Nobel

Created by The Nobel School Physics Department

Dr James Finn

http://www.nobel.herts.sch.uk

Nobel

PHYSICS
TRANSITION BOOKLET
2015

RESOURCES

Sometimes just being in the lesson, listening and working through the questions is not enough to **really** understand the topics you are studying. There are many resources on the internet which are designed to allow you to further understand the mysteries of physics.

PhET (http://phet.colorado.edu)

PhET interactive simulations has numerous different computational simulations ranging from simple density to complex computational chemistry. All these simulations allow you to **play** with different aspects of physics to really see how they work in the real world.

DrPhysicsA (http://www.youtube.com/user/DrPhysicsA)

DrPhysicsA became a firm favourite with year 12 two years ago, where they were able to have short sessions watching questions being solved, and listening to a different point of view on the same topics, as covered in the lessons.

Mr Freemans course notes (http://vle.nobel.herts.sch.uk)

Mr Freeman works tirelessly with students who need more support in both physics and chemistry. He has developed a comprehensive set of notes that can be accessed through the school VLE. Please ask for access.

OCR Past Papers (http://www.ocr.org.uk)

Ask any physics A-Level alumni for their best tips to revise for the dreaded exams, and they will always come back with the same answer, 'use the past papers'! The OCR website is the best place to access a large number of past papers (use the pre-linear course as a good idea on the type of questions for the new specification).

PHYS.ORG (http://phys.org/physics-news/)

Anyone who wants to go on to study physics at university should make sure that they are keeping up to date with different aspects of physics in the news. Phys.org is a really great place to start.

IFLS (http://www.iflscience.com)

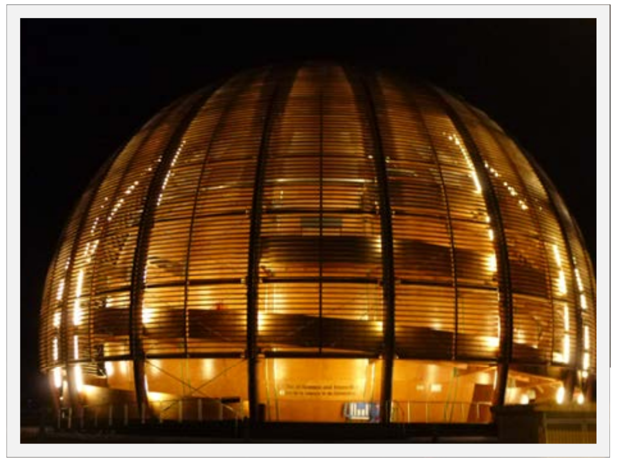
One of the best ways in which to find out what is going on in all of the fields of science!

RECOMMENDED READING

MODULE 2	**Foundations of Physics** • A cartoon guide to physics, Larry Gonick and Art Huffman • Maths skills for A-Level Physics, Carol Tear
MODULE 3	**Forces and Motion** • Structures and why things don't fall down, Gordon J E • Fatal Forces, Nick Arnold • Newton: A very short introduction, Rob Iliffe • The New Science of Strong Materials , J E Gordon
MODULE 4	**Electrons, waves and photons** • In search of Schrodinger's Cat, John Gribbon • Particle physics and very short introduction, Frank Close • QED, the strange theory of light and matter, Richard Feynman • The ghost in the atom, Paul Davies and Julian Brown • How music works, John Powell
GENERAL	**Physics Books** • A short history to nearly everything, Bill Bryson • A brief history of time, Steven Hawking • Chaos, James Gleick • Einstein for Beginners, J Schwartz and M McGuiness • Physics of the Impossible, Michio Kaku • What the Victorians got wrong, Trevor Yorke

CONTENTS

INTRODUCTION



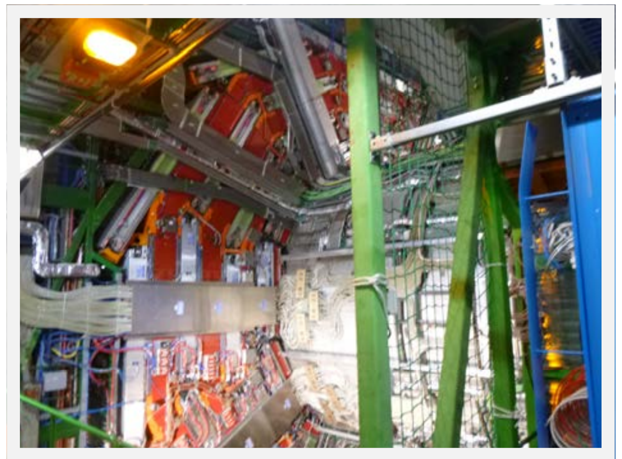


Figure 1—Pictures from the last trip to CERN in Switzerland, 2014 (top—globe of science and innovation, middle—compact muon solenoid 150m underground; bottom– CERN logo).

Welcome to the Nobel School transition booklet taking you from GCSE physics and introducing you to A-Level physics. This booklet should be worked through over the summer before you start in September on the Physics course.

The story of your physics A-Level will take you from the strange properties and behaviors of the very small, touching upon the field of quantum and particle physics, all the way to understanding and describing the life and death of stars, to an explanation of the way in which the universe has evolved since the beginning of time. Stopping off with discussions on electricity, waves, and solid state physics.

Physics is well known to be a hard subject, in fact it is believed that physics is the hardest possible A-Level that can be taken. However, in reality physics is a topic that requires understanding, the more you practice using your physics skills the more that your physics skills will improve.

We look forward to going to CERN with you all in September, where you will have an amazing opportunity to explore the bleeding edge of particle physics, walking amongst famous physicists (and even having your lunch in the same room). You will experience what it is like to work in a multicultural science establishment, and will get to see different aspects of the CERN campus.

In addition we will be heading off to the **Physics in Action** lecture course in London in December, where we will hear exciting seminars about different aspects of physics, and get the opportunity to question different lecturers. Last year we even got to hear about the story of the Big Bang Theory from Simon Singh!

Please remember that questions are a good way in which to explore a topic in further depth, and myself and Mr. Boycott are always willing to expand upon anything we have discussed in the classroom.

Dr Finn

(b) Fig. 4.1 shows a side view of a roller coaster.

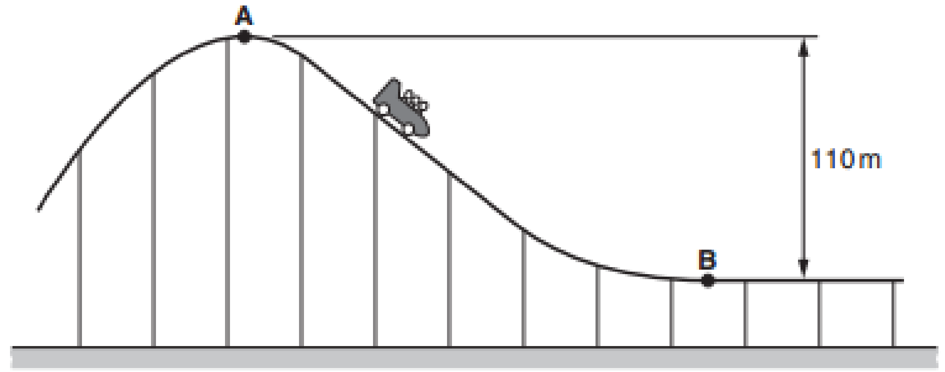


Fig. 4.1

The carriage and its passengers start at rest at **A**. At **B**, the bottom of the ride, the maximum speed of the carriage is 20 m s^{-1}. The vertical distance between **A** and **B** is 110 m. The length of the track between **A** and **B** is 510 m. The mass of the carriage and the passengers is 4000 kg.

(i) Complete the sentence below.

In your answer, you should use appropriate technical terms, spelled correctly.

As the carriage travels from **A** to **B**, ... energy

is transferred to .... energy and heat. **[2]**

(ii) By considering this energy transfer from **A** to **B**, determine the average frictional force acting on the carriage and passengers between **A** and **B**.

(ii) Fig. 6.2 shows the concrete paving slab in equilibrium.

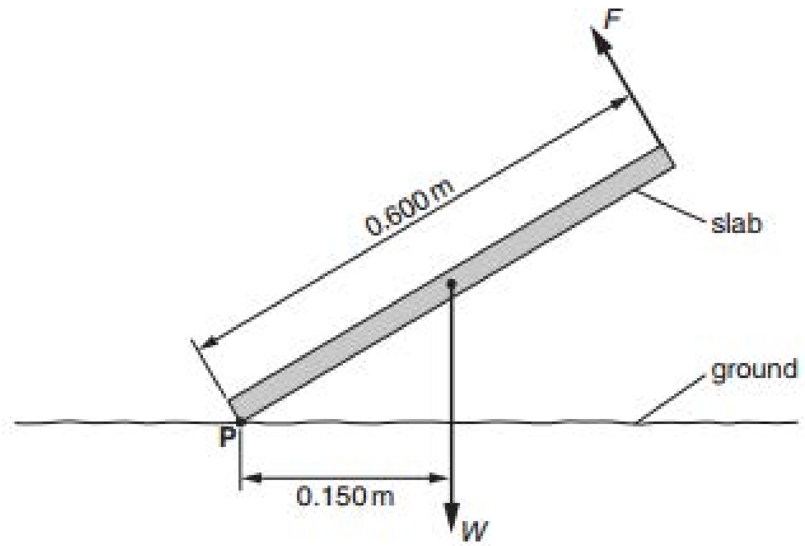


Fig. 6.2

Two forces acting on the slab are shown. The weight of the slab is *W*. The force *F* is applied at right angles to the end of the slab. By taking moments about **P**, determine the size of the force *F*.

OCR, G481 (June 2010)

P0.10 CHALLENGE QUESTIONS

Various

3 **(a)** Define a *vector* quantity and give one example.

....

.... **[2]**

(b) Fig. 3.1 shows a force *F* at an angle of 30° to the horizontal direction.

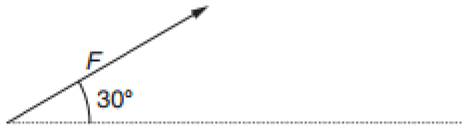


Fig. 3.1

(i) The **horizontal component** of the force *F* is 7.0 N. Calculate the magnitude of the force *F*.

F = ... N **[2]**

(c) Fig. 3.2 shows the forces acting on a stage light of weight 120 N held stationary by two separate cables.

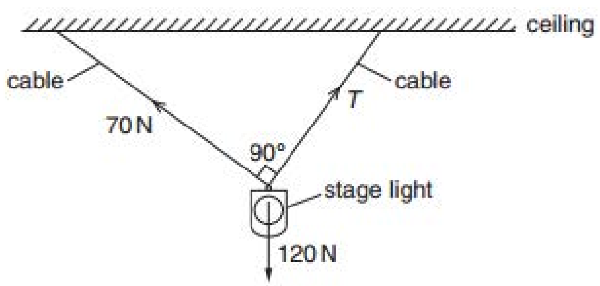


Fig. 3.2

The angle between the two cables is 90°. One cable has tension 70 N and the other has tension *T*.

(i) State the magnitude and the direction of the **resultant** of the tensions in the two cables.

magnitude ....

direction .... **[2]**

(ii) Sketch a labelled vector triangle for the forces acting on the stage light. Hence, determine the magnitude of the tension *T*.

OCR, G481 (June 2011)

FUTURE IN PHYSICS

Options are wide and varied when completing an A-Level in physics, most students go on to study physics at university, and this page is a guide of how to make yourself and your application to university look attractive.

Physics as a degree is highly regarded in the working world, graduates have an acute skill in problem solving in a logical manner, being able to complete complicated mathematics and understand important principles of the topics.

Oxbridge

Oxbridge consists of both Cambridge and Oxford universities, these universities are a little different to the norm as they only have a degree of *natural science* at undergraduate level, where you will learn all three different sciences until you start to specialise in second and third year. The gravitas which comes from going to one of these universities is second to none in the world and will make a large difference when applying to jobs after graduation, however, needless to say the work ethic expected and level of work required to reach the top degree grade is also of a top level.

Russell Group

Russell group universities are a series of universities in the UK which are highly regarded for their degrees. Here you would be able to specialise from the outset and can take physics with different secondary subjects. These universities are an excellent stepping stone to a further career in physics, but don't forget that once a degree is completed there is always the option to move up the ladder to a higher regarded university.

Other Universities

All other universities which offer physics are well regarded, just completing a physics degree will open doors to other opportunities after graduation. All universities have well equipped physics laboratories and professors who have a strong understanding of the topics they are teaching.

UNIVERSITY OF CAMBRIDGE

KING'S College LONDON

Queen Mary University of London

UNIVERSITY OF LIVERPOOL

University of Glasgow

Imperial College London

The University Of Sheffield.

UCL

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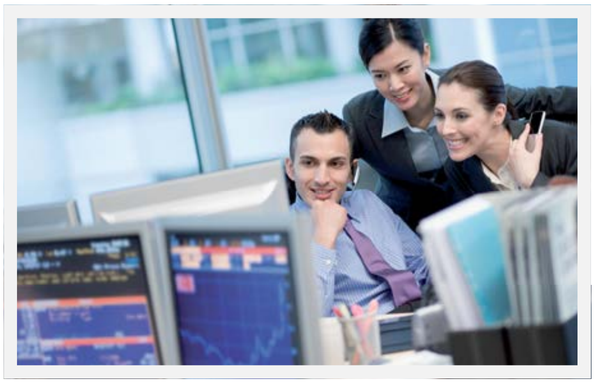
CAREERS IN PHYSICS



Physicists have the choice of many different career paths all of which are very varied. To give you a taste the following are just some of the possibilities.

Finance

Students who excel in school and in physics at university have the option to go on to work in finance, this can either be in risk assessment, looking at how 'risky' different loans are, to trading in the stock market, or developing new software to buy and sell shares quickly.

Research

If you enjoy the idea of developing and testing new ideas in science, working at the boundary of human knowledge and finding out new aspects of physics then research is for you. Heading off to conferences in far off places in the world, as well as working with other scientists in a team and on your own.

Patent Lawyer

Patent lawyers is one of the more interesting and different careers that could be entered into after a physics degree. Working with industry professionals you would be responsible for writing patent applications, understanding the science behind the invention itself., and working to protect the invention from being copied.

Engineering

Physics is one possible route into engineering, you could be responsible for developing designs for new wind turbines, to designing new aerodynamic cars or planes. A large number of engineering jobs will use software to test designs, so a strong understanding of different aspects of computational physics would be very advantageous.

Computer Games Programmers

Physics in games has become a very important buzzword in the industry. As a games programmers you could be responsible for the development of the physics of the game, making sure that object behave correctly, accurately and how a player expects them too in the game.

Fascinating Fact

Even going into research does not preclude you from being able to pursue different careers. Some students have been known to go into games programming after having developed algorithms to understand heart arrhythmia.

ADDITIONAL INFORMATION

In physics, just as all the science A-Level courses you are expected to keep on top of your own notes, as well as keep a folder to showcase the work you have completed so far in the course.

Periodically your teacher will complete a folder check to make sure that your folder contains:

⇒ Complete notes

⇒ Completed homework

⇒ Evidence of target completion

⇒ Evidence of additional reading around the topics

⇒ Practical assignments

Please ensure that your folder contains sections for each of these parts of the course.

Structure of the Course

Your teachers will split the course into separate modules which will be taught concurrently. This has an added advantage of making each lesson with a different teacher follow on from the previous, and means that on blocked days you will feel like you've learnt different aspects of the course.

Homework

Homework will be set periodically, and can either be assessed in the class through peer assessment or by your teacher. We expect that you should be completing as many hours of homework (or additional reading or thinking about the subject matter) as you have lessons in a two week period. We are aiming to develop your independent learning skills to stand you in good stead for university life.

Examinations

End of topic examinations will be set at the end of each chapter, and self assessment sheets will be provided to be included within your homework.

Please also be prepared for spot assessments in the lessons where your previous knowledge will be checked as well as your definitions and equation knowledge.

Challenge course

An additional challenge course will be run from September aimed at those students who would like to read physics at university, these sessions will consist of looking at more advanced physics problems and working on them together.

Additional help

Remember that your teachers are here to help you, please feel free to ask questions in the lessons, or to come and see one of us during or after school hours.

P0.9 GCSE DEFINITIONS

KS4 definitions

Throughout your GCSE you will have learnt some definitions to go with your understanding of the different topics, however in your physics A-Levels (and physics in general), these definitions need to be learnt to be word perfect. As you might have seen in spread P0.2 where the first definitions were given examiners have words that they expect to see when answering questions, these will be underlined in the mark schemes, and miss these words and you'll miss the marks!

Notice how some of the definitions given below are just the equations you have used in word form, this is an excellent way to learn both the definitions and equations in one.

Useful Hint

If you learn the definitions as the lessons progress then these will help you with your answers and understanding of the topics. Ensure that your units and definitions match each other to check you have them correct!

Previous Physics Definitions

- ⇒ Specific heat capacity is the amount of energy required to change the temperature of 1kg of a material by 1˚C.
- ⇒ Efficiency is the ratio between the amount of useful energy transferred by a device and the amount of energy supplied by the device multiplied by 100 to turn into a percentage value.
- ⇒ Power is the rate of energy used in a given time.
- ⇒ Electrical energy is defined as the power of a device multiplied by the time the device is used for.
- ⇒ Wave speed is equal to the frequency of the wave multiplied by the wavelength of a wave, and is a constant value for electromagnetic waves.
- ⇒ Velocity is the distance travelled per second in a given direction.
- ⇒ Acceleration is change in **velocity** in a given period of time.
- ⇒ (Note that this is now velocity as it is speed in a given direction).
- ⇒ Forces can change the shape of an object, change its state of rest, or change its motion. They are equal to the mass of an object multiplied by the acceleration of the object.
- ⇒ Hooke's law states that the extension of an object is directly proportional to the force applied, provided its limit of proportionality is not exceeded.
- ⇒ Work is force applied multiplied by the distance moved parallel to the force.
- ⇒ Gravitational potential energy is the work done when changing height of an object in a gravitational field.
- ⇒ Kinetic energy is proportional to the mass multiplied by the velocity squared and halved.
- ⇒ Momentum of an object is equal to the mass multiplied by the velocity of the object.
- ⇒ Electrical current is the number of electrons that pass a given point in a time period of one second.
- ⇒ The potential difference in an electrical circuit is equal to the work done per Coulomb, or the resistance multiplied by the current.
- ⇒ In a series circuit the same current passes through each component.
- ⇒ In a parallel circuit the current going into a junction must equal the current exiting the same junction (current is always conserved).
- ⇒ Electrical power is the energy transferred to a component or device per second.
- ⇒ A Half life of a radioactive isotope is equal to the time taken for the activity to drop by half from its initial value.

BREAKDOWN OF THE COURSE

AS LEVEL (H156)		A LEVEL (H556)	
Module 1 – Development of practical skills in physics		Module 1 – Development of practical skills in physics	
Module 2 - Foundations of physics		Module 2 - Foundations of physics	
Module 3 – Forces and motion		Module 3 – Forces and motion	
Module 4 – Electrons, waves and photons		Module 4 – Electrons, waves and photons	
EXAM 1 Breadth in physics (1hr 30min) 50%	EXAM 2 Depth in physics (1hr 30min) 50%	Module 5 – Newtonian world and astrophysics	
		Module 6 – Particles and medical physics	
		EXAM 1 Modelling Physics (2hr 15min) 37%	EXAM 2 Exploring Physics (2hr 15min) 37%
		EXAM 3 Unified Physics (1hr 30min) 26%	PRACTICAL ENDORSEMENT Teacher Report

Content for A Level Exams

Exam 1: M1, M2, M3, M5

Exam 2: M1, M2, M4, M6

Exam 3: M1, M2, M3, M4, M5, M6

Considering applying to Oxbridge?

Make sure that you are entered into the AS Level examinations at the end of year 1 to give an accurate indicative grades for your UCAS application.

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P0.1 UNITS AND POWERS

2.1.1 - Physical Quantities

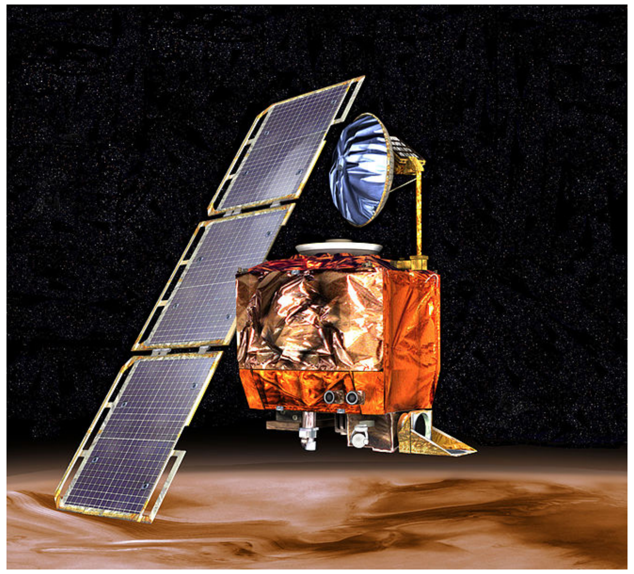


Figure 1—An artists impression of the Mars Climate Orbiter.

In the world of physics units can change outcomes of experiments , cause rockets to either perform spectacular of other worlds or fail catastrophically.

Famously in 1998 NASA launched the Mars Climate Orbiter, sent to Mars to investigate the Martian atmosphere and act as a communication relay for the Polar Lander. Some of the important work was outsourced to Lockheed which meant that due to the use of non-standard units the $327.6 million probe was lost during an orbital insertion maneuver which meant the probe orbited at too low an altitude and burnt up in the Martian atmosphere!

Units

Since 1960 a standard system of units called the International System of Units (*Système International d'Unités*, SI) has been used in science to try to ensure all scientists are using the same definitions. These SI units are both the basic units (see **table 1**) and the more complex **defined units** which you will come across in the A-Level course.

Quantity	Unit	Symbol
Mass	kilogram	kg
Length	meter	m
Time	seconds	s
electrical current	ampere	A
temperature	kelvin	K

Table 1—Standard prefixes used in all sciences.

Notice that all unit symbols are lower case unless they are named after a person, for example N is Newton named after Sir Isaac Newton, and A stands for Ampere, named after Andre-Marie Ampere.

As the example of the Mars Climate above has shown it is important to ensure that you stick to the expected SI units, your teacher will point out any units which you have got wrong.

Fascinating Fact

The SI unit for mass, the kilogram, is the hardest unit to define, and currently consists of a sphere of platinum alloy stored in vaults around the world. Metrologists are currently looking for a better way in which to define this important unit.

Prefixes

As well as just the use of symbols for different units, science also can use prefixes to show the size of different units. These different prefixes show different factors of ten to distinguish between different sizes. Each different prefix in general is either a 1000 larger or smaller than the previous, with two exceptions (**table 2**); the centi and the deci.

To convert to a prefix you should always complete the intermediary step reaching the 10^1 factor. This is as simple as just using the factor of 10. From this then to convert just

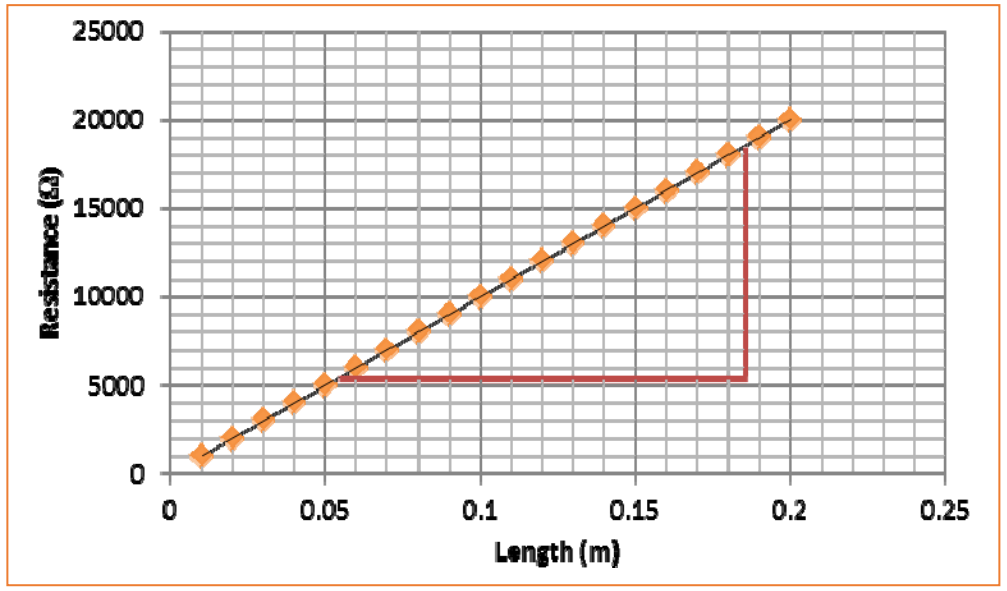


Figure 3—graph to show resistivity of a wire.

Relating equations

If an experiment is calculating something which has an equation, like resistivity, then it is possible to use the data which you have plotted onto the graph to determine what the gradient represents in the equation. As long as the line of best fit is a straight line then it follows the equation for a straight line of:

$$y = mx + c$$

This can then be equated to equation for resistivity:

$$R = \frac{\rho l}{A}$$

Looking at the graph for this (**figure 3**) the x-axis is the length (the independent variable) and the y-axis is the Resistance (dependent variable), this means that the gradient of the line is equal to:

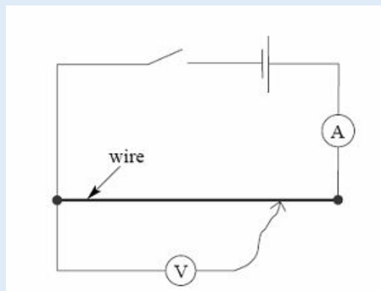
$$m = \frac{\rho}{A}$$

Therefore, if you have worked out the cross sectional area of the wire, A, and drawn the graph to calculate the gradient then the resistivity of the wire can be determined.

Questions

Marks

1. Using the circuit diagram shown below, data for the resistance of a wire has been obtained. Use this data for the resistance of the wire to draw an accurate graph, plot the points correctly and determine the cross sectional area of the wire if the resistivity is $1.68 \times 10^{-8}\ \Omega$ m. **[8 Marks]**



(**Hint:** Remember; labels, units, ruler and pencil etc.)

L (m)	R (μΩ)
0.01	5.0×10^{-2}
0.02	8.1×10^{-2}
0.03	0.12
0.04	0.23
0.05	0.17
0.06	0.24
0.07	0.37
0.08	0.38
0.09	0.38
0.1	0.50
0.2	1.10
0.3	1.30
0.4	2.10
0.5	1.90
1	3.70

P0.8 GRAPH SKILLS

1.1.3 - Analysis

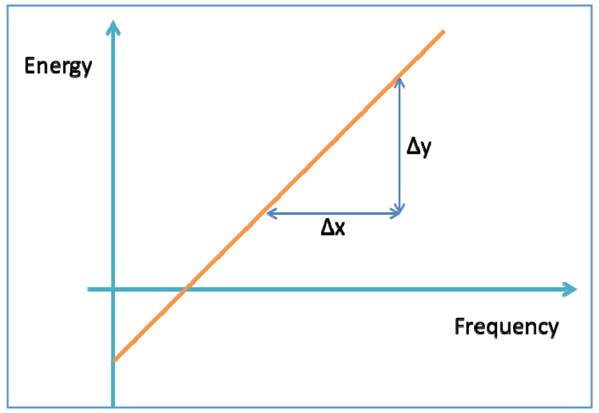


Figure 1—Graph showing the work function of a metal. Note the x and y-intercept.

Famous Quote

"The greatest moments are those when you see the result pop up in a graph or in your statistics analysis - that moment you realise you know something no one else does and you get the pleasure of thinking about how to tell them.
- Emily Oster"

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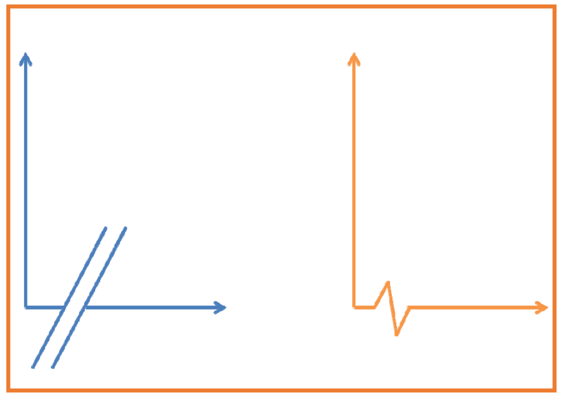


Figure 2—different ways to show contractions on the graph.

As you will have no doubt realized throughout your school career so far, graphs are one of the most important methods in which data can be shared with other scientists. Graphs allow you to determine trends, predict future data, as well as calculate constants related to the calculation.

In this section the basics of drawing a graph will be discussed as well as giving an example of a perfect A-Level standard graph.

Plotting your data

Data should be correctly plotted on both axes, ensuring that it is in the correct position to at least ±1mm (one small square on the graph paper). In addition to this it is vital to make sure that the scale used on both the x and y axes are usable. The use of odd scales such as 3 or 7 should definitely be avoided, 2, 5 or 10 is usually a good bet to work with.

It is possible to not need to start all of the axes from 0, instead you can use a broken line to indicate that all the other numbers you haven't included can be found in this contraction.

However, note that if you are required to determine a y-intercept or predict data within that contraction it is impossible too. Similarly you should ensure that you do not include the line of best fit within that section.

Finding an x or y-intercept

An intercept on the graph infers that the line must cross either of the axes, and quite simply can be determined by using a straight line of best fit which crosses one of the two axes.

Calculating the gradient

The gradient of a line can be calculated by drawing a large triangle from two points **which you have not plotted** (i.e. don't use data points). Determine the change in both the x and y-directions. Then to calculate the gradient use the following formula: $m = \frac{\Delta y}{\Delta x}$

divide by the factor of 10 value (**table 2**).

Using Prefixes Example

300km (kilometers) is the same as 300 x 10^{3} m which is the same as 3.0 x 10^{5} m.

300pm (picometers) is the same as 300 x 10^{-12} m which is also equal to 3.0 x 10^{-11} m.

Convert 4.3µm into m

4.3µm = 4.3 x 10^{-6} m

How many millimeters are there in 5 megametres?

Number of mm in a meter = 1 / 10^{-3} = 1000 mm

Number of meters in a megametre = 10^{6} m

Number of mm in a megametre = 1000 x 10^{6} = 10^{9}

Number of mm in a megametre = 10^{3} x 10^{6} = 10^{9} mm

Make sure to learn the unit information as it is used extensively throughout the A-Level course as well as in further physics at university. You are expected to be able to convert units easily.

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

Table 2—Table of standard prefixes used in all sciences.

Questions	Marks
1. What is the standard form for 10mm in SI units?	[1 Marks]
2. A) What are the standard units for time?	
B) How many seconds are there in a kilosecond?	[2 Marks]
3. Modern computer processors have transistors (components) that are just 20nm long, what is this in femtometers, centimeters, meters and kilometers using standard form.	[4 Marks]
4. The distance from London to Stevenage is 53.5km, write this in SI units.	[1 Marks]
5. A hydrogen bond between water molecules is typically 110pm, what is this in SI units?	[1 Marks]
6. The area of a stamp is 20mm x 25mm = 500mm^{2}, what is this in SI units?	[1 Marks]
7. How many micro Amps are there in 40 A?	[1 Marks]
8. Without looking at table 2 make sure you can write all the different prefixes and symbols out correctly.	[4 Marks]

P0.2 VECTORS

2.3.1 - Scalars and Vectors

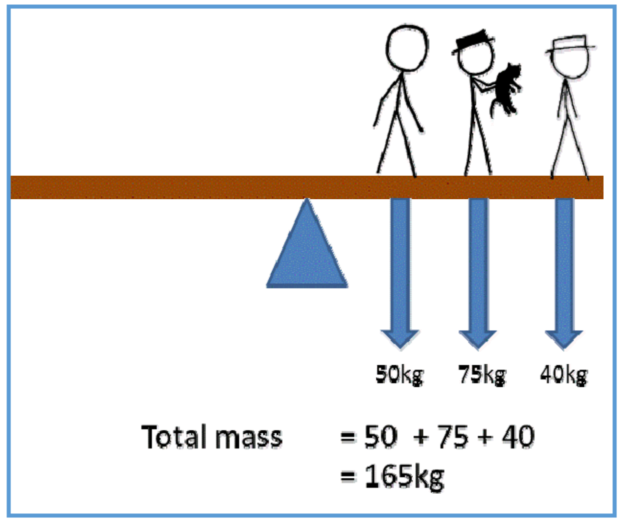


Figure 1—Different **scalar** masses on a sea-saw.

Definition

A scalar quantity is a unit with a magnitude and <u>no direction</u>.

Underlined words in a definition have to be included in any answer. They will be marked wrong without them!

Fascinating Fact

The SI unit for mass, the kilogram, is the hardest unit to define, and currently consists of a sphere of platinum alloy stored in vaults around the world. Metrologists are currently looking for a better way in which to define this important unit.

Definition

A vector quantity has both a magnitude <u>and a direction</u>.

Up to this point in your physics education, you will have been faced with values of units that can easily be added together as they have just a value and no direction (other than the positive and negative which is implied). When working with **vectors** the direction of the unit is just as important as the unit itself.

An example of **scalar** units is adding the masses of people sat on a sea-saw. In this case all the masses are added together, e.g. 50kg, 75kg and 40kg makes 165kg of mass acting downwards (**figure 1**).

These two terms have very important **definitions** that you will be expected to know for your examinations, make sure you learn them early to save on *stress* later on in the year.

Figure 2 shows a velocity vector for the motion of a boat in the water, boats cannot easily be shown to be pointing at anything, and so have vectors directions from North (normally towards the top of any page). This boat has a velocity of 40ms^{-1} at 45 degrees from North.

Examples of Scalar quantities

- Density
- Pressure
- Potential Difference
- Frequency
- Wavelength
- Power
- Energy

Examples of Vector quantities

- Displacement
- Velocity
- Acceleration
- Force
- Impulse
- Momentum
- Electrical Current
- Magnetic Field
- Electrical Field

Ensure that you know some of these examples, and their units and be able to quote them in an exam.

Using vector Quantities

Vector quantities must have a magnitude and size to indicate

electrical and magnetic. Most of these can be explained by the use of gravitational or kinetic energy and will be explored in the A Level course.

Definition

Kinetic energy is the stored ability to do work by virtue of an objects speed.

Definition

Gravitational energy is the stored ability to do work by virtue of an objects position in a gravitational field.

Definition

Energy is the stored ability to do work.

Worked examples

If a car is moving with a velocity of 20 ms^{-1} with a mass of 2000kg, what is its kinetic energy?

$$E_K = ½mv^2$$

$$= ½ \times 2000 \times 20^2$$

$$= 400000J$$

$$= 400 kJ$$

This calculation is nothing more advanced than the GCSE level calculations you have completed before, however at A Level you will be expected to put equations together and use algebra in order to rearrange the equations.

Remember that kinetic energy and the vibration or motion of particles within a solid, liquid or gas can be equated to the temperature of a substance. This will be discussed further and in more depth in Module 6. The greater the thermal energy of the particles the greater the kinetic energy, which means that they vibrate more (and thus collide with other particles in the substance), see **figure 2**.

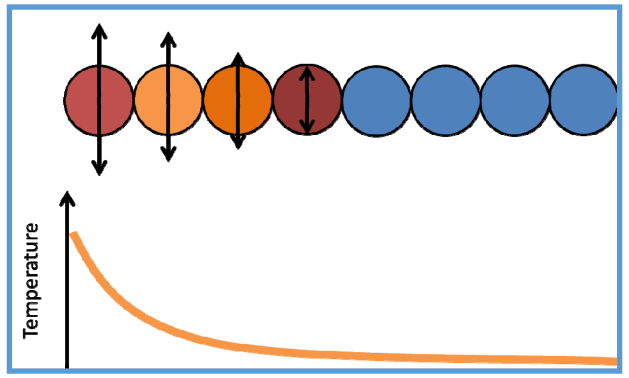


Figure 2—Motion of particles showing the transfer of energy through atoms.

Questions	Marks
1. What is the kinetic energy when an object of mass 3000kg is moving at 30ms^{-1}.	[1 Mark]
2. What is the gravitational potential energy of an object of mass 3000kg that is raised up 20m?	[1 Mark]
3. What is the average energy used per second in Question 2 if the time taken to lift the object is 5 seconds?	[1 Mark]
4. If a car has a total kinetic energy of 122.5kJ and a mass of 400kg, what is the speed?	[2 Marks]
5. If an object of mass 5kg has 500J of gravitational potential energy and is dropped from the top of a building, ignoring air resistance, how fast will the object be travelling at the point of impact?	[3 Marks]
6. Using the two equations for energy in this spread, create a new equation to calculate the speed an object falls at from a given height.	[3 Marks]

P0.7 ENERGY

3.3.2 - Kinetic and Potential Energies

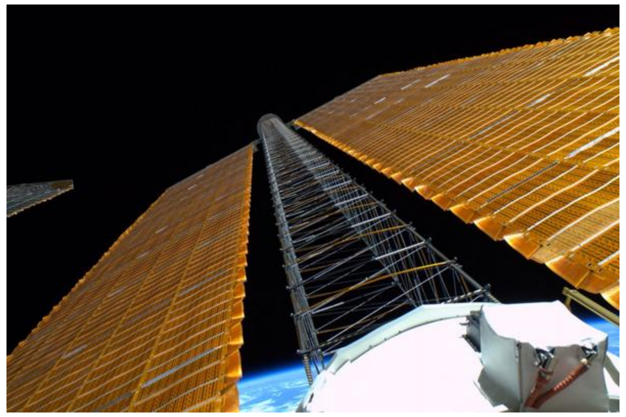


Figure 1—Solar panels on the International Space Station (ISS) converting light to electrical energy.

Famous Quote

"It is important to realize that in physics today, we have no knowledge of what energy is. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way. However, there are formulas for calculating some numerical quantity, and we add it all together it gives "28" - always the same number. It is an abstract thing in that it does not tell us the mechanism or the reasons for the various formulas."

- Richard Feynman

QR

Use the PhET resource to understand how energy is transferred.

Energy is a very complicated topic, even the great Feynman once stated that *"we have no knowledge of what energy is"*. Throughout your GCSEs you will have been given different formula to learn which allow you to calculate this abstract quantity of energy, each of which can be equated to one another, as due to the law of energy conservation;

Energy can neither be made nor destroyed only transformed from one type to another.

Types of Energy

There are three different types of energy that can be easily calculated, this spread is just a primer to remind you of the ones you have learnt in your GCSEs. All of these different calculations have a **proof** associated with them which you will need to learn and be able to reproduce.

Remember that work done is force multiplied by the distance moved in the direction of the force, as this can lead to an explanation for the first type of energy, gravitational energy. Here the force is the weight of the object, *mg*, and the movement parallel to the direction of the force is *Δh*.

Gravitational Potential Energy

This is the potential energy gained when moving an object with mass in a gravitational field. It is defined as;

$$E_{GPE} = mg\Delta h$$

Kinetic Energy

This is the energy an object has when it is moving with a mass, and is defined as;

$$E_{KE} = \frac{1}{2}mv^2$$

These two equations can be used to determine different aspects of a calculation; either an object that is moving and gaining height or an object that is losing height and so increasing in speed.

Other types of energy that you will have learnt are; light, thermal, elastic potential, nuclear, sound, chemical,

the direction in which the vector has been applied. For example for a climber to remain in **equilibrium** when he is hanging from a rope on a cliff face his weight must equal the force of the rope on him, these are both vector quantities as the weight is acting in a downwards direction and the force due to the rope must act in an upwards direction.

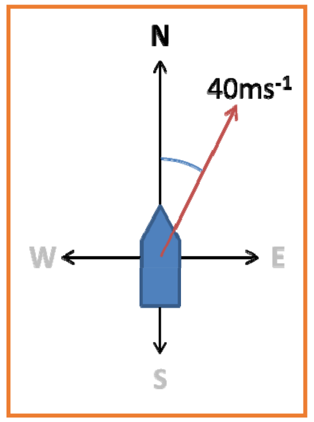


Figure 2—A boat moves with a velocity of 40 ms^{-1} at a direction of 45 degrees from North.

Free force diagrams are important as they show all the different forces acting on an object, an example can be seen in **figure 3**. The tension of the rope (the rope acting on the climber) is drawn in an upwards direction, and the climbers weight acts in a downward direction. As the climber is in equilibrium she will neither move up or down as the forces are balanced.

Force Pairs

A hint to work out which forces will act on an object is to think about the force pairs that are in action. Remember Newton's third law '*every action has an equal and opposite reaction*'. This means that if there is a weight of the climber pulling down on a rope (**figure 3**) then there must be an opposite and equal force if the climber is in equilibrium.

Always think of the force pairs in action with the object you are describing, and make sure to cover all possible forces that can be applied. A key force to think about for an object in motion is air resistance or drag.

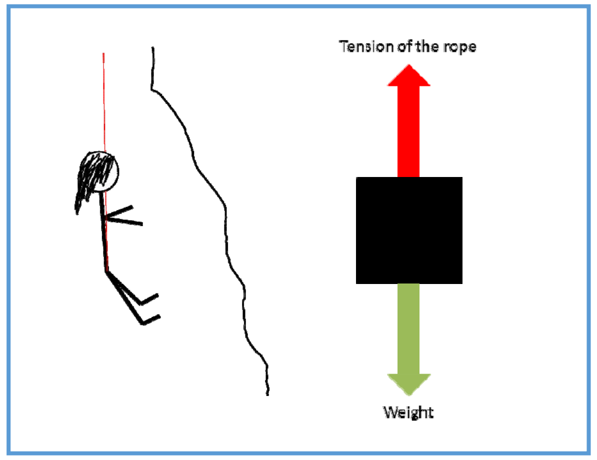
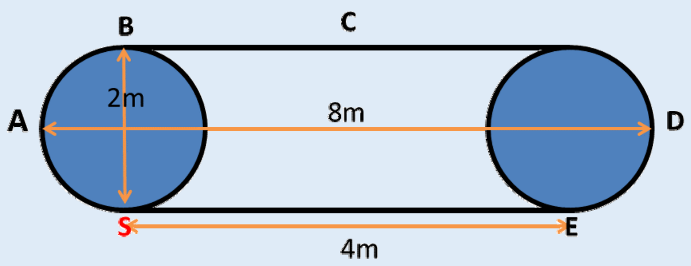


Figure 3 - A climber in equilibrium and a **free force diagram**.

Questions

Questions	Marks
1. Give an example of a scalar quantity not in this page spread.	[1 Mark]
2. Give an example of a vector quantity not in this page spread.	[1 Mark]
3. A woman walks 50m East and 50m North, find the total distance she has travelled.	[1 Mark]
4. What is her displacement from the start point?	[1 Mark]
5. What is the difference between a vector and scalar quantities?	[1 Mark]
6. The following diagram is of caterpillar tracks, find the distance and displacement to each point as follows:	
A) SA	[2 Marks]
B) SB	[2 Marks]
C) SC	[2 Marks]
D) SD	[2 Marks]
E) SE	[2 Marks]



P0.3 RESOLVING VECTORS

2.3.1 - Scalars and Vectors

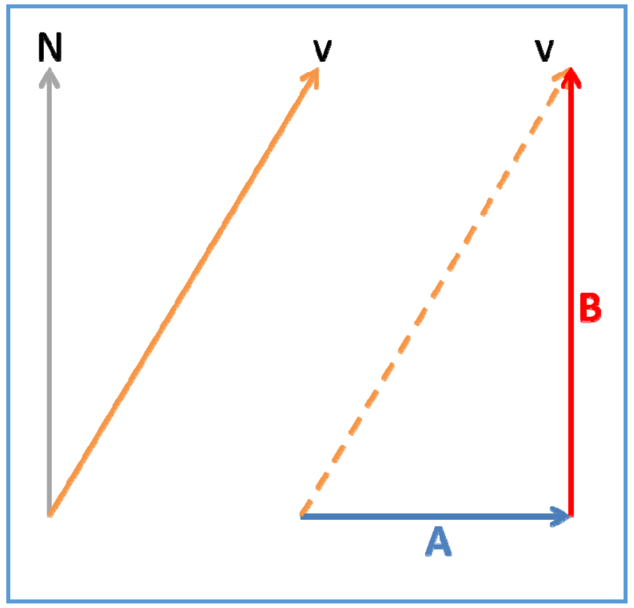


Figure 1—Velocity vector diagram showing how two perpendicular vectors can make any vector.

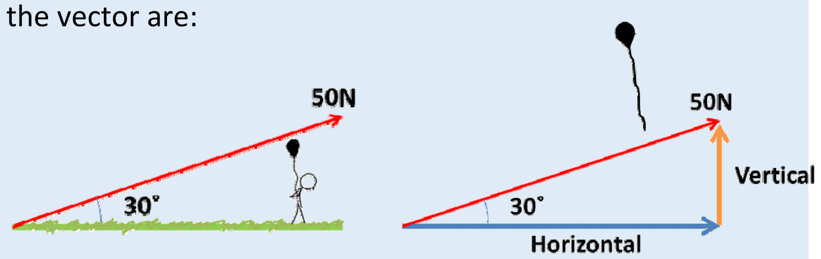
In the previous spread you have seen that vectors have both a direction and magnitude. This means that they can be expressed in terms of a horizontal and vertical component of the magnitude.

Vectors can be split this way using the **SOHCAHTOA** rule from GCSE mathematics, which allows the different sides of the to be determined from the information you have to hand.

Decomposing Vector Quantities

Example:

If the Force vector is 30 degrees from the horizontal with a magnitude of 50N then the two components that make up the vector are:



Using **figure 2** and SOHCAHTOA the vector can be decomposed into horizontal and vertical components. The opposite side (the vertical component as it is not touching the angle) is the unknown, but we do know the hypotenuse (the magnitude) and the angle, so we have both 'H' and 'O', this means we should use 'SOH'. As the Horizontal component is touching the angle it is adjacent to the angle, so we should use 'CAH'.

$$Sin\theta = \frac{Opposite}{Hypotentuse} \qquad Cos\theta = \frac{Adjacent}{Hypotentuse}$$

Rearranging these equations will allow you to determine the components of the vector (**figure 3**).

Using this gives a value of:

$$50Sin\theta = x \qquad 50Cos\theta = y$$

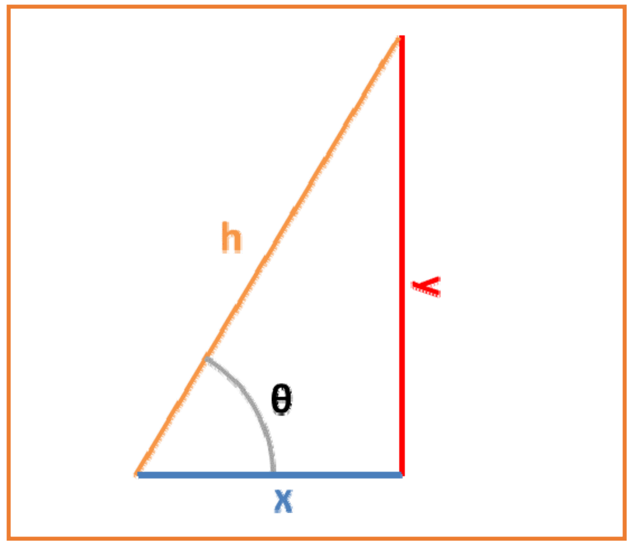


Figure 2—Defining the different sides of a triangle.

In a series circuit current remains constant throughout the circuit, the number of charge carriers flowing through the wire per second remains the same as no electrons are lost within the circuit. The number of electrons leaving the source is equal to the number of electrons returning to the source.

Kirchhoff's First Law

Kirchhoff's first law states that when an electrical current enters a junction with more than one possible exit, the total current entering the junction must equal to the total current exiting the junction. In other words electrons cannot be said to disappear or be used up, instead charge is said to be **conserved**.

"The sum of the currents entering a junction is equal to the sum of the currents exiting the junction".

Even batteries can be said to follow this law, it is a common misconception to say that electrons are created in the cell, however, in actuality, electrons are taken in at the positive terminal and given more energy through chemical reactions in the battery to be released back out through the negative terminal. Batteries act as an electron pump, moving the electrons around the circuit.

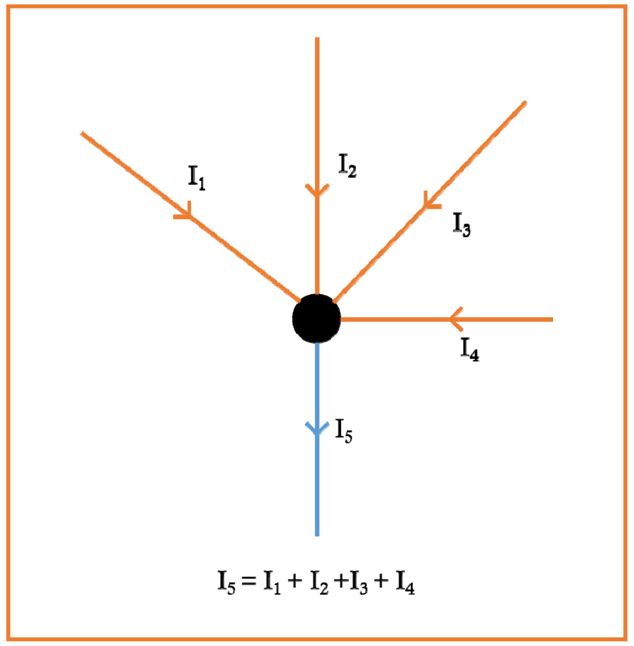


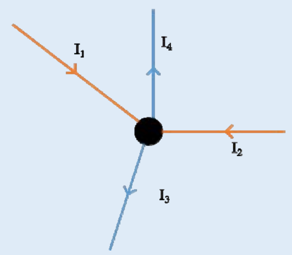
Figure 2—A simplified diagram showing Kirchhoff's first law. *Charge is conserved.*

Quote

"Simply put, what goes into a junction has to come out, whether that is the number of electrons, the current flowing through, or the total charge!"

Questions

Questions	Marks
1. If the current in a series circuit is measured as 2A, and there is a potential difference across a component of 8V, what is the resistance of the component?	[2 Marks]
2. Looking at the circuit to the right, if I_1 = 4A, I_2 = 3A and I_3 = 0.5A what is the current in I_4?	[1 Mark]
3. If the bulb in **figure 1** has a resistance of 2000 Ω with a potential difference across it of 12V.	
a) What is the current?	[1 Marks]
b) What would happen to the bulb as the potential difference increases?	[2 Marks]
c) If the bulb is left on for 20 minutes how much charge has passed through the bulb?	[2 Marks]
d) Why does the bulb ultimately 'blow' with too much potential difference?	[3 Marks]
e) Show a flow diagram to explain how the energy changes in the bulb, ensure that you account for all the energy.	[2 Marks]



P0.6 SERIES CIRCUITS

1.2.5 - Turning Forces

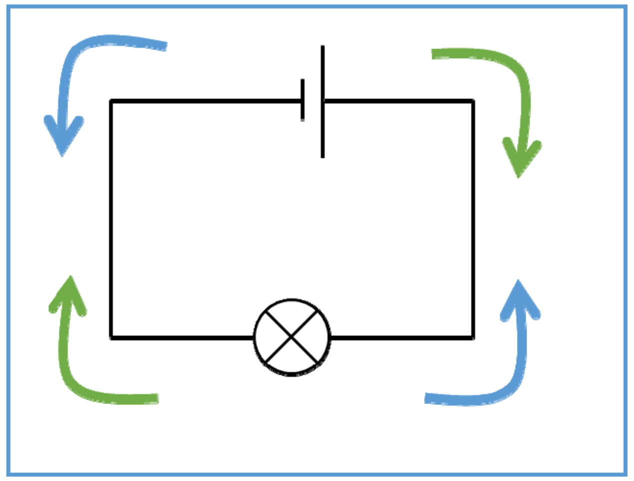


Figure 1—A simple series circuit with a bulb and cell. Note the conventional current green and actual current blue.

Electricity can flow in two different types of circuits, either in **series**, or in **parallel** circuits. Series circuits are the simplest of all possible circuits, and allow current to flow from the source; either a battery or a power supply, to a component.

Current Flow

Conventionally it was thought that electricity flowed from the positive terminal of the battery to the negative terminal, this is known as **conventional current**. However, as the charge carrier is negative, electricity's true direction of flow is from negative to positive (where the simple aspect of having a negative side of a battery just implies that there are additional electrons at that point).

Remember that if negative electrons flow from left to right, then positive particles would flow from right to left, so conventional current is the direction current would flow if electrons were of a positive charge.

Circuit Rules

The flow of charge carriers, in this case electrons, is known as the current, and can be defined as the total charge passing a point in the circuit in a given time.

$$I = \frac{Q}{t}$$

Current is measured in Amperes which is the current which flows when one Coulomb of charge passes one point in the circuit in a time period of one second. We measure current using an Ammeter, this device counts charge passing through it, and thus in the circuit, in a given time. Ammeters have to have **negligible** resistance so as to not change the outcome of the measurement of the circuit, if Ammeters had a finite resistance (something much larger than a negligible resistance) then the process of measuring the charge would change the current measured in the circuit, so to avoid this Ammeters must be placed into the circuit in series, and have a small enough resistance for it not to change the total current.

Definition

Charge is measured in Coulombs and 1C is 1A moved passed a point every 1 second.

QR

Determining the magnitude

Sometimes you will be asked to calculate the size of the vector (the magnitude), this is just using the mathematics learnt at GCSE, remembering that the decomposed vectors can be moved around without changing the outcome of the vector a right angled triangle can be created.

Pythagoras' theorem states that for a right angled triangle the sum of the square of the two smaller sides is equal to the square of the hypotenuse. This allows you to easily calculate the overall magnitude, and can be used to check any calculations of the two decomposed vectors as they should obey Pythagoras' theorem.

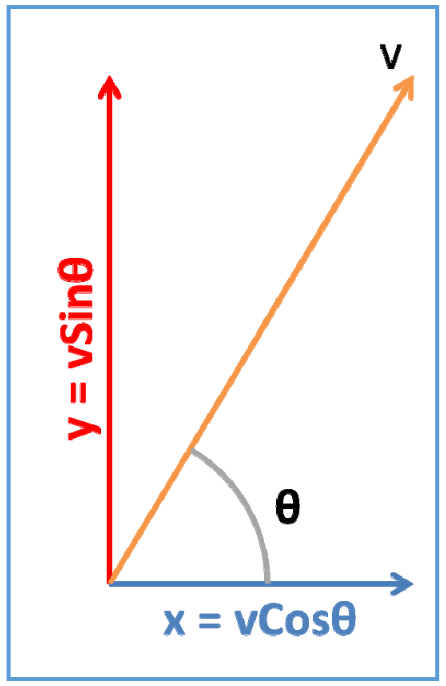


Figure 3—decomposition of a vector into horizontal and vertical components.

Worked example

If a cannon ball is fired at 40 ms^{-1} with a direction of 30˚ upwards, what is the total speed in the horizontal direction?

$v = 40ms^{-1}$

$v_x = 40Cos30$

$= 34.6\ ms^{-1}$

If a question gives a value to 2 significant figures always give your answer to **at least** 2 significant figures.

Fascinating Fact

Vectors don't have to remain in two dimensions, when working in three, consider the different triangles that can be formed. Calculate the first hypotenuse using two axes then use this with the third to calculate the three dimensional vector.

Questions

Questions	Marks
1. A force of 55N is applied at 15˚ to the horizon, calculate the vertical and horizontal components of the force.	[2 Marks]
2. An airplane flies 90km North, and 30km East, before it lands, calculate the displacement from the starting runway.	[1 Mark]
3. Calculate the resultant force of a car with weight of 40000N and a horizontal driving force of 13kN.	[1 Mark]
4. A boat is sailing from one side of a river to another, it has a forward velocity of 5 ms^{-1}. The river has a current of $3ms^{-1}$ parallel to the banks.	
a) Sketch a vector triangle of showing all the velocities.	[3 Marks]
b) What is the overall velocity of the boat?	[1 Mark]
b) How long does it take the boat to cross?	[1 Mark]
5. A lorry of weight 72000 N is at rest on a hill of gradient of 4˚. Calculate the component along the slope.	[2 Marks]

P0.4 VECTOR CALCULATIONS

2.3.1 - Scalars and Vectors

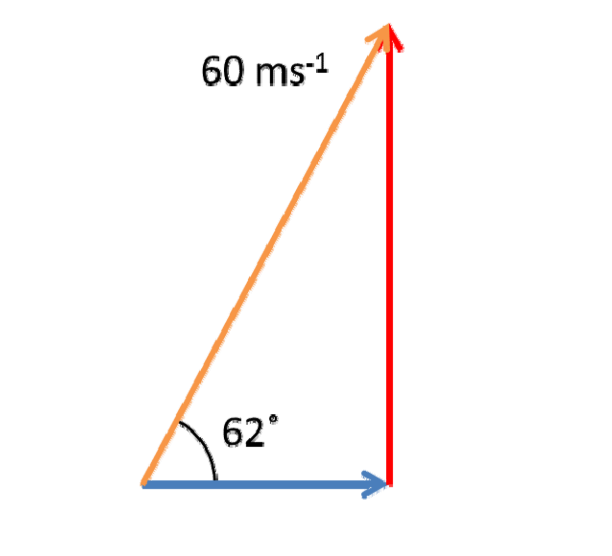


Figure 1—A scale vector diagram, use your ruler to calculate the scale then determine the decomposed vectors.

Vectors are one aspect of physics in A-Level that can always get students in a muddle, there are two different ways in which to deal with vectors, the first is the calculation way (as seen in the previous spread), using Pythagoras' theorem. The second is called scale drawings and requires that you are accurate.

Vector triangles

All vectors can be decomposed into vector triangles, this can be splitting a resultant vector up into the horizontal and vertical components, or (as we'll see later in this spread), splitting them into other more useful but still perpendicular values). Vector triangles will always be closed as the two components by definition make up the total vector.

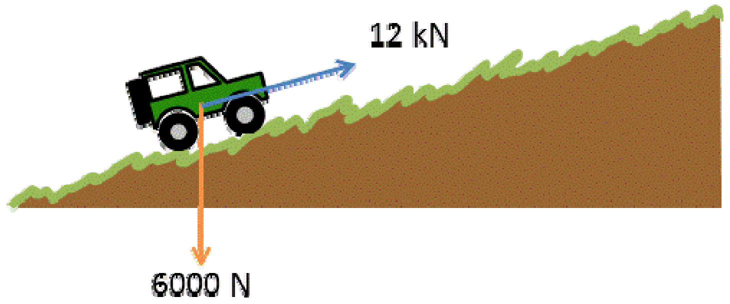
Scale drawings

The second method in which vectors can be calculated, and could potentially be examined in your exams relates to the use of scale drawings. This is where the vector itself is drawn accurately on the page, at the correct angle to the horizontal. Then using a ruler the two components of the vector can be calculated using the same scale.

Objects on a slope

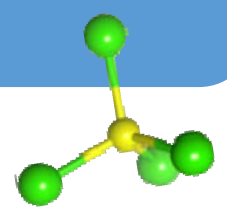
When objects are on a slope vector decomposition can be used to either find out the components along the horizontal or vertical axes, or they can be used to determine the components along the slope and perpendicular to the slope (note that both of these are still perpendicular to each other).

If we look at the following example we can see that a Land rover is moving up a slope, it has a driving force and a force due to the weight of the vehicle.



Fascinating Fact

It is impossible to do any three dimensional programming (think video games or animation) without some kind of use of vectors. Vectors can be used for scaling of models as well as three dimensional rotations.



Moments is a very important concept in designing buildings, as it allows architects and engineers to determine what the maximum possible load on any support strut is, or the maximal load any given floor can hold.

The principle of moments states that the value of the moments acting in the clockwise direction is equal to the value of the moments acting in the anticlockwise direction if the object is in equilibrium.

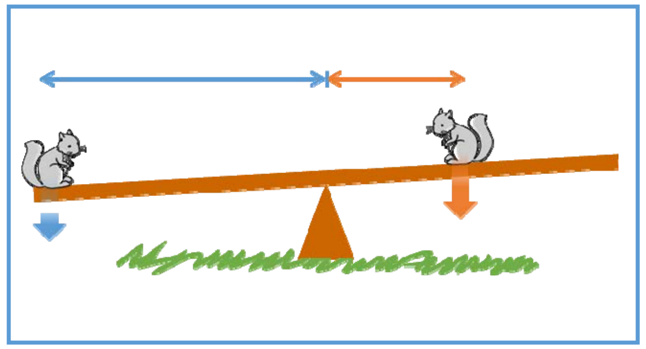


Figure 3—Moments of two identical squirrels on a sea-saw.

Example:

If the squirrels on the sea-saw both have a weight of 20N, the blue squirrel is 0.75m away from the fulcrum, and the orange is 0.2m away, what is the moment of the blue squirrel?

Moment = Force x Perpendicular distance

= 20 x 0.75

= 15 Nm

When working with more complex problems (**figure 4**), then it is important to determine which forces are going to cause the rotation of the object in different ways. Determine the moment in the clockwise direction, and then equate that to the anticlockwise with the unknown variable acting in the correct way. Solve the algebra to calculate the answer.

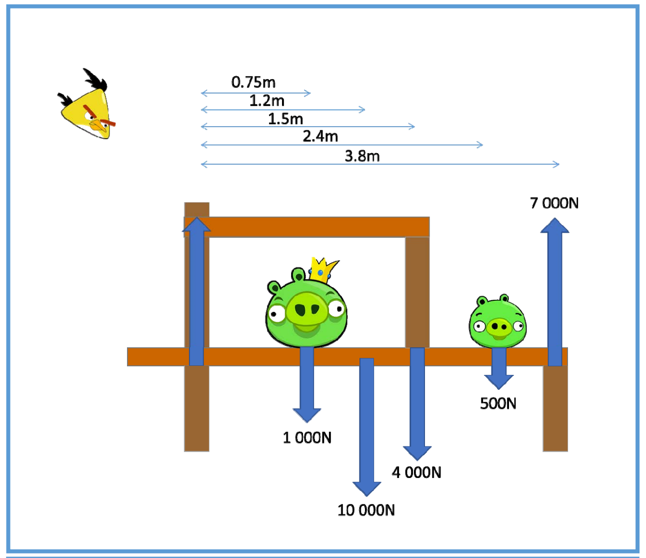
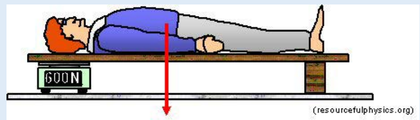


Figure 4—A typical loading scenario with multiple moments.

Questions	Marks
1. The plank is set up as shown and the balance zeroed. When the student lies on the plank the reading is 600 N. The balance is 2 m from the student's feet and the centre of gravity of the student is 1.5 m from their feet. What is the student's weight? 	[2 Marks]
2. A van and trailer cross the bridge above, the axel loads and the position of the vehicles are shown in **figure 2**. The single span bridge is supported at points 21m apart. Take a moment from either support points on the bridge.	
a) Calculate the vertical forces at each of the supports caused by the van and trailer on the bridge.	[4 Marks]
b) The support forces are higher than you calculated, explain why.	[2 Marks]
3. Using all the information found on **figure 4**, calculate the total force in the primary beam which is unlabelled.	[4 Marks]

P0.5 MOMENTS

1.2.5 - Turning Forces

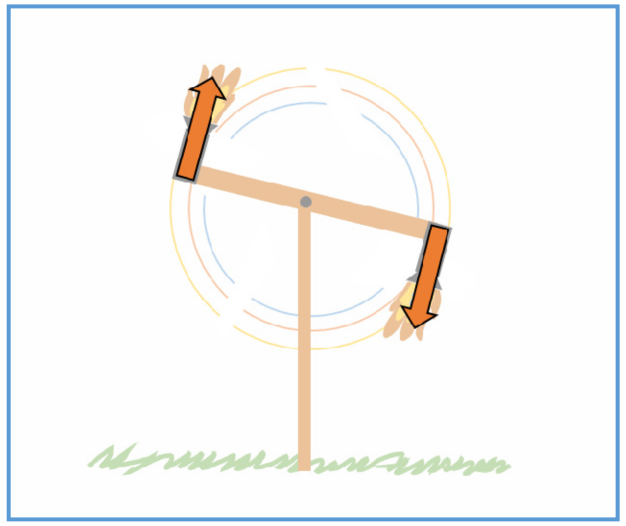


Figure 1—A Catherine wheel is a good example of a **couple**.

Definition

The moment of a force is the force multiplied by the perpendicular distance from a stated point.

Definition

A **couple** is a pair of equal, parallel but opposite forces which produces rotation of an object.

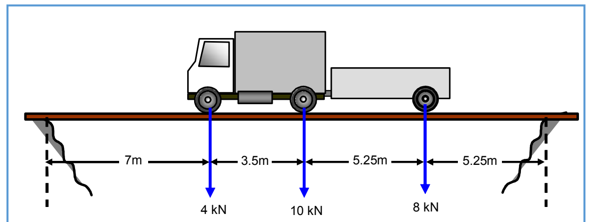


Figure 2—An engineering eyed view of moments to determine the required strength of bridge supports.

In your GCSEs you will have worked your way through moment calculations, making sure that you are able to determine if an object will rotate when forces are applied.

In physics a moment is a turning force applied to an object that is potentially not in equilibrium (or in a state that could change from equilibrium easily).

Turning Forces

There are two different terms that are used to describe turning forces, a **couple** occurs when two forces with the same magnitude are acting in opposite direction to each other on an object that is allowed to freely rotate. As two forces are equal but opposite there is no resultant force, and so no linear motion. However, the object does rotate around a fixed point

The **torque** of an object is related to a couple and is defined as one of the forces multiplied by the perpendicular distance between the forces. Torque is measured in Newton metres (Nm), and relates to the rotational motion that an object can provide.

Example:

If the Catherine wheel in **Figure 1** has two rockets with constant thrust of 500N and has a piece of wood with distance 0.5m, what is the torque of the firework?

Using the equation for torque we can see that:

torque = one force x perpendicular distance

= 500 x 0.5

= 250 Nm

Moment of a Force

The **moment** of a force is no different to the way in which it was taught in your GCSEs, it is the turning effect of a single force on an object, and defined as the force multiplied by the perpendicular distance from any stated point.

If we wanted to determine the amount of the weight force which was acting down the slope against the motion of the vehicle then we have to resolve the forces parallel and perpendicular to the direction of the slope.

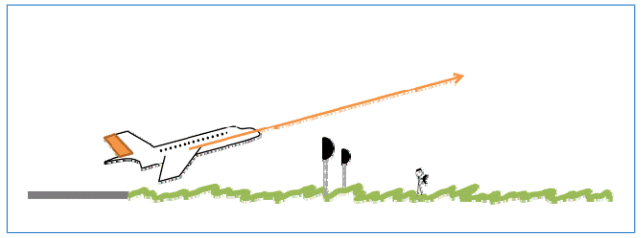
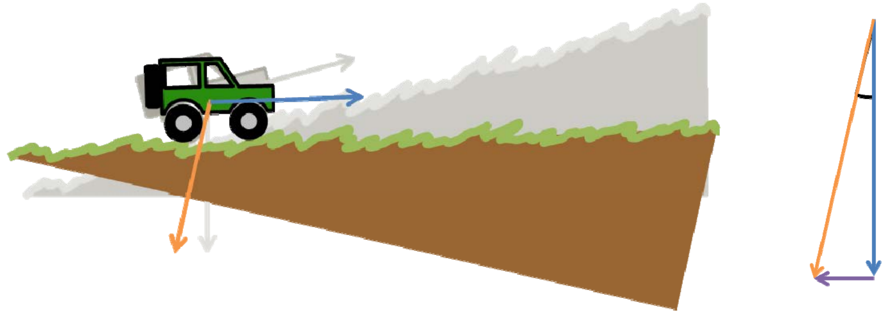


Figure 2 - Force diagram showing the taking off speed of an airplane.

If you imagine that both the slope and the car are turned so that the car is now driving along a horizontal road (and the driving force is horizontal), then it is easy to see that the angle of rotation required to achieve this is equal to the angle of the slope. Thus, the angle in which the weight rotates is also equal to the angle of the slope.

This is a scaled up force diagram of the rotation, the angle between the two forces is equal to the angle of rotation. The new purple arrow is now the component of the force acting down the slope (against the driving force of the land rover). Using simple mathematics it is now possible to determine this new purple vector force and so calculate many different aspects of the car in question.



Questions	Marks
1. The plane in figure 2 is climbing at an angle of 35 to the horizon with a ground speed of 100 ms-1.	
a) What is the velocity of the plane in the direction of travel?	[2 Marks]
b) If the mass of the plane is 100000 kg what is the component of the force acting against the motion of travel?	[2 Marks]
2. A car is moving up a hill with an incline of 1:20, the car has a weight of 5500N, a driving force of 12kN and a maximum frictional force of 1.2kN.	
a) Draw a diagram to show all the forces acting upon the car.	[4 Marks]
b) Calculate the angle of the hill	[1 Mark]
c) Calculate the total resultant force on the car parallel to the direction of travel.	[2 Marks]
d) Calculate the reactionary force of the car upon the slope.	[2 Marks]