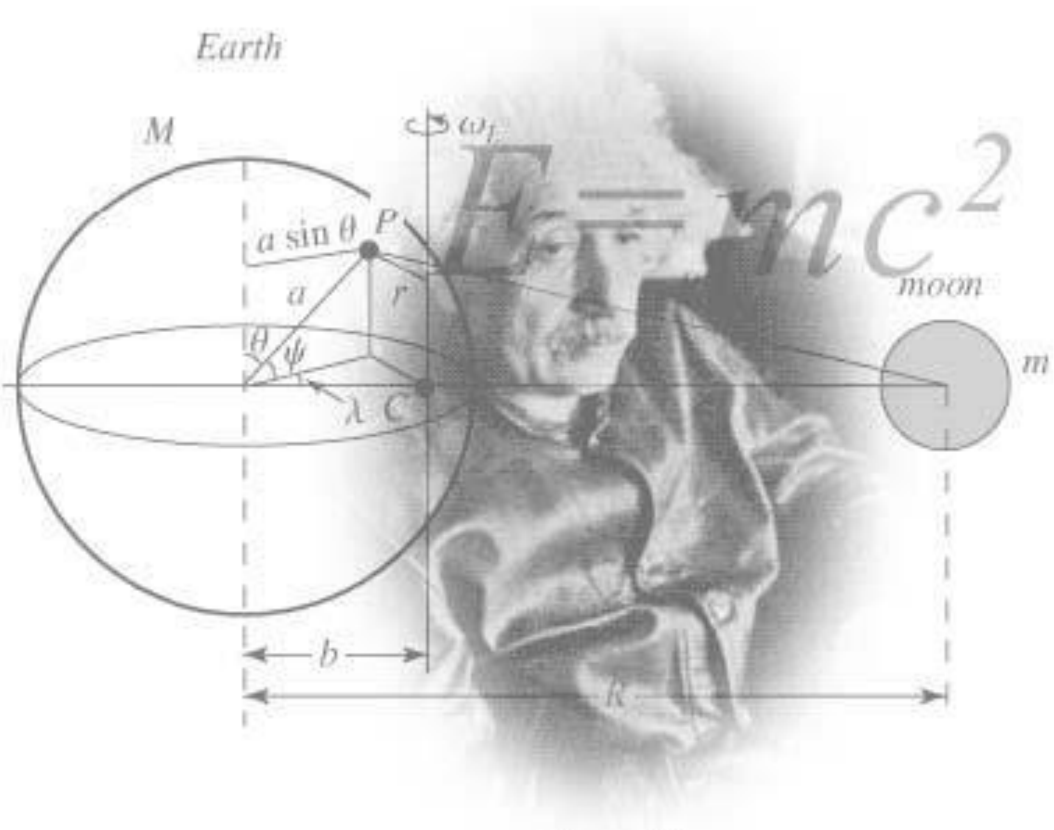
Shenley Brook End Sixth Form
Summer transition tasks for
A Level Physics

Due date Monday 16 September 2024

Subject:
A Level Physics

Exam Board/Course:
OCR (Physics A)



Objectives: 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 after you complete your GCSE, throughout the remainder of the Summer term and over the Summer Holidays to ensure you are ready to start your course in September. The tasks will be utilised as part of our baseline assessment of your abilities and knowledge in the subject.

Tasks

Tasks to complete

1. Workbook (Time to complete – approx. 4 hours):

Answer the questions in the workbook (attached after page 13 in this document) as fully as possible. Use your notes/revision guides and the internet to support you. You can either do this in a Word/Pages document or on paper/on a printed copy. Your answers will then need to be handed in on Monday 16th September on a paper copy.

2. Research and Presentation Task (Time to complete – approx. 4-5 hours):

Choose a question you are interest in surrounding Physics. It can be anything you want to find out about! Research around this question and produce a 10 minute presentation on what you have found out along with a A4 or A3 poster summarizing your findings.

Your presentation should be aimed at someone who has a GCSE knowledge of Physics but no specific knowledge of your topic and include:

- An introduction – what is the question and why did you choose it
- Background research – what information is there about the topic you chose
- Main findings – what were the main things you found out/possible answers to the question (ensure you give good scientific detail)
- Conclusions – summarise what you found out
- Further questions – what further questions did the research give you, how would you investigate further.

Examples of questions that you could research include:

- How does radiotherapy in cancer treatment work?
- What is dark matter and how do we know if it exists?
- What is the Schrödinger's cat thought experiment and what does it tell us?
- What is a black hole?
- How could you take the perfect penalty?
- Who was Stephen Hawking and what did he discover?
- What is the most scientifically accurate science fiction film?

You will be expected to give your presentation within the first four weeks of Year 12. You must submit your presentation (electronically) and an A4 or A3 poster (paper) w/c 16th September 2024.

Resources/Research

The Course: OCR Physics A

The link below provides access to information about the course and the specification. I would recommend downloading a copy.
https://www.ocr.org.uk/qualifications/as-and-a-level/physics-a-h156-h556-from-2015/

Physics A Level is one of the most universally accepted qualifications for progression to university. The course content covers the basis of how things work, from the constituent parts of atoms out to the extent of the universe. You will integrate the concepts studied with a range of practical experiments throughout each topic giving the course both an academic and practical focus. You will learn to apply your knowledge of the key concepts to solve problems in a range of different contexts and applications.

Content included:

Year 12:

Development of practical skills in Physics
Physical quantities and units
Making measurements and analysing data
Motion
Forces and Motion
Work, Energy and Power
Materials
Momentum
Charge and Current
Energy, Power and Resistance Electrical
Circuits
Waves
Quantum Physics

Year 13:

Development of practical skills in Physics
Thermal Physics
Circular Motion
Oscillations
Gravitational Fields
Astrophysics
Cosmology
Capacitors
Electric Fields
Electromagnetism
Nuclear Physics
Particle Physics
Medical Imaging
Circular Motion

Emphasis throughout the course is on developing knowledge, competence and confidence in practical skills and problem solving.

How will you be assessed?

A Level is covered by three examinations:
Total of 6 hours of examinations (2 x 2 hours 15 minutes and 1 x 1 hour 30 minutes) taken at the end of the course. A wide range of questions types which include multiple choice, short answer and extended response questions.

Practical endorsement

This is a separate certificate that you are awarded a pass or fail on based upon a wide range of practical experience incorporating apparatus, skills and techniques. With experiments such as: Measuring resistance in a circuit with various resistor combinations, Analysing the discharge of a capacitor, Obtaining a value for 'g' from a pendulum.

Your work is assessed against a set of criteria by teachers during practical activities.

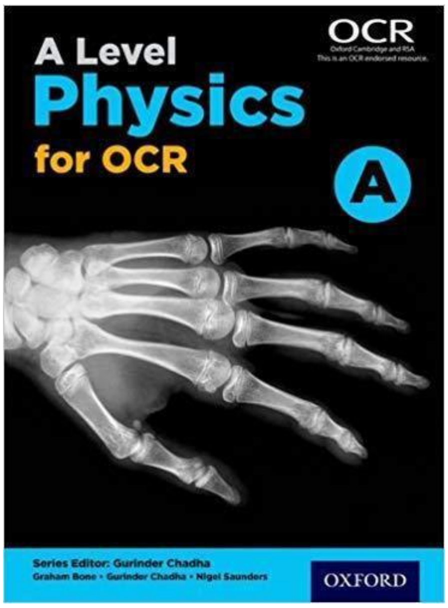
Where can the qualification take me?

STEM degrees, varieties of Physics, Maths and Engineering.
Advanced apprenticeships in industry, at present aerospace, nuclear power generation and electrical power distribution.

Resources for the course:

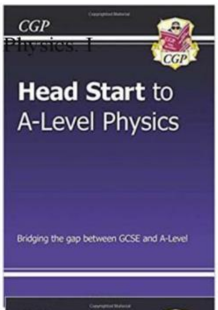
Lab book for practical endorsement work - school will provide this
Text book - you will be provided online access to the textbook. If you would like a physical copy you can locate this using the information below:

A level Physics A for OCR Student Book, Exam board: OCR, ISBN 13: 978-0198352181



A4 Lined paper
Large A4 ring Binder (one of your choice to store notes)
Dividers (to go in the A4 ring binder)
Calculator (graphical calculator is preferable but not necessary)
Maths Kit (including a compass and protractor)
Ruler (30 cm is preferable)
Pens and Pencils
You can also bring a device such as a laptop to lessons but ensure you look after it as this is your responsibility.

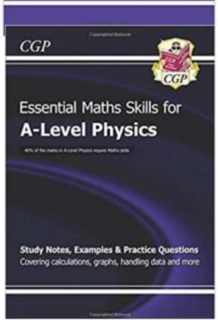
I would also highly recommend these books to help over the summer as you may not have finished the entire GCSE Physics or Maths content. This will help bridge the gap between GCSE knowledge and basic A-Level Knowledge.



This revision guide is aimed at bridging the gap between GCSE and Alevel It is particularly recommended if you completed double science.

Publisher: Coordination Group Publications Ltd (CGP) (2 Mar. 2015)

Language: English



This revision guide is aimed at supporting the maths skills needed for Alevel Physics.

Publisher: Coordination Group Publications Ltd (CGP) (15 Sept. 2015)

Language: English

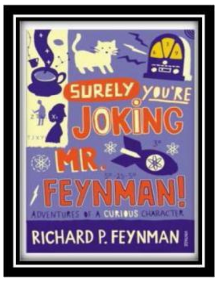
ISBN-10: 1782944710

Wider Reading

This section contains **optional** extra reading and activities that you could complete.

Useful books to read:

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.



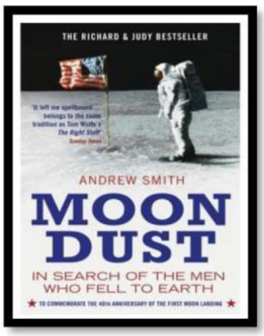
1. Surely You're Joking Mr Feynman: Adventures of a Curious Character

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.
(Also available on Audio book).

https://www.waterstones.com/books/search/term/surely+youre+joking+mr+feynman++adventures+of+a+curious+character

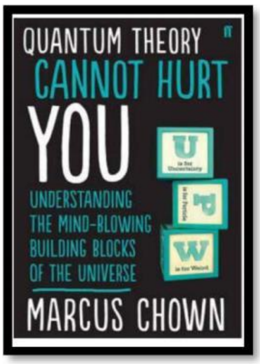
2. Moondust: In Search of the Men Who Fell to Earth

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.

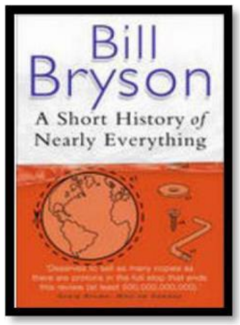


https://www.waterstones.com/books/search/term/moondust++in+search+of+the+men+who+f ell+to+earth

3.



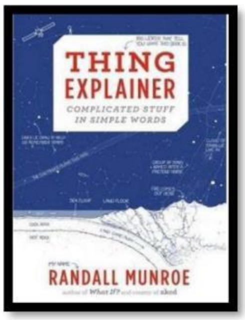
Quantum Theory Cannot Hurt You: Understanding the Mind-Blowing Building Blocks of the Universe
ISBN - 057131502X - Any Physics book by Marcus Chown is an excellent insight into some of the more exotic areas of Physics that require no prior knowledge. In your first year of A-Level study you will meet 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!
https://www.waterstones.com/book/quantum-theory-cannot-hurt- you/marcus-chown/9780571315024



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.

https://www.waterstones.com/books/search/term/a+short+history+of+nearly+everything

5. Thing Explainer: Complicated Stuff in Simple Words



ISBN – 1408802384 - 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.
https://www.waterstones.com/book/thing-explainer/randall-munroe/9781473620919

Free online courses:

Why not get ahead by exploring some of these free online courses – there are loads out there, these are just a few I chose which even go beyond A-level! For some, you even get a qualification at the end!

1. An Introduction to Physics: https://www.udacity.com/course/intro-to-physics--ph100

2. How things work: An Introduction to Physics:
https://www.classcentral.com/course/how-things-work-431

3. From Atoms to Stars – How Physics explains our world:
https://learning.edx.org/course/course-v1:MEPhIx+MEPHI003x+2T2016/home

4. Mechanics: Motion, Forces, Energy and Gravity – From particles to planets:
https://www.coursera.org/learn/mechanics-particles-planets?ranMID=40328&ranEAID=bt30QTxEyjA&ranSiteID=bt30QTxEyjA-X5LXIB7X4imabYuA9bWHqw&siteID=bt30QTxEyjA-X5LXIB7X4imabYuA9bWHqw&utm_content=10&utm_medium=partners&utm_source=linkshare&utm_campaign=bt30QTxEyjA#about

5. Understanding Nuclear Energy: https://www.edx.org/course/understanding-nuclear-energy

6. Nuclear Reactor Physics, Basics: https://www.edx.org/course/nuclear-reactor-physics-basics

7. Introduction to Astrophysics: https://www.edx.org/course/introduction-to-astrophysics

8. Quantum Mechanics for Everyone: https://www.edx.org/course/quantum-mechanics-for-everyone

9. Introduction to Electricity and Magnetism: https://www.edx.org/course/electricity-and- magnetism-part-1

10. Particle Physics, An introduction: https://www.classcentral.com/course/particle-physics-8252

11. Understanding Einstein: The special theory of relativity:
https://www.coursera.org/learn/einstein-relativity?ranMID=40328&ranEAID=bt30QTxEyjA&ranSiteID=bt30QTxEyjA-5NtKRk4v3hjTC5GC7T4a3w&siteID=bt30QTxEyjA-5NtKRk4v3hjTC5GC7T4a3w&utm_content=10&utm_medium=partners&utm_source=linkshare&utm_campaign=bt30QTxEyjA

You can find many, many more at: https://www.classcentral.com/report/physics-free-online- courses/

Project Ideas:

Why not get your hands stuck in to making something in a Physics project? This website has loads of great ideas using items you should be able to find around the home!
https://learning-center.homesciencetools.com/science-projects/physics/

Movie/Clip Ideas:

Here are some ideas for films to watch or clips to find online:

Films

1. Moon
2. Gravity
3. Interstellar
4. The Imitation Game
5. The Prestige Online

Clips / Series

1. 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

2. Wonders of the Universe / Wonders of the Solar System –
Brian Cox explains the Cosmos using some excellent analogies and wonderful imagery.

3. 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. The link below takes you to a stream of all three parts joined together but it is best watched in hourly instalments. Don't forget to boo when you see Edison. (alternatively watch any Horizon documentary – loads of choice on Netflix and BBC I-Player)
https://www.youtube.com/watch?v=Gtp51eZkwoI

4. 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/

5. 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.
https://www.youtube.com/watch?v=H9fjhQMsDW4

Podcasts:
1. Listen to the 'Infinite Monkey Cage' BBC Radio 4 Podcast (new podcast released every month)
2. Physics World Weekly or Physics World Stories – the latest news, breakthroughs and innovations.
3. Physics Frontiers – high level conversations about little known Physics ideas.

Trip Ideas:
Here is a list of some museums you probably haven't visited that are offering free virtual tours!

1. Nasa's Langley Research Centre:
https://oh.larc.nasa.gov/oh/

2. Nasa's Glenn Research Centre:
https://www.nasa.gov/glennvirtualtou
rs

3. Oxford University's History of Science Museum:
https://hsm.ox.ac.uk/past-exhibitions-and-displays

And how about exploring these virtual field trips:

1. Nuclear Re-imagined Virtual Field Trip:
https://www.navigatingnuclear.com/nuclear-reimagined-
vft/

2. Boeing:
https://www.boeingfutureu.co
m/

3. Johnson Space Centre:
https://www.boeingfutureu.com/virtual-field-
trips/space

4. Toyota - Artificial Intelligence and Automated Vehicles:
https://www.teendrive365inschool.com/CarsOfTheFuture?utm_source=DE&utm_medium=D
E%20carousel&utm_campaign=VFT_Archive_carousel_spring2016

5. NASA, Missions operations:
https://www.nasa.gov/content/goddard/hubble-360-degree-virtual-
tour

6. Aviation:
https://www.manufactureyourfuture.com/VirtualFieldTrip

And these are some great places around the UK that you can visit if you are able:

Northern England and Scotland

1. Jodrell Bank Observatory – Cheshire – one of the largest moveable radio telescopes in the world and the location of the filming of the BBC's Stargazing Live. The site has both indoor and outdoor activities.

2. MOSI – Manchester – Massive free museum showing how science helped Britain lead the way through the industrial revolution. Contains hands on exhibits and displays and often host regular travelling exhibitions.

3. Liverpool World Museum / Spaceport – Liverpool/Wirral – Start the day off at an excellent family science museum with a top floor dedicated to astronomy including a planetarium.Take the ferry cross the Mersey to another family friendly museum dedicated to spaceflight.

4. Kielder Observatory – Northumberland – Book ahead at this popular observatory in the midst of the darkest night skies the UK has to offer. Regular tours and opportunities to view the stars through professional telescopes take place on a nightly basis.

5. Glasgow Science Centre - The Centre is home to hundreds of interactive exhibits throughout the three engaging floors

The Midlands and Wales

1. Electric Mountain – Snowdonia – Set against a mountainous backdrop is a working pumped storage power station. Take a tour deep into the heart of the mountain and see the turbines spring into action to meet our ever increasing demand for electricity. Take a stroll up on of the UKs highest peaks in the afternoon.

2. National Space Centre – Leicester - With six interactive galleries, the UK's largest planetarium, unique 3D Simulator experience, the award-winning National Space Centre in Leicester is an out of this world visitor attraction.

3. Alton Towers – Staffordshire – Treat yourself to a go on a few rollercoasters whilst discussing Newton's Laws. You may want to download and take these handy rollercoaster physics notes with you http://www.explainthatstuff.com/rollercoasters.html

Southern England

1. Royal Observatory – London - Visit the Royal Observatory Greenwich to stand on the historic Prime Meridian of the World, see the home of Greenwich Mean Time (GMT), and explore your place in the universe at London's only planetarium.

2. Herschel Museum of Astronomy – Bath – As you walk around the picturesque Roman city – take an hour or two out at the home of one of the great scientists – discoverer of Infra-red radiation and Uranus.

3. @Bristol – Bristol - home to the UK's only 3D Planetarium and one of the biggest science centres.

4. The Royal Institution – London – The birthplace of many important ideas of modern physics, including Michael Faraday's lectures on electricity. Now home to the RI Christmas lectures and many exhibits of science history.

Task 1 – Workbook

The workbook consists of the next page and lasts until the end of this document.

Retrieval questions

You need to be confident about the definitions of terms that describe measurements and results in A Level. Fill in the definition for the key terms below:

Practical science key terms

When is a measurement valid?	
When is a result accurate?	
What are precise results?	
What is repeatability?	
What is reproducibility?	
What is the uncertainty of a measurement?	
Define measurement error	
What type of error is caused by results varying around the true value in an unpredictable way?	
What is a systematic error?	
What does zero error mean?	
Which variable is changed or selected by the investigator?	
What is a dependent variable?	
Define a fair test	
What are control variables?	

Foundations of Physics

Fill in the answers to the questions below:

What is a physical quantity?	
What are the S.I. units of mass, length, and time?	
What base quantities do the S.I. units A, K, and mol represent?	
List the prefixes, their symbols and their multiplication factors from pico to tera (in order of increasing magnitude)	
What is a scalar quantity?	
What is a vector quantity?	
What are the equations to resolve a force, F, into two perpendicular components, F_x and F_y?	
What is the difference between distance and displacement?	
What does the Greek capital letter Δ (delta) mean?	
What is the equation for average speed in algebraic form?	
What is instantaneous speed?	
What does the gradient of a displacement–time graph tell you?	
How can you calculate acceleration and displacement from a velocity–time graph?	
Write the equation for acceleration in algebraic form.	
What do the letters *suvat* stand for in the equations of motion?	
Write the four *suvat* equations.	
Define *stopping distance*	
Define *thinking distance*	
Define *braking distance*	
What does *free fall* mean?	

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:

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

If a car travels 2 metres in 2 seconds:

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

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.):

<u>3.62</u> <u>25.4</u> <u>271</u> 0.0<u>147</u> 0.<u>245</u> <u>39 4</u>00

(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:

<u>207</u> <u>405</u>0 <u>1.01</u> (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,

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

$$\text{percentage uncertainty} = \frac{0.002}{6.500} \times 100\% = 0.03\%.$$ 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 × 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 3.0×10^{8} m s^{-1}. Use the equation $v = f\lambda$ (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:

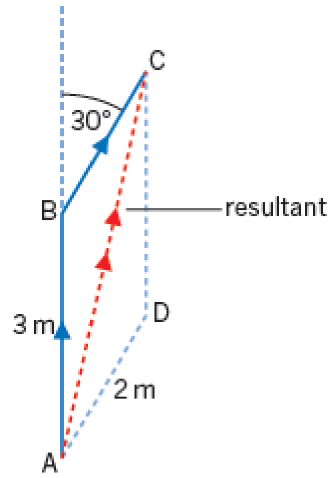
3 ms^{-1},
+20 ms^{-1},
100 m NE,
50 km,
−5 cm,
10 km
S 30° W,
3 × 10^8 ms^{-1}
upwards,
273 °C,
50 kg,
3 A.

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

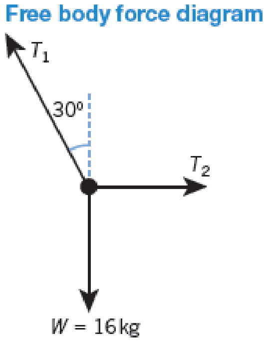
3 Two tractors are pulling a log across a field. Tractor 1 is pulling north with force 1 = 5 kN and tractor 2 is pulling east with force 2 = 12 kN. By scale drawing, determine the resultant force.

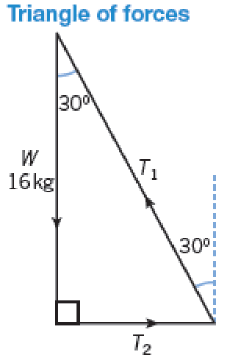
3.3 Free body force diagrams

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.

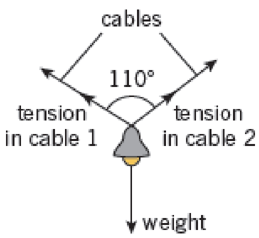




Notice that each force starts from where the previous one ended and they join up to form a triangle with no resultant because the mass is in equilibrium (balanced).

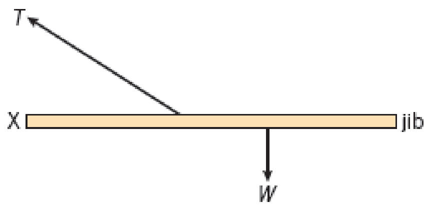
Practice questions

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.



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:

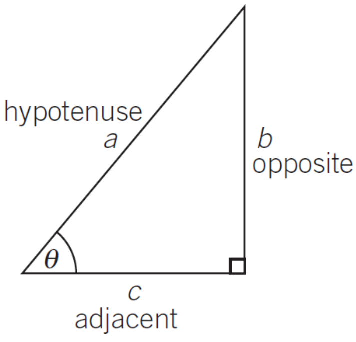
$h^2 = o^2 + a^2$

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

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

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

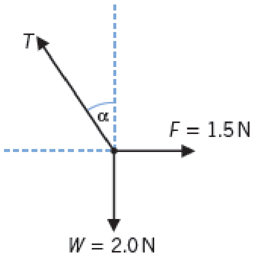
(soh-cah-toa).



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

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

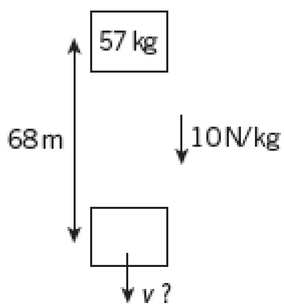
1 The potential difference across a resistor is 12 V and the current through it is 0.25 A. Calculate its resistance.

2 Red light has a wavelength of 650 nm. Calculate its frequency. Write your answer in standard form.
(Speed of light = $3.0 \times 10^8\ \text{m s}^{-1}$)

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

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:

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

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

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.

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

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

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

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.

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

(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:

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

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

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.

Submission Date (for students)

Monday 16 September