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# Effects of an Electric Current & Domestic Circuits

## Effects of an Electric Current & Domestic Circuits

#### **Three effects of an Electric Current**

- 1. Heating Effect Demonstrate with an electric coil in beaker of water plus thermometer.
- 2. Magnetic Effect\* Demonstrate with an electromagnet (connected up to source of electricity).
- 3. Chemical Effect Demonstrate with a voltameter (see below).

### Relationship between Work, Current, Resistance and Time

#### $W = I^2 Rt$

Now Power is defined as the rate at which work is done, i.e. Power = Work/time, so Power =  $l^2R$ .

This is known as Joule's Law

•  $\mathbf{P} = \mathbf{I}^2 \mathbf{R}$ 

**Joules Law** states that the rate at which heat is produced in a conductor is proportional to the square of the current, provided its resistant is constant.

#### "What the f%&k"?

Okay little one – just for you: If the current goes up by a factor of 2 ("doubles"), the heat produced goes up by a factor of 4 ( $2^2$ ). If the current goes up by a factor of 3 ("triples") the heat produced will go up by a factor of 9 ( $3^2$ ).

You dig?

### The Chemical Effect of an Electric Current: the voltameter

You must know the meaning of each of the following as they relate to the diagram (below).

- Voltameter (the system) {as opposed to 'voltmeter' which measures potential difference or voltage)
- Electrolyte (the solution)
- Electrodes (the metal contacts)
- Anode (electrode connected to the positive terminal)
- Cathode (electrode connected to the negative terminal)
- Inactive Electrodes do not take part in the reaction (e.g. Platinum in water)
- Active Electrodes take part in the chemical reaction (one terminal gets lighter while the other gets heavier e.g. copper electrodes in a solution of copper sulphate)



#### Applications of the Chemical Effect of a Current

- 1. Electroplating
- 2. Extracting metals from their ores
- 3. Purifying metals

#### Why is electrical energy transmitted using high voltage power lines?\*

We have seen that the heat produced by an electric current is given by the formula  $P = I^2 R$ .

This means that a large current will produce a lot of heat energy. This is a waste of energy and therefore should be minimised if possible.

Now we also know that P = VI, which means we can halve the current if we double the voltage and still keep the power constant.

In practice we make the current very small by making the voltage very large (e.g. 300 kVolts) when electrical energy is being carried across the countryside.

#### Transformers are used to change the voltage up or down

# **Domestic Electric Circuits**







3-Pin plug with fuse

Miniature Circuit Breakers (MCB)

Residual Current Devices (RCD)

Plugs	Brown – Live wire
_	Blue – Neutral wire
	Green/Yellow – Earth wire
	Current comes in on the live
Fuses	Melts if too large a current flows through it.
	The fuse is always on the live wire
Earthing and Bonding	See the picture on page 4 of these notes.
	All metal taps are connected to wires which in turn are connected to earth.
	This prevents electrocution if the tap was to become accidentally 'live' (or
	maybe because the electrician or plumber was a bit of a cowboy).
MCBs	Miniature Circuit Breakers have the advantage that they do not need to be
	replaced when they trip.
	They can contain an electromagnet and/or a bimetallic strip.
	Either way, when the current exceeds a preset value, the circuit should break.
RCDs	Residual Current Devices operate by detecting a difference between the current
	on the live wire and the current on the neutral wire.
	These should be the same, but if they are not this indicates a problem, and so
	the RCD trips.
	Note that RCBs act quicker and are therefore safer than MCBs.
Ring Circuits	In a ring circuit the live wire from each of the sockets are connected to a
	common line, as is the case with the neutral wire from each socket (on that
	particular ring).
Radial Circuits	Appliances that take a large current have their own live wire going in, and
	neutral wire coming out of, the appliance (from the fuse box).
	Examples would include a cooker or a washing machine.

### The kiloWatt hour (kWhr)

The *kiloWatt hour* is the unit of energy used by the ESB.

One kiloWatt hour is the amount of energy used by a 1000 Watt appliance in one hour.

**Rule:** Number of kiloWatt hours = Number of kilowatts × Number of Hours.

# **Relationship between Current and Voltage for different conductors**

You must be able to draw a graph for each of the following, list the charge carriers in each case, and explain the shape of each graph.

Note that in this case we are not looking to obtain a value for the slope of the graph, and therefore we put the independent variable (Voltage) on the X-axis.

Conductor	Graph	Charge	Explanation
		Carriers	
A Metallic conductor	1.	Electrons	As the <u>p.d.</u> is increased, the current
	'		increases proportionally.
	v		
	· · · · ·		
A Filament Bulb		Electrons	As current increases, the wire heats up,
			⇒resistance increases.
			⇒ current does not rise as ranidly.
			- current abes not rise as rapidity.
	<u>/</u>		
	V		
Ionic solutions		Positive and negative	Conner ions discharged at the cathode are
(active electrodes)		ions	replaced by conner atoms entering the solution
(active electroaces)		electrons	as jons in the anode.
	V		
Ionic solutions	1 2	Positive ions,	Oxygen is produced at the anode. This
(inactive electrodes)	T	electrons	combines with the platinum to become a 'cell'
			which opposes the driving current and has to be
			overcome.
	<b>V</b> .		
Vacuum	8 .	electrons	Stage one - thermionic emission
			Stage two - saturation
	v		
	· ·		
Gases		Positive ions,	Stage one - Normal
	I) ,	electrons	Stage two - Saturation
			Stage Three - Avalanche Effect
			-
	v		
Semiconductors		Positive holes	See shapter 25 for a detailed evaluation
Semiconductors	I	Positive notes,	see chapter 25 for a detailed explanation
		negative electrons	
	V		

- To Investigation the variation of current (I) with p.d. (V) for Copper electrodes with Copper Sulphate solution
- Joule's Law Experiment\*

# **Leaving Cert Physics Syllabus**

Content	Depth of Treatment	Activities	STS
Effects of electric current	Heating: $W = I^2 Rt$ Chemical effect – an electric current can cause a chemical reaction. Magnetic effect of an electric current.	Demonstration of effect. Appropriate calculations. Demonstration of effect. Demonstration of effect.	Everyday examples. Advantage of use of EHT in transmission of electrical energy. Uses of the chemical effect. Everyday examples.
Domestic circuits	Plugs, fuses, MCBs (miniature circuit breakers). Ring and radial circuits, bonding, earthing, and general safety precautions. RCDs (residual current devices). No drawing of ring circuits required.	Wiring a plug. Simple fuse calculations.	Electricity at home • fuse box • meter, etc. Electrical safety.
	The kilowatt-hour. Uses.	Appropriate calculations.	
Conduction in materials	Conduction in • metals • ionic solutions (active and inactive electrodes) • gases • vacuum • semiconductors References in each case to charge carriers.	Interpretation of <i>I</i> – <i>V</i> graphs.	Neon lamps, street lights.

# **TO VERIFY JOULE'S LAW**

#### **APPARATUS:**

Calorimeter with a lid, heating coil, power supply, rheostat, ammeter, thermometer, stopwatch, electronic balance.

#### DIAGRAM:



#### **PROCEDURE:**

- 1. Set up the circuit as shown.
- 2. Note the temperature.
- 3. Switch on the power and simultaneously start the stopwatch.
- 4. Make sure the current stays constant throughout; adjust the rheostat if necessary.
- 5. Note the current using the ammeter and note the time for which the current flowed using the stopwatch.
- 6. Stir and note the highest temperature. Calculate the change in temperature ( $\theta\Delta$ )
- 7. Repeat the above procedure for increasing values of current I, taking at least six readings.
- 8. Plot a graph of  $I^2$  (y-axis) against  $\theta \Delta(x$ -axis).

#### **RESULTS:**

$\theta_{\text{initial}}(^{0}\text{C})$						
efinal (°C)						
$\Delta \theta$ (°C)						
I (A)	0.5	1.0	1.5	2.0	2.5	3.0
$I^2(A^2)$						

#### **CONCLUSION:**

A graph of our results produced a straight-line through the origin thus verifying that  $\Delta \theta \propto l^2$  and therefore verifies Joule's law.

#### **PRECAUTIONS:**

- 1. Put sufficient water in the calorimeter to cover the heating coil.
- 2. Take care not to exceed the current-rating marked on the rheostat and/or the calorimeter.

#### NOTES

1. See the note in the text-book to see how this experiment (where  $\Delta \theta \propto I^2$ ) verifies Joule's Law (P  $\propto I^2$ ).

2. Allow the coil to heat the water for about five minutes. This must be the same for each run.

### TO INVESTIGATE THE VARIATION OF CURRENT (I) WITH P.D. (V) FOR COPPER ELECTRODES IN A COPPER-SULPHATE SOLUTION

#### **APPARATUS** :

Low voltage variable power supply, voltmeter, ammeter, copper electrodes in a copper-sulphate solution.

#### DIAGRAM:



#### **PROCEDURE:**

- 1. Set up the circuit as shown.
- 2. Record the potential difference (V) and the current (I) using the voltmeter and ammeter respectively.
- 3. Adjust the rheostat to obtain different values for V and I.

- 4. Obtain at least six values for V and I.
- 5. Plot a graph of I against V.

#### **RESULTS:**

V (V)	 	 	 	
I (A)	 			

#### **CONCLUSION** :

- 1. We obtained a straight line through the origin therefore the current through the copper-sulphate solution is proportional to the potential difference across it.
- 2. We believe our results to be reliable because they resulted in a straight line through the origin, as the theory predicted.

#### **SOURCES OF ERROR:**

- 1. The copper-sulphate solution may not be concentrated enough.
- 2. The copper electrodes may have become oxidised and will no longer conduct.

#### **PRECAUTIONS:**

• Sand the electrodes beforehand.

### NOTES

This is one of the few experiments which actually works very well, so take your time and get it right.

- 1. Get a 250 ml beaker.
- 2. Clean it !!
- 3. Grab a pair of electrodes form the box.
- 4. Sand them well, until both are shiny.
- 5. Separate the copper electrodes by putting a rubber bung between them, and secure the set-up with an elastic band (all supplied).
- 6. Place in the 250 ml beaker.
- 7. Shake the container of Copper Sulphate solution well.
- 8. Slowly pour the solution into the beaker (using the funnel) until it is at roughly the 150 ml level. Any higher and it might come in to contact with the crocodile clips and short-circuit (can you see how?).
- 9. Set up the circuit as shown in the diagram. Using the rheostat is optional as you could just use the dial on the power-supply to vary the voltage (p.d.), and therefore the current. The advantage of using the rheostat is that you can control it to give you nice even numbers for the voltage, the disadvantage is that it can be a pain in the ass to set-up. So no prizes for guessing what most of you are going to choose.
- 10. **Now** follow the conventional instructions: Take the readings, plot the graph, blah blah blah (remember none of this goes in your report!)
- 11. Remember to take apart the apparatus and put them back in the containers supplied.

### **Exam Questions**

- 1. [2006 OL] Give one use for electricity in the home.
- 2. [2004 OL][2008 OL][2010] List three effects of an electric current.
- [2002][2004 OL] Describe an experiment that demonstrates the heating effect of an electric current.
- 4. [2004 OL]

State two factors on which the heating effect of an electric current depends.

5. [2003 OL]

Hans Oersted discovered the magnetic effect of an electric current in 1820 while demonstrating electricity to his students. Describe how you would demonstrate the magnetic effect of an electric current.

Effects of an electric current

6. [2005]

Joule's Law

- Explain why high voltages are used in the transmission of electrical energy.
- 7. [2002]

Suggest a method of reducing the energy "lost" in ESB power lines.

8. [2002]

The ESB supplies electrical energy to an industrial park from a local power station Total resistance of the cables = 9.6  $\Omega$ . Current flowing in the cables= 200 A Calculate the rate at which energy is "lost" in the cables.

9. [2006]

What is the resistance of the filament of a light bulb, rated 40 W, when it is connected to the mains?

Fuses and Plugs

- [2004 OL][2005 OL][2007 OL] Name two safety devices that are used in domestic electric circuits.
- 11. [2006 OL]

What is the colour of the earth wire in an electric cable?

- 12. [2009 OL] What is the colour of the wire that should be connected to the fuse in a plug?
- 13. [2003 OL]

Give the standard colour of the insulation on the wires connected to each of the terminals L, N and E on the plug in the diagram.

14. [2003 OL]

What is the purpose of the wire connected to the terminal E on the plug?

15. [2004] [2008 OL]

Name and give the colour of the wire that should be connected to the fuse in a standard three-pin plug.

- [2006 OL] Give one safety precaution that should be taken when wiring a plug.
- 17. [2003 OL][2009 OL][2010 OL]



Explain why a fuse is used in a plug.

#### 18. [2009 OL]

Explain how a fuse works.

### 19. [2006 OL]

What will happen when a current of 20 A flows through a fuse marked 13 A?

20. [2009 OL]

Why would it be dangerous to use a fuse with too high a rating?

21. [2004]

Explain why replacing a fuse with a piece of aluminium foil is dangerous.

### 22. [2006 OL]

Name a common material used to conduct electricity in electric cables.

23. [2004]

A table lamp has a power rating of 100 W. What is the most suitable fuse for the lamp?

### 24. [2009 OL]

Plugs are used to connect electrical appliances in the home to the 230 volt ESB supply. Modern plugs contain a small fuse which comes with a rating of 1A, 2A, 3A, 5A or 13A. A coffee maker has a power rating of 800 W. What is the most suitable fuse to use in the plug of the coffee maker?

What is the most suitable fuse to use in the plug of the coffee maker?

25. [2003 OL]

A kettle has a power rating of 2 kW when connected to the ESB mains voltage of 230 V. Calculate the current that flows when the kettle is first plugged in.

26. [2003 OL]

The fuse in the plug of the kettle in the previous question was replaced with a 5 A fuse This current will only flow for a very short time. Explain why.

27. [2004][2006 OL]

Some electrical appliances are supplied with two-pin plugs. Why is an earth wire not required in these devices?

### 28. [2006 OL]

Why is the coating on electric cables made from plastic?

29. [2008]

A toaster has exposed metal parts. How is the risk of electrocution minimised?

### 30. [2003 OL][2010 OL]

Bonding is a safety precaution used in domestic electric circuits. How does bonding improve safety in the home?

31. [2009 OL]

MCBs and RCDs

Name another device with the same function as a fuse.

- 32. [2003][2002 OL][2010 OL] What is the purpose of a miniature circuit breaker (MCB) in an electric circuit?
- 33. [2009][2010 OL]

When will an RCD (residual current device) disconnect a circuit?

34. [2006]

An RCD is rated 30 mA. Explain the significance of this current.

#### 35. [2004][2002]

What is the purpose of a residual current device (RCD) in an electrical circuit?

36. [2003 OL]

Name a device that is often used nowadays in domestic electric circuits instead of fuses.

37. [2004]

Give one advantage of a Residual Current Device (RCD) over a Miniature Circuit Breaker (MCB).

38. [2008]

#### VI graphs and charge-carriers

What are the charge carriers when an electric current passes through an electrolyte?

#### 39. [2003]

Draw a graph to show the relationship between current and voltage for a metal at constant temperature

40. [2003]

How would the VI graph for a metal differ if its temperature were increasing?

41. [2003]

Draw a graph to show the relationship between current and voltage for an ionic solution with inactive electrodes

42. [2003]

How would the graph for the ionic solution differ if its concentration were reduced?

43. [2003]

Draw a graph to show the relationship between current and voltage for a gas.

44. [2004 OL] What is the kilows The kilo-watt hour

- What is the kilowatt-hour?
- 45. [2006 OL] What is the function of the ESB meter?
- 46. [2004 OL]

Calculate the cost of using a 2 kW electric heater for 3 hours at 10 cent per kilowatt-hour.

47. [2009 OL]

The electrical energy supplied by ESB to the home is measured in kWh (kilowatt-hour).

(i) A coffee maker has a power rating of 800 W.

If the coffee maker was in use for 150 minutes calculate the number of units of electricity used by the coffee maker.

(ii) Calculate the cost of the electricity used if each unit costs 15 cent.

#### Mandatory Experiments

48. [2007 OL]

In an experiment to verify Joule's law, a heating coil was placed in a fixed mass of water. A current I was allowed to flow through the coil for a fixed length of time and the rise in temperature  $\Delta \theta$  was recorded. This was repeated for different values of I. The table shows the data recorded. I/A 1.0 1.5 2.0 2.5 3.0 3.5

		110	2.0	2.0	2.0	2.2
I <sup>2</sup> /A <sup>2</sup>			4			
<u>∆</u> θ/°C	2.2	5.0	8.8	13.8	20.0	26.0

4.0

35.2

- (i) Draw a labelled diagram of the apparatus used.
- (ii) How was the current changed during the experiment?
- (iii) Copy the table and complete it in your answerbook.
- (iv)Using the data in the completed table, draw a graph on graph paper of  $\Delta \theta$  against I<sup>2</sup>. Put I<sup>2</sup> on the horizontal axis (X-axis).

- (v) Explain how your graph verifies Joule's law ( $\Delta \theta \alpha I^2$ ).
- 49. [2006]

In an experiment to verify Joule's law a student passed a current through a heating coil in a calorimeter containing a fixed mass of water and measured the rise in temperature  $\Delta\theta$  for a series of different values of the current I. The student allowed the current to flow for three minutes in each case.

- (i) Describe, with the aid of a labelled diagram, how the student arranged the apparatus.
- (ii) Why was a fixed mass of water used throughout the experiment?
- (iii) The student drew a graph, as shown. Explain how this graph verifies Joule's law.
- (iv) Given that the mass of water in the calorimeter was 90 g in each case, and assuming that all of the electrical energy supplied was absorbed by the water, use the graph to determine the resistance of the heating coil. The specific heat capacity of water is 4200 J kg<sup>-1</sup> K<sup>-1</sup>.



In an experiment to verify Joule's law, a heating coil was placed in a fixed mass of water. The temperature rise  $\Delta\theta$  produced for different values of the current *I* passed through the coil was recorded. In each case the current was allowed to flow for a fixed length of time.  $\frac{I/A}{\Delta\theta / {}^{\circ}C} = 3.5 + 7.0 + 10.8 + 15.0 + 21.2 + 27.5$ 

The table shows the recorded data.

- (i) Describe, with the aid of a labelled diagram, how the apparatus was arranged in this experiment.
- (ii) Using the given data, draw a suitable graph on graph paper and explain how your graph verifies Joule's law.
- (iii) Explain why the current was allowed to flow for a fixed length of time in each case.
- (iv) Apart from using insulation, give one other way of reducing heat losses in the experiment.
- 51. [2004 OL]

The diagram shows a circuit used to investigate the variation of current with potential difference for a copper sulfate solution.

- (i) Name the instrument used to measure the current.
- (ii) How was the potential difference measured in the experiment?
- (iii) Name the apparatus Y and give its function in the experiment.
- (iv) The following table shows the values recorded for the current and the potential difference during the experiment.

Potential Difference /V	0	0.5	1.0	1.5	2.0	2.5	3.0
Current /A	0	0.3	0.6	0.9	1.2	1.5	1.8



45

33.0

used

Using the data in the table, draw a graph on graph paper of the current against the potential difference. Put current on the horizontal axis.

- (v) Calculate the slope of your graph and hence determine the resistance of the copper sulphate solution.
- 52. [2002]

In an experiment to investigate the variation of current I with potential difference V for a copper sulfate solution, the following results were obtained.  $V/V = 0.5 \pm 1.0 \pm 1.5 \pm 2.0 \pm 2.5 \pm 3.0 \pm 3.5 \pm 4.0 \pm 4.5 \pm 5.0$ 

[	V/V	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
	I/mA	24	48	79	102	120	143	185	195	215	263

- (i) Draw a diagram of the apparatus in this experiment, identifying the anode and the cathode.
- (ii) Draw a suitable graph on graph paper to show how the current varies with the potential difference.
- (iii) Using your graph, calculate the resistance of the copper sulfate solution. (Assume the resistance of the electrodes is negligible.)
- (iv) Draw a sketch of the graph that would be obtained if inactive electrodes were used in this experiment.



# **Exam Solutions**

- 1. Heating / cooking / lighting /named electrical appliance etc.
- 2. Magnetic effect, heating effect and chemical effect.
- 3. Connect a electrical calorimeter containing water to a power supply and notice the increase in temperature using a thermometer.
- 4. Size of current, length of coil.
- Apparatus: see diagram Procedure: close the switch Observation: compass deflects
- 6. High voltages result in smaller currents therefore less energy is lost as heat.
- 7. Transfer the electrical energy at a higher voltage which would result in a lower current, therefore less energy lost as heat.
- 8.  $P = I^2 R = (200^2)(9.6) = 3.8 \times 10^5 W$
- 9.  $P = V^2 / R$

 $40 = (230)^2 / R$ 

- R = 1320 Ω
- 10. Fuse, miniature circuit breaker, residual current device, earthing, 3 pin plug etc.
- Green and yellow
- 12. Brown
- 13. L (live) is brown, N (neutral) is blue, E (earth) is green-yellow
- 14. The earth wire protects from electrocution / shock by conducting the current to earth.
- 15. Live, brown
- 16. Screw connections are fully tightened / fit the correct size fuse / ensure to match the colour codes
- 17. It 'blows' and breaks the circuit if too large a current flows, preventing possible electrocution.
- 18. When too high a current flows the thin wire heats up and melts which breaks the circuit.
- 19. The fuse blows which stops the current.
- 20. It would allow too large a current to flow so the device could overheat.
- 21. If a very large current flows the foil may still not break and so may start a fire.
- 22. Copper
- 23.  $I = P/V \implies I = 100/230$
- Range: 0.5 A fuse
- 24.  $P = VI \implies I = P/V = 800/230 = 3.4 A$ So the most suitable fuse is the 5 A fuse.
- 25.  $P = VI \implies I = P/V \implies I = 2000/230 = 8.7 A$
- 26. The current is larger than the fuse rating, so the fuse will blow.
- They have a plastic housing so even if they are in contact with a live wire the current will not travel along the cover.
- 28. It is an insulator.
- 29. The metal parts are earthed.
- 30. Bonding is where all metal pipes are connected to earth preventing accidental electrocution.
- 31. Circuit breaker, trip switch, RCD, MCB
- 32. It behaves as a fuse when too large a current flows
- 33. When the magnitude of the current flowing in is different from that flowing out.
- 34. The RCD trips the circuit if the current reaches 30 mA.
- 35. It acts as a safety device by breaking the circuit if there is a difference between the live and the neutral in a circuit.
- 36. Miniature circuit breakers (MCBs) or residual current devices (RCDs).
- 37. RCD responds v. Quickly, RCD responds to tiny currents
- 38. Ions
- See graph
- 40. If temperature was increasing it would no longer be linear; instead there would be a curve to the right because resistance would increase.
- 41. Axes and straight line starting at v > 0
- 42. The slope of the graph would be less (the resistance increases) due to less ions (charge carriers) being present.
- 43. Axes, curve and plateau
- 44. The kilo-watt hour is the amount of energy used by a 1000 Watt appliance in one hour.
- 45. It records the amount of units used.
- 46. Number of kiloWatt hours = Number of kilowatts x Number of Hours =  $2 \times 3 = 6$  kW hrs.  $6 \times 10 = 60$  cent



- 47.
- (i) Number of kiloWatt hours = Number of kilowatts × Number of Hours. Power = 800 W = 0.8 kW Time = 150 minutes = 2.5 hours Number of kiloWatt hours = 0.8 × 2.5 = 2 kWh
  (ii) Cost = 2 × 15 = 30 cent
- 48.
- (i) See diagram below.
- (ii) Adjust the (variable) power supply // adjust the (variable) resistor
- (iii)

I/A	1.0	1.5	2.0	2.5	3.0	3.5	4.0
$I^{2}/A^{2}$	1	2.25	4	6.25	9	12.25	16
$\Delta \theta / ^{\circ}C$	2.2	5.0	8.8	13.8	20.0	26.0	35.2

ŝ

40/

(iv)See graph

(v) We got a straight line through the origin showing that  $\Delta \theta \alpha I^2$ 





#### 49.

- (i) See diagram.
- (ii) The mass of water would be a third variable and you can only investigate the relationship between two variables at a time.

(iii) Straight line graph through origin 
$$\Rightarrow \Delta \theta \alpha I^2 \Rightarrow P \alpha I^2$$
  
(iv) Electrical energy in = Heat energy out

(iv) Electrical energy in = Heat energy out  $BI^2 t = maA0$ 

 $RI^{2}t = mc\Delta\theta$   $Rt = mc(\Delta\theta/I^{2}) \implies Rt = mc(slope) \implies R = mc(slope)/t$  (.09)(4200)(3.8)/180 $R = (7.8 \leftrightarrow 8.2) \Omega$ 



#### 50.

#### (i) See diagram.

(ii)	I/A	1.5	2.0	2.5	3.0	3.5	4.0	4.5
	<u>Δθ</u> / °C	3.5	7.0	10.8	15.0	21.2	27.5	33.0
	$I^2 / A^2$	2.25	4.0	6.25	9.0	12.25	16.0	20.25

#### Label axes

At least 6 correct points Straight line Good fit

A straight line through origin shows that  $\Delta \vartheta \propto I^2$  which verifies Joule's Law.

(iii) You can only investigate the relationship between two variables at a time and time is a third variable.

(iv) Start with cold water, change the water for each run, use a lid, shorter time interval, polish calorimeter.



- 51.
- (i) An ammeter
- (ii) Using a voltmeter.
- (iii) Y is a rheostat which is a variable resistor; by adjusting it you vary the resistance which in turn varies the resistance and current.
- (iv) See graph
- (v) Take any two points and use the formula

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

Slope = resistance =  $1.67 \Omega$ .

52.

(i) See diagram. Cathode = negative electrode, anode = positive electrode

2.5

>

Difference

Potential

- (ii) Axes labelled
  - 6 points plotted correctly Straight line Good fit
- (iii) Resistance = slope of graph = 19.5 to 20.5 Ohms
- (iv) Straight line starting at v > 0



copper sulfate

# **Extra Credit**

#### \*Magnetic Effect of an Electric Current

One interesting application of the magnetic affect is the Levitating Trains which are used in Japan. In order to generate a large magnetic field, large currents are needed, but because of resistance in the line, this can get very expensive. To get around this, engineers make use of something called SUPERCONDUCTIVITY; this is where the resistance of the metal drops to zero, resulting in very large currents and therefore very large magnetic fields.

The problem with this is that the superconducting metals must be very, very cold, and keeping the metals this cold can get very, very expensive.

#### \*Why is Electrical Energy transmitted using high voltage power lines?

In practice we make the current very small by making the voltage very large (e.g. 300 kVolts) when electrical energy is being carried across the countryside.

These voltages are then lowered before they enter a town, using transformer stations, and are lowered even more (to 220 volts) using a transformer outside your house. Every three or four houses have their own transformer. Now each time the voltage is lowered, the current is raised, but now at least it's only for a short distance.

Many of your electrical appliances have transformers inside then which reduce the voltage further still, often to as low as nine of twelve volts. These appliances can also probably use batteries.

A few further points of interest:

While the current running through the power-lines is small, it may still be enough to heat the wire slightly. I am reliably informed that this is why birds prefer to sit on power-lines rather than on branches!

If you are passing under a high voltage line you may notice a slight hiss. This is because the high voltages are ionising the air around them.

#### Mnemonics :

- V = IR: Very Intelligent Rachel
  P = VC: (PVC) (Power = Voltage x Current)