



DATA HARVEST

Committed to Science and Technology



GCSE Required Practical Activities

Introduction

These worksheets are designed to work with the new practical skills assessment for GCSEs in England. They have been written to show how data logging can, and should, be incorporated into the practical skills. In many cases there will be a gain in efficiency by adopting a data logging practical, for example using multiple modern dynamics systems and low friction trolleys with a data logger to replace a single air track or old heavy wooden ramps and ticker timers.

All the practical activities have been tested and proven to have advantage over more traditional methods and apparatus. They should not require the purchase of additional apparatus if data logging is already incorporated into lesson plans and schemes of work

The style has been influenced by the spirit of the examination boards' exemplar materials and assumes the students have been exposed to similar practical as well as the data logging hardware and software. Instructions are therefore deliberately brief to allow full assessment of the student in the skills indicated on each worksheet. Skills indicated are not absolute and small changes to the detail and focus of the activity could change the skills that are assessable for a given activity. Teacher's guidance is provided.

We would hope that with the guidance given that you will be inspired to consider other practical work outside the published lists of the examination boards and make data logging as natural to use in a practical as a Bunsen, test tube or electronic balance.

If teaching worksheets are required they are available for purchase from Data Harvest in a set of 7 volumes of practical activities with full descriptions of set up, apparatus and use of the software. Additionally full manuals for the software, data loggers and sensors are available on the original software installation CD or as individual downloads from www.data-harvest.co.uk.

With the large variation in school practical apparatus it is essential that pre-trialling of the activities takes place and the instructions modified accordingly.

Risk assessment(s)

Risk assessment and risk management are the responsibility of the school.

Simple advice and indicated risks are highlighted but the adopted policy and policy documents of the school, trust or authority will be the guiding principle.

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Teacher's notes: GCSE Physics required practical activity (1)

Specific Heat Capacity

This practical will determine the specific heat capacity of one or more materials.

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT5 Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done.

Apparatus

1. Temperature sensor
2. Current sensor ± 10 A
3. Voltage sensor ± 12 or 20 V
4. d.c. power supply
5. Rheostat
6. 4 mm leads
7. Metal block calorimeter (2 holes, one for heater and one for Temperature sensor)
8. There should be selection of blocks e.g. iron, aluminium, copper, steel, lead
9. A heating coil
10. Pipette
11. Lagging
12. Electronic balance
13. Balance (capable of weighing the blocks being used, i.e. +1 kg)

Risk assessment

- Check mains leads and heater connections
- The heater will get very hot if left outside the block
- The blocks if left unattended could become very hot

It is the schools responsibility to complete a risk assessment according to the local policy.

Practical notes

The energy input into the metal block will be calculated from the voltage and current used to power a heater immersed into the heating chamber. To ensure heat transfer from the heater to the metal block, the space surrounding the heater is filled with a heat conducting material with a high boiling point. Water, glycerol or oil is suggested. The software is used to calculate the electrical power from the voltage and current graphs. The area under the power vs. time curve will produce watts per second which will be equal (in this case) to the energy.

The blocks are sold as calorimeter blocks and have a nominal mass of 1 kg. A balance will be required to find the exact mass. The holes bored into the blocks for the heater and thermometer are quite snug but will have a small airgap. It is suggested that something like oil, water or glycerol is used to fill the small void and make good thermal continuity between the heater, thermometer and block.

For simplicity of calculations a temperature rise of 10 degrees is worth aiming for. In reality, it does come down to how much time you have available. Factor in the time lag between turning the power off and the maximum temperature being reached. There will be a lag before a temperature rise is detected and before peak temperature is reached after disconnecting the power.

The current drawn by a heater can be large; this is why a ± 10 A Current sensor is suggested. Experience of your apparatus may mean you can substitute this sensor for a lower ranged device. Heaters for the blocks have a power rating, typically, of 30 W.

A d.c. power supply is suggested as Voltage sensors are being used. The sensor will record the voltage every 30 ms – 10 ms, with an a.c. voltage you will get a “pseudo sine wave” which will make results difficult to interpret.

Set up

The timing of the investigation is open ended so use **EasyLog**. This will record the voltage, current and temperature data until the user intervenes and stops the logging.

Recording method
EasyLog

If you are confident with the apparatus you may prefer to use a setup that records data every xtime period. For example to set up a data recording for a measurement every 30 seconds,

Recording method	Recording time	Intersample time
Graph	> 5 minutes	30 seconds

Results

Students will be required to plot a graph of work done vs. temperature.

Students will have voltage, current, temperature and time data. From this data they can calculate power, work. The data logger will have recorded more data than is required for the plot. Students will have to decide at what time frequency they will use the data for the graph plot.

There is a lag in the heating. The graph will show a curve initially; once the block has evenly warmed the data will become more linear.

Students will use the curve and mass of the block to work out the specific heat capacity.

Background information

The heat capacity of a substance is the work done raising the temperature of a substance by 1 degree Kelvin / Celsius. Heat capacity is per unit mass (per kg) and is the specific heat capacity (i.e. the energy required to raise the temperature of a kg of the material by 1 K (kelvin).

	Copper	Aluminium	Iron	Lead	Steel
Values quoted for Specific heat capacity ($\text{J kg}^{-1}\text{K}^{-1}$)	384, 385, 386	897, 900, 902, 904, 913	448, 449, 450, 500	126, 128, 127, 129, 130	420, 466

Student sheet: GCSE Physics required practical activity (1)

Specific Heat Capacity

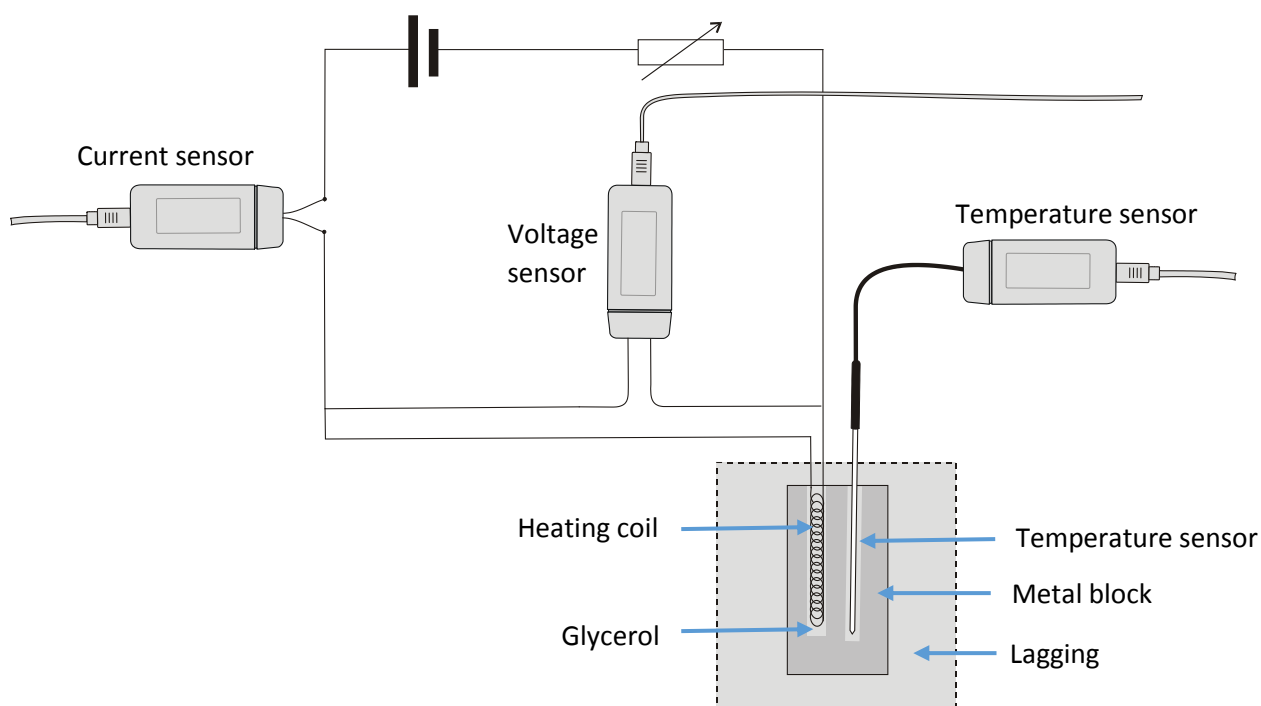
This practical will determine the specific heat capacity of one or more materials.

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects

AT5 Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done.

In this activity you will heat up a metal block calorimeter using an electrically powered heater. You will measure the voltage, current, time and temperature and calculate the work done. A graph of temperature against work will be plotted and using the gradient of this curve the specific heat capacity of the metal block will be worked out. A comparison to blocks made of other metals will be made.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Temperature sensor
2. Current sensor ± 10 A
3. Voltage sensor ± 12 or 20 V
4. d.c. power supply
5. Rheostat
6. 4 mm leads
7. Metal block calorimeter (2 holes, one for heater and one for Temperature sensor)
8. There should be selection of blocks e.g. iron, aluminium, copper, steel, lead

9. A heating coil
10. Pipette
11. Lagging
12. Electronic balance
13. Balance (capable of weighing the blocks being used, i.e. +1 kg)

Additionally: Glycerol, oil or water will be required to fill the space between the Temperature sensor and heater and the walls of the holes they are inserted into. Your teacher will advise which is available.

Read these instructions before starting work

1. Find and record the mass of the block.
2. Set up the apparatus as shown in the diagram. The Current sensor, heater and power supply should be in series.
3. Connect the Temperature, Voltage and Current sensors to the logger.
4. Fill the space between the Temperature sensor and heater and the walls of the metal block as advised by your teacher.
5. You will need to record the initial temperature (the temperature of the block before connecting the power).
6. To record the data use **EasyLog**, this will allow data to be collected until you decide it is time to stop.
7. When everything is ready select **Start** to commence logging and switch on the power supply to the heater.
8. Keep the power on until a satisfactory temperature rise has been achieved (about 10 to 20 degrees).
9. Turn the power off and let the logging continue for a short time until a drop in temperature is noticed. Stop logging.
10. Calculate the power of the heater.
11. Calculate the work done by the heater (time x power).

Time in seconds	Work done in J	Temperature in °C
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12. Plot a graph of temperature (°C) against work done (J).
13. Calculate the gradient over the straight part of the graph.
The heat capacity is 1/gradient.
14. Use the mass of the block to work out specific heat capacity.
15. If possible repeat for blocks made of different metals.

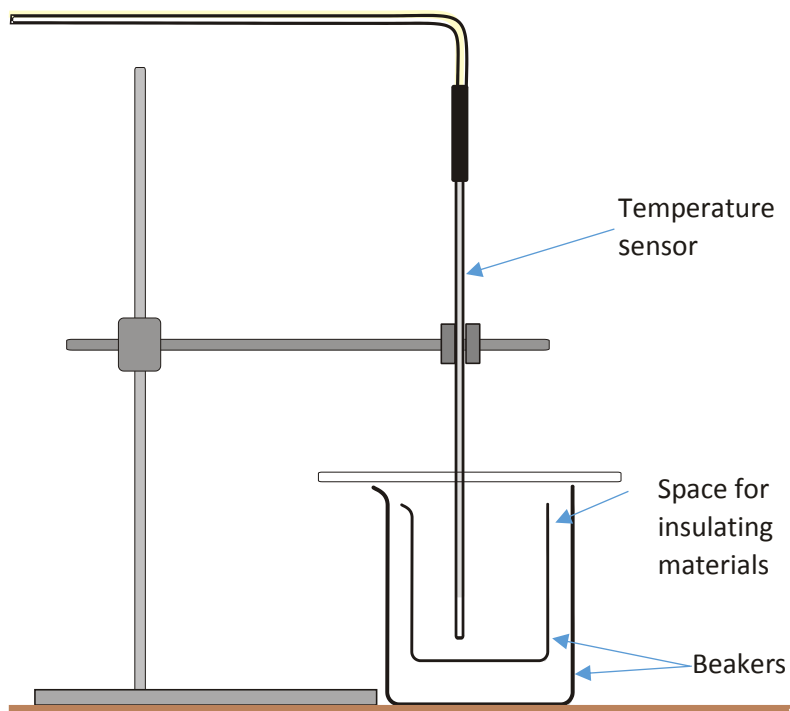
Teacher's notes: GCSE Physics required practical activity (2)

Thermal insulation: Investigating the effectiveness of different materials as thermal insulators

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT5 Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done.



Apparatus

1. Temperature sensor
2. Retort stands and clamps
3. Beakers (these should fit inside each other) (quantity to match the class size)
 - a. 100 ml
 - b. 250 ml
 - c. 800 ml
4. Cardboard sheet (for making lids)
5. Insulating materials for example:
 - a. Newspaper
 - b. Corrugated cardboard
 - c. Bubble wrap
 - d. Sawdust
 - e. Polystyrene (expanded) beads / packaging.

6. Rubber bands

Dependant on the number of Temperature sensors available, more than one test can be conducted at once. This is an obvious advantage of using a data logger over a thermometer.

Set up

Recording method	Total recording time	Intersample time
Graph	20 minutes	10 seconds

If the same setup is used by all groups it is possible to import and merge data from different groups. This opens the possibility of each group working one condition only and pooling the data in plenary session at the end of the activity.

Practical notes

If the card lids are not used the rate of cooling for all pots is nearly identical. All you are measuring is heat loss from the water surface.

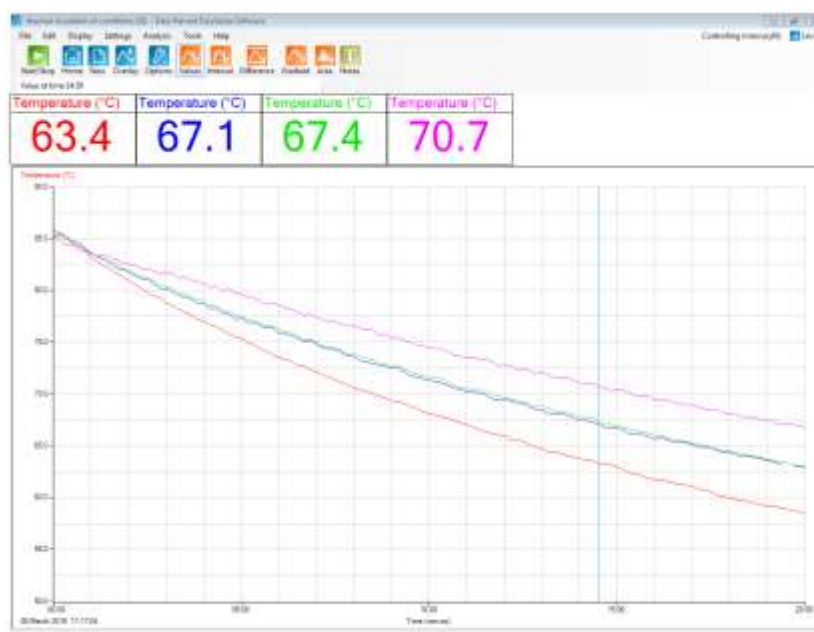
Make sure the area under the inner beaker is insulated with the same material that surrounds the sides.

Expect about 10 degrees difference after 20 minutes.

The axis needs to be rescaled before starting to give an axis scale of 50 to 100°C.

Sample results

You should end up with a set of graphs that look similar to the example below.



Typical set of results of a set of four beakers with different insulation surrounds

Student sheet: GCSE Physics required practical activity (2)

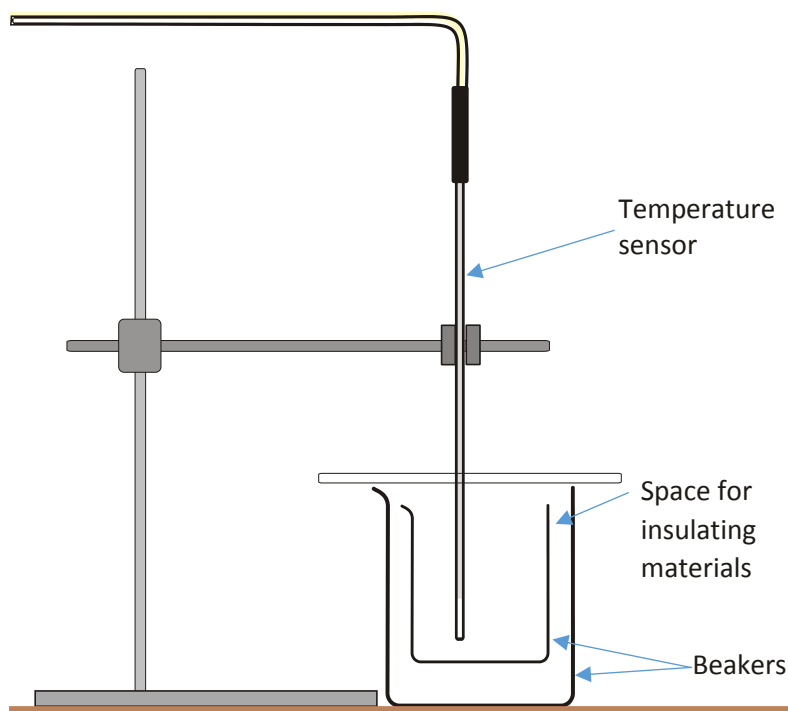
Thermal insulation: Investigating the effectiveness of different materials as thermal insulators

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT5 Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done.

This practical requires you to study the rate of cooling of a beaker of water surrounded by various insulating materials.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Temperature sensor
2. Retort stands and clamps
3. Beakers (these should fit inside each other)
 - a. 100 ml
 - b. 250 ml
 - c. 800 ml
4. Cardboard sheet (for making lids)

5. Insulating materials for example:
 - a. Newspaper
 - b. Corrugated cardboard
 - c. Bubble wrap
 - d. Sawdust
 - e. Polystyrene (expanded) beads / packaging.
6. Rubber bands

Risk Assessment:

Take care with near boiling water from the kettle. If any of the hot water splashes onto you cool immediately by holding under running cold water.

Take extreme care moving hot water around the lab.

Read these instructions before starting work

1. Use the diagram as an aid to setting up the apparatus. Place the small beaker inside the larger beaker
2. Use some cardboard to create a lid for the larger beaker, with a hole for the sensor.
3. Connect the Temperature sensor(s) to the logger, use some system to identify which sensor creates which data if you are using multiple sensors.
4. Use a kettle to heat some water to boiling and let it cool for a few minutes before use.
5. Use **Graph** and set up the recording time as shown in the table below.

Recording method	Total recording time	Intersample time
Graph	20 minutes	10 seconds

6. Add the hot water from the kettle to the inner beaker.
7. After a quick check to ensure sensors are in the water and lid is in place, select **Start**.
8. Data collection will stop after 20 minutes.
9. Select Overlay to get the next set of data on the same axis.
10. Place some insulating material between the small and large beaker and repeat.

Results

- Use **Values** to find and record the start temperature and the end temperature.
- Calculate the change in temperature.
- Work out the gradient (rate of cooling).
- Alternatively use the tools in the software (values, gradient, difference, etc.) to find the change or rate of temperature change.

From the data collected determine which material is the best insulator of the ones tested, and suggest reasons for this.

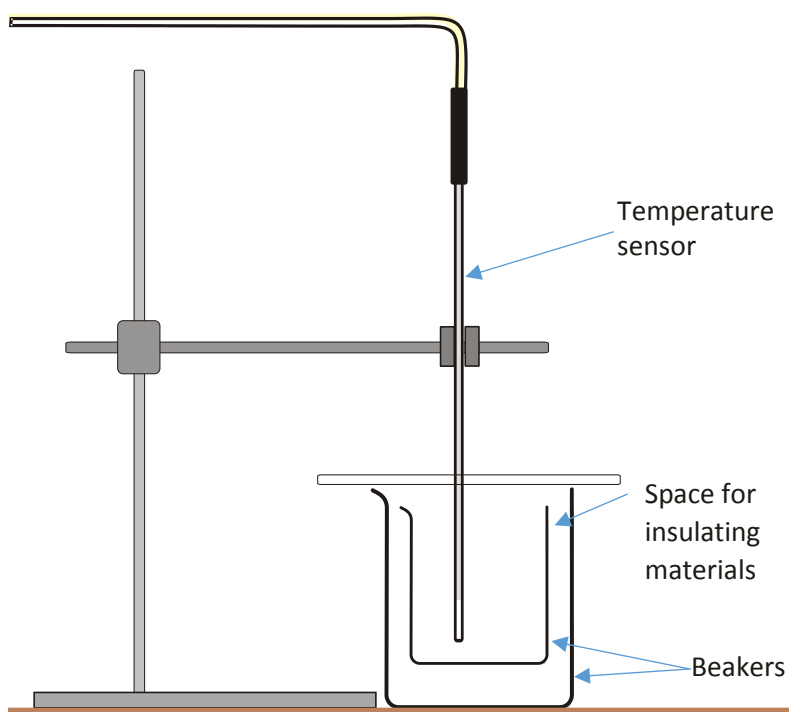
Teacher's notes: GCSE Physics required practical activity (2)

Thermal insulation: Investigating the factors that may affect the thermal insulation properties of a material

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT5 Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done.



Apparatus

1. Temperature sensor
2. Retort stands and clamps
3. Beakers (these should fit inside each other) (quantity to match the class size)
 - a. 100 ml
 - b. 250 ml
 - c. 800 ml
4. Cardboard sheet (making lids)
5. Insulating materials for example:
 - a. Newspaper
 - b. Corrugated cardboard
 - c. Bubble wrap

- d. Sawdust
 - e. Polystyrene (expanded) beads / packaging
6. Rubber bands

Dependant on the number of Temperature sensors available, more than one test can be conducted at once. This is an obvious advantage of using a data logger over a thermometer.

Set up

Recording method	Total recording time	Intersample time
Graph	20 minutes	10 seconds

If the same setup is used by all groups it is possible to import and merge data from different groups. This opens the possibility of each group working one condition only and pooling the data in plenary session at the end of the activity.

Practical notes

If the card lids are not used the rate of cooling for all pots is nearly identical. All you are measuring is heat loss from the water surface.

Make sure the area under the inner beaker is insulated with the same material that surrounds the sides.

Watch out for over stuffing of the space, which will alter the insulating properties.

Expect about 10 degrees difference after 20 minutes.

The axis needs to be rescaled before starting to give an axis scale of 50 to 100°C

Allocate a material to test to each group. Perhaps organise groups to give repeat data.

Student sheet: GCSE Physics required practical activity (2)

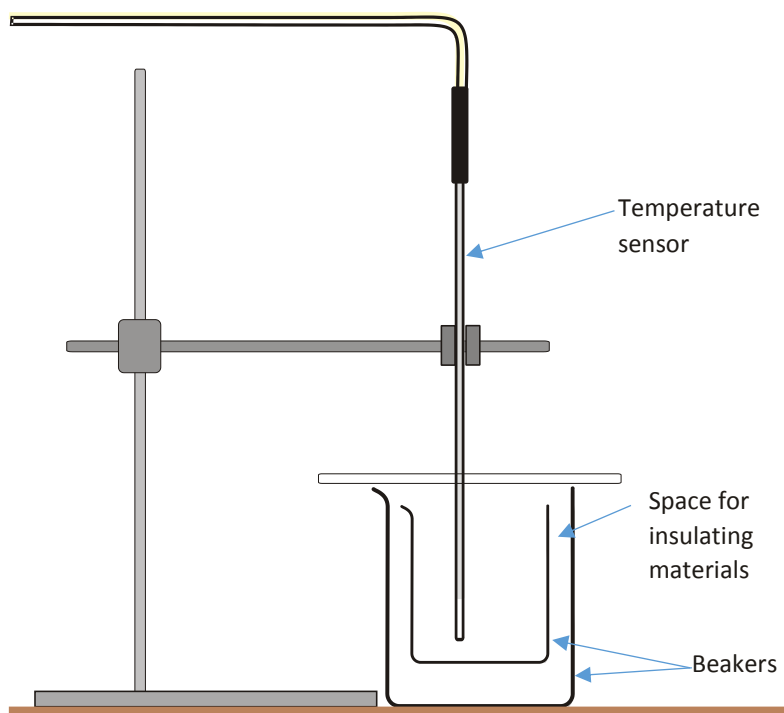
Thermal insulation: Investigating the factors that may affect the thermal insulation properties of a material

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT5 Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done.

This practical requires you to study the rate of cooling of a beaker of water surrounded by different thicknesses of insulating materials.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Temperature sensor
2. Retort stands and clamps
3. Beakers (these should fit inside each other)
 - a. 100 ml
 - b. 250 ml
 - c. 800 ml
4. Cardboard sheet (for making lids)
5. Insulating materials for example:

- a. Newspaper
 - b. Corrugated cardboard
 - c. Bubble wrap
 - d. Sawdust
 - e. Polystyrene (expanded) beads / packaging)
6. Rubber bands

Risk Assessment:

Take care with near boiling water from the kettle. If any of the hot water splashes onto you cool immediately by holding under running cold water.

Take extreme care moving hot water around the lab.

Read these instructions before starting work

1. Use the diagram as an aid to setting up the apparatus.
2. Wrap a small beaker with a single layer of the insulating material. Place the small beaker inside an appropriate sized larger beaker.
3. Use some cardboard to create a lid for the larger beaker, with a hole for the sensor.
4. Connect the Temperature sensor(s) to the logger; use some system to identify which sensor creates which data if you are using multiple sensors.
5. Use a kettle to heat some water to boiling and let it cool for a few minutes before use.
6. Use **Graph** and set up the recording time as shown in the table below.

Recording method	Total recording time	Intersample time
Graph	20 minutes	10 seconds

7. Add the hot water from the kettle to the inner beaker.
8. After a quick check to ensure sensors are in the water and lid is in place, select **Start**.
9. Data collection will stop after 20 minutes.
10. Select Overlay to get the next set of data on the same axis.
11. Place a second layer of insulating material around the small beaker and repeat.

Results

- Use **Values** to find and record the start temperature and the end temperature.
- Calculate the change in temperature.
- Work out the gradient (rate of cooling).
- Alternatively use the tools in the software (values, gradient, difference, etc.) to find the change or rate of temperature change.

From the data collected describe how the number of insulating layers affects the cooling rate.

Teacher's notes: GCSE Physics required practical activity (3)

How does the resistance of a wire depend upon its length?

Tests

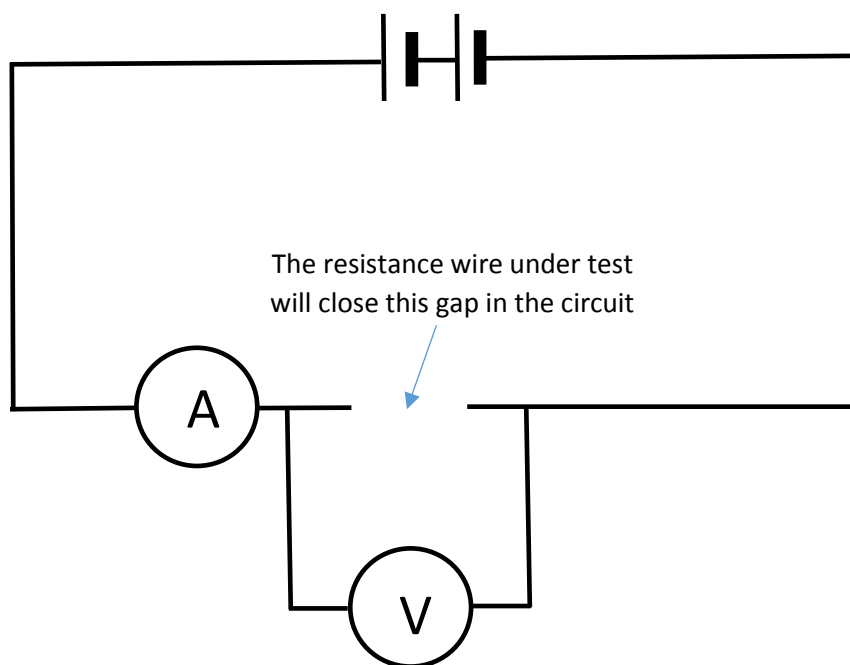
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.

Apparatus

1. Current sensor $\pm 1\text{A}$
2. Voltage sensor ± 12 or 20 V
3. A 1.5 V battery or suitable (smoothed) power supply
4. Two crocodile clips
5. 0.236 mm diameter (34 swg) constantan wire ($11.2\text{ ohms per metre}$)
6. Metre rule
7. 4 mm patch leads
8. Masking tape



Risk assessment: Short lengths of wire will get hot. Reduce p.d. to reduce heating effect. Allow cooling time between readings.

Practical notes

The recommended wire (34 swg constantan) gives a reading of just under 1 A at 10 cm with a 1.5 V cell. The current will vary with the condition of the cell being used and the cell technology. On this basis we would recommend instructing the students to go no closer than 20 cm from zero. Data will be a good straight line and a line that passes through 0/0 is easily achievable as a value for the resistance per meter that is within 5% of the given specification for the wire.

The crocodile clip connected to the end of the wire will remain fixed; the other crocodile clip will be used as a jockey along the length of the wire. The position of the jockey relative to the fixed crocodile clip will be the length measurement. It may be necessary to show students and reassure them of the language used to describe the set up and use of the apparatus.

The resistance of the wire is proportional to the length of the wire. Constantan wire has defined values of resistance per metre; the information should be on the spool. You can use a resistance meter to find the ohms per metre value for reference.

Set up

Snapshot
The user clicks in the graph area to record the currently displayed data

OR

Meters
Open 2 Numeric sections to make essentially a two channel multimeter, (voltage and current). Values will need to be copied down into a table of results.

If using Snapshot to collect the data the EasySense software can calculate and display the resistance if required. Go to Tools > Pre-log Function > Electricity > Resistance. Make note of the multiplier that is required to correct for mA and mV.

When you click on the graph area to record a reading the resistance will be calculated and displayed. Students should adjust the reading for significant figures.

Alternative (s)

1. Put a lamp in series with the resistance wire and use the change in brightness of the lamp as an indicator of current. You could use a Light sensor to give a reading for the lamp brightness.
2. Have preselected wires of the same length but different diameters. Measure and relate diameter to resistance.

Student sheet: GCSE Physics required practical activity (3)

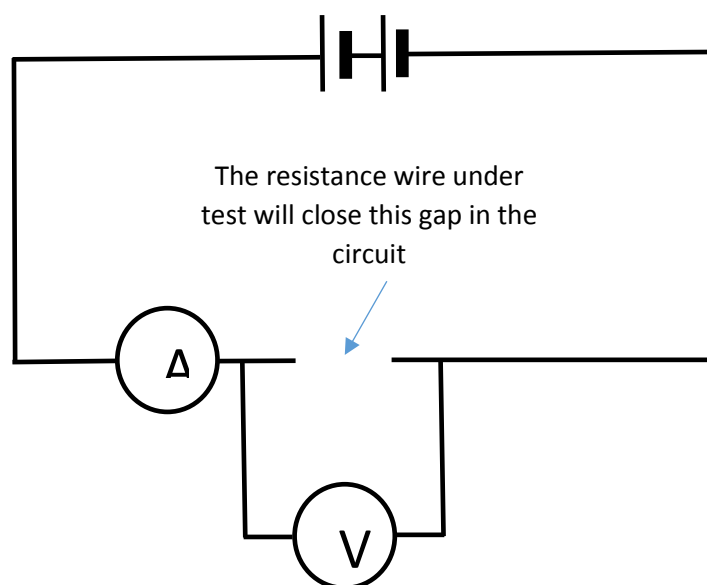
How does the resistance of a wire depend upon its length?

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Current sensor $\pm 1\text{A}$
2. Voltage sensor ± 12 or 20 V
3. 1.5 V battery or suitable power supply
4. Two crocodile clips
5. 0.236 mm diameter (34 swg) constantan wire
6. Metre rule
7. 4 mm patch leads
8. Masking tape

Set up

Snapshot
Click in the graph area to record the currently displayed data

OR

Meters
Open 2 Numeric sections (voltage and current). Values need to be copied down into table of results.

Your teacher will tell you which method you are to use.

Read these instructions before starting work

1. Make up the circuit as shown in the diagram. The metre stick and wire fills the gap in the circuit as indicated.
2. Connect the red lead of the Current sensor (ammeter) to the black lead of the Voltage sensor. Fix a crocodile clip onto the exposed 4 mm plug and clip to the 0 metres end of the metre rule and wire.
3. Fix a crocodile clip to the red lead of the Voltage sensor; this will be the contact to the resistance wire at the measured distances. Do not attach this clip to wire at this stage. This wire is the jockey.
4. Connect the other wires to complete the circuit. Check the pathway of the circuit against the diagram before progressing.
5. Use the software to check the readings are giving a voltage and current and that the values are positive when the jockey is touched to the resistance wire.
6. If you are using the Snapshot method of recording select Start.
7. Touch the jockey to the required distance position on the wire and record the voltage and current. Work quickly to record the data before the wire gets too hot and burns through or damages the metre rule.
8. Repeat for a set of distances (90, 80, 70 cm, etc.). Wait for 30 s to 1 min between readings to let the wire cool.
9. Disconnect the battery when finished.
10. Transfer the data to a table of results. Record the voltage given by the sensor.

Length of wire (m)	Voltage (V)	Current (A)	Resistance (Ω)

Results

- Calculate the resistance from the voltage and current data for each distance.
- Plot a graph of resistance (Ω) against the length of the wire (m).
- Draw a line of best fit through the data, it may not go through the 0/0 point. Where would the extra resistance come from?

Teacher's notes: GCSE Physics required practical activity (3)

How does the resistance of a wire depend upon its diameter?

Tests

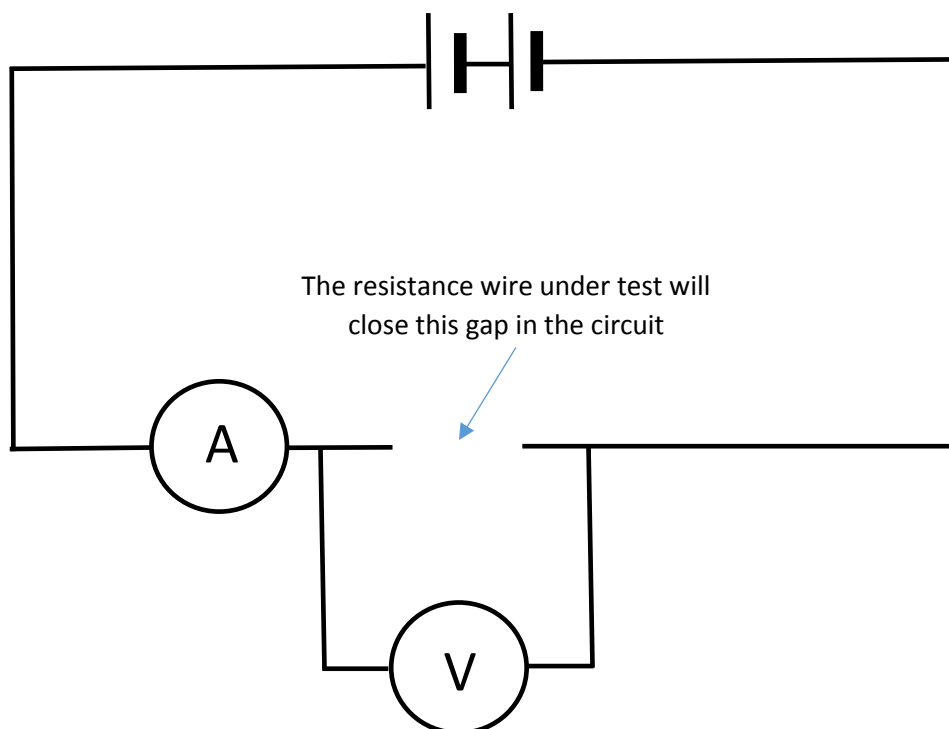
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.

Apparatus

1. Current sensor ± 1 A
2. Voltage sensor ± 12 or 20 V
3. 1.5 V battery or suitable (smoothed) power supply
4. Two crocodile clips
5. 1 metre lengths of wire of differing diameters
6. Micrometre (optional)
7. Metre rule
8. 4 mm patch leads
9. Masking tape



Practical notes

Constantan wire is a copper – nickel alloy that has a specific resistance. The part table below indicates the resistance per metre of some common standard wire gauge (swg).

SWG	mm	Ohms m ⁻¹
16	1.626	0.24
20	0.914	0.75
30	0.315	6.27
32	0.274	8.27
34	0.234	11.4

It is suggested that several metre rules are prepared with wires taped to them. Students would then select enough different wires to produce a meaningful plot of resistance against $1/\text{diameter}^2$

Students would record the voltage across the wire and the current flow through the wire. All other data would be derived.

You could provide the diameter data, the SWG or a micrometer. This will depend on the focus of the assessment and any learning objectives you are piggy backing onto the assessment.

You can use a resistance meter to find the ohms / metre value.

Set up

Snapshot
The user clicks in the graph area to record the currently displayed data
Or:
Meters
Open 2 Numeric sections (voltage and current). Values need to be copied down into table of results.

If using Snapshot to collect the data the EasySense software can calculate and display the resistance if required. Go to Tools > Pre-log Function > Electricity > Resistance. Make note of the multiplier that is required to correct for mA and mV.

When you click on the graph area to record a reading the resistance will be calculated and displayed. Students should adjust the reading for significant figures.

Student sheet: GCSE Physics required practical activity (3)

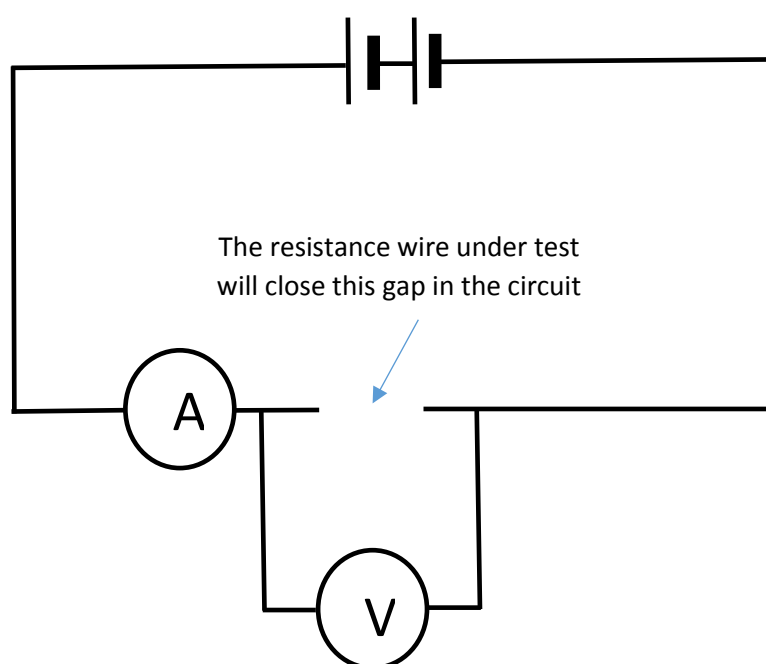
How does the resistance of a wire depend upon its diameter?

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Current sensor ± 1 A
2. Voltage sensor ± 12 or 20 V
3. 1.5 V battery or suitable power supply
4. Two crocodile clips
5. An assortment of constantan wires of uniform length
6. Metre rule
7. 4 mm patch leads
8. Masking tape

Set up

Snapshot
Click in the graph area to record the currently displayed data

Or:

Meters
Open 2 Numeric sections (voltage and current). Copy values into a table of results

Your teacher will tell you which method you are to use.

Read these instructions before starting work

1. Make up the circuit as shown in the diagram. The supplied metre stick and wire fills the gap in the circuit as indicated.
2. Connect the red lead of the Current sensor (ammeter) to the black lead of the Voltage sensor. Fix a crocodile clip onto the exposed 4 mm plug and clip to the 0 metre end of the metre rule and wire.
3. Fix a crocodile clip to the red lead of the Voltage sensor; this will clip to the other end of the wire.
4. Connect the other wires to complete the circuit. Check the pathway of the circuit against the diagram before progressing.
5. Use the software to check the readings are giving a voltage and current and that the values are positive. Disconnect a wire to break the circuit.
6. If you are using the Snapshot method of recording select **Start**.
7. Complete the circuit and record the voltage and current. Work quickly to record the data before the wire gets too hot and burns through or damages the metre rule.
8. Repeat for a set of wires of different diameters.
9. Transfer the data to a table of results. Record the voltage given by the sensor.

Diameter of wire (m)	Diameter ² of wire (m)	1/Diameter ² of wire (/m ²)	Voltage (V)	Current (A)	Resistance (Ω)

Results

- Calculate the resistance from the voltage and current data for each distance.
- Plot a graph of resistance (Ω) against $1/\text{diameter}^2$.
- Draw a line of best fit through the data, it should go through the 0/0 point.

Teacher's notes: GCSE Physics required practical activity (4)

V – I characteristics: Filament lamp and resistor

Tests

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

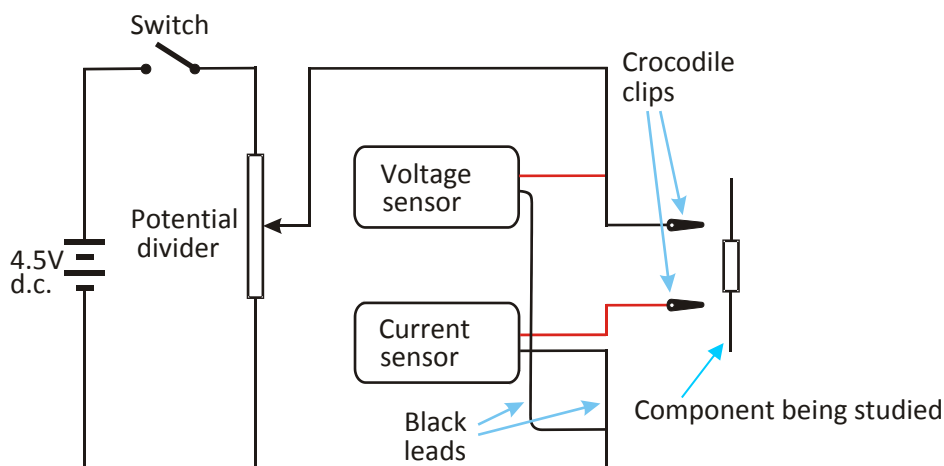
AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.

The activity will find what happens to the current through a component as the voltage changes. They will examine the V – I curve for an ohmic resistor (standard component resistor) and a filament lamp.

Apparatus

1. Current sensor ± 1 A
2. Voltage sensor ± 12 or 20 V
3. Battery or suitable variable power supply
4. Two crocodile clips
5. Rheostat / variable resistor e.g. 25 Ω , 2 W or 5 W (not required if a variable voltage power pack is available – subject to technical note below)
6. Resistor in the range 5 – 50 Ω
7. 3.5 V lamp and holder
8. 4 mm patch leads

Generic circuit for the activity. Note the black leads for the sensors are linked together.



Practical notes

Using a data logger and Voltage and Current sensors lets the student develop the characteristic curve of the three suggested components.

Students should be given advice from a pre assessment trial of:

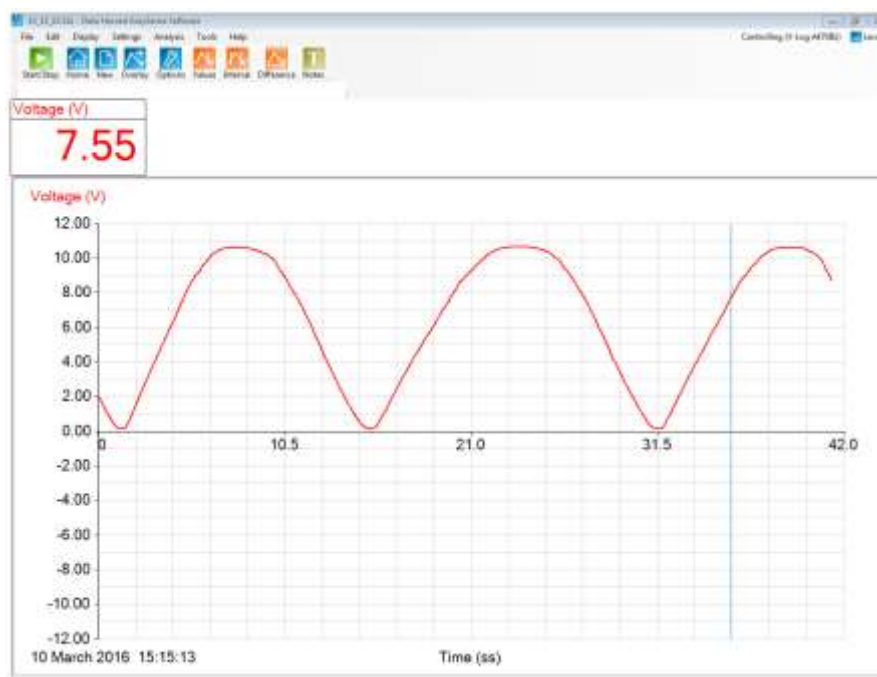
1. Sensors to use with which components.

2. Maximum voltage to be used.
3. Voltage increments to be expected for data collection.
4. Set up the meters display of the software for showing voltage and current.

If you have a good smoothed power supply with a variable voltage control you would not have to use the voltage divider / rheostat.

It would be better if the students used an electricity kit that they are familiar with to lay out the circuit.

Use a fully isolated mains power supply with a regulated d.c. output (smoothed and fully rectified). Be aware that some power supplies are $\frac{1}{2}$ wave rectified producing an average rather than true d.c. The Voltage sensor will 'pick up' the fluctuations in voltage and current from this type of power supply. The screen shot below is typical recording of a d.c. voltage set to 7 volts from a poorly smoothed and rectified school power supply.



If an EasySense software logging mode is used to record, and you need to swap the sensors in a circuit use the New function to detect the change.

Set up

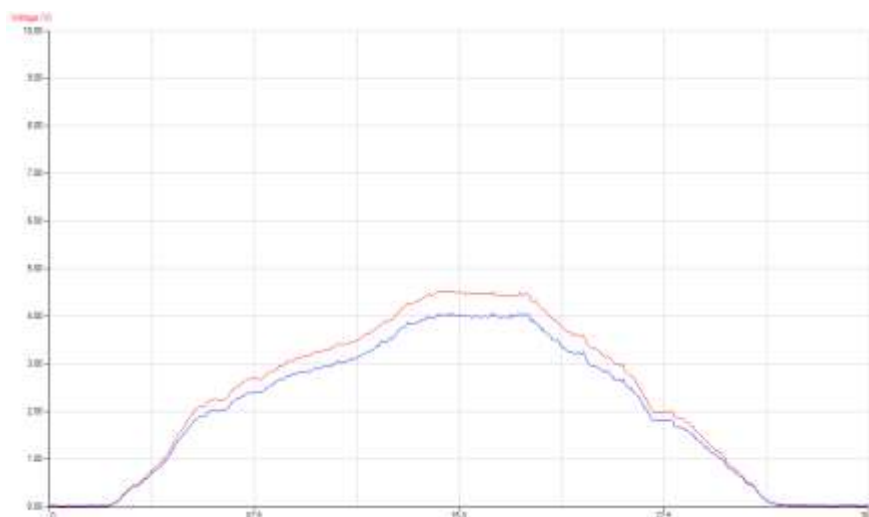
The simplest data collection mode is to use the data logger as a two channel voltage and current meter. The students will view the current and voltage and record the values at every (for example) 0.5 volts change.

Meters in the EasySense software starts active with the data from one sensor. Open another Numeric section window, right click in this section window and select the other sensor.

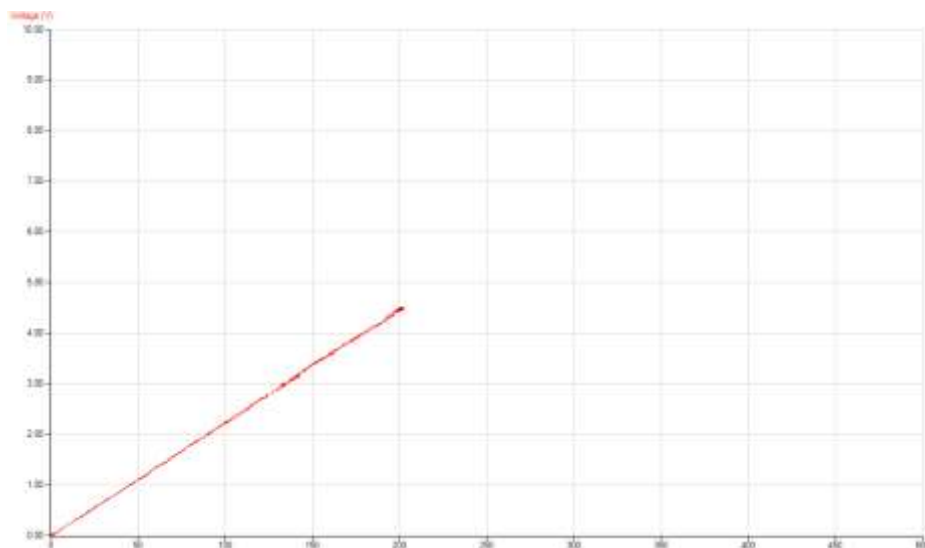
Alternative method

Alternatively you can monitor the data in real time and use the software to plot voltage against current. The suggestion is to use EasyLog which gives 30 seconds of fast data collection. The students will start with the voltage divider set to one extreme, the recording is started and the voltage increase smoothly to reach the other limit of the divider within 30 seconds.

Typical data collected for an ohmic resistor.



The graph shows the change in current as voltage is changed over a 30 second period.



Data replotted as channel vs. channel plot of voltage (y-axis) against current (x-axis)

A considerable advantage is the time from collection of data to the visualisation of characteristic.

Risk assessment

Checking the power supplies and connecting mains leads should be a matter of routine before use.

It is the schools responsibility to complete a risk assessment according to their local policy.

Student sheet: GCSE Physics required practical activity (4)

V – I characteristics: Filament lamp and resistor

Tests

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.

You will find what happens to the current through a component as the voltage changes.

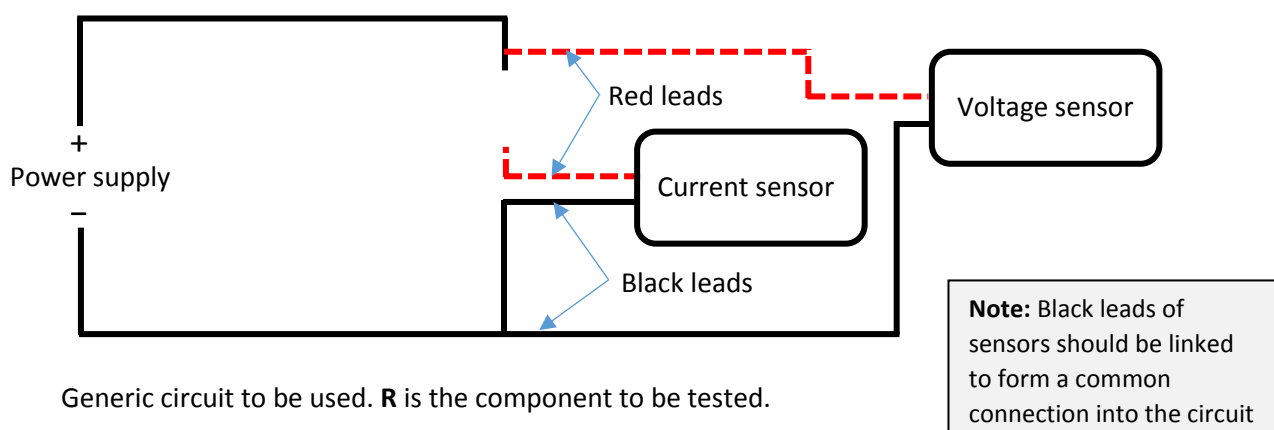
You are to make the appropriate circuit to test a resistor and filament lamp for the V – I characteristics.

The data you collect will be used to construct a V – I curve by plotting A against V.

Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Current sensor ± 1 A
2. Voltage sensor ± 12 or 20 V
3. Battery or variable power supply
4. Two crocodile clips
5. Rheostat / variable resistor e.g. $25\ \Omega$, 2 W or 5W (not required if a variable voltage power pack is available)
6. Resistor in the range $5 - 50\ \Omega$
7. 3.5 V lamp and holder
8. 4 mm patch leads



Read these instructions before starting work

1. Make up the circuit as shown in the diagram. It may help to work from the positive (red terminal of the power supply).
2. Use the lead that will connect to the negative terminal of the power supply as a switch.
3. Check the continuity of the circuit before applying any power.

4. Connect the Voltage and Current sensor to the logger. Make sure the black leads of the sensors are linked together.
5. Connect the component to be studied.
6. Select Meter, with two numeric sections windows, one for voltage and one for current.
7. Connect the power and record in a results table the voltage and current.
8. Increase the voltage by 0.5 V (maximum) and note down the meter value of voltage and current. If you can use smaller voltage increments then do so.
9. Continue to the maximum voltage indicated by your teacher.

Component	Voltage (V)	Current (A)

10. Reset the voltage to zero / min. Swap the leads on the power supply and repeat.
11. Swap the component and put the leads back to the original positions and repeat the data collection. Record the data in a new table of results.

Component	Voltage (V)	Current (A)

Results

For all three components plot current in A against p.d. in V. The origin 0/0 will be in the centre of the graph.

- For the resistor plot a straight line best fit which should pass through 0/0.
- For the filament lamp plot a best fit curve

Teacher's notes: GCSE Physics required practical activity (4)

V – I characteristics: LED and diode

Tests

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

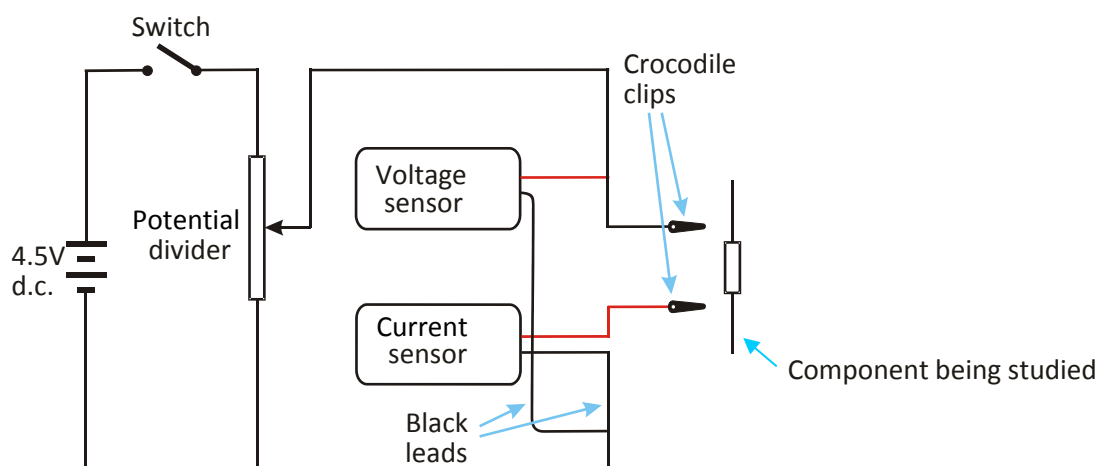
AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.

The activity will find what happens to the current through a component as the voltage changes for an LED and a diode.

Apparatus

1. Current sensor ± 100 mA
2. Voltage sensor ± 12 or 20 V
3. Battery or suitable variable power supply
4. Two crocodile clips
5. Rheostat / variable resistor e.g. $25\ \Omega$, 2 W or 5 W (not required if a variable voltage power pack is available – see practical notes)
6. Diode e.g. 1N4000
7. LED with protecting resistor (typically $300\ \Omega$, see practical notes)
8. 4 mm patch leads

Generic circuit for the activity. Note the black leads for the sensors are linked together.



Practical notes

Using a data logger and Voltage and Current sensors lets the student develop the characteristic curve of the three suggested components.

The LED and diode will require a protecting resistor usually $300\ \Omega$. Check the forward voltage of the LED and adjust resistance as necessary. This should be an assembled component with the resistor already soldered onto the LED, polarity identified. Voltage across the diode, only, should be possible.

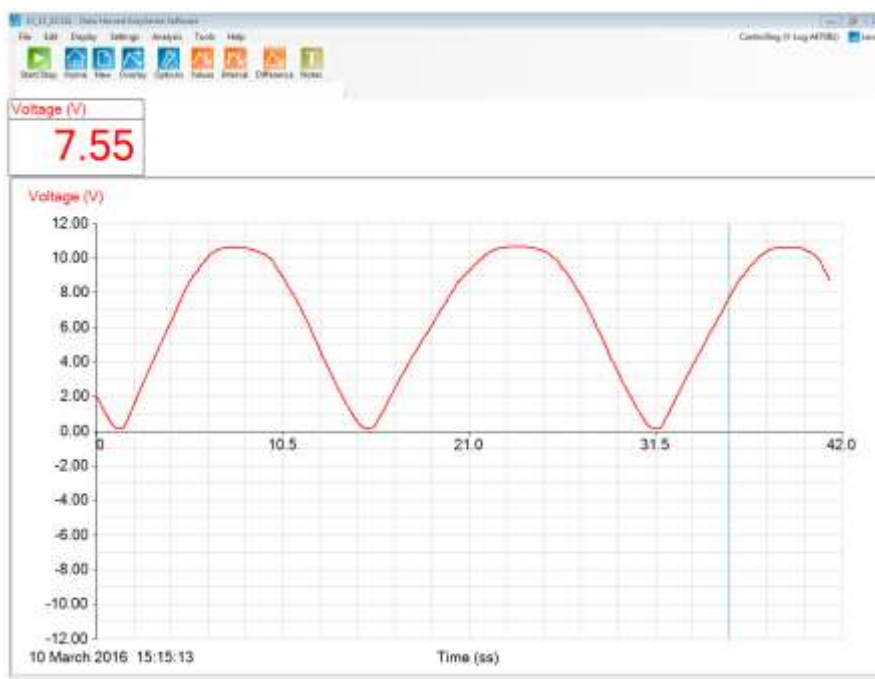
Students should be given advice from a pre assessment trial of:

1. Sensors to use with which components.
2. Maximum voltage to be used.
3. Voltage increments to be expected for data collection.
4. Set up the meters display of the software to show voltage and current.

The diode and LED will require a 100 mA Current sensor. If you have a good smoothed power supply with a variable voltage control you would not have to use the voltage divider / rheostat.

It would be better if the students used an electricity kit that they are familiar with to lay out the circuit.

Use a fully isolated mains power supply with a regulated d.c. output (smoothed and fully rectified). Be aware that some power supplies are $\frac{1}{2}$ wave rectified producing an average rather than true d.c. The Voltage sensor will 'pick up' the fluctuations in voltage and current from this type of power supply. The screen shot below is typical recording of a d.c. voltage set to 7 V from a poorly smoothed and rectified school power supply.



If an EasySense software logging mode is used to record and you need to swap the sensors in a circuit use the New function to detect the change

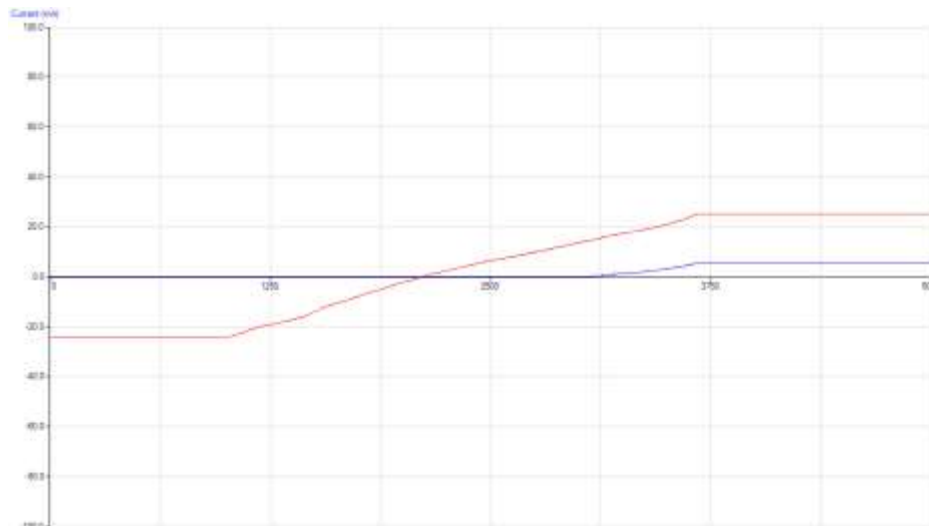
Set up

The simplest data collection mode is to use the data logger as a two channel voltage and current meter. The students will view the current and voltage and record the values at every (for example) 0.2 volts change (or finer if they are to show the sudden current flow at a given voltage).

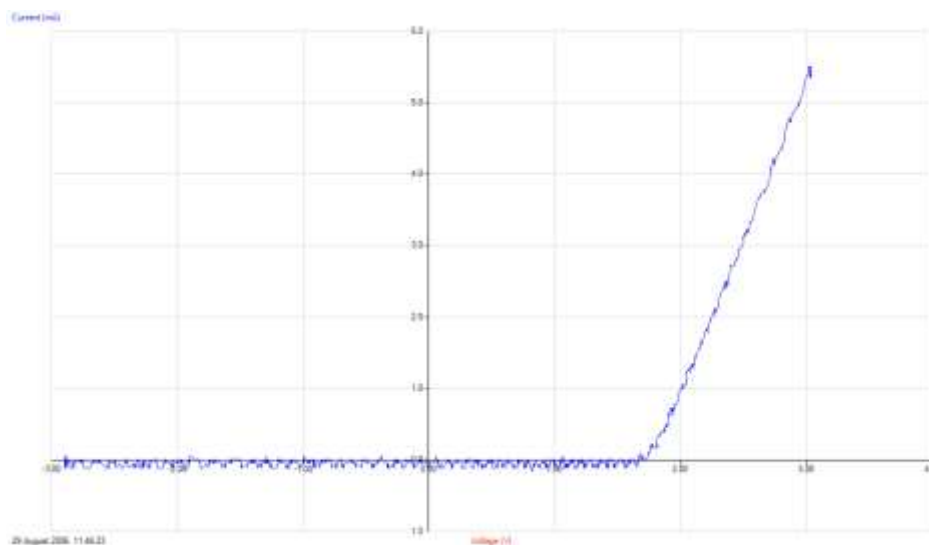
Meters in the EasySense software starts active with the data from one sensor. Open another Numeric section window, right click in this section window and select the other sensor.

Alternative data collection method

Alternatively you can monitor the data in real time and use the software to plot voltage against current. The suggestion is to use EasyLog which gives 30 seconds of fast data collection. The students will start with the voltage divider set to one extreme, the recording is started and the voltage increase smoothly to reach the other limit of the divider within 30 seconds.



Typical data collected for an LED. The graph shows the change in current as voltage is changed over a 30 second period.



Data replotted as channel vs. channel plot of current (y-axis) against voltage (x-axis), auto-scaling active. A considerable advantage is the time from collection of data to the visualisation of characteristic.

Risk assessment

Checking the power supplies and connecting mains leads should be a matter of routine before use. It is the schools responsibility to complete a risk assessment according to their local policy

Student sheet: GCSE Physics required practical activity (4)

V – I characteristics: LED and diode

Tests

AT6 Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements.

AT7 Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements.

The activity will find what happens to the current through a component as the voltage changes.

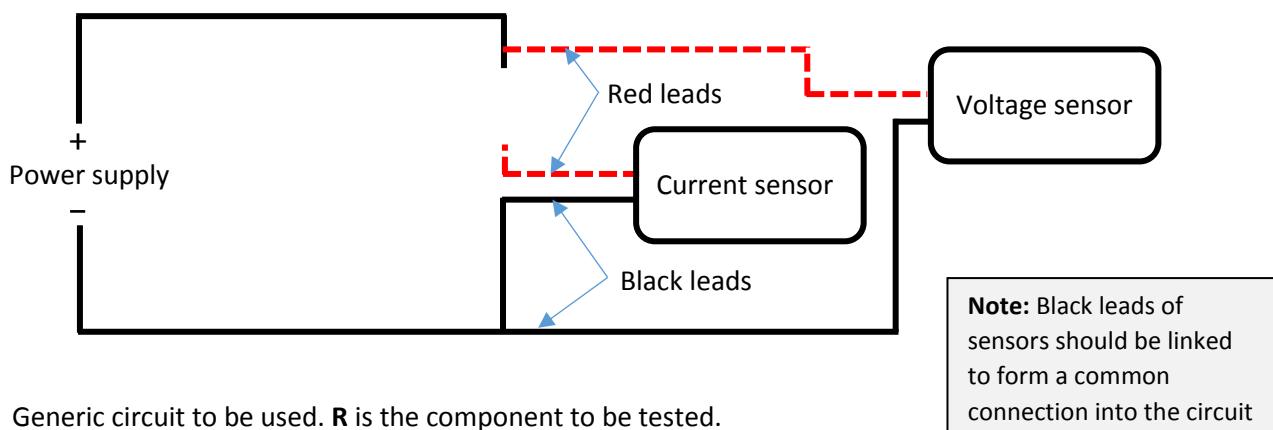
The components to be tested are an LED and a diode. You are to make the appropriate circuit to test a component for the V – I characteristics.

The data you collect will be used to construct a V – I curve by plotting A against V.

Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Current sensor ± 100 mA
2. Voltage sensor ± 12 or 20 V
3. Battery or variable power supply
4. Two crocodile clips
5. Rheostat / variable resistor e.g. 25 Ω , 2 W or 5 W (not required if a variable voltage power pack is available)
6. Diode e.g. 1N4000
7. LED with protecting resistor (typically 300 Ω)
8. 4 mm patch leads



Read these instructions before starting work

1. Make up the circuit as shown in the diagram. It may help to work from the positive (red terminal of the power supply).
2. Use the lead that will connect to the negative terminal of the power supply as a switch.

3. Check the continuity of the circuit before applying any power.
4. Connect the Voltage sensor and Current sensor to the logger. Make sure the black leads of the sensors are linked together.
5. Connect the component to be studied.
6. Set the logger or software to Meters mode. Set up two numeric section windows, one for voltage and one for current.
7. Connect the power and record in a results table the voltage and current.
8. Increase the voltage by 0.2 volt (maximum) and note the meters values of voltage and current. If you can use smaller voltage increments do so.
9. Continue to the maximum voltage indicated by your teacher

Component	Voltage (V)	Current (A)

10. Reset the voltage to zero / min. Swap the leads on the power supply and repeat.
11. Swap the component and put the leads back to the original positions and repeat the data collection. Record the data in new table of results.

Component	Voltage (V)	Current (A)

Results

- Plot current in A against p.d. in V. The origin 0/0 will be in the centre of the graph.
- Plot a best fit curve.

Teacher's notes: GCSE Physics required practical activity (7)

Acceleration (1): Using two Light gates, constant mass varying force

Tests

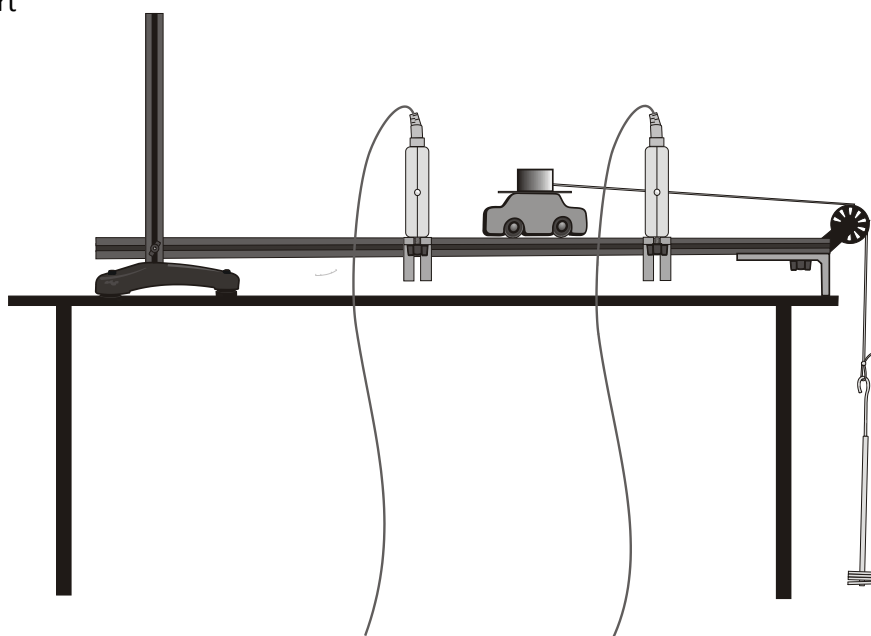
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT2 Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs.

AT3 Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration).

Apparatus

1. Dynamics track and support
2. Dynamics cart for track system
3. Spoked pulley attachment, string and mass carrier
4. 2 x Light gates
5. Single interrupt card
6. 2 x fixing and positioning brackets for Light gates
7. Large and small fixing brackets to support the track and add stop barriers
8. Set of masses 10 x 10 g
9. Blu-Tack to fix masses to cart or a small plastic container that can be fixed to the roof of the cart



Connect the Light Gates to inputs A and B on the logger. The cart should travel through Light gate connected to input A first.

There are choices to be made in the presentation of this practical to the students, which will depend upon the practical skills you wish to assess and the learning outcomes.

1. Have the software present the data as velocity at A and B and time from A to B. Get the students to extract the data from the software, tabulate it themselves and calculate the acceleration. Then plot the acceleration force graph.
2. Have the software set to record acceleration from A to B. Get the students to extract the data from the software, then plot the acceleration force graph.

Using a logger with built in timing functions

The restricted nature of the logger means that not all timing functions of the software are duplicated into the logger. Use either:

- Acceleration from A to B with two Light gates and a single interrupt card or,
- Acceleration at A with a single Light gate and a double interrupt card.

This will give data as acceleration. Ideal if the students are familiar with relationship between velocity and acceleration.

Practical notes

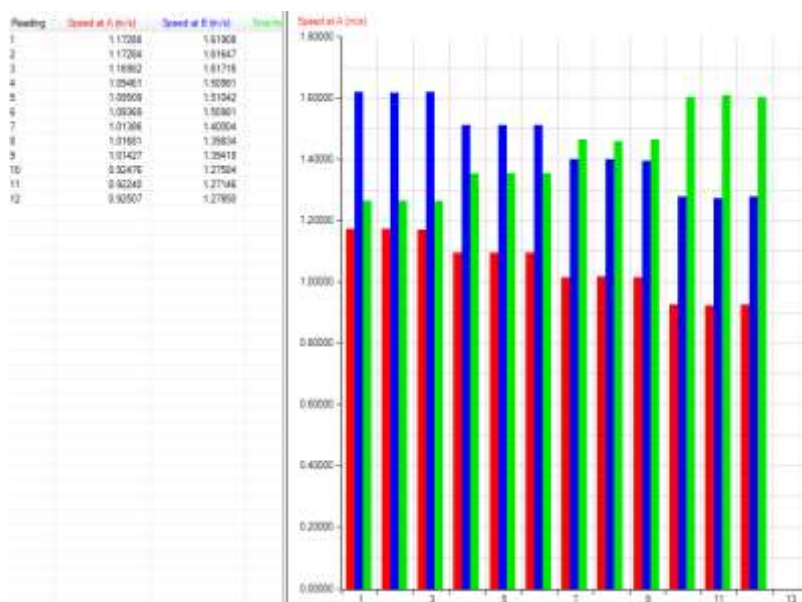
Modern dynamics systems give results as good and as clear as air tracks, with less time overhead in setting up and preparation.

1. Make sure the cart will pass through the Light gate connected to port A first.
2. Make sure the cart does not pass / is not passed through the Light gates as it is returned to the start position.
3. Use a bracket to create a back stop and hence a standard start position for the cart, there is enough accuracy in the cart and software for variations in the start to have significance.
4. When using two Light gates, check the correction for friction by setting the software to measure velocity at A then B and push the cart to travel through the gates. When there is an equal velocity found at A then B or a marginal decrease in velocity at B compared to A the track will be compensated.
5. Weigh the masses and calculate the force. There is a variation in the individual masses. If you are looking for ability to generate a best fit line then take mass as given.
6. To make it easier to transfer the masses use a small container screwed to the top of the cart by the same bolt that holds the interrupt card in place. The bottom half of a plastic drinks cup is ideal.
7. Make sure that when the masses have reached the floor the cart has passed through all Light gates on the apparatus or you will get a slowing of the cart.
8. Students should be able to catch the cart but you may wish to consider attaching a crash box at the end of the track.

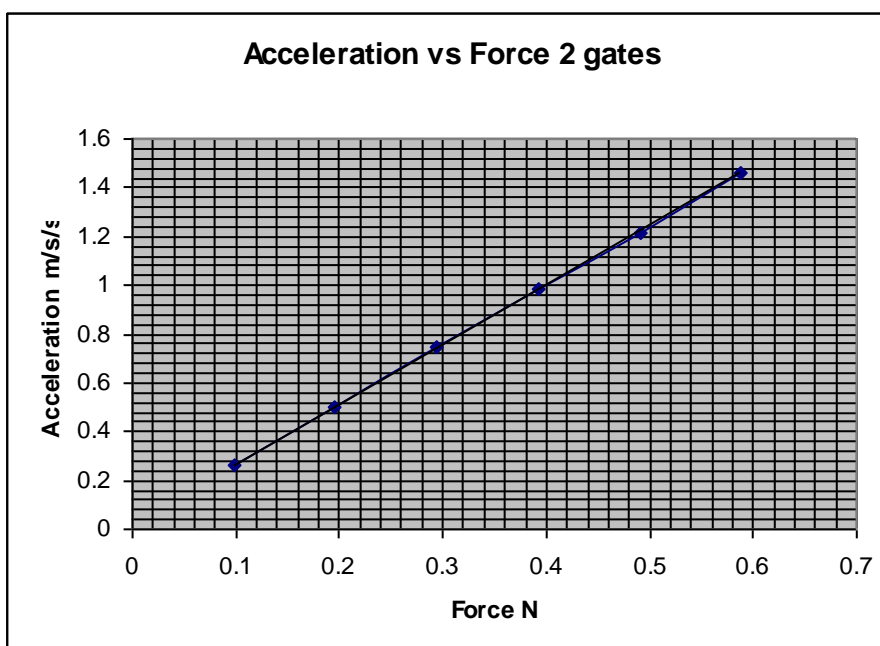


Sample results and analysis

For double Light gates, velocity at A then B.



Typical data of velocity at A then B and time from A to B with changing force. Transfer of mass from mass carrier to top of cart. Table revealed to show data.



Plot of acceleration vs. force

Student sheet: GCSE Physics required practical activity (8)

Acceleration (1): Using two Light gates, constant mass varying force

Tests

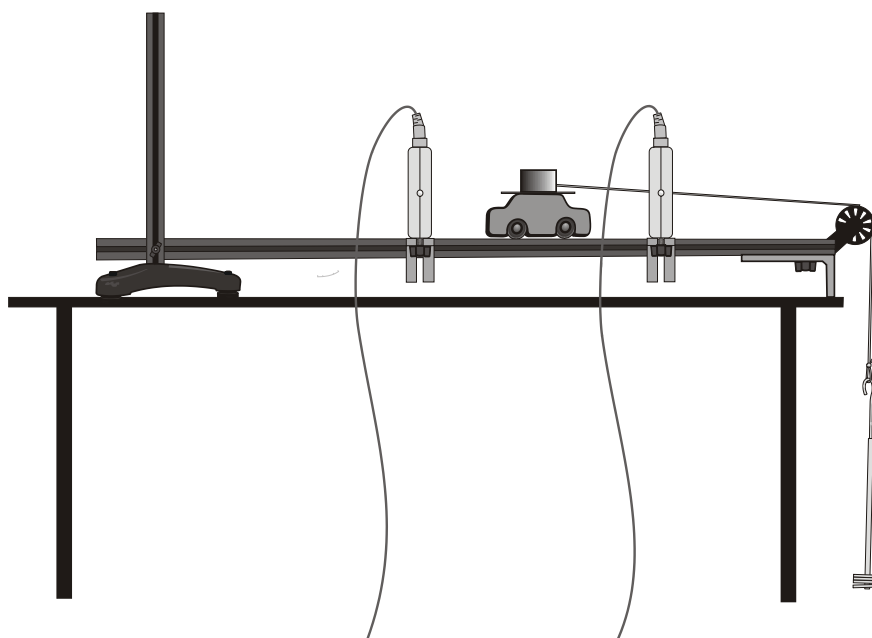
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT2 Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs.

AT3 Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration).

You are going to investigate the acceleration for a constant mass as the force acting on it is varied.

The relationship between force, mass and acceleration is described by Newton's second law.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Dynamics track and support
2. Dynamics cart for track system
3. Spoked pulley attachment, string and mass carrier
4. 2 x Light gates
5. Single interrupt card
6. 2 x fixing and positioning brackets for Light gates
7. Large and small fixing brackets to support the track and add a stop barrier
8. Set of masses 10 x 10 g
9. Blu-Tack to fix masses to cart or small plastic container that can be fixed to the roof of the cart.

Read these instructions before starting work

It can be useful to temporarily Stop logging when returning the cart back to the start, swapping masses, etc. as it will prevent Light gates being activated out of sequence.

1. Assemble the apparatus as shown. Attach the Light gates A and B at approximately 40 cm and 90 cm marks respectively (the exact distance and separation is not critical in this investigation). Check that the mass on the carrier will not have reached the floor before the cart has passed through both the Light gates being used.
2. Attach the single interrupt card to the cart.
3. Adjust slope to compensate for friction by raising/lowering the track against the upright. Test using Velocity at A then B for a constant velocity at both Light gates.
4. Fit the spoked pulley to the end of the track. Make sure the string to the pulley is running straight (a small angle is acceptable).
5. Use a paper clip to make a hook. Attach the string and hook to the interrupt card.
6. Add 50 g to the cart, secure the masses in place.
7. Hang the 10 g hanger from the string.
8. Set up the software to record Speed/Velocity at A then B, using a single interrupt card, enter the length of the interrupt card and to also show the Time from A to B column.
9. Select **Start** and release the cart from its start position (this will be same for each run), to run freely along the track through the two Light gates. The velocity at A then B and time from A to B will be displayed as a set of bars.
10. Repeat this at least three times. Delete and repeat any results obviously away from the norm (anomalous).
11. Make a note of the mass for the first "x" runs.
12. Transfer 10 g from the cart to the hanger and repeat.
13. Carry on repeating until all the weights have been transferred to the hanger. The total moving mass of the cart and hanger must be the same for all repeats. Select **Stop** to finish logging.
14. Work out the average of the acceleration for each value of the falling mass.
15. Plot a graph of force vs. acceleration using graphing software or by hand.

Example results table

Mass (g)	Newtons (n)	V1 (m/s)	V2 (m/s)	Time from A to B (s)	Acceleration (m/s/s)	Average acceleration (m/s/s)

Teacher's notes: GCSE Physics required practical activity (8)

Acceleration (1a): Using one Light gate, constant mass varying force

Tests

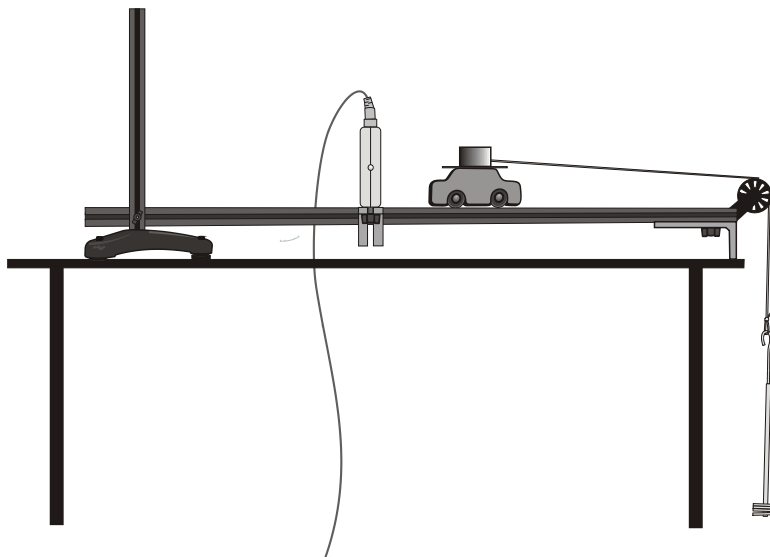
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT2 Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs.

AT3 Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration).

Apparatus

1. Dynamics track and support
2. Dynamics cart for track system
3. Spoked pulley attachment, string and mass carrier
4. Light gate
5. Double interrupt card
6. Fixing and positioning brackets for Light gates
7. Large and small fixing brackets to support the track and add a stop barrier
8. Set of masses 10 x 10 g
9. Blu-Tack to fix masses to cart or small plastic container that can be fixed to the roof of the cart



There are choices to be made in the presentation of this practical to the students, which will depend upon the practical skills you wish to assess and the learning outcomes.

1. Use a single Light gate and a double interrupt card. Have the software present the data as acceleration at A and have the students tabulate the data and plot the acceleration force graph.
2. Export the data from the software, from any method, directly into Excel and use the spreadsheet for any calculations and plotting of the acceleration vs. force chart.

Set up

Measure	Select apparatus	Length of interrupt card segment	Decimal Places	Units	Columns to Display
Acceleration at A	Double interrupt card	40 mm	3	s, m/s, m/s/s	Acceleration at A

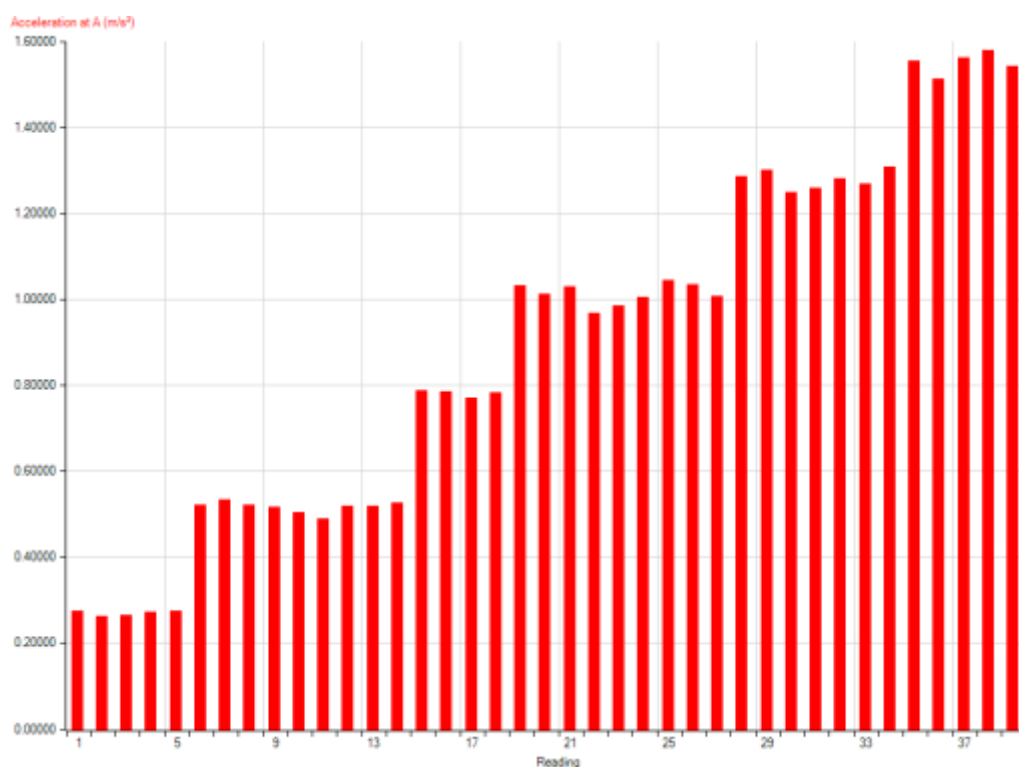
Practical notes

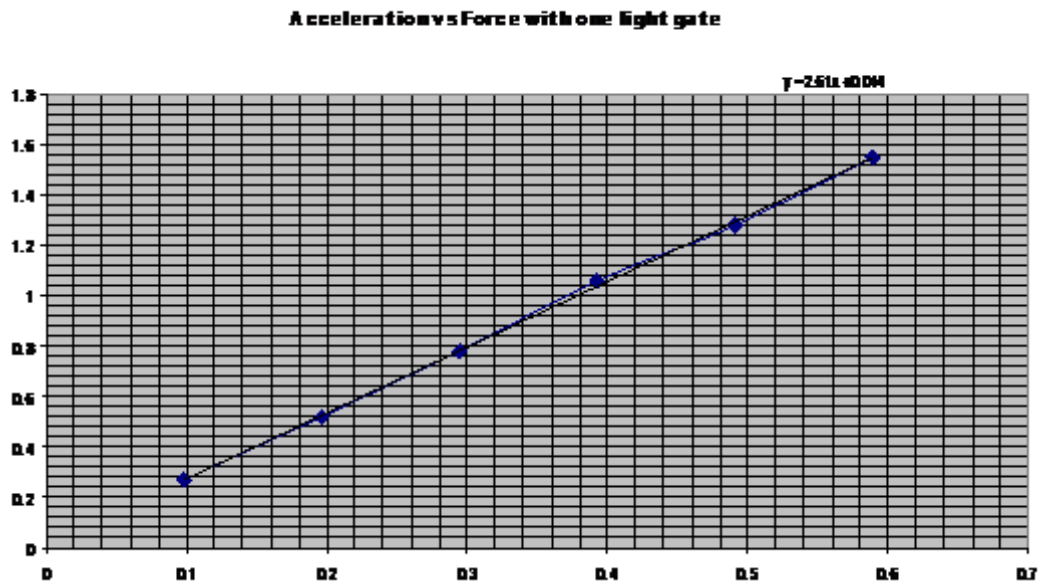
Modern dynamics systems give results as good and as clear as air tracks, with less time overhead in setting up and preparation.

1. Make sure the cart is not passed back through the Light gate as it is returned to the start position.
2. Use a bracket to create a back stop and hence a standard start position for the cart, there is enough accuracy in the cart and software for variations in the start to have significance.
3. Weigh the masses and calculate the force. There is a variation in the individual masses. If you are looking for ability to generate a best fit line then take mass as given.
4. To make it easier to transfer the masses use a small container screwed to the top of the cart by the same bolt that holds the interrupt card in place. The bottom half of a plastic drinks cup is ideal.
5. Make sure that when the masses have reached the floor the cart has passed through all Light gates on the apparatus or you will get a slowing of the cart.
6. Students should be able to catch the cart but you may wish to consider a stop bar or attach a crash barrier at the end of the track.

Sample data

Acceleration at A. Constant system mass, transfer of mass from cart to falling mass hanger.





The graph of force vs. acceleration (best fit line applied)

X axis = Acceleration

Y axis = Force (Newtons)

Student sheet: GCSE Physics required practical activity (8)

Acceleration (1a): Using one Light gate, constant mass varying force

Tests

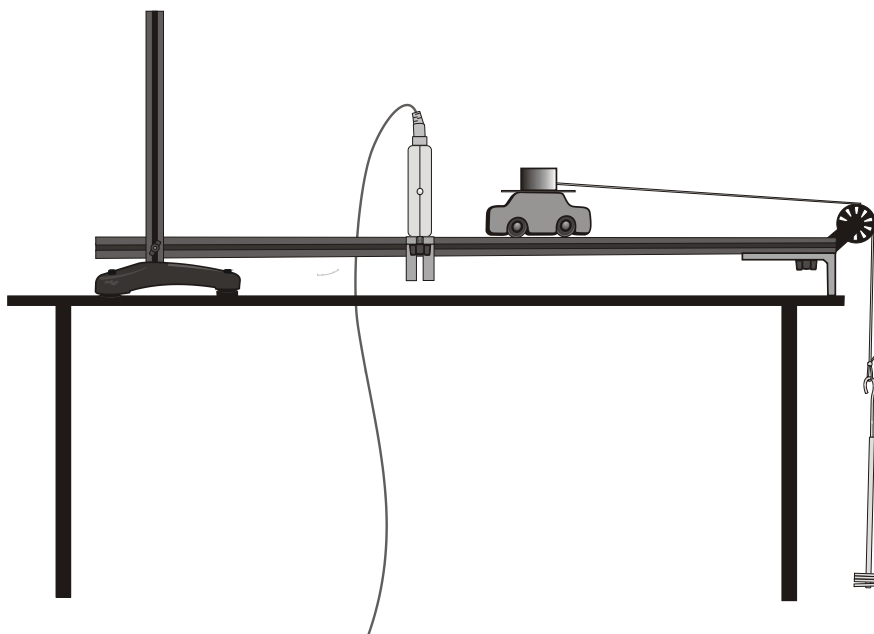
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT2 Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs.

AT3 Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration).

You are going to investigate the acceleration for a constant mass as the force acting on it is varied.

The relationship between force, mass and acceleration is described by Newton's second law.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Dynamics track and support
2. Dynamics cart for track system
3. Spoked pulley attachment, string and mass carrier
4. Light gate
5. Double interrupt card
6. Fixing and positioning brackets for Light gates
7. Large and small fixing brackets to support the track and add a stop barrier
8. Set of masses 10 x 10 g

9. Blu-Tack to fix masses to cart or a small plastic container that can be fixed to the roof of the cart.

Read these instructions before starting work

It can be useful to temporarily Stop logging when returning the cart back to the start, swapping masses, etc. as it will prevent Light gates being activated out of sequence.

1. Assemble the apparatus as shown. Attach the Light gate at approximately the 90 cm mark (the exact distance and separation is not critical in this investigation). Check that the mass on the carrier has not reached the floor before the cart has passed through the Light gate.
2. Attach the double interrupt card to the cart. Check it is the correct orientation.
3. Adjust the slope to compensate for friction by raising/lowering the track against the upright.
4. Fit the spoked pulley to the end of the track. Make sure the string to the pulley is running straight (a small angle is acceptable).
5. Use a paper clip to make a hook. Attach the string and hook to the interrupt card.
6. Add 50 g to the cart, secure the masses in place.
7. Attach the 10 g hanger to the string.
8. Set up the software to record Acceleration at A with a double interrupt card. Enter the length of the interrupt card segment.
9. Select **Start** and release the cart from the start position (this will be same for each run), to run freely along the track through the Light gate.
10. Repeat this at least three times. Delete and repeat any results that are obviously away from the norm (anomalous).
11. Make a note of the mass for the first 3 runs.
12. Transfer 10 g from the cart to the hanger and repeat.
13. Carry on repeating until all the weights have been transferred to the hanger. The total moving mass of the cart and hanger must be the same for all repeats. Select **Stop** to finish logging.
14. Work out the average acceleration for each value of force.
15. Plot a graph of force (N) vs. acceleration (m/s/s) using the graphing software or by hand.

Example results table

Mass (g)	Newtons (N)	Acceleration (m/s/s)	Average acceleration (m/s/s)

Teacher's notes: GCSE Physics required practical activity (8)

Acceleration (2): Using one Light gate, varying mass with a constant force

Tests

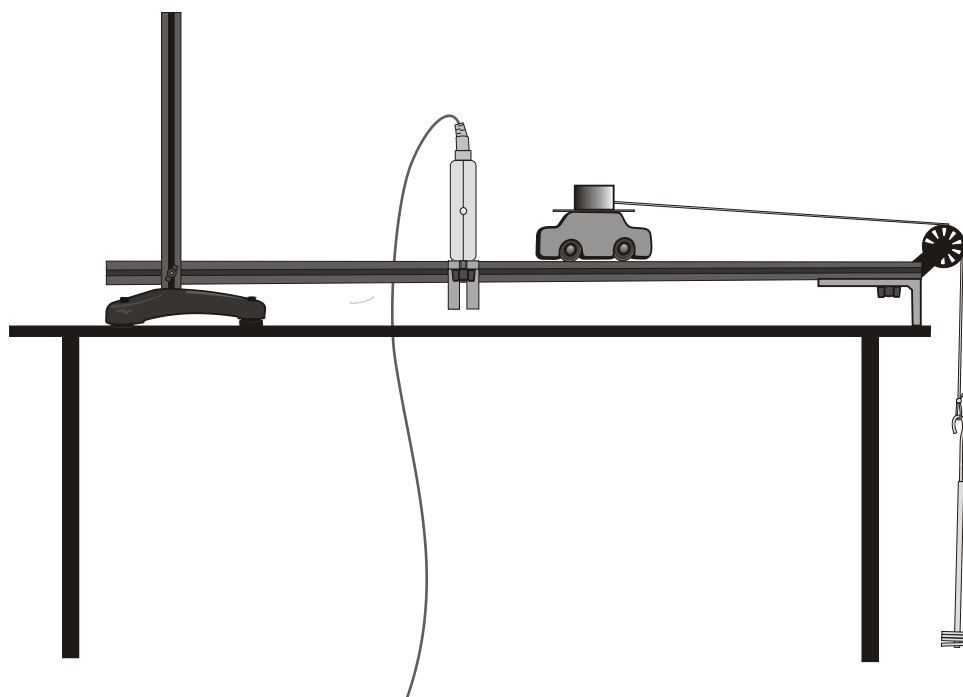
AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT2 Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs.

AT3 Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration).

Apparatus

1. Dynamics track and support
2. Dynamics cart for track system
3. Spoked pulley attachment, string and mass carrier
4. Light gate
5. Double interrupt card
6. Fixing and positioning brackets for the Light gate
7. Large and small fixing brackets to support the track and add a stop barrier
8. Set of masses 10 x 10 g
9. Blu-Tack to fix masses to cart or a small plastic container that can be fixed to the roof of the cart



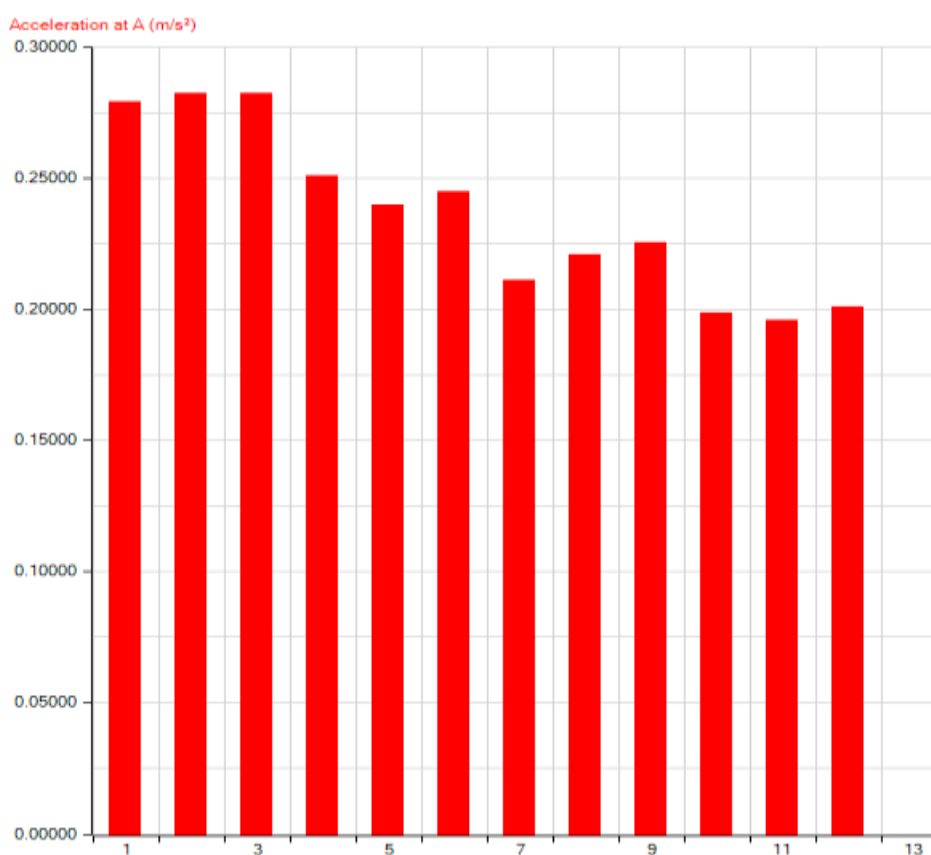
Practical notes

The nominal mass of the cart without any additional items is 0.330 kg. A 10 g mass is sufficient to pull the cart along the track.

Adding 10 g increments of mass to the cart produces data that is getting close to the outlier data from repeats. Each 10 g is only 3% of the mass of the cart. Use 50 g or 100 g masses to add to the cart for results that show the pattern.

Much of the variation in the acceleration data can be tracked back to the cart release method. If you take great care about the release, the data collected is more even and small mass increments can be used. In a busy class with time working against larger mass increments reduces the spread of error / outliers.

Sample results (increasing mass of cart each 3 runs)



Typical sample of data collected using Acceleration at A (using double interrupt card), a 10 g mass for the force and +50 g mass at every 3 repeats. The presentation of the data exaggerates the spread of data.

A graph of acceleration vs $1/\text{mass}$ should be a straight line through the origin.

Student sheet: GCSE Physics required practical activity (8)

Acceleration (2): Using one Light gate, varying mass with a constant force

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT2 Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs.

AT3 Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration).

You are going to investigate the acceleration for a constant mass as the force acting on it is varied.

The relationship between force, mass and acceleration is described by Newton's second law.

Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Dynamics track and support
2. Dynamics cart for track system
3. Spoked pulley attachment, string and mass carrier
4. Light gate
5. Double interrupt card
6. Fixing and positioning brackets for the Light gate
7. Large and small fixing brackets to support the track and add a stop barrier
8. Set of masses 10 x 10 g
9. Blu-Tack to fix masses to cart or a small plastic container that can be fixed to the roof of the cart.

Read these instructions before starting work

1. Assemble the apparatus as shown. Attach the Light gate approximately at the 90 cm mark (the exact distance is not critical in this investigation). Check that the mass on the carrier will not reach the floor before the cart has passed through the Light gate.
2. Attach the double interrupt card to the cart. Check it is the correct orientation.
3. Adjust the slope to compensate for friction by raising/lowering the track against the upright.
4. Fit the spoked pulley to the end of the track. Make sure the string to the pulley is running straight (a small angle is acceptable).
5. Use a paper clip to make a hook. Attach the string and hook to the interrupt card. Attach the 10 g hanger to string.
6. Set up the software to record Acceleration at A with a double interrupt card. Enter the length of the interrupt card segment.

7. Select **Start** and release the cart from the start position (this will be same for each run), to run freely along the track through the Light gate
8. Repeat at least three times, delete and repeat if any results are obviously away from the norm (anomalous).
9. Make a note of the mass for the first 3 runs. Include the initial mass of the cart.
10. Add 10 g to the cart to the hanger and repeat.
11. Repeat for 10, 20, 30, 40, 50 g of additional mass. Select **Stop** to finish logging.
12. Work out the average of the acceleration for each value of the forces
13. Plot a graph of force (N) vs. acceleration (m/s/s) using graphing software or by hand.

Example results table

Mass of cart (g)	Newtons (N)	Acceleration (m/s/s)	Average acceleration (m/s/s)

Plot a graph of acceleration vs. 1/mass.

Teacher's notes: GCSE Physics required practical activity (9)

Waves

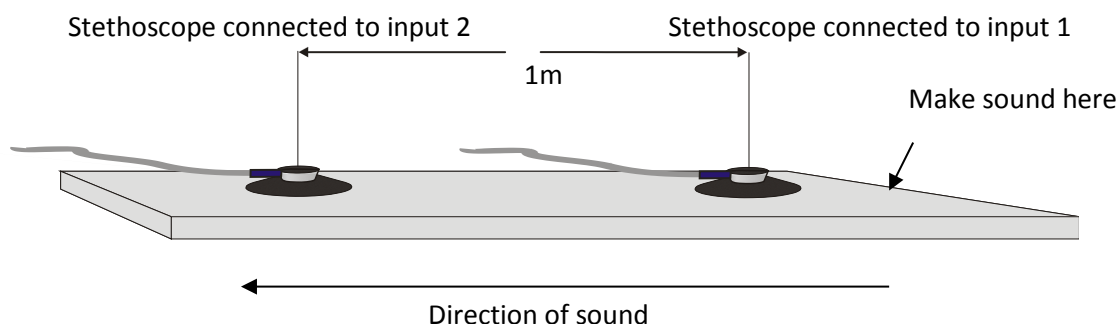
Test:

AT4 Make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in (a ripple tank) and waves in a solid and take appropriate measurements.

The activity depends on the student having worked on calculations of the speed of sound. The activity will either:

1. Require the students to calculate the speed of the test sound in the material being used, or
2. Be given a value for the speed of sound for the material (or a very similar material)

In the experiment a pair of microphones (stethoscope / speed of sound sensors are used as they lie flat on the surface) are arranged to receive a sound from a point source.



By placing the 2 sensors in line on the bench you can record the time taken for the sound to travel from sensor 1 and then pass onto sensor 2.

You need to arrange the apparatus so that any noise created passes sensor 1 before sensor 2.

We are using modified Stethoscope sensors to make the two sound receivers lie flat against the surface.

Apparatus

1. 2 x Stethoscope sensors set to the Sound range (mV)
2. 2 x long sensor cables
3. 2 x extension cables (optional)
4. 1 x measuring tape
5. 2 x small masses, modelling clay or masking tape
6. Oscillator to produce a pure tone (sine wave form)
7. Small speaker matched to oscillator (typically a computer speaker 4 Ω)

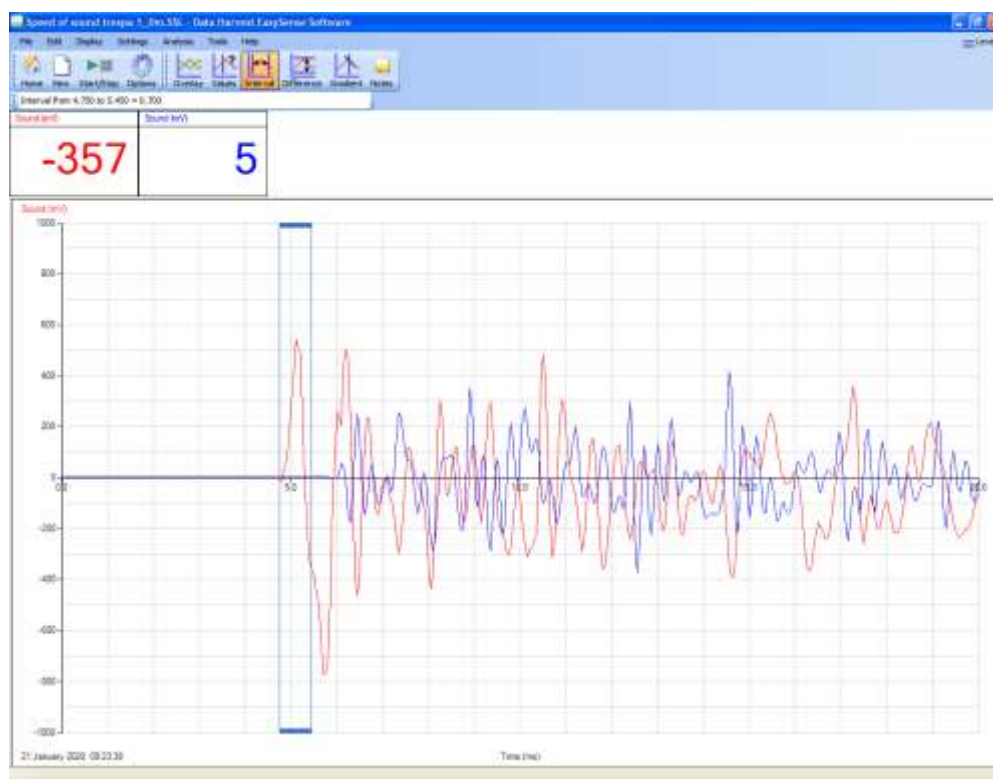
Set up

Recording mode	Length of recording	Intersample time	Trigger event	Pre-trigger
Graph	50 ms	50 μ s	When Stethoscope 1 rises above 100 mV	25%

The trigger allows you to make the sound trigger the recording period.

Essentially you want the recording to be as fast as the logger you have will allow.

Sample result from two sound sensors separated by the length of standard school lab table.



Use the Interval tool or the table of results to find time between the start of the noise on sensor 1 and the start of the noise on sensor 2.

Calculate speed of sound using the distance and time interval.

You could verify the accuracy of the answers against published tables, sample below. In solids additional waves to do with shear can be propagated. The presence of these additional waves can lead to widely varying speeds being quoted in tables of comparison. Many tables express the theoretical values while others use values calculated by experiment.

Solids	V (m/s)
aluminium	5100
brass	4700
brick	3650
copper	4760
cork	500
glass, crown	5100
glass, flint	3980

Solids	V (m/s)
glass, pyrex	5640
granite (293 K)	5950
iron	5950
lead	2160
marble	3810
silver	3650
steel, stainless	5790

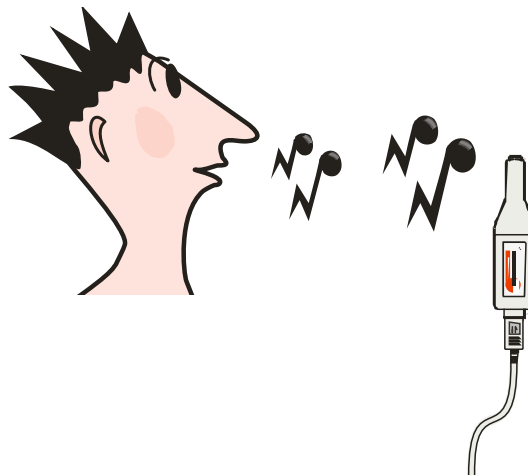
Solids	V (m/s)
wood, ash	4670
wood, elm	4120
wood, maple	4110
wood, oak	3850
wood, pine	3313

To get good values (in agreement to published results) by experiment:

1. Have at least 1 m between the sensors, the bigger the distance the better.
2. Measure the distance to the nearest mm. Errors in this measurement has a big effect.
3. Use the fastest recording time possible.
4. Use a trigger.
5. Make sure the stethoscopes are lying flat on the solid.

Alternatives

1. Place the sensors in very waterproof plastic bags and measure the speed of sound in water.
2. Use a single Sound level sensor, get students to hum or whistle and capture the "noise". Look at how pure the produced tone is; find the frequency, period, wavelength.
3. Find the wavelength by interference (audio Young's slits!)

**Waves in a solid**

The activity uses a small speaker connected to an oscillator / signal generator. The speaker is mounted flat to the surface and held in place using tape, masses or Blu-Tack. Sound from the speaker enters the solid and a remote Stethoscope sensor picks up the signal.

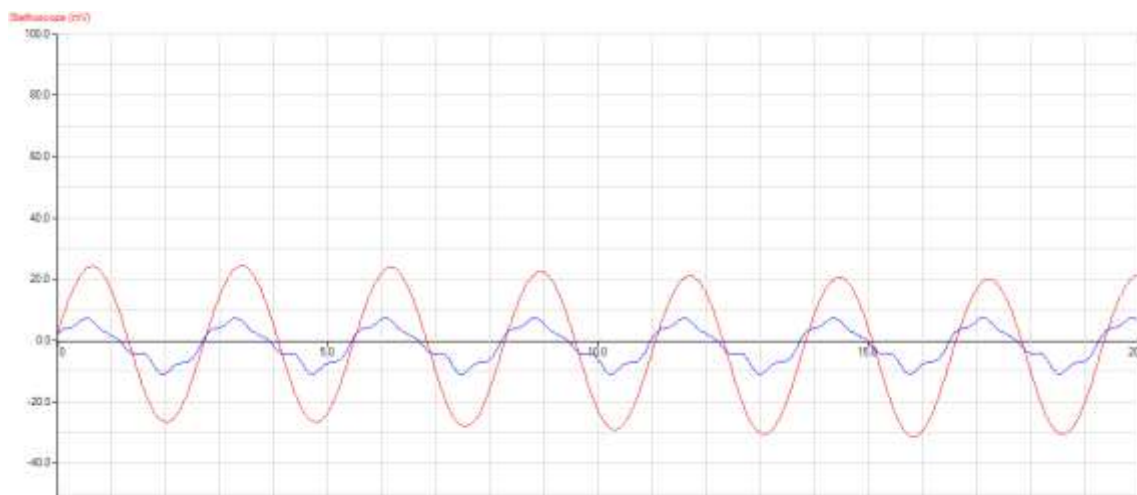
The data logger captures the sound data with sufficient speed and resolution to provide a waveform that can be analysed. Using the tools in the data logging software the period can be found and subsequently the frequency and wavelength calculated.

Apparatus (For this activity only)

1. A Stethoscope sensor set to the Sound range (mV)
2. Long sensor cables
3. Small masses, modelling clay or masking tape
4. Oscillator / signal generator produce a pure tone (sine wave form)
5. Small speaker matched to oscillator / signal generator (typically a computer speaker 4 Ω)

Practical notes

1. You may wish to cover the speaker with some muffling materials, it was not found to make a difference but the possibility of the sound being detected from the air borne frequencies needs to be considered.
2. It was found that the detecting sensor worked better at a distance of 10 -20 cm, but this will depend upon the volume of the speaker. Pre testing is required.



Typical set of results showing sound wave picked up from solid and air. In both cases the same frequency, speaker and sound sensor was used.

1. Waveform is different; the smoother more sinusoidal wave came from the solid.
2. The erratic lower amplitude wave came from air measurement.
3. The surface used was a Trespa work top.
4. Nominal frequency on the signal generator was $30 \times 10 \text{ Hz} = 300 \text{ hertz}$.
5. Calculated frequency = 362 Hz.

As the sound is being measured in both cases after transmission through air the period and frequency will be the same?

Student sheet: GCSE Physics required practical activity (9)

Waves

Tests

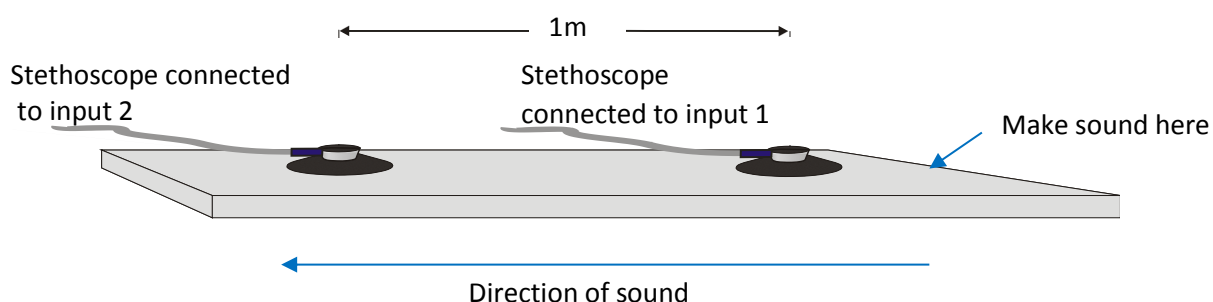
AT4 Make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in (a ripple tank) and waves in a solid and take appropriate measurements.

The activity assumes you have completed work on the calculation of the speed of sound in air and a solid. The activity is divided into two parts.

- Finding the speed of sound in the material being used. This may be given to you by the teacher.
- Investigating a tone introduced into a solid surface and finding its period, frequency and with the speed data, the wavelength.

To find the speed of sound in a solid you arrange a pair of microphones to receive a sound from a point source:

You can skip this if your teacher has given you the speed of sound in the table tops you are using.



By placing the 2 Stethoscope sensors in line on the bench you can record the time taken for the sound to reach from sensor one to sensor 2.

You need to arrange the apparatus so that the point where you will create the noise is first, then sensor 1 and then sensor 2.

Measure the distance between the sensors to the nearest mm.

To get good values:

1. Have at least 1 m between the Stethoscope sensors.
2. Measure the distance between the sensors as accurately as possible.
3. Use the fastest recording time possible.
4. Use a trigger.
5. Make sure the stethoscope is lying flat on the solid.
6. Use something like a pencil or ball point pen to make the noise, you shouldn't need a large force to make a sound that the sensors can detect. If the noise is too large you may end up with a pattern containing a large quantity of confusing, irrelevant data.

Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. 2 x Stethoscope sensors set to the Sound range (mV), diaphragm removed
2. 2 x long sensor cables
3. 1 x measuring tape
4. 2 x small masses, modelling clay or masking tape
5. Oscillator to produce a pure tone (sine wave form)
6. Small speaker matched to oscillator (typically a computer speaker 4 Ω)

Read these instructions before starting work

1. Remove the diaphragm from the Stethoscope sensors and place them in a safe place.
2. Place the Stethoscope sensors onto the bench with the microphone facing down onto the bench top. Use tape, a mass or Blu-Tack to hold it in place.
3. Measure the distance (in metres) between the two sensors. Make sure you measure between the same points on the sensors (e.g. centre to centre or front edge to front edge). Make a note of the distance.
4. Set up the logger and recording, using the guidance in this table.

Recording mode	Length of recording	Intersample time	Trigger event	Pre-trigger
Graph	50 ms	50 μ s	When Stethoscope 1 rises above 100 mV	25%

(You want the logger to go as fast as it can)

5. When you are ready select **Start**.
6. Make a noise on the bench top by striking it with an object; something metal gives a sharper sound. You do not have to make a strong blow to the table; a slight tap may be all that is required. The noise must travel from where you strike the table to sensor 1 and then sensor 2.
7. The logging will be triggered and you will see 2 traces.
8. You should notice the peaks on one trace appear before the peaks on the other trace. Use **Interval** to find the time difference between the sound first reaching sensor 1 and sensor 2.

Sample results

Sensors placed on a school work bench topped with Trespa.

For example:

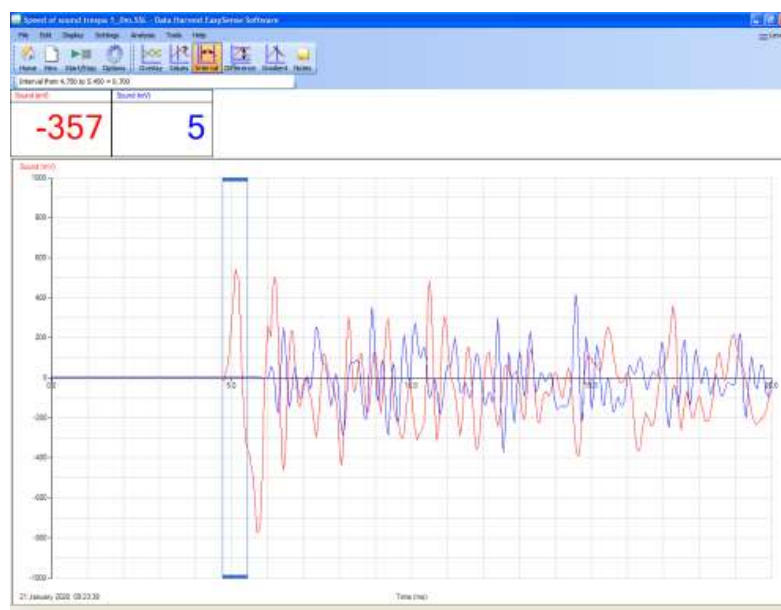
Interval = 0.70 ms

Separation between sensors = 1.0 m

Speed of sound in the Trespa

$$= 1.0 / 0.0007$$

$$= 1428 \text{ m/s}$$



Waves in a solid material

To find the wavelength, period and frequency of a sound wave in a solid surface.

The activity will use a small speaker to create a sound in a solid surface. A Stethoscope sensor a short distance away will be used to record the sound as it passes through the solid.

The distance you place the Stethoscope sensor away from the sound source is not critical, about 30 cm should be ample. You may want to place some sound reducing material over the sound source to convince you that the sound is being transferred through the solid and not the air.

Use the logger set up as shown in the following table:

Recording mode	Length of recording	Intersample time	Trigger event	Pre-trigger
Graph	50 ms	50 μ s	When Stethoscope 1 rises above 100 mV	25%

When you are ready turn on the sound source and let it settle for a few moments then **Start** recording.

You will collect a graph of sound intensity (mV) plotted against time.

Use the table, tools or interval to find

- The period of the wave recorded
- Calculate frequency
- Calculate wavelength

Use and calculate the theoretical values of

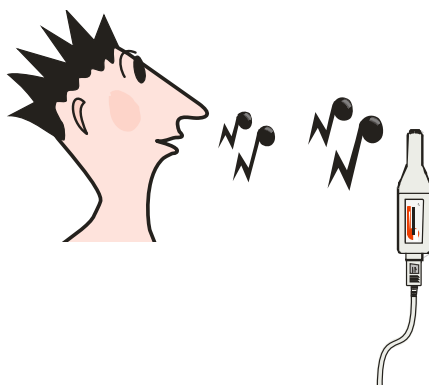
- Period
- Wavelength
- Speed of sound

Compare the results you derived from the practical to the theoretical values.

- How well did the apparatus perform?
- Where the results from the practical close to the theoretical.
- Calculate a % error between practical and theoretical.

Extension activity

Use a single Sound level sensor and either hum or whistle, capture the “noise” – look at how pure the produce tone is, find the frequency, period, wavelength.



Teacher's notes: GCSE Physics required practical activity (10)

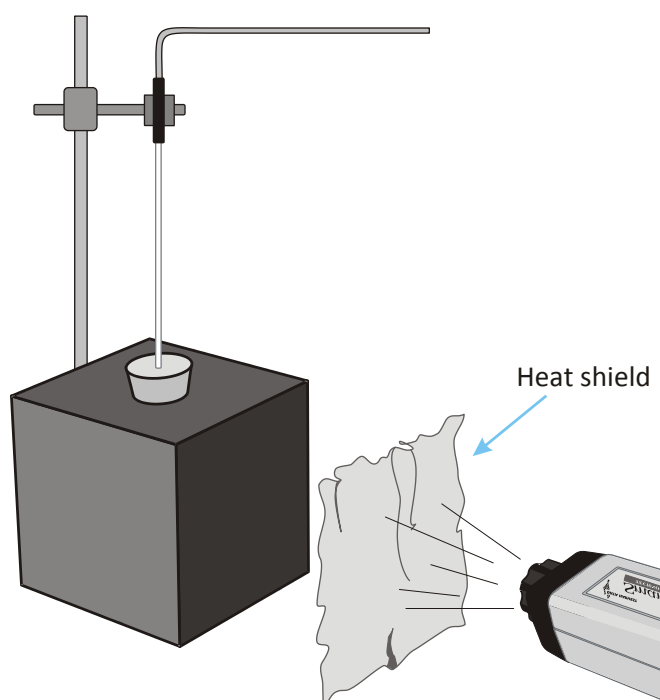
Radiation

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT4 Make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in (a ripple tank) and waves in a solid and take appropriate measurements.

Investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.



Apparatus

1. Infrared sensor set to the Rad $30 \text{ W/m}^2 \text{ sr}^{-1}$ range*. The silica glass filter should not be fitted
2. Temperature sensor (to monitor the temperature of the hot water in the can)
3. A Leslie's cube or a large can with the surface painted and textured
4. Kettle or a supply of hot water (90°C)
5. Heat proof mat
6. A foil covered card shutter or heat resistant screen
7. Ruler
8. Stirrer
9. Retort stand, clamp etc.

* Note on range to use: This is a comparative investigation; the range is selected to provide readings that will show a difference. In the tests of this work the Rad $30 \text{ W/m}^2 \text{ sr}^{-1}$ range gave the best show of difference. You may need to or wish to change the range to suit local conditions.

Practical notes

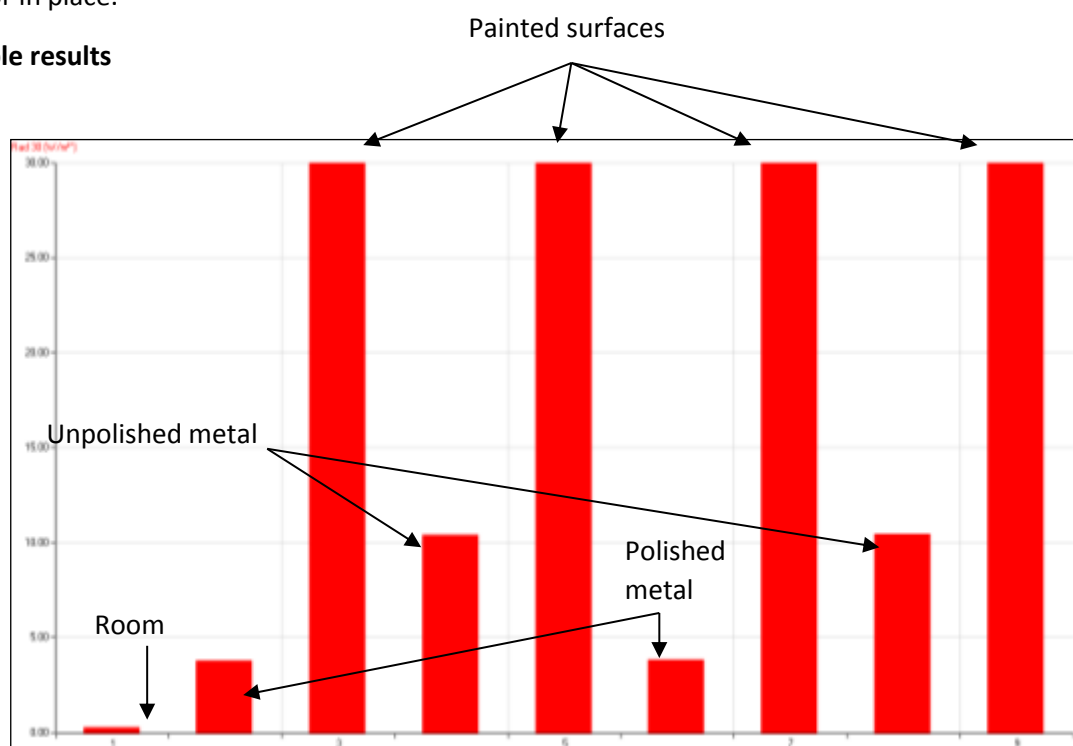
If a Leslie's cube is not available a large tin can e.g. a catering sized coffee tin, could be used. The can's surface should be divided into four panels, each of which will be treated in a different way, e.g. shiny metal, matt metal, matt black and gloss black. If you have access to several cans each could be treated to give a set of finishes e.g. 1 colour in a gloss and matt finish. Each side /panel must have an area of at least 5 cm in diameter. Consider deliberately choosing black and white as these colours will cause the biggest conflict with perceived ideas. Many students will have picked up the idea that pale finishes keep you cooler and this is why Mediterranean housing is painted white. If the experiment works well they will have to consider other explanations for colour selection!

The best results come from apparatus where the water can be gently stirred; this prevents the build-up of convection plumes in the cooling water. Allowing a stirrer, can compromise the apparatus by leaving an uncovered "top" to the water body – you will have to decide which is the greatest error, and which teaches the most about the principles of the "fair test" in a scientific investigation.

Either use a foil covered card shutter or a heat resistant screen. This should be placed between the sensor and the Leslie's cube between readings to prevent the sensor from heating up. The sensor uses a thermopile which requires there to be temperature difference between the front and back surfaces of the sensor element.

The distance between the sensor and can needs to remain constant. Use a retort and clamp to fix the sensor in place.

Sample results



The four highest peaks show the infrared radiation from the painted surfaces of the Leslie's cube. For the high radiant surfaces, one was painted matt black the other gloss white. Note how there is no difference in heat radiation.

The two mid peaks came from the roughened metal surfaces of the cube.

The two lower peaks came from the polished metal surfaces of the can.

The first, very low, column was a record of the back ground infrared of the room.

The evidence tends to suggest that the texture of the can is much more important than the colour, if you want to keep cool, cover with a highly reflective shiny surface!

Alternatives

1. Use a lamp equidistant from a surface. Use 4 Temperature sensors and cover each with a treated surface. E.g. black paper, white paper, shiny foil, dull foil and record the temperature over 10 minutes. Examine the rate of heating detected by the Temperature sensor or the final temperature.
2. Use a radiant heater and place foils between the heater and the Infrared sensor. Measure the radiant energy at the back of the foil.
3. Use a fast reacting Temperature sensor (unhoused) and the Infrared sensor to record energy vs temperature and calibrate the Infrared sensor as a noncontact thermometer.

Student sheet: GCSE Physics required practical activity (10)

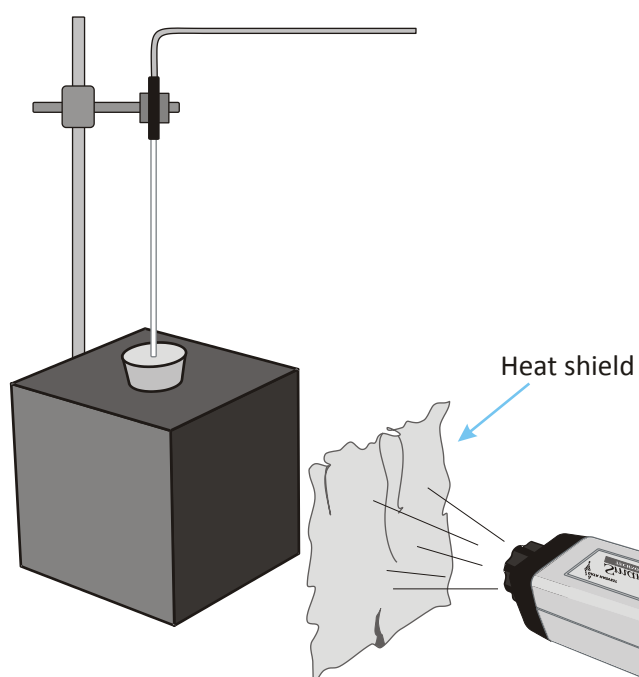
Radiation

Tests

AT1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.

AT4 Make observations to identify the suitability of apparatus to measure the frequency, wavelength and speed of waves in (a ripple tank) and waves in a solid and take appropriate measurements.

Investigate how the amount of infrared radiation absorbed or radiated by a surface depends on the nature of that surface.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Infrared sensor set to the Rad $30 \text{ W/m}^2 \text{ sr}^{-1}$ range. The silica glass filter should not be fitted
2. Temperature sensor (to monitor the temperature of the hot water in the can)
3. A Leslie's cube or a large can with the surface painted and textured
4. Kettle or a supply of hot water (90°C)
5. Heat proof mat
6. A foil covered card shutter or heat resistant screen
7. Ruler
8. Stirrer
9. Retort stand, clamp etc.

Risk assessment

You will be using water that is very close to boiling and creating reservoir of very hot water. Make sure the can cannot be dropped or the contents spilled.

Read these instructions before starting work

1. Connect the Infrared and Temperature sensor to the logger. Check the silica glass filter in the end cap of the Infrared sensor has been removed.
2. Set up the apparatus as shown in the diagram. Place the Infrared sensor about 5 cm from the can surface - at this distance the sensors will detect from an area of about 5 cm in diameter.
3. Place the can on a heat proof mat, which will be used to rotate the can easily and safely once it is filled with hot water. Once started you need to be able complete the investigation fairly quickly as the can will cool down.
4. Place a foil covered card shutter between the sensor and the cube; this will stop the sensor becoming 'warmed' between readings. Keep the shutter in place when readings are not being taken, and then move it away when you want to take a reading.
5. Set the software to record in Snapshot mode. This lets you decide when it is right to collect the data.
6. Fill the can with hot water (at about 90°C). Leave the apparatus to reach an even temperature; this should take about 3 to 4 minutes.
7. **Start** logging.
8. Remove the shutter from between the sensor and the can and click in the graph area to record the value. Place the shutter back between the sensor and the can.
9. Rotate the can so the next surface faces the sensor, check the distance from the sensor to the can is the same, remove the shutter and record the next value.
10. Repeat for all the surfaces you have prepared on the can. You may wish to repeat this several times more to enable averages to be calculated.
11. Right click on the graph and use **Add Text** to label each value with the surface that produced each result.

Note: If any one reading reaches maximum move the sensor away from the can until the reading is just below maximum and then retake all the readings. If the sensor reading is at maximum you do not know if the reading was more or if the sensor had simply reached the end of its range.

Teacher's notes: GCSE Chemistry required practical activity (2)

Neutralisation

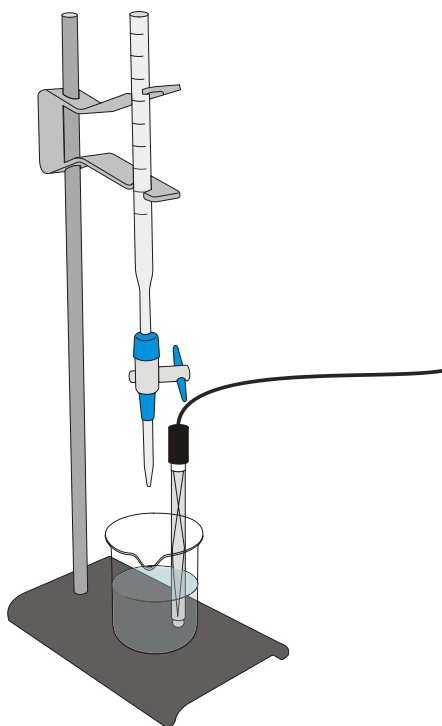
Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 8 Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis (links to A level AT d).

Apparatus

1. Volumetric pipette – 25 cm³
2. Pipette filler
3. 50 cm³ burette
4. 0.1 mol dm⁻³ Sodium hydroxide (NaOH)(concentration shown for all levels)
5. 0.1 mol dm⁻³ Hydrochloric (HCl) or Sulfuric (H₂SO₄) acid (concentration hidden for higher tier students)
6. 100 ml beaker (you need to cover the skirt of the pH sensor with the alkali). A beaker is often easier for the user than the traditional conical flask
7. 50 ml beaker
8. Indicator solution (methyl orange)
9. pH sensor
10. Retort stand and clamps, bosses, burette clamps
11. Protective eyewear, gloves and lab coats



Practical notes

The practical activity is to determine the reacting volumes of solutions of a strong acid and strong alkali by titration. This will require solutions of known strengths.

As an extension, for higher tier, the concentration of the unknown can be determined. This will require one solution to have a known concentration and the other to be unknown.

The use of a pH sensor allows the student to see more detail in the transition from basic to acidic. Methyl orange changes at pH less than 3.1, which represents a slight over shoot in the equalisation point. For students not used to using indicators and titrations the colour change can be difficult to determine with repeatability. Using the indicator and pH allows reinforcement of both methods.

The examination board materials suggest 0.8 M sulfuric acid; one assumes this is to ensure an exact known but not obvious value for volume is found. A burette will provide 3 litres before refilling at this concentration.

Convention uses the acid in the burette and alkali in the flask. With glass burettes and ground glass stopcocks this was to prevent alkali erosion of the glassware. It is a matter of debate with modern hardened (borosilicate) glass and Teflon stop cocks if the acid has to be in the burette, one suspects that examination questions may question which you put where.

Technical detail about use of the burette does not have to be included, but there is an opportunity to verify start volume - final volume = volume, filling skills, etc.

Refer to local guidance e.g. SS or SSERC about acid dilution techniques if making from concentrated stock and labelling of student stock with harmful, corrosive, etc. Purchased dilutions are perfectly acceptable for the work.

An indicator should not be necessary if the pH sensor is being used, but is another chance to piggy back the colour changes in indicators to a piece of practical. Phenolphthalein indicator is an acceptable substitute for methyl orange. A white tile should be provided if an indicator is being used, learners find the colour changes difficult to ascertain.

The data logger / software uses Snapshot mode. In this mode the user decides when it is time to take a reading by clicking in the area of the graph.

Risk assessment

1. Acid is irritant. Check details against hazcards for acid being used and dilutions.
2. Alkali – Sodium hydroxide is irritant at less than 0.5 mol dm^{-3} and corrosive at 0.5 mol dm^{-3} and higher.
3. Indicators – congo red in the indicator is carcinogenic. Methyl orange is toxic if swallowed (CLEAPSS safety sheets, 70 dyes and indicators).

Set up

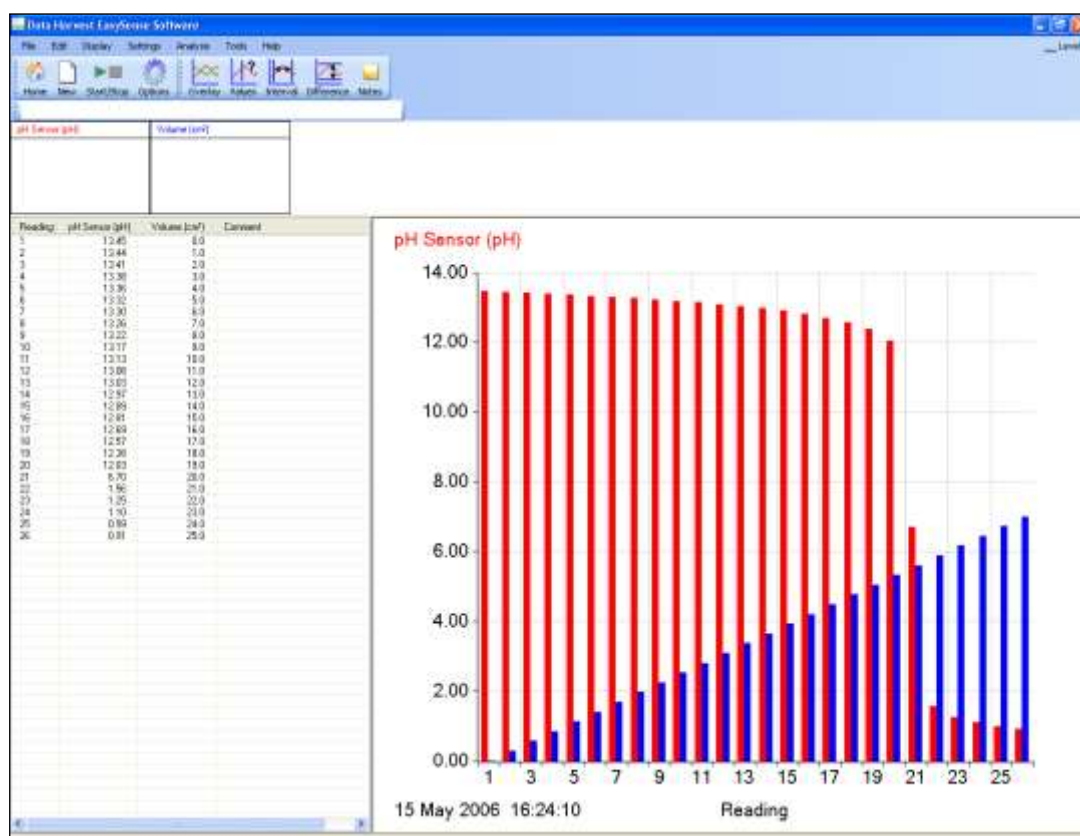
The recording of the data should be in either:

- Snapshot mode, if the data is to be recorded or
- Meters mode if the apparatus is to be used as a meter

In **Snapshot mode** the user decides when the data is collected, this is unlike normal data logging collection that uses a time period and a sampling frequency.

In the practical the user would add a volume of the titrant and then click on the graph area to record the pH value.

If before starting data collection a Pre-log Function > Titration > Asks for the Volume added can be created. With this function the user is asked to enter the volume added so far each time you click in the graph area, the value will normally be the burette reading.



Subsequently the graph can be converted to a “channel vs. channel” graph with volume on the x-axis and pH on the y-axis.

Alternatively the table of data can be used to hand draw the plot of pH vs. volume.

The method chosen will depend upon the focus of the learning outcome or assessment activity.

Student sheet: GCSE Chemistry required practical activity (2)

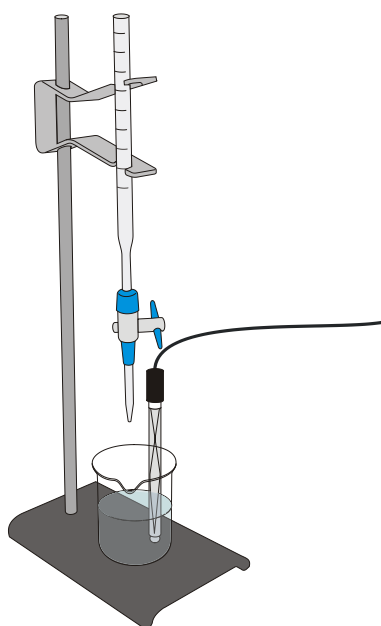
Neutralisation

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases.

AT 8 Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis.

The practical activity is to determine the reacting volumes of solutions of a strong acid and strong alkali by titration.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Volumetric pipette – 25 cm³
2. Pipette filler
3. 50 cm³ burette
4. 100 ml beaker (or as advised by teacher)
5. 50 ml beaker and white tile
6. 0.1 mol dm⁻³ Sodium hydroxide (NaOH)
7. Acid
8. Indicator solution (methyl orange)
9. pH sensor
10. Retort stand and clamps, bosses, burette clamps
11. Protective eyewear, gloves and lab coats

Read these instructions before starting work

Methyl orange indicator is yellow in alkali and changes to red when the pH falls below 3.1.

1. Connect the pH sensor to the logger. Set up the apparatus as shown; make sure the burette is vertical.
2. Fill the burette with the acid to just above the zero line. Place a 50 ml beaker under the burette point and run out the excess acid to the zero mark on the burette. Make an accurate note of the reading on the burette scale.
3. Pipette out 25 cm³ alkali into a 100 ml beaker
4. Stand the beaker on a white tile under the burette point. Adjust the position of the burette to make sure it is just above the beaker and not getting in the way of the pH sensor.
5. Add 5 – 10 drops of the indicator and give the beaker a swirl to mix the indicator evenly.
6. Set up the software to record in Snapshot mode with the Asks for the Volume added function.

Mode	Tools, Pre-log Function		Name	Units	Channel Min / Max
SnapShot	Titration	Asks for the Volume added	Volume	cm ³	0 / 0

7. Select **Start** and click in the graph area to record the pH value of the alkali solution in the flask. A prompt box will open and ask you for a value. Enter the value you recorded in step 2 (0 volume). This records the pH of the alkali before adding any acid.
8. Using the burette add 2 cm³ of acid into the flask. Gently swirl the beaker, wait 10 seconds and click in the graph area to record the new pH value. When prompted enter the new burette volume (accurate).
9. Repeat until you notice the rate of pH change is increasing and when the indicator is staying red longer, now add smaller volumes. You may want to change to 1 cm³ then 0.5 cm³. You do need to be patient, the pH will suddenly change and you don't want to miss this sudden change
10. Continue until the rate of change of pH has slowed down again (this will be 2 or 3 additions after the big change in pH), Stop.

Results

You will have a graph that shows the Volume of acid added and the pH of the solution vs. reading.

You will need to change this to a graph of Volume (x-axis) and pH (y-axis) or plot the graph on paper.

To plot volume against pH directly:

1. **Save** the data (in case you make a mistake and need to get back to the original data).
2. Select **Options**. From the X-Axis tab select **Channel**, OK.
3. Alter the graph so the data is shown as pH on the y-axis (vertical axis) and Volume on the x-Axis (horizontal).
4. Use **Values** to find the point of equivalence (pH 7, or a value given by your teacher for the practical) and read off the pH and Volume.
5. Calculate an average of the Volume from the trails you have conducted.

Calculations for unknown concentration

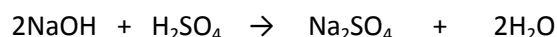
$$\text{Concentration mol dm}^{-3} = \text{number of moles} / \text{volume of solution (dm}^3\text{)}$$

In the example calculations values in *italics* would be substituted by the values in your solutions and answers.

Step 1: How many moles in the known solution?

Moles of sodium hydroxide in 25 cm^3 = concentration of solution x volume

e.g. $0.1 \text{ mol dm}^{-3} \times (25/1000) \text{ dm}^3$

Step 2: Understand the stoichiometry of the reaction (what and how many molecules react)

This shows that 2 moles of sodium hydroxide neutralise 1 mole of sulfuric acid.

So the number of moles of sulfuric acid used = moles of sodium hydroxide / 2

Step 3: Find the concentration of the acid used

Concentration of sulfuric acid mol dm^{-3} = moles / (mean volume of acid / 1000)

The answer will be in mol dm^{-3}

Step 4: Number of moles of sulfuric acid

Number of moles = mass of substance (g) / M_r of substance

M_r of H_2SO_4 =

Concentration of sulfuric acid (g/dm^{-3}) = answer from step 3 x $M_r \text{ H}_2\text{SO}_4$

Teacher's notes: GCSE Chemistry required practical activity (4)

Temperature changes

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

The practical asks the students to monitor the changes in temperature as sodium hydroxide is added to hydrochloric acid in a simple cup calorimeter.

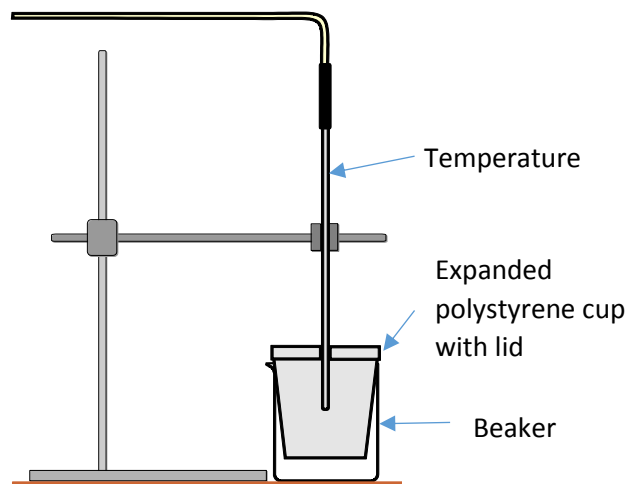
Meters mode is used to collect data; this effectively converts the sensor to a digital thermometer.

Alternatives

- 1a. Conduct a thermometric titration.
- 1b. Monitor the temperature changes in a displacement reaction.

Apparatus

1. Temperature sensor
2. Hydrochloric acid (HCl) 2 mol dm^{-3}
3. Sodium hydroxide solution (NaOH) (2 mol dm^{-3})
4. Retort stand and clamp
5. Glass beaker – the polystyrene cup needs to fit inside so the cup is suspended in the glass beaker
6. Expanded polystyrene cup that fits inside the beaker
7. Lid for the polystyrene cup.
8. 10 cm^3 and 50 cm^3 measuring cylinders



Practical advice (sodium hydroxide and acid variant)

The concentrations suggested are quite strong to ensure a measurable temperature increase.

You may find it simpler to use 10 ml syringes, but they do carry the risk of the water pistol effect!

Student sheet: GCSE Chemistry required practical activity (4)

Temperature changes

Tests

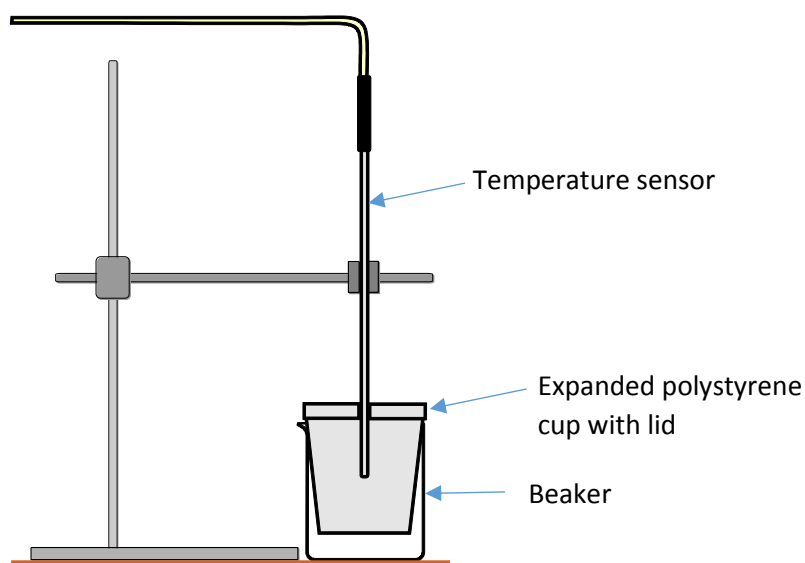
AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

The practical asks you to monitor the changes in temperature as you add small volumes of sodium hydroxide to a dilute hydrochloric acid solution. A graph of the temperature changes is plotted against volume added to make an estimate of the volume of sodium hydroxide to fully react with the acid.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Temperature sensor
2. Hydrochloric acid (2 mol dm^{-3}).
3. Sodium hydroxide solution (2 mol dm^{-3})
4. Retort stand and clamp
5. Glass beaker – the polystyrene cup needs to fit inside so the cup is suspended in the glass beaker
6. Expanded polystyrene cup that fits inside the beaker

7. Lid for the polystyrene cup
8. 10 cm³ and 50 cm³ measuring cylinders

Read these instructions before starting work

You will need to work quickly and orderly. The temperature changes may be small and you do not want to lose any heat created.

1. Set up the apparatus as shown in the diagram. Make sure the polystyrene cup is fully suspended inside the beaker.
2. Add the acid to the beaker, measuring out the volume using the measuring cylinder.
3. Check that the tip of the Temperature sensor is in the acid but not touching the bottom of the cup.
4. Connect the Temperature sensor to the logger.
5. Use the 10 cm³ measuring cylinder to measure out 5 cm³ of the sodium hydroxide.
6. Set up **Meters** mode to show a numeric display of the temperature. Record the temperature at the start.
7. Add the sodium hydroxide to the acid in the beaker and wait until the temperature stops rising. As soon as you see the temperature stop changing write down the temperature reading. Ideally you should be ready to add the next sample as soon as the temperature has been recorded.
8. Add the next sample; again wait for the temperature to stop changing and record.
9. Repeat until the volume added is 40 cm³. The last few readings should see the temperature start to fall again. This is the first run.
10. Dispose of the solution made and start again to give 2 runs of data.

Results

Total volume of sodium hydroxide added (cm ³)	Maximum temperature reached (°C)		
	First run	Second run	Mean
0			
5			
10			
15			
20			
25			
30			
35			
40			

Plot a graph of the mean temperature vs. volume with temperature on the y- axis and the volume on the x- axis.

Draw two lines of best fit, one through the points that are rising and one through the points that are falling. The two best fit lines should intercept. The co-ordinates of the intercept will give the maximum temperature and the volume of sodium hydroxide needed to neutralise the 25 cm³ of hydrochloric acid.

Teacher's notes: GCSE Chemistry required practical activity (4)

Temperature changes: Alternative (1 a) A thermometric titration

Tests

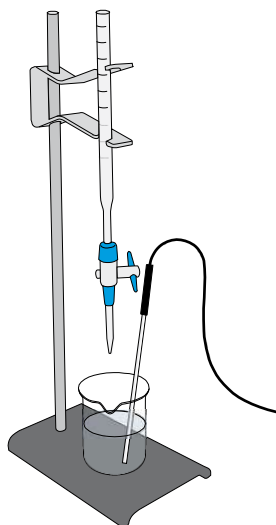
AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

The original activity is in effect a titration, but with very large additions. In this variant of the activity the method is refined by using a burette to add smaller volumes and a data logger in snapshot mode to record both volume and temperature. This should give a better value for the neutralisation volume. A comparison is possible between the methods.



Apparatus

1. Temperature sensor
2. Hydrochloric acid (HCl) (2 mol dm^{-3})
3. Sodium hydroxide (NaOH) solution (2 mol dm^{-3})
4. Retort stand and clamp
5. Glass beaker – either insulate the beaker or use an expanded polystyrene cup that fits inside the beaker
6. 50 cm^3 burette

Practical notes

30 cm³ of the alkali was used as this gave a good depth for the Temperature sensor. With different apparatus you will need to adjust the volume.

With equal molar solutions you should be able to collect the peak temperature and beyond with a single burette.

Time can be critical with this method, take the readings too quickly and the increase in temperature is not realized, take it too slowly and heat will have started to move to the environment. Using polystyrene cups does reduce heat loss. Well insulated glass ware will work but not as well.

Stronger molar solutions are required to generate the heat. One molar represents a good compromise between strength of solution to produce a good change and safety concerns over strong solutions.

Two molar solutions can be used if the group is experienced and the risk assessment is positive.

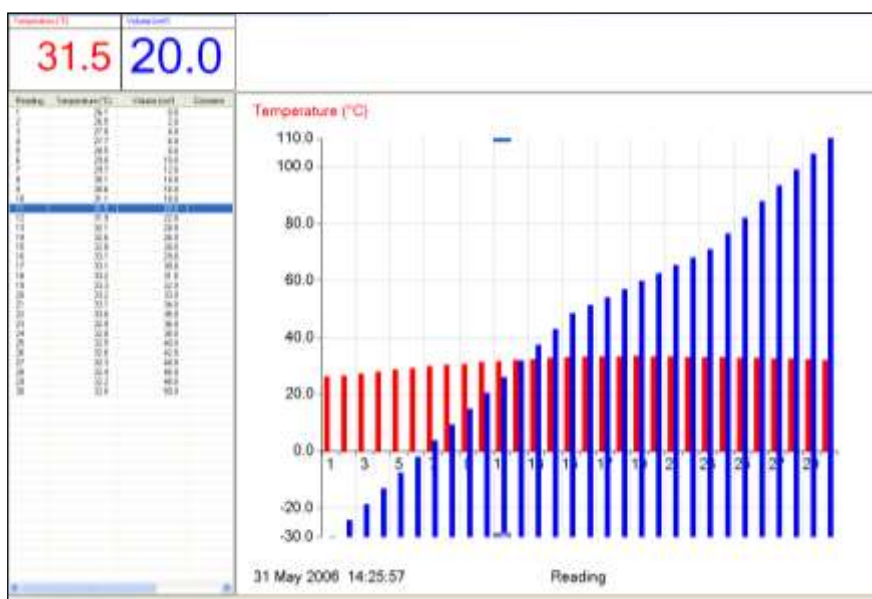
When a measurement is taken, a pop up dialogue box will prompt for a volume; when using a burette it is normally the reading straight of the scale of the burette. The exact value on the burette should be entered for best accuracy.

Set up

Use Snapshot mode. Go to Tools > Pre-log Functions > Preset function > Titration > Asks for the Volume added to set up the dialogue that asks how much you have entered from the burette.

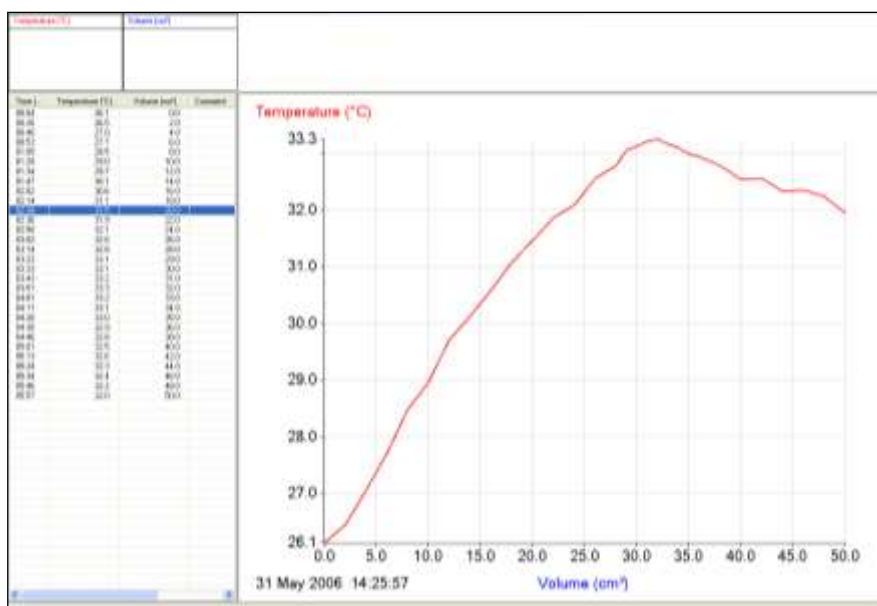
Typical result

From equal 1 mol dm⁻³ Sodium hydroxide and Hydrochloric acid.



Data as collected. Note the change in volume additions as seen in the step change of the data.

Converting the data first to a line graph and then to a volume vs. temperature graph



The final graph. The Values tool can now be used to find the peak (approx. 32 cm³), which is quite impressive as 30 cm³ was the original volume of 'equal molar' solutions. Prepared by serial dilutions, not back titrated – it may be correct!

Student sheet: GCSE Chemistry required practical activity (4)**Temperature changes: Alternative (1 a) A thermometric titration****Tests**

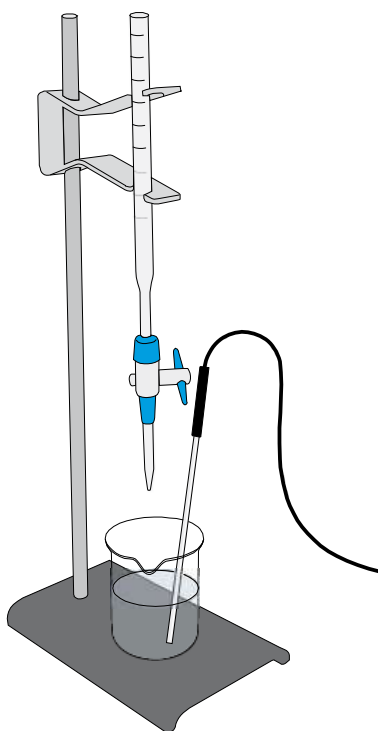
AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

The activity uses a burette to add small volumes and snapshot mode to record both volume added and temperature change.

**Apparatus**

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Temperature sensor
2. Hydrochloric acid (2 mol dm^{-3})
3. Sodium hydroxide solution (2 mol dm^{-3})

4. Retort stand and clamp
5. 100 ml glass beaker insulated or an expanded polystyrene cup that fits inside the beaker
6. 50 cm³ burette
7. Small funnel

Read these instructions before starting work

1. Connect the Temperature sensor to the logger.
2. Set up the apparatus as shown. Fill the burette with either the acid or alkali as advised by your teacher. You may want to place the burette on a lower surface while filling.
3. Level the volume in the burette to 0 cm³.
4. Set the software to record data in Snapshot mode with the pre-log titration function to 'ask for the volume added' active.
5. Select **Start** to begin logging.
6. Click in the graph area to record the pH value of the solution in the beaker. A prompt box will open and ask you for a value, enter 0 (zero).
7. Using the burette add 2 cm³ of acid into the beaker. Gently stir the solution, wait 5 seconds and click in the graph area to record the new temperature value. Enter the total volume indicated on the burette when prompted.
8. Repeat. Continue until all the acid has been added. As you get to the point where the volume of acid being added is close to the volume of alkali originally used you should change the volume added to a smaller amounts (0.5 or even 0.1 cm³).
9. When you notice the temperature start to fall again, select Stop icon to finish logging.
10. You will have a graph of temperature and volume vs. reading. Each reading will show the volume of acid added and the temperature of the solution.



Sample of the data collected

Results

You will need to treat the data to show the peak temperature.

Step 1: Convert the data collected to a line graph format.

1. Select Options and change graph type to Line Graph.
2. Select the X-Axis tab and choose Channel. OK

Step 2: Change the axes to Temperature on the y-axis, and Volume on the x-axis

1. Click the axis label below the x-axis until it reads Volume.
2. Click in the white space left of the y-axis until the label reads Temperature.

Step 3: Find the peak temperature and volume.

1. Select the **Values** tool and move the cross hair cursor to be at the peak.
2. Read off the volume and temperature values from the data boxes.

Alternatively,

1. Plot the graph by hand and use best fit lines on the rising and falling data. At the intersect read of the co-ordinates for the volume and maximum temperature.
2. Print out the graph and draw on the best fit lines. Find the intersect and the temperature and volume values.

Teacher's notes: GCSE Chemistry required practical activity (4)

Temperature changes: Alternative (1b) A displacement reaction

Tests

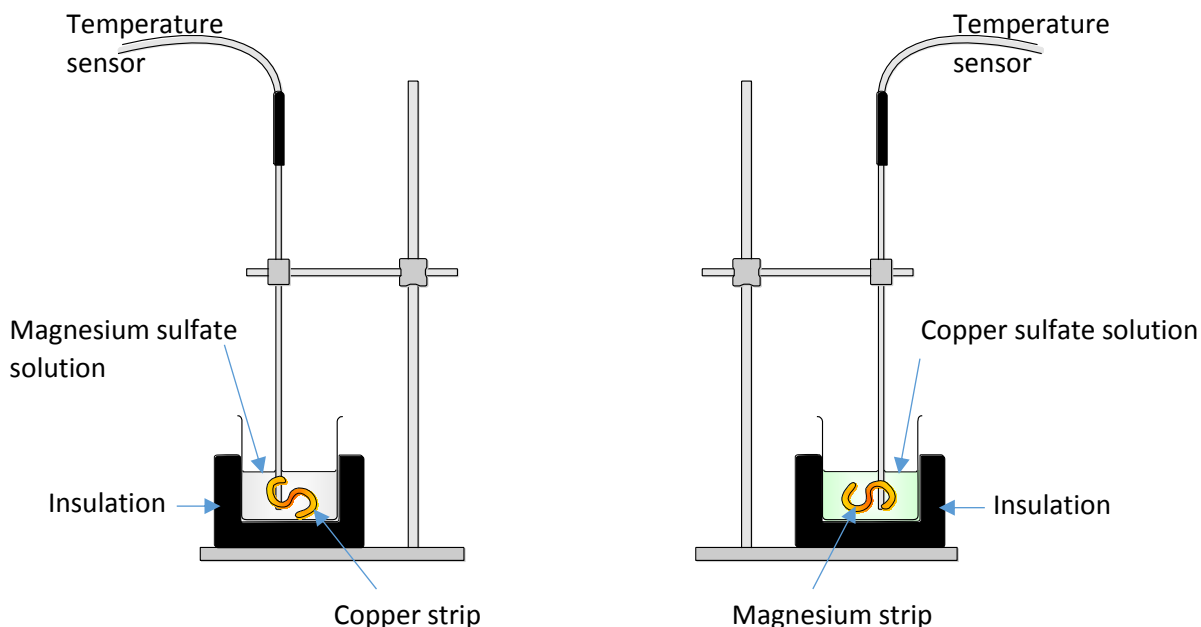
AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

This activity tests if magnesium is more reactive than copper. There are several ways the practical can be conducted. The diagram suggests running two trials side by side or you can do one trial after the other and overlay the data onto the same graph axis. In both cases you add a metal foil to a solution and monitor the temperature change over a period of time.



Apparatus

1. Temperature sensor(s)
2. 50 ml beakers
3. 150 ml beakers
4. Insulating materials (paper towels, foam, etc.)
5. Retort stand and clamps
6. Magnesium sulfate solution – $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$

7. Copper sulfate solution – $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
8. Copper strip – Cu
9. Magnesium strip – Mg

Practical notes

For the experiment to work best the metal strips should be free from any surface corrosion or tarnish, a light rub with a fine emery (carbide) cloth will remove most. Do not use chemical cleaners (such as might be used for cleaning brass, silver, etc.), these often contain oils and lacquers to coat the newly cleaned surface and slow down future tarnish.

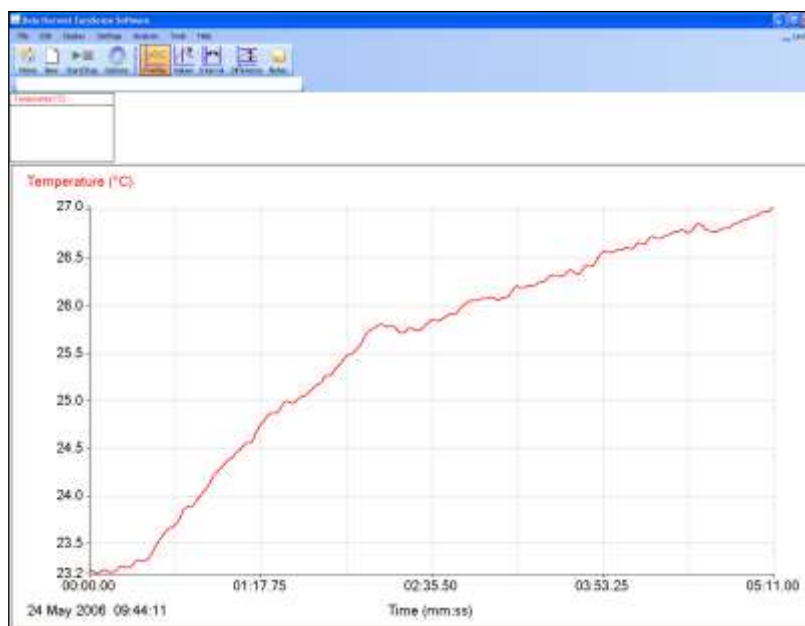
The largest surface area for the mass needs to be used to make the reaction fit into the time scale of an average lesson. The standard ribbon for magnesium is about ideal for all the metals.

The temperature rise is being used as a measure of the chemical reaction taking place. If the results are required to be more qualitative then the solutions should be made up to the same molar strength, 1 mol dm^{-3} should be adequate for most of the salt solutions. Check with data tables for solubility. Sulfates are usually a good compromise between availability, solubility and cost.

To get temperature changes that could be measured and looked convincing we found that using a 50 ml beaker filled to 20 ml mark with 1 mol dm^{-3} copper sulfate and adding approx 0.2 g of magnesium ribbon gave a sufficiently vigorous reaction to be completed in 5 minutes.

When taking the temperature measurements it is advised to use some form of insulation around the reaction vessel, a well cut into piece of insulating foam is ideal. A large beaker filled with insulation and the smaller vessel nested into the insulation also works well.

Sample result



Temperature axis has been auto scaled. There has been about a 5 degree temperature change. If the practical was being used for demonstration of the reactivity series then the rate of change in temperature and the maximum temperature reached will provide the information for relative reactivity.

Student sheet: GCSE Chemistry required practical activity (4)

Temperature changes: Alternative (1 b) A displacement reaction

Tests

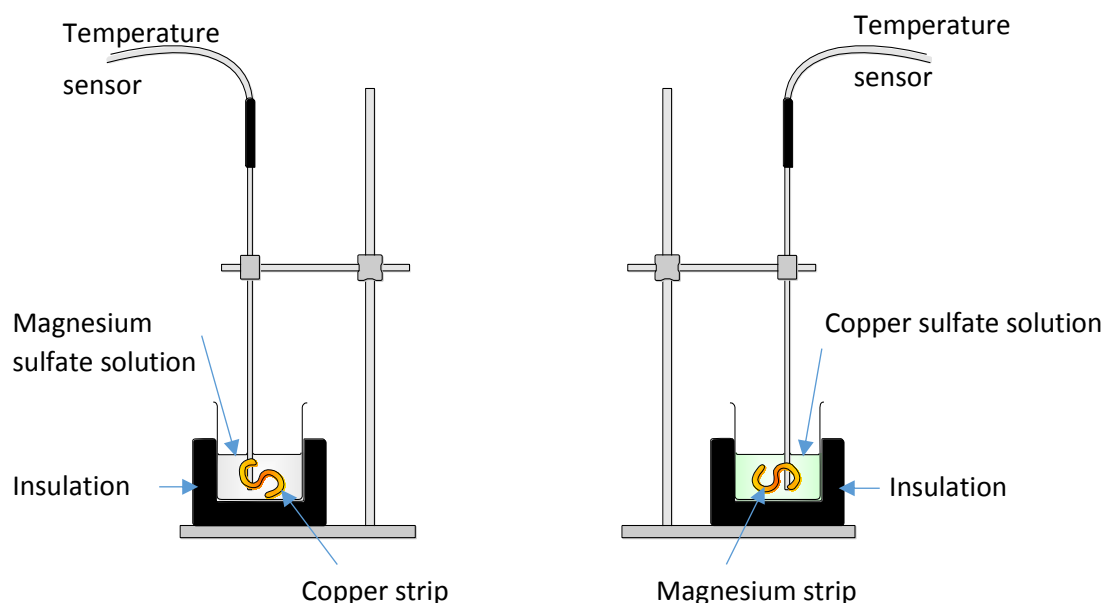
AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

This activity tests if magnesium is more reactive than copper. There are several ways the practical can be conducted. The diagram suggests running two trials side by side or you can do one trial after the other and overlay the data onto the same graph axis. In both cases you add a metal foil to a solution and monitor the temperature change over a period of time.



Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Temperature sensor(s)
2. 50 ml beakers
3. 150 ml beakers
4. Insulating materials (paper towels, foam etc.).
5. Retort stand and clamps.
6. Magnesium sulfate solution
7. Copper sulfate solution

8. Copper strip
9. Magnesium strip

Read these instructions before starting work

1. Set up the apparatus as shown, with the copper sulfate solution in the beaker.
2. Select **Start** and allow a few seconds of data to be collected to show the starting temperature of the solution.
3. Carefully put the magnesium strip into the copper sulfate solution.
4. Run the recording until the temperature has stopped rising and has been stable for 30 seconds, select Stop to finish logging. If the beaker is not insulated you may see a fall in temperature
5. Remove the Temperature sensor from the beaker, and wipe clean.
6. Save the data.
7. Select Overlay and repeat using magnesium sulfate in the beaker and adding the copper strip. Use the same volume and mass as in the first run.

Teacher's notes: GCSE Chemistry required practical activity (5)

Rates of reaction

Investigate how changes in concentration affect the rates of reactions by a method involving a change in colour or turbidity. Time taken for the production of colloidal sulfur in the decomposition of thiosulfate.

A light sensor colorimeter

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

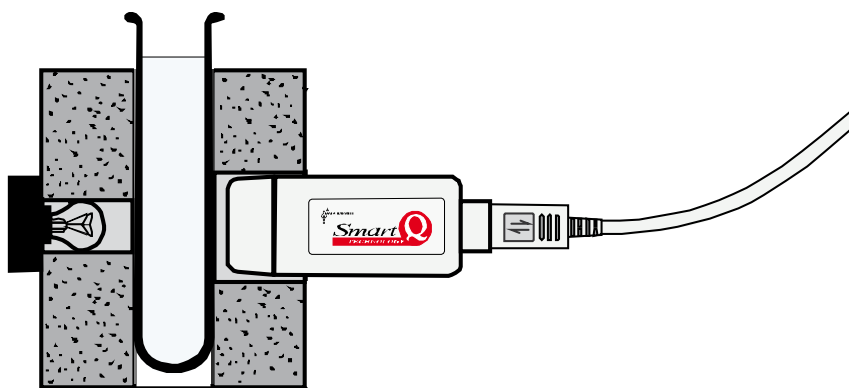
AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

One of the problems of the thiosulfate reaction and the disappearing cross is the determination of when the cross has gone from sight. When using a data logger you can create a standard for determining the end of the reaction, for example when transmission reaches 20%. The advantage is an unambiguous end point. The example here shows a simple homebrew colorimeter.

Simple colorimeter made using Light level sensor and pipe insulation (V1)



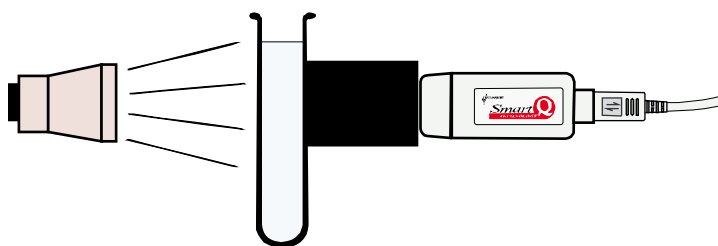
To make this colorimeter (V1):

1. Boiling tubes - this will be the reaction vessel
2. Light level sensor set to transmission range
3. Piece of large bore (22 mm) pipe insulation cut to just short of the length of the boiling tube. Two holes are cut in the insulation, opposite each other. One hole accepts the sensor the other lets light in.
4. Light source – could be a desk lamp or an inset LED or a torch

Simple colorimeter using a Light level sensor (V2)

To make this colorimeter (V2):

1. Light level sensor set to transmission range
2. Boiling tube
3. Light source (desk lamp)
4. Dark card to form a light shield

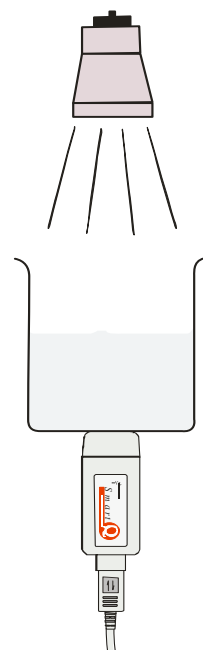


Using the Light level sensor under a beaker as colorimeter (V3)

To make this colorimeter (V3) – the simplest of the alternatives

1. A retort, finger clamp and boss
2. 50 ml beaker
3. Standard lab lamp
4. Light level sensor set to transmission range

You are shining light down through the beaker onto the Light level sensor. The beaker can be clamped or supported by a tripod (in which case you may need a sturdy card of hardboard support with a centre hole for light. If top light in the lab space is good you may be able to dispense with the additional light. If the additional light is not to be used, consider a light proof sleeve to surround the beaker to reduce changes in light intensity by shadows, light from sun altering the room brightness, etc. A top light usually overwhelms such differences. Make sure the Sensor touches the base of the beaker, but does not support the beaker. Adjust light intensity by moving the top light.



Apparatus

1. Light level sensor set to the transmission range
2. Colorimeter (either V1, V2 or V3)
3. 40 g/dm^3 sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) solution. If it is required that graphs should be plotted in mol dm^{-3} then make this 0.2 mol dm^{-3} .
4. 2.0 mol dm^{-3} Hydrochloric acid (HCl)
5. 5 and 10 ml syringes

Practical notes

The student sheet outlines generic method that will need to be trialled and tailored to the colorimeter method being used and volumes of solutions.

Pre defining an end point as a % light transmission should increase the possibility of sharing of data across groups.

It is a long practical and should be scheduled to run across two 60 minute lessons; it is unlikely that all groups would be finished within a single session.

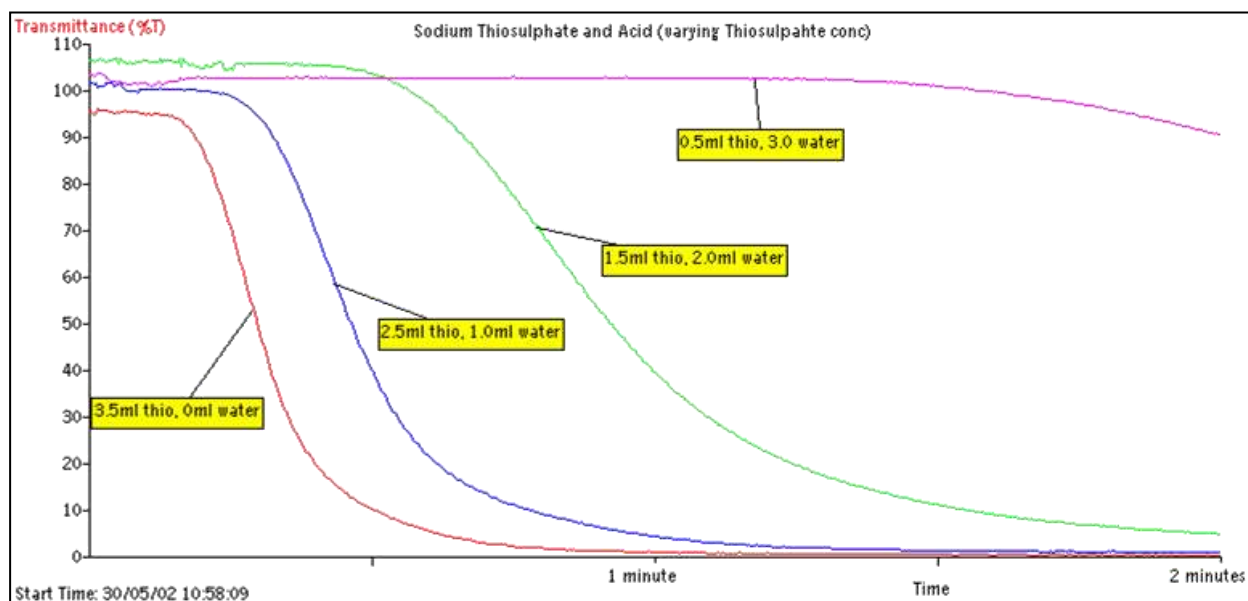
Sulphur dioxide is a by-product of the reaction. The lab should, despite protests, be well ventilated to reduce the effect on individuals with pre-existing conditions such as asthma.

Recording method	Time	Intersample time	Display
Graph	5 minutes	1 second	Overlay selected

Suggested volumes / concentrations to use: 40 cm^3 is about half a standard boiling tube.

Volume of 1 mol dm^{-3} hydrochloric acid (cm^3)	Volume of water (cm^3)	Volume of thiosulfate (cm^3)	Total Volume (cm^3)
5.0	0.0	35.0	40.0
5.0	5.0	30.0	40.0
5.0	10.0	25.0	40.0
5.0	15.0	20.0	40.0
5.0	20.0	15.0	40.0
5.0	25.0	10.0	40.0
5.0	30.0	5.0	40.0

Typical results



The illustration above gives an example of a concentration of a thiosulfate investigation. The data was collected in a standard colorimeter using 4 cm^3 cuvettes. You should expect very similar results from the apparatus described. Note how the first appearance of the colloidal sulphur becomes slower as the thiosulfate is diluted.

To determine a rate the students should take an arbitrary transmission value that is present in all the results they collected and find how long it took each experiment to reach this light value, this is the nominal rate. A plot of rate vs. concentration of the thiosulfate / temperature will show the relationship between rate and the controlled variable.

To produce a better rate plot the time value to reach x% transmission should be plotted as $1/t$ vs. the controlled variable.

Risk assessment

It is the schools responsibility to complete a risk assessment according to their local policy

- Eye protection should be worn
- 2 mol dm^{-3} Hydrochloric acid (IRRITANT).
- Sulfur dioxide (TOXIC).
- Check with guidance in adopted safety guidance e.g. SSERC or CLEAPSS.

Student sheet: GCSE Chemistry required practical activity (5)

Rates of reaction

Investigate how a change in concentration of a solution affects the rate of a chemical reaction.

In this investigation you will be using the reaction between sodium thiosulfate and hydrochloric acid to find how the concentration of the thiosulfate solution affects the rate of the reaction.

A Light level sensor colorimeter

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations (links to A-level AT a and d).

AT 5 Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change (links to A-level AT a and l).

AT 6 Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products (links to A-level AT a and k).

Apparatus

1. Light level sensor set to the transmission range
2. Colorimeter
3. 40g/dm^3 sodium thiosulfate solution. (if it is required that graphs should be plotted in mol dm^{-3} then make this 0.2 mol dm^{-3})
4. 2.0 mol dm^{-3} hydrochloric acid
5. 5 and 10 ml syringes

Read these instructions before starting work

Your teacher will have provided you with a diagram of the apparatus.

1. Connect the Light level sensor to the logger. Use a boiling tube filled with water in the colorimeter to adjust the light source to give a reading of 90%. You may have to readjust the apparatus between runs to re-establish the setting. The glassware you will be using has optical defects.
2. Use the table below to prepare the first test solution. Add the thiosulfate to the boiling tube and any water to make up the first dilution. Do not add the acid!
3. Use a syringe to measure out the required volume of hydrochloric acid.
4. Set up the logger to record for 5 minutes with a sample time of no faster than 1 per second.
5. **Start** recording and immediately use the syringe to add the acid, the force of emptying the syringe should stir the contents of the reaction vessel.
6. Make sure Overlay is turned on and repeat the process using the other dilutions as shown in the table.

Volume of 1 mol dm ⁻³ hydrochloric acid (cm ³)	Volume of water (cm ³)	Volume of thiosulfate (cm ³)	Total Volume (cm ³)	Concentration of thiosulfate g/dm ³
5.0	0.0	35.0	40.0	35
5.0	5.0	30.0	40.0	30
5.0	10.0	25.0	40.0	25
5.0	15.0	20.0	40.0	20
5.0	20.0	15.0	40.0	15
5.0	25.0	10.0	40.0	10
5.0	30.0	5.0	40.0	5

Final concentration is calculated by (volume of thiosulfate x concentration)/ final volume

Results

For each run you will have created a graph that starts with a transmission of 90% and slowly gets to a lower value.

On the advice of your teacher select a transmission value, e.g. 80% and time how long it took for the transmission to reduce to the value. Do this for each run.

If you have repeat data either from your work or pooled from the class calculate mean. Remember to discard data that falls outside your limits (is anomalous).

Plot a graph of thiosulfate concentration (x-axis, controlled variable) vs. mean time to reach x%.

Compare results with other groups.

- Is the data reproducible?
- What can you say about the relationship between the concentration and the rate of the reaction?

Teacher's notes: GCSE Biology required practical activity (5)

Enzymes: Effect of pH on the rate of protease digestion of milk powder protein

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH (links to A-level AT a).

AT 2 Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater (links to A-level AT a).

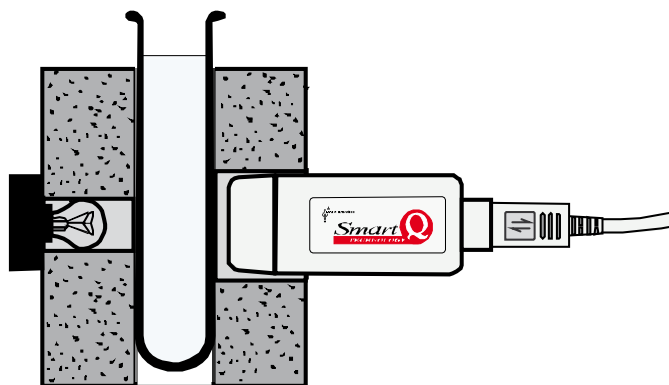
AT 5 Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator (opacity).

AT 8 Use of appropriate techniques and qualitative reagents to identify biological molecules and processes in more complex and problem-solving contexts including continuous sampling in an investigation (links to A-level AT f).

The colorimeter used can be a purchased Colorimeter or a Light level sensor set to its custom transmission range.

To make this colorimeter (V1):

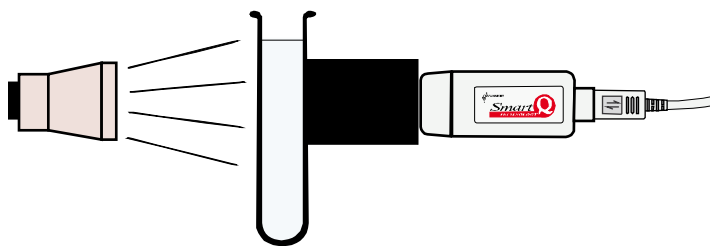
1. Boiling tubes - this will be the reaction vessel.
2. Light level sensor set to transmission range.
3. Piece of large bore (22mm) pipe insulation cut to just short of the length of the boiling tube. Two holes are cut in the insulation, opposite each other. One hole accepts the sensor the other lets light in.
4. Light source – could be a desk lamp or an inset LED or a torch.



Simple colorimeter made using Light level sensor and pipe insulation (V1)

To make this colorimeter (V2):

1. Light sensor set to the transmission range.
2. Boiling tube
3. Light source (desk lamp)
4. Dark card to form a light shield.

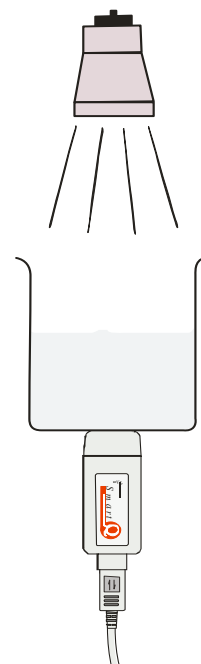


Simple colorimeter using a Light sensor (V2)

To make this colorimeter (V3) – the simplest of the alternatives:

1. A retort, finger clamp and boss.
2. 50 ml beaker
3. Standard lab lamp
4. Light level sensor set to transmission range.

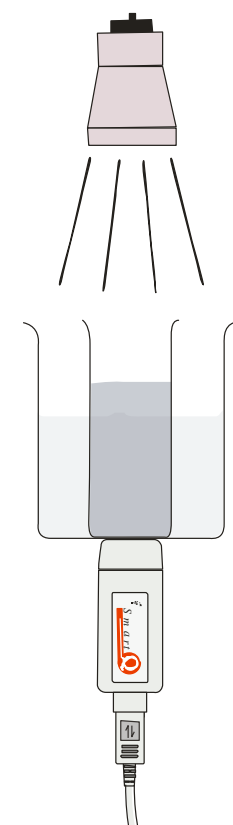
You are shining light down through a beaker onto a Light level sensor. The beaker can be clamped or supported by a tripod (in which case you may need a sturdy card or hardboard support with a centre hole for light). If the top light in the lab space is good you may be able to dispense with the additional light. If the additional light is not to be used, consider a light proof sleeve to surround the beaker to reduce changes in light intensity by shadows, light from sun altering the room brightness, etc. A top light usually overwhelms such differences. Make sure the Sensor touches the base of the beaker, but does not support the beaker. Adjust light intensity by moving the top light.

**To make this colorimeter (V4) – provides the facility for temperature control.**

1. A retort, finger clamp and boss.
2. Tripod
3. 50 ml beaker glued into a 200 ml beaker (or a gallipot inside a 200 ml beaker)
4. Standard lab lamp
5. Light level sensor set to transmission range.
6. Foil

This is a more sophisticated reaction vessel. The method of collecting the light changes is the same as V3

What we do here is take a larger beaker and using glass glue stick a smaller glass pot inside the beaker. Typically a glass specimen bottle or a redundant screw top culture pot, preference is for the culture pot as they are more robust.



A beaker of 150 ml capacity (squat form) has the same height as the inserted tube (in most cases). You can use aluminium foil to cover the inner vessel if you wish to restrict light.

The glass glue is quite robust and will withstand handwashing and scrubbing well.

Advantages of this set up are that you can use the space between the beaker and the inserted pot to act as water bath and gain control over the temperature of the reaction.

Apparatus

1. A Colorimeter (V1, V2, V3 or V4) with the Light level sensor set to transmittance range
Or a Colorimeter set to transmittance range with blue filter and two cuvettes
2. Protease enzyme solution 1% v/v
3. Milk powder suspension 1% w/v
4. Buffer solutions of pH 10, 7, and 4
5. Two syringes or graduated pipettes (one for the protease and one for the milk powder suspension).

Setup

5 minutes allows for the slowest reaction.

Recording method	Time	Intersample	Overlay
Graph	5 minutes	1 second	On

Practical notes

An alternative enzyme practical that provides an opportunity to use a colorimeter. The amylase digestion of starch is a staple of biology teaching but comes with its own set of difficulties. The iodine test can be difficult to determine the end phase, the subtle differentiation between shades of orange with a tinge of black give variance that can often undermine the purpose of the practical.

Modern enzymes do provide a simpler method; nonspecific protease can digest the opaque protein material in powdered milk suspension to create a colour change from white to colourless (opaque to transparent). The enzyme can often be more stable and give cross group comparisons.

In the activity a light is shone through the milk suspension and the increase in light transmitted through the suspension is monitored. A value of transmission is agreed upon and the time taken to reach that level of transparency is taken as the measure of the speed of reaction.

It is advised to run a test before using the enzyme in class to get a measure of the time span needed. The milk powder solution and enzymes will produce variation that needs to be accounted for.

The casein substrate is made by adding 1 g of fat free dried milk powder to 100 cm³ of water (1% w/v casein to water). Scaling up the volume does not present any problems. This stock is stable and can be kept for at least 24 hours if chilled (after this time decomposition will start to take place). If dried milk powder containing fat is used there is no significant difference to the experiment timings but the digested solution will not be as clear.

Protease enzyme solution, the experiments described in these notes used bacterial liquid protease purchased from NCBE*. Its trade name is NEUTRASE. It is a stable form of the enzyme and its activity is

not greatly affected by storage (in stock) or in overnight preparations. Refrigeration at 4°C is adequate for storage. NEUTRASE can be purchased from most chemical suppliers in small quantities.

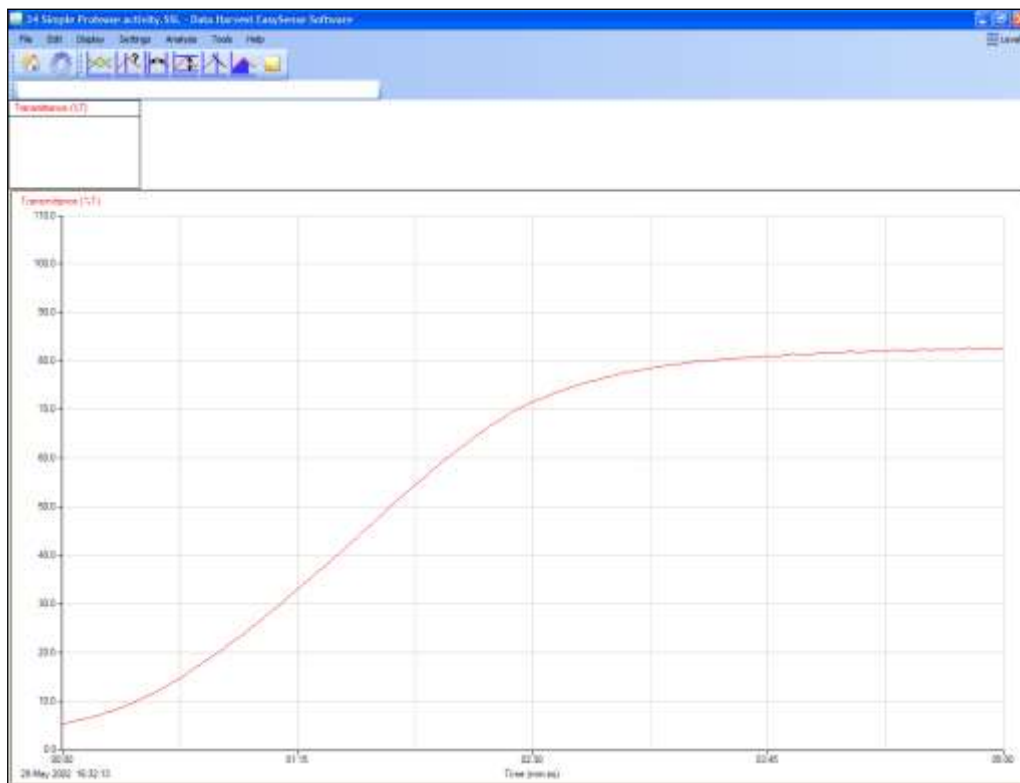
The enzyme was made up as a 0.5% v/v solution with distilled water and allowed to reach room temperature (21°C). The stability of this product means that a buffer is not required, neither is an acid activator. The colour of the enzyme does have an effect on the final values shown in the Colorimeter if its concentration is varied in the experiment. Other proteases can be used but the best concentration will need to be fine-tuned by pre-testing. Experience has shown that 0.1 cm³ to 100 cm³ stock is a good starting reference. The activity of the enzyme needs to be modified to give a completed digestion at room temperature in 3 minutes at pH 7.

If you are using powdered protease care (regarding allergies) needs to be taken when handling the powder.

Milk powder suspension (milk made from dried milk powder) contains mainly a casein protein, which is poorly soluble in water. The suspension has a milky opaque appearance. A non-specific protease enzyme will digest the casein present and create a solution of colourless amino acid particles. The rate at which the opacity of the solution clears is proportional to the rate of the reaction.

*NCBE: The National Centre for Biotechnology Education at the University of Reading (www.ncbe.reading.ac.uk).

Sample result



Once the apparatus is prepared and working the same basic practical activity can be used to test the effect of:

1. Temperature on rate
2. pH on rate

Student sheet: GCSE Biology required practical activity (5)

Enzymes: Effect of pH on the rate of protease digestion of milk powder protein

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH (links to A-level AT a).

AT 2 Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater (links to A-level AT a).

AT 5 Measurement of rates of reaction by a variety of methods including production of gas, uptake tests of water and colour change of indicator (opacity).

AT 8 Use of appropriate techniques and qualitative reagents to identify biological molecules and processes in more complex and problem-solving contexts including continuous sampling in an investigation (links to A-level AT f).

The activity measures the rate of digestion of milk proteins by a protease enzyme. The investigation takes place in laboratory equipment (in vitro) not in living systems (in vivo) and the conditions surrounding the reaction can be modified to investigate the properties of the enzyme.

The protease digests (breaks down) the white, opaque milk powder suspension to a very pale yellow / straw coloured solution. The time taken for the white colour to disappear is used as a measure of the rate of reaction.

Risk assessment

Hot water.

Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. Either a made colorimeter with the Light level sensor set to transmittance range or a Colorimeter set to transmittance range with blue filter and two cuvettes
2. Protease enzyme solution 1% v/v
3. Milk powder suspension 1% w/v
4. Two syringes or graduated pipettes (one for the protease and one for the milk powder suspension).
5. Buffer solutions of pH 10, 7, 4.

Set up

5 minutes allows for the slowest reaction.

Recording method	Time	Intersample	Overlay
Graph	5 minutes	1 second	On

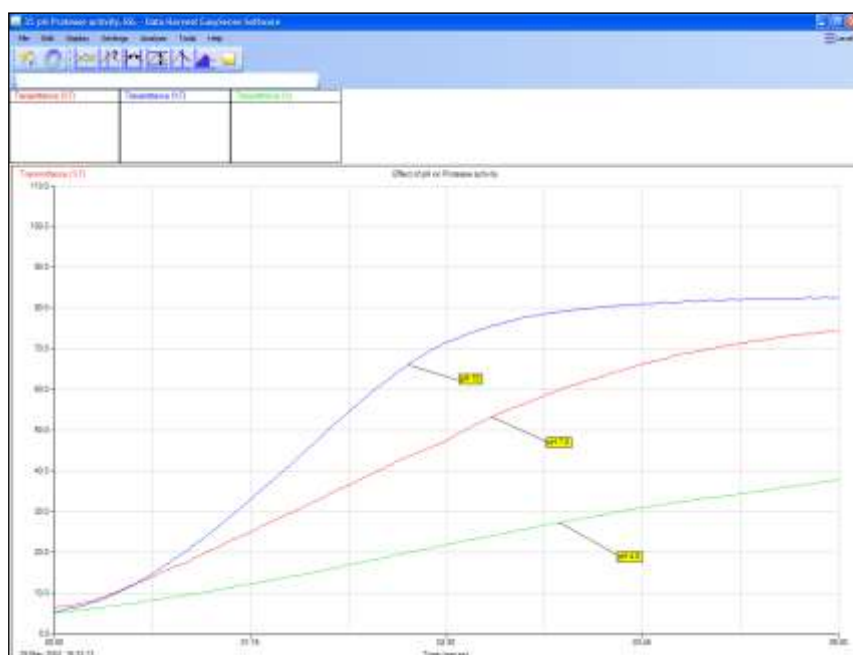
Read these instructions before starting work

1. Connect the Colorimeter or Light level sensor to the logger.
2. Create a 'control' colorimeter by adding 1 unit of water, 1 unit of enzyme and 2 units of milk powder solution into a test tube, mix and leave it to clear. This is simple test to make sure the time of the reaction is good. You will be told what the units are in cm^3 .
3. Set up the logger with the timings in the table.
4. Select Tools, Test Mode.
5. Use the control created in step 1 to adjust the position of the lamp to give a reading of about 90%.
6. Place 1 unit of water and 1 unit of enzyme into a clean test tube in the colorimeter (do not add the milk suspension yet).
7. Add the 2 units of milk suspension and immediately select **Start** to begin logging (Test Mode will be cancelled as logging begins).
8. **Save** the results. Make sure Overlay is selected and repeat using the table below to make up the reaction mixtures. The volumes are units of measurement so you can scale up to match the volume of the apparatus.

Buffer volume/pH	Milk powder solution	1% Protease	Total volume
1.0 of pH buffer 10	2.0	1.0	4
1.0 of pH buffer 7	2.0	1.0	4
1.0 of pH buffer 4	2.0	1.0	4

Sample result

At the end of the activity you should have a graph that looks like:



Use an agreed transmittance value of x% and find out how long it took from the start of the run to reach that %. This will be your rate value

Teacher's notes: GCSE Biology required practical activity (6)

Investigating the effect of light on photosynthesis

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes.

AT 4 Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment (links to A-level AT h).

AT 7 Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator.

There is a range of options to include data logging to this activity.

1. The addition of a Light level sensor to measure the light intensity.
2. To measure activity indirectly by changes to the environment surrounding the plant

The activity requires the user to change the intensity of incident light on the plant material and then to measure by observation or changes to the environment surrounding the plant the rate of photosynthesis.

Apparatus

1. A boiling tube
2. Freshly cut 10 cm piece of pondweed (*Cabomba* or *Elodea*)
3. Light source (controllable)
4. A ruler
5. Test tube rack
6. Stop watch
7. Light level sensor
8. 0.2% solution of sodium hydrogen carbonate (NaHCO_3)
9. Glass rod

Practical notes

Elodea is the plant of tradition; it does however not perform well on expectation. Much better for reliability is *Cabomba*. Both are available in garden centres / aquatic centres. Both should be kept in well aerated and lit holding tanks before use (an old aquaria is ideal). Beakers unless very large are not so good.

If *Elodea* is to be used it should be kept in a very well-lit container for 2 -3 hours before expected time of use. Adding a little carbon source will pay dividends. An Alka Seltzer or sodium hydrogen carbonate (sodium bicarbonate) solution will provide a higher level of CO_2 dissolved in the water.

Tungsten light or good natural light are still the best activators. Modern fluorescents and LEDs do not contain the wavelengths required for photosynthesis (check, if possible the output spectrum if necessary to use).

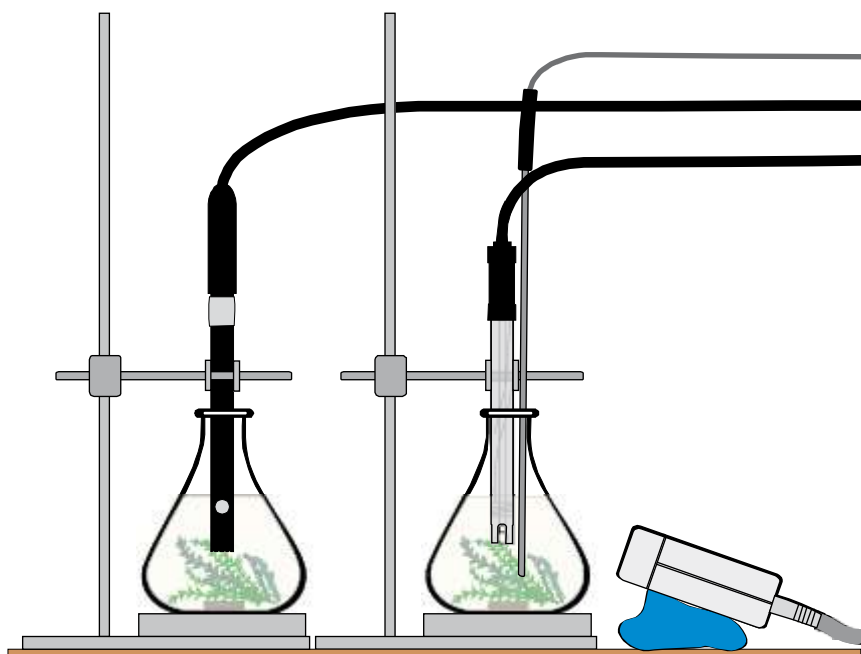
A final plot of distance vs. bubbles will be produced. If simple distance is taken the graph will be curved. Light follows the inverse square law (halve distance quadruple intensity). To get a linear relationship the light intensity needs to be quantified. This is where the Light level sensor comes in useful, simply place the Light sensor next to the tube and measure the distance from the light, the detected intensity and the bubbles per unit time. A plot of bubbles vs. intensity should give a straight line by best fit.

A common error in this activity is to not let the plant equilibrate to the new light intensity before taking measurements. Whenever light intensity is changed wait at least 2 minutes before taking readings.

The variability of the pondweed will make it difficult to pool results; different sections of the weed will produce large variations in the bubbles per minute.

Alternative practical

Measuring photosynthetic activity by changes in the environment



Use a set up as shown and record the pH, oxygen, light and temperature changes over a longer period. You can record only pH and light and still show a good correlation between light and photosynthetic activity. The assumption is that in periods of good light the plant photosynthesises and uses up CO_2 in the water which changes the pH, in periods of low light respiration becomes the dominant activity and pH changes as CO_2 is dumped by the plant into the water.

Student sheet: GCSE Biology required practical activity (6)

Investigating the effect of light on photosynthesis

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH (links to A-level AT a).

AT 3 Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes.

AT 4 Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment (links to A-level AT h).

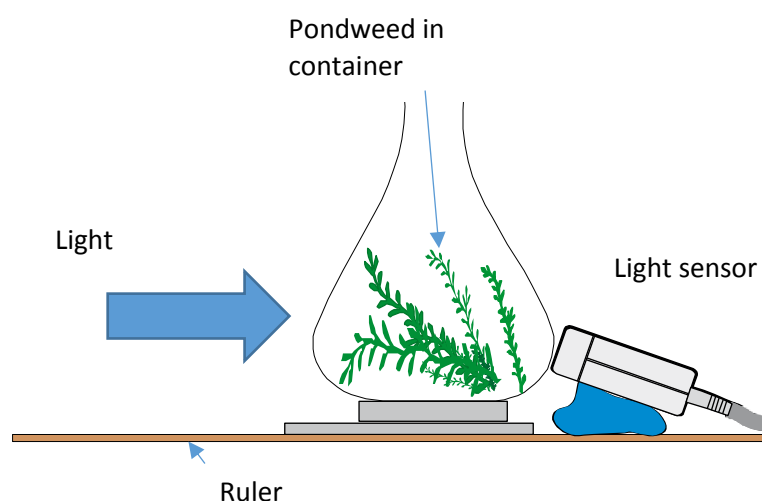
AT 7 Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator.

In this activity you are required to investigate how changing the light intensity changes the rate of photosynthesis.

Apparatus

You are provided with the following specific apparatus. Other apparatus, if required, is available in the lab.

1. A boiling tube
2. Freshly cut 10 cm piece of pondweed (*Cabomba* or *Elodea*)
3. Light source (controllable)
4. A ruler
5. Test tube rack
6. Stop watch
7. Light level sensor
8. 0.2% solution of sodium hydrogen carbonate
9. Glass rod



Read these instructions before starting work

1. Fill the container given (beaker, boiling tube or flask) with the sodium hydrogen carbonate solution.
2. Position the container at a distance of 10 cm from the light source.
3. Place the Light level sensor behind the container such that light from the source passes through the container into it. Fix the sensor in place with a clamp and stand or Blu-Tack.
4. Prepare a piece of pondweed with a clean cut end and place this into the container with the cut end upwards. Use a glass rod to move the weed around if necessary.
5. Turn the light on and leave for 5 minutes.
6. Make a note of the light intensity using the Light sensor. If the light intensity is above the range of the sensor move the sensor away from the container until the reading comes into scale.
7. After 5 minutes count the bubbles of oxygen released from the cut end in 1 minute. Repeat the count two more times. Record the results in a table
8. Move the light 10 cm back from its start position, it will now be 20 cm from the container. Read off the light intensity from the sensor.
9. Leave the pondweed for 5 minutes and then count the bubbles for three 1 minute periods.
10. Repeat for distances of 30 and 40 cm of distance from the light to the container.

Distance between light and container (cm)	Light intensity (lux)	Bubbles counted in one minute			
		1	2	3	Mean
10					
20					
30					
40					
50					

Use your results to plot graphs of:

1. Distance vs. mean bubbles.
2. Light intensity vs. mean bubbles.

Teacher's notes: GCSE Biology required practical activity (7)

Reaction times

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH (links to A-level AT a).

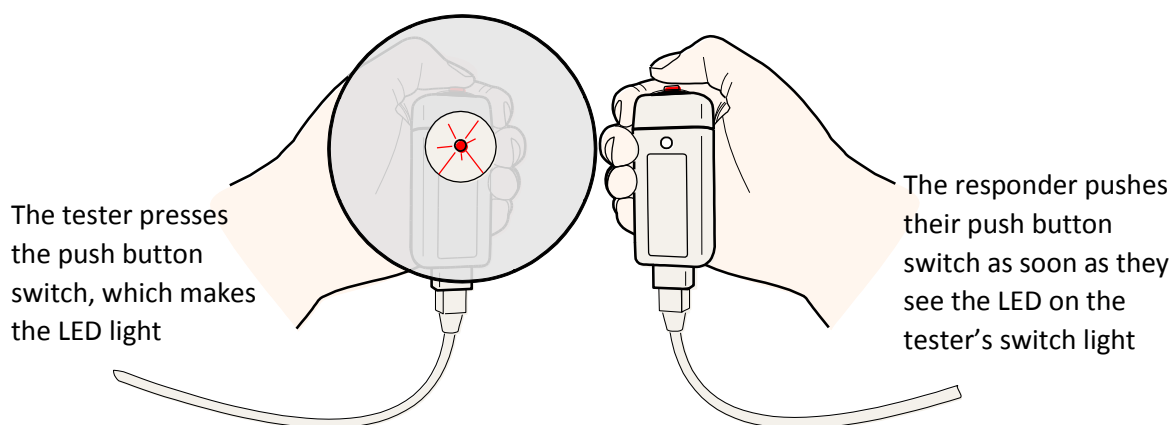
AT 3 Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes.

AT 4 Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment (links to A-level AT h).

The activity requires students to find the base reaction time and then to change factors in their environment to see how much the time will vary. Factors to choose can be quite open ended or more directed dependant on the learning outcomes.

Examples:

1. Is there a gender difference?
2. Is there a difference between sporties and non sporties (could you predict a racing driver)?
3. What happens if you are talking to someone (e.g. phone, listening to music)?
4. Does the time of day (tiredness have an effect)?
5. How does reaction time affect stopping distance in a car?



Apparatus

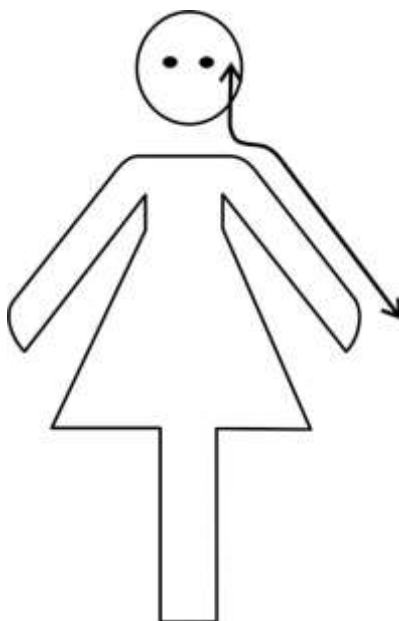
1. Two Push-button Reaction switches
2. Measuring tape for distance from eye to thumb
3. Card or CD to hide the movement of the testers thumb from view

The practical uses the timing functions of the logger / software. Territory more associated with the physics of motion. You need to set up the apparatus to record time and speed from A to B and to display Time from A to B.

Practical notes

The experiment uses EasySense Timing to record the speed of response. Timing assumes a switch is closed by an interrupt card passing through a Light gate, and then the switch opening as the card moves on. The experiment uses a Push button switch to emulate the Light gate and interrupt card.

We use the distance from the finger operating the switch to the eye as the separation between sensors. It represents the time taken for the stimulus to be perceived and the response sent down to the muscles activating the finger pressing the switch. To get a sensor separation length, use the distance from the tip of the hand to eye, following the natural line of the limbs / body. The assumption is being made that the eye is in effect the first push button switch, the speed of light being so fast that physical separation of the switch from the eye is insignificant. See the diagram below for the path to take. The exact path is not critical as there are timing errors due to brain processing anyway. We are after a consistent recording protocol to allow comparison.



Make sure the tester is linked to inputs labelled A on the logger and the responder to inputs labelled B on the logger.

Student sheet: GCSE Biology required practical activity (7)

Reaction times

Tests

AT 1 Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH (links to A-level AT a).

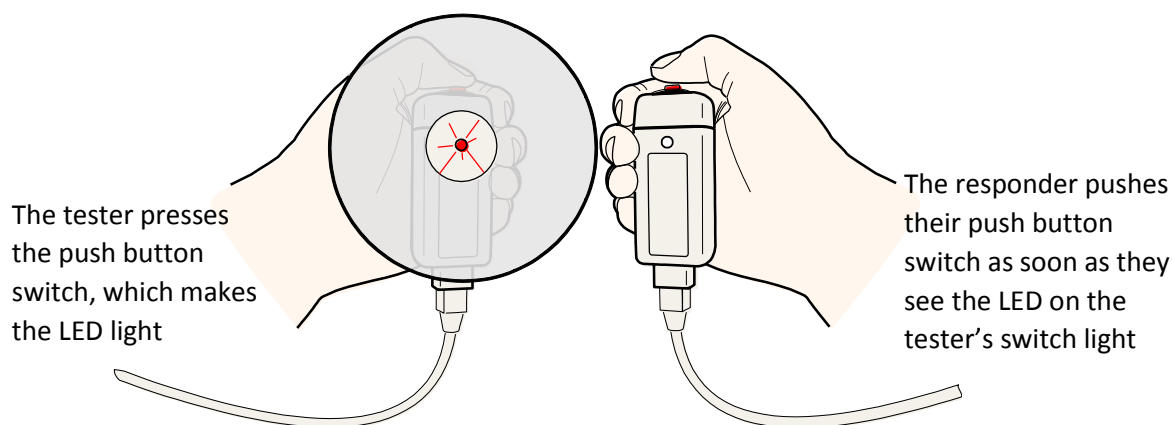
AT 3 Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes.

AT 4 Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment (links to A-level AT h).

The activity makes a determination of your speed of reaction. The speed of reaction is a measure of how quickly messages can travel around your body in the nerves. Anything that interferes with the nerves will slow the reaction time down.

There will be times when the reaction time is critical to you, stopping a car when a child steps out in front of you or getting away from the starting gun in a race. Once you have created the base for your reactions we can look at factors that may change the rate or consequence of relying too much on your reactions and not enough on prediction.

The activity is simple, one of a pair is the tester. They initiate a stimulus, The other person of the pair is the responder and they stop a clock (started by the stimulus) as soon as they can react to the stimulus.

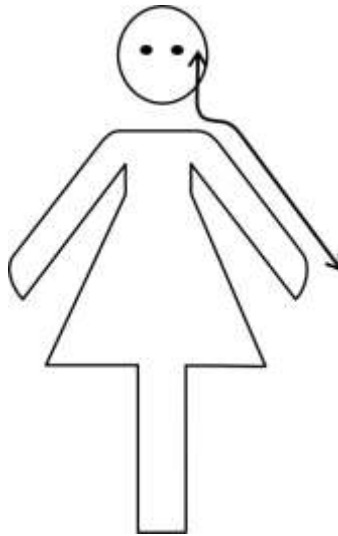


Apparatus

1. Two Push button Reaction switches.
2. Measuring tape for distance from eye to thumb.
3. Card or CD to hide the movement of the testers thumb from view.

Read these instructions before starting work

1. Connect the two Push button Reaction switches to the inputs labelled A and B on the logger.
2. Use the tape to measure the distance from the responder's eye to the thumb tip.



3. Set up the logger / software to record
 - Time from A to B
 - Leave units as s for time and use 3 decimals
4. For the test, the tester should hold the Push button Reaction switch that is connected to input A. Hide the push button part of the switch from the view of the responder so they will not see any movement of the tester's hand or fingers but will still see the LED.
5. The responder should hold the Push button Reaction switch connected to input B. Try few test runs to get used to the experiment.
6. Select **Start** to begin.
7. The tester should press their switch (briefly and quickly) and the responder should press their switch as soon as they see the LED on the tester's switch light.
8. Repeat for at least ten readings.

When you have enough data for an average value, make a note of it and then swap the tester and responder.

- Do you get better with more trials?
- Think about anything that may alter reaction times and set up a test to try.
- Use the distance from the eye to thumb to calculate a speed of nerve impulse from the brain to the thumb.