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WORKSHEETS
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Transformers and electrical power transfer

Electromagnetism 6 Supplying a remote observatory

35–40 minutes independent work + 15–20 minutes review

OCR A H556 | A-level physics | Module 6 | 43 marks

Specification points covered

6.3.3(f)(i) Laminated iron-core transformers; ideal turns, p.d. and current relationships.

6.3.3(f)(ii) Transformer investigations, including measurement, controls and graph analysis.

6.3.3(c), (d)(i) Lenz's and Faraday's laws. Apply prior circuit power, resistance and efficiency skills.

All a.c. voltages and currents quoted here are effective (r.m.s.) values. Use a resistive-load model with $P = VI$ and cable loss = I^2R. No phase or r.m.s. derivation is needed.

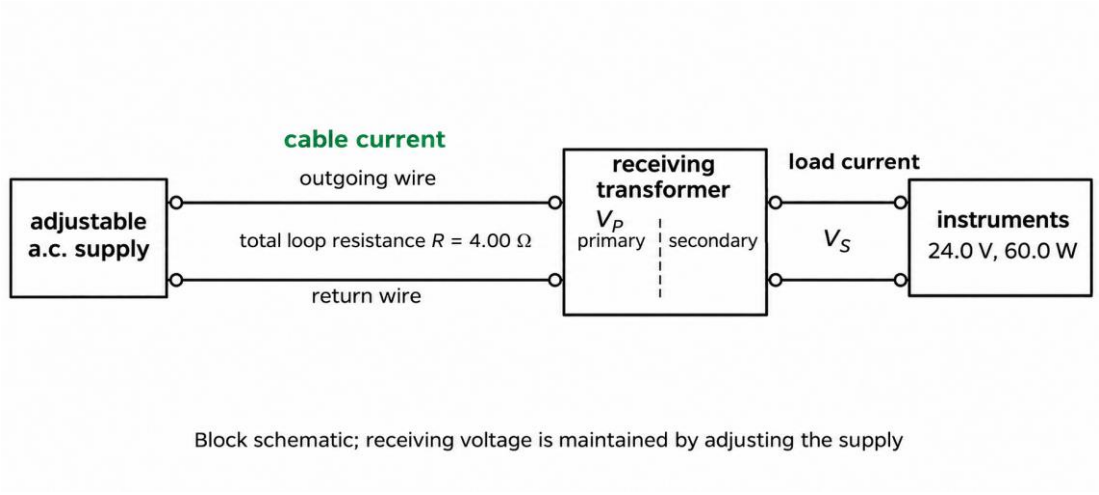
Use a calculator and your OCR A data booklet. Show working, units and directions where relevant.

1 A cable to the observatory

A remote observatory requires 24.0 V a.c. and 60.0 W at its instruments. A receiving transformer steps down the voltage at the end of a long two-wire cable. The total resistance of the complete outgoing-and-return cable loop is 4.00 Ω.

For Questions 2 and 3, treat the receiving transformer as ideal. The supply is adjusted to maintain the specified voltage at its primary, after the cable drop.

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Block schematic; receiving voltage is maintained by adjusting the supply

Figure 1 Supply, complete cable loop, receiving transformer and instruments; schematic

1(a) Explain how an alternating current in the primary coil produces an alternating p.d. across the separate secondary coil. **[3 marks]**

1(b) The core is made from insulated iron laminations. Explain the purposes of the iron and of the laminations. **[2 marks]**

2 An ideal receiving transformer

2(a) The receiving primary has 1000 turns and is maintained at 240 V. Calculate the secondary turns needed for 24.0 V. **[1 mark]**

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2(b) Calculate the current used by the 60.0 W instruments at 24.0 V. **[1 mark]**

2(c) Calculate the ideal primary current at 240 V. Explain why it is different from the secondary current. **[2 marks]**

2(d) If the receiving primary is instead maintained at 48.0 V, what turns ratio N_P : N_S is needed for the same 24.0 V instruments? **[1 mark]**

3 Choose the cable operating voltage

3(a) For an ideal transformer delivering 60.0 W, calculate the cable current when the maintained receiving-primary voltage is (i) 48.0 V and (ii) 240 V. **[2 marks]**

3(b) Calculate the power dissipated in the complete cable loop for each option. **[2 marks]**

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3(c) Calculate the sending-end voltage needed to maintain each receiving-primary voltage. Include the cable p.d. drop. **[2 marks]**

3(d) Cable losses must be below 1.00 W. Select an option and explain why using the instrument current in I^2R would give the wrong answer. **[2 marks]**

4 Account for a real transformer

Use the stated effective readings and resistive/unity-power-factor model. Do not introduce a phase correction.

4(a) The real receiving transformer is 90.0% efficient while delivering 60.0 W. Calculate its electrical input power. **[1 mark]**

4(b) The receiving-primary voltage is still maintained at 240 V. Calculate the cable current for this real transformer. **[1 mark]**

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4(c) Calculate the new cable loss and the efficiency from electrical power at the cable's sending end to useful power at the instruments. Exclude all losses before that sending end. **[3 marks]**

4(d) A pupil uses $I_P/I_S = N_S/N_P$ to claim that the real primary current must still be 0.250 A. Explain the problem with this argument. **[2 marks]**

5 Test the turns and voltage relationship

The secondary p.d. is measured with a high-input-resistance a.c. voltmeter and no separate load. Sketch a circuit in the space beside your method if useful.

5(a) A low-voltage prototype has $N_P = 200$ and an isolated 4.00 V a.c. supply. The secondary can use 40, 60, 80, 100 or 120 turns. Predict the no-load secondary voltage for each turn count. **[2 marks]**

5(b) State what graph should test this prediction and give the expected gradient and intercept, including units where appropriate. **[2 marks]**

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5(c) Write a six-mark-style method to test this relationship. Include a labelled circuit description or sketch, controls, a range and repeats, graph analysis and a justified uncertainty/improvement. Use only the isolated low-voltage a.c. prototype. **[6 marks]**

6 State what is kept constant

6(a) Why does a steady d.c. primary current not give a sustained secondary e.m.f.? Explain what may happen briefly when the d.c. is switched on or off. **[2 marks]**

6(b) In a separate ideal test, keep V_P = 4.00 V, N_P = 200 and the same 40.0 Ω secondary resistor. Calculate I_S for N_S = 40, 80 and 120, and state how I_S depends on N_S under these conditions. **[2 marks]**

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6(c) Now keep output power fixed at 0.0800 W by changing the secondary resistance for each turn count. The primary is still ideal at 4.00 V with 200 turns. Calculate I_S for N_S = 40, 80 and 120. Explain why the trend differs from 6(b). **[2 marks]**

6(d) Improve this explanation: “The core carries charge into the secondary and creates extra power when the voltage goes up.” **[2 marks]**

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