

29 Transformers

While a very strong magnet held stationary inside a coil will not induce a voltage (there is no **relative motion**), if the magnetic field **gets stronger** a voltage will be induced. This is because the increase in magnetic field at the coil could have been caused by an ordinary magnet **moving closer**. Permanent magnets cannot change strength readily, but you can change the strength of an **electromagnet** if you change the **current** flowing in it.

This is the principle of the transformer. Transformers only work on **alternating current (a.c.)**. The current in the primary coil causes it to become an electromagnet. The continually changing current produces a **continually changing** magnetic field in an iron core. This in turn induces a continually changing **voltage** in the nearby secondary coil wound round the iron core. A transformer won't work on **direct current (d.c.)** because a stationary magnet will only produce a steady magnetic field - and steady, stationary magnetic fields do not **induce voltages**. A transformer does not change the frequency of the alternating current.

Transformers have two coils

- the **primary** coil, connected to an a.c. supply of known voltage, and
- the **secondary** coil, which does work on other components using energy from the primary.

The voltage across the secondary coil, V_s , is not usually the same as the primary coil's supply voltage, V_p . It could be greater (a **step-up** transformer) if the number of turns on the secondary is greater, $N_s > N_p$, or less if the number of turns on the secondary is fewer, $N_s < N_p$.

secondary (a.c.) voltage = primary (a.c.) voltage $\times \frac{\text{no. of turns on secondary}}{\text{no. of turns on primary}}$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \text{or} \quad \frac{N_p}{V_p} = \frac{N_s}{V_s}$$

This means that the number of 'turns per volt' is the same on both coils.

Example 1 – A transformer has an input voltage of 240 V a.c. and output of 48 V. If there are 3 000 turns on the primary coil, how many are there on the secondary?

$$V_s/V_p = N_s/N_p, \text{ so } 48/240 = N_s/3\,000.$$

Thus $0.2 = N_s/3\,000$, so $N_s = 0.2 \times 3\,000 = 600$ turns.

Or, you could solve it like this: the primary coil has $3\,000/240 = 12.5$ turns/volt

So the secondary must have $48 \times 12.5 = 600$ turns.

29.1 Complete the table below. Each row is a separate question.

a.c. Voltage (V)		No. of turns on coil		Step up or down?
Primary	Secondary	Primary	Secondary	
240	(a)	2 000	200	(b)
11 000	240	(c)	600	(d)
23 000	230 000	(e)	1 000	(f)
240	12	(g)	300	(h)
240	4.96	1 500	(i)	(j)

29.2 A doorbell for a house works from 8.0 V a.c. To operate the bell from the 240 V mains supply, a transformer can be used.

(a) How many turns would be in the primary winding for each turn in the secondary winding?

(b) Would the transformer be a step-up or a step-down type?

29.3 To produce an output of 48 V a.c. from an input of 240 V a.c., how many turns would be required in the primary winding if there were 100 turns in the secondary?

29.4 The input voltage to a step-down transformer is 240 V a.c. at a frequency of 50 Hz. The primary winding has 6 000 turns and the secondary 300 turns.

(a) What is the voltage output?

- (b) What is its output frequency?
- 29.5 A step-up transformer has 500 turns in the primary coil and 10 000 turns in the secondary coil. A voltage of 250 V a.c. is applied to the primary at 50 Hz.
- (a) What is the voltage of the output at the secondary?
- (b) What is the frequency of the output at the secondary?
- 29.6 A 12 volt car battery is placed across the primary coil of a 1:20 step-up transformer. What is the output voltage across the secondary?
- 29.7 These questions should show you why we bother with transformers on our electrical distribution system. Calculate:
- (a) The current needed to distribute the 2 000 MW generated at 22 kV at a large power station.
- (b) The current needed to carry 2 000 MW if the voltage is 400 kV.
- The cables used have a total resistance of $9.0\ \Omega$.
- (c) Calculate the power wasted in heating the wire if the current from 22 kV flows in the wire.
- (d) Calculate the power wasted if the current carrying 2 000 MW at 400 kV passes through the wire.
- 29.8 A computer power supply unit can be switched to work on European (230 V a.c.) or United States (115 V a.c.) mains. In the European setting, there are 2000 turns on the primary coil. When switched into United States mode, how many turns are now on the primary?
- 29.9 If 0.45 A were flowing in the primary of part (a) in the above table, what would the current in the secondary be if the transformer were 100 % efficient? *[Hint: Power = Current \times Voltage.]*
- 29.10 The power station generator of 29.1(e) produces a current of 22 kA. If the transformer is 97 % efficient, what will the output current onto the 230 kV national grid be? *NB - Your answer to Q29.1(e) does not need changing.*