Physics

GCSE (9–1) | AQA | 8463

Targeting a Top Grade

in GCSE AQA Physics

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Contents

Teacher's Introduction

Remember!
Always check the exam board website for new information, including changes to the specification and sample assessment material.

The aim of this resource is to provide your students with revision materials, guidance and practice to help them secure a grade 8/9 in GCSE (9–1) AQA Physics.

As teachers, we always want our students to attain the highest grades possible. For many of your students entered for the Higher Tier paper, the challenge is to secure a grade 8/9. It is interesting as professionals to reflect that, on average, around 15% of candidates taking the Higher Tier paper will achieve grade 9, and around 18% will achieve grade 8. Data from AQA suggests that in both Paper 1 and Paper 2 candidates perform relatively poorly on questions associated with practical activities, and for Paper 2 extended responses can be an area where marks are often lost. As such, these resources focus additional attention on these areas and provide activities for your students to build their confidence in these key areas of assessment. Practice for answering questions based on practical work appears from Chapter 9 onwards.

Alongside general examination advice, reminders about good exam practice and an overview of the command words, the specification has been divided into 15 units. Each unit consists of the following:

- A student-focused introduction, setting out the key knowledge required to obtain a level 8/9
- Explanations, worked examples, challenges, tips and interesting facts – forming the main content of each unit.
- A set of tasks, questions and have-a-go ideas that help students to test their knowledge, understanding and application.
- Exam-style questions – a chance to practise.
- A set of final challenges to help students prepare for Year 1 of A Level.
- Answers to the exam-style questions.

All of these photocopiable sections are designed to be used either in class, during a tutorial, during one-to-one sessions or by the students working alone in self-study. They are equally valuable for students currently working at grades 6 and 7 and aiming for grade 8 or 9. Although the primary focus is on securing that 8/9, any Higher Tier student will find valuable support in these materials.

April 2022

Student Introduction

Securing a grade 8/9 in Physics is not just about knowing the right information, alt
about practice and focusing on the content that has in the past proved a barrier to

What is in the pack?

1. **Exam advice and guidance.** [Don't skip this bit; it will help with more than ju
   General advice on taking exams, some tips about sitting the exam and a few
   and how to use that in your revision planning.
2. **Command words section.** Every exam question uses command words to info
   expected of them for that question. Read this section to gain a better unders
   much to do for each question.
3. **15 chapters** covering all the sections of Physics that you need to know about

   Each chapter contains:
   - An introduction telling you what is in the chapter and what skills you wi
   - The main content – explanations, diagrams, worked examples, tips and i section of the syllabus.
   - Test yourself time – tasks, quick questions and quizzes to see how you're
   - Practice exam-style questions – time to practise. Here, if you are seriou cheat. Do the questions without looking at books, notes or these resour can) and write on the paper, just like the real thing. There's no point pra under exam-style conditions.
   - Although no time limit is given for these, you can time yourself to see ho Remember, it is better to get them right now than to rush. However, in paper is expected to take you approximately one minute to answer.
4. **'A Level' challenge.** The final section has some self-challenge tasks and ques
   first year of A Level Physics. Even if you don't plan to do A Level Physics, hav
   even some of the A Level it's going to make you feel a lot more confident in t
   realise your aim at getting the top grade.
5. **Answers.** All the answers to the exam-style questions for each chapter. Rea
   and guidance on how to do your self-marking. Marking your answers is as va
   answering the questions, providing you do it the right way. This section also
   tasks and other quick questions for each chapter.

> Being the best at anything – sport, music, gaming or exams – is about prac
> Most of all – if you get something wrong – don't give up, just ke

Exam advice

Revision – general advice

- ❖ Work somewhere comfortable – ideally at a desk.
- ❖ Do not study on your bed.
  - o Why not? Not only is it too comfortable, but over time your subconscio with work, and this can affect some people's ability to sleep. Getting a important factor in exam success.
- ❖ Put your phone and tablet, etc. on silent. Better still, put them on 'Do Not Di Your messages can wait for 15 minutes.
- ❖ Focus on one or two topics at a time – ideally the ones you feel least confide Don't try to learn everything at once. Be disciplined and have a written plan.
- ❖ Music – this is a personal choice, but there are a few rules to follow:
  - o Not too loud – it has to be background music. If your brain is concentra processing the music, it isn't focusing on learning.
  - o Try to avoid songs with lyrics – if you're singing along, you aren't using a brain power for revision.
  - o Don't have any music playing when doing practice exam-style questions listen to in the real exam, and the more realistic the conditions are whe you will be in the exam and the better prepared you will be.

Timing your revision

This is really important to understand. When you revise is up to you – some peop mornings, others later in the evenings.

No one can concentrate for hours at a time. You might 'work' for two hours, but you actually concentrating? On average, a person can focus for one minute for ev about 25, then it starts to level off. So, most GCSE students can really only focus a before they start to drift a little.

Try this:

15 minutes – revision of first topic; Chapter 1 of the content, for example.

5 minutes – break. Check your phone, get a drink, etc. – anything but revision.

5 minutes – recap of first topic. Do the tasks for a chapter, for example, or just can recall on a blank piece of paper without looking at your notes. Then check y

15 minutes – revision of second topic (or, for longer chapters, the second half of

5 minutes – break.

5 minutes – recap of second topic.

15–20 minutes – complete practice exam-style questions and then self-mark the

Finish – if you move on to another subject, make sure you leave a reasonable g brain do some 'filing' and resting before starting something different.

You might see this combination of symbols in the chapters; it is a reminder to stop, rest a little, recap and check before moving on.

Some simple brain science

This may be physics, but a little biology lesson will help you understand more abou

Revision starts with the process of remembering information. Then you can use it a helps you get an 8/9 in an exam. But first you have to know the facts, the definitio

The brain has several memory systems; put in simple terms – immediate, medium- human brain evolved to survive in the wilds of the plains of Africa, and passing ex The brain functions to store useful information in the long-term memory that it e associates with a dramatic/traumatic event.

When we read, watch or listen to information it goes into our immediate memory so – just long enough to make sense of what is being said or watched. If we do so straight away, it gets passed to the medium-term memory. Here it stays with us f after a while, new information comes in and the brain has to decide what to keep use something in the medium-term memory soon, we just forget it, i.e. no learnin we use it by answering a question, write or type it out, or speak to someone abou then the brain thinks it might be worth keeping for a bit longer. The more often w more the brain thinks it is probably important, so it shifts it over to the long-term can start to say we have learnt something. This might be over several days or we

Do this: take a five-minute break, come back and rewrite what you just read abou sentences, bullet points, a drawing or, if you're feeling creative, a song – it doesn' has to use the information and starts to think it's worth learning. However you re just thinking isn't enough – you must do something with the information.

Exam advice

Get a good night's sleep

- ✓ Don't be tempted to panic revise the night before.
- ✓ Look over your notes for 30 minutes then put them aside.
- ✓ Don't revise in the hour before you go to bed.
- ✓ Try not to use your phone, etc. just before bed – if you do, set it to night mode t

On the day – have breakfast/lunch. Your brain is an organ and it needs fuel and oxy the body. Some people even do a little meditation – try it, it might be right for you.

Have everything ready – pens, pencil, calculator, ruler, eraser and a bottle of wate summer and in the heat – dehydration affects brain function and reduces your abil water with you – but remember, the container cannot have any labels on it.

In the exam:

1. Make sure you are comfortable – if there is light in your eyes from a window, invigilator before the exam starts.
2. Check through the paper at the start – make sure you know how many quest back page – you would be amazed how many candidates miss the last questi
3. Check for the page or insert with the equations and keep it to hand.
4. **Always show your working out** – even if you miscalculate an answer, you wi answer and your calculations.
5. **For each question, check the number of marks available** – don't waste time wri
6. Look for **command words** – see the 'Command words' help sheet in this pack type of answer to provide and the amount of detail needed for a grade 9.
7. Most exams are designed to give you 10 minutes at the end to check your wo finished, **check everything carefully**.

After the exam – forget it. Don't start panicking and trying to second-guess weth

Concentrate on the next paper. When you get home, or during a short break, jot be honest with yourself – what did you find a challenge and what was easy? Use t But don't worry about Paper 1.

After Paper 2, relax, and concentrate on the next subject.

Command words

Command words are the words used in exams that tell candidates how they shou
what they mean and use them in the exam to guide you on how to answer the qu
needed for full marks.

Calculate	Use the **numbers from the question** to work out an answer. *Example:* **Calculate** the velocity of a train that travels a distance of 100 m The numbers to use are 100 m and 10 s $velocity = \frac{distance}{time}$ or $v = \frac{d}{t}$ So: $v = 100 \div 10 = 10\,\text{m/s}$
Choose	Select from a range of alternatives. Pick your answer from the options given in the question. This is basically Always check how many options you need to choose; it is not always just
Compare	A common error is to mention only one of the options, or discuss only the not both. Write about the similarities and differences **between all** the options give *Example question:* **Compare** the processes of nuclear fission and nuclear *Answer:* They both produce large amounts of energy from atoms (*simila* of hydrogen to form helium to do this, whereas fission <u>splits</u> large radioa release the energy (*difference*).
Define	Give the meaning of a word or phrase, like a dictionary explanation. *Example:* **Define** the term specific heat capacity. *Answer:* The amount of energy, in joules, needed to increase the tempera **Tip:** Knowing the meanings (definitions) of keywords in physics is an impo communicating your understanding. Definitions are not a higher-level sk confident in using the right words in the right places. As you revise, write notes, and write a definition for each one to go with it. Put these up arou read one or two of them every day. **Note:** It is important to write or type these yourself; don't copy and paste words and producing the work yourself makes you think, and thinking ai longer-term memory, i.e. you learn.
Describe	Write about the topic in the question – an event, a fact or a practical – a *Question:* Describe how you would measure the resistance of a wire, usi *Answer:* Place the wire in series with a power supply such as a battery or ammeter in series with the wire and the voltmeter in parallel with the wi supply and note the readings on both meters. Use the equation $V = IR\ such\ that\ R = V / I$ to calculate the resistanc **Tip**: As with all exam questions, check the number of marks given for the detail to give. Generally, one mark is given for each important point the write about.
Design	Suggest how a practical could be carried out. This is asking you to put together a method or plan for an experiment. Th experiments you have done in class with your teacher.

Determine	Use given data or information to obtain an answer; this might come from a t mistake is to misread the data from the axis of a graph. This is a key scientifi
Draw	Draw a diagram to illustrate your understanding. Examples would be to d isotope, or a set-up for an investigation. You don't have to be an artist, but do remember to label the key element
Estimate	Use the data/information provided in the question to suggest an approxi question. You are not expected to show any calculations. **Tip:** Look at the accuracy of the data provided. If it is to one or two decim to the same level of accuracy – never be more accurate, i.e. if the data is t not to 2 dp. Check the question – does it tell you how accurate you need to provide a range, e.g. $2.5\,V\ \pm\ 0.25\,V$?
Evaluate	Use your knowledge and understanding as well as the information given i **evidence for and against** an idea. **Tip:** Marks are NOT awarded for your opinion – there is no right or wrong your arguments and your use of data and knowledge. There will be marks evidence. Don't defend your personal opinion – be impartial and try to se
Explain	Give clear reasons for an opinion or idea, based on your knowledge and a Occasionally you may be asked to do this using a diagram.
Give	This is a short answer, stating something. It could be a value from a table These questions do not require a long explanation or justification.
Identify	Name or identify an object or a point on a graph. These are short answers explanation.
Justify	Make use of the information given and your knowledge to explain why yo Try to refer to data if it is available. These questions require longer answe
Label	Add appropriate labels to a diagram. Take care to check the details of wh
Measure	Use the diagram or image provided to find the size of an object. Take car been provided.
Name	Very short, often one-word answers, asking you to identify something. Yo your answer.
Plan	This is instructing you to write a method for an experiment or investigatio maximum number of marks given and aim to say one key thing for each m Check whether the question asks for specific details, such as a list of equip measure a given quality, etc.
Plot	Use the data provided, often in a table, to draw or complete a graph. Check the scale for each axis and the data table carefully before beginning awarded for these types of question, and most are simply given for accura graph. Check whether the question asks for a line to be drawn with the d of best fit.
Predict	Use the information given along with your knowledge to suggest what mi than one correct answer – your prediction just has to be reasonable.
Show	Draw a conclusion to data or information but give a sensible and reasoned come to that conclusion. One way to approach these questions is to use a simple structure. Give your conclusion then join this to your reasons with the word *because*
Sketch	A quick drawing with minimum details. It may help to add a couple of label
Suggest	This will be linked to new situations relating to something you have studie expected to revise. You have to use your knowledge and understanding a
Use	This command tells you that you must make use of the information given in this data/information. The marks are for applying the information provided Don't waste valuable time coming up with or recalling your own examples – in the question.
Write	Very short answers, possibly only one word or a phrase. No explanation i

Equations

You will need to know and be able to use the equations below (not all of them ar

weight = mass × gravitational field strength
work done = force × distance
force applied to a spring = spring constant × extension
moment of a force = force × perpendicular distance
pressure = force normal to a surface ÷ area
distance travelled = speed × time
acceleration = change in velocity ÷ time taken
resultant force = mass × acceleration
momentum = mass × velocity
kinetic energy = 0.5 × mass × speed
gravitational potential energy = mass × gravitational field strength × height
power = energy transferred × time
power = work done × time
$efficiency = \frac{useful\ power\ output}{total\ power\ input}$
wave speed = frequency × wavelength
charge flow = current × time
potential difference = current × resistance
power = potential difference × current
power = $current^2$ *× resistance*
energy transferred = power × time
energy transferred = charge flow × potential difference
$density = \frac{mass}{volume}$

The following equations will be provided in the exam, but you should know what th

pressure due to a column of liquid = height of column × density of liquid × gravitatio
$(final\ velocity)^2 - (initial\ velocity)^2 = 2 \times acceleration \times distance$
force = change in momentum × time taken
elastic potential energy = 0.5 × spring constant × $extension^2$
change in thermal energy = mass × specific heat capacity × temperature change
$period = \frac{1}{frequency}$
$magnification = \frac{image\ height}{object\ height}$
force on a conductor at right angles to a magnetic field carrying a current = magnetic flux dens
thermal energy for a change of state = mass × specific latent heat
potential difference across primary coil ÷ potential difference across secondary coil =number of turns on primary coil ÷ number of turns on secondary coil
potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil
For gases: pressure × volume = constant

Chapter 1: Energ

Introduction

This section looks at the higher-level concepts in the first unit on energy. The foc your skills in recalling, rearranging and applying formula.

It is important to recall that energy cannot be created or destroyed. Instead, it is another; for example, a light bulb changes electrical energy into heat and light. T (in this case the bulb) the more of the initial energy is converted to a useful energ to improve the efficiency of systems is a higher-level skill.

Equations used in this chapter

kinetic energy = ½ × mass × velocity²

gravitational potential energy = mass × gravity × height

change in energy = mass × specific heat capacity × change in temperature

$$\text{efficiency} = \frac{\text{useful energy output (or transferred out)}}{\text{total energy input (or transferred in)}} \quad (\times\ 100\ \%)$$

Kinetic and gravitational potential energy

- **Kinetic energy** is the energy an object has due to **movement**.
- **Gravitational potential energy** is the energy an object has because of its **hei**

Imagine cycling up a hill – to get to the top, your body uses **chemical energy** from As you pedal and move, you are transferring **the chemical energy** into **kinetic ene** transferred to **gravitational potential energy** as you gain height. When you reach longer moving, all the **kinetic energy** is 'gone'. But energy cannot be destroyed, s Answer: The **kinetic energy** has been transferred to the **gravitational potential er** higher up than you were at the start.

In reality, some of the energy has been lost as **thermal energy** due to friction between the moving parts of the bike, the tyres and the surface, and between you, the bike and the air (air resistance). At GCSE all this is ignored for the calculations, but you should be aware of it for written answers and suggesting improvements to efficiency in mechanical systems.

On the way down the hill, you can freewheel without pedalling at all. The kinetic energy comes from the gravitational potential energy as you move downhill. You of the hill depends only on the height, h, of the hill. Mass has been cancelled out 9.8 N, so height, h, is the only variable.

We can say that: $E_k = E_p$ or $\frac{1}{2}mv^2 = mgh$

but the ***mass*** term in each equation cancels out the other, so in this example we c as follows, overleaf:

Key s
a key
9. Se
sectio
for m

gravity = 9.8 N/kg   height of hill (h) = 20 m

$E_k = E_p$

$\frac{1}{2}mv^2 = mgh$

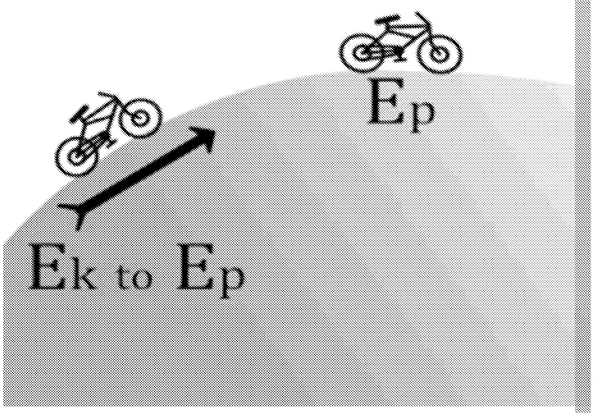
$\frac{1}{2}v^2 = gh$

$v^2 = 2gh$

$v = \sqrt{2gh}$

$v = \sqrt{(2 x 9.8 x 20)}$

$v = \underline{19.8\ m/s}$



Task A

A roller coaster cart of mass 500 kg is pulled up to a height of 15 m at the start c
a height of 5 m in the first section.

1. What is the maximum theoretical speed of the cart at the bottom of the fir
   your working out.
2. What could the designers do to bring the real speed closer to the theoretical
3. What could the owners do when maintaining the ride to increase the actua
   your suggestion.
4. A student says, 'The ride would be much faster when it's full as it would be
   Do you agree with them? Explain your answer.
5. In reality, the velocity would be lower than the value calculated. Why?

Specific heat capacity

Specific heat capacity (SHC) – denoted by '*c*' in equations – is a property of all materials that indicates how quickly (or slowly) the material changes temperature.

The higher the value of '*c*', the more energy it takes to change the temperature of the material.

SHC is defined as ***the amount of energy needed to increase the temperature of 1 kg of a material by 1 °C***, measured in *joules per kilogram per degree Celsius* (J/kg/°C).

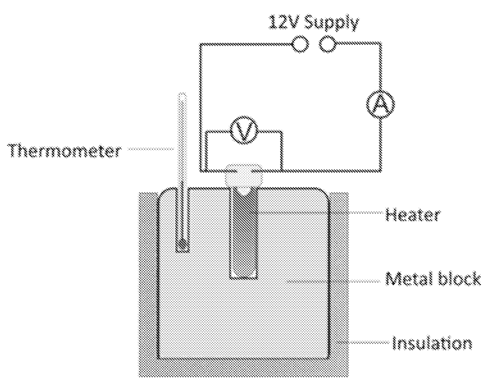
There are two ways to think about this:

1. Some materials need more energy than others to heat them up, e.g. water n 1 °C, whereas air needs a little over 1000 J per kg per °C.
2. It affects how quickly a material warms up or cools down. Water heats up a land at the same ambient temperature because water has a higher specific h more energy from its surroundings to heat up than the land does.

Formula:

$\Delta E = mc\Delta\emptyset$ where m = mass, c = specific heat capacity, $\emptyset$ = temperat

The symbol Δ (delta) in any equation means 'a change in' the value of the variable So ΔE means the change in energy, and $\Delta\emptyset$ means the change in temperature.



Using this apparatus, data can be co specific heat capacity of various ma

Below is an example of the data for example of how to use the equatio

- Material: aluminium of mass 0
- Starting temperature, 21 °C
- End temperature, 23.03 °C
- Energy supplied, 1000 J – this i

Worked example: Find the specific heat capacity of aluminium.

$$\Delta E = mc\Delta\emptyset$$

$$c = \frac{\Delta E}{m\,\Delta\emptyset} \qquad c = \frac{1000}{0.5 \times (23.03 - 21.00)} \qquad c = \frac{1000}{0.5 \times 2.03}$$

$$c = \frac{1000}{1.015} \qquad c = 985\ J/kg/°C$$

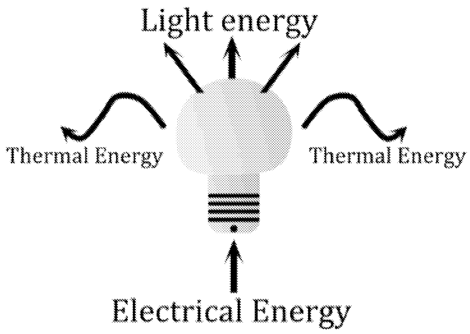
Before you read anything else:
Turn over this page – on a scrap of paper write a definition of s capacity and the equation. Check your answers.

Do not cheat – you have to write it or type it, not just think it.

Efficiency

In order for actions to take place in any system, there must be a transfer of energ The initial energy or input energy is normally changed into a useful form of energ and waste energy that doesn't perform a useful or required function.

Example: light bulb



Input energy – electrical
Output energies – thermal and ligh

The useful energy is the light. The energy. The more efficient the bul energy is transferred to light energ

The efficiency is calculated using the following formula. It can be expressed as d

$$\text{efficiency} = \frac{\text{useful energy output (or transferred out)}}{\text{total energy input (or transferred in)}}$$

To gain a higher grade it is important to understand and be able to explain how s efficient. Often this is a question of how to reduce the loss of thermal energy pr dissipated into the air or water around the object.

Mechanical system: Thermal energy is lost by friction between moving parts of t system and between the moving object and the air or water through which it is m

Solutions:

- Designs that reduce contact between moving parts
- Use of lubricants such as oil, grease and low-friction bearings made from pla
- Aerodynamic (hydrodynamic in water) objects – streamlined outlines

Electrical systems: Thermal energy is lost due to the resistance of the componen

Solutions:

- Replace components with lower-resistant alternatives
- Reduce the current flowing through the components

Note: using the electrical item less / turning it off when not in use **does not** chan and, therefore, suggesting this as a solution would not gain any marks in an exam

Task B

A manufacturer has built a new kettle – it has a capacity of 1 L and has a stylish When tested, 400 kJ of energy was supplied to heat the full kettle from 20 °C t

1. How much energy should be required to heat the water to boiling point in specific heat capacity of 4200 J/kg/°C? [assume 1 mL of water has a mass
2. Why is there a difference between the energy required to heat the water measured?
3. Suggest a change in the design of the kettle that would make it more effici

Exam-style questions

1.

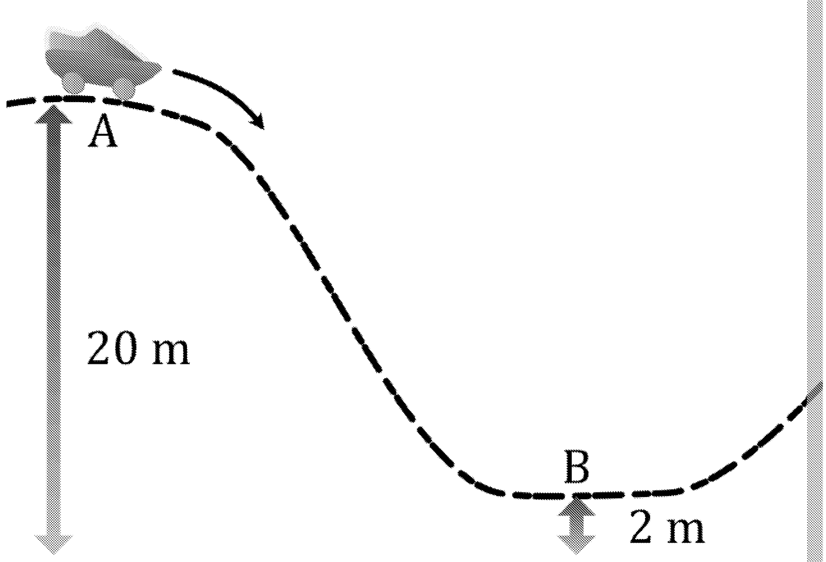


Figure 1

Figure 1 shows the plans for a section of a new roller coaster ride.

a. State the energy transfer taking place as the cart descends from point A

....

....

b. Assuming the cart has a mass of 200 kg, calculate the gravitational pote point A.

c. The owner wishes to know the speed of the cart at the bottom of this se loss of energy due to friction, **calculate** the speed of the cart when it rea

2.

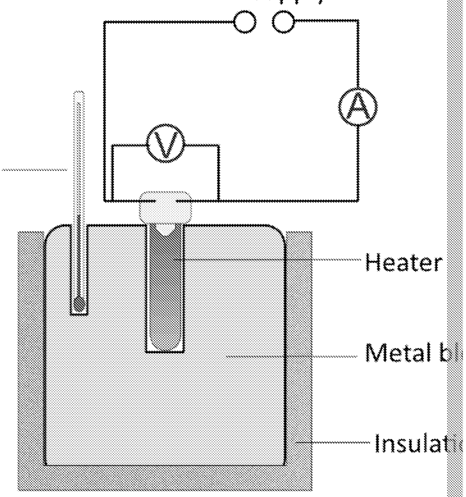


Figure 2

Figure 2 shows the set-up for an experiment to determine the specific heat c data from the ammeter and the voltmeter can be used to determine the ene

a. Why is the metal block surrounded by a layer of insulation?

....

....

b. Define the term specific heat capacity.

....

....

c. During the investigation, a 1 kg block of iron is used and 5000 J of energy The student records a starting temperature of 20 °C and a final tempera specific heat capacity of the iron used in this experiment?

3. As a cyclist moves along a road they are transferring energy from chemical e
However, some energy is lost to thermal energy due to friction and air resist

a. State one way that the cyclist could improve the efficiency of the bike. E
the efficiency of the energy transferred in this system.

....

....

....

....

b. A cyclist of mass 70 kg uses 1000 J of chemical energy to travel at a spe
percentage efficiency of this energy transfer?

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....

End of paper

Chapter 2: National and energy resources

Introduction

Access to affordable, sustainable energy is now a serious issue. The demand for e
greater, and, with a growing population and an increasing dependence on the Int
and cloud data storage, this is set to rise rapidly over the coming decades.

One of the key skills required to gain a 9 in Physics is the ability to review, **analys**e
arguments and **compare** situations and solutions to problems. Therefore, in this c
analysis and answering '*compare*' and '*justify*' questions based on data in the form

Reading graphs

Graphs present a 'picture' of how variables affect each other or how one variable
four basic patterns to look for in any graph.

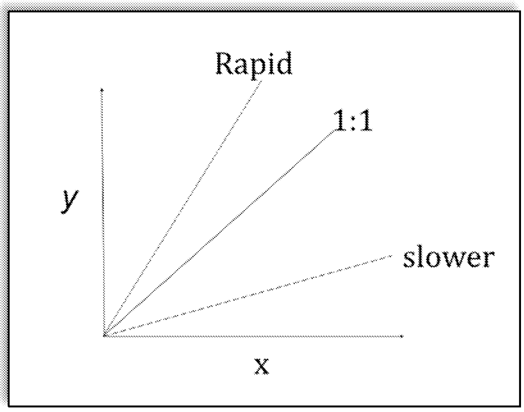


Figure 1 – increasing

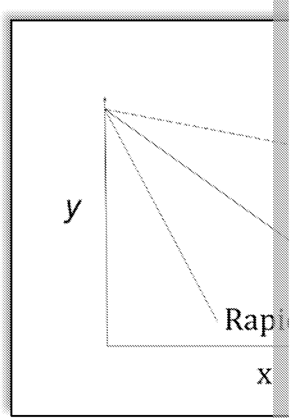


Figure 2 – d

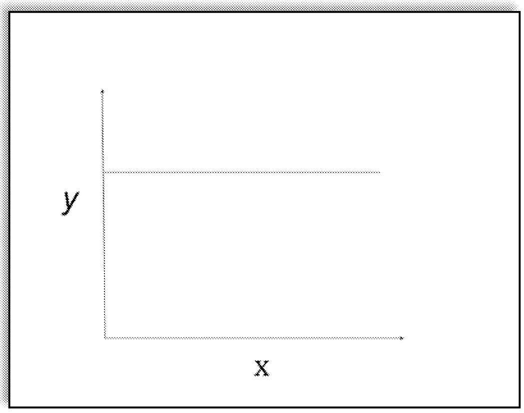


Figure 3 – no effect

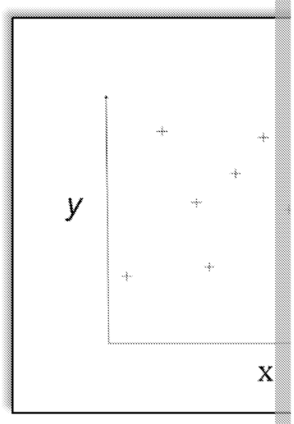


Figure 4 – no r

Figure 1 shows that as *x* increases in value so does *y*.
Figure 2 shows the reverse – the value of *y* decreases as the value of *x* increases.
Figure 3 shows that *x* has no effect on the value of *y*.
Figure 4 is a scatter diagram. There is no pattern in the data. *x* and *y* are not link

Using these four basic structures can help you to phrase an answer when describi
Remember in real data figures 1, 2 and 3 might be combined to show that *y* is aff
different values.

Type of energy source

These are grouped into **renewable** and **non-renewable** resources. Non-renewab
they are gone forever.

Non-renewables (finite – they will run out)	**Renewa**
Fossil fuels • Coal • Oil (petrol, diesel, jet fuel, etc.) • Natural gas	• Solar • Wind • Tidal • Wave
Nuclear fuels for fission • Plutonium • Uranium • Thorium, etc.	• Biomass and biofu • Geothermal • Hydroelectric • Hydrogen fuel cell

Don't confuse renewables with low carbon – biofuels still release CO_2 during comb
etc. produces a large amount of greenhouse gases too.

Each of these can be used to perform different functions, such as:

- **Production of electricity** – all of them can be used to generate electricity.
- **Transport** – oil-based products, and increasingly electricity. Remember, an e
  the electricity has to be generated and this could be producing CO_2.
- **Domestic** – heating and cooking.

Before looking at some real data, take a few moments to think about UK and global energy trends. Jot down your initial ideas.

i. What has happened to UK energy demand overall since 2000?
ii. Is this the same for the rest of the world?
iii. What percentage of the energy produced in the UK comes from renewable resources?

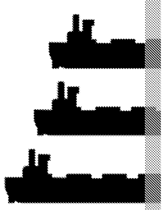
The UK actually uses less energy per person now than it did in 2000. Why migh
this be? Just jot down a few ideas – remember, thinking of and recalling ideas
helps you to learn, and in an exam you will not be able to look anything up so a
bit of practice now is good preparation.

Units used to compare energy usage on large scales

Kilowatt-hour (kWh) – used for electricity usage, e.g. a 5 kW kettle used for 10

Joule (J) – the standard SI unit of energy is only used occasionally; this is simply
be so large they would be too confusing to use, e.g. in 2019 the UK used 5 945 2
is too inconvenient.

Millions of tonnes of oil equivalent (Mtoe) – when comparing very different en
and solar, the amount of energy is compared to how much energy can be suppl
tonnes of crude oil.



In joules, that is a massive 4.1868×10^{16} J!

Put another way, that's roughly the same as **3.7 oil tankers'** worth of energy.

Data interpretation

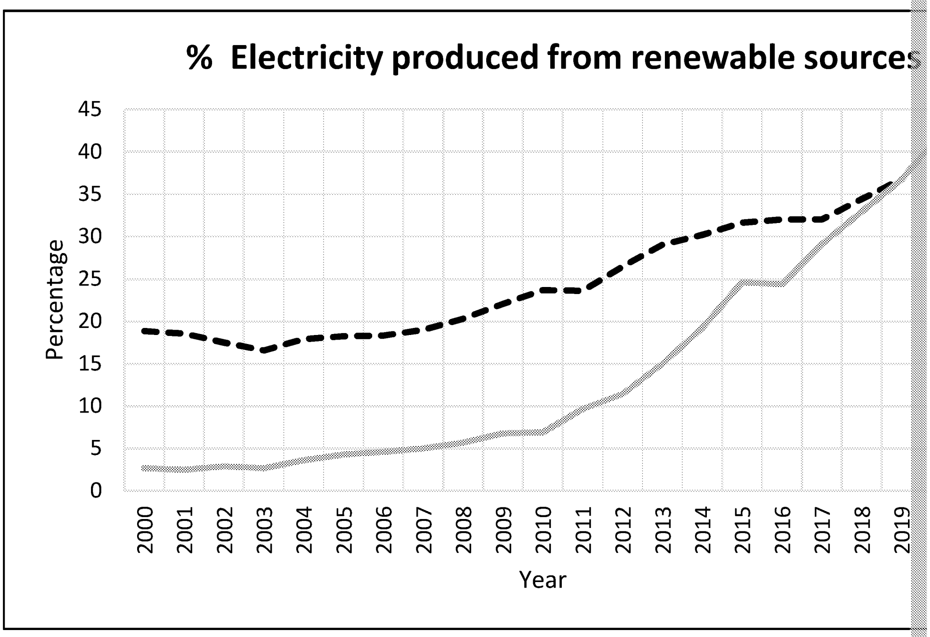


Figure 5

Figure 5 shows what percentage of electricity generated in the UK and in Europe s
renewable energy sources.

Example question 1

Describe the change in percentage of electricity generated from renewable energ
2000 and 2020.

Tip: Because the command word in the question is ***describe***, you only need to say
to explain why it changes or to justify your answer – just literally describe what ha
the values to do this. Look for **overall trends** and any **sudden changes**.

Example answer: In 2000, the UK produced around 2.5 % of its electricity from re
had risen to 42 % *[overall trend]*. It increased steadily from 2000 to 2010, then in
[sudden change].

Example question 2

Compare the changes in percentage of electricity produced by renewable energy
the UK between 2000 and 2019.

Tip: **Compare** questions require you to write about **both** options (Europe and the
is the **same** about the trends in the data, then any **differences**.

Example answer: The percentage of electricity produced from renewable sources
increases from 2000 to 2019 *[similarity in both data trends]*. However, in 2000 Eu
from renewables; in the UK, it was only 2.5 % *[difference]*. By 2019, the UK and Eu
36 % from renewables *[similarity]*; therefore, the increase for the UK was greater
19-year period *[difference]*.

Task A

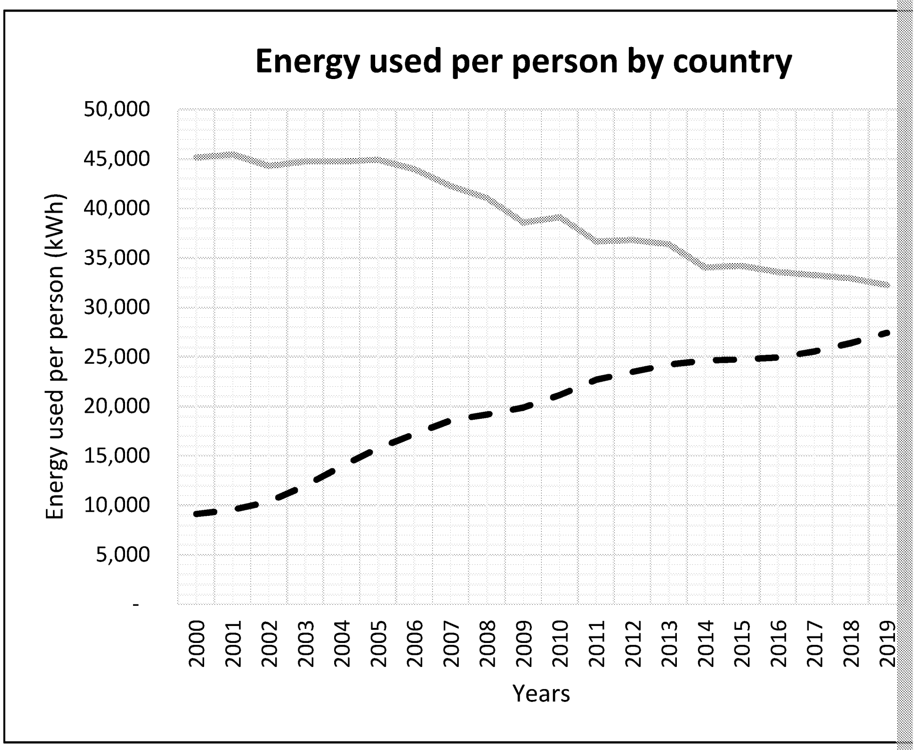


Figure 6

This graph illustrates how the energy used by China and the UK has changed be
data is shown as kilowatt-hours per person. In 2000, the UK had a population o
67.9 million. Over the same period of time, China's population has increased fr
1439 million.

1. Compare the energy used per person in the UK and China from 2000 to 20
2. Suggest two reasons why the energy used per person is changing in China
   Justify your answer.
3. The trend in the data suggests that the UK is now using less energy per pe
   On average, how much is this changing per year, and why do you think it i
   Give two suggestions.

Tip: Make sure in part 1 you are comparing the two countries. What do they hav
different? Try to use a few values taken from the graph to help explain and illust

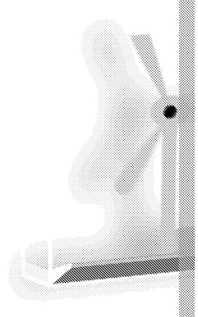
Environmental impact of different energy sources

All energy sources have an impact on the environment – there is no such thing as energy source. It is a matter of balance between impact on the environment and The impact can be divided into four main areas of consideration:

- **Construction** – building the infrastructure for extraction, production or gener
  - A wind farm needs land or seabed to sit on. The concrete has to be brou it sets, etc.
- **Extraction** – the processes need to collect or access the energy source.
  - Oil extraction burns off excess gas and produces CO_2, etc.
  - All sources need land and/or seabed to build on.
  - Uranium, coal and gas all need to be mined, causing damage to the land
- **Transport/storage**
  - Oil needs either to be shipped or to flow through pipelines. Electricity n generation site to point of use, such as your house.
- **Point of use**
  - Burning a fuel – fossil fuels and biomass produce CO_2 and other airborne produces nuclear waste that is radioactive for millions of years.
  - Making magnets for electricity production creates heavy metal toxic was certain provinces in China, for example.

Task B

One area of concern over the use of wind farms has been the impact that the structures and the rotating blades could have on birds as they fly through a wind farm. One study collected data on the causes of death to birds and used this to estimate the annual global death rate for different causes of death to birds, not including natural causes or predation from wild animals.



Cause	Annual deaths (estimate)
Aeroplanes	25,000
Buildings/windows	550,000,000
Cats	100,000,000
Communication towers	4,500,000
Overhead power lines	130 000,000
Pesticides	67,000,000
Vehicles	80,000,000
Wind turbines	28,500

Research suggests that b wind turbines, with some flight path by several kilo is that the noise from the detected by the birds and

If this is true it has implic wind farms near nature r sites of endangered spec migration routes.

1. How many birds on average are estimated to be killed by each of the follow standard form.
   a. Wind turbines
   b. Cats
   c. Communication towers
2. The research team concluded that wind farms have no significant impact o result of building and operating wind farms.

   Do you agree with this conclusion? Use the data provided to justify your o

Exam-style questions

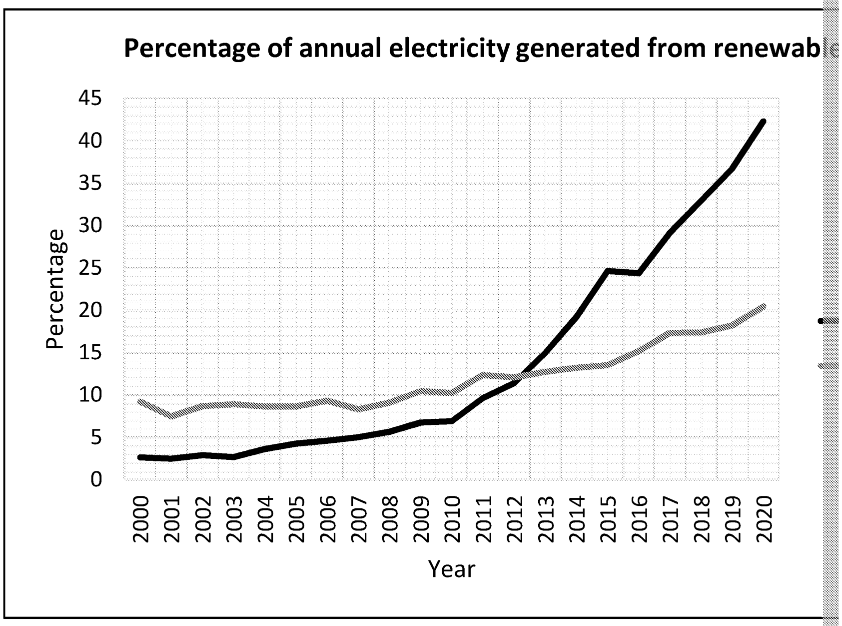


Figure 1

1. Over the last two decades, the use of renewable energy sources to generate common in many countries around the world. Figure 1 shows the percentag renewable sources in the UK and the USA since 2000.

   a. Give two examples of renewable energy sources that could be used in both

      1. ....

      2. ....

   b. In what year did the UK and the USA generate the same amount of elec renewable sources?

      ....

   c. In 2000, the UK gained only 9 % of its energy from renewable sources. energy source that were used to make up the other 91 %.

      1. ....

      2. ....

      3. ....

      4. ....

   d. Describe the changes in the UK use of renewable energy sources from 2

      ....

      ....

      ....

      ....

      ....

      ....

e. Compare the change in use of renewable energy sources between the U

....

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2.

Year	Oil	Gas	Coal	Nuclear	Solar	H
2000	955	1013	427	236	0.003	
2019	863	788	73	139	31	

Table 1: UK energy consumption (Mtoe)

a. In 2000, which energy source had the highest level of consumption?

....

b. Which of the non-renewable sources is not classed as a fossil fuel?

....

c. Figure 2 below shows the data for 2000. Complete the graph using the
The first set of data has been added for you as an example.

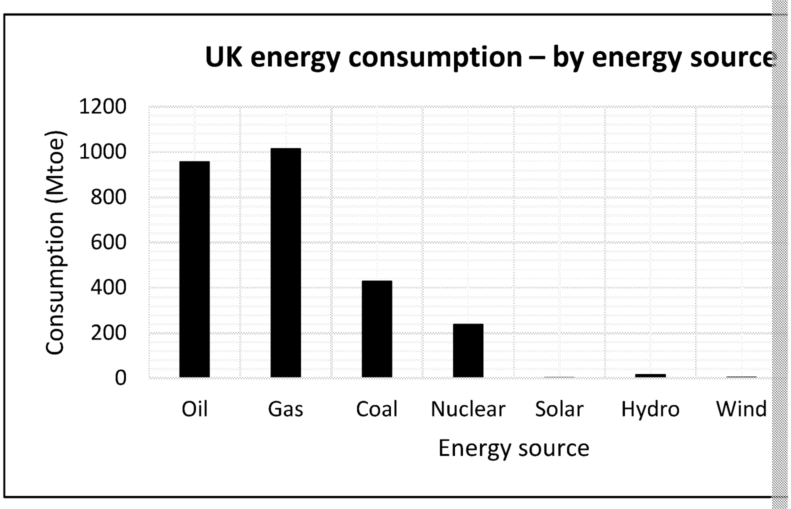

Figure 2

d. The UK government believes that the UK is moving to a sustainable ene
is also better for the environment. Do you agree with this statement?
your answer.

....

....

....

....

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....

End of paper

Chapter 3: Power in electric and transformers

Introduction

This chapter focuses on two key aspects of the topic of electricity: **electrical pow transformers**. As well as focusing on an understanding of the theory for each of t chance to further develop your skills in manipulating equations and applying theo

To understand these two topics it is important to have a clear understanding of so

Electrical current denoted in equations by the symbol *I*.

Definition: Electrical current is a flow of electrical charge.

The size of the electric current in a circuit depends on the rate of flow of electr circuits, the charge is carried by the free electrons in the conductor.

Potential difference (p.d.) or voltage denoted in equations by the symbol *V*.

Definition: The amount of energy transferred between points in a circuit.

A useful way to think about p.d. is to imagine it as the *'force'* that makes the c a circuit. So, if the circuit stays the same, and then if you increase the p.d. (vo current flowing in the circuit. (This is Ohm's law.)

A higher p.d. means more energy is being transferred in the circuit.

Electrical power

Power in physics is a measure of the **rate of transfer of energy**. Rate always mea happens. So **power is how much energy is transferred, how quickly**.

In a circuit, the amount of energy transferred is the *potential difference* – this tell need to know how quickly this happens. The energy is 'carried' by the charged pa move is measured by the current.

So, electrical power = how much energy is transferred × how quickly it is transfer

giving the equation: $power = potential\ difference \times current\ (or\ P = VI)$

Power is measured in watts (W) – this is the same as joules per second.

Example: Two bulbs both produce the **same amount of light**; however, one is a modern LED and the other is a traditional filament bulb.

Each second the LED transfers 5 J of energy to produce the light, but the filament bulb needs to transfer 60 J each second.

Given that mains electricity in the UK is 230 V, what is the current flowing through the filament blub?

power = voltage × current $P = VI$ $P = 60\ W, V = 230\ V$ $P = VI$ $\therefore\ I = \frac{P}{V}$ $I = 60 \div 230$ $I = 0.26\ A$	Calculate the current in the LED.

The equation for power can also be expressed as $P = I^2 R$ where *R* is the resista

Explanation

Recall Ohm's law equation: *V = IR (potential difference = current × resistance)*

If *V* is substituted by this in the power equation it becomes $P = (IR) \times I = I^2 R$

Example of finding the resistance of a component

What is the resistance of the 60 W bulb?

We have already worked out the current in this bulb as 0.26 A

So if $P = I^2 R$ then $R = P \div I^2$ $\therefore$ $R = 60 \div (0.26)^2 = 887.6$

Energy transfer in everyday appliances

In most real situations, knowing the energy transferred is more important than th
After all, when the electricity bill arrives it is the energy that we are paying for, no

The power rating on a device tells us how much energy is transferred per second,
transfer we need to know how long the device was operating for.

$$energy\ transferred = power \times time \quad or \quad E = Pt$$

Example: A 5 W LED bulb lights up a room for four hours. How much energy is transferred in this time?

$E = Pt$
$P = 5\ W,\ t = (4\ hours \times 60\ minutes \times 60\ seconds) = 14\ 400\ s$

$E = Pt$
$E = 5 \times 14\ 400$
$E = 72\ 000\ J \equiv 72\ kJ$

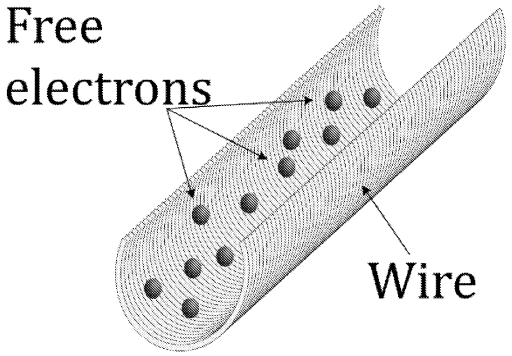
Task A

A standard kettle transfers energy to boil the water. On the base of the kettle is
plate – shown in the diagram. Use this information to answer the following que

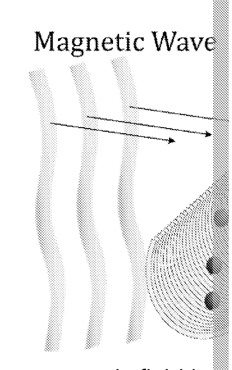
1. What is the power rating of the kettle, in watts?
2. Calculate the current flowing in the kettle's circuit.
3. Assuming the kettle takes five minutes to boil the water, how much energy has been transferred in this time?
4. What is the total resistance of the kettle's circuits?

Induced potential

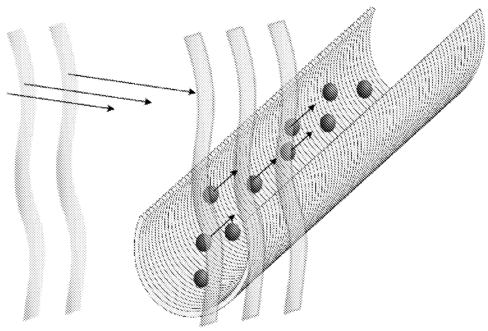
If a magnetic field moves relative to a conductor, a current is induced in it, provid
So waving a magnet over a wire makes the charge (electrons) move in the wire; m
The opposite is also true, so any current flowing in a wire, etc. produces a magnet



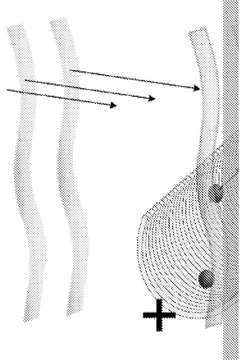
No current: the free electrons are not flowing in the wire; no charge is flowing.



A magnetic field is m



As the magnetic field passes through the wire it induces movement in the electrons. The charge is now flowing, so a current has been induced.
The flow is at **right angles** to the magnetic field.



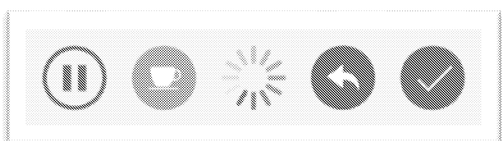
The flow of charge to
creates a pote
One end is more po

It is important to remember that induction of a current will also happen if the magn
(or conductor) moves through it. The conductor and the magnetic field must move

The motion of the charge results in a difference in the electrical potential across the
difference has also been induced, meaning energy is being transferred as the curren

Controlling the induced potential and current

- Magnetic field strength
- Speed of relative motion of the magnetic field and the conductor
- Amount of conductor affected – in a generator, etc., this is the number of c
- Direction of motion – unlike the other factors this does not affect the size o current, but the direction of flow of the current and the polarity of the p.d. which is '–')



This might be a good time to paus come back and think about the wo paper (draw it, write bullet points your notes and correct them if nec on revision.

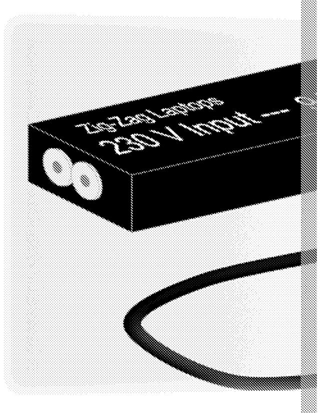
Applications of the generator effect

The induction of a p.d. and a current is also known as the **generator effect**. There
this in the real world:

- generating electricity (AC and DC)
- microphones
- transformers

Transformers

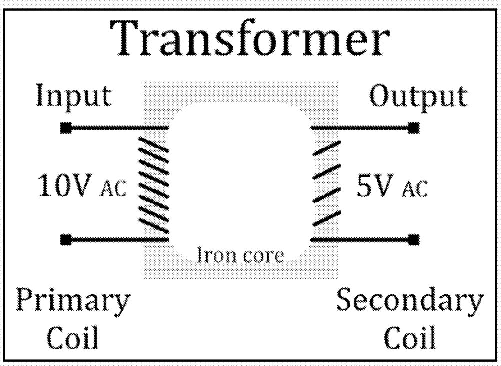
Most modern homes have a wide variety of electrical devices, cookers, TVs, mobile phones, etc. All of these need a different voltage to operate correctly, but in the UK the supply to the house is fixed at 230 V. So we need to be able to vary the voltage for different uses.



The national grid supplies electricity to homes, industry, schools, hospitals, etc. The overhead power lines have to run at very high voltages (400 000 V) to reduce the loss of energy due to heat, but your house needs only a 230 V supply.

Transformers are used to either <u>step up</u> (boost) or <u>step down</u> (lower) the voltag
All transformers operate in the same way.

Transformer design



- The main section is a **laminate** it's a laminated core? See the find out.)
- One side has a coil of wire wra **primary coil**. This is the **input**
- On the opposite side is the **se** **output** side.

Critical fact: No electricity flows through the iron core. The primary and seco

How a transformer works – it's all about induction

Transformers only work with alternating current (AC) electricity.

The alternating p.d. in the primary coil ➔ induces a fluctuating[1] magnetic field in

The fluctuating magnetic field is present in all parts of the iron core.

The fluctuating magnetic field ➔ induces an alternating p.d. in the secondary co

Question: Why do transformers only work with AC electricity, not DC?

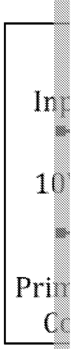
Re

↑ Step-up transformers have fewer coils on the primary coil compared to the secon
(less to more, up – coils and voltage)

↓ Step-down transformers have more coils on the primary coil compared to the sec
(more to less, down – coils and voltage)

Calculating voltage changes in transformers

The principle is very simple – the ratio of the number of turns on each coil is the s
in voltage.



8 : 4 number of turns on coils – ratio is 2 : 1

10 : 5 input V : output V – ratio is 2 : 1

Real transformers use hundreds or even thousands of coils.

Variables:

n_p – number of coils on the primary coil
n_s – number of coils on the secondary coil
V_p – voltage across the primary coil
V_s – voltage across the secondary coil

$\left[\frac{V_p}{V_s} = \frac{n_p}{n_s}\right]$ this equation will be given in the exam on the equation sheet.

Worked example

A transformer has 200 turns on the primary coil and 1000 turns on the secondary
voltage be for a 230 V input?

$\left[\frac{V_p}{V_s} = \frac{n_p}{n_s}\right] \therefore Vs = \frac{Vp \times ns}{np}$

$V_s = (230 \times 1000) \div 200 = \underline{1150\ V}$

Alternative – using rati
$200\ V : 1000\ V \equiv 1$
$\therefore 230\ V \times 5 = 1150$

Power and transformers

In theory, the electrical power output from a transformer should be equal to the
× current we can say that:

$V_p \times I_p = V_s \times I_s$ – *where* I_p *and* I_s *represent the primary and s*

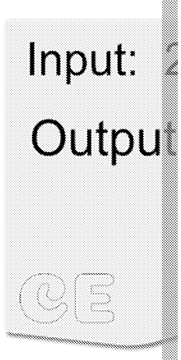
In the above example, if the input current was 10 A, what is the output current?

$V_p \times I_p = V_s \times I_s \quad \therefore \quad I_s = \frac{Vp \times Ip}{Vs}$

$I_s = (230 \times 10) \div 1150 = 2A$

Task B

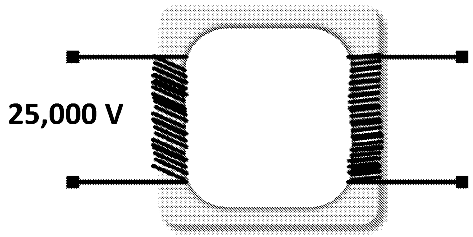
The diagram to the right shows part of the rating plate for a laptop. Unfortunately, the details showing the input current have been rubbed away.



1. The technician needs to replace the fuse for this laptop. Which fuse should they use – 0.5 A, 1 A, 3 A or 5 A? Show how you worked out the answer to this question.
2. The input coil has 1179 coils; how many coils must be on the secondary coil to achieve the change in voltage shown on this rating plate?
3. What is the electrical power rating of this device based on the output data nearest integer.
4. If it was operating for 24 hours, how much energy would the laptop transf (standard form).

Exam-style questions

1. A conventional power station generates electricity at 25,000 V.
The transmission lines use 400,000 V. A transformer is used for this process.



a. What type of transformer is used in this example?

....

b. If the primary coil has 2000 turns, how many turns are needed on the se voltage from 25,000 V to the 400,000 V required for transmission?

....

c. Is the input voltage AC or DC?

....

d. Explain how this transformer is able to increase the voltage from 25,000

....

....

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....

2. A standard domestic electrical cooker uses 230 V at 13 A from the home's ma

a. What is the power rating of this cooker?

....

....

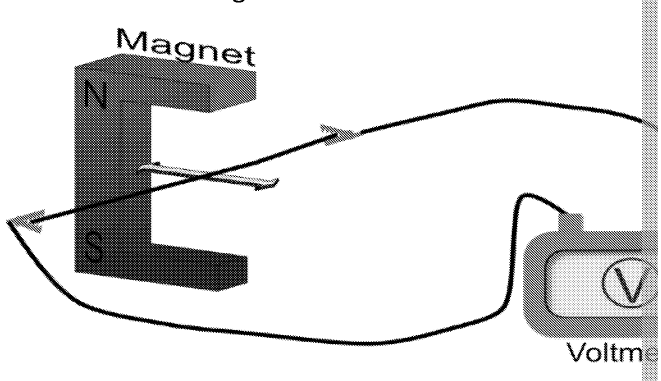
....

....

b. The cooker is used to prepare a meal and is used for 1 hour 45 minutes. transferred in this time by the cooker?

c. Calculate the resistance of the element that is used by the cooker if it ha it of 10 A.

3. A student is investigating the properties of electricity. They have a strong U-s between the poles as indicated in the diagram below. The wire is connected



a. State what will happen to the reading on the voltmeter in this experime shown by the arrow.

....

....

....

....

b. What would happen to the reading on the voltmeter if the wire was mo between the north and south poles of the magnet?

....

....

c. Explain the differences in these two observations.

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End of paper

Chapter 4: Static electri electrical fields

Introduction

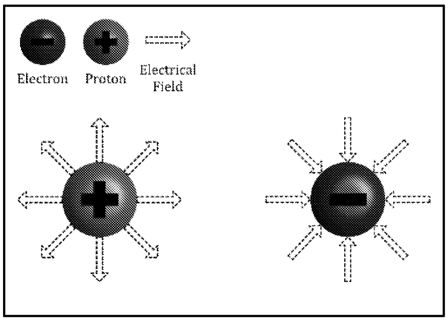
Electrical fields exist around charged particles or objects within which a force car particles. In this section you will concentrate on understanding how these fields on other charged objects.

In this chapter you will concentrate on improving your skills at providing grade 9 questions that require explanation and use of definitions. It is also a good oppor your own diagrams to help illustrate more complex answers.

Radial electrical fields

All charged particles such as electrons and protons have an electric field that rea them. The strength of this field decreases with the distance from the particle.

All drawings of this idea of a field around a particle use arrows to represent the fi the direction that a positively charged particle would move if placed inside this fi



Electrical field arrows point

- away from the positive
- towards the negative

This type of field aro as a **radial field**.

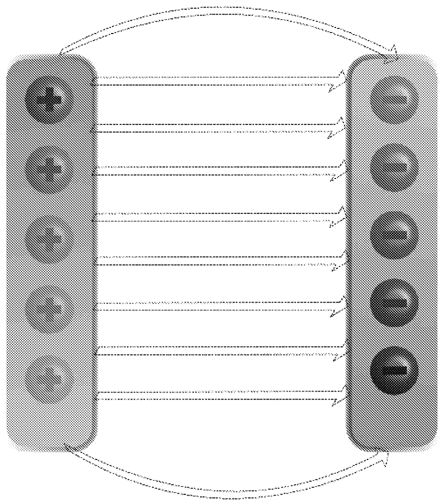
Two **unlike** charges and the forces act in the same direction to pull the particles together; the particles **attract** each other.

Two positive charges and the **forces push against** each other to **repel** the particles.

Two negative charges and the **forces push away** from each other to **repel** the particles.

The closer the particles are, the stronger the force and so the greater the speed **contact forces**.

Linear uniform fields



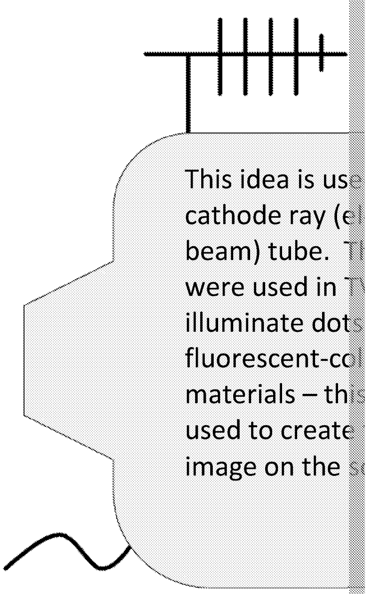
When two objects of opposite charge ar
electrical field exists between them.

If the objects are free to move they will

If they are fixed then the field remains b

The field will affect the motion of any ch
field.

A beam of electrons would be pulled in t
plate; in this example, they would bend t



Question:
What would happen to the electrical field if the two charged plates in the diagram above were brought closer together?

How might you show this on the diagram?

Task A

As part of your practice for writing longer answers in the formal exam, in this tas
written presentation.

In your presentation you need to explain:

- what an electrical field is
- the effect of an electrical field on charged particles
- the difference between a radial field and a uniform field

If you have someone to present or show this to who is not a physicist, try seeing

The answer sheet gives you the key ideas that you should have covered, but how
but you should include at least one diagram of your own design.

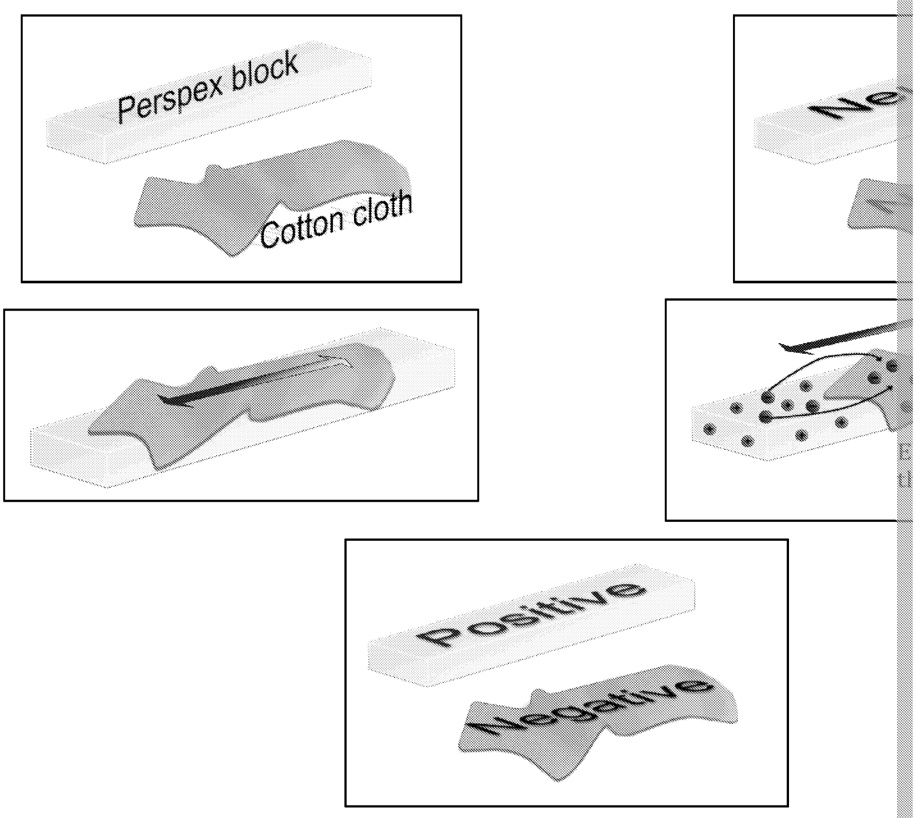
Static electricity

Normally objects are electrically neutral. This is because they have an **even numb** charged particles in them that are **evenly distributed**.

If this balance is changed, the objects will become charged. This can happen in th

1. Electrons (negative) are added ➔ negativel
2. Electrons are removed ➔ positively
3. Electrons are moved from one end/side to the other ➔ a polarise

> Although protons could be moved to create a charged objec much larger and are held in the nucleus of the atom; elect smaller and not as tightly held by many nuclei.



The act of rubbing the cloth on the Perspex creates friction; this force moves electrons from the Perspex to the cloth, leading to a static charge on each of the objects.

All charged objects try to return to a neutral state by allowing excess electrons to flow away, or by gaining extra electrons from their surroundings, such as the air or any solid objects they are touching.

> **Did yo**
> The soun
> caused b
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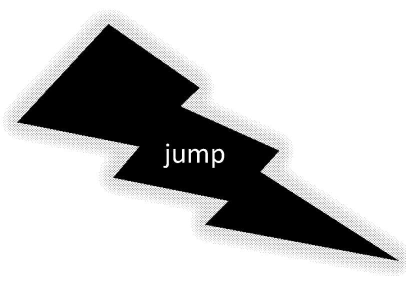
> as sound
> a lightni

A spark is a dramatic example of this. Negative on this side (extra electrons).



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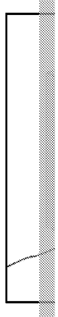
1 polarised means that there is a difference in the charge across the object (as in a magnet

Task B



In this application of the use of static electricity, the metal plate to be sprayed with paint from the spray gun can be charged.

The plate is given a positive charge via the wire connected at the base.

The paint in the spray gun can be charged too.

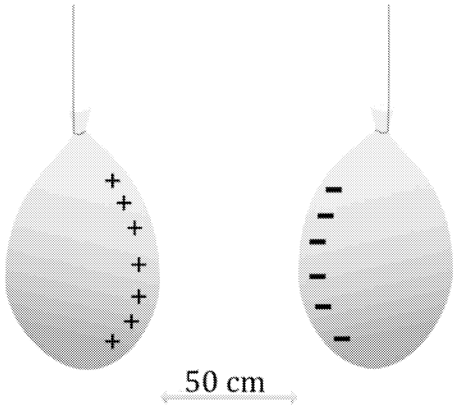
a. In this example, what charge would be given to the paint? Explain your answer.

b. What would need to happen to the metal plate in order for it to become p

c. This system is used in many manufacturing processes that require the pain especially useful for objects with complex shapes, such as a car body. Expl useful in this situation and why it results in less wastage of paint during the use a diagram to help illustrate your answer.

Exam-style questions

1.



A group of students are investigating the effects of static electricity on the m

Two balloons are suspended from freely moving pieces of string. Both ballo with cloths made from different materials. Their respective charges are sho

a. Explain what effect the rubbing with the cloth had on the right-hand sid charge state shown.

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b. At the start of the investigation the balloons are stationary and 50 cm a move them closer together, and at 10 cm apart the balloons swing on t above, draw arrows to show the direction of movement of each balloon

c. Using a suitable diagram, explain in terms of electrical fields why the ba

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d. One of the students suggests that once the balloons touch they will lose back to their original positions. State whether you agree with this state

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2. During a high-energy collision of atoms, a new subatomic particle is discove
Physicists notice that it was repelled in the presence of stationary electrons

a. What does this suggest about the electrical charge of the zagatron?

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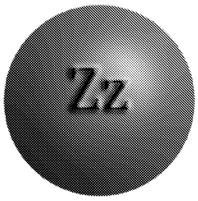
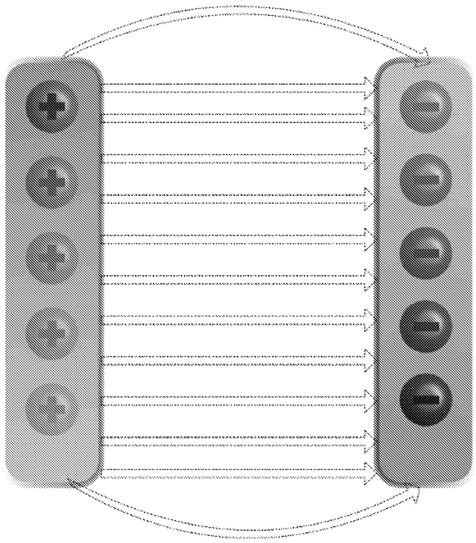
b. On the diagram below, draw arrows to indicate the possible electrical fi
the information discovered about it so far.



c. i. On the diagram below, draw a line to show how a beam of zagatro
as it passes between the charged plates from the bottom upwards



ii. Explain why this is likely to happen in terms of forces involved and
electrical fields.

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iii. Is the force experienced by the beam of zagatrons a contact force

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End of paper

Chapter 5: Temperature ch
system and specific heat

Introduction

In this chapter you will look at latent heat capacity of materials and how this affec
materials. A recap of specific heat capacity is included here as it is related to later

In addition this is a chance to further develop your skills in understanding and usi
to write grade 9 answers.

Temperature and internal energy

To understand this module it is important to understand the concept of *temperat*
energy and the motion of the particles in the material.

All atoms/molecules above absolute zero are in motion, from vibration in solids to
gases. This is the basis of the *kinetic theory of matter*.

The total of the ***kinetic energy*** and the ***potential energy*** of all the moving particle
its ***internal energy***. This internal energy is measured as its **temperature**.

If we **add thermal energy** to a material this **increases the total internal energy** of
temperature increases. (Heating up)

If we allow some of the internal energy to escape to the surroundings as thermal
temperature of the material decreases. (Cooling down)

Task A

Complete the following sentences:
When a beaker of water is heated by a Bunsen burner, the t __________ energy

i__________________ the movement of the water molecules. This means the

i____________ energy. This is measured as an i____________ in t__________

How quickly will a material change temperature?

How quickly these changes take place is a measure of the <u>specific heat capacity</u> of

- Metals have low specific heat capacities so change their internal energy quic
  internal energy is high).
- Water has a high specific heat capacity so changes its internal energy slowly (
  energy is low).

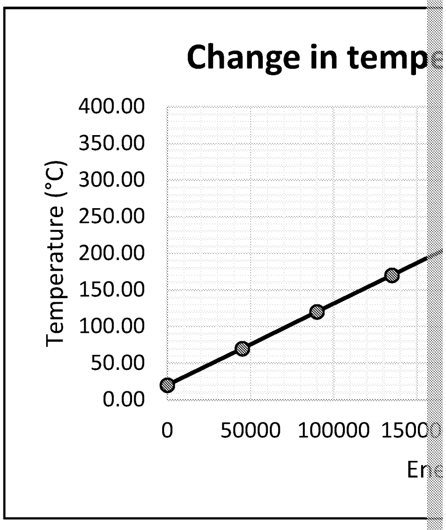
Question:
Given the same amount of additional thermal energy from a heater, which materi
the most – aluminium or water?

Answer:
In Chapter 1 you used the formula for specific heat capacity:
$\Delta E = mc\Delta t$ *or change in energy = mass × specific heat capacity × chan*

1 kg of water was heated from 20 °C using a heater connected to a joule meter; th
every 45,000 additional joules of energy.

The data is shown below.

Energy (J)	Temperature (°C)
0	20.00
45 000	30.71
90 000	41.43
135 000	52.14
180 000	62.86
225 000	73.57
270 000	84.29
315 000	95.00



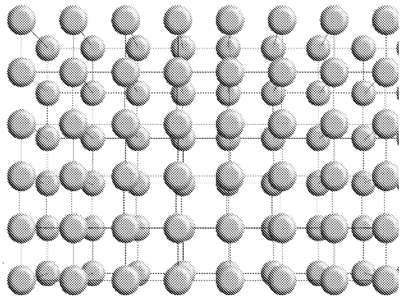
Task B

1. Describe the change in the temperature of the water in relation to the ener
2. Aluminium has a specific heat capacity of 900 J/kg/°C. If this experiment we aluminium, how would the gradient of the line on the graph **compare** to th

Specific latent heat

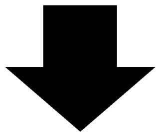
In both experiments described previously, the temperatures were controlled to e changed state, i.e. the water remained liquid and the aluminium remained solid.

What happens to the internal structure of a material as it changes state?



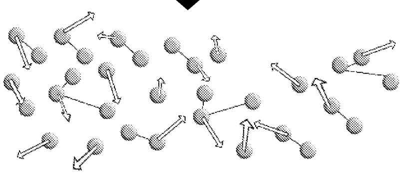
Solid: The molecules are in a close structur them. As they take in thermal energy they internal energy of the material.

Any thermal energy added is used to make Thus the temperature increases in a unifor



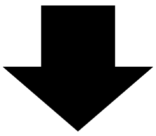
Melting

The thermal energy is used to break the bo liquid. There is no increase in temperature.



Liquid: There are still some bonds remainin substance.

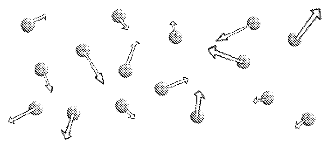
Any added thermal energy increases the m energy increases and so does the tempera



Boiling

The bonds are being broken.

The thermal energy is used to break the re become a gas. There is no increase in temp



Gas: Additional thermal energy increases t increasing the internal energy, which leads

During each change in state:

- there is **no change in temperature**
- the energy is being used to break the bonds during melting and boiling

When a material is cooling down – gas to liquid to solid – the opposite is true. A comes from the formation of the bonds not the slowing down of the particles.

The amount of energy used or released to change state is known as the **specific** l

This is measured in **joules per kilogram**, **J/kg**.

Latent heat of fusion: the amount of energy required for 1 kg of a material to ch with no change in temperature. (*Melting and freezing*)

Latent heat of vaporisation: the amount of energy required for 1 kg of a materia gas (or vapour) with no change in temperature. (*Boiling and condensing*)

Both are calculated using the same formula:

$$E = mL \quad \text{energy for change in state} = \text{mass} \times \text{specific latent heat}$$

The value of '*L*' is different for fusion and vaporisation for each material.

e.g. Water – $L_{(fusion)} = 334\,000\ J/kg \quad L_{(vaporisation)} = 2\,260\,000\ J/kg$

So, for 1 L (1 kg) of water to go from water to steam at 100 °C takes 2260 kJ of en

Worked example

How much energy in total has to be supplied to turn 0.1 kg of ice into steam at 10

To make the numbers easier to work with we will use kilojoules rather than joules

Melting ice to water

$E = mL_{(f)}$ where $m = 0.1\ kg$ $L_{(f)} = 334\ kJ/kg$

$E = 0.1 \times 334 = 33.4\ kJ$ (to melt the ice to water)

Heating water from 0 °C to 100 °C

$\Delta E = mc\Delta t$ where $m = 0.1\ kg$, $c = 4.2\ kJ/kg/°C$ and $\Delta t = 100$

$\Delta E = 0.1 \times 4.2 \times 100 = 42\ kJ$

Boiling water to steam at 100 °C

$E = mL_{(v)}$ where $m = 0.1\ kg$ and $L_{(v)} = 2260\ kJ/kg$

$E = 0.1 \times 2260 = 226\ kJ$

$Total = 33.4 + 42 + 226 = 301.4\ \underline{kJ}$

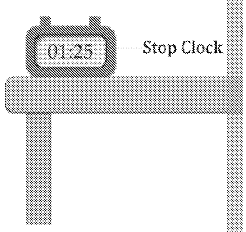
Note how most of the energy supplied (nearly 75 % of the energy) is actually just t than heating the water.

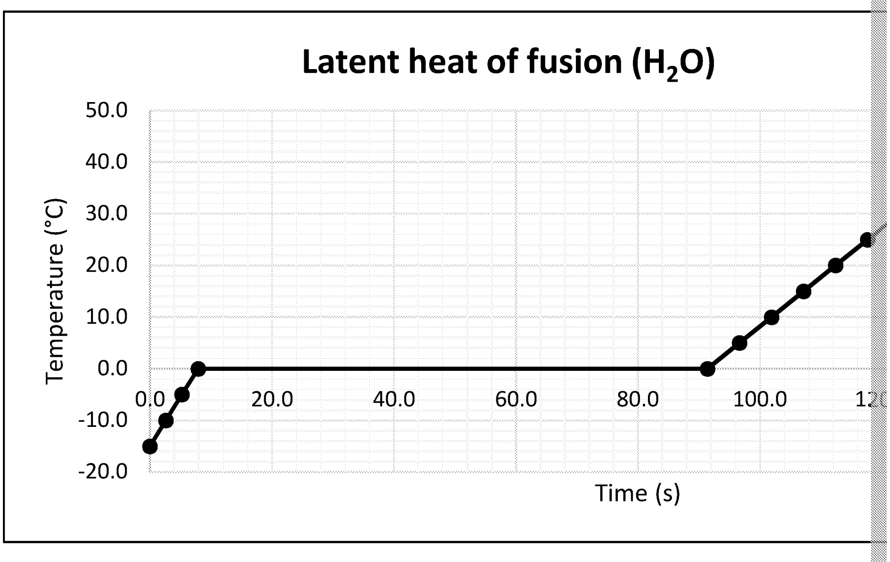
Observing latent heat

To observe the latent heat of fusion for water, a sample of ice can be gently heated and the temperature recorded over time.

To the right is an example of the equipment and set-up that can be used.

In this example, the heater and the thermometer were 'frozen' into the ice before the experiment began. The data from the investigation is shown below.





The period of time where the temperature remains on zero represents the time t
point any supplied energy from the heater is not changing the temperature of the

From the graph it is possible to calculate the latent heat of fusion.

The graph levels out at 0 °C after 7.9 s and remains at this temperature until 91.4
heater with 0.5 kg of ice.

Recall that energy = power × time (E = Pt) ∴ $E = 2000 \times (91.4 - 7.9) = 167\ 00$

energy = mass × latent heat of fusion

$E = mL_f$

$\therefore L_{(f)} = E \div m = 167\ 000 \div 0.5$

$= 334\ 000 \equiv 334$ kJ/kg – latent heat of fusion for water

Task C

The aforementioned investigation was continued until the water had boiled and
Use this information to calculate the latent heat of vaporisation of this water sa

Time (s)	Temp (°C)
133.4	40.0
138.7	45.0
143.9	50.0
149.2	55.0
154.4	60.0
159.7	65.0
164.9	70.0
170.2	75.0
175.4	80.0
180.7	85.0
185.9	90.0
191.2	95.0
196.4	100.0
763.5	100.0
764.0	105.0
766.5	110.0

Exam-style questions

1. a. Define the term latent heat of vaporisation.

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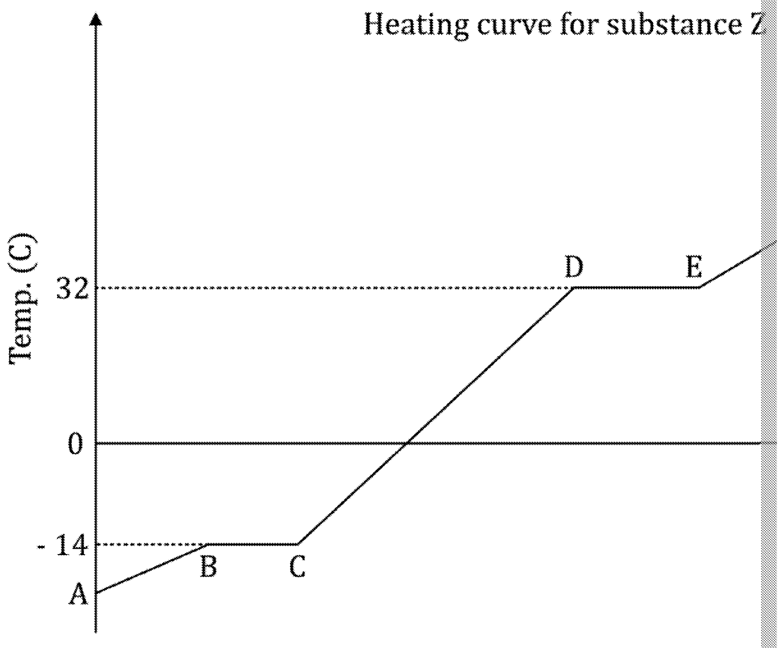
b. The graph below shows the temperature of substance Z as it is heated o



i. Explain what is happening to substance Z in sections **CD** and **DE** of t

Section **CD**: ....

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Section **DE**: ....

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ii. What is the melting point of substance Z?

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iii. What is the state of substance Z in section **EF** of the graph?

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c. Explain what effect the thermal energy supplied from the heater is havi[ng on] substance Z from section **AB** of the graph.

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2. A sample of stearic acid of mass 20 g is heated using a 60 W heater from 20 °

a. What apparatus could be used to measure the temperature of the stear

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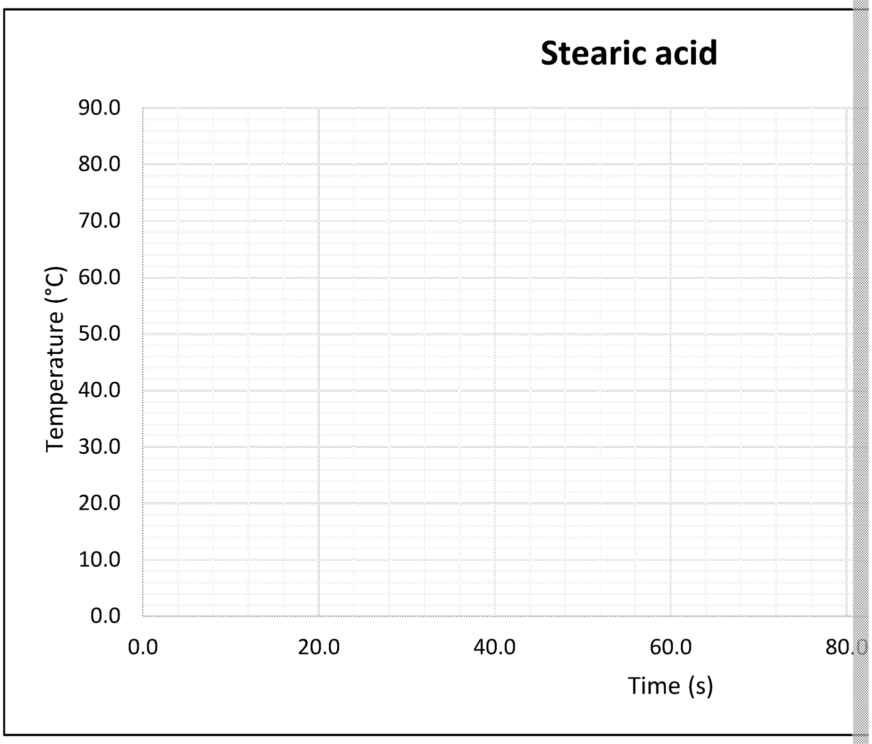
b. Suggest one piece of personal safety equipment that should be used wh this experiment.

....

c. The data from this investigation is presented in the table below.

Temperature (°C)	Time (s)
20.0	0.0
30.0	7.7
40.0	15.3
50.0	23.0
60.0	30.7
69.3	37.8
69.3	104.1
80.0	111.8

i. Use this data to plot a graph using the axes provided.



ii. From the data, state the melting point of the stearic acid. Justify th
from the graph.

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iii. Given that the stearic acid was heated using a 60 W heater, calculat
of the stearic acid. Show all your calculations.

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3. a. Define the term specific heat capacity.

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b. Compare the terms specific heat capacity and specific latent heat.

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End of paper

Chapter 6: Increasing the of a gas

Introduction

This section looks at the higher-level theory of how gases are affected by forces, to simple practical applications such as the bicycle pump.

There are further opportunities to practise using and manipulating equations and style questions that require the use of theory to be applied to specific real-world

Key ideas and concepts required for this chapter

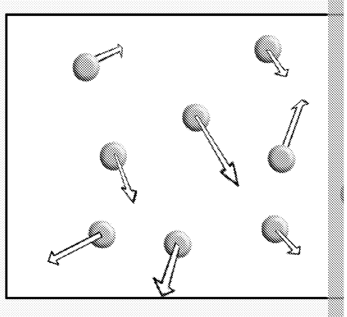
Work is the transfer of energy to a system by the application of a force. Work is

$(work = force \times distance\ moved \quad W = Fs)$

Pressure is a measure of the force applied to an object over a given area. Pressu

$(pressure = \frac{force}{area} \quad \rho = \frac{F}{A})$

Gas – has particles that are moving quickly and in a random manner. The speed of the particles increases with temperature. Particles of a gas collide with each other and the surfaces of any container they are in.

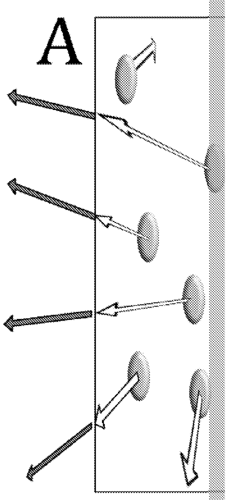


Pressure in a gas

Imagine a box containing a single gas. The box is sealed so that no gas can enter or leave; there is a fixed mass of gas in the box. It is at a constant temperature.

Look at side A.

A



The particles are moving randomly. When a particle collides with the side, it pushes on it, applying a small force that tries to move the wall outwards.

Although each collision creates only a small push, there are millions of particles so the total effect can be very large. The combined 'pushes' from the collisions creates a force spread out over the whole area of the wall.

A force over an area is pressure – $\rho = \frac{F}{A}$

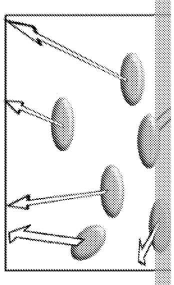
The pressure exerted on the walls depends on:

- the number of collisions } Force
- the speed of the collisions } Force
- the **area** of the wall

What would happen to the pressure if only the size of the box was changed?
The mass of gas (number of particles) and the temperature (speed of the particles

Two key factors have changed.

1. The area of wall '*A*' has reduced.
2. The space for the particles to move about in has reduced, increasing the chances of them colliding with the wall.



> **Question**: What two things (factors) have **not** changed?

The volume has reduced, meaning there are more collisions, and the area of the wall is smaller; therefore, the pressure has increased.

In a gas the pressure is inversely proportional to the volume. As the volume goe
As the volume goes up, the pressure goes down.

This is expressed as the formula:

$$pV = constant \quad (pressure \times volume = constant)$$ This is known a

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Worked example

A diver begins an ascent from 20 m to the surface holding a balloon with a volume of 1 L. What would the volume of the balloon be on the surface?

> **Did you know?**
> Boyle's law explains
> hold their breath whe
>
> If they did, as they c
> expand and could c

At 20 m the pressure is approx. 303 kPa

At the surface it is approx. 101 kPa

$$At\ 20\ m \quad pV = constant = 303\ 000 \times 1 = 303\ 000$$

At the surface, V must still equal 303,000 but the pressure is now only

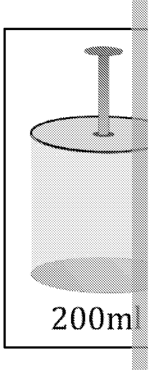
$$so \quad pV = 303\ 000 \quad \therefore \quad V = 303\ 000 \div 101\ 000 = 3\ L$$

The pressure dropped by a factor of three; therefore, the volume increased by a f
product of the two would remain constant.

Task A

a. A 200 mL syringe is sealed at one end. Assuming that the temperature remains constant and that the gas in the syringe is at atmospheric pressure (approx. 101,000 Pa), what would be the pressure of the gas if the syringe plunger was used to reduce the volume of the gas to 50 mL?
Show your calculations.

b. What two factors have changed in this system that result in this change in the pressure of the gas in the syringe?



Work and pressure in a gas

The idea that as the volume of a gas is reduced the pressure goes up in proportio assuming nothing else is allowed to change can easily be felt if you squeeze a balloon – if you get the pressure high enough the balloon bursts.

In the real world we can't simply ignore the effect that the force we are applying t the balloon or the syringe is having on the gas particles. Any time a force is applie we are doing ***work*** – that is, we are **transferring energy**.

That energy has to do something – it can't be destroyed (first law of thermodynamics – more on this in the A Level Bridging Section).

Question: What happens to a substance if you add energy to it? (Not sure, then s

Answer: **Adding energy** to a system, like a gas, results in an **increase in the intern** another way, the particles move faster – meaning **the gas heats up**.

Task B

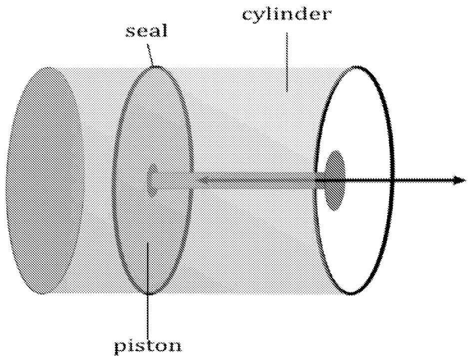
Grab a bicycle pump – plug the end with a bit of Blu-Tack® or just put your finge down quickly and see what happens to the temperature of the pump.

Rearrange these statements to explain why this happens.

- This results in an increase in the temperature of the gas in the bicycle pum
- The plunger moves
- Work is force in a given direction
- The transferred energy increases the internal energy of the gas particles
- Work transfers energy as a result of the force
- A force is applied to the plunger
- This results in the transfer of the force

Exam-style questions

1.



A solid cylinder has a piston placed into it, shown above. The piston has an a
moving past the piston's head. The piston is free to move.

On the ground, at sea level (0 m), the cylinder contains 500 mL of gas.

a. The open end of the cylinder allows air to push on the outside of the pis
101 kPa at sea level.

Explain how the air creates pressure on the outer surface of the piston.

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b. The pressure of the gas on the inside of the cylinder is also 101 kPa at se
the open cockpit of a small plane and flown to a height of 3000 m. At th
and outside the cylinder has reduced to 69 kPa.

i. What will be the new volume of the air inside the cylinder behind th
this altitude?

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ii. Explain why there has been a change in the volume of the gas in the

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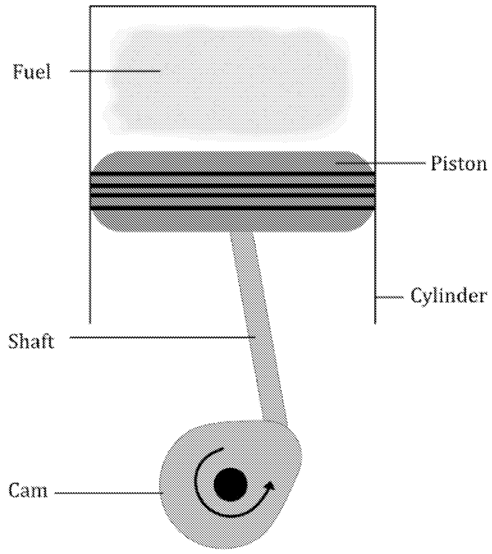
2. The diagram below shows a simplified cross section of a standard diesel eng



Fuel vapour is injected into the cylinder at the top. As the cam turns, the sha
reducing the volume at the top of the cylinder, which contains the fuel vapo

When the volume at the top is at its minimum, the fuel vapour ignites and d

a. State what happens to the pressure of the fuel vapour as the piston mo

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b. When the fuel vapour reaches 80 °C it will ignite. Explain why the fuel i
the piston rises up the cylinder.

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3. A balloon is filled with 1.5 L of air at the surface; a diver then takes it down t
pressure is double that on the surface.

a. What will happen to the volume of air inside the balloon as the diver de

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b. What will be the volume of air inside the balloon at 10 m? Justify your a

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End of paper

Chapter 7: Atoms and nuclea

Introduction

This chapter recaps the basic structure of atoms so that you can understand thei
properties of the subatomic particles and the properties of the three types of rad
the decay of radioactive isotopes.

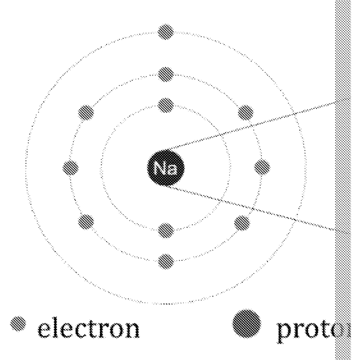
A detailed understanding of all these concepts is required for Chapter 8, which co
equations and half-lives.

Subatomic particles – the basics

Particle	Relative mass	Charge	Location in atom
Electron	0	-1	Orbit
Proton	1	+1	Nucleus
Neutron	1	0 (no charge)	Nucleus

Atomic structure

In all atoms the protons and neutrons are found in the nucleus, and the electrons in orbits around the nucleus.



As the electrons have no effective mass, all the mass of the atom is concentrated in the nucleus.

Each proton and each neutron has a mass of 1; therefore, the mass of an atom is the total of all the protons and neutrons, known as the **mass number**. For sodium this is 23.

The **atomic number** is the number of protons. For sodium this is 11.

This is written as $^{23}_{11}Na$ $\quad ^{Mass\ number}_{Atomic\ number}Symbol$

To find the number of neutrons in an atom, subtract the atomic number from the

neutrons = mass number – atomic number

The electrons around the atom are not significant in the study of nuclear physics,

Worked example – how many protons and neutrons are found in neptunium 23
Neptunium $^{237}_{93}Np$
Atomic number = 93 ∴ there are **93 protons**
Number of neutrons = mass number – atomic number = 237 – 93 = **144 neutrons**

Task A

How many protons and neutrons make up each of these isotopes?

Strontium $^{87}_{38}Sr$ Lead $^{208}_{82}Pb$ Th

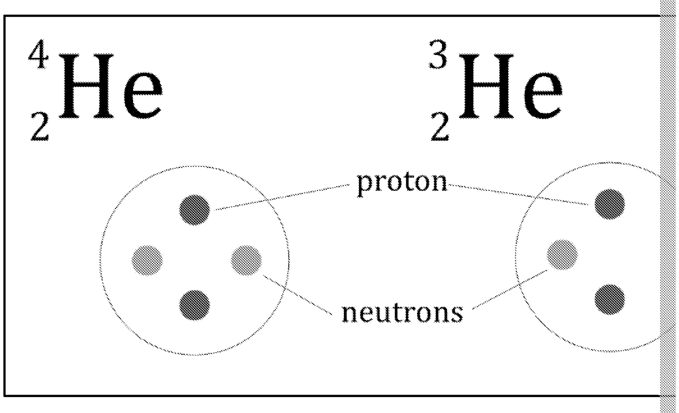
Isotopes

All atoms of the **same element** always have **the same number of protons**.

If the number of protons in a nucleus changes, the atom becomes a different ele
in understanding nuclear decay. One element can change (decay) to another ele
An element can have atoms with **different numbers of neutrons**. This makes the
are all the same element.

These lighter/heavier versions of an element are known as **isotopes** of an eleme

Examples
Isotopes of helium



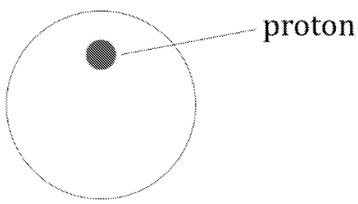
There are two naturally occurring isotopes of helium: helium 4 and helium 3.

- Both contain two protons
- Both have the same atomic number
- They have different masses – helium 4 is heaver then helium 3

Task B

Draw your own diagrams for these isotopes of hydrogen. The most common is
for you.

$^{1}_{1}H$ $^{1}_{2}H$ $^{1}_{3}$

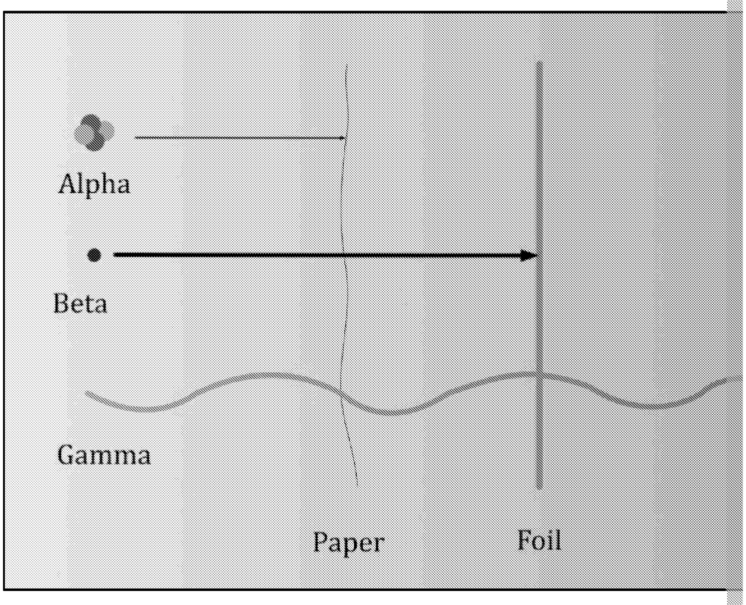


Many larger isotopes are made unstable as a result of the additional neutrons. T
mass to become more stable. This is known as nuclear decay.

This results in the release of radiation in the form of **alpha (α)**, **beta (β)**, **gamma**

Properties of alpha (α), beta (β), gamma (γ) radiation

Radiation	Charge	Structure	Penetration in air	Penet ma (stop
Alpha	+2	Helium nuclei (2 protons + 2 neutrons)	Low (few cm)	Paper
Beta	-1	Fast-moving electron	Medium (few m)	Metal f
Gamma	None	Electromagnetic radiation (beyond X-rays in the EMS)	High	Lead, c



[2] Ionisation power indicates how easily the type of radiation can remove electrons from (charged). This is important as it can affect organic compounds such as DNA and prote health if absorbed by the body.

Exam-style questions

1. Nitrogen is the most abundant gas found in the atmosphere. It is represente by the following symbol:

$$^{14}_{7}N$$

a. i. What is the atomic mass of nitrogen?

....

ii. Using the information provided, state the number of neutrons in a

....

b. The gas chlorine is a mixture of two isotopes:

$$^{35}_{17}Cl \text{ and } ^{37}_{17}Cl$$

i. What is meant by the term isotope?

....

....

ii. The following table contains information comparing the atomic stru

Isotope of Cl	Number of electrons	Number of protons	Nu ne
^{35}Cl	17		
^{37}Cl		17	20

Complete the table.

2. Uranium 235 ($^{235}_{92}U$) is a radioactive element that undergoes nuclear decay t thorium 231 ($^{231}_{90}Th$). As it does so it emits alpha (α) radiation.

a. What subatomic particles have been lost from the uranium that have re element of thorium?

....

b. Describe the structure of an alpha particle.

....

....

....

....

c. i. Explain why alpha radiation is potentially harmful to people.

....

....

....

....

ii. Alpha radiation can be stopped by a single sheet of paper, but beta this. State the two differences in the properties of alpha and beta r difference in their penetration properties.

....

....

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....

End of paper

Chapter 8: Nuclear equ and half-lives

Introduction

Nuclear decay occurs when unstable isotopes release subatomic particles and en more stable.

In this chapter you will have a chance to look at some common alpha and beta d these are represented as equations. These take the form of a 'chemical' style eq half-lives is also covered. This is a topic that candidates often find challenging in to look again at the theory and use data from graphs to calculate the half-lives of A reminder of the properties of alpha (α), beta (β) and gamma (γ) radiation is cov familiar with these, take a moment to review this and keep the final table handy

Nuclear decay and nuclear equations

An **isotope** is an atom of an element with **different numbers of neutrons**.

Isotopes of the same element have the **same atomic number** (protons) but **diffe** (protons + neutrons).

Examples of isotopes

$^{12}_{6}C\ -\ carbon\ 12\ (common\ and\ stable)$ $^{14}_{6}C\ -\ carbon\ 14\ (less\ comm$

$^{230}_{90}Th\ -\ thorium\ 230\ (radioactive)$ $^{234}_{90}Th\ -\ thorium\ 234\ ($

For some isotopes these additional neutrons add additional energy and forces that means that at random points in time they will emit (give out) radiation to try to be

Some isotopes do this in a single step – carbon 14, for example, decays in a single Uranium 235, however, undergoes a number of decay steps until it eventually fo

Alpha decay (α – helium nuclei – ${}^{4}_{2}He$)

Radon (Rn) is a common gas found in areas with granite rocks; it has three comm

${}^{211}_{86}Rn$ ${}^{220}_{86}Rn$ ${}^{222}_{86}R$

All of them are radioactive – radon 220 and radon 222 decay by emitting an alpha

Example

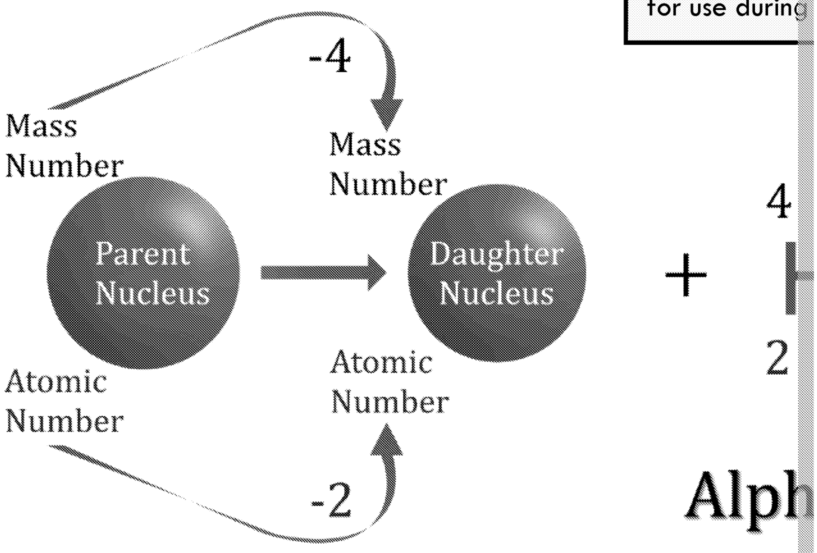
Radon 220 decays to polonium 216 plus an alpha particle.
The decay equation for this is:

$$ {}^{220}_{86}Rn \rightarrow {}^{216}_{84}Po + {}^{4}_{2}He $$

Did you kno
Polonium was
discovered by
there. She wa
Nobel Prizes –
Chemistry in 1

She also inve
for use during

General rule for alpha decay:



In the GCSE exam you **do not** need to know which element is produced by the de
exam question. However, it's very easy to work out – just look up the correct ele
the atomic number of the daughter nucleus.

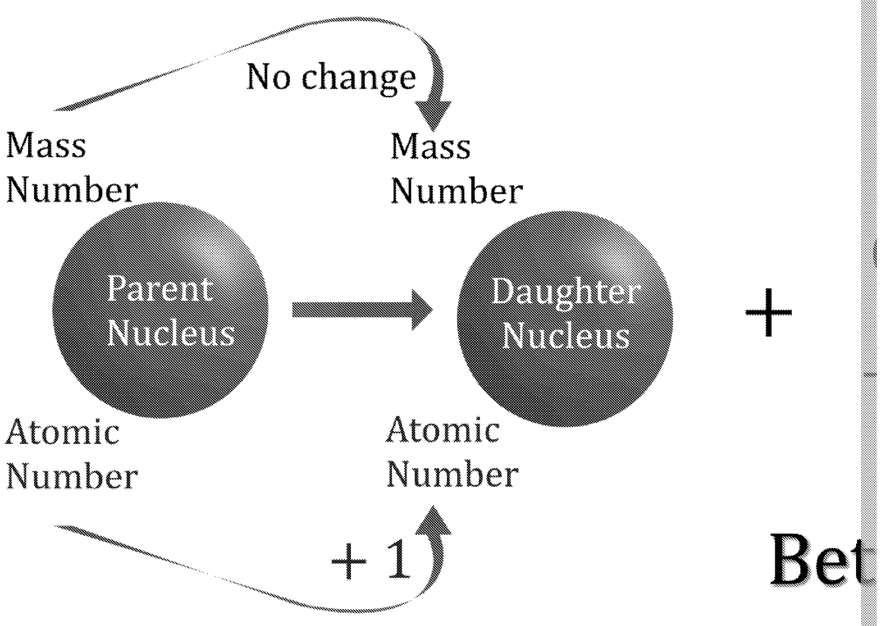
Task A

Write an alpha decay equation for each of the following:

1. Radon 222
2. Uranium 234 (U, atomic number 92) becomes an isotope of thorium (Th)
3. The thorium isotope becomes an isotope of radium (Ra)
4. The radium isotope decays by alpha decay. What does it become? Give th

Beta decay (β – fast-moving electron – $^{0}_{-1}e$)

Beta decay results in a new element being formed by the loss of an electron fron
As electrons have no mass, the **mass number** of the parent nucleus and the daug
the **atomic number increases by 1**.



Example 1

Carbon 14 is a common isotope of carbon found in our atmosphere as CO_2. It ma
part of our biochemistry alongside the more common, and stable, carbon 12. Ca
by beta (β) decay.

$^{14}_{6}C \rightarrow ^{14}_{7}N + ^{0}_{-1}e$ Carbon 14 becomes nitrogen plus a beta particle.

Some students think beta decay isn't logical; how can you *lose* an electron but th
The answer is simple… (**You *DO NOT need this for the exam***, but it's good to kno

During beta decay, a neutron (electrically neutral) gives out an electron (negative
particle – a proton. As the electron has no mass, the mass number stays the sam
from a neutron we have made a proton – so the atomic number goes up. See, sin

This also tells us that protons, neutrons and electrons are not really separate part
other particles. (This subatomic physics is part of A Level study.)

Example 2

Thorium 234 undergoes β decay to become protactinium:

$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}e$

Task B

1. Provide a β decay equation for each of the following:
   a) Hydrogen 3 (H, atomic number 1) to an isotope of helium
   b) Caesium 137 (Cs, atomic number 55) to an isotope of barium

Half-lives

Every radioactive isotope eventually decays and gives out radiation (α, β, γ); over the mass of the isotope.

How long it takes to reduce in mass varies with each isotope – some decay very rap geological time (millions of years). To compare these rates of decay we use a meas

Half-life is the amount of time needed for a mass of a radioactive isotope to re

Examples

1 kg of carbon 14 will reduce to 0.5 kg of carbon 14 in 5730 years, so the half-life (The other 0.5 kg has turned into nitrogen gas and mixed with the air.)

The half-life of radon 222 is only 3.82 days, so 1 kg of radon 222 will decay to lea 19 hours and 41 minutes.

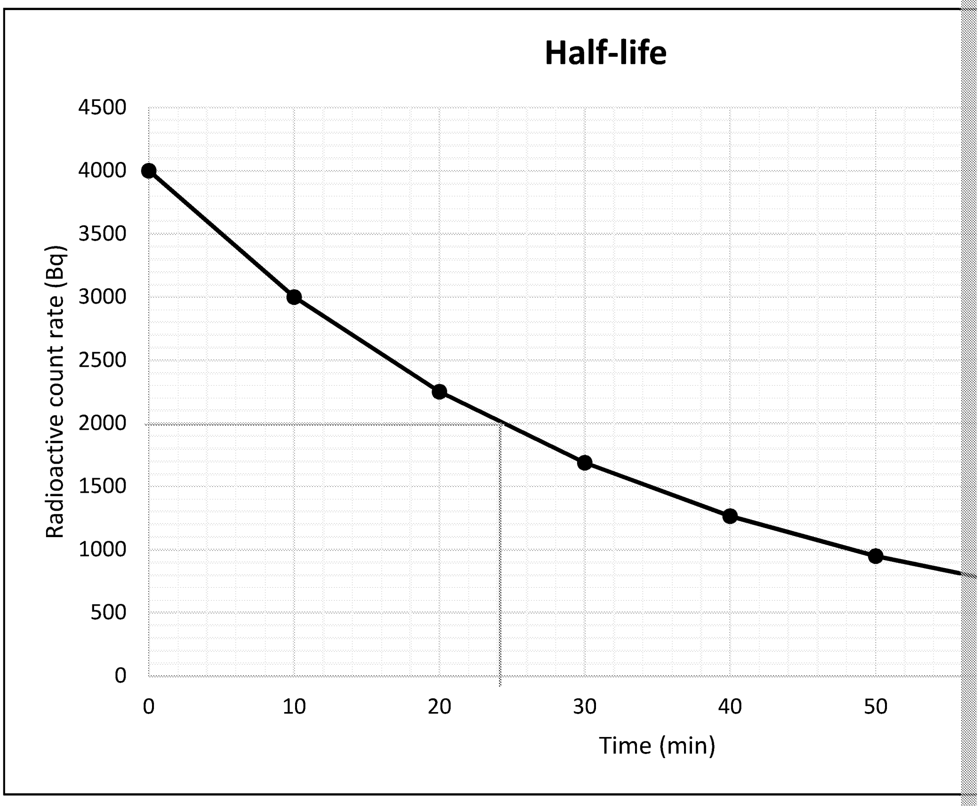
Measuring half-lives

Although it would be possible to sit and measure the loss of mass of radon 222 a to ensure accuracy and repeatability, work out the half-life, it might take a few w However, doing that for carbon 14 would be impossible (in practical terms).

To measure half-lives the mass is not normally considered; instead, the amount o using a Geiger counter (a Geiger–Müller tube connected to an electronic counter) number of detected emissions per seconds (becquerels, Bq).

Example

A sample of a radioactive material was monitored with a Geiger counter for a per count rate in becquerels was recorded every 10 minutes. A graph of the data is s



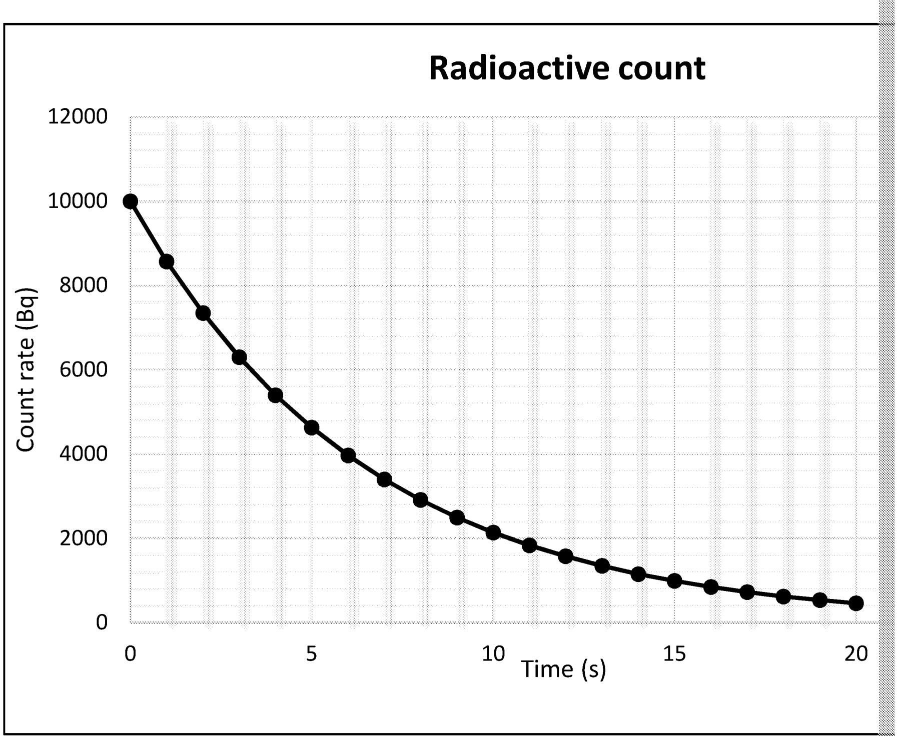
The count begins at 4000 Bq. The time taken for this to drop by half, to 2000 Bq,

Therefore, the half-life of this isotope is 20.4 minutes. This can be confirmed by l
half-lives) – the count is now 1000 Bq (half of 2000).

Half-life can also be defined as the time taken for the radioactivity of a mass of a

Task C

The graph shows the count rate for an isotope – use this data to find the half-li

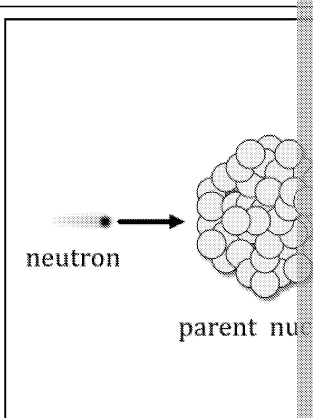


Nuclear fission and fusion

- **Fission** means to divide or **split**
- **Fusion** means to **join**

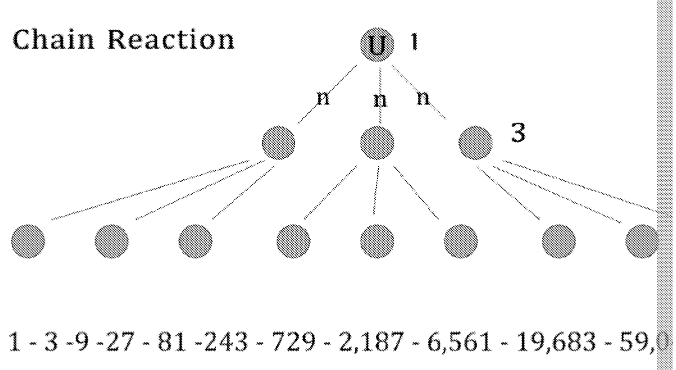
Fission

Many **large unstable nuclei** can **split into two smaller more stable nuclei** in the process of **nuclear fission**. This can occur naturally in some isotopes, but it is rare. Fission can be started by 'firing' a fast-moving neutron at a large nucleus such as uranium.



Fission **produces gamma (γ) radiation** and because **all the products of the fission process have kinetic energy** this increases the internal energy of the material, leading to a rise in temperature and the release of thermal energy. This thermal energy can be used to heat water to make steam which in turn can drive a turbine to make electricity. This is the basis of a nuclear power statio

The same energy can also be released in an uncontrolled fashion to produce a nucle



The number of nuclei undergoing fission increases ra

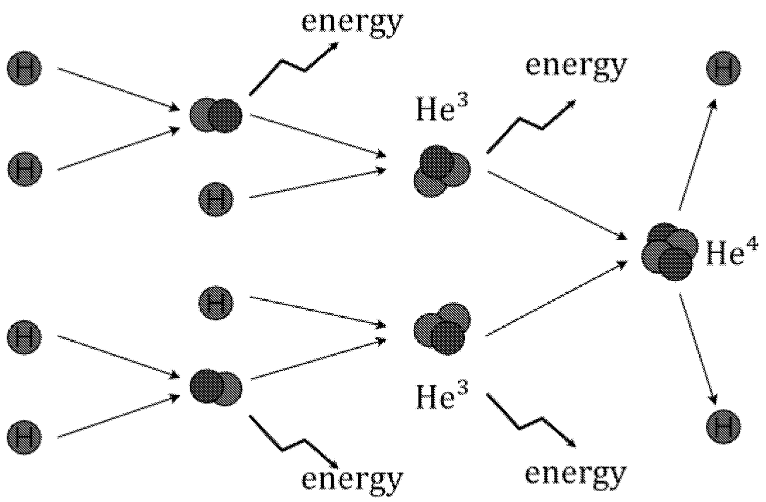
If left uncontrolled, one neutron will cause the fission of one nucleus, but this rel in turn cause the fission of three more nuclei; each of these does the same, and v millions all releasing their energy in a fraction of a second. This happens in a nuc reactor, two of the three neutrons are absorbed by a control material, so the fissi the energy is released in a controlled and gradual fashion.

Important: Do not confuse nuclear fission and nuclear decay. This is a common e
Decay – naturally occurring; one parent nucleus produces one daughter nucleus.
Fission – generally artificial; one parent nucleus results in two daughter nuclei. γ

Fusion

In this process small nuclei are joined together to form larger nuclei and in the pr energy. This occurs naturally in all stars, including our Sun.

Hydrogen nuclei (protons) are forced together to form a helium nucleus. This is w light and heat.



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Scientists and engineers are developing fusion reactors that will one day provide e seawater and produce a harmless but useful 'waste' of helium. This would be ver The fusion process needs to be held inside a magnetic field as it is so hot. This ta challenge is to make the process produce more energy than it uses.

The UK plans to have a prototype fusion reactor working commercially by 2040.

It plans to hold the superheated fusion material in a magnetic field shaped like a c normal doughnut shape. UK scientists believe this will allow their reactor to prod making it the world's first commercially viable fusion reactor!

Exam-style questions

1. Americium has two isotopes. The most common isotope is shown below.

$$^{243}_{95}Am$$

   a. What is the mass number of this isotope of americium?

   ....

   b. What is meant by the term 'isotope'?

   ....

   ....

   ....

   ....

   c. Americium 243 is very stable; however, americium 241 is unstable with
   It decays by alpha decay to form an isotope of neptunium (Np).

   i. Draw a decay equation to show this nuclear decay.

   ii. The alpha particles emitted from the decay of americium 241 are use
   Suggest one reason why these particles of radiation do not cause any

   ....

   ....

2. A rare sample of the metal francium (Fr) is studied to measure its radioactivit
electrons is detected coming from the sample. Analysis also shows a build-u
of the study.

   The isotope of francium used is known to have 87 protons and 136 neutrons

   a. Give the atomic number and the mass number of the isotope used in th

   i. Atomic number: ....

   ii. Mass number: ....

   b. i. Draw the decay equation for the nuclear decay of francium.

ii. What type of nuclear decay does this isotope of francium undergo?

....

....

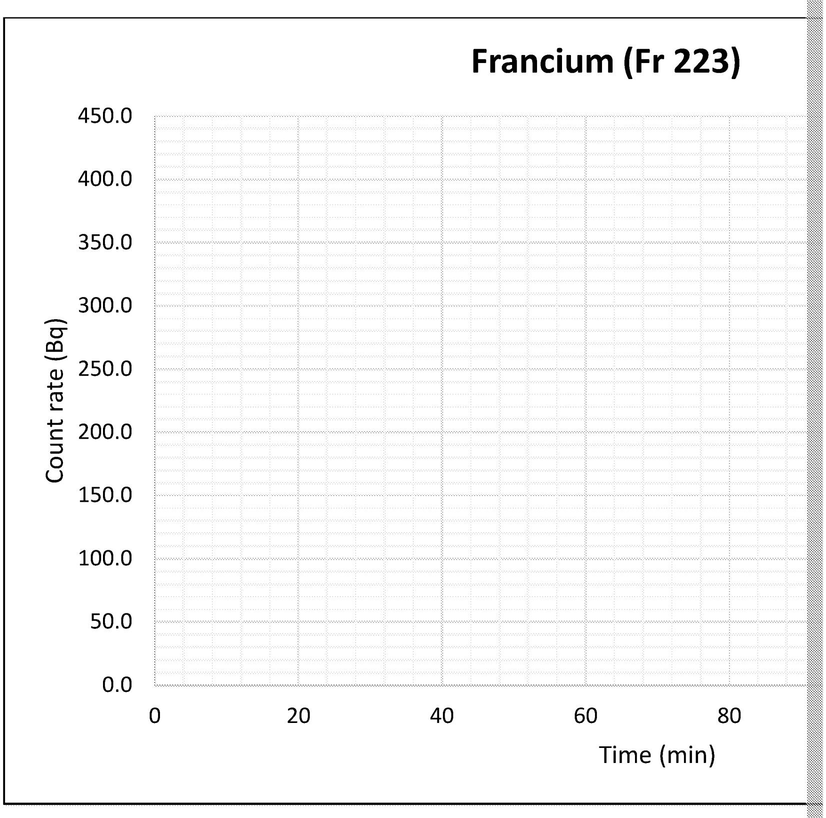
....

....

c. As part of this study the level of radioactivity was measured and recorde of two hours. The data is shown in the table below.

Time (min)	Count rate (Bq)
0	420.0
10	306.5
20	223.7
30	163.2
40	119.1
50	86.9
60	63.4
70	46.3
80	33.8
90	24.6
100	18.0
110	13.1
120	9.6

i. Use the graph provided to plot the data. The axes and scales have



ii. Draw a non-linear line of best fit for the data.

iii. Use the graph to find the half-life of francium 223. Show your wor graph to find your answer.

iv. What apparatus could be used to measure the count rate in this ex

....

3. Uranium 235 is a heavy element with large unstable nuclei that is used in nu electricity. It is also a naturally radioactive material.

$$^{235}_{92}U$$

The chemical symbol for this isotope of uranium is given above.

a. i. Complete the decay equation below for this isotope of uranium.

$$^{235}_{92}U \rightarrow \ ^{231}_{90}Th \ +$$

ii. State what type of nuclear decay is represented by this equation.

....

b. During nuclear fission, the nuclei of this isotope undergo a change repre equation below.

$$^{235}_{92}U + \ ^{1}_{0}n \rightarrow \ ^{141}_{56}Ba + \ ^{?}_{36}Kr + 3\ ^{1}_{0}n$$

Where n = a neutron.

What is the mass number of the krypton (Kr) isotope in the equation?

c. Electricity can be generated from the process of nuclear fission and is us fusion is not currently used as a power source.

i. Compare the processes of nuclear fission and nuclear fusion.

....

....

....

....

....

....

....

....

ii. State one reason why nuclear fusion is not currently used commerc of electricity.

....

....

End of paper

Chapter 9: Resultant f

Introduction

This chapter looks at forces, how they can be combined to produce a resultant fo
represented in vector diagrams. The use of these diagrams is explained with exa
measure forces acting at right angles to each other. As this process involves the d
essential that you have a pencil, a protractor and a ruler with at least centimetre
chapter.

Reminder

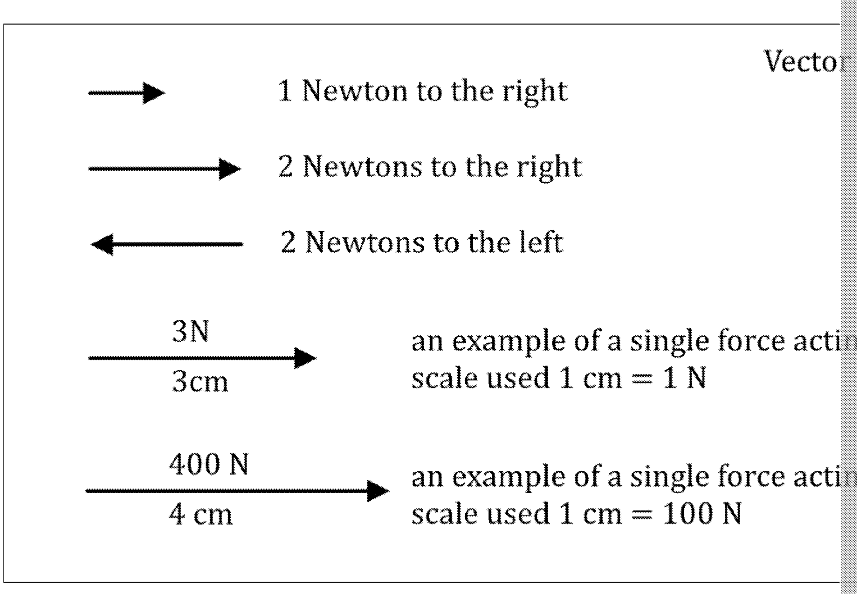
- Scalar – a quantity with magnitude (size) only – e.g. speed and distance.
- Vector – a quantity with both magnitude and direction – e.g. forces, velocity
- ➲ Question: Speed is the scalar equivalent of the vector velocity. What is the v

Forces result in the motion of objects; they **are vector quantities**.

A force has a magnitude given in newtons (N) that acts on an object in a stated

Example: Gravity at Earth's surface acts on a 1 kg mass with a force of 9.81 N dow
towards the centre of Earth).

Representing forces graphically



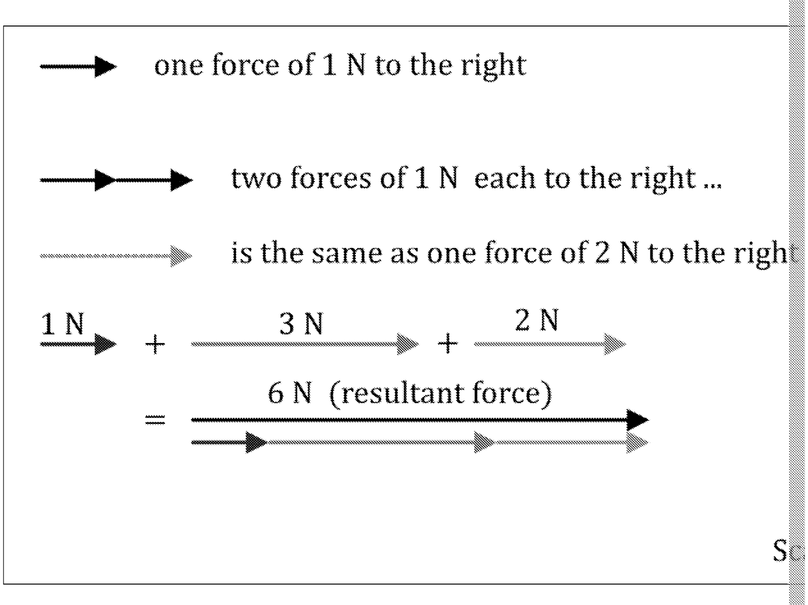
Forces are drawn as arrows where the length of the arrow shows the magnitude
direction of action.

Note in the diagram above that the arrows are drawn to scale. The top arrows u
the last arrow uses 1 cm = 100 N.

Combining forces

When a single force acts on an object it will move in the direction of that force; th depend on the magnitude of the force, as stated in Newton's laws of motion.

When there is more than one force acting on the object, the forces will be combi overall force, known as the **resultant force**.



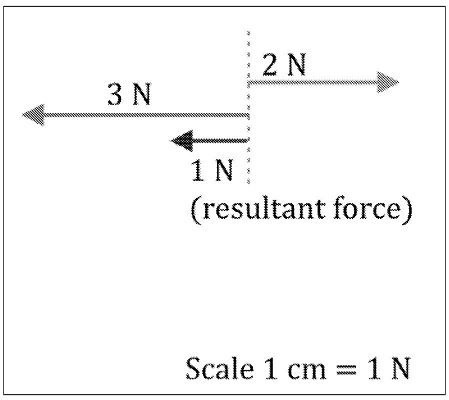
As shown in the examples above, when the forces act in the same direction, they give a larger overall force still acting in the same direction as each of the individu

Example

Most small passenger planes have two jet engines – each one produces 90,000 N forwards. This means they produce a resultant force of 180,000 N forwards actin

It is very rare for all the forces to be acting in the same direction. When an obje air resistance (also called drag) or water resistance acting on the object where it i air, etc.

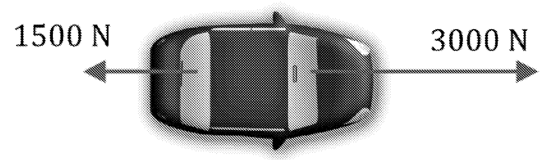
Forces acting in **opposite directions are subtracted** from each other.



In this example a **2 N force to the right** and a **3 N force to the left** produce a **resu** This can be written as +2 N + (-3 N) = -1 N where '+' is right and '-' is left.

The effect would be the same as a single 1 N force to the left – the object will mo

Example



Scale 1 cm = 1000 N

A car's engine produces a forward driving force of 3000 N. The friction between t
air resistance is 1500 N.

The resultant force on the car is:

+3000 N + (-1500 N) = +1500 N where '+' is right and '-' is left

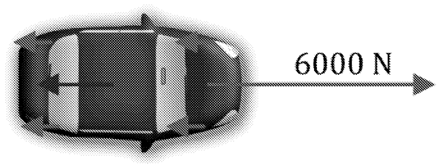
There is a resultant force of 1500 N to the right. (The car will be accelerating to th

Task A

1. A Boeing 747 is lined up for take-off on the runway at Stansted Airport wit
   Its four identical engines each produce 252,000 N of thrust at take-off.

   Ignoring friction and air resistance, what is the resultant force acting on the

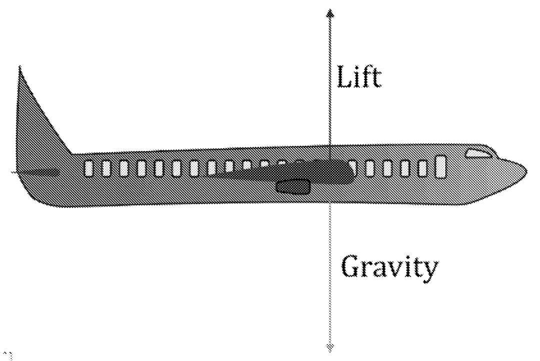
2. What is the resulant force on the car shown below?



← Air resistance (2000 N)

← Friction (500 N)

Balanced forces



Lift = Gravity therefore the resultant force =

The plane shown in the diagram above has two opposing forces acting on it: gravity (weight) of the plane acting downwards, and the force of lift generated from the flow of air over the wings.

When the plane is in level flight, the forces of lift and gravity are balanced – they are equal. So when they combine to give a resultant force, the sum of these is equal to zero.

This is not the same as saying there is no force; both forces are present, but they cancel each other out to give a **0 N resultant force**.

Did you know?
All planes are de
the centre of gra
of the plane.

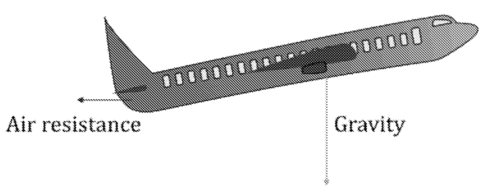
Should the engin
and gravity will p

However, the cen
automatically des
angle.

A commercial pla
to London from a
way with no engi

Task B

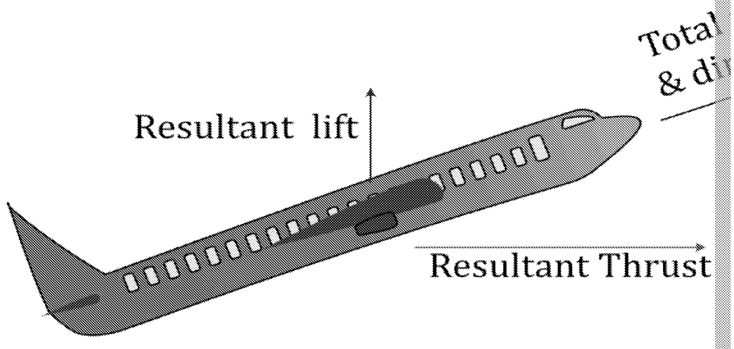
Planes in flight have four main forces acting on them: thrust (forward), gravity (do
(backward), lift (up). For the plane shown below, draw on the missing forces as ar
scale matters.)

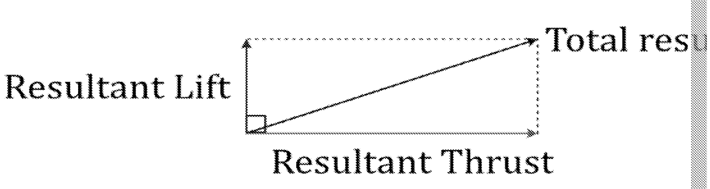


Air speed = 145 m/s

Forces at an angle

A resultant force can be created by the combination of forces acting at an angle t
the resultant force will be in a different direction from either of the two individu





When a plane is ascending, the angle of the climb and the forward velocity of th combination of the lift and the thrust. These two forces act at right angles to eac acts at an angle determined by finding the diagonal of the vector diagram.

> ***Note:*** *it is possible to calculate the magnitude and the direction of the resultant Pythagoras' theorem as long as the angle between the forces is 90°. This is not example of how to do this is shown – if you enjoy the maths of physics you can l to be able to do it in the exam.*

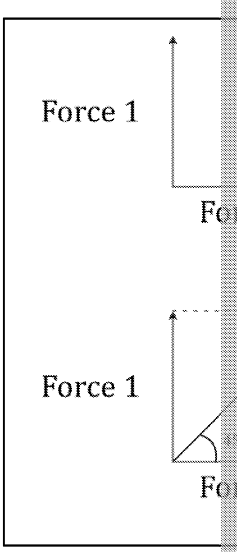
Finding the resultant force of two forces at right angl

A vector diagram is used to find the resultant force when two forces are acting at an angle to each other.

The two individual forces are drawn to scale meeting at the base of each force arrow.

The parallelogram (square or rectangle) is completed by drawing in the parallel sides to the two forces.

The diagonal created by this parallelogram is the resultant force.

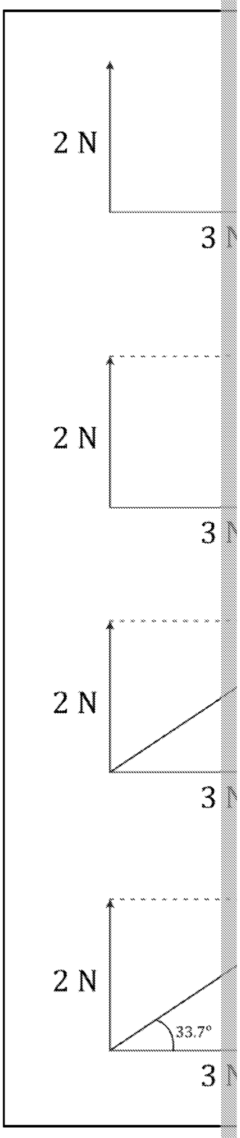


Example
Note that for this exam the forces will always be at 90° to each other.

Example of how to calculate the resultant force. (NOT needed in the exam.)

<u>Magnitude</u> (Pythagoras' theorem)
R = resultant force
F_1 = *horizontal force* F_2 = *vertical force*
$R^2 = (F_1)^2 + (F_2)^2$

$R = \sqrt{(F_1)^2 + (F_2)^2}$
$R = \sqrt{2^2 + 3^2}$
$R = 3.61\ N$



Angle of resultant force

Tan(Θ) = $F_2 \div F_1$ *(opposite / adjacent)*
Θ = $\text{Tan}^{-1}(F_2 \div F_1)$
Θ = $\text{Tan}^{-1}(2 \div 3)$
Θ = 33.69°

This is not required for the exam but is useful preparation for further study of p

Task C

Use a vector diagram to find the resultant force created by a 25 N force acting u
acting horizontally to the right. Use any suitable scale, which should be include

Exam-style questions

1. Forces are examples of vector quantities.

   a. Which of the following provide the information needed to fully describe
   Choose all that apply.

   - ☐ Magnitude
   - ☐ Altitude
   - ☐ Direction
   - ☐ Displacement
   - ☐ Distance

   b. Draw a simple vector diagram to represent a force of 50 N acting to the
   Use a scale of 1 cm = 10 N

   c. Two teams are competing in a tug-of-war. Team A is pulling to the left
   Team B is pulling to the right with a combined force of 200 N.

   i. Draw a simple vector diagram to represent the forces in this tug-of-
   have used for this diagram.

   ii. What is the resultant force in this tug-of-war?

   ....

   ....

   iii. Which team is currently winning in this game? Explain your answer

   ....

   ....

   ....

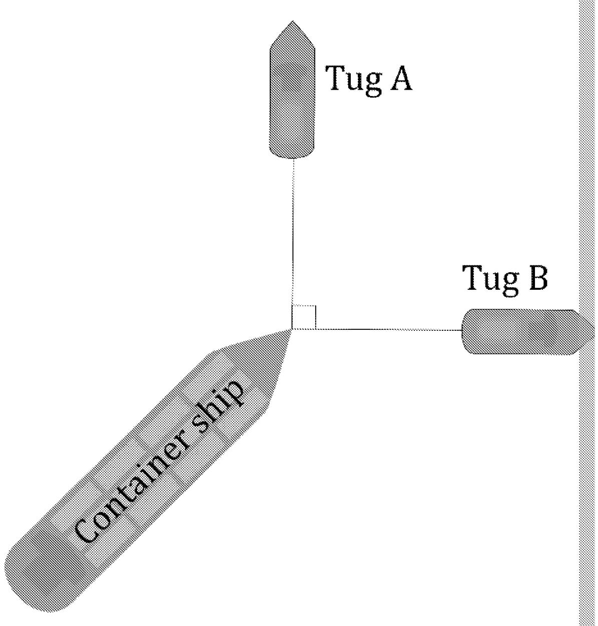
   ....

   d. If team B pulls harder and increases their combined force to 250 N to th
   on the resultant force?

   ....

   ....

2. Two tugs (A and B) are pulling a large container ship into port as shown in th



Tug A produces a pulling force of 2500 N at 90° to tug B that produces a pull

a. i. Draw a vector diagram to represent this situation. Include in the di resultant force and the scale you have used.

ii. State the magnitude and direction of the resultant force.

....

....

End of paper

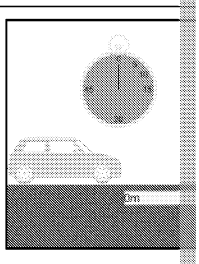
Chapter 10: The distanc relationship

Introduction

When objects are in motion they move over a distance in space during a certain a between the distance moved and the time taken is described by speed or velocity changing is acceleration. All of these quantities can be represented as graphs.

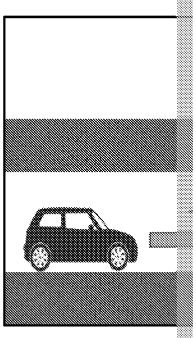
This chapter will start with a brief refresher on speed, velocity and acceleration, b practise the drawing and use of distance–time and velocity–time graphs. Reports higher-level candidates find these hard to do in the exam, especially finding the a graph. So these will be the skills to practise in this chapter. You will be drawing a a pencil and ruler ready.

Speed and velocity



Speed is a measure of the time taken to cover a given distance. It is a scalar quantity so there is no direction given. In the example, right, the car moves 100 m in each 5-second interval, given a speed of 20 metres per second (20 m/s).

$speed = distance \div time$ in metres per seconds (m/s)



Velocity is speed in a given direction and is therefore a vector.

These two cars are moving at the same speed but in opposite directions.

They have the same magnitude of velocity but different directions.

In this example, this is shown by the + and – values.

Equation: this is given as $distance = velocity \times time \quad s = vt$

This can be rearranged to $v = \frac{s}{t}$

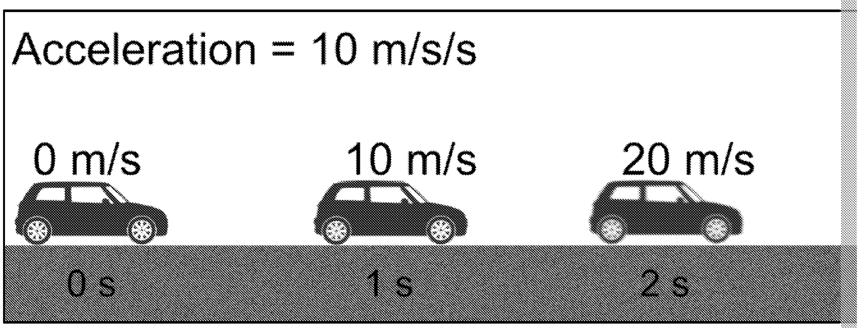
Examples

i. A car travels at 20 m/s for 10 minutes. How far has it travelled?
   $s = vt \quad \therefore \quad s = 20 \times (10 \times 60) = 12\,000 \text{ m or } 12 \text{ km}$

ii. A car travels along a 5 km section of a motorway in three minutes. What is its velocity?
   $s = vt \;\therefore\; v = s \div t \quad v = 5000 \div (3 \times 60) = 27.78 \text{ m/s}$

Acceleration is defined as the rate of change of velocity – this means **how quickly** Acceleration is also a vector.

Acceleration measures how quickly an object is speeding up (positive acceleratio acceleration – deceleration).



In this example, the car increases its velocity by 10 m/s every second.

Acceleration is measured in metres per second per second (m/s/s).

$$a = \frac{\Delta v}{t} \quad or \quad acceleration = change\ in\ velocity \div time\ t$$

Circular motion – an example of acceleration

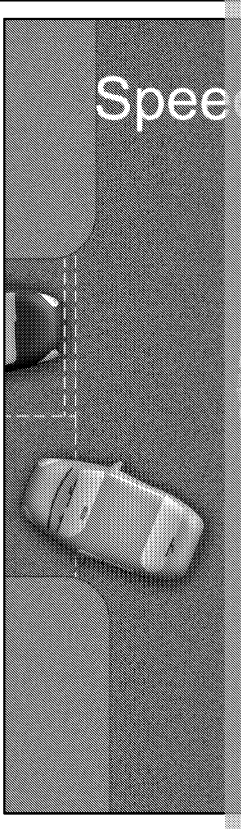
One example of acceleration that is often misunderstood is circular motion.

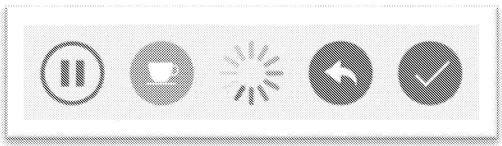
At GCSE you will not be asked to do any calculations for circular motion; that is part of A Level Physics.
However, you should understand the logic:

- Acceleration is defined as a change in velocity.
- Velocity is speed in a given direction.
- If the speed **or the direction** changes, so does the velocity.
- How quickly this happens is acceleration.

When a car goes round a roundabout, the speed may be constant (10 mph, for example), but because it is changing direction all the time the car must be accelerating.

Acceleration is, therefore, speeding up, slowing down or changing direction.

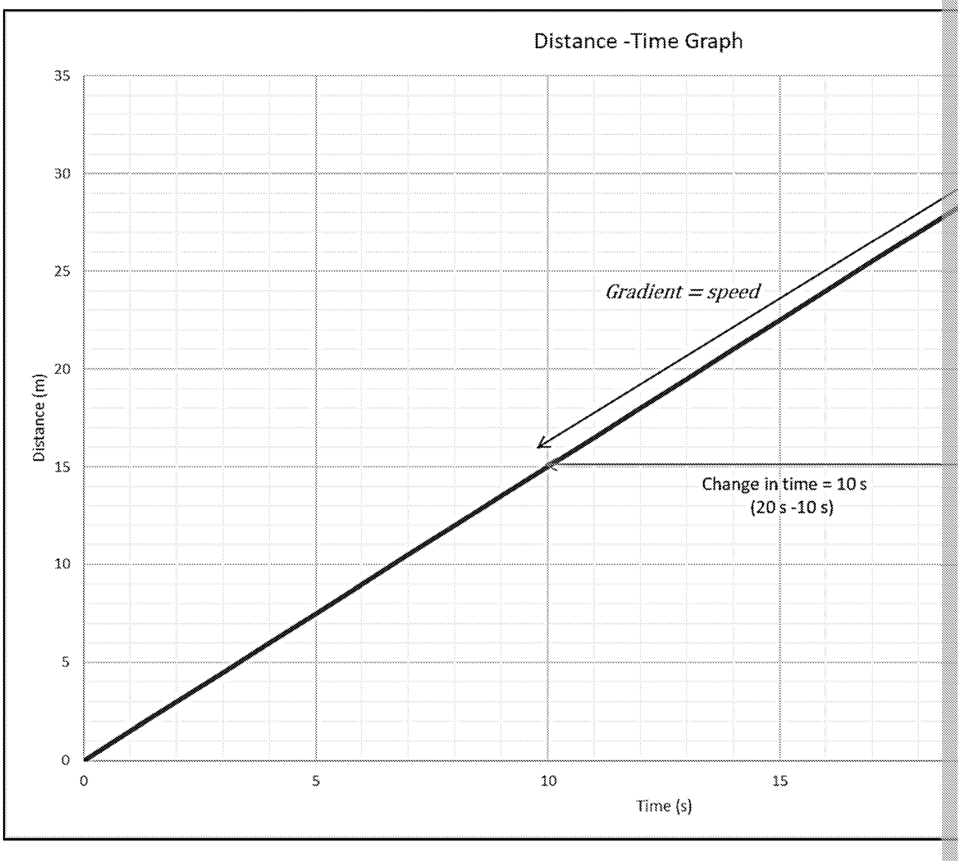




Take a break. Come back in five m
equations before moving on.

Distance–time graphs

The movement of an object can be represented by the use of a *distance–time gra*



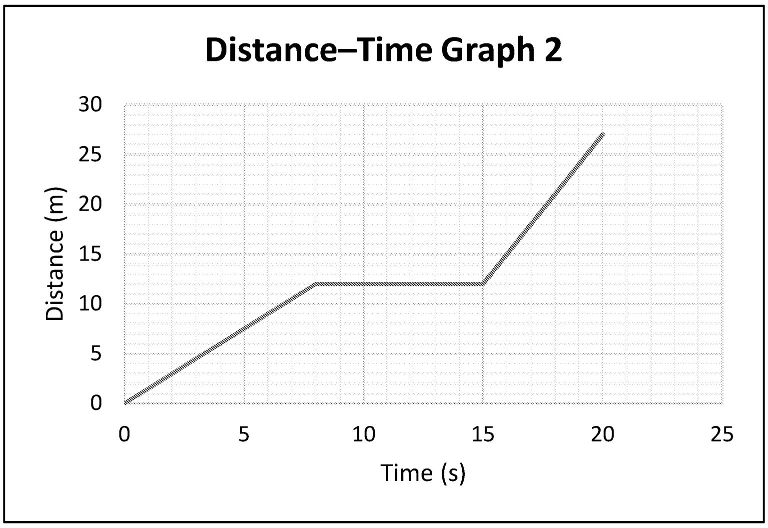
The blue line shows how the distance the object has travelled increases with time
constant increase, showing this object has a constant speed.

The **gradient of the line is equal to the speed**.

Gradient of a graph = change in *y* ÷ change in *x*

Gradient of this graph = change in distance ÷ change in time (speed = distance ÷

$$speed\ (gradient) = (30\ m - 15\ m) \div (20\ s - 10\ s) = 15$$



In this example,
time in three se

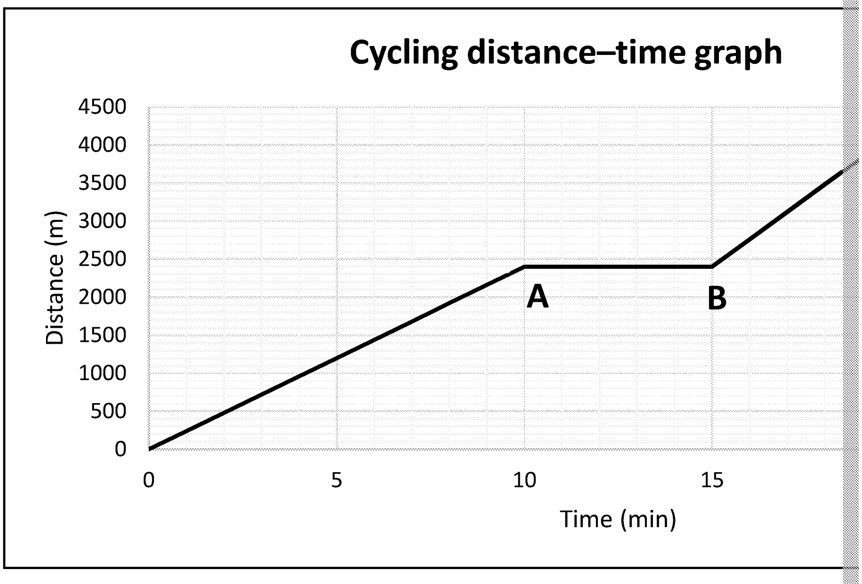
The line from 0
the original grap

From 8 s to 15 s
with time (gradi
object is station
time).

The final sectio
the object is mo

Task A

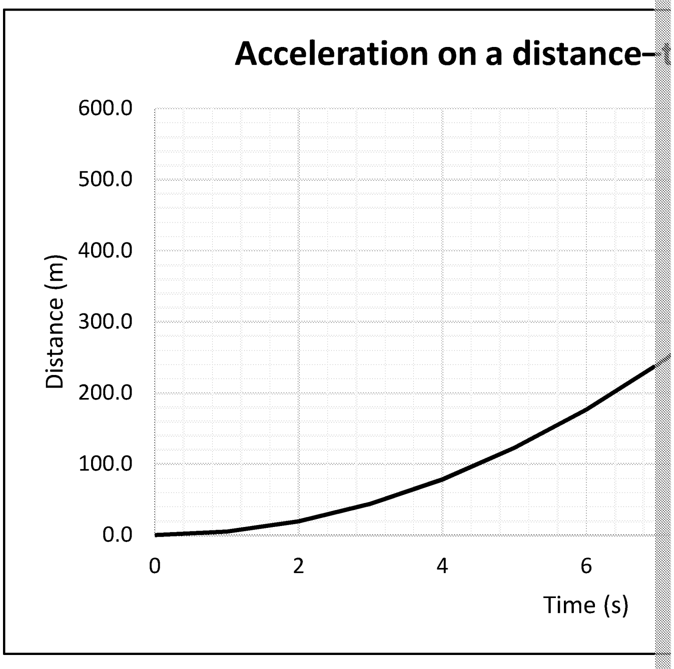
A cyclist records their journey on a fit-app via their smartphone. The app provi[d]
their journey, which is shown below.



1. Calculate their speed from the start of their ride until time A marked on th[e]
2. What speed were they travelling after time B marked on the graph?
3. Describe their movement from point A to point B.

Acceleration on a distance–time graph

When an object is accelerating, the line on a distance–time graph will be curved, as shown in the example (right). This shows the motion of an object accelerating due to gravity (ignoring air resistance). If the object was decelerating, the curve would bend the other way.



To find the speed of the object at any point along the line, a tangent to the line must be drawn. This will give the gradient of the slope at this point, which is equal to t[he]

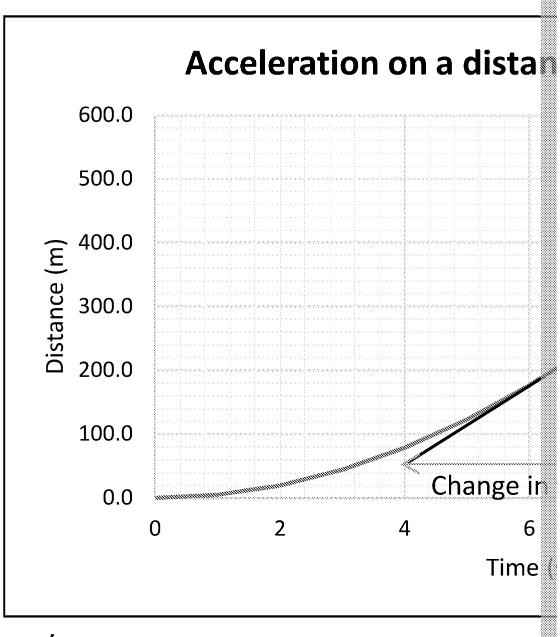
Example: speed at t = 6 s

At t = 6 s the tangent to the distance–time curve has been drawn.

The tangent line is drawn so that it covers 4 s (it can be any length, but it is easier to draw it between two whole numbers).

The change in distance is measured as shown.

The gradient of the tangent can then be calculated as normal.



gradient = change in y ÷ change in x

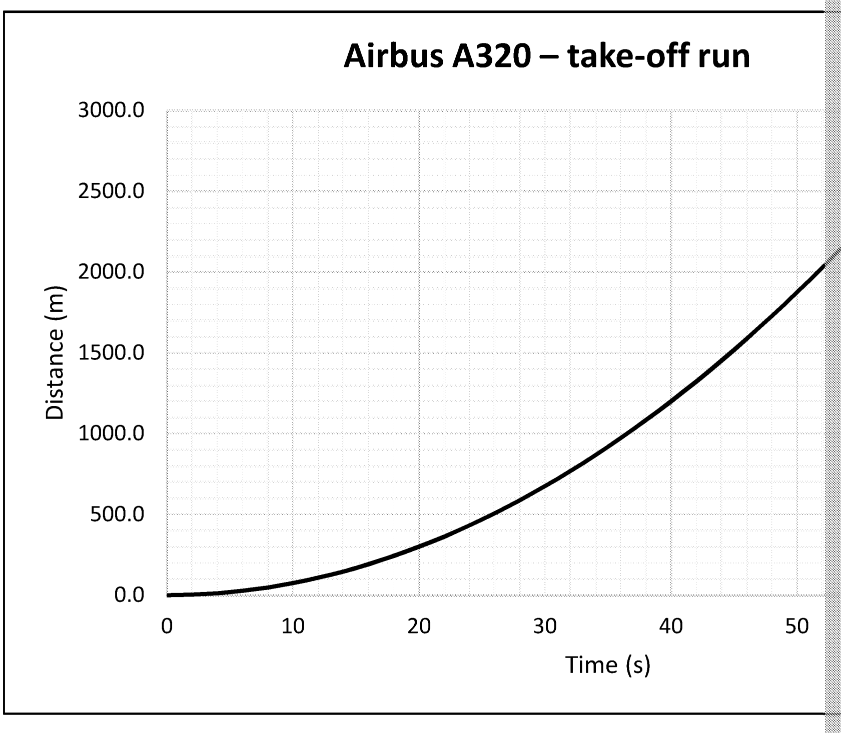
gradient = (385 – 60) ÷ 4 = 81.25

∴ *as speed = gradient of the line:* speed = 81.25 m/s

[It is important to remember that for an accelerating object the speed is constantl the speed at exactly 6 s]

Task B

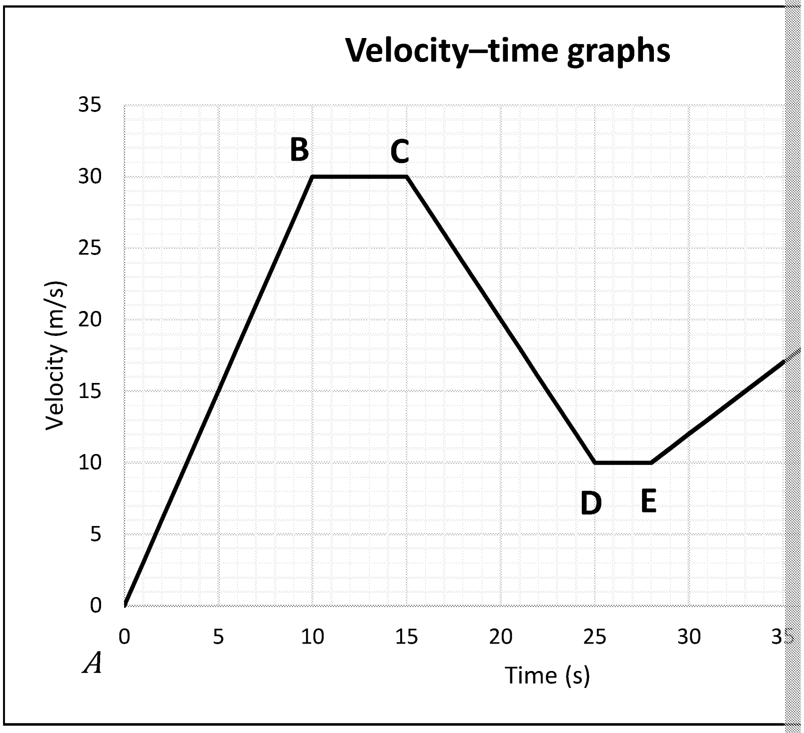
The graph below shows the data from an Airbus A320 as it makes a take-off run weather conditions.



1. At 50 s the plane reaches V_1 – *the decision speed*. At this point the pilot mu the take-off. Above V_1 the plane must take off. What is the value of V_1 for
2. Why is this '*distance–time*' line curved?

Velocity–time graphs

Motion can also be represented by a *velocity–time* graph. Velocity–time graphs lo
graphs. **In the exam, always check the label on the *y-axis* carefully before writi
of graph look the same but the lines mean very different things about the motio**



Point A: The object starts to move from 0 ms^{-1}
A to B: The object is **<u>accelerating</u>** at constant rate (3 ms^{-2} in this example)
B to C: The object is moving at a **<u>constant velocity</u>** (30 ms^{-1})
C to D: The object is **<u>decelerating</u>** (-2 ms^{-2})
D to E: **<u>Constant velocity</u>** (10 ms^{-1})
E to F: **<u>Acceleration</u>** at a lower rate than *A to B* (1 ms^{-2})

The acceleration of the object is equal to the gradient of the line.

Example

A to B: change in x = 10 s change in y = 30 ms^{-1}
acceleration = change in velocity (y-axis) ÷ change in time (x-axis)
acceleration = 30 ÷ 10 = 3 ms^{-2}

Finding the distance travelled from a velocity–time graph

The distance travelled by an object can be worked out from the velocity–time gra
line. This means the area created between the line and the *x-axis*.

In this exam you need to count only the number of squares on the graph paper th
x-axis. There is no need to apply any formula.

Task C

Using the graph above, find the distance travelled by the object between point

Now find the distance travelled between point C and point D.

Tip: where the squares are not whole, try to fit two together to make one whole
total number of whole squares.

Exam-style questions

1. a. State the difference between speed and velocity.

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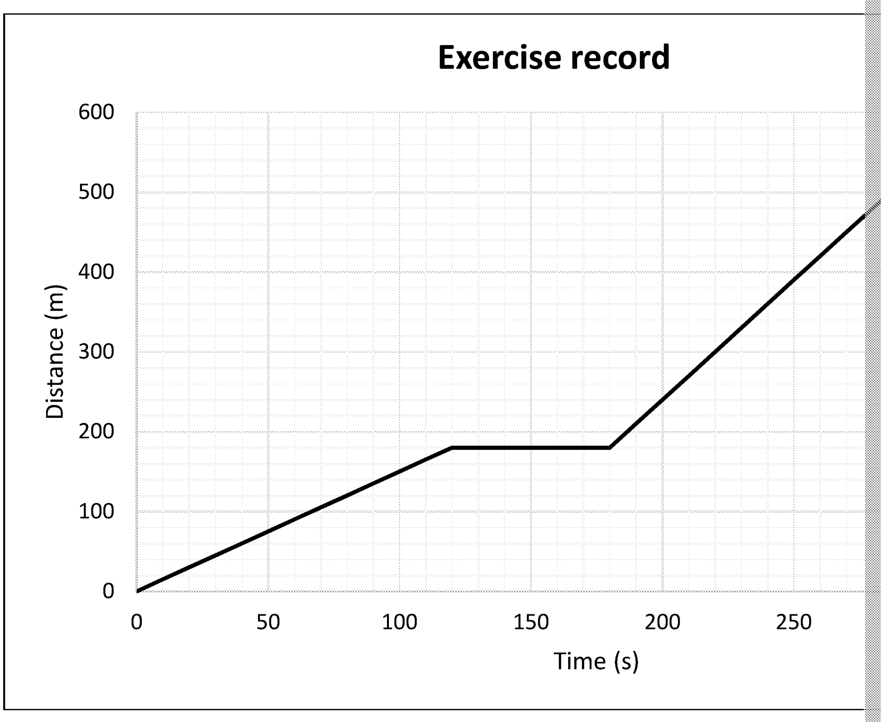
b. A person takes some exercise and begins by walking. They are wearing a exercise and provides a distance–time output when connected to their c

The graph for the first section of their exercise is shown below.



i. How many minutes of the exercise routine are shown in this read-o

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ii. For the first two minutes, the person warms up by walking. Calcula this warm-up.

iii. For what period of time did they take a brief rest? Explain your ans

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iv. After this rest, the person continued with their exercise routine. Co rest with that before. Suggest what exercise they were taking at th

....

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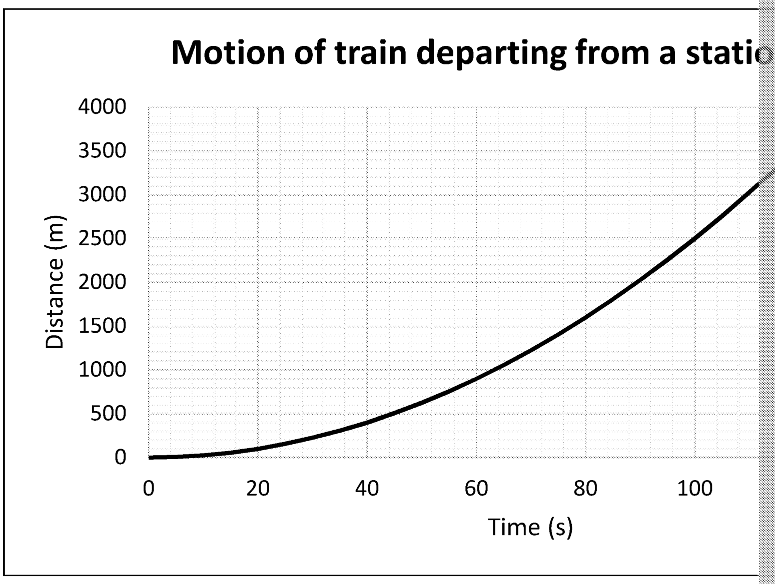
c. The device was set to record the distance travelled every 10 seconds. Su could be made more accurate in a future update to the firmware.

....

....

2. The graph below shows the data from a train's on-board computer as the tra



a. Describe the motion of the train as shown in this graph.

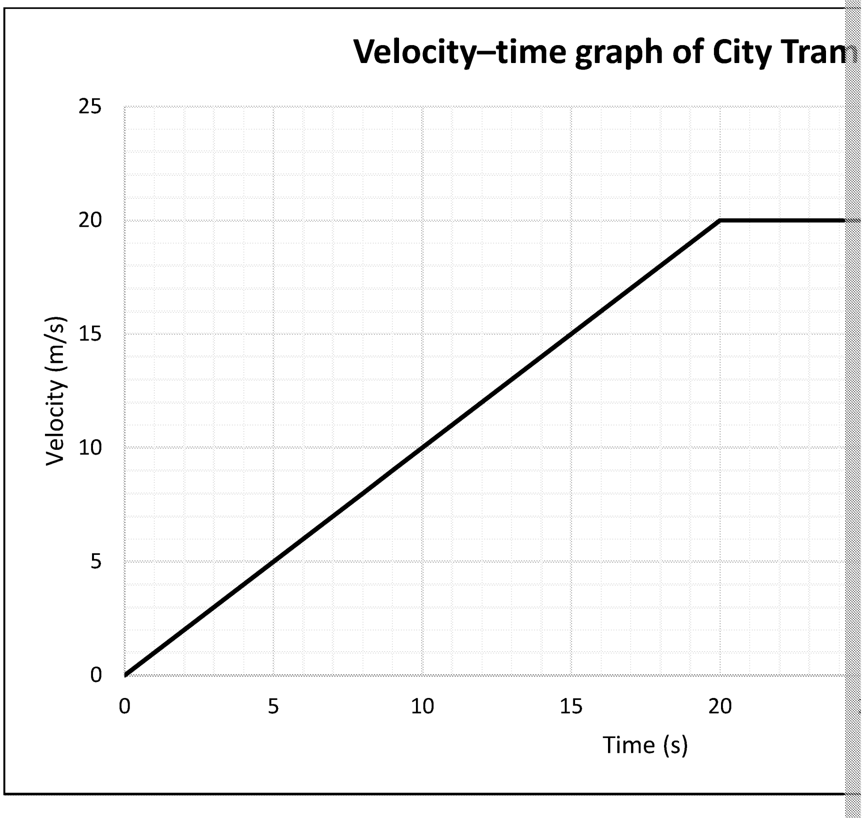
....

....

b. For safety reasons, the train should not exceed a speed of 25 m/s before train meet this safety requirement? Justify your answer using the graph

Show your calculation in the space below.

c. The data from a new City Tram pulling out of a station is shown below. the journey.



i. Calculate the acceleration of the City Tram as it pulls out of the sta

ii. What is the maximum velocity of this tram as shown in this graph?

....

iii. How far has the tram travelled in the first 30 seconds of its journey

End of paper

Chapter 11: Newton's Sec of Motion

Introduction

Newton's laws of motion help to describe the way objects move here on Earth a achievement given they were first published 270 years before humans managed (Sputnik 1957).

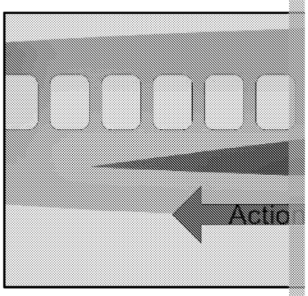
In this section there is a reminder about Newton's three laws of motion before c how it can be investigated in the lab and its implications for vehicle safety. The t Newton's second law.

The experiment discussed in this chapter is a required investigation; you may be part of the exam-style questions there is a six-point question focusing on this inv experimental skills and knowledge.

Newton's first and third laws of motion

First law: An object will remain stationary unless acted upon by an outside force a constant velocity (direction and speed) unless acted upon by an outside force.

Which means that things do not move by themselves – they need a push or a pu moving they speed up, slow down or turn only if there is a push or a pull to make



Third law: For every action there is an equal but opposite reaction.

A jet engine pushes air out of the back of the jet (action) and the plane is pushed forward (reaction). You push down on a chair when you sit in it (action) and the chair pushes back (reaction). Which might sound odd, but think about it. If it didn't push back enough you would carry on moving down due to gravity – so not a very useful ch

Newton's second law of motion

When a force acts upon an object, the object will accelerate, speed up, slow dow this (the magnitude of the acceleration) depends on two variables:

1. The magnitude of the resultant force applied
2. The mass of the object itself

The greater the resultant force, the greater the acceleration; the greater the ma

Acceleration is proportional to the resultant force and inversely pro

Giving the formula: $acceleration\ (a) = force\ /\ mass$

Which is conventionally written as $force = mass \times acceleration\ \ (F = ma)$

This is actually just common sense written in maths.

Example

You want to pick up an empty-looking sports bag. You automatically prepare to a biceps, etc., but the bag is actually full of boots and sports gear and so is very hea fast as you expected and you think, 'Whoa, this is heavier than I was expecting', s from your muscles to get the required acceleration to pick up the bag and put it o second law in action and you don't even need to know about Newton or physics, know how it works! You already know this law; you use it all the time. You just n or multiplication to show this in the exam.

Worked examples

1. What force is required to make a 3 kg bag accelerate at a rate of 10 ms^{-2}?

$$force = mass \times acceleration$$

$$force = 3 \times 10 = \underline{30\ N}$$

2. A 5 kg sports bag is picked up with an upward force of 61 N. What is the acc Remember that the force is the resultant force on the object. In this exampl and a force downwards due to gravity, the weight of the object.

$$weight = mass \times gravity = 5 \times 9.81 = 49.05\ N\ downwards$$

$$resultant\ force = upwards\ force - downwards\ force = 61 - 49.05$$

$$F = ma$$

$$\therefore a = F \div m$$

$$a = 11.95 \div 5 = 2.39\ ms^{-2}$$

Road transport

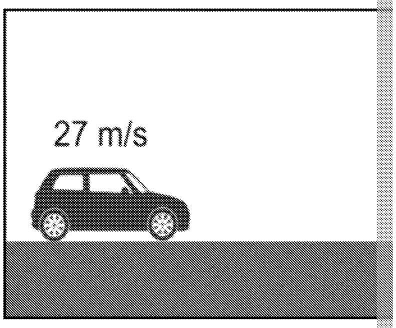
One application of Newton's second law is in road transport, especially in road sa

In the UK, cars are limited on a main road to 60 mph which is ~ 27 m/s (the symbo approximately). For a lorry this is 50 mph or ~ 22 m/s.

A normal car has a mass of ~ 1500 to 2000 kg.

What force is needed to make a car of mass 2000 kg accelerate to 27 m/s in 9 s fr

acceleration = change in velocity ÷ time $(27 - 0) \div 9 = 3\ ms^{-2}$



$F = ma$

$F = 2000 \times 3$

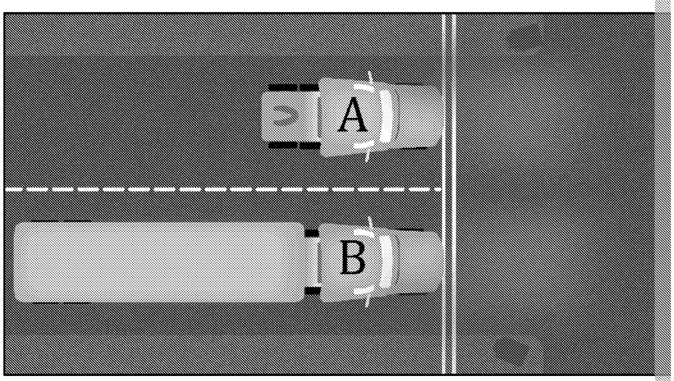
$F = 6000\ N$ *(resultant force)*

In a crash, however, the velocity can decrease from 27 m/s to 0 m/s in 0.5 s

$F = ma$

$F = 2000 \times (27 \div 0.5) = 108\,000\ N$ *acting on the car and the occupan*

Task A

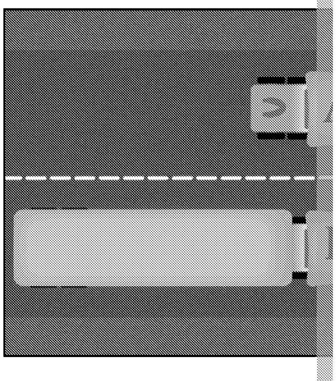


Two vehicles are waiting at a set of traffic lights. Vehicle A is a truck with no tra trailer. Vehicle A has a mass of 15,000 kg and Vehicle B has a mass of 35,000 kg engines and can produce the same overall resultant driving force.

a. When the traffic lights turn green, which truck will have the highest acceler

b. The resultant force from the trucks' engines is 18,000 N. Calculate the acc

Inertia



In this example of two objects in motion, common sense tells us that truck A will accelerate away from the lights faster than truck B. Experience tells us that **the heavier object will change velocity more slowly** and is harder to get moving.

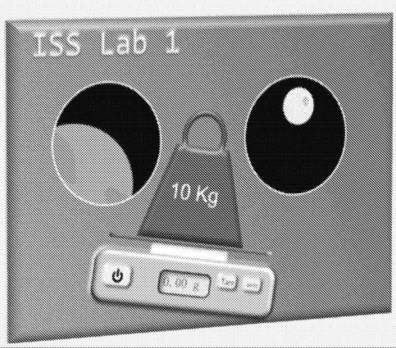
This tendency for an object to resist a change velocity is known as inertia.

The ***inertial mass*** is a measure of this tendency for objects to resist changes in their velocity.

It is defined as the ratio of the force to acceleration for an object $m = F \div a$

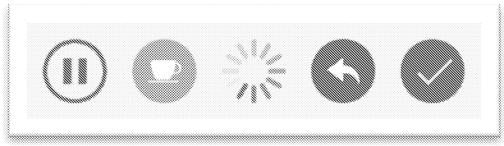
Example
What is the inertial mass of a minibus if it takes a force of 10,000 N to make it acc

inertial mass = force ÷ acceleration
= 10 000 ÷ 1.8 = 5556 kg (to the nearest whole kg)



Did you know?
In space, or in obit, you can't use a normal b of an object. The balance needs gravity to pan and the springs to work out the mass.

Instead in orbit mass is measured using inert a measuring pan and the amount of vibratic mass. More mass = less vibration (the inerti change in the velocity of the vibrating pan).



Investigating Newton's second law of motion (required

As part of the exam you will be asked to discuss a range of investigations you have known as the *required practical activities.* The investigation into Newton's second

Acceleration and force

In this experiment a trolley (car) is pulled along a track using a variable force. The trolley is pulled along the track as the mass attached to it falls. The force can be varied by adding additional mass to the end. The acceleration of the trolley is recorded. This can be done by timing the trolley along a given length of track and calculating the average acceleration from rest, or by using light gates and sensors connected to a computer. The use of the computer-aided measuring is more **accurate**.

To ensure a **fair test**, the trolley and the track should not be changed. The only variable should be the force used to pull the trolley along the track.

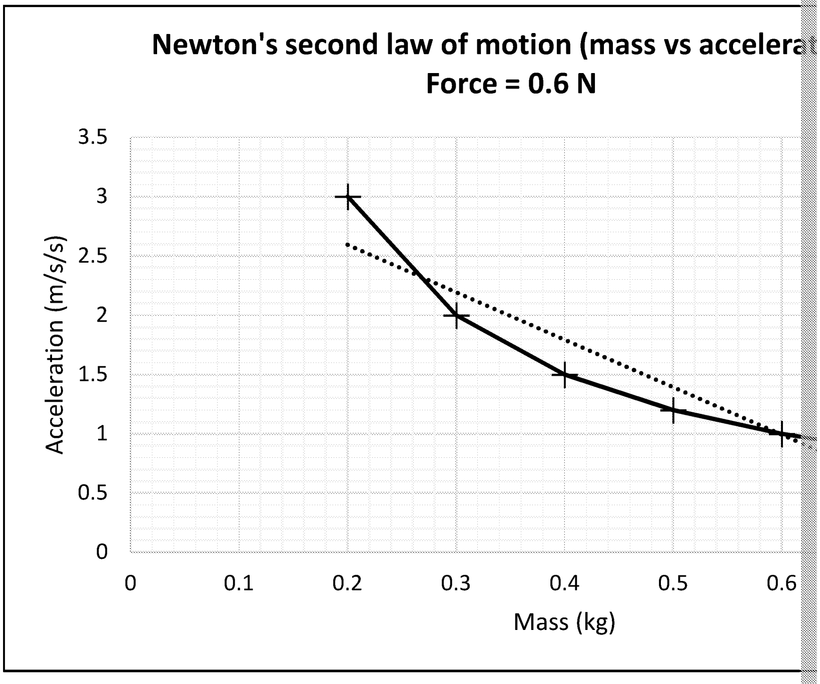
As with all experiments, each condition should be tested at least three times to g
prove that each result is **repeatable** and, therefore, **reliable**.

Acceleration and mass

The same basic set-up can be used to investigate the effect of varying the mass of
force. In this situation the additional masses are **securely** added to the trolley, bu
remains unchanged.

Data using a pulling force of 0.6 N along a 2 m track:

Mass (kg)	Time taken (s)	Final velocity (m/s)	Average acc
0.2	1.83	2.74	
0.3	2.24	2.24	
0.4	2.58	1.94	
0.5	2.89	1.73	
0.6	3.16	1.58	
0.7	3.42	1.46	



Task B

A trolley was pulled along a 2 m ramp using different forces as shown in the tab

The acceleration of the 200 g trolley was measured using a radar sensor connec
is presented below.

Force (N)	Time taken (s)	Final velocity (m/s)	Average acc
0.2	2.65	0.76	
0.4	1.87	1.07	
0.6	1.53	1.31	
0.8	1.32	1.51	
1	1.18	1.69	

Use the data provided to plot a graph of the force against acceleration.

a. Describe the pattern shown in the graph.

b. Suggest one way the data could have been made more reliable.

Exam-style questions

1. A student carries out an experiment to explore the relationship between the object and the acceleration of that object.

   Table 1 gives the data obtained from the student's investigation.

Force (N)	Acceleration (m/s/s)
1	2.5
2	4
3	7.5
4	10.5
5	12

Table 1

   a. Describe an experiment the student could have used to obtain the data
   You may include a labelled diagram.

   Your answer should include any safety considerations in carrying out th

   ....

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b. i. Plot the data in *Table 1* on the graph paper below. You should inclu the data.

ii. Describe the relationship shown by the data in the graph.

....

....

iii. Use the data to estimate the mass of the object used in this investi

2. A newton meter is used to measure the force required to make two metal cu
wooden surface. The reading on the newton meter was recorded at the poi
The cubes have the same physical dimensions.

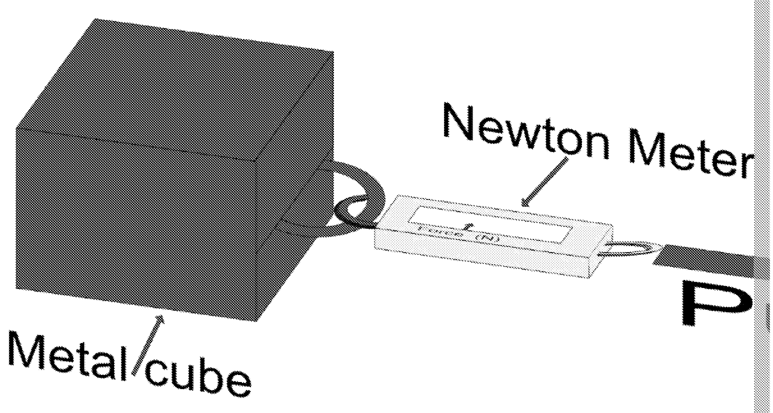

Figure 1

Figure 1 shows the set-up of this investigation. The result for each block is s

Block	Force (N)			Average fo
A	20	22	19	
B	45	60	42	

Table 2

a. Complete *Table 2*.

b. Explain why there is a difference in the force required to make each blo

....

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c. State which measurement is likely to be the least accurate. Justify your

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3. A fully loaded car of mass 2500 kg is travelling at 18 m/s and accelerates to 2
entering a single-carriageway main road where the national speed limit appli

a. Calculate the resultant force required for this change in speed.

b. A lorry produces a resultant force of 14,400 N and accelerates away fror
0.4 ms^{-2}. What is the inertial mass of the lorry?

End of paper

Chapter 12: Moment

Introduction

Continuing from Chapter 11, this section explores the properties of objects in mo conservation of momentum and how this can be applied in simple collisions as we changes in momentum.

In this section certain assumptions are made. The effects of external forces are ig friction, etc. during a collision. This is known as a **closed system** – which means th away and no forces act from outside the collision or system.

Momentum

Momentum is a property of all objects in motion and is defined by the equation:

$$momentum = mass \times velocity \quad or \quad p = mv$$

The units for momentum come from the SI units of the two variables mass and ve

Mass in kg and velocity in m/s gives **momentum the unit kg m/s (kilogram metre**

Momentum is a vector so has both magnitude and direction.

Momentum is an abstract property, but one way to think about what momentum measure of how difficult it is to stop a moving object.

Examples – the momentum of different balls used in sports

Think about catching these four different balls if they were thrown to you:

- Tennis ball
- Football
- Golf ball
- Cricket ball

Which one has the most momentum? To work this out, the velocity and mass of each ball are required:

- Tennis ball 56 g (0.056 kg)
- Football 450 g (0.45 kg)
- Golf ball 45 g (0.045 kg)
- Cricket ball 160 g (0.16 kg)

A ball thrown leaves the hand at the same velocity as the hand at release, which is throwing action.

Momentums

Tennis ball

$p = mv$

$p = 0.056 \times 15 = 0.84\ kg\ m/s$

Football

$p = mv$

$p = 0.45 \times 15 = 6.75$ k

Task A

Calculate the momentum of the golf ball and the cricket ball.

In a real sports situation, however, these balls will be moving at very different vel
normally thrown by hand.

Example

A football can have a velocity of ~ 60 m/s. What is its momentum?

$p = mv$

$p = 0.45 \times 60 = 27\ kg\ m/s$

A cricket ball can be travelling at ~ 27 m/s from a bowler. What is the momentu

$p = mv$

$p = 0.16 \times 27 = 4.32\ kg\ m/s$

Task B

Calculate the momentum of the golf ball and the tennis ball given that a golf ba
and a tennis ball a velocity ~ 78 m/s.

Conservation of momentum

When one or more moving objects collide and interact there can be changes in the momentum of the objects involved.

Important: total momentum before = total momentum after

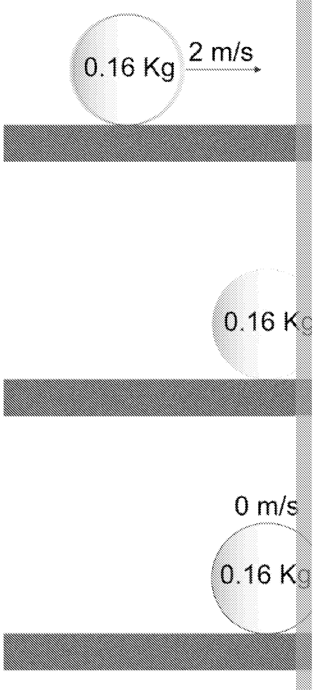
This is known as the law of **conservation of momentum**.

This is only true in a **closed system** where there are no forces acting from outside the system.

Snooker is a good example of the conservation of momentum.

A snooker ball has a mass of 160 g (0.16 kg) and the white ball moves at 2 m/s in a normal play shot.

When it collides with another ball it transfers some or all of its momentum to that ball.



If the white ball stops completely then all the momentum is transferred and, beca
red ball moves off at the same velocity of 2 m/s.

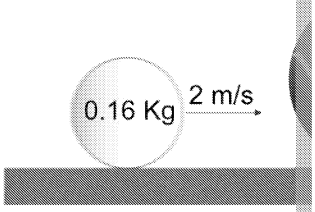
How much momentum does each ball have before the collision?

White ball: $p = mv \quad \therefore \quad p = 0.16 \times 2 = 0.32\ kg\ m/s$

Red ball – logically as it is not moving the momentum must be zero

After the collision the situation is reversed. Momentum is conserved so the tota
the total after the collision. The red ball now has 0.32 kg m/s of momentum and
momentum as it is stationary.

What happens if the two objects have different masses?
Imagine that a snooker ball collides with a tennis ball.



Momentum before:

White ball: $p = mv$

$p = 0.16 \times 2 = 0.32\ kg\ m/s$

The tennis ball has no motion so has no momentum.
Total momentum = 0.32 kg m/s

After the collision, all the momentum has been transferred to the tennis ball; how
its velocity must be greater than the 2 m/s of the white ball.

$$p = mv \therefore v = \frac{p}{m} = v = 0.32 \div 0.056 = 5.71\ m/s$$

What happens if after the collision the two objects are both moving?
Normally in a game of snooker the white ball will not stop. In this situation only p
transferred to the other ball.

Example: A white ball of mass 160 g collides at 4 m/s with a stationary red ball of
the white ball is moving at 1 m/s. Calculate the velocity of the red ball.

Before:

White ball $p = mv = 0.16 \times 4 = 0.64\ kg\ m/s$

Red ball $p = mv = 0.16 \times 0 = 0\ kg\ m/s$

Total before $= 0.64\ kg\ m/s$

After:

Total momentum must equal 0.8 kg m/s

White ball: $p = mv = 0.16 \times 1 = 0.16\ kg\ m/s$

$\therefore$ *the red ball must retain the remaining momentum* $0.64 - 0.16 = 0.4$

As $p = mv \therefore v = \frac{p}{m} = 0.48 \div 0.16 = 3\ m/s$

Task C

A football with a mass of 450 g is kicked by a person – the leg and foot have a m
the ball at 2 m/s. At the point of collision the foot stops. At what velocity does
kicked (ignore friction)?

How would this velocity be different if the foot and leg kept moving after the co

Changes in momentum

Newton's **first law of motion** reminds us that **for an object to** start to move, or **t**
force must be applied to the object.

A change in velocity must, therefore, cause a change in momentum: momentum

The force and the change in momentum must be related.

Mathematical proof of relationship between force (F) and a change in moment

Recall that acceleration (a) is a change in velocity (v)

$$as\ a = \frac{\Delta v}{t}\ (where\ \Delta = a\ change\ in)$$

$$and\ F = ma\quad (where\ m = mass)$$

$$\therefore F = \frac{m\Delta v}{t}$$

$$and\ as\ m\Delta v = \Delta p\ \therefore\ F = \frac{\Delta p}{t}$$

This shows that the force (F) is equal to the rate of change of momentum.

Also $\Delta p = Ft$ *so the change in momentum is proportional t*
length of time the force is applied.

Which means that a bigger force applied for longer results in a bigger change in m

Example

A car of mass 1500 kg is travelling at 15 m/s.

a. What is the momentum of the car?

$$p = mv\quad so\ p = 1500 \times 15 = 22\,500\ kg\ m/s$$

b. The resultant force from the engine is increased for 3 s and the car's velocit
additional force was applied to achieve this change in velocity?

$$New\ momentum\quad p = mv = 1500 \times 25 = 37\,500\ kg\ m/s$$

$$\therefore the\ change\ in\ momentum\ (\Delta p) = 37\,500 - 22\,500 = 15\,000\ kg$$

$$as\ F = \frac{\Delta p}{t}$$

$$F = \frac{15\,000}{3} = 5000\ N$$

Question: If the driver of the car wanted to increase the velocity to 32 m/s (~ 70
5000 N resultant force have to be applied, given the starting velocity of 15 m/s?

Exam-style questions

1. Two rail-cargo wagons are rolling along a track in the same direction as show

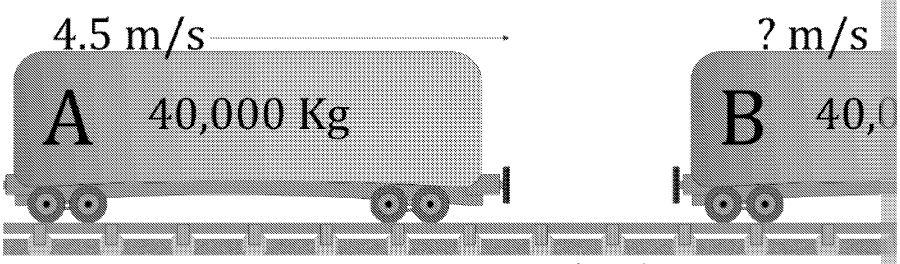


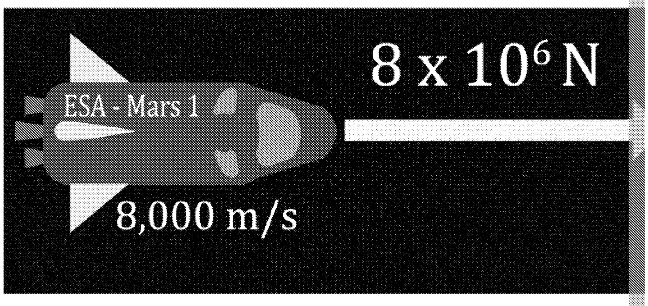
Figure 1

a. Calculate the momentum of wagon A.

b. The momentum of wagon B is 80,000 kg m/s. Calculate its current veloc

c. When wagon A catches up with wagon B they link together to form trai velocity of train AB? (Ignore friction and air resistance.)

2. The spacecraft ESA - Mars 1 with a mass of 12,000 kg is just outside Earth's o
The rocket engines can produce 8×10^6 N of thrust.



a. What is the current momentum of ESA - Mars 1?

b. To reach Mars, the spacecraft must accelerate to 20,000 m/s. Calculate
must burn for to reach this velocity.

End of paper

Chapter 13: Soundw

Introduction

A sound wave is a vibration or a disturbance in a substance. Sound waves can tra solids but not a vacuum. This chapter looks at how sound is transferred between the human ear. It ends by considering how waves can be used to detect items in archaeology. As there are few equations in this section of the syllabus, the empha justifying skills, with more attention on longer answers and definitions.

Types of wave and wave properties

Before discussing sound waves and the application of waves, it is important to ha types of wave and the definitions used in describing a wave's properties.

The term ***medium*** is used in the study of waves to mean the material that a wave be air, water, rock, etc.

Transverse waves, e.g. water waves, light waves and

These waves cause a disturbance in the medium so that the material is displaced level go up and down as the wave passes through the material.

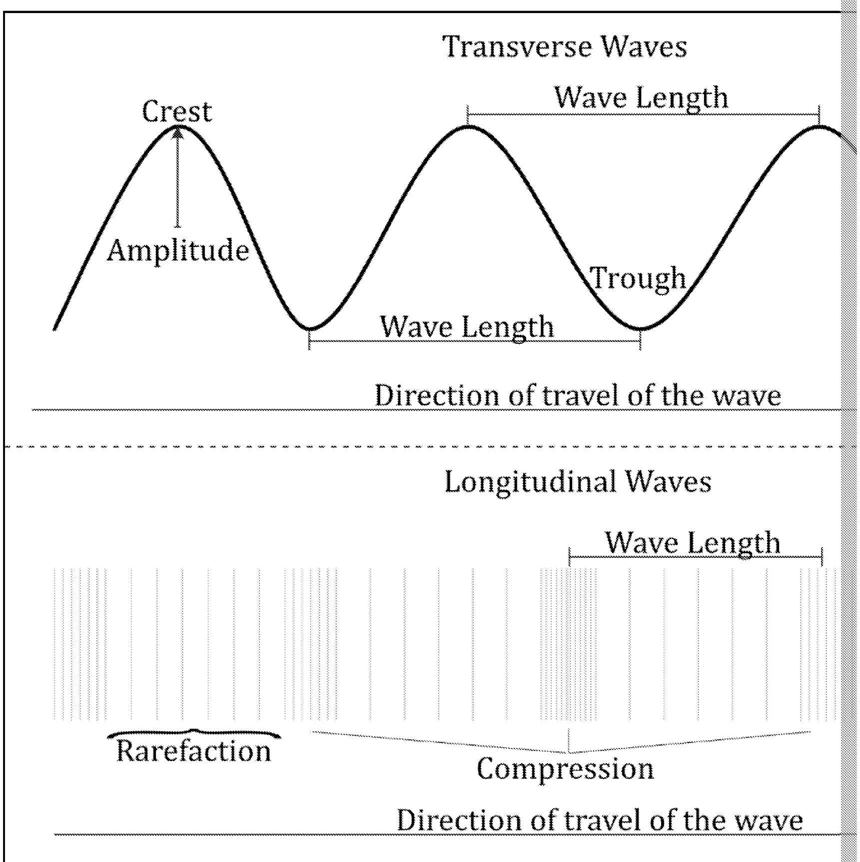


Figure 1

Longitudinal waves, e.g. sound waves and seismic P

These waves are made up of areas of compression of the material; the source (e.g
together and creates areas of more compressed and less compressed material, k
rarefactions, as shown in *Figure 1* on the previous page. These waves move thro
compression, similar to a *Mexican wave* moving round a crowd in a stadium. The
does not.

Properties of waves:

- Amplitude – the height of the wave from the middle to the top of a crest or t
- Wavelength – from crest to crest (trough to trough) or from the middle of a compression to the middle of the next compression
- Frequency (in hertz, Hz) – number of waves per second
- Wave speed – how fast a wave travels in m/s
  Examples: light speed in a vacuum, 3×10^8 m/s; sound in air, 330 m/s

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Most of the chapter is about longitudinal waves – sound, ultrasound and seismic
a moment to make sure you understand their structure and properties before co

Sound waves

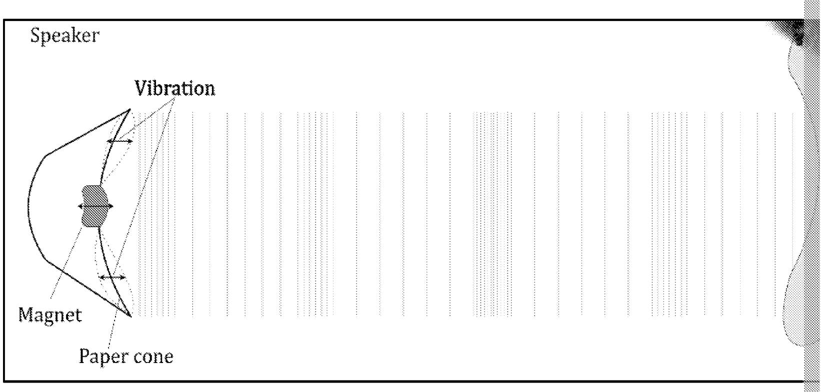


Figure 2 – sound waves

Sound is created by an object vibrating and pushing on the air around it; this caus
the vibrating solid. These compressions travel away from the vibrating solid.

They are detected as sound if these waves of compression enter the ear and mak
vibrate too.

A speaker from a TV or laptop or in a set of earbuds has a cone of paper attached
from the device creates an electrical signal that alternates and makes the magnet
and pushes on the paper cone which in turn vibrates the air, sending out a sound

When this wave hits a solid object it will try to make the solid vibrate too. The en
the solid, making it vibrate in the same pattern as the sound wave (frequency and

In a sound wave the frequency affects the pitch of the sound (low frequencies giv

The amplitude of the wave (the amount of compression) affects the volume of th
a louder sound and, importantly, carries more energy.

The human ear and hearing

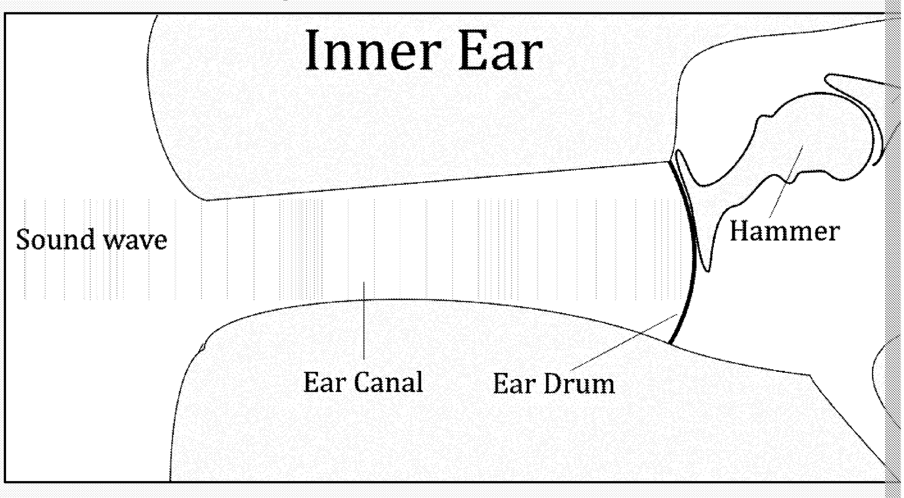


Figure 3 – the inner ear

How we hear (simplified)

1. Sound waves enter the ear canal – directed in by the *pinna* (outer ear).
2. The vibration from the sound wave makes the eardrum (a thin membrane) vi
3. The vibration of the eardrum makes a small bone called the *hammer*, which i
4. This in turn makes another two small bones called the *anvil* and the *stirrup* vi
5. These vibrations pass into the fluid-filled tube called the *cochlea* and in here vibrate and send signals to the brain so we can hear.

Limits of human hearing

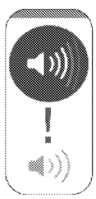
When a sound wave strikes a solid object, such as the eardrum, it will try to make frequency of the wave is too low we will not hear the sound. Too high and the sa

- Too low a frequency – the vibrations are too small to make the eardrum and passed all the way to the cochlea.
- Too high a frequency – the vibration is too fast for the hairs in the cochlea to the brain.

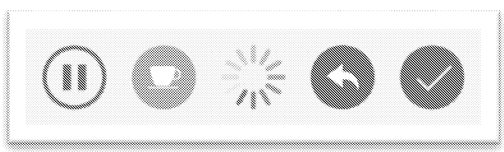
When we are young we can hear sounds in the range **20 Hz to 20,000 Hz (20 kHz)**.

As we age this decreases, so most adults can hear sounds up to about 15–17 kHz (

Bats on the other hand can hear sounds from 9 Hz up to 200,000 H



Loud music, especially from earphones and earbuds, damages the deli the ear's cochlea – they literally snap off and can never regrow. So eac happens we lose a part of our hearing!



You have had to take in a lot of fac and then summarise the informati Check your summary before attem

Task A

1. Compare the wave structures of a sound wave and a water wave.
2. State the limit of human hearing and explain how this is affected by age a as listening to loud music.
3. Explain how sound is detected by the human ear.

Using waves for detection

There are many situations where we cannot easily 'see' objects or see inside the

Examples:

➲ Studying the internal structure of Earth down to the core
➲ Depth sounding and sonar (e.g. for commercial fishing at sea)
➲ Medical examinations without risking surgery

When **a wave** (transverse or longitudinal) **moves from one medium to another** it ca

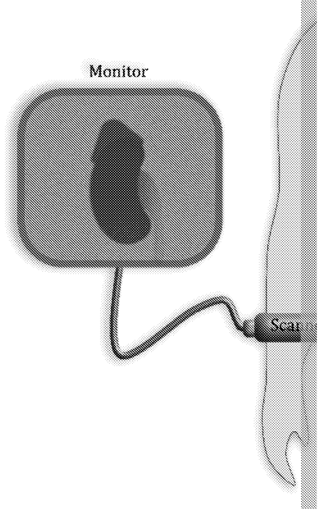
- Some materials will **absorb** the wave energy and the wave cannot pass thro
- Waves can **change velocity**
  - Longitudinal waves move fast in denser materials
    - Speed of sound in air ~ 330 m/s
    - Speed of sound in water ~ 1500 m/s
  - Transverse waves slow down in denser media – light is slower in glass t that allows light to be refracted and allows lenses to work
- At the boundary between media some waves will be **reflected** (i.e. an echo)

Together these changes can provide information about the internal composition human body.

Medical examination – ultrasound scanning

Recall that the human ear can detect sounds up to a maximum frequency of 20 k higher than this is known as **ultrasound**.

A medical ultrasound scanner (sonograph) uses sound with frequency from 2–18 any animal or human. The sound waves are emitted from a scanner as it is move waves are reflected as they move from one tissue type to another; the amount o change in density. These reflected waves are detected and the computer display show an internal image of the body. Sonography is much safer than an X-ray and is frequently used to examine the foetus as it develops in the uterus.



Sonar (sound **na**vigation and **r**anging**)**
Sonar works by sending out sound waves at a frequency between 1 and 100 kHz. emitter on the bottom of the ship and if they hit an object, such as the sea floor o waves will be reflected and captured by a detector on the ship's hull.

As each wave has to travel to the bottom and back up, the time has to be halved t

$$depth = velocity \times \tfrac{1}{2}\, time = 1500 \times \tfrac{1}{2}\,(0.04) = 30\ m$$

Task B

1. Sonar is used by a fishing vessel to detect shoals of fish. The sonar takes 0.(without the shoal. Once detected, the signal returns in 0.02 seconds. Calculate the depth of the sea floor and the shoal of fish from this informat (Speed of sound in water = 1500 m/s)
2. Explain how a sonograph can detect the bones in a developing foetus in the diagram to illustrate your answer.

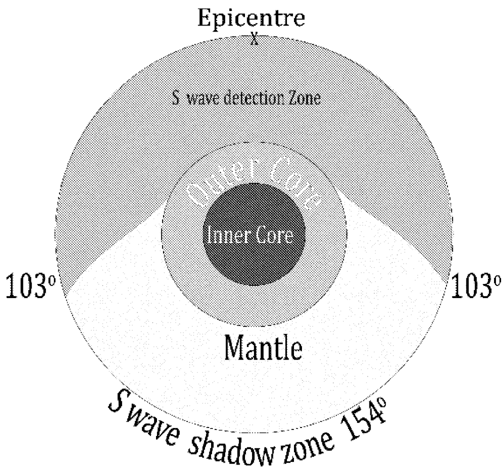
Internal structure of Earth

To examine the internal structure of Earth, geologists study the pattern of earthq they move around and through Earth. There are thousands of earthquake detect globe. These act as the detectors whenever an earthquake occurs.

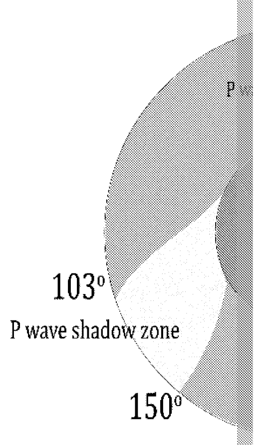
There are two types of seismic waves:

- P waves – longitudinal waves that make the ground slide from side to side
    - Can travel though solids, liquids and semi-solids
- S waves – transverse waves that make the ground rise and fall
    - Can travel through solids and semi-solids

S wave detection pattern



P wav



As *S waves* cannot pass through liquid, the pattern shows that Earth's core must b pass through it but are deflected by the changes in density, indicating the inner co

Exam-style questions

1. a. Which of the following is an example of a longitudinal wave?
   - ☐ Light
   - ☐ Seismic S wave
   - ☐ Seismic P wave
   - ☐ Water wave

   b. A longitudinal wave consists of a series of compressions and rarefaction such as air.

   Label an area of compression and an area of rarefaction on *Diagram 1*, b

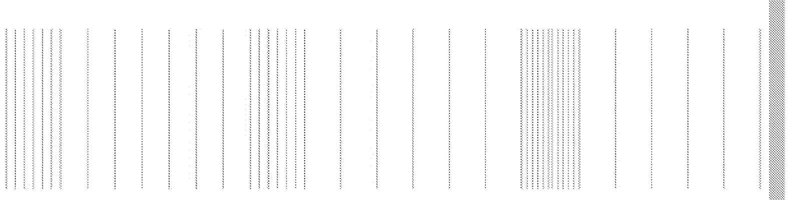


Diagram 1

   c. Explain how the pitch of a sound is related to the properties of the wav

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   d. Sound waves are detected by structures in the inner ear and converted brain. *Diagram 2* shows the main structures involved in this process.

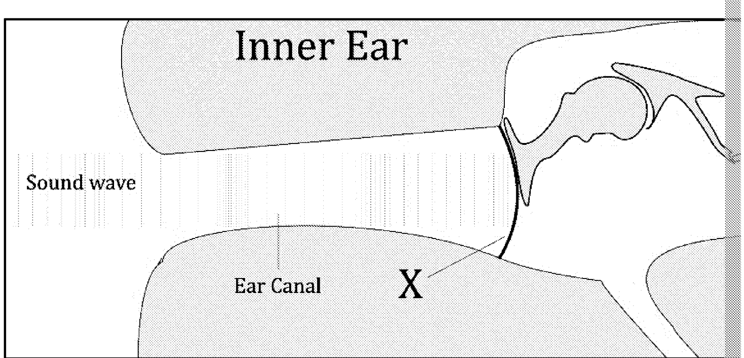

Diagram 2 – the inner ear

   i. State the name of the structure labelled X in Diagram 2.

   ....

ii. Explain how the sound wave affects the structures in the inner ear a sensation of sound. (You do not need to name each of the other st

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iii. What is the upper limit of human hearing?

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2. When an earthquake occurs there are two types of seismic waves produced: These travel along Earth's surface and through Earth's inner structures – the inner core.

a. Which of the two types of seismic wave is an example of a transverse wa

....

b. When a P wave passes through Earth's crust it makes it move. Describe movement of Earth's surface where this is occurring.

....

c. Around the world there is a series of earthquake detection facilities. An Earth's crust at point X as shown in *Diagram 3*, below. This is the epicen and S waves spread out from this point.

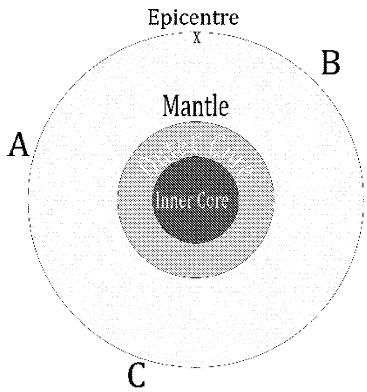

Diagram 3

Three earthquake detection facilities are shown at points A, B and C.

i. At which facility would you expect the waves to have the greatest a Explain your answer.

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ii. At which facility would you expect to detect only P waves? Explain

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iii. What does this observation tell geologists about the nature of Earth

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3. Longitudinal waves can be used for the examination of the body without the as a diagnostic sonograph and it uses ultrasound.

a. Define the term ultrasound.

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b. Explain how ultrasound can be used to examine the internal structures include a diagram to help illustrate your answer.

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End of paper

Chapter 14: Properties of

Introduction

The electromagnetic spectrum (EMS) covers a range of related transverse waves chapter you will have a chance to review the different parts of the EMS along wi applications of these different parts of the spectrum.

The key higher-level skills and knowledge covered are to understand the differen with materials, especially the process of refraction. You will be drawing ray diag this section, so it is a good idea to have a ruler and pencil ready to use.

This chapter also considers the interaction between radio waves and electrical ci produced by internal changes within atoms. If you are unfamiliar with the intern review Chapter 7 in this publication or refer to your Chemistry notes.

Electromagnetic spectrum (EMS)

All parts of the EMS are essentially the same in structure. They are all **transverse** from the source from which they are emitted to the object(s) that absorb(s) this wavelength and frequencies. **The shorter the wavelength the higher the energy**.

Recall that: $speed\ of\ a\ wave\ (v) = frequency\ (f) \times wavelength\ (\lambda)$

All parts of the EMS move at the speed of light: 3×10^8 m/s in a vacuum.

$\therefore$ frequency $\propto \frac{1}{\text{wavelength}}$ so **as the frequency increases the wavelength de**

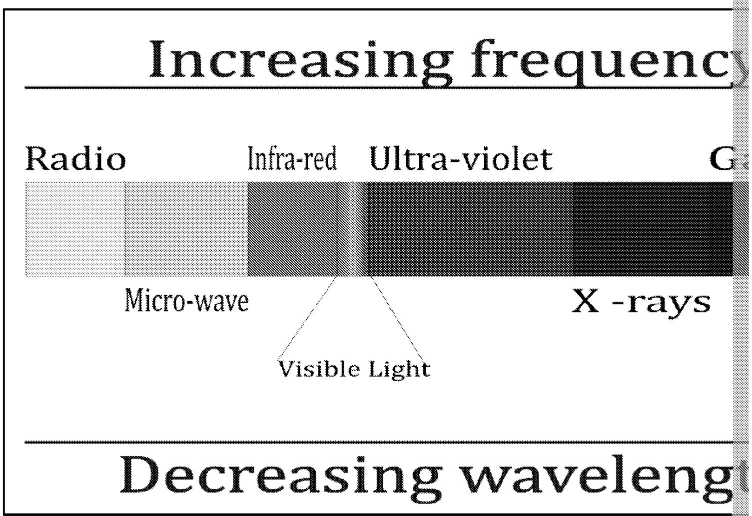


Figure 1 – the electromagnetic spectrum

Applications

Part of the EMS	Application
Radio waves	Communications – TV, radio, Bluetooth™, Wi-Fi, etc.
Microwaves	Cooking; Communications – mobile phone signals for c
Infrared	Remote-control signals; Night-vision cameras; Heaters
Visible light	Lasers – scanners at tills, and CD, DVD and Blu-ray™ pla
Ultraviolet	Scanning bank notes for forgery; Causing tanning of the
X-rays	Medical examinations; Examination of machinery for de
Gamma rays	Kill pathogens on surgical equipment and on food items

Table 1 – applications of EM radiation

In each of these examples, energy is being transferred from one object to another

How EMS waves interact with different materials

There are four ways in which EMS waves interact with materials (solids, liquids or

- **Emission** – This happens when a material gives out EMS radiation.
  - Gamma radiation from nuclear decay
  - Infrared from a warm object
  - Visible light from a bulb or a mobile phone screen
- **Absorption** – The opposite to emission; the energy of the wave is taken in b the material.
  - Visible light by the retina of the eye or the sensor on a camera
  - Microwaves taken in by the water molecules in a microwave cooker to heat the food
  - Gamma rays – taken in by molecules in the body causing damage to proteins and DNA, potentially causing cancers
- **Reflection** – The waves bounce off the material, such that the angle of inci the reflection.
  - Mirrors
- **Refraction** – Bending of the wave from its original path due to changes in ve density of the two materials.
  - Lenses
  - Prisms
  - Mirage

Each of these interactions can be affected by the properties of the materials and th

Examples

Emission: The temperature of a material will affect the wavelength of the infrared surface, the shorter the wavelength; this also means the waves carry more energy

Refraction: Water refracts visible light more than glass because water is denser th

Refraction

Any wave can be refracted as it passes from one material to another. This is caus of the materials through which the wave is travelling. **As the density of a materia wave reduces.**

Although this process affects all waves in the EMS, for the rest of this section vis illustrate the process.

When a ray of light moves from air to glass **the path of the ray is deflected by the**

Glass has a higher density than air. As the light passes from the less dense air to t This change in speed results in a change in the path of the ray of light.

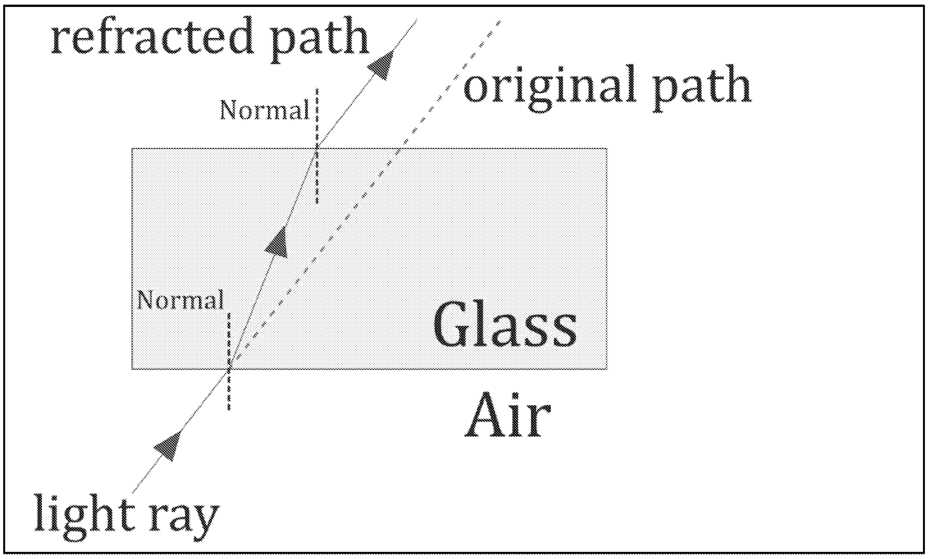


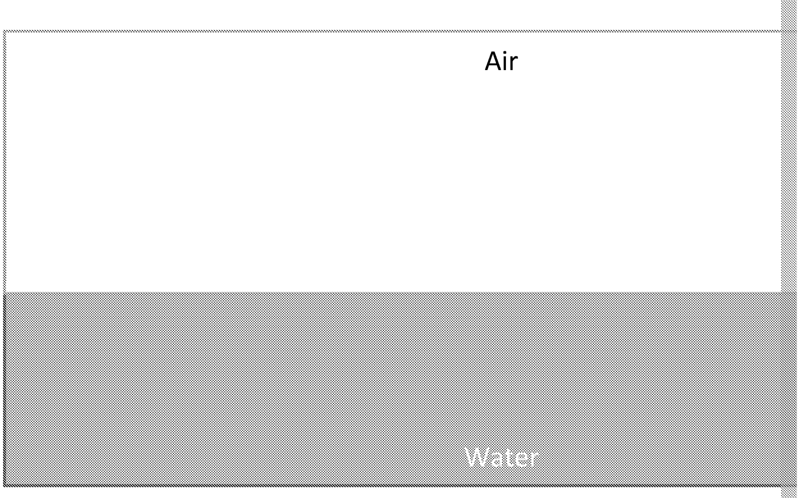
Figure 2 – refraction – ray diagram

Less dense to denser material (air to glass) – ray **bends towards the normal**.

Denser to less dense material (glass to air) – ray **bends away from the normal**.

Task A

Draw a ray diagram to illustrate the refraction of a ray of light as it passes from a Label the ray of light and add a normal at the boundary between the two media



Why does refraction occur? Why does a change in speed

To understand this, a **wave front diagram** is used.

A wave front diagram uses lines to mark the crest of each part of the wave; it is li
wave and drawing a line to mark the top of each wave.

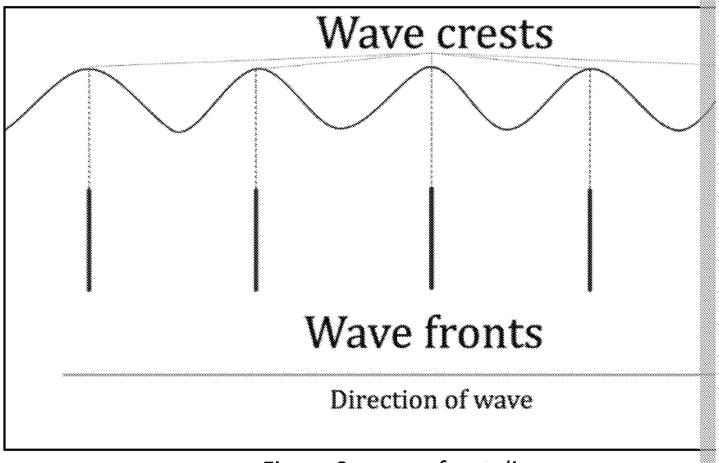


Figure 3 – wave front diagram

As the wave front enters a medium, only that part of the wave inside the new medi
part in the original medium is moving at the original speed. This results in each wav
example below, the part inside the glass is moving more slowly so results in the wav

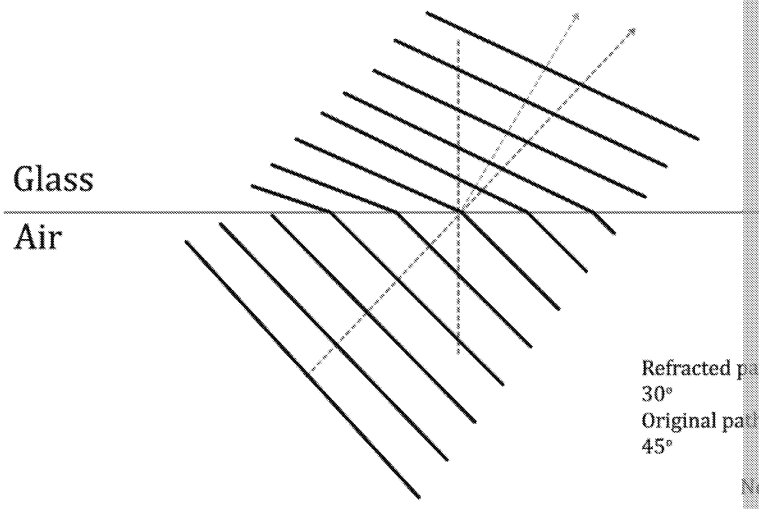


Figure 4 – wave front diagram – air to glass

Task B

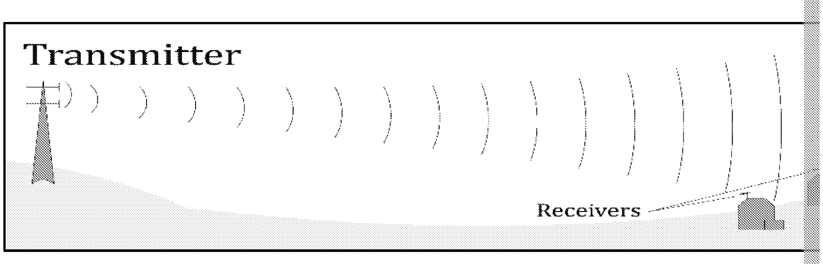
Draw a wave front diagram to explain the refraction of light as it travels from gl

Radio waves

When an alternating current flows in an electrical circuit (a wire), these oscillatio waves. The oscillations in the radio wave mirror that of the AC current.

This is used to broadcast information via TV, radio, Wi-Fi, etc.

When a radio wave is absorbed by a conductor, such as an aerial, the opposite ha wave produce an AC current in the conductor. This alternating current can then b device to reproduce the originally broadcast information – this might be an image (Wi-Fi, Bluetooth™).



Atoms as emitters

Atom structure

All atoms have a nucleus containing neutrons and protons. The nucleus is surrounded by the electrons organised into orbits.

Each orbit has a certain amount of energy associated with it. The further out an orbit is from the nucleus, the higher the energy state of the electrons in that orbit.

To make an electron '*jump*' to a higher orbit, an input of external energy is required.

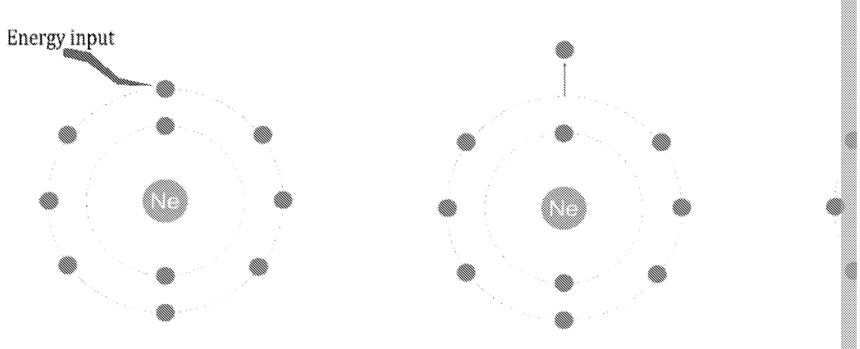
If an electron '*falls*' to a lower orbit it must release the additional energy as a burst of electromagnetic radiation. (This is actually given off as a photon.)

The amount of energy given off determines the type of radiation, from low-energ visible light, etc. This is the basis of a fluorescent tube light – electricity makes an to a high-energy orbit. This is unstable so the electron falls back down to its norm radiation in the process. The energy level results in a burst of visible light.

Very high-energy radiation, such as gamma rays, is the result of the energy chang emitted from the nuclei of atoms. (See Chapter 7 for more details.)

Exam-style questions

1. a. Choose the type of electromagnetic radiation with the shortest wavelen list below.
   - ☐ Radio waves
   - ☐ Visible light
   - ☐ X-rays
   - ☐ Infrared



b. Suggest two applications for microwave radiation.

1. ....

2. ....

c. Radio waves of different frequencies are used extensively for different f Other than for broadcasting radio signals, suggest two forms of commu radio waves to carry information.

1. ....

2. ....

d. Radio signals are produced by controlling the oscillations in the circuit o Explain how these signals are detected by a receiving device to recreate broadcasted information.

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e. Helium gas is used in fluorescent tubes to produce a pale pink / white li atomic structure of a helium atom. Use this to explain how visible light i a fluorescent tube.

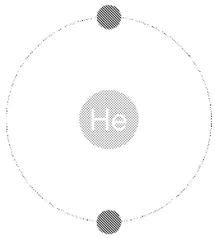

Diagram 1 – helium nucleus

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2. A student is investigating the refraction of light through a glass block using a produce a single ray of light which is directed into the glass block at an angle boundary of the block and the air. The set-up is shown in Diagram 2, below.

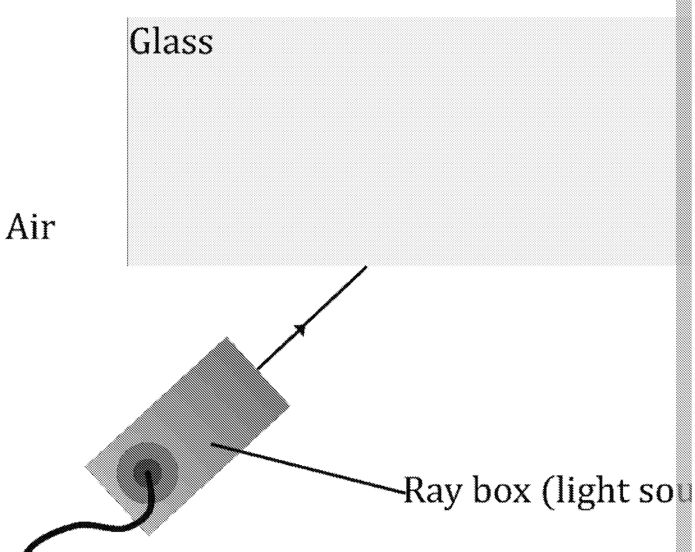

Diagram 2

a. Complete the diagram to show the path of the ray of light as it passes in block. Include a *normal* at the interface between the air and glass at the ray enters the glass.

b. Using a wave front diagram, explain why the ray of light behaves in the w
question 2a, as it enters the glass block from the air.

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End of paper

Chapter 15: Space ph

Introduction

All stars have a common beginning, but the death of a star depends on its solar m processes that lead to the birth of stars and their eventual deaths are considered.

Investigating the endless expanse of the universe represents huge challenges to a deduce the history, current structure and potential futures from clues they can de radiation that reaches Earth from across the vast emptiness of space. One key ide the universe is the ***red shift*** of visible light from distant galaxies.

There are no calculations in this section, but the ability to provide clear explanatio grade 9 in this section on the physics of space.

Distances in space – distances in space are all but impossible for the human mind need some means to measure distance. Using metres or kilometres would requir instead we use two main units for distances in outer space.

Light year (ly) – not a measurement of time but of distance. It is defined as the di vacuum in one Earth year, which is ~ 9,461,000,000,000,000 or 9.461×10^{15} m.

Parsec (parallax second) – this is 3.26 ly in distance. There is no requirement in th unit of measurement, but if you are interested in space you will come across it in *the original* Star Wars™ *film, Han Solo uses parsec to describe how fast the Millen a measure of time not distance – not so good for a space pilot!]*

The life cycle of stars

Birth of all stars
All stars begin life as a vast cloud of gas (mainly hydrogen) called a **nebula**. The Horsehead Nebula, for example, is over 3.5 ly across.

Gravity pulls this nebula together over billions of years to form a **protostar**; protostars are over 10 million km in diameter – our Sun is only 1.4 million km across in comparison. These are not true stars as they do not give out much radiation (light, heat, etc.).

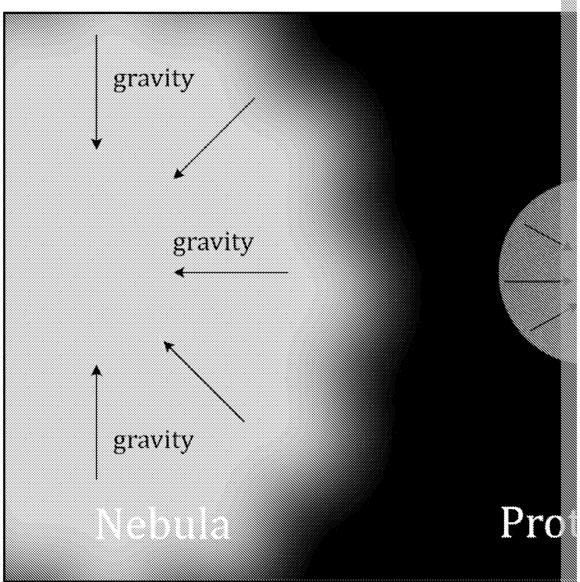
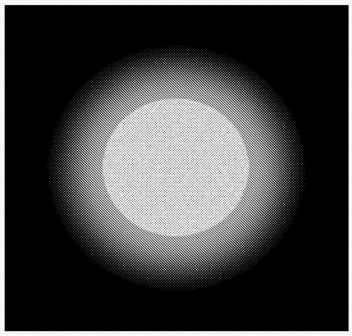


Figure 1 – the birth of

Gravity continues to make them contract until eventually the internal pressure is **fusion** to start. Hydrogen is forced together to make helium and give out light an

A star is born! In a stable main sequence star (such as our Sun) the size remains co **Gravity is pulling it inwards** but **heat from fusion is making it expand**. In a star the



The Sun

Our Sun is a medium-sized star and has been ar
years. It has enough fuel to stay as it is now for
before it begins to die.

Mass: ~ 2×10^{30} kg

Distance from Earth: ~ 150 million km

It takes light about eight minutes to reach Earth.

When a star begins to run out of hydrogen for fusion it begins to decline, but wha
of the star.

Small/Medium stars (about the size of our Sun)

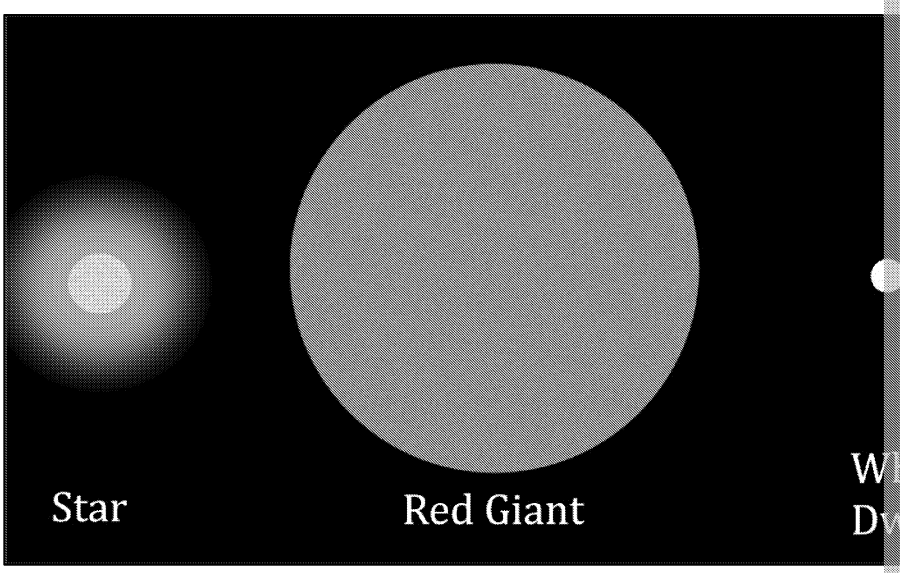


Figure 2 – death of a small/medium star

Red giant: With no more hydrogen to use in fusion, the star begins to use helium, in the process. The heat from this causes a vast and rapid expansion of the star in expand to engulf Mercury, Venus and Earth (and possibly Mars, too).

White dwarf: When no more fusion is possible, gravity beings to make the star co smaller and denser. The star no longer shines and it begins to cool.

Black dwarf: This is a small but very dense mass of material that has cooled to alm space. It is black as it does not emit any EM radiation.

Large stars

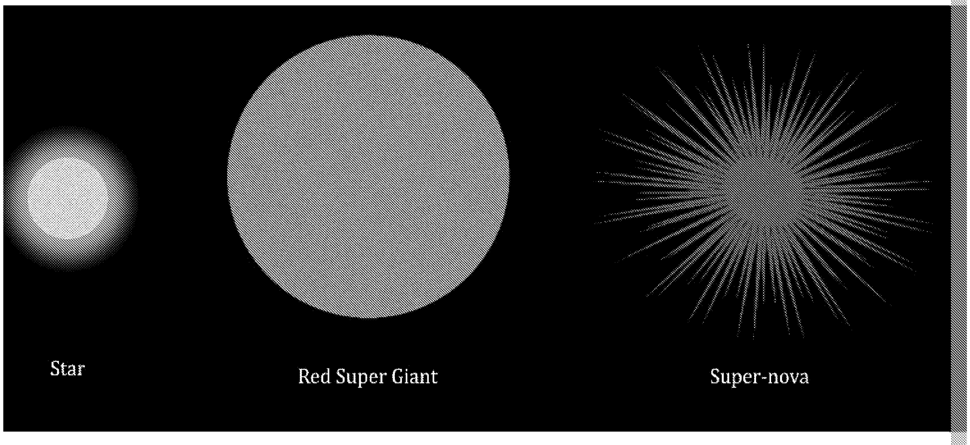


Figure 3 – death of large stars

Red supergiant: When the hydrogen runs out, these stars also start to fuse heliu
As the star is larger, the resulting red giant is much larger too.

Supernova: The forces inside a red supergiant are huge, and eventually the syste
suddenly explodes in a supernova, sending out matter and energy. Only in a sup
than iron be forged. Without them there would be no life in this universe. The r
supernova can no longer produce heat from fusion, so gravity makes it collapse.

Neutron star: The huge mass left after a supernova will begin to shrink; in large s
extremely dense remnant of a star, called a neutron star. Inside, the pressures a
longer exist as they do here on Earth; they are reduced to neutrons. Some neutr
giving out beams of radiation (microwaves and X-rays); these are known as pulsa

Black hole: In very large stars, the mass of material is so high that it is crushed by
with all the mass of a star, known as a singularity. The gravity this produces is so
moves fast enough to escape it. Even time is stretched out within the black hole.

> Scientists think there is a supermassive black hole at the centre of our galaxy,
> stars into its singularity, like water spinning down a plug hole!

Task A

Compare the life cycle of our Sun with that of Betelgeuse, a star in the Orion co
supergiant with a mass over 16 times greater than that of our Sun. (It is so larg
of our solar system its outer edge would stretch out as far as the asteroid belt

You can use diagrams to help illustrate your ideas.

Red shift

The current theory about the origin and potential future of our universe states th
Big Bang when all of time and matter were created and since then the matter has
explosion. This means the universe is constantly expanding.

For this theory to be true there must be evidence that the universe is expanding.
good as the evidence that supports it.

Red shift is one of the key pieces of evidence to support these ideas; it is based o
measurements that have been confirmed by different teams of scientists over ma

Recall: The colour of visible light is related to the wavelength of the wave. Short
blue/purple light, **longer wavelengths give red light**.

Scientific observation: The light from nearby galaxies is redshifte
the light contains more red wavelengths than you would expect.
The more distant the galaxy, the greater the amount of red shif
All galaxies observed showed evidence of red shift in their light sp

Conclusions: All observed galaxies must be moving away from us.
The more distant galaxies are moving at a faster rate away from

Explanation

A galaxy contains billions of stars. These each emit light of different frequencies, producing a wide spectrum of colours. When seen from a distance these colours should merge to make the galaxy appear white. So any light from any galaxy should show a broad but balanced distribution of wavelengths.

Imagine a **galaxy that is stationary** compared to the *Milky Way* (our galaxy). The galaxy emits a wave at regular intervals, giving a set wavelength (one unit long).

Over time the wave moves forward and there is a set distance between each wave (one unit). **All the waves are the same.**

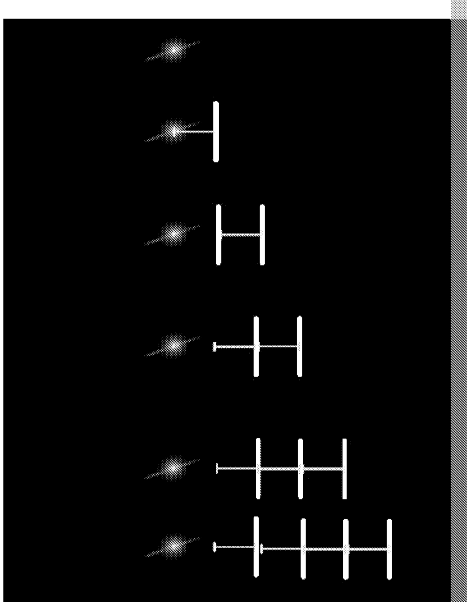


Figure 4 – waves from a

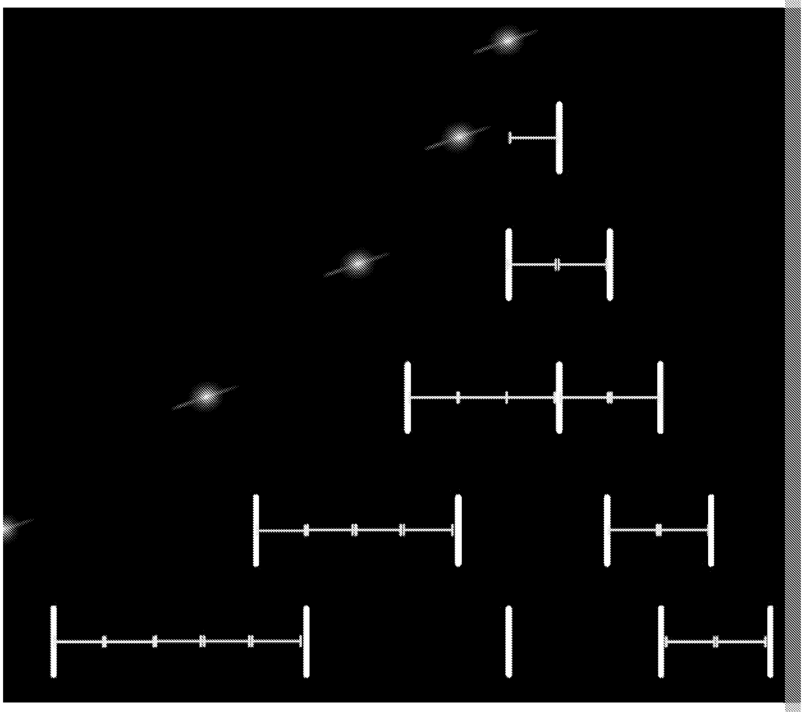


Figure 5 – waves from a receding galaxy

If the galaxy is receding and a wave is emitted at a set interval, this would give a b
however, between each period of emission the galaxy moves away, increasing the
wave as shown above. The faster it recedes, the greater the separation between
the waves, giving wavelengths that are shifted to the red end of the visible spect

This is the same process that creates the Doppler effect – the change in pitch of t
a stationary observer. (Moving towards you, the waves are pushed together, de
making the pitch higher; as it recedes away from you, the waves stretch out, low
Doppler effect acting on light, rather than sound.

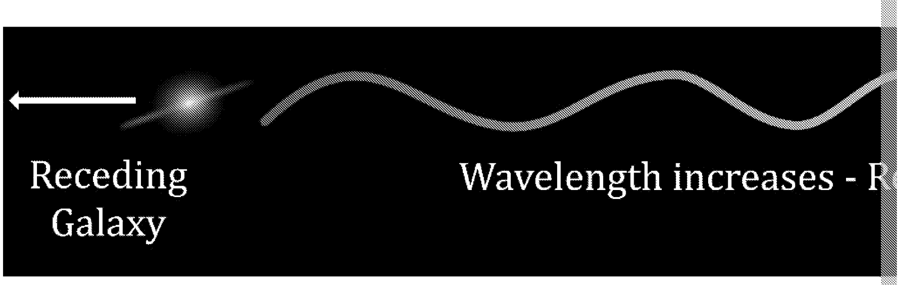


Figure 6 – red shift summary

Conclusions from the observation of red shift

- If all the **galaxies are moving away** from each other **the universe must be e**
- Logically if this is true and you could wind back time they must all get closer, eventually they must all be in one place – the site of the Big Bang.

Task B

Prepare a presentation (on your PC, Mac, etc. or on paper) to explain red shift t
Design your own illustrations and make sure you explain why this means the un

Make notes on the key ideas to include and later on check them against the sug
answer sheet.

(Alternative: Produce your own poster on the topic of red shift – be creative.)

Time limit – you should aim to finish this within 20 mi

Exam-style questions

1. In 1929, Edward Hubble observed the wavelengths of light coming from dist
He observed that the spectrum of light was not as expected.

a. What did Hubble observe about the spectrum of the light from distant g

....

....

b. How was this different for galaxies closer to the Milky Way compared to
greater distance?

....

....

c. In the middle of the twentieth century there were two main theories ab
Theory A: The universe started with the Big Bang and has been expandi
Theory B: The universe has always existed but is expanding over time.

i. Which of the following is true based only on Hubble's observations
☐ The observations support theory A but disprove theory B
☐ The observations do not support either theory
☐ The observations can be used to support parts of both theori

ii. Theory B was rejected by most scientists during the 1960s. Why mi
rejected and theory A accepted?

....

....

d. Explain how Hubble's observations support the idea of an expanding uni

....

....

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....

....

....

2. Stars are created inside large gas clouds known as nebulae. Over time, parts

a. What force results in the formation of protostars from the gases in the

....

....

b. The protostar continues to collapse; eventually it becomes dense enoug electromagnetic radiation, such as visible light and infrared.

i. What process inside the star creates these?

....

ii. Why does this process prevent the star from continuing to collapse

....

....

c. Our Sun is a medium-sized star and has enough fuel to maintain its curr billion years.

i. Describe the likely sequence of changes that will occur to our Sun w

....

....

....

....

....

....

ii. The star UY Scuti, which is 5219 ly from Earth, is believed to be the is estimated to be 1700 times more massive than our Sun.

Compare its likely future changes with that of our Sun.

....

....

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....

....

....

End of paper

Challenges – A Level AQA Physic

Introduction

It is important to understand **that nothing in this section is required for the GCS** a set of challenges for students considering studying Physics at GCE Advanced Le

There are no exam questions in this section; each part contains some informatio some challenges. In each case it is the thinking and the effort to come up with y

These are not tasks for the search engines of the Internet; they are tasks for your

You don't have to be right all the time; here it really is the effort that counts. At this publication you will find some suggestions and possible answers and solutio remember, they are not the only answers. Like real science, not all the answers valid and worthy of exploration and experimentation.

1. Measurement and uncertainty

At the heart of **all science** is the ability to **collect data** and **compare this with a h** we may expand the range and detail of our knowledge and understanding.

There is a problem that as Physics students we must consider whenever we take result from the use of an equation. **No measurement is 100 % accurate** all the t the collecting of the data. There are always assumptions and mistakes.

Challenge 1.1 – Uncertainty in measuring quantities

During your time so far as a science student, you have had the chance to measur quantities using a range of measuring equipment.

Table 1 shows some common – and some less common – quantities that are mea branches of science). What could you use to measure them, and why might they Copy and complete the table with your ideas and include the SI units plus a few too. The first section has been completed for you as an example.

Physical quantity	Measuring devices	Sources of
Time **SI units:** *seconds (s)* **Other units:** *hours, minutes, days*	*Stop clock, stopwatch, mobile phone, atomic clock, wristwatch*	*Misreading the dial* *Limit of the watch* *Limit of a stop clock* *Not stopping the sto* *(human reflexes)*
Length (distance) **SI units:** **Other units:**		
Mass **SI units:** **Other units:**		
Temperature **SI units:** **Other units:**		

Physical quantity	Measuring devices	Sources of
Electrical current **SI units:** **Other units:**		
Amount of a substance **SI units:** **Other units:**		
Luminosity **SI units:** **Other units:**		

Table 1 – measurement and sources of error

The quantities in Table 1 are the ***seven base quantities***; none of these can be exp
They are the seven building blocks of all other quantities and their units of measu
included in the AQA A Level syllabus.

Derived units of measurement – these are made up from the seven base quantit

Velocity, acceleration and speed are made up of **time and length (distance)** *[m.s*

Weight, which is a measurement of force **[N]** and is derived from **length, mass a**

Explanation: Newton's second law of motion $F = ma$ $N = kg.ms^{-2}$

Frequency [Hz] is the inverse of **time** *[*$\frac{1}{s}$ *or* s^{-1}*]*

Have a go – give the base quantities (from the seven listed in Table 1) an

Volume:

Density:

Pressure:

Moment of a force:

Calculating and recording uncertainty

There are two main reasons why data may not be 100 % accurate:

1. Limitations of the measuring device
2. Human error in reading the scale / using the device

1. Limitations of the measuring device

A typical ruler used in science may have divisions on its scale marked to 1 mm. It most people to be able to take a measurement to the nearest 0.5 mm. 0.5 mm is, for this device.

If, for example, a student measures the length of the side of a cube to be 30 mm, within 0.5 mm: 30 mm ± 0.5 mm, i.e. the *real* length is between 29.5 mm and 30.5

This can also be expressed as a **percentage uncertainty**

$$\text{percentage uncertainty} = \frac{uncertaintyinthemeasurement}{valueofthemeasurement} \times 100\%$$

For the example above:

$$\text{percentage uncertainty} = \frac{0.5}{30} \times 100 \ = 1.67\ \%$$

… but these are normally limited to 1 or 2 sf. Therefore, it would be expressed as

Values below 5 % are considered to be repeatable. Above 5 % and the error is oft repeatable and, therefore, of limited value in providing proof.

2. Human error

All students are familiar with this; it is why we take three or more readings and th One way of calculating the uncertainty is to **find half the range** and use this with t

Example

A student measures the mass of a cube of copper as part of working out its densit readings from their electric balance:

20.25 g, 20.66 g and 20.14 g

$$\text{Mean} = \frac{(20.25 + 20.66 + 20.14)}{3} \ = 20.35\ \text{g}$$

Range of the results = 20.66 – 20.14 = 0.52 g

Uncertainty = range ÷ 2 = 0.52 ÷ 2 = 0.26 g

Thus the result is 20.35 ± 0.26 g (percentage uncertainty of 1.3 %)

Challenge 1.2 – Recording uncertainty

Find an object (nothing too large – a phone, a tablet or a book, for example).

Take a ruler – any ruler will do. Note the smallest division (1 mm, 1 cm, etc.) and (normally half the smallest unit division on the ruler, but it's up to you to decide).

Now measure one side or height of your object. Do this three or four times or, be people to do it as well as yourself. Record each answer then work out the mean a the percentage uncertainty.

How accurate were your measurements – were they repeatable?
How could you improve the uncertainty in these measurements?

2. Mechanics

Mechanics is the study of moving objects (or *moving bodies* as they are often refe
includes the familiar works of Sir Isaac Newton's three laws of motion as well as h
In this challenge your mathematical skills will be needed as it focuses on the equa
acceleration.

Equations

At A Level you will be dealing with equations in their algebraic form; they will gen
words. Therefore, you need to know the standard symbols and the SI units used.

Copy and complete Table 2 with the correct symbols and SI units for some of the

Variable	Symbol	SI u
Initial velocity	u	ms^{-1}
Final velocity or velocity		
Acceleration		
Time		
Distance or displacement		
Gravity		
Force		
Mass		

Table 2 – variables in mechanics

Recall the symbol Δ (delta) means the change in the value of a variable.

$$v = \frac{\Delta s}{\Delta t} \quad a = \frac{\Delta v}{\Delta t}$$

$$v = u + at \qquad s = \left(\frac{u+v}{2}\right)t \quad s = ut + \tfrac{1}{2}at^2 \quad v^2 - u^2 = 2as$$

A critical skill in physics beyond GCSE is to be able to select the correct equations
rearrange them to make any variable the subject of the equation.

Any variable or constant can be moved from one side of the *equals sign* as long as
function.

+ becomes – and – becomes +

× becomes ÷ and ÷ becomes ×

x^2 becomes $\sqrt[2]{x}$ etc.

Example

Rearrange $v = u + at$ such that t is the subject of the equation.

$v = u + at$

$\therefore\ v - u = at$ so $\frac{v-u}{a} = t$

By convention, the subject of the equation is written on the left of the equals si

$t = \frac{v-u}{a}$

Challenge 2.1

A car moves in a straight line from point A to point B in 10 s. At point B the car's v
AB is measured as 200 m.

a. What was the velocity of the car at point A?
b. Point A is ½ AB. Show that the time taken for the car to cover the distance A

Challenge 2.2

Calculate the acceleration of a sphere moving with an initial velocity of 5 ms^{-1} if it
distance of 1000 m (ignore the effect of friction).

What was the velocity of the sphere after the 1000 m?

3. Astrophysics

As you progress with Physics (or any subject) you will encounter articles and book
information than that provided in GCSE textbooks and on websites. Being able to
and extract useful information is a vital skill to develop. So in this challenge you h
NASA.gov by Brian Dunbar. Your challenge is to read the article and ***summarise*** i
can include any key words or data.

One tip to help with this is to ***read it once without making any notes***, so you can
use a highlighter to mark any ***important information, key sentences, words***, etc.
libraries tend to take a poor view of borrowers that do this to their books!)

In physics, any ***numbers or equations*** are probably worth highlighting; after all,
maths is the first language of physics.

Summary

- NASA.gov by Brian Dunbar
- Summarise – write a list of bullet points
- Read it once without making any notes
- Use a highlighter
- Important information
- Key sentences, words
- Numbers or equations
- Maths is the first language of physics

Challenge 3.1

What are black holes?
A black hole is an astronomical object with a gravitational pull so strong that not it. A black hole's 'surface,' called its event horizon, defines the boundary where th exceeds the speed of light.

Stellar-mass black holes with three to dozens of times the Sun's mass are spread galaxy, while supermassive monsters weighing 100,000 to billions of solar masse big galaxies, ours included.

Astronomers had long suspected an in-between class called intermediate-mass bl than 10,000 solar masses. While a handful of candidates have been identified wit convincing example to date came on May 21, 2019, when the National Science Fo Gravitational-wave Observatory (LIGO), located in Livingston, Louisiana, and Han gravitational waves from a merger of two stellar-mass black holes. This event res 142 Suns.

A stellar-mass black hole forms when a star with more than 20 solar masses exha and collapses under its own weight. The collapse triggers a supernova explosion t layers. But if the crushed core contains more than about three times the Sun's ma collapse to a black hole.

Once born, black holes can grow by accreting matter that falls into them, includin stars and even other black holes.

In 2015 scientists first detected gravitational waves, ripples in the fabric of space- by Albert Einstein's general theory of relativity. LIGO detected the waves from an two orbiting black holes spiraled into each other and merged 1.3 billion years ago facilities have observed numerous black hole mergers via the gravitational waves

Although light can't escape a black hole's event horizon, the enormous tidal force matter to heat up to millions of degrees and emit radio waves and X-rays. Some o closer to the event horizon may be hurled out, forming jets of particles moving ne radio, X-rays and gamma rays. Jets from supermassive black holes can extend hu years into space. (Dunbar, 2020)

References

Dunbar, B (2020, November 23). What Are Black Holes? (R Garner, Editor) Retri
https://www.nasa.gov/vision/universe/starsgalaxies/black_hole_description.htm

Make some notes and write a summary of the article on black holes from NASA.

Questions

A. The article mentions three classes of black hole; what are these, and how ar system? Explain why our Sun could not form one of these.

B. Black holes do not emit any radiation (all radiation is pulled into them by the phenomena have been used to help detect some black holes.

C. It is suggested that at the centre of our Milky Way galaxy there is a superma need to be supermassive, and what does this suggest for the eventual futur

Answers

Chapter 1

Task A

1. $E_p = E_k$

   $mgh = \frac{1}{2} mv^2$

   $gh = \frac{1}{2} v^2$

   $v = \sqrt{2gh}$

   $v = \sqrt{2 \times 9.8 \times (15 - 5)}$

   $\underline{v = 14 \text{ m/s}}$

2. The designers could change the shape of the cart to make it more aerodynamic. Th
   dissipated into the air as thermal energy.

3. During maintenance of the ride, the owners could apply a lubricant to the moving p
   due to friction.

4. The student's suggestion would be incorrect. This is because the mass of the cart h
   Look at the equation in part 1 of this task; you will see that the mass (m) cancels ou

   It is important to remember that equations describe what is happening in the real w
   equation is telling you about a real system when dealing with them. It will help you
   help you gain a 9.

5. This is due to the energy lost as thermal energy due to friction between the moving
   the cart through the air, known as air resistance.

Task B

1. $\Delta E = mc\,\Delta \emptyset$ *[change in energy = mass × specific heat capacity × change in te*

   $\Delta E = 1 \times 4200 \times (100 - 20)$

   $\Delta E = 1 \times 4200 \times 80$

   $\Delta E = 336\,000\,J \equiv 336\,KJ$

2. Some of the heat energy has been dissipated into the environment, such as the bod
   around the kettle.
   [Actually this would be 400 kJ (actual) – 336 kJ (theoretical) = 64 kJ of energy is diss
   into the surroundings. So the kettle is about 84 % efficient.]

3. One suggestion would be to change the body of the kettle to use a material with a l
   thermal conductivity, such as a plastic. This would allow less heat to escape into th
   and means more of the supplied energy would be used to heat the water.

Exam-style questions

1. a. The main energy changes will be from gravitational potential energy *[1]* to kine *mark for both kinetic and thermal*]

b. $E_p = mgh$

$E_p = 200 \times 9.8 \times 20$ [1]

$E_p = 39\,200\,J$ [1]

c. $E_p = E_k$

$mgh = ½\, mv^2$

$gh = ½\, v^2$

$\therefore v = \sqrt{2gh}$ *[1 mark for rearranging the equation correctly]*

$v = \sqrt{2 \times 9.8 \times (20 - 2)}$ *[1 mark for correct substitution including the change i*

<u>$v = 18.78$ m/s</u>

[*1 mark* for the answer. *Note that as long as the answer matches the sum descri be correct.*]

Example $v = \sqrt{2 \times 9.8 \times (20)}$

v = 19.80 m/s --- here the candidate has forgotten to use the chan but they still get a mark for the 19.8 m/s because it is the correct a

2. a. The insulation is to reduce the loss of thermal energy to the air. This improves experiment. [1]

b. Specific heat capacity is a property of a material that indicates the amount of e material and its surroundings to change the temperature of 1 kg of the materi

or

The amount of energy needed to increase the temperature of 1 kg of a materia

1 mark is awarded for a correct definition. There are several ways to explain th most commonly used at GCSE. The first one is a more accurate description.

c. During the investigation, a 1 kg block of iron is used and 5000 J of energy are s records a starting temperature of 20 °C and a final temperature of 30.8 °C. W the iron used in this experiment?

Before the answer, a tip: Many people find it hard to find the right information variables within an equation. This is especially true for anyone with dyslexia, fo highlighting the numbers in the question – it's OK to do this in the exam. Then, variables and pick the numbers needed from those highlighted. See the exampl

$\Delta E = mc\, \Delta Ø$

$\Delta E = 5000\, J$

$m = 1\, kg$

c =? (This is the one to calculate)

$\Delta Ø$ = *start 20 °C end = 30.8 °C change = 30.8 – 20 = 10.8 °C* [1]

Answer: $\Delta E = mc\, \Delta Ø$

$\therefore c = \frac{\Delta E}{m \Delta Ø}$

$c = \frac{5000}{1 \times 10.8}$ [1] $= 463\, J/kg/°C$ [1]

3. a. The cyclist could add lubrication (oil or grease) to the moving parts, such as th efficiency by reducing the loss of energy as thermal energy due to friction betw *[1 mark for stating the solution – lubrication. 1 mark for the explanation – reduci*

b. $E_k = ½\, mv^2$

$E_k = ½ \times 70 \times (5)^2$

$E_k = 875$ J [*1 mark for calculating the kinetic energy*]

$Efficiency = \frac{Useful\ energy\ output\ (or\ transferred\ out)}{Total\ energy\ input\ (or\ transferred\ in)}\ (\times 100\,\%)$

$Efficiency = \frac{875}{1000} \times 100\,\%$ [*1 mark for correct use of the efficiency questi*

$Efficiency = 87.5\,\%$ [*1 mark for the correct answer expressed as a percen*

Chapter 2

Task A

1. Key points to include in your answer:
   - State the starting values for each country: China, 9000 kWh per person; UK, 45, can be ± 500.
   - State that the energy used per person in the UK gradually and steadily declines
   - By contrast, the energy consumption in China increases over the same period to
   - The values are converging, showing that the two countries are now using rough per person.

   There is no need in this answer to explain why this is happening.

2. There are several possible answers to this question, but for each you must provide a correct – this is the '*justify*' part of the question.
   - The population of China has increased by 149 million, so there are more people
   - There has been an increase in the use of electrical devices, especially mobile an
   - China is a richer country so more people can afford electrical devices and there manufacturing, etc.
   - The last two can be justified by seeing that the population increased by only 11.5 increased by over 200 %, so not only are there more people but each person mus

3. On average the energy consumption per person has decreased at a rate of 684 kWh in 2000 declines to 32,000 in 2019 – that is a decrease of 13,000 kWh per person divi data = 684 kWh per person per year to the nearest integer value.)

   The reasons might include:
   - Better education / information on energy-saving behaviours – turning off lights
   - Wider/cheaper accessibility to energy-efficient devices such as LED light bulbs.
   - Changes in design and manufacturing of devices to make them more efficient.
   - A decline in the UK's manufacturing output and a move to a service-based econ

Task B

1. a. Wind turbines = 2.85×10^4
   b. Cats = 1×10^8
   c. Communication towers = 4.5×10^6

2. The statement would seem to be reasonable and you should have agreed with the co make it very hard to provide a justification based on the data, and in an exam would of the marks.

   Example answer: On average only 28,500 deaths can be attributed to wind farms. Th number of deaths caused by cats or collisions with buildings, both of which are in the data is not accurate, they do claim these are only estimates – there is a fourfold orde the deaths due to wind farms and that due to the largest causes.

   The key points are:
   - Use the data to compare the death rates.
   - State the order of magnitude difference between the death rate due to wind fa [The bigger difference in the order of magnitude the more compelling your ans
   - Recognise that the numbers are only estimates but explain why this still makes the difference.

Remember: The examiner marking your exam paper does not have a perfect model answe or ideas that they will give a mark for if you include it in your response.

Think about this when writing or checking your answer.

Try listing the points you have made in your answer – the number of points made should e available for the question. You might make more points than that, but there are no bonus writing to get all the marks but not wasting time writing more than is needed.

Time in an exam is short and you don't have time to waste.

Exam-style questions

1. a. Any two from the following: [1 mark each, max. 2 marks]
   - Solar
   - Wind
   - Tidal
   - Wave
   - Biomass and biofuels (including wood)
   - Hydroelectric
   - Hydrogen fuel cells (from water)

   [Note: nuclear fission and geothermal are incorrect because fission is not curre
   country and geothermal requires areas of active volcanic activity – there are no

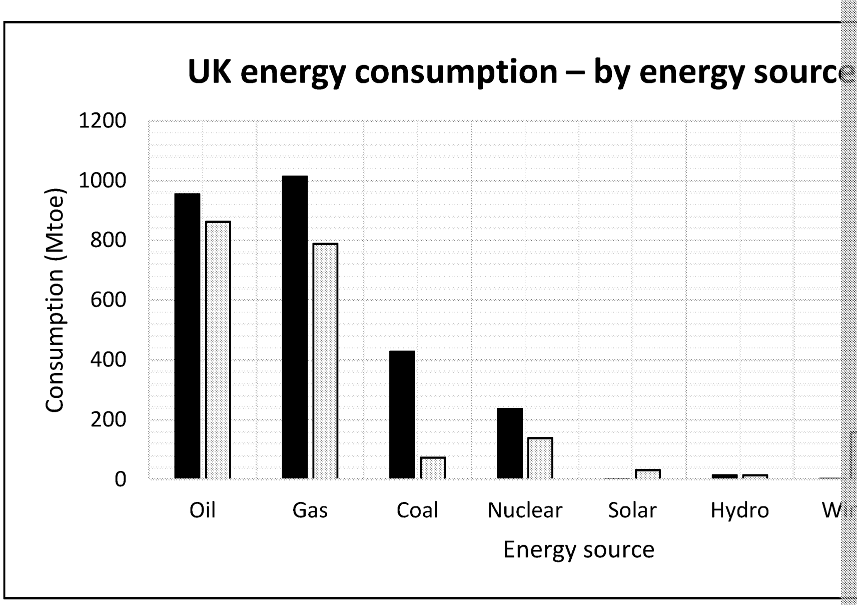
   b. 2012 [1]
   [This is the point on the graph where the two data lines cross over]

   c. 2 marks for all four, 1 mark for three, 0 marks for two or fewer:
   - Coal
   - Oil [do not accept single examples such as petrol, etc.]
   - Natural gas [accept 'Gas']
   - Nuclear fission [accept nuclear, fission, nuclear power] [max. 2 marks]

   d. The response should include the following: [1 mark for each valid statement]
   - The percentage has increased (between 2000 and 2020)
   - In 2000 the UK gained 3 % from renewables [accept values from 2–5 %]
   - In 2020 this had increased to 43 % [accept values from 40–45 %]
   - The change in percentage was higher after 2010 than before [max. 3 mark

   e. The response should include the following: [1 mark for each valid statement]
   - Both the UK and the USA have increased the percentage (of electricity gen
   - The USA produced more electricity from renewable sources from 2000 to
     expressed as the UK produced less than the USA]
   - The rate of increase in the USA has been consistent (steady, regular, etc.)
     rapidly increasing since 2010
   - The UK produces more electricity from renewable sources than the USA si

2. a. Gas [accept natural gas] [1]
   b. Nuclear [accept nuclear power, fission, nuclear fission] [1]
   c. Award a maximum of 2 marks for correctly adding all the columns [award only
   award 0 marks if three or more are inaccurate]
   Award 1 mark for updating the key to show 2019 [max. 3 marks]



   d. The response may include: [1 mark for each, max. 4 marks – there are no marks
   the statement as this is a matter of opinion]
   - The data indicates that there is a reduction in reliance on unsustainable no
   - The data indicates there is an increase in the use of sustainable renewable
   - Burning fewer fossil fuels means less carbon dioxide released into the atm
     benefit to the environment.
   - There is no data provided on the environmental impact of the increase in
     of the statement cannot be fully justified.

Chapter 3

Calculate the current in the LED
power = voltage × current   P = VI
P = 5 W, V = 230 V
P = VI
$\therefore\ I = \frac{P}{V}$
I = 5 ÷ 230
I = ***0.02 A***

If you don't know the power rating of a component, such as a bulb or a motor, what tw could you use to work out the power?
Voltmeter and an ammeter

Task A

1. 2.4 kW ≡ **2400 W** – this type of conversion is important because in equations you mu the multiples of them. So kW must be converted to W, mA to A, etc.
   Not doing this is a common error in exams when candidates are under pressure.

2. *P = VI*   *V = 240 V, P = 2400 W*
   $\therefore\ I = \frac{P}{V}$
   I = 2400 ÷ 240
   I = 10A

3. *E = Pt (energy = power × time)   P = 2400 W t = 5 min × 60 s = 300 s*
   E = 2400 × 300 = 720 000 J ≡ 720 KJ

4. $P = I^2R$ *P = 2400 W, I = 10 A*
   $\therefore R = \frac{P}{I^2}$
   $R = 2400 \div 10^2 = 2400 \div 100 = \underline{24\ \Omega}$

Why do transformers only work with AC electricity, not DC?
DC means direct current; therefore, the current and the p.d. are not changing direction. T field in the iron core is stationary. There is no relative motion between the magnetic field and, therefore, no electrical potential or current are induced in them. Thus there is no ou

Well done if you got this answer right: being able to explain why things don't work shows a c

Task B

1. $V_p I_p = V_s I_s$
   $\therefore I_p = (V_s I_s) \div V_p$
   $I_p = (19.5 \times 2.31) \div 230\ = \underline{0.2\ A}$
   The technician should use the 0.5 A fuse as this is the nearest next highest value avai

2. $\left[\frac{V_p}{V_s} = \frac{n_p}{n_s}\right]$
   $\therefore N_s = (V_s \times n_p) \div V_p$
   $N_s = (19.5 \times 1179) \div 230 = 100$ ∴ 100 turns would be used on the secondary coil

3. *power = voltage × current   P = VI*
   P = 19.5 × 2.31 = 45.05 ∴ 45 W

4. *energy transferred = power × time   E = Pt*
   t is in seconds ∴ 24 hours × 60 minutes × 60 seconds = 86 400 s
   E = Pt
   $E = 45 \times 86\,400 = 3\,888\,000\ J \equiv \underline{3.888 \times 10^6\ J}$ (or 3.89×10^6 J)

Exam-style questions

1. a. This is a step-up transformer [1]

   b. $\left[\frac{V_p}{V_s} = \frac{n_p}{n_s}\right]$ [1]

   ∴ $n_s = (n_p \times V_s) \div V_p$ [1]

   $N_s = (2000 \times 400\,000) \div 25\,000 = 32\,000$ *turns* [1]

   c. AC [accept alternating current] [1]

   d.
   - The alternative potential [accept AC or alternating current] in the primary field in the iron core [1]
   - The fluctuating magnetic field is present in all parts of the iron core [1]
   - The fluctuating magnetic field induces a p.d. (or current) in the secondary
   - The voltage (p.d.) is greater in the secondary coil than the primary becaus wire or coils] [1]

   In all parts accept alternative words or fluctuating/alternating provided it is cle

2. a. *power = voltage × current* $P = VI$ [1]

   $P = 230 \times 13 = 2990$ W ≡ 2.99 kW [1]

   b. energy = power × time $E = Pt$

   t = (1 hour × 60 min × 60 s) + (45 min × 60 s) = 6300 s [1]

   $E = Pt$

   $E = 2990 \times 6300 = 18\,837\,000$ J ≡ 18.84 MJ [1]

   c. $P = I^2R$ and $P = VI$

   $\therefore R = \frac{VI}{I^2}$

   $R = V \div I$

   R = 230 ÷ 10 = 2.3 Ω

   Accept:
   $V = IR$ (Ohm's law)
   $\therefore R = V \div I$
   $R = 230 \div 10 = 2.3\ \Omega$

   For either solution gain 1 mark for the correct rearrangement(s) of equation(s)

3. a.
   - The voltmeter will show a changing value [1]
   - The value will vary from positive to negative [1]
   - [accept it will show an AC or alternating current for 1 mark only]

   b. The value will remain at 0 V (zero volts) [1]

   Accept:
   - Nothing
   - The reading will change only a little – or similar

   c.
   - When the wire is moved at right angles [90° or perpendicular] to the mag [p.d. or voltage] is induced in the wire [1]
   - As the wire changes direction the induced potential [p.d., voltage] change
   - When the wire moves vertically [up and down, in line with the magnetic f
   - because the wire and the magnetic field are not moving relative to each o

Chapter 4

What would happen to the field if the two charged plates in the diagram above were br
It would become stronger.
How might you show this on the diagram? Add more arrows.

Task A

The style of your presentation is an individual choice but for each key idea you should hav

- What an electrical field is (a definition is needed here)
  - Electrical fields exist around charged particles or objects within which a force can b
- The effect they have on charged particles
  - The force can move charged particles. Opposite charges attract, whereas like c
- The difference between a radial field and a uniform field
  - A radial field is the electrical field that exists around a charged particle; a unifor objects and extends between them.

Any diagram showing any or all of these ideas would help to illustrate your understanding a diagram as part of an answer, you must refer to it at least once in your written response

Task B

a. The paint would have to be **negative**; this is important to ensure the paint is **attracte**

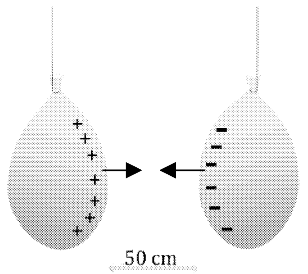
b. In order for the metal plate to become positively charged, **electrons would have to b** This would leave it with more positively charged protons (nuclei) than electrons, givi

c. This is useful in this situation because the **paint is attracted to all the surfaces of the places will still be coated in the paint**. **Less paint is wasted** because the **paint dropl** of the object and fewer **are likely to end up missing it** and coating the area around t

Exam-style questions

1. a. The rubbing **removes electrons** [1] from the surface of the balloon. This happe **two surfaces** [1].

   b.



   1 mark for each arrow – they must point towards each other as shown.

   c. The balloons move in this way as they are **attracted to each other** [1]. This is because they have **opposite charges** [1]. The two fields result in **forces that are pulling in the same direction** [1]; thus the objects move towards each other.

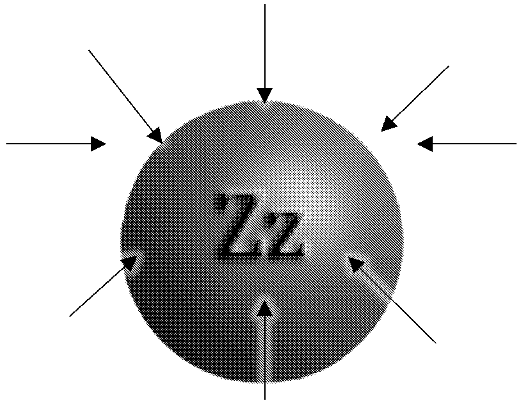
   [1 mark for a suitable diagram showing the arrows on both balloons pointing left to right.]

   d. There are no marks for agreeing or disagreeing with the statement.
   Agree: The electrons from the negatively charged balloon will [*eventually*] mov so they will become neutral. When this happens they will move apart again as them together.
   Or
   Disagree: This will not happen because the balloons are both made of non-cond therefore, the electrons cannot easily move from one to the other. This means the force that pulled them together is still present so they remain 'stuck' toget

   Each answer gains 1 mark for stating what happens to the electrons and 1 mark of the balloons.

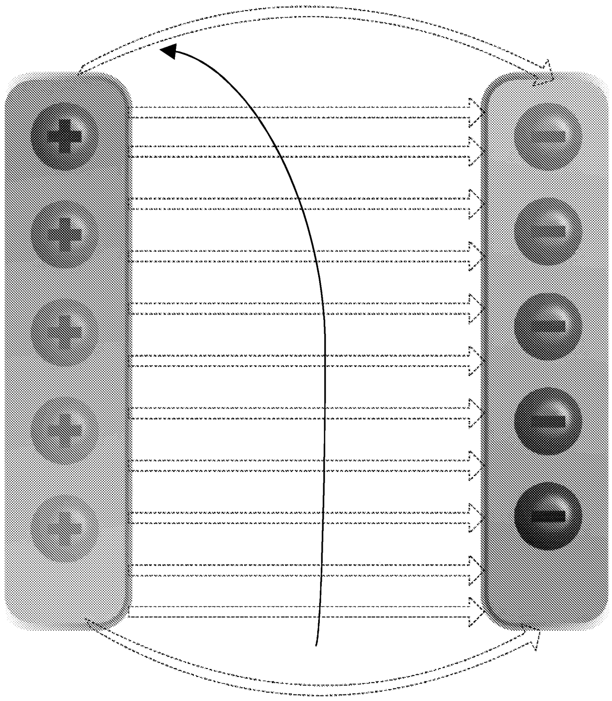
2. a. It suggests it has a **negative charge**. [1 mark]

b.



1 mark for the arrows p
1 mark for the arrows s

c. i.



c. ii. This happens because the zagatrons are negatively charged. They have a
creates a force that attracts [1] them to the positive plate and repels [1] th

iii. Non-contact force [1]

Chapter 5

Task A

When a beaker of water is heated by a Bunsen burner, the ***thermal*** energy from the flame i molecules. This means the water molecules have more ***internal*** energy. This is measured a

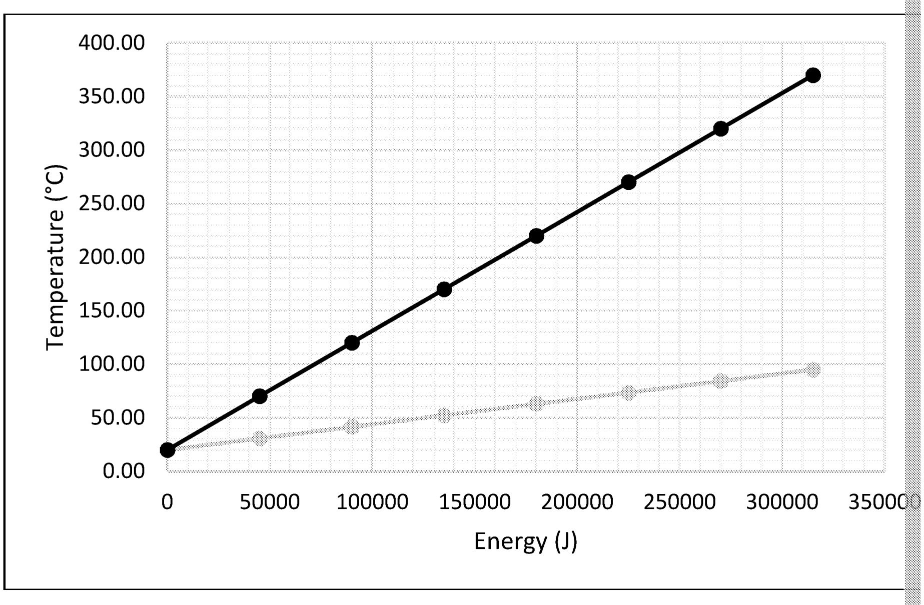
Given the same amount of additional thermal energy from a heater, which material wil – aluminium or water?
Aluminium. This is because as a metal it has a lower specific heat capacity than water; the thermal energy is absorbed, its temperature will increase more than that of the water.

Task B

1. As the energy supplied increases so does the temperature; there is a positive propor variables.

2. The line would also show a positive proportional relationship between the energy su however, as the specific heat capacity of the aluminium is lower than that of the wat be higher (steeper).

   Note: the question asks you to compare; therefore, you should have attempted to fin differences in the pattern shown in the graph.



You are not expected to plot the graph shown above – this is to help you understand t

Task C

Recall that on the diagram it indicated that a 2 kW heater was used in this experiment an The temperature remains constant at 100 °C; as we know, this is the boiling point.

It remained at this temperature from 196.4 s until 763.5 s.

Using $E = Pt$ you can work out the energy supplied in this time.

$E = 2000 \times (763.5 - 196.4) = 1\,134\,200\ J$
and as $E = mL_{(v)}$
$\therefore\ L_{(v)} = E \div m$ where $m = 500\ g$ or $0.5\ kg$
$L_{(v)} = 1\,143\,200 \div 0.5 = 2\,268\,400\ J/kg \equiv \underline{2268.4\ kJ/kg}$

Note: this is slightly higher than the theoretical value of 2260 kJ/kg; this is probably due t such as mineral salts or the chlorine added during water purification treatment.

Exam-style questions

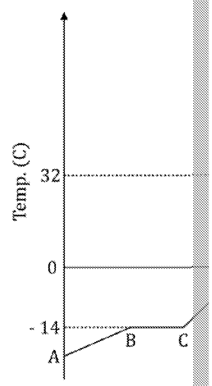
1. a. Latent heat of vaporisation is the amount of energy required for 1 kg of a mate[r] a gas (or vapour) with no change in temperature.

   b. i. Section **CD** – any two from:
   - The substance is getting hotter (warmer, increasing in temperature) [1]
   - Remains as a liquid – not changing state [1]
   - Increasing its internal energy [1]

   Section **DE**:
   - Boiling [1]
   - The remaining bonds between the particles are breaking [1]

   ii. -14 °C [1]

   iii. Gas (gaseous, vapour) [1]



Graph

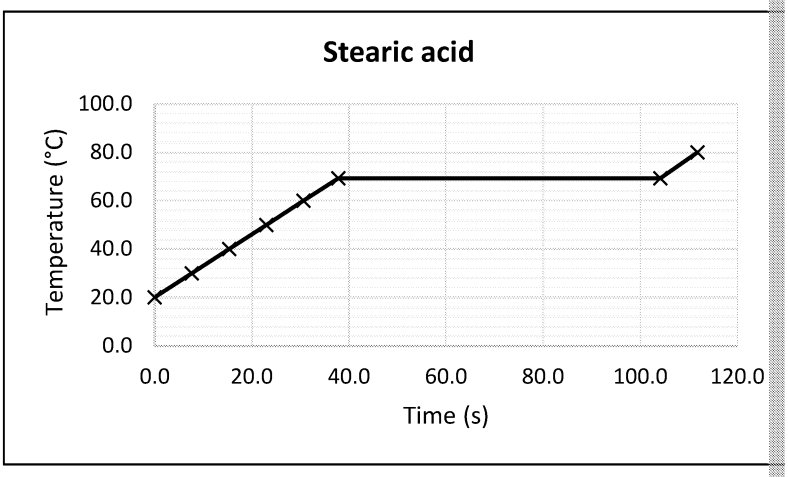
   c. During section **AB** on the graph the substance is taking in thermal energy and t **energy** [1]. This is **because** the thermal energy is **increasing the kinetic energ** that make up the substance.
   Accept if the answer also mentions potential energy of the particles.

2. a. Thermometer (accept temperature probe) [1]

   b. Any one from: [1]
   - Goggles
   - Heatproof gloves
   - Lab coat or similar

   Do not accept heatproof mat as this is not personal protective equipment.

   c. i.



   Max. 3 marks for plotting all points accurately [2 marks if one is incorrect, 0 marks if three or more are inaccurate].
   [1 mark for a straight line linking the points as shown.]

   ii. Melting point is 69.3 °C [1] (accept 70 °C)
   This is the point at which the temperature is not increasing – the horizon

   iii. 60 W heater
   Time to melt – from 37.8 s until 104.1 s
   $E = Pt$
   $E = 60 \times (104.1 - 37.8)$ [1]
   $E = 3978$ J [1]
   $E = mL_{(f)}$
   $\therefore\ L_{(f)} = E \div m$ [1]
   $L_{(f)} = 3978 \div 0.02$
   $L_{(f)} =$ <u>198 900 J/kg</u> or 198.9 kJ/kg accept 199 kJ/kg [1]

3. a. Specific heat capacity is the amount of energy required to heat 1 kg of a mater

   b. Specific heat capacity and specific latent heat both explain how changes in ene Specific heat capacity indicates how much energy is needed to change the tem changing state. [1] Specific latent heat indicates how much energy is needed fo

Chapter 6

What two things (factors) have *not* changed?

1. The mass of the gas (number of particles)
2. The temperature of the gas

Task A

a. ρV = constant

Before ρV = 101,000 × 0.2 = 20 200

After ρV = 20 200 ∴ V = 20 200 ÷ 0.05 = <u>404 000 Pa or 404 kPa</u>

b. 1. Reduction in volume resulting in a higher probability of collisions between the par
2. The area of the walls is now reduced.

What happens to a substance if you add energy to it?

The internal energy of the particles increases, leading to an increase in the temperature o

Task B

1. A force is applied to the plunger
2. The plunger moves
3. This results in the transfer of the force
4. Work is force in a given direction
5. Work transfers energy as a result of the force
6. The transferred energy increases the internal energy of the gas particles
7. This results in an increase in the temperature of the gas in the bicycle pump

Exam-style questions

1. a. The air creates a pressure on the outside section of the piston when the particles piston [1]. This produces a pushing force [1] that is spread out over the areas of t

b. i. Before ρV = constant = 101 000 × 0.5 = 50 500 [1]
After ρV = 50 500 ∴ V = 50 500 ÷ 69 000 = 0.732 L or 731.8 mL [1]

ii. As the cylinder ascends in the plane, the air pressure decreases, reducing t the pressure decreases the volume increases [1] as the product of pressur [1] (for a fixed mass of gas at a fixed temperature).

2. a. It increases (gets higher, gets larger) [1]

b. As the piston moves, a force is applied to the fuel vapour [1]. This force does wor energy (to it) [1]. This energy increases the internal energy of the vapour [1] whic

3. a. The volume will decrease [1]

b. 0.75 L or 750 mL [1]

Any reasonable explanation giving an understanding of the proportional nature

- The pressure has increased by a factor of 2 so the volume must decrease b
- The change in volume is inversely proportional to the change in the pressu

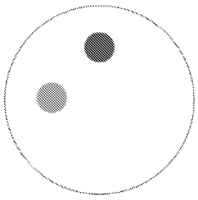
Chapter 7

Task A

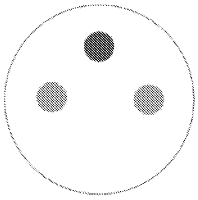
Strontium $^{87}_{38}Sr$ **protons = 38** **neutrons = 87 – 38 = 49**
Lead $^{208}_{82}Pb$ **protons = 82** **neutrons = 208 – 82 = 126**
Thorium $^{230}_{90}Th$ **protons = 90** **neutrons = 230 – 90 = 140**

Task B

$^{1}_{2}\mathrm{H}$



$^{1}_{3}\mathrm{H}$



Exam-style questions

1. $^{14}_{7}N$
   a. i. Atomic mass = 7 [1]
      ii. Neutron number = 7 (mass number – atomic number = 14 – 7 = 7) [1]

   b. $^{35}_{17}Cl$ and $^{37}_{17}Cl$
      i. Atoms of the same element with different mass numbers (or different nu
      ii. The following table contains information comparing the atomic structure

Isotope of Cl	Number of electrons	Number of protons	Nu ne
^{35}Cl	17	**17**	**18**
^{37}Cl	**17**	17	20

[1 mark for completing both number of electrons and number of protons
[1 mark for completing the number of neutrons.]
[1 mark for each of the correct mass numbers.]

2. a. Protons [1]

   b. Two protons and two neutrons, or helium nuclei [2]
   1 mark only if the answer states only protons and neutrons without reference

   c. i.
      - Ionising (highly ionising) [1]
      - Ionisation can damage structures in the body (DNA, proteins, etc.) [1
        - o Causes cancers allowed for this mark.

      ii. 1 mark for each of the following ideas:
      - Alpha particles are large; beta particles are much smaller (helium nu
      - Alpha particles are slow-moving; beta particles are fast-moving.

Chapter 8

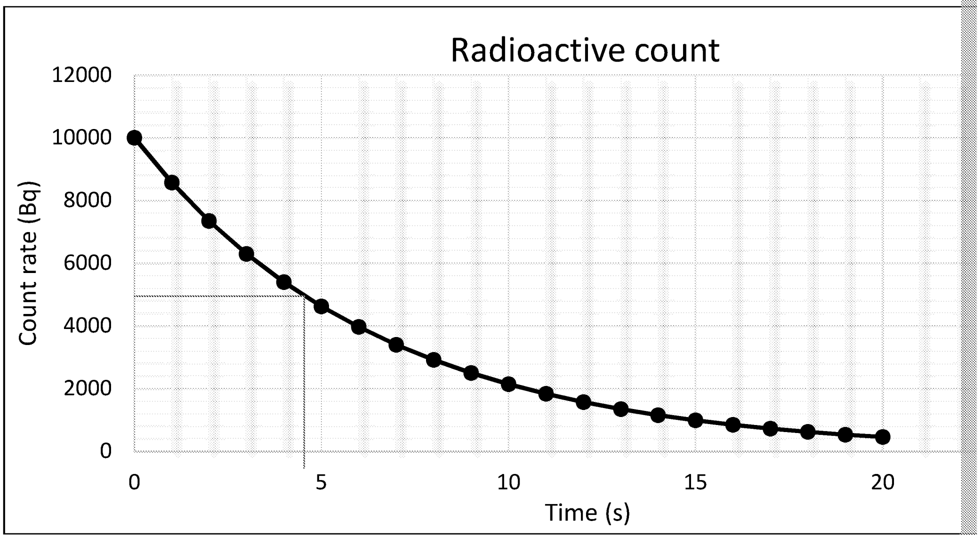
Task A

1. ${}^{222}_{86}Ra \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$
2. ${}^{234}_{92}U \rightarrow {}^{230}_{90}Th + {}^{4}_{2}He$
3. ${}^{230}_{90}Th \rightarrow {}^{226}_{88}Ra + {}^{4}_{2}He$
4. ${}^{226}_{86}Ra \rightarrow {}^{222}_{84}Po + {}^{4}_{2}He$

Task B

a. ${}^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{0}_{-1}e$
b. ${}^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + {}^{0}_{-1}e$

Task C



The point at which the count rate has halved to 5000 Bq is at 4.5 seconds. This gives the h
confirmed by checking that after another nine seconds the count has dropped by half agai

Exam-style questions

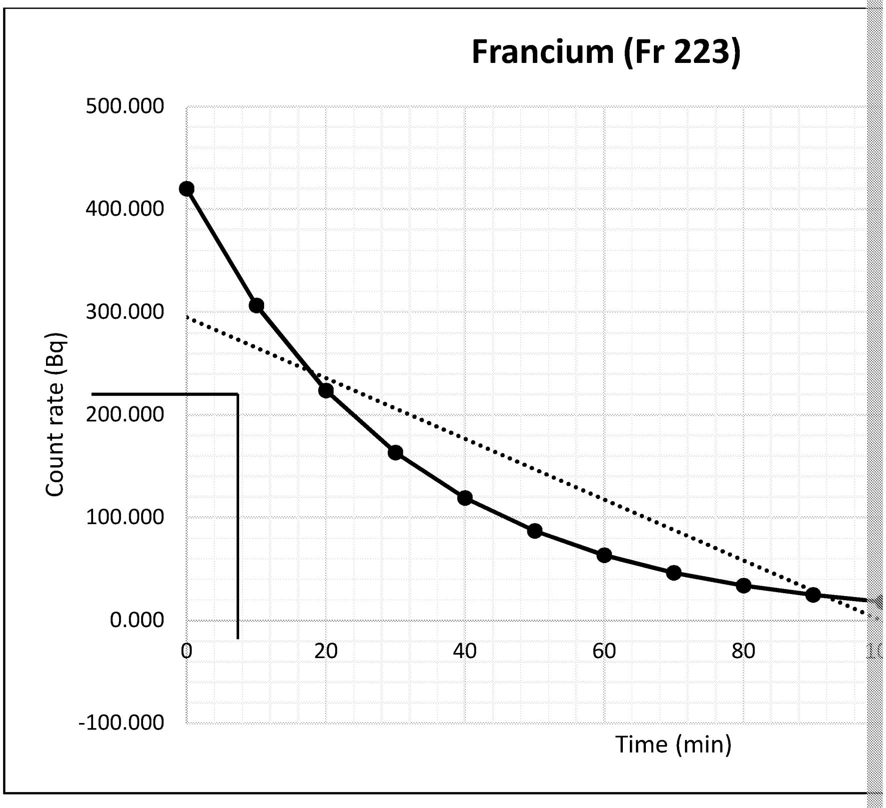
1. a. 243 [1]

   b. Atoms of an element with different numbers of neutrons [1] but the same num
   Or
   Atoms of the same element with different mass numbers [1] because of the diff
   nucleus [1].

   c. i. ${}^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}He$ 1 mark for each section of the equation.
   ii. The alpha particles are easy to stop [1] – [the plastic of the device would p
   and so could not be absorbed by a person]

2. a. i. Atomic number: 87 [1]
   ii. Mass number: 223 (87 + 136) [1]

   b. i. ${}^{223}_{87}Fr \rightarrow {}^{223}_{88}RA + {}^{0}_{-1}e$ 1 mark for each section of the equation.
   ii. Beta (β) decay [1]. This is shown by the detection of fast-moving electrons



c. i. 2 marks if all the points are plotted accurately. Deduct 1 mark if two or th
more than three points are inaccurate.

ii. 2 marks for the addition of the line as shown. 1 mark only if the line is a st
line shown.

iii. 2 marks for showing on the graph how the half-life was found, i.e. showin
count and 22 (20–24) minutes.
1 mark for recognising that the half-life is 22 ± 2 minutes.

iv. Geiger counter or a Geiger–Müller tube [1]

3. a. i. $^{235}_{92}U \rightarrow ^{231}_{90}Th + ^{4}_{2}He$ [1 mark for the correct element symbol, 1 m
and atomic number.]

ii. Alpha decay [1]
accept just alpha or α

b. combined mass before 235 + 1 = 236 [1]
combined mass after must = 236
mass after 141 + 3 × 1 = 144 [1] 236 – 144 = 92 [1]
Award full marks if 92 is given with no logic or working out shown.

c. i. Fission involves the splitting (division) of a large unstable nucleus [1]; fusi
nuclei (hydrogen) to form a larger nucleus (helium) [1]. Fission results in t
nucleus [1]. Both processes release large amounts of energy [1].

ii. Needs more energy than it produces [or similar] [1]

Chapter 9

Speed is the scalar equivalent of the vector velocity. What is the vector equivalent of di
Displacement is the vector equivalent of distance, how far and in which direction.

Task A

1. *Resultant force = 4 × 252 000 = 1 008 000 N forwards*
   Each of the four forces produced by the engines is acting in the same direction so th
   the final resultant force. Remember with forces you should try to provide both a dir
   force as they are vectors.

2. Forces to the left:
   There are four equal frictional forces acting to the left of 500 N each
   Total friction is 4 × 500 N = 2000 N (left)
   Total forces to the left = friction + air resistance = 2000 + 2000 = 4000 N (left)

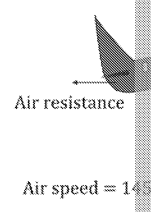
   

   We will call forces to the right positive (+) and forces to the left negative (-)
   The forces are then added together
   Resultant force = +6000 + (-4000) = +2000 N or 2000 N to the right

Task B

As the plane is travelling at a constant 145 m/s the forces **of thrust and air resistance** must be **equal** to each other **but** in **opposite** directions.

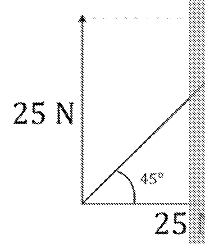
The plane is inclined upwards into an ascent (climbing) so the lift must be greater than the gravity (weight). The lift arrow must be in the opposite direction to the gravity. You do not need to have this to scale for this task, as long as the lift arrow is longer than the gravity arrow.



(Fine details that you might have included: the thrust arrow should ideally come from the engines, actually the back of the engines pointing forwards. The lift should start on the wing directly above the gravity arrow or just forward of it. If you got these, well done!)

Task C

You could use any reasonable scale that sensibly fits into the space provided. This is important in the exam as you will be given a space to fill in on the paper and you are expected to draw in this space only. The question may tell you what scale to use, but practise making up your own scales so that in the exam, if you have to, you are confident in doing so. Tip: if two forces meet at right angles and they have the same magnitude, the angle of the resultant force will always be 45° – the angle of the diagonal of all squares.



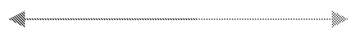
Exam-style questions

1. a. 1 mark for each correct selection:
      Magnitude [1]
      Direction [1]

   b. 1 mark for a 5 cm arrow pointing to the left

   c. i. Scale 1 cm = 10 N [1 mark for reasonable scale that allows the drawing to

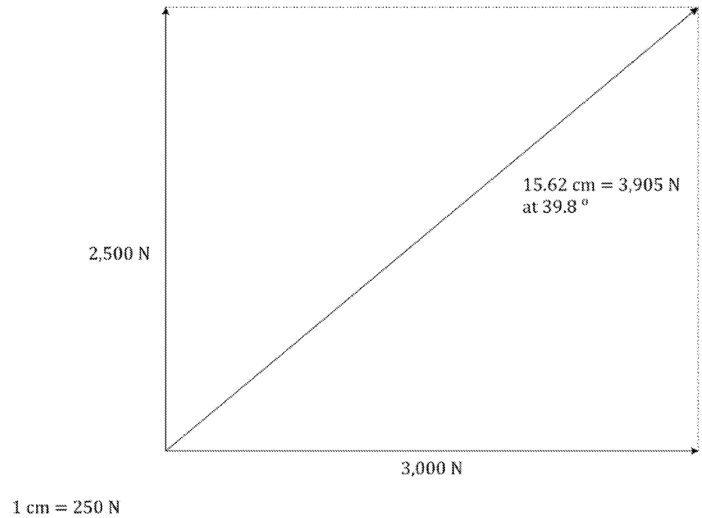
      1 mark for each correctly drawn arrow using the scale indicated.

      ii. 5 N to the left [1 mark for magnitude (5 N). 1 mark for indicating the dire

      iii. Team A is winning [1] because the resultant force is in their direction [1].
      Allow the explanation 'the left force is greater than the right force' for 1 m

   d. The resultant force will decrease to 0 N [1]

2. a. i. Any sensible scale can be used for this diagram for 1 mark.
1 mark for the correctly drawn forces to the scale indicated.
1 mark for completing the rectangle.
1 mark for the correctly drawn resultant force (there is no requirement to the diagram).



ii. Magnitude: 3905 N [1]
Direction: 39.8° [1]

Chapter 10

Task A

1. speed = gradient of the line
gradient = change in y ÷ change in x
= 2400 ÷ (10 × 60) = 4 ≡ 4 m/s

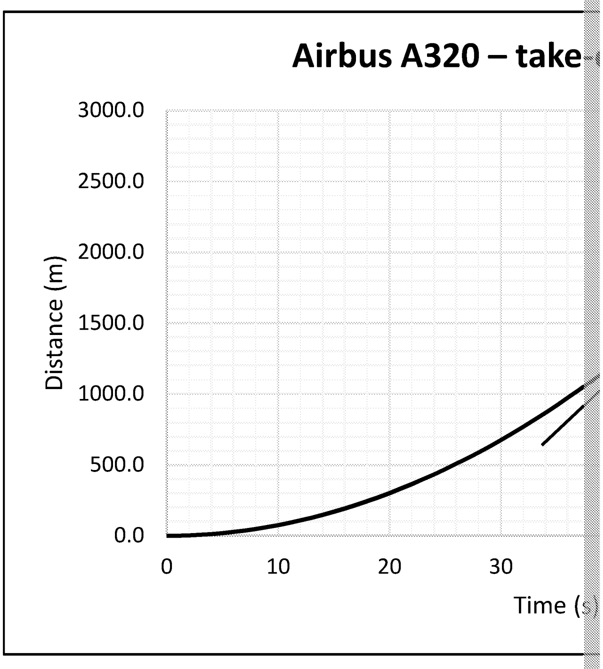
2. speed = gradient of the line
(4200 − 2400) ÷ ((20 − 15) × 60) = 6.0 m/s

3. They are stationary (not moving).

Task B

1. Draw a tangent line at t = 50 s on the graph as shown.
Then find the gradient of this tangent.
Change in *y = 2550 – 1150 = 1400*
Change in x = 60 – 40 = 20
V_1 speed = gradient of the tangent = 1400 ÷ 20 = 70.0 m/s

2. The line is curved because the plane is accelerating.



Task C

1. The area under the line from B to C contains 150 squares (six blocks of 25 squares); there
2. From C to D there are eight blocks of 25 squares equalling 200 m. Several of the larg
These can be combined to form whole squares; this can be judged by eye.

Exam-style questions

1. a. Speed is a scalar and velocity is a vector [1]
Allow velocity has direction as well as magnitude (size) for 1 mark.

b. i. 5 minutes [1]
ii. speed = gradient of the line
change in distance (*y*) = 180 m [1]
change in time (*x*) = 120 s [1]
$\text{speed} = \frac{\text{change in distance}}{\text{change in time}} = 180 \div 120 = 1.5 \text{ m/s}$ [1]
iii. They were at rest for 1 minute (60 s) [1]. This is the period of time that th
iv. The speed is greater (double or higher) [1]. They might be running / joggi

c. The device could take readings more frequently than once every 10 seconds. [1

2. a. The train is accelerating [1]

b. 1 mark for drawing a tangent line at 80 seconds.
1 mark for measuring the change in the *y-axis* value along the tangent.
1 mark for measuring the change in the *x-axis* value along the tangent.
1 mark for the speed: 20 m/s ± 2
1 mark for suggesting the train does meet the safety requirement.

c. i. change in time = 20 s [1]
change in velocity = 20 m/s [1]
acceleration = 1 m/s/s [1]
ii. The maximum velocity of the tram is 20 m/s [1]
iii. 1 mark for counting the square (16 large blocks of 25) = 400 [1]
distance = area under the line = 400 m [1]

Chapter 11

Task A

a. Truck A will have the highest magnitude of acceleration. This is because it has a low produce a higher acceleration than truck B, which has a higher inertial mass.

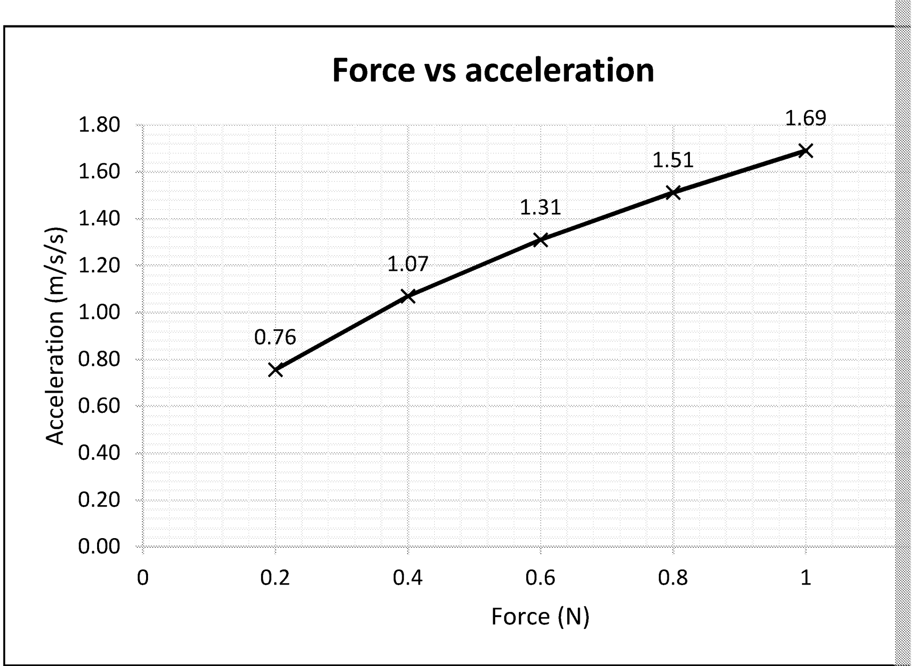
b. $F = ma$

$\therefore a = \frac{F}{m}$

Truck A: a = 18 000 ÷ 15 000 = 1.2 ms^{-2}
Truck B: a = 18 000 ÷ 35 000 = 0.51 ms^{-2}

Task B

a. The acceleration increases as the force applied increases. The acceleration is propor



b. The data could be made more reliable (repeatable) by repeating the experiment thr and calculating the average.

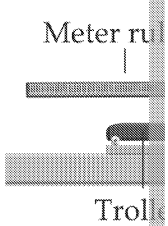
Exam-style questions

1. A model answer is provided. The method assumes gravity is 10 N/kg for convenienc

Apparatus

- Stop clock / stopwatch
- Track or length of bench 2 m
- Trolley or toy car large enough to attach the string to
- 5 × 1 N stacks of weights with holders
- Electric balance
- Metre ruler
- String
- Pulley and cla
- Blu-Tack®
- Video camera

Method



1. Draw a results table to record the time taken for the trolley to move along each section of the track. You will use this to calculate the velocities and acceleration of the trolley for the five different magnitudes of force.
2. Set up the apparatus as shown in the diagram, right.
3. Use the metre ruler to mark along the side of the track at 10 cm divisions.
4. Place the trolley at the far end of the track from the pulley. Set up the camera so that it can video the whole of the track – ensure that the divisions are visible.
5. Place the first weight on the end of the string – this will give a pulling force of 1

6. Start the video recording and then release the trolley. **Remember to catch the table.** Stop the video recording.
7. Review the video in slow motion if possible, and using either the built-in timer c how long it took the trolley to move between each of the 10 cm divisions. Recc results. Use this data to calculate the average acceleration (a = Δv ÷ t).
8. Add one more weight to the stack, adding an additional 1 N of force. Then repe this process until you have reached 5 N of force.

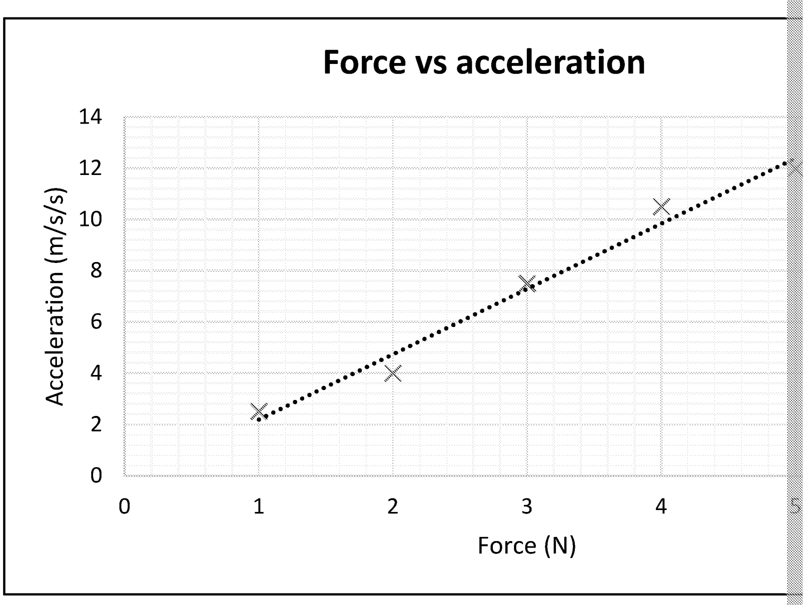
Safety: be aware of falling weights and moving trollies in this practical. Do not let th floor. Do not place hands or feet in the way of falling weights or moving objects.

The official mark scheme uses this scheme:

Level	Band	Description
Level 3	5–6	Identifies and presents the main parts of the method in a produce a valid outcome.
Level 2	3–4	Identifies and presents most parts of the method, but not outcome would not be fully valid.
Level 1	1–2	Identifies some parts of the method, but steps are not cle would not be valid.
	0	No relevant content.

Note that you do not lose any marks for not including a labelled diagram, but it is ger quicker to draw a diagram than to describe how to set up the apparatus.

b. i.



- Correct axes with appropriate scales [1]
- Correct plotting of data points [2]
- Line of best fit [1]

ii. Acceleration is proportional to the applied force [1]

iii. Mass ~400 g or 0.4 kg ± 0.1 kg [1]

Any reasonable method: [1]

- Using the change in force and acceleration taken from the line of bes
- Choosing a suitable pair of data points from the table.
- Applying m = F ÷ a to the data points selected by any means.

2. a.

Block	Force (N)			Average force (N)
A	20	22	19	20
B	45	60	42	49

1 mark for each correctly calculated average.

b. Each block must have a different inertial mass [1]. The larger the inertial mass, make it start to move [1].
Allow full marks if the word mass is used rather than inertial mass.

c. The second measurement for block B [1]. It is much larger than either of the o this block [1].

3. a. mass = 2500 kg, initial speed = 18 m/s, final speed = 27 m/s, time = 3 s

$a = \frac{\Delta v}{t}$ = (27 – 18) ÷ 3 = 9 ÷ 3 = 3 ms^{-2} [1]

$F = ma$ [1]

F = 2500 × 3

F = 7500 N [1]

b. F = ma

$\therefore\ m = \frac{F}{a}$ or inertial mass = ratio of force to mass [1]

m = 14 400 ÷ 0.4

m = 36 000 kg [1]

Chapter 12

Task A

Golf ball mass = 0.045 kg velocity = 15 m/s
$p = mv$ = 0.045 × 15 = 0.68 kg m/s

Cricket ball mass = 0.16 kg velocity = 15 m/s
$p = mv$ = 0.16 × 15 = 2.4 kg m/s

Task B

Golf ball mass = 0.045 kg velocity = 91 m/s
$p = mv$ = 0.045 × 91 = 4.1 kg m/s

Tennis ball mass = 0.056 kg velocity = 78 m/s
$p = mv$ = 0.056 × 78 = 4.37 kg m/s

Task C

Mass of foot and leg kicking ball = 3 kg
Mass of football = 0.45 kg
Velocity of foot and leg before collision is 2 m/s – after collision is 0 m/s
Velocity of ball before collision is 0 m/s
Because the leg stops in the collision (kick) and momentum is conserved, all the momentum
Before kick (collision)
Momentum of the leg: $p = mv$ = 3 × 2 = 6 kg m/s
Momentum of ball after kick = 6 kg m/s
$\therefore$ as $p = mv$

$v = \frac{p}{m}$

$v = \frac{6}{0.45}$ = 13.3 m/s

If the leg and foot kept moving, less momentum would have been transferred to the ball a ball would have been lower.

Question
Mass of car = 1500 kg Initial velocity = 15 m/s Final velocity = 32 m/s Force applied
Change in velocity (Δv) = 32 – 15 = 17 m/s

$F = \frac{m\,\Delta v}{t}$

$\therefore\ t = \frac{m\,\Delta v}{F}$

$t = \frac{1500 \times 17}{5000} = \frac{25\,500}{5000} = 5.1$ s

Exam-style questions

1. a. p = mv [1]
   p = 40 000 × 4.5 = 180 000 kg m/s [1]

   b. p = mv
   $\therefore\ v = \frac{m}{p}$ [1]
   v = 80 000 ÷ 40 000 = 2 m/s [1]

   c. Momentum before = 180 000 + 80 000 = 260 000 kg m/s [1]
   Mass of train AB = 40 000 + 40 000 = 80 000 [1]
   $v = \frac{m}{p}$ = 260 000 ÷ 80 000 = 3.25 m/s [1]

2. a. p = mv [1]
   p = 12 000 × 8000 = 96 000 000 or 96×10^6 kg m/s [1]

   b. Change in velocity (Δv) = 20 000 – 8000 = 12 000 m/s [1]
   $F = \frac{m\,\Delta v}{t}$
   $\therefore\ t = \frac{m\,\Delta v}{F}$ [1]
   $t = \frac{12\,000 \times 12\,000}{8 \times 106}$ = 18 s [1]

Chapter 13

Task A

1. Key points:
   - Water waves are transverse
   - Sound waves are longitudinal
   - Water waves and sound waves have similar properties, wavelength, velocity, fr
   - Both waves travel (the energy does) but the medium they pass through does nc
   - Water waves displace the water vertically (up and down)
   - Sound waves are made up of areas of compression and rarefaction of the air

2. The limit of human hearing is between 20 Hz and 20 kHz. The range reduces with age, sounds (high pitch). Loud music and other sounds also damage hearing, leading to a de

3. Sound waves interact with the solid (but thin) eardrum, making it vibrate in time wit rarefaction of the sound wave. These vibrations are passed to the hammer and then bones in the inner ear in contact with the eardrum and each other). These vibration like structure in the inner ear filled with fluid. The vibrations move through the liqui produces a nervous impulse that travels to the brain to create the sensation of soun

Task B

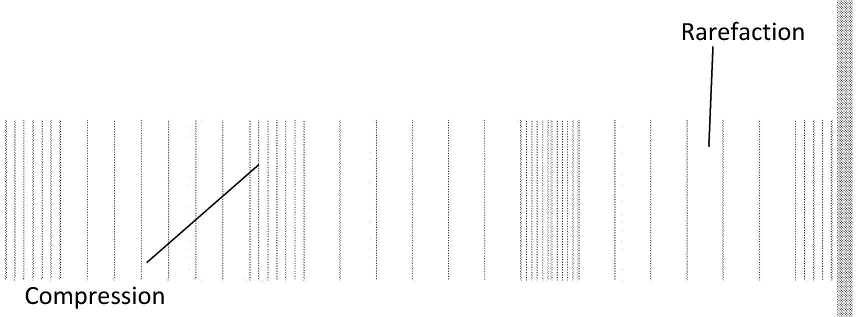
1. Depth of sea floor:
   depth = velocity of sound × (½ time taken for signal to return to the boat)
   depth = 1500 × (½ × 0.06) = 45 m
   Shoal of fish:
   depth = velocity of sound × (½ time taken for signal to return to the boat)
   depth = 1500 × (½ × 0.02) = 15 m

2. Waves of ultrasound (sound waves above the range of human hearing – over 20 kHz) are harmlessly through the various tissues. When they pass from soft tissue into the bone, s boundary. These are detected by the scanner and the computer uses these to produce a

Exam-style questions

1. a. Seismic P wave [1]

   b.



   c.
   - Pitch is controlled by (related to) the frequency of the wave [1]
   - The higher the frequency, the higher the pitch of the sound [1]

   d. i. Eardrum or tympanic membrane [1]
   ii.
   - The sound waves make the eardrum vibrate [1]
   - These vibrations pass from the eardrum via small bones to the cochle
   - The vibrations produce nerve impulses in the cochlea that pass to the

   iii. 20,000 Hz or 20 kHz [1]

2. When an earthquake occurs there are two types of seismic waves produced: P waves Earth's surface and through Earth's inner structures – the mantel, the outer core and
   a. S waves [1]

   b. Side to side, sliding, horizontal [1]

   c. i. The greatest amplitude would be detected at facility B [1]
   Any reasonable explanation such as:
   - Closest
   - Less energy will have been absorbed because it is closest
   - Nearest

   [Any one for 1 mark only.]

   ii. Only P waves will be detected at C [1]
   S waves cannot pass through Earth's core (outer core) [1]
   P waves can pass though all parts of the core [1]

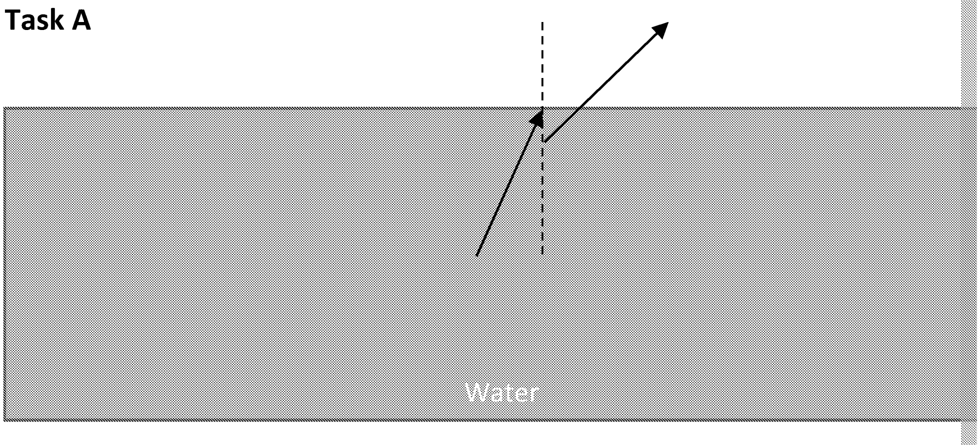
   iii.
   - The outer core is liquid [1]
   - S waves cannot pass through liquid but P waves can [1]

3. a.
   - A sound wave with a frequency above the maximum range of human hear
   - Above 20 kHz [1]

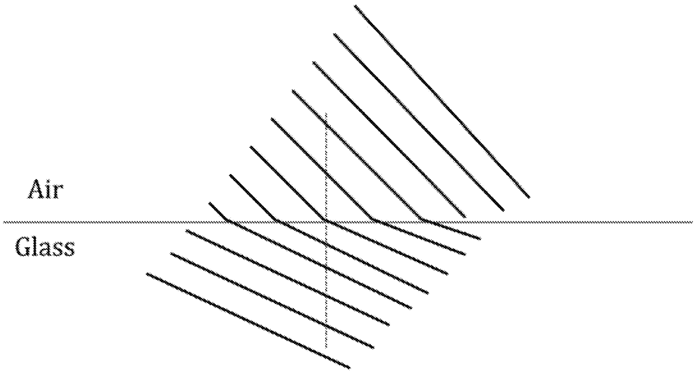
   b.
   - Ultrasound is directed into the body by an emitter device [1]
   - Ultrasound passes through the different tissues of the body [1]
   - At the boundary between different tissues (different densities), some are
   - These reflected waves are detected and used to produce an image [1]

Chapter 14

Task A



Task B



Exam-style questions

1. a. X-rays [1]

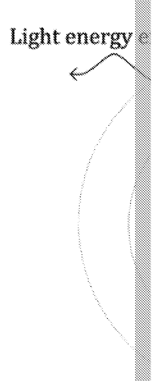
   b. Any two from: [max. 2]
   - Cooking
   - Mobile phone data and phone calls
   - Examination of microwaves from space
   - Communications
   - Detection (similar

   c. Any two from: [max. 2]
   - TV (Freeview or terrestrial; not streaming)
   - Bluetooth™ (Airdrop, etc.)
   - Wi-Fi

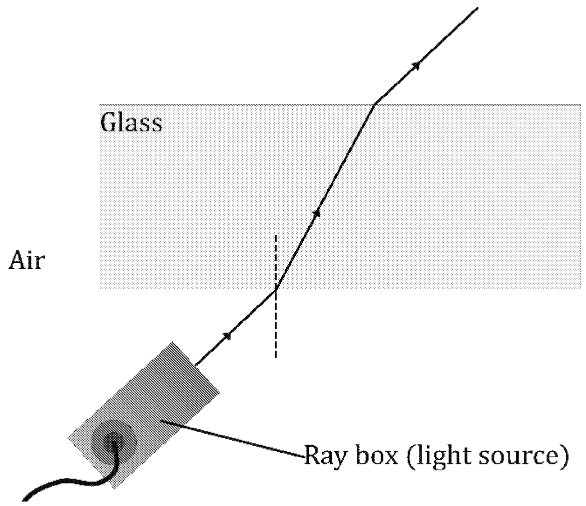
   d. Key points: [1 mark per point]
   - Radio signal picked up by an aerial
   - Variations in the signal cause an oscillation in the attached circuit
   - AC current replicates the original broadcasted information

   e. The electrical energy (energy) from the tube makes an electron in the outer object jump [1] to a higher energy level orbit [1]. When this electron falls back to the original orbit, light energy is emitted [1].

   1 mark for completing the diagram to illustrate this information.

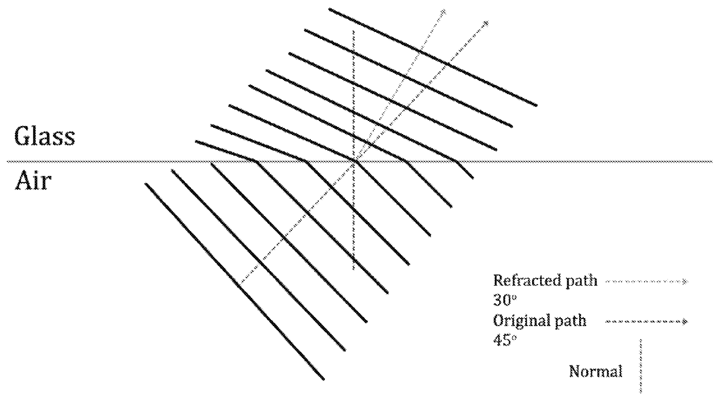


2. a.



1 mark for the ray of light bending towards the normal on entering the glass.
1 mark for the ray of light bending away from the normal as it exits the glass bl
1 mark for correct positioning of the normal.

b.



1 mark for a diagram that illustrates the bending of the ray of light and the diff
as they enter the glass from the air, as shown above.
Note: the diagram does not need to show a normal or direction of ray arrow; th
same direction as that shown in the answer to Q2a, above.

Key ideas in text of answer: [1 mark for each point]

- Glass is denser than air
- Light travels more slowly in denser materials
- The wave fronts slow down at different rates as they enter the block at an
- This causes the ray of light to bend / change direction at the boundary of t

Chapter 15

Task A

Recall that the command word *compare* means that you need to give both similarities an
of the two stars.

Similarities:

- Both start as a nebula
- Both formed from a protostar – created by the gravitational collapse of a region of a
- Nuclear fission provided the heat to make them expand and stop gravity from makin
- Both have used up all their hydrogen and are using helium

Differences:

- Betelgeuse is more massive so has formed a super red giant; the Sun will form a red
- The Sun will collapse under gravity to form a white dwarf then a black dwarf
- Betelgeuse will eventually go supernova, after which it will collapse to form either a

Task B

Key ideas:

- Red shift is seen in the light from galaxies (not from local stars in the Milky Way)
- Red shift results from the fact that the galaxies are moving away from us (receding)
- The further away a galaxy is, the greater the red shift and, therefore, the faster it is r
- Discovered by Edward Hubble and published in a scientific paper in 1929
- Caused by the stretching of the wave as the galaxy moves
- Similar to the process of the Doppler effect we hear in the sound of a moving vehicle
- Red shift supports the idea that the universe is expanding and the idea that the univ Big Bang

Exam-style questions

1. a. The light was redshifted or had more wavelength in the red part of the spectru

   b. The closer the galaxy, the less red shift was observed [1]

   c. i. The observations can be used to support parts of both theories [1]
      ii. The idea that new evidence was found to support theory A [1]
      Note: there is no need to know what this was – it is a test of the basic prin and approach.

   d. • Red shift is found in the light from all galaxies [1]
      • Red shift happens when a light source (galaxy) is moving away from the ob
      • If all galaxies are moving away from us, the universe must be getting large

2. a. Gravity [1]

   b i. Nuclear fusion (fusion) [1]
      ii. It creates heat that tends to make the star expand [1]; this balances the pu constant size.

   c. i. The sequence is:
      - Red giant
      - White dwarf
      - Black dwarf

      1 mark for each, providing they are in this order only. Note: 1 mark only n starts with the red giant but the other two are incorrectly placed.

      ii. Similarities:
      - They will both run out of hydrogen and use helium for fusion [1]
      - They will both eventually collapse due to gravity [1]

      Differences:
      - UY Scuti will go supernova and form a black hole [1]
      - The Sun will collapse to form a black dwarf [1]

Challenges – A Level AQA Physics

1. Measurement and uncertainty

1.1

Physical quantity	Measuring devices	Sources
Length (distance) **SI units:** metre (m) **Other units:** parsec, light year, centimetre, millimetre	Ruler Laser Tape measure	Limitation of the Human error in r errors
Mass **SI units:** kilogram **Other units:** gram, solar mass	Electric balance Scales (balance)	Human error in r Limitation of the mass to which th
Temperature **SI units:** kelvin (°K) **Other units:** Celsius	Thermometer Thermocouple (electrical)	Limitation of the (minimum scale) Human error
Electrical current **SI units:** ampere (A) **Other units:** n/a	Ammeter Multimeter	As above
Amount of a substance **SI units:** moles (mol) **Other units:** n/a	This is normally calculated using mass in chemistry	As above
Luminosity **SI units:** candela (cd) **Other units:** lux	Light meter	As above

Have a go

Volume: distance (length) m^3

Density: mass and distance $kg.m^3$

Logic: density = mass / volume kg / m^{-3}

Pressure: mass, length and time $kg.m^{-1}\ s^{-2}$

Logic: pressure = force / area (force = mass × acceleration)

$$\therefore \text{ pressure } = \frac{Kg\ .\ ms^{-2}}{m^2} = \frac{Kg\ .\ s^{-2}}{m} \text{ or } kg.m^{-1}\ s^{-2}$$

Moment of a force: mass, distance and time $kg.m^2.s^{-2}$

Logic: moment of a force = force × perpendicular distance and fo

$\therefore$ Moment = $(Kg.\ ms^{-2})\ .\ m = kg.m^2.\ s^{-2}$

1.2 Your answer will depend on the measurements used; however, the percentage unce and uncertainty should be less than 0.5 mm for most rulers.

How accurate were your measurements – were they repeatable?
If they had an uncertainty below 5 % then they are repeatable.

How could you improve the uncertainty in these measurements?
Use a device that has a higher level of accuracy (finer division on the ruler, for examp of the human error, such as a laser linked to a computer sensor (such as might be us

2. Mechanics

Variables	Symbol	SI unit
Initial velocity	u	ms^{-1}
Final velocity	v	ms^{-1}
Acceleration	a	ms^{-2}
Time	t	s
Distance	s	m
Gravity	g	N
Force	F	N
Mass	m	kg

2.1 A car moves in a straight line from point A to point B in 10 s. At point B its velocity i
AB is measured as 200 m.

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

$\therefore\ 2s = (u + v)t$

$\frac{2s}{t} = u + v$

$u = \left(\frac{2s}{t}\right) - v$

$u = \left(\frac{2 \times 200}{10}\right) - 40 = 0\ ms^{-1}$

The car was, therefore, stationary at the start.

Point A is ½ AB. Show that the time taken for the car to cover the distance AB was 5

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

$\therefore\ t = \left(\frac{2s}{u+v}\right) = (2 \times 100) \div (0 + 40) = \underline{5\ s}$

2.2 Calculate the acceleration of a sphere moving with an initial velocity of 5 ms^{-1} if it ta
of 1000 m (ignore the effect of friction).

Recall *t* I s in seconds = *2 min × 60 s = 120 s*

$s = ut + \frac{1}{2}at^2$

$\therefore\ s - (ut) = \frac{1}{2}at^2$

$2(s - (ut)) = at^2$

$\frac{2(s - (ut))}{t^2} = a$

$a = \frac{2(1000 - (5 \times 120))}{120^2} = \frac{800}{14\,400} = \underline{0.06\ ms^{-2}}$

What was the velocity of the sphere after the 1000 m?

$v = u + at$

$v = 5 + (0.06 \times 120) = \underline{12.2\ ms^{-1}}$

3. Astronomy

3.1 A. Stellar mass
Supermassive
Intermediate mass black holes
They are classified according to their size relative to the mass of our Sun (a sola
Our Sun is too low in mass to produce a supernova and a black hole; its fate is t

B. Gravitational waves, radio waves, X-rays and gamma rays.

C. It would need to be supermassive to exert enough gravitational pull to hold the
etc. that make up the galaxy together and slowly pull it inwards. Eventually all
spiral into the black hole and become part of the singularity at the heart of the