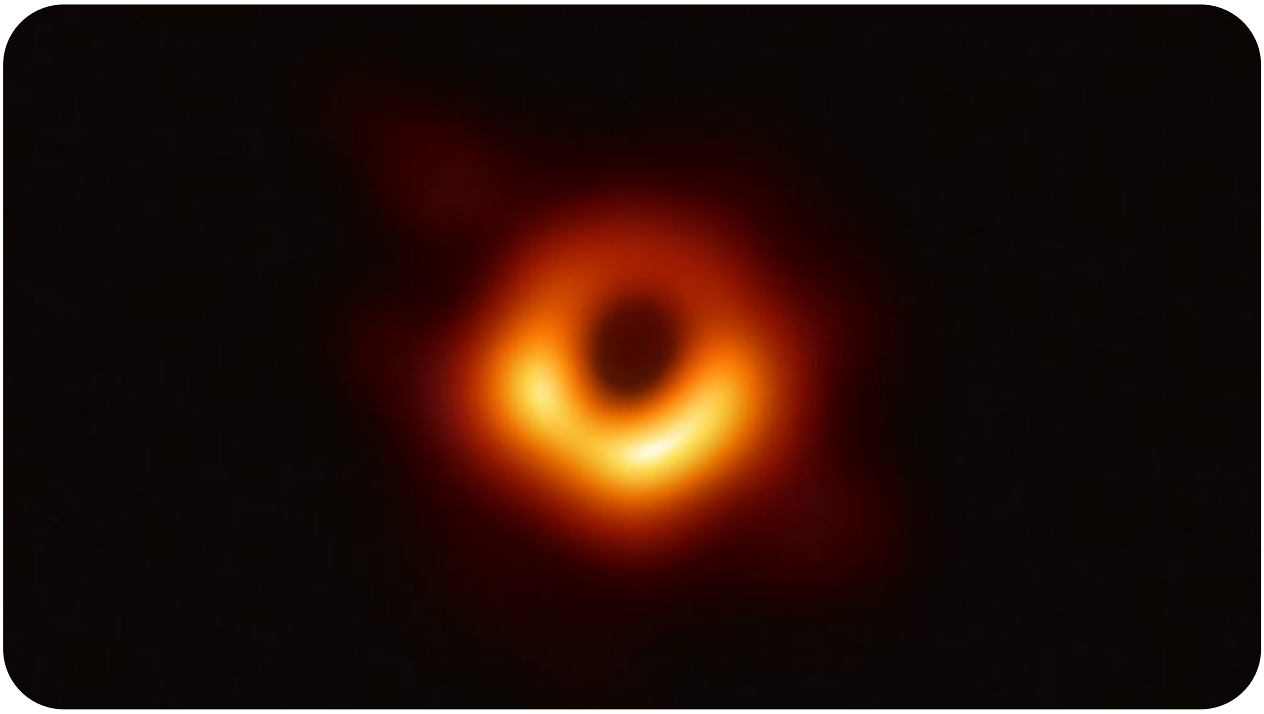
EDEXCEL International Advanced Level



Edexcel IAL Physics Unit 3

Summary©

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HS

Introduction

A scientific investigation goes through the following phases:

- Planning
  - Apparatus
  - Instruments and techniques
  - Method

- Implementation and measurements
  - Significant figures
  - Readings

- Analysis
  - Graph
  - Error and uncertainty
  - Conclusion

A. PLANNING

Apparatus

- You should produce a list of all the apparatus you will need to take all necessary measurements. Your list must include both the item under investigation and the means to experiment on it.
- A diagram will help, so this is a good place to draw your diagram. Make sure that your diagram is clear. Your diagram should show the apparatus assembled as a scientific diagram not an illustration.

Instruments and techniques

Measurement	Instrument	Technique(s)
Length of rubber band	Metre rule	Place rule close to band Lay the rubber band out straight without stretching it Read the position of each end of the band and subtract
Diameter of a wire	Micrometer screw gauge	Take a pair of readings at right angles to make sure it is circular and find the mean Take readings at several places down the length and find the mean
Time for a model car to roll down a ramp	Stopwatch	Draw clearly defined start and stop points on a ramp Make sure the car starts from rest Repeat and find the mean
Temperature of water in a water bath	Thermometer	Place thermometer close to object being heated Stop heating before reading Stir water
Potential difference	Multimeter	Use the most sensitive voltage range Check connections are secure
Length of a simple pendulum	Metre rule	Clamp rule alongside Record the position of the bottom of support (top of string) and the centre of mass of the bob Read the rule with your eyes at the same horizontal level as the position recorded
Diameter of a test tube	Callipers	Repeat readings in different orientations Repeat readings at different places down the tube

Digital Multimeter vs Analogue Ammeter + Voltmeter

Idea	Analogue		Digital
Equipment /cost	two meters needed / may be more expensive	Or	only one meter needed / may be cheaper option
Ease of reading	two readings must be taken	Or	one reading only / fluctuates
Parallax	needs to be considered	Or	digital display / no parallax error
Systematic errors	zero errors contact resistance	Or	zero error contact resistance
Scales	fixed/ requires interpolation	Or	variable/can be changed / numeric reading
Sensitivity	limited by size of scale divisions	Or	two decimal places
Setting up	requires both series and parallel connections / additional apparatus	Or	only requires series connection / must set function switch / use correct terminals
Heating effect of current	heating may change resistance of wire	Or	unlikely to be much heating effect
Power supply	meters do not require individual batteries / but circuit needs a power supply	Or	internal battery required
Uncertainties	greater since two readings	Or	smaller since only one reading
Data	needs calculation from two readings	Or	no calculation required/direct reading
Graphical method	possible	Or	less simple for a fixed wire

Stopwatch vs light gates or sensors and a data logger

Idea	Datalogger/light gates		Stopwatch
Comparison of errors	Advantage - fewer errors	or	Disadvantage - more errors e.g. random, systematic or parallax (not just human error)
Reaction time	No need to account for reaction time	or	Disadvantage - effect of reaction time
Precision	e.g. readings to nearest millisecond	or	e.g. insufficient precision for shortest times
Power supply	Disadvantage - power supply (or electricity) needed.	or	Advantage - no power supply required
Complexity	Needs 'training' setting up, alignment issues, time needed to set up	or	Simple to operate or to set up
Graph	Advantage - any graph could be drawn automatically	or	Any graph would have to be drawn manually
Availability, cost or transport	Not easily available Expensive Not easily transportable	or	Readily available Cheaper Easily transportable

Method

- Write out your method using bullet points.
- You should identify the dependent and independent variables.
- You should describe the graph you will plot and how you will use to find the value you require.
- You should identify any factors that might affect the outcome and state how you will control these variables. You should not be too ambitious here but consider only those things that are likely to have a real effect on your work.

B. INTERPRETATION AND MEASUREMENTS

You should follow your plan but keep in mind what you are trying to find out.

- Draw up a table and head each column with the quantity and the unit.

Significant figures

- You are going to record what your instruments read and this is usually to 3 s.f.
- You should use the least number of significant figures when calculating values for derived quantities.
- Your graph should be as precise as possible. In general, 3 s.f. are needed for plotting the points, so gradient calculations should also be given to 3 s.f.

Readings

- You need to take enough readings to plot a reliable graph. If you expect your graph to be a straight line then you should have six readings. For a curved graph you should take more readings where the graph curves and the readings change rapidly, and take fewer readings when it is straight.
- You do not always need to use equal increments of the independent variable.

Critising measurements

- Units present or missing in the table
- Repetition / at least 6 readings
- Inconsistent precision / Inconsistent significant figures
- Precision of readings too low

C. ANALYSIS

- First, plot your readings on a graph. You must do this by hand without using a software programme.
- You then evaluate your findings and move towards a conclusion.

Graph

- Your graph should have the correct axes, as described in your plan, and for giving the axes correct units. The gradient of a graph has no units because the axes are labelled with units and, therefore, you plot pure numbers. Independent variable is usually plotted on the x-axis and the dependent variable on the y-axis. You should have a good reason for plotting the independent variable on the y-axis.
- One purpose of a graph is to display data. The data points should occupy at least half of both axes of your graph; you should not include the origin unless you can do so without confirming the points to one corner. The other purpose of a graph is to enable you to take

readings from intermediate points (interpolate), so make sure your scale is sensible and easy to read.

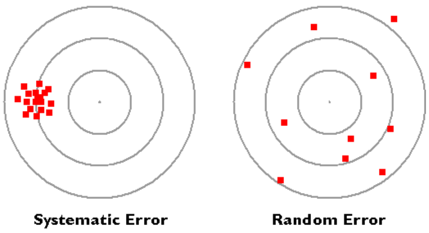
- Plotting should be accurate.
- The best-fit line should have points above and below it and should not necessarily pass through the origin.
- You should describe your graph using appropriate vocabulary. If the graph is a straight line through the origin then the two variables are directly proportional; if the y-intercept is not zero then you can say there is a linear relationship between the variables. You should also note how close the points are to a straight line.

Error and uncertainty

Error in a reading may be systematic or random. The value of a derived quantity will have an uncertainty that comes from the readings used in the calculation.

Error

- A systematic error is caused when something affects all of the readings of an instrument in the same way. Systematic errors can be minimised by taking sensible precautions, such as checking for zero errors and avoiding parallax errors, and by drawing a suitable graph. A systematic error has poor accuracy, definite causes and is reproducible.
- A random error results from variability in what you are reading. Random error is shown by the spread in repeated readings, which might also come about because what you are reading is difficult to measure. Random errors can be minimised by taking the average of a number of repeat measurements and by drawing a graph, that, in effect, averages a range of values. A random error has poor precision, non-specific causes and is not reproducible.



Uncertainty

Uncertainty arises when you consider the effect of the errors in the context of the actual measurement. There are two ways to take this into account.

- Uncertainty in measurements is unavoidable and estimates the range within which the answer is likely to lie. This is usually expressed as an absolute vale, but can be given as a percentage. The normal way of expressing a measurement x_0 with its uncertainty, u, is:

$$x_0 \pm u$$

- Absolute uncertainty and percentage uncertainty are calculated by using the following equations:

$$mean = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

$$u = \frac{x_{max} - x_{min}}{2}$$

,where x_{max} is the maximum and x_{min} the minimum reading of x. (Ignoring any anomalous readings)

$$Percentage\ uncertainty = \frac{Uncertainty}{Mean\ value} \times 100\%$$

- Uncertainties can be combined when 2 or more values with absolute uncertainties are treated.

1-) Multiplying and dividing: The percentage uncertainty in a quantity, formed when two or more quantities are combined by either multiplication or division, is the sum of the uncertainties in the quantities which are combined.

2-) Raising to a power: The percentage uncertainty in x^n is n times the percentage uncertainty in x.

Note: The percentage uncertainty in $\frac{1}{x^n}$ is again times the percentage uncertainty in x.

Note: The percentage uncertainty in $\sqrt{x}$ is half the percentage uncertainty in x.

3-) Multiplying by a constant: The percentage uncertainty is unchanged.

- The other way to consider uncertainty is to use a graph. Plot error bars on the graph – these are lines drawn vertically and horizontally from the plot and indicate how much error there is in the reading. Now draw a best-fit line through the data points on the graph and then draw a worst-fit line that just fits through all the error bars. The uncertainty in the gradient is given by the difference between the two gradients.

Conclusion

The aim of the uncertainty calculation is to give a measure of the confidence you can have in your conclusion. The conclusion is the answer to the question in the hypothesis and the uncertainty, informed by your thoughts on errors, will give your results some validity.

As part of your conclusion you need to think about how you might improve the experiment. Your suggestions should reduce the uncertainty and improve your final answer in terms of accuracy and precision.

Glossary

Term	Definition or meaning
Accepted value	The accepted value of a measurement is the value of the most *accurate measurement* available. It is sometimes referred to as the 'true' value.
Accuracy	Accuracy is a measure of confidence in an *accurate measurement*, often expressed as an upper and lower limit of the measurement based on the *uncertainty* in the measurement (eg $g = 9.8 \pm 0.3\,\text{m s}^{-2}$).
Accurate measurements	A measurement which can be described as accurate is one that has been obtained using accurately calibrated instruments correctly and where no systematic errors arise.
Dependent variable	Dependent variables are those variable physical quantities whose values change as a result of a change of value of another variable quantity. The dependent variable is usually plotted on the vertical or y-axis of a graph.
Error	The difference between a measurement and its accepted value. Often a misnomer suggesting that a mistake was made in taking a reading.
Independent variable	Independent variables are those variable physical quantities whose values are controlled or selected by the experimenter. Changing the value of an independent variable usually results in a change of value of a dependent variable. The independent variable is usually plotted on the horizontal or x-axis of a graph.
Linearity	This is a design feature of many instruments and it means that the readings are directly proportional to the magnitude of the variable being measured. *The scale of a moving coil meter is linear if it has evenly spaced graduations on its scale each representing equal increases in current.*
Mean value	The mean value of a set of readings is calculated by adding the readings together and dividing by the number of readings.
Percentage uncertainty (of a mean value)	$\text{percentage uncertainty} = \dfrac{\text{uncertainty}}{\text{mean value}} \times 100$
Precision	The precision of a measurement is the degree of exactness (sometimes the number of significant figures) to which the measurement of a quantity or value can be obtained and reproduced consistently. • If a reading is constant when repeated, the precision of the measurement will be the precision of the instrument. • If a reading fluctuates the precision of the measurement (its mean value) is given by half the maximum range of the readings.
Precision of an instrument	The precision of an instrument is the smallest non-zero reading that can be measured using the instrument.
Probable error	See 'uncertainty'.
Random error	Random errors are errors with no pattern or bias. Readings with random errors vary in an unpredictable manner with no discernable pattern or trend. The effect of random variations in measurements of a quantity is reduced by taking more readings and finding a mean value.
Range	The range of a set of readings or calculated values is the difference between the smallest and the largest values.
Reliability	Reliability is the extent to which the measurements of a quantity remain consistent over repeated measurements of the same quantity under identical conditions. • An experiment is reliable it if yields consistent results of the same measurement. • An experiment or investigation is unreliable if repeated measurements give different results or if the scatter of measurements on a line graph is too great to establish the line. • Reliability is higher when random errors are reduced. • The reliability of data can be improved by carrying out repeat measurements and calculating a mean value.

Sensitivity	The traditional meaning of sensitivity is based on the ratio: $\text{sensitivity} = \dfrac{\text{output response}}{\text{input stimulus or signal}}$ (ie output per unit input quantity). The sensitivity of an instrument with a scale is the scale reading it gives per unit of the physical quantity it measures: $\text{sensitivity} = \dfrac{\text{scale reading}}{\text{quantity measured}}$ *eg The sensitivity of a moving-coil instrument is the number of scale divisions its pointer moves per milliamp of current.* These definitions result in a larger value for the sensitivity of an instrument when it is more sensitive, ie gives a larger response. **Note about alternative scale calibrations** However, some measurement applications use an alternative 'sensitivity' definition which is in fact the ***reciprocal*** of the traditional concept and should be considered as a method of calibrating a scale. *A prime example of this is the format used for the scale divisions on the screen of an oscilloscope where the 'sensitivity' or scale calibration is given in volts per scale division. An appropriate term for this calibration is the **y-gain** of the oscilloscope rather than its sensitivity. The voltage reading is obtained by multiplying the number of scale divisions by the volts per scale division.* This approach is a method of ***calibration*** of a scale in which a value is assigned to each scale division. e.g. *graduations on a thermometer scale each worth 0.2°C;* *centimetre squares on an oscilloscope screen each worth 2.0 mV.*
Systematic error	Systematic errors in measurements are errors which show a pattern or a bias or a trend. Systematic errors can result from an instrument calibration error (eg zero errors), from incorrect use or reading of instruments (eg parallax errors) or be caused by another factor changing the quantity in an unknown or unrecognised manner.
Uncertainty	The uncertainty of a measurement is an expression of the spread of values which are likely to include the accepted value. *For these physics specifications,* the uncertainty in a measurement is taken as half the range from the lowest to the highest value obtained. The uncertainty in a measurement is expressed as a ± value attached to the mean value. The uncertainty of a value may also be indicated by an error bar on a graph. *For these specifications the 'uncertainty' and 'probable error' in a measurement will be taken to have the same meaning.*
Valid	Valid measurements are those which give the required information by an acceptable method.
Zero error	A zero error arises when an instrument gives a non-zero reading for a true zero value of the quantity it measures. A zero error is a systematic error which must be added to (or subtracted from) all readings obtained with a particular instrument. *An example is often found with micrometer screw gauges which give a non-zero reading when the jaws are closed together.*

AS Physics Experiments

1. Determination of speed and acceleration
2. Factors affecting acceleration
3. Measurement of the acceleration due to gravity
4. Potential and kinetic energy
5. Force-extension experiments
6. Measurement of the Young modulus
7. Measuring the viscosity of a liquid
8. Refractive index of solids
9. Refractive index of liquids
10. Melde's experiment
11. The plane of polarisation
12. Current and voltage
13. Ohmmeter and the total resistance of copper
14. I - V characteristics for a tungsten filament lamp
15. I - V characteristics for a semiconductor diode
16. I - V characteristics for a NTC thermistor
17. The resistance of a thermistor
18. Resistivity of a metal and polythene
19. The emf and internal resistance of a cell
20. Flow of electrical charge
21. Potential along a wire
22. Efficiency of an electric motor
23. Determining the Planck constant

1-Determination of speed and acceleration

A. Introduction

The aim of this experiment is to measure the speed and acceleration of an object.

B. Safety

Set up this experiment away from the edges of the bench so that the trolley will come to a stop on the bench.

C. Apparatus

- Trolley
- Stopwatch
- Ruler
- Runway
- Two light gates
- Data logger PC
- Blocks for tilting runaway
- Interrupter card

D. Procedure

Traditional approach to measure average speed

- The distance travelled by trolley down the slope is measured using a ruler or metre rule.
- The time is measured using a stopwatch.
- The average velocity is found by dividing the distance moved down by the plane by the time taken. $v = \frac{s}{t}$

ICT approach to measure instantaneous speed

- An interrupter card is placed on the trolley.
- The interrupter card cuts through the light beam directed at a light gate, and the time is electronically recorded.
- The instantaneous velocity at that position is calculated by dividing the length of the card by the time taken to cross the beam.

Acceleration

The equation, $s = ut + \frac{1}{2}at^2$, or the equation, $v^2 = u^2 + 2as$, can be used.

E. Sources of uncertainty

- Zero error – parallax error
- Reaction time
- Acceleration is assumed to be constant
- The initial velocity is assumed to be zero

2-Factors affecting acceleration

A. Introduction

The acceleration of the trolley in the figure is found by measuring the time taken for the card to cut the light beams and the separation of the gates:

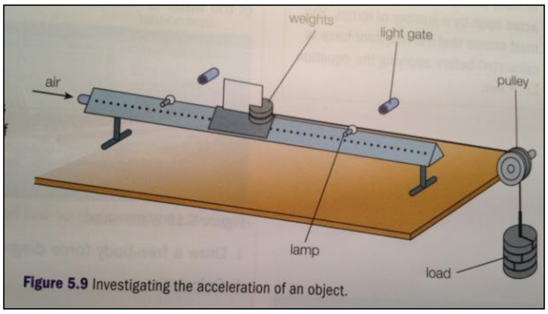


Figure 5.9 Investigating the acceleration of an object.

Initial velocity= l/t1

Final velocity= l/t2

The acceleration can be calculated using the equation of motion:

$$v^2 = u^2 + 2as$$

The resultant force is provided by the weight of the hanger.

B. Safety

Place a piece of sponge beneath the hanging masses.

C. Apparatus

- Linear air track
- Air blower
- Rider
- Two light gates
- Timing unit
- A piece of sponge
- Power supply
- Interrupter card
- Set of slotted masses
- Thread
- Pulley
- Spirit level

D. Procedure

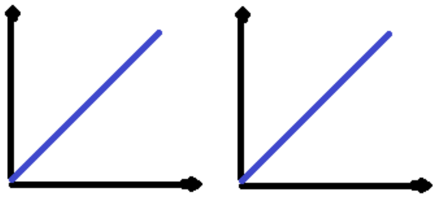
Effect of force acting on a fixed mass

- Resultant force can be increased without altering the mass, by taking a weight off the trolley and placing it on to the hanger.
- A range of forces is used.
- A graph of acceleration against force is then plotted.

Effect of mass on the acceleration produced by a fixed force

- The weight on the hanger is kept constant.
- Weights are added to the trolley to increase the mass of the system.
- The acceleration is found for each mass.
- A graph of acceleration against the inverse mass is plotted.

E. REPRESENTATION OF DATA



F. VALIDITY OF THE STUDY AND IMPROVEMENTS

- The air minimises the effects of friction.
- The track must be level.

G. CONCLUSION

Acceleration is directly proportional to the resultant force applied. Acceleration is inversely proportional to the mass of the system. Therefore, this experiment confirms the Newton's second law: F=ma

3-Measurement of the acceleration due to gravity

A. Introduction

For an object dropped from rest, the acceleration due to gravity can be calculated using the equations of motion:

$$s = ut + \frac{1}{2}at^2 \qquad v^2 = u^2 + 2as$$

As u= 0, s=h and a=g, these equations become:

$$h = \frac{1}{2}gt^2$$

$$v^2 = 2gh$$

B. Safety

A block of sponge should be placed beneath the light gates to stop the weighted card.

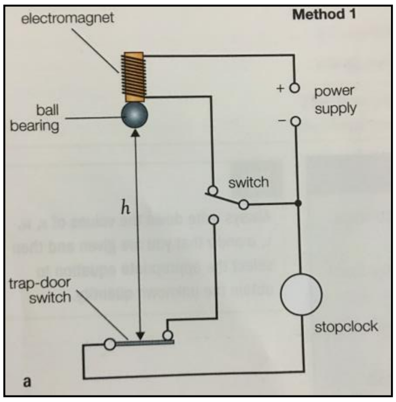
C. Apparatus

- Ball bearing (M1)
- Electromagnet (M1)
- Power supply (M1)
- Circuit shown (M1)
- Stopclock (M1 and M3)
- Metre rule (M1 and M3)
- Cylinder (M2)
- Glass tube (M2)
- Light gate and light source (M2)

D. Procedure

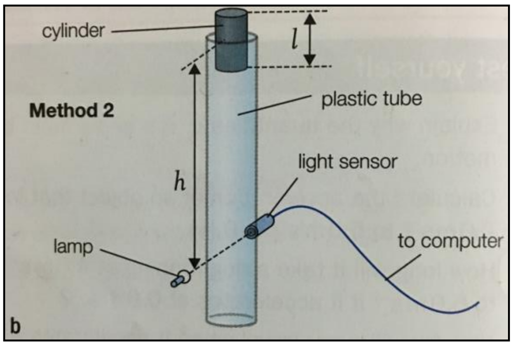
Method 1

- A ball-bearing is held by an electromagnet at height, h, above a trapdoor switch.
- When the switch is thrown, the circuit to the electromagnet is broken and the ball begins to fall.
- At that instant the stopclock starts timing.
- When the ball strikes the trapdoor, the lower circuit is broken and the clock is stopped.
- The height is measured using a metre rule. The timing is repeated several times, and an average value of t is recorded.
- The experiment is repeated for a range of different heights.
- A graph of t^2 against h is plotted. Rearranging $h = \frac{1}{2}gt^2$ gives $\frac{t^2}{h} = \frac{2}{g}$, so the gradient of the line will be $\frac{2}{g}$.



Method 2

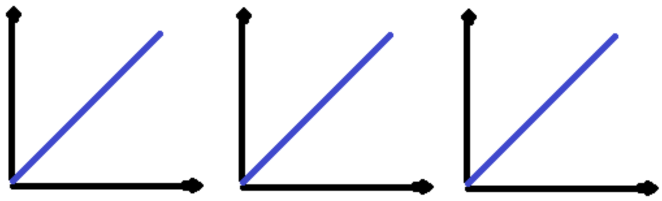
- A metal cylinder is dropped from rest down a glass tube.
- A light gate is positioned close to the outside of the glass tube. The light gate measures the the taken for the cylinder to pass through it.
- This time t is used to calculate the velocity of the cylinder at a distance s from the top of the tube.
- Length of cylinder is measured using a Vernier calliper.
- Velocity of the cylinder is calculated by dividing the length of the cylinder by time t.
- U=0 and a=constant, so rearranging $v^2 = u^2 + 2as$ gives $v^2 = 2gh$.
- A graph of v^2 against h is drawn. The gradient of the line is 2g.



Method 3

- A ball is dropped from a height which is measured with a metre rule.
- A video camera is used to record the motion of the ball.
- Height of which the ball is dropped is known.
- Total time of journey is recorded.
- $h = \frac{1}{2}gt^2$ is used.
- $g = \frac{2h}{t^2}$ is used to find the acceleration due to gravity.

E. Representation of Data



F. Improvements

- Drop the ball/cylinder from rest.
- Drop cylinder to prevent touching sides of tube. (Method 2)
- Make sure the ball drops vertically / Arrange the tube vertically.
- Repeat readings of t for each value of h and average.
- Check light gate for zero error / Reset light gate to zero. (Method 2)
- Light gates should be perpendicular to the tube. (Method 2)
- Use a longer cylinder. (Method 2)
- Exclude anomalous readings from repeat readings.

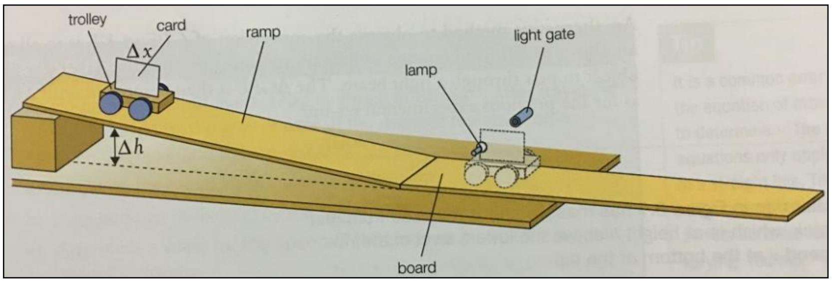
4-Potential and kinetic energy

A. Introduction

Energy can be neither created nor destroyed, but it can be transferred. This means that, in any process, total energy at the start = total energy at the end. The aim of this experiment is to investigate the transfer of gravitational potential energy to kinetic energy.

B. Safety

- Place the trolley and light gate far enough from the edge of the bench so that the trolley will stop on the bench.



C. Apparatus

- Trolley
- Runway
- Light gate

D. Procedure

- A trolley is held at the top of a track. The difference in height, Δh, of the trolley when it is at the top of the ramp and when it is on the horizontal board is measured.
- The trolley is allowed to run down the ramp onto the horizontal board, and it cuts through the light gate.
- The speed, v, of the trolley and masses is found by measuring the time, Δt, for the card (width Δx) to cross the light gate:

$$v = \frac{\Delta x}{\Delta t}$$

- The experiment is repeated several times and an average value of v is found. If the mass of the trolley is known, the loss in potential energy and the gain in kinetic energy can be calculated.

$$\Delta GPE = mg\Delta h$$

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

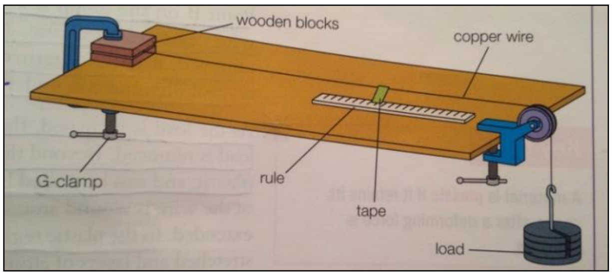
E. Validity of the study and improvements

The values of ΔGPE and ΔKE should be equal, but experimental uncertainties and work done against air resistance and the friction in the bearings are likely to affect the readings.

5-Force-extension experiments

A. Introduction

A thin copper wire is clamped between wooden blocks at one end of a bench and passed over a pulley wheel at the opposite end of a bench as shown in the diagram.



B. Safety

- It is important that safety glasses are worn to reduce the risk of eye damage when the wire breaks.
- Place a tray continuing sand or foam rubber beneath the weights to prevent them falling on your feet should they fall.

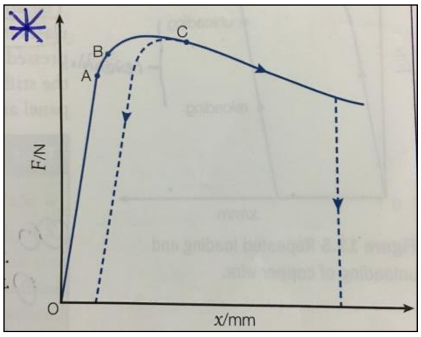
C. Apparatus

- Bench pulley
- G clamp
- Lengths of copper wire
- Metre ruler
- Set of slotted masses
- Tape
- Two wooden blocks
- A piece of sponge

D. Procedure

- A weight hanger is attached to the wire close to the pulley.
- A metre rule is fixed to the bench and a strip of sticky tape is attached to wire at the lower end on the metre scale.
- The length of the wire from the fixed end to the tape is measured using a tape metre. (This gives the original length.)
- Weights are placed on the hanger in 2N increments.
- Extensions are read using the attached rule.
- Loads should be added until the wire breaks.
- A graph of force against extension is plotted.

E. REPRESENTATION OF DATA



F. VALIDITY OF THE STUDY AND IMPROVEMENTS

- The extensions of the wire depend on its length in addition to the load. A short wire will give very small extensions even for large loads. These will be difficult to measure and lead to large percentage uncertainties in the values. Typically, a length of two to three metres of copper wire is needed to give extensions of several centimetres for the maximum applied load.
- If there is a gap between the marker and the scale there is a possibility of parallax error. If the marker is viewed from different angles, the scale reading will vary. If the marker touches the scale there will be no parallax error.

G. CONCLUSION

The wire obeys the Hooke's law up to a certain limit. This is illustrated by the initial linear region (OA) of the graph. Then, it starts to deform plastically retaining its ability to contract back up to a limit and it never turns back to its original dimensions once the elastic limit is passed.

Interpretation of C: The wire still has some elasticity and contracts when the load is removed. However, there has been some plastic flow resulting in a permanent deformation of the wire.

6-Measurement of the Young modulus

A. Introduction

The aim of this experiment is to measure the Young modulus for a material.

B. Safety

- Eye protection should be worn at all times while conducting this experiment.
- Suspended masses should be arranged close to the floor.
- A piece of sponge should be placed beneath the hanging masses.

C. Apparatus

- Bench pulley
- G clamp
- Copper wire
- Metre ruler
- Set of slotted masses
- Tape
- Two wooden blocks
- Piece of sponge

D. Procedure

- A weight hanger is attached to the wire close to the pulley.
- A metre rule is fixed to the bench and a strip of sticky tape is attached to wire at the lower end on the metre scale.
- The length of the wire from the fixed end to the tape is measured using a tape metre. (This gives the original length.)
- The diameter of the wire is measured using a micrometer.
- Weights are placed on the hanger in 2N increments.
- Extensions are read using the attached rule.
- Loads should be added until the wire breaks.
    - Safety note: It is important that safety glasses are worn to reduce the risk of eye damage when the wire breaks. Place a tray continuing sand or foam rubber beneath the weights to prevent them falling on your feet should they fall.
- Using measurements stress and strain for each different force applied is calculated using the equations:

$$stress = \frac{F}{A}$$

$$strain = \frac{\Delta l}{l}$$

- A stress against strain graph is drawn.
- The gradient of the graph equals Young modulus.

E. DATA

Force/N	Extension/mm	Stress/Pa	Strain/%
0	0	0	0
5.0	0.5	3.0×10^6	0.017
10.0	1.0	6.0×10^6	0.033
15.0	1.5	9.0×10^6	0.050
20.0	2.0	12×10^6	0.067
25.0	2.5	15×10^6	0.083
30.0	3.0	18×10^6	0.100
35.0	4.0	21×10^6	0.133
40.0	6.0	24×10^6	0.200
35.0	300	21×10^6	10.0
30.0	750	18×10^6	25.0

F. REPRESENTATION OF DATA

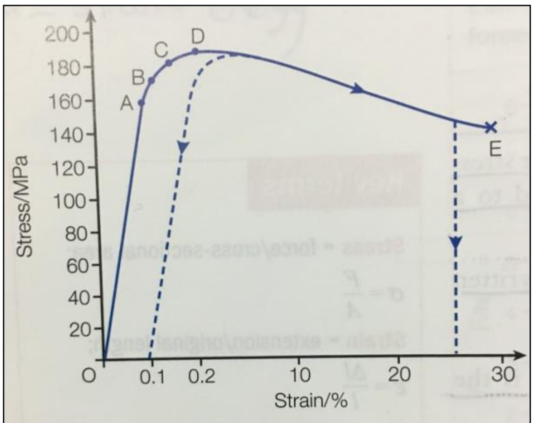


Figure 13.12 Stress-strain graph for copper wire.

G. VALIDITY OF THE STUDY AND IMPROVEMENTS

Choice of measuring instruments and their uncertainties

A metre rule is suitable for measuring the length of the wire. The uncertainty of the reading is:

$$\frac{\pm\, 0.005\ \text{m}}{3.000\ \text{m}} \times 100\% = \pm\, 0.2\%$$

A micrometer is needed to measure the diameter of the wire. It needs to measure a thickness of about 0.5 mm to a precision of +-0.01 mm. The uncertainty is:

$$\frac{\pm\, 0.01\ \text{mm}}{0.46\ \text{mm}} \times 100\% = \pm\, 2\%$$

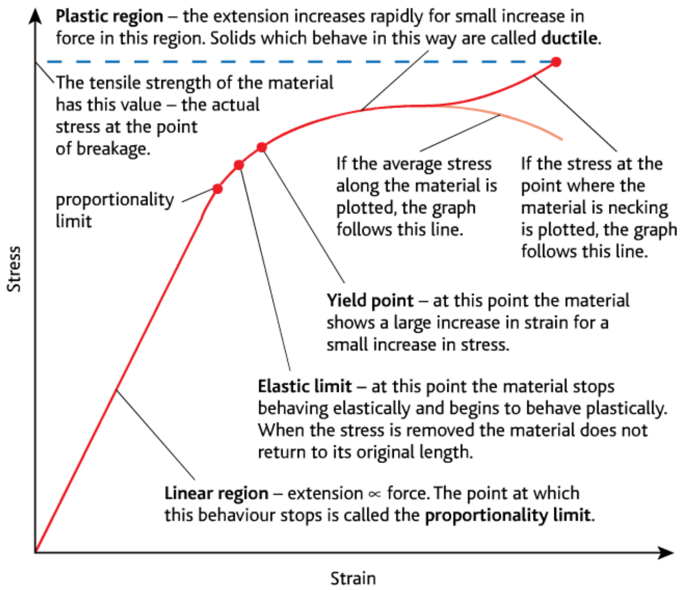
The extension needs to be measured over a range of 750 mm to a precision of +-0.5 mm, so a metre rule is used. The uncertainty in the measurements up to 6 mm is:

$$\frac{\pm 0.5\ \text{mm}}{6.0\ \text{mm}} \times 100\% = \pm 8\%$$

Improvements

- When measuring the diameter of the wire, check the zero error of the micrometer and take pairs of readings at right angles at several positions along the wire, to ensure the wire is uniform.
- When measuring extension, ensure that the edge of the marker tape is in contact with the scale so that parallax errors are avoided.
- To improve the accuracy of the experiment, the uncertainty in the extension reading could be reduced by a using a longer wire or by using a Vernier scale to measure the initial extensions.
- A thin wire is better used because it does not need such a large force to show extension.

H. CONCLUSION



Stress–strain curve for a metal.

7-Measuring the viscosity of a liquid

A. Introduction

The aim of this experiment is to measure the viscosity of a liquid.

B. Safety

- Wear gloves.
- Make sure there is proper ventilation. (Glycerol)
- Wear eye protection at all times while conducting the experiment.

C. Apparatus

- Micrometer
- Number of spheres
- Electronic balance
- Stopclock
- Meter stick
- Flexible pick-up tool
- 2l graduated cylinder filled with liquid glycerol

D. Procedure

- A large measuring cylinder is filled with glycerol. (Liquid must be transparent to allow falling spheres to be observed.)
- Draw lines around the cylinder at regular intervals of 5.0 cm.
- A small steel ball bearing is released into the liquid; the time for a ball for each level is taken by a stopwatch. If the ball is small and less sticky, the measurements will all be similar which indicates that terminal velocity is reached shortly after the sphere enters the liquid.
- The timings are repeated.
- Terminal velocity is calculated.

$$T = \frac{distance\ between\ markers}{average\ time\ taken\ for\ ball\ to\ fall\ between\ markers}$$

- Find diameter of the ball by using micrometer and calculate the radius.
- Calculate the density using the mass of one ball calculated by placing 10-100 balls on a balance. Density of the liquid needs to be found by taking the mass of a measured volume.
- Viscosity is calculated using the equation:

$$\eta = \frac{2(\rho_s - \rho_f)gr^2}{9v}$$

E. REPRESENTATION OF DATA

Plot a graph of v against r^2. This gives a straight line through the origin showing that v is directly proportional to r^2.

F. VALIDITY OF THE STUDY AND IMPROVEMENTS

- The temperature of the fluid should be kept constant.
- The greatest uncertainty is in the measurement of the time (particularly for the larger balls). To increase the time interval, and so reduce the percentage uncertainty, the distance between the marks could be made bigger (or smaller bearing used).

8- Refractive index of solids

A. Introduction

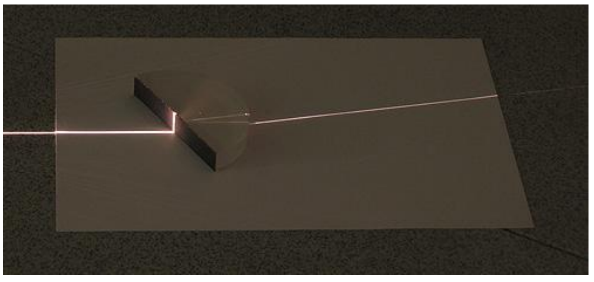
The aim of this experiment is to measure the refractive index of a glass block.

B. Apparatus

- Semicircular acrylic or Perspex block
- Sheet of white paper
- Protractor
- Ray box and suitable power supply

C. Experimental procedure

- Place the semicircular block on the sheet of white paper and draw round block.
- Remove the block and draw a normal line (a line at right angles) to the block so that it passes through the centre of the straight side of the block.
- Set up the ray box so that a ray meets the intersection of the normal line and the block.
- Mark a point on the incident ray and the refracted ray with a pencil at any position outside the block.
- Remove the block, join up the points to show the ray directions and measure the angle of incidence i and the angle of refraction r.
- Repeat the experiment for a number of different values of i.



D. Analysis

Draw a graph of sin i against sin r. Gradient equals the refractive index of the glass. It would be better to carry out the experiment in a dark room.

9-Refractive index of liquids

A. Introduction

The aim of this experiment is to measure the refractive index of a liquid.

B. Apparatus

- Liquids
- Tall beaker or gas jar with flat base
- Sheet of paper with writing on it
- Pot of cornflour
- Travelling microscope

C. Experimental procedure

- Place a sheet of paper on the table and focus on the writing using travelling microscope. Take the reading from the microscope scale. (d_1)
- Fill the beaker with one of the liquids, place it on the sheet of paper and focus on the writing viewed through the liquid. Take the reading from the microscope scale (d_2).
- Finally focus on the top of the liquid. Take the reading from the scale (d_3). It may be necessary to sprinkle a little fine powder on the liquid's surface to make it easier to focus on this.

D. Analysis

Calculate the refractive index of the liquid from:

$$\mu = \frac{Real\ depth}{Apparent\ depth} = \frac{d_1 - d_3}{d_2 - d_3}$$

You should ignore the effect on the refraction of the small thickness of glass between the liquid and the paper.

10- Melde's experiment

A. Introduction

The aim of this experiment is to investigate the standing waves and the factors that affect the frequency of vibrations on a stretched string. These factors are namely the length, tension and mass per unit length of the string.

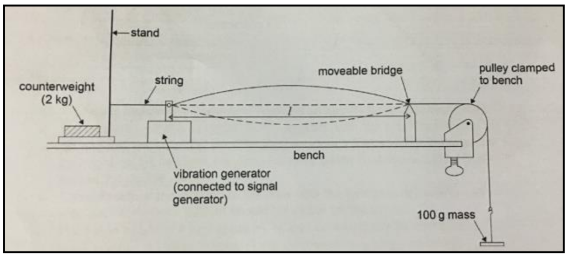
B. Safety

- To protect the signal generator do not turn the voltage up too high.
- To prevent electric shock do not turn the voltage up too high.
- Avoid frequencies in the range 5-30 Hz as they may trigger epileptic fits in some individuals.
- Use a G clamp to hold the vibration generator steady and to ensure it does not topple over.

C. Apparatus

- Vibration generator
- Elastic cord
- Set of slotted masses
- Signal generator
- Leads
- Bench pulley
- G clamp to hold the vibration generator steady

D. Procedure



A standing wave can be produced by connecting one end of the wire to a vibration generator so that the alternating current in the wire interacts with the magnetic field to make the wire vibrate with the frequency of the generator. The other end of the wire is passed on a moveable bridge and a pulley wheel. A weight hanger is attached to the hanging end of the wire. This creates tension on it. When the frequency of the alternating current equals the natural frequency of the wire, the wire vibrates with a large amplitude. This is called resonance. Other harmonics could also be investigated, however, they all have different equations for their speed and this practical is only related to the factors affecting the fundamental frequency.

The relationships between the frequency and length, tension and the mass per unit length can be investigated by keeping the two quantities constant and varying the third one. At the fundamental frequency of a spring, $\lambda = 2l$. It has one antinode and two nodes. The speed of a transverse wave moving along a stretched wire is given by: $c = \sqrt{\frac{T}{\mu}}$. Wave equation is $v = \lambda f$. Combining these:

$$f = \frac{v}{\lambda} = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

Frequency and length

- Weight on the hanger is kept the same.
- Position of the bridge is adjusted so that l is 1.50 m measured using the metre ruler.
- The frequency of the signal generator is increased from zero until the string resonates at its fundamental frequency.
- The frequency, f, is read on the signal generator dial.
- The procedure is repeated with shorter lengths. Length intervals should be uniform.
- The experiment is repeated at each length to obtain more sets of results and find the mean value of f for each value of l.
- A graph of mean f against $1/l$ is plotted.
- The gradient of the graph is $1/fl$ and $2/gradient$ gives the speed of the wave. (c=2fl)

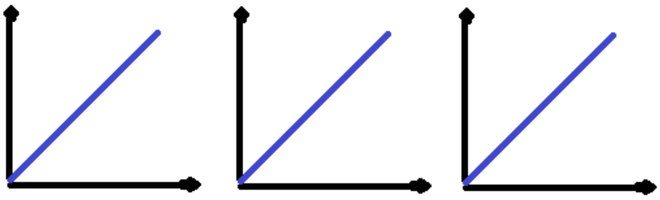
Frequency and tension

- The length of the wire is kept constant.
- The frequency of the signal generator is increased from zero until the string resonates at its fundamental frequency when a particular weight is attached on it.
- The frequency is recorded.
- The experiment is repeated for a range masses. Changing masses, changes the tension on the spring.
- The frequency of the vibration generator is adjusted so that the wire resonates at each tension.
- Corresponding frequencies are recorded for each weight.
- A graph of f against $\sqrt{T}$ or f^2 against T is plotted.

Frequency and mass per unit length

- Measure the length of each piece of wire using a metre rule and its mass on a digital balance. Calculate the mass per unit length of the wires.
- Clamp one end of one wire to the bench and feed the other over a pulley wheel and hold taut with a mass of 5.0 kg fixed to the end.
- Place two bridges under the wire with the poles of a magnet on each side of its mid-point.
- Connect the ends of the wire to a signal generator. Adjust the frequency of the signal generator until the wire resonates.
- Measure l and f.
- Repeat for the other wires keeping the length and tension the same.
- A graph of frequency squared against mass per unit length is drawn.

E. Representation of Data



F. Uncertainties

- Systematic error in the measurement of the length.
- Systematic error on the scale of the signal generator.
- Not allowing enough time for the frequency value on the generator to stabilise.

G. Conclusion

In conclusion, the length, tension and mass per unit length of the string affect the fundamental frequency. There is a direct proportion between the variables represented in the graphs since they are all linear and pass through the origin.

11- Effect of the concentration of sugar solution on the plane of polarisation of light

When polarised light passes through a sugar solution, the plane of polarisation rotates through an angle. The angle of rotation of the plane of polarisation depends on the concentration of the sugar solution. This angle of rotation can be measured using a polarimeter.

- Light from a LED is plane polarised by passing it through a polariser inside the polarimeter.
- Distilled water is put into the cell to check that the scale reading is zero when the filters are crossed and the light-emitting diode (LED) blacked out.
- A number of sugar solutions of different concentrations are prepared.
- The polarising filter is rotated until minimum or maximum intensity. (The upper filter is rotated until the light source disappears.
- The angle of rotation is measured for all the known concentrations.
- A graph of the angle of rotation against the concentration is plotted and used to find the values for unknown concentrations.

Uncertainties:

- Inaccurate concentration of solution.
- Systematic error in the polarimeter.
- Random error with using the polarising filter.

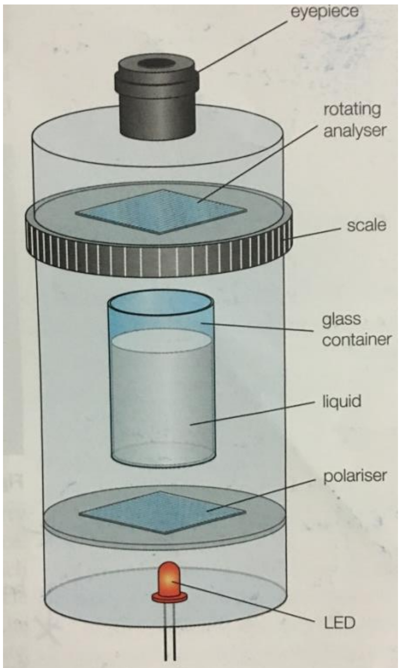


Figure 15.25 Polarimeter.

12- Current and voltage in series and parallel circuit

A. Introduction

The aim of this experiment is to investigate the current and voltage in series and parallel circuits.

Series circuit

Current: The current flowing through each component connected in series is the same. That is due to the conservation of charge.
Potential difference: The potential difference across each component connected in series is different and depends on their resistance.

Parallel circuit

Current: The current flowing through each component connected in series is different and depends on their resistance.
Potential difference: The potential difference across each component connected in series is the same.

B. Safety

Do not use high voltages. → It is essential to start the variable resistor at its maximum value so that the pd across (or the current in) the lamp is a minimum. The resistance of the variable resistor can then be gradually reduced until the current in the lamp is sufficient to make it glow brightly. If it is done the other way round, the bulb would burn out.

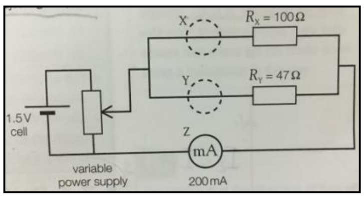
C. Apparatus

- Ammeter
- Voltmeter
- Connecting wires
- Battery
- Resistors

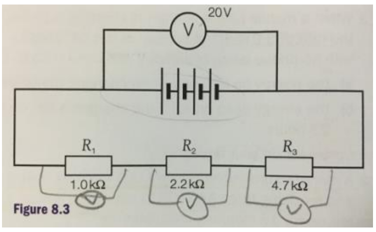
D. Procedure

Investigation of current

- Series: A series circuit is set up and the ammeter is moved to different positions.
- Parallel: The parallel circuit shown is set up. The variable power supply is adjusted so that the current I_Z at Z is a particular low current value. Without altering the power supply, the current is measured, in turn, at points X and Y. This procedure is then repeated by adjusting the power supply to get further values of I_Z and corresponding I_X and I_Y.



Investigation of potential differences in a circuit



- The circuit shown is prepared.
- The emf of four cells is determined.
- The voltmeter is then connected across each of the resistors R_1, R_2 and R_3 and the corresponding potential differences recorded. The sum of pd is then calculated.
- The experiment is repeated using three cells instead of four.

E. Validity of the study and improvements

The values of resistors are only nominal values and that there is a manufacturing tolerance of probably 2%-5%.

F. Conclusion

Investigation of current

- Series: The current is the same wherever the ammeter is in a series circuit. By the conservation of charge, the rate of flow of charge must be the same throughout a series circuit because there is nowhere else for the charge to go.
- Parallel: It is found that, allowing for experimental error, $I_Z = I_X + I_Y$ in all cases. This is an example of the conservation of charge – the rate of charge flowing out of a junction must always equal the rate at which it enters the junction because charge cannot be lost or gained.

Investigation of potential differences in a circuit

Within experimental error, it is found that, $V = V_1 + V_2 + V_3$. This shows that the sum of the energy per unit charge converted in each resistor is equal to the energy per unit charge produced by the cells. As the resistors are in series with the cells, the current, or the rate of flow of charge is the same in each component. The amount of energy converted in the resistors is therefore equal to the amount of energy produced by the cells. This is an example of the fundamental law of conservation of energy.

13- Ohmmeter and the total resistance of circuits

A. Introduction

The aim of this experiment is to investigate the use of an ohmmeter to measure the total resistance of series and parallel circuits.

Resistors in series: At any point in a circuit, the charge flowing in must be the same as the charge flowing out. When resistors are joined in series, the current is the same through all of them. The total energy supplied per coulomb of charge is converted by the resistors. Therefore, the sum of the individual pds across each resistor is equal to the total pd applied.

$$V_{total} = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$$
$$R_{total} = \frac{V}{I} = R_1 + R_2 + R_3$$

Resistors in parallel: When resistors are joined in parallel, the total current into any junction is equal to the sum of the currents coming out. The pd across each resistor is equal to the pd applied.

$$I_{total} = I_1 + I_2 + I_3 = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$
$$\frac{I_{total}}{V} = \frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

B. Safety

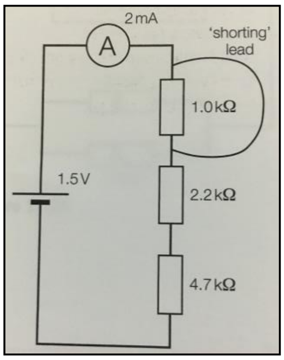
- Care must be taken not to short-circuit all the resistors at once otherwise cell will get hot
- Low pd/current, so no danger of electrocution
- Resistor may get hot, so handle with care.

C. Apparatus

- Ohmmeter
- Circuit board or crocodile clips
- Resistors
- Leads

D. Procedure

Series:



- The circuit shown is set up. The ammeter should be set on the 2 mA range.
- The circuit current, I, recorded by the ammeter is the current combination of the three resistors in series.
- A spare lead is connected across one of the resistors so that it is 'short-circuited'. In effect, a 'bypass' has been built for the current so that there is no current (or at least a negligible amount) in the resistor.
- This is then repeated to get values of resistance for all possible series combinations of the resistors.

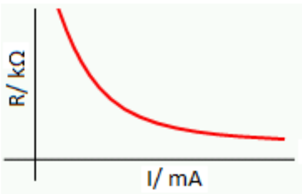
- A graph of R against I is drawn.

Parallel: The same steps are repeated, but this time for a parallel circuit.

E. Data

R/ kΩ	7.9	6.9	5.7	4.7	3.3	2.2	1.0
I/ mA	0.19	0.22	0.26	0.32	0.45	0.68	1.50

F. Representation of Data



G. Validity of the Study and Improvements

Possible sources of error may arise as a result of:

- Meter errors
- Contact resistance
- Resistor values being only nominal
- The cell running down

H. Conclusion

The equations stated in the introduction section have been proven.

14- I – V characteristics for a tungsten filament lamp

A. Introduction

The aim of this experiment is to investigate how the current through a circuit varies with applied voltage with a filament lamp.

Resistance of metallic conductors increases with increasing temperature. This is the case in a filament lamp, where the gradient of the I-V graph is not constant.

In terms of the transport equation, $I = nAvq$, **A and q are constant** for a given wire. For a metallic conductor, n does not depend on the temperature and so **n is also constant**. As the temperature rises, the increased vibrations of the lattice will reduce the drift velocity, v, of the electrons and so I will also decrease – that is, the resistance increases with temperature.

Metallic conductors are, therefore, referred to as having positive temperature coefficient. A material has a positive temperature coefficient if its resistivity increases when its temperature increases.

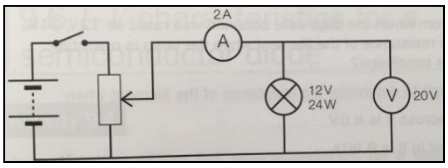
B. Safety

- It is important to start with the power supply set to its minimum value so that the lamp starts with the lowest current and is then gradually heated up as the current is increased. It also prevents the possibility of blowing the filament of the lamp, should the voltage increase too much.

C. Apparatus

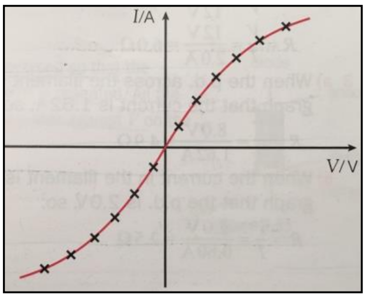
- Filament lamp
- Ammeter (0-5 A)
- Voltmeter (0-10 V)
- Variable voltage
- Dc power supply
- Current limiting resistor

D. Procedure



- The circuit shown is set up with the voltage from the power supply set at its minimum value.
- The circuit is switched on and the p.d. is gradually increased. The p.d., and corresponding current are recorded at intervals up to a maximum p.d.
- A graph with I on the y-axis against V on the x-axis is then drawn.
- After at least five minutes have elapsed, the power supply connections are reversed.
  - Time is allowed for the filament to cool down.
- Experiment is repeated for the negative values and these are added to the graph.

E. REPRESENTATION OF DATA



F. SOURCES OF INACCURACY

- The cell has internal resistance.
- Connecting wires also have a resistance.
- Zero errors in the ammeter and voltmeter.

G. CONCLUSION

As the current increases, the filament heats up and its resistance increases. This can be deduced from the graph by observing that the rate at which the current increases with voltage gets less as the voltage increases. This means that the resistance must be getting greater and that is because resistance is equal to the inverse of the gradient of a I – V graph.

15- I – V characteristics for a semiconductor diode

A. Introduction

The aim of this experiment is to investigate how the current through a circuit varies with applied voltage with a semiconductor diode.

Diodes let current flow only in one certain direction and they let current pass through after a certain value.

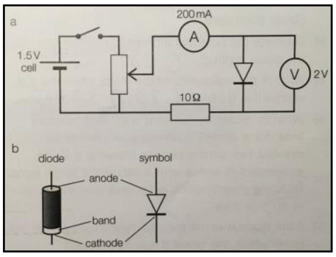
B. Safety

- It is important to start with the power supply set to its minimum value so that the lamp starts with the lowest current and is then gradually heated up as the current is increased. It also prevents the possibility of blowing the filament of the lamp, should the voltage increase too much.
- Make sure that you keep within the voltage – current limitations of the diode.

C. Apparatus

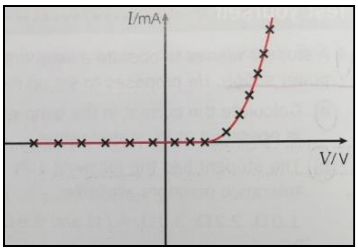
- Semiconductor diode
- Milliammeter (0-100 mA)
- Voltmeter (0-10 V)
- Variable voltage
- Dc power supply
- Current limiting resistor

D. Procedure



- The circuit is set up as shown in the figure. It is essential to observe the polarity of the diode.
- The diode is said to be forward biased when connected this way around.
- The resistor is included to limit the current in the diode and prevent is being damaged.
- The circuit is switched on and the p.d. is very slowly increased. Values of I and V up to the maximum current obtainable are recorded.
- The power supply connections are now reversed so that the diode is reverse biased and the experiment is repeated. A graph of I against V is drawn.

E. REPRESENTATION OF DATA



F. SOURCES OF INACCURACY

- The cell has internal resistance.
- Connecting wires also have a resistance.
- Zero errors in the ammeter and voltmeter.

G. CONCLUSION

Past a certain voltage, the resistance of a diode drops very steeply provided that it is forward biased.

16- I – V characteristics for a NTC thermistor

A. Introduction

The aim of this experiment is to investigate how the current through a circuit varies with applied voltage with a NTC thermistor.

NTC thermistors have a negative temperature coefficient. A material has a negative temperature coefficient if its resistivity. A negative temperature coefficient can also be explained using $I = nAvq$. In a semiconductor, an increase in temperature can provide extra energy to release more charge carriers. So, n increases and it increases exponentially with temperature. A and q are constant s before but n increase much more than the relatively small decrease in v. The overall effect is that I increases, so that resistivity decreases with temperature.

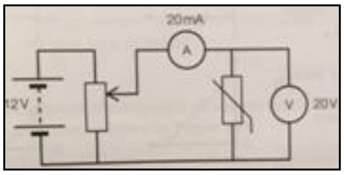
B. Safety

- It is not advised to use high currents because there is a danger that the thermistor may over-heat and get damaged. When the current increases, the resistance gets less and so the current will get even bigger. The temperature will therefore increase, causing a further decrease in resistance, and so an even greater increase in the current and so on… This can produce what is known as thermal runaway.

C. Apparatus

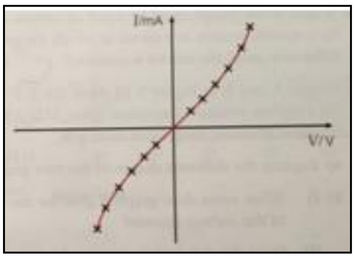
- NTC thermistor
- Milliammeter (0-100 mA)
- Voltmeter (0-10 V)
- Variable voltage
- Dc power supply
- Current limiting resistor

D. Procedure



- The circuit shown is set up, with the voltage from the power supply set at its minimum value.
- The circuit is switched on and the p.d. is gradually increased. Value of I are recorded at regular intervals of p.d.
- A graph with I on the y-axis against V on the x-axis is drawn.
- After at least five minutes have elapsed, the power supply connections are reversed and the experiment is repeated, remembering to start with the minimum p.d. as before. Negative values are also added to the graph.

E. Representation of data



F. Validity of the study and improvements

- The cell has internal resistance.
- Connecting wires also have a resistance.
- Zero errors in the ammeter and voltmeter.

G. Conclusion

Resistance values indicate that the resistance of the thermistor gets less as the current increases. This is because the current causes the thermistor to warm up and the resistance of a thermistor decreases with temperature. This is illustrated by the shape of the graph; as the current increases, the line curves upwards. This means that the rate of increase in current is increasing, i.e. the resistance is decreasing. ($V = IR$)

17- The resistance of a thermistor

A. Introduction

The aim of the experiment is to investigate how the resistance of an NTC thermistor changes with temperature. The hypothesis is that as temperature increases the resistance of the thermistor decreases.

B. Safety

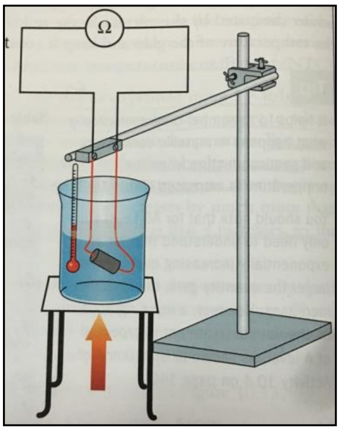
- Take care not to spill the beaker, the water will be hot.
- The wires will heat up after a while.
- Wear eye protection – safety goggles.

C. Apparatus

- NTC thermistor connected to leads that have been insulated with silicone jelly
- Beaker of water
- Thermometer (0-100 °C) or temperature sensor
- Ohmmeter or:
- Variable voltage dc power supply (0-6 V)
- Milliammeter (0-100 mA)
- Dc voltmeter (0-6 V)
- Bunsen burner, tripod, gauze and mat
- Set of connecting leads

D. Procedure

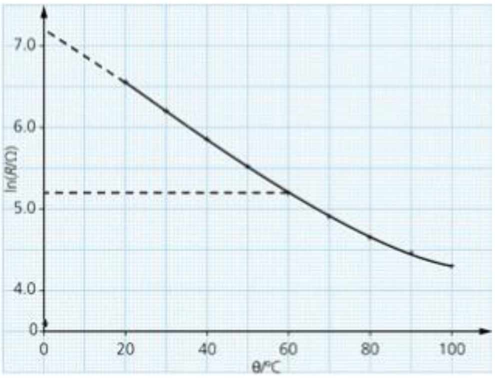
- The investigation is started with thermistor immersed in crushed ice.
- The beaker of ice is now heated up, ensuring that the leads are kept away from the flame and hot gauze.
- At intervals of about 10 °C, the Bunsen burner is taken away and the water is stirred thoroughly before the temperature and corresponding resistance are recorded.
- This is continued every 10 °C until the water boils.
- The results are tabulated and a graph of R against θ is plotted.



E. Data

θ/ °C	20	30	40	50	60	70	80	90	100
R/ Ω	706	491	350	249	179	135	105	87	74

F. REPRESENTATION OF DATA



G. UNCERTAINTIES

- Simultaneous reading of two variables
- Systematic error on thermometer
- Parallax error of scale readings
- Meter zero error
- Uneven temperature in liquid

H. CONCLUSION

It can be deduced from the graph that the resistance initially falls very rapidly as the temperature increases. The rate of decrease of resistance then gradually gets less and less.

As the resistance gets less as the temperature increases the thermistor must have a negative temperature coefficient of resistivity.

18- Resistivity of a metal and polythene

A. Introduction

The aim of this experiment is to measure the resistivity of a metal in the form of wires and that of a polythene strip. Resistivity is a measure of the resisting power of a specified material to the flow of an electric current. Polythene is thought to have a greater resistivity.

B. Safety

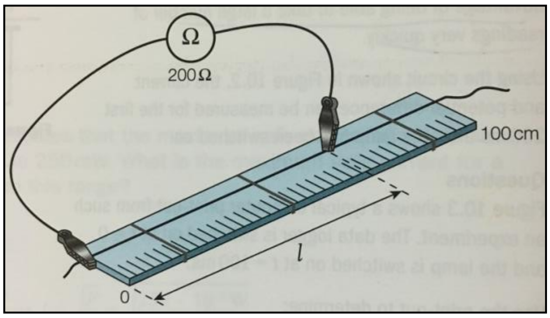
- Wires might get hot.
- A variable resistor is advised to limit the current.

C. Apparatus

- 1.1 m lengths of wire
- Multimeter
- Two crocodile clips
- 4 mm connecting leads
- Metre ruler
- Micrometer screw gauge
- Strip of polythene

D. Procedure

- Measuring resistance
- Measuring length of wire with metre rule
- Measure diameter with micrometer. Readings should be taken at different places to average out any non-uniformity along the length of the pencil lead and at different angles to average out any non-uniformity in the circular cross-section of the lead.
- Calculate the area of cross-section of the wires by using πr^2
- $Resistivity\ (r) = \frac{resistance\ (R) \times area\ (A)}{length\ (L)}$
- This experiment could be repeated for different lengths to produce resistance against length graphs. Crocodile clips may be used to change length. One crocodile clip is kept fixed at the zero end of the wire, while the other is pressed firmly on the wire to make contact at different lengths along the wire. The gradient of the graph is multiplies with area to calculate the resistivity.
- It could also be repeated with wires of different thickness to produce resistance against area of cross-section graphs.



E. SOURCES OF UNCERTAINTY

- Small diameter or diameter only measured once
- Any zero error
- Kinks in the wire
- Contact resistance
  - Before taking any readings, the moveable crocodile clip should be touched firmly on the crocodile clip at the zero end of the rule to check for any contact resistance or any zero error in the meter.
- Resistance of connecting wires

F. CONCLUSION

The metal wire has a lower resistivity than the polythene strip because the metal is a conductor with a lower resistance whereas polythene is an insulator with a much higher resistance.

Resistivity increases with length – if the wire is longer, it will be more difficult for the electrons to drift from one end to the other.

Resistivity decreases with increasing cross-sectional area of the wire – if the wire has a larger cross-sectional area, it will be easier for the electrons to flow.

19- The emf and internal resistance of a cell

A. Introduction

The aim of this experiment is to find the emf and internal resistance of a cell. The electromotive force of an electrical source is defined as the energy per unit charge converted into electrical energy by the source. The internal resistance of a cell, or other power supply, opposes the flow of charge through the cell. Some of the energy converted by the cell, or power supply, will be used up inside the cell to overcome this resistance.

B. Safety

- Low pd/ current/ power, so no danger of shock (electrocution).
- Solar cell/ variable resistor/ protective resistor/ lamp may get hot, so handle with care.
- Ensure cell is not short-circuited otherwise cell will get hot.

C. Apparatus

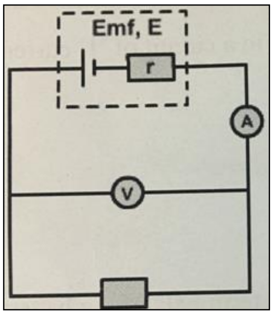
- Two digital multimeters (Milliammeter (100 mA-1A) and voltmeter(5V))
- Cell
- Variable resistor
- Connecting leads

D. Procedure

- Starting with the variable resistor at its highest value (to minimise any heating effects), the current, I, in the cell and the potential difference, V, across its terminals are recorded for different settings of the rheostat (variable resistor).
- Rearranging, $V = \varepsilon - Ir$:

$$V = -Ir + \varepsilon$$

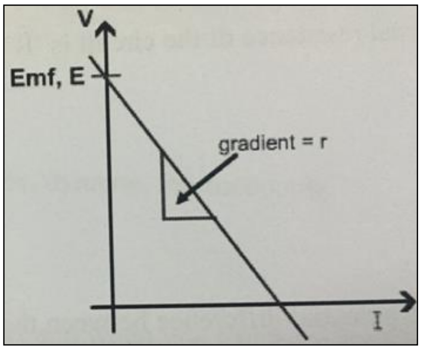
- A graph of V against I is plotted, we would expect to get a straight line of gradient –r and intercept ε on the y-axis. (In practice, the line may not be straight because the internal resistance may not be constant – particularly for large currents.



E. Data

I/A	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60
V/V	1.44	1.32	1.20	1.09	0.95	0.84	0.73	0.59

F. REPRESENTATION OF DATA



G. SOURCES OF UNCERTAINTY

- Zero error in meter
- Parallax error
- Fluctuating reading on digital meter

H. CONCLUSION

Cells have an internal resistance so work needs to be done to overcome this resistance. Therefore, emf is always greater than the potential difference.

20- Flow of electrical charge

A. Introduction

The aim of this experiment is to investigate the velocity of charged ions in an electric field. This is of the same order as the drift velocity of electrons in a wire under the influence of the same field.

B. Safety

- The dc voltage must not exceed +40V.
- Use plastic forceps to handle the potassium manganate (VII) crystals.
- Potassium manganate is an oxidising agent.
- Eye protection (safety goggles) should be worn.
- Gloves should be worn.
- Avoid short-circuiting.

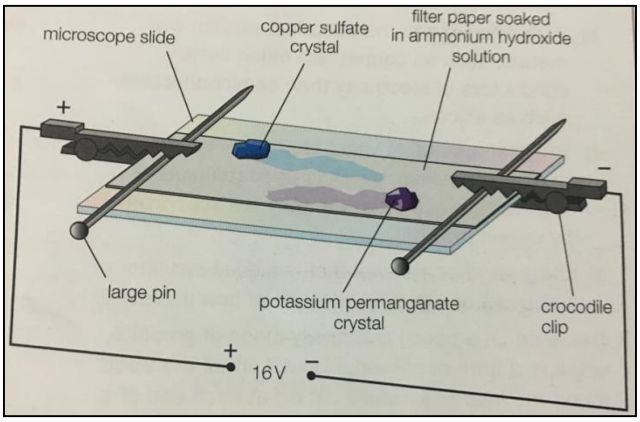
C. Apparatus

- Dc power supply (0-40 V)
- Two digital in multimeter
- Microscope slide
- Retort stand
- Two crocodile strips
- Wooden block
- Leads
- Filter paper
- Scissors
- Potassium manganate (VII) crystals
- Beaker of water
- Stop clock
- 30 cm ruler
- Plastic forceps

D. Procedure

- Soak the filter paper with water.
- Using the forceps place one crystal of potassium manganate (VII) on the paper between the crocodile clips.
- Switch on the power supply and adjust it to about 25 V.
- Measure how long it takes for the ion colour to drift one centimetre. Hence work out the velocity of the ions.
- The milliammeter is used simply to check that the current is not too large.
- (Repeat this for a series of voltages between 10 V and 40 V.

E. Representation of Data



F. Conclusion

Potassium manganate (VII) ions have a negative charge and therefore they drift towards the positive terminal. It is found that the drift speed is very slow.

21- Potential along a wire

A. Introduction

The aim of this experiment is to measure the variation of potential along a wire carrying current by varying the length of the wire.

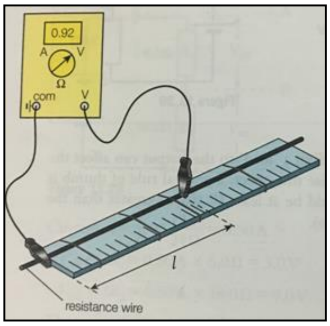
B. Safety

- Low pd/ current/ power, so no danger of shock (electrocution).
- Wire may get hot, so handle with care and if the ruler is wooden it might catch fire.
- Ensure cell is not short-circuited otherwise cell will get hot.

C. Apparatus

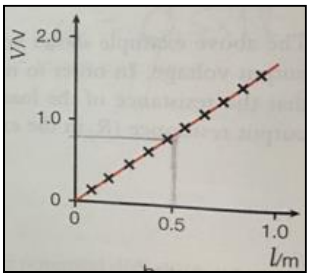
- 1.1 m length of wire
- Two multimeters
- Battery or low voltage supply
- Three crocodile clips
- Connecting leads
- Wood or plastic metre ruler

D. Procedure



- Wire is taped to a metre rule.
- A 1.5 V cell is connected across the wire.
- A digital voltmeter, set on the 2 V dc range, has its common terminal connected to the zero end of the wire. A long lead terminating in a crocodile clip is connected to the volts terminal.
- The zero end of the wire has is at a potential of 0 V.
- The potential at different points along the wire can be read off from the voltmeter at 10 cm intervals by touching the wire firmly with the crocodile clip.
- A graph of potential difference, V, against the length, l, along the wire can then be plotted.

E. Representation of data



F. Sources of uncertainty

- Contact resistance
    - Before taking any readings, the moveable crocodile clip should be touched firmly on the crocodile clip at the zero end of the rule to check for any contact resistance or any zero error in the meter.
- Any zero error.
- Fluctuating values in the multimeters.

G. Conclusion

The straight line through the origin obtained shows that the potential difference along the wire is proportional to the distance along it, which is the principle of rheostat when it is being used as a potential divider.

22- Efficiency of an electric motor

A. Introduction

The aim of this experiment is to measure the efficiency of an electric motor.

B. Safety

Place a piece of sponge beneath the hanging masses.

C. Apparatus

- Low voltage electric motor on stand
- Suitable power supply
- Leads
- Thread or string
- Set of slotted masses
- Metre ruler
- Ammeter
- Voltmeter

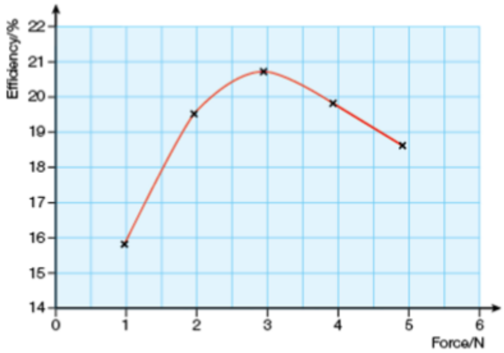
D. Procedure

- The power supply is adjusted so that the motor can lift a mass of 100 g through a height of about 1 m in a few seconds.
- The time, t, that it takes to lift the mass, m, thorough a measured height, h, is measured and the corresponding pd, V, and current, I, are recorded in a table.

E. Data

V/ V	I/ A	Power in, IV/ W	Force, mg/ N	Height, h/ m	Time, t/ s	Power out $\frac{mgh}{t}$	Efficiency, $\frac{P_o}{P_i} \times 100\%$
6	0,24	1,44	0,98	0,95	4,1	0,227	15,8
5,9	0,28	1,65	1,96	0,95	5,8	0,321	19,4
5,8	0,31	1,80	2,94	0,95	7,5	0,372	20,7
5,6	0,36	2,02	3,92	0,95	9,3	0,400	19,9
5,4	0,40	2,16	4,90	0,95	11,6	0,401	18,6
		A2*B2				(D2*E2)/F2	(G2/C2)*100

F. REPRESENTATION OF DATA



G. CONCLUSION

The graph shows that the efficiency is dependent on the load and that the motor has maximum efficiency for a load of about 3.0 N. The low efficiency is due to some electrical energy in the motor being transferred as internal energy in the coils and some of the output is used as work against resistive forces.

23- Investigating the photoelectric effect

A. Introduction

A phototube can be used to investigate the photoelectric effect by connecting a variable potential difference across it and measuring the current in it with a very sensitive ammeter.

B. Safety

- Exposure to UV light is harmful.

C. Apparatus

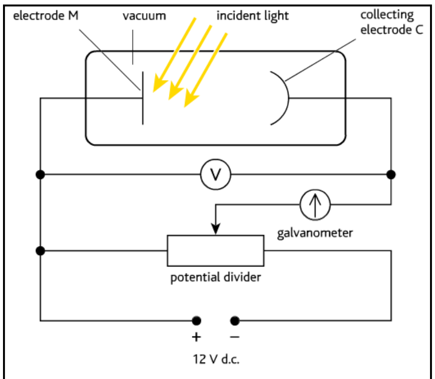


fig. 5.1.8 Apparatus for the investigation of the photoelectric effect. This apparatus also enables a value for Planck's constant to be obtained.

D. Procedure

- Light of a known frequency is shone onto a metal electrode M. Photoelectrons from M travel towards a collecting cathode C and then flow round the external circuit through the galvanometer.
- The maximum kinetic energy of the ejected electrons can be found by applying a potential difference across C and M, making C negative with respect to M.
- As this potential difference is increased by means of the potential divider, the number of electrons reaching C from M will decrease as fewer and fewer electrons have sufficient energy to overcome the potential barrier.
- Eventually the potential difference will be such that even the most energetic electrons will just fail to reach C. This potential is called the stopping potential, V_{stop}.
- The measured value of this stopping potential gives the maximum kinetic energy of the electrons:

$$\frac{1}{2}mv_{max}^2 = eV_{stop}$$

- Using an apparatus like this, the frequency of the incident light may be varied and the maximum kinetic energy of the electrons found from the stopping potential.

E. REPRESENTATION OF DATA

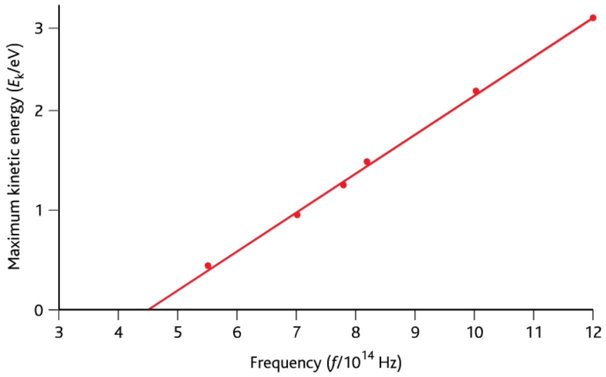


fig. 5.1.7 This graph shows the maximum kinetic energy for photoelectrons emitted from caesium by light of different frequencies. The energy is given in units of electronvolts (eV).

F. UNCERTAINTIES

- Systematic error/ zero error on voltmeter
- Parallax error of analogue voltmeter
- Random errors in voltmeter reading
- The vacuum is not perfect
- Wavelength of light is not checked

G. CONCLUSION

Measuring the stopping potential enables us to determine the maximum kinetic energy of the photoelectrons.

Rearranging,

$$hf = \frac{1}{2}mv^2 + \emptyset$$

gives,

$$\frac{1}{2}mv^2 = hf - \emptyset$$

Assuming that this is equivalent to y= mx + c,

- Planck constant, h, will be the gradient of the graph.
- Work function, $-\emptyset$, will be the y-intercept.
- Threshold frequency, f_0, will be the x-intercept.