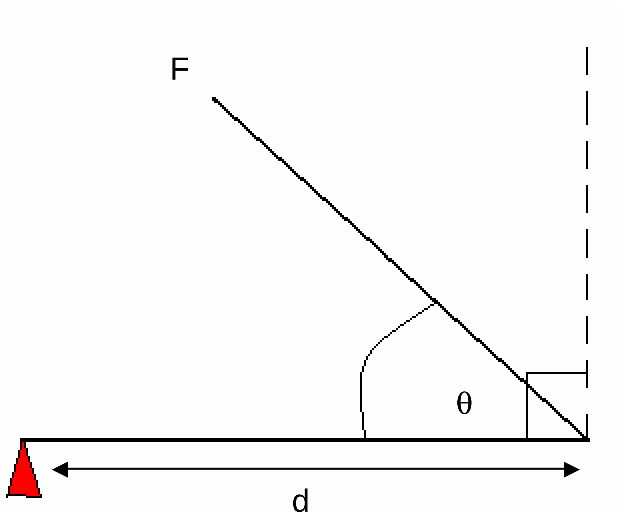
Topic 2 **Focus 1** **Motors use the effect of forces on current-carrying conductors in magnetic fields.**	
• **Discuss the effect on the magnitude of the force on a current carrying conductor of variations in:** o **The strength of the magnetic field in which it is located** o **The magnitude of the current in the conductor** o **The length of the conductor in the external magnetic field** o **The angle between the direction of the external magnetic field and the direction of the length of conductor.**	**Factors Affecting the magnitude of the force:** • The strength of the external magnetic field. The force is **proportional to magnetic field strength**, *B*. • The magnitude of the current in the conductor. The force is **proportional to the current**, *I*. • The length of the conductor in the field. The force is **proportional to the length**, *l*. • The angle between the conductor and the external magnetic field. The force is at a **maximum** when the conductor is at **right angles** to the field, and it is at **zero** when the conductor is **parallel** to the field. If the angle is anywhere in between, the force must be multiplied by the Sine of that angle. **Mathematically:** $F = BIl \sin\theta$ Where: **F** – **Force** in newtons (**N**) **B** – **Strength** of the **magnetic field** in Teslas (**T**) **I** – **Current** in the conductor in amps (**A**) ***l*** – **Length** of the conductor in **metres**
• **Describe qualitatively and quantitatively the force between long parallel current carrying conductors.** $\frac{F}{l} = k\frac{I_1 I_2}{d}$	**Factors affecting the force:** • The currents of the two current carrying conductors. The force is **proportional to the product of the two currents**, I_1 & I_2. • The distance between the two current carrying conductors. The force is **inversely proportional to the distance**, *d*, between the two conductors. **Rules:** • **Like** currents **attract**. • **Unlike** currents **repel**. • The force is **equal** on both conductors. **Equation:**

	$\frac{F}{l} = k\frac{I_1 I_2}{d}$ Where: F – Force in Newtons (N) l – Length of the wire in metres (m) d – Distance between the two wires in metres (m) k – Constant = 2 x 10^{-7} NA^{-2}. $I_1 I_2$ – Currents in each wire in Amps (A)
• **Define torque as the turning moment of a force using: $T = Fd$**	**Torque** is the turning effect of a force. It is the product of the tangential component of the force and the distance the force is applied from the axis of rotation.  **Equation:** $T = F \times d \times Sin\,\theta$ Torque is at a maximum when the direction of applied force is perpendicular to the plane of the coil. There are instances where we need to substitute in other values to solve problems involving torque. A common problem is to use the equation for force on a conductor: $F = BIl\sin\theta$ And the force due to gravity: $F = mg$ And equate them: $BIl\sin\theta \times d = mg \times d$
• **Identify that the motor effect is due to the force acting on a current carrying conductor in a magnetic field.**	The **motor effect** is the action of a force experienced by a current carrying conductor in an external magnetic field. When a **current** flows through a **current carrying conductor**, a **magnetic field** is produced. This produced **magnetic field** interacts with the **external magnetic field**, causing movement of the **current carrying conductor**. This

	is the **motor effect**.
• **Describe the forces experienced by a current carrying conductor in a magnetic field and describe the net result of these forces.**	A **force** is applied to a **current carrying conductor** by an **external magnetic field**. This **force** will create **torque** which enables the wire or loop to move or spin. The **right hand push rule** is used to find the direction of the force acting on a **current carrying conductor** in an **external magnetic field**.
• **Describe the main features of a DC electric motor and the role of each feature.**	The **magnets** provide the **external magnetic field** and are fixed to casing of the motor. As the magnets are part of the casing, they are stationary and therefore become known as the **stator**. The **armature** is a frame around which the coil of wire is wound, which rotates in the motor's magnetic field. As this is the part that rotates, it is known as the **rotor**. A **commutator** is a device for reversing the direction of a current flowing through an electric circuit, for example, the coil of a motor. A **split metal ring** is the two-piece conducting metal surface of the **commutator**. The **brushes** are conductors that make electrical contact with the moving **split metal ring** of the **commutator**.
• **Identify that the required magnetic fields in DC motors can be produced either by current carrying coils or permanent magnets.**	There are two ways to produce the required **magnetic fields** for a **DC motor**. • **Permanent magnets** can be used to supply a permanent magnetic field. • **Current carrying coils** can be used. When a current flows through a current carrying conductor and magnetic field is produced around that conductor. This field could then be used in a motor. This is effectively an **electromagnet** without a core.
• **Solve problems using $\frac{F}{l} = k\frac{I_1 I_2}{d}$**	Substitute the known values into the equation to solve for the variables that are unknown.
• **Perform a first-hand investigation to demonstrate the motor effect.**	<u>Experiment:</u> <u>Aim:</u> To observe the motor effect and the force on a current carrying conductor in an external magnetic field. <u>Method:</u> 1. Set up apparatus.. 2. Position the horseshoe magnet so that the strip of aluminium is between the poles. 3. Turn on the current and record the movement of the aluminium strip.

	4. Reverse the North and South poles of the magnet and turn the current back on. Record the movement of the strip. Conclusion: The strip will experience a force, and hence move, in the direction as stated by the **right hand push rule**.
• **Solve problems and analyse information about the force on current-carrying conductors in magnetic fields using:** $F = BIl\sin\theta$	Substitute appropriate values into the equation. Then do appropriate calculations before finding the values of the unknown variables.
• **Solve problems and analyse information about simple motors using** $T = BAIn\cos\theta$	Substitute appropriate values into the equation. Then do appropriate calculations before finding the values of the unknown variables.
• **Identify data sources, gather and process information to qualitatively describe the application on the motor effect in:** o **Galvanometer** o **Loudspeaker**	**Galvanometer:** The coil consists of many loops of wire which are connected in series with the rest of the circuit so that the current in the circuit flows through the coil. When the current flows, the coil experiences a force due to the presence of the external magnetic field (motor effect). The iron core of the coil increases the magnitude of this force. The needle is rotated until the magnetic force acting on the coil is equalled by a counterbalancing spring. It is important to note that the magnetic field in a galvanometer is radial so that the magnetic field is uniform for any degree of rotation by the needle. **Loudspeakers:** A loudspeaker consists of a circular magnet that has one pole on the outside and the other on the inside. A coil of wire (voice coil) sits in the space between the poles. The voice coil is connected to the output of an amplifier. The amplifier provides a current that changes direction at the same frequency as the sound that is to be produced. The voice coil is caused to vibrate in and out of the magnet by the motor effect.
Focus 2 **The relative motion between a conductor and a magnetic field**	

is used to generate an electrical voltage.	
• **Outline Michael Faraday's discovery of the generation of an electric current by a moving magnet.**	**Faraday's Experiment:** Faraday set out to **produce** and **detect** a current in a **coil of wire** by the presence of a **magnetic field** set up by another coil. **Faraday** managed to create a **current** only when the battery circuit switch was opened or closed. **Faraday** then went on to show that **moving a magnet** near a coil could generate an **electric current** in the **coil**. Another observation from **Faraday's** experiments with a **coil** and a **moving magnet** showed that the **magnitude** of the **induced current** depends on the speed the magnet is moved. When the rod was moved in the presence of an **external magnetic field**, its motion caused a change in the **magnetic flux**. This changing **magnetic flux** caused an **EMF** in the rod and this in turn produced an **electric current**. The quicker the magnet is moved, the greater the **magnitude** of the **induced current**.
• **Define magnetic field strength B, as magnetic flux density.**	**Magnetic flux** is the amount of magnetic field passing through a given area. The SI unit for flux is the **Weber** (Wb). The strength of the **magnetic field**, B, is also known as **magnetic flux density**. The SI unit for **magnetic flux density** is the **Tesla** (T) or **Weber per square metre** ($Wb\ m^{-2}$).
• **Describe the concept of magnetic flux in terms of magnetic flux density and surface area.**	**Magnetic flux** (in Webers) is the amount of **magnetic flux density** (T) passing through a given **surface area** (m^2). $\phi_B = BA$
• **Describe generated potential difference as the rate of change of magnetic flux through a circuit.**	**Faraday's Law of Induction**: The **induced EMF** in a circuit is equal in magnitude to the rate at which the **magnetic flux** through the circuit is changing with time. Therefore, it is the rate of change of **magnetic flux** through a circuit. $E = -\frac{\Delta\phi_B}{\Delta t}$
• **Account for Lenz's law in terms of conservation of energy and relate it to the**	**Lenz's Law:** An **induced EMF** always gives rise to a **current** that creates a **magnetic field** which opposes the original change in **flux** through the circuit. The **principle of conservation of energy** states:

production of back EMF in motors.	**Energy** cannot be created nor destroyed, but it can be **transformed** from one form to another. Without this law, energy could be produced without any work done. To create **electrical energy** in a coil, work must be done. **Energy** is required to move a magnet towards or away from a coil. This **kinetic energy** can be transformed into **electrical energy** in the **coil**. **Back EMF** is an **electromagnetic force** that opposes the main current flow in a circuit. When the coil of a motor rotates, a **back EMF** is induced in the **coil** due to its motion in the **external magnetic field**. The **back EMF** in a coil is **proportional** to **rotational speed**. For this reason, when a motor starts up, it must have a significant **resistance** applied so that it does not overheat, but can build up speed slowly. This **resistance** is gradually removed because when a motor is running at full speed, the **back EMF** produced is sufficient to keep the motor running at a constant speed.
• **Explain that, in electric motors, back EMF opposes supply EMF.**	**Back EMF** is an **electromagnetic force** that opposes the main current flow in a circuit. When the coil of a motor rotates, a **back EMF** is induced in the **coil** due to its motion in the **external magnetic field**. Due to **Lenz's Law**, the **back EMF** is produced to oppose the motion of the **force**. $V_{NET} = V_i - EMF$
• **Explain the production of eddy currents in terms of Lenz's law.**	An **eddy current** is a circular or whirling current induced in a conductor that is stationary in a changing magnetic field, or that is moving though a magnetic field. **Eddy currents** are an application of **Lenz's law**. The magnetic fields set up by the **eddy currents** oppose the changes in the **magnetic field** acting in the regions of the metal objects.
• **Perform an investigation to model the generation of an electric current by moving a magnet in a coil or a coil near a magnet.**	<u>Experiment:</u> <u>Aim:</u> To generate an electric current in a coil by moving a magnet in a coil or a coil near a magnet. <u>Method:</u> 1. Connect the coil with the fewest number of turns to the galvanometer. Push the North pole of a bar magnet into the coil and record what happens. 2. Hold the bar magnet stationary and describe what happens.

	3. Withdraw the magnet from the coil and describe what happens. 4. Repeat steps 1-3 but faster. <u>Conclusion:</u> An electric current is produced but only when there is a changing magnetic flux. Therefore, when the magnet is pushed in or pulled out of the coil, an electric current flows. When the magnet is stationary, no current is induced.
• **Plan, choose equipment or resources for, and perform a first hand investigation to predict and verify the effect on a generated electric current when:** o **The distance between the coil and magnet is varied** o **The strength of the magnet is varied** o **The relative motion between the coil and the magnet is varied.**	<u>Experiment:</u> <u>Aim:</u> To generate an electric current in a coil by moving a magnet in a coil or a coil near a magnet. The to analyse the effect of the distance between the coil and the magnet, the strength of the magnet and the relative motion of the coil has on the current. <u>Method:</u> 1. Connect the coil with the fewest number of turns to the galvanometer. Push the North Pole of a bar magnet into the coil and record what happens. 2. Hold the bar magnet stationary and describe what happens. 3. Withdraw the magnet from the coil and describe what happens. 4. Repeat steps 1-3 but faster. 5. Use another coil with the same number of turns but a larger diameter and repeat steps 1 to 4. 6. Repeat steps 1 to 5 with a stronger magnet. <u>Conclusion:</u> • The greater the distance between the coil and the magnet, the smaller the magnitude of the force and current. • The stronger the magnet, the greater the magnitude of the force and hence the greater the current. • The faster the relative motion of the magnet, the greater the force and current.
• **Gather, analyse and present information to explain how induction is used in cooktops in electric ranges.**	**Induction Cooking:** Put simply, an induction-cooker element is a powerful, high-frequency electromagnet, with the electromagnetism generated by sophisticated electronics in the "element" under the unit's ceramic surface.
<u>Focus 3</u> **Generators are used to provide large scale power production.**	

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- **Describe the main components of a generator.**

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A **generator** converts mechanical **rotational kinetic energy** into **electrical energy**.
In its simplest form, a **generator** consists of a coil of wire that is forced to rotate about an axis in a **magnetic field**.

As the **coil** rotates, the magnitude of the **magnetic flux** threading through the area changes. This **changing magnetic flux** produces a changing **EMF** across the ends of the wire.

The **magnetic field** can either be produced by **permanent magnets** or an **electromagnet**.

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- **Compare the structure and function of a generator to an electric motor.**

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A generator's structure is similar to an electric motor. The main difference is that the terminals of either the commutator or slip rings do not go to a power source, but rather go to a battery or circuit.

The main difference between the two is:
A Generator:
Rotational Kinetic Energy ⟶ Electrical Energy + Heat

An Electric Motor:
Electrical Energy ⟶ Rotational Kinetic Energy + Heat

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- **Describe the differences between AC and DC generators.**

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Differences:

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<tr><th>AC Generator</th><th>DC Generator</th></tr>
<tr><td>Slip rings</td><td>Commutator</td></tr>
<tr><td>Current changes direction every 180°</td><td>Current travels in a constant direction</td></tr>
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- **Discuss energy losses that occur as energy is fed through transmission lines from the generator to the consumer.**

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Power stations are usually situated large distances from cities where most of the consumers are located. This presents a problem with power losses in the **transmission lines**.

Transmission lines are essentially long metallic conductors which have significant resistance. This means that they have a significant voltage drop across them when they carry a large current. This could result in a greatly decreased voltage being available to the consumer.

AC can reduce energy loss by being transformed to have a high voltage.

We must remember that the **power loss** during transmission is **proportional** to the **square of the current**.
$P_{LOSS} = I^2R$
For that reason, **AC current** has **smaller energy losses** because it can be **transformed** to a **low current** and **high voltage**.

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- **Assess the effects**

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Affects on Environment:

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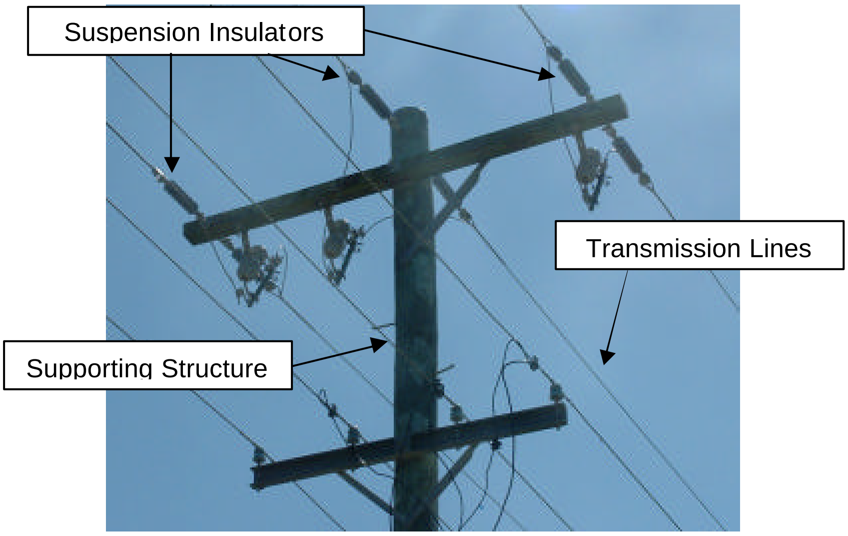
of the development of AC generators on society and the environment.	• AC generators are usually coal powered which creates air pollution. • Nuclear power stations provide problems with toxic waste. **Affect on Society:** • Power can be provided to the public at cheaper rates. • Improved standard of living. • Improves health, defence and entertainment. • Danger with electrocution. • Changes the skills required in the workplace.
• **Plan, choose equipment and resources for, and perform a first-hand investigation to demonstrate the production of an alternating current.**	Experiment: Aim: To produce an alternating current. Method: 1. Use a small bar magnet and a hollow coil of wire. 2. Connect the ends of the coil to a galvanometer. 3. Move the magnet back and forwards inside the coil and observe the reading on the galvanometer. Conclusion: The galvanometer records a reading that changes direction every time the magnet's movement changes direction. A current only flows when the magnet is moving (when a change in magnetic flux occurs) and does not occur when the magnet is stationary inside the coil. The faster the relative motion of the magnet, the greater the current produced.
• **Gather secondary information to discuss advantages/ disadvantages of AC and DC generators and relate these to their use.**	**DC Generators:** • Massive voltage needed initially due to the power loss over long distances. • Cannot be transformed. • Design is slightly simpler. **AC Generators:** • Can be produced a low voltages. • Have a smaller loss in voltage when transported over long distances. • Have the ability to be transformed.
• **Analyse secondary information on the competition between Westinghouse and Edison to supply electricity for cities.**	**Thomas Edison** was the founder of the **Edison General Electric Company** that was the first to supply electricity to street lamps. Edison used and supported **DC current**. Due to the nature of the current, the generators, nicknamed 'dynamos', had to be placed close to the output sources due to the drop in voltage. **Nikola Tesla** developed an **AC generator** that didn't have the same problems with voltage loss while still working for

	Edison. **Edison** refused to pay him for it so **Tesla** left. **Westinghouse** bought the patent for AC current and began to go into production. Over the ensuing years, the two tried to discredit each other's form of electricity. **Westinghouse** eventually won.
• **Gather and analyse information to identify how transmission lines are:** o **Insulated from supporting structures** o **Protected from lightning strikes**	**Insulation from supporting structures:** As sparks can jump a certain distance for high levels of potential difference, **transmission lines** must be **insulated** from the metal supporting structures. **Suspension insulators**, which consist of large, disk shaped **insulators**, are used in most **transmission line structures**.   **Protection from lightning strikes:** As **lightning** strikes the highest point above the ground, metal power towers are a common target. To prevent the **lightning** from doing damage to the tower and providing a surge to the grid, a **continuous earth line**

	runs from the top of the cable to the ground.
Focus 4 **Transformers allow generated voltage to be either increased or decreased before it is used.**	
• **Describe the purpose of electric transformers in electrical circuits.**	A **transformer** is a magnetic circuit with two multi-turn coils wound onto a common core. **Transformers** allow generated voltage to be either **increased** or **decreased** before it is used. **Factors Affecting the Performance of a Transformer:** • The distance between the primary and secondary coil. The greater the distance, the more inefficient the transformer. • The type of core. Certain types of cores allow the transformer to be more efficient. A transformer can also be used to change AC current into DC current.
• **Compare step-up and step-down transformers.**	A **step-up transformer** provides an **output voltage** that is greater than the **input voltage**. A **step-down transformer** provides an **output voltage** that is less than the **input voltage**.
• **Identify the relationship between the ratio of the number of turns in the primary and secondary coils and the ratio of primary to secondary voltage.**	In a **step-up transformer**, the number of turns of wire on the **primary coil** will be less than the number of turns of wire on the **secondary coil**. Conversely, in **a step-down transformer** the **primary coil** has a greater number of turns of wire than that of the **secondary coil**. **Mathematically:** $\frac{V_p}{V_s} = \frac{n_p}{n_s}$
• **Explain why voltage transformations are related to conservation of energy.**	The law of **conservation of energy** states that no energy can be created nor destroyed. If a **step-up transformer** gives a greater voltage at the output than there was at the input, there must be sum kind of trade-off as the **power supplied** must **equal** the **power output**. Since **P = VI**, and in an ideal **transformer** there would be no power loss:

	$V_p I_p = V_s I_s$
• **Explain the role of transformers in electricity sub-stations.**	Generated **voltage** from power stations **is transformed** up to 330kV for distribution. **Electricity sub-stations** are used either to boost up that voltage to account for losses during transmission or to reduce the voltage so it can be used in the home at **240V**.
• **Discuss why some electrical appliances in the home that are connected to mains domestic power supply use a transformer.**	Some **appliances** that are connected to mains power supply require a **transformer** for them to work. The majority of appliances in the home use **transformers** to step-down the **voltage** due to the fact that they do not require such high **voltages**. **Televisions** use a **step-up transformer** as they require large voltages to power the **cathode ray tube**. Other devices, such as mobile phone chargers, require DC current, so a transformer is used to change the supplied AC current into DC current.
• **Discuss the impact of the development of transformers on society.**	**Transformers** have allowed: • Electricity supply to be transported over large distances. • A cheap supply of power for the consumer once the infrastructure is established. • The access provides higher quality of health and standard of living. • Have allowed all electric supplies to be either stepped up or down. • AC generated current to be transformed into DC current.
• **Perform an investigation to model the structure of a transformer to demonstrate how secondary voltage is produced.**	Experiment: Aim: To set up a simple transformer and to observe the output voltage. Method: 1. Place a smaller (primary) coil in a larger (secondary) coil. Connect the secondary coil to the galvanometer. Connect the primary coil in series with the switch, variable resistor and cell. 2. Set the variable resistor to its lowest value. 3. Observe the effects on the galvanometer as you close the switch, keep it closed for five seconds and then open the switch. 4. Describe what happens 5. Close the switch and change the value of the variable resistor slowly and rapidly. Open the switch. 6. Record your observations. Conclusion: When the switch is opened or closed, a current flows in the circuit. When the value of the variable resistor is changed, a

	current flows in the circuit. The faster the variable resistor value is changed, the greater the current. No current flows when the resistance or voltage in the circuit is constant.
• **Solve problems and analyse information about transformers.**	Substitute appropriate values into the formula and carefully calculate unknown values.
• **Gather, analyse and use available evidence from secondary sources to discuss how difficulties of heating caused by eddy currents in transformers may be overcome.**	The **heat loss** can be reduced by constructing the **core** out of many layers with **insulators** between them. This reduces the size of the current and also the amount of heat generated. Alternative **ferrites** can also be used. These are good transmitters of **magnetic flux** but poor conductors of **electricity** making them more ideal.
• **Gather and analyse secondary information to discuss the need for transformers in the transfer of electrical energy from a power station to its point of use.**	The power generated at a power station is generated at 500V before it is stepped up to 500kV. It then suffers power loss through transmission before gradually being stepped down to 33kV, and finally 240V. The power that reaches the household is running at a voltage of 240V.
<u>Focus 5</u> **Motors are used in industries and the home usually to convert electrical energy into more useful forms of energy.**	
• **Describe the main features of an AC electric motor.**	Most AC motors have a cylindrical rotor that rotates about the axis of the motor's shaft. This type of rotor is usually referred to as a squirrel cage. An AC motor uses slip rings instead of the commutator. One of the bonuses of using induction motors over conventional motors is the fact that, due to less physical contact between parts, the motor runs with smaller losses due to friction.
• **Perform an investigation to**	<u>Experiment:</u> <u>Aim:</u>

demonstrate the principle of an AC induction motor.	To demonstrate the principle of an AC induction motor. Method: 1. Place two bar magnets on two books with a North pole on the left and a South pole on the right. 2. Put the conductor in between the magnets. 3. Connect conductor to galvanometer. 4. Move the conductor around inside the field both quickly and slowly. Conclusion: The faster the movement, the greater the rate of change in magnetic flux, and hence the greater the current flowing through the conductor.
• **Gather, process and analyse information to identify some of the energy transfers and transformations involving the conversion of electrical energy into more useful forms in the home and industry.**	There are a number of conversions that take place in the home or industry. • A hair dryer converts electrical energy into rotational kinetic energy and heat. • A light bulb converts electrical energy into light and heat. • Some stoves will convert electrical energy into eddy currents resulting in heat energy. • Speakers convert electrical energy into sound.