GCE AS/A LEVEL

wjec cbac

WJEC GCE AS/A LEVEL in PHYSICS

ACCREDITED BY WELSH GOVERNMENT

TEACHERS' GUIDE

Teaching from 2015

This Welsh Government regulated qualification is not available to centres in England.

INTRODUCTION

The **WJEC AS and A level Physics** qualifications, accredited by Welsh Government for first teaching from September 2015, are available to:

- All schools and colleges in Wales
- Schools and colleges in independent regions such as Northern Ireland, Isle of Man and the Channel Islands

The AS will be awarded for the first time in Summer 2016, using grades A–E; the A level will be awarded for the first time in Summer 2017, using grades A*– E.

The qualification provides a broad, coherent, satisfying and worthwhile course of study. It encourages learners to develop confidence in, and a positive attitude towards, physics and to recognise its importance in their own lives and to society.

The specification is intended to promote a variety of styles of teaching and learning so that the course is enjoyable for all participants. The optional topics have been developed to allow learners to gain an insight into topics in the world of work which use physics on a daily basis.

Practical work is an intrinsic part of physics, and is highly valued by higher education. It is imperative that practical skills are developed throughout this course and that an investigatory approach is promoted.

Additional ways that WJEC can offer support:

- Specimen assessment materials
- Face-to-face CPD events
- Question paper database
- Examiners' reports on each question paper
- Free access to past question papers and mark schemes via the secure website
- Direct access to the subject officer
- Free online resources
- Exam Results Analysis
- Online Examination Review

If you have any queries please do not hesitate to contact:

Helen Francis
Domain Leader - Mathematics and Science
Subject Officer - Physics and Electronics
helen.francis@wjec.co.uk

KEY ASPECTS OF THE SPECIFICATION FROM 2015

AS UNIT 1: MOTION ENERGY AND MATTER	
AREA OF STUDY	**DESCRIPTION**
1.1 Basic Physics	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Measurement of the density of solids" and "Determination of unknown masses by using the principle of moments".
1.2 Kinematics	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Measurement of g by freefall".
1.3 Dynamics	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work document "Investigation of Newton's 2^{nd} law".
1.4 Energy Concepts	Provides amplification of statements in the specification, with links to related resources.
1.5 Solids Under Stress	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Determination of Young modulus of a metal in the form of a wire" and "Investigation of the force–extension relationship for rubber".
1.6 Using Radiation to Investigate Stars	Provides amplification of statements in the specification, with links to related resources.
1.7 Particles and Nuclear Structure	Provides amplification of statements in the specification, with links to related resources.

	SPECIFICATION STATEMENT	COMMENT
(a)	The 6 essential base SI units (kg, m, s, A, mol, K)	See terms, definitions and units booklet.
(b)	Representing units in terms of the 6 base SI units and their prefixes	Candidates will be expected to know how units such as the newton, joule and watt can be expressed in terms of base units.
(c)	Checking equations for homogeneity using units	
(d)	The difference between scalar and vector quantities and to give examples of each – displacement, velocity, acceleration, force, speed, time, density, pressure etc.	See terms, definitions and units booklet. Note: pressure is not an example of a vector.
(e)	The addition and subtraction of coplanar vectors, and perform mathematical calculations limited to **two** perpendicular vectors	
(f)	How to resolve a vector into two perpendicular components	See terms, definitions and units booklet.
(g)	The concept of density and how to use the equation the concept of density and how to use the equation $\rho = \frac{m}{V}$ to calculate mass, density and volume	See terms, definitions and units booklet. In both theoretical and practical contexts.
(h)	What is meant by the turning effect of a force	Familiarity with the terms *torque* and *moment* (used interchangeably). See terms, definitions and units booklet.

Select the image (left) for "Measurement of the density of solids" practical work.

Select the image (left) for "Determination of unknown masses by using the principle of moments" practical work.

Continued on next page

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(i)	The use of the principle of moments	See terms, definitions and units booklet.
(j)	The use of centre of gravity, for example in problems including stability: identify its position in a cylinder, sphere and cuboid (beam) of uniform density	See terms, definitions and units booklet.
(k)	When a body is in equilibrium the resultant force is zero and the net moment is zero, and be able to perform simple calculations	These are the conditions for a body to remain in equilibrium.

Select the image (left) for "Measurement of the density of solids" practical work.

Select the image (left) for "Determination of unknown masses by using the principle of moments" practical work.

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 1 . 1 BASIC PHYSICS EXAM LEVEL: AS

NAME OF EXPERIMENT:

Measurement of the Density of Solids

THEORY:

The density of regularly shaped solids can be determined by measuring their mass, m, and calculating their volume, V. The density, ρ, can then be found using: $\rho = \frac{m}{V}$

APPARATUS:

Various regularly shaped solids both rectangular and circular
30 cm ruler (resolution ± 0.1 cm)
Vernier calipers/micrometer (resolution ± 0.01 mm)
Balance (resolution ± 0.1 g/1 g)

FURTHER GUIDANCE FOR TECHNICIANS:

Possible objects to include could be steel ball bearings of various sizes, an optical glass/perspex block, blocks of various metals, wood, polystyrene sphere etc.

Experimental Method:

Determine the mass of the object using the balance. The volume of a rectangle can be found by measuring the length, l, width, w, and height, h. Calculate the volume, V using:
$V = l \times w \times h$. The volume of a sphere is found by measuring the diameter to find the radius, r, and then calculate the volume using: $\boldsymbol{V = \frac{4}{3}\pi r^3}$.

In both cases calculate the density using: $\boldsymbol{\rho = \frac{m}{V}}$.

Extension:

This is an excellent opportunity to introduce the concept of uncertainty to the students.
This could be extended to determine the density of irregular objects by putting them in water and measuring the volume of water displaced.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2008 Q3

PH3 2014 Task A1

PH3 2013 Task A1

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Related practical past questions

UNIT: 1 . 1 BASIC PHYSICS EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Unknown Masses by Using the Principle of Moments

THEORY:

Apply the principle of moments to a metre rule to first determine its mass and then determine the mass of an unknown object.

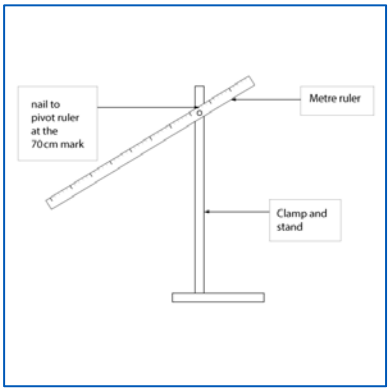
APPARATUS:

Metre rule
Clamp and stand
Nail
200 g mass and hanger
150 g mass (covered in tape and labelled as W) and hanger
Loops of thread

FURTHER GUIDANCE FOR TECHNICIANS:

An alternative would be to pivot the metre rule off-centre on a prism. The unknown weight could be a mass with the real value covered, a reel of wire or a glass bottle top.

Experimental Method:



Loop a 200 g (1.96 N) mass over the metre rule and adjust it until the ruler is horizontal. **Select the image (*left*)** for a larger diagram.

Note down the distance, l, of the mass from the pivot. The mass (or weight) of the metre rule can now be calculated using the principle of moments:

$0.20 \times$ metre rule weight $= l \times 1.96$

Now remove the 200 g mass and replace it with the unknown weight, W, and again adjust the position of the weight until the ruler balances. Measure the distance, d, of the unknown weight from the pivot. The unknown weight can again be calculated by applying the principle of moments:

$0.20 \times$ metre rule weight $= d \times$ unknown weight

The unknown weight can be converted into a mass (in kilograms) by dividing by 9.81. This can then be checked using a top pan balance.

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WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 1 . 1 BASIC PHYSICS EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Unknown Masses by Using the Principle of Moments

EXTENSION:

The practical can be used to familiarise students with calculating uncertainties and combining percentage uncertainties. It can be further extended to include equilibrium of forces.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2004 Experiment 1

PH3 2009 Task A2

PH3 2013 Task A2

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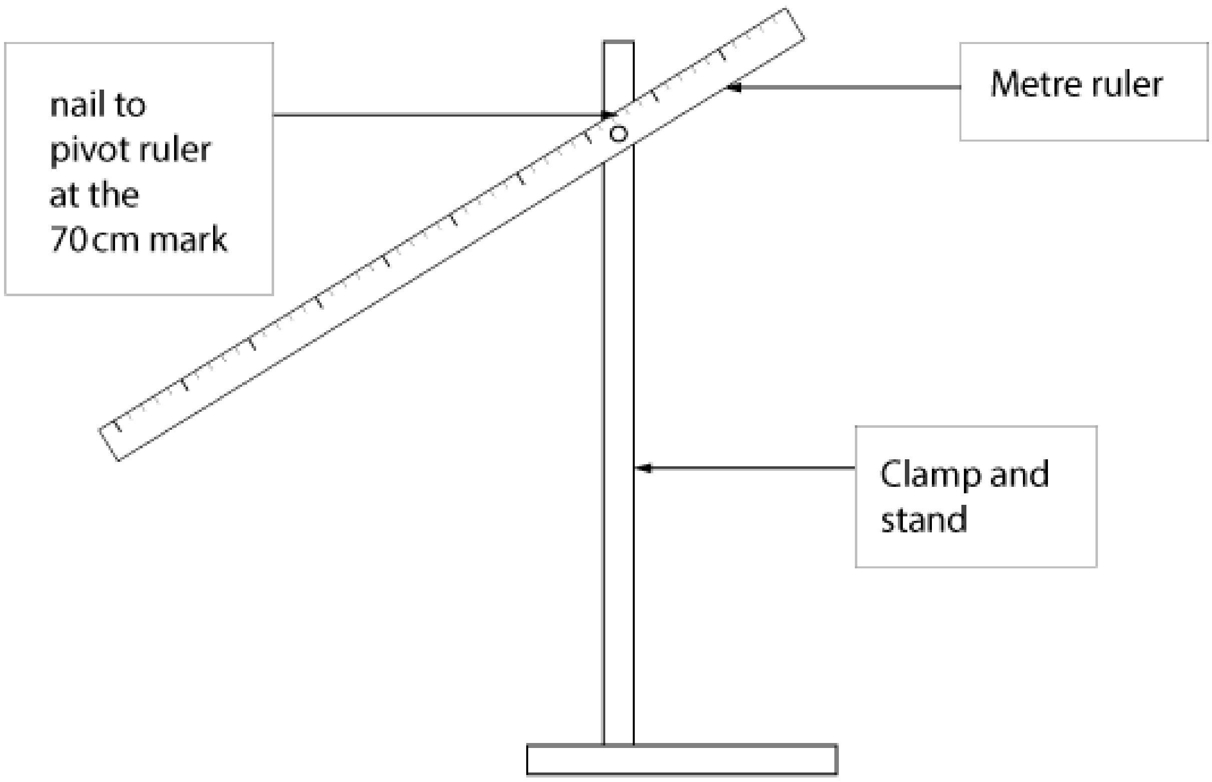
WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 1 . 1 BASIC PHYSICS EXAM LEVEL: AS

DIAGRAM:

Determination of Unknown Masses by Using the Principle of Moments



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WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 1 . 2 KINEMATICS — EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(a)	What is meant by displacement, mean and instantaneous values of speed, velocity and acceleration	See terms, definitions and units booklet.
(b)	The representation of displacement, speed, velocity and acceleration by graphical methods	
(c)	The properties of displacement-time graphs, velocity-time graphs, and interpret speed and displacement-time graphs for non-uniform acceleration	Candidates will need to be familiar with acceleration–time graphs.
(d)	How to derive and use equations which represent uniformly accelerated motion in a straight line	It is expected that candidates approach these derivations by both graphical and algebraic methods.
(e)	How to describe the motion of bodies falling in a gravitational field with and without air resistance - terminal velocity	See terms, definitions and units booklet.
(f)	The independence of vertical and horizontal motion of a body moving freely under gravity	Applies to projectile motion for objects being launched either horizontally or at an angle to the ground.
(g)	The explanation of the motion due to a uniform velocity in one direction and uniform acceleration in a perpendicular direction, and perform simple calculations	

Select the image (left) for "Measurement of g by freefall" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 1 . 2 KINEMATICS EXAM LEVEL: AS

NAME OF EXPERIMENT:

Measurement of *g* by Freefall

THEORY:

An equation of motion can be used to calculate the acceleration due to gravity, g.

$$s = ut + \tfrac{1}{2}at^2$$

Where: u = initial velocity = 0,
s = height, h and
a = acceleration due to gravity, g

This gives $h = \tfrac{1}{2}gt^2$

If a graph of height, h (y-axis), is plotted against time squared, t^2 (x-axis), the gradient will equal $g/2$, or $g = 2 \times$ gradient.

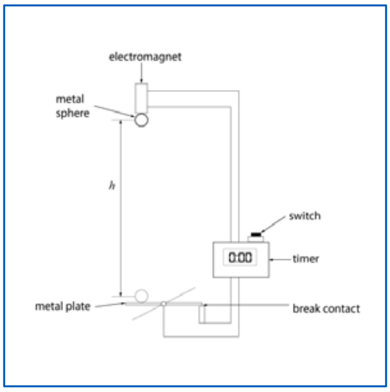
APPARATUS:

Electromagnet	Metal plate
Metal sphere	Timer
Switch	Break contact

FURTHER GUIDANCE FOR TECHNICIANS:

A metre rule of resolution ± 0.001 m will be needed to record the height, h. A ball bearing of diameter 1–2 cm will work well.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

When the switch is pressed it disconnects the electromagnet releasing the metal sphere. At the same instant the timer starts. When the sphere hits the magnetic switch it breaks the circuit stopping the timer, thus recording the time it takes for the sphere to fall through a height, h. The time taken for the ball bearing to fall through a range of different heights needs to be measured. Plot a graph of height, h (y-axis), against time squared, t^2 (x-axis), and calculate the value of g using: $g = 2 \times$ gradient.

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WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

NAME OF EXPERIMENT:

Measurement of g by Freefall

EXTENSION:

Students could progress to use their value for g to estimate the mass of the Earth, M_E.

From $F = \dfrac{GM_E m}{r^2}$ and $F = mg$ we get: $M_E = \dfrac{gR^2}{G}$

Where:

M_E = mass of the Earth

R = radius of the Earth (6.38×10^6 m)

G = gravitational constant (6.67×10^{-11} N m^2 kg^{-2})

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use calipers and micrometers for small distances, using digital or vernier scales.
- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH6 2014 Data analysis task

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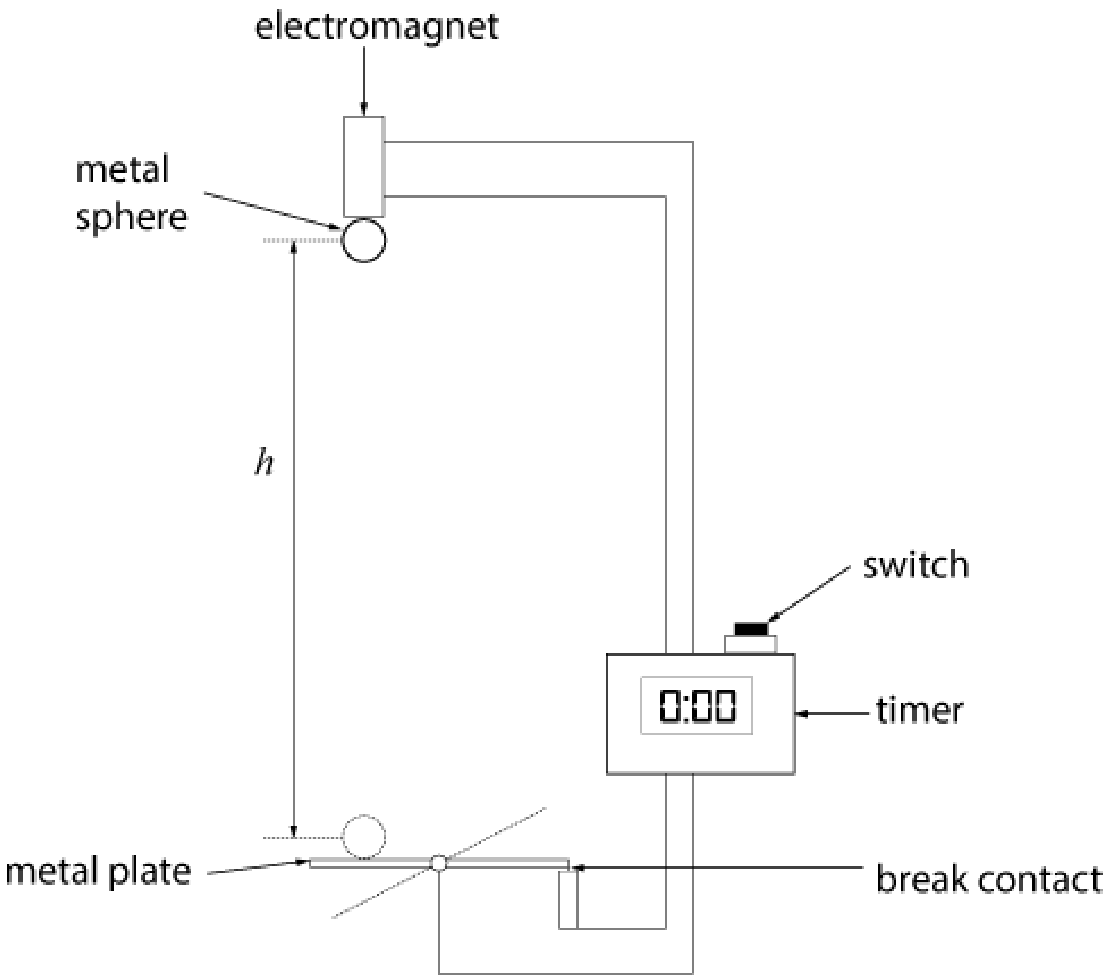
DIAGRAM:

Measurement of g by Freefall



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[WJEC](#) > [A Level Physics](#) > [Terms, definitions and units booklet](#)

[WJEC](#) > [A Level Physics](#) > [Related practical past questions](#)

	SPECIFICATION STATEMENT	COMMENT
(a)	The concept of force and Newton's 3rd law of motion	In addition to being able to state Newton’s 3rd law, candidates should be able to understand the key rules for identifying Newton’s 3rd law pairs of forces. See terms, definitions and units booklet.
(b)	How free body diagrams can be used to represent forces on a particle or body	Candidates will be expected to draw or complete free body diagrams as well as to be able to interpret and use diagrams provided for them.
(c)	The use of the relationship $\sum F = ma$ in situations where mass is constant	See terms, definitions and units booklet.
(d)	The idea that linear momentum is the product of mass and velocity	See terms, definitions and units booklet.
(e)	The concept that force is the rate of change of momentum, applying this in situations where mass is constant	See terms, definitions and units booklet. Candidates should be able to show how $\sum F = ma$ arises from F = rate of change of momentum.
(f)	The principle of conservation of momentum and use it to solve problems in one dimension involving elastic collisions (where there is no loss of kinetic energy) and inelastic collisions (where there is a loss of kinetic energy)	See terms, definitions and units booklet. Candidates should be able to calculate loss of kinetic energy where appropriate.

Select the image (left) for "Investigation of Newton's 2nd law" practical work.

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USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 1 . 3 DYNAMICS | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Investigation of Newton's 2nd Law

THEORY:

The gravitational force of the slotted masses attached via the pulley causes the entire mass of the system to accelerate. That is the mass of the rider, M, and the total mass of the slotted masses, m. Newton's second law, therefore, can be written as:

$$mg = (M + m)a$$

and so the acceleration of the system is:

$$a = \frac{mg}{(M + m)}$$

We can use this to test Newton's second law. If the total mass of the system (M + m) remains constant, then the acceleration, a, should be proportional to the gravitational force, mg.

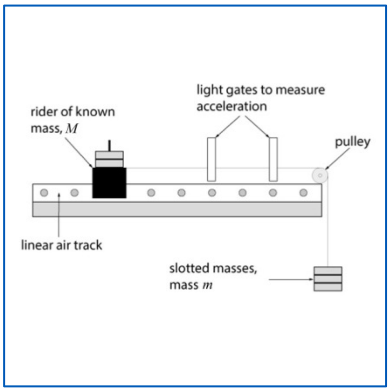
APPARATUS:

Linear air track
Pulley
Slotted masses, mass m
Rider of known mass, M
Light gates to measure acceleration

FURTHER GUIDANCE FOR TECHNICIANS:

It is possible to use just one light gate set to measure the final velocity, v, if two are not available. If the starting velocity is taken to be zero then the acceleration, $a = \frac{v^2}{2s}$. Where s is the distance measured from the starting point of the rider to the light gate.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Fix the thread to the rider and attach five slotted 5 gram masses to the other end as shown in the diagram. Set the light gates to record the acceleration and allow the slotted masses to fall to the ground. Record the gravitational force, mg and the acceleration, a. Remove one of the slotted masses and place it on the rider (so keeping the total mass of the system constant).

Repeat the experiment until all the different accelerating masses have been removed. Plot a graph of acceleration (y-axis) against gravitational force, mg (x-axis). This should be a straight line through the origin.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 1 . 3 DYNAMICS EXAM LEVEL: AS

NAME OF EXPERIMENT:

Investigation of Newton's 2nd Law

EXTENSION:

By finding the gradient of the graph it is possible to get a value for the mass of the rider, M.

$$\text{gradient} = \frac{1}{(M+m)}$$

Where m = 25 grams – the total mass of the slotted masses.

This set up can also be used to investigate many collision and momentum problems.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use appropriate digital instruments, including electrical multimeters, to obtain a range of measurements (to include time, current, voltage, resistance, mass).
- Use stopwatch or light gates for timing.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

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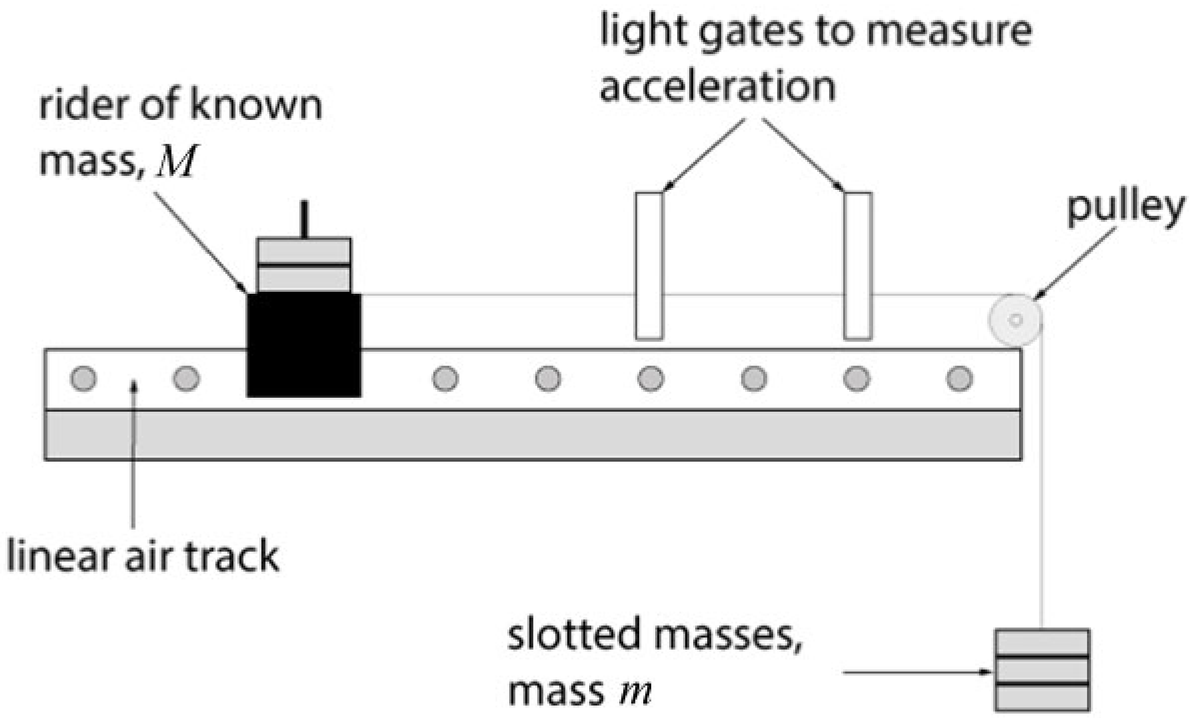
UNIT: 1 . 3 DYNAMICS | EXAM LEVEL: AS

DIAGRAM:

Investigation of Newton's 2nd Law



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UNIT: 1 . 4 ENERGY CONCEPTS | EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(a)	The idea that work is the product of a force and distance moved in the direction of the force when the force is constant	See terms, definitions and units booklet.
(b)	The calculation of the work done for constant forces, when the force is not along the line of motion (work done = $Fx\cos\theta$)	
(c)	The principle of conservation of energy including knowledge of gravitational potential energy $(mg\Delta h)$, elastic potential energy $(\frac{1}{2}kx^2)$ and kinetic energy $(\frac{1}{2}mv^2)$	See terms, definitions and units booklet.
(d)	The work–energy relationship: $Fx = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$	See terms, definitions and units booklet.
(e)	Power being the rate of energy transfer	See terms, definitions and units booklet.
(f)	Dissipative forces, for example friction and drag, cause energy to be transferred from a system and reduce the overall efficiency of the system	
(g)	The equation: efficiency = $\frac{\text{useful energy transfer}}{\text{total energy input}} \times 100\%$	

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 1 . 5 SOLIDS UNDER STRESS	EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(a)	Hooke's law and use $F = kx$ where the spring constant k is the force per unit extension	Candidates will be expected to be able to state Hooke's law. See terms, definitions and units booklet.
(b)	The ideas that for materials the tensile stress, $\sigma = \frac{F}{A}$ and the tensile strain, $\varepsilon = \frac{\Delta l}{l}$ and the Young modulus, $E = \frac{\sigma}{\varepsilon}$ when Hooke's law applies	See terms, definitions and units booklet. Candidates need an understanding that the gradient of a stress–strain curve for a material represents the Young modulus of the material.
(c)	The work done in deforming a solid being equal to the area under a force-extension graph, which is $\frac{1}{2}Fx$ if Hooke's law is obeyed	Appreciate that $W = \frac{1}{2}Fx$ and $F = kx$ may be combined to give $W = \frac{1}{2}kx^2$
(d)	The classification of solids as crystalline, amorphous (to include glasses and ceramics) and polymeric	See terms, definitions and units booklet.
(e)	The features of a force–extension (or stress–strain) graph for a metal such as copper, to include • elastic and plastic strain • the effects of dislocations, and the strengthening of metals by introducing barriers to dislocation movement, such as foreign atoms, other dislocations, and more grain boundaries • necking and ductile fracture	Candidates should be able to identify (or label) the key features of these graphs, namely: • elastic limit • limit of proportionality • elastic/plastic regions • yield point • breaking point. See terms, definitions and units booklet.

Select the image (left) for "Determination of Young modulus of a metal in the form of a wire" practical work.

Select the image (left) for "Investigation of the force–extension relationship for rubber" practical work.

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USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(f)	The features of a force–extension (or stress–strain) graph for a brittle material such as glass, to include • elastic strain and obeying Hooke's law up to fracture • brittle fracture by crack propagation, the effect of surface imperfections on breaking stress, and how breaking stress can be increased by reducing surface imperfections (as in thin fibres) or by putting surface under compression (as in toughened glass or pre-stressed concrete)	See terms, definitions and units booklet.
(g)	The features of a force–extension (or stress–strain) graph for rubber, to include • Hooke's law only approximately obeyed, low Young modulus and the extension due to straightening of chain molecules against thermal opposition • hysteresis	See terms, definitions and units booklet. An understanding of permanent set in the context of hysteresis is expected.

Select the image (left) for "Determination of Young modulus of a metal in the form of a wire" practical work.

Select the image (left) for "Investigation of the force-extension relationship for rubber" practical work.

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 1 . 5 SOLIDS UNDER STRESS — EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Young Modulus of a Metal in the Form of a Wire

THEORY:

Young modulus $E = \frac{\text{Stress}}{\text{Strain}}$ or $E = \frac{F/A}{x/l}$ rearranging $E = \frac{Fl}{xA}$

F = applied load
A = area of cross-section of the wire
x = extension
l = original length

If a graph of applied load, F (y-axis), is drawn against extension, x (x-axis), the gradient is $\frac{F}{x}$ and so:

$$E = \text{gradient} \times \frac{l}{A}$$

The original length l can be measured and the area of the wire found using $A = \pi r^2$ hence E can be determined.

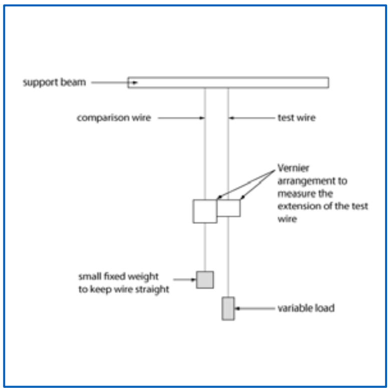
APPARATUS:

Support beam
Comparison wire
Test wire
Variable load
Small fixed weight to keep wire straight
Vernier arrangement to measure the extension of test wire

FURTHER GUIDANCE FOR TECHNICIANS:

The wires are usually steel and should be as long as is convenient, typically up to 2 metres and also as thin as possible in order to obtain a measurable extension. A micrometer will also be needed to measure the diameter of the wire. Suggested loads could be up to 60 N in 5 N steps.

Experimental Method:



Select the image (left) for a larger diagram.

Hang two identical wires from a beam and attach a scale to the first wire and a small weight to keep it straight. Also put a small weight on the second wire to straighten it and a vernier scale linking with the scale on the comparison wire. Measure the original length, l, of the test wire and its diameter at various points along its length. Use this to calculate the mean cross-sectional area A.

Then place a load of 5 N on the test wire and find the extension, x. Repeat this in 5 N steps up to at least 50 N. Plot a graph of load (y-axis) against extension (x-axis) and calculate the gradient. Use this to find a value for the Young modulus.

UNIT: 1 . 5 SOLIDS UNDER STRESS — EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Young Modulus of a Metal in the Form of a Wire

EXTENSION:

By comparing the Young modulus to known constants it would be possible to determine the type of metal the wire was made from.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use calipers and micrometers for small distances, using digital or vernier scales.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2005 Q3

PH6 2012 Experimental task

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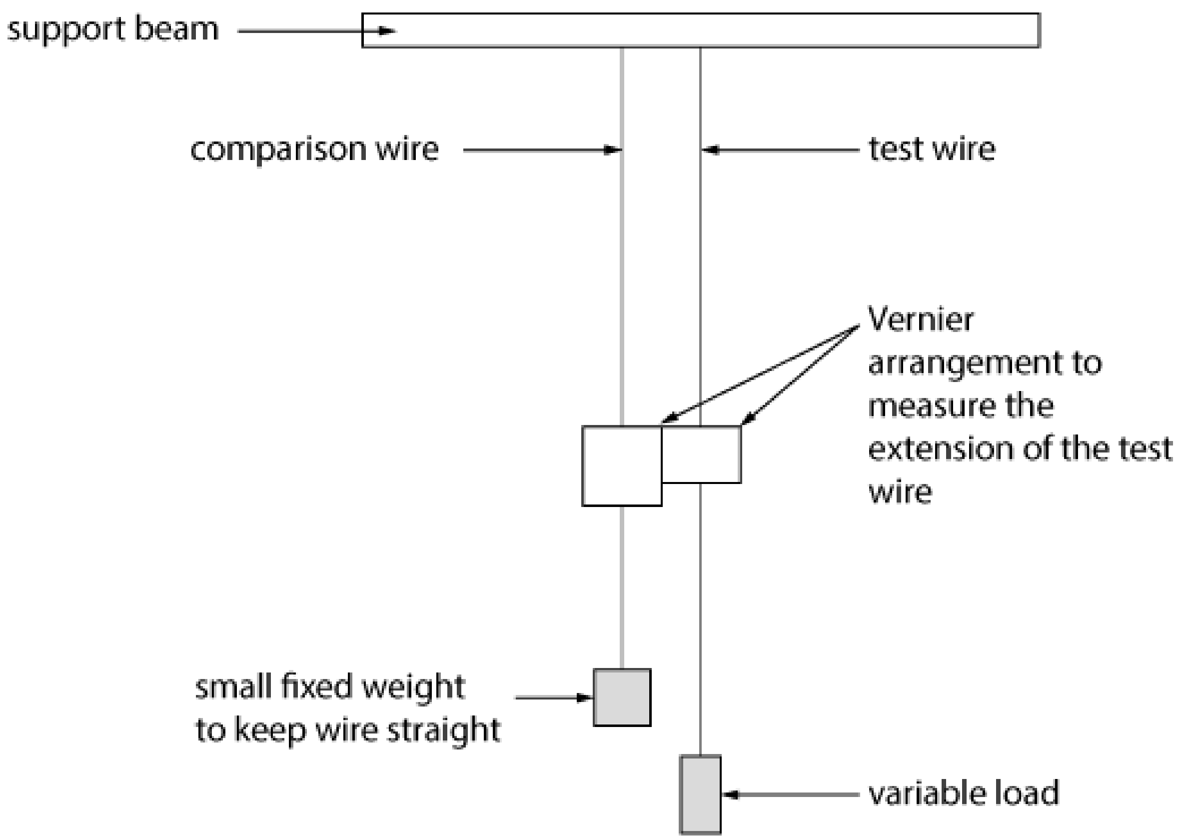
WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

DIAGRAM:

Determination of Young Modulus of a Metal in the Form of a Wire



USEFUL INTERACTIVE RESOURCES

[WJEC] > [A Level Physics] > [Terms, definitions and units booklet]

[WJEC] > [A Level Physics] > [Related practical past questions]

UNIT: 1 . 5 SOLIDS UNDER STRESS | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Investigation of the Force–Extension Relationship for Rubber

THEORY:

Rubber – an example of a polymer with weak cross bonds. Natural rubber is a polymer of the molecule isoprene. It has weak van der Waals cross bonds and only a few covalent (strong) cross bonds.

APPARATUS:

Clamp and stand
Metre rule (resolution ± 0.001 m)
Optical pin (for use as a pointer if required)
Rubber band of cross-section approximately 1 mm by 2 mm
G-clamp to secure (if required)
Micrometer (resolution ± 0.01 mm)
50 g mass holder plus a number of 50 g masses

FURTHER GUIDANCE FOR TECHNICIANS:

Hoffmann clips are useful to suspend the rubber band, and, if you wish, to attach the masses. The dimensions of the elastic band are only approximate and don't need to be exact.

Experimental Method:

Hang a (cut) rubber band of (approximate) cross-section 1 mm by 2 mm vertically from a stand, boss and clamp. The base of the stand should be secured using a G-clamp. Hang a 50 gram mass holder from the band. Place a metre rule as close as possible to the mass holder. The length can be read using an optical pin attached to the base of the mass holder.

Measure the length, width and thickness of the rubber when it is supporting the 50 gram holder. Try to avoid squashing the rubber with the micrometer screw gauge.

Increase the mass in 50 gram steps, measuring the extension each time. Continue until the band breaks.

Plot the force–extension curve and determine the Young modulus from the linear section.

EXTENSION

A similar experiment could be carried out on polyethene and a comparison of the two curves made. Another investigation could be made comparing the properties of the plastic shopping bags from various supermarkets. Measurements could be taken when unloading both the rubber band and the polyethene and the hysteresis determined.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings
- Use methods to increase accuracy of measurements such as timing over multiple oscillations, or use of fiducial marker, set square or plumb line.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

	SPECIFICATION STATEMENT	COMMENT
(a)	The idea that the stellar spectrum consists of a continuous emission spectrum, from the dense gas of the surface of the star, and a line absorption spectrum arising from the passage of the emitted electromagnetic radiation through the tenuous atmosphere of the star	Through analysis of a star's stellar spectrum candidates will be expected to be able to identify the electromagnetic radiation emitted from the star.
(b)	The idea that bodies which absorb all incident radiation are known as black bodies and that stars are very good approximations to black bodies	See terms, definitions and units booklet.
(c)	The shape of the black body spectrum and that the peak wavelength is inversely proportional to the absolute temperature (defined by: T (K) = θ (°C) + 273.15)	
(d)	Wien's displacement law, Stefan's law and the inverse square law to investigate the properties of stars – luminosity, size, temperature and distance [N.B. stellar brightness in magnitudes will not be required]	See terms, definitions and units booklet.
(e)	The meaning of multiwavelength astronomy and that by studying a region of space at different wavelengths (different photon energies) the different processes which took place there can be revealed	Useful links are: http://herschel.cf.ac.uk/education http://blogs.cardiff.ac.uk/physicsoutreach/resources/star-in-a-box/

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(a)	The idea that matter is composed of quarks and leptons and that there are three generations of quarks and leptons, although no questions will be set involving second or third generations	See terms, definitions and units booklet. See introduction to particle physics notes.
(b)	The idea that antiparticles exist for the particles given in the table above, that the properties of an antiparticle are identical to those of its corresponding particle apart from having opposite charge, and that particles and antiparticles annihilate	
(c)	Symbols for a positron and for antiparticles of quarks and hadrons	
(d)	The idea that quarks and antiquarks are never observed in isolation, but are bound into composite particles called hadrons. There are three types of hadron: the baryon (combinations of 3 quarks), or antibaryons (combinations of 3 antiquarks) or mesons (quark–antiquark pairs)	See terms, definitions and units booklet.

	leptons		quarks	
particle (symbol)	electron (e^-)	electron neutrino (ν_e)	up (u)	down (d)
charge (e)	–1	0	$+\frac{2}{3}$	$-\frac{1}{3}$

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(e)	The quark compositions of the neutron and proton	
(f)	How to use data in the table above to suggest the quark make-up of less well-known first generation baryons and of charged pions	To include the neutral pion (π°).
(g)	The properties of the four forces or interactions experienced by particles as summarized in the table below: (see table below)	Neutrino involvement is a sign of weak interactions which typically take 10^{-8} s. The absorption or emission of photons is a sign of e-m interactions. The total quark number is conserved in e-m interactions. These interactions typically take 10^{-16} s. Strong interactions are not felt by leptons and the total quark number is conserved. Strong interactions occur in times of the order of 10^{-23} s.
(h)	How to apply conservation of charge, lepton number and baryon number (or quark number) to given simple reactions	
(i)	The idea that neutrino involvement and quark flavour changes are exclusive to weak interactions	

Interaction	Experienced by	Range	Comments
gravitational	all matter	infinite	very weak – negligible except between large objects such as planets
weak	all leptons, all quarks, so all hadrons	very short	only significant when the e-m and strong interactions do not operate
electromagnetic (e-m)	all charged particles	infinite	also experienced by neutral hadrons, as these are composed of quarks
strong	all quarks, so all hadrons	short	

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

AS UNIT 2: ELECTRICITY AND LIGHT	
AREA OF STUDY	**DESCRIPTION**
2.1 Conduction of Electricity	Provides amplification of statements in the specification, with links to related resources.
2.2 Resistance	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Investigation of the I–V characteristics of the filament of a lamp and a metal wire at constant temperature", "Determination of the resistivity of a metal" and "Investigation of the variation of resistance with temperature for a metal wire".
2.3 D. C. Circuits	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Determination of the internal resistance of a cell".
2.4 The Nature of Waves	Provides amplification of statements in the specification, with links to related resources.
2.5 Wave Properties	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Determination of wavelength using Young's double slits" , "Determination of wavelength using a diffraction grating" and "Determination of the speed of sound using stationary waves".
2.6 Refraction of Light	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Measurement of the refractive index of a material".
2.7 Photons	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Determination of h using LEDs".
2.8 Lasers	Provides amplification of statements in the specification, with the links to detailed laser notes and additional resources.

UNIT: 2.1 CONDUCTION OF ELECTRICITY — EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(a)	The fact that the unit of charge is the coulomb (C), and that an electron's charge, e, is a very small fraction of a coulomb	See terms, definitions and units booklet.
(b)	The fact that charge can flow through certain materials, called conductors	
(c)	Electric current being the rate of flow of charge	
(d)	The use of the equation $I = \frac{\Delta Q}{\Delta t}$	Includes idea that area under an I–t graph gives charge flow. See terms, definitions and units booklet.
(e)	Current being measured in ampères (A), where A = C s^{-1}	
(f)	The mechanism of conduction in metals as the drift of free electrons	
(g)	The derivation and use of the equation $I = nAve$ for free electrons	Diagram of cylindrical wire would help derivation.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 2 RESISTANCE | EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(a)	The definition of potential difference	See terms, definitions and units booklet.
(b)	The idea that potential difference is measured in volts (V) where V = J C^{-1}	
(c)	The characteristics of I – V graphs for the filament of a lamp, and a metal wire at constant temperature	Candidates will be expected to be able to sketch these graphs.
(d)	Ohm's law, the equation $V = IR$ and the definition of resistance	See terms, definitions and units booklet.
(e)	Resistance being measured in ohms (Ω), where Ω = V A^{-1}	See terms, definitions and units booklet.
(f)	The application of $P = IV = I^2R = \dfrac{V^2}{R}$	Candidates will be expected to be able to derive these equations.
(g)	Collisions between free electrons and ions gives rise to electrical resistance, and electrical resistance increases with temperature	

Select the image (left) for "Investigation of the I-V characteristics of the filament of a lamp and a metal wire at constant temperature" practical work.

Select the image (left) for "Determination of the resistivity of a metal" practical work.

Select the image (left) for "Investigation of the variation of resistance with temperature for a metal wire" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(h)	The application of $R = \frac{\rho l}{A}$, the equation for resistivity	See terms, definitions and units booklet.
(i)	The idea that the resistance of metals varies almost linearly with temperature over a wide range	Over a wide range *of temperatures.*
(j)	The idea that ordinarily, collisions between free electrons and ions in metals increase the random vibration energy of the ions, so the temperature of the metal increases	
(k)	What is meant by superconductivity, and superconducting transition temperature	Familiarity with a sketch graph of resistance against temperature showing the transition. No theory required (e.g. Cooper pairs). See terms, definitions and units booklet.
(l)	The fact that most metals show superconductivity, and have transition temperatures a few degrees above absolute zero (–273 °C)	Values of transition temperatures not needed.
(m)	Certain materials (high temperature superconductors) having transition temperatures above the boiling point of nitrogen (–196 °C)	No examples of high temperature superconductors need be known.
(n)	Some uses of superconductors, for example MRI scanners and particle accelerators	These machines need very strong magnetic fields; candidates do not need to know the reasons why. If ordinary wire were used in the electromagnets, too much power would be dissipated.

Select the image (left) for "Investigation of the I-V characteristics of the filament of a lamp and a metal wire at constant temperature" practical work.

Select the image (left) for "Determination of the resistivity of a metal" practical work.

Select the image (left) for "Investigation of the variation of resistance with temperature for a metal wire" practical work.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 2 RESISTANCE EXAM LEVEL: AS

NAME OF EXPERIMENT:

Investigation of the I–V Characteristics of a Filament Lamp and a Metal Wire at Constant Temperature

THEORY:

Ohm's law states that for a conductor the current, I, is directly proportional to the potential difference, V, provided physical factors such as temperature and pressure remain constant. Therefore by plotting the I–V characteristic of a metal wire and of a filament lamp, the validity of Ohm's law, as applicable to each of these components, can be determined. A graph of I against V is linear for a metal wire and non-linear for a filament of a lamp.

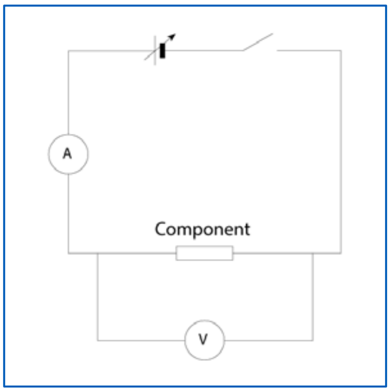
APPARATUS:

Variable D.C. voltage supply
Switch
Ammeter
Voltmeter
Component either in the form of a filament bulb, e.g. 12 V, 24 W bulb or a metal wire, e.g. 1 m length of constantan – mounted on a wooden batten

FURTHER GUIDANCE FOR TECHNICIANS:

The variable D.C. voltage supply can be constructed from 1.5 V cells and a rheostat. The resolution of the voltmeter and ammeter depend on the D.C. voltage supply used in the circuit.

Experimental Method:



The circuit should be set up as shown. **Select the image (*left*)** for a larger diagram.

Starting with the output of the variable d.c. voltage supply set to its minimum value, slowly increase the value of the applied voltage. The current through the component and the potential difference across the component should be recorded for a range of values of the applied voltage. A graph of current against voltage should then be plotted. This procedure can be repeated for different components.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 2 . 2 RESISTANCE EXAM LEVEL: AS

NAME OF EXPERIMENT:

Investigation of the I–V Characteristics of a Filament Lamp and a Metal Wire at Constant Temperature

EXTENSION:

The I–V characteristics of other components such as a semiconductor diode or an electrolytic solution such as copper sulfate could be investigated.

Data Logging: Digital ammeters or voltmeters could be used as part of a data logging set-up.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use calipers and micrometers for small distances, using digital or vernier scales.
- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2005 Q2

PH3 2010 Task A3

USEFUL INTERACTIVE RESOURCES

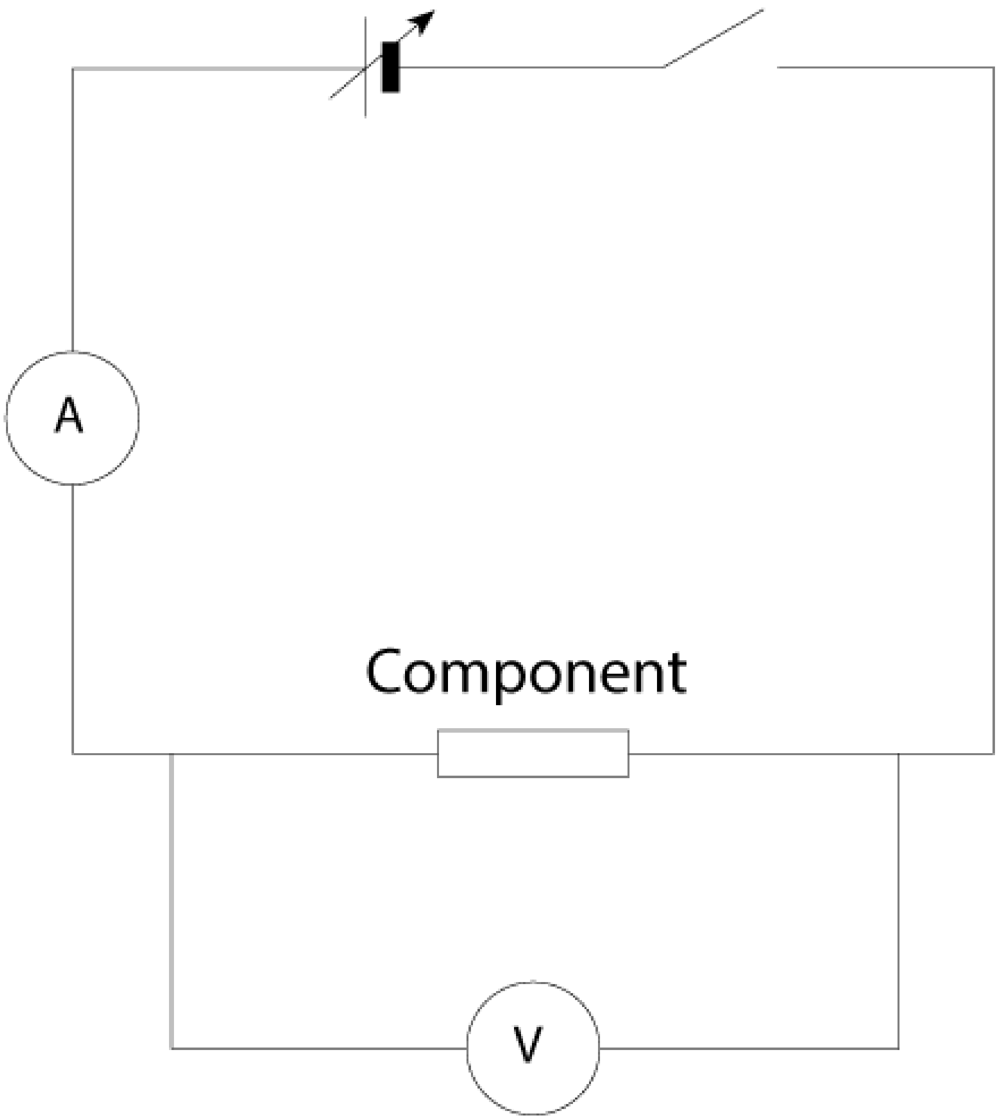
WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 2 . 2 RESISTANCE EXAM LEVEL: AS

DIAGRAM:

Investigation of the *I*–*V* Characteristics of a Filament Lamp and a Metal Wire at Constant Temperature



USEFUL INTERACTIVE RESOURCES

[WJEC] > [A Level Physics] > [Terms, definitions and units booklet]

[WJEC] > [A Level Physics] > [Related practical past questions]

UNIT: 2 . 2 RESISTANCE EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of the Resistivity of a Metal Wire

THEORY:

Resistivity, ρ can be found using the equation $R = \rho\frac{l}{A}$ where l is the length of the wire, A the cross-sectional area and R the resistance. This can be compared with the equation for a straight line $y = mx + c$. A graph plotted of R (y-axis) against l (x-axis) will be a straight line through the origin of gradient $\frac{\rho}{A}$. The cross sectional area can be found using $A = \pi r^2$ and the resistivity calculated by ρ = gradient $\times A$.

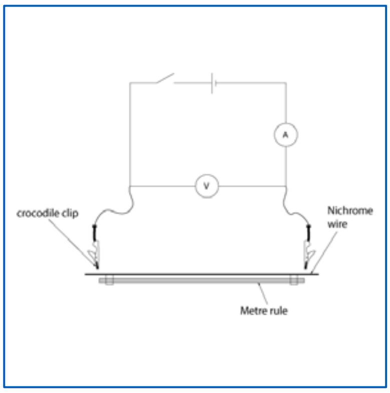
APPARATUS:

7 × 4 mm leads	Ammeter
Voltmeter	1.5 V 'D' type battery
Metre rule	110 cm length of nichrome wire
Micrometer/vernier calipers (resolution ±0.01 mm)	30 cm ruler (resolution ±0.001 m)

FURTHER GUIDANCE FOR TECHNICIANS:

Wires of SWG 24 to 28 will give accurate results whilst still being robust enough not to snap when adding or removing the crocodile clips. If nichrome is not available, then constantan is a suitable alternative. The ammeter should have a resolution of ± 0.01 A and the voltmeter a resolution of ± 0.01 V

Experimental Method:



Select the image (left) for a larger diagram of the circuit.

Leaving one crocodile clip fixed at one end of the wire, the other clip should be moved along at suitable intervals, e.g. every 10 cm/20 cm to cover the whole range of the wire. Readings on the voltmeter and ammeter should be noted for each length and the resistance determined using $R = \frac{V}{I}$.

The diameter of the wire can be found using a micrometer or vernier calipers and the cross-sectional area determined. Plot a graph of R (y-axis) against l (x-axis) and calculate the resistivity using: ρ = gradient $\times A$.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 2 . 2 RESISTANCE EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of the Resistivity of a Metal Wire

EXTENSION:

By comparing the resistivity value obtained to known constants, it is possible to determine the type of metal making up different wires.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use appropriate digital instruments, including electrical multimeters, to obtain a range of measurements (to include time, current, voltage, resistance, mass).
- Use calipers and micrometers for small distances, using digital or vernier scales.
- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2009 Task A3

PH3 2014 Task B4

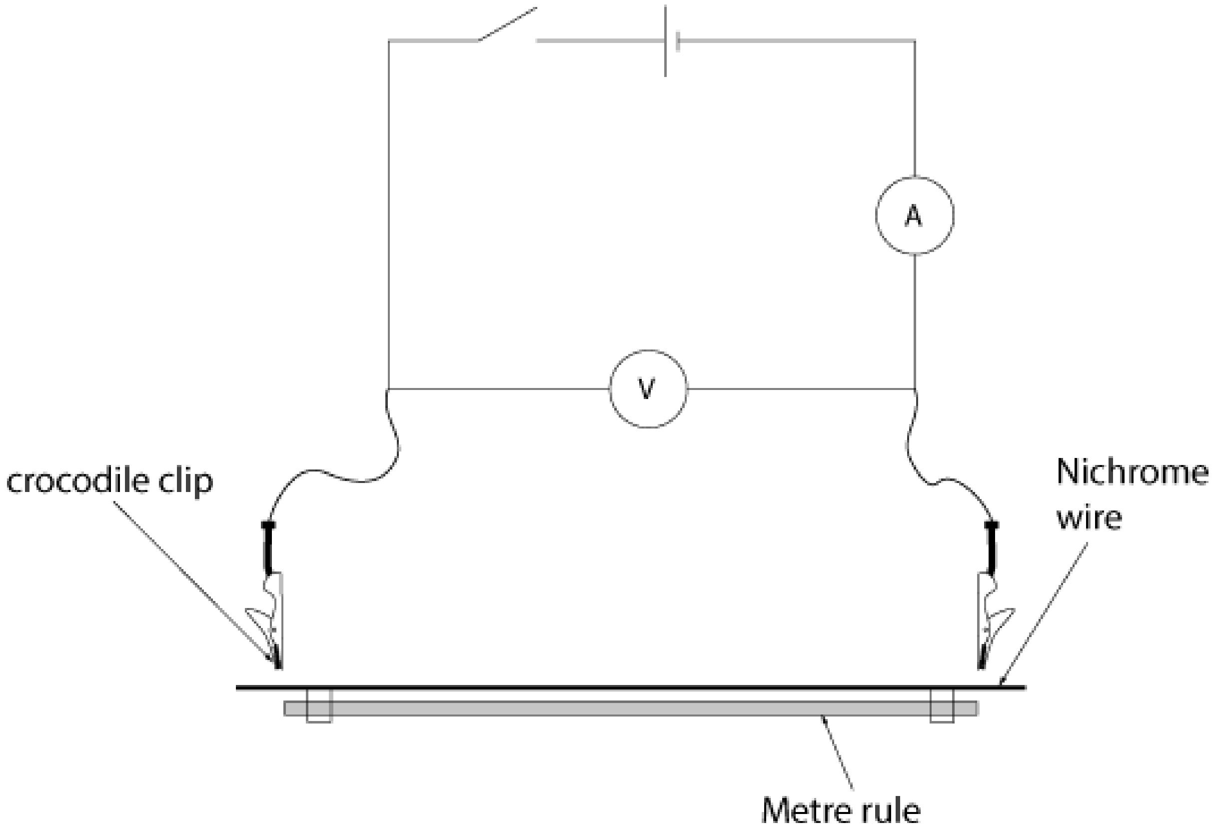
USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

DIAGRAM:

Determination of the Resistivity of a Metal Wire



USEFUL INTERACTIVE RESOURCES

[WJEC] > [A Level Physics] > [Terms, definitions and units booklet]

[WJEC] > [A Level Physics] > [Related practical past questions]

UNIT: 2 . 2 RESISTANCE EXAM LEVEL: AS

NAME OF EXPERIMENT:

Investigation of the Variation of Resistance with Temperature for a Metal Wire

THEORY:

Resistance increases with temperature for metals in a linear relationship.This practical will enable data to be obtained to investigate this relationship.

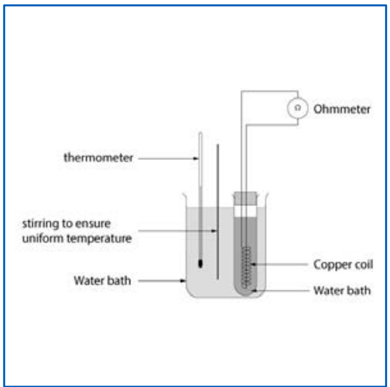
APPARATUS:

Bunsen burner	Stand and clamp
Tripod	Gauze and stand
Ice	250 ml beaker of water or water bath with heating element
Thermometer 0–100 ^{o}C	Multimeter set on ohm range to measure resistance
Copper coil	Stirrer

FURTHER GUIDANCE FOR TECHNICIANS:

A fixed D.C. voltage supply can be used with an ammeter and voltmeter instead of the ohmmeter, if preferred. The resistance can be determined by using $R = \frac{V}{I}$. The coil can be placed in a boiling tube full of oil and then placed in the water bath or in ice.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

The water bath should be heated and the water stirred continuously in order to ensure an even temperature throughout the water bath. Once the required temperature has been reached then remove the heat and record the reading of resistance or take the ammeter and voltmeter readings. This process should be repeated at intervals until the water boils.

Repeat the experiment during cooling. Plot a graph of resistance (y-axis) against temperature (x-axis). This should be a straight line through the origin.

An ice water mixture can be used to record the resistance at a temperature of 0 ^{o}C.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 2 . 2 RESISTANCE EXAM LEVEL: AS

NAME OF EXPERIMENT:

Investigation of the Variation of Resistance with Temperature for a Metal Wire

EXTENSION:

The variation of resistance with temperature for a thermistor could also be investigated.

Data Logging: Digital ammeters, voltmeters and thermometers could be used that are part of a data logging set-up.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use calipers and micrometers for small distances, using digital or vernier scales.
- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH6 2014 Data analysis task

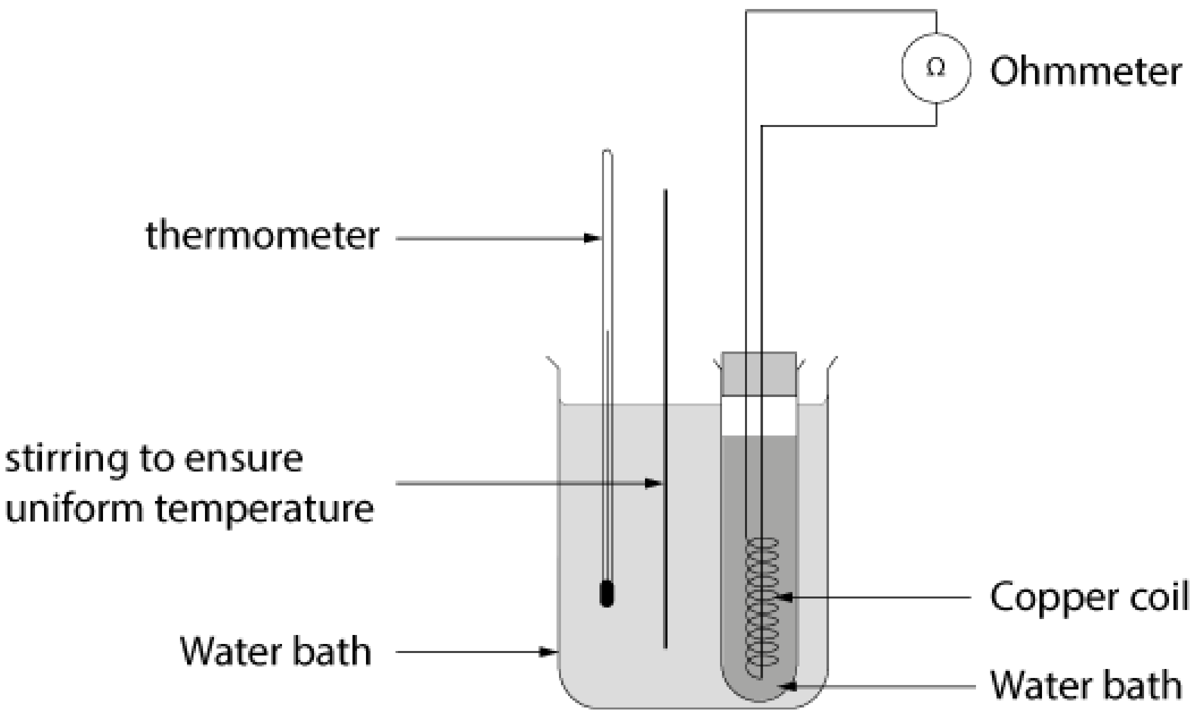
USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

DIAGRAM:

Investigation of the Variation of Resistance with Temperature for a Metal Wire



USEFUL INTERACTIVE RESOURCES

[WJEC] > [A Level Physics] > [Terms, definitions and units booklet]

[WJEC] > [A Level Physics] > [Related practical past questions]

	SPECIFICATION STATEMENT	COMMENT
(a)	The idea that the current from a source is equal to the sum of the currents in the separate branches of a parallel circuit, and that this is a consequence of conservation of charge	See terms, definitions and units booklet.
(b)	The sum of the potential differences across components in a series circuit is equal to the potential difference across the supply, and that this is a consequence of conservation of energy	
(c)	Potential differences across components in parallel are equal	
(d)	The application of equations for the combined resistance of resistors in series and parallel	
(e)	The use of a potential divider in circuits (including circuits which contain LDRs and thermistors)	Quantitative analysis expected. When one element is an LDR or thermistor, the other will be a fixed resistor.
(f)	What is meant by the emf of a source	
(g)	The unit of emf is the volt (V), which is the same as that of potential difference	See terms, definitions and units booklet.
(h)	The idea that sources have internal resistance and to use the equation $V = E - Ir$	Sometimes V or I will have to be calculated from other data, such as 'load' resistance.
(i)	How to calculate current and potential difference in a circuit containing one cell or cells in series	

Select the image (left) for "Determination of the internal resistance of a cell" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 3 D.C. CIRCUITS	EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of the Internal Resistance of a Cell

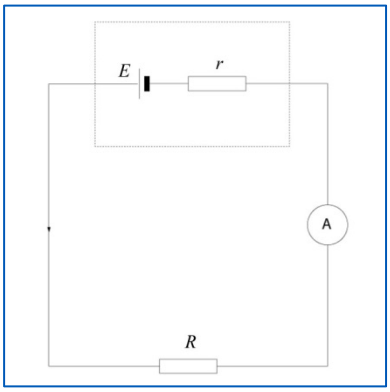
THEORY:

The equation used for determining the internal resistance is $V = E - Ir$ where V is the terminal p.d. of a cell; E is the emf of the cell; I is the current flowing in the circuit and r is the internal resistance. $V = IR$ and the equation can be rewritten as $R = \frac{E}{I} - r$. Therefore a graph of R against $\frac{1}{I}$ should be linear.

APPARATUS:

Switch
Cells, e.g. 3 or 4 $\times$ 1.5 V “D” type batteries connected in series
Ammeter or multimeter set to A range ±0.01 A
Various resistor values 0 – 60 Ω

Experimental Method:



The circuit should be set up as shown. **Select the image (*left*)** for a larger diagram.

The resistor values should be varied and the current values recorded.

Plot a graph of R (y-axis) against $\frac{1}{I}$ (x-axis). The graph should be a straight line with the intercept on the y-axis which is equal to the value of the internal resistance.

USEFUL INTERACTIVE RESOURCES

[WJEC](#) > [A Level Physics](#) > [Terms, definitions and units booklet](#)

[WJEC](#) > [A Level Physics](#) > [Related practical past questions](#)

UNIT: 2 . 3 D.C. CIRCUITS | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of the Internal Resistance of a Cell

EXTENSION:

The current can also be varied and the terminal potential difference measured. A graph of potential difference against current should be linear and the emf of the cell could be determined.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use calipers and micrometers for small distances, using digital or vernier scales.
- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2007 Q2

PH3 2011 Task B4

USEFUL INTERACTIVE RESOURCES

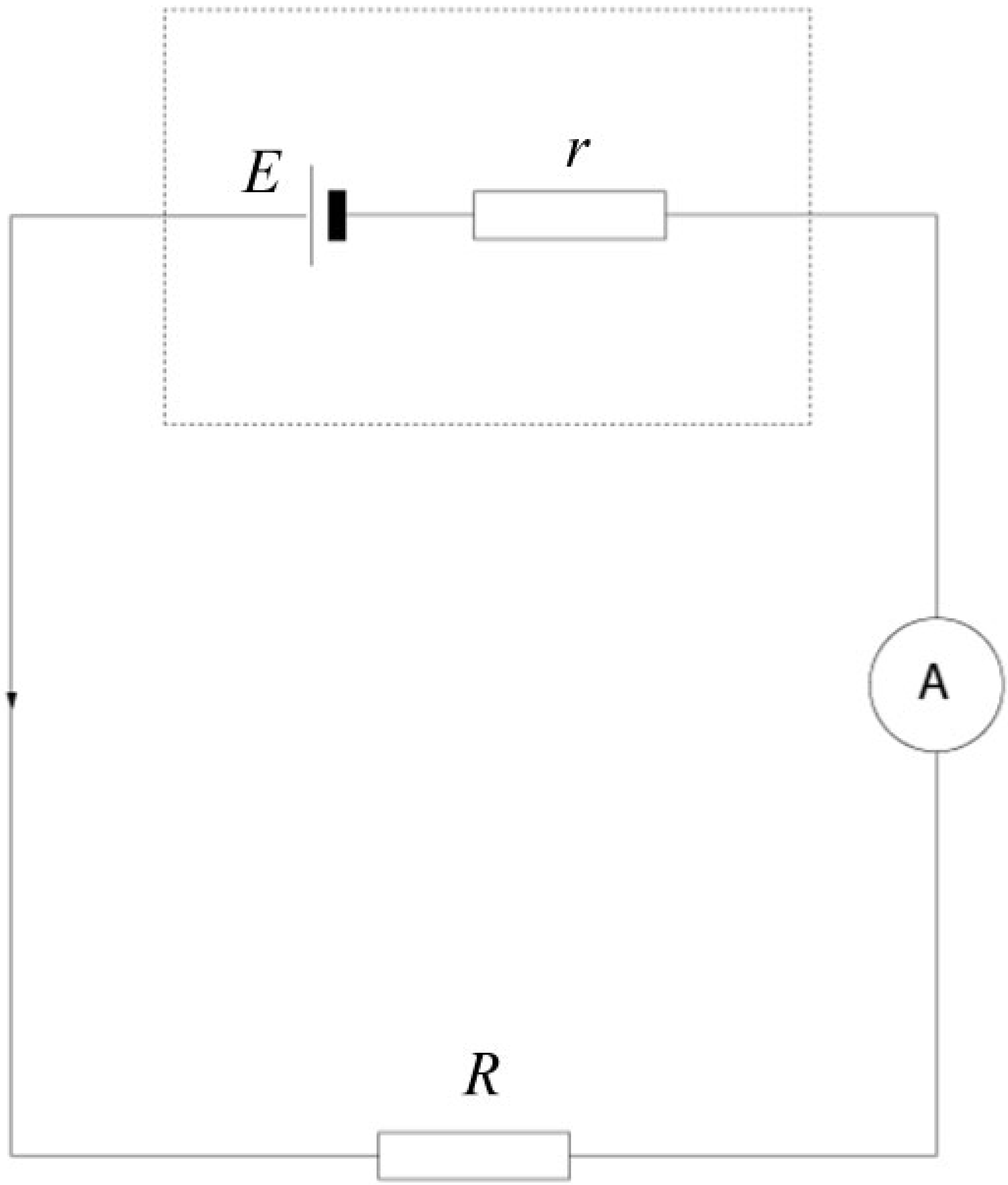
WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 2 . 3 D.C. CIRCUITS EXAM LEVEL: AS

DIAGRAM:

Determination of the Internal Resistance of a Cell



USEFUL INTERACTIVE RESOURCES

[WJEC](#) > [A Level Physics](#) > [Terms, definitions and units booklet](#)

[WJEC](#) > [A Level Physics](#) > [Related practical past questions](#)

	SPECIFICATION STATEMENT	COMMENT
(a)	The idea that a progressive wave transfers energy without any transfer of matter	See terms, definitions and units booklet.
(b)	The difference between transverse and longitudinal waves	See terms, definitions and units booklet.
(c)	The term polarisation	See terms, definitions and units booklet.
(d)	The terms in phase and in antiphase	See terms, definitions and units booklet.
(e)	The terms displacement, amplitude, wavelength, frequency, period and velocity of a wave	See terms, definitions and units booklet.
(f)	Graphs of displacement against time, and displacement against position for transverse waves only	See terms, definitions and units booklet.
(g)	The equation $c = f\lambda$	See terms, definitions and units booklet. In both theoretical and practical contexts.
(h)	The idea that all points on wavefronts oscillate in phase, and that wave propagation directions (rays) are at right angles to wavefronts	Familiarity with the terms *torque* and *moment* (used interchangeably). See terms, definitions and units booklet.

Select the image (left) for "Measurement of the intensity variations for polarisation" practical work.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 4 THE NATURE OF WAVES EXAMB LEVEL: AS

NAME OF EXPERIMENT:

Measurement of the Intensity Variations for Polarisation

THEORY:

The light waves in a ray of light from a lamp have vibrations in all planes and directions.The light is unpolarised. When the light passes through a polaroid filter, the vibrations will be in one plane or direction only. In the experiment with two pieces of polaroid, the first polarises the light. The light will then not pass through the second polaroid if the direction in which the second filters polarises light is at right angles to the polarising direction of the first polaroid.

APPARATUS:

Two pieces of polaroid
Lamp, e.g. 24 W
12 V bulb in holder

FURTHER GUIDANCE FOR TECHNICIANS:

Fluorescent lights from the room can be used instead of a lamp.

Experimental Method:

Investigate the variation in intensity by looking through the lamp through both polaroids and rotating one of the polaroids through 360°. Note the change in intensity that occurs.

EXTENSION:

Microwaves could be used instead of light with 3 metal plates used to create a double-slit arrangement.

A transmitter and a suitable receiver could be used with an analogue measuring instrument to show the intensity variations corresponding to the fringes.

PRACTICAL TECHNIQUES:

- Generate and measure waves, using microphone and loudspeaker, or ripple tank, or vibration transducer, or microwave/radio wave source.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(a)	Diffraction occurring when waves encounter slits or obstacles	See terms, definitions and units booklet.
(b)	The idea that there is little diffraction when λ is much smaller than the dimensions of the obstacle or slit	
(c)	The idea that if λ is equal to or greater than the width of a slit, waves spread as roughly semicircular wavefronts, but if λ is less than the slit width, the main beam spreads through less than 180°	
(d)	How two source interference occurs	For example, for water waves, sound, microwaves, light.
(e)	The historical importance of Young's experiment	Earliest demonstration of the wave-like properties of light.
(f)	The principle of superposition, giving appropriate sketch graphs	See terms, definitions and units booklet.
(g)	The path difference rules for constructive and destructive interference between waves from in phase sources	
(h)	The use of $\lambda = \dfrac{a\Delta y}{D}$	
(i)	The derivation and use of $d\sin\theta = n\lambda$ for a diffraction grating	Derivation by considering parallel rays leaving the slits (and interfering at a very distant point).

Select the image (left) for "Determination of wavelength using Young's double slits" practical work.

Select the image (left) for "Determination of wavelength using a diffraction grating" practical work.

Select the image (left) for "Determination of the speed of sound using stationary waves" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES | EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(j)	The idea that for a diffraction grating a very small d makes beams ("orders") much further apart than in Young's experiment, and that the large number of slits makes the bright beams much sharper	See terms, definitions and units booklet.
(k)	The idea that coherent sources are monochromatic with wavefronts continuous across the width of the beam and, (when comparing more than one source) with a constant phase relationship	
(l)	Examples of coherent and incoherent sources	Laser is the only example needed of a coherent source.
(m)	The idea that for two source interference to be observed, the sources must have a zero or constant phase difference and have oscillations in the same direction	See terms, definitions and units booklet.
(n)	The differences between stationary and progressive waves	In terms of variation of phase and amplitude with distance, and in terms of energy transport.
(o)	The idea that a stationary wave can be regarded as a superposition of two progressive waves of equal amplitude and frequency, travelling in opposite directions, and that the internodal distance is $\frac{\lambda}{2}$	Contexts could include waves on a string, sound waves in air, microwaves. Candidates should know that there are nodes at the ends of a string if these are fixed. The distinction between pressure and displacement nodes and antinodes for stationary sound waves is not required. See terms, definitions and units booklet.

Select the image (left) for "Determination of wavelength using Young's double slits" practical work.

Select the image (left) for "Determination of wavelength using a diffraction grating" practical work.

Select the image (left) for "Determination of the speed of sound using stationary waves" practical work.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Wavelength Using Young's Double Slits

THEORY:

The fringe spacing, Δy is given by the equation $\Delta y = \frac{\lambda D}{d}$ where λ is the wavelength of the light; D is the distance from the slits to the screen where the fringes are viewed and d is the distance between the slits. A graph of Δy against D should be a straight line and the gradient can be used to determine the wavelength of the light.

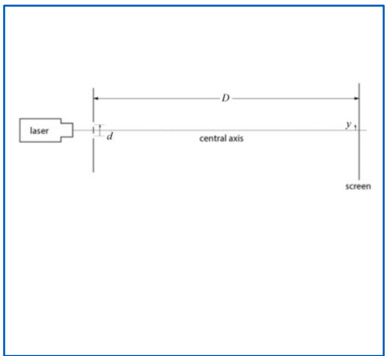
APPARATUS:

Laser pen
Stand and clamp
Double slit
Screen
Metre rule
30 cm ruler or digital calipers

FURTHER GUIDANCE FOR TECHNICIANS:

The value of d can be given to students when using the apparatus. The experiment can be undertaken in the main laboratory and does not require darkroom facilities.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Measure the fringe spacing Δy, the spacing between the double slits, d, and the distance, D, from the slits to the screen using either the ruler or digital calipers. Vary the distance, D in equal intervals. Plot a graph of the fringe spacing Δy (y-axis) against the slit-screen distance D (x-axis). This should be a straight line through the origin.

If the fringes are close together; Δy can be determined by measuring the separation of a number of fringes. So determine Δy by dividing the distance by the number of fringes measured.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Wavelength Using Young's Double Slits

EXTENSION:

Microwaves could be used instead of light with 3 metal plates used to create a double-slit arrangement.

A transmitter and a suitable receiver could be used with an analogue measuring instrument to show the intensity variations corresponding to the fringes.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use laser or light source to investigate characteristics of light, including interference and diffraction.

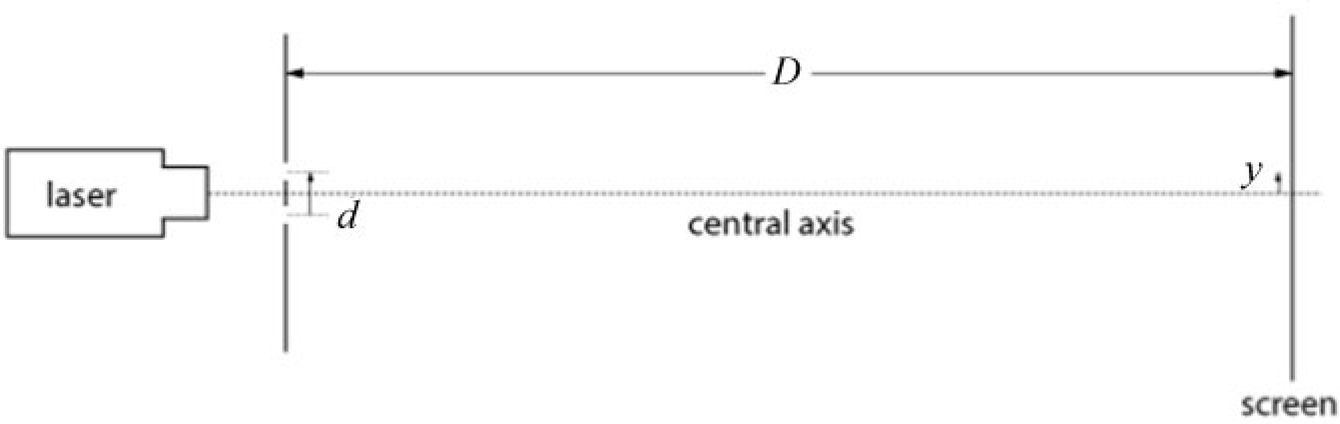
USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES EXAM LEVEL: AS

DIAGRAM:

Determination of Wavelength Using Young's Double Slits



USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Wavelength Using a Diffraction Grating

THEORY:

The diffraction grating equation is given by $n\lambda = d\sin\theta$. The spacing between the lines in a diffraction grating is usually specified or can be found from the grating ruling. By measuring the angle θ, the wavelength of the light can be determined.

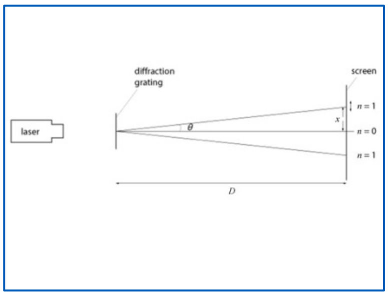
APPARATUS:

Laser pen
Diffraction grating of known d value or ruling e.g. 300 lines cm^{-1}
Metre rule
Screen
Stand and clamp for laser pen and grating

FURTHER GUIDANCE FOR TECHNICIANS:

The experiment can be undertaken in the main laboratory and does not require dark room facilities.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

The value of θ can be determined from $\tan\vartheta = \frac{x}{D}$.

Using the equation $n\lambda = d\sin\vartheta$ then the wavelength can be determined for various orders of diffraction.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of Wavelength Using a Diffraction Grating

EXTENSION:

A spectrometer could be used with different spectra lamps and the wavelength of various lines in the spectra could be determined.

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use laser or light source to investigate characteristics of light, including interference and diffraction.

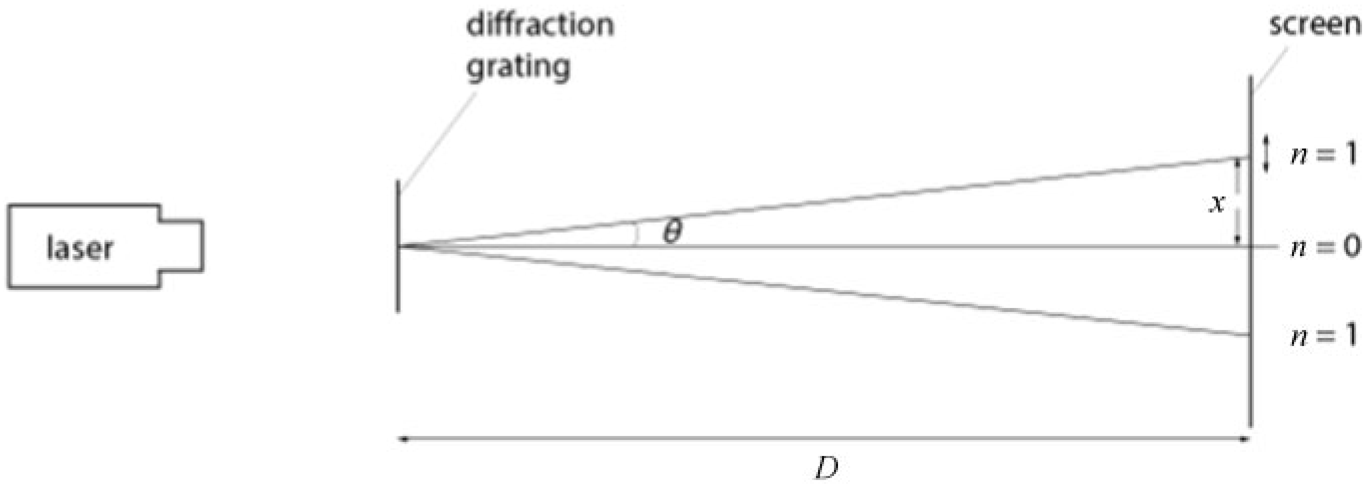
USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES EXAM LEVEL: AS

DIAGRAM:

Determination of Wavelength Using a Diffraction Grating



USEFUL INTERACTIVE RESOURCES

[WJEC] > [A Level Physics] > [Terms, definitions and units booklet]

UNIT: 2 . 5 WAVE PROPERTIES	EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of the Speed of Sound Using Stationary Waves

THEORY:

When resonance first occurs, the length of air in the tube, l, plus a small end correction, e (to account for the position of the tuning fork above the tube) will be equal to a quarter of a wavelength. Hence:

$$l + e = \frac{\lambda}{4} \quad \text{but} \quad \lambda = \frac{c}{f} \qquad\qquad \text{so} \quad l = \frac{c}{4f} - e$$

If a graph is plotted of l (y-axis) against $\frac{1}{f}$ (x-axis) it should be a straight line with a small negative y-intercept.

The gradient of the graph equals $\frac{c}{4}$, and so the speed of sound, c, can be found. The small negative intercept will give the end correction.

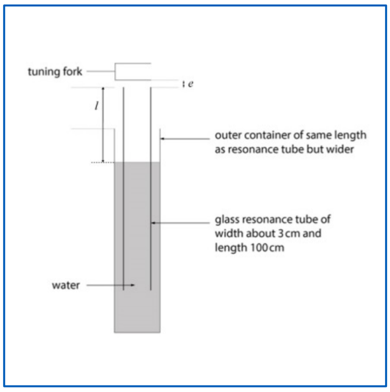
APPARATUS:

A range of at least five different tuning forks
Glass resonance tube of width about 3 cm and length 100 cm
Outer container of same length as resonance tube, but wider
Water

FURTHER GUIDANCE FOR TECHNICIANS:

An alternative to the above would be to use a very wide burette (about 3 cm diameter) and allow the water to drain out as the tuning fork is held over the top of it.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Initially place the resonance tube as deep as possible into the water. Then gradually raise it. As this is being done hold a vibrating tuning fork over the top. When resonance occurs (a loud sound will be heard), measure the length of the tube above the water level.

Repeat the above for each of the tuning forks. Plot a graph of length (y-axis) against $\frac{1}{\text{frequency}}$ (x-axis). Use the gradient to determine a value for the speed of sound.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 5 WAVE PROPERTIES | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of the Speed of Sound Using Stationary Waves

EXTENSION:

The resonance tube could be raised past the first resonance point until the second resonance point is reached. The results could then be used to show that for the two resonant lengths l_1 and l_2 then:

Speed of sound, $c = 2f(l_2 - l_1)$

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use signal generator and oscilloscope, including volts/division and time-base.
- Generate and measure waves, using microphone and loudspeaker, or ripple tank, or vibration transducer, or microwave/radio wave source.

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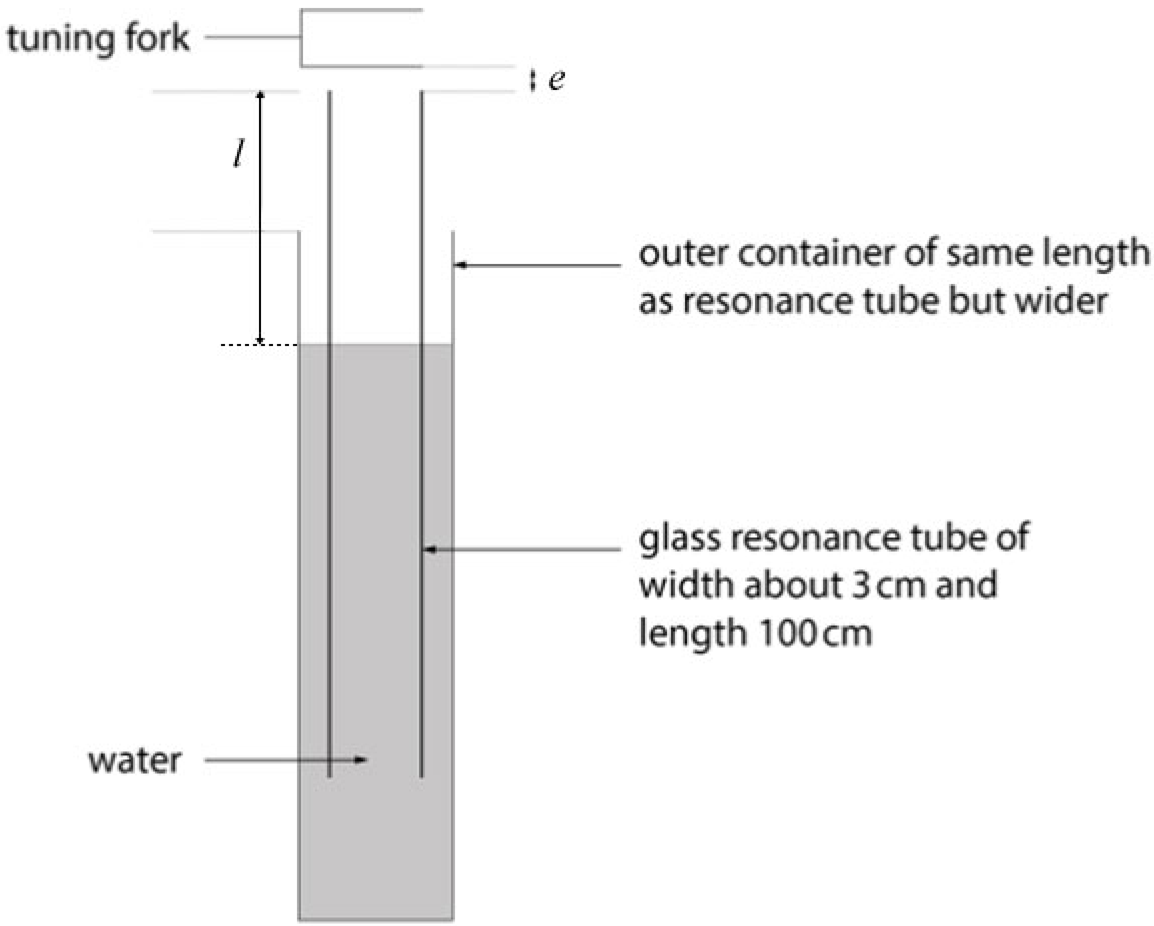
USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

DIAGRAM:

Determination of the Speed of Sound Using Stationary Waves



USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 6 REFRACTION OF LIGHT — EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(a)	The refractive index, n, of a medium being defined as $\frac{c}{v}$, in which v is the speed of light in the medium and c is the speed of light in a vacuum	See terms, definitions and units booklet.
(b)	The use of the equations: $n_1v_1 = n_2v_2$ and $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (regarded as Snell's law)	See terms, definitions and units booklet.
(c)	How Snell's law relates to the wave model of light propagation and for diagrams of plane waves approaching a plane boundary obliquely, and being refracted	Huygens' principle is not needed, but the ability to perform time and distance calculations on incident and refracted wavefronts is required.
(d)	The conditions for total internal reflection	
(e)	The derivation and use of the equation for the critical angle $n_1 \sin\theta_C = n_2$	See terms, definitions and units booklet
(f)	How to apply the concept of total internal reflection to multimode optical fibres	
(g)	The problem of multimode dispersion with optical fibres in terms of limiting the rate of data transfer and transmission distance	Candidates need to be able to perform calculations based on the transit times of pulses via the straight path and a zigzag path.
(h)	How the introduction of monomode optical fibres has allowed for much greater transmission rates and distances	Includes the knowledge that monomode fibres are very thin: their diameters are only a few wavelengths of the near infra-red radiation they transmit.

Select the image (left) for "Measurement of the refractive index of a material" practical work.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 2 . 6 REFRACTION OF LIGHT | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Measurement of the Refractive Index of a Material

THEORY:

The refractive index, n, of a material can be determined from the equation $\sin\theta_i = n\sin\theta_r$ where n = refractive index, θ_i is the angle of incidence and θ_r is the angle of refraction. The above equation assumes that the incident ray is travelling in air. A graph of $\sin\theta_i$ (y-axis) against $\sin\theta_r$ (x-axis) will give a straight line through the origin and the gradient is equal to the refractive index, n.

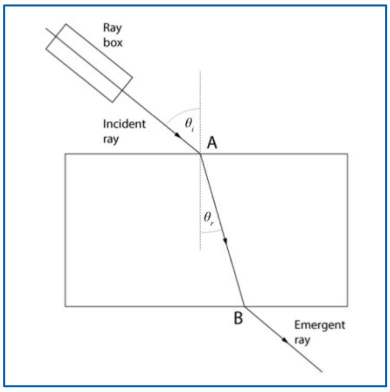
APPARATUS:

Suitable white light source, e.g. ray box fitted with a single slit to produce a narrow parallel beam of light
Power supply for ray box and connecting leads
Rectangular block of glass or Perspex
1 or 2 sheets of plain paper
Protractor
30 cm ruler

FURTHER GUIDANCE FOR TECHNICIANS:

The investigation may be conducted in normal laboratory lighting. A dark room is not required.

Experimental Method:



The arrangement should be set up as shown. **Select the image (*left*)** for a larger diagram.

The angle of refraction θ_r can be measured by drawing in the line joining the incident and emergent rays for different values of the angle of incidence. The angles can be measured using the protractor after drawing in the normals. A graph of $\sin\theta_i$ (y-axis) against $\sin\theta_r$ (x-axis) can be plotted, which should give a straight line. A value of n can then be determined from the gradient.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 2 . 6 REFRACTION OF LIGHT | EXAM LEVEL: AS

NAME OF EXPERIMENT:

Measurement of the Refractive Index of a Material

PRACTICAL TECHNIQUES:

- Use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings.
- Use laser or light source to investigate characteristics of light, including interference and diffraction.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2012 Task A2

USEFUL INTERACTIVE RESOURCES

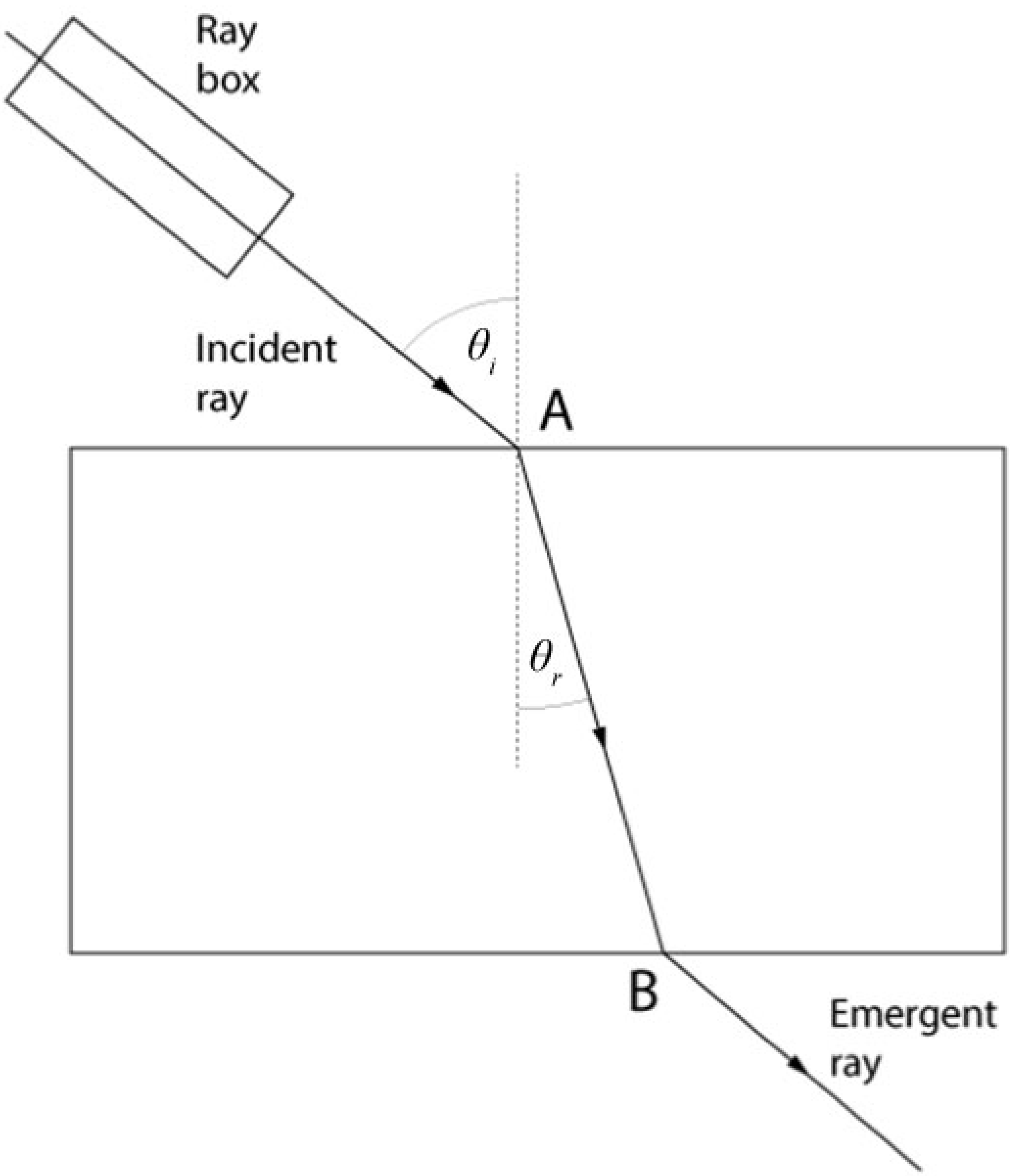
WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 2 . 6 REFRACTION OF LIGHT | EXAM LEVEL: AS

DIAGRAM:

Measurement of the Refractive Index of a Material

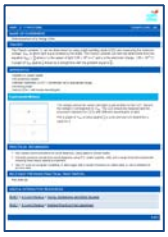


USEFUL INTERACTIVE RESOURCES

[WJEC] > [A Level Physics] > [Terms, definitions and units booklet]

[WJEC] > [A Level Physics] > [Related practical past questions]

	SPECIFICATION STATEMENT	COMMENT
(a)	The fact that light can be shown to consist of discrete packets (photons) of energy	
(b)	How the photoelectric effect can be demonstrated	For example, with electroscope or vacuum photocell. See terms, definitions and units booklet.
(c)	How a vacuum photocell can be used to measure the maximum kinetic energy, $E_{k\,\mathrm{max}}$, of emitted electrons in eV and hence in J	
(d)	The graph of $E_{k\,\mathrm{max}}$ against frequency of illuminating radiation	
(e)	How a photon picture of light leads to Einstein's equation, $E_{k\,\mathrm{max}} = hf - \phi$, and how this equation correlates with the graph of $E_{k\,\mathrm{max}}$ against frequency	Includes determining h from graph gradient and ϕ from intercept. See terms, definitions and units booklet.
(f)	The fact that the visible spectrum runs approximately from 700 nm (red end) to 400 nm (violet end) and the orders of magnitude of the wavelengths of the other named regions of the electromagnetic spectrum	
(g)	Typical photon energies for these radiations	Need to know or be able to calculate from typical wavelength.
(h)	How to produce line emission and line absorption spectra from atoms	Line emission spectrum produced by bombarding atoms with electrons (no practical details needed) or (for example in a flame) by other atoms.
(i)	The appearance of such spectra as seen in a diffraction grating	



Select the image (left) for "Determination of h using LEDs" practical work.

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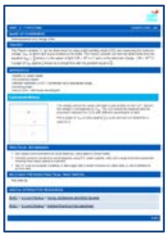
USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(j)	Simple atomic energy level diagrams, together with the photon hypothesis, line emission and line absorption spectra	Energy levels could be in J or eV. See terms, definitions and units booklet
(k)	How to determine ionisation energies from an energy level diagram	See terms, definitions and units booklet
(l)	The demonstration of electron diffraction and that particles have a wave-like aspect	
(m)	The use of the relationship $p = \frac{h}{\lambda}$ for both particles of matter and photons	
(n)	The calculation of radiation pressure on a surface absorbing or reflecting photons	Candidates will be expected to be able to use the equations for photon energy and momentum. Therefore they should be able, for example, to calculate the momentum arriving per second at a surface when a beam of light of a given power strikes the surface normally. According to Newton's 2nd and 3rd laws, this gives the force on the surface if it doesn't reflect. If the surface is 100% reflecting, then the force is double because momentum is a vector and the change in momentum of the photons is double when their momentum is reversed. Pressure is calculated as normal force divided by (beam) area.



Select the image (left) for "Determination of *h* using LEDs" practical work.

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[WJEC](#) > [A Level Physics](#) > [Specification from 2015](#)

[WJEC](#) > [A Level Physics](#) > [Terms, definitions and units booklet](#)

UNIT: 2 . 7 PHOTONS EXAM LEVEL: AS

NAME OF EXPERIMENT:

Determination of h using LEDs

THEORY:

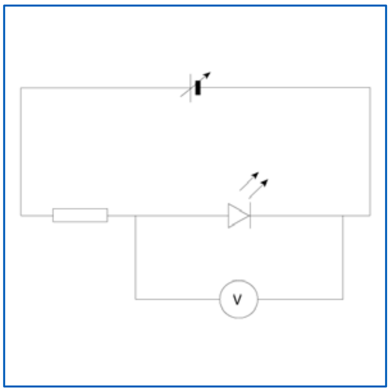
The Planck constant, h, can be determined by using a light-emitting diode (LED) and measuring the minimum voltage, V_{min}, at which light is just emitted by the diode. The Planck constant can then be determined from the equation $V_{\text{min}} = \frac{hc}{e\lambda}$ where c is the speed of light 3.00×10^{8} m s^{-1} and e is the electronic charge, 1.60×10^{-19} C.

A graph of V_{min} against $\frac{1}{\lambda}$ should be a straight line with the gradient equal to $\frac{hc}{e}$.

APPARATUS:

Variable D.C. power supply
1 kΩ protective resistor
Voltmeter (resolution ± 0.01 V) [multimeter set to appropriate range]
Connecting leads
Various LEDs – with known wavelengths

Experimental Method:



The voltage should be varied until light is just emitted by the LED. Record the voltage to which it corresponds, namely V_{min}.

The LED should be replaced and the procedure repeated for LEDs with different wavelengths of light.

Plot a graph of V_{min} (x-axis) against $\frac{1}{\lambda}$ (y-axis) and use it to determine a value for h.

PRACTICAL TECHNIQUES:

- Use calipers and micrometers for small distances, using digital or vernier scales.
- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2006 Q2

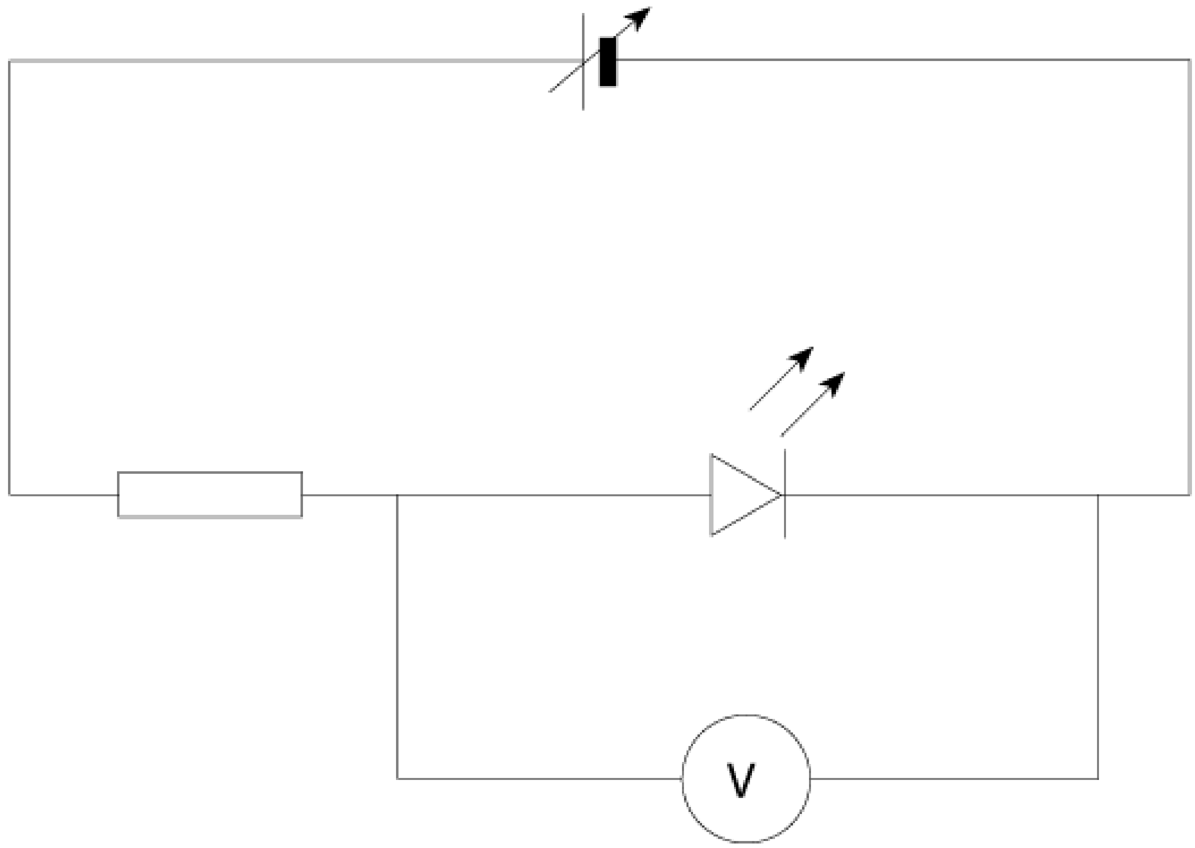
USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

DIAGRAM:

Determination of *h* using LEDs



USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

	SPECIFICATION STATEMENT	COMMENT
(a)	The process of stimulated emission and how this process leads to light emission that is coherent	See detailed laser notes. See terms, definitions and units booklet.
(b)	The idea that a population inversion ($N_2 > N_1$) is necessary for a laser to operate	See terms, definitions and units booklet.
(c)	The idea that a population inversion is not (usually) possible with a 2-level energy system	
(d)	How a population inversion is attained in 3 and 4-level energy systems	
(e)	The process of pumping and its purpose	See terms, definitions and units booklet.
(f)	The structure of a typical laser, i.e. an amplifying medium between two mirrors, one of which partially transmits light	Diagrams of the structure of a laser diode are not required.
(g)	The advantages and uses of a semiconductor laser, i.e. small, cheap, far more efficient than other types of laser, and it is used for CDs, DVDs, telecommunication, etc.	

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

A2 UNIT 3: OSCILLATIONS AND NUCLEI	
AREA OF STUDY	**DESCRIPTION**
3.1 Circular Motion	Provides amplification of statements in the specification, with links to related resources.
3.2 Vibrations	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Measurement of g with a pendulum" and "Investigation of the damping of a spring".
3.3 Kinetic Theory	Provides amplification of statements in the specification, with links to related resources.
3.4 Thermal Physics	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Estimation of absolute zero by use of the gas laws" and "Measurement of the specific heat capacity for a solid".
3.5 Nuclear Decay	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Investigation of radioactive decay – a dice analogy" and "Investigation of the variation of intensity of gamma radiation with distance".
3.6 Nuclear Energy	Provides amplification of statements in the specification, with links to related resources.

UNIT: 3 . 1 CIRCULAR MOTION	EXAM LEVEL: AS

	SPECIFICATION STATEMENT	COMMENT
(a)	The terms period of rotation, frequency	See terms, definitions and units booklet.
(b)	The definition of the unit radian as a measure of angle	See terms, definitions and units booklet.
(c)	The use of the radian as a measure of angle	
(d)	The definition of angular velocity, ω, for an object performing circular motion and performing simple harmonic motion	See terms, definitions and units booklet.
(e)	The idea that the centripetal force is the resultant force acting on a body moving at constant speed in a circle	
(f)	The centripetal force and acceleration are directed towards the centre of the circular motion	Idea that continuous change in direction implies a change of velocity and acceleration.
(g)	The use of the following equations relating to circular motion: $v = \omega r$, $a = \omega^2 r$, $a = \frac{v^2}{r}$, $F = \frac{mv^2}{r}$, $F = m\omega^2 r$	

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(a)	The definition of simple harmonic motion as a statement in words	See terms, definitions and units booklet.
(b)	$a = -\omega^2 x$ as a mathematical defining equation of simple harmonic motion	Candidates should appreciate that the maximum acceleration $a_{max} = -\omega^2 A$.
(c)	The graphical representation of the variation of acceleration with displacement during simple harmonic motion	
(d)	$x = A\cos(\omega t + \varepsilon)$ as a solution to $-\omega^2 x$	
(e)	The terms frequency, period, amplitude and phase	See terms, definitions and units booklet.
(f)	Period as $\frac{1}{f}$ or $\frac{2\pi}{\omega}$	
(g)	$v = -A\omega\sin(\omega t + \varepsilon)$ for the velocity during simple harmonic motion	In general ε = 0 or $\pi/2$ although other values may be used at times. Candidates should appreciate that the maximum velocity $v_{max} = A\omega$.
(h)	The graphical representation of the changes in displacement and velocity with time during simple harmonic motion	

Select the image (left) for "Measurement of g with a pendulum" practical work.

Select the image (left) for "Investigation of the damping of a spring" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(i)	The equation $T = 2\pi\sqrt{\frac{m}{k}}$ for the period of a system having stiffness (force per unit extension) k and mass m	No derivation required but the use and understanding of the equation is required.
(j)	The equation $T = 2\pi\sqrt{\frac{l}{g}}$ for the period of a simple pendulum	No derivation required but the use and understanding of the equation is required.
(k)	The graphical representation of the interchange between kinetic energy and potential energy during undamped simple harmonic motion, and perform simple calculations on energy changes	Candidates should know the equations for potential, kinetic and total energy.
(l)	Free oscillations and the effect of damping in real systems	See terms, definitions and units booklet.
(m)	Practical examples of damped oscillations	Bridges – resonance leads to destruction. Car shock absorbers.
(n)	The importance of critical damping in appropriate cases such as vehicle suspensions	See terms, definitions and units booklet.

Select the image (left) for "Measurement of g with a pendulum" practical work.

Select the image (left) for "Investigation of the damping of a spring" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 3 . 2 VIBRATIONS — EXAM LEVEL: A2

	SPECIFICATION STATEMENT	COMMENT
(o)	Forced oscillations and resonance, and to describe practical examples	See terms, definitions and units booklet.
(p)	The variation of the amplitude of a forced oscillation with driving frequency and that increased damping broadens the resonance curve	Candidates should be able to sketch a resonance curve.
(q)	Circumstances when resonance is useful for example, circuit tuning, microwave cooking and other circumstances in which it should be avoided for example, bridge design	Note that although microwave cooking is related to resonance, the frequency of microwaves is chosen away from the resonant peak.

Select the image (left) for "Measurement of g with a pendulum" practical work.

Select the image (left) for "Investigation of the damping of a spring" practical work.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 3 . 2 VIBRATIONS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Measurement of g with a Pendulum

THEORY:

The period of oscillation of the pendulum is given by the equation $T = 2\pi\sqrt{\frac{l}{g}}$ where l is the length of the pendulum and g is the acceleration due to gravity. The equation can be written as $T^2 = \frac{4\pi^2}{g}l$ which can be compared with the equation for a straight line $y = mx + c$. Thus a graph of T^2 against l should be a straight line through the origin with the gradient of the line equal to $\frac{4\pi^2}{g}$. The acceleration due to gravity can be determined from the value of the gradient and is equal to $\frac{4\pi^2}{\text{gradient}}$.

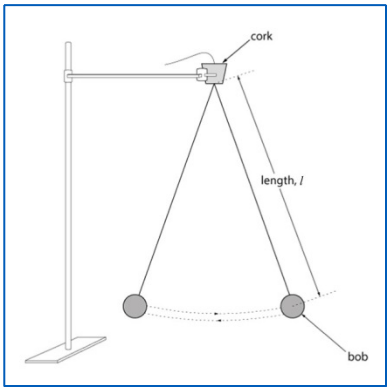
APPARATUS:

Stopwatch
Metre rule
G-clamp to secure the stand
Simple pendulum mass in the form of either a lead or brass bob
Length of cord or thread – at least 1.0 m in length
Stand, clamp and boss – the height of the stand should enable the length to be adjusted to at least 1.0 m
Either a rubber or cork bung split in two so that learners can change length easily

FURTHER GUIDANCE FOR TECHNICIANS:

The resolution for the stopwatch should be $\pm$ 0.01 s. The G clamp ensures that the apparatus is stable during the oscillations of the pendulum.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Adjust the length of the pendulum (measured from where the thread emerges from the cork/bung to the centre of the bob) by drawing the thread through the cork. The pendulum should be given a small displacement. The time for a number of oscillations (a minimum of 5) should be measured and the period of 1 oscillation determined. The oscillations can be determined by measuring against a fixed point. Repeat with different lengths at suitable intervals.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

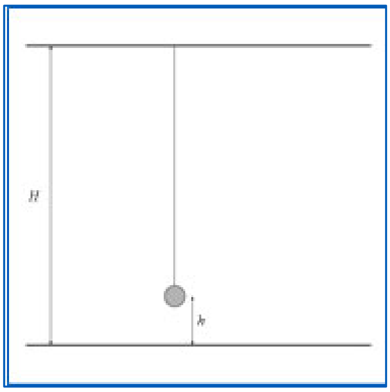
WJEC > A Level Physics > Related practical past questions

UNIT: 3 . 2 VIBRATIONS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Measurement of g with a Pendulum

EXTENSION:



The apparatus should be set up as shown, **select the image (*left*)** for a larger diagram

The height of the room can be determined by writing the equation as $T = 2\pi\sqrt{\frac{H-h}{g}}$ where H is the height of the room and h is the distance from the floor to the centre of the bob.

Data Logging: Displacement sensors could be used to obtain individual oscillations digitally.

PRACTICAL TECHNIQUES:

- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2010 Task B4

PH6 2013 Data analysis task

USEFUL INTERACTIVE RESOURCES

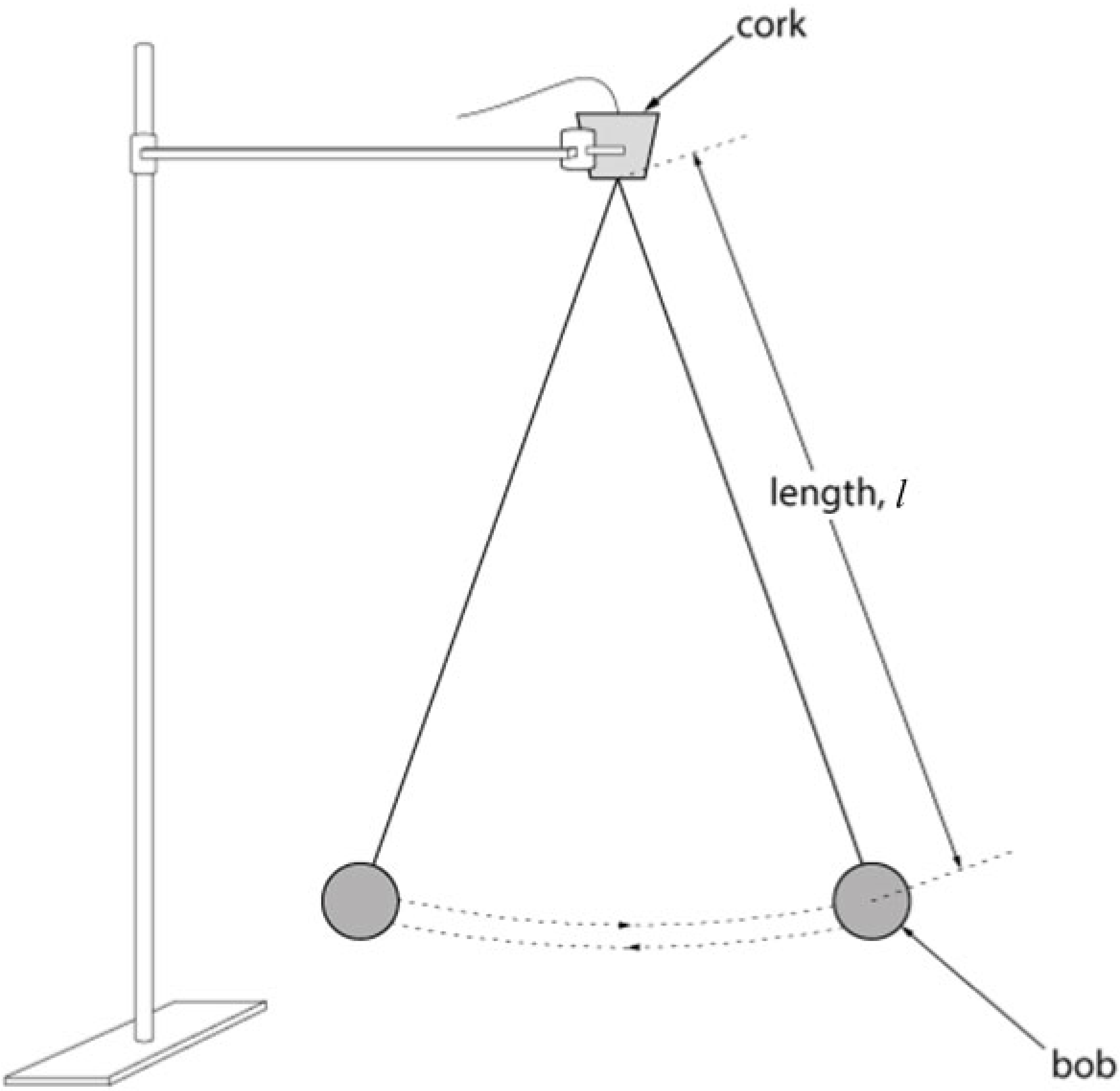
WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 3 . 2 VIBRATIONS EXAM LEVEL: A2

DIAGRAM:

Measurement of g with a Pendulumn



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WJEC > A Level Physics > Related practical past questions

UNIT: 3 . 2 VIBRATIONS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Damping of a Spring

THEORY:

The relationship between the amplitude of oscillation, A, and time, t, can be expressed by:

$A = A_0 e^{-\lambda t}$

Where A_0 = initial amplitude

And λ = an unknown constant

If we take the log of both sides we get $\ln A = -\lambda t + \ln A_0$. This can be compared with the equation for a straight line $y = mx + c$ and so a graph of $\ln A$ against t will give a straight line of gradient λ and intercept $\ln A_0$.

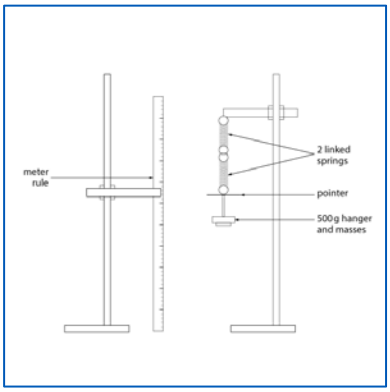
APPARATUS:

500 g hanger and masses
2 linked springs
2 clamps and stands
G-clamps (if required)
Pointer
Metre rule (resolution ± 0.001 m)
Stopwatch

FURTHER GUIDANCE FOR TECHNICIANS:

The resolution of the stopwatch should be ± 0.01 s. The G-clamp ensures that the apparatus is stable whilst the spring is oscillating.

Experimental Method:



Select the image, left for a larger diagram.

Place the 500 g mass on the spring system and attach a pointer so its position can be easily read on the metre rule. Displace the mass by a further 2.5 cm. Let go of the mass and simultaneously start the stopwatch. Let the mass oscillate continuously and measure the new amplitude of the system every minute for the next eight minutes. Repeat this two more times and find the mean amplitude at each time. Determine $\ln A$ for each time t and plot a graph to enable you to find λ.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 3 . 2 VIBRATIONS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Damping of a Spring

EXTENSION:

A series of cards of different diameters could be included to investigate the effect of different surface area on damping (the cards could be placed on top of the different masses).

PRACTICAL TECHNIQUES:

- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH3 2007 Q1

PH6 2012 Experimental task

USEFUL INTERACTIVE RESOURCES

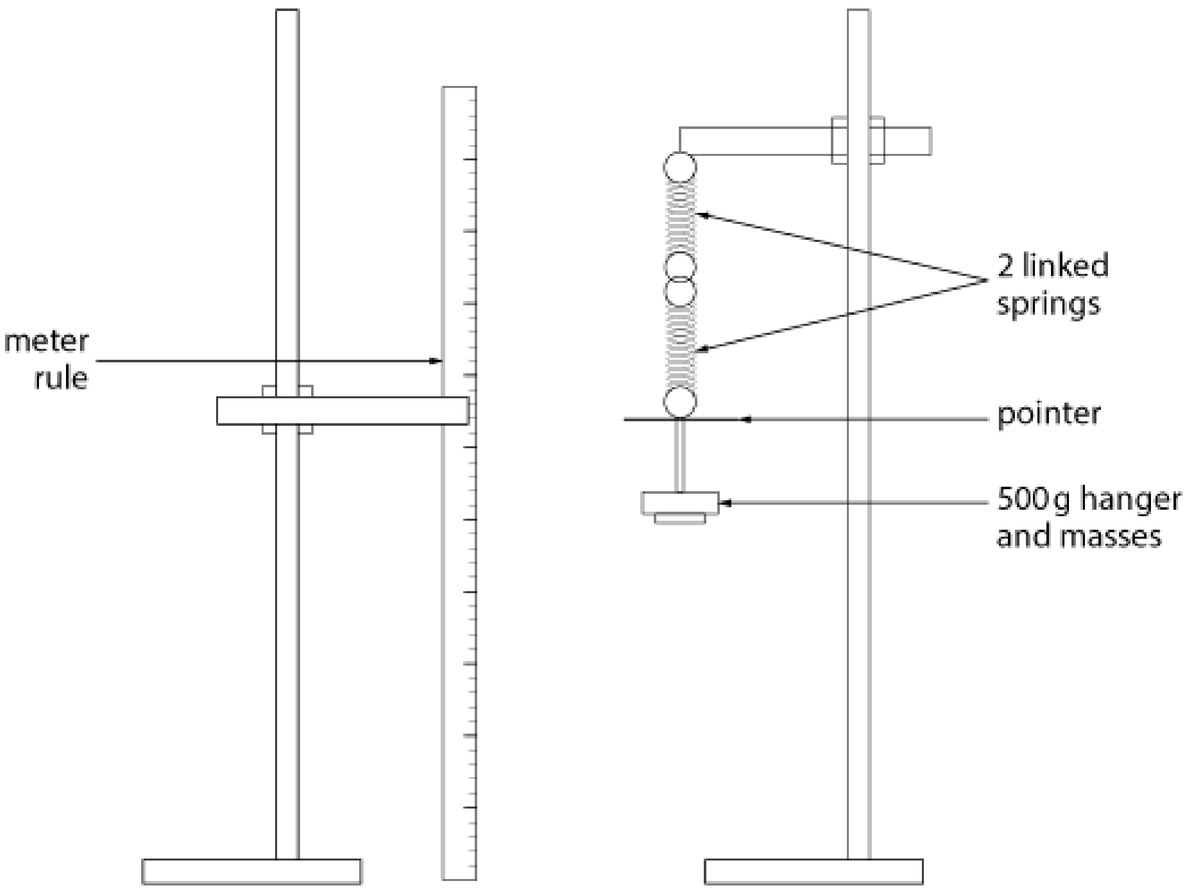
WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 3 . 2 VIBRATIONS EXAM LEVEL: A2

DIAGRAM:

Investigation of the Damping of a Spring



USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

	SPECIFICATION STATEMENT	COMMENT
(a)	The equation of state for an ideal gas expressed as $pV = nRT$ where R is the molar gas constant and $pV = NkT$ where k is the Boltzmann constant	Knowledge of the details of Boyle's Charles' and the pressure laws are not needed but candidates need to have an awareness that the ideal gas equation can be applied to these special cases. Candidates need to know the basic conditions for a gas to be considered ideal. See terms, definitions and units booklet.
(b)	The assumptions of the kinetic theory of gases which includes the random distribution of energy among the molecules	
(c)	The idea that molecular movement causes the pressure exerted by a gas, and use $p = \frac{1}{3}\rho\overline{c^2} = \frac{1}{3}\frac{N}{V}m\overline{c^2}$ where N is the number of molecules	
(d)	The definition of Avogadro constant N_A and hence the mole	See terms, definitions and units booklet.
(e)	The idea that the molar mass M is related to the relative molecular mass M_r by $M\,/\,\text{kg} = \frac{M_r}{1000}$, and that the number of moles n is given by $\frac{\text{total mass}}{\text{molar mass}}$	
(f)	How to combine $pV = \frac{1}{3}Nm\overline{c^2}$ with $pV = nRT$ and show that the total translational kinetic energy of a mole of a monatomic gas is given by $\frac{3}{2}RT$ and the mean kinetic energy of a molecule is $\frac{3}{2}kT$ where $k = \frac{R}{N_A}$ is the Boltzmann constant, and that T is proportional to the mean kinetic energy	

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 3 . 4 THERMAL PHYSICS EXAM LEVEL: A2

	SPECIFICATION STATEMENT	COMMENT
(a)	The idea that the internal energy of a system is the sum of the potential and kinetic energies of its molecules	This is essentially a definition to be learnt. See terms, definitions and units booklet.
(b)	Absolute zero being the temperature of a system when it has minimum internal energy	Again, a definition to be learnt but there is an opportunity to discuss the Heisenberg uncertainty principle here to explain why it is a 'minimum internal energy' and not zero energy. This is not necessary but it is an interesting teaching point.
(c)	The internal energy of an ideal monatomic gas being wholly kinetic so it is given by $U = \frac{3}{2}nRT$	
(d)	The idea that heat enters or leaves a system through its boundary or container wall, according to whether the system's temperature is lower or higher than that of its surroundings, so heat is energy in transit and not contained within the system	See terms, definitions and units booklet.
(e)	The idea that if no heat flows between systems in contact, then they are said to be in thermal equilibrium, and are at the same temperature	
(f)	The idea that energy can enter or leave a system by means of work, so work is also energy in transit	See terms, definitions and units booklet.

Select the image (left) for "Estimation of absolute zero by use of the gas laws" practical work.

Select the image (left) for "Measurement of the specific heat capacity for a solid" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(g)	The equation $W = p\Delta V$ can be used to calculate the work done by a gas under constant pressure	
(h)	The idea that even if p changes, W is given by the area under the $p - V$ graph	
(i)	The use of the first law of thermodynamics, in the form $\Delta U = Q - W$ and know how to interpret negative values of ΔU, Q, and W	See terms, definitions and units booklet.
(j)	The idea that for a solid (or liquid), W is usually negligible, so $Q = \Delta U$	
(k)	$Q = mc\Delta\theta$, for a solid or liquid, and this is the defining equation for specific heat capacity, c	See terms, definitions and units booklet.

Select the image (left) for "Estimation of absolute zero by use of the gas laws" practical work.

Select the image (left) for "Measurement of the specific heat capacity for a solid" practical work.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 3 . 4 THERMAL PHYSICS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Estimation of Absolute Zero by use of the Gas Laws

THEORY:

Charles' law states that for a constant amount of gas, the volume is proportional to the absolute temperature if the pressure remains constant.

$V \alpha T$ for constant P

A plot of volume versus Centigrade temperature intercepts the x-axis at -273 °C which suggests that the gas would occupy no volume at this temperature. This theoretical value is known as absolute zero, and is also known as 0 Kelvin.

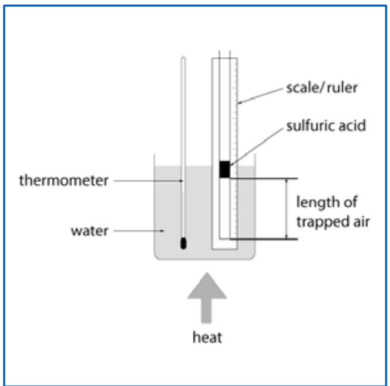
APPARATUS:

Thermometer	Scale/ruler
Water	Sulfuric acid
Heat	Length of trapped air

FURTHER GUIDANCE FOR TECHNICIANS:

A small bead of concentrated sulfuric acid can be trapped in a capillary tube by first heating the tube with boiling water. When the air cools down it contracts and the sulfuric acid will move down the tube.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Heat the water using a Bunsen burner and stir regularly. Measure the length of the trapped air every 10 °C up to 80 °C. Plot a graph of the length of trapped air (y-axis) against temperature (x-axis). The temperature scale should cover the range -400 °C to 100 °C. The length scale should start at zero. Draw a line of best fit extended back until it cuts the x-axis, this is absolute zero.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

NAME OF EXPERIMENT:

Estimation of Absolute Zero by use of the Gas Laws

EXTENSION:

The pressure law will also give a value for absolute zero. Air trapped in a flask can be heated in a water bath and the pressure measured using a pressure gauge. A graph of pressure (y-axis) against Centigrade temperature (x-axis) can be extrapolated back to give a value for absolute zero.

PRACTICAL TECHNIQUES:

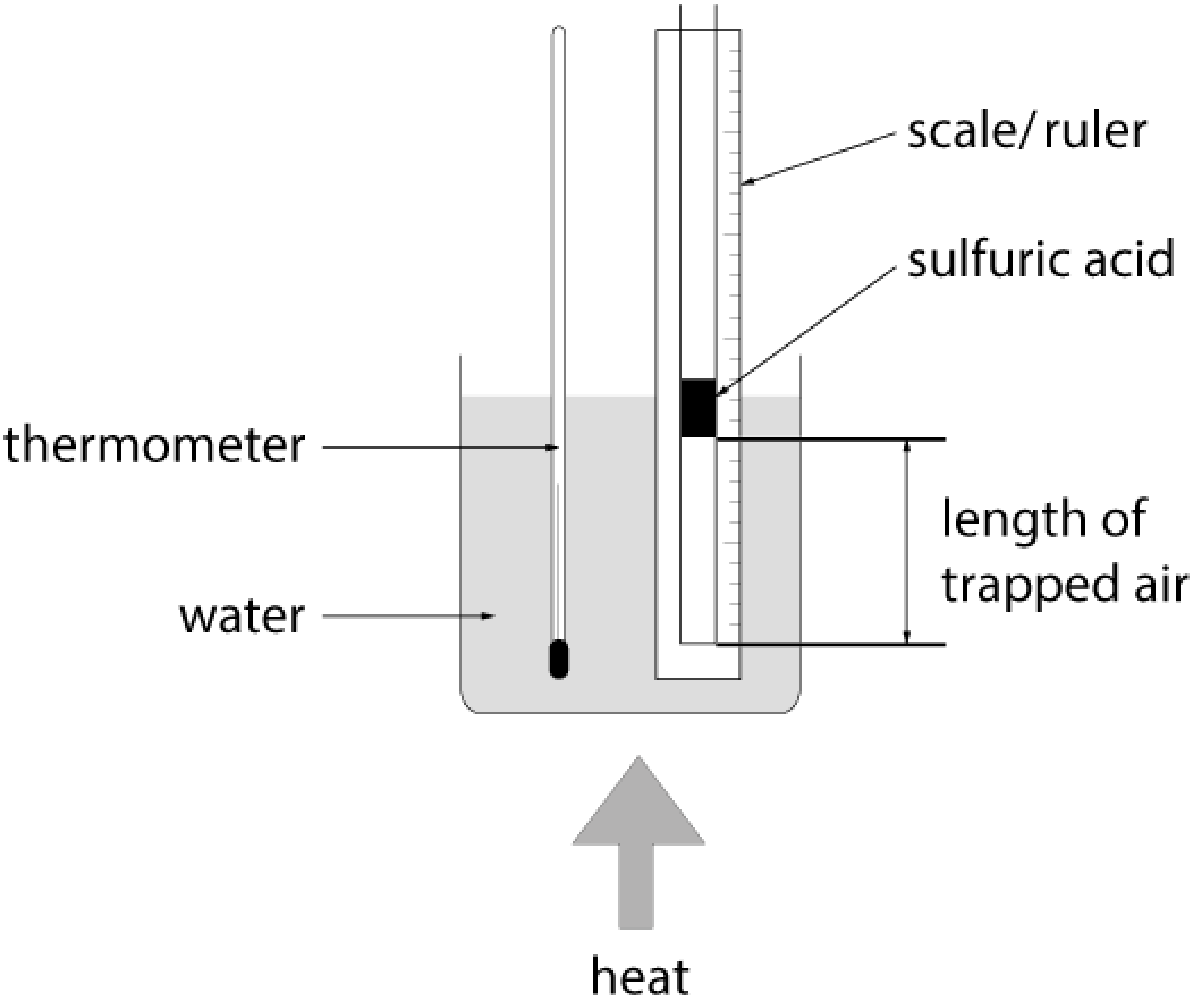
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

DIAGRAM:

Estimation of Absolute Zero by use of the Gas Laws



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[WJEC] > [A Level Physics] > [Terms, definitions and units booklet]

UNIT: 3 . 4 THERMAL PHYSICS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Measurement of the Specific Heat Capacity for a Solid

THEORY:

Assuming no energy losses:

Electrical energy supplied by the heater = heat received by the block

$$ItV = mc(\theta_2 - \theta_1)$$

Where c = specific heat capacity and $(\theta_2 - \theta_1)$ = 30 °C. Hence:

$$c = \frac{ItV}{30m}$$

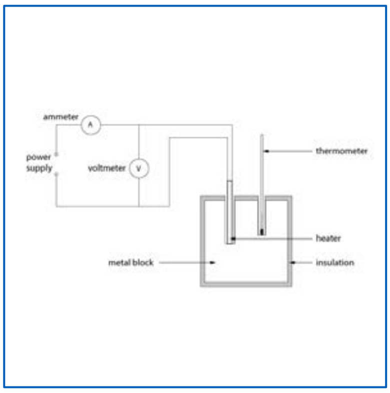
APPARATUS:

Power supply	Ammeter	Stopwatch
Voltmeter	Thermometer	
Heater	Metal block	
Insulation	Balance	

FURTHER GUIDANCE FOR TECHNICIANS:

Blocks pre-drilled and with surrounding insulation can be purchased from most school science suppliers. A few drops of glycerol could be placed in the thermometer hole to improve thermal contact with the block.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Use a cylindrical block of the metal to be tested (such as copper or aluminium). The block should be well-lagged using an insulator such as polystyrene and it needs two pre-drilled holes, one for a heater and one for a thermometer. Measure the mass, m, of the block and record its initial temperature, θ_1. Switch the heater on and start the stopwatch. Record the voltmeter and ammeter readings. When the temperature has risen by 30 °C switch the heater off and record the time taken, t. The formula can then be used to determine a value for c.

Extension:

By comparing the specific heat capacity to known constants it is possible to determine the type of metal the block is made from.

PRACTICAL TECHNIQUES:

- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

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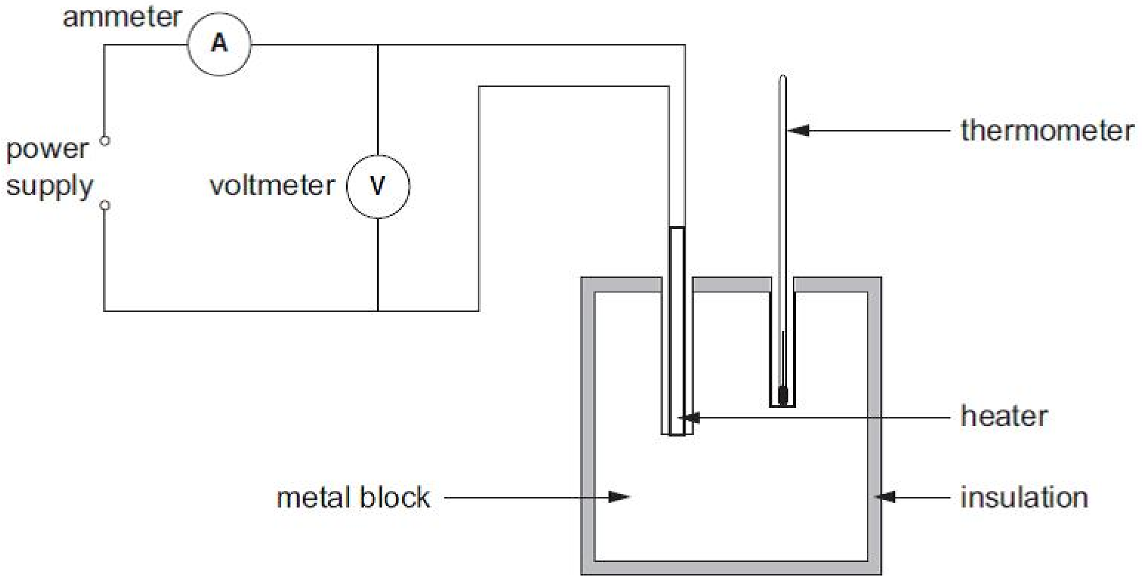
DIAGRAM:

Measurement of the Specific Heat Capacity for a Solid



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UNIT: 3 . 5 NUCLEAR DECAY — EXAM LEVEL: A2

	SPECIFICATION STATEMENT	COMMENT
(a)	The spontaneous nature of nuclear decay; the nature of α, β and γ radiation, and equations to represent the nuclear transformations using the ${}^{A}_{Z}\mathrm{X}$ notation	See terms, definitions and units booklet.
(b)	Different methods used to distinguish between α, β and γ radiation and the connections between the nature, penetration and range for ionising particles	Strongly ionising particles in motion lose energy quickly and therefore less penetrating (for a given initial energy).
(c)	How to make allowance for background radiation in experimental measurements	
(d)	The concept of the half-life, $T_{½}$	See terms, definitions and units booklet.
(e)	The definition of the activity, A, and the becquerel	See terms, definitions and units booklet.

Select the image (left) for "Investigation of radioactive decay – a dice analogy" practical work.

Select the image (left) for "Investigation of the variation of intensity of gamma radiation with distance" practical work.

Continued on next page

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

	SPECIFICATION STATEMENT	COMMENT
(f)	The decay constant, λ, and the equation $A = \lambda N$	See terms, definitions and units booklet.
(g)	The exponential law of decay in graphical and algebraic form, $N = N_o e^{-\lambda t}$ and $A = A_o e^{-\lambda t}$ or $N = \frac{N_o}{2^x}$ and $A = \frac{A_o}{2^x}$ where x is the number of half-lives elapsed – not necessarily an integer	
(h)	The derivation and use of $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$	

Select the image (left) for "Investigation of radioactive decay – a dice analogy" practical work.

Select the image (left) for "Investigation of the variation of intensity of gamma radiation with distance" practical work.

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 3 . 5 NUCLEAR DECAY EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of Radioactive Decay – A Dice Analogy

THEORY:

Radioactive decay is based on the assumption that the disintegrations are entirely at random. This can be modelled using dice to represent the atoms of a radioactive isotope.

APPARATUS:

1 000 dice

10 × cups to hold 100 dice each

FURTHER GUIDANCE FOR TECHNICIANS:

Cubes with only one side coloured and cups can be purchased as a kit from Philip Harris (catalogue number B8G85951)

Experimental Method:

Each student should have an equal share of the 1 000 dice (or cubes) and a cup. Throw the dice onto the table. Suppose all the dice with the number 1 uppermost have disintegrated. Remove these dice and count the number remaining. Repeat this for a further 9 throws (making 10 in all) and note down the number of throws and the number of dice remaining each time.

When complete combine the results of the class so you have data for 1 000 dice rolled 10 times. Plot a graph of number of dice remaining (y-axis) against number of throws (x-axis). This should give an exponential curve with a half-life of about 3.8 throws.

PRACTICAL TECHNIQUES:

- Use ICT such as computer modelling, or data logger with a variety of sensors, to collect data, or software to process data.

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, Definitions and Units Booklet

UNIT: 3 . 5 NUCLEAR DECAY EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Variation of Intensity of Gamma Radiation with Distance

THEORY:

The relationship between count rate, C, and distance, d, follows an inverse square relationship and students can investigate this relationship or use a power relationship to determine the values i.e $C = kd^n$. The equation can be rearranged using logs and values for n and k determined. Similarly students can verify the relationship $C = \frac{k}{d^2}$ and determine a value for k and investigate the effect of background radiation on the equation.

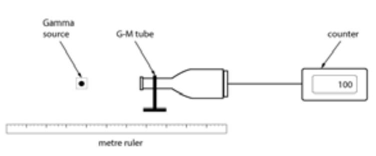
APPARATUS:

Gamma emitter, e.g. 241 Americium
Metre rule
Geiger Muller tube and counter

FURTHER GUIDANCE FOR TECHNICIANS:

Measurements for the background radiation need to be taken prior to students undertaking the experiment. This will enable students to appreciate whether this should be taken into account when analysing their results.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Candidates measure the count rate at various distances.

Extension:

Different radiation sources can be used to determine whether the inverse square relationship is valid and the factors that affect the value of the constant k can be investigated.

PRACTICAL TECHNIQUES

- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.
- Use ionising radiation, including detectors

RELEVANT PREVIOUS PRACTICAL PAST PAPERS

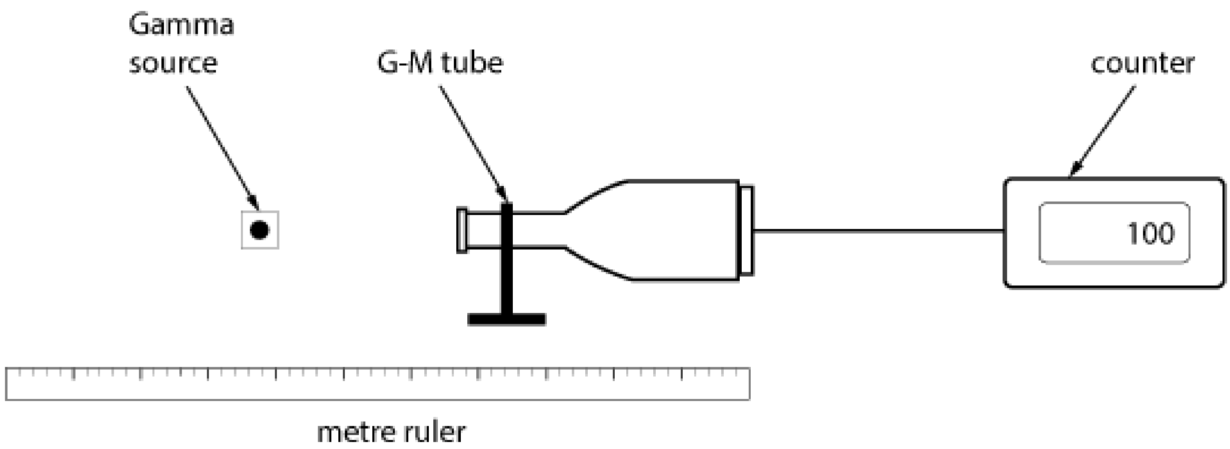
PH6 2011 Data analysis task

USEFUL INTERACTIVE RESOURCES

WJEC > A Level Physics > Terms, definitions and units booklet

DIAGRAM:

Investigation of the Variation of Intensity of Gamma Radiation with Distance



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WJEC > A Level Physics > Terms, definitions and units booklet

WJEC > A Level Physics > Related practical past questions

UNIT: 3 . 6 NUCLEAR ENERGY | EXAM LEVEL: A2

	SPECIFICATION STATEMENT	COMMENT
(a)	The association between mass and energy and that $E = mc^2$	
(b)	The binding energy for a nucleus and hence the binding energy per nucleon, making use, where necessary, of the unified atomic mass unit (u)	See terms, definitions and units booklet.
(c)	How to calculate binding energy and binding energy per nucleon from given masses of nuclei	
(d)	The conservation of mass/energy to particle interactions – for example: fission, fusion	See terms, definitions and units booklet
(e)	The relevance of binding energy per nucleon to nuclear fission and fusion making reference when appropriate to the binding energy per nucleon versus nucleon number curve	

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

A2 UNIT 4: FIELDS AND OPTIONS	
AREA OF STUDY	**DESCRIPTION**
4.1 Capacitance	Provides amplification of statements in the specification, with the links to related resources. Here you will also find links to the related specified practical work documents "Investigation of the charging and discharging of a capactior to determine the time constant" and "Investigation of the energy stored in a capactior".
4.2 Electrostatic and Gravitational Fields of Force	Provides amplification of statements in the specification, with links to related resources, including a table of fields.
4.3 Orbits and the Wider Universe	Provides amplification of statements in the specification, with links to related resources.
4.4 Magnetic Fields	Provides amplification of statements in the specification, with links to related resources. Here you will also find links to the related specified practical work documents "Investigation of the force on a current in a magnetic field" and "Investigation of magnetic flux density using a Hall probe".
4.5 Electromagnetic Induction	Provides amplification of statements in the specification, with links to related resources.
OPTION A - Alternating Currents	
OPTION B - Medical Physics	
OPTION C - The Physics of Sport	
Option D- Energy and the Environment	

	SPECIFICATION STATEMENT	COMMENT
(a)	The idea that a simple parallel plate capacitor consists of a pair of equal parallel metal plates separated by a vacuum or air	See terms, definitions and units booklet.
(b)	A capacitor storing energy by transferring charge from one plate to the other, so that the plates carry equal but opposite charges (the net charge being zero)	
(c)	The definition of capacitance as $C = \frac{Q}{V}$	See terms, definitions and units booklet.
(d)	The use of $C = \frac{\varepsilon_o A}{d}$ for a parallel plate capacitor, with no dielectric	
(e)	The idea that a dielectric increases the capacitance of a vacuum-spaced capacitor	The relative permittivity is not required nor is the theory of polarisation of the dielectric via dipoles. See terms, definitions and units booklet.
(f)	The E field within a parallel plate capacitor being uniform and the use of the equation $E = \frac{V}{d}$	

Select the image (left) for "Investigation of the charging and discharging of a capacitor to determine the time constant " practical work.

Select the image (left) for "Investigation of the energy stored in a capacitor " practical work.

Continued on next page

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 4 . 1 CAPACITANCE | EXAM LEVEL: A2

	SPECIFICATION STATEMENT	COMMENT
(g)	The equation $U = \frac{1}{2}QV$ for the energy stored in a capacitor	Familiarity with equivalent versions $\frac{1}{2}CV^2$, $\frac{1}{2}\frac{Q^2}{C}$ useful.
(h)	The equations for capacitors in series and in parallel	Candidates should be able to analyse circuits with more than two capacitors present
(i)	The process by which a capacitor charges and discharges through a resistor	
(j)	The equations: $Q = Q_0\left(1 - e^{-\frac{t}{RC}}\right)$ and $Q = Q_0 e^{-\frac{t}{RC}}$ where RC is the time constant	Note that charging (as well as discharging) is included. Candidates do not need to know the half-life derivation for a capacitor, however they should be able to perform calculations to determine the time taken for the capacitor to gain/lose half its charge.

Select the image (left) for "Investigation of the charging and discharging of a capacitor to determine the time constant " practical work.

Select the image (left) for "Investigation of the energy stored in a capacitor " practical work.

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 4 . 1 CAPACITANCE EXAMTIC LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Charging and Discharging of a Capacitor to Determine the Time Constant

THEORY:

The *discharge* of a capacitor is given by the equation: $Q = Q_o e^{-\frac{t}{RC}}$ which can be written in terms of the voltage across the capacitor as: $V = V_o e^{-\frac{t}{RC}}$.

By using logs, the above equation can be written as: $\ln V = -\frac{t}{RC} + \ln V_0$ which can be compared with $y = mx + c$.

The *charging of a capacitor* is given by: $V = V_0 \left(1 - e^{-\frac{t}{RC}}\right)$.

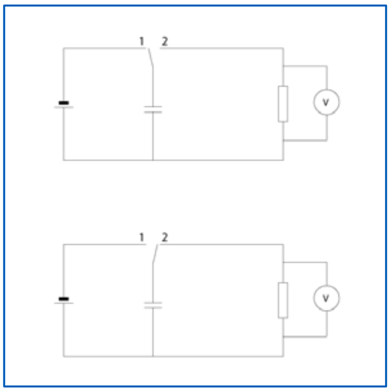
APPARATUS:

D.C. power supply
Voltmeter (multimeter set on d.c. voltage range or CRO) – resolution ± 0.01 V
Stopwatch – resolution: either ± 1 s or ± 0.01 s
4 mm leads
Suitable switches
Electrolytic capacitors e.g. 1 000 μF or 2 200 μF
Resistors e.g. 100 kΩ or other values

FURTHER GUIDANCE FOR TECHNICIANS:

The polarity of the electrolytic capacitors should be indicated to learners so that the circuits can be set up correctly.

Experimental Method:



The circuit shown above left in the diagram (**select the image, left** for a larger diagram) can be used to investigate the *charging* of a capacitor.

The circuit can then be re-arranged to investigate *the discharging* of a capacitor as shown below left in the diagram.

Charging the capacitor:

Learners can set up the circuit from the above diagram and by using electrolytic capacitors the correct polarity connection needs to be checked by supervisors. The two way switch needs to be in position 1 so that the capacitor can be charged and then switched over to position 2 to discharge. Pre-trial readings can be taken to determine suitable time intervals.

Discharging the capacitor:

The method is similar to charging the capacitor. Initially the switch is to be left open and then connected so that the capacitor charges.

UNIT: 4 . 1 CAPACITANCE | EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Charging and Discharging of a Capacitor to Determine the Time Constant

EXTENSION:

The value of the capacitor could be hidden and the experimental set-up used to determine its value.

The equation ($t_{\frac{1}{2}} = 0.69RC$) i.e. the time taken for the voltage to fall to half its initial value could be investigated using the data obtained.

Data Logging: The voltage across the capacitor can be measured using a suitable voltage sensor.

PRACTICAL TECHNIQUES:

- Use signal generator and oscilloscope, including volts/division and time-base.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

RELEVANT PREVIOUS PRACTICAL PAST PAPERS:

PH6 2011 Experimental task

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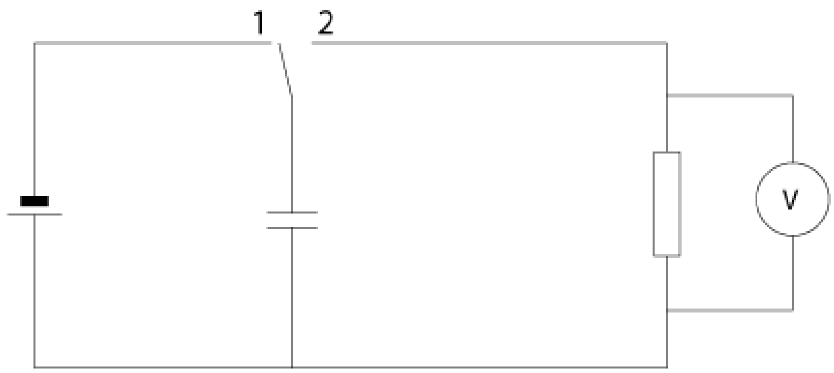
UNIT: 4 . 1 CAPACITANCE EXAM LEVEL: A2

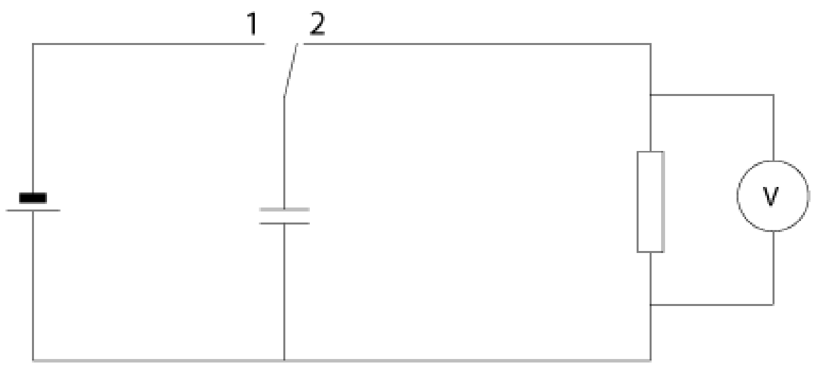
DIAGRAM:

Investigation of the Charging and Discharging of a Capacitor to Determine the Time Constant

Charging the capacitor



Discharging the capacitor



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WJEC > A Level Physics > Related practical past questions

UNIT: 4 . 1 CAPACITANCE | EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Energy Stored in a Capacitor

THEORY:

The energy stored by a capacitor is given by the equation: $U = \frac{1}{2}QV$. Given that $Q = CV$ then the equation for the energy stored can be written in the form: $U = \frac{1}{2}CV^2$. The capacitor can be charged to various values of V and then the energy stored can be determined by using a Joule meter. The energy stored can be measured as the capacitor discharges. A graph of energy stored against V^2 should be linear and the value of the capacitance can then be measured.

APPARATUS:

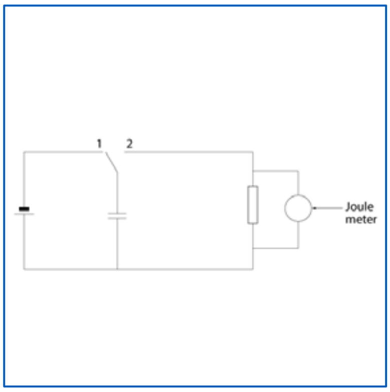
D.C. power supply
Digital joule metre
4 mm leads
Suitable switches

Electrolytic capacitors, e.g. a 1 000 μF or 2 200 μF
Voltmeter (multimeter set on d.c. voltage range or CRO) – resolution ± 0.01 V
Resistors, e.g. 100 kΩ or other values

FURTHER GUIDANCE FOR TECHNICIANS:

The polarity of the electrolytic capacitors should be indicated to learners so that the circuits can be set up correctly.

Experimental Method:



The circuit shown can be used. **Select the image (*left*)** for a larger diagram.

Learners can set up the circuit from the above diagram and by using electrolytic capacitors the correct polarity connection needs to be checked by supervisors. The two switch needs to be in position 1 so that the capacitor can be charged and then switched over to position 2 to discharge.

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UNIT: 4 . 1 CAPACITANCE EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Energy Stored in a Capacitor

EXTENSION:

The value of the capacitor could be hidden and the experimental set-up used to determine its value.

The equation ($t_{\frac{1}{2}} = 0.69RC$), i.e. the time taken for the voltage to fall to half its initial value could be investigated using the data obtained.

Data Logging: The voltage across the capacitor can be measured using a suitable voltage sensor.

PRACTICAL TECHNIQUES:

- Use signal generator and oscilloscope, including volts/division and time-base.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

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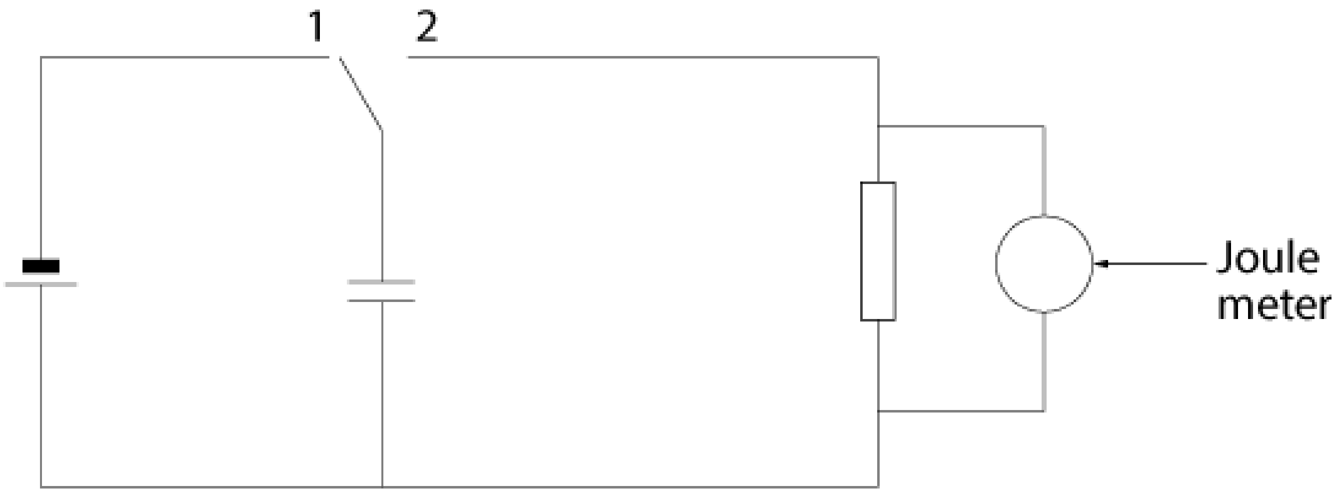
UNIT: 4 . 1 CAPACITANCE EXAM LEVEL: A2

DIAGRAM:

Investigation of the Energy Stored in a Capacitor



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	SPECIFICATION STATEMENT	COMMENT
(a)	The features of electric and gravitational fields as specified in the **table**	Candidates need to be familiar with the units for g, E, V_E and V_g. See the **table**. Candidates need to be able to perform calculations to determine the escape velocity of planets, see the **table**. See the terms, definitions and units booklet.
(b)	The idea that the gravitational field outside spherical bodies such as the Earth is essentially the same as if the whole mass were concentrated at the centre	
(c)	Field lines (or lines of force) giving the direction of the field at a point, thus, for a positive point charge, the field lines are radially outward	Candidates only need to be familiar with the field lines for single point charges.
(d)	Equipotential surfaces joining points of equal potential and are therefore spherical for a point charge	Only for a single point charge is required.
(e)	How to calculate the net potential and resultant field strength for a number of point charges or point masses	Candidates should be able to calculate the neutral point between 2 charges or masses.
(f)	The equation $\Delta U_P = mg\Delta h$ for distances over which the variation of g is negligible	

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ELECTRIC FIELDS	GRAVITATIONAL FIELDS
Electric field strength, E, is the force per unit charge on a small positive test charge placed at the point	Gravitational field strength, g, is the force per unit mass on a small test mass placed at the point
Inverse square law for the force between two electric charges in the form $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$ (Coulomb's law)	Inverse square law for the force between two masses in the form $F = G\frac{M_1 M_2}{r^2}$ (Newton's law of gravitation)
F can be attractive or repulsive	F is attractive only
$E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2}$ for the field strength due to a point charge in free space or air **Unit: N C^{-1} or V m^{-1}**	$g = \frac{GM}{r^2}$ for the field strength due to a point mass **Unit: N kg^{-1} or m s^{-2}**
Potential at a point due to a point charge in terms of the work done in bringing a unit positive charge from infinity to that point **This definition can be used to calculate escape velocities.**	Potential at a point due to a point mass in terms of the work done in bringing a unit mass from infinity to that point **This definition can be used to calculate escape velocities.**
$V_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ **Unit: J C^{-1}** and $PE = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r}$ **Unit: J**	$V_g = -\frac{GM}{r}$ **Unit: J kg^{-1}** and $PE = -\frac{GM_1 M_2}{r}$ **Unit: J**
Change in potential energy of a point charge moving in any electric field $= q\Delta V_E$ **Unit: J**	Change in potential energy of a point mass moving in any gravitational field $= m\Delta V_g$ **Unit: J**
Field strength at a point is given by E = - slope of the $V_E - r$ graph at that point	Field strength at a point is given by g = - slope of the $V_g - r$ graph at that point
Note that $\frac{1}{4\pi\varepsilon_0} \approx 9 \times 10^9 \text{ F}^{-1}\text{m}$ is an acceptable approximation	

	SPECIFICATION STATEMENT	COMMENT
(a)	Kepler's three laws of planetary motion	See terms, definitions and units booklet.
(b)	Newton's law of gravitation $F = G\frac{M_1 M_2}{r^2}$ in simple examples, including the motion of planets and satellites	
(c)	How to derive Kepler's 3rd law, for the case of a circular orbit from Newton's law of gravity and the formula for centripetal acceleration	
(d)	How to use data on orbital motion, such as period or orbital speed, to calculate the mass of the central object	
(e)	How the orbital speeds of objects in spiral galaxies implies the existence of dark matter	See terms, definitions and units booklet.
(f)	How the recently discovered Higgs boson may be related to dark matter	The Higgs boson is thought to be linked with the mass of particles including dark matter. Further experiments at the Large Hadron Collider may reveal links between the Higgs boson and dark matter and thus the nature of dark matter itself. A useful link is: http://blogs.cardiff.ac.uk/physicsoutreach/resources/heavens-kitchen/
(g)	How to determine the position of the centre of mass of two spherically symmetric objects, given their masses and separation, and calculate their mutual orbital period in the case of circular orbits	
(h)	The Doppler relationship in the form $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$	

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UNIT: 4 . 3 ORBITS AND THE WIDER UNIVERSE		EXAM LEVEL: A2
	SPECIFICATION STATEMENT	**COMMENT**
(i)	How to determine a star's radial velocity (i.e. the component of its velocity along the line joining it and an observer on the Earth) from data about the Doppler shift of spectral lines	See terms, definitions and units booklet.
(j)	The use of data on the variation of the radial velocities of the bodies in a double system (for example, a star and orbiting exo-planet) and their orbital period to determine the masses of the bodies for the case of a circular orbit edge-on as viewed from the Earth	
(k)	How the Hubble constant (H_0) relates galactic radial velocity (v) to distance (D) and it is defined by $v = H_0 D$	Although H_0 usually takes the value 68 km s^{-1} Mpc^{-1} the parsec is not included in this syllabus hence Hubble's constant will usually be provided in the SI unit (2.2 × 10^{-18} s^{-1}). See terms, definitions and units booklet.
(l)	Why $\frac{1}{H_0}$ approximates the age of the universe	This is simply that the radial velocity has been approximately constant since the beginning of the universe so that $D = vT$. Hence, $v = H_0 \times vT$ and $= \frac{1}{H_0}$.
(m)	How the equation $\rho_c = \frac{3H_0^{\ 2}}{8\pi G}$ for the critical density of a 'flat' universe can be derived very simply using conservation of energy	For a flat universe, the radial velocity of galaxies becomes zero when the time is infinite i.e. the radial velocity of galaxies is equal to the escape velocity. $\frac{1}{2}mv^2 = \frac{GMm}{r}$ but the mass of the universe inside the sphere upon whose outer surface lies the galaxy is $M = \frac{4}{3}\pi r^3 \times \rho_C$. The velocity of the galaxy is given by Hubble's law ($H_0 D$ or $H_0 r$ in this case) giving. $\frac{1}{2}m(H_0 r)^2 = \frac{G\frac{4}{3}\pi r^3 \times \rho_C \times m}{r}$ which after a bit of algebra, gives the desired result.

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UNIT: 4 . 4 MAGNETIC FIELDS EXAM LEVEL: A2

	SPECIFICATION STATEMENT	COMMENT
(a)	How to determine the direction of the force on a current carrying conductor in a magnetic field	Use of this equation to define the Tesla.
(b)	How to calculate the magnetic field, B, by considering the force on a current-carrying conductor in a magnetic field, i.e. understand how to use $F = BIl\sin\theta$	See terms, definitions and units booklet.
(c)	How to use $F = Bqv\sin\theta$ for a moving charge in a magnetic field	
(d)	The processes involved in the production of a Hall voltage and understand that $V_H \propto B$ for constant I	See terms, definitions and units booklet.
(e)	The shapes of the magnetic fields due to a current in a long straight wire and a long solenoid	Also the magnetic field between two long straight wires.
(f)	The equations $B = \dfrac{\mu_o I}{2\pi a}$ and $B = \mu_o nI$ for the field strengths due to a long straight wire and in a long solenoid	The derivation of both of these equations is not required.

Select the image (left) for "Investigation of the force on a current in a magnetic field" practical work.

Select the image (left) for "Investigation of magnetic flux density using a Hall probe" practical work.

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	SPECIFICATION STATEMENT	COMMENT
(g)	The fact that adding an iron core increases the field strength in a solenoid	No theory or explanation required.
(h)	The idea that current-carrying conductors exert a force on each other and to predict the directions of the forces	
(i)	Quantitatively, how ion beams of charged particles, are deflected in uniform electric and magnetic fields	
(j)	The motion of charged particles in magnetic and electric fields in linear accelerators, cyclotrons and synchrotrons	The working of linear accelerators, cyclotrons and synchrotrons is not required. Any relevant diagrams and required text will be provided in assessments.

Select the image (left) for "Investigation of the force on a current in a magnetic field" practical work.

Select the image (left) for "Investigation of magnetic flux density using a Hall probe" practical work.

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WJEC > A Level Physics > Specification from 2015

WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: 4 . 4 MAGNETIC FIELDS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of the Force on a Current in a Magnetic Field

THEORY:

The force on a current carrying wire in a magnetic field is described by the relationship: $F = BIl\sin\theta$. In this practical arrangement, the value of $\theta = 90^0$, so the equation can be simplified to $F = BIl$. The value of F is determined by the weight of the magnet placed on a balance. In effect $F = \Delta mg$ where Δm is the apparent change in mass as F varies due to the magnitude of the current. The current can be varied and a graph of F against I can be plotted which should be linear. The length of the wire can be measured and the magnetic flux density of the magnet can be determined from the gradient of the graph and the value of length of wire within the pole pieces of the magnet.

APPARATUS:

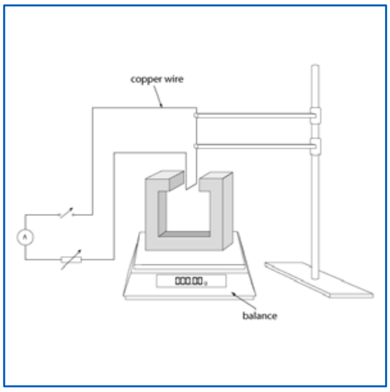
Ammeter	Electronic scales with resolution ± 0.001g
Stand and clamp	U-shaped soft iron section with ceramic pole pieces
Variable D.C. power supply	Ammeter or mutlimeter set to A range ± 0.01 A
Metre rule	20 SWG copper wire

Rheostat – value can be chosen so that the current can be varied in the range 0 to 3.00 A or 5.00 A

FURTHER GUIDANCE FOR TECHNICIANS:

Electronic scales of resolution ± 0.01 g can also be used.

Experimental Method:



The apparatus should be set up as shown. **Select the image (*left*)** for a larger diagram.

Set up the apparatus as shown in the diagram. Measure the length, l of the wire which is between the poles of the magnet. Use the rheostat to increase the current in steps from zero. For each chosen current value, record Δm, the apparent change in mass of the magnet (this can be an increase or decrease, depending upon the orientation of the current and the magnetic field). The force, F on the wire is calculated from $F = \Delta mg$ for each value of current I. A graph of F (y-axis) against I (x-axis) should be a straight line through the origin. The magnetic flux density, B of the magnet can be determined from: $B = \frac{\text{gradient}}{\text{length of wire}}$

PRACTICAL TECHNIQUES

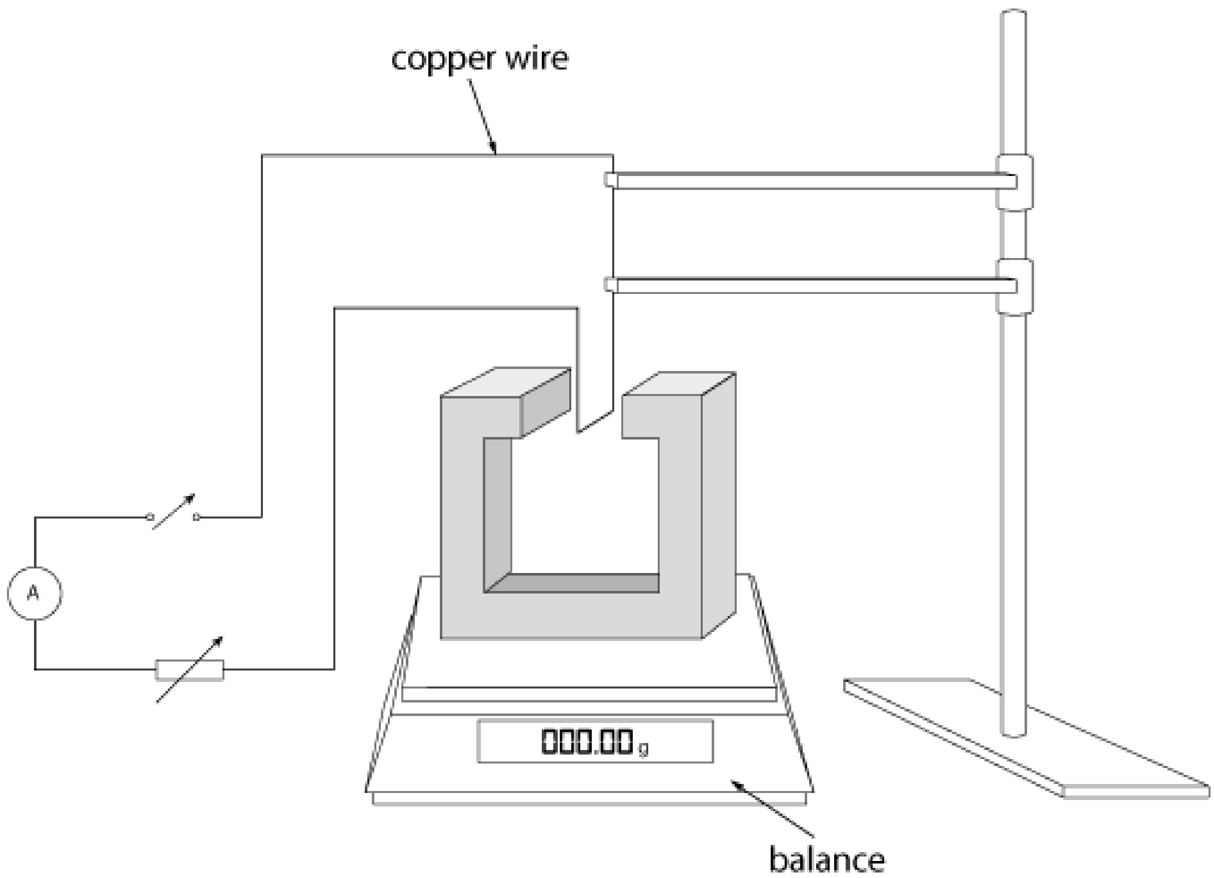
- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.

- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data.

UNIT: 4 . 4 MAGNETIC FIELDS EXAM LEVEL: A2

DIAGRAM:

Investigation of the Force on a Current in a Magnetic Field



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UNIT: 4 . 4 MAGNETIC FIELDS EXAM LEVEL: A2

NAME OF EXPERIMENT:

Investigation of Magnetic Flux Density Using a Hall Probe

THEORY:

A Hall probe is a slice of doped semiconductor with a connecting wire at each end to provide a steady current. Another two wires are connected across the edges of the slice to allow the Hall potential difference, V_H to be measured. Note that the slice must be placed so that it is at right angles to the magnetic field lines. When a constant current flows, the Hall pd is proportional to the magnetic field strength, and so can be calibrated using a known magnetic field.

APPARATUS:

Hall probe	Ammeter
Solenoid	D.C. power supply
Voltmeter	Magnet of known magnetic field strength

Experimental Method:

Place the Hall probe into a known magnetic field, B_1 and note the Hall potential difference, V_1. Then place the Hall probe in the centre of a solenoid. Ensure, in both cases, that the probe is at 90° to the magnetic field. Again measure the Hall potential difference, V_2 when the probe is in the solenoid. The unknown magnetic field of the solenoid, B_2, can be found using:

$$B_2 = \frac{B_1}{V_1} V_2$$

EXTENSION:

A graph of field strength against distance along the solenoid could be drawn to show the difference in magnetic field at the ends. It is also possible to investigate the variation of magnetic field strength with the solenoid diameter.

PRACTICAL TECHNIQUES:

- Correctly construct circuits from circuit diagrams using D.C. power supplies, cells, and a range of circuit components, including those where polarity is important.
- Use signal generator and oscilloscope, including volts/division and time-base.
- Use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data

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	SPECIFICATION STATEMENT	COMMENT
(a)	The definition of magnetic flux as $\phi = AB\cos\theta$ and flux linkage = $N\phi$	See terms, definitions and units booklet.
(b)	The laws of Faraday and Lenz	See terms, definitions and units booklet.
(c)	How to apply the laws of Faraday and Lenz (i.e. emf = - rate of change of flux linkage)	
(d)	The idea that an emf is induced in a linear conductor moving at right angles to a uniform magnetic field	
(e)	Qualitatively, how the instantaneous emf induced in a coil rotating at right angles to a magnetic field is related to the position of the coil, flux density, coil area and angular velocity	

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WJEC > A Level Physics > Terms, definitions and units booklet

UNIT: OPTION A – ALTERNATING CURRENTS	EXAM LEVEL: A2

	SPECIFICATION STATEMENT	COMMENT
(a)	Using Faraday's law, the principle of electromagnetic induction applied to a rotating coil in a magnetic field	
(b)	The idea that the flux linkage of a rotating flat coil in a uniform magnetic B-field is $BAN \cos \omega t$ because the angle between the coil normal and the field can be expressed as $\theta = \omega t$	
(c)	the equation $V = \omega BAN \sin \omega t$ for the induced emf in a rotating flat coil in a uniform B-field	This equation will be provided on the data sheet. The derivation using calculus will not be required.
(d)	The terms frequency, period, peak value and rms value when applied to alternating potential differences and currents	See terms, definitions and units booklet.
(e)	The idea that the rms value is related to the energy dissipated per cycle, and use the relationships $I = \frac{I_0}{\sqrt{2}}$ and $V = \frac{V_0}{\sqrt{2}}$, (including $V_{rms} = \frac{\omega BAN}{\sqrt{2}}$)	
(f)	The idea that the mean power dissipated in a resistor is given by $P = IV = I^2R = \frac{V^2}{R}$ where V and I are the rms values	
(g)	The use of an oscilloscope (CRO or PC based via USB or sound card) to measure • A.C. and D.C. voltages and currents • frequencies	

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	SPECIFICATION STATEMENT	COMMENT
(h)	The 90° phase lag of current behind potential difference for an inductor in a sinusoidal A.C. circuit	
(i)	The idea that $X_L = \frac{V_{\text{rms}}}{I_{\text{rms}}}$ is called the reactance, X_L, of the inductor, and to use the equation $X_L = \omega L$	See terms, definitions and units booklet.
(j)	The 90° phase lead of current ahead of potential difference for a capacitor in a sinusoidal A.C. circuit, and to use the equation $X_C = \frac{V_{\text{rms}}}{I_{\text{rms}}}$, where $X_C = \frac{1}{\omega C}$	See terms, definitions and units booklet.
(k)	The idea that the mean power dissipation in an inductor or a capacitor is zero	The derivation is not required.
(l)	How to add potential differences across series RC, RL and RCL combinations using phasors	Will be expected to derive the impedances of various R, L and C combinations. See terms, definitions and units booklet.
(m)	How to calculate phase angle and impedance, Z, (defined as $Z = \frac{V_{\text{rms}}}{I_{\text{rms}}}$ for such circuits)	See terms, definitions and units booklet.
(n)	How to derive an expression for the resonance frequency of an RCL series circuit	See terms, definitions and units booklet.
(o)	The idea that the Q factor of a RCL circuit is the ratio $\frac{V_L}{V_R}\left(=\frac{V_C}{V_R}\right)$ at resonance	See terms, definitions and units booklet.
(p)	The idea that the sharpness of the resonance curve is determined by the Q factor of the circuit	

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	SPECIFICATION STATEMENT	COMMENT
(a)	The nature and properties of X-rays	
(b)	The production of X-ray spectra including methods of controlling the beam intensity and photon energy	Know the X-ray emission spectrum including the minimum wavelength, and the production of line and background spectrum. See terms, definitions and units booklet.
(c)	The use of high energy X-rays in the treatment of patients (therapy) and low energy X-rays in diagnosis	
(d)	The equation $I = I_0 \exp(-\mu x)$ for the attenuation of X-rays	Use this equation to derive an expression for the half value thickness i.e. $x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$ See terms, definitions and units booklet.
(e)	The use of X-rays in imaging soft tissue, and fluoroscopy to produce real time X-rays using image intensifiers	See terms, definitions and units booklet.
(f)	Techniques of radiography including using digital image receptors	X-rays recorded in a digital format rather than using film.
(g)	The use of a rotating beam X-ray computed tomography (CT) scanner	Advantages and disadvantages of using CT scans. See terms, definitions and units booklet.
(h)	The generation and detection of ultrasound using piezoelectric transducers	See terms, definitions and units booklet.
(i)	Scanning with ultrasound for diagnosis including A-scans and B-scans incorporating examples and applications	A-scans to determine depth by detecting echoes and B-scans to build up a 2D image. See terms, definitions and units booklet.
(j)	The significance of acoustic impedance, defined by $Z = c\rho$ for the reflection and transmission of sound waves at tissue boundaries, including the need for a coupling medium	Use of acoustic impedance values to determine the reflection coefficient, R. The equation $R = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ will be provided if needed. See terms, definitions and units booklet.

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	SPECIFICATION STATEMENT	COMMENT
(k)	The use of the Doppler equation $\frac{\Delta f}{f_0} = \frac{2v}{c}\cos\theta$ to study blood flow using an ultrasound probe	See terms, definitions and units booklet.
(l)	The principles of magnetic resonance with reference to precession nuclei, resonance and relaxation time, and to apply the equation $f = 42.6 \times 10^6 B$ for the Lamor frequency	This gives the Lamor frequency for protons (hydrogen) and it varies linearly with the magnetic field. See terms, definitions and units booklet.
(m)	The use of MRI in obtaining diagnostic information about internal structures	Explain precession nuclei resonance and relaxation time.
(n)	The advantages and disadvantages of ultrasound imaging, X-ray imaging and MRI in examining internal structures	
(o)	The effects of α, β, and γ radiation on living matter	
(p)	The Gray (Gy) as the unit of absorbed dose and the Sievert (Sv) as the unit of equivalent dose and effective dose. Define absorbed dose as energy per kilogram	
(q)	The use of the equations • equivalent dose = absorbed dose × (radiation) weighting factor $H = DW_R$ and • effective dose = equivalent dose × tissue weighting factor $E = HW_T$	Tissue weighting factors W_T will be given where needed but candidates are expected to know the radiation weighting factors for alpha, beta, gamme and X-rays. See terms, definitions and units booklet.
(r)	The uses of radionuclides as tracers to image body parts with particular reference to technetium-99m (Tc-99m)	
(s)	The use of the gamma camera including the principles of the collimator, scintillation counter and photomultiplier/CCD	See terms, definitions and units booklet.
(t)	Positron emission tomography (PET) scanning and its use in detecting tumours	See terms, definitions and units booklet.

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	SPECIFICATION STATEMENT	COMMENT
(a)	How to use the centre of gravity to explain how stability and toppling is achieved in various sporting contexts	
(b)	How to use the principle of moments to determine forces within • various muscle systems in the human body and • other sporting contexts, for example, sailing	Candidates will not be assessed on their knowledge and names of the various muscle systems. Similarly any technical aspects of any sporting contexts will not be assessed.
(c)	How to use Newton's 2nd law in the form $Ft = mv - mu$ in various sporting contexts	Candidates are not expected to know that Ft is referred to as the *Impulse*.
(d)	The coefficient of restitution as $e = \frac{\text{Relative speed after collision}}{\text{Relative speed before collision}}$ and also use it in the form $e = \sqrt{\frac{h}{H}}$ where h is the bounce height and H is the drop height	See terms, definitions and units booklet.
(e)	What is meant by the moment of inertia of a body	Candidates will be expected to know the definition of a moment of inertia and how it can be increased or decreased in a sporting context. See terms, definitions and units booklet.
(f)	How to use equations to determine the moment of inertia, I, for example • a solid sphere $I = \frac{2}{5}mr^2$ • a thin spherical shell $I = \frac{2}{3}mr^2$ where m is the mass and r is the radius	The equation to determine the moment of inertia will be given to candidates within the context of the question.
(g)	The idea that angular acceleration, α, is defined as the rate of change of angular velocity, ω, and how to use the equation $\alpha = \frac{\omega_2 - \omega_1}{t}$	See terms, definitions and units booklet.

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	SPECIFICATION STATEMENT	COMMENT
(h)	The idea that torque, τ, is given as $\tau = I\alpha$	See terms, definitions and units booklet.
(i)	Angular momentum, L, is given as $L = I\omega$ where ω is the angular velocity	See terms, definitions and units booklet.
(j)	The principle of conservation of angular momentum and use it to solve problems in sporting contexts	See terms, definitions and units booklet.
(k)	How to use the equation for the rotational kinetic energy, rotational $KE = \frac{1}{2}I\omega^2$	
(l)	How to use the principle of conservation of energy including the use of linear and rotational kinetic energy as well as gravitational and elastic potential energy in various sporting contexts	Candidates will be expected to use the equations for linear kinetic energy as well as gravitational and elastic potential energy taught in the main part of the specification.
(m)	How to use projectile motion theory in sporting contexts	
(n)	How to use Bernoulli's equation $p = p_0 - \frac{1}{2}\rho v^2$ in sporting contexts	See terms, definitions and units booklet.
(o)	How to determine the magnitude of the drag force using $F_D = \frac{1}{2}\rho v^2 A C_D$ where C_D is the drag coefficient	This statement and also Bernoulli's equation from statement (n) leads to an explanation of the Magnus force or effect. See terms, definitions and units booklet.

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	SPECIFICATION STATEMENT	COMMENT
(a)	Understand how the following affect the rate at which the temperature of the Earth rises including:	
(ai)	The need for thermal equilibrium: that is the balance between energy inflow from the Sun and energy re-radiated from the Earth in the context of global energy demand and the effect of CO_2 levels in the atmosphere	Appreciate that increasing CO_2 levels lead to increasing global temperatures which implies an imbalance between energy inflow and that re-radiated from the Earth – termed the greenhouse effect. Appreciate and compare relative energy quantities in broad percentage terms. Analyse, compare and draw conclusions from data in the form of charts and graphs. See terms, definitions and units booklet.
(aii)	The origin and means of transmission of solar energy and the form of the Sun's power spectrum including the idea that wavelengths are converted into the near infrared in the atmosphere	Compare with absorption and emission from other planets.
(aiii)	The use of Wien's law ($\lambda_{max} T$ = constant) and Stefan-Boltzman T^4 law in the context of solar power	
(aiv)	Use of the density equation and Archimedes' principle to explain why rising sea levels are due to melting ice caps and that the melting of ice on land increases sea levels but melting icebergs do not	See terms, definitions and units booklet.

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	SPECIFICATION STATEMENT	COMMENT
(b)	The common sources of renewable and non-renewable energy and be able to compare their development and use both in the UK and internationally	Analyse, compare and draw conclusions from data in the form of charts and graphs.
(bi)	Solar power: • the idea that the main branch of the proton-proton chain is the main energy production mechanism in the Sun • the intensity of power from the Sun $I = \frac{P}{A}$ and the inverse square law for a point source How to perform energy conversions using photovoltaic cells (including efficiency calculations)	Knowledge of the main branch of the proton-proton chain required. See terms, definitions and units booklet.
(bii)	Wind power: • the power available from a flowing fluid $= \frac{1}{2} A\rho v^3$ • the factors affecting the efficiency of wind turbines	• 'Flowing fluids' limited to applications involving wind and underwater turbines. • Derivation of $P = = \frac{1}{2} A\rho v^3$ required.
(biii)	Tidal barrages, hydroelectric power and pumped storage: • the principles of energy conversion (E_p to E_k) in tidal barrage, hydroelectric and pumped storage schemes and be able to carry out energy and power calculations related to these schemes and compare with the energy produced from wind	
(biv)	Nuclear fission and fusion: • the principles underlying breeding and enrichment in nuclear fission applications • the difficulties in producing sustained fusion power - fusion triple product	See terms, definitions and units booklet.

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	SPECIFICATION STATEMENT	COMMENT
(c)	The principles of fuel cell operation and the benefits of fuel cells particularly regarding greenhouse gas emissions	See terms, definitions and units booklet.
(d)	The thermal conduction equation in the form $\frac{\Delta Q}{\Delta t} = -AK\frac{\Delta \theta}{\Delta x}$	Candidates will not be expected to have knowledge of K values. See terms, definitions and units booklet.
(e)	The effect of insulation on thermal energy loss and be able to calculate the heat loss for parallel surfaces using the rate of energy transfer = $UA\Delta\theta$ including cases where different materials are in contact	Candidates will not be expected to have knowledge of U values. See terms, definitions and units booklet.

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