

The transformer

Transformers are used to raise or lower an **alternating** voltage.

A transformer consists of two coils of insulated wire wound around an iron core. An alternating voltage is applied to the primary coil producing an alternating current which generates a changing magnetic field in the iron core. This changing magnetic field induces an alternating current in the secondary coil.

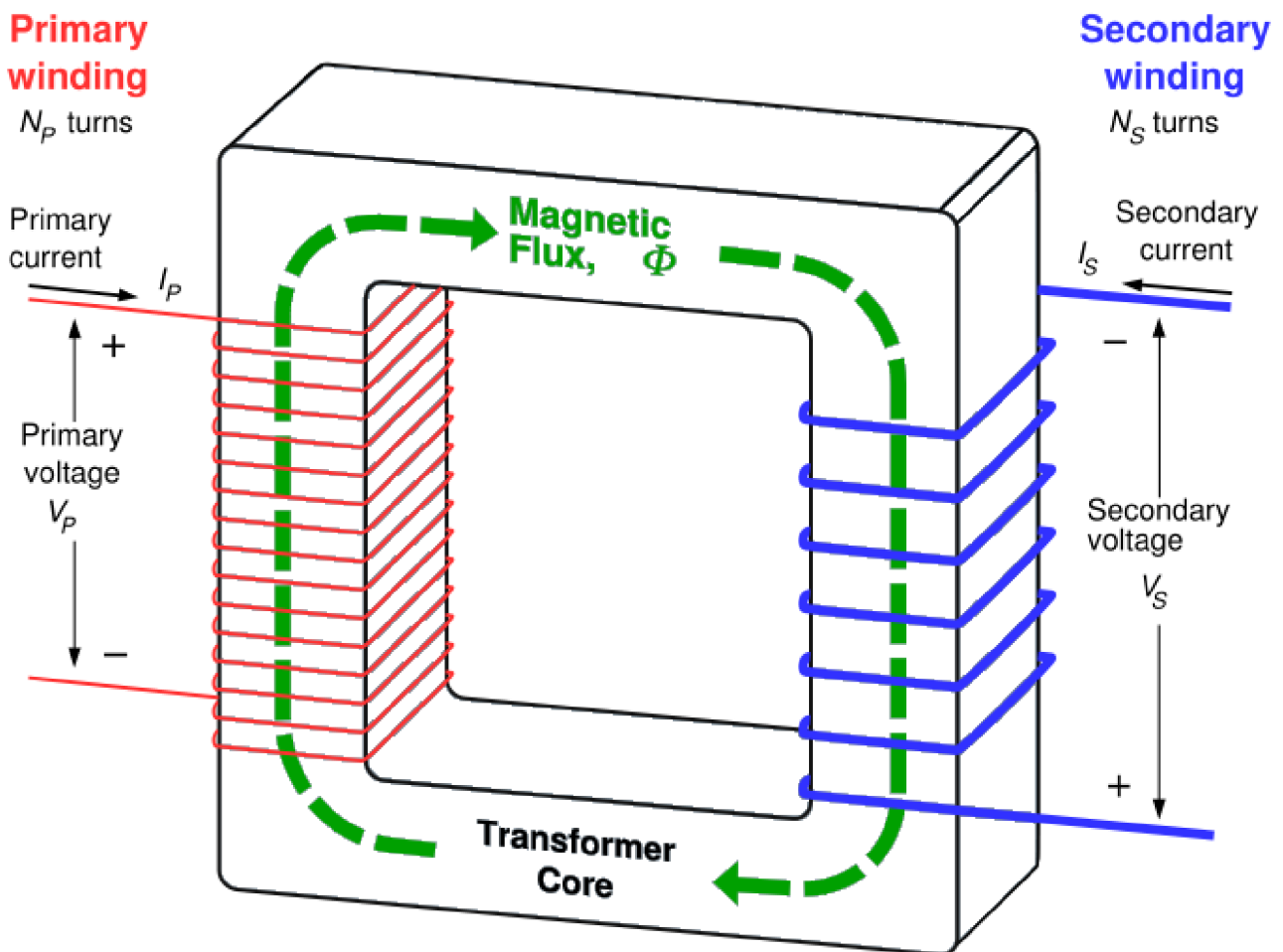
If there are more turns on the secondary coil than on the primary the voltage is increased (a step-up transformer).

If there are less turns on the secondary than on the primary the voltage is decreased (a step-down transformer).

If we assume that the transformer is ideal (i.e. no energy is lost) then:

$$\frac{\text{primary voltage}}{\text{secondary voltage}} = \frac{\text{number of turns on primary coil}}{\text{number of turns on secondary coil}}$$

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$



Transmission of electrical energy

The **national grid** is the system of pylons and cables that supply electricity to houses and factories around the country.

Since: **power = current x voltage** , the same amount of electrical power can be transported using either of the following:

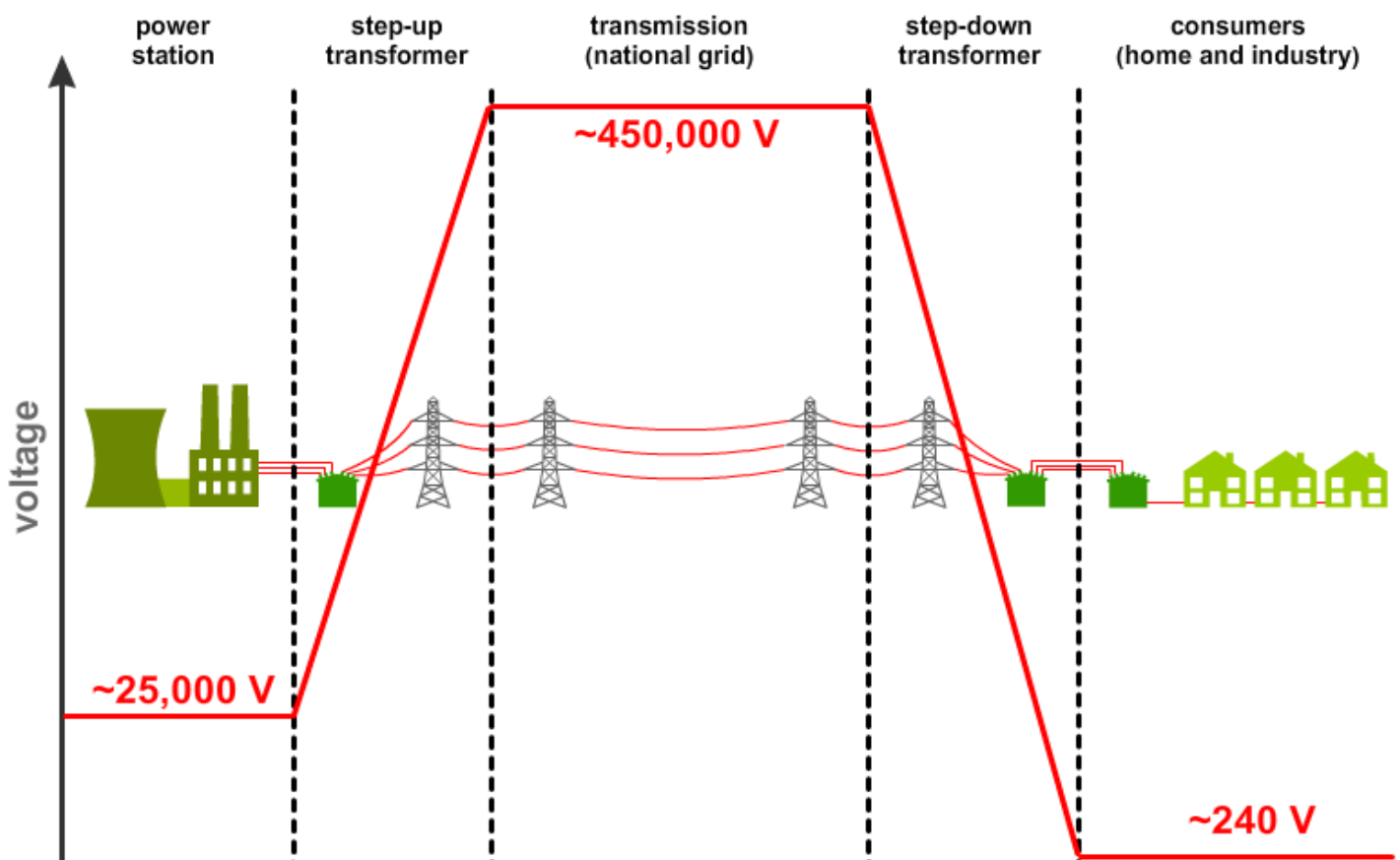
(A) a high voltage and a low current

(B) a low voltage and a high current

The electricity often has to travel a long way before reaching its destination. Since a current travelling along a wire will cause it to heat up, a lot of energy can be lost in transporting electricity. To reduce the energy losses the current must be reduced as much as possible, so the national grid always use method (A) and transport electricity at a high voltage and low current. This is where a transformer comes in handy.

A transformer is used to step-up the electricity leaving the power station to a very high voltage. Electricity is usually transported on the national grid at around 450,000 Volts. Since the voltage is increased then this means the current is reduced proportionally and less energy is lost as heat.

Obviously a supply of 450,000 V coming into your house would be a hazard so the voltage is reduced using a step-down transformer before being used in homes or factories.



Energy losses in transformers

When we perform calculations we assume that the transformer is ideal (i.e. no energy is lost) and so we can write:

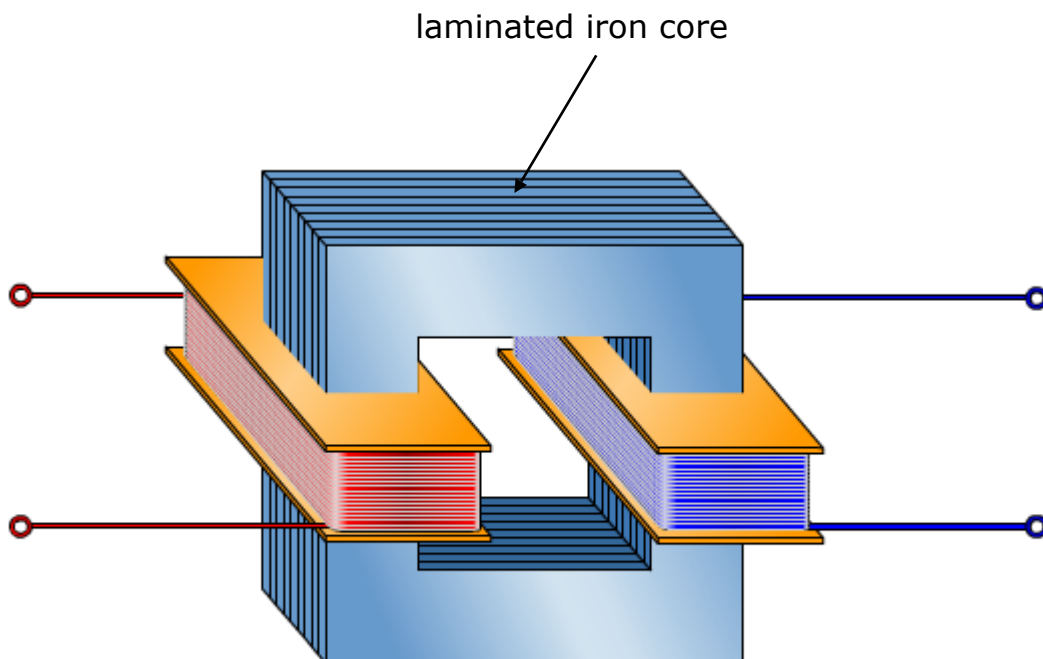
$$\text{power supplied to primary coil} = \text{power delivered to secondary coil}$$

$$V_P I_P = V_S I_S$$

In reality the efficiency of a transformer is never 100%.

The changing magnetic field causes **eddy currents** to flow through the iron core. These currents heat the iron core. Since some energy is lost as heat the efficiency of the transformer is reduced.

To reduce these eddy currents the core is made by sandwiching thin sheets of iron between an insulating material. The **laminated** core drastically reduces the eddy currents.



WORKED EXAMPLE

Calculate the output voltage from a transformer when the input voltage is 240 V, the primary coil has 1000 windings and the secondary coil has 50 windings.

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} \longrightarrow \frac{240}{V_S} = \frac{1000}{50} \longrightarrow \frac{240}{V_S} = 20 \longrightarrow V_S = \frac{240}{20}$$

$$V_S = 12 \text{ V}$$