Level 2/3 Award in Hybrid Electrical Vehicle Routine Maintenance Activities and System

LKQ Academy

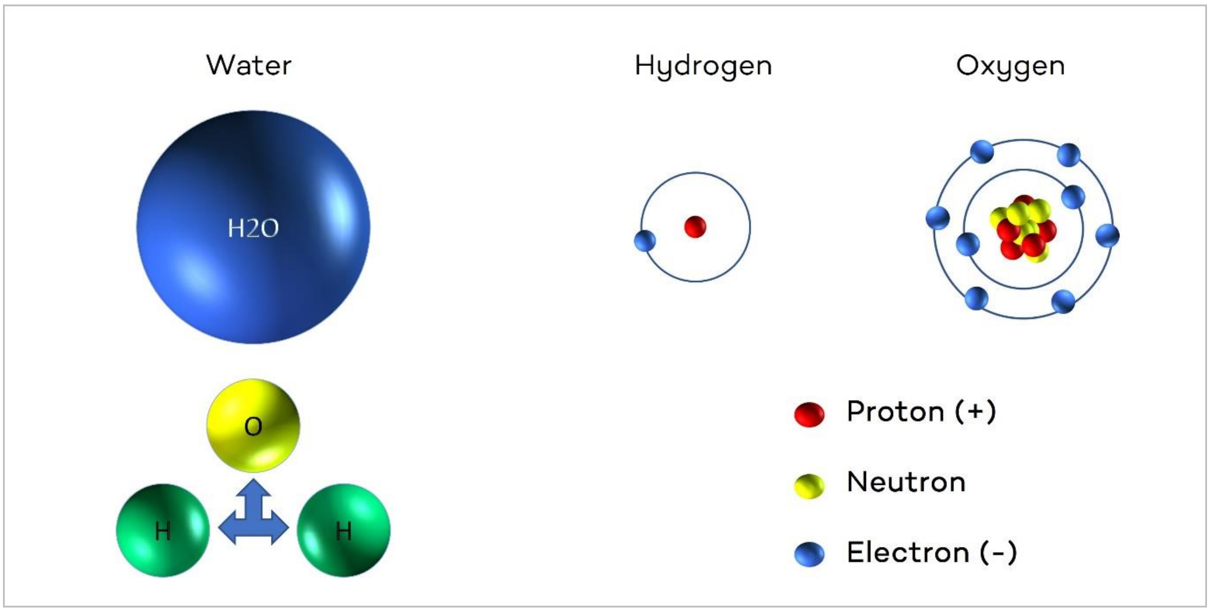
Repair and Replacement

Pre-course Self Study Module

Contents

1: Fundamentals of Electricity

1.1: Electrical Energy



Electricity is a form of energy that we can define as the movement or flow of electric charge. But how do we control its movement?

We must look at science and nature. Every tangible object contains molecules which in turn are a combination of atoms. Naturally occurring atoms are composed of Positively charged Protons, and Neutrons which have no charge. They bond together to form a positively charged Nucleus.

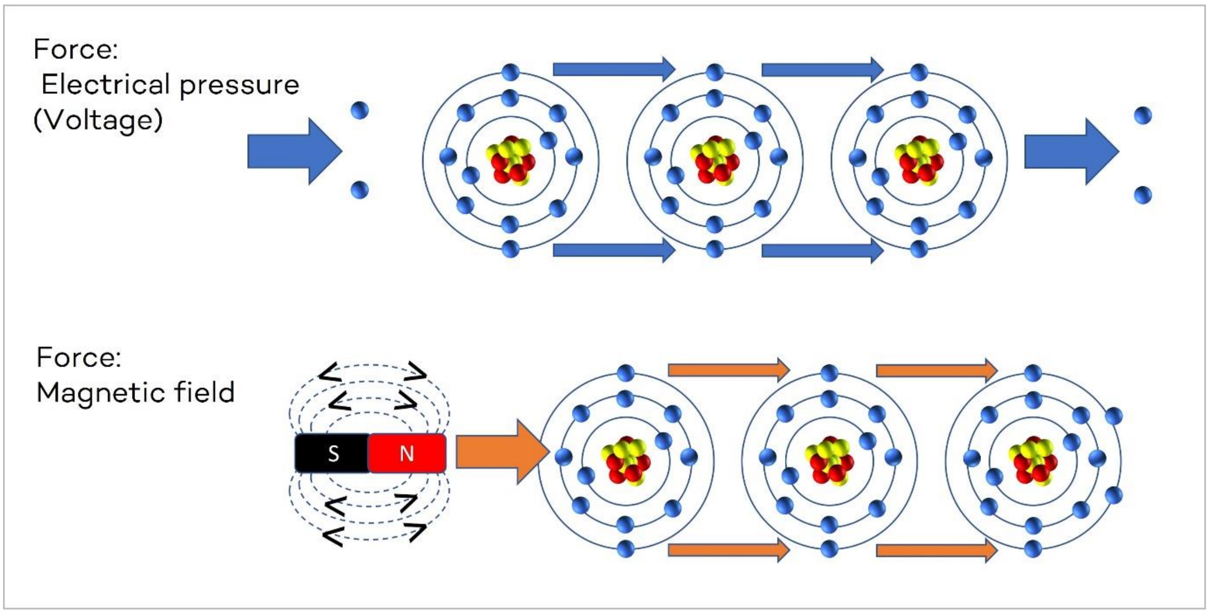
To balance the atom, an equal number of negatively charged Electrons sit in orbit around the Nucleus, arranged into shells. The shell closest to the Nucleus have the strongest bond. The electrons orbiting in the outer shell have a weaker bond and are named Valance electrons.

The number of Protons and Neutrons define the properties of that atom (The substance). In the example above we have a Hydrogen atom which has only one proton and one electron. An Oxygen atom on the other hand has eight protons, eight neutrons and eight electrons.

When placed near each other, the electron of the Hydrogen atom is attracted to the proton of the Oxygen atom, the atoms bond together to create a different substance, in this case water!

Remember the valance electrons? We use these to transport electrical energy.

Movement of Electric charge



The valance electrons will move from one atom to another if we apply a force. The amount of force needed to make this happen is relative to the bonding strength between the electrons and the nucleus.

Atoms with a weaker valance electron bond (Copper for example) make good Conductors. Atoms with a strong bond (Glass for example) make good Insulators.

If we apply electrical pressure as a force to a length of copper wire, the valance electrons will move from one atom to the next. This is how we move electrical energy.

Electrical pressure is represented by the term Voltage, the higher the voltage the higher the pressure, the greater the force being applied.

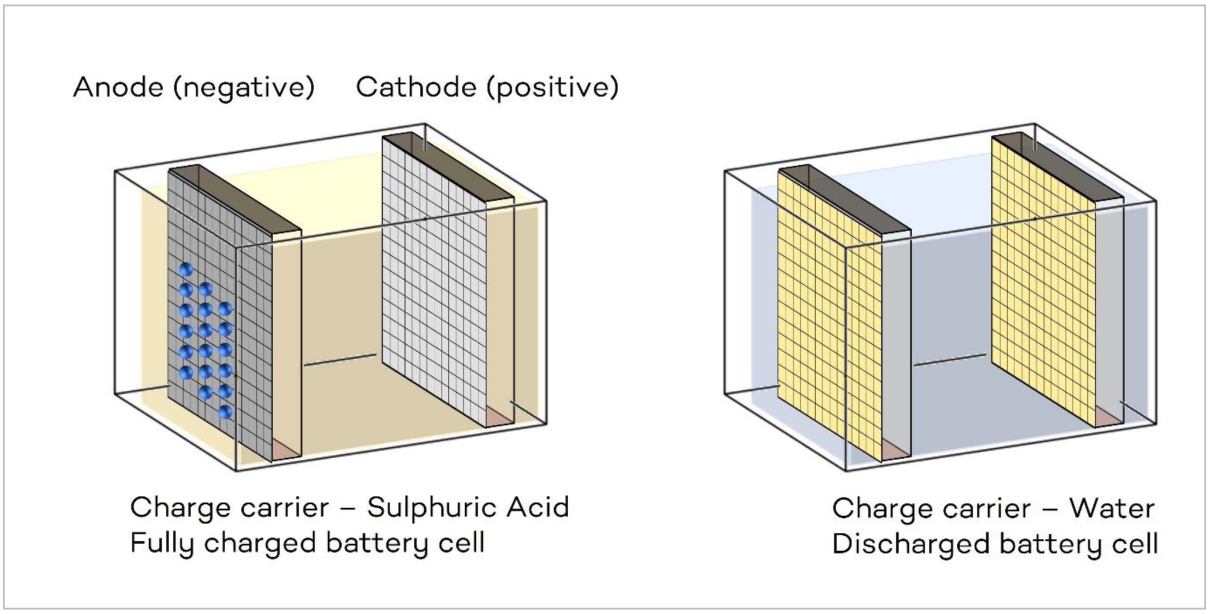
Voltage is measured using the unit Volt. The range can be as little as 1 Volt (1000mV) up to and exceeding a Million Volts (1 Megavolt).

If we place a magnetic field close to a length of copper wire (magnetic force) the valance electrons are repelled or attracted to the magnetic field and will move. In effect creating electron pressure at one end of the wire. Take the field away and the electrons will naturally migrate to balance the electron pressure in the length of wire.

This action is often referred to as Electro Motive Force (EMF). An electrical action caused by a non-electrical source.

This relationship between magnetic force and electron movement is especially useful. We use this reaction to create the movement of electrical charge or in other words, generate electrical energy.

1.2: Energy Storage



To make use of electrical energy within the automotive world we need a reserve of energy, and that reserve must be replenished as we use it. The battery supplies a solution to this issue.

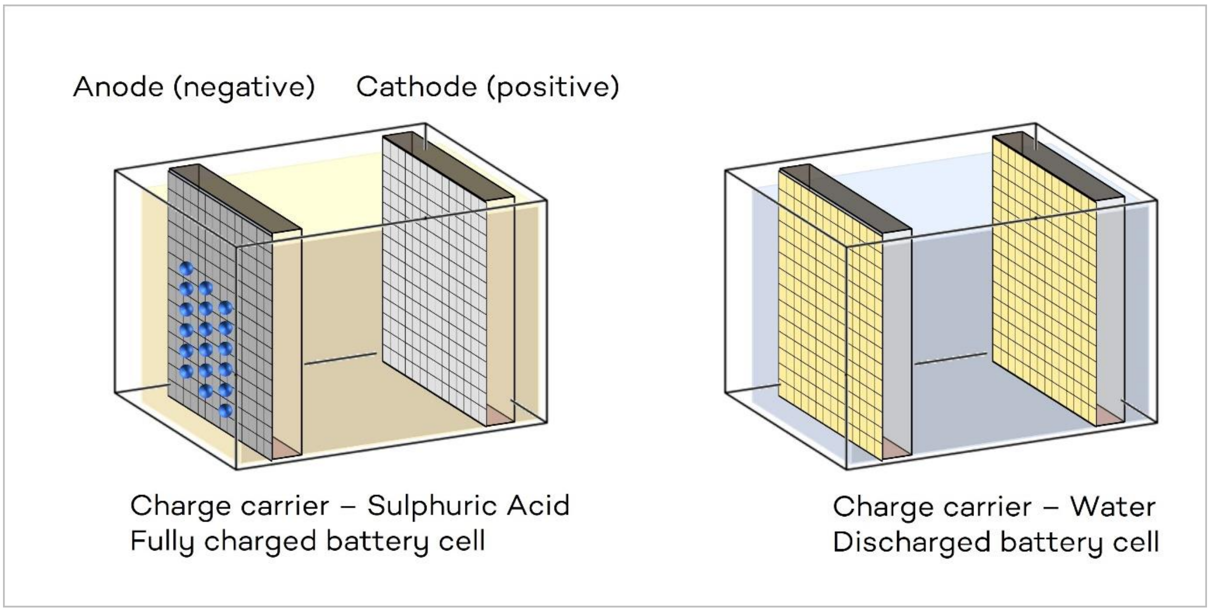
Energy is stored in a battery using a chemical process, this process is reversible allowing the possibility for replenishing the reserve as and when we need.

A standard Lead Acid battery is made up of six cells, capable of storing around 2.2 volts of electrical energy. The cells are connected in series giving a total output of around 12.8 Volts.

Each cell is constructed with two plates, a negative (Anode) and a positive (Cathode). The plates are emersed in a liquid which supplies a method for carrying electrical charge (Electrolyte).

The anode is constructed from porous Lead, the cathode is constructed from Lead Oxide. In the discharged state, each plate is covered with a layer of Sulphate crystals.

Using a suitable charger, we supply an electrical pressure (electrons) to the positive plate. The positive plate now has too many electrons and electrical pressure starts to build. The movement of the valance electrons allow the oxygen atoms of the Lead Oxide plate to become attracted to the Sulphate atoms and the water molecules. They combine to form Sulphuric acid.



The porous Lead negative plate (Anode) absorbs the charged Oxygen atoms from the electrolyte to become Lead Oxide. As this chemical change occurs the negative plate builds up an excess of charged electrons.

The Electrolyte is also electrified, this in turn creates a resistance. This resistance prevents movement of valance electrons, so when the charger (electrical pressure) is removed the charged electrons are held in place on the negative plate.

In nature, pressure always tries to stay balanced. In a charged state we have an unbalanced condition, the negative plate is holding a greater electrical pressure than the positive plate.

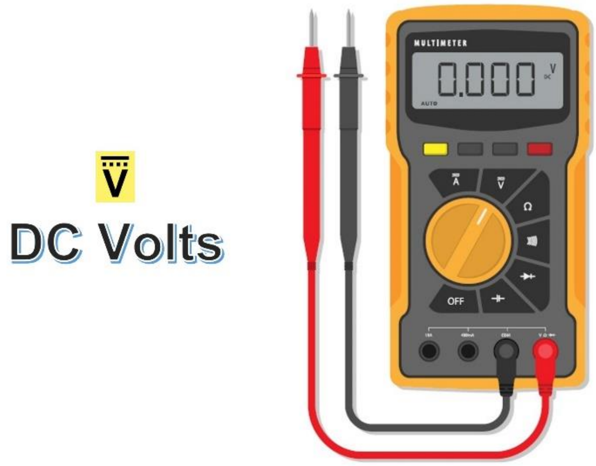
The stored energy has nowhere to go so remains still (static), however the electrons possess the potential to deliver energy when they are allowed to move (Kinetic). The only place the stored energy wants to move towards is the positive plate so both plates become balanced.

The negative plate has a greater potential than the positive plate. In electrical terms this is referred to as potential difference. Potential difference is the method used to get energy to move from one side of the battery to the other, all that is needed is a path with no resistance for the energy to follow!

When a path is created, charged electrons will flow from the negative plate to the positive plate. This continues until each side of the battery has an equal potential therefore electron flow will stop. The battery is discharged!

The chemical reaction is the reverse of the charging process. As the battery discharges, the negative, lead oxide plate gives up the oxygen atoms to become lead. The positive plate absorbs Oxygen atoms to become Lead Oxide. Sulphate from the acid forms crystals on both plate surfaces, the acid electrolyte weakens.

State of Charge (SOC)



100%	>12.7 Volts
90%	12.6 – 12.7 V
80%	12.5 – 12.6 V
70%	12.4 – 12.5 V
60%	12.3 – 12.4 V
50%	12.2 – 12.3 V
40%	12.1 – 12.2 V
30%	12.0 – 12.1 V
20%	11.9 – 12.0 V
10%	11.8 – 11.9 V
0%	< 11.8 V

The State of Charge of a battery is the measurement of the amount of energy available from the battery. The measurement is often represented as a percentage.

As the battery discharges the pressure on each side of the battery equalises. There is no potential difference between the two sides, so we no longer have any push to move energy.

We can measure the potential difference between the positive and negative side of a battery using a voltmeter. The energy will only move in one direction, either into, or out of the battery. Known as Direct Current, so we must set the measuring tool to the correct setting.

The table above gives an indication of the State of Charge relative to the measured Voltage.

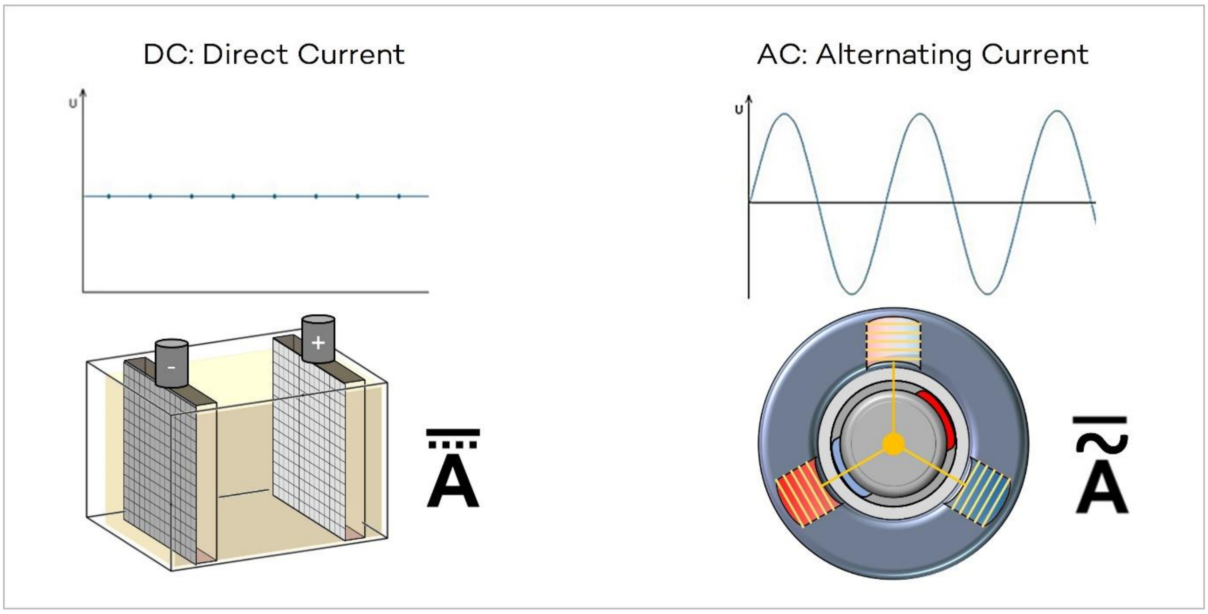
The State of Charge supplies a guide as to how long the battery can support a constant energy supply. This is a sign of the battery's capacity – the quantity of energy stored in the battery.

This measurement becomes vitally important when we are charging batteries. Remember a chemical process occurs inside the battery and this takes time to achieve.

Most modern battery testers will calculate the State of Charge of a battery and is a good indicator of the overall capacity and health of that battery.

Note: For accurate results, measure the battery voltage with a voltmeter when the battery is disconnected (Open circuit Voltage).

1.3: Current flow



When a conductive path is created between the negative and positive plates of a battery, the electrons will move! This process will continue until the plates have an equal potential (electrical pressure).

The quantity of electrons that pass a reference point in one second can be measured. (6.241509074x10^{18}). The unit is the Ampere, and we express this as Amps.

Often identified by the letter "I" (I = intensity)

1 Amp = 1000mA (milli amps) or 0.001 Amps

As the movement of electrons in a battery is in one direction, we refer to this type of current as Direct Current.

When we look at a generator though, the current moves in both directions. We refer to this as Alternating Current. (The current moves forwards when positive and then moves backwards when negative) This is the normal output of generators because of the way the mechanical energy is turned into electrical energy.

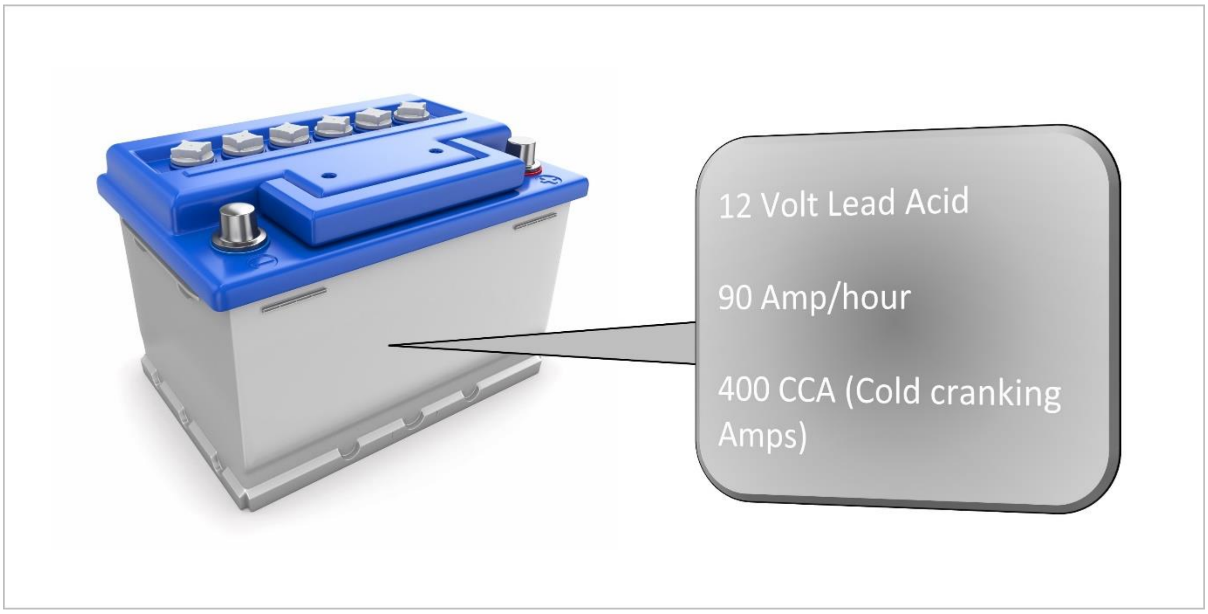
We can measure both types, we need to be careful that we have set the Ammeter to the correct setting.

An AC output produces a repeated sine wave or cycle (Climbs from neutral to a peak positive voltage, drops back down to neutral, descends to a negative peak voltage and then rises back to neutral). The quantity of complete cycles in one second are expressed as the frequency and displayed using the unit Hertz.

For example: 1 cycle/second = 1 Hz while 1000 cycles/second = 1000 Hz

Tip: To measure current we place the Ammeter in the circuit (series) to allow the current to pass through the meter. (Alternatively, an inductive Amps clamp works well)

Battery Capacity (State of Health SOH)



Returning to the energy reserve we can now make sense of the battery rating figures.

The 12 Volt lead acid simply defines the type and construction of the battery. It has been designed to deliver 12 Volts of electrical pressure, so all the consumers of that energy are designed to work with the specified voltage.

The Lead acid label tells us what type of battery charging equipment is needed to charge the battery. There are distinct types of battery construction, each having a unique charging requirement or programme. We can damage a battery if we apply the wrong charging method!

The Amp/hour information:

In basic terms this specification relates to the quantity of energy the battery has been designed to store. In a perfect environment the battery in this example should be able to deliver the following:

The State of Charge is 100%

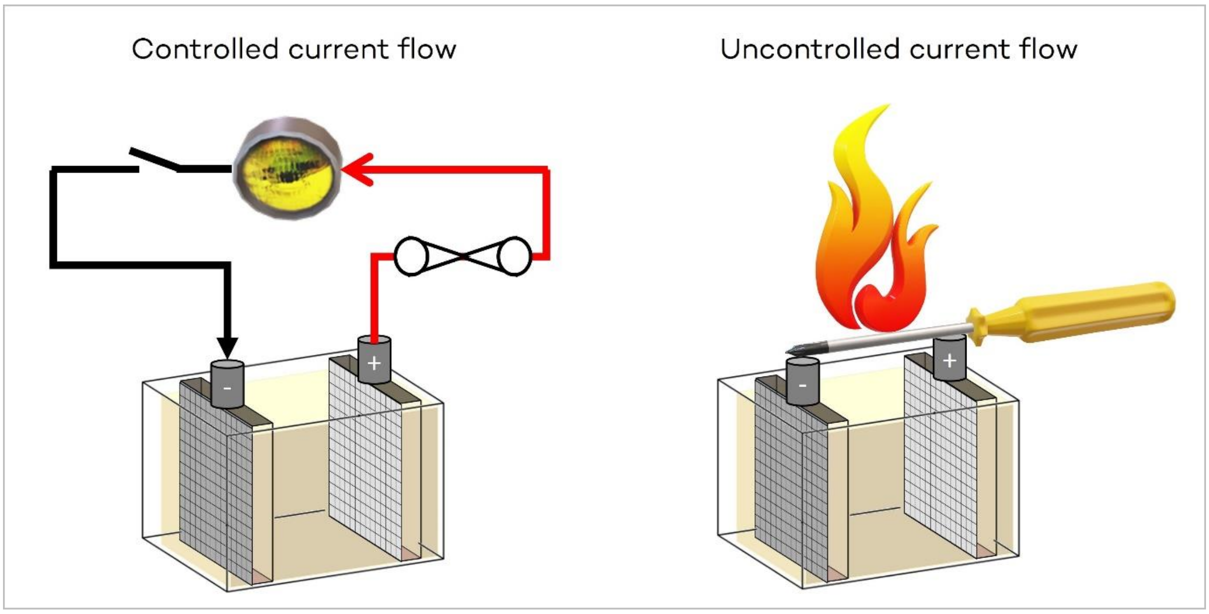
12 Volts of constant pressure

90 Amps of current for one hour – or one Amp of current for 90 hours.

Cold Cranking Amps – the maximum quantity of current that can be delivered by the battery in one go – (Starter motor draw when the engine and battery are cold)

The battery is subjected to various influencing factors such as temperature changes, the state of charge, the battery age for example. It is unlikely to achieve the figures quoted repeatedly!

1.4: Resistance



Conductor: A substance that allows the movement of an electric charge. The Valance electrons have a weak bond with the Nucleus.

Insulator: A substance that resists the movement of an electric charge. The valance electrons have a strong bond with the nucleus.

Resistance: Is the measurement of opposition to current flow – Measured using the unit Ohms (Ω).

Electricity, stored in a battery possess a large quantity of energy (potential). When a path is supplied which allows the flow of electric charge, energy is released. Electricity travels at a similar speed to light (300,000,00 metres/second) so as the electrons fight for a place within that path they are subjected to a force (Friction). Electrical energy is converted to heat energy and a thermal event occurs!

In the electrical world, this condition is referred to as a Short Circuit. The energy travels from one side of the battery to the other with little resistance – the time of the journey is short!

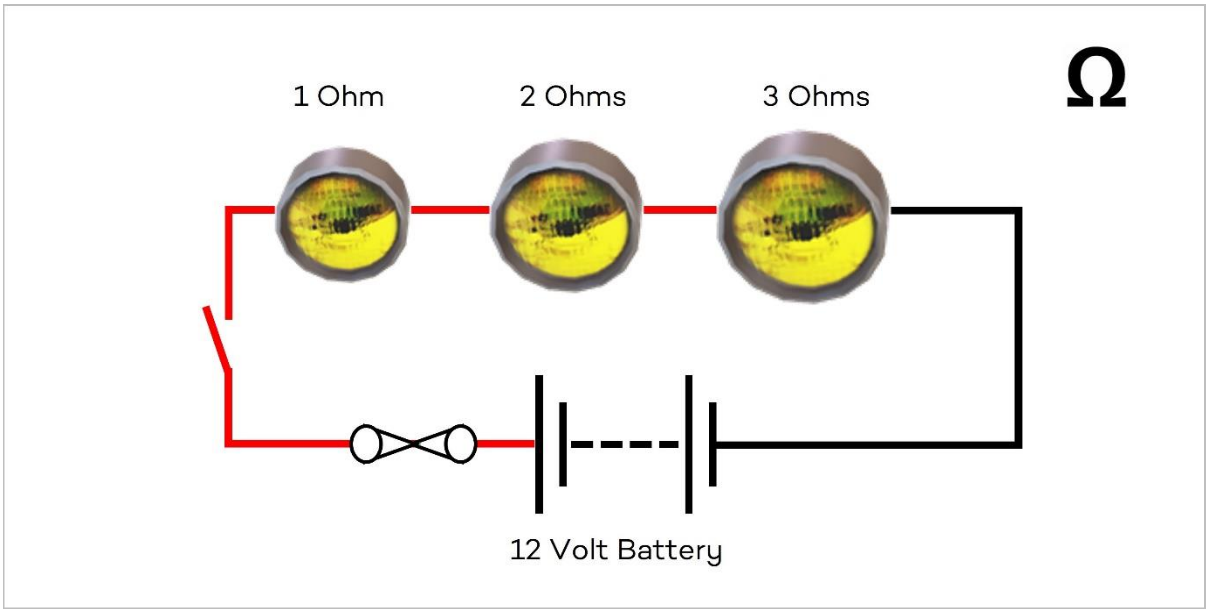
To prevent this occurrence Resistors are used to control the flow of electric charge. They supply a method for slowing down the flow of electric charge so that the electrical energy can be used safely.

In the example above, the resistor in the circuit is the bulb itself.

To protect the circuit from accidental short circuits a fuse is installed close to the power source. The fuse is designed to melt faster than the wiring or components. Once the fuse has melted the circuit has a hole in it and current flow stops.

This is referred to as an Open Circuit – the resistance is incredibly high as air is a good insulator!

Circuit properties – Series and Parallel (Effect on resistance)



Series Circuit:

In a series circuit there is only one path for the current to flow. When multiple consumers are installed, the output of the first consumer is the input to the second consumer and so on.

One consumer can affect the entire circuit. If one of the consumers fails, the circuit becomes open and current flow will stop.

The overall resistance of the circuit is easy to measure. There is only one current path so it is simply a case of measuring the resistance between the beginning and the end of the circuit.

Tip: Isolate the circuit before measuring resistance. Voltage is electrical pressure, if we measure resistance with pressure present the result is much higher than we expect.

In the example above:

Resistor 1 = 1 Ohm: Resistor 2 = 2 Ohms: Resistor 3 = 3 Ohms

In total: R1 + R2 + R3 = 6 Ohms (Ω)

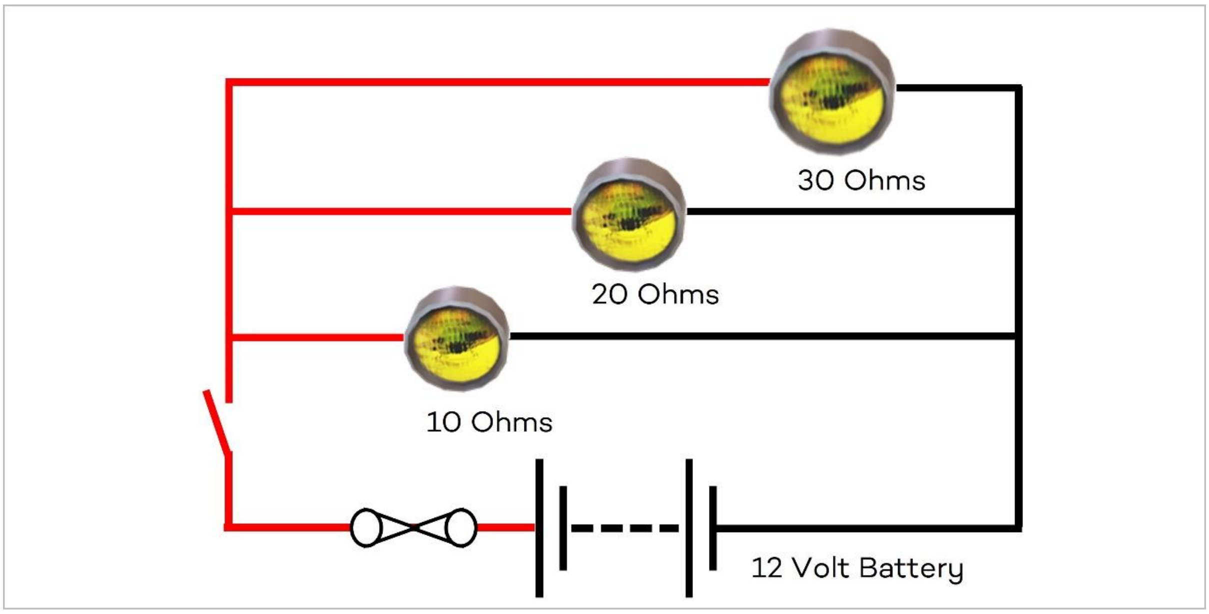
Electrical Properties of a Series Circuit:

Voltage: The voltage will vary throughout the circuit – each resistor will affect the common voltage supply.

Amperage: The current flow in a series circuit is consistent – The same at the beginning as it is at the end.

Resistance: Each resistor in the circuit will influence the overall resistance of that circuit.

Circuit properties – Series and Parallel (Effect on resistance)



Parallel Circuit:

A parallel circuit has multiple paths for the current to flow, so the current flow is shared. If the resistance of each path is different, so is the current flow. If one of the paths becomes open circuit, current will still flow in the remaining closed circuits.

The overall resistance of the entire circuit can be measured in the same way as a series circuit, but the total resistance measured will always be lower than the smallest resistor in that circuit. As the current flow is shared, so is the resistive value!

To calculate the circuit resistance, we need to apply a formula:

Total resistance (TR) = The value 1 divided by (1/R1 + 1/R2 + 1/R3)
For example: TR =1 divided by 0.1833 = 5.46 Ω
1 divided by 10 (0.1) + 1 divided by 20 (0.05) + 1 divided by 30 (0.033) = 0.1833

As a rule of thumb: If a parallel circuit has two resistors of the same value, then the total resistance will be half of the value of one resistor. If there were three, then the total value would be a third. Four would be a quarter, and so on.

For example: Two 120Ω resistors will calculate to a circuit resistance of 60Ω.

Electrical Properties of a Parallel Circuit:

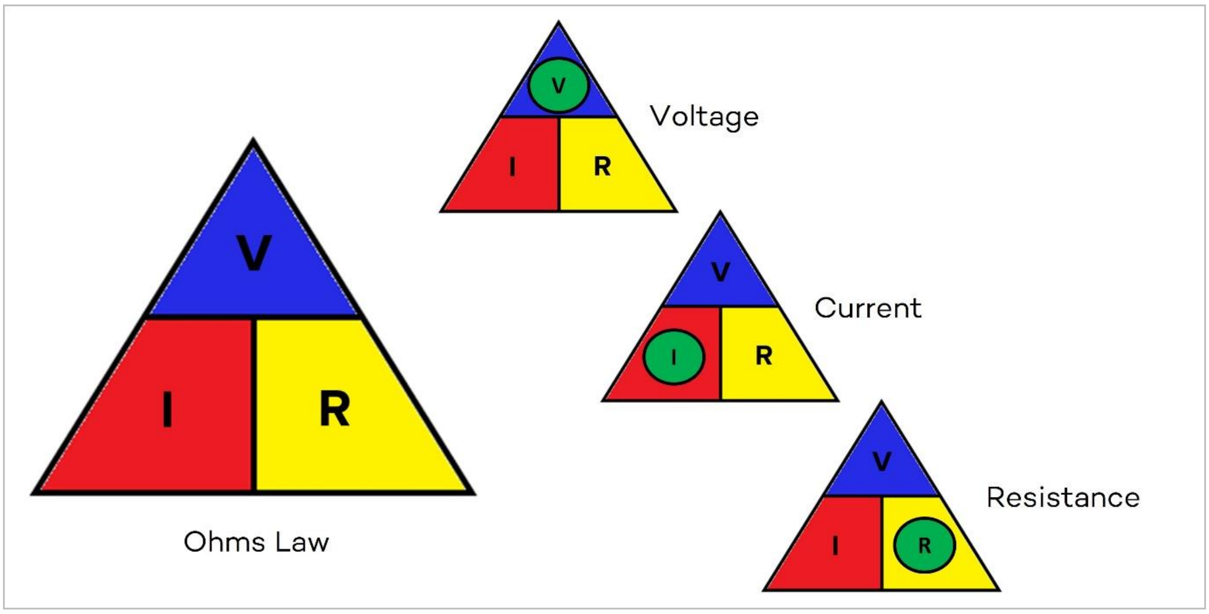
Voltage: The voltage will remain constant throughout the circuit – each resistor will have the same common voltage supply.

Amperage: The current flow in a series circuit will vary, depending on the value of the resistor on that path.

Resistance: Adding or removing a resistor will affect the overall resistance of the entire circuit.

1.5: Ohms law

From the earlier sections we can deduce there is a relationship between Voltage,



Amperage and Resistance. If we change one of these variables it will affect the other two. In the same respect, if we know what two of the variables are we can calculate the third. This makes electricity predictable!

To make these calculations we use a formula known as Ohms law.

Ohms law: The Voltage (V) is equal to the Amperage (I) multiplied by the Resistance (R). V=I x R

If we arrange the formula inside a triangle the solution to calculating any of the variables becomes clearer.

To calculate the current: Divide the voltage by the resistance: I = V/R

To calculate the resistance (Ohms): Divide the voltage by the current: R = V/I

Ohms Law Challenge: Can you calculate the following?

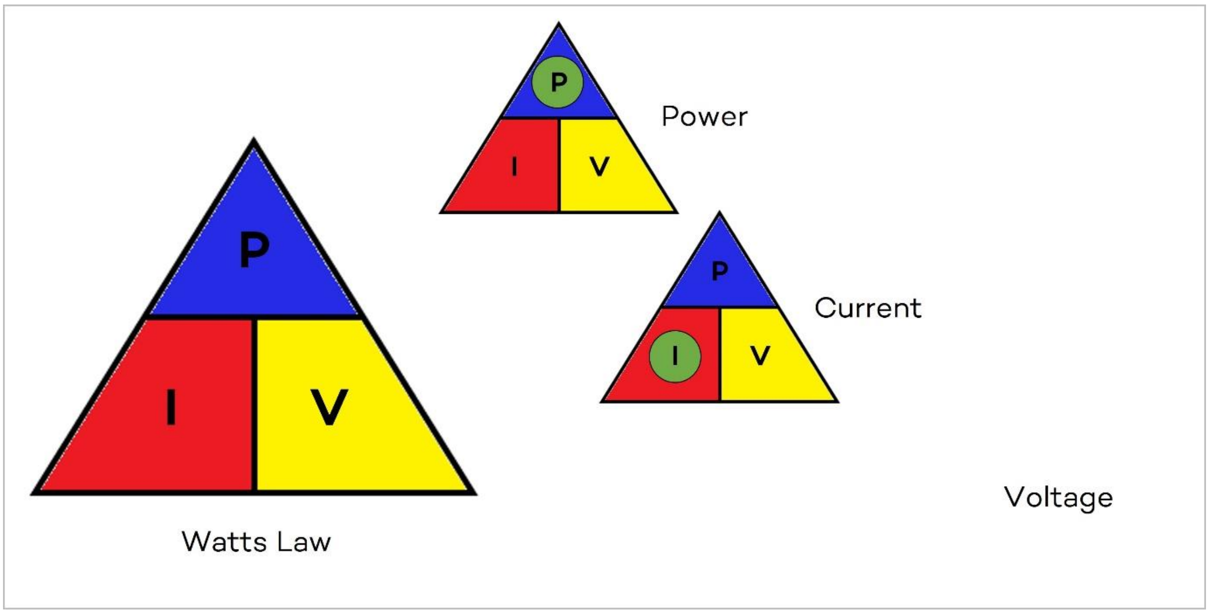
(a) A circuit has a 24 Ohm resistance and needs 0.5 Amps of current. Calculate the voltage supply needed to make it work?

(b) A circuit has a 12 Volt power supply and a resistance of 6 Ohms. Calculate the current flow in this circuit?

(c) A circuit has a 12 Volt power supply and needs 4 Amps of current flow. What is the correct resistance for this circuit?

Please refer to the end of this module to check your calculations:

Watts Law



Ohms Law supplies a method for calculating voltage, current and ohmic resistances when applied to a circuit. There is also a formula for calculating the electrical power requirements for consumers and a circuit.

The relationship between the voltage and current flow defines the electrical power. Watts Law enables the calculation of electrical power, expressed using the unit Watt. This Law states that, one Watt is the rate that work done when one Amp flows through an electrical potential of one volt.

The range can be as small as 1 Watt up to Mega-Watts (Millions of Watts)

The formula is as follows: Power (P) is equal to the Voltage (V) multiplied by the Amperage (A) P=V x A

The formula works just like Ohms Law does, if we know two of the variables, we can calculate the third.

Take a standard, twin element, stop and side light bulb. The brake light filament is brighter than the side light filament. Written on the base of the bulb are the power ratings. 5 Watt for the side light and 22W for the brake light. The brighter filament needs more power to light up! Both filaments have a 12 Volt supply.

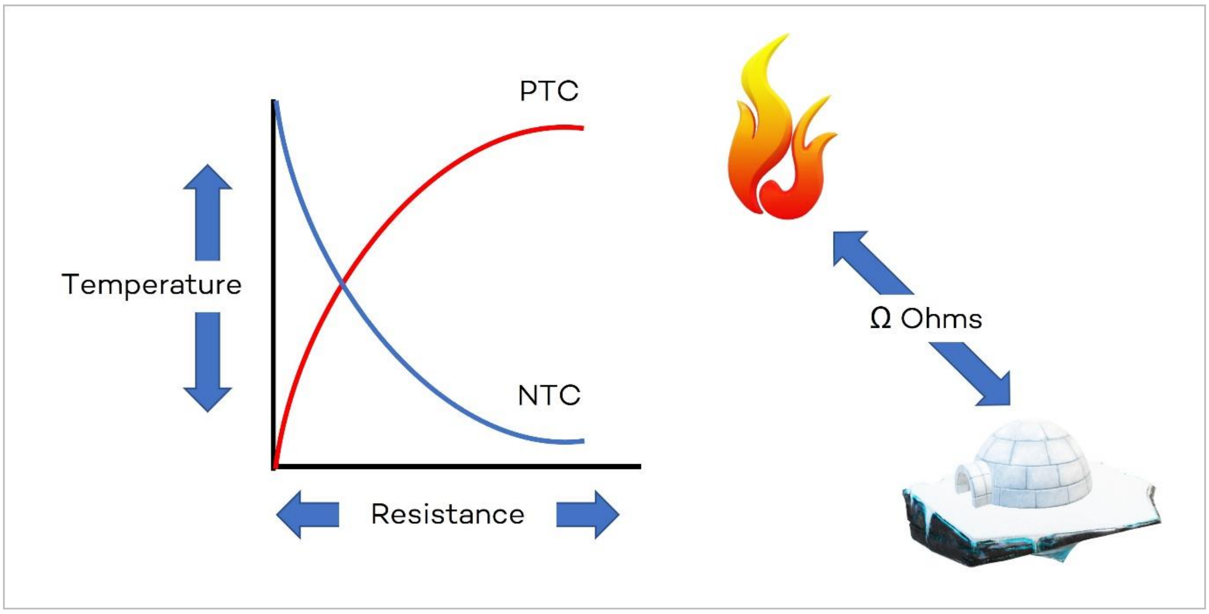
Watts Law challenge:

(d) How many amps flow in the side light circuit?

(e) How many amps flow in the stop light circuit?

Please refer to the end of this module to check your calculations:

1.6 Electrical Devices and Temperature



Electrical devices, a device that relies on electrical energy (AC or DC) to drive their core parts:

Electrical devices are supplied electrical energy. The device transforms that energy into either heat (thermal energy), motion (Kinetic energy) or static or stored energy (Potential energy).

Effect of heat on resistance:

A bulb for example: The bulb has a filament, usually made from Tungsten which acts as a resistor. As current flows through the resistor it warms up (thermal energy), eventually the filament is so hot that it glows, producing a light source.

If we measured the resistance of a cold bulb and then compared it with the resistance of the hot bulb, we would find the resistance has increased.

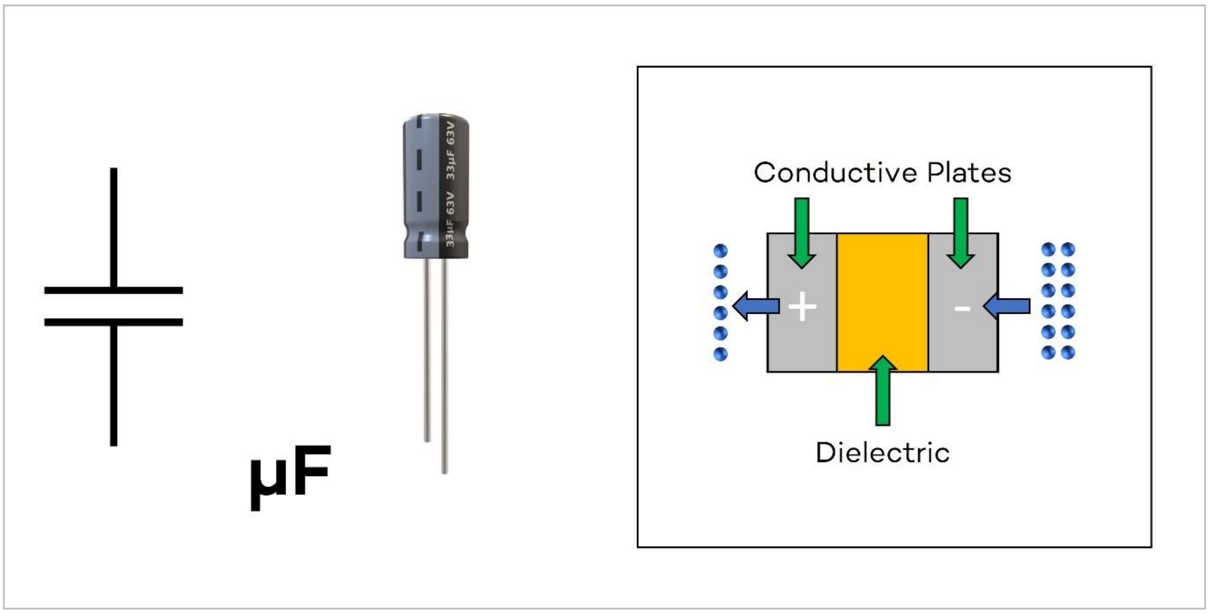
This principle is used to our advantage when designing components such as temperature sensors

As some conductive materials warm up, their resistance to the flow of electrical energy increases. The complete opposite can be said if we were to cool the same material, the resistance would decrease. These conductors are known as Positive Temperature Coefficient (PTC).

Other conductors are the opposite of this, as the temperature increases the resistance decreases. These conductors are known as Negative Temperature Coefficient (NTC).

Others remain neutral, their resistance remains stable regardless of the temperature! Precision resistors can be constructed with this type of material!

1.7: Capacitors



A Capacitor is an electrical component that stores electrical energy, a bit like a battery. Unlike a battery, no chemical process takes place, so it is unable to produce energy. It can discharge the stored energy in a fraction of the time it takes a battery. Capacitors will store energy at a level that matches the voltage supplied to it.

A capacitor has two conductive plates (a positive and a negative) which are insulated from each other using a non-conductive material, such as glass, plastic, paper etc. The non-conductive material is referred to as a Dielectric (Insulating or an extremely poor, conducting material).

When a capacitor is supplied a voltage the negative plate absorbs electrons, the positive plate releases electrons. The electron imbalance is created (just like a battery) that matches the supply voltage. The capacitor will store this charge until the supply voltage drops, then discharges until the charge level equals the lower supply voltage.

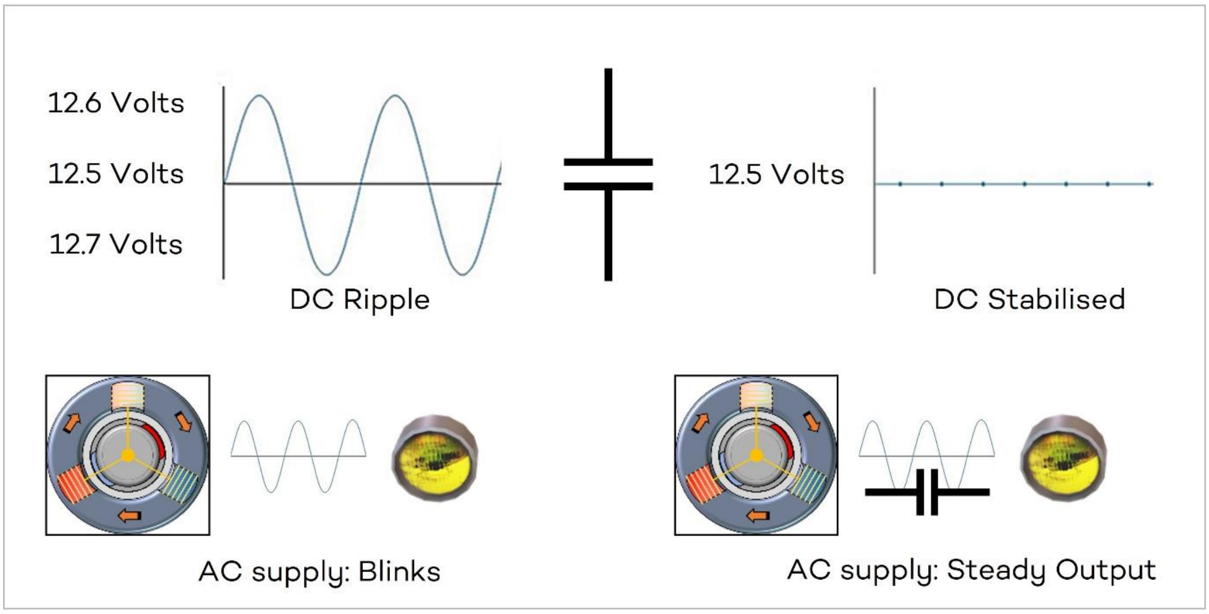
The unit Farad represents the energy capacity of a capacitor.

One Farad can store one Coulomb (6.25 billion electrons). One Amp equals the electron flow of one Coulomb in a second. So, a 1 Farad capacitor can supply 1 Amp/second at 1 Volt. This capacitor would however be around the size of a one litre bottle of water!

Instead, capacitors are rated as Micro Farads µF (millionths of a Farad)

Just like a battery, capacitors cannot store energy for ever. A percentage of leakage exists in the dielectric, so over time the excess electrons on the negative plate will “leak” to the positive plate until they are both balanced – no potential difference exists, the capacitor is completely discharged.

Capacitor Usage



Capacitors can be found in many electrical circuits or consumers, so what function do they perform?

Storing energy for high-speed use.

As a capacitor will discharge energy much faster than a battery, they are ideal for providing short bursts of energy. A simple example of this would be a for a high-pressure fuel injector. A capacitor will deliver the correct voltage required for precise injection timings and duration.

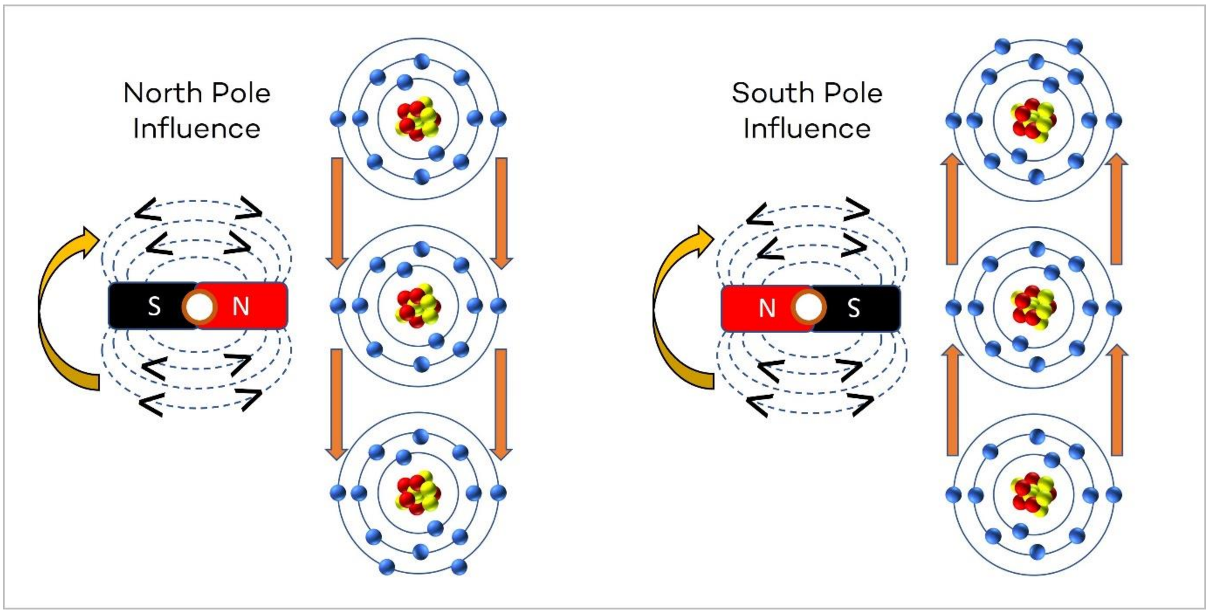
As a filter:

In a DC circuit the voltage level can fluctuate up and down, known as a voltage ripple. If a capacitor is placed in the circuit voltage peaks are absorbed by the capacitor. When the voltage level drops the capacitor will discharge voltage. By absorbing the peaks and filling the valleys a capacitor stabilises the circuit voltage.

As a current block (Diode):

When a capacitor is fully charged it will no longer absorb any more electrons, in effect creating a block to direct current flow. However, if placed in an alternating current circuit the capacitor will charge and discharge, in effect creating an uninterrupted alternating current flow.

1.8: Magnetism



What makes a magnet different to other materials? Remember that materials are made up of atoms, the electrons within those atoms move around constantly and randomly. A magnet on the other hand has special properties, the electrons are held stationery and line up in a uniform pattern. This property creates an invisible force of energy around the magnet referred to as a magnetic field (Lines of flux). The field has two opposing yet equal poles, a North and a South.

There is a relationship between electricity and magnetism. Electric charge produces an invisible electric field. When this field changes a magnetic field is produced. Likewise, every time a magnetic field changes an electrical field is created.

When two magnets are placed next to each other, the opposite poles are attracted to each other whereas the same poles repel each other.

In a piece of copper wire, the electrons are free to move, they just need a force to push them along. Electrons will move in one direction when exposed to the North pole. The direction is reversed when they are exposed to the South pole. As the electric charge moves, a magnetic field is created.

This relationship is used to change electric energy into kinetic energy (A motor for example) or vice versa, kinetic energy is converted into electrical energy (A generator for example).

1.9: Test Your Knowledge

1	**Which component of an atom carries electrical energy?**	
a	Proton	
b	Nucleus	
c	Electron	
d	Neutron	

2	**Electrical pressure within a battery is called?**	
a	Dielectric strength	
b	Potential difference	
c	Ohmic resistance	
d	Electrolyte	

3	**Potential Difference is measured using which unit?**	
a	Farads	
b	Amperage	
c	Resistance	
d	Voltage	

4	**The quantity of electrons moving past a point in a second is referred to as?**	
a	Voltage	
b	Current	
c	Resistance	
d	Capacity	

5	**To operate correctly, a circuit must?**	
a	Have a useable resistance	
b	Have resistors which must be in parallel	
c	Have a fusible link	
d	Have resistors, which must be in series	

6	**Ohms Law: How do we calculate Resistance?**	
a	Multiply the voltage by the amperage	
b	Divide the amperage by the voltage	
c	Divide the voltage by the amperage	
d	Divide the wattage by the voltage	

7	**Which of the following statements are true?**	
a	In a series circuit, the voltage remains constant throughout	
b	In a parallel circuit the voltage remains constant throughout	
c	In a series circuit the amperage varies throughout	
d	Ina parallel circuit the amperage remains constant throughout	

8	**What would the approximate, open circuit voltage be of a battery that is charged to 80% state of charge?**	
a	11.8 – 11.9 volts	
b	>12.7 volts	
c	12.1 – 12.2 volts	
d	12.5 to 12.6 volts	

9	**Which of the following, best describes a magnet?**	
a	A magnet creates an invisible electrical field	
b	The electrons are free to move around randomly	
c	The electrons are held in a fixed uniform pattern	
d	A magnet can be charged with electricity to store energy	

10	**Which of these statements is NOT true?**	
a	Once isolated a capacitor will store energy, just like a battery	
b	A capacitor can discharge energy very quickly	
c	A capacitor will store energy at a level equal to the applied voltage	
d	A capacitor can be used to stabilise a voltage supply	

1.9: Calculation Solutions:

Ohms Law:

(a) A circuit has a 24 Ohm resistance and needs 0.5 Amps of current. Calculate the voltage supply needed to make it work? (V=I x R) = 12 Volts

(b) A circuit has a 12 Volt power supply and a resistance of 6 Ohms. Calculate the current flow in this circuit? (I=V/R) = 2 Amps

(c) A circuit has a 12 Volt power supply and needs 4 Amps of current flow. What is the correct resistance for this circuit? (R=V/I) = 3 Ohms

Watts law:

(d) To light up the side light: Current (A) = Power/Voltage = 0.42 Amps

(e) To light up the stop light: Current (A) Power/Voltage = 1.83 Amps

2: Electric/Hybrid Vehicle Awareness (High Voltage)

The Electricity at Work Regulations 1989

Health and Safety at Work Act 1974

HSE Health and Safety Executive

IMI INSTITUTE OF THE MOTOR INDUSTRY

The Electricity at Work Regulations 1989:

The electricity at work regulation is aimed at preventing death or injury to any person by electricity whilst working or in a work environment. The regulation applies to every employer and self-employed personnel in a workplace. Every employee must co-operate with the employer by doing everything possible to ensure electrical safety is followed under this regulation.

As fossil fuel supplies are depleting and environmental awareness is growing the use of Hybrid and Electric cars, that contain "High Voltages" has grown significantly. Therefore, the risk of exposure to these types of vehicles has also increased.

People who work within vehicle repair or recovery industry need to be made aware of the additional hazards they may be exposed to when working with these vehicles. The need for developing a wider range of skills and knowledge is required to ensure they can continue to work safely.

To offer guidance the Health and Safety Executive has listed four levels of qualification to match the duties of personnel who work within this industry.

Level 1: Electric/Hybrid Vehicle Awareness

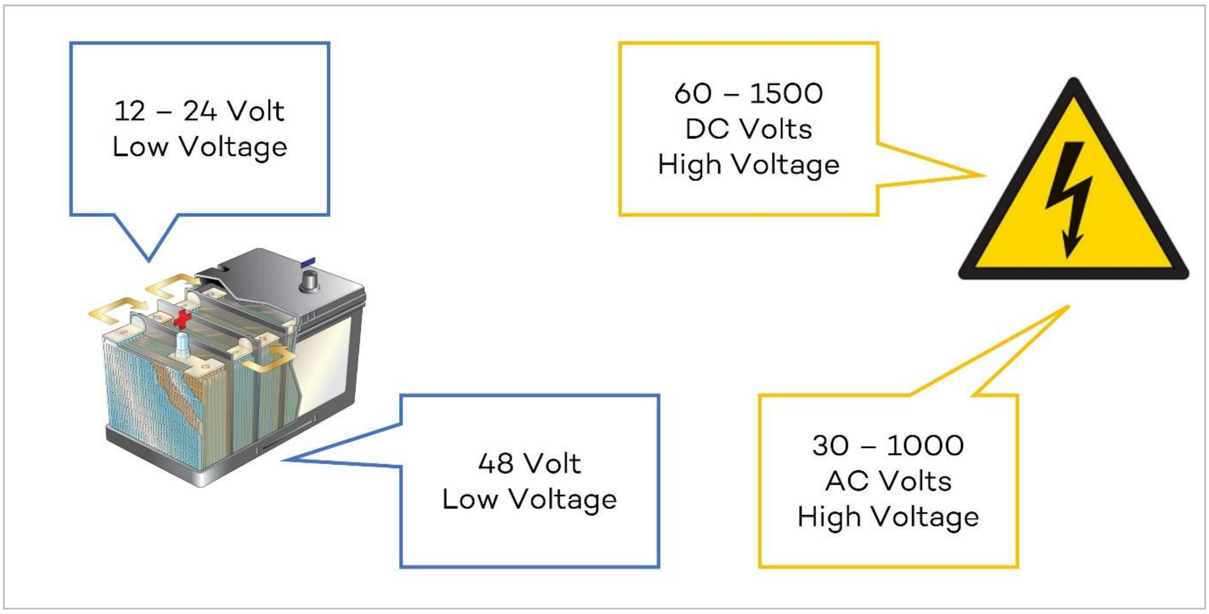
Level 2: Electric/Hybrid Vehicle Routine Maintenance Activities

Level 3: Electric/Hybrid Vehicle Systems repair and Replacement

Level 4: Diagnosing, Testing and repair of Electric/Hybrid Vehicles

In this training module we will cover the subject matter for Level 1.

Electric/Hybrid Vehicle Awareness



What is High Voltage?

High voltage electricity refers to an electrical energy potential, which can cause injury or damage.

Currently within the UK, automotive voltage levels are classified as follows:

A DC voltage greater than 110 has the potential to cause harm or even be fatal. To provide a safety net, all DC voltages between 60 and 1500 are classed as High Voltage. In the case of AC voltages, this range is 30 - 1000 Volts (AC RMS).

The voltage level used in Hybrid and Electric cars can range from forty-eight volts up to a thousand volts. This is significantly higher than the 12- or 24-volt systems we are used to! Also, the Personnel Protection Equipment (PPE) and appropriate tooling differs from what we have been used to working with.

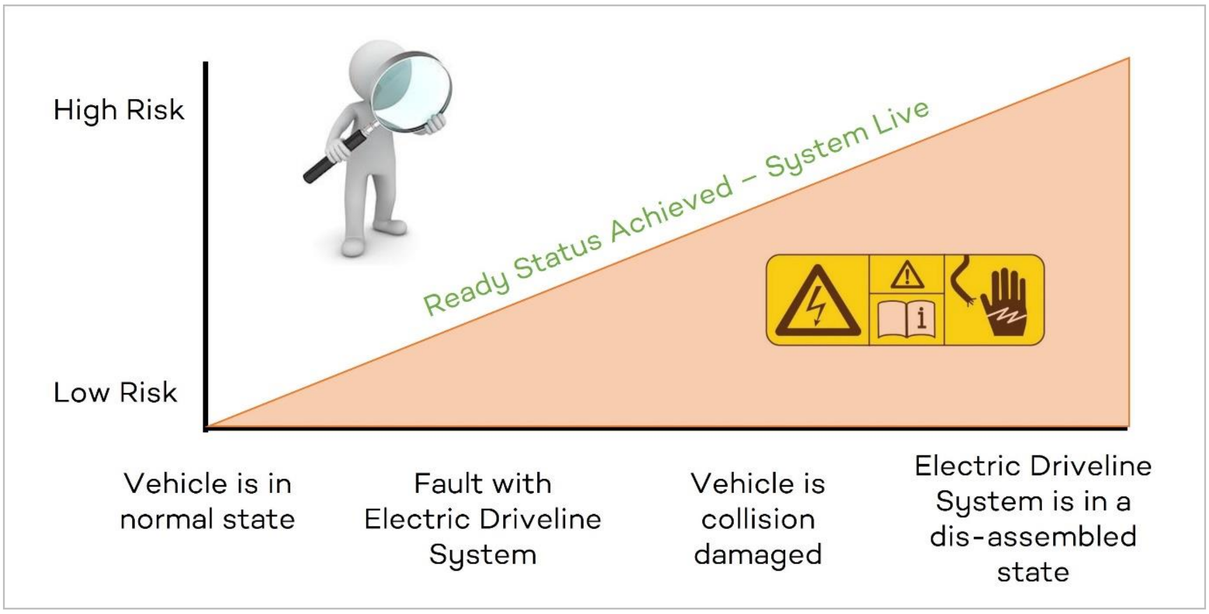
When it comes to selecting and using the correct equipment, voltage levels are classified. We simply use the correct class of PPE and tooling to work safely with these vehicles.

For example:

Class 0 – Offers protection from electric shock up to one thousand Volts.

CAT 3 - Rated to 1000V: – Digital Voltmeter - Offers protection when measuring voltages up to one thousand.

2.2: Hybrid and Electric Vehicles



There are many variations of these vehicles, but it is fair to say that most of them are using electricity at a level that is classed as High Voltage (Greater than 60V DC or 30VAC).

Bearing this in mind the manufacturers who build these vehicles must comply with stringent regulations. The regulations ensure the vehicles pose no greater risk than ones that only use fossil fuels.

The vehicles are equipped with on board safety systems, designed to guarantee the vehicle remains "Intrinsically Safe" (available energy is reduced quickly to a level that causes no harm). With regards to the High Voltage system, provided there is no damage, no faults and all components are fitted correctly, this vehicle poses little threat. However, if any of these variables change, then the risk rating can increase dramatically.

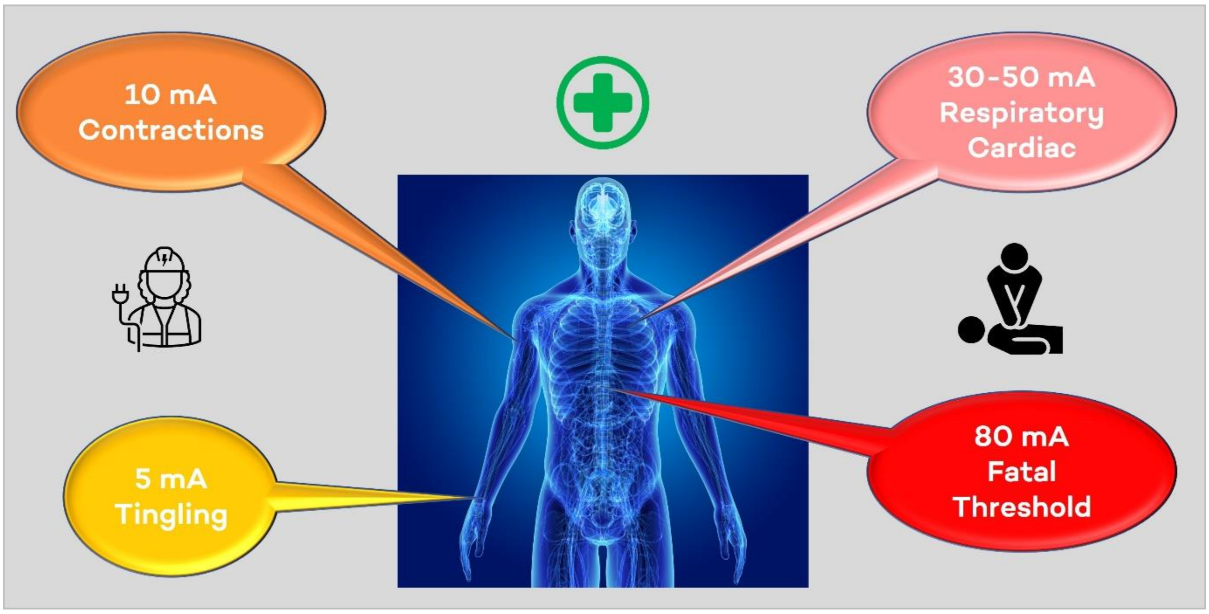
The HV system can produce strong magnetic fields. These fields can influence the behaviour of life saving medical devices such as pacemakers or insulin pumps.

Another issue we must consider is the energy reserve itself. The batteries used for storing High Voltage are constructed using different chemicals etc when compared to the low voltage system (12 Volt). The potential to release poisonous gases or leak harmful/corrosive chemicals exists.

This module provides guidance for identifying and assessing a Hybrid or Electric vehicle before making physical contact with them. At the very least, "Look" but do not "Touch" will keep you safe!

If there is any doubt regarding the safe handling of a Hybrid or Electric car, always refer to the manufacturer's instructions before proceeding.

2.3: The Effect of Electricity on the Human Body – Electric Shock



The human body uses small electrical impulses to operate our nervous and muscular systems. The introduction of electrical energy into the human body can disrupt the normal impulses. The amperage and exposure time dictates the effect of the disruptions but may also cause deep and severe burning that we cannot see.

This would suggest that amperage is the factor to be avoided, which is true, but we should not ignore voltage. As a basic measurement the human body has a resistance of one thousand Ohms, providing a level of protection from electrical energy flow. Voltage is electrical pressure, the higher the voltage the greater the pressure. The greater the pressure, the easier it is for electrical energy to flow through a resistance!

The following describes the effect of electrical energy moving through a human body: The figures quoted are designed to provide a safe limit.

5 Milliamps (0.005): A tingling sensation is felt, the body's warning system!

10 Milliamps (0.010): Muscular contractions. The ability to let go is compromised which in turn extends the exposure time – internal burning may occur.

30 – 50 Milliamps (0.030 – 0.050): The muscles that make us breath start to paralyse. As the current rises the heart starts to quiver instead of beating (Ventricular Fibrillation). This can be fatal if not corrected very quickly (Cardiac Arrest).

80 Milliamps and above (0.080): This is considered the fatal threshold unless immediate medical attention is sought.

These limits will vary from person to person and the exposure time plays a crucial role. The best advice would be to always avoid the passage of electrical current!

2.3: Hazards associated with High Voltage

Fire and Explosion

We do not need a description to define the danger of a fire! Electricity is a form of energy which will release at an alarming rate if allowed. Electrical fires are rare, but they do occur. If the fire is in a circuit, we can switch the circuit off and remove the energy before addressing the issue with the appropriate equipment.

A battery on the other hand cannot be switched off, we must wait until all the energy reserve has depleted. Potentially, with an electrical fire, as the thermal energy rises, electrical energy is released quickly – an explosion can occur!

High Voltage fires are best left to the experts to combat. When dealing with this situation, call the emergency services immediately. Only isolate the vehicle if it is safe to do so.

Arc Flash

Electrical Arcing occurs when an electric current flows through the air from one conductive surface to another. Air is an insulator, however if the voltage has enough push it will jump across an air gap. When current flows through air, the oxygen reacts in the following way.

The oxygen atoms become devoid of electrons, allowing conductive plasma to be released. As electrons are now moving through air which has a resistance, the temperature of the oxygen atoms increases rapidly, we can see this as the light emitted is very bright.

Apart from the obvious risk of electric shock there are other factors which must be considered.

Involuntary muscle reaction. A fast and aggressive muscle reaction may occur. Enough energy to throw the victim across a room or break bones. This condition is not limited to Arcing, an electric shock can produce the same result.

Burning. The heated oxygen can reach temperatures of 4000°C, enough to melt metal!

Poisoning. Plasma is toxic to a human, risk of poisoning if inhaled.

To avoid Arcing, never disconnect an electrical component whilst current is flowing through that component.

Chemicals

There are several types of high voltage batteries all of which contain chemicals. The chemicals used are corrosive and if these chemicals over-heat they can release combustible or toxic gases.

The manufacturer has gone to great lengths to prevent these chemicals or gasses from leaking out of the batteries. They only become a risk if the battery has failed, been damaged (dropped for example) or has exceeded the maximum operating temperature for a given length of time.

In all cases the manufacturer has safety instructions which must be followed if presented with a battery leaking issue.

Another point to consider is the weight of the battery. They present a manual handling risk as most exceed the recommended lifting weight. Once again, the manufacturer will advise what type of lifting equipment should be used when moving these batteries using physical force.

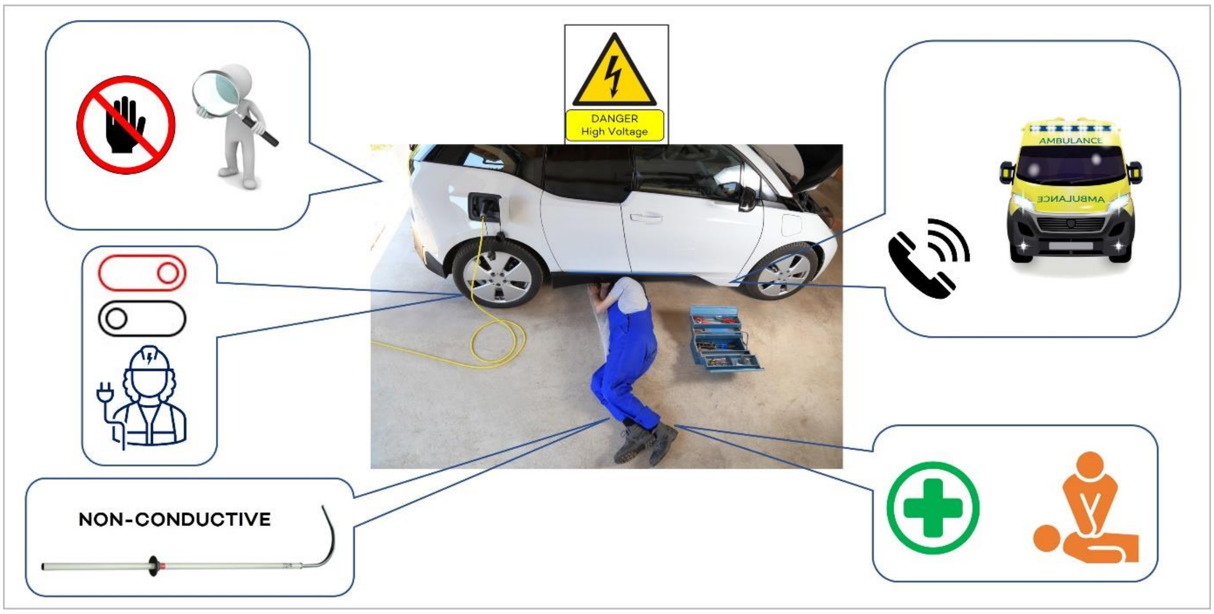
Electromagnetic Force (EMF)

When the high voltage system is active it will create strong magnetic fields. High voltage components are shielded to contain the fields. The motor/generator contains strong permanent magnets which also create magnetic fields, even when the motor is switched off!

If placed near to the high voltage components there is a risk that the magnetic fields can influence the electronic behaviour of medical devices such as pacemakers or insulin pumps.

It is recommended that people who have electronic medical devices fitted, do not work on or near to the high voltage system.

First Aid – Electric Shock



Without doubt, prevention is better than cure but if presented with an accident involving electricity, we should follow the rules!

Even if a casualty insists, they are not feeling unwell, seek medical advice before leaving the casualty.

1: Assess the environment before the casualty.

Make sure the power supply has been switched off and isolated before making any physical contact with the casualty.

If you unable to switch off/isolate the power supply, remove the casualty from the environment using a non-conductive implement such as a wooden broom handle, a rope or a “rescue hook”. Remember do not make physical contact with the casualty.

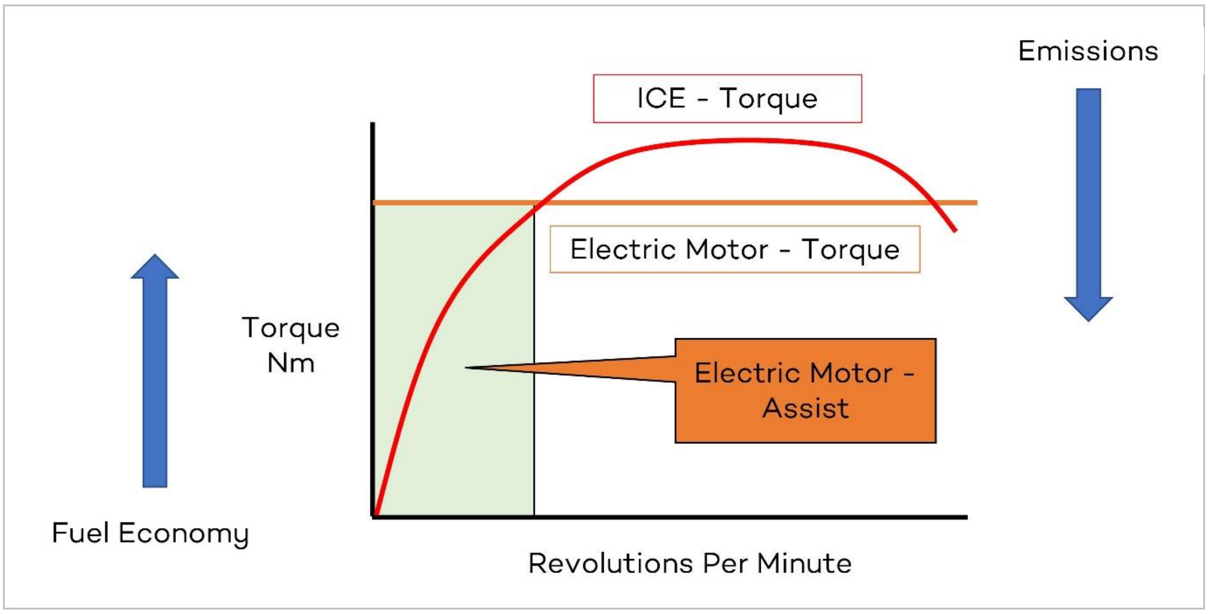
2: Call the emergency services – they will advise you how to proceed.

3: Administer first aid - Locate or take advice from a trained first aider.

Consider attending a first aid course where you are taught basic first aid such as CPR etc.

4: Remain with the casualty until the emergency services arrive and take over.

2.4: Hybrid Vehicles – Concept and Architecture



A hybrid car is one that uses more than one means of propulsion. In most cases an Internal Combustion Engine (ICE) and a powerful electric motor.

There are two types of hybrid drive, a parallel drive system where the electric motor is used to assist the ICE and can provide a limited amount of purely electric drive. A series hybrid drive where the ICE is used to generate electricity to supply an electric motor which provides all the propulsion.

Either drive system is designed to be fuel efficient, less fuel equals less emissions! Also, a hybrid drive system can provide excellent performance yet still with a fuel saving advantage.

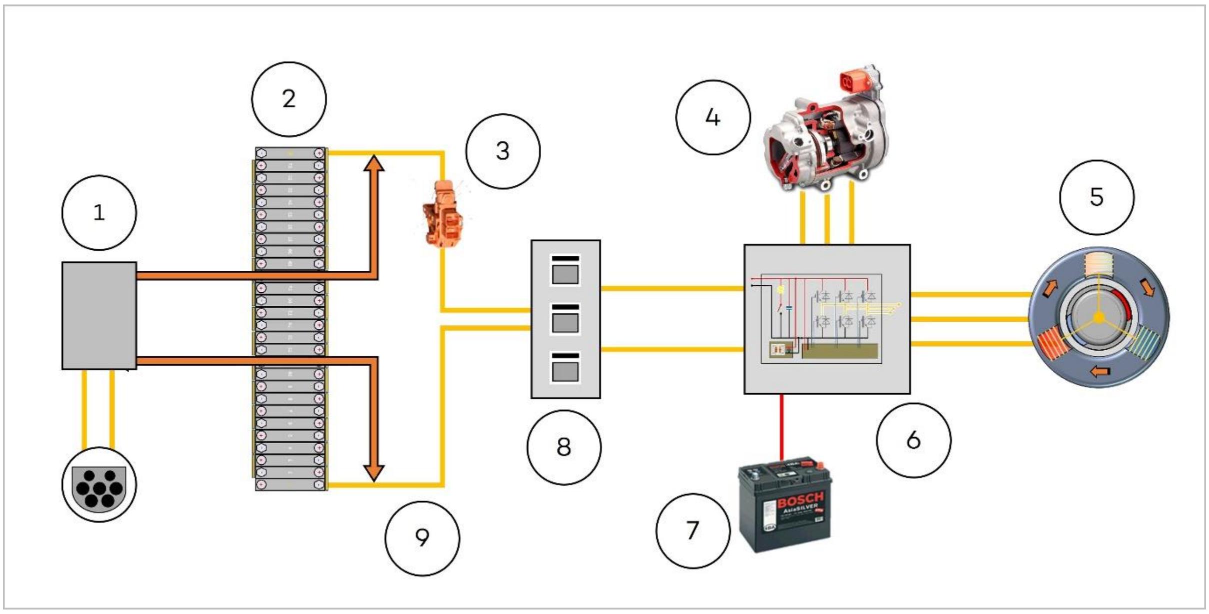
Manufacturers of automobiles often blend these two concepts to create their own distinct models. Toyota for example use a unique power split hybrid drive. The drive system combines both parallel and series drives, the car chooses which drive system is the most efficient for the current driving environment.

The overall concept of Parallel Hybrid drive is shown in the graph above. The green shaded area indicates the ICE generating torque to overcome the engine load. This requires additional fuel and is therefore the least fuel efficient!

Electric motors can produce torque instantly and efficiently. Using the instant torque of an electric motor, the engine load is reduced enabling the ICE to reach maximum torque output without using excessive fuel! This effect works best when pulling away from standstill, creeping in traffic, rapid acceleration, and cruising.

In a series hybrid, all propulsion is made by an electric motor. The ICE is only run when there is a demand for electricity. The ICE is always running at peak efficiency as the load is generally a constant. Over a distance and time this drive system is far more efficient than just using fossil fuels.

2.4: High Voltage Components



Item	Description	Item	Description
1	On-board charger	6	Inverter / Converter
2	High Voltage Battery	7	Low Voltage Battery
3	Service Plug	8	Contactor Set
4	Air Conditioning Compressor	9	High Voltage Cabling
5	Motor - Generator		

1: Only applicable with Plug-in Hybrids or Battery Electric Vehicles.

A high voltage device to covert AC, mains supply electricity to a DC supply for charging the high voltage battery.

2: High Voltage Battery.

Electrical energy storage device – Voltage can range from 100 Volts DC up to or even above 800 Volts DC. Any disassembly of the high voltage battery is only to be conducted by a Level 4 trained person.

3: Service Plug

A method provided by most manufacturers for disconnecting the energy reserve from the Hybrid system. As the name suggests, removal of the plug should render the vehicle safe to work on. Always refer to the manufacturer's instructions before removing this plug – Minimum Level 2 Qualified personnel.

4: Air Conditioning Compressor.

All HEV or BEV vehicles use a High Voltage AC Compressor. The compressor is a three phase AC motor. Depending on the type fitted, there may be an AC supply (3 cables) or a DC supply (2 cables).

5: Motor – Generator (MG).

A High Voltage AC motor used for the propulsion of the vehicle. Can also run as a generator, capable of generating a substantial amount of electrical energy. There may be more than one MG fitted depending on the operating strategy of the Hybrid system (Series or parallel)

6: Inverter – Converter.

A device that converts the DC supply from the battery to an AC output for the HV motor. When the MG is operating as a generator, the Inverter converts the AC output of the Generator to a DC supply to charge the HV battery.

7: Low Voltage Battery.

Provides electrical support for the vehicle, just like any other vehicle, except no 12 Volt alternator is fitted to the Internal Combustion Engine. The Converter part of the HV Inverter is responsible for charging the low voltage battery. The supply to the low voltage battery comes from the HV Hybrid system.

8: Contactor Set.

A series of contactors (relays), depending on the manufacturer may consist of a pair or three contactors. The contactors provide a method for electronically disconnecting the HV energy reserve from the Hybrid system. The contactors are switched on or off by a low voltage ignition supply from the vehicle.

This system permits the deactivation of the hybrid system if the vehicle should be involved in a collision, or a fault develops with the Hybrid system.

9: High Voltage Cabling.

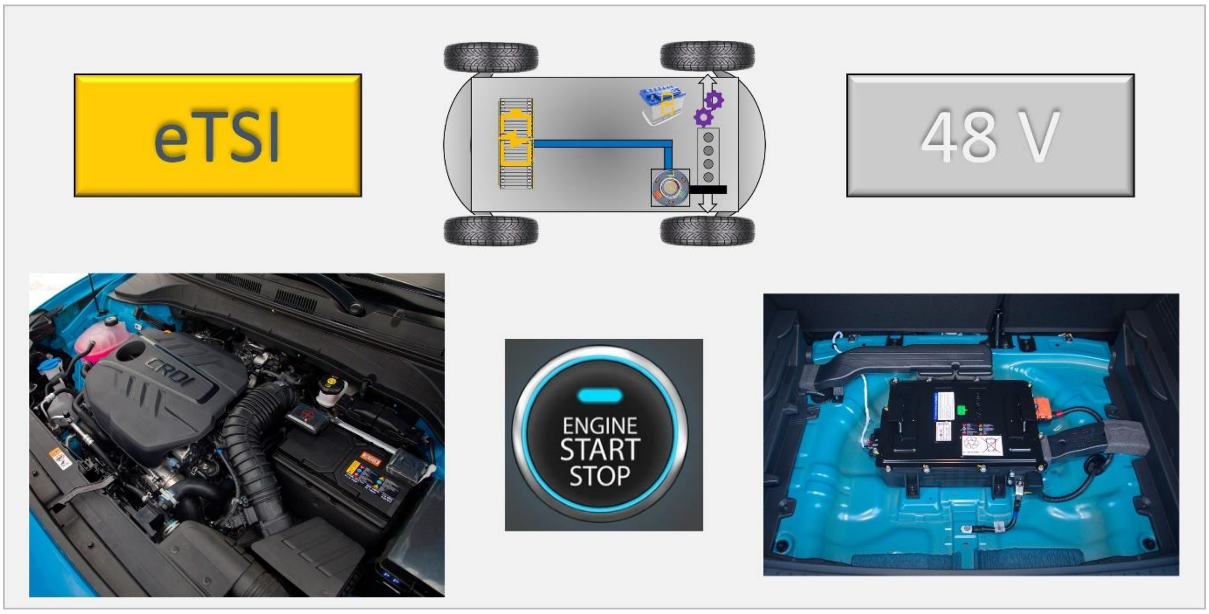
The cables used to connect all the components of the HV system. The cables are highly insulated and are therefore larger in diameter than the low voltage wiring running around the vehicle. To emphasise their presence, they are brightly coloured. mostly Orange but other colours may be used.

All the HV components are installed out of the way with protective covers to avoid accidental contact. The cabling is brightly coloured, so they are easy to identify. As a golden rule, do not make physical contact with any of the components until you have the necessary skills and knowledge to do so safely.

Warning:

Most of the HV components contain Capacitors. Capacitors provide a temporary energy storage facility. They are charged to the same voltage level as the Hybrid system and will retain this energy reserve for a time after the system has been switched off. The manufacturer will state the duration of waiting time required before the capacitors have naturally discharged to a safe working level.

2.5: Types of Hybrid or Electric vehicles – Mild



Mild Hybrid Electric Vehicle (MHEV)

Belt Integrated Starter/Generator (BISG), Crank Integrated Starter/Generator (CIMG)

Technically a Mild Hybrid does not qualify as a High Voltage vehicle. The Hybrid drive is a 48 Volt system so is under the 60V DC threshold. The system consists of a 48 Volt battery, a 48V motor/generator which takes the place of the 12 Volt alternator and an Inverter/Converter.

The powerful motor can transmit torque to the ICE crankshaft via a drive belt, on some models this arrangement can provide a small degree of electric drive. Creeping in traffic for example. The motor is used to start the engine, but most have a conventional starter motor for cold engine starting.

When the driver releases the throttle or when braking, the drive belt drives the motor, it operates as a generator and recharges the 48 Volt battery. There is no option to connect the vehicle to an external charger, technically a "self-charging" hybrid.

A fuel saving concept is the length of time the Ice is switched off in a normal Stop/start scenario. With a 12 Volt system the electrical loading of the vehicle dictates the engine stop duration. When the 12 Volt system is supported with a 48 Volt energy reserve the duration and frequency is extended.

In summary, the high voltage energy reserve, reduces the electrical loading of the vehicle, therefore reducing the fossil fuel required to support these systems.

A Mild Hybrid is not classed as a High Voltage vehicle; therefore, the risk of injury is like a standard Internal Engine Equipped vehicle.

2.5: Types of Hybrid or Electric vehicles - HEV

Hybrid Electric Vehicle (HEV)

Classed as a High Voltage vehicle, typically the operating voltage of this type ranges from one hundred Volts up to three hundred Volts.

They have a small energy reserve, providing a limited zero emissions range (1 -2 miles). Described as self-charging hybrids, there is no facility to connect them to an external charger.

In either configuration it is frequent practice for these vehicles not to have a 12 Volt starter motor. The High Voltage motor is used to start the ICE. Be wary of this, if the hybrid system is switched on, the ICE may start without any warning!

From the exterior the vehicle can be identified as a hybrid by the badging (see above).

On the inside, usually the instrument cluster displays the state of the hybrid system. An indication that the vehicle is hybrid equipped. Using a “READY” icon informs the driver that the hybrid system is switched on and is ready to be used.

If the hybris system is faulty then a warning message or malfunction indicator lamp is illuminated on the instrument cluster. The “READY” status may not be displayed, indicating the hybris system has not switched the high voltage system on. In this state the risk involved with working on these vehicles has increased.

The appropriately qualified person should only conduct any repairs or maintenance.

Do not work on the high voltage system when the Internal Combustion Engine is running. In this state the battery is being charged!

Tip: Once identified as a Hybrid, place a sign on the vehicle to alert all personnel!

2.5: Types of Hybrid or Electric vehicles - PHEV

Plug In Hybrid Electric Vehicle (PHEV)

The operating voltage is higher on this type, up to and beyond four hundred Volts are common.

They have a larger energy reserve and a bigger electric motor. The electric motor can assist the ICE over a greater range. This provides an extended zero emissions range of around 20 – 30 miles.

Just like a HEV it is frequent practice for these vehicles not to have a 12 Volt starter motor. The High Voltage motor is used to start the ICE. Be wary of this, if the hybrid system is switched on, the ICE may start without any warning!

From the exterior the vehicle can be identified as a hybrid by the badging, plus a flap or cover for the external charging socket.

Within the vehicle, the instrument cluster displays are like a HEV. The “READY” status and any fault messages indicate the same safe working practices also apply.

The appropriately qualified person should only conduct any repairs or maintenance.

Do not work on the high voltage system when the Internal Combustion Engine is running. In this state the battery is being charged!

Do not work on the high voltage system when the vehicle is connected to an external power source.

Tip: Once identified as a Hybrid, place a sign on the vehicle to alert all personnel!

2.5: Types of Hybrid or Electric vehicles - BEV

Battery Electric Car (BEV)

As the name suggests, these vehicles have no Internal Combustion Engine, propulsion is by electric motor alone. With a large, rechargeable energy store the operating voltages can be as high as eight hundred volts.

External badging identifies the vehicle as “Zero Emissions” there are no exhaust tailpipes. As they are zero emissions, they are eligible to be fitted with “Green” number plates (not compulsory). They must be connected to an external charger therefore they will have a charging port instead of a fuel flap.

Another clue is the lack of cooling vents on the front of the vehicle, they usually have a solid surface.

A BEV can be equipped with two electric motors, one for each axle. This allows manufacturers to produce four-wheel drive capability without the need for heavy/complicated transfer boxes and prop-shafts etc.

The appropriately qualified person should only conduct any repairs or maintenance.

Do not work on the high voltage system when the vehicle is connected to an external power source.

Tip: Once identified as a Hybrid, place a sign on the vehicle to alert all personnel!

2.6: PHEV/EV Charging and Cables

In Europe, the most common type of charging cable is a Type 2, however there are some manufacturers that use a Type 1. Manufacturers will provide the correct one when the vehicle is purchased from new. Charging stations are configured to take either cable, it is the connection at the vehicle that differs.

Type 1 cables (SAE J1772) can be identified by the pin configuration and the round shape. The locking mechanism is part of the cable to car connector.

Type 2 (Menenekes – IEC62196-2) cables can be identified by their pin configuration and “D” shape. The locking mechanism is part of the vehicle charging port.

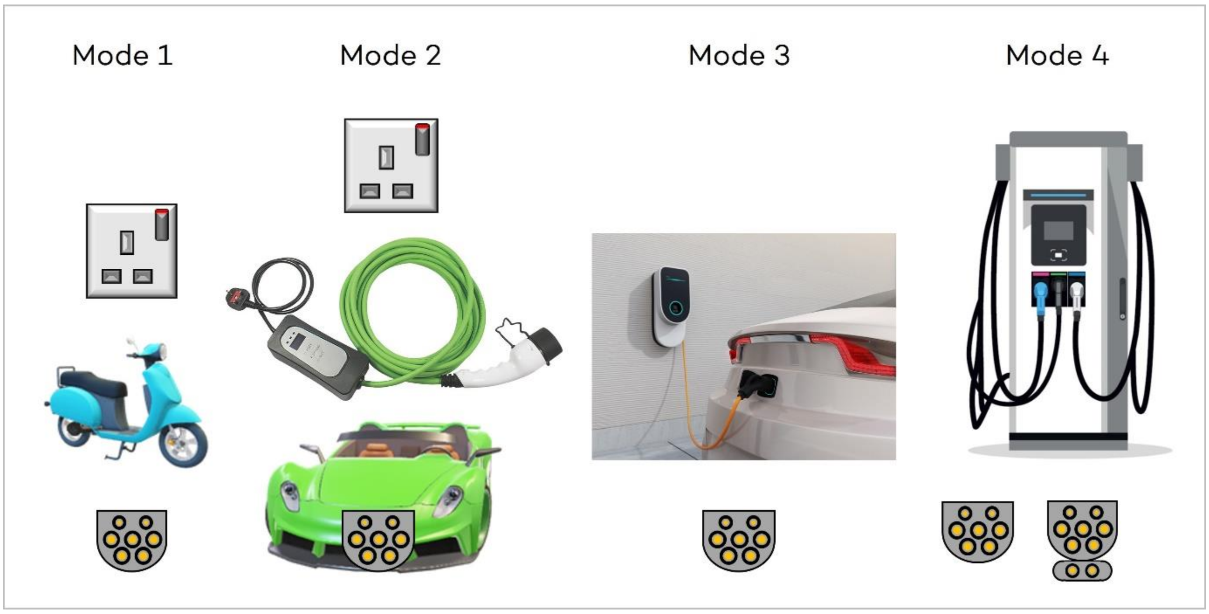
An additional cable (CCS – Combined Charging System) is available for rapid charging at the appropriate charging facility. This cable has additional pins to allow DC voltage to charge the vehicle high voltage battery (no need to invert from AC).

Inspect the cable, insulation, and connections for any sign of damage prior to use. Do not repair damaged cables or connectors, replace with new.

The cabling, charger and the vehicle are designed with a high degree of insulation, preventing the risk of electric shock, even if connecting in the rain! Always follow the manufacturer instructions for connection or disconnection procedures.

Do not work on the High Voltage system when the high voltage battery is being charged!

2.6: PHEV/EV Charging Modes



There are four different charging modes:

Mode 1: A method for charging using a standard domestic socket without any additional equipment. This has a limited power output and should not exceed 16 Amps or 250 volts (Single phase supply). Due to this charging time may take a considerable time, so is best suited to smaller vehicles such as scooters.

Mode 2: A method for charging using a standard domestic socket using an inline charging unit to regulate current flow and protect from electric shock. This enables a safe, higher current flow (Up to 32 Amps). Most domestic sockets are not capable of delivering this amount of current but a commercial, three phase supply would.

Mode 3: A purpose-built charger with a permanent connection to an AC supply. Communication between the charger and the vehicle is made using the two smaller pins of the charging cable. The charging system can provide between 3.7 and 22 Kilowatts of power, so charging is faster than mode 1 or 2.

Mode 4: DC Rapid Charging

Charging is taken from a DC supply so in theory can bypass the on-board charger and pass directly into the battery. Communication between the vehicle and the charger is established by the charging cable which allows the charging process to be conducted safely.

The use of extension cables for mode 1 and 2 charging is not permitted. It is unlikely the extension cables meet the required electrical standards; the risk of electrical fires is high!

2.7: Working with HEV or EV

To avoid any accidents or injury when working with High Voltage vehicles it is simply a case of reducing risk. This can be easily achieved by employing a "best practice" procedure within the workplace.

1: Identify the vehicle – Is it a High Voltage vehicle? If there is any doubt, this can be determined by identifying the vehicle from a reputable source or the manufacturer themselves.

Is the vehicle damaged to an extent that the high voltage system may have been compromised? If yes, then seek advice from the appropriate source or person before making physical contact with the vehicle.

2: Driving HV vehicles:

They can be silent in operation when using electric drive, be wary of this when manoeuvring the vehicle as other people may not hear it!

Is the "READY" status displayed on the instrument cluster? This indicates the high voltage system is activated with no safety faults present, vehicle propulsion is possible.

Are there any high voltage system faults displayed? If yes, switch off the ignition and remove the keys from the vehicle. Seek advice from the appropriate source before re-starting the vehicle.

3: Parked or Displayed vehicles:

A high voltage vehicle with no system faults, no damage and is completely intact poses no threat of electrocution. If the ignition is switched off, the high voltage system is disabled. It makes perfect sense then if the vehicle keys are removed from the vehicle, this will prevent any accidental activation of the high voltage system.

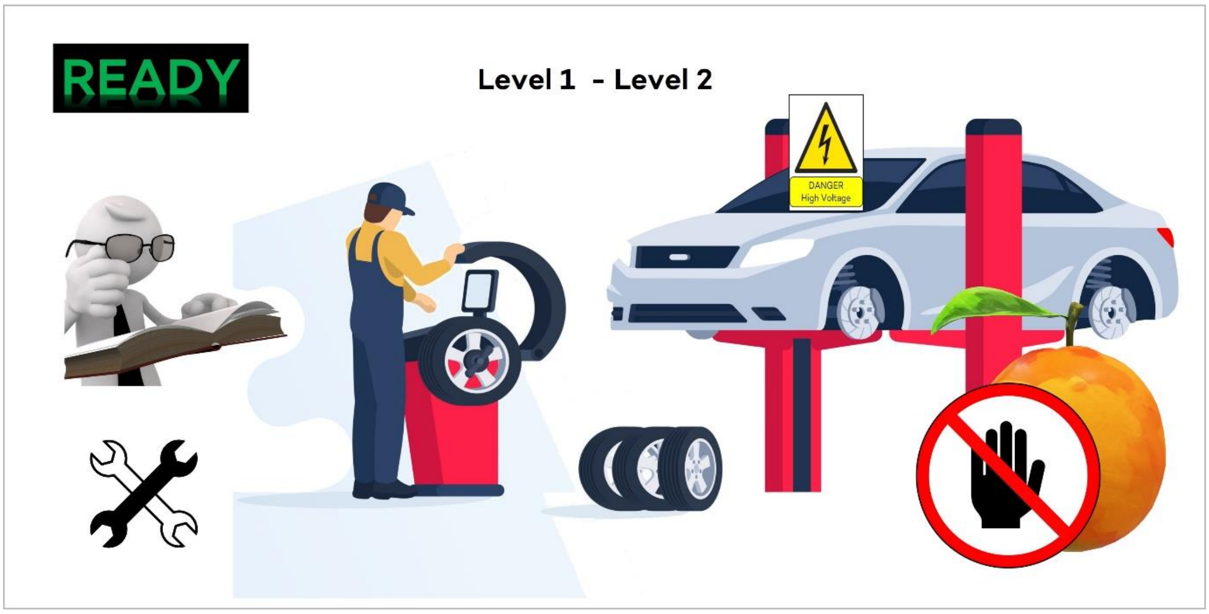
Keyless ignitions:

Removing the “Key Fob” from the vehicle does not switch off the ignition! Always ensure the ignition has been switched off by pressing the “Stop-Start” button before the keys are removed. Once removed store/secure the keys at least three metres from the vehicle to ensure they are out of range of the vehicle ignition system.

4: Valeting:

The high voltage system is insulated against the ingress of water. It is perfectly safe to wash a HEV/EV by hand or in a carwash and even a jet wash. If jet washing, ensure the high voltage system is switched off. Avoid any prolonged or high-pressure water contact with the high voltage system components. Ensure all these components are dry before restarting the high voltage system.

As a precaution consider switching the ignition off and removing the keys.



5: General maintenance or Servicing:

When in a workshop/repair environment the vehicle should be identified using the appropriate warning sign to highlight that this vehicle contains high voltage. The signage warns other people to avoid contact with the vehicle unless they have been instructed to do so by the person working with the vehicle.

It is recommended any person conducting these duties has the necessary knowledge to be able to identify the high voltage components and recognise if the vehicle is in a safe state (Level 1)

Working away from the high voltage system, then there is little requirement for the high voltage system to be placed in service mode. The vehicle can be worked on like any other, changing a tyre or a brake inspection for example.

Always check with the manufacturer for guidance before starting work on a high voltage vehicle. For the safest option, always have the high voltage system decommissioned and proven safe before starting any repairs.

Remember, do not touch Orange!

The correct procedures must be followed – refer to the manufacturer's instructions.

The working area must be secured using the appropriate warning signs etc

6: Vehicle Repairs:

Working close to or making physical contact with any of the high voltage system components must be avoided. If this is not possible then the high voltage system must be put into service mode (Decommissioned). Only a Level 2 qualified person should conduct this process.

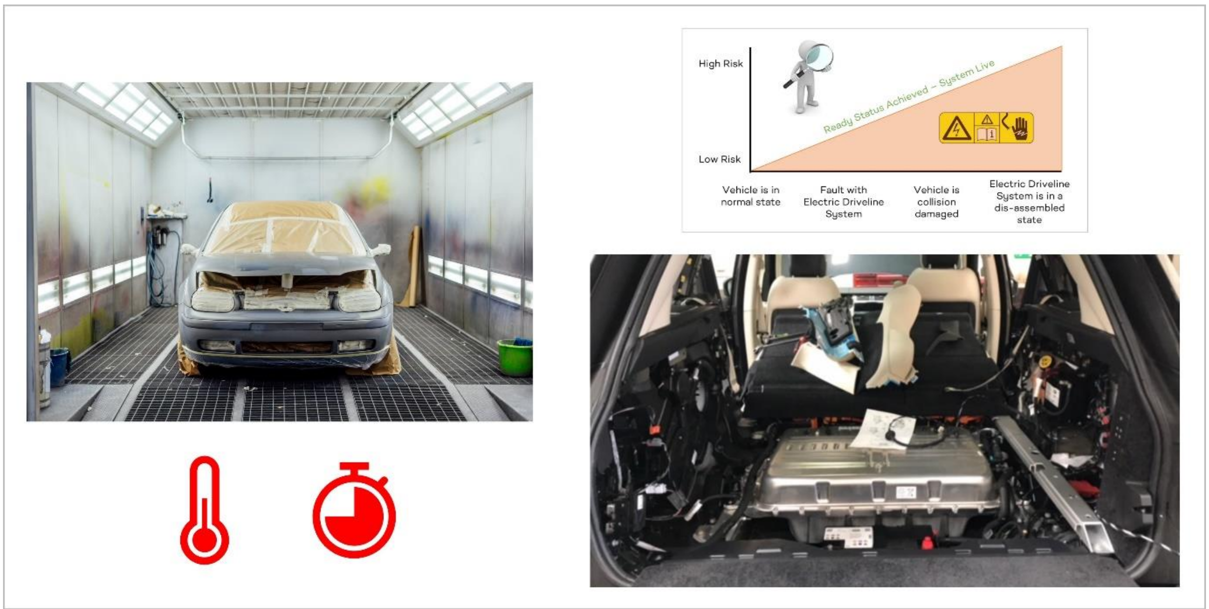
Removing High Voltage components. This task must be performed by either a level 3 or level 4, qualified person.

Working with the high voltage system when active (Live) must only be conducted by a level 4 qualified person. Tasks may include high voltage battery dismantling or system diagnosis for example. A level 4 trained person has the necessary skill set and knowledge to conduct this type of work safely.

The appropriate PPE must be used when working with High Voltage Vehicles.

The correct procedures must be followed – refer to the manufacturer's instructions.

The working area must be secured using the appropriate warning signs etc



7: Bodywork - Painting

High Voltage Battery packs are susceptible to high temperatures.

The vehicle may be labelled advising of its maximum temperature and exposure time, this should be considered when carrying operations such as painting where booth temperatures may exceed this limit.

If this information is not displayed, always check with the manufacturer prior to placing the vehicle inside the booth.

Always identify or locate all the high voltage components before cutting or welding body panels.

Measures should be implemented to alleviate any potential risks, for example remove the batteries or by providing insulation to limit any temperature increase in the batteries.

Making safe should only be conducted by a minimum, Level 2 qualified person.

Removal of components, the battery for example should only be conducted by a minimum Level 3 qualified person.

In general a through risk assessment should be made of any damaged high voltage vehicle to ensure the correct procedures are followed.

The appropriate PPE must be used when working with High Voltage Vehicles.

The correct procedures must be followed – refer to the manufacturer's instructions.

The working area must be secured using the appropriate warning signs etc

8: Recovery and Towing

Before recovery of the vehicle, conduct a risk assessment.

A vehicle submerged in water presents little risk from electric shock – vehicles are designed and constructed to prevent this from occurring. Recover from water and allow to drain. Wearing the appropriate PPE (Class 0 gloves) remove the ignition keys and disconnect the low voltage battery. Isolate the high voltage battery when possible. (Minimum Level 2 qualified personnel only).

Clearly a damaged vehicle poses a higher risk. Always wear PPE, inspect vehicle for signs of damage to the high voltage system, particularly for signs of damaged cabling – exposed wiring. If possible, remove ignition keys, disconnect low voltage battery, and isolate high voltage battery if it is safe to do so.

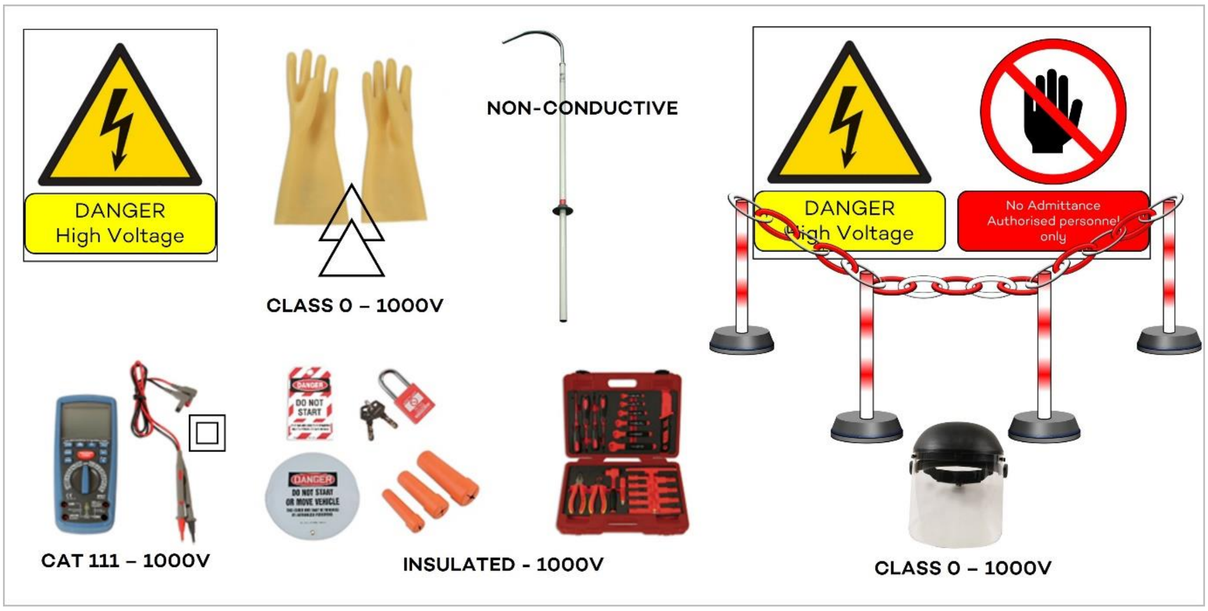
Recovery of damaged vehicle should only be conducted by personnel who are qualified as Level 2 or above.

When towing these vehicles, do not flat tow! Even if the high voltage system has been made safe. The movement of the driven wheels can generate electricity which can be stored in the high voltage system even if the high voltage battery has been isolated.

If presented with the recovery of a high voltage vehicle, approach with care and conduct a visual risk assessment before making physical contact with the vehicle.

Every manufacturer publishes a first responder/rescue sheet for their vehicles. Consult these details before making physical contact with the vehicle.

2.8: Personal Protection Equipment (PPE)



As a minimum, all automotive repair/service business that engage with Hybrid or Electric vehicles should have the appropriate PPE and Tooling:

Warning Sign – High Voltage

Sign should be displayed on any HEV/EV to identify vehicle as high voltage. Personnel should be wary of this vehicle – If in doubt ask the appropriate person – do not make physical contact with any of the high voltage components.

Insulated Gloves

Must be worn when making physical contact with any high voltage components. Must be the correct type (Class 0) and designed for electrical work (Marked with double triangle). The wearer must test the gloves (correct procedure) prior to their use.

Rescue Hook

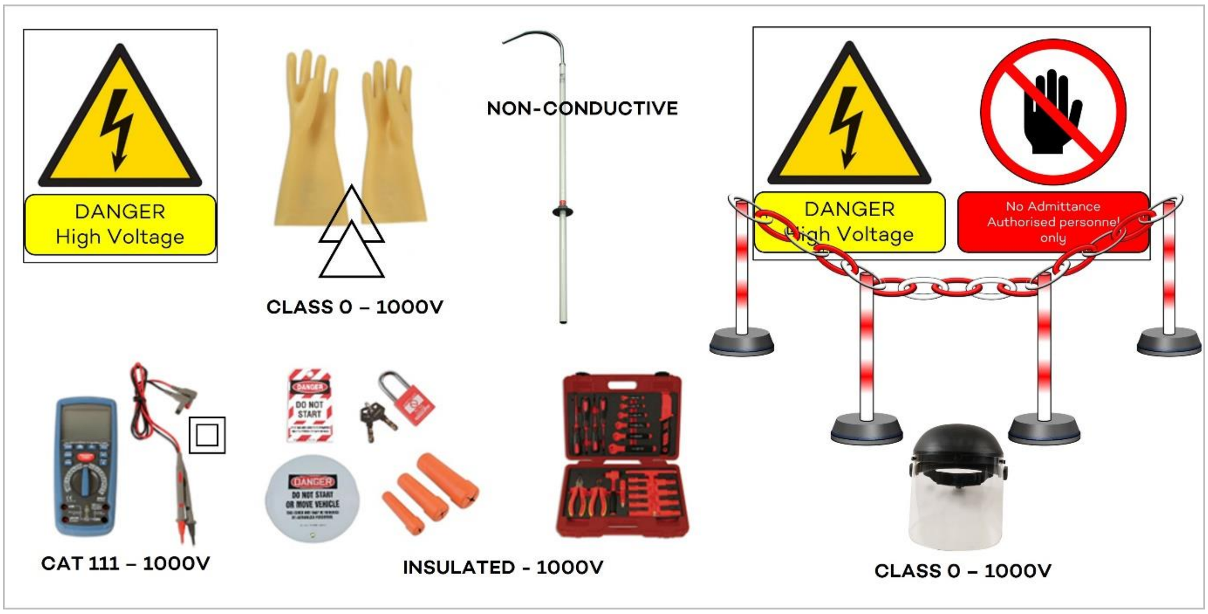
Non-conductive rescue hook. Used for removing a casualty from a dangerous environment - The power source cannot be switched off/isolated.

High Voltage – Do Not Approach – Warning Sign

Placed on vehicle to warn others not to approach this vehicle. The sign indicates the high voltage system has been exposed/disassembled. The risk for contacting the high voltage system has increased! Always seek permission from the appropriate person before making physical contact with this vehicle.

Safety Chain – Barrier

Placed around vehicle when high voltage system has been exposed. The chain is to secure the working environment, do not enter without permission!



DVOM – Digital Voltmeter

Used for measuring high voltage system to prove the system has been decommissioned and declared safe to work with. This process is referred to as the Absence of Voltage. Remember the high voltage battery will still contain energy but has been isolated from the rest of the high voltage system.

Must be the correct type – CAT 111 – Rated to 1000 Volts. The markings indicate the manufacturer guarantees the equipment is insulated up to 1000Volts. Always inspect casing etc for damage prior to use.

Test leads are marked with a double triangle. These are the correct test leads to use. Double square means double insulated – Always inspect leads for damage etc prior to use.

Lock off Tooling – Insulators – Rated to 1000V

Used to prevent vehicle from starting – booting up high voltage system. Safety procedure to ensure personnel are safe from accidental electric shock. Insulators are used to “cap off” disconnected high voltage cabling.

Insulated Tooling

Must be used when working on potentially live high voltage components. Insulation protects against accidental grounding/shorting of high voltage components.

Safety glasses – Full Face Mask

Must be correct class rated (Minimum Class 0) used for protecting wearer from electric flash/Arcing. Risk exists when disconnecting or reconnecting high voltage components.

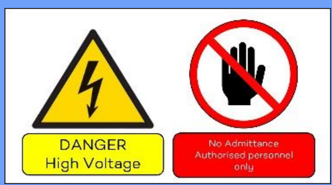
2.9: Test your knowledge

1	**Which of the following is classed as High Voltage?**	
a	12 Volts DC or 6 Volts AC	
b	30 Volts DC or 15 Volts AC	
c	48 Volts DC or 24 Volts AC	
d	60 Volts DC or 30 Volts AC	

2	**Which statement best describes "Intrinsically Safe"?**	
a	Available energy is completely isolated from the vehicle	
b	Available energy is reduced quickly to a level that causes no harm	
c	Available energy is kept at a level that causes no harm	
d	Available energy is completely discharged when the system is off	

3	**Which of these values is considered the Fatal Threshold?**	
a	10 Milliamps – (0.010 Amps)	
b	50 Milliamps – (0.050 Amps)	
c	80 Milliamps – (0.080 Amps)	
d	30 Milliamps – (0.030 Amps)	

4	**Which of these is not classed as a high voltage vehicle?**	
a	A Mild Hybrid	
b	A Hybrid Electric Vehicle	
c	A Plug-in Hybrid Vehicle	
d	A Battery Electric Vehicle	

5	**The graphic shows a sign. If a vehicle has this sign placed on it, what does this mean?** 	
a	Vehicle has been made safe, high voltage system is isolated	
b	Identified as a HV vehicle – safe to start or drive	
c	Risk of electrocution reduced – proceed with caution	
d	Do not approach vehicle, high voltage components exposed!	

6	**What is the name of the component that temporarily stores energy after the high voltage system has been switched off?**	
a	Capacitor	
b	Battery	
c	Contactor set	
d	Service Plug	

7	**What is the minimum time limit allowed before a capacitor is fully discharged?**	
a	5 Minutes	
b	10 Minutes	
c	Refer to the manufacturer's technical data	
d	2 Minutes	

8	**Which is the missing word:** **Once removed, store/secure the keys at least _____ metres from the vehicle to ensure they are out of range of the vehicle ignition system.**	
a	Two	
b	One	
c	Four	
d	Three	

9	**Which of the following would be "Best Practice" when working with HEV/EV vehicles?**	
a	Only level 2 or above, qualified people should work with these cars.	
b	Always check with the manufacturer for guidance before conducting any work on these cars.	
c	Level 3 and above qualified people should strip and repair high voltage batteries	
d	Personnel should wear Class 0 gloves when washing these vehicles.	

10	**AN HEV displays:" READY" on the instrument cluster>** **Which of the following applies?**	
a	All these statements	
b	The vehicle is Ready to drive	
c	The hybrid system is free of any safety faults	
d	The Internal Combustion Engine may start unexpectedly	

Congratulations on completing this module.

We hope that you enjoyed participating and found the information enclosed useful.

For us to ensure the content and format has achieved this we would kindly ask you to leave some feedback.

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