Name:

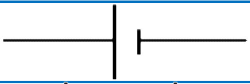
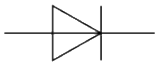
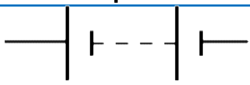
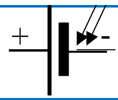
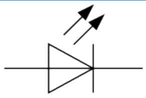
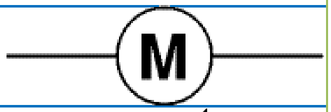
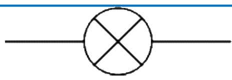
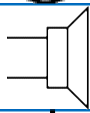
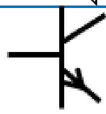
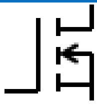
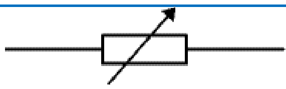
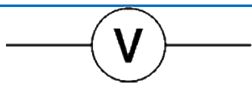
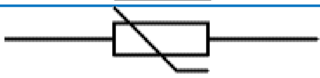
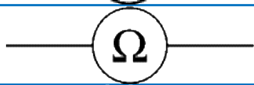
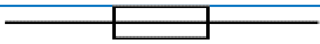
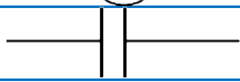
Electricity and Electronics

Block 1

Voltage, Current and Resistance

1. Circuits			
I can describe the symbol, function and application of standard electrical components including cell, battery, lamp, switch, voltmeter, ammeter, motor, microphone, loudspeaker, photovoltaic cell,			
I can define electrical current as the electrical charge transferred per unit time.			
I can carry out calculations using ***Q=It*** where t is measured in seconds.			
I can define the potential difference (voltage) of the supply as a measure of the energy given to the charge carriers in a circuit.			
I can describe and explain practical applications of series and parallel circuits.			
I can make measurements of I and V using appropriate meters in simple and complex circuits.			
I can apply the current and voltage relationships in a series circuit. $I_s=I_1=I_2=\ldots$ $V_s=V_1+V_2=\ldots$			
I can apply the current and voltage relationships in a parallel circuit. $I_s=I_1+I_2=\ldots$ $V_s=V_1=V_2=\ldots$			
I can describe the symbol, function and application of standard electrical components: resistor, variable resistor			
I can make measurements of IR using appropriate meters in simple and complex circuits.			
I can make use of a *V-I* graph to determine resistance. (gradient of V against I graph = resistance)			
I can make use of an appropriate relationship to calculate potential difference (voltage), current and resistance ***V = IR***			
I can describe the relationship between temperature and resistance of a conductor.			
I can describe that increasing the temperature of a conductor increases the resistance of the conductor. Increasing the temperature does not affect the resistance of a resistor.			
I can describe an experiment to prove Ohm's Law.			
I can use the relationship $Rs=R_1+R_2+R_3$ to solve problems involving total resistance of resistors in a series circuit			
I can perform calculations involving current and voltage relationships in a parallel circuit.			
I can use the relationship $\frac{1}{R_{total}} = \frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\cdots$ to calculate the resistance of resistors in parallel circuits			
I can use the appropriate relationships to calculate the resistance of resistors in with circuits with combinations of resistors in series and parallel			
I know what happens in a circuit when I increase the resistance in both series and parallel circuits.			

Circuit Symbols

Name	Symbol	Name	
Cell		Diode	
Battery		Photovoltaic Cell	
DC Supply		LED	
AC Supply		Motor	
Lamp		Loudspeaker	
Switch		NPN Transistor	
Resistor		N-channel enhancement MOSFET	
Variable Resistor		Voltmeter	
LDR		Ammeter	
Thermistor		Ohmmeter	
Fuse		Capacitor	

Analogue Circuits (Simple Resistive Networks)

Common Terminology

Throughout the course, you will need to use special terminology to describe circuits and their operation. Some of the common terms that you will need to use throughout the course are detailed below:

Terminology	Definition	Symbol	Units
Potential Difference (or Voltage)	Energy supplied to each coulomb of charge passing through the supply	V	volt (V)
Current	The amount of charge passing a point each second/rate of flow of charge	I	ampere (A)
Resistance	A measure of how difficult it is for charge to flow through a material	R	ohm (Ω)
Power	The amount of energy transferred every second	P	watt (W)

Current

Current is the rate of flow of charge

$$Q = It$$

Q	Charge	–	Coulombs (c)
I	Current	–	Amperes (A)
t	time	–	Seconds (s)

Questions: (in Jotter)

1. Calculate the charge flowing through a lamp in 3 seconds if the current in the lamp is 2 amperes?

2. Calculate the charge flowing through a lamp in 25 seconds if the current in the lamp is 0.5 amperes?

3. Calculate the charge flowing through a lamp in 1 minute if the current in the lamp is 2 mA amperes?

4. Fifty coulombs flow through a heater in 10 seconds. Calculate the current in the heater

5. 1000 coulombs flow through a heater in 25 seconds. Calculate the current in the heater

6. 1 kC flow through a heater in 2 hours. Calculate the current in the heater

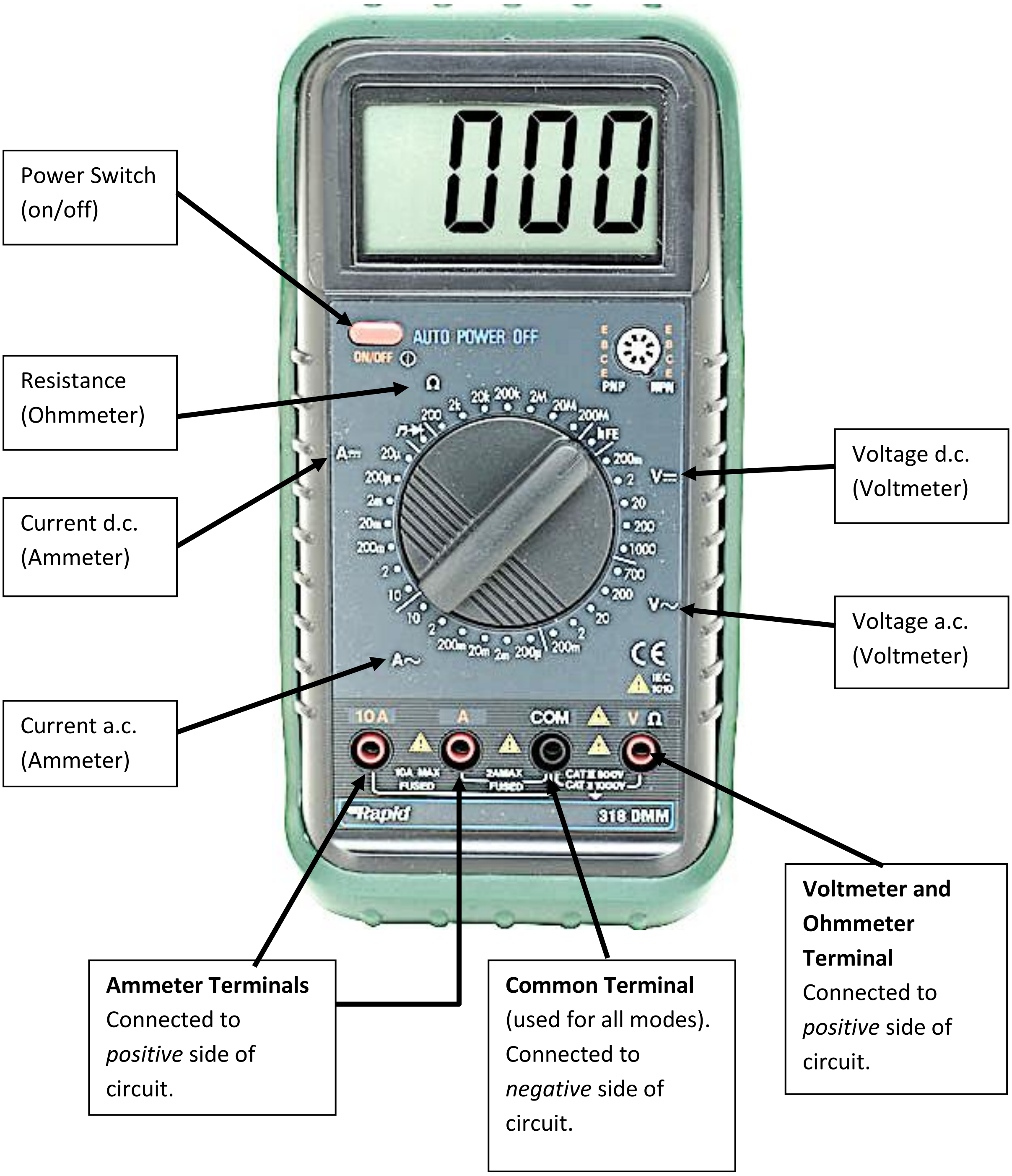
7. A lamp operates at 0.5 Amperes. How long will it take for 5000 C of charge to pass through the lamp?

8. A lamp operates at 1.5 A. How long will it take for 10 C of charge to pass through the lamp?

9. An LED light operates at 500 mA. How long will it take for 750 C of charge to pass through the lamp?

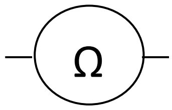
The Multimeter

The multimeter is an electronic measuring instrument that combines several functions into one device. A typical multimeter can measure the three main variables of *voltage*, *current* and *resistance* but many have other functions too.



Measuring Resistance

An *ohmmeter* can be used to measure resistance directly.

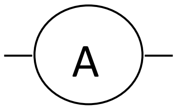


Notes:

- An ohmmeter must be connected <u>in parallel</u> with the component.
- The ohmmeter has several range settings. The range that gives a sensible reading, with the greatest number of significant figures, should be used.
- Ensure that there is no electrical supply connected when the ohmmeter is in use.

Measuring Current

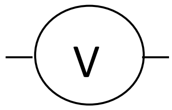
An *ammeter* is used to measure electric current.



Notes:

- An ammeter measures the current flowing *through* a component.
- An ammeter must be connected <u>in series</u> with the component.
- The red terminal of the ammeter should be connected at the side nearer to the **positive** terminal of the supply.
-

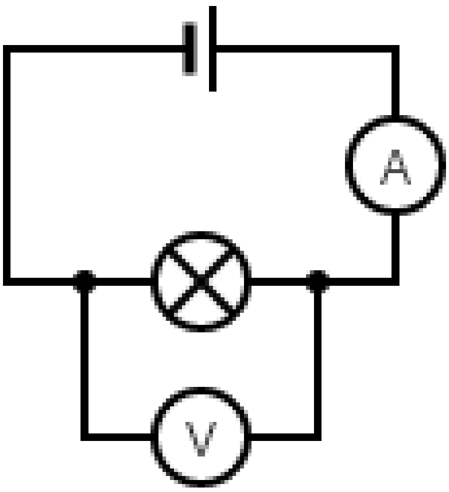
Measuring Potential Difference (or Voltage)



A *voltmeter* is used to measure potential difference or voltage.

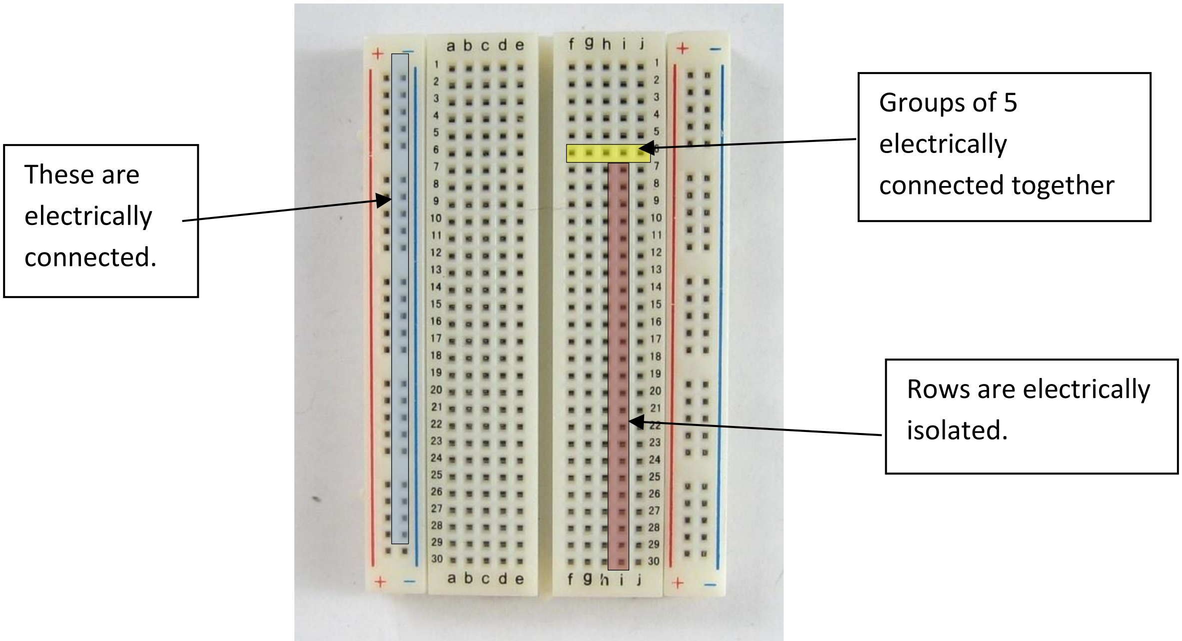
Notes:

- A voltmeter measures the potential difference *across* a component.
- A voltmeter must be connected <u>in parallel</u> with the component.
- The red terminal of the voltmeter should be connected at the side nearer to the **positive** terminal of the supply.



Prototype Board

Prototype board (commonly known as “breadboard”) is a non-permanent, solderless circuit-building device. It is used for building and testing prototype circuits before permanent construction.



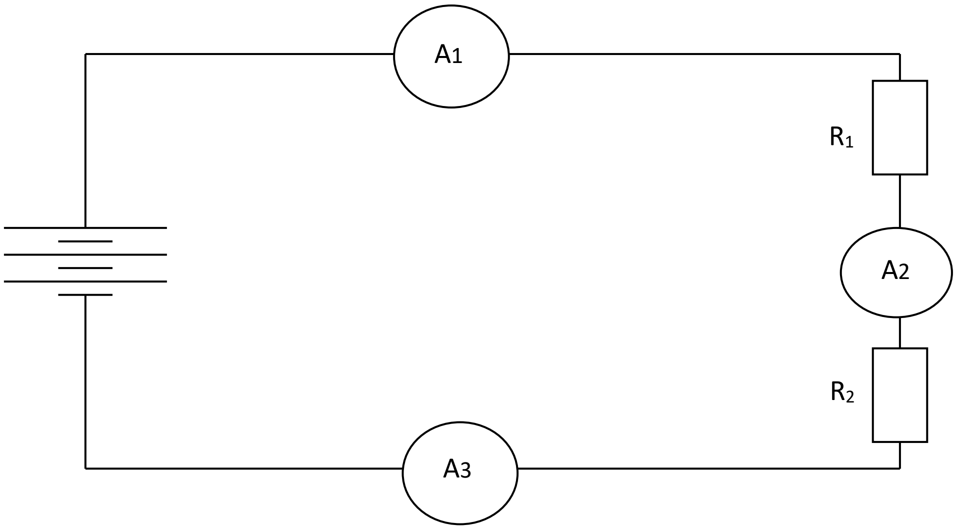
The holes vertically down the left and right of the board, on the picture above, are known as “buses”. Underneath, they are electrically connected, and are used as power rails as they are generally used for supplying power to a circuit.

The holes in the centre are in groups of five and are all electrically connected underneath the plastic. These groups, known as socket strips, are electrically isolated from each other.

Prototype boards come in many shapes and sizes but all have the above common features. It is important you familiarise yourself with the board you are provided so you can use it correctly.

Circuit Rules

Current in a series circuit

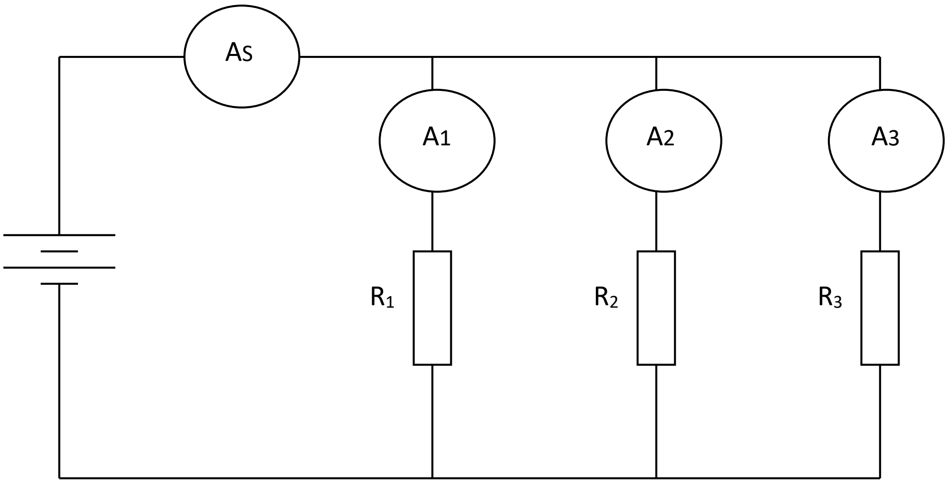


In a series circuit, the current is the same at all points.

$$I_1 = I_2 = I_3$$

Note: If the supply p.d. remains constant, the current in a series circuit is inversely proportional to the total resistance.

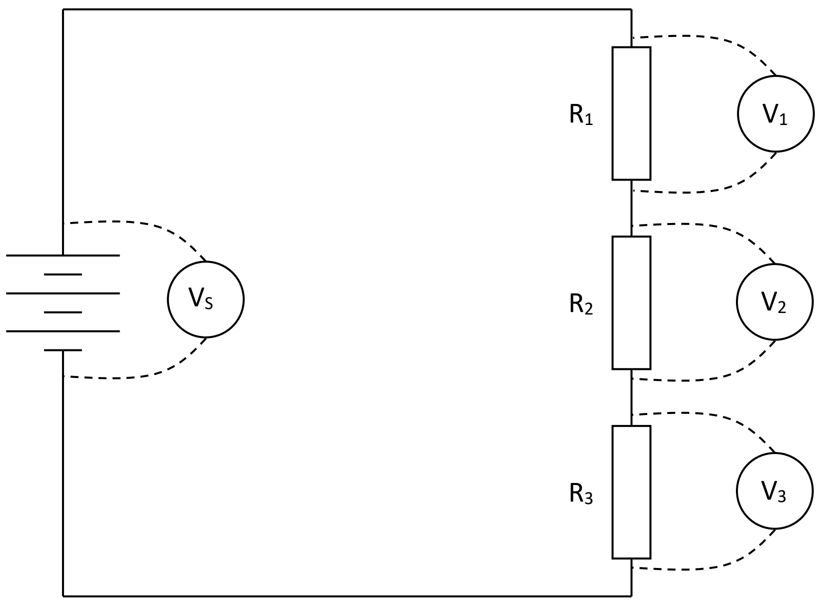
Current in parallel circuit



The current drawn from the supply is equal to the sum of the currents flowing in the separate branches.

$$I_S = I_1 + I_2 + I_3$$

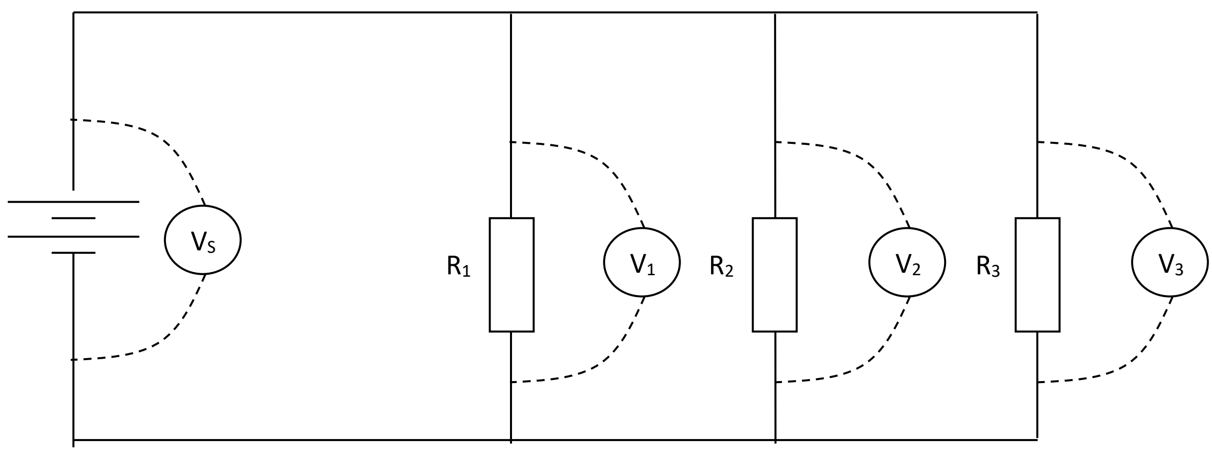
Potential difference in a series circuit



The sum of the potential differences across the individual components is equal to the potential difference across the supply.

$$V_S = V_1 + V_2 + V_3$$

Potential difference in a parallel circuit



The potential difference across each branch in parallel is the same as the potential difference across the supply.

$$V_S = V_1 = V_2 = V_3$$

Summary:

	Series	Parallel
Current	Stays the same	Adds Up
Potential Difference	Adds Up	Stays the same

Resistance

All materials oppose current through them. This opposition to the flow of charge is called **resistance**. Components that are constructed to have a particular resistance are called **resistors**.

For most resistors, total resistance depends on several factors:

- **Length**

  As the length of the resistor increases, the resistance increases.

- **Thickness**

  As the thickness of the resistor decreases, the resistance increases.

- **Temperature**

  As the temperature of the resistor increases, the resistance increases.

- **Material**

  Resistance depends on the molecular structure of the material.

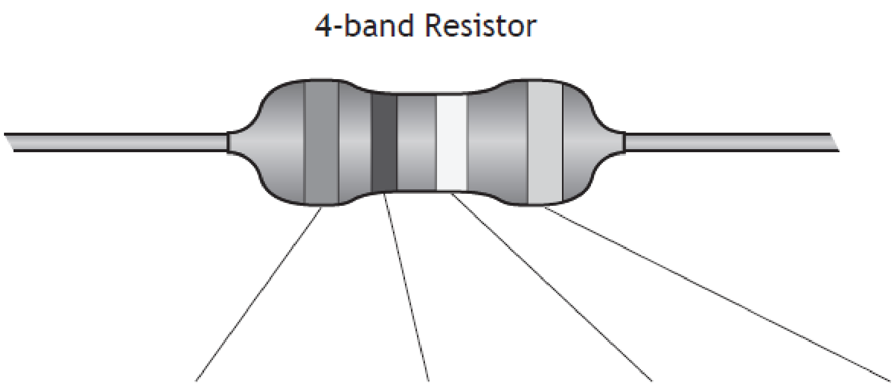
Resistance is given the symbol R and it is measured in units called **ohms (Ω).**

The Resistor Colour Code

The value of a resistor is marked on the body of a resistor using a colour band code.

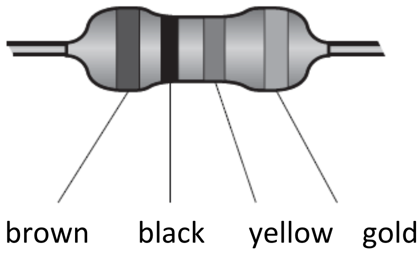
The first two bands are simply digits, the third is a multiplier and the fourth is the stated tolerance of the resistor. Manufacturing resistors of exact resistance is difficult, so all resistors come with a tolerance rating. i.e the real value of the resistor should be lie somewhere near the quoted value give or take the percentage stated.

Resistor Colour Codes



Colour	*1st band value*	*2nd band value*	*Multiplier*	*Tolerances*
Black	0	0	× 1	
Brown	1	1	× 10	±1%
Red	2	2	× 100	±2%
Orange	3	3	× 1 000	±3%
Yellow	4	4	× 10 000	±4%
Green	5	5	× 100 000	±0·5%
Blue	6	6	× 1 000 000	±0·25%
Violet	7	7	× 10 000 000	±0·10%
Grey	8	8	× 100 000 000	±0·05%
White	9	9	× 1 000 000 000	
Gold			× 0·1	±5%
Silver			× 0·01	±10%
No band				±20%

Worked Example



(i) determine the resistance of the resistor;
Brown – 1

Black – 0

Yellow – x 10 000

Therefore, R = 10 x 10 000 = 100 000 Ω = ***100 kΩ***

(ii) state the tolerance in the resistance of the resistor;
Gold = ***± 5%***

(iii) determine the maximum and minimum resistance of the resistor.

Maximum value = 100,000 x 0.95 = ***95 KΩ***

Minimum value = 100,000 x 1.05 = ***105 KΩ***

Complete the following table:

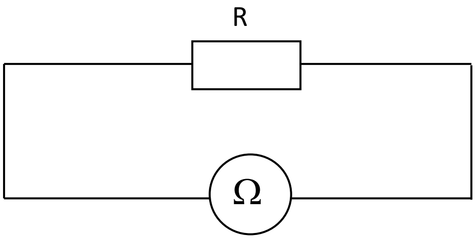
Resistor Bands				Quoted Resistance	Tolerance	Maximum Value	Minimum Value
1	2	3	4				
Orange	Orange	Brown	Silver				
Green	Blue	Red	Silver				
Brown	Green	Orange	Gold				
Red	Black	Orange	Red				
				470 Ω	± 5%		
				820 Ω	± 10%		
				390 kΩ	± 0.5%		

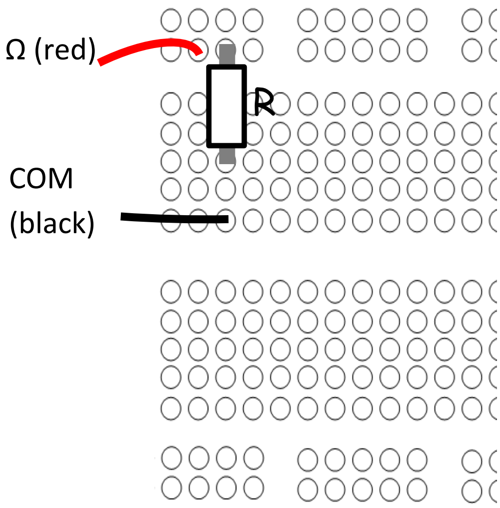
Practical: **Measuring resistance using an ohmmeter**

AIM To determine the resistance of a resistor using an ohmmeter.

APPARATUS Collect: a digital multimeter
a set of unknown resistors (label them A, B, C, D and E)

METHOD





- Connect the ohmmeter directly across resistor A.
- Repeat for resistors B, C, D and E.

RESULTS

Resistor	Quoted Resistance value / Ω	Tolerance	Measured Resistance value / Ω	Within tolerance? (Y/N)
A				
B				
C				
D				
E				

Ohms Law

$$R = \frac{V}{I}$$

$$\boxed{V = I\,R}$$

Where: V – p.d. (V)

I – current (A)

R – resistance (Ω)

Definition: **The potential difference across a fixed resistor at constant temperature is directly proportional to the current flowing through it.**

Worked Example

A current of 0.28 A flows through a resistor of resistance 47.0 Ω. Calculate the potential difference across the resistor.

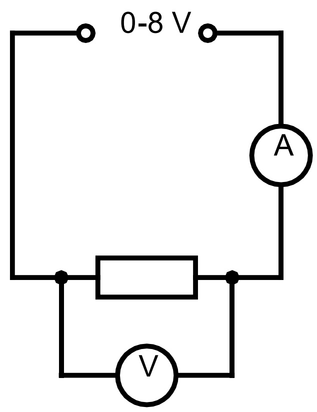
$$V = I\,R$$

$$= 0.28 \times 47$$

$$= 13.16$$

Potential difference across resistor is 13.2 V

Ohms Law Practical 1



Aim

To Prove that current and potential difference are directly proportional for a fixed resistor.

Method

1. Adjust supply 1- 5 V
2. Measure V and I each time
3. Plot a graph of V against I
4. Gradient = R

Task:

- Complete the experiments in groups.
- Write up your finding Individually.

Ohms Law Practical 2

Aim

To discover the link between voltage and current of a nonohmic conductor

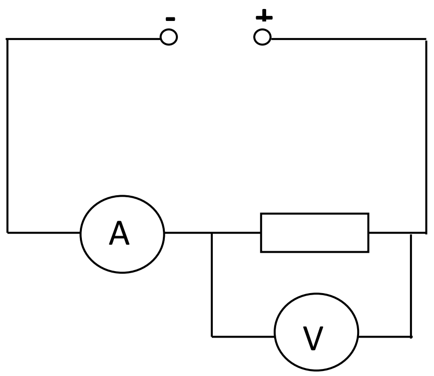
Method

1. Adjust supply 1- 5 V
2. Measure V and I each time
3. Plot a graph of V against I

Questions:

1. How do the graphs from practical 1 and 2 compare?

The Effect of Resistance in a Circuit



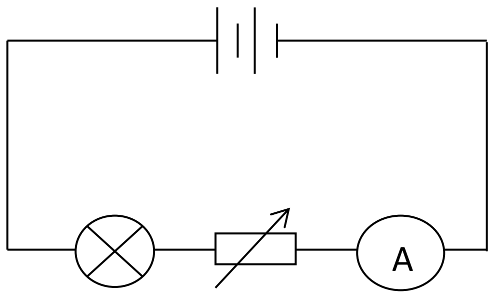
$$\text{resistance} = \frac{\text{potential difference across resistor}}{\text{current through resistor}}$$

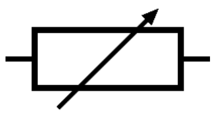
$$R = \frac{V}{I}$$

$$\therefore \quad I = \frac{V}{R}$$

Using this equation, we can predict that if the voltage in the circuit remains the same and the resistance of the resistor is increased, then the current flowing in the circuit will decrease.

Variable Resistors



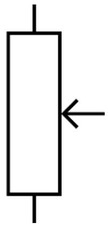


A resistor whose resistance can be changed is known as a variable resistor. Variable resistors can be used to vary the current in a circuit in a gradual and controlled way. Decreasing the resistance, increases the current and increasing the resistance, decreases the current.

Variable resistors are often used as:

- Light dimmer switch
- Temperature control
- Volume control

A variable resistor that is used to vary the potential difference across it is called a potentiometer and has three terminals, rather than two.



Resistors in Series and Parallel

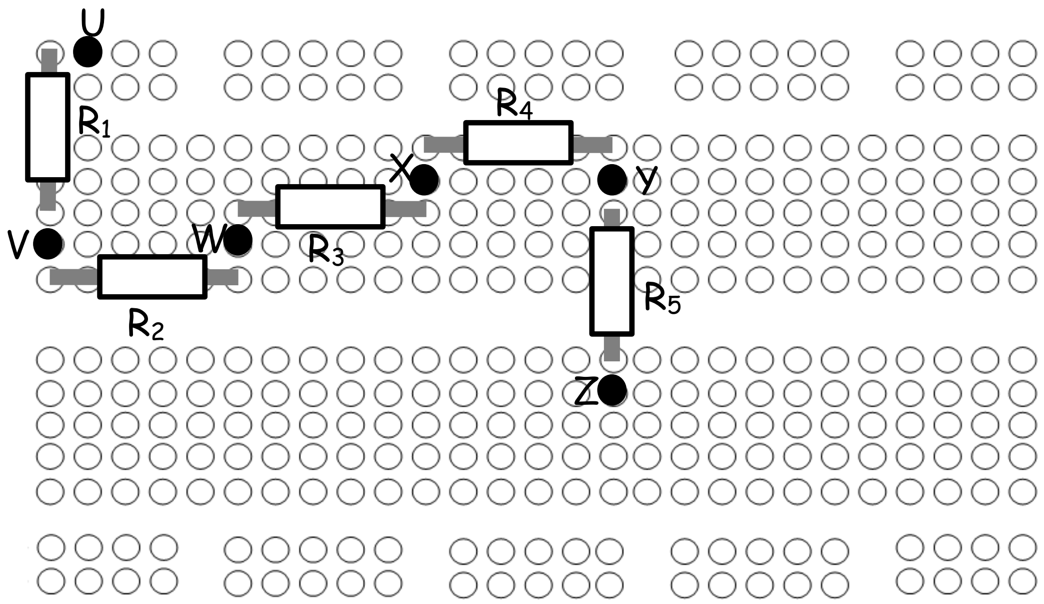
Practical: **Combining Resistors in Series and Parallel**

AIM To measure the total resistance of several resistors in series and in parallel.

APPARATUS Collect: a digital multimeter
the set of resistors labelled A, B, C, D and E
prototype board

Part 1 – Resistors in Series

Connect the 5 resistors as shown below on prototype board:



Using an ohmmeter, complete the table below:

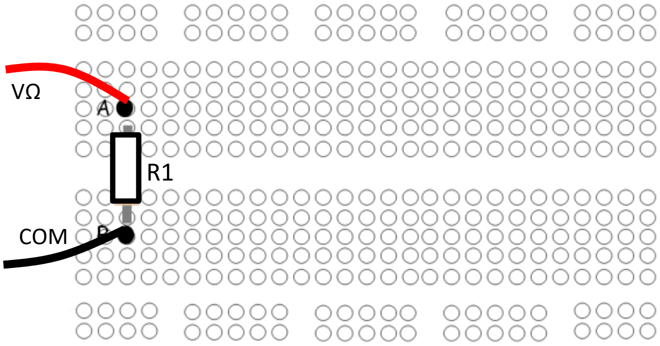
Meter position	Prediction (Ω)	Ohmmeter reading (Ω)
U and W		
U and X		
U and Y		
U and Z		
V and X		
W and Y		
X and Z		

Part 2 – Resistors in Parallel

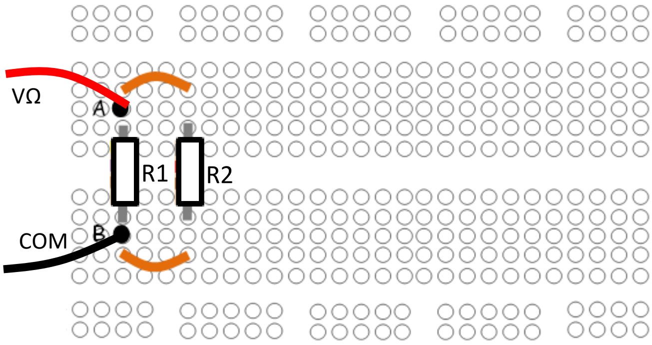
Construct circuits 1-4 in turn.

Connect an ohmmeter between A and B. Record measurements in table below.

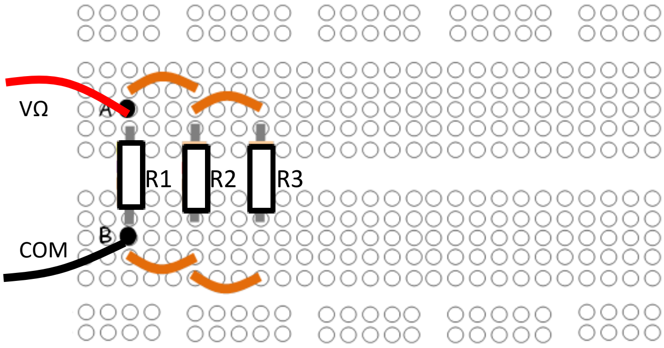
Circuit 1



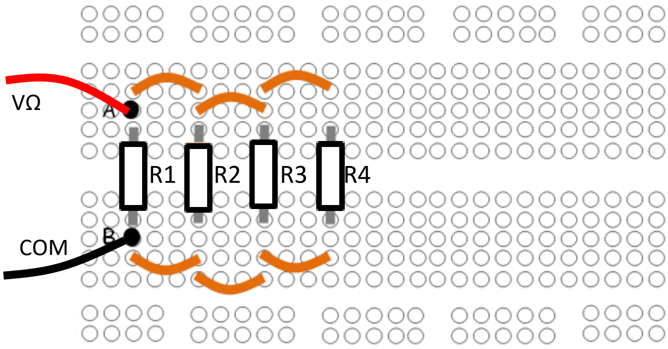
Circuit 2



Circuit 3



Circuit 4

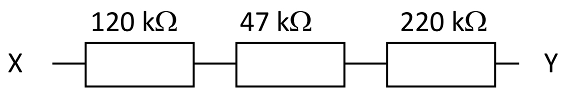


Circuit	**Prediction (Ω)**	**Ohmmeter reading (Ω)**
1		
2		
3		
4		

What can you conclude about resistors in Parallel?

Worked Examples

1. Determine the total resistance between points X and Y in the circuit below:



$$R_T = R_1 + R_2 + R_3$$

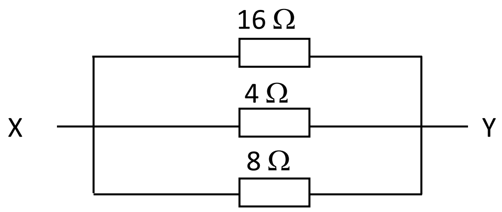
$$= 120 \times 10^3 + 47 \times 10^3 + 220 \times 10^3$$

$$= (120 + 47 + 220) \times 10^3$$

$$= 387 \times 10^3$$

Total resistance between points X and Y is <u>$3.87 \times 10^5\ \Omega$</u>

2. Determine the total resistance between points X and Y in the circuit below:



$$\frac{1}{\mathrm{R_T}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{\mathrm{R_T}} = \frac{1}{16} + \frac{1}{4} + \frac{1}{8}$$

$$\frac{1}{\mathrm{R_T}} = \frac{7}{16} (or\ 0.4375)$$

$$R_T = \frac{1}{7/16} (or \frac{1}{0.4375})$$

$$R_T = 2.285714$$

Total resistance between points X and Y is <u>2.3 Ω</u>