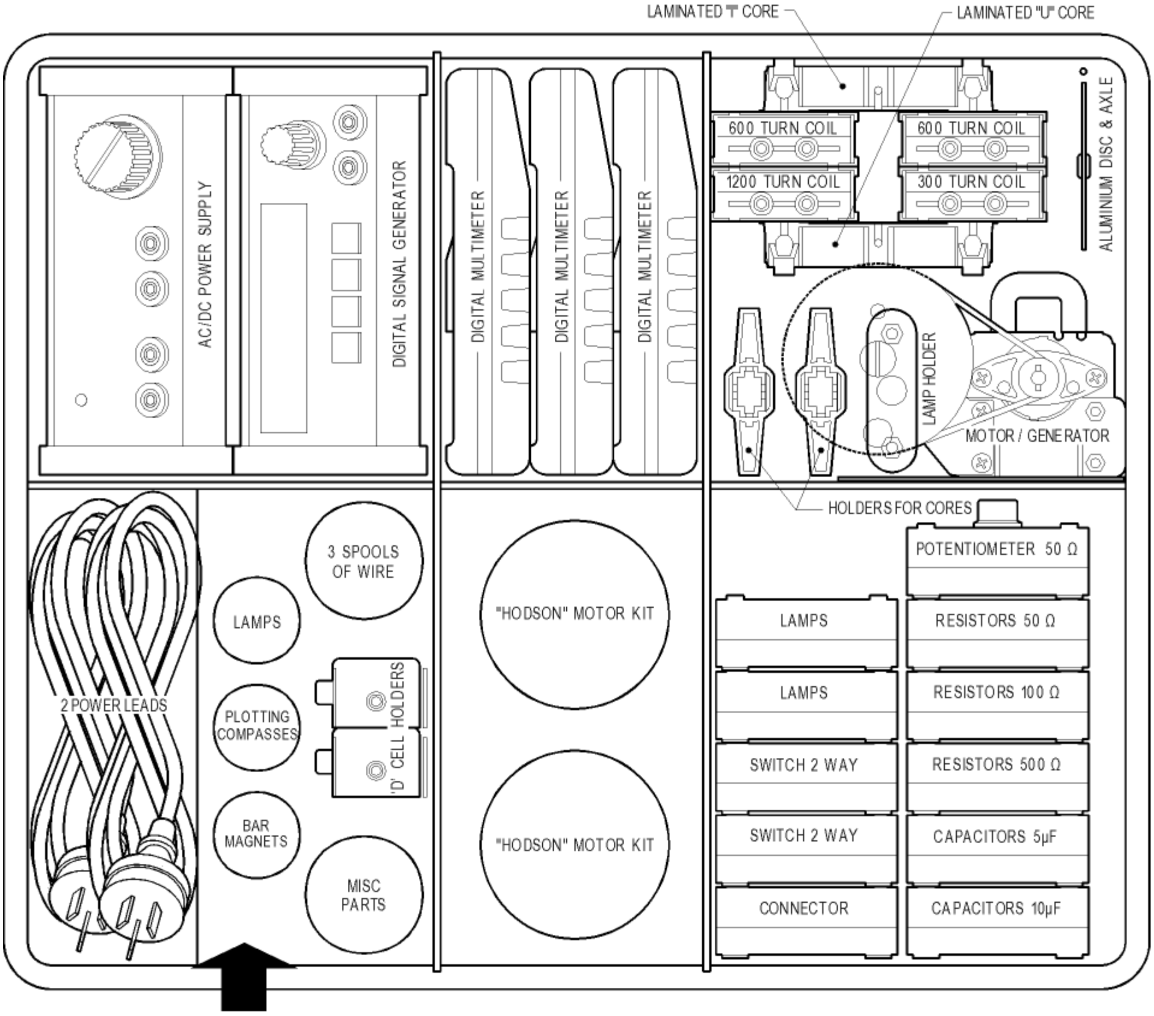
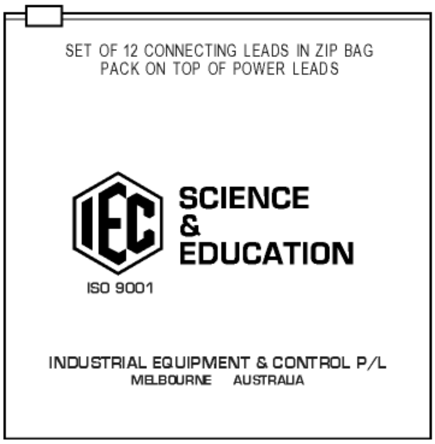
ELECTRICITY KIT - Experiments for DC

Cat: EM1763-020 KIT LAYOUT





3 SPOOLS VIAL CONTAINS:

1 ROLL BARE COPPER 0.2mm DIA.
1 ROLL RESISTANCE (CONSTANTAN) WIRE 0.2mm DIA.
1 ROLL FUSE WIRE 1A, 0.05mm DIA.
4 WIRES FOR METER uF
2 PAPER CLIPS

MISC PARTS VIAL CONTAINS:

4 ALLIGATOR CLIPS TO FIT TO BANANA PLUGS
4 ALLIGATOR CLIPS WITH BANANA PLUGS
1 PAIR, ELECTRODE PLATES, ZINC & COPPER
1 PAIR, CONDUCTIVITY PLATES, S/STEEL
1 RING FOR THOMSON'S EXPERIMENT
1 COMPASS FOR CHECKING N/S POLES

PART 1

KIT CONTENTS: Standard transparent housings for components:

- 1 x Potentiometer, 50 Ohms, 3 Watt, wire wound, in housing.
- 1 x Dual Resistors 50 Ohms, in housing.
- 1 x Dual Resistors 100 Ohms, in housing.
- 1 x Dual Resistors 500hms, in housing.
- 1 x Dual Capacitors 5uF (+/-10%) in housing
- 1 x Dual Capacitors 10uF (+/-10%) in housing.
- 2 x Dual lamp holders, in housing.
- 2 x Switch, single pole, two way, in housing..
- 1 x Connector box (for alligator clips to hold wires)

NOTE: this list can vary slightly. Some versions of kits do not have dual components.

Standard general components for experiments:

- 1 x Power Supply. Input: 220/240V.AC. 50/60Hz, Output: Switched at 2, 4, 6, 8, 10, 12V output, both AC and DC at 5 amps total load. DC is full wave, unfiltered. Automatically resetting overload with indication. With removable mains cable.
- 1 x Digital Signal Generator. Input: 220/240V.AC. Output: Sine, Square, Triangle & Sawtooth waveforms. 5V.RMS or 15V p/p, Frequency from 0.1Hz to 100 kHz. Output current up to a useful 1 amp. Automatic overload protection. With removable mains cable.
- 1 x AC & DC Motor/Generator, hand driven, with both commutator and slip rings.
- 1 x Set of 12x cables with moulded and stackable 4mm Banana Plugs.
- 1 x Set of “U” and “I” core for transformer study, with elastic bands.
- 4 x Coils to fit the “U” & “I” core. 1x 300T, 2x 600T, 1x 1,200T.
- 1 x Set/3 plain iron cores (1x long, 2x short) for magnetic experiments.
- 1 x Aluminium Disc & Axle for eddy current brake experiment.
- 3 x Multi-meters, digital, with 4mm banana plug cables.
- 2 x Cell holders for ‘D’ cell.
- 2 x Plastic supports for holding iron cores to “U” core.
- 1 x Pair of strong bar magnets, ‘Alnico’ (75mm long x12mm x8mm).
- 2 x ‘Hodson’ motor kits. For students to wind and assemble their own DC motor. All parts provided: yoke, magnets, wire, base, axle, rotor, instructions.

2x small screw-top vials:

- 10x Plotting Compasses.
- 10x MES lamps for 2.5 Volts 200mA 10x MES lamps for 12 Volts 100mA.

3x Rolls of wire & capacitor measuring wires:

- 1x Roll: 100m Copper wire, 0.2mm diameter
- 1x Roll: 100m Resistance wire, “Constantan” 0.2mm diameter
- 1x Roll: 50m 1 Amp fuse wire, 0.05mm diameter.
- 2x Paper clips for connections etc.

Various items:

- 4x Alligator Clips, plain. Can fit to 4mm banana plugs.
- 4x Alligator Clips, fitted with 4mm banana plugs (for holding all wires).
- 2x electrode plates. 1x Copper, 1x Zinc, size 70 x 20mm.
- 2x conductivity plates, stainless steel. Size 70 x 20mm.
- 1x Ring for ‘Thompson’s Ring’ experiment.
- 1x Compass for determining North/South Pole of magnetic fields.

GLOSSARY OF TERMS USED IN THIS MANUAL:

AC: Means Alternating Current. This is current that flows both forward and backwards following a sine wave waveform. AC does not have a + and - polarity so red and black terminal and wire colours are usually not used.

AMPS: This is the name or unit given to the flow of electricity or electrical current. If one Volt of potential is applied to one Ohm of resistance, then one Amp of current flows. If currents are small, the unit can be milliamps or 'mA' (one thousandth of an amp). If currents are very small, the unit can be microamps or 'uA' (one millionth of an amp).

AVERAGE: The average value of a sine wave voltage or current is: Peak value x 2/Π. This equals the Peak value of the Sine wave x 0.636. See also RMS.

BOOST: Term used to indicate that two separate windings on a transformer are connected so that one voltage adds to the other.

BUCK: Term used to indicate that two separate windings on a transformer are connected so that one voltage subtracts from the other.

CAPACITOR: A capacitor is a device that can store electric charge (something like a battery). The energy is stored as voltage is applied and current flows into it until it is 'charged'. At a later time, this energy can be released, or 'discharged' again to perform a function. These are commonly used in circuits that rectify AC to DC to try to make rectified DC smoother. When the AC waveform falls to zero, the energy stored in the capacitor is discharged to try to fill the gaps in the AC waveform. As the AC waveform rises again, the capacitor is re-charged. This occurs 100 times per second and when used in this manner, they are called 'filter capacitors'. Large filter capacitors are polarised and are designed to be connected only to a DC voltage source. They are called 'electrolytic' capacitors. CAUTION::: If electrolytic capacitors are connected to AC or if they are connected backwards to the DC voltage, they get hot and burst with a loud 'bang'. Some capacitors are designed for AC but these are not electrolytic and are much smaller capacitance. There are many types of capacitors for various voltages and uses.

CHOKE or INDUCTOR: A Choke, sometimes called an Inductor, is an AC device. For very high frequencies (radio frequencies etc) the coil is air or ferrite cored, but for low frequencies it is usually fitted with a laminated iron core. The magnetic field in the iron caused by the current through the coil also cuts the turns of wire in the same coil and causes a reverse voltage in the winding that opposes the applied voltage. This tries to stop the flow of current through the coil and this effect is called Reactance. If the iron core is removed from the coil, the Reactance is reduced and the AC current increases greatly.

CORE: Means the iron shape that is used to couple the magnetic field between two or more coils. A magnetic field can exist much more easily in an iron core than it can in air. When an iron core is used inside the coils, the induction effect is much more efficient. See 'Reluctance'.

CURRENT: This is the conventional flow of electricity through a conductor. It is caused by an EMF or voltage causing electrons to flow in a conductor if a circuit is closed. In DC circuits, the current flows in a conductor 'in phase' (see glossary) with the voltage. In AC circuits this is not always the case, but this phenomenon is reserved for more advanced AC studies.

DC: Means Direct Current. This is current that flows in one direction only. It might be a smooth, non-varying current from a battery, or it might be a pulsating current which is obtained when AC is rectified to DC. The AC sine wave is converted by the rectifier to flow in one direction, but rises and falls 100 times per second from zero to maximum in the shape of half of a sine wave. DC has a polarity and normally red means positive and black means negative. Current flows in a DC circuit from positive to negative.

EMF: Means Electro Motive Force. This is the voltage generated in a conductor when it moves within a magnetic field. Voltage is like the pressure of electricity and, when the circuit is closed, a current is forced through the conductors because of the presence of an EMF. The amount of current flowing depends on the magnitude of the EMF and the resistance of the circuit (Ohm's Law).

FIELD: This is a general name given to magnetic lines of force either in an iron core or in air.

FILTER: When AC voltage is rectified to create DC, the DC is not smooth like a battery. It follows the AC sine wave shape and, although it does not reverse direction, it rises from zero volts up to a peak and falls again 100 times per second (full wave rectification) or 50 times per second (half wave rectification). A filter, which is usually a large value capacitor connected across the DC, charges up to the peak voltage and discharges into the load to try to level out the humps and make it closer to a smooth DC. The effect is best seen on an oscilloscope.

FLUX: Is a general term meaning the magnetic field present usually in an iron core.

FREQUENCY: This is the number of times per second that the AC wave passes through one full cycle of rising from zero to maximum, then falling through zero to minimum and then rising to zero again. The unit is Hertz. Normal mains power in Australia has a frequency of 50Hz. Other countries such as USA and Canada (and many others) use a 60Hz power system.

IMPEDANCE: In the world of DC, resistance (ohms) is the factor that controls the current in a circuit. In the world of AC, there is a mixture of both Resistance and Reactance which alter the flow of current through an AC circuit. The term Impedance means the combination of these two phenomena. The term 'Low Impedance' means a circuit that has only small total resistive effect to an AC current flow.

INDUCTANCE: This is the measurement of a coil's inductive effect in Henrys. Inductance depends on the number of turns in the coil and the amount of iron in the core. Coils of low inductance (micro Henrys) are used in radio sets for tuning stations and coils of larger inductance (milli Henrys or Henrys) are used as Chokes for power supply filters or high power oscillators and special equipment.

INDUCTION: Means the inducing of a voltage in a coil of wire by the application of a magnetic field from either a magnet or another coil of wire. The coils of wire are usually not electrically connected.

INDUCTOR: An inductor is a coil of many turns of wire mounted on an iron core (see Choke).

LAMINATIONS: Iron cores in an AC device are made from thin strips of iron instead of from solid blocks of iron. These thin strips are called laminations and are insulated electrically so current cannot flow from one to another. This is to reduce or eliminate wasteful and unwanted circulating currents in the iron.

LEAKAGE: This is stray magnetic field that appears outside the iron core. Any field leaking outside the iron core cannot be used by the transformer in driving the secondary coil. Transformer design tries to keep magnetic leakage to a minimum.

LOAD: The term 'load' is used for any circuit that draws power from a power source. If a resistor is connected to a battery so that current flows, the resistor can be called the 'battery's load'. The current drawn by the resistor can also be called the 'load' on the power source.

LOSSES: This is the name given to energy provided by the Primary coil to the system but not available as usable energy from the secondary coils. Transformer losses include:

- The energy required in magnetising and de-magnetising and reversing the magnetisation in the core 100 times per second. Special iron used for transformers has low losses.
- Resistance in the copper wire of the windings causing voltage loss and heat generated.
- Circulating currents in the iron core causing heating of the iron.
- Loss of magnetic field (leakage) into the air from the iron core.

MAGNETISING CURRENT: This is the current drawn from the power source by the primary coil required to magnetise the iron core and to overcome leakage and losses. Transformer design tries to keep the magnetising current as small as possible because it is wasted energy from the power source and causes unwanted heating in the primary coil.

PARALLEL CONNECTION: When two or more devices are connected so that the current divides and flows through side-by-side paths, they are said to be connected 'in parallel'. The total current from the source is the sum of the parallel currents.

PEAK VOLTAGE: Unfiltered DC voltage is a sine wave shape that rises to a peak value and falls to zero volts 100 times per second. When a DC voltmeter meter is placed on the DC, it shows the average DC voltage (not the peak voltage). If a capacitor is placed on the output when there is no load connected to the power supply, it will charge to the peak value which is the highest point of the sine wave. The voltmeter will show this higher peak voltage (average x approx.1.4). When a load is placed on the power supply, the capacitor will discharge this extra energy into the load as the sine wave falls 100 times per second and the voltmeter will then show the average voltage again. But this will be a higher average than before because the capacitor adds extra energy to the load.

PHASE: If you raise both arms and lower them together, they are 'in-phase'. If one arm rises as the other arm falls, they are 'out of phase'. The timing relationship of two voltages or two currents or a voltage compared to a current is called the 'phase relationship'. In the world of DC, currents and voltages are usually 'in phase'. This is not always the case in the world of AC.

As an AC voltage rises in a coil with an iron core, the current through the coil rises slightly later than the voltage. Therefore the magnetic field also rises slightly later than the voltage. The voltage induced in a secondary coil therefore appears at a different instant when compared to the applied voltage. Look at these voltages on a double beam oscilloscope. If a secondary coil is wound the same direction (clockwise or anti-clockwise) as another secondary coil, the AC voltage on these two coils will be rising and falling at exactly the same time. This means they are 'in phase'. If they are connected in series, their voltages will add (see 'boost' in the glossary). If one coil is wound in the opposite direction, they will be 'out of phase' and their voltages will subtract (see 'buck' in the glossary). Phase angle is from 0 to 360 degrees. The term 'in phase' means a shift of zero degrees in phase. 'out of phase' means a shift of 180 degrees in phase.

PRIMARY; The name given to the transformer winding that is connected to the power source. It provides the energy to both magnetise the iron core and to transfer to the secondary winding(s).

RMS: Means "Root Mean Square". It is the value of the square root of the average of the sum of all the instantaneous values squared. Say the whole sine wave was divided into say 1000 separate instantaneous readings and say each reading was squared in value. If they were all added and divided by 1000, we would have the average of all the squared values. When the square root is taken of this average of the squares, we have a close approximation of the 'effective' or the RMS value of the sine wave.

Average power of a sine wave is half the peak power $(V_p \times A_p) / 2$, thus it follows that average power equals $V_p / \sqrt{2} \times A_p / \sqrt{2}$. It follows then that the 'effective' voltage and 'effective' current that causes average power is peak voltage / 1.414 or peak current / 1.414 (this is $\sqrt{2}$). (This equals peak value x 0.707).

Useful conversions::

RMS value = peak value x 0.707 or AVERAGE value x 1.11

PEAK value = RMS value x 1.414 or AVERAGE value x 1.57

AVERAGE value = peak value x 0.64 or RMS value x 0.90

REACTANCE: The world of DC has Resistance (Ohms) that controls the flow of DC current in a circuit and generates heat (Watts). In the world of AC, resistance exists but, in addition to resistance, AC circuits have Reactance. It behaves like resistance but does not generate heat. Reactance depends on the Inductance (Henrys) of a coil or Capacitance (microfarads) of a capacitor and the Frequency (Hertz) of the AC current flowing through it.

RECTIFICATION: AC can be changed to DC by 'rectification'. If a single diode is used, only one half of the AC waveform passes through the diode as DC and the voltage appears as 50 humps per second. If 4 diodes are connected in a 'bridge' configuration 'full wave' rectifier, both halves of the AC waveform are rectified and the DC appears as 100 humps per second. If a transformer winding has a 'centre tapping', only 2 diodes are required to create 'full wave' rectification. Rectification is reserved for electronic study and is not covered in this booklet.

RELUCTANCE: The ability of a material to support a magnetic field is called the 'reluctance' of the material. Air has a very high reluctance and iron has a low reluctance. The special laminated iron used to make transformer cores usually has a very low reluctance.

RESISTANCE: Means the ease or difficulty that electrons have in flowing through a circuit. Glass does not conduct electricity, so it can be said that it has an extremely high resistance. Metals allow easy flow of electrons, and can be said to have a very low resistance. Every material has resistance value in OHMS. 'Kilohms' means thousands of ohms. 'Megohms' means millions of ohms.

Ohm's law: 1 volt EMF causes 1 AMP of current to flow through 1 OHM of resistance.

ROTOR: The rotor of a motor is the part that rotates

SECONDARY: The name given to winding(s) of a transformer that are not the 'Primary' winding.

SERIES CONNECTION: When two or more devices are connected so the current must pass from the end of one into the beginning of the next so that the same current flows through all of them, they are said to be connected 'in series.

STATOR: The stator of a motor is the part that does not rotate.

TAPPING: If a coil is wound part way (say 20 turns) and the wire is then looped from the bobbin to a connection point and then returned to the coil and the coil wound further, the coil is said to have a tapping. Transformer coils can have as many tappings as desired to provide many voltages from the one coil. If two coils of say 50 turns are connected in series, this is the same effect as one 100 turn coil tapped at the mid point.

TRANSFORMER: This is a device where two or more coils of wire are coupled by an iron core so that the magnetic field in the iron created by one of the coils (the primary coil) induces a voltage in the other coils. The coils are not normally electrically connected to each other. Depending on the number of turns of wire on the coils, the voltage applied to the primary coil can be changed or transformed to a different voltage on the secondary coil(s). The thickness of the wire forming the coils has no effect on the voltages created. The wire thickness should be calculated to suit the current flows in and out of the transformer to avoid overheating of the wire.

VOLTAGE: This is the electrical 'pressure' that is created in a conductor when a conductor moves relative to a magnetic field to cut the lines of magnetic force. The voltage cannot cause current to flow until the circuit is closed. The voltage is dependent on the strength of the field and the speed of motion of the conductor. Voltage can be created also chemically as in a battery or by heat or light or by electric charge as in static electricity, lightning and similar. To understand voltage, it can be considered to be similar to pressure of water in a pipe. Pressure of water is present in a pipe but the flow of water (like electrical current) cannot occur until a circuit is made with pipes (like electrical wires) and until the tap is opened (like an electrical switch turned on).

VOLTS: This is the name or unit given to the potential of electricity or electrical pressure. If one Volt of potential is applied to one Ohm of resistance, then one Amp of current flows. If voltages are small, the unit can be millivolts or 'mV' (one thousandth of a volt). If voltages are very small, the unit can be microvolts or 'uV' (one millionth of a volt).

WATTS: When a voltage causes a current to flow through a resistance, heat is generated in the resistance. The unit of the power generated is Watts. If powers are small, the unit can be milliwatts or 'mW' (one thousandth of a watt). If powers are very small, the unit can be microwatts or 'uW' (one millionth of a watt). For a DC circuit, Volts x Amps = Watts. For AC circuits it is more complicated and this is reserved for later study.

METERS: There are several different common types of measuring meters.

Meaning of Analogue: All analogue meters move in the same way as an electric motor turns in a magnetic field. A very fine coil of wire is held in pivots in a very strong magnetic field. If any current flows in the coil, it tries to twist in the magnetic field against springs that are trying to keep it stationary. A pointer is attached to the coil and the pointer moves on the scale to indicate a reading or measurement. Being mechanical, analogue meters can usually be repaired. Analog meters clearly show voltages changing as the pointer moves back and forth.

Meaning of Digital: Digital meters provide a numeric reading and there are no moving parts. They are normally more accurate than analogue types. Digital meters require batteries to operate and the main difficulty is that digital meters do not clearly indicate voltages that are changing because it is impossible to follow the numbers changing. Digital meters are not easily repaired.

Analogue student meters: These are used commonly in classrooms and are individual meters with terminals. They can be either AC or DC meters and are usually made from plastic and have either one or two ranges for either Volts or Amps. They have pointers that pass over a scale, are low cost and are very good for student experiment work.

Analogue demonstration meters: These are very large meters used in a classroom for all the students to see from a great distance. They have a long and fat pointer and the large scale can often be interchanged to change the meter from AC to DC and from Volts to Amps and to change the measuring ranges.

Analogue multimeters: An analogue multimeter is one that has a pointer that passes over a scale and has many ranges and functions that can be selected by a switch on the meter. The one meter can usually read many ranges of Amps, Volts and Ohms. They are sometimes called AVO meters.

Mirror backed scale: Most analogue meters have a strip of mirror below the scale to that the user can place the pointer over the reflection of the pointer to be sure the eye is exactly vertically over the pointer. This eliminates errors due to reading the pointer at an angle (called parallax).

Digital multimeters: The kits contain digital multimeters. They are usually accurate and have no moving parts. They use 9 Volt batteries internally and have many AC and DC Amps, Volts and Ohms ranges. Often they can measure also Capacitance, Inductance, Temperature, Transistor Gain and Frequency.

The small student series digital meters in the kit measure AC or DC Amps (up to 10A), AC or DC Volts (up to 1000V), Ohms (up to 200 megohms), Capacitance up to 20uF and Transistor Gain.

USING METERS:

Always be careful to select AC or DC correctly. Think about the values you are measuring and always be sure to select a range higher that the readings you expect. It is always better to begin on a high range and reduce it than to start at a low range and damage the meter. The meters are supplied with instruction sheets and connection cables with 4mm banana plug connectors.

MEASURING CAPACITANCE: The meters supplied in the kit can read capacitance to 20 microfarads (uF). The connection for capacitance is by a small socket on the front of the meter because usually capacitors have wires at each end of their bodies to place into the small sockets. This kit however has all 4mm banana socket connections.

To connect cables to the meter for capacitance, the kit contains some short lengths of tinned copper wire to press into the socket and for attachment of alligator clips.

<u>ALWAYS TURN DIGITAL METERS OFF AFTER USE.</u>

Experiment list: for D.C. for A.C.

1	Turn lamp on and off	41	AC current in capacitors. Reactance.
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5	Voltage measurement, 2x cells in series	45	Field around a single coil
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10	Smaller currents through liquids	50	Using AC instead of DC
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19	Connecting 2 resistors in series	59	Leakage in iron cores
20	Voltage divider using resistors	60	Measure DC magnetising current
21	Connecting 2 lamps in parallel	61	Measure AC magnetising current
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23	Connecting resistors in series/parallel	63	Thompson's ring experiment
24	Internal resistance of a cell	64	Measure DC resistance of a Resistor
25	Why use 2 cells in parallel ?	65	Measure the DC Resistance of an Inductor
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27	Using a potentiometer (voltage divider)	67	Measure the Impedance of an Inductor
28	Making a Rheostat from a potentiometer	68	Measure the Reactance of an Inductor
29	Creating heat energy from electricity	69	Measure the Inductance of an Inductor
30	Creating light energy from electricity	70	Measure the Impedance of a Capacitor
31	Making a fuse	71	Measure the Reactance of a Capacitor
32	Power in an electrical circuit	72	Measure the Capacitance of a Capacitor
33	Making a heater for water	73	Capacitors in series and parallel
34	Work performed by an electric current	74	Resonance: Inductor and Capacitor in series
35	Voltage created by chemistry	75	Resonance: Inductor and Capacitor in parallel
36	Capacitors charge and voltage	76	Power Factor
37	Charge one capacitor from another	77	DC Generators, permanent magnet, adj.field.
38		78	AC Generators, permanent magnet, adj.field.
39		79	DC Motors, shunt, series.
40		80	AC Motors, series, synchronous.

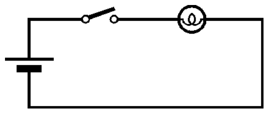
D.C. EXPERIMENTS. using dry cells and Power Supply:

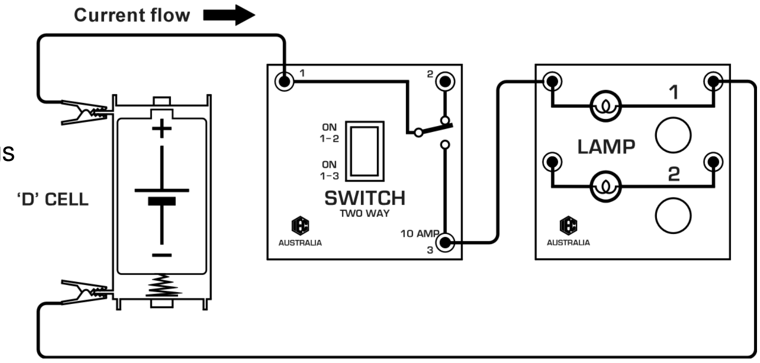
Read the Glossary to find the meaning of "DC".

1) Electric circuit to turn 1 lamp on and off.

Equipment required:

- 1x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lamp holder fitted with 2.5V lamp
- 2x alligator clips to fit to banana plugs
- 3x cables with banana plugs
  Fit alligator clips to 2 cables





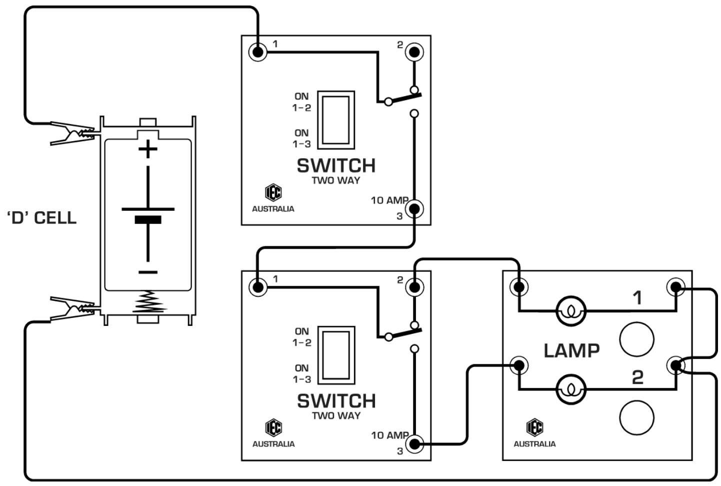
Connect the circuit as shown by pushing the cable banana plugs into the sockets provided on each component. Use alligator clips to connect the cables to the cell holder. The cell provides a voltage, when a circuit is connected to a voltage, a current flows. When the switch is turned ON, socket 1 connects to socket 2, current flows from the positive end of the cell, through the switch connections, through the lamp and back to the negative end of the cell. The lamp will come ON. The arrow on the circuit shows the direction of current flow.

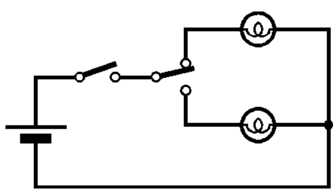
Turn the lamp OFF and disconnect the cell and reverse the direction. This time, the current will flow the opposite way around the circuit. The lamp comes ON and the lamp works the same if the current flows either direction.

2) Electric circuit to select between two lamps.

Equipment required:

- 1x 'D' size cell in holder
- 2x switch, single pole, 2 way
- 2x lamp holders fitted with 2.5V lamp
- 2x alligator clips to fit to banana plugs
- 6x cables with banana plugs
  Fit alligator clips to 2 cables





Connect the circuit as shown by pushing the cable banana plugs into the sockets provided on each component. When the 1 way switch is ON, sockets 1 & 2 are connected to carry current to the lamps. The 2 way switch has 3 sockets and this switch can switch two different ways. One way it joins socket 1 to socket 2 and the other way it joins socket 1 to socket 3. This switch can select which lamp to operate.

EXERCISE: repeat experiment 1) again, but use the 2 way switch. First connect sockets 1 and 2 in the circuit. Then try again using sockets 1 and 3.

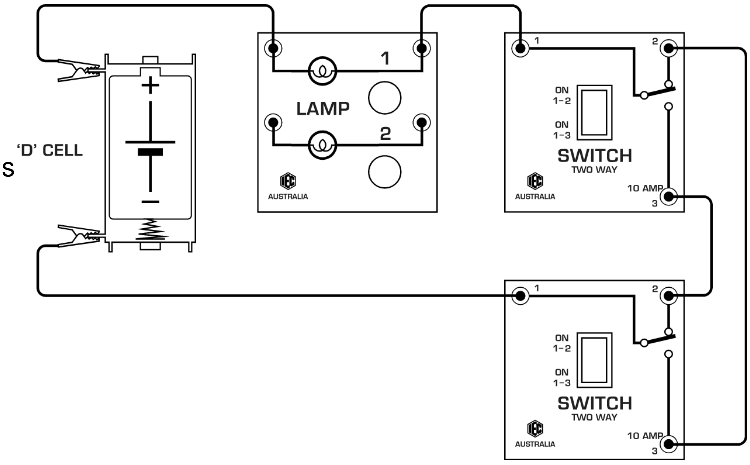
What happens if you use sockets 2 and 3 ? Explain why ?

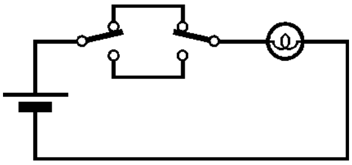
3) Electric circuit to light a lamp from two switches (2 way switching).

Equipment required:

- 1x 'D' size cell in holder
- 2x switch, single pole, 2 way
- 1x lamp holder fitted with 2.5V lamp
- 2x alligator clips to fit to banana plugs
- 5x cables with banana plugs

Fit alligator clips to 2 cables





Connect the circuit as shown by pushing the cable banana plugs into the sockets provided on each component. Use alligator clips to connect the cables to the cell holder. When the switch is turned ON, socket 1 joins to socket 2 OR socket 1 joins to socket 3. Try switching either switch one way then the other. The lamp will go ON or OFF from either switch. This type of '2 way' switching is done in houses so the same light can be switched from two different switches.

Follow the current flow through the two switches when they are switched in different positions to explain how the system works.

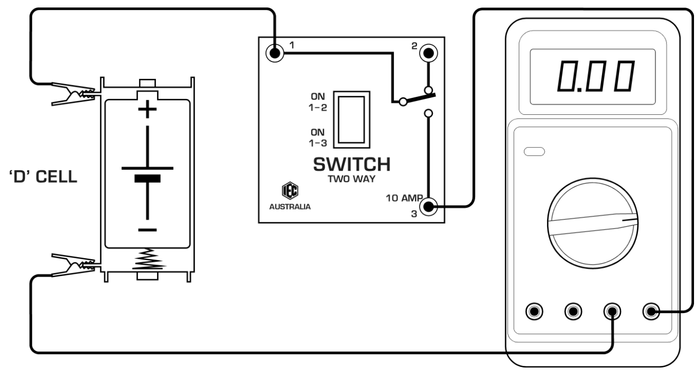
4) Voltage measurement. One cell, using a voltmeter:

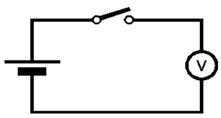
READ PREVIOUS NOTES ON METERS.

Equipment required:

- 1x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x multimeter or 0-5V DC voltmeter
- 2x alligator clips to fit to banana plugs
- 3x cables with banana plugs

Fit alligator clips to 2 cables





Connect the circuit as shown by pushing the cable banana plugs into the sockets provided on each component. Use alligator clips to connect the cables to the cell holder. On the meter, select DC. VOLTS and select a range of 20 volts. Be sure the positive (+) connection of the meter is connected to the positive end of the cell. The positive side of a meter is usually coloured RED and the positive end of a cell has the raised centre contact. If you connect a meter backwards it will try to deflect backwards and it might be damaged. If a digital meter is used, they can be connected backwards without damage, but a negative (-) sign usually appears on the display.

When the switch is turned ON, socket 1 joins to socket 2. The meter is then connected directly to the power source (cell). The voltmeter will read the voltage of the cell (close to 1.5V).

Voltage: Volts is the measurement of the 'pressure' of electricity. It is this 'pressure' that causes the current to flow in the circuit. Now *read the glossary* at the front of this book for the meaning of Volts.

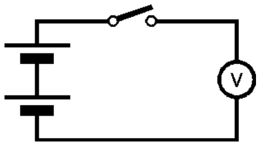
5) Voltage measurement. Two cells in series, using a voltmeter:

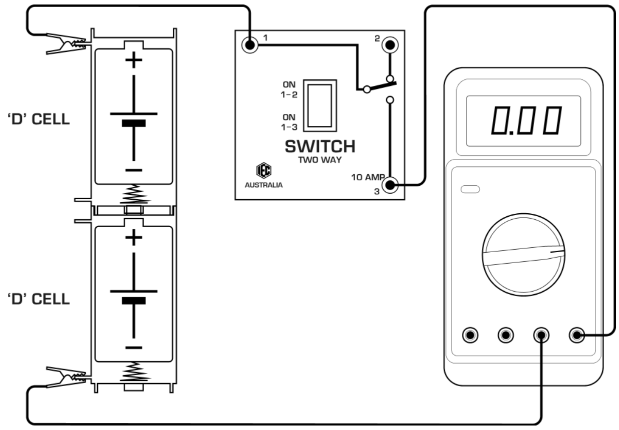
INCLUDING CONNECTING CELLS IN SERIES

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x multimeter or 0-5V DC voltmeter
- 2x alligator clips to fit to banana plugs
- 3x cables with banana plugs

Fit alligator clips to 2 cables





Connect the 2 cells with the positive of one cell to the negative of the other. This is called a 'series' connection. Use alligator clips to connect the cables to the cell holders. On the meter, select DC. VOLTS and select a range of 20 volts. Be sure the positive (+) connection of the meter is connected to the positive end of the cell. The positive side of a meter is usually coloured RED and the positive end of a cell has the raised centre contact. If you connect a meter backwards it will try to deflect backwards and it might be damaged. If a digital meter is used, they can be connected backwards without damage, but a negative (-) sign usually appears on the display.

When the switch is turned ON, socket 1 joins to socket 2. The meter is then connected directly to the power source (cell). The voltmeter will read the voltage of the 2 cells in series connection (close to 3V). Notice that the two voltages of the cells are adding together.

Using the alligator clips to connect to the cell holders, measure the voltage of one cell and then measure the voltage of only the other cell.

EXERCISE: Disconnect one cell and turn it around so that it is in reverse direction to the other one.

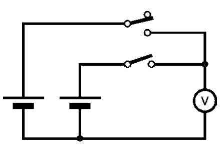
What voltage will be measured across both of them now ? Explain why ?

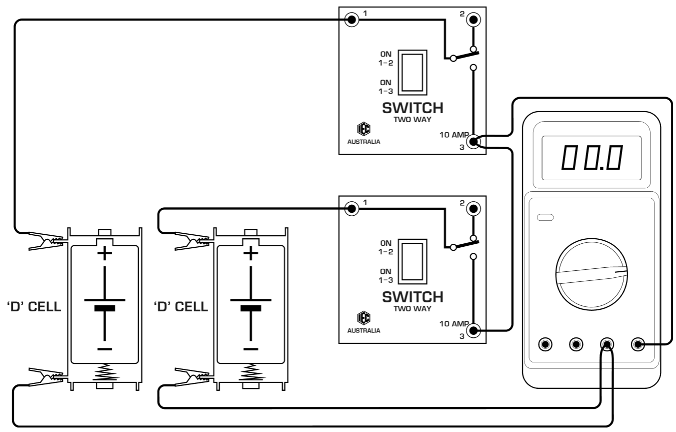
6) Voltage measurement. Two cells in parallel, using a voltmeter:

Equipment required:

- 2x 'D' size cell in holder
- 2x switch, single pole, 2 way
- 1x multimeter or 0-5V DC voltmeter
- 4x alligator clips to fit to banana plugs
- 6x cables with banana plugs

Fit alligator clips to 4 cables





Connect the circuit as shown. Use alligator clips to connect the cables to the cell holders. On the meter, select DC. VOLTS and select a range of 20 volts. Be sure the positive (+) connection of the meter is connected to the positive end of the cell. When the switch is turned ON, socket 1 joins to socket 2. The meter is then connected directly to the first cell. When the second switch is closed, another cell will be connected positive to positive and negative to negative *(in parallel)* to the first.

What voltage will be measured with two cells in parallel ? Explain why ?

Do not reverse the direction of one cell. *What would happen if you did ?*

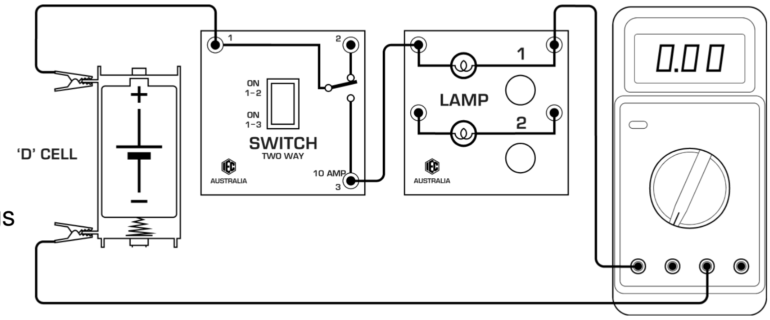
7) Current measurement. Using an ammeter.

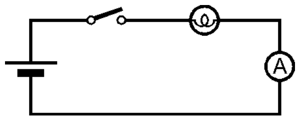
READ PREVIOUS NOTES ON METERS.

Equipment required:

- 1x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lamp holder fitted with 2.5V lamp
- 1x multimeter or 0-5A DC ammeter
- 2x alligator clips to fit to banana plugs
- 4x cables with banana plugs

  Fit alligator clips to 2 cables





Connect the circuit as shown. Notice that the ammeter is connected 'in series' with the circuit so that the current flow goes through one cable into the meter and out the other cable. On the digital meter, select DC and the 10 amp range. Turn ON the switch and measure the small current through the lamp.

The meter is measuring as the current LEAVES the lamp. Turn off the voltage, unplug the meter cables and reconnect the meter between the switch and the lamp. *What value do you expect the current to be on the other side of the lamp ?* Now turn switch ON and measure current BEFORE the lamp.

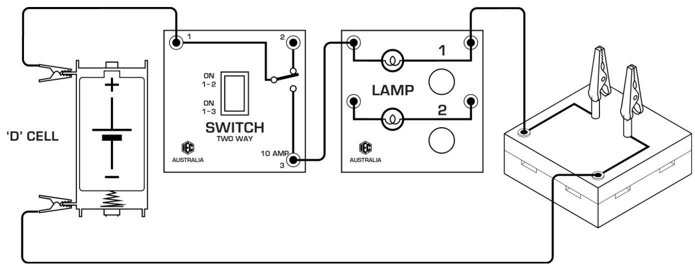
Has the lamp 'used up' electricity ? *Try to explain the results.*

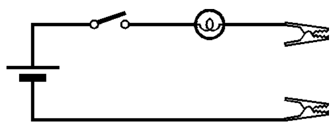
8) Conductors and Non-Conductors.

Equipment required:

- 1x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lamp holder fitted with 2.5V lamp
- 1x connector block
- 2x alligator clips fitted with banana plugs
- 2x alligator clips to fit to banana plugs
- 4x cables with banana plugs

  Fit alligator clips to 2 cables





Connect the circuit as shown. When the switch is closed, the cell is connected to the lamp, but the lamp cannot light until current can pass through the connector. Plug in the 2 alligator clips with banana plugs fitted into the connector block so that these alligator clips can be made to clip to various materials.

Try many different materials between the alligator clips to find out what conducts electricity and what does not conduct. Materials that cannot conduct electricity are called *insulators.*

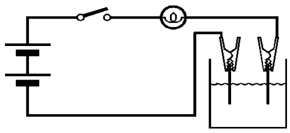
Some materials partly conduct and the globe will be dim. Some materials (like most metals) conduct well and the globe will be bright. Try different metals, plastics, paper, coal, centre lead of a pencil, carbon, glass, wood, and burned wood. Try resistance wire (Constantan), copper wire and thin fuse wire. Try different lengths of wire from the kit.

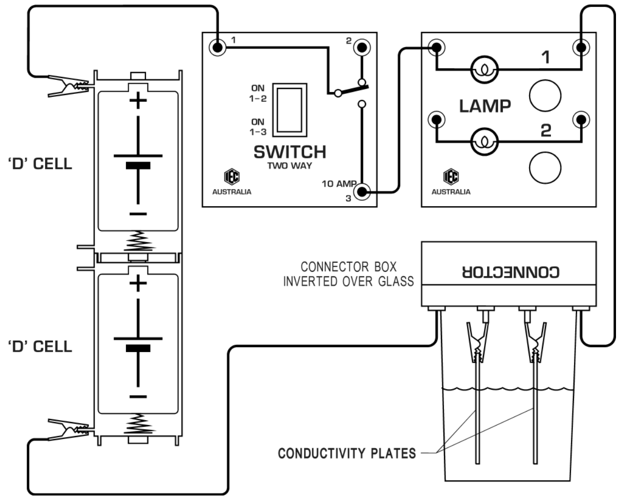
What difference have you discovered between copper and resistance wires of the same diameter ?

9) Can liquids carry electric current ? Can they conduct ?

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lamp holder fitted with 2.5V lamp
- 1x connector block
- 2x stainless steel conductivity plates
- 2x alligator clips fitted with banana plugs
- 2x alligator clips to fit to banana plugs
- 4x cables with banana plugs
  Fit alligator clips to 2 cables





Connect the circuit as shown with the 2 cells in series to provide double cell volts. When the switch is closed, the cells are connected to the lamp, but the lamp cannot light until current can pass through the connector. Plug in the 2 alligator clips with banana plugs fitted into the connector block so that these alligator clips can hold the conductivity plates.

Take a drinking glass and place the connector block upside down over it so the conductivity plates hang down into the glass. *Do not immerse the alligator clips in the liquids or they will rust.*

If a conducting liquid is placed into the glass, the lamp will light when the switch is closed. Try plain water. Add some salt to the water. Try some vinegar. Try sugar dissolved in water. Try CocaCola, try other soft drinks you like.

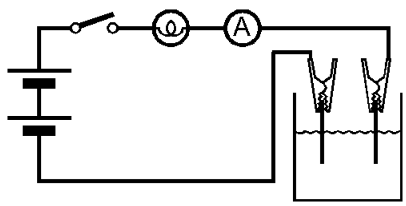
What have you discovered about liquids conducting electric current ?

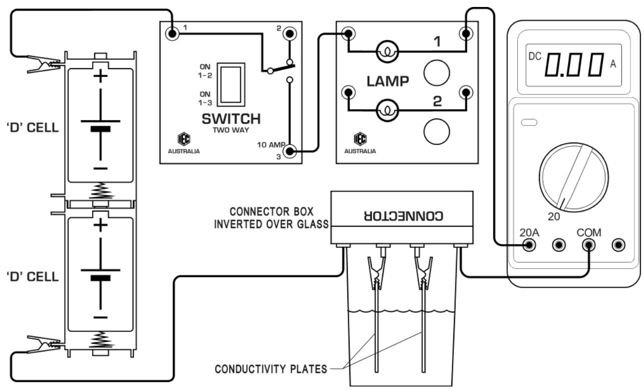
Why did we use 2 cells in series instead of only 1 cell ?

10) Measure smaller currents through liquids:

Equipment required:

- Same as previous experiment
  PLUS…….
- 1x multimeter and cables 0-10A.DC.





To make a lamp glow requires a large current. To make a more sensitive circuit so we can see how much current is flowing through the liquids, an ammeter is required to measure the actual current flowing. Select DC and select the 10A.DC. range and connect the multimeter is series with the electrode plates as shown in the circuit above. For higher sensitivity, select 0-200mA.DC. range. Be careful not to touch the stainless steel electrode plates together.

Try the liquids again to see if small currents flow through the liquids. You will see amounts of current flowing but the current may not be enough to make the lamp glow.

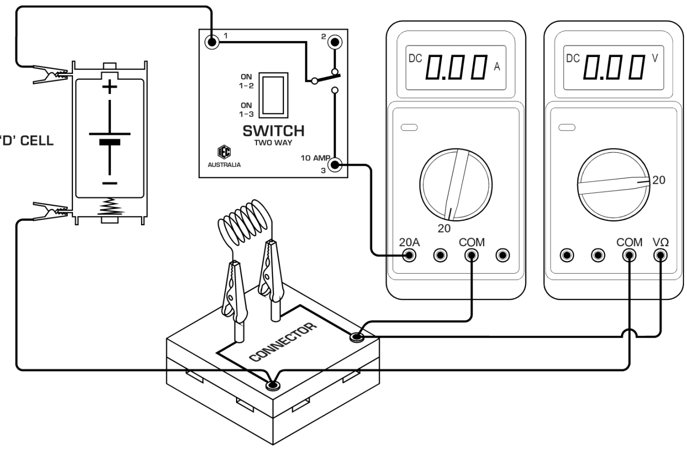
What are your findings ? *Why did we leave the lamp connected in the circuit ?*

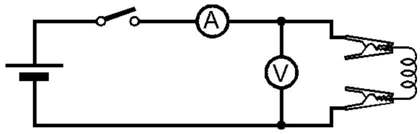
11) Ohm’s Law using wires (part 1)

Equipment required:

- 1x ‘D’ size cell in holder
- 1x switch, single pole, 2 way
- 1x connector block
- 1x multimeter or 0-5V.DC. voltmeter
- 1x multimeter or 0-1A.DC. ammeter
- 2x alligator clips fitted with banana plugs
- 1x 50cm of resistance wire (Constantan).
- 2x alligator clips to fit to banana plugs
- 6x cables with banana plugs

  Fit alligator clips to 2 cables





Connect the circuit with 1 cell as shown. The voltmeter measures the voltage applied to the load and the ammeter measures the electric current flow through the load. Plug the 2 alligator clips into the connector block. Take the roll of resistance wire (0.2 diam.Constantan) and cut off a length about 50cm long. Wind the wire around a pencil or similar to form coils, remove the pencil and clip the two ends into the 2 alligator clips in the connector This length of coiled wire is called the ‘Load’.

When the switch is closed, the cell is connected to the resistance wire with the ammeter in series. Read the current flowing through the load in milliamps (thousandths of an amp) and read the voltage across the load in volts. Note these values. Ohm’s Law states that in a simple circuit, the value of the voltage applied to a load divided by current through the load (in amps) is a constant called the ‘Resistance’ of the load.

R = V / A where R is resistance (ohms) and V is voltage (Volts) and A is current (Amps).

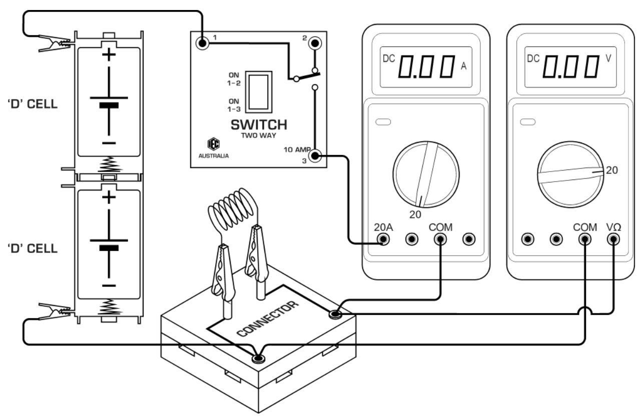
To obtain the value of resistance, divide the Volts by the Amps (Amps = milliamps/1000).

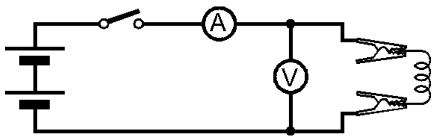
What is the resistance of 50cm of the 0.2mm Constantan resistance wire in Ohms ?

12) Ohm’s Law using wires (part 2)

Equipment required:

- Same equipment as the previous experiment PLUS………..
- 1x ‘D’ size cell in holder





Now join 2 cells in series to obtain double voltage. Repeat the experiment and measure the current and voltage. Note the values using the same piece of resistance wire.

To again obtain the value of resistance, divide the Volts by the Amps (Amps = milliamps/1000).

What is the resistance of 50cm of the 0.2mm Constantan resistance wire in Ohms ?

Is it the same value that you calculated when using one cell ?

13) Ohm's Law using wires (part 3)

Continued from experiment 12)

Turn off the current and now take 100m (double length) of the same 0.2mm diameter Constantan resistance wire, coil it up on a pencil and repeat the experiment. Calculate the resistance.

What have you discovered ?

14) Ohm's Law using wires (part 4)

Continued from experiment 13)

Turn off the current and cut another 100cm piece of 0.2 diameter Constantan wire and join the second coiled up wire between the same alligator clips but do not let the coils touch the coils of the first wire. Now the current must flow through 2 wires side by side (this is called connecting 'in parallel'). Close the switch and check the current. It should be double the previous current when one wire was used because now 2 coils are connected and each coil is the same length and so the same current should flow in each coil.

As previously, divide the volts by the amps to calculate the resistance of the 2 coils in parallel.

Is it the same ohms value as a previous experiment ? *Explain why.*

15) Ohm's Law using wires (part 5)

Continued from experiment 14)

Repeat the experiment 13) *but use only one cell* and 100cm length of 0.2mm diameter COPPER wire. As previously, divide the volts by the amps to calculate the resistance of the copper wire. Compare the resistance of the copper wire with the value you calculated in experiment 13) for the 100cm of Constantan resistance wire.

Which metal has the higher resistance, copper or Constantan ?

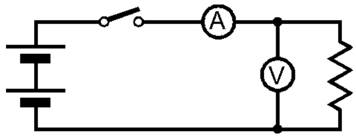
About how many times more resistive is 0.2mm diameter Constantan compared to 0.2mm diameter copper ?

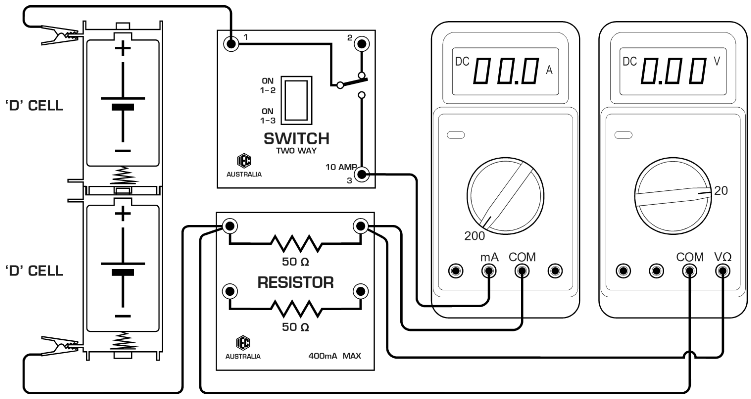
16) Using Ohm's Law: Single resistors and series connection.

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x resistor, 50 ohms
- 1x resistor, 100 ohms
- 1x multimeter or 0-5V DC v/m
- 1x multimeter or 0-100mA DC a/m
- 2x alligator clips to fit to ban.plugs
- 6x cables with banana plugs

Fit alligator clips to 2 cables





Up to now we have used wires to make resistance, but resistors of many different values are available for building electrical and electronic circuits. Values of less than 0.1 ohms up to millions of ohms are available. In this kit there are 3x resistors and for this experiment we will use these instead of wires. The current will be small, so select DC and 200mA on the ammeter range.

Connect the circuit with 2 cells as shown but connect the alligator clip to only one cell. The voltmeter measures the voltage applied to the resistor load and the ammeter measures the electric current flow through the load in milliamps. To change milliamps to amps, divide by 1000.

Before reading the ammeter, use Ohm's Law to calculate the current that *SHOULD flow* through the 50 ohm resistor

1x cell should be about 1.5 volts and the resistor is 50 ohms.

Ohm's Law states that R = V / A Resistance in ohms = Volts divided by Amps

Therefore, A = V / R Current in Amps = Volts divided by Resistance in ohms.

So, Amps should be 1.5V / 50ohms = 0.030 amps (= 30/1000 amps = 30 milliamps)

Now, close the circuit and measure the current to find out if you are correct. Note the value.

If the resistance was double (100 ohms) would you expect the current to be double or half ?

After deciding, replace the 50 ohm resistor with 100 ohm value and check. *Were you correct ?*

Move the alligator clip to now use 2 cells in series. Voltage should now be close to 3 volts. If the voltage is double, the current should double. Measure and see if this is correct.

Try with the 50 ohm and the 100 ohm resistors in series to make total resistance of 150 ohms.

Using one cell and later using 2 cells, calculate the expected currents then measure the current to find out if you are correct.

Note the various voltages and currents like the table below:

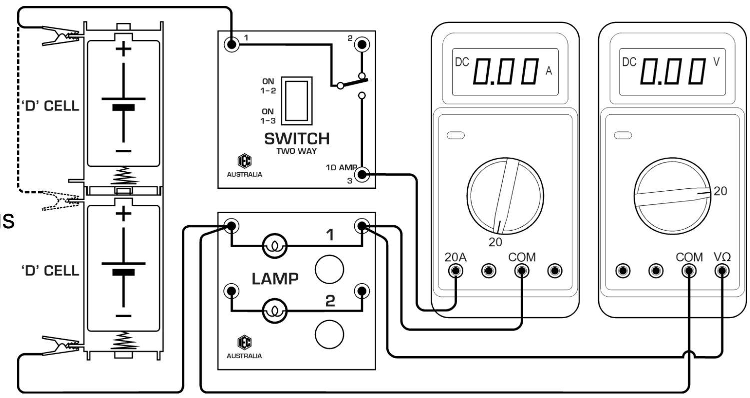
Cells used	Voltage	Resistance	Current mA	Current in A
1	1.5 volts	50 ohms	30 mA	0.030 A
2	3 volts	50 ohms	60 mA	0.060 A
1	1.5 volts	100 ohms	15 mA	0.015 A
2	3 volts	100 ohms	30 mA	0.030 A
2	3 volts	150 ohms	20 mA	0.020 A

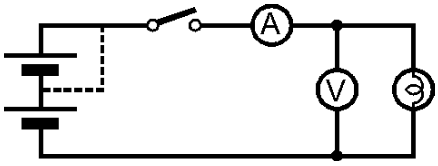
17) Using Ohm's Law: Is a lamp a resistor ?

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lamp 2.5V
- 1x multimeter or 0-5V.DC. voltmeter
- 1x multimeter or 0-1A.DC. ammeter
- 2x alligator clips to fit to banana plugs
- 6x cables with banana plugs

  Fit alligator clips to 2 cables





This experiment is similar to the previous one, except we are using one of the lamps instead of a fixed resistor. The lamp is 2.5V. When only one cell is connected (about 1.5V), it will not be fully bright. When both cells in series are used (about 3V), the lamp will be at full brightness.

On the multimeter, select DC and 10 Amps. Close the switch so the lamp lights and measure the volts and amps and calculate the resistance of the lamp in ohms and note this value.

Now turn off the lamp and connect the alligator clip so both cells are used in series. Close the switch and measure volts and amps again.

The volts are now double, but what do you notice about the amps ? Have amps exactly doubled ? Calculate the resistance of the lamp and note this value.

Notice that the resistance of the lamp has changed. The resistance value of the lamp is higher when it is brighter. Notice that in the previous experiment, when the voltage was doubled, the amps also doubled. This means that the 50 ohm and 100 ohm resistance values in the previous experiment did not change their values when the voltage and current was changed.

A lamp is a type of resistor, but it is different from the resistors in the kit. As seen in the previous experiment, a normal resistor value in ohms remains constant as the voltage changes and as the current through the resistor changes. This experiment shows that a lamp does not behave exactly like this.

EXERCISES: Take a lamp from the kit, fit a 2.5 volt globe **and use the multimeter to measure the resistance of a cold lamp** (not glowing). What is the resistance in ohms ? Note the value.

Compare this 'cold' lamp resistance with the values you calculated when the lamp was glowing with 1 cell and with 2 cells.

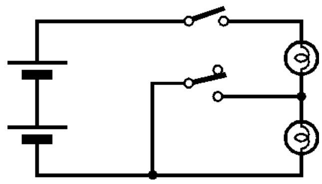
Try to explain why the lamp resistance changes if the lamp is brighter.

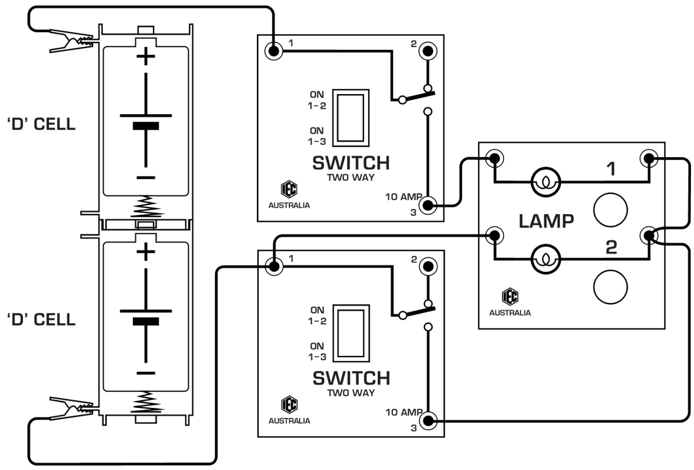
Is a lamp a good type of resistor to use in electrical circuits ? Why ?

18) Connecting two lamps in series: using a 'short circuit':

Equipment required:

- 2x 'D' size cell in holder
- 2x switch, single pole, 2 way
- 1x Dual lamp holder,
  fitted with 2x 2.5 Volt lamps
- 2x alligator clips to fit to banana plugs
- 6x cables with banana plugs
  Fit alligator clips to 2 cables





The two cells are connected in series to provide approximately 3 volts to the circuit.

The 2 lamps are connected in series so the same current flows through each of them. The switch is connected across one lamp so that when the switch is ON, one lamp is 'short circuited'. This means that when the switch is ON, the current will flow through the switch because the resistance of the switch is zero ohms. The current will flow through the switch and almost zero current will flow through the lamp. It is the same as having only one lamp in the circuit.

Making the current flow through a zero ohm circuit around a resistor is called 'short circuiting' the resistor. When the switch is turned OFF, the current must flow through the lamp like normal.

Turn the short circuit ON across the second lamp. Connect the cells to the circuit by turning ON the other switch and see the brightness of one lamp.

Turn OFF the short circuit to make two lamps in series. See both lamps glow, but at a lower brightness.

Remove one lamp from a lampholder. *What happens ?* *Is your house wired like this ?*

Replace the lamp and remove the other lamp. *What happens ?*

Turn ON the short circuit. Explain what will happen if you remove the lamp that is short circuited.

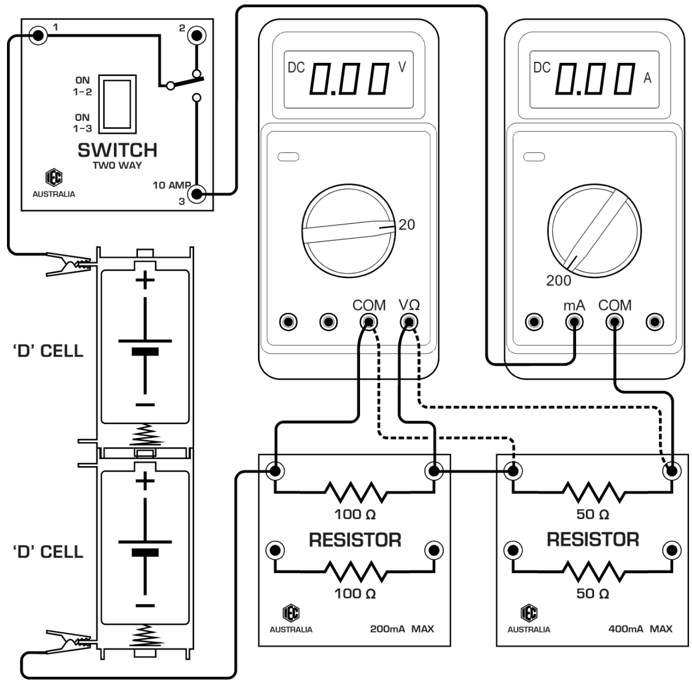
Try it and see if you are correct.

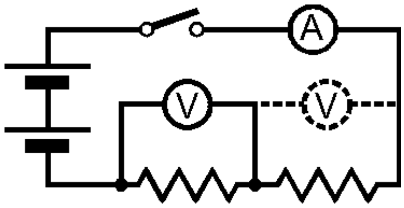
19) Connecting two resistors in series:

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x resistor 50 ohms
- 1x resistor 100 ohms
- 1x multimeter or 0–5 V voltmeter
- 1x multimeter or ammeter 0-200mA.
- 2x alligator clips to fit to banana plugs
- 7x cables with banana plugs

Fit alligator clips to 2 cables





The two cells are connected in series to provide 3 volts to the circuit.

The 2 resistors are in series so the same current will flow through each of them. The ammeter is measuring current flowing in milliamps. The voltmeter is connected across one resistor. Note the voltage and then connect the voltmeter across the other resistor (or you can connect a separate voltmeter across each resistor).

Using R = V / A (Ohm's Law) calculate the value of each resistor (R1 and R2). Then connect a voltmeter across both resistors and calculate the total resistance (R3).

Does R1 + R2 = R3 ? Do two resistors in series equal the sum of both resistors ?

20) Voltage Divider using resistors in series:

Equipment required:
Same circuit as experiment 19.

The previous experiment you measured the resistance of each resistor and showed that two resistors in series add together to make a higher value resistor in ohms.

This time, note the voltage you measured across each resistor (V1 and V2) and note the voltage of the power supply (the 2 cells in series, V3). See that V1 + V2 = V3.

The value of V1 is part of the total voltage, so the two resistors are forming a voltage divider.

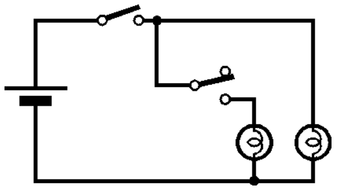
If the 2 resistors were the same value in ohms, what would the voltage be at the mid point ?

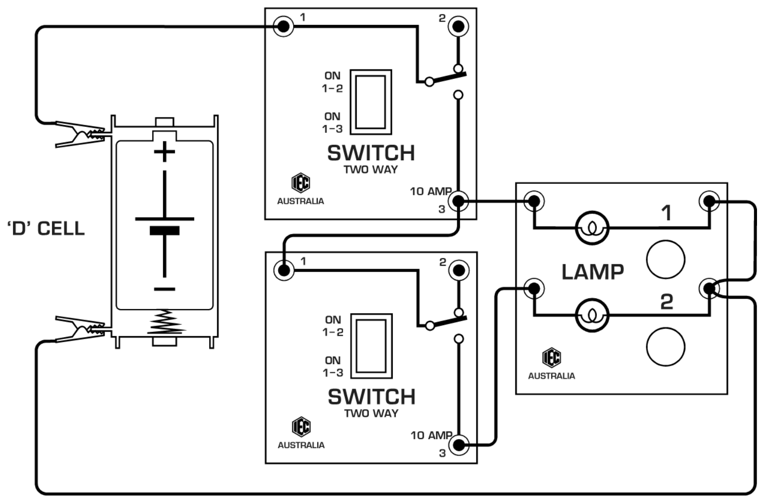
If both resistors were 50 ohms, or if both resistors were 100 ohms or 500 ohms or 1000 ohms, would this change the result ?

21) Connecting two lamps in parallel:

Equipment required:

- 1x ‘D’ size cell in holder
- 2x switches, single pole, 2 way (both used as 1 way).
- 1x Dual lamp holder, (fitted with 2x 2.5 Volt lamps)
- 2x alligator clips to fit to banana plugs
- 6x cables with banana plugs
  Fit alligator clips to 2 cables





The single cell provides approximately 1.5 volts to the circuit.

The 2 lamps are connected in parallel so that the same voltage will be applied to each of them. The first switch connects the cell to the lamps and the second switch connects the second lamp in parallel to the first lamp.

Set the second switch to OFF so that only one lamp connects to the cell and turn ON the first switch. Note the brightness of the lamp.

Connect the second lamp to the cell by turning ON the second switch. *Note that both lamps are about the same brightness.*

Remove one lamp. What happens to the other lamp ? Is your house wired like this ?

If many lamps are connected in parallel, the current from the power source increases each time another lamp is connected. In the circuit above, the cell will go flat quickly if several lamps are connected in parallel because each lamp takes more current from the cell.

Take the third lamp from the kit and try 3 lamps in parallel..

*NOTE: The single cell will be probably be falling in voltage with the extra load causing a larger current. If you connect another good cell **in parallel** to the first cell, the 2 cells together will be the same voltage as one cell but both together can supply a larger current without the voltage falling so much.*

Don’t forget: you must connect both positive ends and both negative ends together to connect cells in parallel.

Try it and see. When the second cell is connected in parallel to the first cell, do all the lamps now glow a bit brighter ?

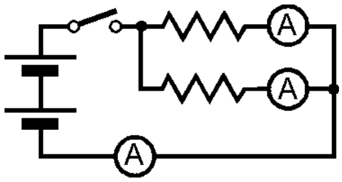
If the current becomes too large in your house with too many lamps connected in parallel, what does your house have to protect the wires in your house from becoming overloaded and hot ?

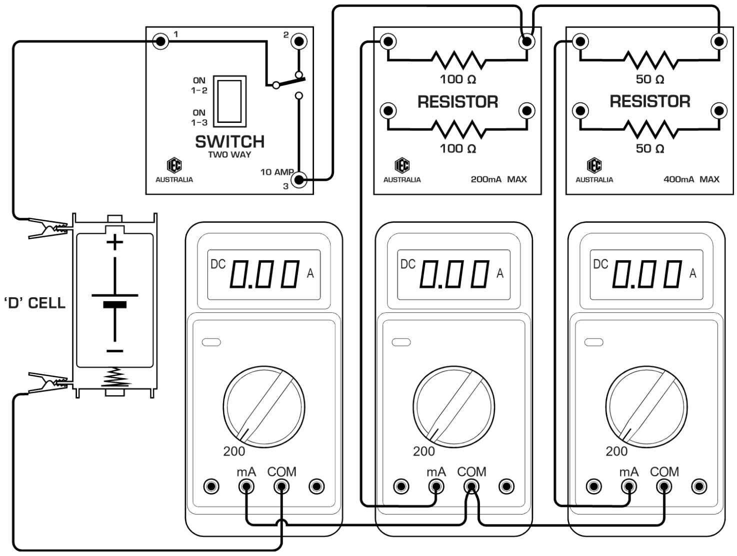
22) Connecting two resistors in parallel:

Equipment required:

- 1x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x resistor, 50 ohms
- 1x resistor, 100 ohms
- 3x multimeter or ammeters 0-200mA.
- 2x alligator clips to fit to banana plugs
- 8x cables with banana plugs

Fit alligator clips to 2 cables





The single cell provides approximately 1.5 volts to the circuit.

The 2 resistors are connected in parallel so that the same voltage will be applied to each of them. An ammeter is connected in series with each resistor to measure the current flowing in each resistor. The switch connects the cell to the resistors. A third ammeter is connected to measure the total current flowing from the cell.

Set the switch to ON and note the current flowing in each resistor. Note that the cell is connected to each resistor in parallel, so the voltage on each resistor is the voltage of the cell (1.5 Volts).

Note the total current flowing from the cell.

Note that the total current = the sum of the two resistor currents.

Using 1.5V for the cell voltage, calculate the total resistance of the two resistors in parallel.

R = V / A so, R (ohms) = 1.5 volts / total current in amps (mA x 1000).

Is the value of the total resistance larger or smaller than ***either*** *of the 2 resistors ?*

MATHS: *For resistors in parallel, 1/R3 (total resistance) = 1/R1 + 1/R2*

When this is transposed by maths, it becomes R3 (total resistance) = (R1 x R2) / (R1 + R2)

For 2 resistors in parallel, the total resistance R3 = (R1 x R2) / (R1 + R2). This is called the "product (multiplication) of the two resistors divided by the sum of the two resistors".

In this case: 50 x 100 / (50 + 100) = 33.33 ohms.

For many resistors (say 6 resistors) in parallel, the above formula cannot be used. You must use:

1/R6 = 1/R1 + 1/R2 + 1/R3 + 1/R4 + 1/R5 + 1/R6

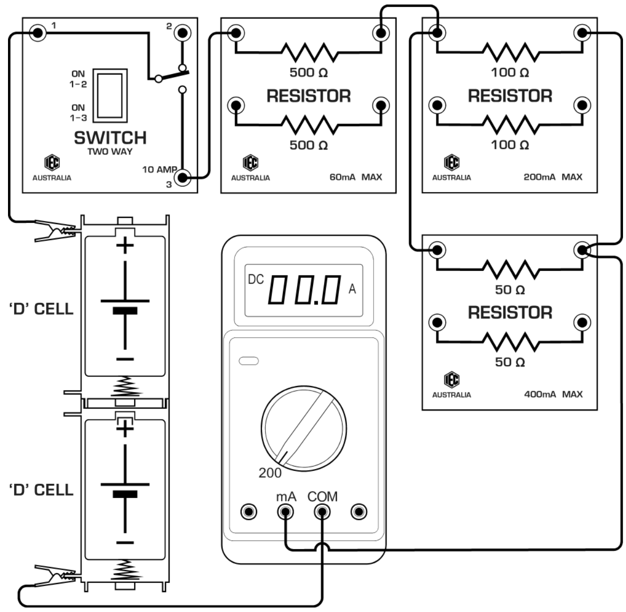
NOTE: If say 4 resistors are in parallel, you can calculate the total of the first 2 in parallel, then the total of the next 2 in parallel, then take the two results and do the same "product over sum" calculation again to get total of all 4 resistors in parallel.

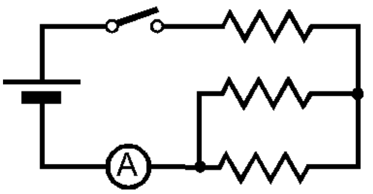
23) Connecting two resistors in parallel, plus another resistor in series:

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x resistor, 50 ohms
- 1x resistor, 100 ohms
- 1x resistor, 500 ohms
- 1x multimeter or ammeter 0-200mA
- 2x alligator clips to fit to banana plugs
- 7x cables with banana plugs

Fit alligator clips to 2 cables





The 2 cells provide approximately 3 volts to the circuit.

The 50 ohm and the 100 ohm resistors are in parallel plus the 500 ohm resistor is in series with the parallel circuit.

From the previous experiment, we know the resistance of the 50 ohm and 100 ohm resistors in parallel is 33.33 ohms (product over sum). We know also that if a resistor is added in series, the values add together. So the total resistance of the circuit is 33.33 ohms plus 500 ohms = 533.33 ohms.

Measure the total current through the circuit and measure the voltage of the cells and, using Ohm's law, calculate the total resistance. R = V / A R (total) = Volts of cells / Amps flowing.

Your current reading will be in milliamps so remember to change milliamps to amps by dividing by 1000.

What ohms value do you get ? Is it close to 533.33 ohms ?

USING THE MULTIMETER TO READ OHMS:

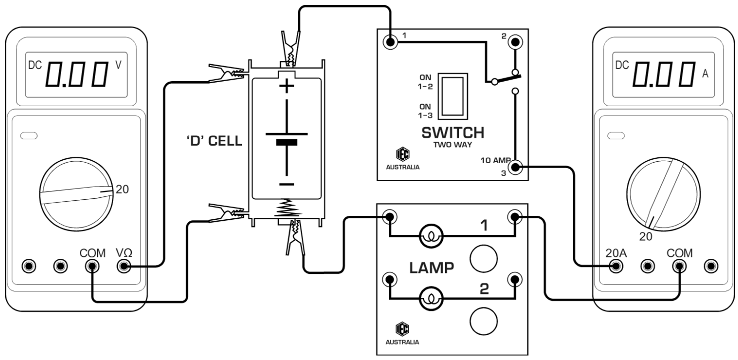
To check the values of the resistors, you can select OHMS on the multimeter and you can measure the ohms exactly. Choose an OHMS range that will suit the expected value of the resistor.

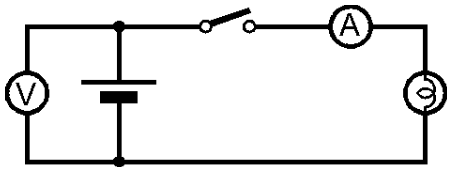
Using the digital ohm meter, measure the value of the 50 ohm and 100 ohm resistors connected in parallel, then add the 500 ohm resistor in series to the parallel pair and measure the whole resistor network. Is it close to what you measured and calculated ?

24) Internal resistance of Power Source (a dry cell):

Equipment required:

- 1x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lampholder fitted with 2.5V lamp
- 1x multimeter or voltmeter 0-5V
- 1x multimeter or ammeter 0-10A
- 4x alligator clips to fit to banana plugs
- 6x cables with banana plugs
  Fit alligator clips to 4 cables





Connect a switch and a lamp in series across a single cell (about 1.5V).

Connect voltmeter across the cell to check cell voltage. With switch OFF, note the cell voltage at zero amps flowing. Turn switch ON. Note the current flowing in amps and note the lower voltage of the cell.

To calculate the internal resistance of the cell, first subtract second voltage from the first voltage to show the drop in voltage from the cell. Call this Vd.

Call the current flowing A1.

The resistance of the cell (Rc) in ohms causes this voltage difference Vd to occur when A1 current flows.

Ohm's Law states: R = V / A

So, cell resistance = Voltage change / Cell current   Rc = Vd / A1   Rc = ? ohms

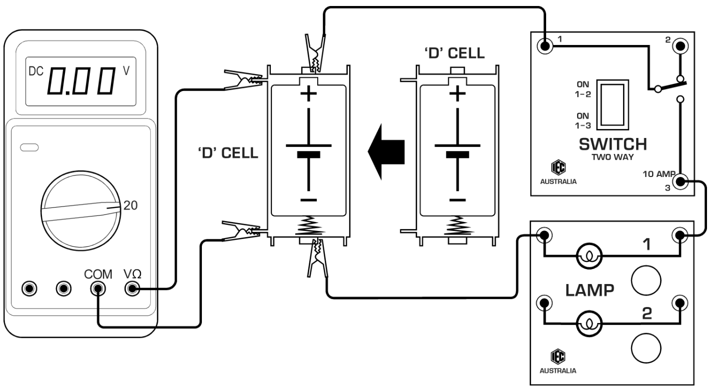
If 2 cells are connected in series, will the total internal resistance of the cells be higher or lower ?

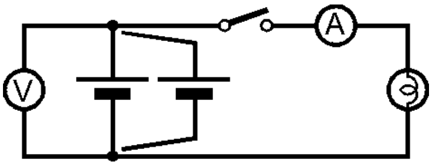
If 2 cells are connected in parallel, will the total internal resistance of the cells be higher or lower ?

25) Why use 2 cells in parallel ?

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lampholder fitted with 2.5V lamp
- 1x multimeter or voltmeter 0-5V
- 4x alligator clips to fit to banana plugs
- 5x cables with banana plugs
  Fit alligator clips to 2 cables





As seen in previous experiment, if two cells are connected in parallel, the cell internal resistances are in parallel and the total internal resistance will be about half the internal resistance of one cell. When connected in parallel, cell voltages do not add together, but the voltage will not fall so much when a load is connected. This experiment proves this.

Connect a switch and a lamp in series across a single cell (about 1.5V).

Connect voltmeter across the cell to check cell voltage. With switch OFF, note the cell voltage at zero amps flowing. Then turn switch ON. Note the lower voltage of the cell. Turn switch OFF.

Now connect a second cell in parallel. *BE SURE THE CELL IS THE CORRECT WAY AROUND. POSITIVE TO POSITIVE AND NEGATIVE TO NEGATIVE.*

NOTE: If the cells are reversed, each cell will discharge into the other cell. A large current will flow between them and they will both flatten very quickly.

Now note voltage of both cells in parallel. Turn switch ON again and note voltage with 2 cells in parallel. This difference in voltage between OFF and ON using two cells in parallel should be about half of the voltage drop measured when using one cell.

The effect will be greater if you connect two lamps in parallel to increase the current from the cell.

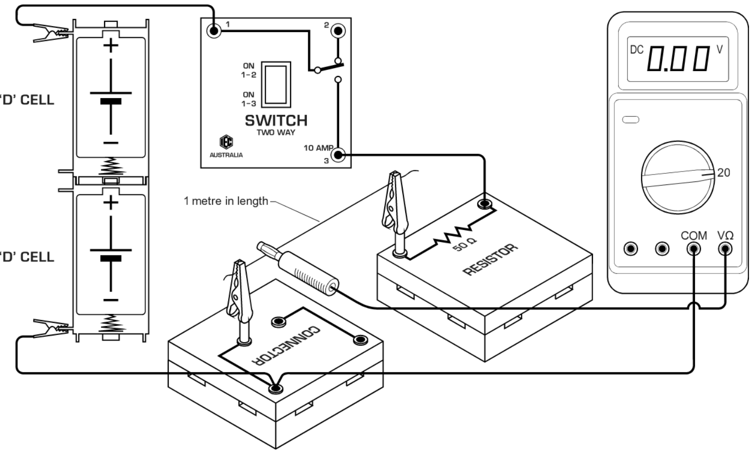
SUMMARY: Normally it is not good to have the cells or a battery reduce voltage when the load is applied. To stop this effect, cells can be added in parallel to reduce internal resistance and therefore to reduce voltage drop when the load is applied.

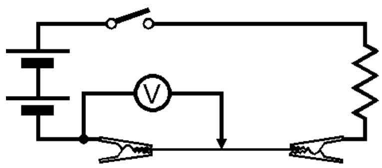
26) Making a voltage divider (or Potentiometer):

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x resistor, 50 ohms
- 1x connector block
- 1x multimeter or voltmeter 0-5V
- 2x alligator clips with ban.plugs fitted.
- 1x resistance wire, 1m x 0.2mm d.
- 2x alligator clips to fit to banana plugs
- 5x cables with banana plugs

Fit alligator clips to 2 cables





Connect a switch and the connector block in series across 2 cells (about 3V). Use about 100cm of resistance wire either as a straight wire or coiled.

Connect voltmeter between the negative end of the cells and the join between the resistance wire and the resistor. This connection will measure the voltage across the wire.

Later you will slide the voltmeter connection along the wire to measure voltages along the length of the wire (see illustration).

EXERCISES:

1) *If the applied voltage is 3 volts and the resistor is 50 ohms and if the wire was 50 ohms, what would the voltage measure across the wire ?*

Clue: *The total resistance is 100 ohms and the measuring point is 50 ohms (half-way) from the end.*

Resistance ratio = 50/100 ohms, therefore, Voltage = 50/100 x 3 volts = 1.5 V

2) *If the applied voltage is 3 volts and the resistor is 50 ohms and if the wire was 1 ohm, what would the voltage measure across the wire ?*

Clue: *The total resistance is 51 ohms and the measuring point is 1 ohm from the end.*

Resistance ratio = 1/51 ohms, therefore , Voltage = 1/51 x 3 volts. = 3/51 = 0.0588 V (58.8 mV)

Now, in the above circuit, measure the cell voltage and the voltage across your resistance wire. You know that the resistor in series is 50 ohms, so, using the formulae above, calculate the resistance of the resistance wire.

An adjustable Voltage Divider:

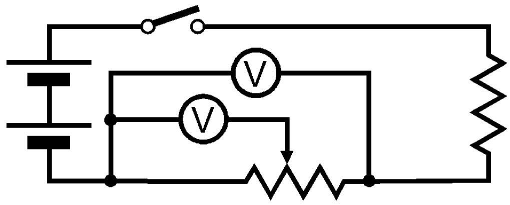
Move the positive voltmeter connection along the resistance wire and see the voltage rise and fall as you slide the voltmeter connection along the wire. This is an adjustable voltage divider or Potentiometer.

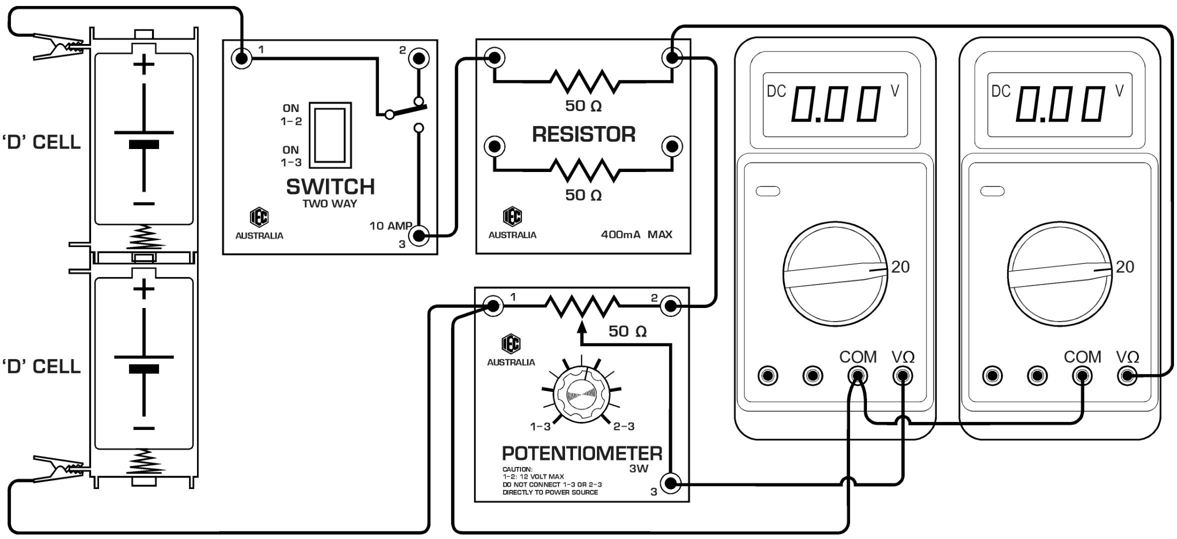
Take the 50 ohm Potentiometer from the kit and look at the construction. Notice it is a coil of resistance wire connected to two terminals and a 'wiper' that contacts the wire coil. The wiper is connected to the centre connection and moves around the wire coil as the knob is turned.

27) Potentiometer: Using a real potentiometer:

Equipment required:

- 2x ‘D’ size cell in holder
- 1x switch, single pole, 2 way
- 1x resistor, 50 ohms
- 1x potentiometer, 50 ohms
- 2x multimeters or voltmeters 0-5V
- 2x alligator clips to fit to ban.plugs
- 8x cables with banana plugs
  Fit alligator clips to 2 cables





Connect the switch, the 50 ohm resistor and the 50 ohm Potentiometer in series across 2 cells (about 3V). The two resistance values are the same, so there will be about 1.5V across the resistor and about 1.5V across the potentiometer.

The wiper of the Potentiometer can move smoothly from one end of the 50 ohms to the other (look through the plastic to see the Potentiometer working). This means that the Potentiometer can smoothly divide the 1.5V across it from zero volts to 1.5 volts.

Connect one voltmeter across the outside connections of the Potentiometer (sockets 1 & 2) and check the voltage is about half the cell voltage (1.5V).

Now connect the other voltmeter from the negative end of the Potentiometer to the moving wiper connection (sockets 1 & 3). Turn the knob and see the voltage change from zero to about 1.5V.

CAUTION:: A potentiometer can adjust its resistance from zero to maximum. If a potentiometer is connected directly to a power source by using socket 3, there is a danger that you can place zero resistance across the power source. A very large current will flow and the Potentiometer will be destroyed.

QUESTION: So, explain the purpose of the 50 ohm resistor in this circuit ?

ANSWER: If the 50 ohm resistor was not there, the potentiometer would work OK and divide the cell voltage of 3V from zero to 3V. It is not required for the circuit to work, but it provides resistance in the circuit to protect the potentiometer from damage if accidentally connected to the cells by the wrong sockets.

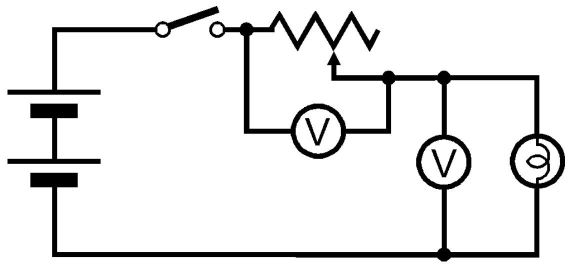
Think of other uses for a Potentiometer or voltage divider………….

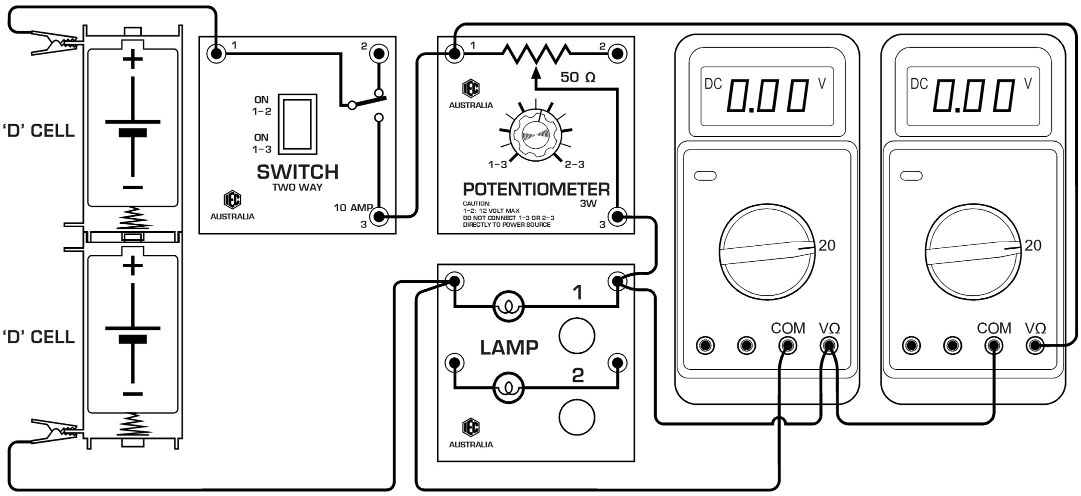
Maybe you need exactly 2.0 volts for an experiment. So, it can be placed across a voltage source (cell or power supply) using sockets 1 & 2 ONLY and then adjusted to provide an EXACT voltage between sockets 1 & 3.

28) Rheostat (variable resistor): Using a potentiometer as rheostat:

Equipment required:

- 2x 'D' size cell in holder
- 1x switch, single pole, 2 way
- 1x lamp 2.5V
- 1x potentiometer, 50 ohms
- 2x multimeters or voltmeters, 0-5V
- 2x alligator clips to fit to banana plugs
- 8x cables with banana plugs
  Fit alligator clips to 2 cables





Connect the switch, the Potentiometer sockets 1 & 3 and the lamp in series across the 3V power source. As the Potentiometer knob is turned, the resistance between sockets 1 & 3 will change from zero to 50 ohms. This connection makes a variable resistance or 'Rheostat'.

Connect one voltmeter across the lamp and connect the other voltmeter across the rheostat.

Close the switch and turn the knob to change the resistance in series with the lamp. This change in resistance from zero to 50 ohms will change the current flowing through the lamp and it will smoothly alter from bright to dim.

You now have a simple lamp dimmer.

Check the change in voltage on the lamp as you dim it.

*Check the change in voltage across the rheostat as it dims the lamp. Note that the two voltages add together to **always** equal the voltage of the cells (about 3V).*

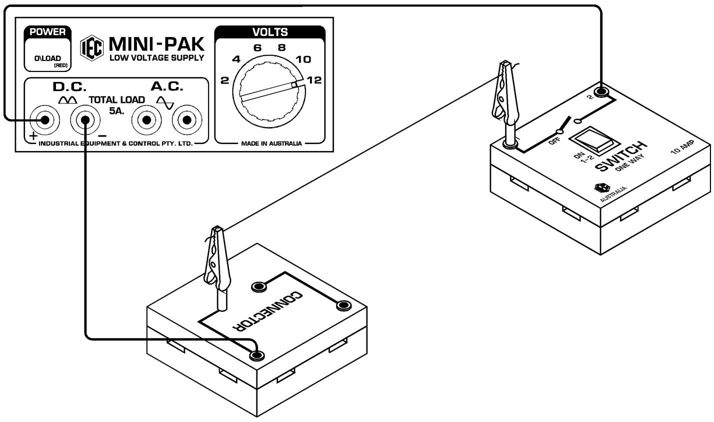
Think of other uses for a Rheostat…………

- It can change the heating in a resistance wire.
- It can reduce the volume of a loud speaker.
- It can be used as an "unknown" resistor value in experiments.
- It can be adjusted to be a certain resistance (measured by ohm meter) and then used in other experiments as that value.

29) Creating heat energy from electrical energy:

Equipment required:

- 1x Power Supply, 2-12V.AC/DC
- 1x switch, single pole, 2 way
- 1x connector block
- 2x banana plugs fitted to alligator clips.
- 1x resistance wire, 30cm x 0.2mm d.
- 2x cables with banana plugs



WARNING: This experiment makes wires heat and can burn. Do not touch hot wires.

Connect a switch and connector block in series across the DC terminals of the power supply. Look at the circuit diagram and fit the banana plug alligator clip connectors as shown. Cut 30cm length of resistance wire and hold it between the 2 alligator clips so it is taut.

Set the power supply to 2V and turn on by switch at rear panel. Cut small strips of paper, crease them to make a vee shape upside down and hang them on the wire. Do not touch the wire with fingers. Is the wire becoming hot ?

Select 4 volts on the power supply and check wire for heating. Select 6 volts on the power supply and check if the paper pieces are charring or smoking and showing signs of being burned.

Select a voltage that makes the wire just gently glow. If you can find some styrene foam packaging anywhere, keep the wire taut and you can neatly cut the foam by using this 'hot wire' cutter.

30) Creating light energy from electrical energy:

Keep the same circuit as above experiment but reduce the voltage to 2V and turn off the Power Supply. Take the same piece of resistance wire and wind a tight coil on a pencil so that the turns are very close together (but not touching). Take several coils and stretch them gently to be straight wire again.

Put this wire (part straight and part closely coiled) between the alligator clips. Check the power supply is ON and set to 2 volts. Turn on the circuit switch.

Wait for few seconds to see if wire glows. If not, raise voltage to 4 volts. Check again. Raise voltage to 6 volts. Notice that when the coils are close together the wire beginning to glow makes the other coils glow because the coils heat one another.

Notice the straight wire is not glowing because the circulating air is removing the heat from the wire.

Blow on the coils and watch the glowing stop suddenly as the air takes the heat away.

Raise the voltage until the wire glows brightly and gives off heat AND light energy.

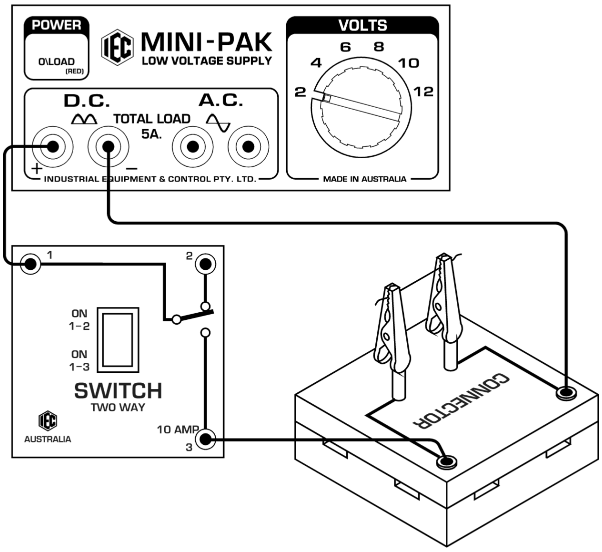
Good efficiency means that you receive good results from a circuit with the minimum amount of energy used. For the above circuit, the energy appears as both heat and light.

For lighting, do you think this method is very efficient ? Explain why ?

31) Making a fuse:

Equipment required:

- 1x 'D' size cell in holder
- OR……..
- 1x Power Supply, 2-12V.AC/DC
- 1x switch, single pole, 2 way
- 1x connector block
- 2x banana plugs fitted to alligator clips
- 1x length of fuse wire 0.05mm diam.
- 3x cables with banana plugs
  Fit alligator clips to 2 cables (if using cells)



Connect a switch and connector block in series across the cell or across the AC or DC terminals of a power supply. Look at the circuit diagram and fit the banana plug/alligator clip connectors as shown. Cut 10cm length of thin fuse wire and wrap it and hold it between the 2 alligator clips.

If using a power supply, set the power supply to 2V and turn on by switch at rear panel.

Switch ON the circuit switch and the fuse wire will carry a large current and get so hot that it will give off light and will melt (fuse will blow). Try again at 4 volts or use 2 cells in series. It will blow faster because more current will flow through the wire.

Try another fuse using double the length of fuse wire. It should blow again.

A fuse is a device that will blow to make the circuit dead if the current exceeds a certain value. It is a safety device used in houses on all electrical circuits. The fuse wire is fitted inside a removable plug that fits into a special socket. Fuses for low current circuits have small diameter wire and circuits for large currents use thicker wire.

Fuses are old fashioned nowadays. *Do you know the name of the device that has replaced fuses ?*

If the fuse wire is thicker, it requires more current to blow it.

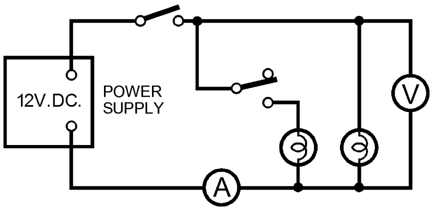
Try using the 0.2mm diameter copper wire as a fuse.

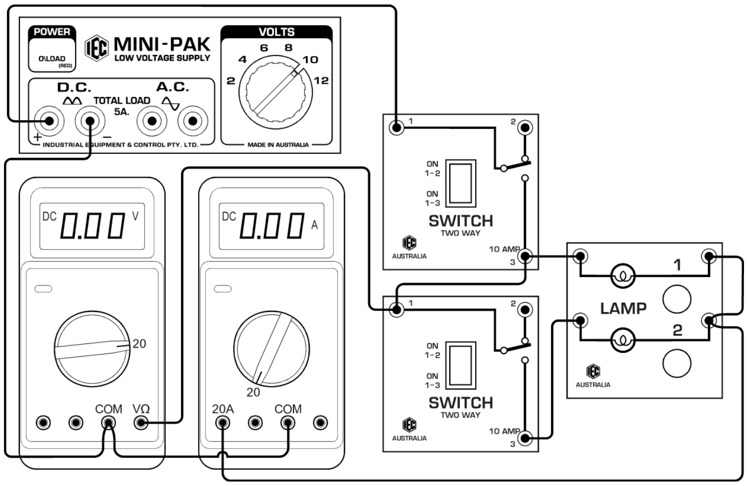
Can you get enough current from the power supply to blow it ?

32) Power in an electrical circuit:

Equipment required:

- 1x Power Supply, 2-12V.AC/DC
- 2x switch, single pole, 2 way (both used as 1 way)
- 1x dual lampholder (with 12V lamps fitted)
- 1x multimeter or voltmeter 0-12V.DC.
- 1x multimeter or ammeter 0-10A.DC.
- 9x cables with banana plugs





Connect a switch and 2 lamps in parallel with one lamp controlled by the second switch across the DC terminals of the power supply. Connect the voltmeter to measure the voltage across the lamps and connect the ammeter to measure the total current flowing.

If using a power supply, set the power supply to 2V and turn on by switch at rear panel. Turn ON the first switch so the one lamp is connected. Raise the volts on the power supply until the lamp is glowing brightly (about 10 or 12 volts).

Note the volts and the amps measured on the meters.

The unit for power is Watts (W). This is the result of multiplying the volts across a load by the current flowing through the load. Watts = Volts x Amps W = V x A

What is the power consumed by the one lamp ?

Switch ON the second switch so that both lamps are in parallel and both glowing brightly. Both lamps have the same voltage across them but see that the current is approximately double.

Calculate Watts again W = V x A. See that 2 lamps consume double the power of one lamp.

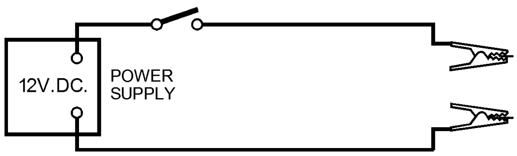
Change the voltage to a lower value and read the current again. Lower the volts so the globes are just glowing a dull red. See the heat in the filaments increase as the voltage is increased. The filaments inside the globes are made from a special resistance wire that can glow white hot and will not melt. The name of this special metal is 'Tungsten'.

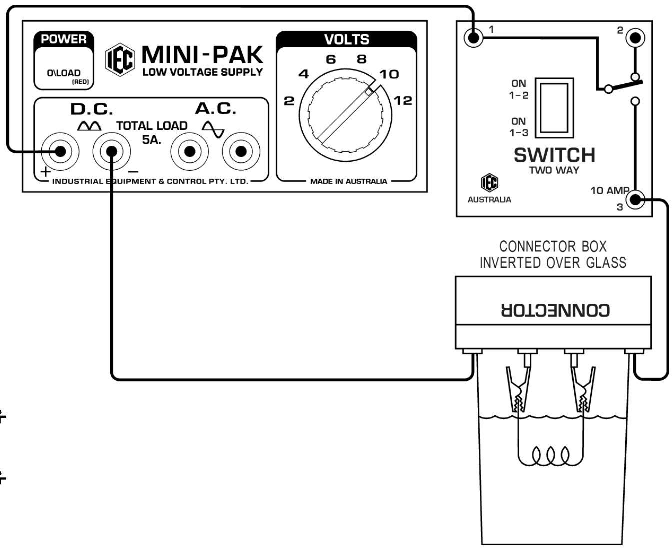
Feel the heat coming from the lamps as they are glowing. Notice that as the power is higher, the amount of heat and light given off is greater. The power in any electrical circuit is given off as heat and sometimes light.

33) Making a heater for water:

Equipment required:

- 1x Power Supply, 2-12V.AC/DC
- 1x switch, single pole, 2 way
- 1x connector block
- 2x banana plugs fitted to alligator clips
- 1x 30cm of resistance wire 0.2mm diam.
- 3x cables with banana plugs





Connect a switch and connector block in series across the DC terminals of the power supply. Look at the circuit diagram and fit the banana plug/alligator clip connectors as shown. Cut 30cm length of 0.2mm diameter resistance wire, coil it on a pencil and hold it between the 2 alligator clips.

Set the power supply to 2V and turn on by switch at rear panel.

Take a drinking glass and invert the connector block with all the resistance wire coil under the water. Do not allow the alligator clips to go in the water or they will rust.

Turn ON the switch and allow current to flow through the resistance wire.

Raise the volts and observe the resistance wire. *Why does it not glow like previous experiments ?*

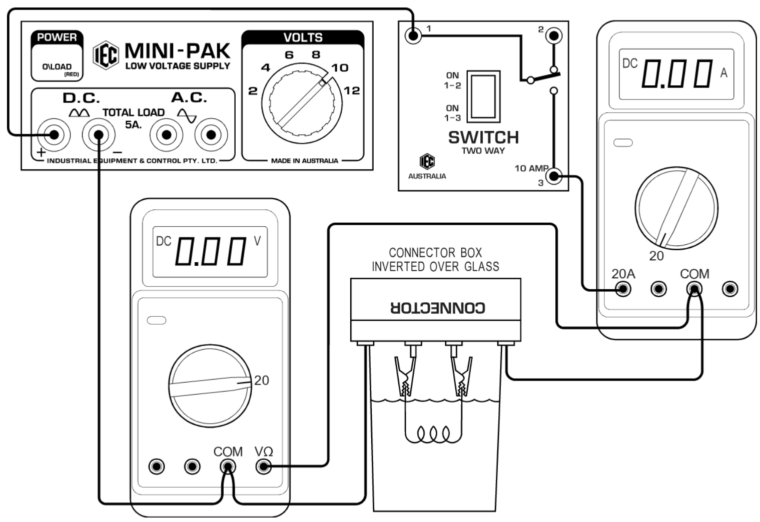
The water will slowly rise in temperature as the hot resistance wire heats the water.

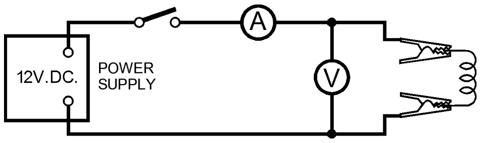
To double the heating, wind another heating element and connect it in parallel to the first element (twist the tails together and hold in the alligator clips). Do not allow the coils to touch together.

34) Work performed by an electric current:

Equipment required:

- 1x Power Supply, 2-12V.AC/DC
- 1x switch, single pole, 2 way
- 1x connector block
- 2x banana plugs fitted to alligator clips
- 1x multimeter or voltmeter 0-12V.DC.
- 1x multimeter or ammeter 0-5A.DC.
- 1x 30cm of resistance wire 0.2mm d.
- 6x cables with banana plugs
- 1x drinking glass (not in the kit)
- 1x thermometer (not in the kit)
- 1x stopwatch (not in the kit)





As in the previous experiment, connect a switch and connector block in series across the DC terminals of the power supply but connect the ammeter in series and the voltmeter across the heating coil. Use the same 30cm length of coiled resistance wire immersed in the water.

Take a thermometer and a stopwatch from the laboratory (ask your teacher for them) and place the thermometer in the water in the drinking glass. We will now measure work done by an electric current and the effect it has on the water.

Work = Power multiplied by a period of time. The unit for Work is the Joule.

1x Joule is 1x Watt second (1 Watt of power consumed for a time of 1 second)

J = W x t Watts = Volts x Amps, so Joules = Volts x Amps x seconds

Be sure the circuit switch is OFF. If using a power supply, set the power supply to about 10V and turn on by switch at rear panel.

Note the initial temperature of the water, then turn ON the circuit switch and start the stopwatch at the same moment. Measure the DC volts and the DC amps and note them. Stir the water by carefully swirling the thermometer. When the water has risen exactly 10^{o}C, note the stopwatch time in seconds.

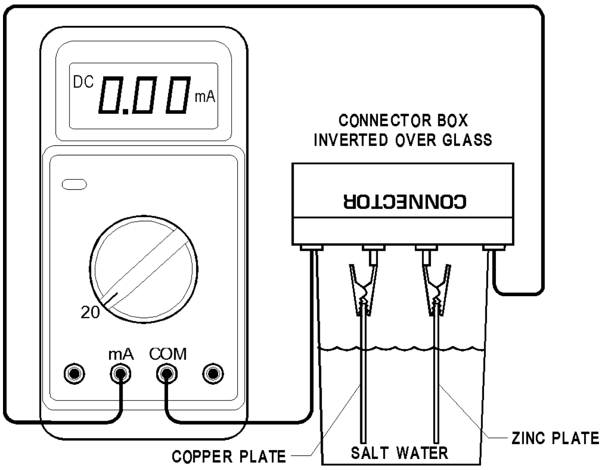
Multiply Volts x Amps to obtain Watts, then multiply the Watts x seconds to get Joules of work done on the water. We have discovered the amount of work required to raise this amount of water in the drinking glass by 10^{o}C.

If the container was well insulated (like a calorimeter) and if the weight of the water was known, this experiment can find out the amount of work required to raise 1kg of water by 1^{o}C. This is an important Physics experiment.

35) Voltage created by chemistry:

Equipment required:

- 1x connector block
- 2x banana plugs fitted to alligator clips
- 1x pair Zinc & Copper plates
- 1x multimeter or milliammeter 0-20mA.DC.
- 2x cables with banana plugs
- 1x drinking glass (not in the kit)
- normal table salt (not in the kit)



Connect the simple circuit as shown in the diagram. The ammeter is connected between two plates of dissimilar metals. Immerse the Zinc and Copper plates into the water as seen in the diagram.

If the water is clean, there will be zero current on the ammeter.

Add some salt to the water. *What do you see on the milliammeter ?*

Which direction is the current flowing ? From zinc to copper ? or copper to zinc ?

When 2 dissimilar metals are immersed in an electrolyte (conductive liquid), a current flows between them. This is caused by the atomic structure of the metals and the number of electrons in their atoms. Electrons are released by one metal into the electrolyte and electrons are absorbed by the other metal.

Which metal is releasing electrons ?

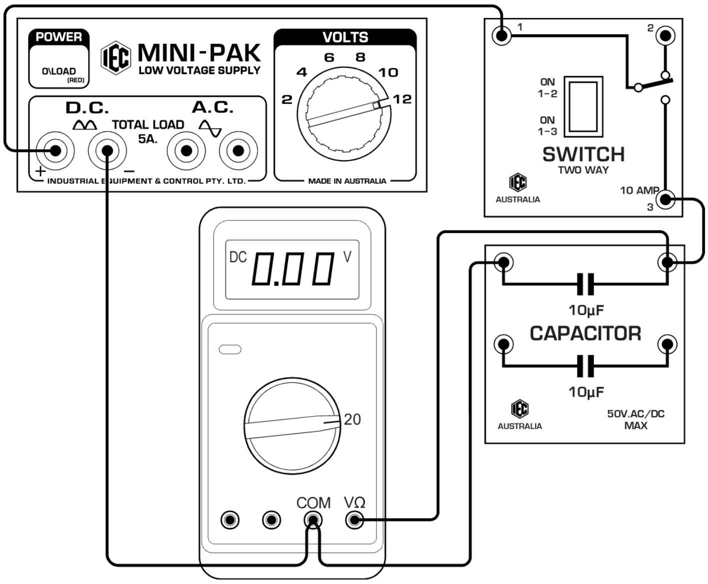
Clue: *Remember that electron flow in any circuit is in the reverse direction to conventional current flow as measured by a meter.*

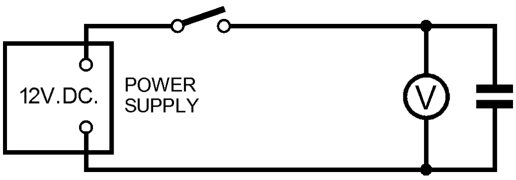
NOTE: Dry cell batteries and wet cell batteries all create voltage by chemical methods but, because of the need for dangerous acids, these battery experiments are not part of this manual.

36) Capacitors: Charge and voltage:

Equipment required:

- 1x Power Supply, 2-12V.AC/DC
- 1x switch, single pole, 2 way
- 1x capacitor 10uF
- 1x multimeter or voltmeter 0-20V.DC.
- 5x cables with banana plugs





A capacitor is a device that can store electrical energy and give out the energy at a later time. Read about capacitors in the Glossary. The unit is *Farad.* This is a huge amount of capacitance so the normal unit used is millionths of a Farad (called microfarads or 'uF').

Set the power supply to 12V.DC. and, using a switch, connect the DC voltage to the discharged (empty) 10uF capacitor. When the switch is closed, the current from the power supply rushes into the capacitor to charge it. As the capacitor charges, the current falls to zero.

The power supply will instantly 'charge' the capacitor to the maximum voltage coming from the power supply. This is called 'peak voltage' which is higher than the DC voltage as measured by a DC meter.

IMPORTANT NOTE: The power supply provides "unfiltered" DC voltage. Read about "Filter" in the Glossary. Also read about "Peak Voltage" in the Glossary.

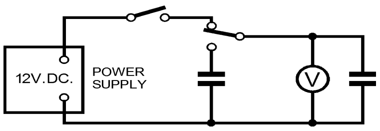
Turn the switch OFF to disconnect the power supply and leave the voltmeter connected to the capacitor to see the voltage slowly falling as the capacitor discharges its voltage through the meter's resistance. A digital meter has a very high resistance and it will take a long time for the capacitor to discharge. Analogue meters have a lower resistance, therefore if an analogue meter is used, the capacitor will discharge much more quickly through the meter resistance.

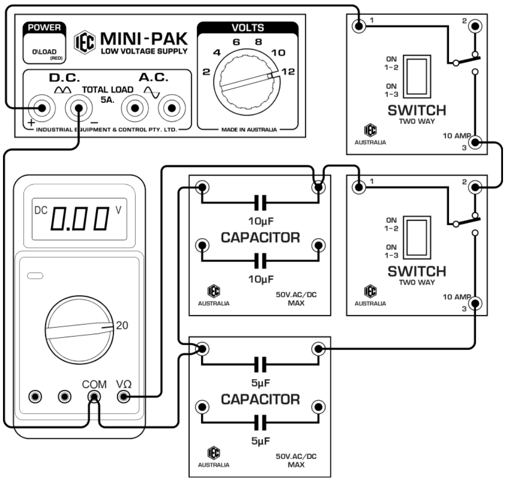
Charge the capacitor again to maximum power supply voltage. Again disconnect the power supply and, using a cable, connect the two capacitor sockets together. Notice the small spark as the energy in the capacitor instantly discharges.

37) Capacitors: Charge one capacitor from another:

Equipment required:

- 1x Power Supply, 2-12V.AC/DC
- 2x switch, single pole, 2 way
- 1x capacitor 10uF
- 2x capacitors 5uF
- 1x digital multimeter 0-20V.DC.
- 8x cables with banana plugs





Connect the 1 way switch from the power supply and connect the 2 way switch so that in one direction the 10uF capacitor is charged from the power supply and in the other direction the 10uF capacitor disconnects from the power supply and discharges into one of the 5uF capacitors. Connect the voltmeter across the 10 microfarad capacitor.

Discharge both capacitors by shorting them with a cable. With the 2 way switch, select the 10uF capacitor. Turn on the power supply and select 12V.DC. Turn on the 1 way switch to charge the 10uF capacitor. Note the DC charged voltage.

Now use the 2 way switch to dump the charge of the 10uF capacitor into the 5uF capacitor. When the two capacitors connect, their voltages must be equal. Note the new voltage as the 10uF capacitor loses some charge into the 5uF capacitor.

MATHS: *If the 10uF capacitor had say 20 volts charge, say energy is 20Vx 10uF = 200 units. When the total capacitance is 10+5 = 15uF, the voltage should be 200/15 = 13.3 volts.*

What were your results ?

Discharge the capacitors. If you swap the 5uF and the 10uF capacitors, what voltage should be on the 15uF combination ?

Original energy: 20Vx5uF = 100 units. Voltage on 15uF should be 100/15 = 6.7 volts.

What were your results ?

Discharge the capacitors. NOW use a cable to connect the two 5uF capacitors in series. Use this combination to charge to full voltage and dump this into the 10uF capacitor. If the voltage is lower than using one 5uF capacitor, this means that putting capacitors in series makes the capacitance LESS. Try it and see the voltage on the 10uF capacitor.

Original energy: 20Vx2.5uF = 50 units. Voltage on 12.5uF should be 50/12.5 = 4 volts.

What were your results ? So, you have proved that 2x 5uF capacitors in series = 2.5uF.

Discharge the capacitors. Now use 2 cables to connect the two 5uF capacitors in parallel. Use this combination to charge to full voltage and dump this into the 10uF capacitor. If the voltage is higher than using one 5uF capacitor, this means that putting capacitors in parallel makes the capacitance GREATER. Try it and see the voltage on the 10uF capacitor.

Original energy: 20Vx10uF = 200 units. Voltage on 20uF should be 200/20 = 10 volts.

What were your results ? So, you have proved that 2x 5uF capacitors in parallel = 10uF.

If you fully charge one of the 5uF capacitors and dump its charge into the other 5uF capacitor, what should the voltage be on the 10uF combination ? Do you think it would be half voltage ?

Try it and see. Describe what you are discovering about capacitors ?

EXPERIMENT NOTES

Designed and Manufactured in Australia