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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

Charged particles in magnetic fields

Electromagnetism 2 Guiding an electron beam

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

OCR A H556 | A-level physics | Module 6 | 39 marks

Specification points covered

6.3.2(a–b) Magnetic force on moving charge and circular orbits in a uniform field.

Prior learning applied: 5.2 circular motion; kinetic energy and electrical work.

Entry velocity is perpendicular to B. Crossed-field selection belongs to Worksheet 3.

Use $m_e = 9.11 \times 10^{-31}$ kg, $|e| = 1.60 \times 10^{-19}$ C and $g = 9.81$ m s^{-2}.

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

1 Read the beam guide

An evacuated materials-testing instrument bends an electron beam through a quarter-circle towards an adjustable target. Figure 1 is a model of the bend, not a scale drawing.

Unless a question changes a value, use entry speed $v = 1.20 \times 10^{7}$ m s^{-1} and $B = 3.00$ mT. The field is uniform and perpendicular to the beam plane. Neglect gravity, collisions, fringing and interactions between electrons.

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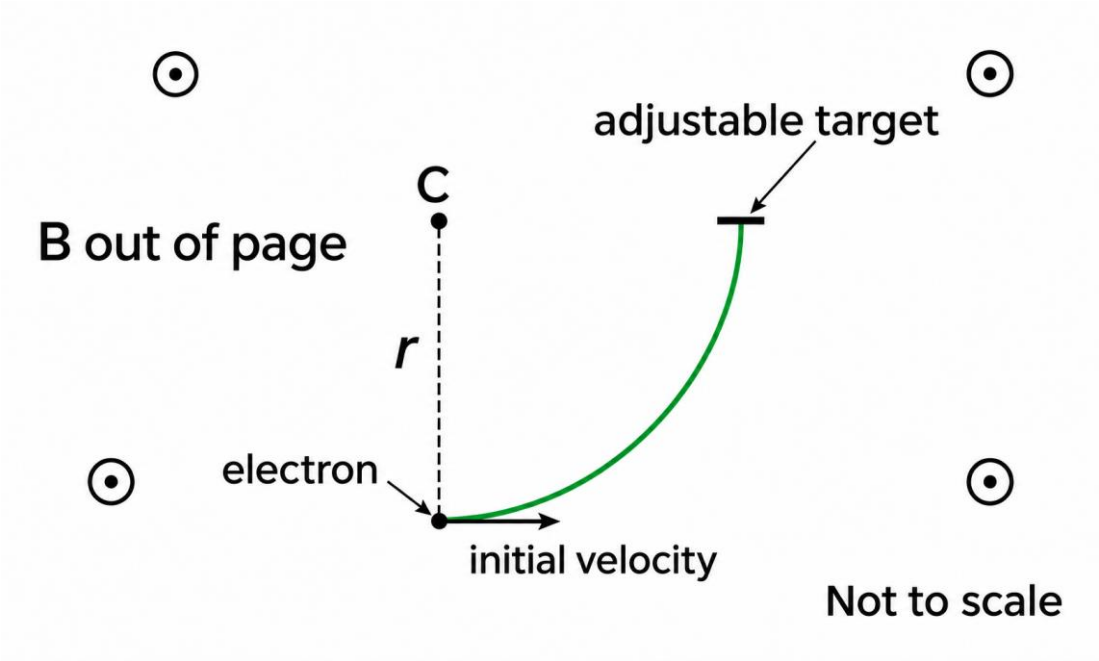


Figure 1 Electron beam guide

1(a) An electron enters to the right and B points out of the page. State its initial magnetic force direction. **[1 mark]**

1(b) In the magnetic region, which can change: the electron's speed, its velocity direction, or both? Explain briefly. **[2 marks]**

2 Connect force and motion

2(a) Calculate the magnetic force magnitude on one electron at the baseline setting. **[1 mark]**

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2(b) Calculate the ratio of magnetic force to electron weight and use it to assess the gravity approximation. **[2 marks]**

2(c) Explain why the magnetic field can produce acceleration without increasing the electron's kinetic energy. **[2 marks]**

2(d) A pupil draws the electron's curved orbit as a magnetic field line. Explain why these are different. **[2 marks]**

3 Derive the bend radius

3(a) Starting with the magnetic force and the force needed for circular motion, derive $r = mv/(B|q|)$. **[2 marks]**

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3(b) Calculate the baseline electron orbit radius in millimetres. **[1 mark]**

3(c) A particle has the same mass and speed as the electron but charge +e. In blank space, sketch its path from the same entry point and compare its radius with the electron's. **[2 marks]**

3(d) The speed becomes 1.25 times its baseline value and B is halved. Find the factor by which the radius changes. **[1 mark]**

4 Link the upstream accelerator

The accelerator and magnetic bend are separate regions. The accelerating p.d. is changed only when the question says so.

4(a) Before the bend, electrons accelerate from rest through a p.d. of magnitude U. Find U for the baseline entry speed. **[2 marks]**

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4(b) At B = 3.00 mT, a new test requires r = 25.0 mm. Calculate the required accelerating p.d. from rest. **[3 marks]**

4(c) At fixed B, the accelerating p.d. is doubled. By what factor does the orbit radius increase? Assume non-relativistic motion from rest. **[1 mark]**

4(d) A positive ion's mass is increased by a factor of four with |q| unchanged. Compare the radius factors at (i) fixed speed and (ii) fixed accelerating p.d. from rest, with B unchanged. **[2 marks]**

5 Use time and calibration data

Table 1

B / mT	r / mm
2.00	34.2
2.50	27.3
3.00	22.8
4.00	17.1

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5(a) Calculate the time for a baseline electron to complete the quarter-circle. Use the arc length, not the chord. **[2 marks]**

5(b) Derive the full-orbit period in terms of m, B and |q|. State what the result predicts if only speed is increased. **[2 marks]**

5(c) The entry speed is held fixed while B is varied. Choose graph axes using Table 1 that should give a straight line through the origin, and identify its gradient. **[1 mark]**

5(d) Use the readings at 2.00 mT and 4.00 mT to find the gradient in T m and infer m/|q|. The speed is 1.20×10^{7} m s^{-1}. **[2 marks]**

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6 Check the channel limit

6(a) The maximum permitted orbit radius is 26.0 mm. At the baseline speed, find the minimum permissible B. **[1 mark]**

6(b) Available nominal settings are 2.60 mT and 2.80 mT. Calculate the orbit radius at each and select a setting that meets the 26.0 mm limit. **[2 marks]**

6(c) For the 2.80 mT setting, B may be 5% below nominal and speed may be 2% above baseline. Does this setting guarantee the radius limit? Use the combined worst case. **[3 marks]**

6(d) Correct this response: “A stronger magnetic field gives a larger force, so it speeds up the electrons and increases their kinetic energy.” **[2 marks]**

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