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WORKSHEETS
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Magnetic flux and electromagnetic induction

Electromagnetism 4 A warehouse docking sensor

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

OCR A H556 | A-level physics | Module 6 | 42 marks

Specification points covered

6.3.3(a–b) Magnetic flux, flux linkage and the weber.

6.3.3(c), 6.3.3(d)(i–ii) Faraday's and Lenz's laws; e.m.f. and search-coil investigations.

Graph gradients and pulse areas are used without requiring calculus.

Use $\Phi = BA\cos\theta$, $\lambda = N\Phi$ and $\varepsilon = -\Delta\lambda/\Delta t$. The angle θ is between B and the area normal.

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

1 Read the pickup sensor

A permanent magnet on a warehouse shuttle approaches a fixed pickup coil, pauses before it, then withdraws along the same axis. Its north pole faces the coil during this movement.

The coil has N = 250 turns and area A = 6.00 cm^2 per turn. Initially the field is normal to its plane. Treat B as uniform over each turn. The sensor measures open-circuit e.m.f.; appreciable current flows only in a separately stated closed-loop test.

For signed graph calculations, positive flux is along the stated rightward normal and the e.m.f. reference is defined by $\varepsilon = -\Delta\lambda/\Delta t$. No terminal polarity is inferred from an unmarked winding.

The positive area normal points right along the magnet–coil axis.

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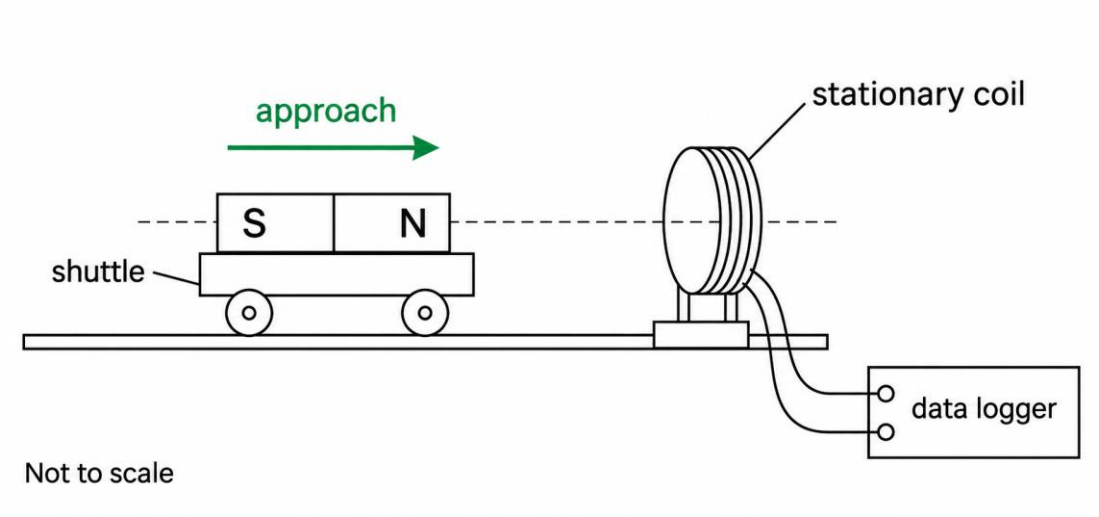


Figure 1 Magnet and stationary pickup coil

1(a) Distinguish magnetic flux density B, flux Φ through one turn, and flux linkage λ for this coil. **[2 marks]**

1(b) If the coil's plane is perpendicular to the field, what is θ in Φ = BA cos θ? State the SI unit of flux. **[1 mark]**

2 Calculate magnetic linkage

2(a) At B = 40.0 mT with θ = 0°, calculate the flux through one turn. **[2 marks]**

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2(b) Calculate the corresponding flux linkage. **[1 mark]**

2(c) At the same B, the area normal is turned to 60.0° from the field. Calculate the new linkage. **[1 mark]**

2(d) A replacement coil has twice as many turns but half the area per turn. At the same field and angle, what happens to its flux linkage? **[1 mark]**

3 Read a docking trace

For this prescribed docking motion, B along the positive normal varies linearly between successive readings. Use the actual table values for numerical work.

Table 1

t / ms	B along positive normal / mT
0	0
20	40.0
50	40.0
90	0

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3(a) Using Table 1, sketch λ against time. Label the linkage values and the times at each change of gradient. **[2 marks]**

3(b) Calculate the signed e.m.f. during each of the three time intervals. Sketch the corresponding e.m.f.–time graph in blank space. **[3 marks]**

3(c) Calculate the average e.m.f. from 0 to 50 ms. Explain why it differs from the largest e.m.f. magnitude during that interval. **[2 marks]**

3(d) The same approach and withdrawal changes occur in half the time, with the pause also halved. State the effects on pulse heights, widths and area magnitudes. **[2 marks]**

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4 Explain the induced direction

4(a) For 4(a) and 4(b), close the coil through a resistor. Viewed from the approaching magnet towards the coil, state the induced current direction and explain using Lenz's law. **[2 marks]**

4(b) State and explain the current direction from the same viewing side while the north pole withdraws. **[2 marks]**

4(c) During the pause, B is 40.0 mT but the measured e.m.f. is zero. Explain. **[1 mark]**

4(d) In the closed-loop test the total resistance is 12.0 Ω and inductance is negligible. Find the approach-current magnitude. Explain the source of the energy dissipated as heat when the shuttle is driven at its prescribed motion. **[2 marks]**

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5 Use pulse areas and limits

5(a) Find the signed area under the approach e.m.f.–time pulse and the corresponding signed change in flux linkage. **[2 marks]**

5(b) A separate 250-turn, 6.00 cm^2 search coil is turned from maximum flux to zero flux in a uniform field. The pulse area magnitude is 0.00590 V s. Infer the field magnitude. **[1 mark]**

5(c) The docking sensor triggers only when $|\varepsilon| \geq 0.200$ V and its input accepts up to $|\varepsilon| = 1.00$ V. Choose a 250-turn or 400-turn coil so both approach and withdrawal trigger. Only N changes. Justify using both pulse magnitudes and the input limit. **[3 marks]**

5(d) Evaluate: “The signed pulse areas over the full docking cycle add to zero, so electromagnetic induction never occurred.” **[2 marks]**

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6 Plan a search-coil measurement

6(a) A thin rectangular search coil will be used to measure an unknown uniform field. Explain how to determine its effective turn area and suggest one way to reduce area uncertainty. **[2 marks]**

6(b) Suggest a suitable instrument for recording the voltage pulse during a rapid 90° turn and explain one recording or processing control that matters. **[2 marks]**

6(c) Write a method to determine an unknown uniform magnetic field using a search coil of known N and measured A. The gap permits a full 90° turn while the coil remains in the uniform region. Explain the starting and final orientations, measurements, processing and evaluation. **[6 marks]**

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