1.4 How transmission lines are:

- *Insulated from supporting structures:*
- Static electricity can jump about 1cm for every 10 000V potential difference. Thus, transmission lines must be well insulated and some distance away from the metal towers that carry them.
    - **Insulation chains**: saucer shaped stacks of ceramic material used whenever the transmission wires need to be joined to any other metal structure, like the supporting tower.

- *Protected from lightning strikes*:
    - **Shield conductors**: two non-current carrying wires at the top of every tower protect them from lightning strikes because they will intercept the lightning strike and divert it to the earth.
    - **Earth cable**: runs from the top of the pole down to earth
    - **Metal tower**: an earth protection against lightning strikes as it is set deep in the ground.
    - **Distance**: the distance between the towers is at least 150m, which is enough to protect each tower from adjacent towers if one is hit by lightning.

Transmission lines must be protected from lightning strikes because:

- Strikes produce voltage surges that damage both the supply system and connected appliances
- They are expensive to repair
- Damage interrupts energy supply

1.5 discuss the energy losses that occur as energy is fed through transmission lines from the generator to the consumer

Energy losses from the generator:

Some of the mechanical energy used to drive the generator is lost before it reaches the consumer. This can occur because of:

- Friction in the bearings of the rotor
- Production of sparks (heat and light) between the rings and the brushes
- Production of heat in the wires of the coil, and in the transmission wires

Energy losses through transmission lines:

- Consider the immense length of transmission wire needed to carry the electrical energy from the generator to your home
- The resistance of a wire is proportional to the length of the conductor
- This means that the current has to pass through substantial resistances leading to a substantial amount of heat being produced in the transmission wires leading to substantial energy losses.
- This energy (power loss) is proportional to the resistance of the wire and to the square of the current
- $\mathbf{P_{lost} = I^2R}$

Strategies to minimise energy loss:
Electricity is transmitted at very high voltages - this lowers the current. “Step up” and “step down” transformers vary the voltage and current flowing through the transmission grid.

When AC electrical power is transmitted at high voltages, the current is reduced since power is constant.

Power loss in the wire is proportional to the square of the current, so since the current is decreased due to the high voltage, the power loss decreases by the square root.

Physics principle:
By the law of conservation of energy, the power output from a transformer cannot exceed the power input, so if voltage is stepped up, current must be stepped down by an equivalent factor.

$\mathbf{P_{in} = P_{out}}$

$\mathbf{V_{in}\, I_{in} = V_{out}\, I_{out}}$

4. Transformers

4.1 Describe the purpose of transformers in electric circuits

- Transformers are devices that change the supply voltage to a circuit.

- They are a magnetic circuit with two coils wound onto a common iron core. AC voltage is delivered to the primary coil and the secondary coil is the output connected to a load.
- The soft iron core acts as the medium through which the magnetic flux can flow.
- The magnetic flux is intensified by the iron core.

1. An alternating current flows through the primary coil.
2. The AC current produces a changing magnetic field.
3. Changing magnetic flux passes through the secondary coil.
4. Magnetic field from primary coil is intensified through the secondary coil by the iron core.
5. This increased changing flux through the secondary coil induces an emf across the secondary coil

Since a changing magnetic flux is required in electromagnetic induction, transformers do not work for DC due to the constancy in its current and constant magnetic field.

4.2 Compare step up and step down transformers

Step up:

- Provides an output voltage that is greater than the input voltage
- E.g. fluorescent lights, cathode ray TVs and x-ray machines require high voltages

Step down:

- Provides an output voltage that is less than the input voltage.
- E.g. phone chargers and other appliances require lower voltages.

4.3 Voltage transformations and conservation of energy

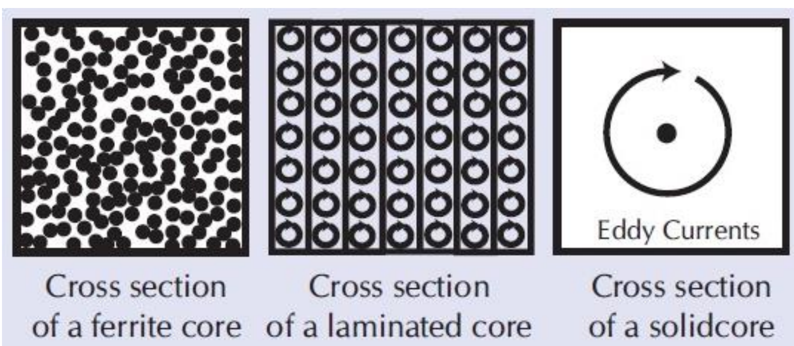
- Since power is a rate of energy and as energy cannot be created or destroyed, **power in = power out**
- The voltage to current ratio cannot change: if you increase the voltage, the current decreases, if you decrease the voltage, the current increases.
- This means that if a step up transformer gives a greater voltage at the output, its current must decrease.

- The energy output of a transformer is always less than the input due to energy losses.
- Energy losses because eddy currents induced in the transformer core by the AC current result in resistive heat losses.
- The efficiency of a transformer is the ratio of the energy output to the energy input

4.4 Disadvantage of eddy currents in transformers

Since eddy currents heat up the metal they are induced in, they are a disadvantage in transformers and generators which use changing magnetic fields and AC current. They transform useful forms of energy, including electrical energy into heat. This causes energy loss from these devices and reduces their efficiency and output of electricity. Heat is lost from the primary and secondary but mainly from the soft iron core.

To minimise the loss of energy by eddy currents, transformers may use magnetic core materials such as **ferrite cores** that have low electrical conductivity. This prevents the flow of eddy currents in the devices, reducing the amount of heat produced. Devices may have thin sheets of magnetic material such as **laminated magnetic cores** which are stacked between insulating layers. Since the laminations are thin, they have a higher resistance, reducing the size of the induced eddy currents. Each laminated sheet will have a reduced number of eddy currents in it. The sum of the eddy currents in each sheet is much less compared to using a single iron core. A reduced number of eddy currents reduces the amount of energy lost as heat.



4.5 the role of transformers in electricity sub-stations

The distribution of electrical energy involves substations which are responsible for stepping up voltage for transmission and stepping it down for use.

1. Electricity is generated by an AC generator.
2. For long distance transmissions, the electricity is fed into a step up transformer that increases the voltage, decreasing the size of the current.
3. After the electricity has been transmitted over a long distance, the voltage ios stepped down at different regional substations, increasing the current.
4. The voltage is stepped down to 240V at the local telegraph pole transformers for domestic uses. Industries may use slightly higher voltages.

4.6 discuss the need for transformers in the transfer of electrical energy from a power station to its point of use

Transformers are used at generating stations to step up transmission voltage to minimise energy losses by heating effects during transmission. Step down transformers lower the voltage at the consumer end to safer and more useable voltage sizes to be used by various appliances.

4.7 discuss why some electrical appliances in the home that are connected to the mains domestic power supply use a transformer.

- Devices such as battery chargers and phone chargers need a step down transformer to lower the input voltage below 240V to avoid damaging the battery or phone.
- Devices such as cathode ray TV tubes or fluorescent lights require a step up transformer to supply sufficient energy for their operation.
- It would be expensive and inefficient to supply homes with input power lines at all the voltages needed, so appliances come with appropriate transformers built into them.