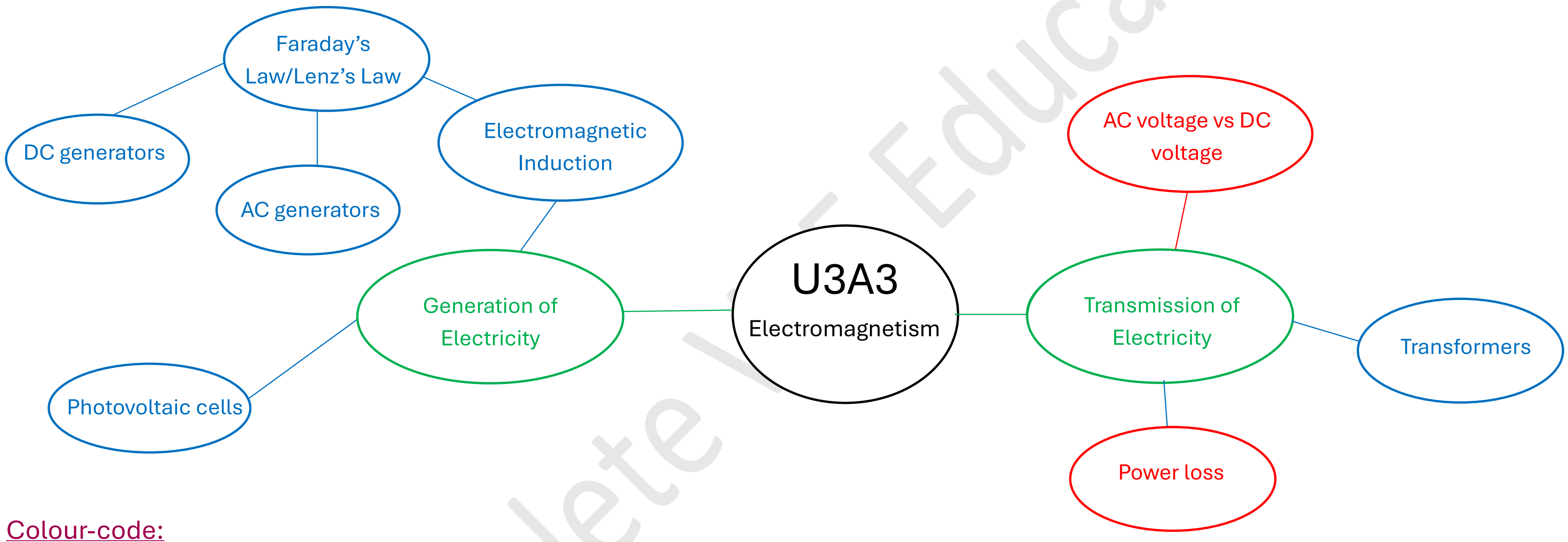
# U3A3 Introduction - Electromagnetism

## Overview




Colour-code:

Black = area of study

Green = topics within area of study

Blue = new in year 12

Red = also covered in year 11

# Topic 1: Generation of Electricity

| Subtopic | Elaboration | Relevant Year 11 knowledge | Formulas and concepts | SAC/Exam tips | Example questions |
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| **Electromagnetic Induction** | Covers the generation of a voltage and therefore electricity via the changes in magnetic flux through the area of a coil. | • Voltage/EMF<br>• Ohm's Law<br><br>Some knowledge from U3A2 is also important:<br>• Magnetic field strength<br>• Right hand coil rule | • **Magnetic flux**: defines the amount of magnetic field lines passing through the area of a coil. $\emptyset_B = B_{\perp}A$<br>• **Faraday's Law:** states that a coil subject to a changing magnetic flux experiences an induced EMF (voltage).<br>• **Lenz's Law:** states that the direction of the induced current in a coil is such that its induced magnetic field opposes the initial change in magnetic flux (use right hand grip/coil rule).<br><br>$\varepsilon = -N\frac{\Delta\emptyset_B}{\Delta t}$<br>• **Flux-time and EMF-time graphs**: from the above equation, the EMF-time graph is the negative derivative (ie. negative gradient or rate of change) of the flux-time graph. | • Both calculation problems and theory problems.<br><br>• Calculation questions will mainly ask you to find the magnitude of the induced EMF.<br>TIP: You do not need the negative sign (-) when using the EMF formula.<br>• Theory questions will mainly ask you to apply Lenz's law to find the direction of induced current.<br>• TIP: Lenz's Law deals with the direction of the 'change in magnetic flux', not the magnetic flux itself.<br>• NOTE: when using the right-hand coil rule for Lenz's law, the thumb points in the direction of the magnetic field due to the induced current, which is opposite the direction of the initial change in flux. The fingers curl in the direction of induced current. | • Calculate the magnitude of the induced EMF in this coil.<br>• Determine the direction of the induced current. |
| **AC Generators and DC Generators** | Apply your knowledge of electromagnetic induction to cover AC and DC electricity generation. | • Voltage/EMF<br>• Current<br>• Ohm's law | • **AC generators:** these are devices that convert mechanical energy into electrical potential energy, | • Mainly calculation problems, with occasional theory questions. | • Calculate the average EMF induced in this AC generator |

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| | | Some knowledge from U3A2 is also important:<br>• Magnetic fields<br>• DC motors<br><br>It is also important to have a solid understanding of the following concepts:<br>• Magnetic flux<br>• Faraday's Law and Lenz's Law | generating AC electricity. Utilise slip rings.<br>• **DC generators:** very similar to AC generators except they utilise split ring commutators instead of slip rings to generate DC electricity.<br><br>NOTE: Even though the set up of a generator is very similar to a DC motor, the energy conversions between these devices are the exact opposite. | • It is important to understand the use of Lenz's Law in determining the direction of the induced current.<br>• Understand the difference between slip rings and split ring commutators.<br>• Note that DC generators produce current flowing in a constant direction only. The magnitude of the current still changes. | using Faraday's Law.<br>• Sketch the EMF-time graph for this AC generator.<br>• Explain the purpose of a split ring commutator in DC generator. |
| **Photovoltaic Cells** | Covers the generation of electricity through the conversion of light energy into electrical potential energy in photovoltaic (PV) cells that make up solar panels. This topic is largely unrelated to electromagnetic induction | • Basics of electrical circuits<br>• Ohm's Law<br>• Calculating total current, resistance and voltage in series and parallel circuits | • **Basics of circuits:** understand how to analyse series and parallel circuits using current, voltage and resistance.<br>• **Photovoltaic cells:** cells that generate a DC voltage, hence electricity, through the conversion of light energy into electrical potential energy.<br>• **Inverter:** devices needed to convert DC electricity produced by PV cells into AC electricity that can be easily used by household appliances | • Mostly involves theory questions however can also be given calculation questions involving circuits.<br><br>• Revise the topic of parallel circuits before commencing this topic<br><br>• Note: in the 2024 VCAA exam, there is a question regarding the voltage across multiple photovoltaic cells. However, the concept of voltage summation in a series circuit isn't explicitly covered in the Y12 syllabus (however it is assumed knowledge from Y11). | • Explain how photovoltaic cells generate DC electricity.<br>• Explain the role of an inverter in households fitted with solar panels.<br>• Calculate the current outputted by this photovoltaic cell in this circuit. |

# Topic 2: Transmission of Electricity

| Subtopic | Elaboration | Relevant Year 11 knowledge | Formulas and concepts | SAC/Exam tips | Example questions |
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| **AC voltage vs DC voltage** | AC voltage graphs can be analysed to determine the peak voltage ($V_p$) and peak-to-peak voltage ($V_{p-p}$). Current graphs can be analysed in a similar way.<br><br>To analyse an AC circuit, we need to convert the AC voltage to its equivalent DC voltage, also known as the RMS voltage ($V_{RMS}$). | • AC electricity<br>• Peak voltage and peak-to-peak voltage<br>• Peak current and peak-to-peak current<br>• RMS voltage and RMS current | • **RMS Voltage**: DC equivalent of changing AC voltages. $V_{RMS} = \frac{V_p}{\sqrt{2}}$<br>• **RMS Current:** DC equivalent of changing AC currents $I_{RMS} = \frac{I_p}{\sqrt{2}}$<br>• **Peak-to-peak voltage:** difference between highest and lowest voltage values in AC. $V_{p-p} = 2V_p$<br>• **Ohm's Law:** $V_{RMS} = I_{RMS}R$<br>• **Power Formula:** $P_{RMS} = I_{RMS}V_{RMS}$ $P_{RMS} = \frac{P_p}{2}$ | • Mainly comprises calculation questions, however some theory questions can also be given.<br>• Remember if AC peak values for current and voltage are given in a circuit, these need to be converted to their RMS counter parts before commencing circuit analysis | • Given the peak voltage, calculate the RMS voltage.<br>• From the corresponding current graph, determine the peak-to-peak current. |
| **Transformers** | Transformers are circuit devices that can change the voltage and current of electricity in transmission lines whilst preserving the power.<br><br>They utilise electromagnetic induction to function; hence they rely on AC electricity. | • Power, voltage and current | • **Step-up Transformers:** transformers which increase the voltage and therefore reduce the current ($N_2 > N_1$)<br>• **Step-down Transformers:** transformers which reduce the voltage and therefore increase the current. ($N_2 < N_1$)<br>• **Ratios Formula:** $\frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$ | • Questions are usually calculation based however some theory questions can also be given.<br>• If a question gives the ratio of the turns of wire, e.g. 'a transformer has a ratio 1:4', then you can set up the ratio equation $\frac{N_2}{N_1} = \frac{4}{1}$. This also means that the voltage is being 'step-upped' by a factor of 4, therefore the current must be reduced by a factor of 4 as they are inversely proportional. | • Explain how transformers can reduce the power loss in transmission lines.<br>• Explain why transformers do not function with DC electricity. |

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| | | | | • Beware of trap questions that tell you a transformer is supplied with a DC voltage. In these cases, a transformer does not work, and the output voltage is always 0. | |
| **Power loss** | An important consideration when transmitting power to people's homes is reducing power loss in the transmission lines. This can be achieved using step-up and step-down transformers. | • Voltage, current and power<br>• Resistance<br>• Ohm's Law | • **Ohm's Law:** $V = IR$<br>• **Power Formulas:** $P = IV$<br>$P = I^2R$<br>$P = \frac{V^2}{R}$<br>• **Voltage Loss:** $V_{drop} = I_{line}R_{line}$<br>• **Power Loss:** $P_{loss} = {I_{line}}^2R_{line}$<br><br>Power loss can be reduced using a step-up (close to the generator) and step-down transformer (close to the end user):<br>• A **step-up transformer** increases the transmission voltage, which reduces the transmission current (since power is constant). The reduced current leads to reduced power loss ($P_{loss} = {I_{line}}^2R_{line}$).<br>• The **step-down transformer** close to the end reduces the voltage to a usable value for the end user. | • Questions are usually calculation based however some theory questions can also be given.<br>• IMPORTANT: Despite not being explicitly mentioned in the equations, all electricity equations use RMS values, not peak values.<br>• TIP: To power loss in the transmission lines you can use any one of the power formulas, however the $'V'$ in the formulas is actually the voltage drop, not the total voltage. You can replace $V$ with $\Delta V$ or $V_{drop}$ in the power loss equations to help you remember the correct voltage to use. | • Explain why AC electricity is preferred over DC electricity for long distance transmission.<br>• Given the following transmission line circuit, calculate the voltage supplied to the household.<br>• Calculate the power loss in the transmission lines.<br>• Explain why high voltage transmission reduces power loss. |