



# PHYSICS EXPERIMENTS (ELECTRICITY)

*‘In the matter of physics, the first lessons should contain nothing but what is experimental and interesting to see. A pretty experiment is in itself often more valuable than twenty formulae extracted from our minds.’ - Albert Einstein*

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# LEAVING CERTIFICATE PHYSICS

## LISTED EXPERIMENTS

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#### ELECTRICITY

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Experiment at Higher Level only\*

## **NOTE**

For examination purposes any valid method will be acceptable for describing a particular experiment unless the syllabus specifies a particular method in a given case.

Students will be expected to give details of equipment used, assembly of equipment, data collection, data manipulation including graphs where relevant. Students will also be expected to know the conclusion or result of an experiment and appropriate precautions.

## **SAFETY**

1. The Leaving Certificate Physics syllabus states on page three:

‘Standard laboratory safety precautions must be observed, and due care must be taken when carrying out all experiments.

The hazards associated with electricity, EHT, lasers etc. should be identified where possible, and appropriate precautions taken. The careful use of sources of ionising radiation is essential. It is important that teachers follow guidelines issued by the Department of Education and Science.’

2. The guidelines referred to here consist of two books, which were published by the Department of Education in 1997. The books are

‘Safety in School Science’

and

‘Safety in the School Laboratory (Disposal of chemicals)’

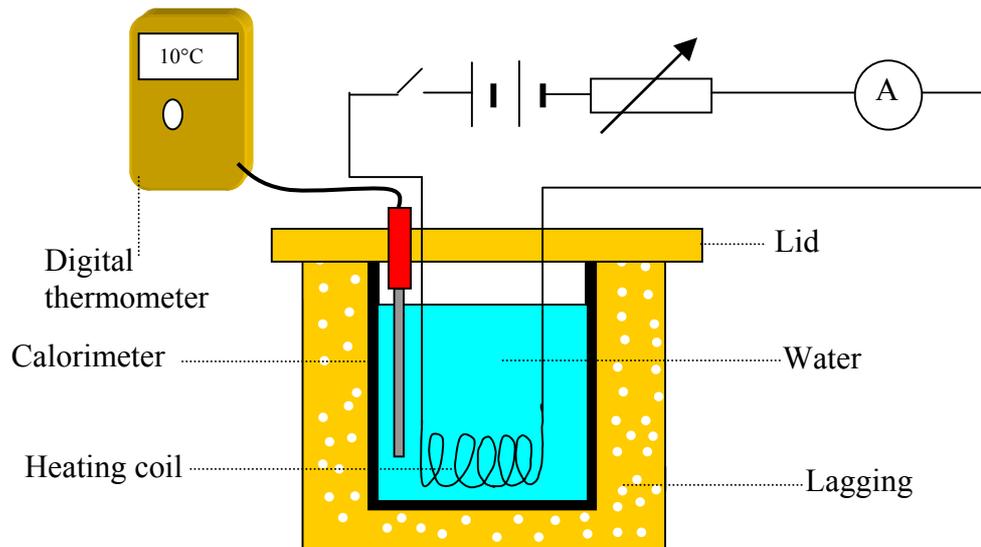
When these books were published they were distributed to all schools. They have been revised and are available on the ‘physical sciences initiative’ web site at [www.psi-net.org](http://www.psi-net.org) in the ‘safety docs’ link of the physics section.

3. Teachers should note that the provisions of the **Safety, Health and Welfare at Work Act, 1989** apply to schools. Inspectors appointed under that act may visit schools to investigate compliance.

## VERIFICATION OF JOULE'S LAW (As $\Delta\theta \propto I^2$ )

### Apparatus

Lagged beaker or calorimeter with a lid, heating coil, battery or low voltage power supply, rheostat, ammeter or multimeter, thermometer, stopwatch, balance.



### Procedure

1. Put sufficient water in a calorimeter to cover the heating coil. Set up the circuit as shown.
2. Note the temperature.
3. Switch on the power and simultaneously start the stopwatch. Allow a current of 0.5 A to flow for five minutes. Make sure the current stays constant throughout; adjust the rheostat if necessary.
4. Note the current, using the ammeter.
5. Note the time for which the current flowed.
6. Stir and note the highest temperature. Calculate the change in temperature  $\Delta\theta$ .
7. Repeat the above procedure for increasing values of current  $I$ , taking care not to exceed the current rating marked on the rheostat or the power supply. Take at least six readings.
8. Plot a graph of  $\Delta\theta$  (Y-axis) against  $I^2$  (X-axis).

## Results

$\theta_1/^\circ\text{C}$	$\theta_2/^\circ\text{C}$	$\Delta\theta/^\circ\text{C}$	$I/\text{A}$	$I^2/\text{A}^2$

A straight-line graph through the origin verifies that  $\Delta\theta \propto I^2$  i.e. Joule's law.

## Notes

Ensure that the rheostat current limit exceeds 3 A.

The heat energy produced is the mass multiplied by specific heat capacity multiplied by rise in temperature:

$$H = mc \Delta\theta .$$

The energy liberated per second in the device is defined as the electrical power. This energy is

$$P = RI^2 .$$

Therefore

$$RI^2 = mc \Delta\theta / t$$

or

$$I^2 = (mc/Rt) \Delta\theta .$$

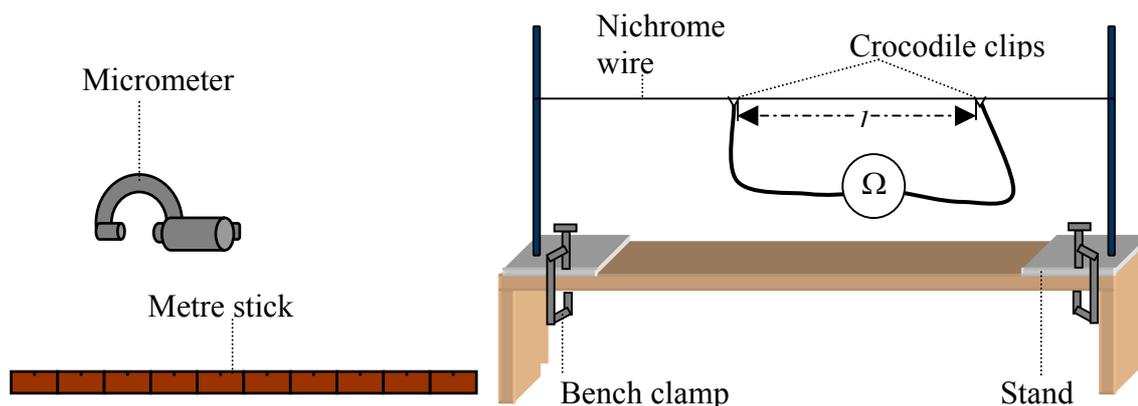
As the mass, specific heat capacity, resistance and time are constant,  $\Delta\theta \propto I^2$ .

Hence  $P \propto I^2$

## TO MEASURE THE RESISTIVITY OF THE MATERIAL OF A WIRE

### Apparatus

Length of wire (nichrome, manganin), micrometer, ohmmeter, metre stick.



### Procedure

1. Note the resistance of the leads when the crocodile clips are connected together.
2. Tie a length (2 or 3 metres) of nichrome/manganin between the bars of the two stands as shown above. Stretch the wire enough to remove any kinks or 'slack' in the wire.
3. Connect the crocodile clips to the wire some distance  $l$  apart. Read the resistance of the leads plus the resistance of wire between the crocodile clips from the ohmmeter. Subtract the resistance of the leads to get the resistance  $R$  of the wire.
4. Measure the length  $l$  of the wire between the crocodile clips, with the metre stick or tape.
5. Increase the distance between the crocodile clips. Measure the new values of  $R$  and  $l$ .
6. Make a note of the zero error on the micrometer. Use the micrometer to find the diameter of the wire at different points, taking the zero error into account. Find the average value of the diameter  $d$ .
7. Calculate the resistivity  $\rho = \left(\frac{R}{l}\right)A$ , where  $A = \frac{\pi d^2}{4}$ .
8. Repeat this procedure for a number of different lengths.
9. Calculate the average value for  $\rho$ .

## Results

Micrometer Reading/mm

Resistance of leads =  
 Micrometer zero error =  
 Average of micrometer readings =  
 Diameter of wire =

$R/\Omega$	$l/m$	$\frac{R}{l}/\Omega \text{ m}^{-1}$	$\rho/\Omega \text{ m}$

Average value of  $\rho =$

## Notes

Safety glasses should be worn as the wire could snap when stretched.

Use a micrometer with a slip-screw.

If clamps are unavailable, two students may hold the stands to keep the wire stretched enough to avoid kinks.

Alternatively stretch the wire between two nails, which are positioned one to two metres apart on a piece of wood.

The resistivity of nichrome is  $100 \times 10^{-8} \Omega \text{ m}$  (at 20 °C).

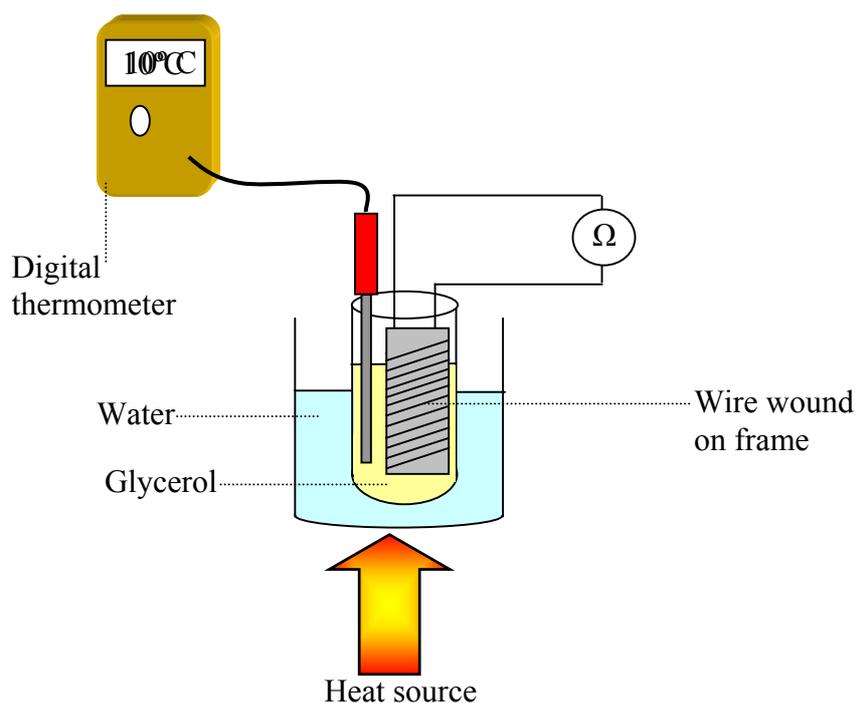
The resistivity of manganin is  $48 \times 10^{-8} \Omega \text{ m}$  (at 20 °C).

The resistivity values given depends on composition of the alloys used.

# TO INVESTIGATE THE VARIATION OF THE RESISTANCE OF A METALLIC CONDUCTOR WITH TEMPERATURE

## Apparatus

Coil of wire (see note), glycerol, beaker, heat source, thermometer, ohmmeter, boiling tube.



## Procedure

1. Place the coil of wire in the boiling tube with the glycerol and place it in a beaker of water.
2. Arrange the beaker over the heat source.
3. Connect the ohmmeter to the coil of wire.
4. Use the thermometer to note the temperature of the glycerol, which is also the temperature of the coil.
5. Record the resistance of the coil of wire using the ohmmeter.
6. Heat the beaker.
7. For each 10 °C rise in temperature record the resistance and temperature using the ohmmeter and the thermometer.
8. Plot a graph of resistance against temperature.

## Results

$R/\Omega$									
$\theta/^\circ\text{C}$									

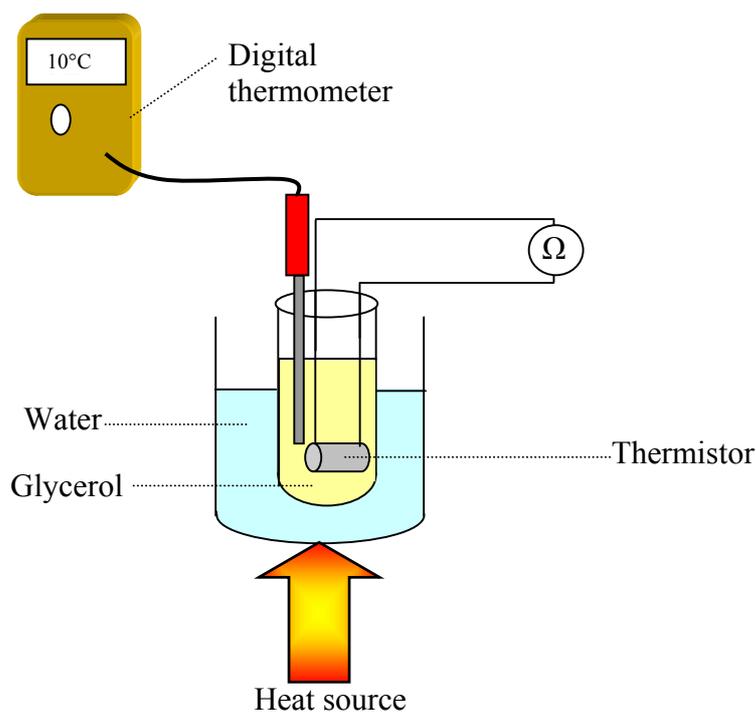
## Notes

The coil is commercially available. It is called the temperature co-efficient of resistance apparatus with temperature apparatus.

# TO INVESTIGATE THE VARIATION OF THE RESISTANCE OF A THERMISTOR WITH TEMPERATURE

## Apparatus

Thermistor, boiling tube containing glycerol or liquid paraffin, beaker, heat source, thermometer, ohmmeter.



## Procedure

1. Set up the apparatus as shown.
2. Connect the ohmmeter to the thermistor.
3. Use the thermometer to note the temperature of the glycerol and thermistor.
4. Record the resistance of the thermistor using the ohmmeter.
5. Heat the beaker.
6. For each 10 °C rise in temperature, record the resistance and the temperature using the ohmmeter and the thermometer.
7. Plot a graph of resistance against temperature and join the points in a smooth, continuous curve.

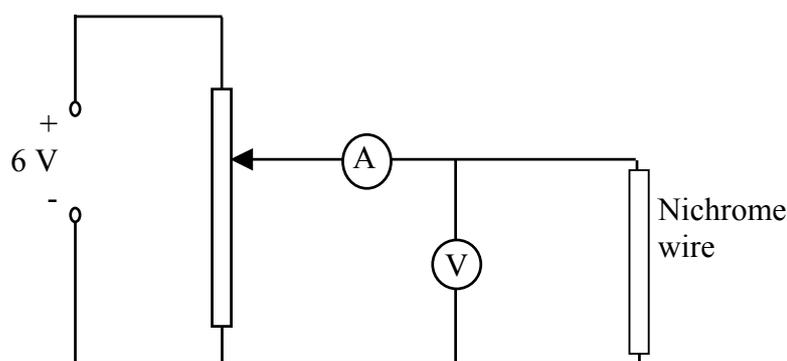
## Results

$R/\Omega$										
$\theta/^\circ\text{C}$										

## TO INVESTIGATE THE VARIATION OF CURRENT ( $I$ ) WITH P.D. ( $V$ ) FOR (a) A METALLIC CONDUCTOR

### Apparatus

Low voltage power supply, rheostat, voltmeter, ammeter, length of nichrome wire.



### Procedure

1. Set up the circuit as shown and set the voltage supply at 6 V d.c.
2. Adjust the potential divider to obtain different values for the voltage  $V$  and hence for the current  $I$ .
3. Obtain at least six values for  $V$  and  $I$  using the voltmeter and the ammeter.
4. Plot a graph of  $I$  against  $V$ .

### Results

$V/V$	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
$I/A$									

### Conclusion

A straight line through the origin  $\Rightarrow I \propto V$ .

### Notes

A varying voltage can be obtained from a fixed supply voltage by using a potential divider. It consists of a variable resistor or fixed resistors in series. Move the slider to change the output voltage. This results in the output voltage from the potential divider being a fraction of the input voltage.

The value of  $R$  may be determined from the reciprocal of the slope of the graph.

1 m of 26 s.w.g. nichrome wire, wound on a plastic comb, may be used in this experiment. This has a resistance of approximately  $7.0 \Omega$ .

## TO INVESTIGATE THE VARIATION OF CURRENT ( $I$ ) WITH P.D. ( $V$ ) FOR (b) A FILAMENT BULB

### Apparatus

Replace the length of nichrome wire in the circuit with a 6 V, 0.06 A filament bulb and replace the ammeter with a milliammeter.

### Procedure

1. Adjust the potential divider to obtain different values for the voltage  $V$  and hence for the current  $I$ .
2. Obtain at least ten values for  $V$  and  $I$  using the voltmeter and the milliammeter.
3. Plot a graph of  $I$  against  $V$  and join the points in a smooth, continuous curve.

### Results

$V/V$	0.2	0.5	0.8	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
$I/mA$											

### Notes

The resistance of the filament increases with temperature.

The shape of the curve shows that Ohm's law is not obeyed as the temperature of the filament changed with changing current.

If a multimeter is used as the ammeter, change the lead from the 10 A socket to the mA socket and select the appropriate current scale.

## TO INVESTIGATE THE VARIATION OF CURRENT ( $I$ ) WITH P.D. ( $V$ ) FOR (c) COPPER SULFATE SOLUTION WITH COPPER ELECTRODES

### Apparatus

Replace the filament bulb in the circuit with copper electrodes in copper sulfate solution.

### Procedure

1. Adjust the potential divider to obtain different values for the voltage  $V$  and hence for the current  $I$ .
2. Obtain at least six values for  $V$  and  $I$  using the voltmeter and the milliammeter.
3. Plot a graph of  $I$  against  $V$ .

### Results

$V/V$	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
$I/\text{mA}$										

### Conclusion

A straight line through the origin  $\Rightarrow I \propto V$ .

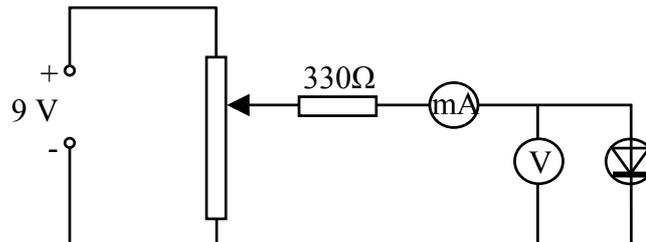
### Notes

The copper sulfate solution may be made by adding 15 g of copper sulfate to 100 cm<sup>3</sup> of warm water. Adding 2 cm<sup>3</sup> of concentrated sulphuric acid ensures that the solution stays clear and this will enable it to be reused a number of times.

## TO INVESTIGATE THE VARIATION OF CURRENT ( $I$ ) WITH P.D. ( $V$ ) FOR (d) SEMICONDUCTOR DIODE

### Apparatus

Low voltage power supply, rheostat, voltmeter, milliammeter,  $330\ \Omega$  resistor, silicon diode, e.g. 1N4001.



### Procedure- Forward Bias

1. Set up the circuit with the semiconductor diode in forward bias as shown and set the voltage supply to 9 V.
2. Adjust the potential divider to obtain different values for the voltage  $V$  and hence for the current  $I$ .
3. Obtain at least ten values for  $V$  and for  $I$  using the voltmeter and the milliammeter.
4. Plot a graph of  $I$  against  $V$  and join the points in a smooth, continuous curve.

### Results – Forward Bias

$V/V$	0.1	0.2	0.4	0.45	0.5	0.55	0.6	0.62	0.64	0.66	0.68	0.70
$I/mA$												

### Notes

A protective resistor, e.g.  $330\ \Omega$ , should always be used in series with a diode in forward bias.

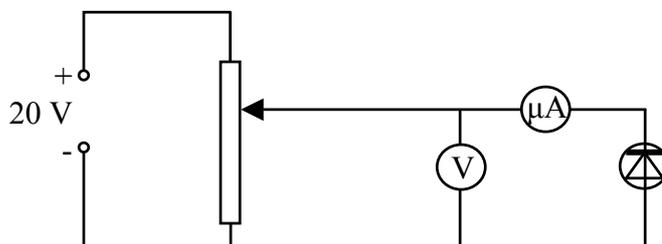
Almost no current flows until the applied voltage exceeds 0.6 V for a silicon diode but then the current rises rapidly.

A germanium diode, e.g. OA91, gives very little current between 0 and 0.2 V but the current then increases above this voltage.

A light emitting diode gives very little current up to 1.6 V but then the current rises rapidly accompanied by the emission of light.

## Apparatus

Low voltage power supply, rheostat, voltmeter, microammeter, silicon diode, e.g. 1N4001.



## Procedure – Reverse Bias

1. Set up the circuit as above and set the voltage supply at 20 V.
2. The microammeter is used in this part of the experiment, as current values will be very low when a diode is in reverse bias.
3. Adjust the potential divider to obtain different values for the voltage  $V$  and hence for the current  $I$ .
4. Obtain at least six values for  $V$  (0-20 V) and for  $I$  using the voltmeter and the microammeter. Higher voltage values are required for conduction in reverse bias.
5. Plot a graph of  $I$  against  $V$  and join the points in a smooth, continuous curve.

## Results – Reverse Bias

$V/V$	0	2	4	6	8	10	12	14	16
$I/\mu A$									

## Notes

The position of the voltmeter has changed since a reverse biased diode has a very large resistance that is greater than the resistance of most voltmeters. It is essential that the microammeter reads only the current flowing through the reverse biased diode as the sum of the currents flowing through the voltmeter and reverse biased diode may be much larger.

Since the resistance of the microammeter is negligible compared with the resistance of the reverse biased diode the potential difference across the microammeter and diode is almost the same as the potential difference across the diode alone.

When using a silicon diode it is very difficult to detect the current in reverse bias as the current is so small and changes very little with temperature variations.

For a germanium diode some reverse current can be detected (a few  $\mu A$ ) at 4 V reverse bias. This conduction increases rapidly when the diode is heated (by hand).

For information on connecting diodes see the 'Teacher's Handbook': Current Electricity p.45.