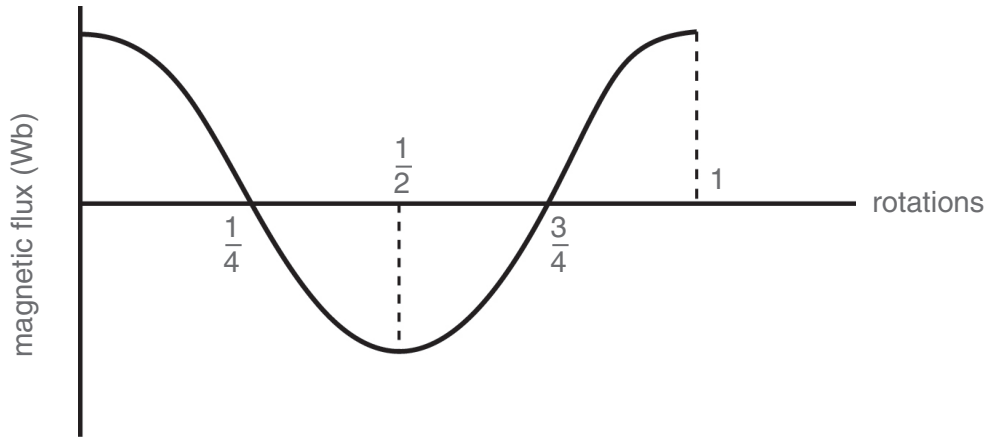
For the same orientation of the coil versus the magnetic field, the following graph is valid:

Note that $\varepsilon \propto \frac{\Delta\phi}{\Delta t}$ so if ϕ is a maximum, then $\frac{\Delta\phi}{\Delta t}$ is a minimum.



The potential difference is at a maximum when the coil moves past the horizontal position in the diagram. Reason:

- The rate of change of flux is then a maximum (even though the flux linkage is a minimum).
- When the coil moves past the vertical position, the rate of change is zero for a very short time, thus the potential difference is zero. After this the polarity of the potential difference reverses and it again grows to a maximum.
- The potential difference and the current change direction every half-cycle, i.e. alternating current is generated.

Interesting facts

In practice, more than one coil is wrapped around the same rotation-axis, but at different angles in respect to each other. The graph then shows repeated identical forms that do not fit exactly over each other, and therefore produce a more even direct current.

2.8 Transformers

Transformers are used daily to change alternating current with a certain potential difference and frequency to alternating current with a different potential difference – greater or smaller – but with the same frequency.

The alternating current is generated by an alternating current generator.

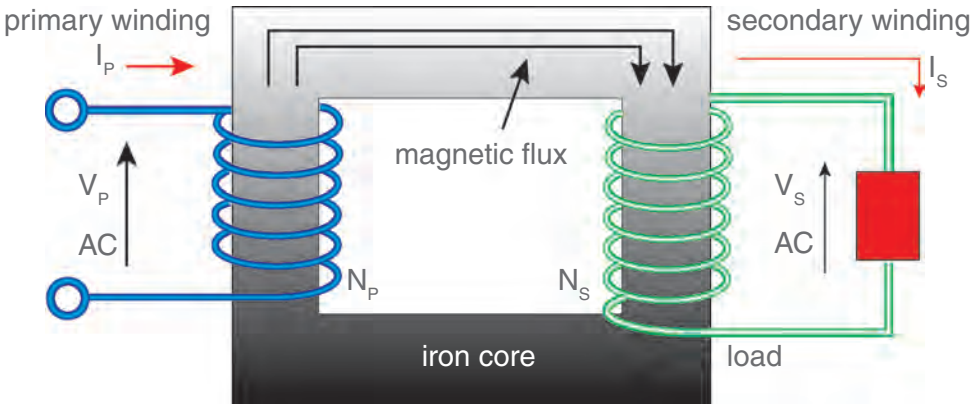
It is then necessary to transport the electric energy to the point where it will be used/sold. Transformers increase the potential difference so there is little energy loss due to heat changes during the transport of the electric energy.

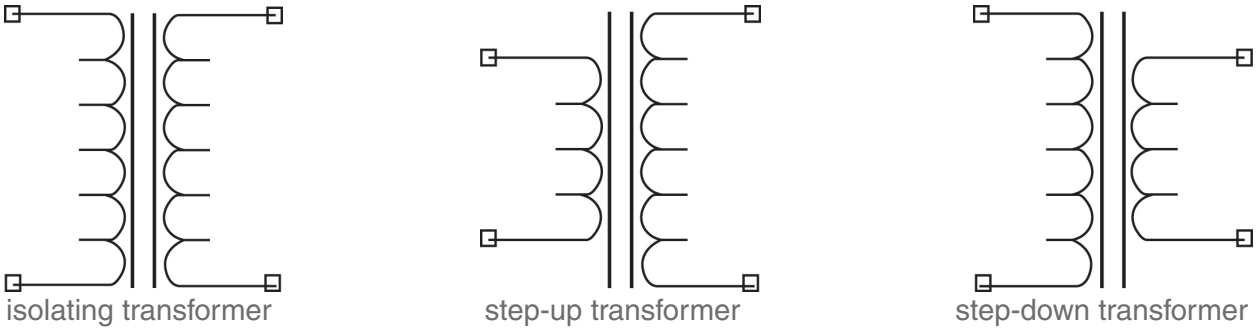
As soon as the electric energy has reached its destination, the potential difference is decreased again so it can be used safely.

2.8.1 The composition of a transformer

A transformer consists of a ferromagnetic core with at least two sets electrically conductive wire windings/coils which are wrapped around it. The coil connected to the alternating current source, is known as the primary coil. The coil which delivers alternating current to the circuit is known as the secondary coil.
The type of transformer is determined by the ratio between the number of windings of the primary coil and that of the secondary coil.

- A step-up transformer has more windings on the secondary coil than on the primary coil.
- A step-down transformer has more windings on the primary coil than on the secondary coil.
- An isolating transformer has the same number of windings for both coils.
  This type of transformer is used to transfer energy between circuits without any electric contact. Boats that are docked in the harbour, cannot touch a source of electricity, since any electrical fault could cause a person's death if they are touching the metal hull of the boat which will electrocute them.





2.8.2 Functioning of a transformer

The alternating current flowing through the primary coil, causes a changing magnetic field which then induces a changing potential difference in the secondary coil.
The basic steps for the functioning of a transformer are as follows:

1. The primary coil is connected to an alternating current source which lets alternating current flow through the primary coil.
2. Alternating current causes a changing magnetic field which has a change in magnetic flux as result.

3. The change in flux is carried in the iron core and then induces a changing potential difference in the secondary coil. This potential difference changes at the same frequency than that of the primary coil. Therefore, an induced alternating current arises in the secondary coil.

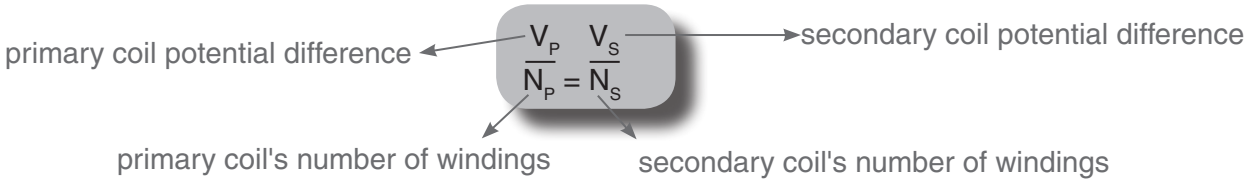
It is important to take note of the following:

- Transformers only work if the primary coil is connected to an alternating current source. A direct current source will induce a momentary current in the secondary coil at the moment when the source is switched on or off.
- The primary and secondary coils have no electrical connection between them.
- According to Faraday's law:

  $\varepsilon = (V) = \frac{-N\Delta\phi}{\Delta t}$ manipulation of the formula gives:

  $\frac{V}{N} = \frac{-\Delta\phi}{\Delta t}$ where $\frac{\Delta\phi}{\Delta t}$ for both coils are the same.

Therefore, the transformer equation looks as follows:



Examples

A transformer has a primary potential difference of 55 V.
The secondary coil has 5 000 windings and the primary coil has 20 windings.
Calculate the potential difference for the secondary coil.

Solution:

$$\frac{V_P}{N_P} = \frac{V_S}{N_S}$$
$$\frac{55}{20} = \frac{V_S}{5\,000}$$
$$V_S = 13\,750 \text{ V}$$

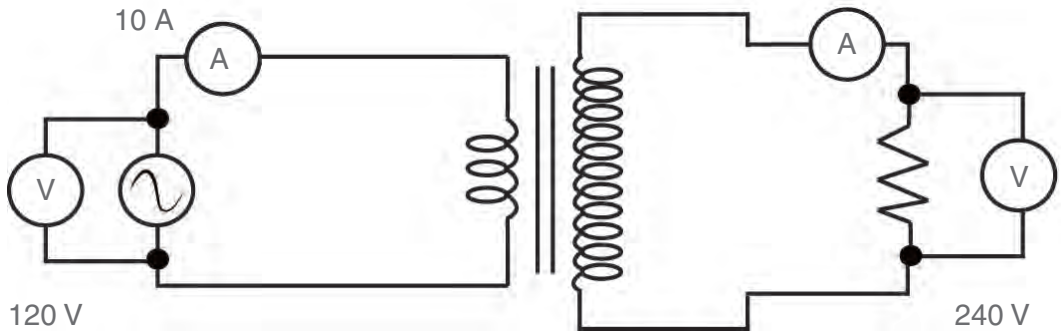
2.8.3 Power

Since energy is always conserved, the power ($P = \frac{W}{\Delta t}$) for the primary coil must be equal to the power for the secondary coil.

$$P_P = P_S$$
$$V_P I_P = V_S I_S$$

Examples

A circuit contains a step-up transformer. There is an alternating current of 10 A in the primary coil connected to an alternating current source with potential difference of 120 V. The induced potential difference in the secondary coil is 240 V. Calculate the current in the secondary coil.

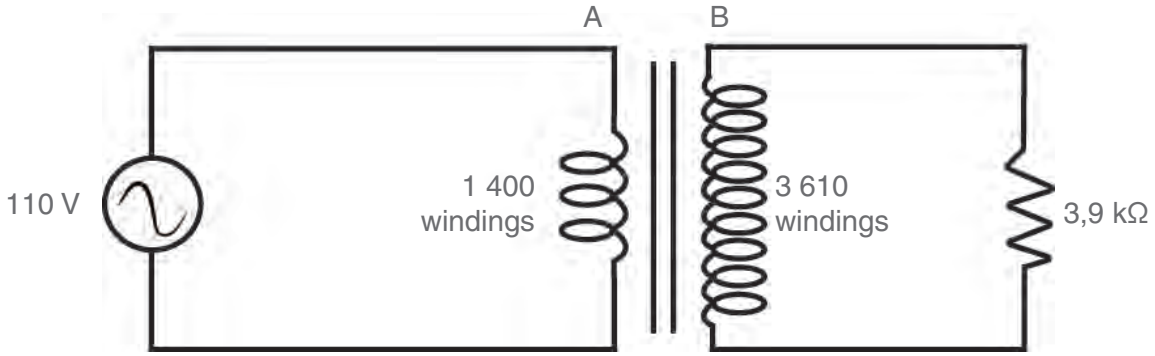


Solution:

$$V_P I_P = V_S I_S$$
$$(120)(10) = 240 I_S$$
$$I_S = 5 \text{ A}$$

Examples

Study the following circuit and answer the questions that follow:



1. Where is the primary coil? A or B? Give a reason for your answer.
2. What type of transformer is represented?
3. Calculate the tension of coil B.
4. Calculate the current of coil B.
5. Calculate the current of coil A.

Solutions:

1. The source of electric alternating current is connected at A.

2. Step-up transformer

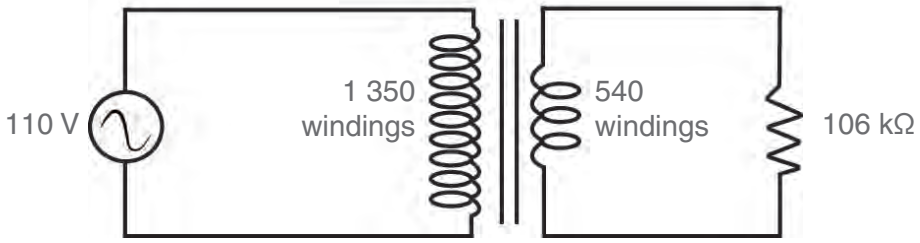
3. $$\frac{V_P}{N_P} = \frac{V_S}{N_S}$$
$$\frac{110}{1\,400} = \frac{V_S}{3\,610}$$
$$V_S = 283{,}64 \text{ V}$$

4. $$I = \frac{V}{R}$$
$$I = \frac{283{,}64}{3\,900}$$
$$I = 7{,}27 \times 10^{-2} \text{ A}$$

5. $$V_P I_P = V_S I_S$$
$$(110)I_P = 283{,}64(7{,}27 \times 10^{-2})$$
$$I_P = 0{,}19 \text{ A}$$

Exercise 29 Date:

1 Study the diagram and answer the questions that follow:



1.1 Calculate the tension in the secondary coil.

1.2 Calculate the current flowing through the resistor.