Transformers

4.7.3.4 · Magnetism and electromagnetism · revision notes

A transformer changes the size of an alternating potential difference using two coils wound on an iron core. You need to explain how it works, use the turns-ratio and power equations (both given on the equation sheet), and explain why the National Grid transmits electricity at a high potential difference. GCSE Physics only, Higher tier only.

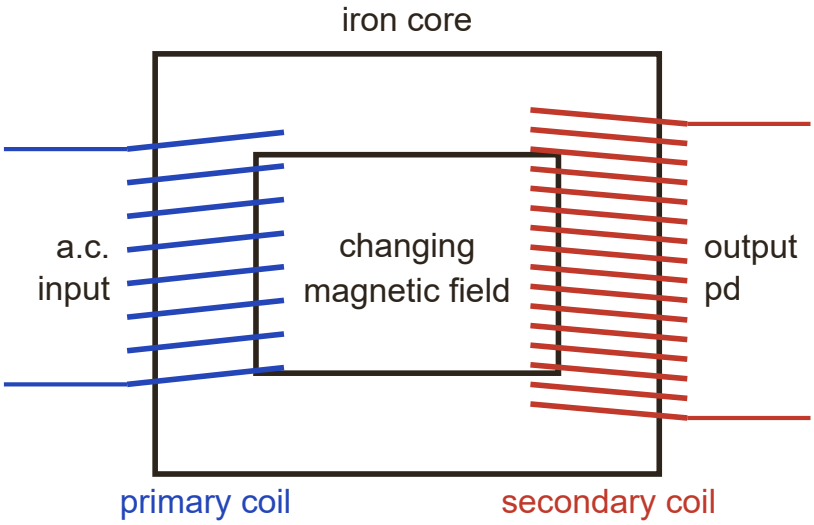
Key facts

- Transformer: primary coil + secondary coil on an iron core
- Iron core: easily magnetised
- $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ (given on the equation sheet)
- $V_s I_s = V_p I_p$ for a 100% efficient transformer (given on the equation sheet)
- Step-up: $n_s > n_p$, $V_s > V_p$, $I_s < I_p$
- Step-down: $n_s < n_p$, $V_s < V_p$, $I_s > I_p$
- Only works with a.c.: it needs a changing magnetic field
- Grade 8+ only High pd transmission → small current → less heating of cables → less energy wasted

Notes

Structure and how it works

- A transformer has a **primary coil** and a **secondary coil** wound on an **iron core**. Iron is used because it is easily magnetised.
- An **alternating current** in the primary coil produces a **changing magnetic field** in the iron core.
- This changing field passes through the secondary coil, so an **alternating pd is induced** across it. If the secondary coil is in a complete circuit, an alternating current flows.
- The two coils are not connected to each other electrically: the link between them is the changing magnetic field in the core.



No wire joins the coils: the changing field in the iron core links them.
Here the secondary has more turns, so this is a step-up transformer.

- A transformer only works with a.c. A direct current makes a constant field, which induces no pd in the secondary coil. Grade 7+ only

The turns-ratio equation

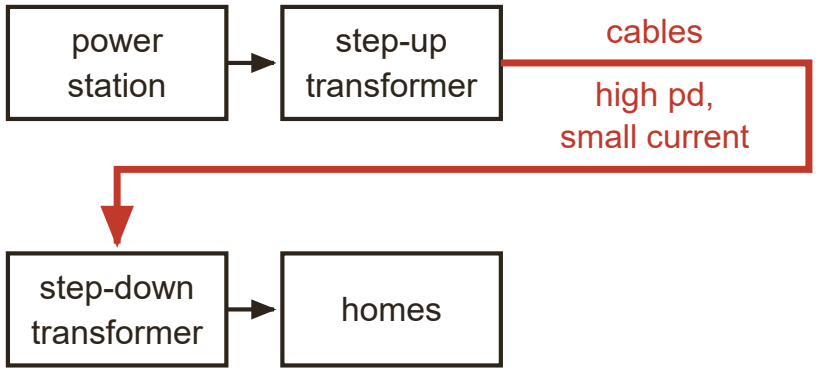
- $\frac{V_p}{V_s} = \frac{n_p}{n_s}$: V is the pd (volts, V), n is the number of turns; p = primary, s = secondary.
- **Step-up** transformer: more turns on the secondary than on the primary, so $V_s > V_p$
- **Step-down** transformer: fewer turns on the secondary, so $V_s < V_p$
- The pds are in the same ratio as the turns, e.g. 10 times as many turns on the secondary gives 10 times the pd.

Power and current

- If a transformer is 100% efficient, the power output equals the power input: $V_s \times I_s = V_p \times I_p$. Both sides are in watts (W).
- So a step-up transformer **increases the pd but decreases the current** by the same factor. A step-down transformer does the opposite.
- To find the current drawn from the supply, work out the output power ($V_s I_s$), then divide it by V_p

Why the National Grid uses a high pd Grade 8+ only

- Step-up transformers increase the pd from the power station to the transmission cables. Step-down transformers reduce it for use in homes.



Small current in the cables → less heating → less energy wasted.

- For a given power, a higher pd means a smaller current in the cables ($P = V I$).
- A smaller current means less heating of the cables ($P = I^2 R$), so less energy is wasted and the system is more efficient.

How to answer each type of question

Explain how a transformer works 3 to 4 marks **Grade 7**

1. Alternating current in the primary coil.
2. Produces a changing magnetic field in the iron core.
3. The changing field passes through the secondary coil.
4. So an alternating pd is induced across the secondary coil.

Example. A transformer is connected to an a.c. supply.
Explain why there is a potential difference across the secondary coil, even though the two coils are not connected to each other. [4 marks]

Model answer. The alternating current in the primary coil (1) produces a changing magnetic field in the iron core (1). The changing magnetic field passes through the secondary coil (1). So an alternating potential difference is induced across the secondary coil (1).

Calculate a pd or number of turns

2 to 3 marks | **Grade 6**

1. Write $V_p / V_s = n_p / n_s$ from the equation sheet.
2. Substitute the three values you know.
3. Rearrange and calculate. Check: step-down means the secondary values are smaller.

Example. A transformer for a garden lighting system steps the 230 V mains down to 12 V. The primary coil has 2300 turns.
Calculate the number of turns on the secondary coil. [3 marks]

Model answer.

$230 \div 12 = 2300 \div n_s$ (1)

$n_s = 2300 \times 12 \div 230$ (1)

$n_s = 120$ (turns) (1)

Calculate a current using $V_p I_p = V_s I_s$

2 to 3 marks | **Grade 7**

1. Write $V_s I_s = V_p I_p$ (the question will say the transformer is 100% efficient).
2. Work out the power on the side where you know both values.
3. Divide by the pd on the other side to find the current.

Example. The garden lighting transformer is connected to the 230 V mains. It supplies a current of 5.0 A to the lamps at 12 V. Assume the transformer is 100% efficient.
Calculate the current in the primary coil. [3 marks]

Model answer.

$230 \times I_p = 12 \times 5.0$ (1)

$I_p = 60 \div 230$ (1)

$I_p = 0.26$ A (1)

Multi-step transformer calculation

4 marks | Grade 9

1. Use the turns ratio to find the missing pd.
2. Use $V_s I_s = V_p I_p$ to find the missing current.
3. Convert kV to V first, and check that the current falls by the same factor as the pd rises.

Example. A step-up transformer at a power station has 500 turns on its primary coil and 8000 turns on its secondary coil. The pd across the primary coil is 25 kV and the current in it is 800 A. Assume the transformer is 100% efficient.
Calculate the current in the secondary coil. [4 marks]

Model answer.

$V_s = 25\,000 \times 8000 \div 500 = 400\,000$ V (1)

$25\,000 \times 800 = 400\,000 \times I_s$ (1)

$I_s = 20\,000\,000 \div 400\,000$ (1)

$I_s = 50$ A (1)

(Check: the pd goes up 16 times, so the current goes down 16 times: 800 ÷ 16 = 50 A.)

Explain why the National Grid uses a high pd

3 to 4 marks | Grade 8

1. Step-up transformers increase the pd.
2. For the same power, this means a smaller current.
3. A smaller current means less heating of the cables, so less energy is wasted.
4. So transmission is more efficient.

Example. Electricity is transmitted through the National Grid at up to 400 000 V.
Explain why step-up transformers are used between the power station and the transmission cables. [4 marks]

Model answer. Step-up transformers increase the potential difference (1). For the same power, this reduces the current in the cables (1). A smaller current causes less heating of the cables, so less energy is wasted (1). So energy is transferred more efficiently (1).

Don’t lose marks

- Saying the current flows from the primary coil into the secondary coil: the coils are not connected, and the changing field induces the pd.
- Writing 'magnetic field' instead of 'changing (alternating) magnetic field' in the explanation.
- Mixing up primary and secondary values in the equations.
- Saying a step-up transformer increases the power: at best the power stays the same. The pd goes up and the current goes down.
- Mixing kV and V in the same power equation.

✗ Saying a high pd reduces the resistance of the cables: it reduces the current, and so the heating.

More tips

Memory tricks

- The pd follows the turns: twice the turns on the secondary, twice the pd.
- Power in = power out (at 100% efficiency): if the pd goes up by some factor, the current goes down by the same factor.
- Sense check a step-down answer: V_s and n_s must be smaller than V_p and n_p, but I_s must be bigger than I_p.
- Write the turns ratio with the primary on top on both sides, so you cannot mix them up.

Exam technique

- Both transformer equations are on the equation sheet: copy the right one, substitute, then rearrange.
- In 'explain how a transformer works', use the key words 'alternating current', 'changing magnetic field', 'iron core' and 'induced'.
- For National Grid questions, build the chain: higher pd → smaller current → less heating → less energy wasted.
- For the core, write 'iron' and 'easily magnetised'. Steel, or 'iron is a good conductor', gets no mark.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 5 — **Describe the structure of a transformer**
A primary coil and a secondary coil wound on an iron core.

Grade 5 — **Identify step-up and step-down transformers**
Step-up: more turns on the secondary coil, so the output pd is bigger. Step-down: fewer turns on the secondary, so the output pd is smaller.

Grade 6 — **Use the turns-ratio equation**
Substitute into $V_p / V_s = n_p / n_s$ and rearrange to find a pd or a number of turns.

Grade 6 — **Explain why the core is made of iron**
Iron is easily magnetised, so it carries the changing magnetic field through the secondary coil.

Grade 7 — **Explain how a transformer works**
Alternating current in the primary → changing magnetic field in the core → alternating pd induced in the secondary.

Grade 7 — **Use the transformer power equation**
For a 100% efficient transformer, find the current drawn from the supply for a given power output.

Grade 8 — **Explain why high-pd transmission is efficient**
For the same power, a higher pd means a smaller current, so less energy is wasted heating the cables.

Grade 9 — **Combine both transformer equations in one problem**
e.g. find the secondary pd from the turns ratio, then the secondary current from the power.

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