Transition Pack for A-Level Physics

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Introduction

Welcome to A-level Physics, this document should serve to set you up to hit the ground running when the A-level begins in September. You should work through the questions on the key skills that are taken for granted at A Level. It is really important that you develop these skills now and identify any problems you have so that you can seek appropriate help from us early days into the course.

Use the section titled Physics folder to be aware of how we expect you to organise your work. You should purchase a large ring binder folder and dividers ready for the first lesson in September.

Finally, bring your completed transition booklets to school on the first day you have physics with myself (could be the very first day at school – so be prepared).

All the best,
Mr Hoskins

Physics folders

The standard expected of your work in physics is as follows:

1. Your folder should be in a ring binder and should be clearly labelled on the front with your name, subject and class.

2. All work should be titled and dated.

3. All work should be in topic or date order.

4. Work should be divided into sections for separate teachers.

5. Lesson work should be complete. If lessons have been missed, the missed work needs to be caught up and included.

6. All work-sheets should be dated and filed within the appropriate section.

7. There should be a clear separate labelled section for Period 9 work, again with work complete as set, dated and titled.

8. There should be a separate, labelled section for private study work beyond lesson notes, including your revision work and examination preparation. These should be titled and dated.

9. Tests and assessments need to be included in a separate section.

10. PAG books should be up to date with all PAGS dated and extension questions completed.

Rules of A Level Physics in OPGS

In order to successfully complete a term in A Level Physics you need to meet the following requirements:

1 – Pass all the test/mock exams in a given term (the pass mark is D)

2 – Complete all home work folders

3 – Complete the lab reports for all PAG experiments

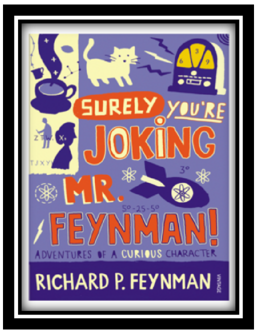
Useful online resources

Minute Physics	https://www.youtube.com/user/minutephysics
Khan Academy	https://www.youtube.com/user/khanacademy/featured
A Level Physics	https://www.youtube.com/channel/UCZzatyx-xC-Dl_VVUVHYDYw
Physics girl	https://www.youtube.com/user/physicswoman
Deep Astronomy	https://www.youtube.com/user/tdarnell
Veritasium	https://www.youtube.com/user/1veritasium
Kurzgesagt	https://www.youtube.com/user/Kurzgesagt
Smarter Everyday	https://www.youtube.com/user/destinws2
SciShow	https://www.youtube.com/user/scishow
Crash Course	https://www.youtube.com/user/crashcourse

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.

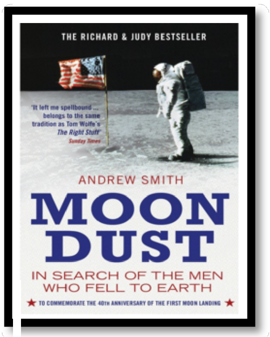
1. **Surely You're Joking Mr Feynman: Adventures of a Curious Character**



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.
(Also available on Audio book).

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

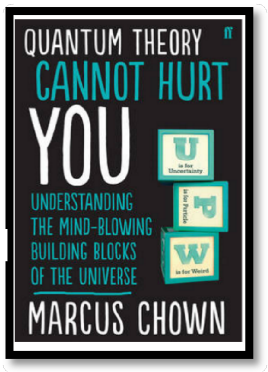
2. **Moondust: In Search of the Men Who Fell to Earth**



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+fell+to+earth

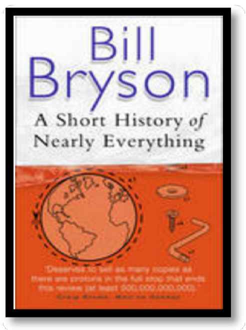
3. **Quantum Theory Cannot Hurt You: Understanding the Mind-Blowing Building Blocks of the Universe**



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

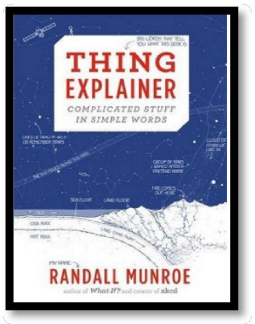
4. **A Short History of Nearly Everything**



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

Movie / Video Clip 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 Fictions Films

1. **Moon (2009)**
2. **Gravity (2013)**
3. **Interstellar (2014)**
4. **The Imitation Game (2015)**
5. **The Prestige (2006)**

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 –** Both available of Netflix as of 17/4/16 – 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 the 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=LyqleIxXTpw

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 each site** covering a topic of your choice.

a) 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.
b) 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.
c) 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.
d) 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.

e) http://www.livescience.com/46558-laws-of-motion.html

Newton's Laws of Motion are fundamental laws for the motion of all the object 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.

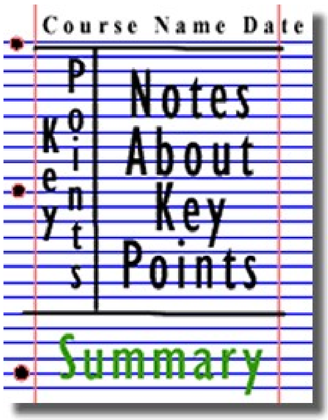


Figure 1: http://coe.jmu.edu/learningtoolbox/images/noteb4.gif

Pre-Knowledge Topics

Below are ten topics that are essential foundations for you study of A-Level Physics. Each topics has example questions and links where you can find our more information as you prepare for next year.

Symbols and Prefixes

Prefix	Symbol	Power of ten
Nano	n	$\times 10^{-9}$
Micro	µ	$\times 10^{-6}$
Milli	m	$\times 10^{-3}$
Centi	c	$\times 10^{-2}$
Kilo	k	$\times 10^{3}$
Mega	M	$\times 10^{6}$
Giga	G	$\times 10^{9}$

At A level, unlike GCSE, you need to remember all symbols, units and prefixes. Below is a list of quantities you may have already come across and will be using during your A level course

Quantity	Symbol	Unit
Velocity	v	ms^{-1}
Acceleration	a	ms^{-2}
Time	t	S
Force	F	N
Resistance	R	Ω
Potential difference	V	V
Current	I	A
Energy	E or W	J
Pressure	P	Pa
Momentum	p	$kgms^{-1}$
Power	P	W
Density	ρ	kgm^{-3}
Charge	Q	C

Standard form

At A level quantities will be written in standard form, and it is expected that your answers will be too.

This means answers should be written as ….x 10^y. E.g. for an answer of 1200kg we would write 1.2 x 10^3kg. For more information visit:
www.bbc.co.uk/education/guides/zc2hsbk/revision

Standardformisusedtomakeverylargeorverysmallnumberseasierto read. It also makes it easier to put large or small numbers in order of size.

In standard form, a number is always written as:**A×10^n**
•**A**is always a number between 1 and 10
•**n**tells us how many places to move the decimal point.

For example	1.234×10^4	1.234×10^{-4}
This means	$1.234 \times 10 \times 10 \times 10 \times 10$	$1.234 \div 10 \div 10 \div 10 \div 10$
Which is	12340	0.0001234

Let's see some more examples.

0.523	$= 5.23 \times 10^{-1}$	(note that $\times 10^{-1}$ means divide 5.23 by 10)
52.3	$= 5.23 \times 10^{1}$	(note that $\times 10^{1}$ means multiply 5.23 by 10)
523	$= 5.23 \times 10^{2}$	(note that $\times 10^{2}$ means multiply 5.23 by 100)
5230	$= 5.23 \times 10^{3}$	(note that $\times 10^{3}$ means multiply 5.23 by 1000)
0.00523	$= 5.23 \times 10^{-3}$	(note that $\times 10^{-3}$ means divide 5.23 by 1000)

Solve the following:

1. How many metresin 2.4 km?

2. How manyjoulesin 8.1 MJ?

3. Convert 326 GWinto W.

4. Convert 54600 mm into m.

5. How many gramsin 240 kg?

6. Convert 0.18 nm into m.

7. Convert 632 nm into m. Expressinstandardform.

8. Convert 1002 mVinto V. Expressinstandardform.

9. How manyeVin 0.511 MeV?Expressinstandardform.

10. How many m in 11 km?Expressinstandardform.

Convert these numbers in to a standard form:

0.00969
0.000312
0.000000149

7400000000
4310000000
0.00000029
953000000
579000
0.0517

Answers:

1) $0.00969 = 9.69 \times 10^{-3}$

2) $0.000312 = 3.12 \times 10^{-4}$

3) $0.000000149 = 1.49 \times 10^{-7}$

4) $7400000000 = 7.4 \times 10^{9}$

5) $4310000000 = 4.31 \times 10^{9}$

6) $0.00000029 = 2.9 \times 10^{-7}$

7) $953000000 = 9.53 \times 10^{8}$

8) $579000 = 5.79 \times 10^{5}$

9) $0.0517 = 5.17 \times 10^{-2}$

More onPrefixes

Often in Physics, quantities are written using prefixes which is an even shorter way of writing numbers than standard form. For example instead of writing **2.95×10^{-9}**m we can write **2.95 nm** where n means 'nano' and is a short way of writing **$\times 10^{-9}$**. Here is a table that shows all the prefixes you need to know:

Prefix name	Prefix symbol	Factor
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}
peta	P	10^{15}

1. Convert these into standard form.

a) 1.4 kW =

b) 10 μC =

c) 24 cm =

d) 340 MW =

e) 46 nF =

f) 0.03 mA =

g) 52 Gbytes =

h) 43 kΩ =

Answers:

a) 1.4×10^3 W

b) 10^{-5} C

c) 2.4×10^{-1} m

d) 3.4×10^8 W

e) 4.6×10^{-8} F

f) 3×10^{-5} A

g) 5.2×10^{10} bytes

h) 4.3×10^4 Ω

Rearranging formulae

This is something you will have done at GCSE and it is crucial you master it for success at A level. For a recap of GCSE watch the following links:

www.khanacademy.org/math/algebra/one-variable-linear-equations/old-school-equations/v/solving-for-a-variable

www.youtube.com/watch?v=_WWgc3ABSj4

Rearrange the following:

1. $E = m \times g \times h$ to find h
2. $Q = I \times t$ to find I
3. $E = \frac{1}{2} m v^2$ to find m
4. $E = \frac{1}{2} m v^2$ to find v
5. $v = u + at$ to find u
6. $v = u + at$ to find a
7. $v^2 = u^2 + 2as$ to find s
8. $v^2 = u^2 + 2as$ to find u

Significant Figures

The significant figures (sf) of a number are digits that carry meaning contributing to its precision. The Rules:

1 - All non-zero digits are always **significant** (1235 has 4 sf)

2 – Leading and trailing zeros are **not** significant (0.0045 has 2 sf and 100 has 1 sf)

3 - Captive zeros (zeros within a number) are always **significant** (30.0809 has 6 sf)

4 – Zeros at the end of number but to the right of the decimal point are **significant** (2.00 has 3 sf)

At A level you will be expected to use an appropriate number of significant figures in your answers. The number of significant figures you should use is the same as the number of significant figures in the data you are given. You can never be more precise than the data you are given so if that is given to 3 significant your answer should be too. E.g. Distance = 8.24m, time = 1.23s therefore speed = 6.75m/s

The website below summarises the rules and how to round correctly.
http://www.purplemath.com/modules/rounding2.htm

State the number of significant figures in the following measurements:

2005 cm	0.050 cm
25 000 g	0.0280 g
25.0 ml	50.00 ml
0.25 s	1000 s
0.00250 mol	1000. 0 J

Answers

2005 cm	4	0.050 cm	2
25 000 g	2	0.0280 g	3
25.0 ml	3	50.00 ml	4
0.25 s	2	1000 s	1
0.00250 mol	3	1000. 0 J	5

We must also show that calculated values recognise the precision of the values we put into a formula. We do this by giving our answer to the same number of significant figures as the least precise piece of data we use.

There is no way we can state the runners speed this precisely.

For example: A man runs 110 m in 13 s. Calculate his average speed.

Speed = Distance / Time = 110 m / 13 s = 8.461538461538461538461538461538 m/s

This is the same number of sig figs as the time, which is less precise than the distance.

= 8.5 m/s to 2 s.f.

Calculate the following and write your answer to the correct number of significant figures:

a) 2.65 m x 3.015 m

b) 22.37 cm x 3.10 cm

c) 0.16 m x 0.02 m

d) $\dfrac{54.401 \text{ m}^3}{4 \text{ m}}$

Answers

a) 7.98975 = **7.99** (3 sf) m^2

b) 69.347 = **69.3** (3 sf) cm^2

c) 0.0032 = **0.003** (1 sf) m^2

d) 13.60025 = **10** (1 sf) m^2

Recording Data

Whilst carrying out a practical activity you need to write all your raw results into a table. Don't wait until the end, discard anomalies and then write it up in neat.

Tables should have column heading and units in this format quantity/unit e.g. length /mm

All results in a column should have the same precision and if you have repeated the experiment you should calculate a mean to the same precision as the data.

Below are link to practical handbooks so you can familiarise yourself with expectations.

http://filestore.aqa.org.uk/resources/physics/AQA-7407-7408-PHBK.PDF

http://www.ocr.org.uk/Images/295483-practical-skills-handbook.pdf

http://www.ocr.org.uk/Images/295483-practical-skills-handbook.pdf

Tables

When labelling table columns we use the following convention: after the name of the physical quantity we put slash '/' followed by SI units.

V/V	I/A	R/Ω
0.15	1.01	0.15
0.32	2.12	0.15
0.38	2.42	0.16

The V values are written to 2 significant figures and the I values are all to 3 significant figures. Therefore the values of R can only be quoted to 2 significant figures (lowest number of significant figures used in the calculation).

Independent variable	Dependent variable		
	Reading 1	Reading 2	Average

- The **independent** variable => the one that we control

- The **dependent** variable => the one that comes from experiment

Below is a table of results from an experiment where a ball was rolled down a ramp of different lengths. A ruler and stop clock were used.

1) Identify the errors the student has made.

	Time			
Length/cm	**Trial 1**	**Trial 2**	**Trial 3**	**Mean**
10	1.45	1.48	1.46	1.463
22	2.78	2.72	2.74	2.747
30	4.05	4.01	4.03	4.03
41	5.46	5.47	5.46	5.463
51	7.02	6.96	6.98	6.98
65	8.24	9.68	8.24	8.72
70	9.01	9.02	9.0	9.01

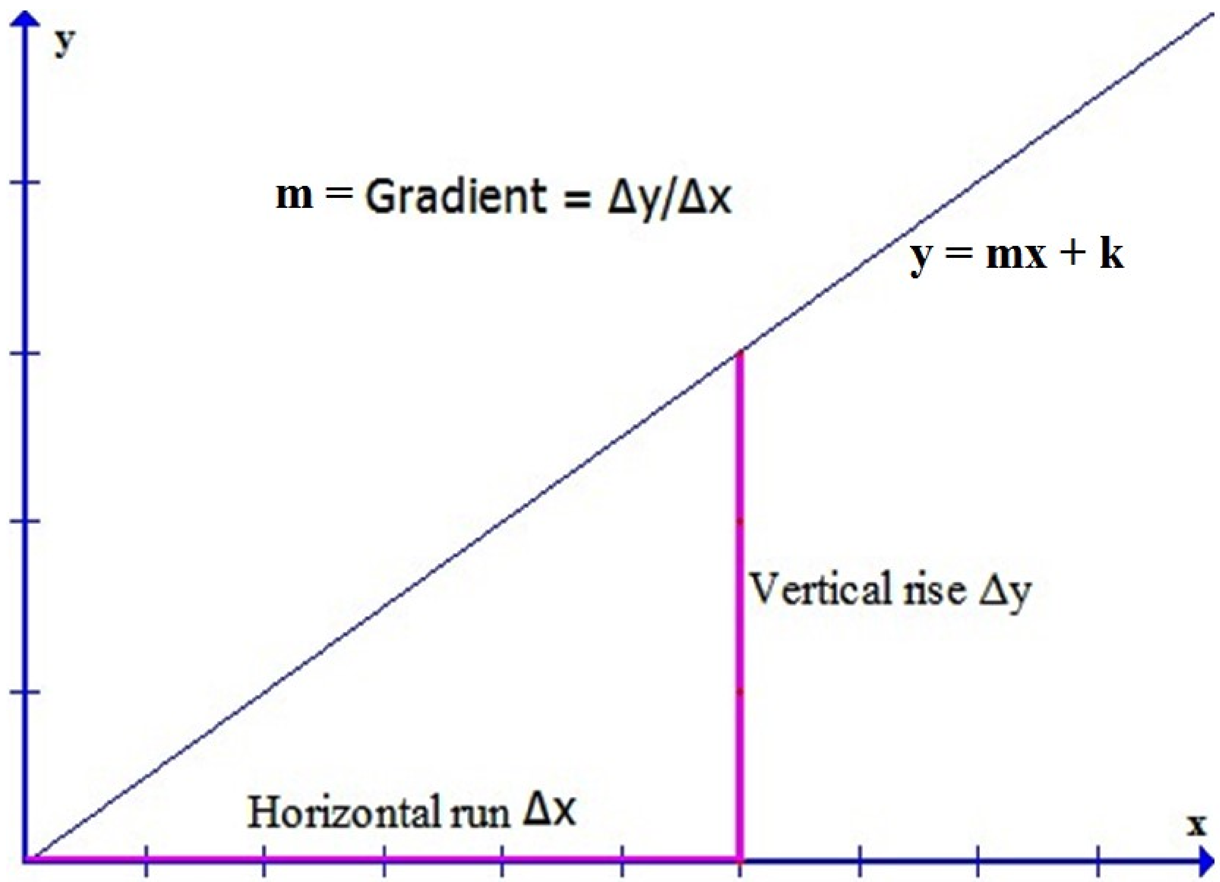
Graphs

Graphs are very useful, highly visual way of demonstrating the relationship between two variables, showing patterns and trends and allowing us to determine values of the gradient, the area beneath the graph and the y-intercept.

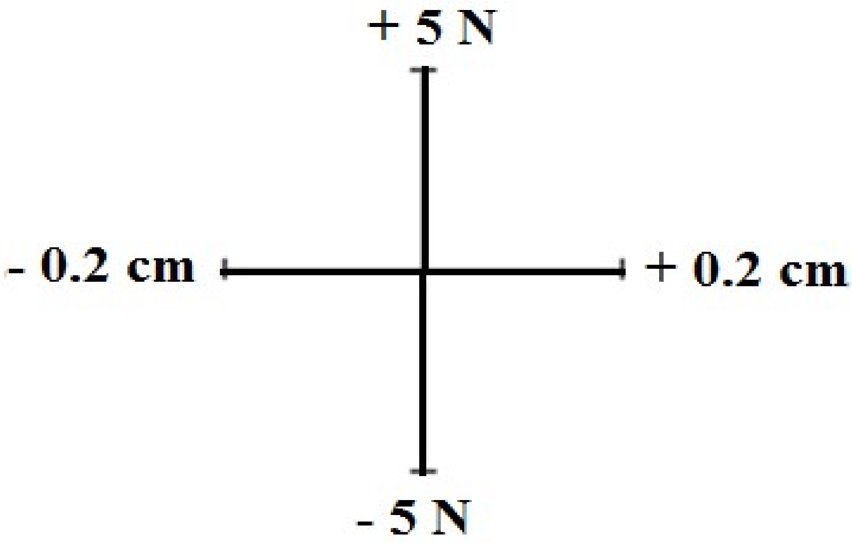
Graphs are most effective when:

- They are large (use as much of the graph paper as possible in both directions)
- The points are plotted clearly and precisely
- The line of the best fit is drawn clearly (thin line with a pencil)
- The gradient can be calculated using two points on the line of the best fit that are as far apart as possible, but within the measured range
- The y-intercept can be read clearly and accurately using the scale on the y-axis

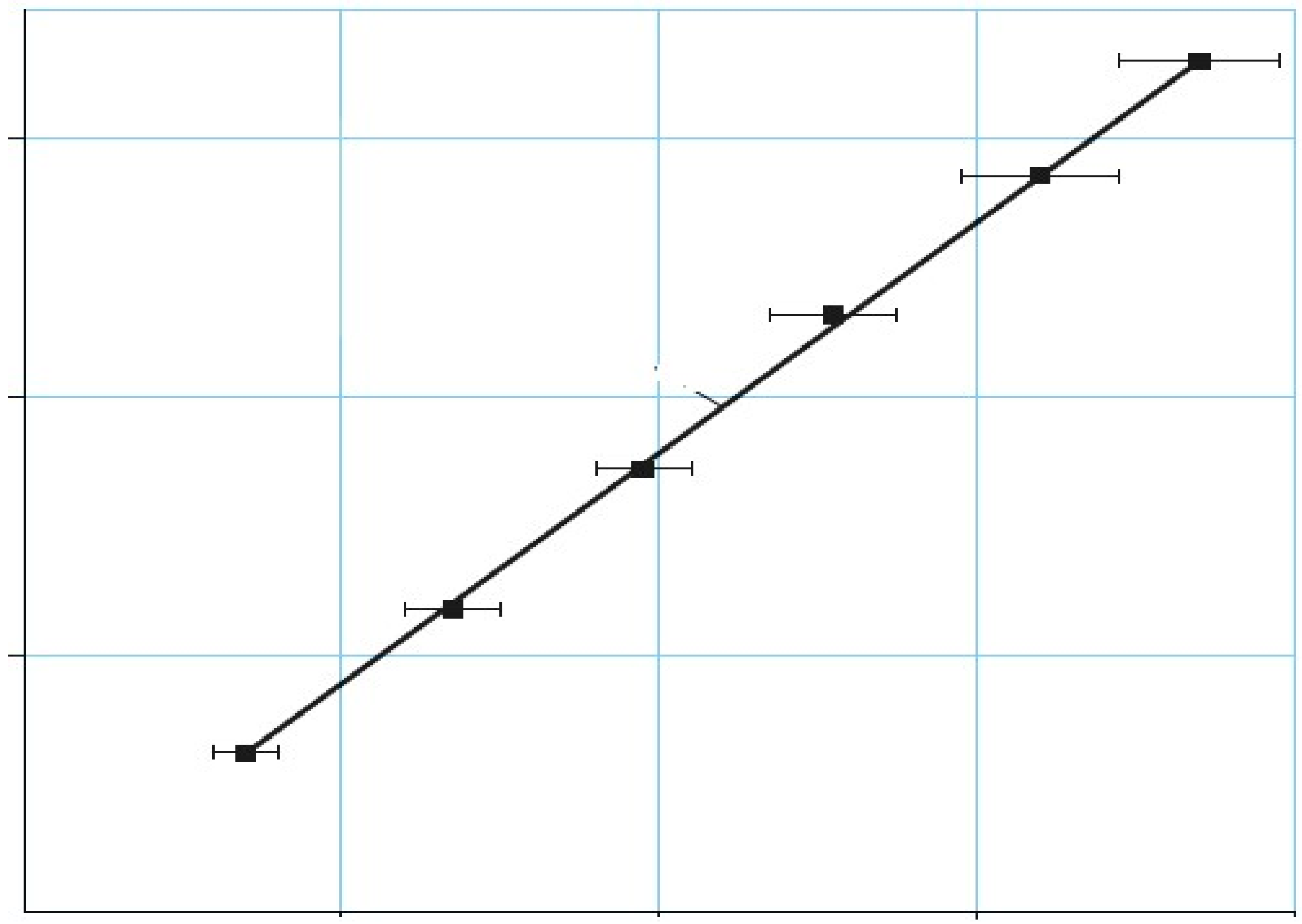
Gradient:



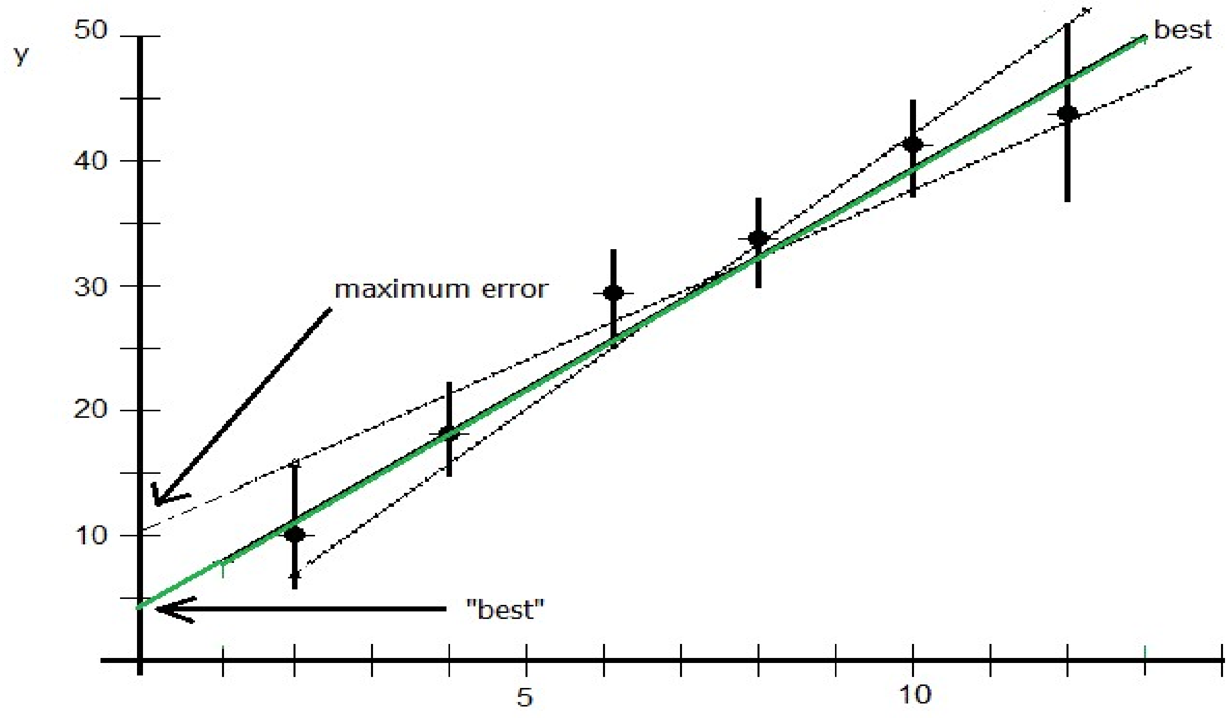
Error bars - represent the **absolute uncertainty** in measurements and can be plotted in both x and y directions.



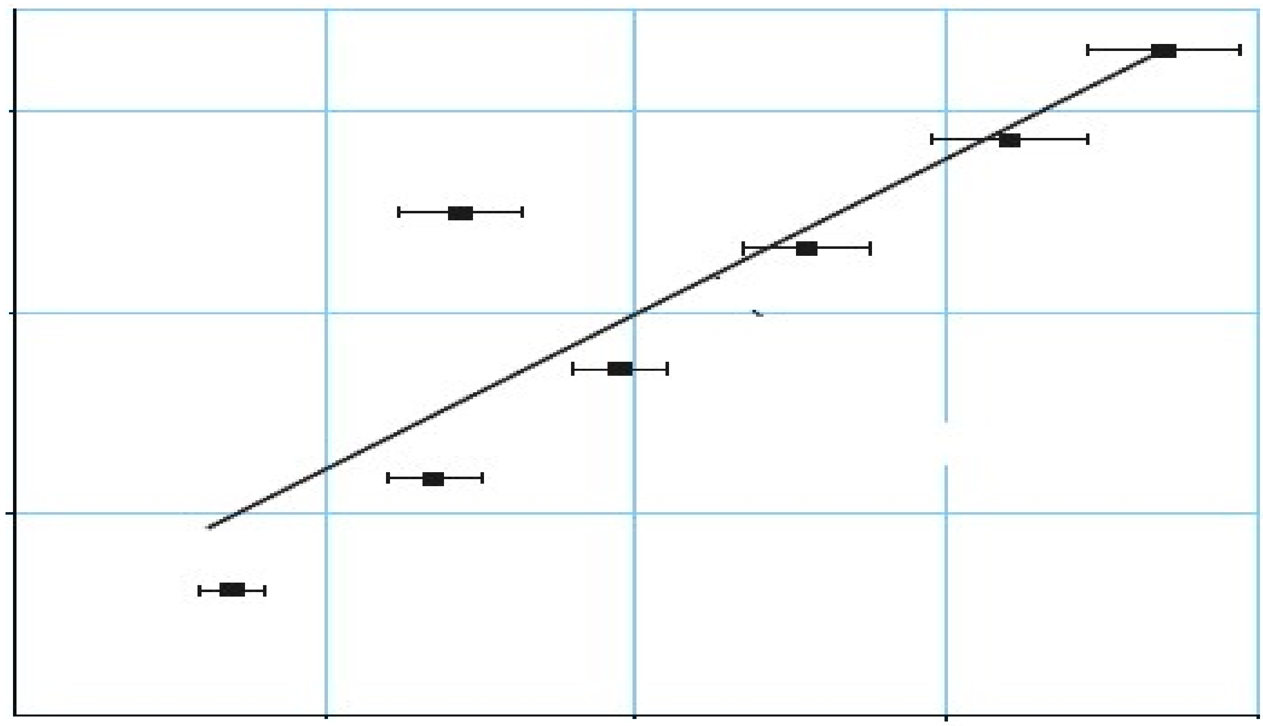
Line of best fit – a line that is going through as many points as possible, with equal numbers of points above and below the line.



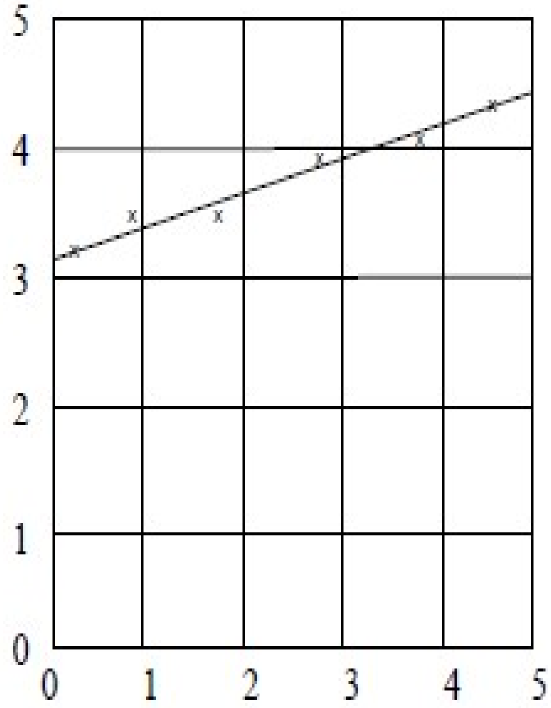
The worst fit lineis the worst acceptable line, still passing through all the error bars. This will be either the steepest possible line of fit or the least steep line of fit. The dotted lines are the lines of worst fit



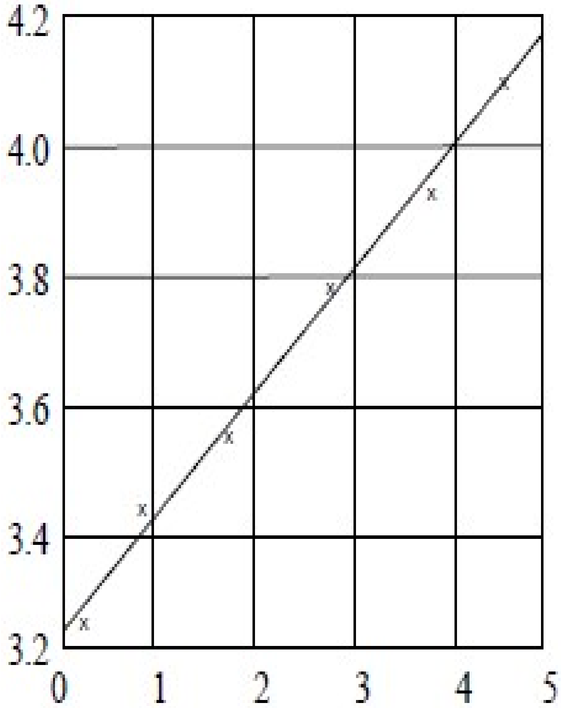
The outliers (anomalous point) - points visibly different from the rest. In the example below the line of best is not crossing through many points because it is affected by the outlier. The anomalous point should be ignored.



Examples

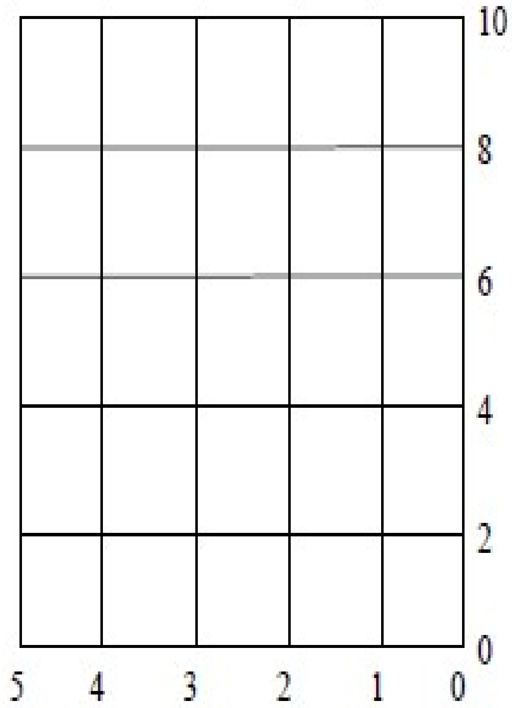


Not acceptable - scale in the *y*-direction is compressed

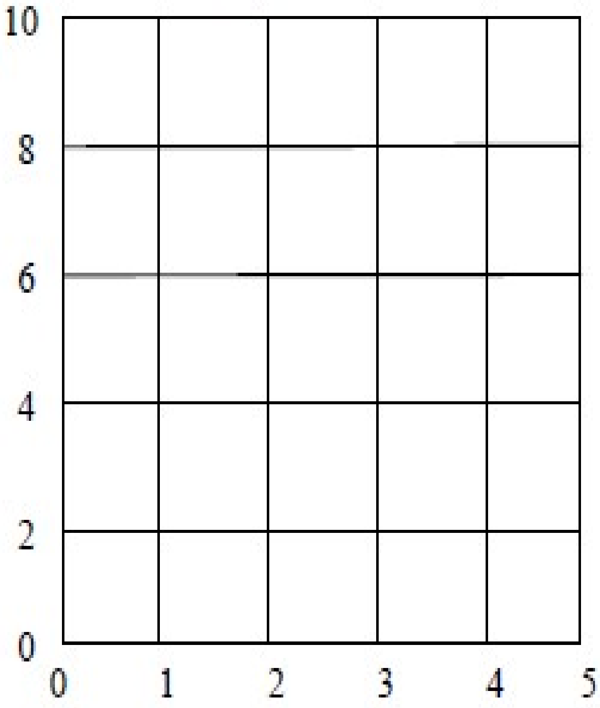


Acceptable - points fill more than half the graph grid in both the *x* and *y* directions

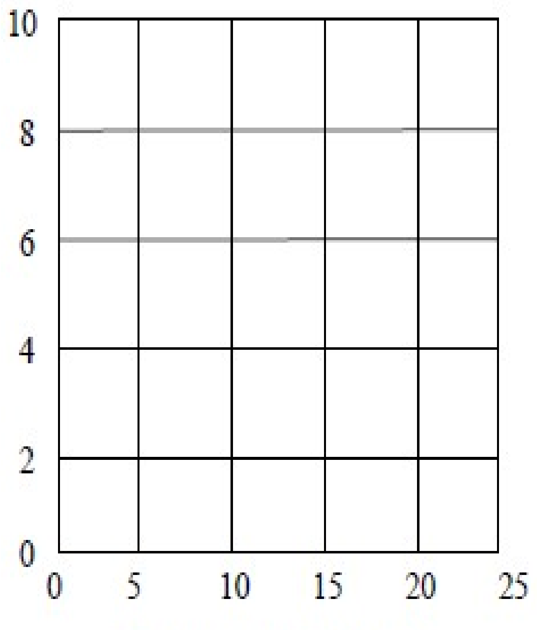
The scale direction must be conventional (i.e. increasing from left to right).



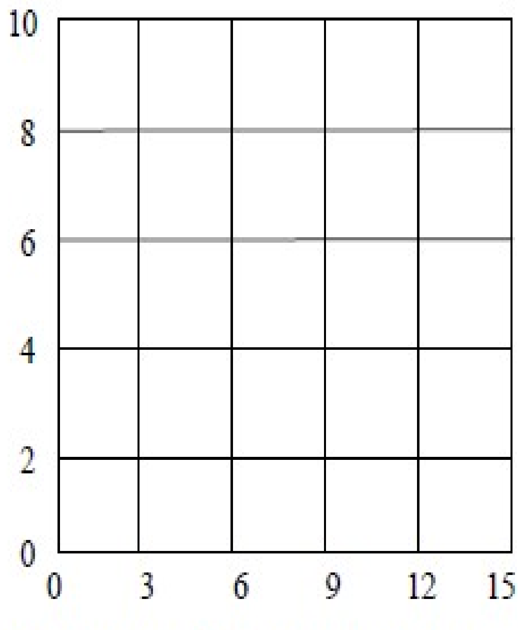
Not acceptable - unconventional scale direction



Acceptable - conventional scale direction



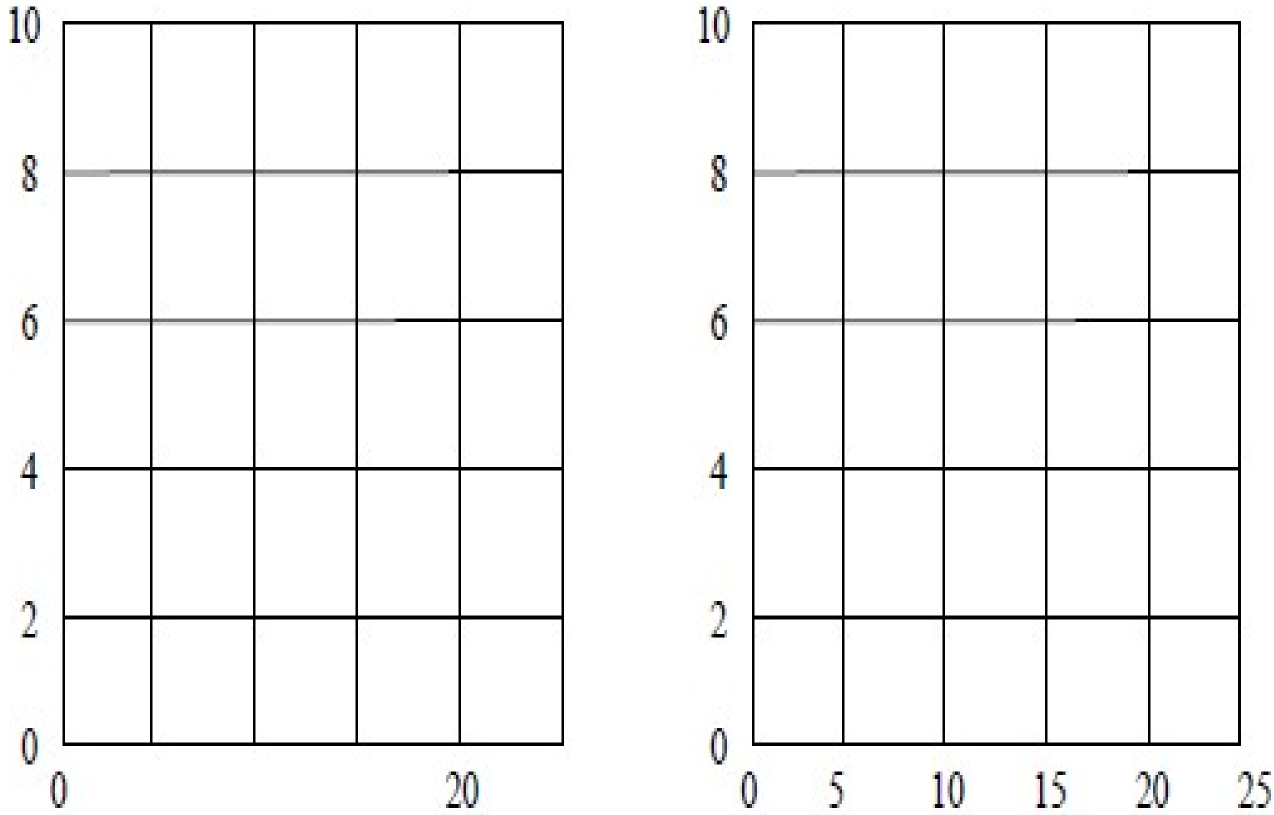
Acceptable scale divisions.



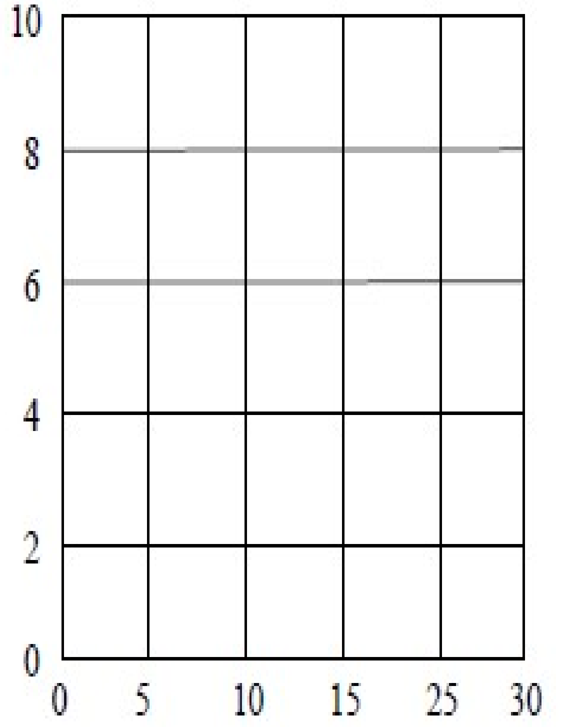
Not acceptable - awkward scale on the *x*-axis.

Learners who choose awkward scales in examinations often lose marks for plotting points (as they cannot read the scales correctly) and calculation of gradient (Δx and Δy often misread – again because of poor choice of scale).

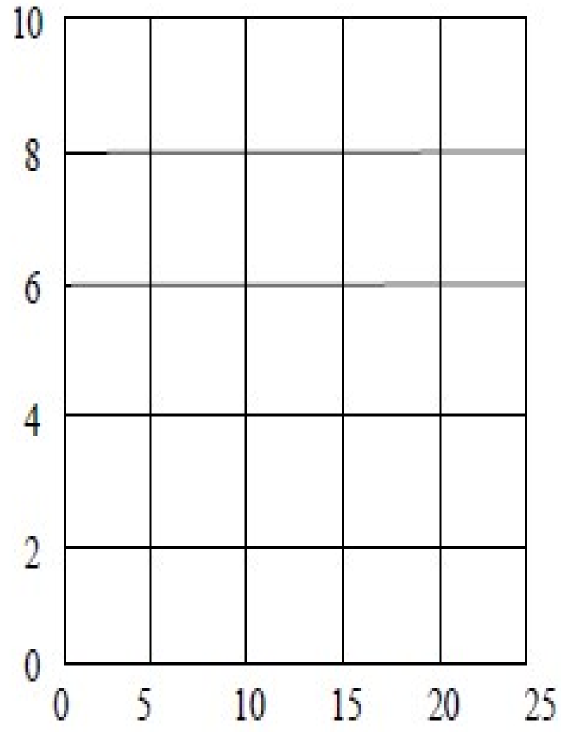
Scales should be labelled reasonably frequently (i.e. there should not be more than three large squares between each scale label on either axis).



There should be no 'holes' in the scale.

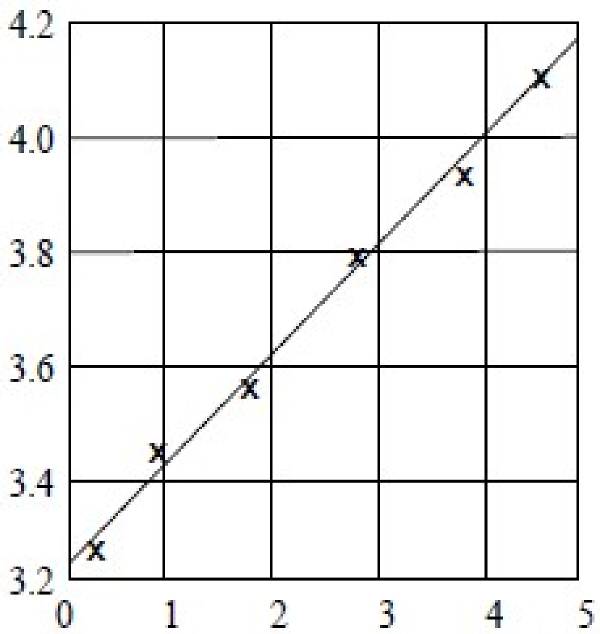


Not acceptable - non-linear scale on the x-axis

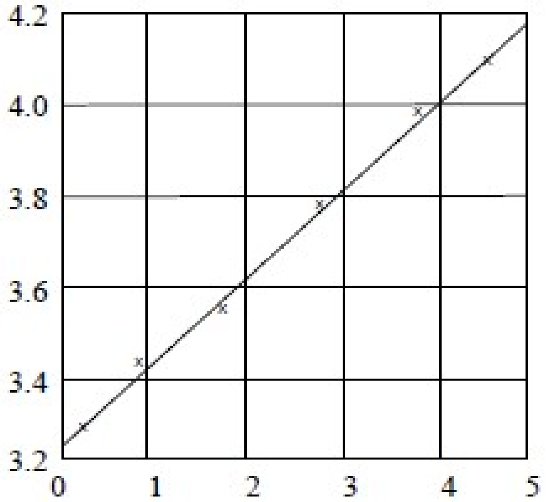


Acceptable - scale labelling is regular

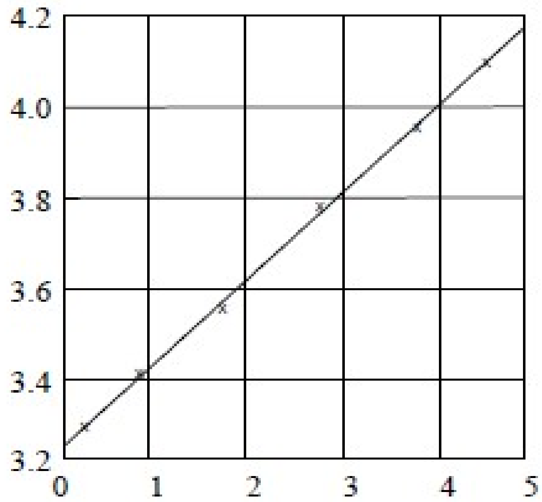
Thick plots are not acceptable. If it cannot be judged whether a plot is accurate to half a small square (because the plot is too thick) then the plotting mark will not be awarded.



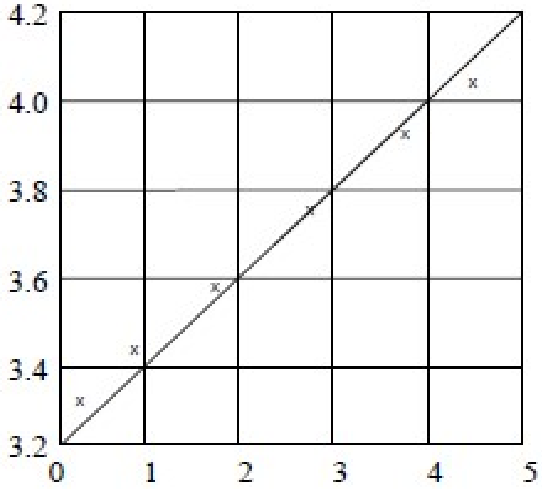
Thick plots not acceptable



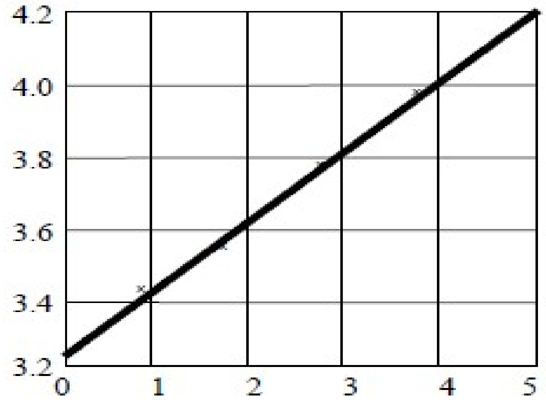
Not acceptable - too many points above the line



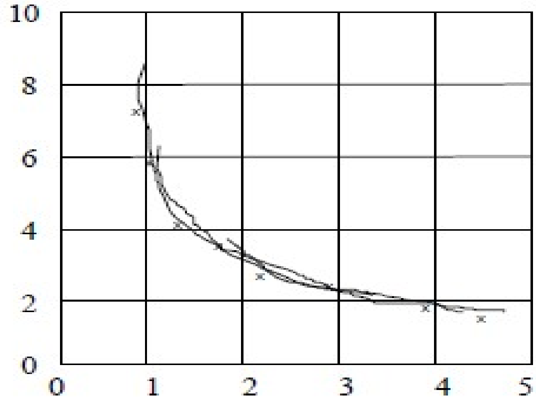
Acceptable balance of points about the line



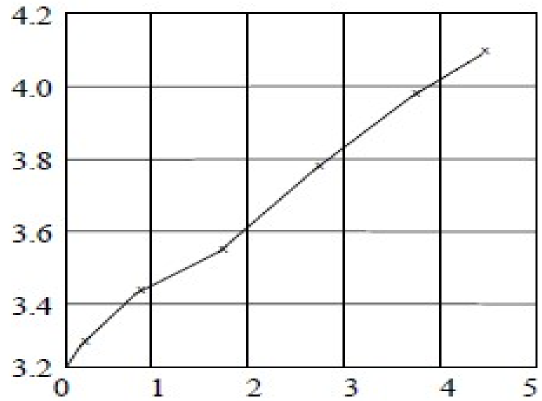
Not acceptable - forced line through the origin (not appropriate in this instance)



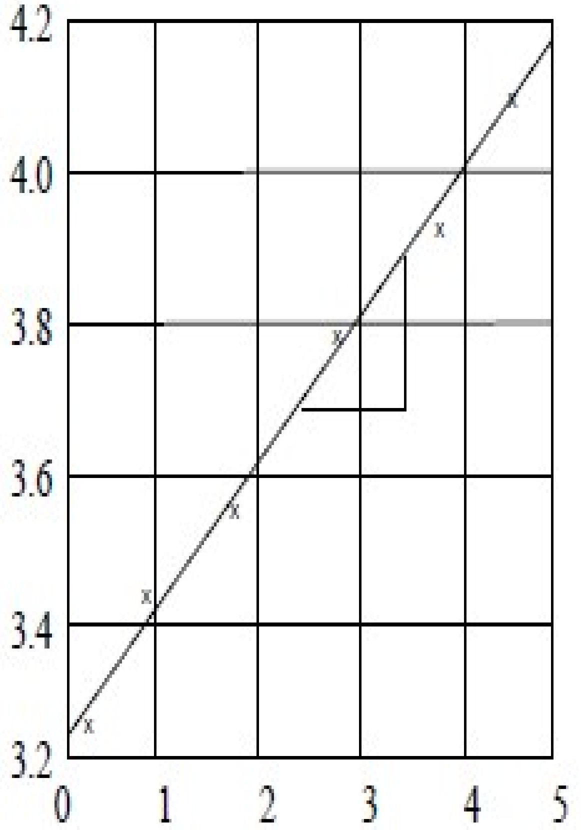
Not acceptable - thick line



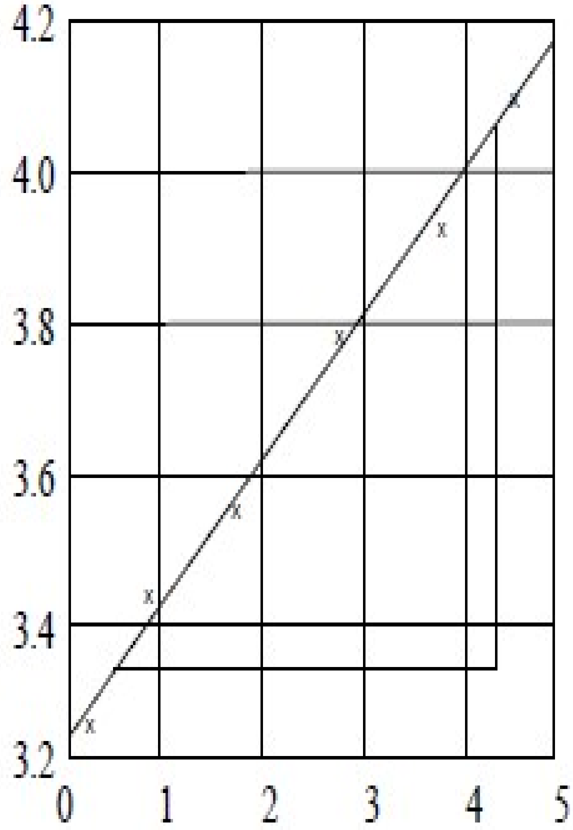
Not acceptable - 'hairy' curve



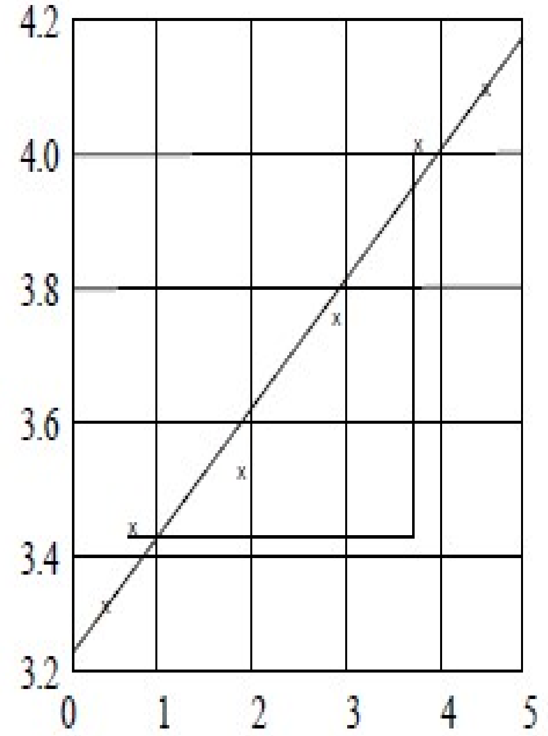
Not acceptable – joining point-to-point



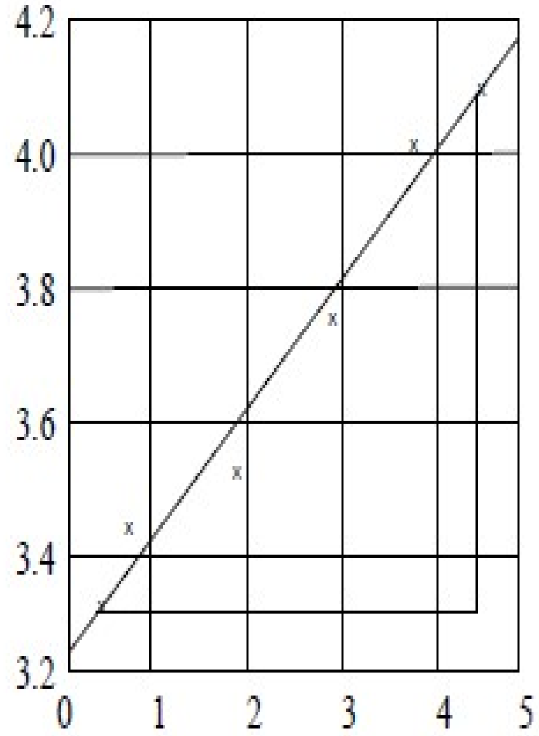
Not acceptable - the 'triangle' used is too small



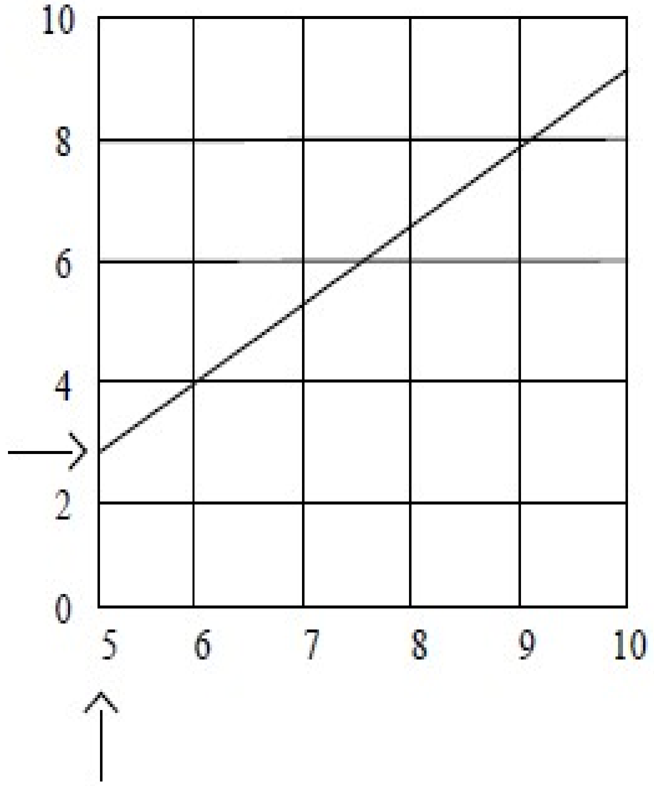
Acceptable – a large 'triangle' used



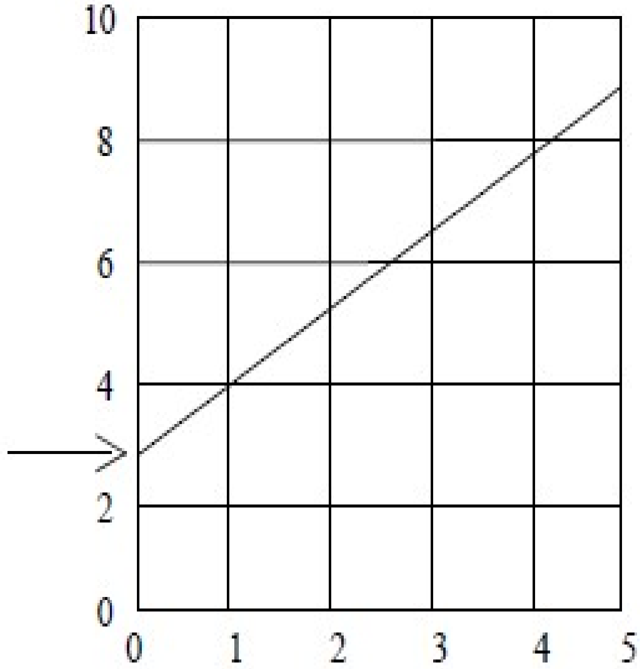
Not acceptable - the data points used which do not lie on the line of best fit



Acceptable - plots on line



Not acceptable – the y-intercept is found from the line $x = 5$



Acceptable – the value taken from the line $x = 0$

Graphs - Summary

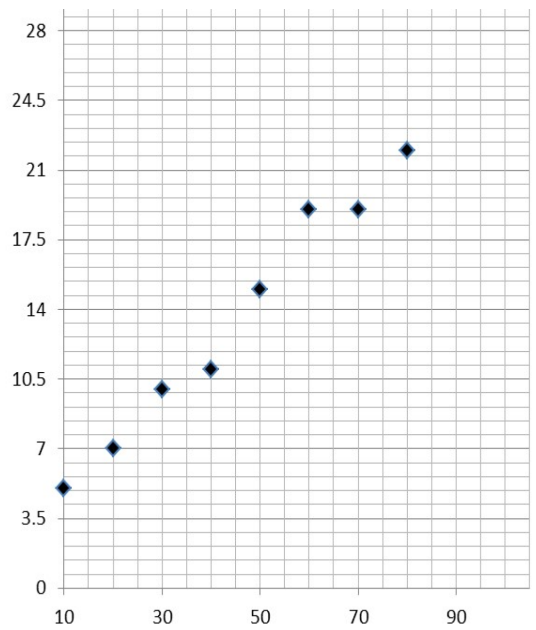
After a practical activity the next step is to draw a graph that will be useful to you. Drawing a graph is a skill you should be familiar with already but you need to be extremely vigilant at A level. Before you draw your graph to need to identify a suitable scale to draw taking the following into consideration:

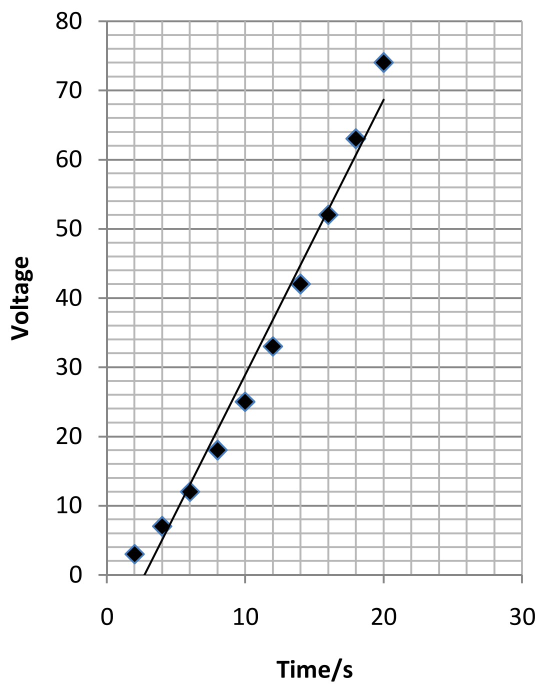
- the maximum and minimum values of each variable
- whether 0.0 should be included as a data point; graphs don't need to show the origin, a false origin can be used if your data doesn't start near zero.
- the plots should cover at least half of the grid supplied for the graph.
- the axes should use a sensible scale e.g. multiples of 1,2, 5 etc)

Identify how the following graphs could be improved

Graph 1

Graph 2





Forces and Motion

At GCSE you studied forces and motion and at A level you will explore this topic in more detail so it is essential you have a good understanding of the content covered at GCSE. You will be expected to describe, explain and carry calculations concerning the motion of objects. The websites below cover Newton's laws of motion and have links to these in action.

http://www.physicsclassroom.com/Physics-Tutorial/Newton-s-Laws
http://www.sciencechannel.com/games-and-interactives/newtons-laws-of-motion-interactive/

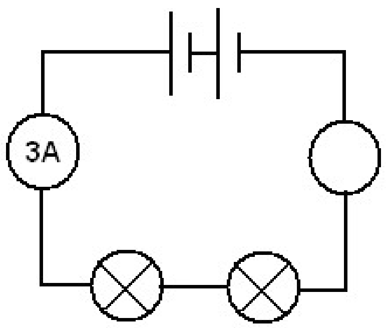
Sketch a velocity-time graph showing the journey of a skydiver after leaving the plane to reaching the ground.

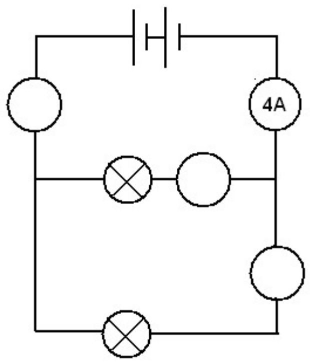
Mark on terminal velocity.

Electricity
At A level you will learn more about how current and voltage behave in different circuits containing different components. You should be familiar with current and voltage rules in a series and parallel circuit as well as calculating the resistance of a device.

http://www.allaboutcircuits.com/textbook/direct-current/chpt-1/electric-circuits/
http://www.physicsclassroom.com/class/circuits

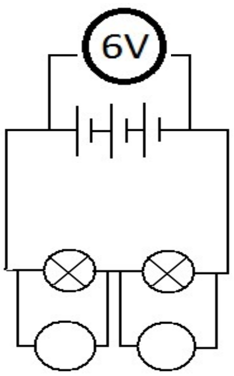
1a) Add the missing ammeter readings on the circuits below.

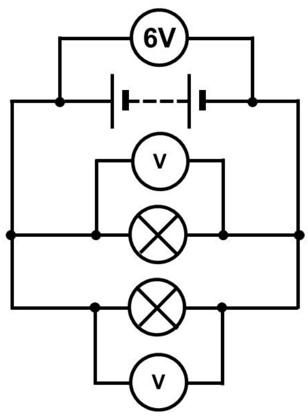




b) Explain why the second circuit has more current flowing than the first.

2) Add the missing potential differences to the following circuits





Waves

You have studied different types of waves and used the wave equation to calculate speed, frequency and wavelength. You will also have studied reflection and refraction. Use the following links to review this topic.

http://www.bbc.co.uk/education/clips/zb7gkqt
https://www.khanacademy.org/science/physics/mechanical-waves-and-sound/mechanical-waves/v/introduction-to-waves
https://www.khanacademy.org/science/physics/mechanical-waves-and-sound/mechanical-waves/v/introduction-to-waves

1) Draw a diagram showing the refraction of a wave through a rectangular glass block. Explain why the ray of light takes this path.

2) Describe the difference between a longitudinal and transverse waves and give an example of each

3) Draw a wave and label the wavelength and amplitude

Atomic Structure

You will study nuclear decay in more detail at A level covering the topics of radioactivity and particle physics. In order to explain what happens you need to have a good understanding of the model of the atom. You need to know what the atom is made up of, relative charges and masses and how sub atomic particles are arranged.

The following video explains how the current model was discovered
www.youtube.com/watch?v=wzALbzTdnc8

Describe the model used for the structure of an atom including details of the individual particles that make up an atom and the relative charges and masses of these particles. You may wish to include a diagram and explain how this model was discovered by Rutherford

Pre-Knowledge Topics Answers:

Symbols and prefixes

1. 2400
2. 8 100 000
3. 326 000 000 000
4. 54.6
5. 240 000
6. 1.8×10^{-8}
7. 6.32×10^{-7}
8. 1.002
9. 5.11×10^{-5}
10. 1.1×10^{4}

Standard Form:

1. 2.53
2. 2.8
3. 7.7
4. 9.1
5. 1.872
6. 1.22
7. 2400
8. 35.05
9. 8 310 000
10. 600.2
11. 0.00015
12. 4300

Rearranging formulae

1. $h = E / (m \times g)$
2. $I = Q/t$
3. $m = (2 \times E)/v^2$ or $E/(0.5 \times v^2)$
4. $v = \sqrt{((2 \times E)/m)}$
5. $u = v - at$
6. $a = (v-u)/t$
7. $s = (v^2 - u^2) / 2a$
8. $u = \sqrt{(v^2 - 2as)}$

Significant figures

1. 3.35
2. 40.7
3. 0.839
4. 1.02
5. 60.0
6. 0.809
7. 237
8. 3.4
9. 0.00330
10. 3343

Recording data

Time should have a unit next to it
Length can be measured to the nearest mm so should be 10.0, 22.0 etc
Length 65 trial 2 is an anomaly and should have been excluded from the mean
All mean values should be to 2 decimal places
Mean of length 61 should be 6.99 (rounding error)

Graphs

Graph 1:

Axis need labels
Point should be x not dots
Line of best fit is needed
y axis is a difficult scale
x axis could have begun at zero so the y-intercept could be found

Graph 2:

y-axis needs a unit
curve of best fit needed not a straight line
Point should be x not dots

Forces and motion

Graph to show acceleration up to a constant speed (labelled terminal velocity). Rate of acceleration should be decreasing. Then a large decrease in velocity over a short period of time (parachute opens), then a decreasing rate of deceleration to a constant speed (labelled terminal velocity)

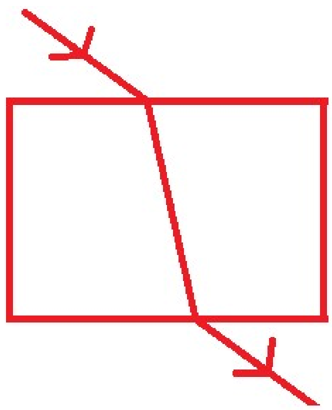
Electricity

1a) Series: 3A, Parallel top to bottom: 4A,2A,2A

b) Less resistance in the parallel circuit. Link to R=V/I. Less resistance means higher current.

2) Series: 3V, 3V, Parallel: 6V 6V

Waves

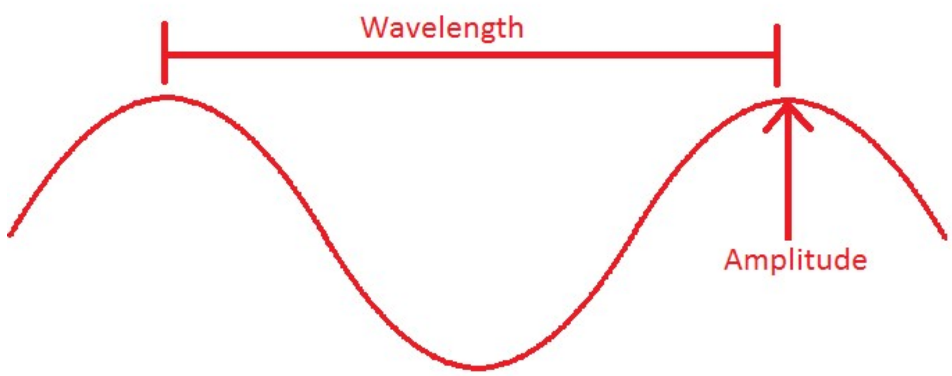


1) When light enters a more optically dense material it slows down and therefore bends towards the normal. The opposite happened when it leaves an optically dense material.

2) A longitudinal wave oscillates parallel to the direction of energy transfer (e.g. sound). A transverse waves oscillated perpendicular to the direction of energy transfer (e.g. light)

3)

.



Atomic Structure
contains protons, neutrons and electrons
Relative charge:
protons are positive (+1)
electrons are negative (-1)
neutrons are uncharged (0)
Relative mass:
proton 1
neutron 1
electron (about) 1/2000
protons and neutrons make up the nucleus
the nucleus is positively charged
electrons orbit the nucleus at a relatively large distance from the nucleus
most of the atom is empty space
nucleus occupies a very small fraction of the volume of the atom
most of the mass of the atom is contained in the nucleus
total number of protons in the nucleus equals the total number of electrons orbiting it in an atom

Ideas for Day Trips

Here are some suggestions for some physics-themed days out for you to enjoy over the summer break (if the lockdown is lifted). Try and have some fun as you prepare for two tough but rewarding years ahead!

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.

SIGNIFICANT FIGURES

A. Significant Figures

Determine the number of significant figures in the following numbers

1.	2.03	6.	190300
2.	5000000	7.	0.00860
3.	0.0224	8.	60060
4.	2300	9.	27.00
5.	15.0800	10.	240240

B. Calculations with Significant Figures

Write the final answer with the right number of significant figures

1. $13\ kg + 5.2\ kg + 7.35\ kg$

2. $10.1\ s + 20.205 s - 7.00\ s$

3. $675\ m\ \times 1.3\ m$

4. $\frac{2230m}{150s}$

5. $11\ cm\ \times 5.2\ cm\ x\ 125\ cm$

SIGNIFICANT FIGURES

A. Significant Figures

Determine the number of significant figures in the following numbers

1.	2.03	(3)	6.	190300	(4)
2.	5000000	(1)	7.	0.00860	(3)
3.	0.0224	(3)	8.	60060	(4)
4.	2300	(2)	9.	27.00	(4)
5.	15.0800	(6)	10.	240240	(5)

B. Calculations with Significant Figures

Write the final answer with the right number of significant figures

1. $13\ kg + 5.2\ kg + 7.35\ kg$ $= 25.55\ kg \simeq \boxed{26\ kg}$

2. $10.1\ s + 20.205s - 7.00\ s$ $= 23.305\ s \simeq \boxed{23.3\ s}$

3. $675\ m \times 1.3\ m$ $= 877.5\ m^2 \simeq \boxed{880\ m^2}$

4. $\frac{2230m}{150s}$ $= 14.866\ \frac{m}{s} \simeq \boxed{15\ \frac{m}{s}}$

5. $11\ cm \times 5.2\ cm\ x\ 125\ cm$ $= 7150\ cm^3 \simeq \boxed{7200\ cm^3}$

Which of the following is the best estimate, to two significant digits, of the quantity: $\frac{\pi \times 8.1}{\sqrt{(15.9)}}$

A. 6.00 B. 6 C. 5.0 D. 6.0

****

When a voltage V of 12.2 V is applied to a DC motor, the current I in the motor is 0.20 A. Which one of the following is the output power VI of the motor given to the correct appropriate number of significant digits?

A. 2 W B. 2.4 W C 2.40 W D. 2.44 W

****

A student measures the current in a resistor as 677 mA for a potential difference of 3.6 V. A calculator shows the resistance of the resistor to be 5.3175775 Ω. Which one of the following gives the resistance to an appropriate number of significant figures?

A. 5.3 Ω B. 5.32 Ω C. 5.318 Ω D. 5.31765775 Ω

****

Which one of the following measurements is stated correctly to two significant digits?

A. 0.006 m B. 0.06 m C. 600 m D. 620 m

****

An object has an acceleration of 2.0 m s^{-2}. Which of the following gives the change in the speed of the object after 7.00 s to the correct number of significant digits?

A. 14 m s^{-1} B. 14.0 m s^{-1} C. 14.00 m s^{-1} D. 14.000 m s^{-1}

****

The mass of a body is measured to be 0.600 kg and its acceleration to be 3 m s^{-2}. The net force on the body, expressed to the correct number of significant figures is

A. 1.8 N. B. 1.80 N. C. 2 N. D. 2.0 N.

****

The density in g cm^{-3} of a sphere with a radius of 3 cm and a mass of 0.54 kg is:

A. 5.00 g cm^{-3} B. 4.77 g cm^{-3} C. 5.0 g cm^{-3} D. 5 g cm^{-3}

A: 4.77 = 5 => 1 sf

****

A student measures the current in a resistor as 655 mA for a potential difference of 2.0 V. A calculator shows the resistance of the resistor to be 1.310 Ω. Which one of the following gives the resistance to an appropriate number of significant figures?

A. 1.3 Ω B. 1.31 Ω C. 1.310 Ω D. 1 Ω

****

If a = 20 ± 0.5 m and b = 5 ± 1 m, then 2a – b should be stated as:

A. 35 ± 1.5 m B. 35 ± 2 m C. 35 ± 0.0 m D. 5 ± 2 m

****

An object falls for a time of 0.25 s. The acceleration of free fall is 9.81 m s^{-2}. The displacement is calculated. Which of the following gives the correct number of significant digits for the calculated value of the displacement of the object?

A. 1 B. 2 C. 3 D.4

****

The universe is considered to have begun with the "Big Bang". The galaxies that have moved the farthest are those with the greatest initial speeds. It is believed that these speeds have been constant in time. If a galaxy 3×10^{21} km away is receding from us at 1.5×10^{11} km y^{-1}, calculate the age of the universe in years.

A: T =d/v = $2*10^{10}$ y (1 sf)

****

How many significant figures are indicated by each of the following:

a) 1247 4 b) 1007 4 c) 0.034 2 d) 1.20×10^7 3 e) 62.0 3 f) 0.0025 2

g) 0.00250 3 h) 3.2×10^{-16} 2 i) 0.0300 3 j) 1.0×10^1 2

****

Calculate the area of a square with a side of 3.2 m. A: 10.24 = 10 (2 sf)

****

Add the following lengths of 2.35 cm, 7.62 m and 14.2 m. A: 24.17 = 24.2 (3 sf)

****

Calculate the volume of a rectangular block 1.52 cm by 103.4 cm by 3.1 cm.

A: 487.2208 = 490 = $49*10^1$;

****

A metal block has a mass of 2.0 g and a volume of 0.01 cm^3. Calculate the density of the metal in g cm^{-3}.

A: $200 = 2.0*10^2$;

****

Round of the following to three significant figures:

	(a) 7.1249	(b) 2561	(c) 2001	(d) 21256	(e) 6.5647
A:	7.12	2560	$2.00*10^3$;	$213*10^2$;	6.56

****

Which of the following is the best estimate, to two significant digits, of the quantity: $\dfrac{\pi \times 8.1}{\sqrt{(15.9)}}$

A. 6.00 B. 6 C. 5.0 **<u>D</u>**. 6.0

****

When a voltage V of 12.2 V is applied to a DC motor, the current I in the motor is 0.20 A. Which **one** of the following is the output power VI of the motor given to the correct appropriate number of significant digits?

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****

Which **one** of the following measurements is stated correctly to two significant digits?

A. 0.006 m B. 0.06 m C. 600 m **<u>D. 620 m</u>**

****

An object has an acceleration of 2.0 m s^{-2}. Which of the following gives the change in the speed of the object after 7.00 s to the correct number of significant digits?

<u>A. 14 m s^{-1}</u> B. 14.0 m s^{-1} C. 14.00 m s^{-1} D. 14.000 m s^{-1}

****

The mass of a body is measured to be 0.600 kg and its acceleration to be 3 m s^{-2}. The net force on the body, expressed to the correct number of significant figures is

A. 1.8 N. B. 1.80 N. **<u>C. 2 N.</u>** D. 2.0 N.

****

The density in g cm^{-3} of a sphere with a radius of 3 cm and a mass of 0.54 kg is:

A. 5.00 g cm^{-3} B. 4.77 g cm^{-3} C. 5.0 g cm^{-3} **<u>D</u>**. 5 g cm^{-3}

<u>A: 4.77 = 5 => 1 sf</u>

****

A student measures the current in a resistor as 655 mA for a potential difference of 2.0 V. A calculator shows the resistance of the resistor to be 1.310 Ω. Which one of the following gives the resistance to an appropriate number of significant figures?

A. 1.3 Ω B. 1.31 Ω C. 1.310 Ω D. 1 Ω

****

If a = 20 ± 0.5 m and b = 5 ± 1 m, then 2a – b should be stated as:

A. 35 ± 1.5 m **B**. 35 ± 2 m C. 35 ± 0.0 m D. 5 ± 2 m

****

An object falls for a time of 0.25 s. The acceleration of free fall is 9.81 m s^{-2}. The displacement is calculated. Which of the following gives the correct number of significant digits for the calculated value of the displacement of the object?

A. 1 **B**. 2 C. 3 D.4

****

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A: T =d/v = $2*10^{10}$ y (1 sf)

****

How many significant figures are indicated by each of the following:

a) 1247 **4** b) 1007 **4** c) 0.034 **2** d) 1.20×10^7 **3** e) 62.0 **3** f) 0.0025 **2**

g) 0.00250 **3** h) 3.2×10^{-16} **2** i) 0.0300 **3** j) 1.0×10^1 **2**

****

Calculate the area of a square with a side of 3.2 m. **A: 10.24 = 10 (2 sf)**

****

Add the following lengths of 2.35 cm, 7.62 m and 14.2 m. **A: 24.17 = 24.2 (3 sf)**

****

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****

A metal block has a mass of 2.0 g and a volume of 0.01 cm^3. Calculate the density of the metal in g cm^{-3}.

<u>A: 200 = $2.0*10^2$;</u>

****

Round of the following to three significant figures:

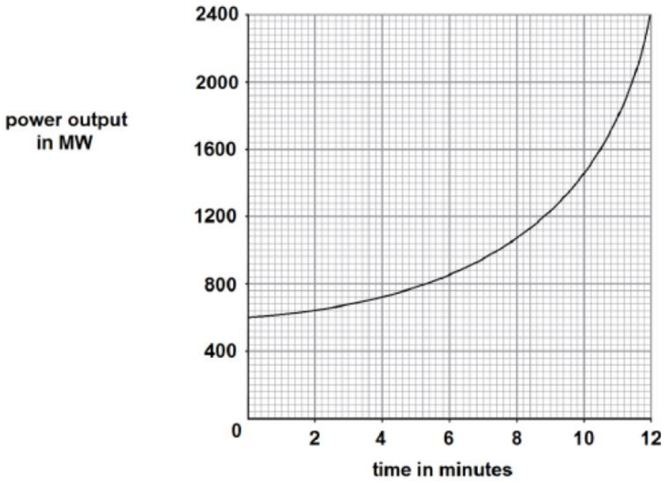
(a) 7.1249 (b) 2561 (c) 2001 (d) 21256 (e) 6.5647

<u>A: 7.12 2560 $2.00*10^3$; $213*10^2$; 6.56</u>

****

Graphical Interpretation Questions

1. Calculate the rate of increase of power output at 10 minutes.



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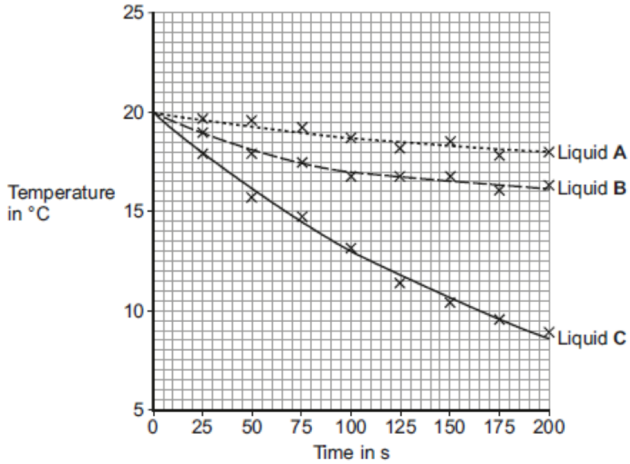
2. Calculate the average rate of temperature decrease of liquid **C** between 0 and 100 seconds.



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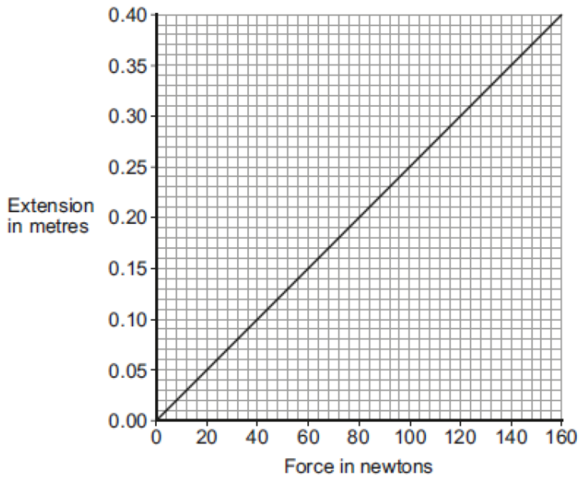
3. The graph shows how the extension of a single spring from the chest expander depends on the force acting on the spring. Use data from the graph to calculate the spring constant of the spring. Give the unit.



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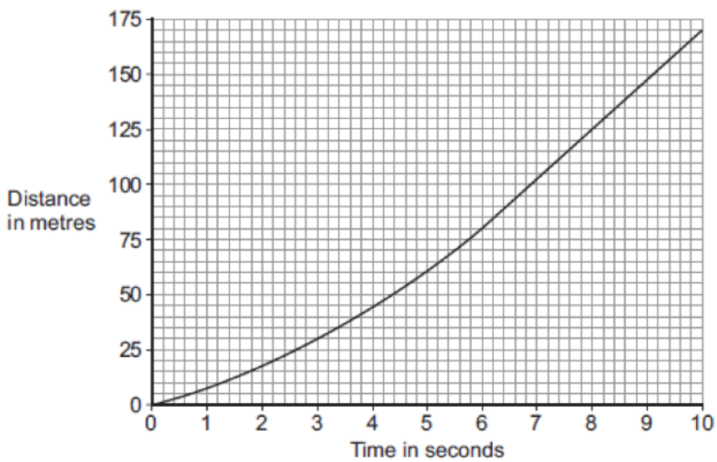
4. The graph shows the distance–time graph for a car. Use the graph to calculate the maximum speed the car was travelling at.



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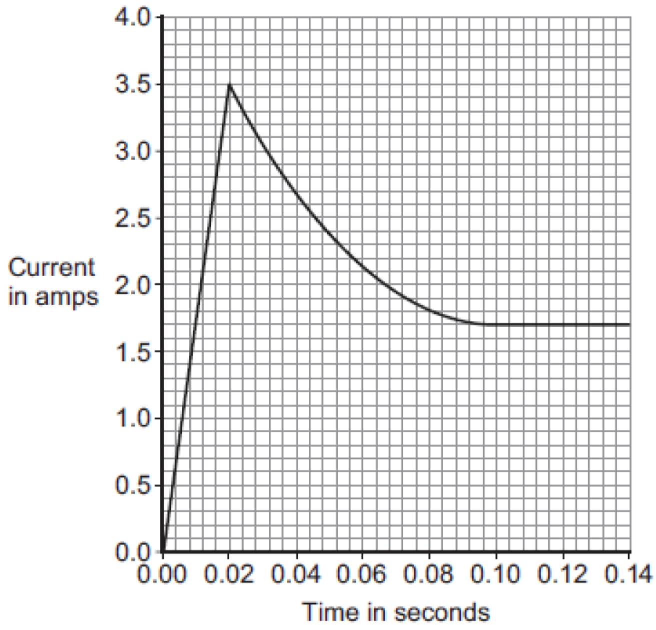
5. A 12 V filament bulb is connected to a 12 V power supply. The graph shows how the current changes after the bulb is switched on.



a) Calculate the rate at which the current increases in the first 0.02s

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b) Calculate the maximum power of the bulb.

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c) Calculate the resistance of the bulb after 0.1s

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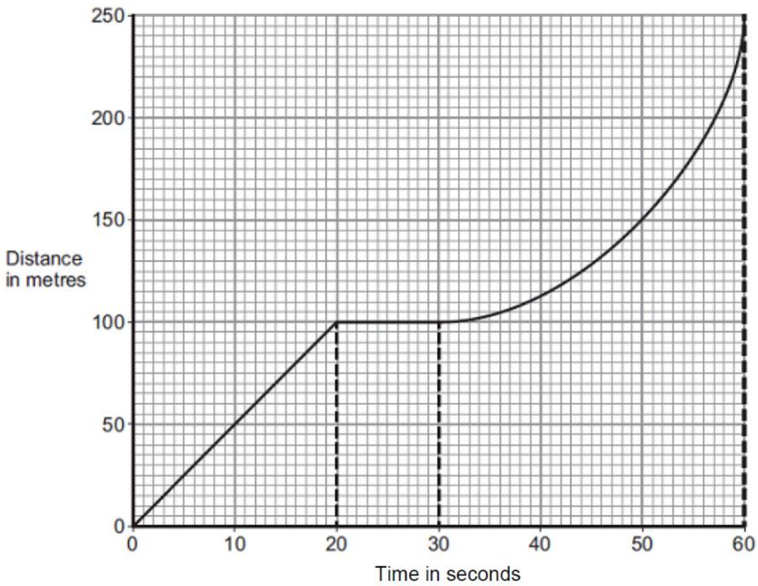
6. A bus is taking some children to school. The bus has to stop a few times. The distance–time graph for part of the journey is shown to the right.



How far has the bus travelled in the first 20 seconds?

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Describe the motion of the bus between 20 seconds and 30 seconds.

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Describe the motion of the bus between 30 seconds and 60 seconds.

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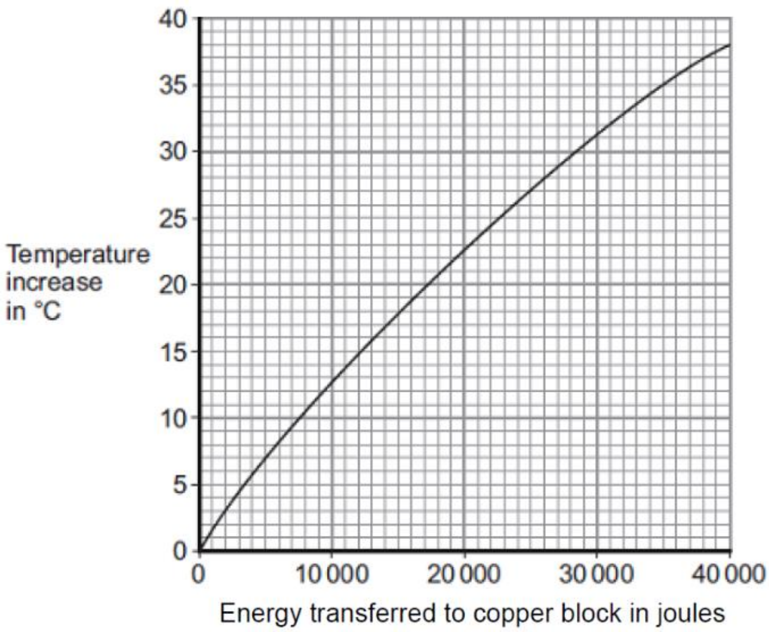
7. The graph shows a 2.0 kg copper block being heated. Use the data in the graph to calculate the specific heat capacity of copper.



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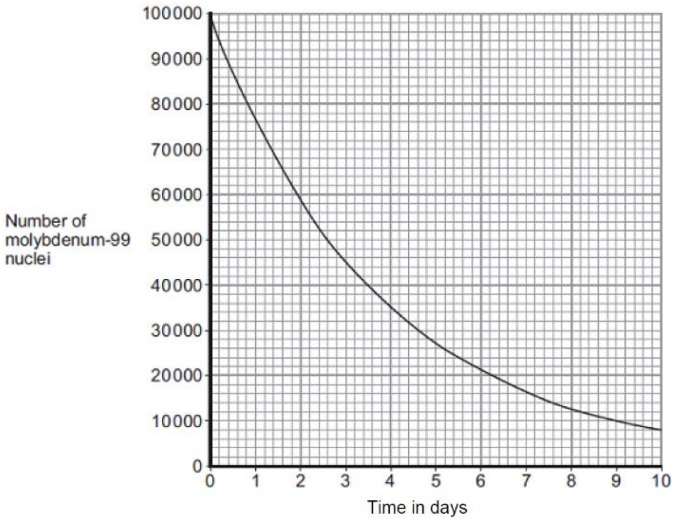
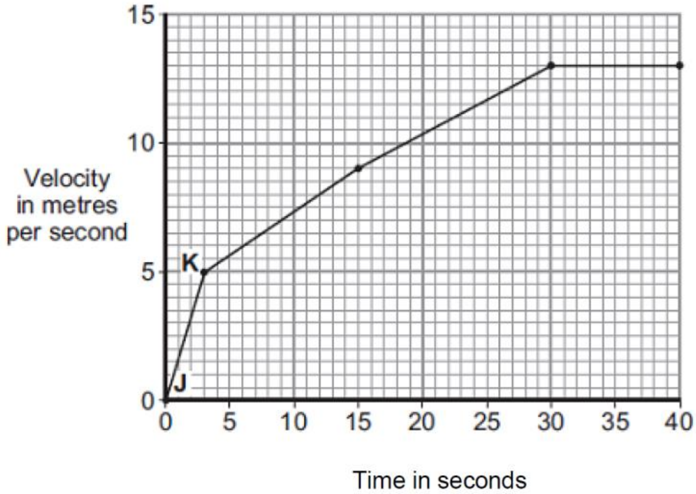
8. The figure below shows how the number of nuclei in a sample of molybdenum-99 changes with time as the nuclei decay.

Calculate the time for 80% of the Mo-99 nuclei in a sample to decay.



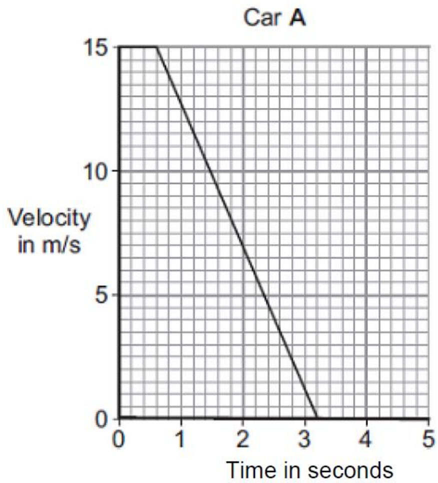
9. The graph shows how the velocity of a go-kart changes during the first 40 seconds of a race. Use the graph to calculate the acceleration of the go-kart between points J and K.

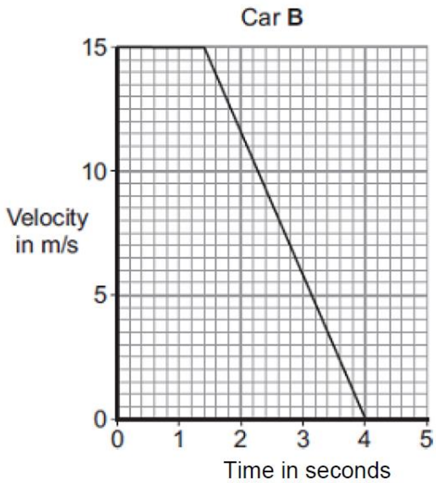
Use the graph to calculate the distance the go-kart travels between points J and K.



10. The graphs show how the velocity of two cars, A and B, change from the moment the car drivers see an obstacle blocking the road. One of the car drivers has been drinking alcohol. The other driver is wide awake and alert.

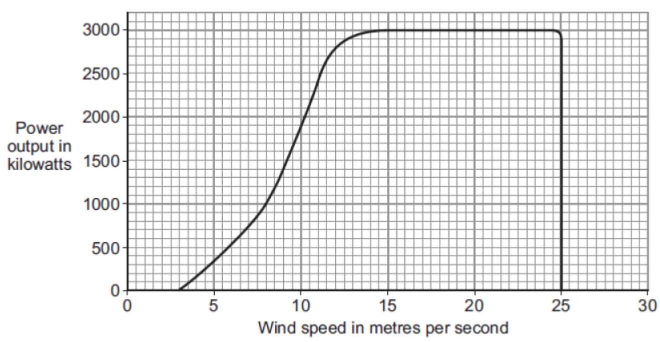
Calculate the acceleration during breaking.



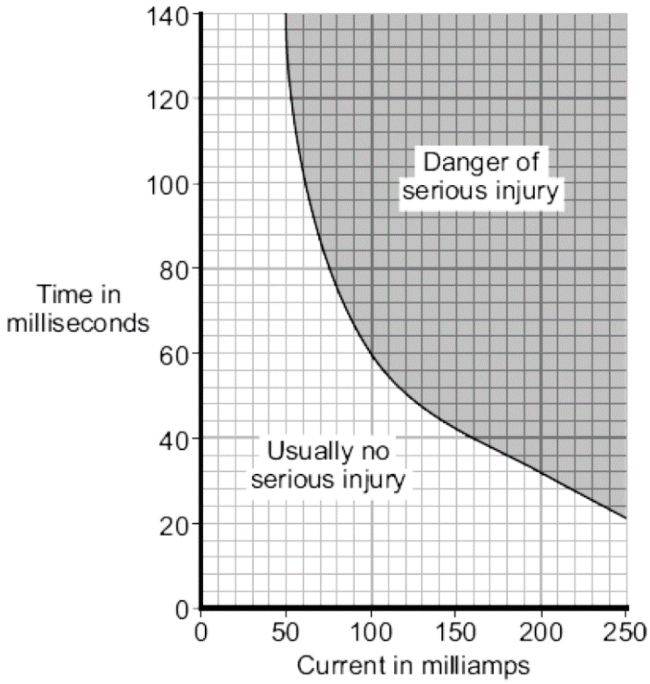


Use the graphs to calculate how much further car B travels before stopping compared to car A.

11. The graph shows how wind speed affects the power output from a wind turbine. In one 4-hour period, the wind turbine transfers 5600 kilowatt-hours of electrical energy. Use the data in the graph to calculate the average wind speed during this 4-hour period.



12. The graph shows how the severity of an electric shock depends on the size of the current and the time that the current flows through the body. Describe the data shown in the graph. Use the relationship Q = It



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13. A driver is driving along a road at 30 m/s. The driver suddenly sees a large truck parked across the road and reacts to the situation by applying the brakes so that a constant braking force stops the car. The reaction time of the driver is 0.67 seconds, it then takes another 5 seconds for the brakes to bring the car to rest.

Using the data above, draw a speed-time graph to show the speed of the car from the instant the truck was seen by the driver until the car stopped.

Calculate the acceleration of the car whilst the brakes are applied.

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Calculate the stopping distance.

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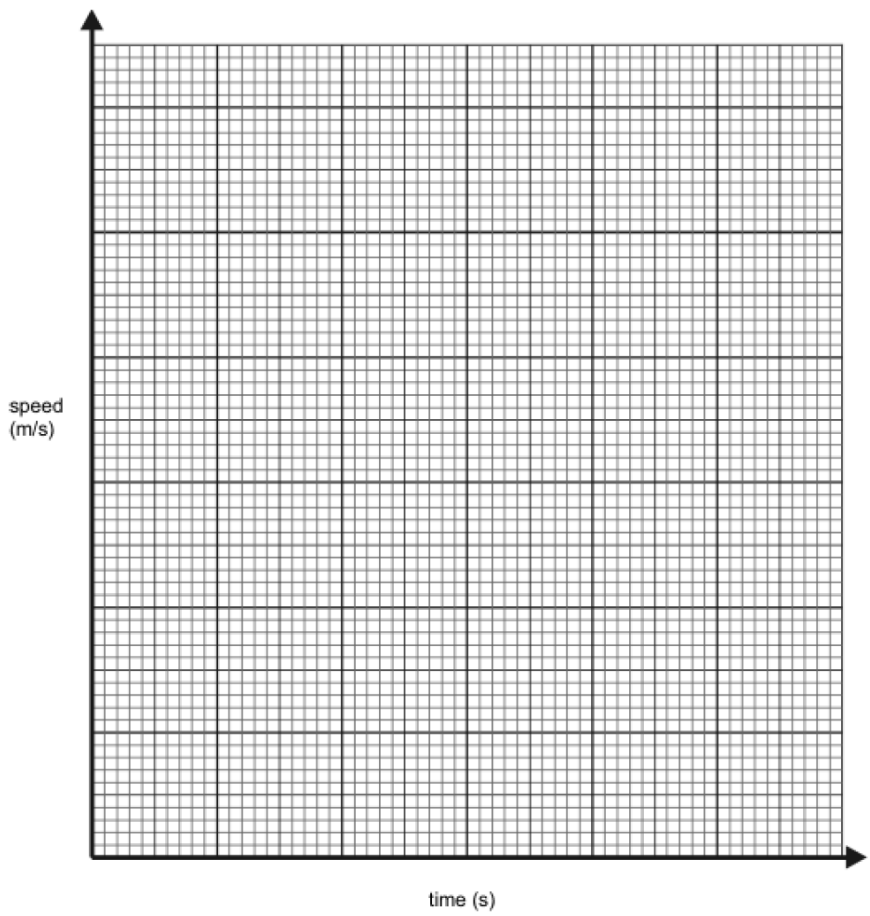
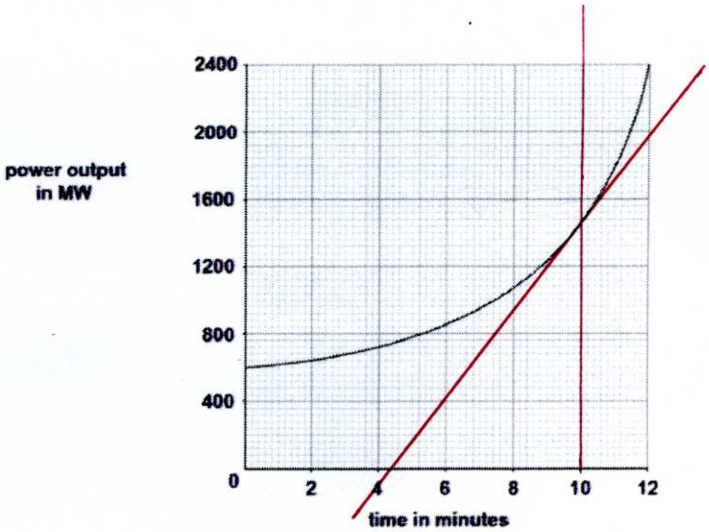


Graphical Interpretation Questions

1. Calculate the rate of increase of power output at 10 minutes.



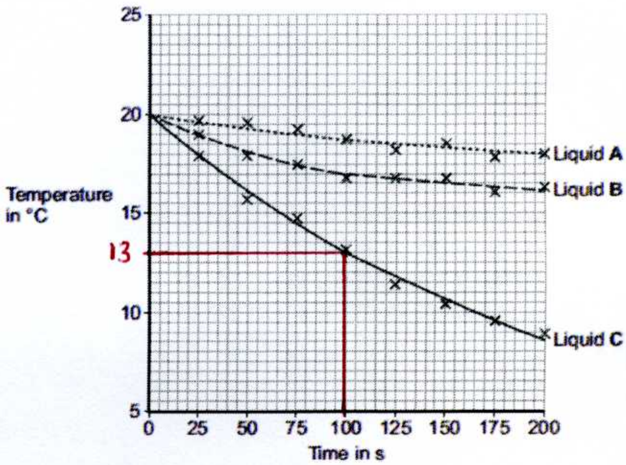
Gradient at 10 min

= 2000/12 − 4.4 = 2000/7.6

= 263 MW/min

(240 − 276 accepted)

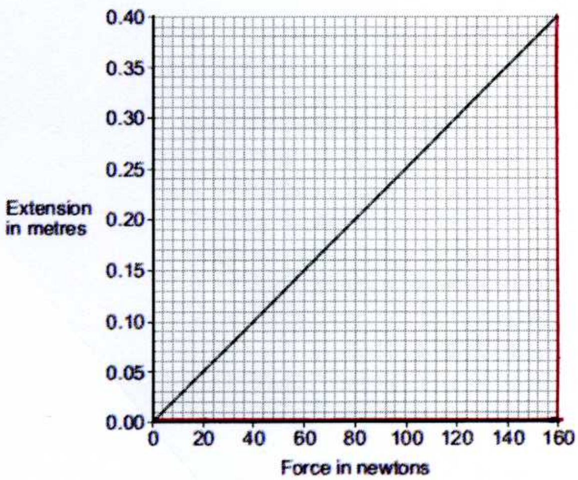
2. Calculate the average rate of temperature decrease of liquid **C** between 0 and 100 seconds.



Temp drop = 20 − 13 = 7°C

Rate = 7/100 = 0.07 °C/s

3. The graph shows how the extension of a single spring from the chest expander depends on the force acting on the spring. Use data from the graph to calculate the spring constant of the spring. Give the unit.

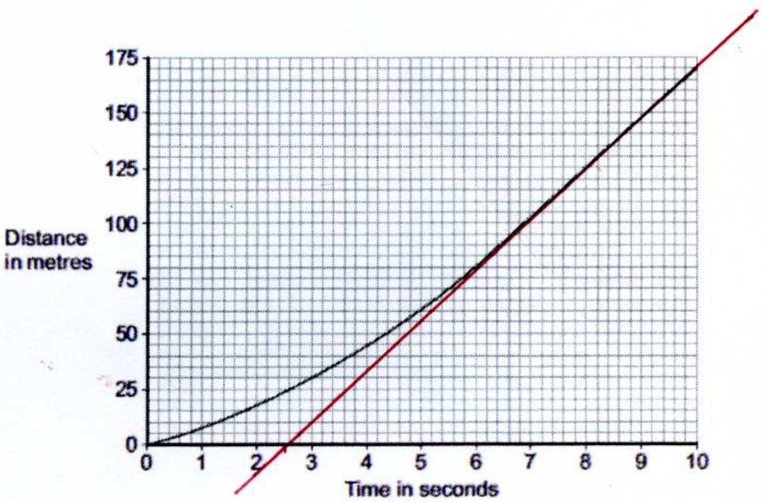


F = ke ∴ k = F/e

= 160/0.4

= 400 N/m

4. The graph shows the distance–time graph for a car. Use the graph to calculate the maximum speed the car was travelling at.

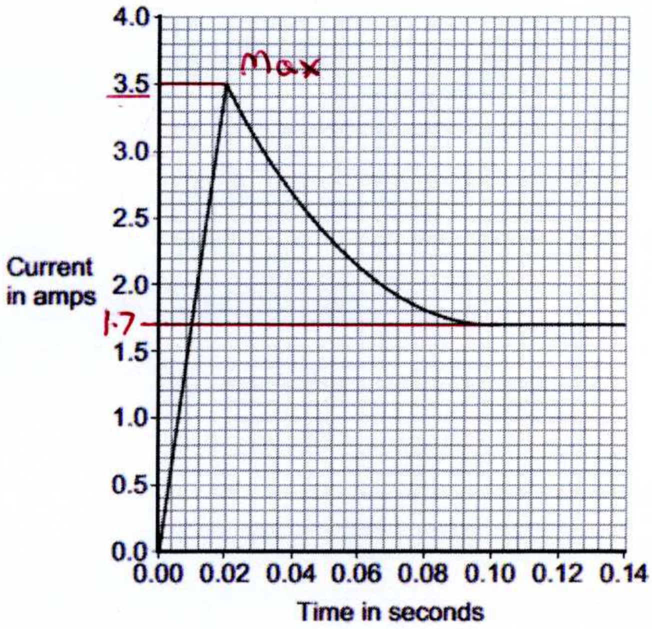


V = s/t = gradient

= 170/10 − 2.6

= 23.0 m/s

5. A 12 V filament bulb is connected to a 12 V power supply. The graph shows how the current changes after the bulb is switched on.



a) Calculate the rate at which the current increases in the first 0.02s → gradient

$3.5 / 0.02 = 175$ A/s

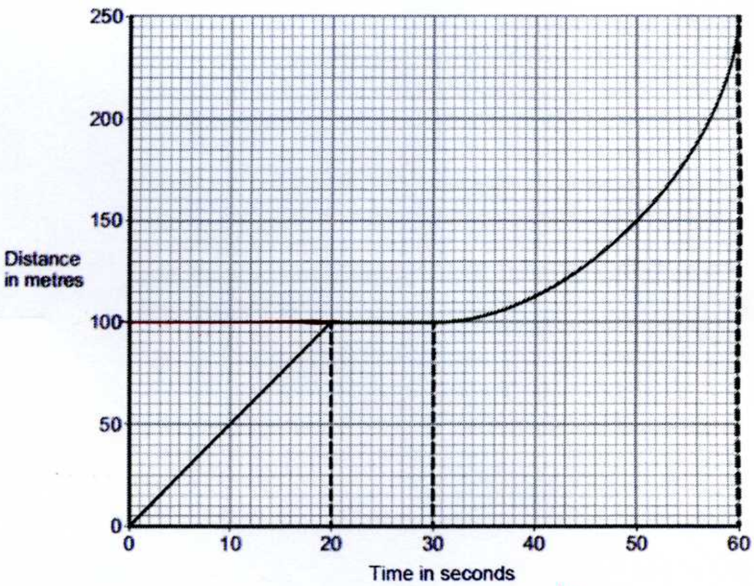
b) Calculate the maximum power of the bulb.

$P = IV = 3.5 \times 12 = 42$ W

c) Calculate the resistance of the bulb after 0.1s

$R = V/I = 12/1.7 = 7.1\ \Omega$

6. A bus is taking some children to school. The bus has to stop a few times. The distance–time graph for part of the journey is shown to the right.



How far has the bus travelled in the first 20 seconds?

100m

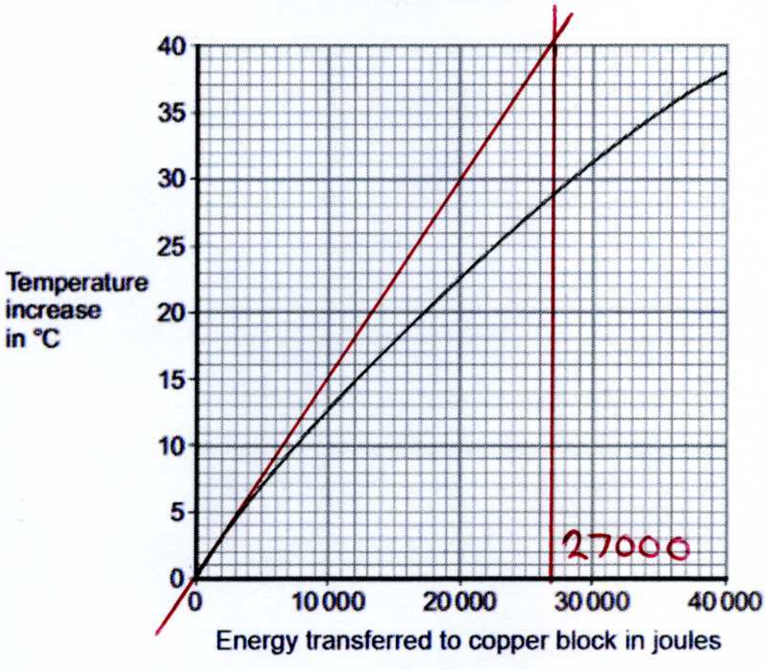
Describe the motion of the bus between 20 seconds and 30 seconds.

stationary

Describe the motion of the bus between 30 seconds and 60 seconds.

accelerating

7. The graph shows a 2.0 kg copper block being heated. Use the data in the graph to calculate the specific heat capacity of copper.

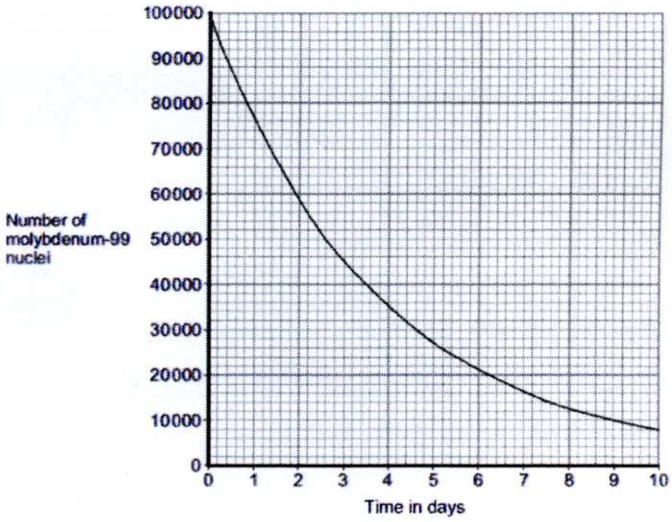


Use gradient at 0°C as no heat loss. $\Delta E = mc\Delta\theta$

$c = \Delta E / m\Delta\theta = 27000 / 2 \times 40$

$= 338$ J/kg°C

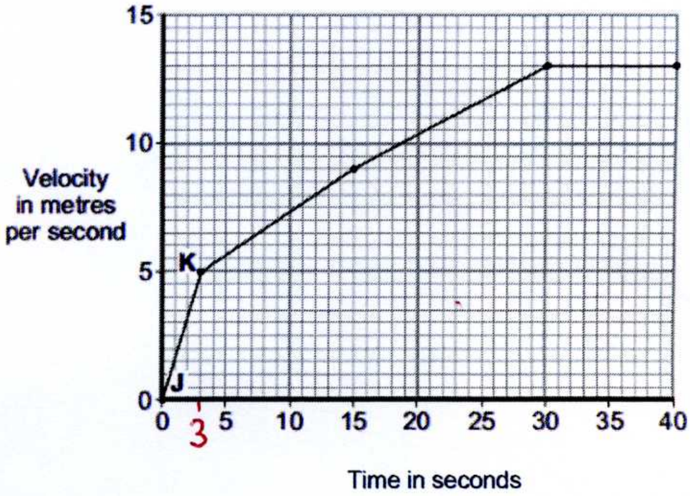
8. The figure below shows how the number of nuclei in a sample of molybdenum-99 changes with time as the nuclei decay.



Calculate the time for 80% of the Mo-99 nuclei in a sample to decay. so 20000 remain

6·2 days

9. The graph shows how the velocity of a go-kart changes during the first 40 seconds of a race. Use the graph to calculate the acceleration of the go-kart between points J and K.



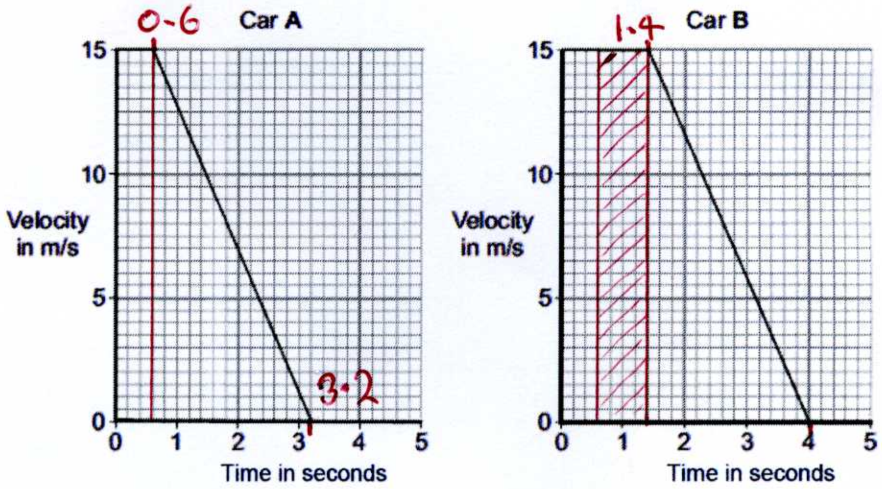
$a = \Delta v / \Delta t = 5/3 = 1.67\ m/s^2$

Use the graph to calculate the distance the go-kart travels between points J and K.

Average speed = $5/2 = 2.5\ m/s$

$s = vt = 2.5 \times 3 = 7.5\ m$

10. The graphs show how the velocity of two cars, A and B, change from the moment the car drivers see an obstacle blocking the road. One of the car drivers has been drinking alcohol. The other driver is wide awake and alert.



Calculate the acceleration during breaking.

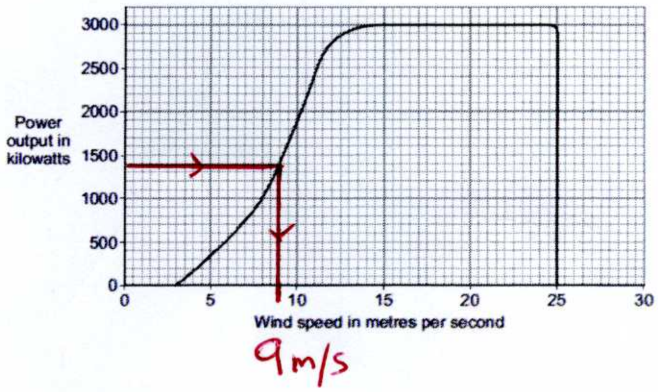
$a = \Delta v / \Delta t = \dfrac{15}{3.2 - 0.6}$

$= 5.77\ m/s^2$

Use the graphs to calculate how much further car B travels before stopping compared to car A.

Extra distance = $(1.4 - 0.6) \times 15 = 12\ m$

11. The graph shows how wind speed affects the power output from a wind turbine. In one 4-hour period, the wind turbine transfers 5600 kilowatt-hours of electrical energy. Use the data in the graph to calculate the average wind speed during this 4-hour period.

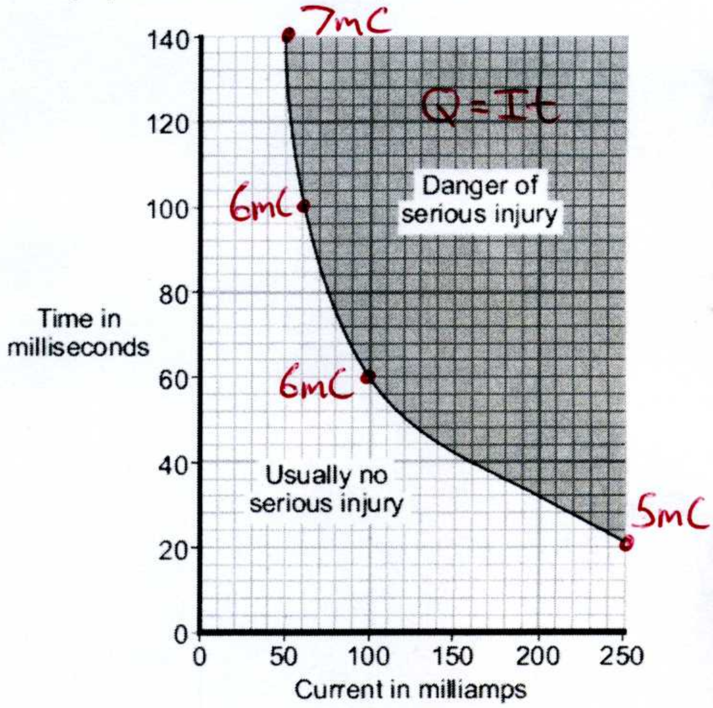


$5600/4 = 1400\ kW$

$\rightarrow$ 9 m/s

12. The graph shows how the severity of an electric shock depends on the size of the current and the time that the current flows through the body. Describe the data shown in the graph. Use the relationship Q = It

For currents below 50mA there is no danger. and above 250mA there is danger within 20ms. The bigger the current and the time it lasts the higher the danger. For charge transfers below around 5mC there is usually no serious injury



13. A driver is driving along a road at 30 m/s. The driver suddenly sees a large truck parked across the road and reacts to the situation by applying the brakes so that a constant braking force stops the car. The reaction time of the driver is 0.67 seconds, it then takes another 5 seconds for the brakes to bring the car to rest.

Using the data above, draw a speed-time graph to show the speed of the car from the instant the truck was seen by the driver until the car stopped.

Calculate the acceleration of the car whilst the brakes are applied.

$a = \Delta v / \Delta t = 30/5$

$= 6 m/s^2$

Calculate the stopping distance.

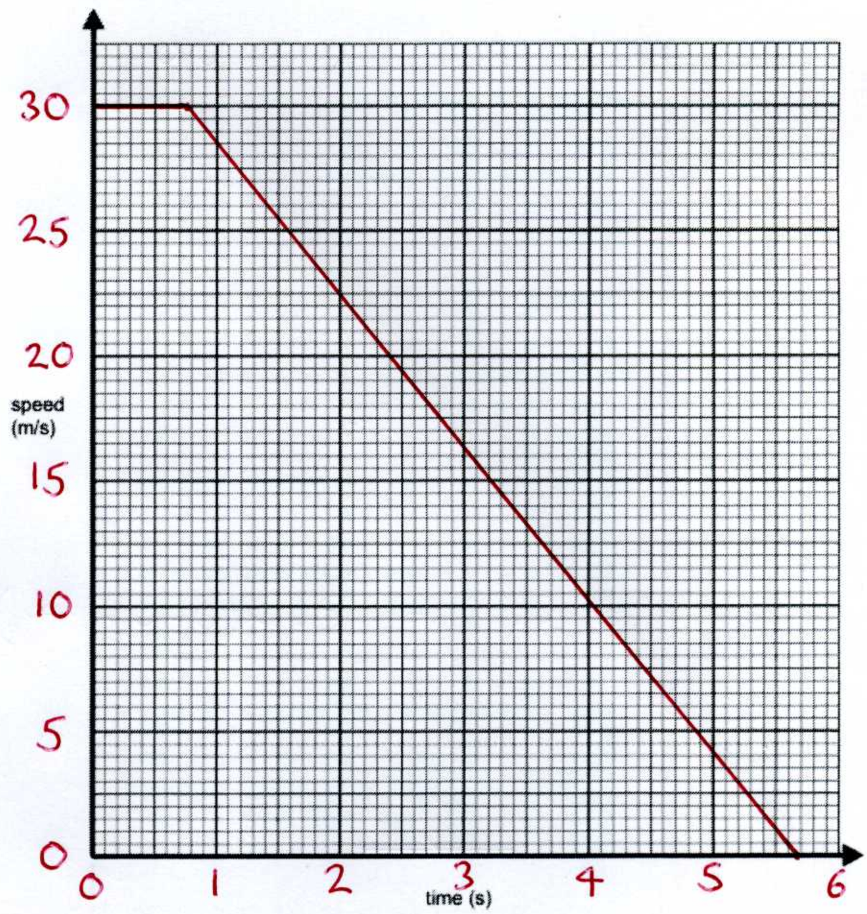
Thinking dist = 30×0.67

= 20.1m

Breaking dist = 0.5×30×5

= 75m

Stopping dist = 95.1m



Subject specific vocabulary (Science)

The following subject specific vocabulary provides definitions of key terms used in our GCSE Science specifications.

Wherever possible we have used the definitions derived from a booklet created in a joint project of the Association for Science Education and the Nuffield Foundation, *The Language of Measurement: Terminology used in school science investigation*, ISBN 978 0 86357 424 5, Association for Science Education (ASE), 2010.

Accuracy

A measurement result is considered accurate if it is judged to be close to the true value.

Calibration

Marking a scale on a measuring instrument. This involves establishing the relationship between indications of a measuring instrument and standard or reference quantity values, which must be applied. For example, placing a thermometer in melting ice to see whether it reads zero, in order to check if it has been calibrated correctly.

Data

Information, either qualitative or quantitative, that has been collected.

Error

See also uncertainty.

Measurement error

The difference between a measured value and the true value.

Anomalies

These are values in a set of results which are judged not to be part of the variation caused by random uncertainty.

Random error

These cause readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next. Random errors are present when any measurement is made, and cannot be corrected. The effect of random errors can be reduced by making more measurements and calculating a new mean.

Systematic error

These cause readings to differ from the true value by a consistent amount each time a measurement is made. Sources of systematic error can include the environment, methods of observation or instruments used. Systematic errors cannot be dealt with by simple repeats. If a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.

Zero error
Any indication that a measuring system gives a false reading when the true value of a measured quantity is zero, eg the needle on an ammeter failing to return to zero when no current flows. A zero error may result in a systematic uncertainty.

Evidence
Data which has been shown to be valid.

Fair test
A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

Hypothesis
A proposal intended to explain certain facts or observations.

Interval
The quantity between readings, eg a set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres.

Precision
Precise measurements are ones in which there is very little spread about the mean value. Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value.

Prediction
A prediction is a statement suggesting what will happen in the future, based on observation, experience or a hypothesis.

Range
The maximum and minimum values of the independent or dependent variables; important in ensuring that any pattern is detected. For example a range of distances may be quoted as either: 'From 10 cm to 50 cm' or 'From 50 cm to 10 cm'.

Repeatable
A measurement is repeatable if the original experimenter repeats the investigation using same method and equipment and obtains the same results. Previously known as reliable.

Reproducible
A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained. Previously known as reliable.

Resolution
This is the smallest change in the quantity being measured (input) of a measuring instrument that gives a perceptible change in the reading.

Sketch graph
A line graph, not necessarily on a grid, that shows the general shape of the relationship between two variables. It will not have any points plotted and although the axes should be labelled they may not be scaled.

True value
This is the value that would be obtained in an ideal measurement.

Uncertainty
The interval within which the true value can be expected to lie, with a given level of confidence or probability, eg 'the temperature is 20 °C ± 2 °C, at a level of confidence of 95%'.

Validity
Suitability of the investigative procedure to answer the question being asked. For example, an investigation to find out if the rate of a chemical reaction depended upon the concentration of one of the reactants would not be a valid procedure if the temperature of the reactants was not controlled.

Valid conclusion
A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.

Variables
These are physical, chemical or biological quantities or characteristics.

Categoric
Categoric variables have values that are labels, eg names of plants or types of material.

Continuous
Continuous variables can have values (called a quantity) that can be given a magnitude either by counting (as in the case of the number of shrimp) or by measurement (eg light intensity, flow rate etc). Previously known as discrete variable.

Control
Control variable is one which may, in addition to the independent variable, affect the outcome of the investigation and therefore has to be kept constant or at least monitored.

Dependent
Dependent variable is the variable of which the value is measured for each and every change in the independent variable.

Independent
Independent variable is the variable for which values are changed or selected by the investigator.

2

2b. Content of A Level in Physics A (H556)

The A Level in Physics A specification content is divided into six 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. The assessable content is divided into two columns: **Learning outcomes** and **Additional guidance**.

The Learning outcomes may all be assessed in the examinations (with the exception of some of the skills in module **1.2** which will be assessed directly through the Practical Endorsement). The Additional guidance column is included to provide further advice on delivery and the expected skills required from learners.

References to HSW (Section 5e) are included in the guidance to highlight opportunities to encourage a wider understanding of science.

The mathematical requirements in Section 5f are also referenced by the prefix *M* to link the mathematical skills required for A Level Physics to examples of the physics content where those mathematical skills could be linked to learning.

The specification has been designed to be co-teachable with the standalone AS Level in Physics A qualification. The first four modules comprise the AS in Physics A course and learners studying the A level continue with the content of modules 5 and 6 in year 13.

The Data, Formulae and Relationships booklet in Section 5d will be available in examinations and learners are expected to become familiar with this booklet throughout the course.

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

Module 1 – Development of practical skills in physics

1.1 Practical skills assessed in a written examination
1.2 Practical skills assessed in the practical endorsement

Module 2 – Foundations of physics

2.1 Physical quantities and units
2.2 Making measurements and analysing data
2.3 Nature of quantities

Module 3 – Forces and motion

3.1 Motion
3.2 Forces in action
3.3 Work, energy and power
3.4 Materials
3.5 Momentum

Module 4 – Electrons, waves and photons

4.1 Charge and current
4.2 Energy, power and resistance
4.3 Electrical circuits
4.4 Waves
4.5 Quantum physics

Module 5 – Newtonian world and astrophysics

5.1 Thermal physics
5.2 Circular motion
5.3 Oscillations
5.4 Gravitational fields
5.5 Astrophysics and cosmology

Module 6 – Particles and medical physics

6.1 Capacitors
6.2 Electric fields
6.3 Electromagnetism
6.4 Nuclear and particle physics
6.5 Medical imaging

The full A level Physics A specification (first assessment in 2017) is available here:

http://www.ocr.org.uk/Images/171726-specification-accredited-a-level-gce-physics-a-h556.pdf

2 The specification overview

2a. Overview of A Level in Physics A (H556)

Learners must complete all components (01, 02, 03 and 04).

Content Overview	Assessment Overview	
Content is split into six teaching modules: • Module 1 – Development of practical skills in physics • Module 2 – Foundations of physics • Module 3 – Forces and motion • Module 4 – Electrons, waves and photons • Module 5 – Newtonian world and astrophysics • Module 6 – Particles and medical physics Component 01 assesses content from modules 1, 2, 3 and 5. Component 02 assesses content from modules 1, 2, 4 and 6. Component 03 assesses content from all modules (1 to 6).	Modelling physics (01) 100 marks 2 hours 15 minutes written paper	**37%** of total A level
	Exploring physics (02) 100 marks 2 hours 15 minutes written paper	**37%** of total A level
	Unified physics (03) 70 marks 1 hour 30 minutes written paper	**26%** of total A level
	Practical endorsement in physics (04)* (non exam assessment)	Reported separately (see Section 5h)

* Details to be confirmed by Ofqual.
All components include synoptic assessment.

5d. Physics A data sheet

Data, Formulae and Relationships

The data, formulae and relationships in this data sheet will be printed for distribution with the examination papers.

Data

Values are given to three significant figures, except where more – or fewer – are useful.

Physical constants

acceleration of free fall	g	$9.81\ \text{m s}^{-2}$
elementary charge	e	$1.60 \times 10^{-19}\ \text{C}$
speed of light in a vacuum	c	$3.00 \times 10^{8}\ \text{m s}^{-1}$
Planck constant	h	$6.63 \times 10^{-34}\ \text{J s}$
Avogadro constant	N_A	$6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	R	$8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
Boltzmann constant	k	$1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	G	$6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
permittivity of free space	ε_0	$8.85 \times 10^{-12}\ \text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}\ (\text{F m}^{-1})$
electron rest mass	m_e	$9.11 \times 10^{-31}\ \text{kg}$
proton rest mass	m_p	$1.673 \times 10^{-27}\ \text{kg}$
neutron rest mass	m_n	$1.675 \times 10^{-27}\ \text{kg}$
alpha particle rest mass	m_α	$6.646 \times 10^{-27}\ \text{kg}$
Stefan constant	σ	$5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

Quarks

up quark	charge = $+\frac{2}{3}e$
down quark	charge = $-\frac{1}{3}e$
strange quark	charge = $-\frac{1}{3}e$

Conversion factors

unified atomic mass unit	1 u = 1.661×10^{-27} kg
electronvolt	1 eV = 1.60×10^{-19} J
day	1 day = 8.64×10^{4} s
year	1 year $\approx 3.16 \times 10^{7}$ s
light year	1 light year $\approx 9.5 \times 10^{15}$ m
parsec	1 parsec $\approx 3.1 \times 10^{16}$ m

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

surface area of sphere = $4\pi r^2$

area of trapezium = $\frac{1}{2}(a+b)h$

volume of cylinder = $\pi r^2 h$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

cosine rule: $a^2 = b^2 + c^2 - 2bc\cos A$

sine rule: $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$

$\sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$ for small angles

$\log(AB) = \log(A) + \log(B)$ (Note: $\lg = \log_{10}$ and $\ln = \log_e$)

$\log\left(\frac{A}{B}\right) = \log(A) - \log(B)$

$\log(x^n) = n\log(x)$

$\ln(e^{kx}) = kx$

Formulae and relationships

Module 2 – Foundations of physics	
vectors	$F_x = F\cos\theta$
	$F_y = F\sin\theta$

Module 3 – Forces and motion	
uniformly accelerated motion	$v = u + at$
	$s = \frac{1}{2}(u+v)t$
	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
force	$F = \frac{\Delta p}{\Delta t}$
	$p = mv$
turning effects	$moment = Fx$
	$torque = Fd$
density	$p = \frac{m}{V}$
pressure	$p = \frac{F}{A}$
	$p = h\rho g$
work, energy and power	$W = Fx\cos\theta$
	$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$
	$P = \frac{W}{t}$
	$P = Fv$
springs and materials	$F = kx$
	$E = \frac{1}{2}Fx;\ E = \frac{1}{2}kx^2$
	$\sigma = \frac{F}{A}$
	$\varepsilon = \frac{x}{L}$
	$E = \frac{\sigma}{\varepsilon}$

Module 4 – Electrons, waves and photons	
charge	$\Delta Q = I\Delta t$
current	$I = Anev$
work done	$W = VQ$; $W = \mathcal{E}Q$; $W = VIt$
resistance and resistors	$R = \frac{\rho L}{A}$ $R = R_1 + R_2 + \ldots$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
power	$P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$
internal resistance	$\mathcal{E} = I(R + r)$; $\mathcal{E} = V + Ir$
potential divider	$V_{out} = \frac{R}{R_1 + R_2} \times V_{in}$ $\frac{V_1}{V_2} = \frac{R_1}{R_2}$
waves	$v = f\lambda$ $f = \frac{1}{T}$ $I = \frac{P}{A}$ $\lambda = \frac{ax}{D}$
refraction	$n = \frac{c}{v}$ $n \sin\theta = \text{constant}$ $\sin C = \frac{1}{n}$
quantum physics	$E = hf \quad E = \frac{hc}{\lambda}$ $hf = \phi + KE_{max}$ $\lambda = \frac{h}{p}$

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Module 5 – Newtonian world and astrophysics	
thermal physics	$E = mc\Delta\theta$ $E = mL$
ideal gases	$pV = NkT$; $pV = nRT$ $pV = \frac{1}{3}Nm\overline{c^2}$ $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ $E = \frac{3}{2}kT$
circular motion	$\omega = \frac{2\pi}{T}$; $\omega = 2\pi f$ $v = \omega r$ $a = \frac{v^2}{r}$; $a = \omega^2 r$ $F = \frac{mv^2}{r}$; $F = m\omega^2 r$
oscillations	$\omega = \frac{2\pi}{T}$; $\omega = 2\pi f$ $a = -\omega^2 x$ $x = A\cos\omega t$; $x = A\sin\omega t$ $v = \pm\omega\sqrt{A^2 - x^2}$
gravitational field	$g = \frac{F}{m}$ $F = -\frac{GMm}{r^2}$ $g = -\frac{GM}{r^2}$ $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$ $V_g = -\frac{GM}{r}$ energy $= -\frac{GMm}{r}$
astrophysics	$hf = \Delta E$; $\frac{hc}{\lambda} = \Delta E$ $d\sin\theta = n\lambda$ $\lambda_{max} \propto \frac{1}{T}$ $L = 4\pi r^2 \sigma T^4$

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cosmology

$$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$$
$$p = \frac{1}{d}$$
$$v = H_0 d$$
$$t = H_0^{-1}$$

Module 6 - Particles and medical physics

capacitance and capacitors

$$C = \frac{Q}{V}$$
$$C = \frac{\varepsilon_0 A}{d}$$
$$C = 4\pi\varepsilon_0 R$$
$$C = C_1 + C_2 + \ldots$$
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots.$$
$$W = \tfrac{1}{2}QV; \; W = \tfrac{1}{2}\frac{Q^2}{C}; \;\; W = \tfrac{1}{2}V^2 C$$
$$\tau = CR$$
$$x = x_0 e^{-\frac{t}{CR}}$$
$$x = x_0(1 - e^{-\frac{t}{CR}})$$

electric field

$$E = \frac{F}{Q}$$
$$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$$
$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$
$$E = \frac{V}{d}$$
$$V = \frac{Q}{4\pi\varepsilon_0 r}$$
$$\text{energy} = \frac{Qq}{4\pi\varepsilon_0 r}$$

magnetic field

$$F = BIL\sin\theta$$
$$F = BQv$$

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electromagnetism	$\phi = BA\cos\theta$ $\varepsilon = -\frac{\Delta(N\phi)}{\Delta t}$ $\frac{n_s}{n_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$
radius of nucleus	$R = r_0 A^{\frac{1}{3}}$
radioactivity	$A = \lambda N$; $\frac{\Delta N}{\Delta t} = -\lambda N$ $\lambda t_{\frac{1}{2}} = \ln(2)$ $A = A_0 e^{-\lambda t}$ $N = N_0 e^{-\lambda t}$
Einstein's mass-energy equation	$\Delta E = \Delta mc^2$
attenuation of X-rays	$I = I_0 e^{-\mu x}$
ultrasound	$Z = \rho c$ $\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ $\frac{\Delta f}{f} = \frac{2v\cos\theta}{c}$

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Table 2 PAG activities provided by OCR

Activities in PAG7 to PAG12 will be confirmed by September 2015.

PAG1	PAG7
1.1 Comparing methods of determining g 1.2 Investigating terminal velocity 1.3 Investigating the effect of initial speed on stopping distance	7.1 Observing the random nature of radioactive decay 7.2 Investigate the absorption of alpha, beta & gamma by differing materials 7.3 Determine half-life (using an ionisation chamber)
PAG2	**PAG8**
2.1 Determining the Young Modulus for a metal 2.2 Force/extension characteristics for arrangements of springs 2.3 Investigating a property of plastic	8.1 Estimate a value for absolute zero from gas pressure and volume 8.2 Investigating the relationship between pressure and volume 8.3 Estimating the work done by a gas as its temperature increases
PAG3	**PAG9**
3.1 Determining the resistivity of a metal 3.2 Investigating electrical characteristics 3.3 Determining the internal resistance and maximum power available from a cell	9.1 Investigating the charging and discharging of capacitors 9.2 Investigating capacitors in series and parallel 9.3 Investigating the factors affecting the capacitance of a capacitor
PAG4	**PAG10**
4.1 Investigating resistance 4.2 Investigating circuits with more than one source of e.m.f. 4.3 Investigating potential divider circuits including a non-ohmic device	10.1 Investigate the factors affecting simple harmonic motion 10.2 Observing forced and damped oscillations 10.3 Comparison of static and dynamic methods of determining spring stiffness
PAG5	**PAG11**
5.1 Determining the wavelength of light with a diffraction grating 5.2 Determining the speed of sound in air using a resonance tube 5.3 Determining frequency and amplitude of a wave using an oscilloscope	11.1 Investigating transformers 11.2 Determining the specific heat capacity of a material 11.3 Determining the magnetic field of a magnet
PAG6	**PAG12**
6.1 Determining the Planck constant 6.2 Experiments with light 6.3 Experiments with polarisation	12.1 Materials presentation 12.2 Research report 12.3 An appreciation of an aspect of How Science Works