9.3.4 Transformers

Transformers allow generated voltage to be either increased or decreased before it is used

4.1 Describe the **purpose of transformers** in electrical circuits

PICTURE OF SIMPLE TRANSFORMER

- Transformers are devices that **increase or decrease** size of AC voltage
- A simple transformer has **a primary coil, secondary coil and soft iron core**
  - Primary coil: AC voltage fed in
  - Secondary coil (different number of coils): AC voltage fed out
- The **alternating current** of the primary coil **produces changing magnetic flux**
  - Magnetic flux linked through soft iron core to secondary coil and generate **EMF as output**
- **Soft iron core** (pure iron) is a medium that magnetic flux can flow through
  - Also soft iron can amplify magnetic flux as **domains** possess a net magnetic field

4.2 Compare **step-up and step-down transformers**

- **Step-up**: output is **higher than input** (i.e. steps up)
  - Therefore the secondary coil has **more turns**
- **Step-down**: output is **lower than input** (i.e. steps down)
  - Therefore the secondary coil has **less turns**

4.3 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**

$$\frac{n_p}{n_s} = \frac{V_p}{V_s}$$

Where V_p/V_s = voltage in primary or secondary coil (V), n_p/n_s = number of coils in primary or secondary coil

- So, to **increase the voltage** produced (V_s), **increase the number of coils** in the secondary coil (n_s)
  - Increasing number of coils **decreases current** (more turns in B field) and **increases the voltage**

4.4 Explain why voltage transformations are related to **conservation of energy**

$$P = IV$$

Where P = power (W) and **is constant** (assuming 100% efficiency), I = current (A), V = voltage (V)

- This formula when joined with $\frac{n_p}{n_s} = \frac{V_p}{V_s}$:

$$\frac{n_p}{n_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p} \; or \; V_p I_p = V_s I_s$$

- As voltage of **secondary coil increases** (by increasing turns), current **decreases** by conservation of energy

4.5 Explain the role of **transformers in electricity sub-stations**

Process and Reason	Voltage
• Electricity generated by three-phase AC generator, at 10,000 A	23,000 V
• For long distance, electricity fed into a **step-up transformer** • Minimises energy loss due to resistance	Up to 500 kV
• Voltage is **stepped-down** at different sub-stations • Design is simpler, cost of insulation affordable, and safer	
• Voltage is **stepped-down** to 240 V at local telegraph pole transformers	240 V

4.6 Discuss why some **electrical appliances in the home** that are connected to the mains domestic power supply **use a transformer**

- Some appliances require **step-up transformers** as they need more than 240V for operation
- Some appliances require **step-down transformers** for correct operation and safety reasons
    - Some electric ovens and cooktops **increase current** to **increase heating effect**

4.7 Discuss the **impact of the development of transformers** on society

- AC power **could be easily transformed and transmitted efficiently** over long distances
    - Shift from DC to AC power
    - Lower power loss, reduces price of electricity, decreases consumption of fossil fuels
- Power stations could be **placed further away** from cities
    - Decreases hazards and pollution
    - Generation of electricity can be concentrated in one place
- **Remote communities** have access to electricity that can be **stepped down** locally
    - Raises living standards of rural communities (fridges, lighting, air conditioning)
- Multitude of appliances at different voltages can be used in the household

4.P1 Perform an investigation to **model the structure of a transformer** to demonstrate how secondary voltage is produced

- Transformer from a **microwave oven** was observed
    - 240 V **stepped up** to around 2400 V output (to generate microwaves in the oven)
- 8.1 V AC power supplied, and amplified to 87 volts
- **Primary coil**: thick wires
    - Input coils carry a lot of current (low voltage)
- **Secondary coil**: thin wires
    - Output coils carry low current and high voltage, and has ten times the turns
- See https://www.youtube.com/watch?v=UO-0rNcuVNY

4.P2 Solve problems and analyse information about transformers using: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$

- See Physics in Focus Page 153 to 155

4.P3 Gather, analyse and use available evidence to discuss how **difficulties of heating caused by eddy currents** in transformers **may be overcome**

- Heating in a transformer is due to formation of **eddy currents**
  - As there is a changing magnetic flux, a solid conductor will generate **eddy currents** which will become **heat**
  - This causes a **loss in energy** through the transformer
- Prevention of **loss in energy:**
  - **Lamination** – stacks of thin iron sheets coated with insulation to reduce the size of eddy currents
  - **Ferrites** – good magnetic core, but has high resistivity to prevent eddy currents
- Prevention of **heat** (but still loses energy):
  - **Heat-sink fins** or **fans** added to the metal transformer to cool
  - **Non-conducting oil or water** to transport heat away from core

4.P4 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

- Energy lost as heat due to **resistance** of a conductor, based on $P = I^2R$
  - **A long transmission wire has high resistance**, but high voltage means **low current**
  - Therefore, there will be much less energy lost when energy travels with **high voltage**
- Transformers at the point of use required as these very high voltages are dangerous