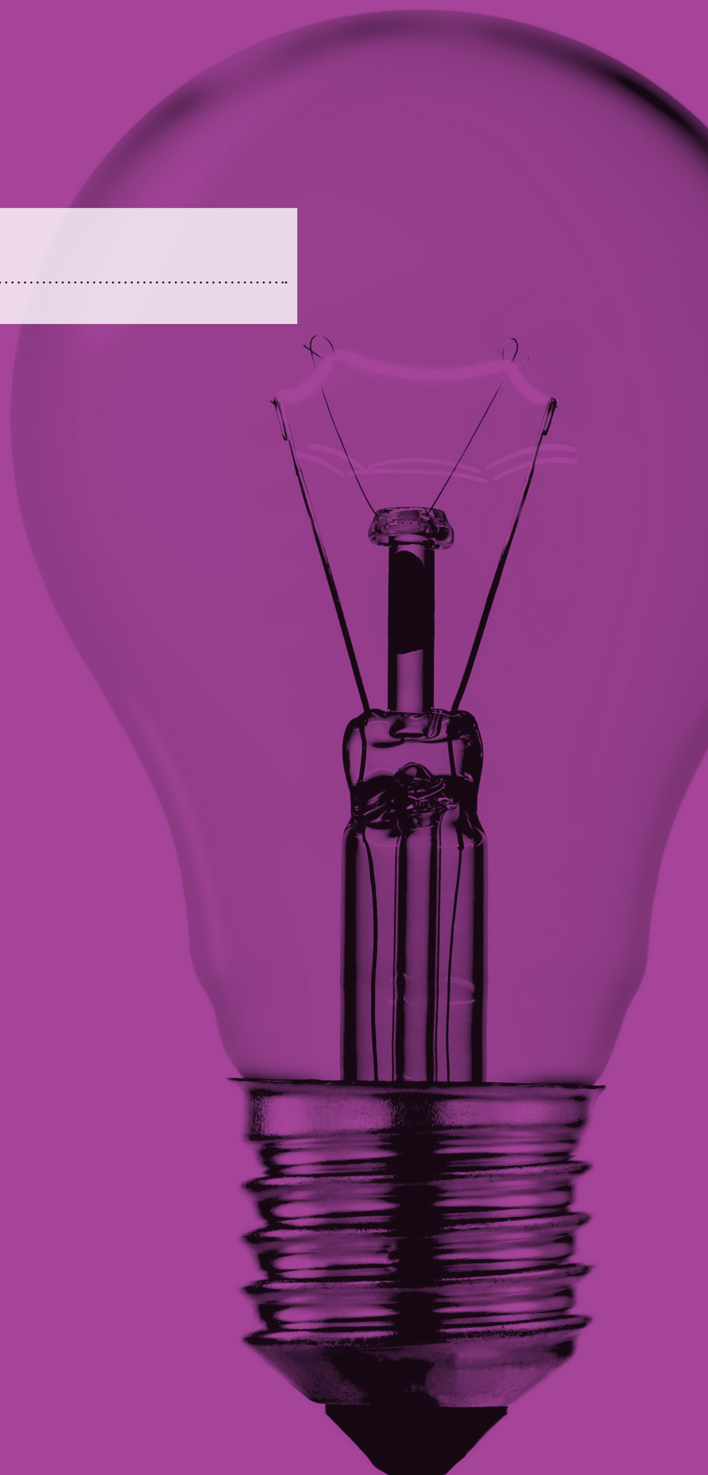
WJEC AS/A LEVEL

PHYSICS

LAB BOOK

Name: ....



Topic	Specified practical work	Date completed	Teacher / Student comments
Basic physics	Measurement of the density of solids		
	Determination of unknown masses by using the principle of moments		
Kinematics	Measurement of g by freefall		
Dynamics	Investigation of Newton's 2nd Law		
Solids under stress	Determination of Young modulus of a metal in the form of a wire		
	Investigation of the force-extension relationship for rubber		
Resistance	Investigation of the I-V characteristics of the filament of a lamp and a metal wire at constant temperature		
	Determination of resistivity of a metal		
	Investigation of the variation of resistance with temperature for a metal wire		
D.C. circuits	Determination of the internal resistance of a cell		
The nature of waves	Measurement of the intensity variations for polarisation		
Wave properties	Determination of wavelength using Young's double slits		
	Determination of wavelength using a diffraction grating		

	Determination of the speed of sound using stationary waves		
Refraction of light	Measurement of the refractive index of a material		
Photons	Determination of h using LEDs		
Vibrations	Measurement of g with a pendulum		
	Investigation of the damping of a spring		
Thermal physics	Estimation of absolute zero by use of the gas laws		
	Measurement of the specific heat capacity for a solid		
Nuclear decay	Investigation of radioactive decay – a dice analogy		
	Investigation of the variation of intensity of gamma radiation with distance		
Capacitance	Investigation of the charging and discharging of a capacitor to determine the time constant		
	Investigation of the energy stored in a capacitor		
Magnetic fields	Investigation of the force on a current in a magnetic field		
	Investigation of magnetic flux density using a Hall probe		

Guidance Notes

In general, you should be able to:

- apply investigative approaches and methods to practical work and think independently when undertaking practical work**;**

- use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification.

Methods of data collection and analysis

You should be able to:

- describe with the aid of a clearly labelled diagram, the arrangement of apparatus for the experiment and the procedures to be followed;

- describe how the data should be used in order to reach a conclusion, including details of derived quantities and graphs to be drawn where appropriate;

- select appropriate apparatus and record the instrument resolution used i.e. the smallest measurable division on the instrument;

- set up apparatus correctly without assistance and follow instructions given in the form of written instructions, diagrams or circuit diagrams;

- undertake and record trial readings to determine the suitability of ranges and intervals;

- take repeat readings where appropriate;

- make and record accurate measurements;

- evaluate experimental methods and suggest improvements.

Safety considerations

You should be able to:

- assess the risks of your experiment;

Hazard	Risk	Control measure

Hazard - an object or chemical and the nature of the hazard

Risk - an ‘action’ in the method that can create a risk from a hazard

Control measure - must be practicable in the context of the practical

- describe precautions that should be taken to keep risks to a minimum.

Table of results

You should be able to:

- present numerical data and values in a single clear table of results;
- produce column headings which have both a quantity and unit e.g. I/mA;
- include columns for all the initial data and values calculated from them;
- record initial data to the same number of decimal places as the instrument resolution e.g. if length is measured to the nearest mm then all lengths in the column should be recorded to the nearest mm;
- use the correct number of significant figures for calculated quantities. For example, if values of pd and current are measured to 2 and 4 significant figures then the corresponding resistance should be given to 2 or 3 significant figures. The number of significant figures may, if necessary, vary down a column of values for a calculated quantity.

Recording readings and significant figures

All raw data should be recorded to the resolution of the instrument used. Any data processed (calculated) from the raw data should be to the same number of significant figures (or a maximum of one extra) as the raw data. The number of significant figures should be consistent within a column of data.

To simplify things a general rule is that:

Processed data should be given to the same number of significant figures as raw data and raw data should always be quoted to the resolution of the instrument used to measure it

Approach to data analysis

You should be able to:

- rearrange expressions into the form $y = mx + c$;
- plot a graph of y against x and use the graph to find constants m and c in an equation in the form $y = mx + c$.

Graphs

You should be able to:

- include a title and axes which are labelled with scales and units;
- make sure the scales are convenient to use, so that readings may easily be taken from the graph – avoid scales which use factors of 3 – and that the plotted points occupy at least half of both the vertical and horizontal extent of the graph grid;
- first consider carefully whether your plotted points suggest a straight line or a curve - then draw in your best fit line either with the aid of a ruler or (if a curve) by a freehand sketch;
- when extracting data from a graph, use the best-fit line rather than the original data;
- when determining the gradient of a graph, show clearly on your graph the readings you use. This is most conveniently done by drawing a right angled triangle – this should be large so that accuracy is preserved.

Estimating uncertainties

You should be able to:

1. Express uncertainties

Use the form $x \pm u$, where x is the quantity being measured and u its estimated uncertainty.

2. Estimate uncertainties using the resolution of an instrument

If a single reading is taken and there is no reason to believe that the uncertainty is greater, take the uncertainty to be the instrument resolution.

3. Estimate uncertainties using the spread of readings

Take the best estimate of the quantity you are determining as the mean of your readings and the estimated uncertainty to be half the spread in the readings, discounting any suspect readings: i.e. $u = \frac{x_{\text{max}} - x_{\text{min}}}{2}$

4. Percentage uncertainties

The percentage uncertainty, p, is calculated from:

$$p = \frac{\text{estimated uncertainty}}{\text{mean value}} \text{x} 100\%$$

Uncertainties in calculated quantities

1. If a quantity is calculated by **multiplying and/or dividing** two or more other quantities, each of which has its own uncertainty, the percentage uncertainty in the result is found by adding the percentage uncertainties in the quantities from which it is derived.

   e.g. If λ is calculated using $\lambda = \frac{ay}{D}$, the percentage uncertainty in λ is:

   $$p_\lambda = p_a + p_y + p_D$$

2. If a quantity is calculated by multiplying by a **constant**, the percentage uncertainty is unchanged.

3. If a quantity is **raised to a power**, e.g. x^2, x^3 or $\sqrt{x}$, the percentage uncertainty is **multiplied** by the same power.

   Example of 2 and 3: The energy, E, stored in a stretched spring is given by $E = \frac{1}{2}kx^2$. Both k and x have uncertainties, but $\frac{1}{2}$ has no uncertainty.
   So: $p_E = p_k + 2p_x$

Conclusions and evaluations

You should be able to:

- draw conclusions from an experiment, including determining the values of constants, considering whether experimental data supports a given hypothesis, and making predictions;

- suggest modifications to the experimental arrangement that will improve the accuracy of the experiment or to extend the investigation to answer a new question.

A LEVEL ONLY:

Approach to data analysis

You should be able to:

- rearrange expressions into the forms: $y = ax^n$ and $y = ae^{kx}$;
- plot a graph of $\log y$ against $\log x$ and use the graph to find the constants a and n in an equation in the form $y = ax^n$;
- plot a graph of $\ln y$ against x and use the graph to find the constants a and k in an equation of the form $y = ae^{kx}$.

Graphs

The following remarks apply to linear graphs.

Error bars

The points should be plotted with error bars. These should be centred on the plotted point and have a total length equal to $y_{max} - y_{min}$, for uncertainties in the y values of the points, and $x_{max} - x_{min}$, for uncertainties in the x values of the points. If identical results are obtained the precision of the instrument could be used. If the error bars are too small to plot this should be stated. This will almost certainly be the case for log graphs.

Maximum and minimum gradients

If calculating a quantity such as the gradient or the intercept a line of maximum gradient and a line of minimum gradient should be drawn which are consistent with the error bars. It is often convenient to plot the centroid of the points to help this process. This is the point, $(\overline{x}, \overline{y})$ the mean x value against the mean y value. The line of maximum gradient and the line of minimum gradient should both pass through this point.

Values for the maximum and minimum gradients, m_{max} and m_{min}, [or intercepts, c_{max} and c_{min}] can now be found and the results quoted as:

$$\text{gradient} = \frac{m_{max} + m_{min}}{2} \pm \frac{m_{max} - m_{min}}{2}$$

$$\text{intercept} = \frac{c_{max} + c_{min}}{2} \pm \frac{c_{max} - c_{min}}{2}$$

The following remarks apply to curved graphs.

If the graph is curved error bars should still be plotted (on both axes if possible) and a curve of best fit drawn to enable a tangent to be constructed if the gradient of any point is needed.

Example of good practice

The following results were obtained when the resistance of a coil of wire was measured at different temperatures. The resistance was measured when both heating and cooling the wire so giving two sets of readings. The mean resistance was calculated using:

$$\text{mean resistance} = \frac{R_{\text{max}} + R_{\text{min}}}{2}$$

and the absolute uncertainty calculated using:

$$\text{absolute uncertainty} = \frac{R_{\text{max}} - R_{\text{min}}}{2}$$

Systematic presentation

Consistent sig figs within each column

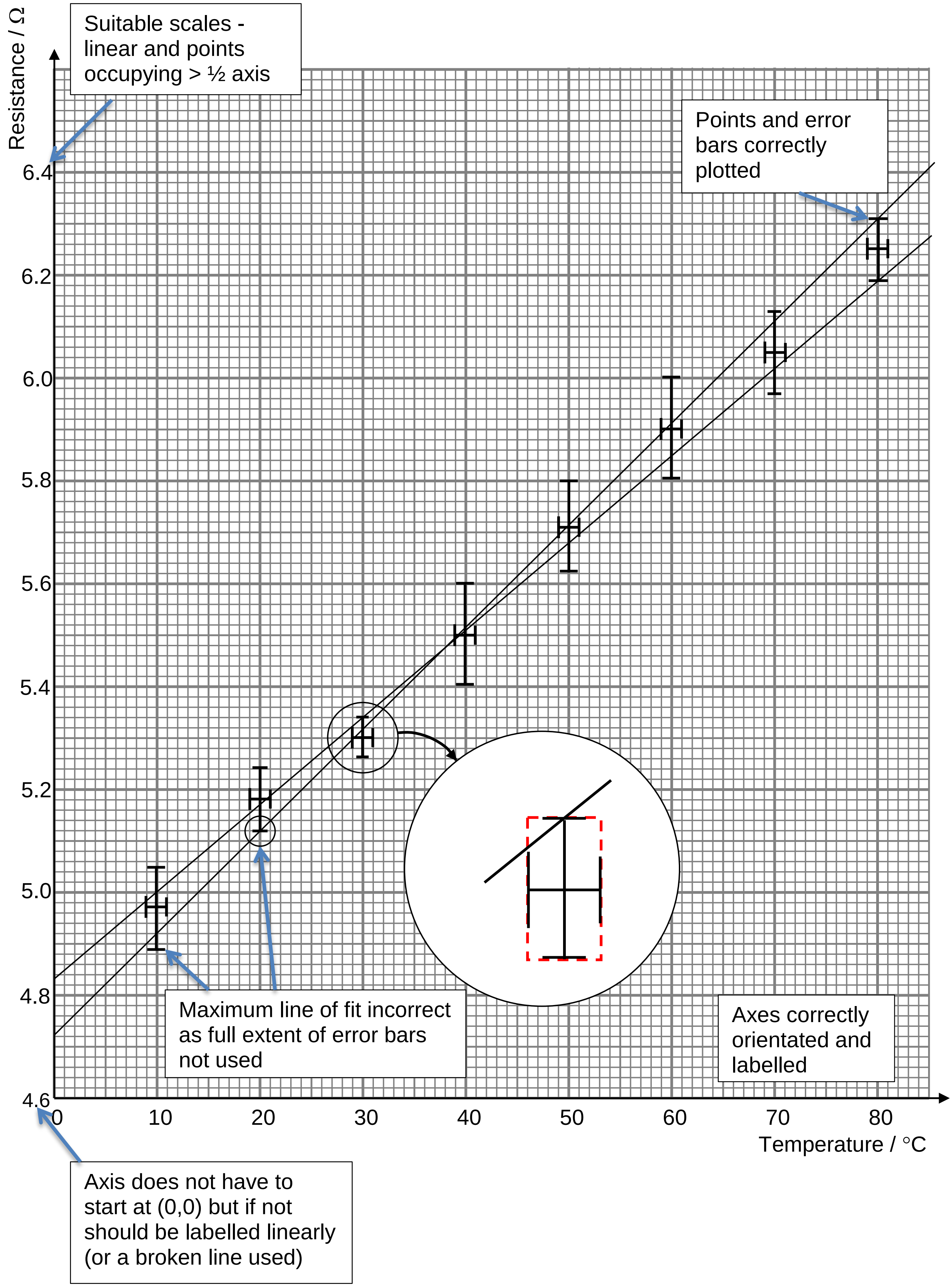
Headings given with units

Temperature ± 1 / ^{o}C	Resistance heating / Ω	Resistance cooling / Ω	Mean resistance / Ω	Absolute uncertainty / Ω
10	4.89	5.05	4.97	0.08
20	5.12	5.24	5.18	0.06
30	5.26	5.34	5.30	0.04
40	5.40	5.60	5.50	0.10
50	5.62	5.80	5.71	0.09
60	5.80	6.00	5.90	0.10
70	5.97	6.13	6.05	0.08
80	6.19	6.31	6.25	0.06

Uncertainty to 1/2 sig figs **max**

All raw data to the resolution of the instruments used

Processed data to the same number of sig. figs as the raw data



Resistance / Ω
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
0
10
20
30
40
50
60
70
80
Temperature / °C
Suitable scales - linear and points occupying > ½ axis
Points and error bars correctly plotted
Maximum line of fit incorrect as full extent of error bars not used
Axes correctly orientated and labelled
Axis does not have to start at (0,0) but if not should be labelled linearly (or a broken line used)

MEASUREMENT OF THE DENSITY OF SOLIDS

Specification reference: **AS Unit 1.1 - Basic Physics**

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)

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: $V = \frac{4}{3}\pi r^3$.
In both cases calculate the density using: $\rho = m/V$.

DETERMINATION OF UNKNOWN MASSES BY USING THE PRINCIPLE OF MOMENTS

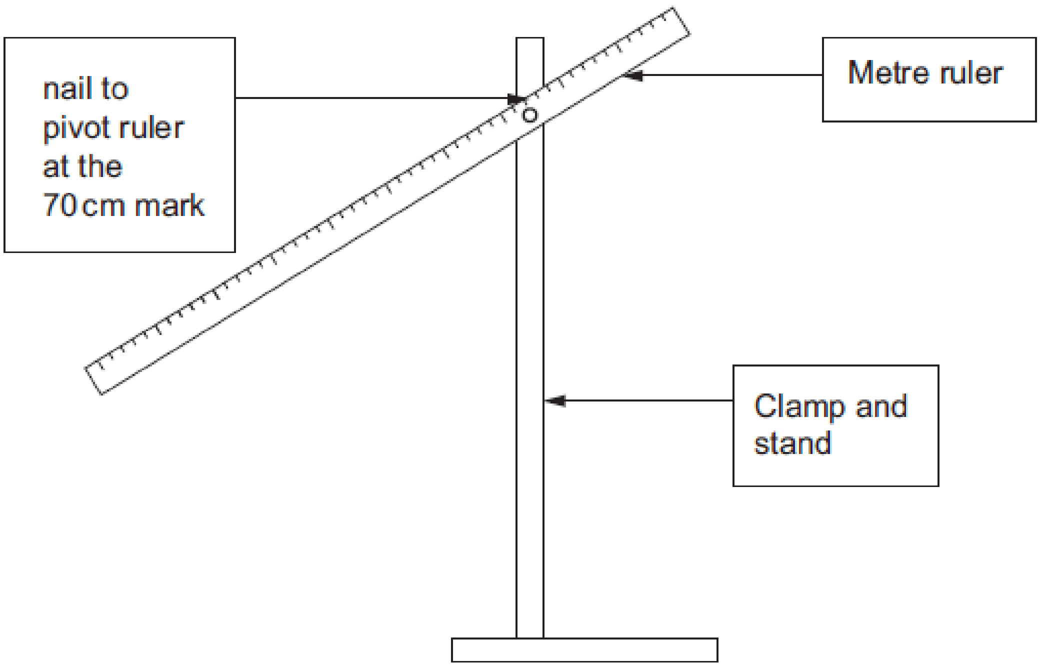
Specification reference: **AS Unit 1.1 – Basic physics**

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:

Meter 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



Experimental Method:

Loop a 200 g (1.96 N) mass over the metre rule and adjust it until the ruler is horizontal. 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:

$$0.20 \times \text{metre rule weight} = l \times 1.96$$

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:

$$0.20 \times \text{metre rule weight} = d \times \text{unknown weight}$$

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.

MEASUREMENT OF g BY FREEFALL

Specification reference: **AS Unit 1.2 - Kinematics**

Theory:

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

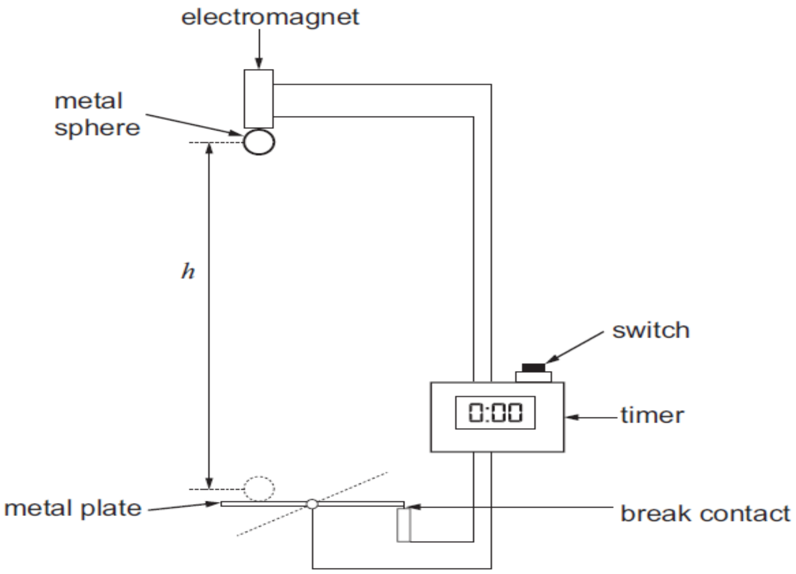
$$s = ut + \tfrac{1}{2}at^2$$

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:



Experimental Method:

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.

INVESTIGATION OF NEWTON'S SECOND LAW

Specification reference: **AS Unit 1.3 - Dynamics**

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:

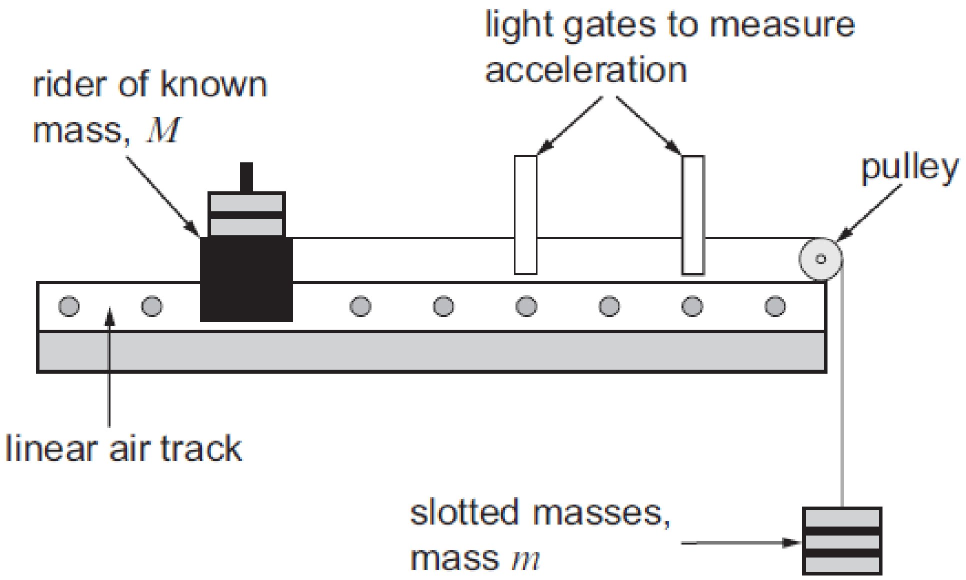
$$mg = (M + m)a$$

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:



Experimental Method:

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.

DETERMINATION OF YOUNG MODULUS OF A METAL IN THE FORM OF A WIRE

Specification reference: **AS Unit 1.5 - Solids under stress**

Theory:

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

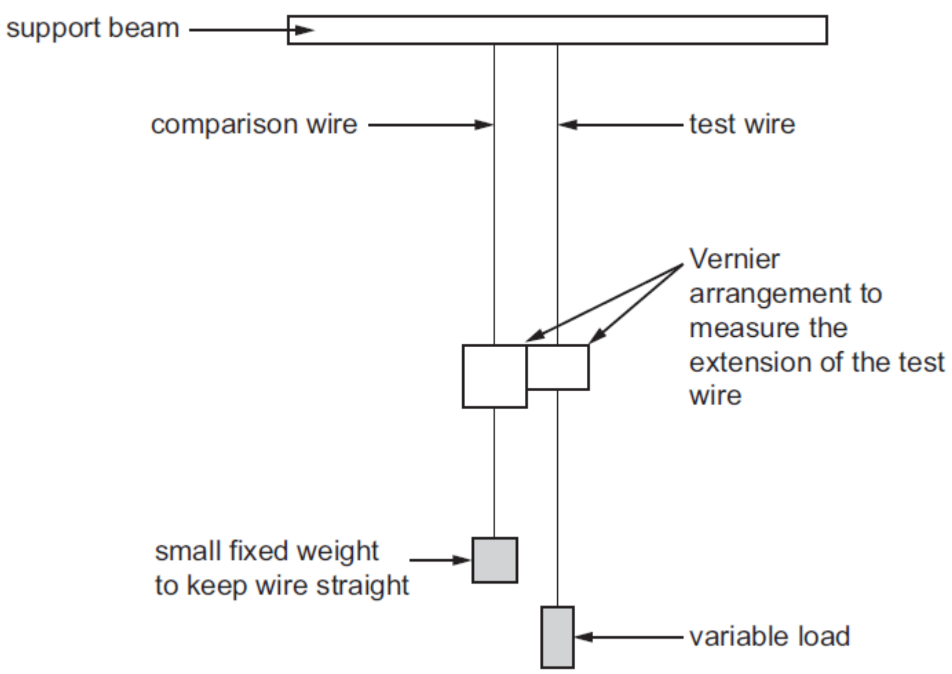
F = applied load
A = area of cross-section of the wire
x = extension
l = original length

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:



Experimental Method:

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.

INVESTIGATION OF THE FORCE – EXTENSION RELATIONSHIP FOR RUBBER

Specification reference: **AS Unit 1.5 - Solids under stress**

Theory:

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

Apparatus:

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

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.

INVESTIGATION OF THE I–V CHARACTERISTICS OF A FILAMENT OF A LAMP AND A METAL WIRE AT CONSTANT TEMPERATURE

Specification reference: **AS Unit 2.2 – Resistance**

Theory:

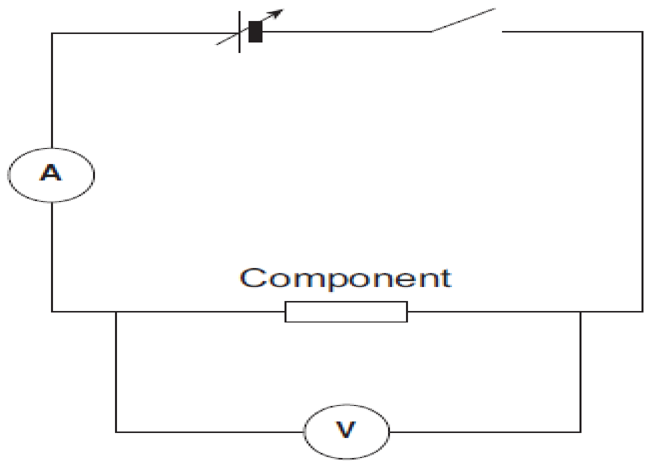
Ohm's law states that for a conductor the current, I, is directly proportional to the potential difference, V, provided physical factors such as temperature and pressure remains constant. Therefore by plotting the I-V characteristic of each of, a metal wire and a filament lamp, the validity of Ohm's 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

Experimental method:

The circuit should be set up as follows:



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.

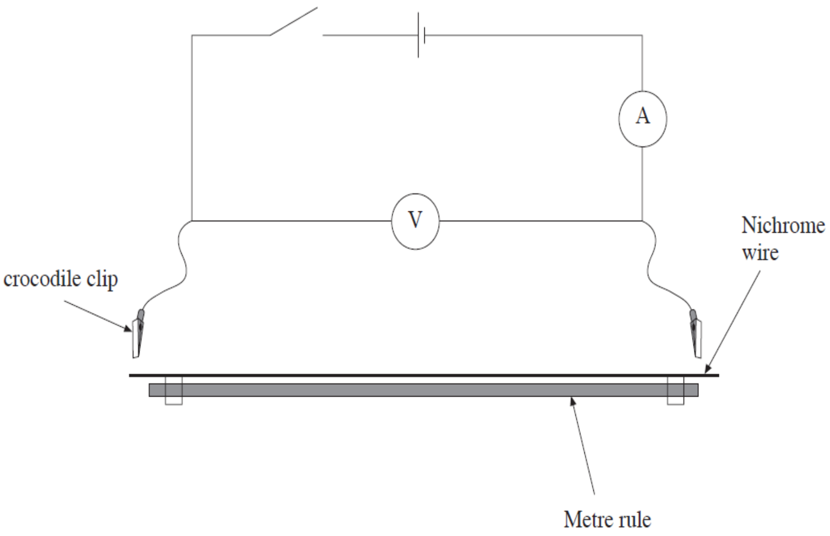
DETERMINATION OF THE RESISTIVITY OF A WIRE

Specification reference: **AS Unit 2.2 - Resistance**

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
1 × ammeter
1 × voltmeter
1 × 1.5 V 'D' type battery
1 × metre rule
1 × 110 cm length of nichrome wire
1 × micrometer / vernier callipers (resolution ±0.01 mm)
1 × 30 cm ruler (resolution ±0.001 m)

Experimental Method:

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 callipers and the cross-sectional area determined. Plot a graph of R (y-axis) against l (x-axis) and calculate the resistivity using: ρ = gradient $\times A$.

INVESTIGATION OF THE VARIATION OF RESISTANCE WITH TEMPERATURE FOR A METAL WIRE

Specification reference: **AS Unit 2.2 – Resistance**

Theory:

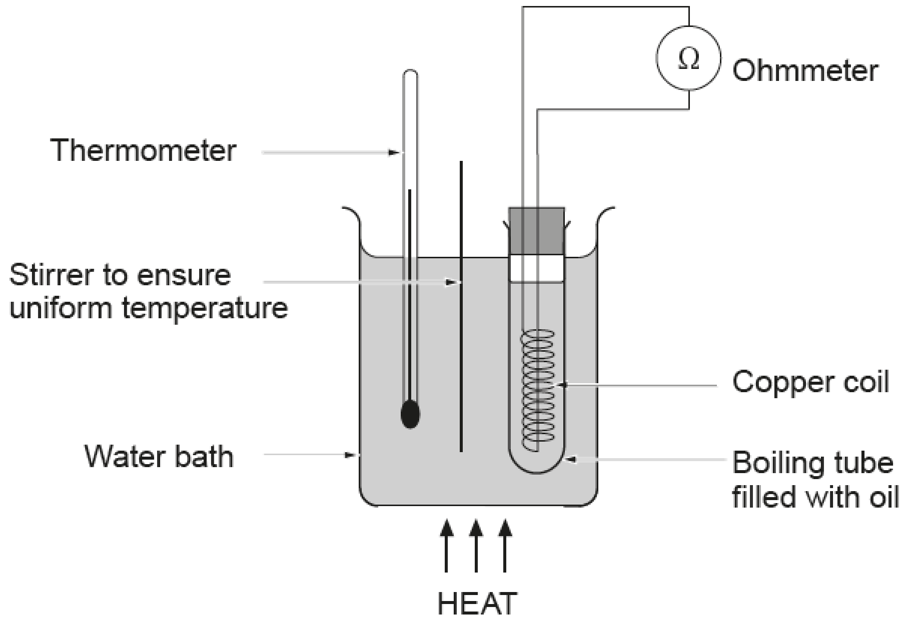
Resistance increases with temperature for metals in a linear relationship. This practical will enable data to be obtained to investigate this relationship.

Apparatus:

Bunsen burner; tripod, gauze and stand
250 ml beaker of water or water bath with heating element
Ice
Thermometer 0 – 100 °C
Multimeter set on ohm range to measure resistance
Copper coil
Stirrer

Experimental method:

The circuit should be set up as follows:



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.

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

DETERMINATION OF THE INTERNAL RESISTANCE OF A CELL

Specification reference: **AS Unit 2.3 – D.C. circuits**

Theory:

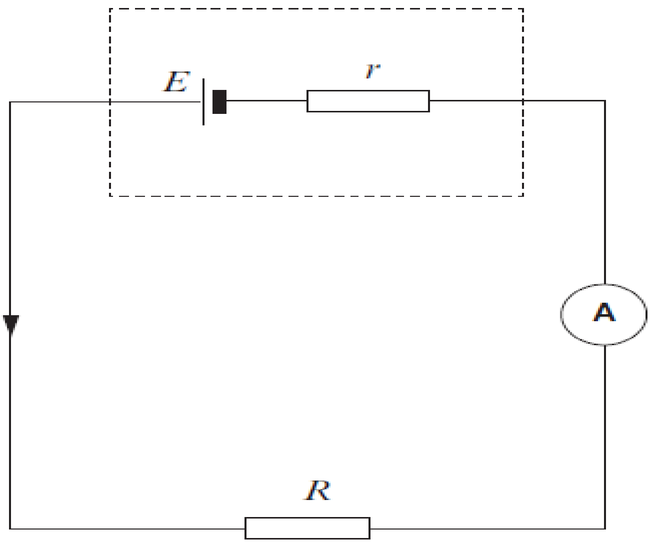
The equation used for determining the internal resistance is $V = E - Ir$ where V is the terminal p.d. of a cell; E is the emf of the cell; I the current flowing in the circuit and r is the internal resistance. $V = IR$ and the equation can be re-written as $R = \frac{E}{I} - r$. Therefore a graph of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

Apparatus:

Cells – e.g. 3 or 4 $\times$ 1.5 V "D" type batteries connected in series
Switch
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 follows:



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.

MEASUREMENT OF THE INTENSITY VARIATIONS FOR POLARISATION

Specification reference: **AS Unit 2.4 – The nature of waves**

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

Experimental method:

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

DETERMINATION OF WAVELENGTH USING YOUNG'S DOUBLE SLITS

Specification reference: **AS Unit 2.5 – Wave properties**

Theory:

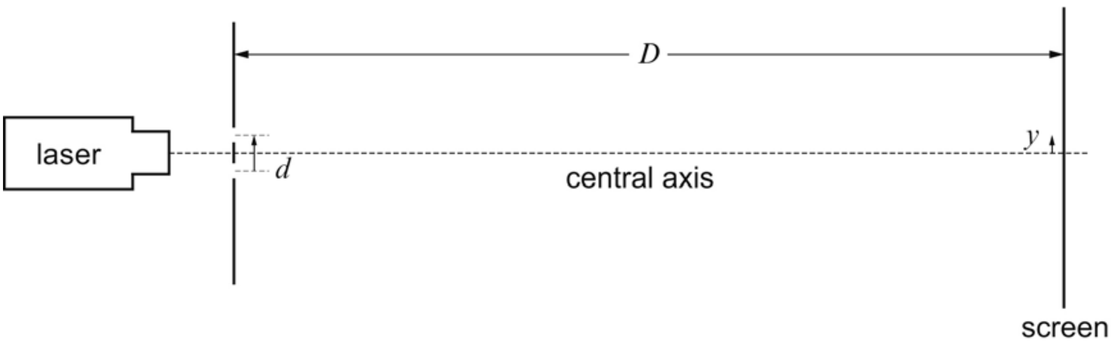
The fringe spacing, Δy is given by the equation $\Delta y = \frac{\lambda D}{d}$ where λ is the wavelength of the light; D is the distance from the slits to the screen where the fringes are viewed and d is the distance between the slits. A graph of Δy against D should be a straight line and the gradient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

Experimental method:

The apparatus should be set-up as follows:



Measure the fringe spacing Δy, the spacing between the slits, d, and the distance, D, from the slits to the screen using either the ruler or digital callipers. 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 by dividing the distance by the number of fringes measured.

DETERMINATION OF WAVELENGTH USING A DIFFRACTION GRATING

Specification reference: **AS Unit 2.5 – Wave properties**

Theory:

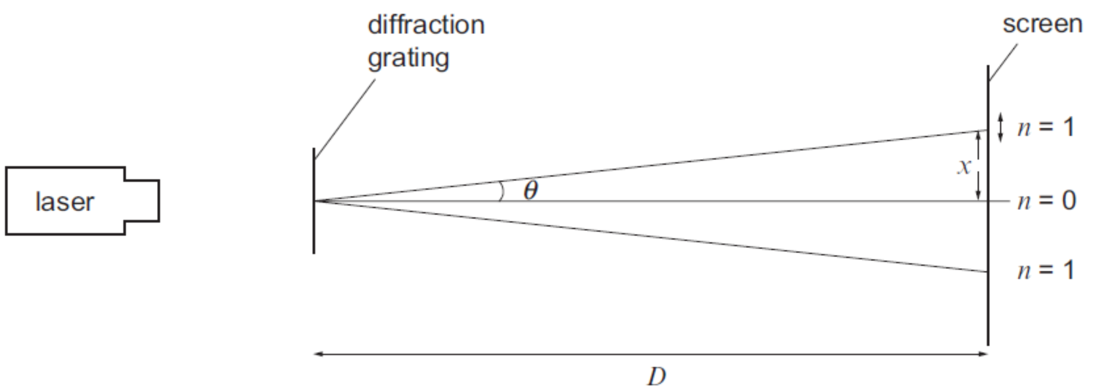
The diffraction grating equation is given by $n\lambda = dsin\vartheta$. The spacing between the lines in a diffraction grating is usually specified or can be found from the grating ruling. By measuring the angle θ, the wavelength of the light can be determined.

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

Experimental method:

The apparatus should be set-up as follows:



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

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

DETERMINATION OF THE SPEED OF SOUND USING STATIONARY WAVES

Specification reference: **AS Unit 2.5 - Wave properties**

Theory:

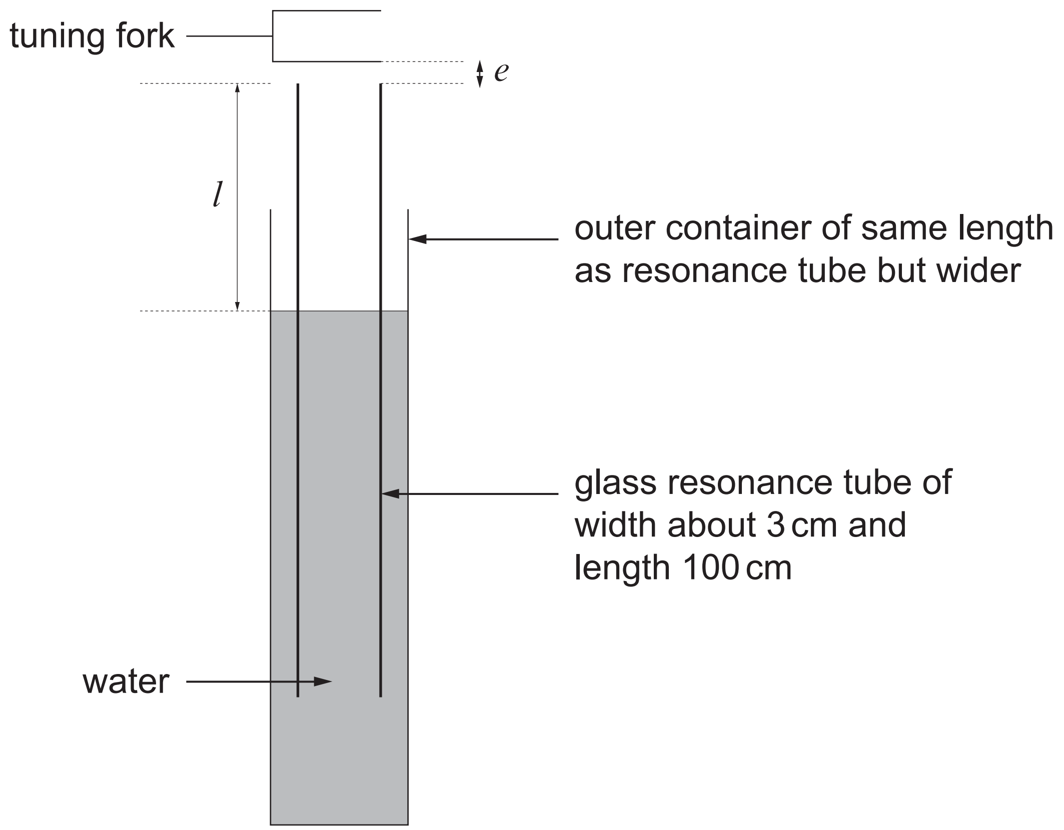
When resonance first occurs the length of air in the tube, l, plus a small end correction, e (to account for the position of the tuning fork above the tube) will be equal to a quarter of a wavelength. Hence:

$$l + e = \lambda/4 \qquad \text{but} \qquad \lambda = c/f$$

$$\text{so} \qquad l = c/4f - e$$

If a graph is plotted of l (y-axis) against $1/f$ (x-axis) it should be a straight line with a small negative y-intercept. The gradient of the graph equals $c/4$, 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 will be needed along with a metre ruler of resolution ± 0.001 m.

Experimental method:

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 1/frequency (x-axis). Use the gradient to determine a value for the speed of sound.

MEASUREMENT OF THE REFRACTIVE INDEX OF A MATERIAL

Specification reference: **AS Unit 2.2 – Wave properties**

Theory:

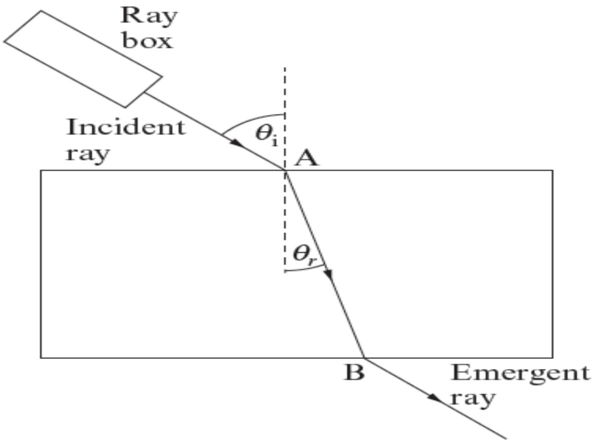
The refractive index, n, of a material can be determined from the equation $\sin\theta_i = n\sin\theta_r$ where n = refractive index, θ_i is the angle of incidence and θ_r is the angle of refraction. The above equation assumes that the incident ray is travelling in air. A graph of $\sin\vartheta_i$ (y-axis) 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

Experimental Method:

The following arrangement should be set-up.



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.

DETERMINATION OF h USING LEDs

Specification reference: **AS Unit 2.7 – Photons**

Theory:

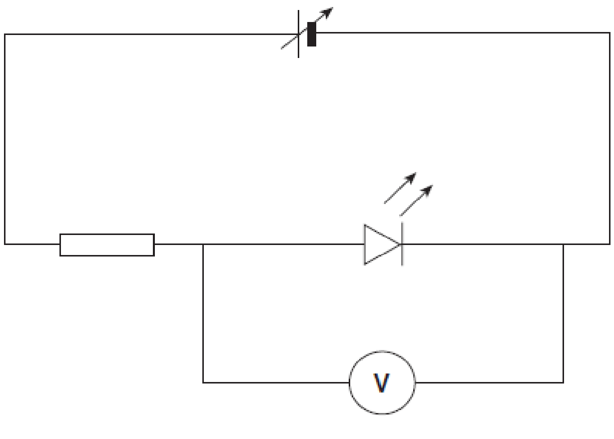
The Planck constant, h, can be determined by using a light emitting diode (LED) and measuring the minimum voltage, V_{min}, at which light is just emitted by the diode. The Planck constant can then be determined from the equation $V_{min} = \frac{hc}{e\lambda}$ where c is the speed of light 3.00×10^8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

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 circuit should be set-up as follows:



The voltage should be varied until light is just emitted by the LED. Record the voltage it corresponds to 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.

ESTIMATION OF ABSOLUTE ZERO BY USE OF THE GAS LAWS

Specification reference: **A2 Unit 3.4 – Thermal physics**

INVESTIGATION OF RADIOACTIVE DECAY – A DICE ANALOGY

Specification reference: **A2 Unit 3.5 – Nuclear decay**

INVESTIGATION OF THE VARIATION OF INTENSITY OF GAMMA RADIATION WITH DISTANCE

Specification reference: **A2 Unit 3.5 – Nuclear decay**

INVESTIGATION OF THE CHARGING AND DISCHARGING OF A CAPACITOR TO DETERMINE THE TIME CONSTANT

Specification reference: **A2 Unit 4.1 – Capacitance**

INVESTIGATION OF THE ENERGY STORED IN A CAPACITOR

Specification reference: **A2 Unit 4.1 – Capacitance**

INVESTIGATION OF THE FORCE ON A CURRENT IN A MAGNETIC FIELD

Specification reference: **A2 Unit 4.4 – Magnetic Fields**

INVESTIGATION OF MAGNETIC FLUX DENSITY USING A HALL PROBE

Specification reference: **A2 Unit 4.4 – Magnetic Fields**