# LABORATORY SCIENCE

## EXPERIMENT 1 WEB RESEARCH

##### Introduction

In this laboratory session we will concentrate on using the WEB for information retrieval and presentation of a report. You should select a possible topic for investigation from the notes on Climatology or Principles & Processes in Agriculture before you come to the lab.

On completion of this session you should be able to:

* Use the WEB to successfully search for information.
* Collate the information and present a report.
* Discuss the topic you have researched.
* Use scientific terms and physical concepts in your report.

**The Task**

This lab is designed to give you experience searching for specific information on the web. You will identify a topic you wish to research, find information from a variety of internet sources, and summarise your findings in a report.

##### Why are we getting you to do this?

This is the sort of exercise you may be required to do quickly and effectively in future employment — for example, your supervisor may need information about Australia’s salinity problems for a meeting that afternoon with a government minister. You, as the Agricultural Science graduate employee in the organisation, might be called upon to locate and summarise that information.

##### Writing the Report

The report should state what it is you wish to understand, what information you have found and your conclusions from your research. It should not be just a collection of printed information from web pages — you should include printouts of diagrams, charts, tables of data and so on, but you must summarise the information you find. List all the web sites from which you have taken information as references.

Activity 1 Selecting a topic and a question

### Logbook 1.1

Select a broad area on Climatology or Principles & Processes in Agriculture for your research topic. Within this topic, identify a specific concept, idea or question you would like to research.

From within these areas, discuss and choose something you want to find out more about (your research question). Discuss whether you are likely to find information about this on the web. Write down your research question stating clearly what you wish to find out.

***Logbook 1.2***

Spend some time on the web investigating and refining your research question. At this stage you are trying to find out if you will be able to answer your research question using the web. If you can’t find much information, you will need to rethink your question.

You can split into groups to search for different aspects of your research question. Good places to start include:

* Australian Bureau of Meteorology www.bom.gov.au
* Meteorological and Oceanographic Society www.amos.org.au
* About.com Climate and Weather geography.about.com/cs/climateweather/
* University of Illinois World Weather ww2010.atmos.uiuc.edu/(Gh)/home.rxml
* Try searching (using Google for example) for sites about your topic.

**Checkpoint 1 Discuss your research topic with your tutor**

##### Activity 2 Researching the Concepts

To research your question, you may split into groups to search for different pieces of information. You should discuss in advance what each group is going to look for.

#### *Logbook 2.1*

Prepare the first part of your report: the Physics Concepts section. You will need to find out:

* What are the physics concepts associated with your research question?
* What are the physical parameters you need to understand?

Consult your notes and search through web sites for this information.

Write a summary of the background information and physics concepts. You may present it as notes, or draw a concept map of your topic and question.

**Checkpoint 2 Discuss the first section with your tutor**

##### Activity 3 Collecting Information and Data

The information you include in your report must be relevant to your research question — so you must be able to state why you have included a graph, a chart or a piece of text. Any information you find should be referenced (keep a note of the web sites you use). Remember to concentrate on the scientific terminology and physical principles related to your question.

### Logbook 3.1

Search the web for relevant information about your research question. You may need to find some data, maps or pictures. If so, you should explain what they mean and why they are important to your report. Write this into a second section of your report, the Data and Findings section.

### Logbook 3.2

Investigate the important effects or consequences associated with your research question — for example, effects on the local and global weather patterns, health consequences, economic consequences. Write this into an Effects and Consequences section of your report.

***Logbook 3.3***

Write a conclusion section, summarising briefly your research question and the information you have found. Include at least one question that you have not been able to answer about your topic that you would like to find information about.

**Checkpoint 3 Show your finished report to your tutor**

# EXPERIMENT 2 HEAT AND TEMPERATURE

**Introduction**

In this session we concentrate on the practical aspects of temperature measurement. We will then use temperature measurements to estimate energy consumption. These topics apply to thermal instruments and measurements in all fields.

On completion of this session you should be able to:

* Apply this knowledge to processes involving transfer of energy and energy balances. Use skills and terminology associated with heat and temperature.
* Use different types of thermometers to take temperature measurements.

**Types of Thermometers**

Thermometer types are defined by their thermometric properties. The table below lists a number of thermometers, with their thermometric properties.

|  |  |  |
| --- | --- | --- |
| **THERMOMETRIC PROPERTY** | **TYPE OF THERMOMETER** | **COMMENT** |
| Expansion (Volume or length) | Mercury in glass  Alcohol in glass  Bi-metal strip | The most familiar type are the oven thermostats |
| EMF | Thermocouple | Common laboratory thermometer |
| Resistance | Thermistor  Resistance temperature  detectors - RTD  Silicon resistive sensors | Usual laboratory standard.  Common laboratory and field thermometer |
| Pressure | Gas thermometer | Used as standard, though impractical for everyday use |
| Power of thermal radiation | Radiometer or pyrometer | High temperature measurement or remote sensing of temperature |
| Reverse current in semi conductor diode | Diode thermometer  Solid state thermometer | Available complete with linearity compensation and calibrated amplifier using integrated circuit techniques |
| Light reflectivity | Liquid crystal  thermometer | Disposable clinical thermometers and novelty thermometers |

Activity 1

Temperature is one of the seven quantities regarded as basic in the International System of Units (SI). The concept of temperature and equilibrium is central to the understanding of thermal physics (thermodynamics). Temperature often governs speeds and relative importance of chemical and biological processes and systems, ranging in size from single cells through whole organisms and ecosystems to the biosphere itself.

We can’t measure temperature directly, we can only measure the values of *thermometric properties* which vary with the temperature and may be easily measured. Examples of such quantities are length, volume, pressure, resistance and voltage. We then choose a *temperature scale* and assign values of temperature to easily reproducible conditions. We measure the values of the thermometric properties under these conditions and use them as reference points on the temperature scale. Other temperatures are determined from the values of the thermometric properties and their assumed relationship with the temperature scale. Note that thermometers are designed to perform under certain conditions and limits. If these guidelines are not followed then the numbers obtained may be totally useless.

Logbook 1.1

(a) What does a thermometer measure?

(b) Two thermometers are used during a very hot and sunny day. One thermometer is placed in the direct sunlight and the other is in the shade? What do the thermometers measure? Comment on the difference in the temperature measured by the two thermometers?

(c) For many hours on this hot and sunny day, a wooden and a metal fence post were left in the sun. What can you say about the temperature of each post? Comment on the sensation you would get by touching each post. Why can't the sense of touch be an indicator of temperature?

**Expansion Thermometers**

The mercury-in-glass thermometer dates from 1659. In spite of its long history, it is still one of the most accurate thermometers up to about 200 °C. Its chief disadvantages are its fragility, and the inconvenience of reading the length of the mercury column.

###### Logbook 1.2

(a) How does the mercury-in-glass thermometer work?

###### (b) Will the accuracy of this instrument be compromised if only half of the 'bulb' is immersed? Predict if a mercury-in-glass thermometer, with the bulb partially immersed, will overestimate or underestimate the true temperature of a liquid if;

(i) The liquid is warmer than the ambient temperature (temperature of the surrounding air)

(ii) The liquid is cooler than the ambient temperature.

Check this experimentally. Discuss your results in terms of heat flow (heat flows from warmer regions to cooler regions), thermal equilibrium and the errors this introduces in measurements.

**Thermocouple Thermometers**

Thermocouples are a common type of laboratory thermometer, particularly for biological applications. The actual temperature probe can be made very small. A common method of insertion into animals is to pass the probe through a hollow needle which has been inserted into the animal. Since the output is a voltage, continuous monitoring is possible. Thermocouples are preferred to many other temperature sensors for laboratory work. Thermocouples are not suitable for field measurements, due to the necessity of maintaining a reference temperature for the cold junction.

The EMF is measured by a voltmeter, in our case a high impedance multimeter, as shown below. A thermos flask, with the cold junction already wired, is available. Set up the thermocouple.

Note that: the multimeter should be switched to the most sensitive mV range.

The ice + water cold junction is quite slushy. Check that this is at approximately 0°C.

The junctions should be fully immersed and shouldn't touch the sides of the flasks.

The readings may take several seconds to stabilise (response time of instruments).



Fig 2.1 Laboratory Thermocouple

***Logbook 1.3***

The following table gives the EMF of a copper-constantan thermocouple thermometer as a function of temperature.

|  |  |
| --- | --- |
| ***temperature T / ( oC )*** | ***EMF ε /(mV)*** |
| 0.0 | 0.000 |
| 10.0 | 0.389 |
| 20.0 | 0.787 |
| 30.0 | 1.194 |

Using linear interpolation between these calibration points, estimate the temperature for the following values of the EMF-

a) 0.500 mV b) 1.000 mV

Logbook 1.4

Set up the thermocouple thermometer as shown in figure 2.1. Place the hot junction in water of known temperature (as measured with a mercury in glass thermometer).

Change the temperature of the water and take several readings of temperature and voltage. Draw a graph of voltage versus temperature and calculate an equation that can be used to convert voltage to temperature. This process is called calibration.

***Logbook 1.5***

Can you maintain 0°C with only ice? With only ice water? With a mixture of ice + water? Discuss your answers in terms of heat flow and absorption of heat (ice may melt and water may boil, absorbing heat in each case).

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| Checkpoint 1 Discuss this section with your tutor |

**Activity 2**

Resistance Thermometers (or thermoresistive sensors)

As early as 1821, Sir Humphrey Davy had noted that electrical resistances of various metals depend on temperature. However the advances in recent years have lead to miniature, practical devices. Resistance thermometers can be divided into 3 groups: thermistors, RTDs and silicon resistive.

Thermistors

A thermistor is a piece of semi-conductor (metal-oxide) whose resistance may either decrease with increasing temperature (negative temperature coefficient, ntc thermistor) or increase with increasing temperature (positive temperature coefficient, ptc thermistor).

A common application is the field measurement of animal temperatures. Very small thermistors may be implanted in small animals without altering their temperature or modifying their behaviour. This technique is being applied even to the larger insects, such as cockroaches.

Get a set of thermometers from the Service Counter. There is one thermistor thermometer: The probe and a multimeter are supplied. The multimeter is switched directly to the temperature scale. These are not very accurate and have been designed specifically to be used for identifying overheating, of electrical and electronic components, where the actual temperature of the components is not critical.

Sensitive thermistors are used in industry for spot checking the environment for human comfort. They are also used for instantaneous measurements within fluids.

**RTD - Resistance Temperature Detectors**

While virtually all metals can be employed as RTDs, platinum or its alloy is used almost exclusively because of its predictable response, long term stability and durability. The sensor may consist of a thin film deposited on a suitable substrate or a wire encapsuated in suitable material. **Pl**atinum **r**esistance thermometers are often referred to as PLRs.

There are two RTDs in the set of thermometers:

a) firstly there is the Digitron hand-held unit which outputs a reading in °C.

b) there is a probe which is marked RTD immersion probe. This probe connects to an interface box which displays temperature in °C. The display gives an approximate value while the accurate value is obtained through an analogue voltage output (back of the box).

***Logbook 2.1***

Place a small quantity of water at temperature TW in a thermos flask. To this add some ice at temperature TI only once. Take measurements of temperature and time till an equilibrium temperature is reached. While waiting do Logbook 2.3.

Plot a graph of temperature versus time. Comment on the shape of the graph.

***Logbook 2.2***

On your graph indicate the sections relating to (a) the equilibrium or steady state condition and (b) a net transfer of energy.

Logbook 2.3

How is information like this important in understanding the environment?

Measurement of air and soil temperatures

Logbook 2.4

The setup on the side bench has a floodlight over a box of soil. Use RTD's to measure the temperature of the soil at different depths and the temperature of the air at different heights. Draw appropriate graphs. How are these graphs different to those drawn above?

Note that there are different probe designs for immersion and air measurements.

Logbook 2.4

If a probe is left on the surface of the soil, what does it measure? Leave a probe on the surface of the soil and take the reading. Shade the probe. Does the reading change?

**Logbook 2.5**

Which of the thermometers used above are suitable for continuously monitoring the environment inside a glass house? Why?

### Logbook 2.6

If you are spot checking the safety and comfort levels for people employed in a factory which instrument would you choose? Why?

### Logbook 2.7

Explain why it would be impractical to implant a thermocouple sensor in a kangaroo and transmit data by radio telemetry. Which thermometer would you choose instead and why?

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| Checkpoint 2 Discuss this section with your tutor |

**Activity 3**

**GROWING TREES - IS THIS A SOLUTION TO THE “ENERGY PROBLEM”?**

A possible renewable fuel for the future could be the wood from trees. But is this a viable option? You can carry out a simple experiment to get some evidence to support or reject the possibility of growing trees as an alternative fuel.

*You have access to the following equipment*:

A thermometer, Test tube, beaker, water, measuring cylinder

Matches (use one match for heating - try to burn the whole match)

Micrometer screw gauge or vernier calipers

***Please place burnt matches in beaker to protect table.***

***At the end, empty beaker in garbage bin and clean beaker and test tube.***

*Physics knowledge you may require*:

Density ρ = *m*/*V*

The amount of energy *Q* (joules, J) needed to raise the temperature of a material of mass *m* (kilogram, kg) by *ΔT* (°C) is

*Q* = *mcΔT*

where *c* is the specific heat capacity of the material.

ρ(water) = 1000 kg.m-3 = 1 g.mL-1 c(water) = 4180 J.kg-1.°C-1

*V* = *L*1 *L*2 *L*3 *V* volume, *L*1, *L*2, *L*3 dimensions



For a typical family of 3 people, the energy for hot water heating is in the order of 4000 kWh per year.

### Logbook 3.1

Determine:

Volume of a match

Volume of a tree

Number of matches from your tree

Energy liberated from one match to heat water?

Energy from tree that could be utilised to heat water?

Number of joules in a kilowatt.hour?

Number of trees needed per year to supply the energy requirements for a family with hot water?

How reproducible are your estimates?

How many trees are needed to supply the energy for hot water in Sydney?

Is there a pollution problem with burning trees?

How much land area might be needed?

***Compare your findings with other groups.***

***What do you think - is the growing of trees a viable alternative as a fuel?***

|  |
| --- |
| Checkpoint 3 Discuss this section with your tutor |

# EXPERIMENT 3 LIQUID FLOW

**Introduction**

In this experiment, we are going to explore the factors which determine the flow of water through a narrow length of glass tubing. The water flow is controlled by adjusting an inlet valve which connects the glass tube to a water storage tank. From your measurements you will use Poiseuille's Law, find Reynolds number and the viscosity of water and state whether the water flow is streamline or turbulent. These concepts are vital for understanding and modeling fluid flow such as blood flow in animals and the flow of water in pipes and canals for irrigation.

On completion of this session you should be able to:

* Use the terms and concepts associated with Poiseuille's Law, viscosity and Reynolds number.
* Describe streamline and turbulent flow and their significance.
* Use a spreadsheet for data analysis, graphing and regression analysis.

Activity 1

Real fluids have a resistance to flow because of inter-molecular frictional forces between the layers of the fluid. This frictional resistance is referred to as the viscosity. The coefficient of viscosity of a fluid η (Pa.s) is used to specify the viscosity of a fluid. It is temperature sensitive, with the coefficient of viscosity decreasing with an increase in temperature (as is the case with honey).

A fluid flows from a region of higher pressure to low pressure. That is, a pressure gradient is responsible for the flow of a fluid between two regions. Consider a cylindrical tube of length *L* and radius *r*. A viscous liquid enters one end at pressure *P*1 and leaves the other end at pressure *P*2. If the flow is steady with streamlines parallel to the sides of the tube (laminar flow) then the volume flow rate can be described reasonably well by Poiseuille's equation. Poiseuille first used this equation to measure the viscosity of blood in horses arteries.



where *Q* is the volume flow rate and is measured by collecting a volume, Δ*V* of liquid in a time interval, Δ*t*, *Q* = Δ*V*/Δ*t* (m3.s-1). The pressure difference between the ends of the glass tube (*P*1 - *P*2 ) is measured using a manometer which is a stationary column of liquid of height (*h*-*h*o) in a vertical tube

*P*1 - *P*2 = ρ*g*(*h*-*h*o)

ρ**  density of liquid in vertical column ( water 1000 kg.m-3 )

*g*  acceleration due to gravity (9.8 m.s-2).

*Q* =

### Logbook 1.1

Write down Poiseuille's equation in your logbook.

List the symbols from the equation and beside each write the physical parameter the symbol represents and the standard (SI) unit the parameter should be measured in.

**Measurement of flow rate *Q* and height (*h*-*h*o)**

Identify the components of the liquid flow apparatus using the schematic in Fig.3.1.

Adjust the tap controlling the in­flow of water to the supply tank to maintain a constant, bubbly flow through the over-flow outlet.

Maintain the water level so that it remains about 10 mm from the top of the water level indicator (this is attached to the water supply tank).

Check that:

* Adjusting inlet valve A varies the water flowing out of the capillary tube and the height of the liquid in the manometer arm.
* The glass tube is firmly fitted to the input vessel.
* Adjust the glass capillary tube so that it is horizontal (level).
* There is a rubber washer near the end of the capillary tube to prevent water from flowing back along the outside of the tube.

***Logbook 1.2: Initial measurements***

Take the following measurements:

length of tube, *L* (m)

radius of tube, *r* (m) Note that the value marked on the tube is the **diameter**.

temperature, *T* (°C) Use the thermometer inserted into the input vessel.

manometer reading for zero flow (*Q* = 0), *h*o (m) This is the vertical tube and ruler.

Measurements

The volume flow rate, *Q*  through the tube is controlled by adjusting the inlet valve A. *Q* is the volume flow rate and is measured by collecting a volume Δ*V* of liquid in a time interval Δ*t*,

*Q* = Δ*V*/Δ*t*. A stopwatch, beaker, measuring cylinder and funnel are used to measure the volume flow rate. Make a minimum of 20 measurements for manometer heights from 20 mm to 950 mm and collect volume of about 100 mL.

Notice the flow becoming turbulent by observing the liquid level in the manometer jumping up and down slightly and/or a change in the flow of the water out of the tube.



**Fig 3.1 Liquid Flow apparatus**

Logbook 1.3: Your data table should have columns for

height of water column, *h*(cm)

time to collect water, Δ*t* (s)

volume of water, Δ*V* (mL) The amount of water collected should always be ~ 100 mL.

visual characteristics of the fluid in the manometer and as it flows out

**Check point 1 Discuss this section with your tutor**

Open an Excel spreadsheet on a computer.

Enter your raw measurements (*h, t, V*) in the first three columns.

Create new columns for

adjusted height of water column, *h* - *h*o (cm)

height of water column in SI units ie, *h* - *h*o (m)

volume flow rate *Q* (mL.s-1) Note that Q = Δ*V* / Δ*t*

volume flow rate *Q* (m3.s-1) Note that 1 mL = 110-6 m3

**Analysis**

Note that all values from here on must be in SI units.

Plot *Q* vs (*h* - *h*o) , in the spreadsheet.

Identify the regions in your graph corresponding to streamline and turbulent flow.

**When printing, click once only and print selection only.**

Print your spreadsheet.

Print your graph.

Logbook 2.1

Paste spreadsheet and graph into your logbook.

If the flow is laminar, work is only done in overcoming the viscosity and the work leads to an increase in temperature. If however, the velocity of flow is too high or there are other unfavourable features, a series of vortices (eddies) may develop in the liquid as the streamlines break up. The flow is now turbulent and some of the work is expended in providing kinetic energy for the vortices causing a reduction in flow rate from that predicted from the Poiseuille's equation.

*Q* = when the flow is laminar.

Use LINEST command to find the slope of the laminar portion of your plot of *Q* vs (*h* - *h*o).

Use this to estimate the coefficient of viscosity of water.

Remember you will only use the data for streamline flow to do this.

From the viscosity data below, determine the viscosity of water at room temperature. The data can be plotted in MS EXCEL and the graph used for interpolation.

**Temperature dependence of the viscosity of water**

|  |  |
| --- | --- |
| **temperature *T* ( C)** | **coefficient of viscosity ** (mPa.s)** |
| 0 | 1.783 |
| 10 | 1.302 |
| 20 | 1.002 |
| 30 | 0.800 |
| 40 | 0.651 |
| 50 | 0.548 |

*Logbook 2.2*

Compare and comment on the ranges for your viscosities determined by the two methods.

**Check point 2 Discuss this section with your tutor**

For a liquid flowing through a tube, there is a critical velocity at which orderly streamline flow changes to turbulent motion. The type of flow is partially specified by a dimensionless quantity called Reynolds number *R*. The transition from streamline motion to turbulent motion occurs when *R* is around 2000. If *R* < 2000, the flow is usually streamline, but if *R* > 2000, the flow maybe turbulent. The definition of the Reynolds number is

*R* = ,

where *v*avg is the average velocity of flow and *d* is some lateral dimension. Applying it to our water flow apparatus, the Reynolds number is given by

*R* = *Q*,

Logbook 3.1

Determine the critical volume flow rate for the transition from streamline to turbulent flow.

Calculate Reynolds number for this critical value.

Comment on these values with the expected valves.

Logbook 3.2

Look carefully at the shape of your graph. Explain in terms of energy considerations,

Why, there is an abrupt change in slope? And why, the curve is steeper in the streamline region compared to the turbulent region?

Logbook 3.3

Which physical parameters should be considered if you are pumping water into a water tank.

Logbook 3.4

Would you choose the parameters such that the flow is laminar flow or turbulent? Why?

Logbook 3.5

Use annotated diagrams to show that you understand the meaning of the terms:

streamline (laminar) flow and turbulent flow.

**Check point 3 Discuss this section with your tutor**

# EXPERIMENT 4 ELECTRIC CIRCUITS

# Introduction

This session introduces the concept of an electrical circuit. The essential features of an electrical circuit are a source of electrical energy (such as a battery), a load (such as a light bulb) and a switch. When the switch is closed the circuit is complete and electrical energy can flow to the load. A torch is an example of a simple electric circuit. In this session we also encounter the concepts of current and potential difference and learn how to use meters to measure them. You will encounter resistors, which are special circuit components, used extensively in electronic circuitry. You will use Ohm's Law: potential difference is proportional to current.

On completion of this session you should:

* Be familiar with the idea of a circuit as a means of transfer of energy from a source of electrical energy (such as a battery) to a load.
* Be able to apply the terms current, voltage and resistance to components of a simple circuit such as found in a torch.
* Be able to measure values of current and voltage using a digital multimeter.
* Be able to use Ohm's Law in simple electrical circuits.

**Activity 1 Simple model of torch**

Have you ever wondered how an electric torch works? In this session we will introduce you to some of the electrical concepts used to describe how such a simple device works.

*Physics is all about building models of the real world*. These models can be of different complexity, involving the use of various physical concepts.

One of the simplest ways of modeling the function of the torch is to look at the transfer of energy from electrical to light and thermal energy.

***Logbook 1.1***

Think about some other types of energy transfer that occur in electrical appliances about your home - electric stove, radio, hair dryer. What energy transfer is involved here? Your electricity bill is calculated from the cost per kilowatt-hour (kWh) of the energy you use.

What will be the cost of running a 2400 W heater for six hours if the cost of consumption is 6 cents per kWh? Note that 2400 W is equal to 2.4 kW.

What will be the cost of running a 40 W light bulb for six hours?

**Logbook 1.2**

To build a more complex model of the torch, we need to look in more detail at the components of the circuit and explore some fundamental physical concepts. A simple representation of the torch circuit is shown in fig. 4.1. Electrical circuits are usually described by diagrams that show the logical rather than the actual layout of the circuit. The elements of the circuit are represented by standardised symbols.

Identify the symbols for the two batteries, the light bulb and the switch? What do the straight lines represent? In which of the two diagrams is the torch switched on?



Fig. 4.1 Circuit diagrams representing a torch.

Collect a torch from the service counter. Take the torch apart and identify the function of the various parts.

***Logbook 1.3***

Draw a rough picture of the torch in your logbook and superimpose the electrical diagram above in a way that illustrates how the torch functions.

**Check point 1 Discuss this section with your tutor**

**Activity 2 Function of each circuit component**

The battery provides the electrical energy. The energy of the battery originates from the chemical reaction that goes on inside the battery. The *bulb* transforms the electrical energy from the battery to light and thermal energy. We use the term ***load*** to describe any ***circuit*** element which converts electrical energy into another form of energy.

**Current**

To expand our model, we need to look more closely at the mechanism of energy transfer. One concept that will help us is that of current. ***Current*** is actually a drift of charge around the circuit. In our simple torch circuit, this drift is imposed on the normal random movement of the electrons in the metal connections (wires). Current can also be used to describe the drift of ions in a gas or solution and even ***holes*** (lack of electrons in outer atomic shells) in ***semiconductors***.

To investigate current further, we need to know how to measure it. The unit of measurement is the ***ampere (***A), usually abbreviated to "***amp"***. We will use a meter to measure its value. A meter which is used to measure current is called an ***ammeter***.

Typical currents in torch circuits are less than 1 A; in a radio they are of the order of milliamps (mA); and for a car starter motor of the order of 200 A.

**To model and measure the current flowing**

Use the components in front of you to connect up the circuit shown below

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Fig. 4.2 Light bulbs in series

To measure current we use an ammeter, which like a watch, can be **digital** or **analog**. For these exercises we will use a digital meter, which actually can be used to measure a lot of different things - appropriately it is called a **multimeter.** To use it as an ammeter we switch the dial to one of the current (A) ranges (the 10A range will be more convenient) and connect the leads to the appropriate sockets(COM and 10A).

***Logbook 2.1***

Record in your logbook a diagram of your circuit. Measure the current and write down the value. Don't forget to write down the units of measurement after the value. Does the reading change if the position of the ammeter is changed? Take a few measurements with the ammeter in different positions.

Note: This type of connection for the ammeter is known as a ***series*** connection. Ammeters are always connected in series.

***Logbook 2.2***

Why does the light bulb glow but not the wires?

Could the switch be put on the other side of the light bulb and would the bulb still light up? Justify your answer.

Logbook 2.3

Write down the conditions that you think are necessary to make a torch function.

***Logbook 2.4***

Would the current measurement be different if you placed the ammeter in another part of the circuit? Try it. What did you find.

***Logbook 2.5***

In no more than five lines write down a description of your concept of current.

From the concept of current we move on to other physical concepts needed to explain why we need a battery in the circuit. These include the concepts of ***potential difference*** and energy conservation.

**Potential Difference**

We need to introduce the more general concept of potential difference between two points in a circuit. The exact nature of the relationship between electrical energy and potential difference is not explained here. For our purposes it is enough to know that when energy transfer occurs between two points in a circuit then there is a potential difference between the two points. A *loss* of electrical energy from the circuit, such as in a light bulb, is associated with current flowing from a point of higher potential to one of lower potential, through the light bulb. A *gain* in energy is associated with current flowing from a point of lower potential to one of higher potential as occurs at the battery. Electrical potential differences are measured in ***volts*** (symbol V). In fact the term *voltage* is commonly used to describe potential differences around the circuit.

**Practical Exercise Measuring potential differences around a circuit**

We can measure the voltage across a light bulb using the digital multimeter as a voltmeter by selecting one of the voltage (V) setting and connecting to the appropriate input sockets (COM and VΩ). To measure voltages the multimeter is placed in parallel ( ie across) the voltage to be measured.

Voltages are always measured between two points in the circuit. Most sensibly across a component such as a bulb or a battery. Currents are measured by breaking the circuit in a certain place and placing the ammeter so that the current runs through it.

We express this by saying that **the voltmeter is placed in parallel while the ammeter is placed in series.**

***Logbook 2.5***

Use the simple circuit containing two light bulbs in series. Use the voltmeter to measure the voltage (potential difference)

(a) across the battery

(b) across each bulb separately

(c) across the series combination (ie the two together)

***Logbook 2.6***

Draw the circuit in your log book and write in the values of voltages measured across each element of the circuit: each of the two bulbs and the battery. Be careful to note the difference between energy rises and drops: on your circuit diagram indicate with plus and minus signs whether the voltage difference represents an energy loss or gain as well as its magnitude.

*What is the relationship between the voltage rise and the sum of the voltage drops in the circuit?Can you deduce a general rule for the sum of all potential changes around a circuit?*

**Check point 2 Discuss this section with your tutor**

**Activity 3 DC CIRCUITS and Ohm’s Law**

The object of this exercise is to measure the current *I* through a resistor as a function of the voltage *V* across the resistor, and hence obtain a value of the resistance,

*R* = *V* / *I*. This is called **Ohm’s Law**. Resistance is measured in ohms (Ω) with

1 ohm =1volt / 1 amp. The circuit should be set up as shown in Fig. 4.3.

Note that:

(a) In principle any resistor *R* could be used, but best to use R = 4700 Ω to avoid measurement problems. Check this value with the multimeter.

(b) The voltage source could be a 1.5 V or a 9 V battery, but it is not possible to vary the voltage of a battery. Rather, you should use the power supply available on the bench. It may have a knob that you can use to vary the voltage, or it may have a selection of different, fixed voltages.

(c) Two meters are available on your bench to measure *V* and *I* in the circuit. One of the meters is a digital meter, with a switch to let you measure *V* or *I* (or *R*). The other may be an analogue or moving coil meter with several different connection points depending on whether you want to measure *V* or *I* (or *R*). It doesn't matter which meter is used to measure *V*, but the moving coil meter needs to be tested to check that it reads zero when it should, and needs to be adjusted if it doesn't read zero correctly. Ask your tutor or other students if you can't figure out how to use these meters.

**Measurement of Resistance**

**Logbook 3.1**

Find and measure the resistance of the 4700 Ω on the circuit board with the multimeter.

***Logbook 3.2***

Connect the circuit shown in Fig. 4.3. Hint: It is easier to connect the voltage source, ammeter and resistor first, then add the voltmeter last.



Fig. 4.3 Circuit for verifying Ohm’s Law

1.

Set V to 1.0 or 2.0 V as measured by a voltmeter and measure *I* (in A or mA). Repeat with *V* = 0.0, 2.0, 4.0, 6.0 and 8.0 V, measuring voltage and current each time. Do not rely on the nominal values on the voltage source. Make a table of your readings in your team logbook.

***Logbook 3.3***

Plot a graph of *V* (vert.) vs *I* (horz.) and a line of best fit (it should pass through (0,0)) in your logbook. The results should ideally lie on a straight line, of slope *V*/*I*. If they don't, then one or both of the meters may be slightly in error. Meters are NEVER perfectly accurate, but the ones in the lab should be correct to within about 3%.

From the slope of your graph, estimate a value for *R*.

Compare and comment the value obtained from the graphical method with that found using the digital meter.

***Logbook 3.4***

Connect the circuit shown in Fig. 4.3, but replace the resistor with a small light bulb. Measure *V* and *I* and make a table of results in your logbook. (The globe may not glow brightly – why?)

Plot a graph of V vs I. The shape of the graph should be quite different from the shape for a resistor. When the light bulb is cold, the resistance of the filament is low, but when a large current flows in the filament, the filament gets hot and its resistance increases. The filament is a non-linear (often called a non-Ohmic) resistor, so V vs I is not a straight line. Estimate the filament resistance, R = V / I, when it is cold and when it is at its maximum temperature.

Note that it will be white hot at about 2000 °C

Write another explanation for why does the light bulb glow but not the wires?

**Review**

* A sustained electric current can exist only in a closed conducting path - called a circuit.
* In a loop without any branches going off to the sides (all the cases studied so far) a steady current must have the same value at all places in the circuit.
* A battery causes a current in a complete circuit.
* A battery is a source of electrical energy.
* Energy and current are different things.
* In a circuit, energy is transferred from a source (eg. battery) to a load (eg. globe).
* Electrical energy can be delivered into devices such as light globes, motors and heaters and then into the environment
* The sum of potential rises equals the sum of potential drops i.e., the sum of potential differences around a circuit is zero.

**Check point 3 Discuss this section with your tutor**