

Transformers Notes

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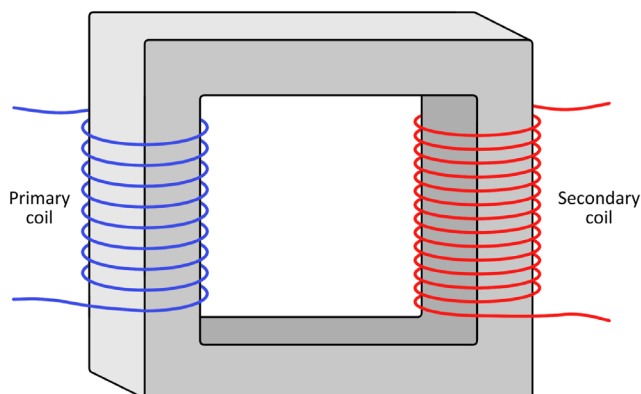
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A transformer: is a component that can be used to change the potential difference in a circuit.

Transformers can be used to either increase or decrease the potential difference in a circuit. Depending on what we need of course. There are two types of transformers, **step up** and **step down transformers**. Let's look at each.

Step Up Transformers

What are step up transformers? They are a type of transformer that increases the potential difference and decreases the current between the primary and secondary coil. The figure below shows a step up transformer.



Note: step up transformers always have fewer turns of coil on the primary coil and more turns of coil on the secondary coil.

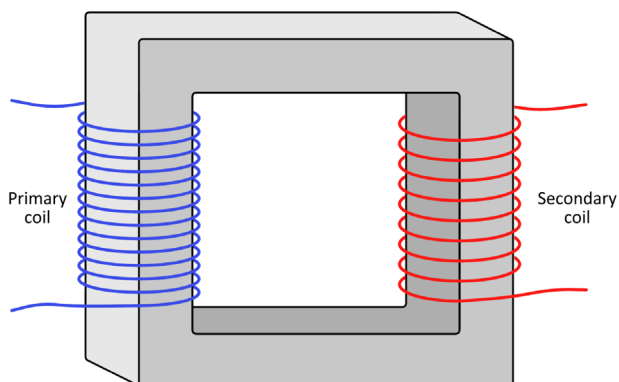
Why are step up transformers used? They are used to increase the efficiency of moving electricity over long distances.

How does a step up transformer increase the efficiency of moving electricity? When a potential difference (voltage) causes a current in a wire, moving electrons collide with metal ions in the wire. These collisions convert electrical energy into heat, resulting in energy loss. For example, phone chargers get warm during use. By increasing the voltage to a high value, fewer electrons collide with metal ions, reducing energy lost as heat and allowing more electrical energy to flow efficiently.

So, having a higher potential difference reduces the current. When the current is lower less energy is lost as heat 😊

Step Down Transformers

What are step down transformers? They are a type of transformer that decrease the potential difference and increase the current between the primary and secondary coil. The figure below shows a step down transformer.



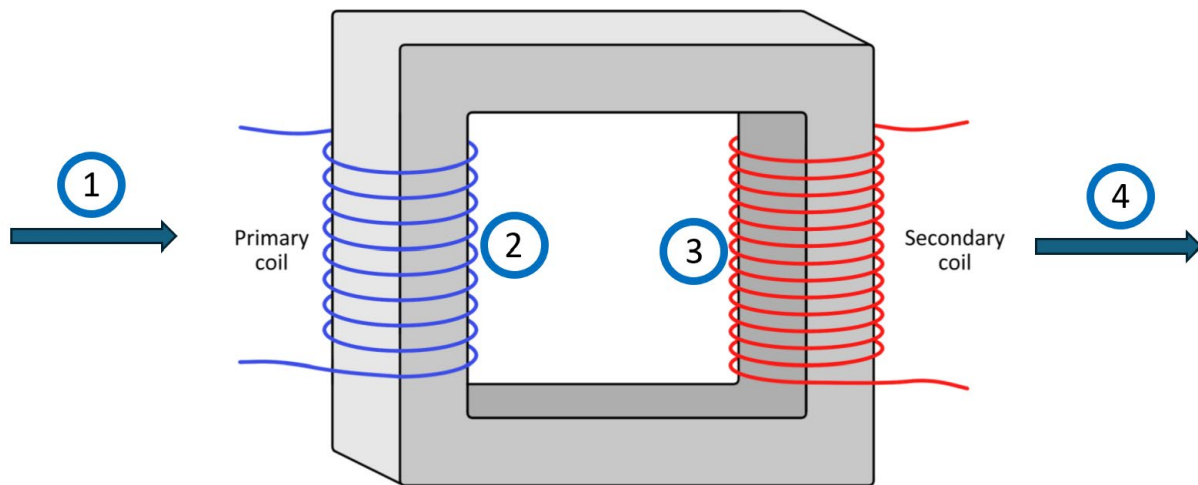
Note: step down transformers always have more turns of coil on the primary coil and fewer turns of coil on the secondary coil.

Why are step down transformers used? They are used to lower the potential difference to a safer level. We use step down transformers in lots of devices, phone chargers and laptop adaptors as these devices require a low potential difference to function. The potential difference of electricity that is supplied to homes in the UK is 230 volts.

Note: please make sure that you are able to tell the difference between a step up and step down transformer just by looking at them. This is really important, especially when it comes to the calculations about transformers.

How do Transformers actually work?

The figure below shows a step up transformer with numbered stages to use as a talk through explanation.



1. **Alternating current enters the primary coil:** An alternating current (AC) is fed into the primary coil. This is our input electricity.

What does this do? Well, because an alternating current is constantly changing direction, it creates a continuously changing magnetic field around the primary coil.

2. **The soft iron core is then magnetised:** The AC in the primary coil creates a constantly changing magnetic field in the soft iron core.

What does this do? The iron core acts a bit like a track! Soft iron is used because it can be easily magnetised and demagnetised very quickly without wasting energy. It traps the changing magnetic field and safely guides it around the core from one side to the other side.

Really important note: Electrical current does not move through the iron core! The copper wires are coated in an insulating material. So, transformers are all about moving magnetic fields through the core, not electricity.

3. **The magnetic field reaches the secondary coil:** The soft iron core guides that changing magnetic field so it passes right through the middle of the secondary coil.

What does this do? It exposes the secondary coil to a magnetic field that is constantly shifting and changing direction inside the core.

4. **Potential difference is induced:** This changing magnetic field "cuts" through the turns of wire on the secondary coil.

What does this do? This is where the physics happens 😊! Because the secondary wire is experiencing a changing magnetic field, it induces (which is a word that means 'creates') an alternating potential difference, or voltage, across the secondary coil.

Alternating current leaves the secondary coil: Because this is a step-up transformer, there are more turns on the secondary coil than the primary. This is the secret! Having more turns means the induced potential difference is larger than the input voltage. The voltage has been "stepped up".

The opposite would be true for a step down transformer 😊

Transformer Calculations

For the GCSE we can be asked to do a few calculations with transformers. The first equation is the one that is best known as it's a bit scary looking and we are not given this equation in the exams so we do need to learn it. This equation links the potential difference on the coils to the number of turns on the coil.

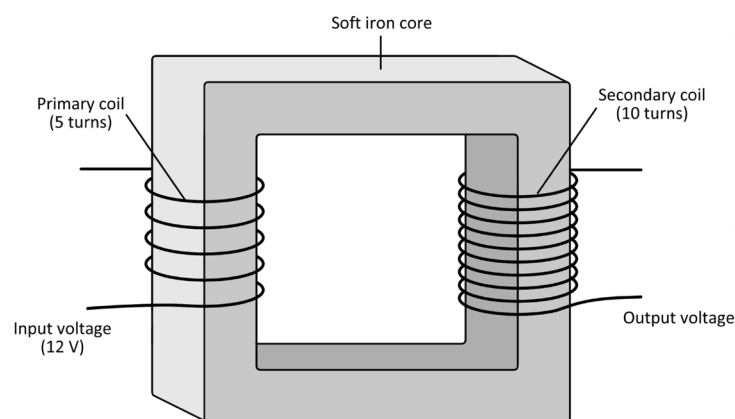
$$\frac{\text{voltage of the primary coil}}{\text{voltage of the secondary coil}} = \frac{\text{number of turns on the primary coil}}{\text{number of turns of coil on the secondary coil}}$$

This can be written in the shorter form of:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

It's very easy to use 😊 Let's look at a few examples 😊

Example 1: a technician makes a model transformer for an experiment. The figure below show the transformer. Calculate the output voltage of the secondary coil.



Step 1: substitute in the values from the figure into the equation.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \quad \frac{12}{x} = \frac{5}{10}$$

Step 2: solve for the missing value by cross multiplying.

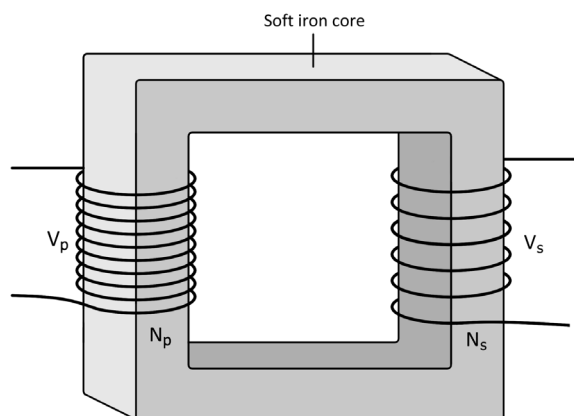
$$120 = 5x$$

$$x = 24 \text{ volts}$$

Example 2: a student sets up a transformer as shown in the figure below. Calculate the potential difference across the secondary coil. The student has the following information:

The number of turns on the primary coil, $N_p = 1000$
 The potential difference across the primary coil, $V_p = 230 \text{ V}$
 The number of turns on the secondary coil, $N_s = 20$

Calculate the potential difference of the secondary coil.



Step 1: substitute in the values from the figure into the equation.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \quad \frac{230}{x} = \frac{1000}{20}$$

Step 2: solve for the missing value by cross multiplying.

$$4600 = 1000x$$

$$x = 4.6 \text{ volts}$$

The second equation we can meet when doing calculations involving transformers is the equation showing the principle of power conservation. It works on the idea of an ideal transformer.

An ideal transformer is one that assumes there is no energy lost between the input and output. In real life though, no transformers are 100% efficient.

We remember that one way to calculate power is:

$$\text{Power} = \text{potential difference} \times \text{current}$$

$$P = V \times I$$

The equation for power conservation across a transformer is just two power equations equal to each other 😊

The equation for power conservation is:

$$\text{voltage of the secondary coil} \times \text{current of the secondary coil} = \text{voltage of the primary coil} \times \text{current of the primary coil}$$

This can be written in the shorter form of:

$$V_s \times I_s = V_p \times I_p$$

Again it's a lovely equation to use, let's look at an example 😊

Example 3: A step down transformer is used to charge a laptop. The transformer has an output current of 3.0 A and an output voltage of 20 V. The transformer is connected to a mains supply with a voltage of 230 V.

(i) Calculate the power that is delivered to the laptop.

Step 1: use the equation to calculate power from the potential difference and current.

$$P_s = V_s \times I_s$$

Step 2: substitute the values for potential difference and current into the equation find the power.

$$P_s = 20 \times 3.0 \qquad P_s = 60 \text{ W}$$

(ii) Assuming that the transformer is 100% efficient, calculate the current from the mains.

Step 1: we use the equation $V_s \times I_s = V_p \times I_p$. We then rearrange the equation to find I_p .

$$I_p = \frac{P}{V}$$

Step 2: We then substitute in the values we have and solve.

$$I_p = \frac{60}{230} \qquad I_p = 0.26 \text{ A}$$