triangle shows us the magnitude and direction of the resultant force.

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.

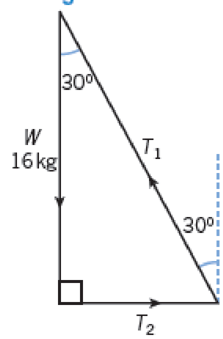
A 16 kg mass is suspended from a hook in the ceiling and pulled to one side with a rope, as shown on the right. Sketch a free body force diagram for the mass and draw a triangle of forces.



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.

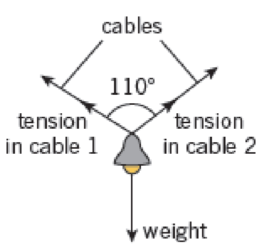


Figure 1

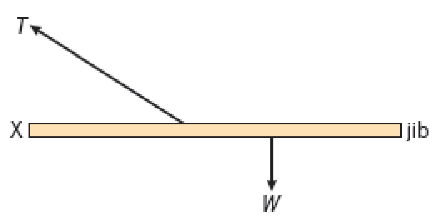


Figure 2

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:

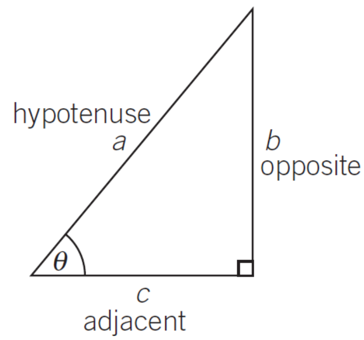
$h^2 = o^2 + a^2$

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

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

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

(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

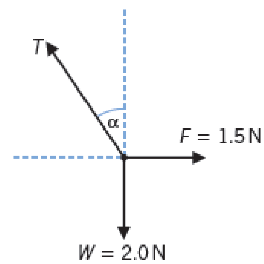


Figure 3

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*) × resistance (Ω) or $V = I\,R$

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 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 $a = g = -9.81$ m s^{-2}
- distance s = ?

Step 2: equation:

(final velocity)^2 − (initial velocity)^2 = 2 × acceleration × 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

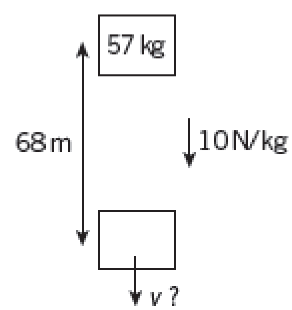
1. The potential difference across a resistor is 12 V and the current through it is 0.25 A. Calculate its resistance.

2. Red light has a wavelength of 650 nm. Calculate its frequency. Write your answer in standard form (speed of light = 3.0×10^8 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 kg h = 68 m g = 10 N kg^{-1} v = ?

Step 2: There are three equations:

PE = $m\,g\,h$ KE gained = PE lost KE = 0.5 $m\,v^2$

Step 3: Rearrange the equations before substituting into it.

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

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

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

$2\,g\,h = v^2$

To get v, 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 m s^{-1}

Practice question

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

4.03×10^4 J of energy melted 120 g of ice.

Use the equation:

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

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.

work done = energy transferred = force × distance

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

Practice question

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

2. 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 watt = 1 joule per second.

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

$P = \Delta W/\Delta t$ *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 kg) × (9.81 m s^{-2}) × (25 m) = 2943 J

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

Practice questions

3. Calculate the power of a crane motor that lifts a weight of 260 000 N through 25 m in 48 s.

4. 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.

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

(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:

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

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

Practice questions

5. 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.

6. An 850 W microwave oven has a power consumption of 1.2 kW. Calculate the efficiency, as a percentage.

7. 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.)

8. Determine the time it takes for a 92% efficient 55 W electric motor take to lift a 15 N weight 2.5 m.