



ELECTRICAL COACH

PRIVATE ELECTRICAL TRAINING

Basic Electricity and House Wiring

By Deon Jacobs

In this course you will learn:

- 1) Electricity - Volts, Amps, Ohms, Watts
- 2) Calculations – Ohms Law, Kirchoff's Law
- 3) Electrical Components
- 4) Wiring Circuits - Lights, Plugs, Stove, Geyser, Distribution Board
- 5) Earthing
- 6) Safety
- 7) Measuring and Testing
- 8) Fault Finding

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Introduction.

Hi, welcome to my course, my name is Deon and Electrical Coach is my business. I started this course for 2 reasons, first to teach people that electricity is far more fun than scary and because of my passion for teaching and sharing knowledge. I have years of experience in training apprentices in the electrical trade and am a qualified Facilitator, Assessor and Moderator in the industry. I have taught many students from how to use a screwdriver to passing their Trade Tests. I qualified as an Electrician in 1998 at Ford Motor Corporation and started to train electricity in 2013.

After completing this short course, you will have a better understanding of electricity and have a good idea of how your house electrics work. Some may choose to further their career in electricity, and in that case, there are options to go and study further to qualify as an Electrician.

This course will not qualify you to practice as an electrician but will give you a good grounding in household electricity. I would still recommend that you call a qualified electrician to do your repairs.

Definitions:

Electricity - the presence and flow of electric charge, a form of energy that can be carried by wires and is used for heating and lighting, and to provide power for machines.

Volts - Voltage is the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop, enabling them to do work such as creating light. In brief, voltage = pressure, and it is measured in volts (V).

Current - An electric current is a flow of charged particles, such as electrons, moving through an electrical conductor in a closed circuit, measured in Amps (I).

Amps - An ampere is a unit of measure of the rate of electron flow or current in an electrical conductor. One ampere of current represents one coulomb of electrical charge (6.24×10^{18} charge carriers) moving past a specific point in one second. (A)

Resistance - The ohm is defined as an electrical resistance between two points of a conductor when a constant potential difference of one volt, applied to these points, produces in the conductor a current of one ampere. (Ω) It resists current flow.

Continuity - The presence of a complete path for current to flow. (Ω)

Insulation - highly resists the flow of electric current. (Ω)

Power - Electric power is the rate at which work is done or energy is transformed into an electrical circuit. Electric power is measured in watts. (W)

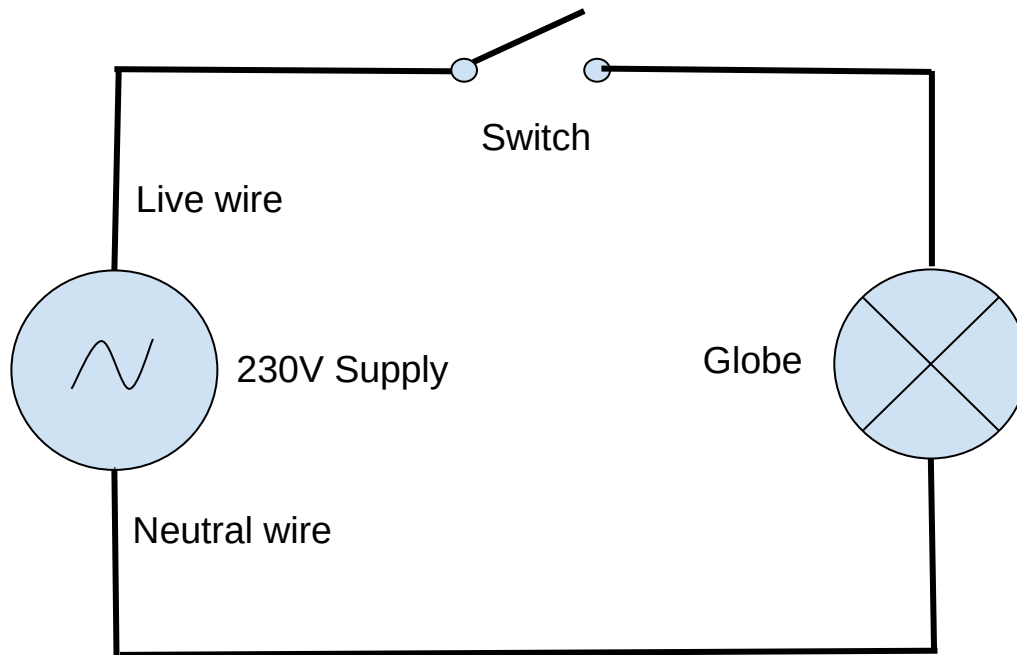
Electrical Circuit - An electrical circuit is a closed loop of conductors that current can travel through, usually consisting of a power source and electrical components or devices like switches and globes.

Basics of Electricity:

Electricity... An invisible force of energy that can give a shocking experience, especially when least expected... Maybe that's why we're scared of it, but should we be? Not scared but certainly cautious, it can hurt us or even kill us... So, let's learn to work with it safely and enjoy the benefits of it.



Let's look at what it takes for a simple thing like a globe to light up. Firstly, you need a supply voltage, thanks to our municipality (sometimes directly from Eskom) we receive our 230 volts supply. They give us a red wire known as the live, a black wire known as the neutral and an earth wire which is normally bare copper or yellow and green. Any circuit, be it a light circuit, a plug circuit or a geyser, needs to be supplied with a live wire (Red) supplying voltage, something to control the circuit (known as the control circuit) and the load (known as the main circuit). A neutral wire (Black) is the path used for the current to return to earth. Before your Energy meter the neutral and earth conductors are connected together and bonded to earth, the ground you stand on. So, all electricity in your house is supplied with a live, the current flows through the entire circuit and it returns to earth. If the conductor loop is broken at any point, no current can flow, therefore no working components.



Let's look at a simple light circuit, we have our supply of 230V, now we need a switch to control the light and a globe. The switch is our control circuit, and the globe is our main circuit. We will use insulated copper conductors to connect our live to the switch, the switch to the light and the light to neutral.

Here we have a supply voltage of 230V, that is the pressure on the circuit measured in Volts. Our components (switch and globe) are connected to each other with insulated conductors made of copper. Copper is a good conductor of electricity because it has free electrons that can move easily. So, the voltage pushes the electrons, but if the circuit is open as can be seen above with the switch in the open position, the electrons have no path to flow, therefore no current can flow, and the globe will be off. When the switch is closed the path for the electrons to flow will be complete and the flowing electrons (current flow) will illuminate the globe. Now we have a closed circuit with current flowing from Live through the switch and light bulb back through neutral. This current flow is measured in Amps. The light bulb is made of tungsten which has a Resistance (R) to the flow of current and gets white hot which gives us our light. The more the resistance (measured in Ohms Ω) there is to the flow of electrons, the less the amps, i.e., the higher the resistance the more difficult it is for electrons to flow.

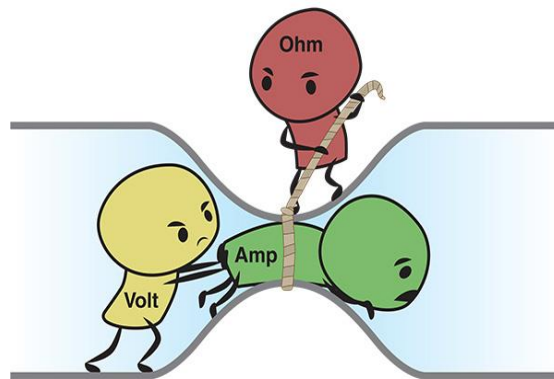
Electrical Calculations:

Ohms Law:

To calculate the volts, amps and resistance in a circuit we use Ohm's Law.

“The current flowing in a circuit is directly proportional to the voltage acting in that circuit, and inversely proportional to the resistance of the circuit”.

In simpler terms: $V = I \times R$ (Voltage = Current x Resistance)



Let's look at 2 examples: a light circuit and a geyser circuit. We have a supply Voltage of 230V on both our circuits, can't change that unless we use a transformer, and then we have our 2 different components with different Resistances which will have a huge effect on our Current. Let's assume the light bulb has a Resistance of 1322Ω and the geyser element has a Resistance of $17,633\Omega$. Let's calculate the Current flow through each component.

Light Circuit:

$$V = I \times R$$

$$I = V/R$$

$$I = 230V/1322\Omega$$

$$I = \underline{0,174A}$$

Geyser Circuit:

$$V = I \times R$$

$$I = V/R$$

$$I = 230V/17,633\Omega$$

$$I = \underline{13,044A}$$

Here we can see that the high resistance of the light bulb produces a low current flow in our circuit and the low resistance of the geyser element results in a high current flow. They say that 0.8A can kill you, not sure who tested this but let's believe them. So, by this we can see that the geyser element, when on, is very dangerous. Therefore, we have extra protection in place which we'll cover later on.

To calculate the Resistance in a circuit we use the same formula, by knowing our Voltage and the Current drawn by the circuit we can work out our Resistance. This is not important for this course but let's have a quick look at it. I'm using my toaster for this example and the values are real measured values. My supply Voltage is 235V and the current in the circuit is 4.26A, what would the Resistance be?

$$V = I \times R$$

$$R = V / I$$

$$R = 235 / 4.26$$

$$R = \underline{55.164 \, \Omega}$$

When I measured the resistance on the toaster while cold it was only 51 Ω , so by this we can see that there are factors that influence Resistance and heat is one of them, the hotter the conductor the higher the resistance. The length of the conductor also has an influence, the longer it is the higher the resistance. The thickness of the conductor is also a factor, the thicker it is the lower the resistance and the type of material used, different materials have different resistivities, those with low resistivity are good conductors like copper and aluminium and those with high resistivities are good insulators like PVC, rubber and glass.

Power:

Let's look at Power which is measured in Watts (W) in our circuits: Electric power is the rate at which work is done, so let's see how much power it takes for the globe to light a room and for the geyser element to heat water. Our formulas to calculate Power look like this:

$$\text{Power (P)} = \text{Volts (V)} \times \text{Current (I)} \quad P = V \times I$$

Light Circuit:

$$P = V \times I$$

$$P = 230V \times 0,174A$$

$$P = \underline{40W}$$

Geyser Circuit:

$$P = V \times I$$

$$P = 230V \times 13,044A$$

$$P = \underline{3000W}$$

Here we can see that it takes a lot more energy or Power to heat water than to light a room. These are just basic calculations to give you an idea and to explain electricity, there are more complex factors at play if you want to study further.

All our appliances, power tools, lights etc. come with power ratings. The geyser is often 3000W, the kettle may be 2000W the globes can be between 3W for LED to 200W or more and so on. Power tools are also rated in Watts, the higher the power rating the stronger the appliance or tool is and the more current it will use. Let's look at an example: My kettle is rated at 2000W, how much current will it draw?

$$P = V \times I$$

$$I = P/V$$

$$I = 2000 / 230$$

$$I = \underline{8.696 A}$$

So why is Power important? Eskom... They bill you on the amount of power you consume. Your energy meter or Electrical Pre-Paid meter as we know them today is what Eskom uses to measure your electrical consumption, billed in Kilo Watt Hours (KWH). On writing this learning material (Sep 2021) I got charged R2.717 per Kilowatt Hour. This means that for every hour that I use 1 Kilo Watt (1 000 Watts) I get billed R2.717. Let's look at our 2 circuits again as examples, each one on for 2 Hours.

Light Circuit for 2 hours:

$$\text{Cost} = \text{Kilowatts} \times \text{Time} \times \text{Rand per unit}$$

$$\text{Cost} = 0.04 \text{ kilowatts} \times 2 \text{ Hours} \times R2.717$$

$$\text{Cost} = 22 \text{ cents.}$$

Geyser Circuit for 2 Hours:

$$\text{Cost} = \text{Kilowatts} \times \text{Time} \times \text{Rand per unit}$$

$$\text{Cost} = 3 \text{ kilowatts} \times 2 \text{ Hours} \times R2.717$$

$$\text{Cost} = R16.30$$

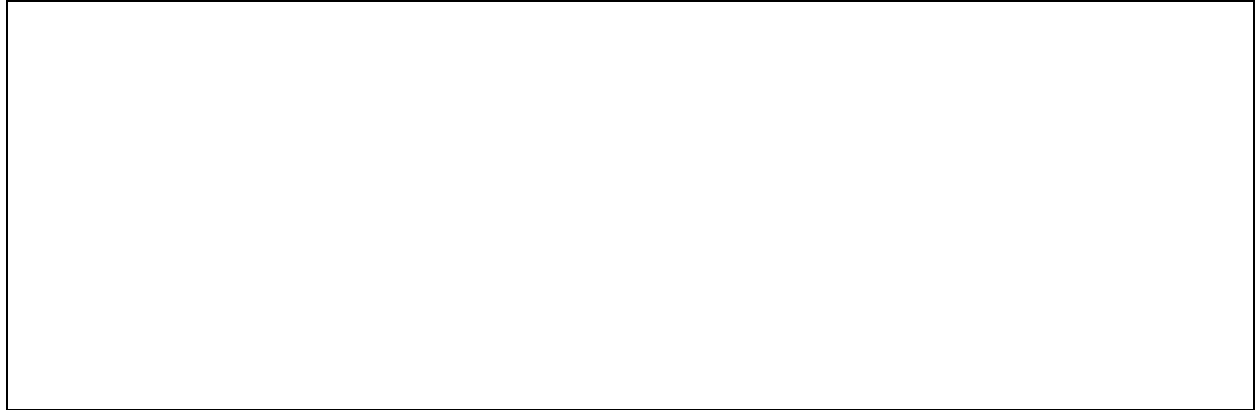
From this we can see that the higher the power the higher the cost, anything that heats consumes plenty of energy, your heater, geyser, kettle, iron, tumble dryer, toaster, stove etc., so if you want to reduce your bill, look at these first.

Exercise 1:

- 1) I have a security light that has a resistance of 264.5Ω with a supply voltage of 230V,
 - A) How much current will this light draw?
 - B) How much power will this light consume?
 - C) What would it cost me to have it on for 8 hours a night for 30 days at a rate of R2.717 /KWH?

Exercise 2:

- 2) Let's use the toaster example here, my supply voltage is 235V and it draws 4.26A.
 - A) How much power does the toaster consume?
 - B) If I used this toaster and a kettle (2000W) at the same time, how many amps would be drawn?
 - C) What would the cost be at R2.717 /KWH if I used them both for 10 minutes each day for 30 days?



For me the most important component in electricity is the current, the amps. I control my circuit by controlling the current flow, i.e. I tell the light to switch on by pressing the switch, I turn my stove on by turning the knob. I control where and when the current can flow. I have very little control of the voltage or the resistance. The amount of current flow or Amps also plays a huge role on the components I use in my circuit.

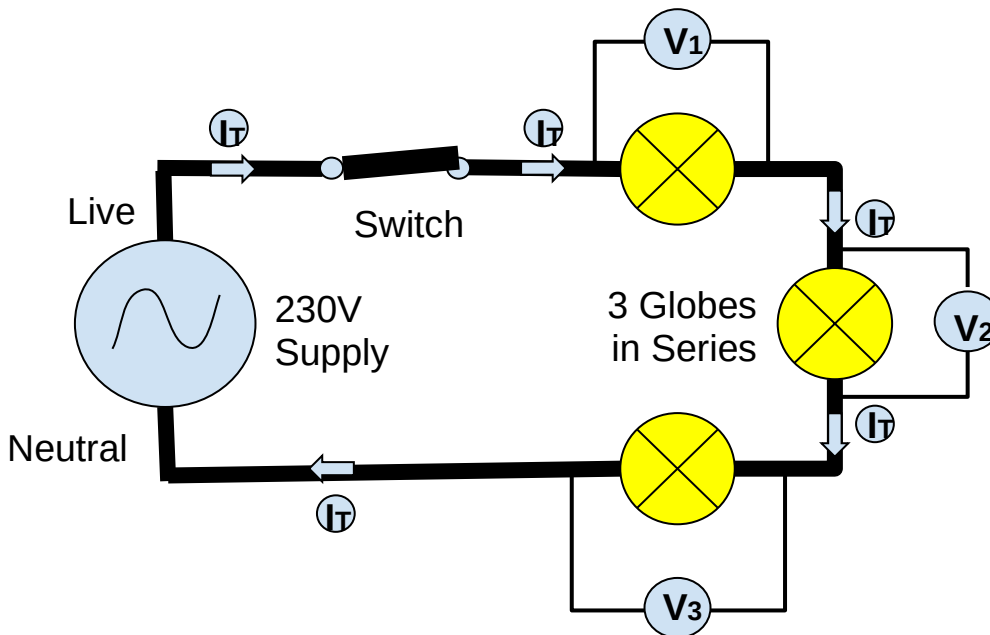
Circuits

Wiring of Circuits: 2 different methods can be used to wire circuits, series and parallel. Here are 2 diagrams to represent the different connection types using a switch and 3 globes. I will use these diagrams to demonstrate the pros and cons of the different connections as well as Kirchoff's Laws.

Kirchoff's Voltage Law: The sum of the voltage drops across a closed circuit is equal to the applied voltage.

Kirchoff's Current Law: The sum of the currents flowing towards a junction is equal to the sum of the currents flowing away from the junction.

Series Connected Circuit:



Here you can see that the 3 globes are connected in series with each other, i.e., they don't each have their own live supply from the power supply. The first globe has a live supply but then it supplies the second globe, and the second globe supplies the third and then the current returns to Neutral. The arrows depict a current flow. In this circuit, if one globe blows the whole circuit will be off, the current path will be broken. If we look at the current flowing in this circuit, we will see that the current is the same throughout the circuit and is referred to as the Total Current (I_T). There is however a voltage drop across each globe and is referred to as V_1 , V_2 and V_3 . Because there are 3 volt drops across these globes, they will burn dimmer than they are supposed to. The supply voltage will be equal to the sum of the three volt drops. $V_t = V_1 + V_2 + V_3$. This is obviously not a good way to connect our lights because if 1 blows all will be off. In short: In a series circuit the current remains the same throughout the circuit, but the voltages differ.

Series Circuit Calculations:

$$\text{Total Voltage (} V_t \text{)} = V_1 + V_2 + V_3$$

$$\text{Total Current (} C_t \text{)} = I_1 = I_2 = I_3$$

$$\text{Total Resistance (} R_t \text{)} = R_1 + R_2 + R_3 \text{ (Resistances of the globes)}$$

Let's say in this series circuit that our supply voltage is 230V (V_t), Globe 1 resistance is 50Ω , Globe 2 resistance is 30Ω and Globe 3 resistance is 20Ω . These are the given values in our circuit that cannot be changed, let's calculate the current in the circuit.

First, we need to calculate the total resistance (R_t) and we know that in a series circuit our total resistance equals the sum of all the other resistances.

$$R_t = R_1 + R_2 + R_3$$

$$R_t = 50\Omega + 30\Omega + 20\Omega$$

$$\underline{R_t = 100\Omega.}$$

Now we have the total resistance and the total volts, so we can calculate our total current using Ohm's Law: $I = V / R$

$$I_t = V_t / R_t$$

$$I_t = 230V / 100\Omega$$

$$\underline{I_t = 2,3A.}$$

Because our globes are connected in series, we are going to have a volt drop across each one of them, let's calculate these volt drops. Remember that our current throughout the circuit is equal and we know the resistances through each globe, so again we can use Ohm's law to calculate the volt drops. $V = I \times R$

$$V_1 = I_t \times R_1$$

$$V_1 = 2,3A \times 50\Omega$$

$$\underline{V_1 = 115V}$$

$$V_2 = I_t \times R_2$$

$$V_2 = 2,3A \times 30\Omega$$

$$\underline{V_2 = 69V}$$

$$V_3 = I_t \times R_3$$

$$V_3 = 2,3A \times 20\Omega$$

$$\underline{V_3 = 46V}$$

Let's test the answers, the total voltage should equal the sum of the 3 volt drops.

$$V_t = V_1 + V_2 + V_3$$

$$230V = 115V + 69V + 46V$$

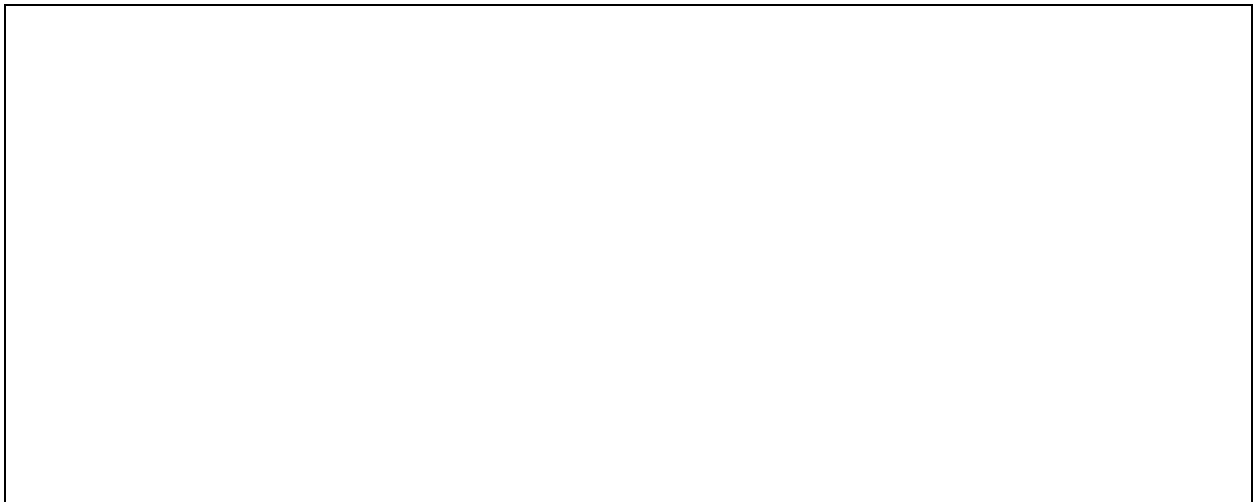
$$\underline{230V = 230V.}$$

Exercise 3:

Draw a series circuit diagram with a supply voltage of 150V, 3 globes with 25Ω , 40Ω and 15Ω resistances respectively.



Now calculate A) The total resistance, B) The Total current and C) The volt drop across each globe. Check your answers in other words do your volt drops = total voltage?

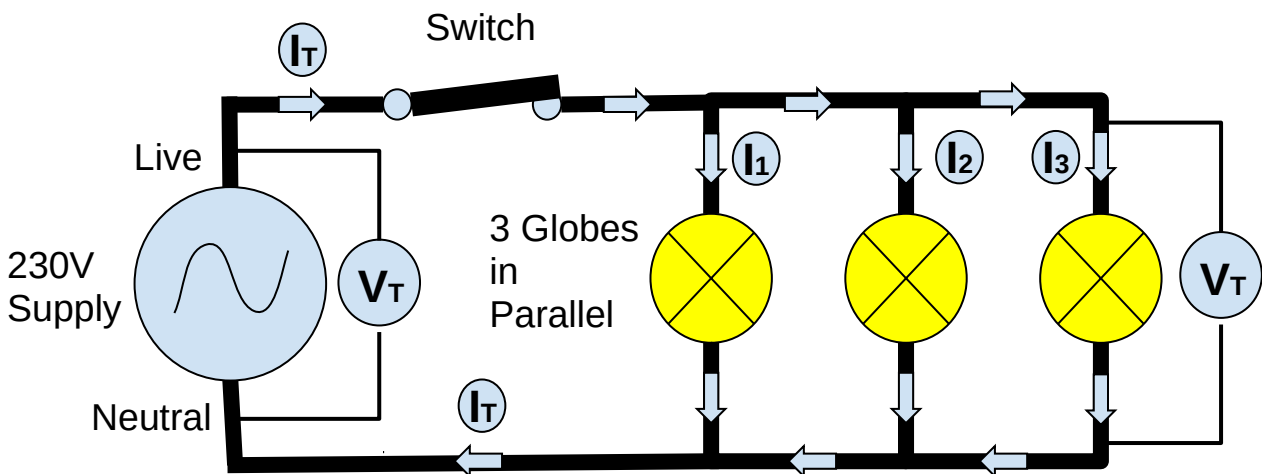


Exercise 4:

Two resistors are connected in series. The supply voltage is 200V and the current through the circuit is 10A.

- A) What is the total resistance of the circuit?
- B) What are the values of the two resistors if the volt drop across one is 70V and the other is 130V?

Parallel Connected Circuit:



In this connection you can see that each globe has its own Live supplying it, and its own Neutral. Again, the arrows will depict current flow. Here you can see that the current splits to each globe. The amount of current that flows through each globe will depend on each globe's resistance in the circuit. The higher the resistance the less current will flow through it. The total current in this circuit is equal to the sum of the other currents. Total Current = $I_1 + I_2 + I_3$. If one or two globes blow in this circuit the remaining globe will still burn. In a parallel circuit the Voltage remains the same across the circuit. This is the way we connect our lights and plugs in the house. In short: In a parallel circuit the voltage remains the same throughout the circuits, but the currents differ.

Parallel Circuit Calculations:

Total Voltage (V_t) = $V_1 = V_2 = V_3$

Total Current (I_t) = $I_1 + I_2 + I_3$

Total Resistance (R_t) $1/R_t = 1/R_1 + 1/R_2 + 1/R_3$ (Resistances of the globes)

Let's use the same values as above and say that in this parallel circuit our supply voltage is 230V (V_t), Globe 1 resistance is 50 Ω , Globe 2 resistance is 30 Ω and Globe 3 resistance is 20 Ω . These are the given values in our circuit that cannot be changed, let's calculate the current in the circuit.

First, we need to calculate the total resistance (R_t). 2 mathematical methods can be used here, in the first method, use as many decimal places as possible.

$$1/R_t = 1/R_1 + 1/R_2 + 1/R_3$$

$$1/R_t = 1/50\Omega + 1/30\Omega + 1/20\Omega$$

$$1/R_t = 0.02\Omega + 0.033333333\Omega + 0.05\Omega$$

$$1/R_t = 0.103333333\Omega$$

$$\underline{R_t = 9.678\Omega.}$$

$$1/R_t = 1/R_1 + 1/R_2 + 1/R_3$$

$$1/R_t = 1/50\Omega + 1/30\Omega + 1/20\Omega$$

$$1/R_t = 6/300 + 10/300 + 15/300$$

$$1/R_t = 31/300$$

$$R_t/1 = 300/31$$

$$\underline{R_t = 9.678\Omega.}$$

Now we have the total resistance and the total volts, so we can calculate our total current using Ohm's Law: $I = V / R$

$$I_t = V_t / R_t$$

$$I_t = 230V / 9.678\Omega$$

$$\underline{I_t = 23.765A.}$$

Because our globes are connected in parallel, the volt drop across each one of them will be equal. However, our current is going to split into the branches and I_1 , I_2 and I_3 need to be calculated, so again we can use Ohm's law to calculate the individual currents.

$$I = V / R$$

$$I_1 = V_t / R_1$$

$$I_1 = 230V / 50\Omega$$

$$\underline{I_1 = 4.6A.}$$

$$I_2 = V_t / R_2$$

$$I_2 = 230V / 30\Omega$$

$$\underline{I_2 = 7.667A.}$$

$$I_3 = V_t / R_3$$

$$I_3 = 230V / 20\Omega$$

$$\underline{I_3 = 11.5A.}$$

According to Kirchoff's current law the sum of these currents should equal the total current, let's check it.

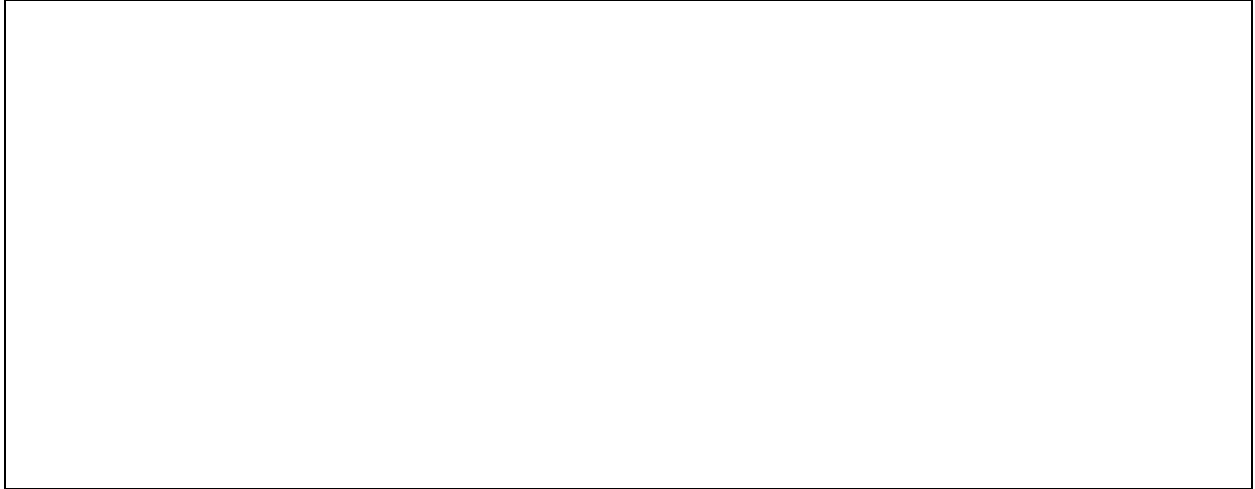
$$I_t = I_1 + I_2 + I_3$$

$$23.765A = 4.6A + 7.6666666A + 11.5A$$

$$\underline{23.765A = 23.765A.}$$

Exercise 5:

Draw a circuit with 3 globes in parallel with each other and the power source, each globe has a resistance of 10Ω , 20Ω and 50Ω respectively. The supply voltage is $200V$.



- 5A) Calculate the total resistance of the circuit
- 5B) Calculate the total current in the circuit
- 5C) Calculate the current in each branch to each globe.



Exercise 6:

Three globes with resistances of 10 ohms, 15 ohms and 30 ohms are connected in parallel across a 120V supply.

6A) Calculate the total Resistance

6B) Calculate the total Current

6C) Calculate the current through each globe.

Ohms Law Formulas				
Known Values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	---	---	$V = I \times R$	$P = I^2 \times R$
Voltage & Current	$R = \frac{V}{I}$	---	---	$P = V \times I$
Power & Current	$R = \frac{P}{I^2}$	---	$V = \frac{P}{I}$	---
Voltage & Resistance	---	$I = \frac{V}{R}$	---	$P = \frac{V^2}{R}$
Power & Resistance	---	$I = \sqrt{\frac{P}{R}}$	$V = \sqrt{P \times R}$	---
Voltage & Power	$R = \frac{V^2}{P}$	$I = \frac{P}{V}$	---	---

Electrical Components

For a circuit to work we need various components. Each component has a specific duty in the circuit and while some components control a circuit others protect the circuit, and they are all equally important. Let's break up our component list into categories:

- 1 - Conductors
- 2 - Protection
- 3 – Earthing
- 4 – Testers and Meters
- 5 - Circuits
- 6 - Wireways and Conduit

Conductors

These are the wires we use to connect all our components together. Here we use different colours of insulation over the conductors to identify our Live (Red/Brown), our Neutral (Black/Blue) and our Earth (Yellow/Green and bare copper). There are more colours that will be dealt with later when we design some light circuits. Most of our conductors that we use are made of copper. Copper atoms have many loose electrons that can flow easily therefore making it a good conductor of electricity i.e., it has a very low resistance to current flow. The thicker the conductor the more current can flow therefore the more Amps it can handle. By this we can see that the geyser element from earlier which draws 13A will need a thicker conductor than the light circuit that only draws 0.17A. Copper is also more resistant to oxidation (Rust) than other metals and its malleable making it easy to work with.

Aluminium is also used as a conductor but more in power lines, aluminium has 61 percent of the conductivity of copper, but has only 30 percent of the weight of copper. That means that a bare wire of aluminium weighs half as much as a bare wire of copper that has the same electrical resistance. Aluminium is cheaper than copper and is not as sought after so theft is limited.

Insulation: An electrical insulator is a material in which electric current does not flow freely. The atoms of the insulator have tightly bound electrons which cannot move easily.

Most of the time when using conductors, we need to insulate them from each other. This is to prevent short circuiting and obviously to protect us from getting shocked. Good insulators include Plastic, wood and rubber, just to mention a few. Our copper conductors are mostly covered with a PVC insulation, (Polyvinyl chloride). This PVC insulation is coloured for us to identify the conductors.

2 different types of conductors are found, solid and stranded. This means that the copper is made of a solid wire, or it is made up of a couple of stranded wires making it easier to work with. Stranded wire is softer to bend and can be pulled through conduit piping much easier for example.



There are many different types and sizes of cables in the industry, here we'll only cover a few that we may recognize. I have inserted a Cable to Current table that gives guidelines to the amount of Amps a cable can withstand as well as the voltage drop of the cable on Page 25. I will refer to this table for calculation purposes.

General purpose wire: In house wiring the most common cables used are the single core cables, i.e., it has only one conductor covered with insulation or not in the case of bare copper for earthing. We will deal with the size of the conductors later. With these conductors you would need to use 3 separate cables to wire a plug for instance, red for live, black for neutral and yellow/green for earth. It is easier to work with these cables because they are separate from each other and are made up of stranded cores, they are

however more expensive. These conductors need to be placed in a conduit or trunking for protection. There is a colour coding on the packaging to make it simpler to identify the size of the conductor inside: Brown for 1mm², Red for 1.5mm², Green for 2.5mm², Orange for 4mm², Pink for 6mm², Purple for 10mm² and Grey for 16mm².



Flat Twin and Earth: This cable is made up of all three conductors in one, insulated from each other and placed next to each other. The earth conductor is bare copper and slightly thinner and is placed in between the live (red) and neutral (black). They are all then covered with extra PVC Sheath to keep them in place and protected. Usually, the conductors are solid up to 2.5mm and then they use stranded cores for the thicker cables. This cable is cheaper and can be used on the surface of walls held there with cable clips or in the wall under the plaster. This cable doesn't need conduit for protection like the house wire making it a good option for wiring a house.

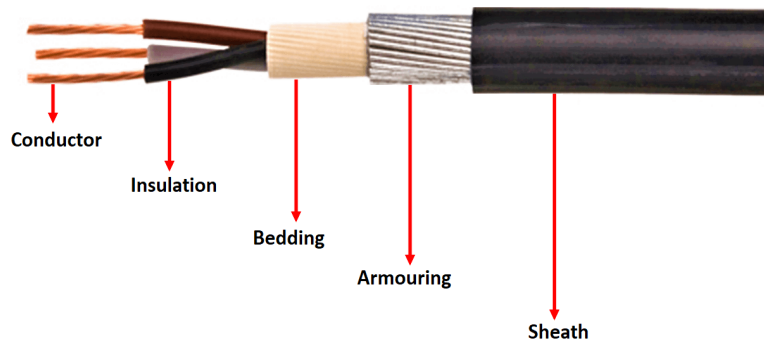


Cabtyre Cable: This is probably the most common cable in use around the house. We use this cable as extension leads and most of our appliances use cabtyre to connect it to the socket outlet (plug in the wall). Cabtyre comes in 2 core or 3 core or even more if needed, here we will work with the 2 and 3 core cabtyre. The cable is usually round or

flat and covered with black or white PVC sheath for protection. Inside you have the conductors, each covered with its own insulation for protection and identification. In the 2 core you'll find 1 Brown conductor for Live and 1 Blue conductor for Neutral. In the 3 core you'll have an extra Yellow/Green conductor for the Earth. Cable is made of stranded conductors for flexibility.



Armoured Cable: This cable has an armouring of steel wires around it to protect it. It is used to supply buildings with power and can be laid underground and up against poles and buildings. It can have 3 or 4 cores all made of copper insulated conductors for insulation and colour identification. Their cores are covered with an inner PVC sheath, then with the armouring and finally with an outer sheath of PVC. The cable's armouring needs to be earthed.



There are many different types of cables, and their purpose is all the same, they all need to connect components so that current may flow to them. The important difference is the amount of current (amps) capacity. If you think of a fuse, its purpose is to rupture or blow when the current is too high for the circuit. It is designed to handle current to a

certain capacity, more current than that and it will fuse and break the circuit. Any copper wire is the same, it can only handle a certain amount of current flow per square millimeter, after that it will rupture. Therefore, we need to know how much current our conductor will need to accommodate and then select the appropriate size conductor. Let's use the cable to current table and see what the current carrying capacity is for our conductors and then use that in an example. Previously we determined that the 40W globe would draw 0.174A.

Let's see how much current a Stove of 7300W will draw.

$$P = I \times V$$

$$I = P / V$$

$$I = 7300W / 230V$$

$$I = \underline{31.739A}$$

Let's round these figures off: The light will draw 0.2A and the stove will draw 32A. So according to the cable to current Table we could use 1mm cable for the light circuit as that can handle up to 13A when laid in conduit. However, our stove circuit is drawing much more current than a 1mm cable can handle and would rupture it and possibly cause a fire, so we cannot use the same conductor for our stove circuit. Let's refer to the table for the correct size conductor to handle our stoves 32A. We can see that a 4mm cable can handle 30A when placed in conduit, that is still not enough so we would need to upgrade our cable to 6mm that can handle 38A. You can always go bigger on your cable size but not smaller.

Cable to Current Table: Below you will see the cable to current table that I have drawn up to give you a guideline. This table was made up from data that I took from SANS10142-1:2019 3rd Edition and may change with newer editions. This is for explanation purposes only.

Size Of Cable	Installed in Air		Installed in a Wall		Installed in Conduit	
mm ²	Amps	Volt drop mV/A/M	Amps	Volt drop mV/A/M	Amps	Volt drop mV/A/M
1	15	44	11	44	13	44
1,5	19,5	29	14	29	16,5	29
2,5	27	18	18,5	18	23	18
4	36	11	25	11	30	11
6	46	7,3	32	7,3	38	7,3
10	63	4,4	43	4,4	52	4,4
16	85	2,8	57	2,8	69	2,8

Protection

Miniature Circuit Breakers: These are the circuit breakers found in your Distribution Board (DB). Their purpose is to protect your cables and the load in a circuit. So, you would purchase the circuit breaker according to the size of the conductor you use, and you would purchase the correct size conductor according to the current drawn by the load on your circuit. The circuit breaker is designed to disconnect the circuit at a certain amperage thereby limiting the amount of current that may flow in that circuit, protecting it. It replaces the old fuse which would have to be replaced once ruptured, now you can just switch the circuit back on. There are different types of circuit breakers, but we are not going to cover that in this course, the important thing here is that you choose the correct amperage breaker. There are 2 different fittings, the way the circuit breaker will mount in the DB, one is Din rail and the other is Samite, choose the correct one or just take the old circuit breaker with you.

You get single pole and double or two pole circuit breakers, the single pole circuit breaker is designed to only be connected in the Live of the circuit while the double pole circuit breaker is designed to disconnect both the Live and Neutral of the circuit. We split our circuits with circuit breakers in the DB, i.e., we will have a light circuit running through a 10A breaker using 1.5mm wire, our plug circuit running through a 20A breaker using 2.5mm wire and our stove circuit running through a 40A breaker using 6mm wire.



Earth Leakage Circuit Breaker (ELCB): Also known as a Residual Current Device (RCD). We call it an Earth Leakage. This is how it works: The Earth leakage is a 2-pole circuit breaker, so it'll break both Live and Neutral. It measures the current going into the circuit through the Live and compares it to the current returning through the Neutral, if there is an indifference of 30 milliamps (30mA) or more it will automatically trip and disconnect the circuit. This would mean that some current has leaked out of the circuit and is going to an Earth somewhere else, possibly through a human. The Earth Leakage comes with a test button which simulates an Earth fault and should be tested often to ensure the unit is still in working order.



Surge Arrester: A surge arrester is a protection device that diverts the extra voltage, from lighting for instance, straight back to earth rather than flowing through your electronic devices. It still allows the normal supply voltage to continue along its path. This device also protects your equipment from power spikes caused by load shedding.



Energy Control Unit: This unit is designed to control the energy of high current devices. It is set to switch off one device when another device draws a certain current. For example: Let's say we have a 20A energy control unit connected to the stove as the "controlling circuit" and the geyser as the "controlled circuit", when you switch the stove on at night and it draws more than 20A the energy control unit will automatically disconnect the geyser to save energy on the power grid. As soon as you turn the stove off the geyser will automatically connect again.



Distribution Board: This is the box on your wall where all the electricity of the house is controlled from. Electricity is supplied to the DB and is then distributed from it to all the circuits in the house. The DB houses all the Circuit Breakers, Earth Leakage, surge arrester and Neutral and Earth Bar. They differ in size depending on the different number of circuits.

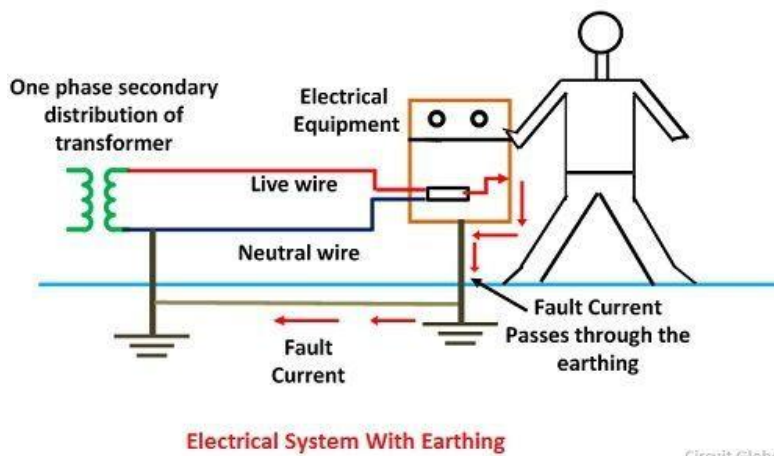


Earth and Neutral Bars: In our DB we need space to connect all the Neutral returns, they cannot all connect into the bottom of the Earth Leakage, so we install a Neutral Bar to give more space for connections, this bar is usually Blue or Black. The same for our Earth, all the Earths get connected at a central point in the DB on an Earth Bar which is green or bare...



Earthing:

Earthing is used to prevent you from getting an electric shock. It does this by creating a path for any leaking current to flow back to earth directly and not through you. All fixed metal parts around the house should be Bonded to earth, like your gutters, corrugated iron roof sheets, geyser, stove, all your lights and socket outlets. Your electrician will make sure that your Earth connection at your DB is sufficient by doing a Loop Impedance Test, if not they would put an Earth Spike in to improve the Earth connection.



Testers and Meters

Voltmeter: A voltmeter is used to measure the Voltage (V) in a circuit, which is the pressure on the circuit. It has a very high resistance to current flow and must be connected in parallel to the circuit. If connected in series it would cause a volt drop and the component needing say 230V would not receive the full voltage, much like the globes that burn dimmer than normal in our series circuits that we'll see later.



Ammeter: An ammeter is used to measure the amperage in the circuit, better known as the amps (A) which is a measure of the current flowing. It has a very low resistance to current flow and must therefore be connected in series. If connected in parallel it will cause a dead short and blow the circuit.



Energy Meter: An energy meter measures the amount of electricity used over a time period in Kilowatts per Hour (kWh). The municipality uses these meters to bill us. If you remember our Power calculations, you'll remember to calculate power we multiply our Voltage by our Amperage, $P = V \times I$, so this meter is made up of an ammeter and a voltmeter connected together to calculate the power used over a period of time. Today we use a Prepaid Energy meter saving the municipality having to come around and read every meter every month.



Ohmmeter: An ohmmeter measures resistance in Ohms (Ω). The important thing about resistance is the effect it has on the current flow, the amps. We often test for continuity using the ohm scale, for instance we can test that the filament of a globe is still complete and not ruptured. We can test the element of any heating appliance, or we can test that our cables are continuous. Any ohmmeter needs to push a small voltage through the component or circuit to measure its resistance.



Multimeter: A multimeter, also often called an AVO (Amps, Volts, Ohms) is a handheld meter that we use to measure or test for volts, amps and ohms. Some of these meters can measure capacitance and temperature as well. There are many different makes of multimeters, but their purpose is the same. Some have clamps or tongs on that are there to measure current flow (Amps) known as a clamp meter or tong tester. When current flows through a conductor a magnetic field is generated around that conductor, these tongs pick up the magnetic field and measure the amps. When using a multimeter, it is important to make sure that the leads are in the correct position and that the correct application and scale is selected.



Insulation Resistance Tester: An Insulation Resistance Tester (IRT) also often referred to as a Megger is a meter that is designed to measure the insulation resistance between conductors. In other words, it tests that the insulation between the conductors is good enough to prevent short circuiting. This test is always done in a Certificate Of Compliance (COC) before the house's power is turned on. Just like the ohmmeter, the IRT needs to push a voltage through the circuit to test it, however, the IRT is designed to push a variety of voltages through the circuit and can be adjusted on the dial according to the circuit being tested. The selected voltage should be as close as possible to double your phase voltage, so at home $2 \times 230V = 460V$, so select the 500V scale. This meter will then push out 500 Volts Direct Current (DC) across its leads, be careful not to get shocked.

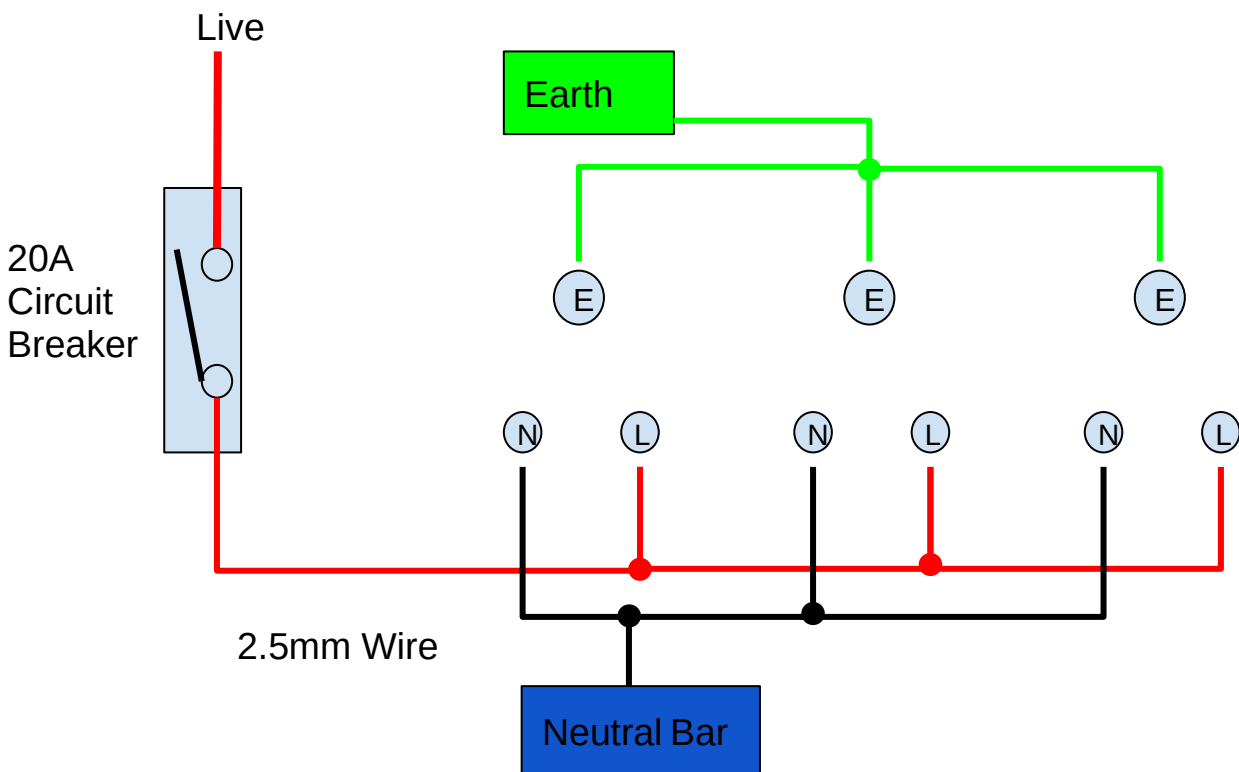


Plug Tester: A plug tester is a small handheld tester that plugs directly into a plug socket outlet to test it. It tests that there is power to the plug, it tests that the polarity is correct at the plug, i.e., that the live, neutral and earth are connected in the correct places, and it is used to test the Earth Leakage. Once plugged into the wall 3 led lights will glow indicating that the plug socket outlet is correctly wired, when you turn the knob, it will divert tiny bits of current from the live conductor to the earth in small increments. Once you reach the 30mA mark the Earth Leakage should trip in the DB proving that it is in good working order.



House Circuits

Plug Circuit: Below is a diagram of how the plug circuit in a house gets wired, there should not be more than 5 plugs per circuit breaker. So, if you have 20 plugs in your house, you should have 4 circuit breakers in your DB. You can see on this diagram that the plugs are wired in parallel, i.e., each plug has its own Live, Neutral and Earth. We use Red for our Live, Black for Neutral and Yellow and/or Green for Earth. The plug circuits are wired with 2.5mm cables and protected with a 20A circuit Breaker. All the plug circuits are protected by the Earth Leakage.



Wiring of a 3 Pin Plug: A 3 pin plug is the standard plug used in South Africa, we have the 2-pin plug and the Schuko also with the latest plug being the Euro plug. The schuko and 2 pin plugs have only 2 pins, Live and Neutral while the 3 pin and Euro plugs have Live, Neutral and an Earth for protection. We often cut the 2 pin and schuko plugs off appliances and replace them with our standard 3 pin plug. The correct way to fit a 3-pin plug is as follows: when the plug top is open so that the pins are pointing away from you the pin on the left is the Neutral, the pin on the right is the Live and the top pin is for Earth. So, you put the Live bRown (R for Right) wire into the right-hand pin, the Neutral bLue (L left) into the left-hand pin and the Earth green/yellow into the top pin, remember to always twist the strands together to make the conductor as solid as possible. The earth wire needs to be longer so that if the cable gets pulled out of the plug, the earth wire is the last wire to disconnect. These colours are for cabtyre cable. Other cables use red for live, black for neutral and green/yellow or bare copper for earth. We often use plug adapters when we need to plug in a 2 pin or schuko plug, these adapters and extension leads are causes of many fires in homes, the Euro plug was introduced to try to eliminate the adapter plugs. It's the shape of a 2 pin but has an extra pin for the Earth, it also comes with a 16 Amp rating.



Wiring a 3 Pin Plug



3-Pin Plug



2-Pin Plug



Schuko Plug



Euro Plug



Plug Adaptor

Geyser Circuit: The geyser, also known as a Hot Water Cylinder (HWC) is connected on its own circuit, i.e., it has its own circuit breaker. A geyser is a water heating appliance normally using a 3- or 4-Kilowatt element which would draw 13A or 17.4A respectively. The element is controlled with a Thermostat which regulates the temperature of the water, the thermostat is connected in series with the element and switches it on and off when needed. You can adjust the temperature of the water on the thermostat. The geyser can be wired with 2.5mm cables and protected with a 20A Circuit Breaker. At the geyser, within arm's reach, is an Isolator. An Isolator is a double pole switch that breaks both the Live and Neutral when switched off. This isolator is also wired in series and is there to isolate the circuit safely when working on the geyser. Earthing of the geyser and all copper pipes connected to it is vitally important. Often the geyser can cause nuisance tripping so it can be put on its own earth leakage, it is law that the geyser is connected through an Earth Leakage. Colour is used to identify different Wattage on Elements: Green for 0.65KW, Brown for 1KW, Yellow for 1.5KW, Red for 2KW, Orange for 3KW and Blue for 4KW.



Geyser



Element



Thermostat

Geyser Timer: A geyser timer is also known as a 24-Hour Timer or Pool Timer. It has many different programs that can be set to switch the geyser on and off. It has a higher amperage rating than other timers, typically 20A to withstand the high current drawn by the geyser. It is believed that by controlling the working times of your geyser you could save electricity. This timer can be used for many applications such as security lights and pool pumps or under floor heating.



Stove Circuit: The stove circuit is also on its own, with its own circuit breaker. Stoves differ a lot with the amount of current they draw but usually they are wired with 4mm or 6mm cables because of the high-power usage. A stove also has an Isolator at arm's reach for maintenance purposes. A stove top and oven can be joined or separate, either way they need to be able to be switched off with an Isolator.



Stove/Oven



Isolator

Lights

Lights seem easy, flick a switch and they turn on or off. But actually, they are the most complicated circuits in the house. There is so much to know about lights and switching them that I have left it till the end. I am only going to touch on certain aspects of lights and not go into too much detail.

Light Fittings: There are many different types of light fittings, how the globe is fitted into a holder. I will cover the most common ones here. The bayonet fitting, this globe has two pins sticking out to twist and lock into place. The Edison or screw in light bulb, this is the one that screws into the holder, it also comes in different sizes. Note that when wiring this holder, the far pin in the back must be connected to Live. The Fluorescent tube, this is the long tube with pins at either end. The fluorescent lights are filled with a mercury vapour that gets ionized in the tube, this causes electrons in the gas to emit photons at UV frequencies. The UV light is converted into standard visible light using a phosphor coating on the inside of the tube, this gives us the light. Compact fluorescent lights are now available which use the bayonet and Edison screw fittings. LED lights, Light Emitting Diode (LED) is the latest in lighting now and has a high output of light for much less power. They come in all the fitting styles possible. GU10 is used for 230V downlighters and GU4 is a type of fitting often used on downlighters that use a 12V supply. LED strips are strips of LED lights that get glued down with double sided tape and are controlled by a driver.



Bayonet



Edison or Screw in



Fluorescent Tubes



Compact Fluorescent



GU10



GU4



LED Strip Lights

Light: When purchasing globes for your house there are a couple of things you need to know. The wattage of the globe, i.e., the amount of power the globe will consume, the brightness of the globe is measured in Lumens (Lm), one lumen is approximately equal to the amount of light put out by one birthday candle that's about 300mm away from you, it's how much light you will get out of the globe, and then the colour of light emitted from the globe which will determine the atmosphere of the room. Lighting a room can be complicated and it's best to get a professional in to advise you. There are many different types of lights and fittings and fixtures and the result of good or bad lighting determines how the room is finished off.



2500k
Extra Warm White



2700k
Warm White



3000k
Warm White



3500k
White



4000k
Cool White



6500k
Daylight

Colour of light chart

	YOU USED TO BUY		CONSIDER	
	LEAST EFFICIENT			MOST EFFICIENT
	Incandescent	Halogen	CFL	LED
450 lumens	40W	29W	9W	7W
800 lumens	60W	43W	14W	10W
1,100 lumens	75W	53W	19W	17W
1,600 lumens	100W	72W	23W	20W

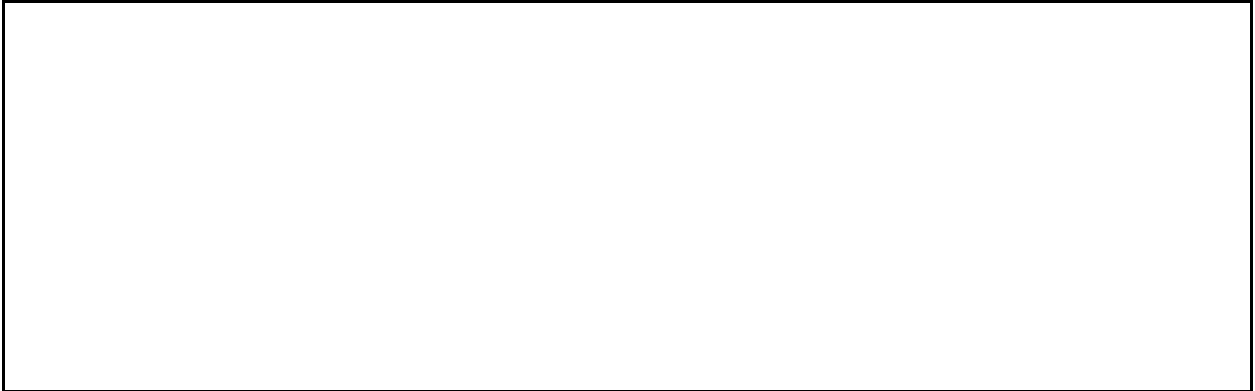
Types of Globes with their Wattage output (W) and their Brightness output (Lumens)



I took this photo from a Major Tech box of a Globe, or Lamp as they call it to explain the label. Lumens - 960 is the amount of light the globe will give, Beam Angle - 270° is the direction of light given, Cool White - 6500k is the colour of the light, Connection - E27 is the fitting of the globe, Edison Screw with a 27mm diameter. Life - 30 000hrs, this is the estimated time of life of the globe, Voltage - 175V-250V, this is the voltage that the globe can operate at, Protection Grade - IP20, this is the degree of protection provided by the casing, Power Factor - >0.5, this is a power loss due to induction circuitry, not important in this course, Non Dimmable - IC Driver, the Integrated Circuit board in the LED globe converts 240V AC to 12V DC and can have extra circuitry in it which would make it possible to dim the globe, this globe cannot be dimmed, LED Source - SMD, means that the LED is surface mounted, not important. In the bottom left corner, they say that this 12W LED globe is equivalent in lumens to a 70W Incandescent globe, CRI RA >80, Color Rendering Index is the measurement of how colours look under a light source when compared with sunlight. The index is measured from 0-100, with a perfect 100 indicating that colors under the light source appear the same as they would under natural sunlight. 80 is considered more than acceptable, the RA means it has an Average Rendering score (not important).

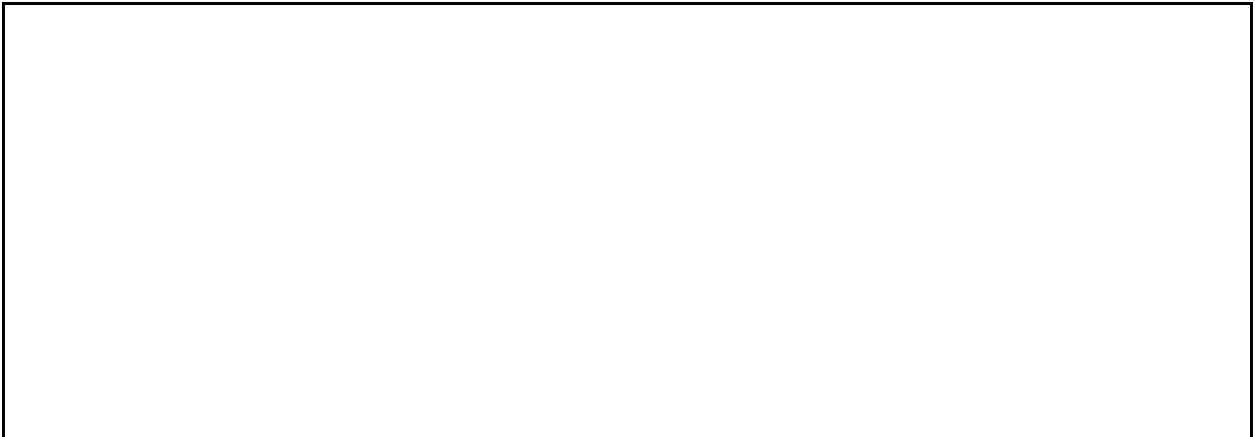
Controlling Lights: Lights need to be controlled, switched on and off and maybe dimmed. Here we are going to not only discuss the different methods of controlling lights, but we are also going to wire the panels and see for ourselves how these circuits work. Let's start by first drawing or planning our first circuit. Draw the schematic diagram for a 1-way switch (Normal on/off Switch) to switch 1 globe on. A 1-way switch has an indicator on it to display when the switch is in the on position. It has 2 connection points at the back for the live in and live out. All our switches (Control Circuit) are wired in series with the globes (Main Circuit). Our switches are always connected in the live part of the circuit and not the neutral. We call the wire that connects the switch to the globe our Return wire and it should be white. Use the space below to design the circuit. When the schematic diagram is correct go and wire it on the panel.

1) 1-Way switch with 1 Globe:



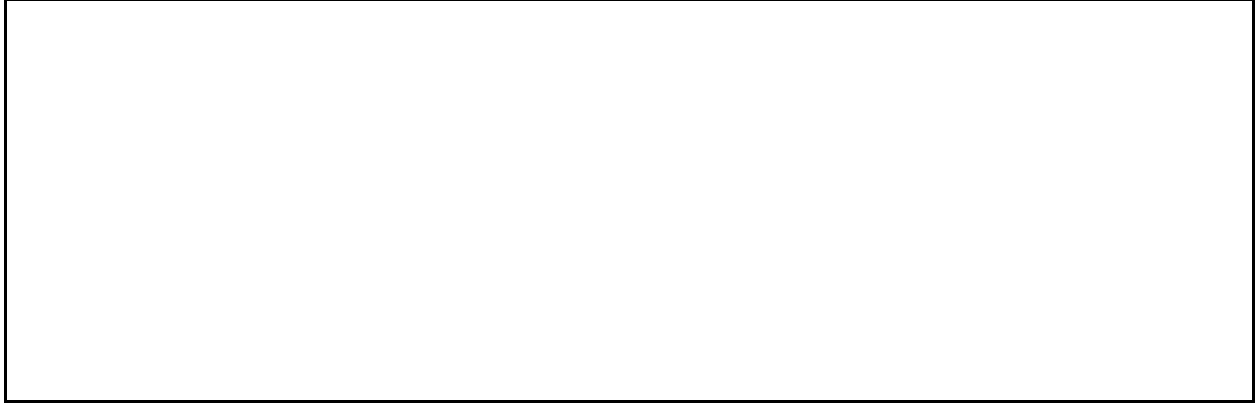
Now let's draw 3 Globes in Series controlled by a 1-way switch as we saw on page 25. Here you will start to see the difference between the control circuit, the switch that controls the lights and the lights that are the main circuit lighting the room. Test the circuit to see effects of connecting lights in series.

2) 1-Way switch controlling 3 Globes in Series:



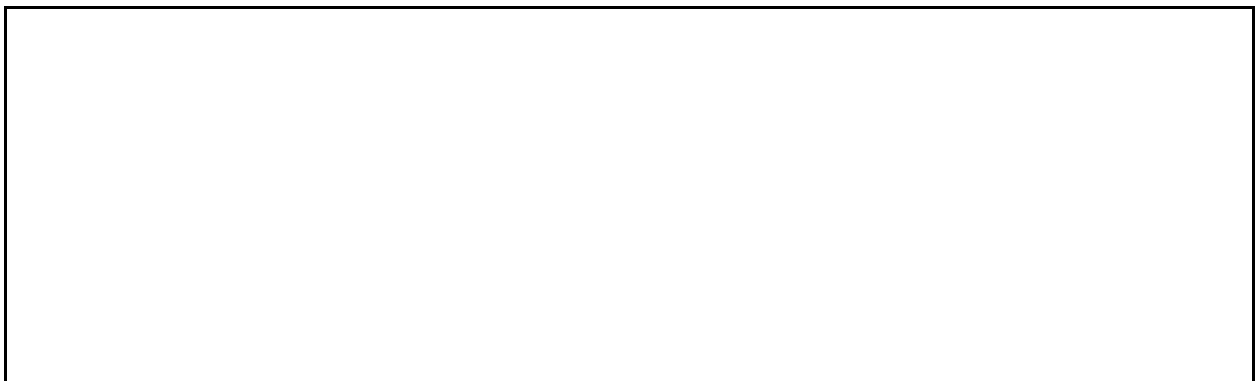
Now connect the 3 globes in Parallel still controlled by the 1-way switch as on page 26. Test the circuit to see effects of connecting lights in Parallel.

3) 3 Globes in Parallel controlled by a 1-Way Switch:



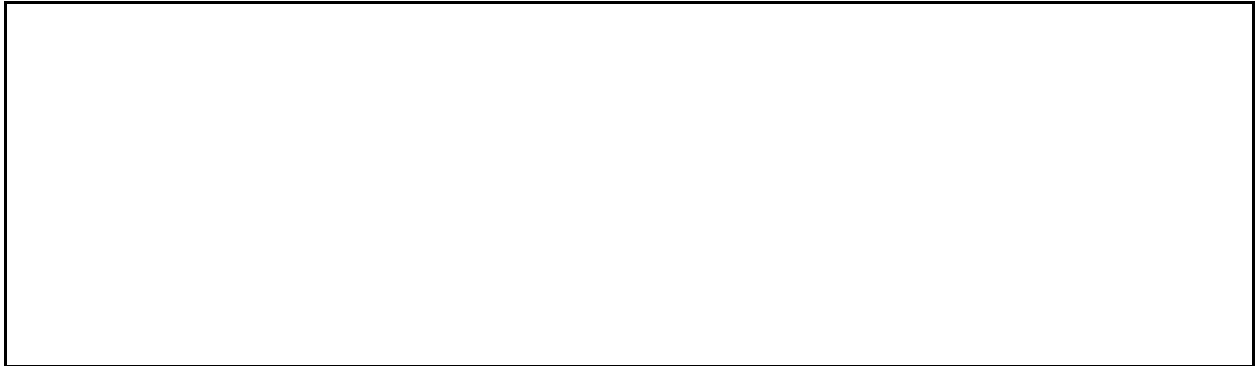
2-Way Switching: This is when you can switch the same globes on and off from 2 different places, i.e., from opposite ends of a passage. Here our main circuit, the 3 globes in parallel are going to stay the same and we are going to change how we control them. A 2-way switch differs from a 1-way switch in that it has 3 connection points at the back as opposed to 2. The switch doesn't have an on and off state so there is no indicator on these switches, they just change the direction of the current. Connect the Live to the common (C) of switch 1, strap numbers 1 and 2 of the 2 switches to each other and use the common (C) of switch 2 to return the live to the globes. We call the wires between the 2 switches the "strappers" and they are usually wired with a different colour to be easily identified. The return live from the 2nd switch's common point we call the "return" and usually use a white wire for it.

4) 3 Globes in Parallel controlled by 2-Way Switching:



Intermediate Switching: Sometimes known as 3-way switching. Here we need to add an Intermediate switch between the 2-Way switches. An Intermediate Switch has 4 contacts on the back numbered 1,2,3 and 4. Now split the strappers between the 2-way switches on your previous circuit, connect 1 and 2 of the first 2-way switch to 1 and 2 of the intermediate switch and connect 3 and 4 of the intermediate switch to 1 and 2 of the second 2-way switch. The rest of the wiring should stay the same. Now we can switch the 3 globes in parallel from 3 different positions. To switch from more places just keep adding intermediate switches between the 2-way switches. These switches, the 2-way and the intermediate switch are designed to change the direction of current flow, sometimes the circuit will be closed, and the globes are on, and sometimes the circuit will be open, and the globes will be off.

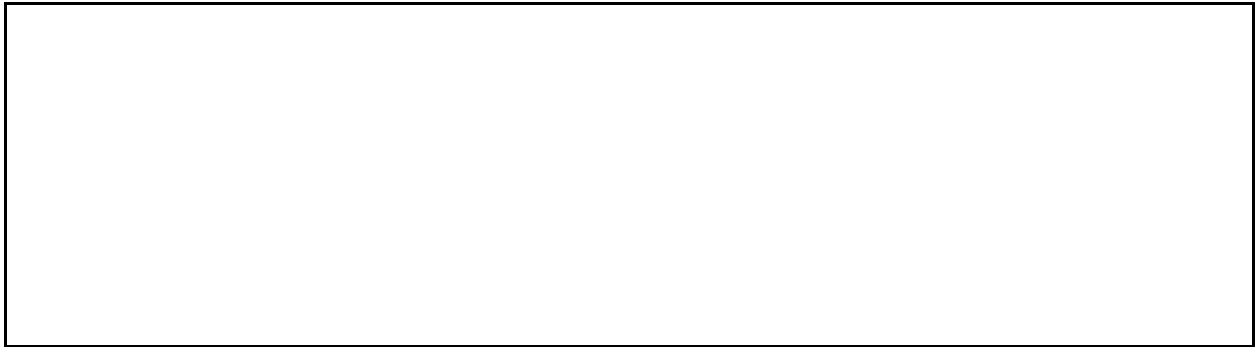
5) 3 Globes in Parallel controlled by Intermediate Switching:



Day/Night Switch: A Day/Night switch, sometimes called a day/light switch has a Photocell sensor switch that detects when it is getting dark and automatically switches the lights on. The next morning it will detect that it is getting light again and will automatically switch the lights off. The Day/Night switch has an electronic board inside which needs to be powered, so attach the live and neutral to it and connect the load (globes) to the load wire, use the diagram supplied with the switch as the colour of the wires on the switch may differ depending on where it was imported from. This switch has a current rating so be sure to check that you purchase one that can manage the load you want to connect to it.



6) 3 Globes in Parallel controlled by a Day/Night Switch:



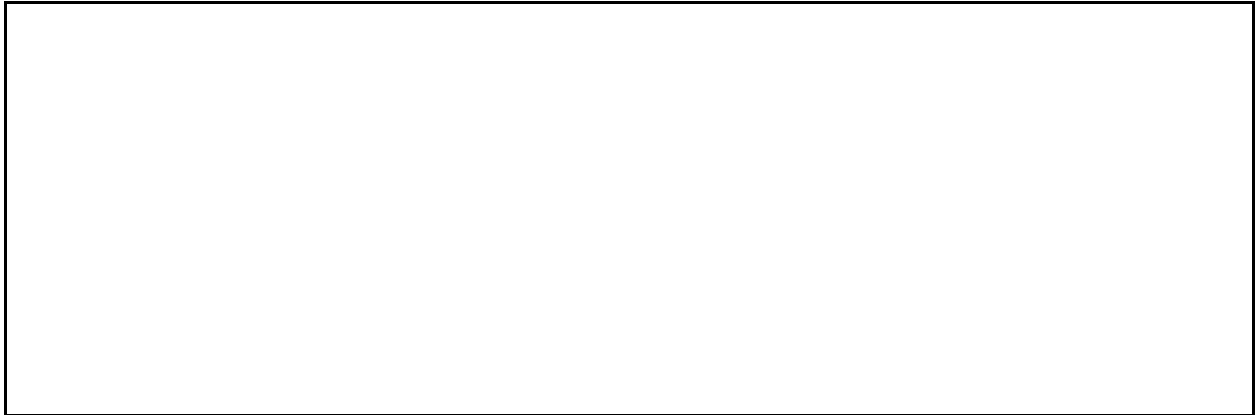
Day/Night Switch with a By-Pass Switch: Let's say we want to control the globes with a switch as well that would by-pass the day/night switch, all we need to do is create a new path for our current to flow to the globes with a switch in it. This current path will need to be in Parallel with the day/night switch. So now we can switch the globes on and off with the switch and it can be switched automatically by the day/night switch. The switch will have to be off for the day/night switch to control the globes automatically.

7) 3 Globes in Parallel controlled by a Day/Night switch and a By-Pass Switch:



Geyser Timer: We covered the working of this timer on page 37. Connect the timer to 3 lights in parallel. The timer needs power to operate like any alarm clock, so connect live to number 1 and neutral to number 2. Supply number 3 with live as well as this is the live in of the switch, connect number 5 to the globes, this wire is white as it is the return. The programming instructions come with the timer when you buy it, they differ from timer to timer. Program the timer to switch the lights on and off at a certain time.

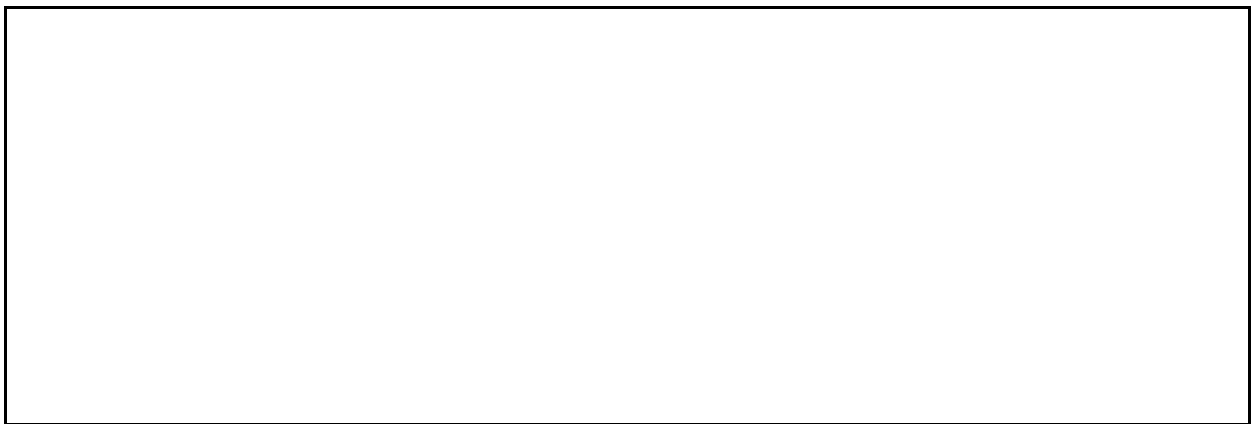
8) Connect 3 Lights in Parallel to a Geyser Timer:



LED Strip Lights: This is a strip of LED lights that can be stuck down with double sided tape. They come in many different sizes and colours. On the strip itself you can see what the wattage will be per meter used, it often comes in roles and can be cut to the desired length. These lights need a driver for them to operate, many other LED lights have the driver built into them already, hence the price. The driver is also rated in Watts and needs to be able to handle the load of LEDs you're connecting to it. The driver drops the voltage from 230V Alternating Current (AC) to 12V Direct Current (DC). Alternating Current is shown with L for live and N for neutral, Direct Current is shown with a + for positive and a - for negative or ground. Connect the live to the live in of the 1 way switch, take the return (white wire) to the live of the driver and connect the neutral to the driver. Connect the + of the driver to the + of the LED strip and the - of the driver to the - of the LED strip.



9) Connect a LED strip light to a Driver controlled by a switch:



Dimming Lights: Sometimes we want to dim the lighting in a room for atmosphere or whatever reason. To dim a light or lights we need a dimmer connected to the correct switch, often a bell press switch and then the globes, if LED, they need to be dimmable. A dimmer changes the voltage waveform supplied to the light which dims and brightens the light. To switch the lights on you need to press the switch once, to change the brightness you need to hold the switch in once the lights are on, release the switch when the desired brightness is reached. Press the switch again to turn the lights off. There are different types of dimmers available and again you need to purchase one that is rated for the correct wattage for your lights. Connect the live to the red wire on the dimmer and connect the yellow wire to the light with a white wire as the return. Connect the orange and pink wires to the bell press switch with a red wire to supply and a white wire to return, doesn't matter which way around as it only gives a signal to the dimmer.



Dimmer Module



Bell Press Switch



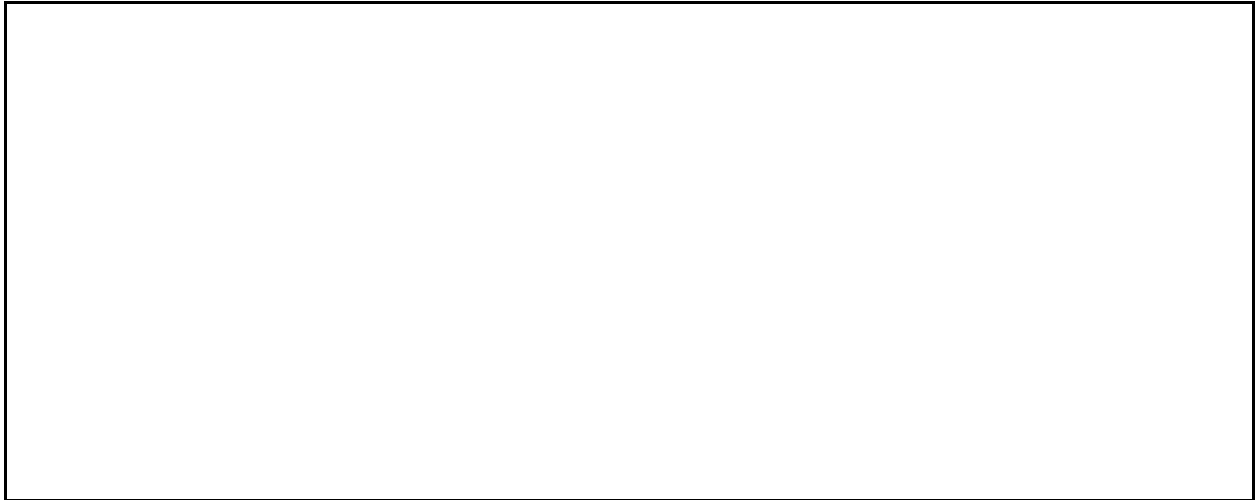
Down Light

10) Connect a dimmable LED down light to a Dimmer controlled by a Bell Press switch:

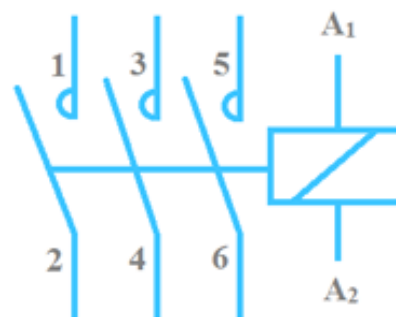


2 Way Dimming: 2-way dimming works the same as normal dimming but from 2 different positions. The lights stay the same and we will still only use 1 dimmer module, we will however need 2 bell press switches. The switches need to be connected in parallel with each other. The operation of the circuit stays the same as well except from 2 different places. Bridge the second bell press switch with a red and white wire.

11) Connect a dimmable LED down light to a Dimmer controlled by 2 Bell Press switches:

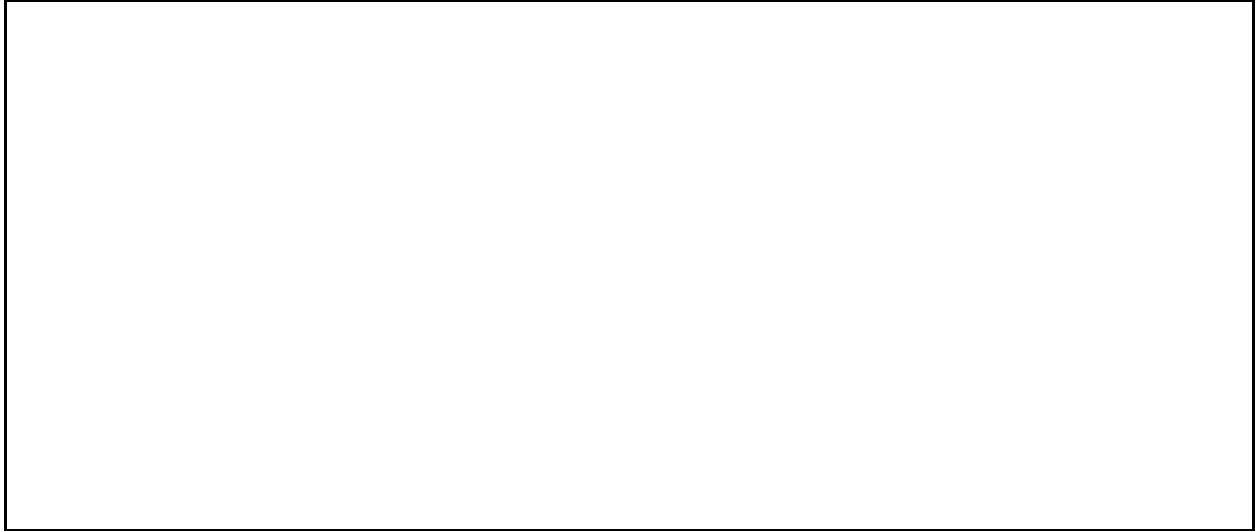


Contactor: A contactor is made up of 2 different components, the coil (Labelled A1 for live and A2 for Neutral) and a set of 4 contacts which are normally open contacts. When the coil is energised, or given power, it produces a magnetic field which attracts the contactor core to the armature and at the same time closes the contacts. The coil is controlled in the control circuit while the contacts operate in the main circuit. For example, we can control the coil with a timer while wiring the geyser through the contacts to carry the load. Contactors are widely used in motor starters. Contactors also have a current (Amp) rating so be sure to buy the correct one. A contactor is designed to have auxiliary attachments connected to it, for example a timer or extra contacts.



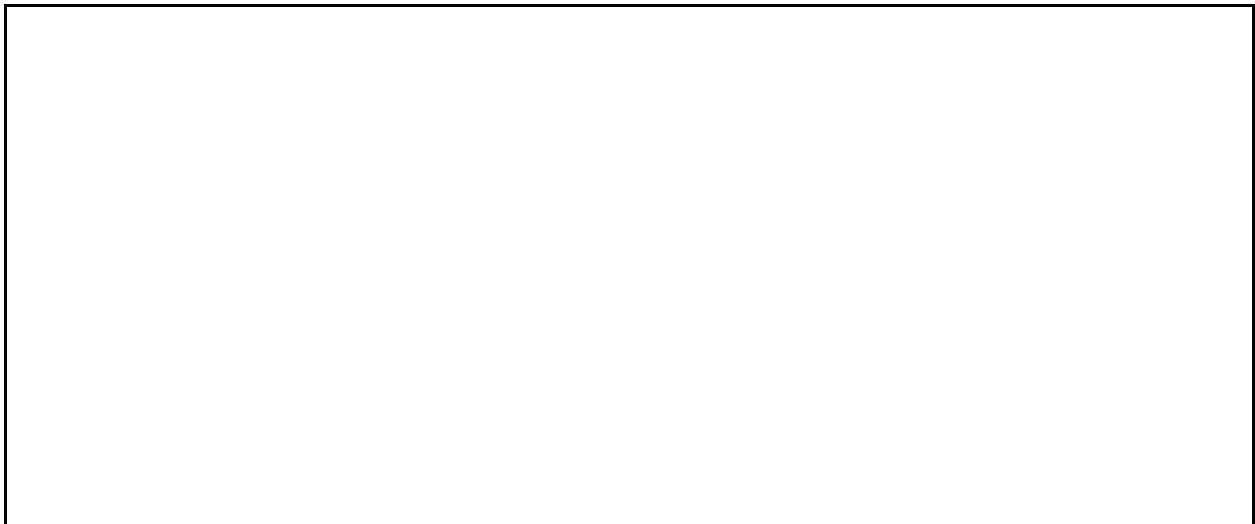
Contactor Symbol

12) Connect 3 lights, each through their own contact of the Contactor controlled by a 1-way switch:

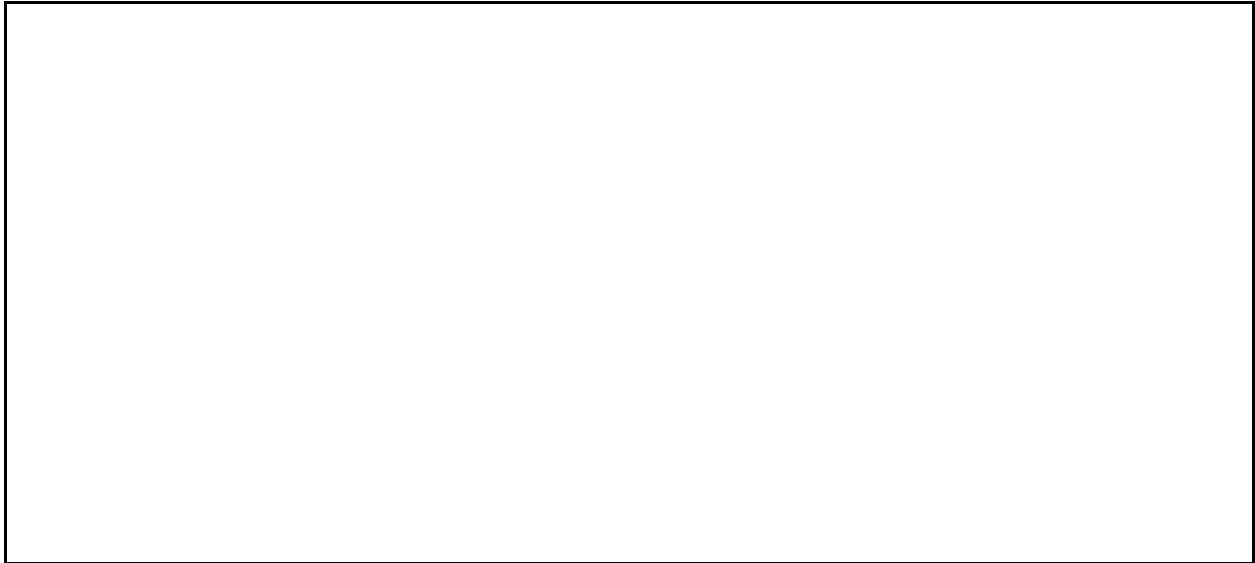


Retaining Contacts: On the contactor we have 4 sets of contacts, the first 3 sets are used for the main circuit switching the 3 lines in a 3-phase circuit, the fourth contact is used to retain or hold our circuit. (We only cover single phase in this course.) The coil of the contactor needs constant power to stay energised and is often energised by a start button which is spring loaded like our Bell press switch. We use the fourth set of contacts on the right-hand side to retain the power onto our coil. Often, but not always labelled 13 and 14.

13) Connect 3 lights, each through their own contact of the Contactor controlled by a Bell press and retained with 13 and 14 of the Contactor:



14) Connect 3 lights, each through their own contact of the Contactor controlled by a Geyser Timer:



Stove Switching: A stove switch is a rotary switch which is designed to give multiple switching positions with 1 switch. In this course we will look at 3-Heat and 5-Heat stove switches. Instead of using elements, we are going to connect lights to demonstrate the outcomes.

A 3-heat stove switch has 4 positions, 0 for off, 1 for low heat which will connect the 2 lights in series with each other giving us a dimmer light (as seen when doing our series circuits) and low amps. Position 2 for medium heat will connect only 1 light and will shine brighter than position 1 with higher amps while in position 3 for high heat the switch will connect the 2 lights in parallel giving off the most light and drawing the highest amps.

Draw the 3-Heat stove switch and the connections below and wire it on the panel.



A 5-Heat stove switch works on the same principle but has an extra 2 heat positions. This switch is connected to 3 elements and again we will use lights to demonstrate the outcomes. Position 0 is off, and no connections are made. Position 1 will connect the 3 lights in series again giving dim light and low amps. Position 2 will connect 2 lights in series shining slightly brighter with higher amps. In position 3 only 1 light will shine but still a bit brighter than position 2 and higher amps. Position 4 will connect 2 lights in parallel again shining brighter than position 3 with even higher amps while in position 5 the 3 lights will all be connected in parallel giving off the most light and drawing the most amps.

Draw the 5-Heat stove switch and the connections below.



Wire Ways:

All cables and wires need to be concealed to protect them from dirt and moisture and to keep them out of peoples reach for safety. There are many different methods to lay electrical cables but here we will only cover a few that are common in our homes. These wire ways have been designed to make maintenance and new installations easier. The most common wire way is PVC Conduit, it comes in different sizes with the most common being 20mm. There are a variety of junction boxes and bends available to simplify the installation. These conduit pipes can be either surface mounted or built into the walls. Inspection lids are available on most bends and joint boxes to assist with wiring and inspection of cables. The conduit can be bent with a bending spring in cases of bends, obstacles and off sets. A fish tape is used to pull the wires through the conduit. Sprague or Flexible Conduit is an easily bendable conduit and can be used with the same fittings.



PVC Conduit



PVC Conduit Fittings



Bending Spring



Fish Tape



Sprague or Flexible Conduit

Fault Finding:

A very important aspect of electrical work is fault finding and fixing, if you're not an electrical installer then you will probably do electrical fault finding and repairing. This task can be simple if your understanding of electricity and the circuit you're working on is good, otherwise it can be dangerous and complicated. The first important step is to know what the circuit needs to do or what needs to happen. If possible, get a diagram for the circuit or draw your own if it's a complicated one, it will give you a different perspective on the problem. Use the steps of elimination when fault finding.

Remember we spoke about control and main circuits, normally a fault is notified by the main circuit not working, for example the light doesn't light up or the water doesn't get hot in the geyser. Often the fault lies in the apparatus that doesn't work like the globe that might have blown or the geyser element being ruptured. But this is not always the case, here we need to do more diagnosing to find the fault before we can repair it. The fault could be a broken or burnt off wire somewhere preventing the voltage from powering the device, it could be a broken switch or something else in the control circuit.

There are 2 ways to identify a fault, test for voltage and/or check the continuity of the circuit. For this we will need a multimeter to test both. Start by analyzing the circuit and identify what is not happening that should happen. Ask the client if you can or switch the circuit on yourself and identify the fault before trying to find the cause. I find it easier to work off the diagram as a schematic trace of the circuit.

Let's use the light circuit as an example to understand how to do fault finding. Firstly, on the light circuit, the most obvious fault would be the globe that's blown, so take it and if it's filament globe test the continuity of the filament, if it's a LED globe either replace it or try it in another light to see if it works. If you find that the globe is not the problem, then you need to test the circuit. Put the power on to the circuit and start by checking the voltage supply between the live point of the light fitting and the neutral point with no globe in it. Be careful when working with live electricity, make sure you isolate yourself with rubber soled shoes and protective gloves. Make sure the switch is in the on position to close the circuit. You should read 230V at this point, if not there is a break (loose connection) in the circuit.

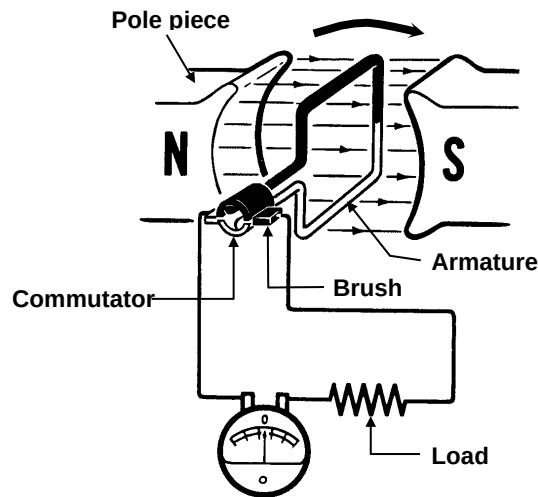
Next step you can do is test between the live point of the fitting to an earth point where you should also read 230V, this is to eliminate the neutral wire being disconnected, in other words, if you do read 230V between Live and earth, your neutral wire is faulty. If you don't get 230V then the supply live wire is the cause. The fault could be between the circuit breaker and the switch or on your return from the switch to the light fitting. To eliminate the supply to the switch, test between the live point at the switch and a neutral or earth point, you should get 230V, if not you know that the supply wire is your fault. If you do get 230V at this point, then the return wire is faulty.

If you choose to work with no power on the circuit, you can test the circuit on the ohm scale and test for continuity between all the points. For this type of testing, you may need to extend the leads of your multimeter to reach from the distribution board to the light fitting. Connect one lead to the bottom of the light circuit breaker, make sure the circuit breaker is off, and the other end to the live of the light fitting, make sure the light switch is in the on position to close the circuit. If you get continuity (low reading or beep) between these points you will know that there is no fault there. If you find it's an open circuit (OL on tester for Open Loop) then test your return wire from the switch to the live point of the light fitting and then from the circuit breaker to the switch. Test your neutral from the neutral point of the light fitting back to the neutral bar in the distribution board. Once you've found the break in the wiring, repair it and test that the light is working before leaving.

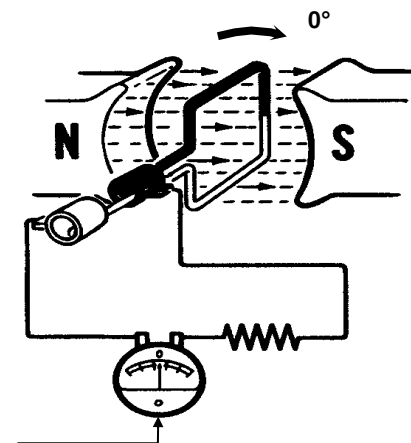
Generating Electricity:

Today electricity is generated in different ways but besides solar energy the principle is the same. When a magnet is moved past a conductor in a closed circuit a current is created in the conductor. Moving the magnet changes the magnetic field around the wire, and the changing magnetic field pushes the electrons through the wire which is current flow. If you stop moving the magnet the current will also stop as there is not a changing magnetic field present. A generator turns a coil of wire known as an armature between magnets generating electricity in that coil. We can either keep the magnets still and turn the armature or we can keep the coil of wire stationary and spin the magnets around or in the coil. We use water, air, steam or motors to turn the armature and thus convert mechanical energy into electrical energy. The difference between Alternating

Current (AC) and Direct Current (DC) is the way we draw the power from the armature. For AC we use Slip Rings as the commutator and for DC we use Split Rings as the commutator. We use brushes to connect the circuit to the generator.



Direct Current Generation



Alternating Current Generation

Solar energy: Solar technology converts sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation. This energy can be used to generate electricity or be stored in batteries or thermal storage. Solar generates Direct Current and needs to be inverted into Alternating Current before it can be used in our homes.

Batteries:

A battery is a device that stores chemical energy and converts it to electrical energy, it is a common source of electrical power, however, it differs in the type of current supplied by it. A battery supplies a Direct Current (DC) as opposed to the Alternating Current supplied to our homes. Batteries are a portable source of electricity, think of your cell phone, torches, electric cars, portable power tools and much more. The basic power unit inside a battery is called a cell, and it consists of three main components. There are two electrodes (electrical terminals), and a chemical called an electrolyte in between them which is all packed into a metal or plastic case for our protection. There are two electrical terminals, one with a plus on it for positive and the other with a minus for negative, they are for access purposes and are connected internally to the electrodes. The difference between a battery and a cell is that a battery consists of two or more cells hooked up internally, so their power adds together.

There are many different types, shapes and sizes of batteries rated in Volts (V) and Amp Hours (Ah) which is the capacity. The voltage refers to the amount of output voltage available from the battery while the Amp Hour or capacity is an indication of how many Amps can be drawn from the battery in an hour. Normally the bigger the battery the more electrolyte it can hold and the longer it will last, in other words the higher the Amp Hour.

Batteries are divided into 2 groups: primary batteries and secondary batteries. Primary batteries are disposable and can only be used once and then discarded of. They are made of Zinc Carbon and Alkaline. Secondary Batteries are designed to be recharged once they go flat, this saves you having to purchase new batteries all the time and could save you a lot of money. They are typically made of Lead Acid, Nickel-cadmium (NiCd, pronounced nicad), Nickel-metal-hydride (NiMH) and Lithium-ion. Lead Acid is mostly used in cars with 12 Volts or 24 Volts while Nickel-cadmium commonly operates at 1.5 Volts and replaces the normal disposable batteries used in toys and torches etc. This battery is known to build a “memory” and needs to get completely flat before recharging. Nickel-metal-hydride batteries are similar to Nickel cadmium but have less of a “Memory” effect. Lithium-Ion batteries are the latest technology and do not have the “memory” effect, they are commonly used in cell phones and laptops etc.

Connecting Batteries in series or parallel will make a difference to the voltage and the capacity. In series the voltages will get added together and the capacity or amp hours will stay the same while in parallel the capacities will get added together and the voltage will stay the same. The total available energy will however be the same in both these connections. Let's see the calculation: Energy (in watt hours) = Volts x Amp hours.

Let's take two 1.5 volt, 1mAh batteries and connect them in Series. Add the voltages together, $1.5V + 1.5V = 3V$, we know that the capacity stays the same.

$$\text{Energy} = 3V \times 1\text{mAh}$$

$$\text{Energy} = 3\text{mAh}$$

Let's connect the same batteries in Parallel. Now the Voltages stay the same and the Capacities get added together, so voltage is 1.5V and the capacity will be

$$1\text{mAh} + 1\text{mAh} = 2\text{mAh}.$$

$$\text{Energy} = 1.5V \times 2\text{mAh}$$

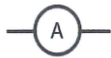
$$\text{Energy} = 3\text{mAh}.$$

After seeing these calculations, you can see that if you need a higher voltage you need to connect the batteries in series but if your need is for more capacity, you should connect them in Parallel.

Symbols:



Earth (E)



Ammeter (A)



Voltmeter (V)

N

Neutral

L

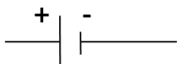
Live



Alternating Current Supply (AC)



Direct Current Supply (DC)



Battery



Conductor



Connecting Conductors



Double Pole Isolator



Connected Conductors Crossing



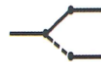
Non-Connected Conductors Crossing



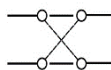
Light



Single Pole Switch



Two-Way Switch



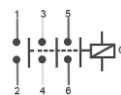
Intermediate Switch



Circuit Breaker (Single Pole)



Circuit Breaker (Double Pole)



Contactor



Timer coil



Thermostat Switch

Closing

I trust that you have enjoyed the course and have learnt a lot about how your house is wired and why. Some of you may want to further your career as an Electrician and there are opportunities available to do so. Apprenticeships are available where you cover what we've done here plus much more and in greater detail. In this course we only covered single phase electricity, 3 phase electricity is the next step and just gets more interesting with the likes of motors and starters. Transformers and supply of electricity as well as PLC and electronics and much more is taught in the full apprenticeship, and it ends with a Trade Test and a Red Seal qualification as an Electrician.

Always Remember- Test before working on electricity...

Exercise Answers

1 A – 0.87A

1 B – 200.1W

1 C – R130.48 per Month

2 A – 1001.1W

2 B – 12.771A

2 C – R40.77 per Month

3 A - 80Ω

3 B – 1.875A

3 C – 46.875V, 75V, 28.125V

4 A – 20 Ω

4 B – 7Ω, 13Ω

5A – 5.882Ω

5B – 34A

5C – 20A, 10A, 4A

6A - 5Ω

6B – 24A

6C – 12A, 8A, 4A

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