7.5.2 Transformer calculations

From section 7.5.1, we saw that transformers are used to increase or decrease the potential difference. 'Step up' transformers have more coils ('turns') on their secondary coil than their primary coil. 'Step down' transformers have less turns on their secondary coil than their primary coil.

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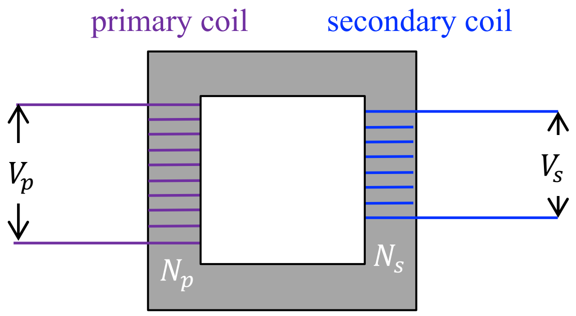

The ratio of turns on the primary and secondary is equal to the ratio of potential differences across the primary and secondary coils:

$$\frac{number\ of\ coils\ on\ secondary}{number\ of\ coils\ on\ primary} = \frac{p.d. across\ secondary}{p.d. across\ primary}$$

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

(1) ✏ Rearrange the equation to make V_s the subject. (e.g. $V_s = \cdots$)

(2) ✏ A transformer has 100 turns on the primary coil and 300 turns on the secondary coil. If an input, alternating potential difference of 12V is applied, what is the potential difference across the secondary coil? (Hint: Use your rearranged equation from previous question.)

(3) ✏ Rearrange the equation to make V_p the subject. (e.g. $V_p = \cdots$)

(4) ✏ A transformer has 200 turns on the primary coil and 1500 turns on the secondary coil. An output potential difference of 3000V is produced across the secondary coil. What is the potential difference across the primary coil? (Hint: Use your rearranged equation from previous question.)

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Power and efficiency

Electrical power is given by the equation:

$$power = current \times p.d.$$
$$P = I \times V$$

Therefore, the electrical power input to a transformer (P_{in}) is given by:

$$P_{in} = I_p V_p$$

where I_p = current in the primary coil, V_p = potential difference across the primary coil

The electrical power output from a transformer (P_{out}) is given by:

$$P_{out} = I_s V_s$$

where I_s = current in the secondary coil, V_s = potential difference across the secondary coil

The efficiency of the transformer is given by:

$$Efficiency = \frac{power\ out}{power\ in} = \frac{P_{out}}{P_{in}} = \frac{I_s V_s}{I_p V_p}$$

(5)✐If a transformer is 100% efficient, and the voltage is stepped up by a factor of 3, what happens to the current? (Hint: power in = power out)

(6)✐Rearrange the efficiency equation

$$Eff = \frac{I_s V_s}{I_p V_p}$$

to make I_s the subject. (e.g. $I_s = \cdots$)

(7)✐Calculate the output current for the following transformer with an efficiency of 0.85 (i.e. 85%). $V_p = 120V, I_p = 2A, N_p = 500, N_s = 200$. (Hint: use your rearranged equation from the previous question.)

Power transmission

In the National Grid, voltages are stepped up to very high voltages before transmission across the network. The reason for this is that power losses are reduced. Power is lost through heating of the transmission cables.

The power loss (P_l), due to the resistance (R) of the transmission cables is given by:

$$P_l = I^2 R$$

where I = current

(8)✐From this equation, what two things can be done to reduce power loss?

(9)✐Why does stepping up the voltage reduce power loss? (Hint: What happens to the current when the voltage is stepped up?)

(10)✐A town requires a supply of 100MW. A power station 10km away is used to supply the town. Transmission cables have a resistance of 1Ω *per kilometre. Work out the power loss in the transmission cables for a transmission voltage of i) 100kV and ii)400kV. (Hint: Calculate the currents in the cables using P=IV for the two different voltages. Calculate the resistance of the transmission cable. Use the power loss equation to calculate the power loss for the two different currents.)*

(11)✐In the problem, above, what would recommend as the best solution?