HL IB Physics

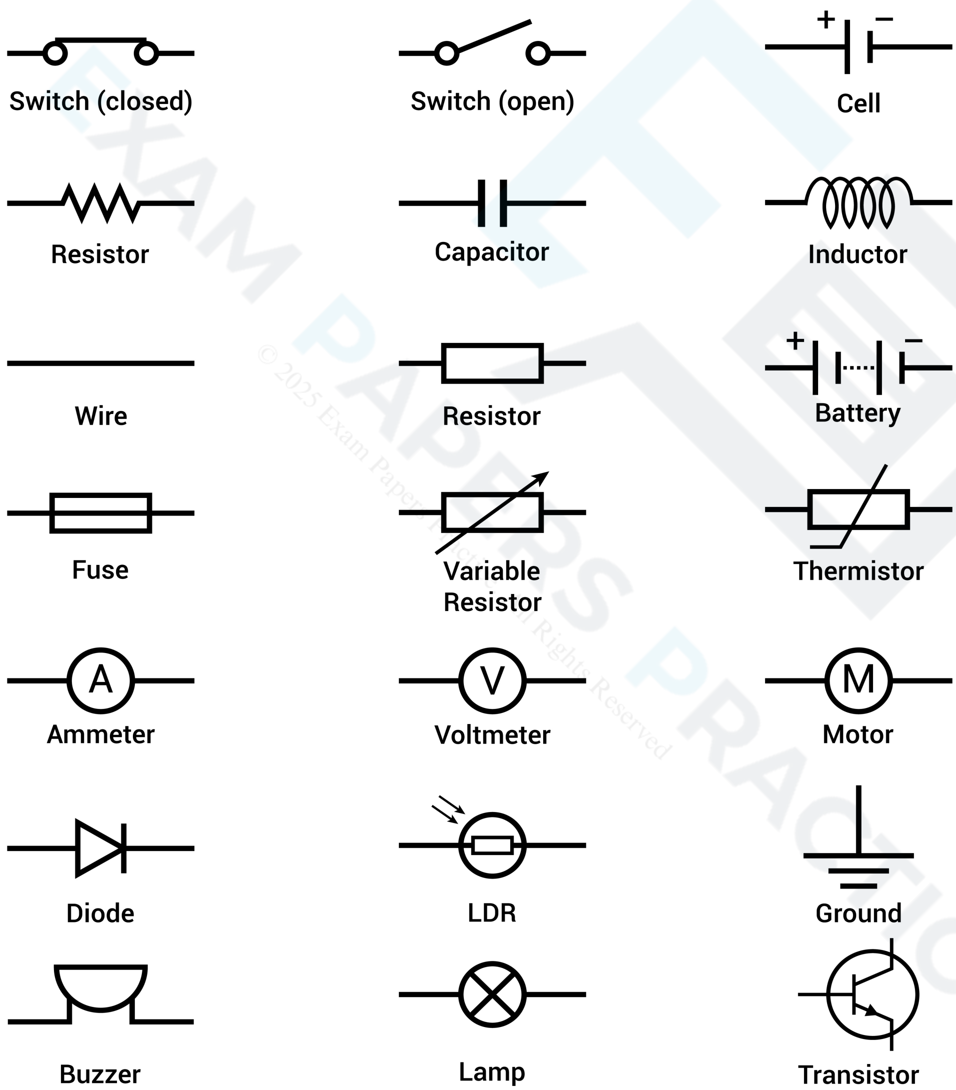
Current & Circuits

Contents

Circuit Diagrams

Circuit Diagrams

- Circuit symbols are used to represent electrical components in circuit diagrams
- These symbols are universally recognised by all scientists in any language
- The following symbols are commonly used in circuit diagrams



Circuit symbols

Cells & Batteries

- A device which converts energy from a chemical energy store to electrical store (one battery)
  - The direction of the current flow is from the **positive** (longer side) to the **negative** (shorter side) terminal
  - This is the opposite direction to the electron flow
- A **battery** is simply a power source made up of multiple cells

Switch

- A device which turns the circuit on (closed), or off (open)
- The switch allows or prevents the flow of current

Voltmeters & Ammeters

- A **voltmeter** is a device which measures the potential difference between two points in a circuit
- An **ammeter** is a device which measures the current flowing in a circuit

Fixed resistor

- A device which increases resistance to limit the flow of current
- As electrons flow through a resistor, they transform energy from its electric potential energy store into other stores (e.g. thermal energy)

Variable resistor

- A resistor with a slider that can be used to **change** its **resistance**
- As the resistance of the variable resistor increases, the current in the circuit decreases and vice versa

Light-dependent resistor (LDR):

- A resistor whose resistance depends on the light intensity
- As light intensity increases, the resistance of an LDR decreases and vice versa

Thermistor:

- A resistor whose resistance depends on its temperature
- As temperature increases, the resistance of a thermistor decreases and vice versa

Potentiometer

- A resistor with a sliding contact to form an adjustable voltage divider

Lamp

- A lighter emitting component consisting of heating a filament inside a glass cover

Light-emitting diode (LED)

- A device that emits light when a current passes through it
- A diode only allows current to flow in one direction only

Heating element

- An element that converts energy from an electrical store into a thermal store through the process of resistance

Motor

- An element that converts energy from an electrical store into a mechanical store

Earth (ground)

- The point in the circuit which is grounded i.e. connected to the Earth
- A connection to the Earth allows an instantaneous discharge to occur if an appliance malfunctions
- Electrons are transferred directly to the Earth through a low-resistance wire

Drawing Circuit Diagrams

- Circuit **diagrams** represent the **arrangement** of components in a circuit
  - This is important, as some components need to be in a certain position in relation to the others to work
- Being able to draw and interpret circuit diagrams using circuit symbols is an essential skill in the electricity topic

A circuit diagram must include:

- An **energy source**
  - This is a source of **potential difference** so a current can flow
  - This can be a cell, battery, or a power supply
- A **closed path** or a **complete circuit**
  - Electrons need to flow in a complete loop for a current to flow
  - A circuit can be open and closed using a switch
- **Electrical components** (using the correct circuit symbol)
  - These could act as sensors that respond to the environment (LDR, thermistor)
  - Or, measure a value (ammeter, voltmeter)
  - Or, transfer electrical energy to other forms of energy (LED, lamp)

Measuring Current

- Electric current is measured using an **ammeter**
- Ammeters should always be connected in **series** within a circuit

- An **ideal** ammeter should have zero resistance
  - This way, it will not take any energy from the electrons flowing through it
  - Otherwise, it would alter the value of the current it is trying to measure

Measuring Potential Difference

- Potential difference (or voltage) is measured using a **voltmeter**
- A voltmeter is always set up **in parallel** to the component being measured
- This means that the voltmeter must be connected across the terminals of the component

- A measurement of potential difference represents the difference between the values of electric potential on either side of the component
  - This is because 1 Volt (V) is equivalent to 1 Joule per Coulomb ($J\ C^{-1}$)
- Therefore, the key rules to remember are:
  - An ammeter is always connected in **series**
  - A voltmeter is always connected in **parallel** to the component the voltage is being measured
  - The direction of current flow is always from the **positive** to the **negative** terminal of the power supply

Electric Current

Electric Current

- Electric current is **the rate of flow of charge** carriers and is measured in units of **amperes (A)** or **amps**
- Charge can be either **positive** or **negative** and is measured in units **coulombs (C)**
- When two oppositely charged conductors are connected together (by a length of wire)
  - The charge will flow between the two conductors, giving rise to a current
  - The greater the flow of charge, the greater the electric current
- In electrical wires, the current is a flow of **electrons**
- Electrons are **negatively** charged so they flow **away** from the negative terminal of a cell **towards** the positive terminal
- **Conventional current** is defined as the flow of positive charge from the **positive** terminal of a cell to the **negative** terminal
  - This is the **opposite** of the direction of electron flow, as the conventional current was described before the electric current was really understood
- The potential difference in the circuit causes the current to flow
- Current is measured using an **ammeter**

- **Direct current** (**dc**) flows through the circuit in **one direction**
  - The direction of conventional current is from the **positive** terminal to the **negative** one
  - This is **opposite** to the **electrons** flow
- Direct current is produced when from cells and batteries
- The equation for current is:

$$I = \frac{\Delta q}{\Delta t}$$

- Where:
  - I = current (A)
  - Δq = change in charge (C)
  - Δt = time interval (s)

Worked example

When will 8 mA of current pass through an electrical circuit?

A. When 1 J of energy is used by 1 C of charge

B. When a charge of 4 C passes in 500 s

C. When a charge of 8 C passes in 100 s

D. When a charge of 1 C passes in 8 s

Answer: B

- The equation relating current, charge and time is:

$$I = \frac{\Delta q}{\Delta t}$$

- Consider option **B**:

$$I = \frac{4}{500} = 8 \times 10^{-3} = 8 \text{ mA}$$

- Therefore, the correct answer is **B**

- **A** is incorrect as it does not contain a value for charge or time, so it can be ruled out
- **C** is incorrect as:

$$I = \frac{8}{100} = 80 \times 10^{-3} = 80 \text{ mA}$$

- **D** is incorrect as:

$$I = \frac{1}{8} = 125 \times 10^{-3} = 125 \text{ mA}$$

Electric Potential Difference

Electric Potential Difference

- Potential difference (p.d.) is a measure of the electrical **potential energy** transferred by electrons as they move between two points in a conductor
- The definition of potential difference, also known as voltage, is:

  The work done per unit charge on moving a positive charge between two points along the path of the current

- Potential difference is measured in volts (V) and is calculated as follows:

$$V = \frac{W}{q}$$

- Where:
  - V = potential difference (V)
  - W = work done (J)
  - q = charge (C)
- From the above equation, one volt is equal to one joule per unit coulomb
  - $1\ V = 1\ J\ C^{-1}$
- The potential difference in a d.c. circuit is provided by **cells** or **batteries**
  - Each cell has a **positive terminal** (high potential location) and a **negative terminal** (low potential location)
  - A battery is a collection of cells arranged positive terminal to negative terminal

- When both terminals of a cell, or battery, are connected to a loop of conducting wire, a **circuit** is formed
- The cell or battery is the **source** of the potential difference needed for the electrons to flow
- Electrons gain electrical potential energy as they move through the cell
  - A small amount of their energy is transferred to the metal ions in the wire
  - The flow of electrons is from the negative to the positive terminal

The Electronvolt

- The energy values associated to electrons and other microscopic particles are very small when expressed in SI units
- For this reason, it is often more convenient to use another unit for energy - the **electronvolt** (**eV**)
- The electronvolt is defined as follows:

  The amount of energy needed to move an electron through a potential difference of one volt

Worked example

Determine the value of 1 eV in joules (J).

Answer:

Step 1: Recall the definition of electronvolt

- One electronvolt is the work *W* associated with an electron of charge e moving through a potential difference *V* = 1V

$$W = qV = eV$$

- Where e is the charge of an electron = 1.6×10^{-19} C

Step 2: Substitute this and the value of the voltage into the above equation for *W*

$$W = (1.6 \times 10^{-19}\ \text{C}) \times 1\ \text{V}$$

$$W = 1.6 \times 10^{-19}\ \text{J}$$

- One electronvolt is equal to 1.6×10^{-19} joules

Electrical Conductors & Insulators

Electrical Conductors & Insulators

Conductors

- A **conductor** is a material that allows **charge** (usually electrons) to flow through it easily
- Examples of conductors are:
  - Silver
  - Copper
  - Aluminium
  - Steel
- Conductors tend to be **metals**
- On the atomic scale, conductors are made up of positively charged metal ions within a sea of delocalised electrons
- Metals are **excellent conductors** of electricity because:
  - Current is the rate of flow of electrons
  - So, the more easily electrons are able to flow in a material, the **better** it is at conducting electricity

Insulators

- An **insulator** is a material that has **no free charges,** hence does **not** allow the flow of charge through them very easily
- Examples of insulators are:
  - Rubber
  - Plastic
  - Glass
  - Wood
- Some non-metals, such as wood, allow some charge to pass through them
- Despite not being very good at producing an electrical current, insulators are able to conduct **static electricity**
  - This occurs when an insulator builds up charge on its surface
  - When a charged insulator comes into contact with a conductor, the charge can be transferred

Electric Resistance

Electric Resistance

- As electrons move through a conductor within a circuit (or any other component), they collide with the metal ions and transfer some of their electrical **potential energy** to the **positive ions** of the metal

- This transfer of energy results in an increase in the kinetic energy of the atoms in the lattice
  - This raises the overall internal energy of the metal
- The macroscopic result of this transfer is the **heating up** of the wire which causes **resistance**
- Some metals heat up more than others
  - The greater the **heating effect**, the higher the **resistance**
  - Copper has a **low** electrical resistance, making it an ideal material to make wires from

- All electrical components have resistance to different degrees, including the wires and batteries
- Voltmeters and ammeters are said to be **ideal** when
  - An ideal voltmeter has **infinite** resistance, such that **no** current passes through it
  - An ideal ammeter has **zero** resistance, such that **all** the current passes through it

Calculating Resistance

- The resistance ***R*** of a component is defined as:

  The ratio of the potential difference across the component to the current flowing through it

- It is calculated as follows:

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

- Where:
  - V = potential difference (V)
  - I = electric current (A)
  - R = resistance (Ω)

- The units for resistance is **ohms** represented by the greek letter 'omega', Ω
- The **higher** the resistance of a component, the **lower** the current flowing through it and vice versa
- In terms of SI base units: 1 Ω = 1 kg m^2 s^{-3} A^{-2}

Worked example

A charge of 5.0 C passes through a resistor at a constant rate in 30 s. The potential difference across the resistor is 2.0 V.

Calculate the resistance R of the resistor.

Answer:

Step 1: Write down the known quantities

- Charge, Δq = 5.0 C
- Time, Δt = 30 s
- Potential difference, V = 2.0 V

Step 2: Write down the equation for the resistance *R*

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

Step 3: Calculate the current *I* from the charge and time

$$I = \frac{\Delta q}{\Delta t}$$

Step 4: Substitute the numbers into the above equation

$$I = \frac{5.0}{30} = 0.17 \text{ A}$$

Step 5: Substitute this value of the current into the equation for the resistance given in Step 2

$$R = \frac{2.0}{0.17} = 12 \, \Omega$$

Electrical Resistivity

Electrical Resistivity

- The **resistance** of a sample depends on:
  - The material it is made of
  - The length of the sample
  - The cross-sectional area of the sample

- The resistance of a conductor (e.g. a wire) is:
  - **Directly proportional** to its **length**
  - **Inversely proportional** to its **cross-sectional area**

- The cross-sectional area of a **wire** is always modelled as a **circle**
  - Therefore, the cross-sectional area is πr^2, where r is the radius of the wire

Resistivity

- This leads to the definition of a new quantity, called **resistivity**
- Resistivity is a property describing the extent to which a material **opposes** the flow of electric current through it
- It is defined as follows:

  The resistivity of a material is equal to the resistance per unit length of a material with unit cross-sectional area

- The equation for the resistivity is:

$$\rho = \frac{RA}{L}$$

- Where:
  - ρ = resistivity in ohm-metres (Ω m)
  - R = resistance in ohms (Ω)
  - A = cross-sectional area of material in square metres (m^2)
  - L = length of material in metres (m)

- Resistivity is measured in ohm-metres (Ω m)

- Resistivity is the **property** of a material

Resistivity of Materials Table

Material	Resistivity ρ (Ω-m) at 20°C	Temperature coefficient of resistivity (ppm/°C)
Copper	1.68×10^{-8}	3900
Silver	1.59×10^{-8}	3800
Gold	2.44×10^{-8}	3400
Aluminum	2.82×10^{-8}	3900
Lead	2.2×10^{-7}	3900
Tin	1.09×10^{-7}	4500
Tungsten	5.28×10^{-8}	4500
Iron	1.0×10^{-7}	5000
Resistive alloy	1.0×10^{-7}	700

- Conductors, such as metals, have **low** values of resistivity
  - This makes metals, such as copper and aluminium, ideal for making wires as they have low values of resistance, which is why they are excellent conductors
- Whereas insulators have such **high** values of resistivity that virtually no current will flow through them
  - This is why insulating materials, such as plastic and rubber, are ideal for housing electrical wires, as they keep current flowing within the circuit and prevent users from receiving dangerous electric shocks

I-V Characteristics

Ohm's Law

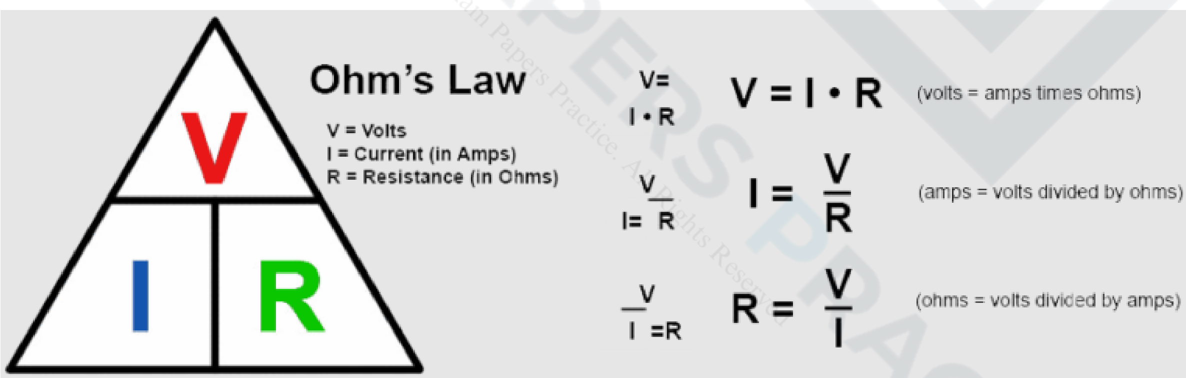
- Ohm's law states that:

  For a component at a constant temperature, the current through it is proportional to the potential difference across it

- It is defined by the equation:

$$V = IR$$

- Where:
  - V = potential difference (V)
  - I = current (A)
  - R = resistance (Ω)
- An electrical component obeys Ohm's law if its graph of current against potential difference is a **straight line** through the origin
  - A **fixed resistor** obeys Ohm's law i.e. it is an **ohmic** component
  - A **filament lamp** does **not** obey Ohm's law i.e. it is a **non-ohmic** component



The current-voltage graph for a fixed resistor is a straight line through the origin. The fixed resistor is an ohmic component

- The resistance of an ohmic component can be calculated from the **gradient** of a current-voltage graph, since resistance is equal to

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

- If **current** I is on the ***y***-axis and **potential difference** V is on the ***x***-axis, then $R = \frac{1}{gradient}$
- If **potential difference** V is on the ***y***-axis and **current** I is on the ***x***-axis, then $R = gradient$
- Any metal conductor at a **constant temperature** can be considered an **ohmic** device
  - This is likely to be a fixed resistance
- Non-ohmic devices include:
  - Lamps
  - LEDs
  - Thermistors

I-V Characteristics

- The Ohmic and non-Ohmic behaviour of an electrical conductor can be deduced by looking at its *I-V* (current-voltage) characteristics
  - This is usually plotted as a graph showing the variation of current against voltage
- The relation between potential difference across an electrical component (e.g. a fixed resistor) and current can be investigated through a circuit such as the one below

- By adjusting the resistance on the variable resistor:
  - The **current** in the circuit will **change**
  - For each value of the current I, the **potential difference** V can be **recorded**

- A graph of current against potential difference can then be plotted

I-V characteristics of common conductors

- Common ohmic conductors include
  - Wires (at constant temperature)
  - Resistors
- Common non-ohmic conductors include
  - Semiconductor diodes e.g. LEDs
  - Filament lamp
  - Thermistors & light-dependent resistors (LDRs)

Resistor

- A resistor is an example of an Ohmic resistor
  - This means the current is **directly proportional** to the potential difference
  - Its *I-V* graph is a **straight line** through the origin

Semiconductor Diode

- When the current is in the direction of the arrowhead symbol, the diode is said to be **forward-biased**
  - There is a sharp increase in current
  - This is shown on the right side of the graph

- When the diode is switched around, it does not conduct and it is said to be **reverse biased**
  - The current through the diode is zero
  - This is shown on the left side of the graph

- The diode is a **non-ohmic** component
  - Its *I-V* graph is not a straight line through the origin

- A specific type of diode is an **LED**
  - The *I-V* characteristic graphs looks the exact same for this

Filament Lamp

- For **very small voltages**, the filament lamp behaves as an **ohmic** component
  - The middle section of the graph (around zero voltage) is straight and passes through the origin

- As voltage increases:
  - More current flows through the filament lamp and the **temperature** of the filament in the lamp **increases**
  - The **higher** the **temperature** of the filament, the **higher** its **resistance**
  - Since resistance opposes current, the **current flows** through the filament **at a slower rate**
  - This is shown by the curved section of the graph

- For slightly **higher voltages**, the filament lamp is **non-ohmic**
  - The *I-V* graph is a curve with decreasing gradient

Series & Parallel Circuits

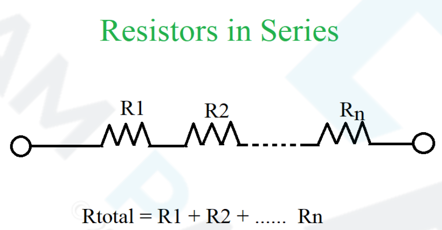
Series & Parallel Circuits

Resistors in Series

- In a **series** circuit:
  - The **current** is the **same** at any point
  - The **potential difference** is **split** across all components depending on their resistance
- When two or more components are connected in series:

The combined resistance of the components is equal to the sum of individual resistances

- Three resistors connected in series will have a **total resistance** of $R = R_1 + R_2 + R_3$



Resistors in series

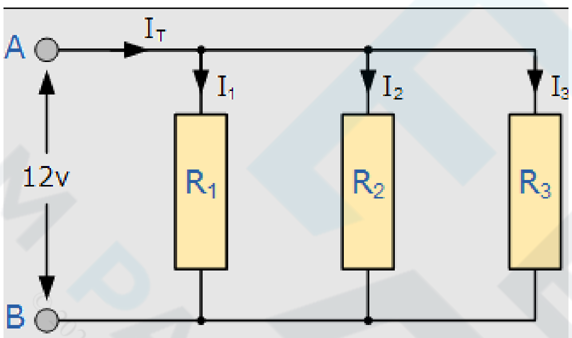
- The equation for the total resistance of **resistors in series** is derived using the above rules for current and potential difference:
  - For example, if two resistors of equal resistance are connected in series, then the combined resistance will **double**

Resistors in Parallel

- In a **parallel** circuit:
  - The total **current** is equal to the **sum** of the currents in each parallel **branch** of the circuit
  - The **potential difference** is the same across each loop
- In a parallel circuit, the combined resistance of the components requires the use of **reciprocals**

The reciprocal of the combined resistance of two or more resistors is the sum of the reciprocals of the individual resistances

- Two resistors connected in parallel will have a **total resistance** of $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$



Resistors in parallel

- The equation for the total resistance of **resistors in parallel** is derived using the above rules for current and potential difference:

Electrical Power

Electrical Power

- When an electrical current does work against electrical resistance:
  - Electrical energy is **dissipated as thermal energy** in the surroundings
  - The heat that is produced will dissipate via thermal conduction, convection and radiation
- The amount of heat produced depends on two factors:
  - **Current:** The greater the current, the more heat that is produced
  - **Resistance:** The higher the resistance, the greater the amount of heat produced (for a given current)
- Note that reducing the resistance can cause the current to increase
  - This could actually **increase** the amount of heat produced

- In mechanics, power *P* is defined as the **rate of doing work**
  - The potential difference is the **work done per unit charge**
  - Current is the **rate of flow of charge**
- Therefore, the electrical power is defined as the **rate of change of work done**:

$$P = \frac{E}{t} = \frac{W}{t}$$

- Where:
  - *P* = power (W)
  - *E* = energy transferred (J)
  - *W* = work done (J)
  - *t* = time (s)
- The work done is the energy transferred so the power is the **energy transferred per second** in an electrical component

- The power dissipated (produced) by an electrical device can also be written as

$$P = IV$$

- Where:
  - *I* = current (A)
  - *V* = potential difference (V)
- Using Ohm's Law ***V* = *IR*** to rearrange for either *V* or *I* and substituting into the power equation, means power can be written in terms of resistance *R*

$$P = I^2 R = \frac{V^2}{R}$$

- Where R = resistance (Ω)
- This means that, for a given resistor, **doubling** the current (or voltage) will yield an electrical power **four** times greater
- Rearranging the energy and power equation, the energy transferred can be written as:

$$E = VIt$$

Sources of Electrical Energy

Sources of Electrical Energy

- An electric cell stores chemical energy that can be transferred to electrical energy
- Electric cells, batteries and other sources of electrical energy come in many forms, such as
  - Chemical cells
  - Solar cells
  - Mains electricity
  - Wind generators

Chemical Cells

- Batteries, or chemical cells, utilise chemical reactions to provide a potential difference
  - They can be rechargeable or non-rechargeable
- Non-rechargeable batteries are by definition, only able to be **used once** as the chemicals within them are used up
  - Examples include alkaline, or AA batteries, common in many small devices
- Rechargeable cells can be **used many times** as they are attached to a charger and the **chemical reaction** is **reversed** allowing the cells to store energy for use once again
- Examples include:
  - Lithium-ion batteries used in laptops and other mobile devices
  - Lead-acid batteries such as those used in cars and other motor vehicles

Solar Cells

- Photovoltaic cells in solar panels convert **electromagnetic radiation** (photons) from the Sun into **electrical** energy
- When photons from the Sun are incident on the **solar heating panels**, the **light** energy is transferred into **thermal** energy
- The solar photons are absorbed by **electrons** on the surface of the photovoltaic cells, giving them enough energy to move and be **released** from the surface
- These electrons transfer the **thermal** energy into **electrical** energy which is then transferred to the external circuit

Advantages & Disadvantages

- Each energy source has its advantages and disadvantages, some of these are shown in the following table

Battery type	Advantages	Disadvantages
Single-use battery (e.g. alkaline AA battery)	high energy density convenient source of energy used in everyday appliances portable source of electrical energy potential to join many in series to increase p.d. low cost	non-rechargeable/limited power supply and will need replacing high internal resistance disposal issues/contributes to pollution made from non-renewable materials
Mobile phone battery (e.g. lithium-ion battery)	very high energy density high electrical efficiency	capacity of the cell degrades over time internal resistance increases over time

	convenient source of energy used in everyday appliances rechargeable, long lifetime fast charging time portable source of electrical energy low internal resistance	expensive
Car battery (e.g. lead-acid battery)	low cost rechargeable able to deliver very high currents in a short time	low energy density - very heavy compared to power output internal resistance increases as battery degrades limited number of full discharge cycles disposal issues/contributes to pollution, uses toxic and corrosive materials made from non-renewable materials
Solar cell	unlimited supply of energy clean to produce the electricity freely available everywhere cheap maintenance no fuel is required for energy	variable output, highly dependent on weather conditions impacted by poor weather limited efficiency only available during the day requires large investment upfront requires large areas
Wind generator	zero fuel costs, freely available no chemical pollution always sustainable and will never run out high set-up cost but becomes economical	inconsistent output, highly dependent on weather conditions requires favourable local conditions to be placed in windy locations noise/visual pollution

Mains electricity (fossil fuel generator)	extensive infrastructure in place high energy density of fuel reliable/available energy at any time well-known and developed technology	produces greenhouse gases unsustainable (non-renewable) produces pollution

Electromotive Force & Internal Resistance

Electromotive Force

- When charge passes through a power supply such as a battery, it **gains** electrical energy
- The **electromotive force (e.m.f.)** is defined as

  The amount of chemical energy converted to electrical energy per coulomb of charge (C) when charge passes through a power supply

- Cells and batteries provide a **source** of e.m.f.
- E.m.f. is measured in **Volts** (V) and can be calculated using:

$$\text{E.M.F.} = \frac{W}{Q}$$

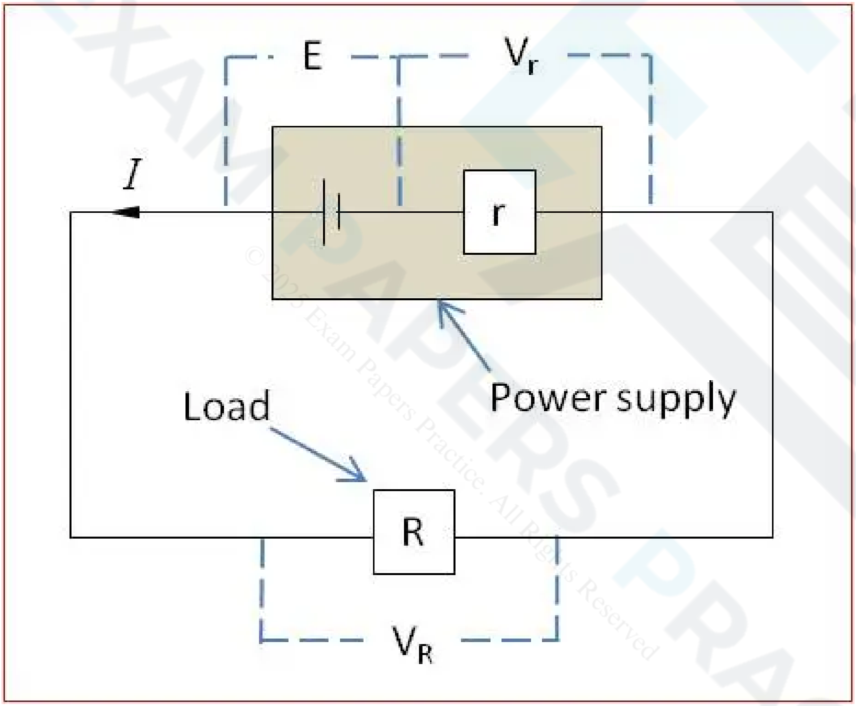
Where:

- E.M.F. = Electromotive force (in volts, **V**)
- W = Work done or energy transferred (in **joules**, J)
- Q = Charge (in **coulombs**, C)

- Emf is also the potential difference across the cell when **no** current is flowing
- The emf of a cell can be measured by connecting a high-resistance voltmeter around the terminals of the cell in an open circuit

Internal Resistance

- All power supplies have some resistance between their terminals
  - This is called **internal resistance** (*r*)
- This internal resistance causes the charge circulating to dissipate some electrical energy from the power supply itself
  - This is why the cell becomes warm after a period of time
- The internal resistance therefore causes **loss of voltage** or energy loss in a power supply
- A cell can be thought of as a source of e.m.f with an internal resistance connected in series. This is shown in the circuit diagram below:



Circuit showing the e.m.f and internal resistance of a power supply

- Where:
  - Resistor *R* is the 'load resistor'
  - *r* is the internal resistance
  - ε is the e.m.f
  - V_r is the **lost volts**
  - V_R is the p.d across the load resistor, which is the same as the terminal p.d
- V_r is called the 'lost volts' as its the potential difference 'lost' due to the internal resistance in the cell

- The e.m.f is the **sum** of these **potential differences,** giving the equation below:

$$\varepsilon = I(R + r)$$

- Where:
  - ε = electromotive force (emf) (V)
  - I = current (A)
  - R = resistance available to the rest of the circuit (Ω)
  - r = internal resistance (Ω)
- Emf is, therefore, the total, or maximum, voltage available to the circuit

Variable Resistance

Variable Resistance

Thermistors

- A thermistor is a non-ohmic conductor and sensory resistor whose resistance varies with temperature
- Most thermistors are negative temperature coefficient (ntc) components.
  - This means that if the temperature **increases,** the resistance of the thermistor **decreases** (and vice versa)
- Thermistors are temperature sensors and are used in circuits in ovens, fire alarms and digital thermometers
  - As the thermistor gets **hotter**, its resistance **decreases**
  - As the thermistor gets **cooler**, its resistance **increases**

Light-dependent resistors (LDR)

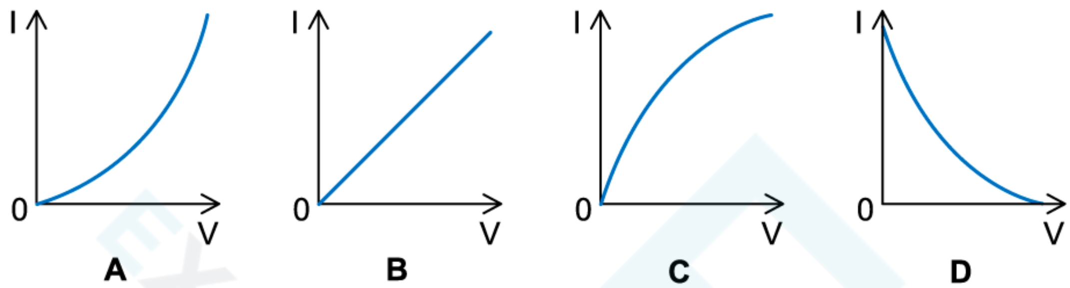
- A light-dependent resistor (LDR) is a non-ohmic conductor and sensory resistor
- Its resistance automatically changes depending on the light energy falling onto it (illumination)
- LDRs can be used as light sensors, so, they are useful in circuits which automatically switch on lights when it gets dark, for example, street lighting and garden lights
  - In the dark, its resistance is very large (millions of ohms)
  - In bright light, its resistance is small (tens of ohms)

Potentiometer

- A potentiometer is similar to a variable resistor connected as a potential divider to give a continuously variable output voltage
- It can be used as a means of comparing potential differences in different parts of the circuit
- It is recognised on a circuit diagram with a resistor fitted with a sliding contact
- The sliding contact has the effect of separating the potentiometer into two parts (an upper part and a lower part), both of which have different resistances

Worked example

Which graph best represents the way in which the current I through an LDR depends upon the potential difference V across it?



ANSWER: **B**

- As the potential difference across the LDR increases, the light intensity increases causing its resistance to decrease
- Ohm's law states that $V = IR$
- The resistance is equal to V/I or 1/R = I/V = gradient of the graph
- Since R decreases, the value of 1/R increases, so the gradient must increase
- Therefore, I increases with the p.d with an increasing gradient