

Magnetic fields and electromagnets

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 2

Worked solutions and teaching prompts | Foundation core and Higher-only section

Specification points covered

Permanent and induced magnets: 8463 4.7.1.1 / 8464 6.7.1.1
Fields, compasses and Earth evidence: 8463 4.7.1.2 / 8464 6.7.1.2
Current, wire fields, solenoids and iron cores: 8463 4.7.2.1 / 8464 6.7.2.1 (shared content)
Higher only: motor effect and $F = B I l$, 8463 4.7.2.2 / 8464 6.7.2.2
Higher only: rotation of a motor coil, 8463 4.7.2.3 / 8464 6.7.2.3 (selected content)

A recycling line separates magnetic components from mixed parts. Engineers test the sorting coil, map its field and check a small motor that moves the collection tray. Use the supplied test results; do not assume that every metal is magnetic.

Q1–4 are shared Foundation/Higher content; Q5–6 are Higher only on both routes. Accept equivalent precise wording and consistent follow-through. Use the diagrams as model sketches, not scale drawings. Timing is suggested, not classroom-tested. Original PhysicsUK questions, not an official AQA paper or mark scheme.

1 Testing the incoming components

The mixed parts are steel bolts, nickel washers, aluminium rivets and plastic spacers. The steel pieces are initially unmagnetised. A permanent test magnet is available at the line.

1(a) State one difference between a permanent magnet and an induced magnet. **[1 mark]**

Answer / mark points: A permanent magnet produces its own magnetic field; an induced magnet becomes magnetic when placed in another magnetic field. [1 for this contrast]

Teacher prompt: Temporary alone does not explain how an induced magnet is formed.

1(b) A steel bolt is attracted without touching the test magnet. Explain why an initially unmagnetised bolt can be attracted, and identify this as a contact or non-contact force. **[2 marks]**

Answer / mark points: The field induces magnetism in the steel, producing attraction. [1]
The force is non-contact because it acts across a gap without the objects touching. [1]

1(c) Name the two types of part that the magnet will not collect. Use one of them to refute the claim that all metals are magnetic. **[2 marks]**

Answer / mark points: Aluminium rivets and plastic spacers are not collected. [1 for both]
Aluminium is a metal but is not a magnetic material, so the claim is false. [1]



1 Testing the incoming components continued

1(d) The north pole of the test magnet repels the near end of an unlabelled bar. What is that end's pole, and why does repulsion show more than attraction would? **[2 marks]**

Answer / mark points: The near end is a north pole: like poles repel. [1]
Repulsion shows that the bar is a magnet; attraction alone could be caused by an induced magnet in an initially unmagnetised material. [1]

2 Mapping the test magnet

Figure 1 shows the test magnet. P is directly above its centre; Q is just beyond the left pole. The magnet's field is much stronger than Earth's field at these two points.

2(a) On Figure 1, draw at least four magnetic field lines outside the bar. Show their directions and how their spacing represents the stronger field near the poles. **[3 marks]**

Answer / mark points: Use smooth, non-crossing curves linking the pole regions. [1]
Outside arrows point from N to S. [1]
Lines are more concentrated near the pole ends and more spread out farther away. [1]

Teacher prompt: The field lines are a model, not tracks travelled by magnetic particles. Never draw outside arrows from S to N.

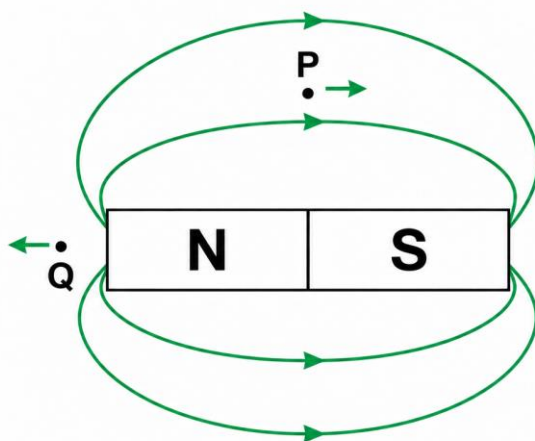


Figure 1

2(b) At P, which way would the north-seeking end of a small compass point: left or right? **[1 mark]**

Answer / mark points: Right, in the local N-to-S field direction above the centre. [1]

2(c) At Q, which way would the north-seeking end of the compass point: left or right? **[1 mark]**

Answer / mark points: Left, away from the nearby north pole. [1]



2 Mapping the test magnet continued

2(d) Far from the sorting equipment, a compass still settles roughly north–south. Explain how its behaviour provides evidence for a magnetic Earth and core. **[2 marks]**

Answer / mark points: The compass contains a small magnet that aligns with the local magnetic field. [1]

Away from local magnets, Earth supplies that field; this is evidence for a magnetic core. [1]

Teacher prompt: Do not describe Earth's hot core as a literal permanent bar magnet.

2(e) Describe how to use a plotting compass to trace several field lines around the fixed test magnet and show their direction. **[3 marks]**

Answer / mark points: Place the compass near a pole and mark the positions of the two ends of its needle. [1]

Move it so one end overlaps the previous north-end mark; mark the new north-end position and continue. Join the marks in a smooth line. [1]

Repeat from other starting positions and add arrows in the direction the north end points, away from N towards S outside the bar. [1]

3 Comparing wire and solenoid fields

Figure 2 shows two field models. A dot is conventional current out of the page. The solenoid's end poles are supplied; do not infer them from its stylised turns. Add your field drawings to the appropriate panel.

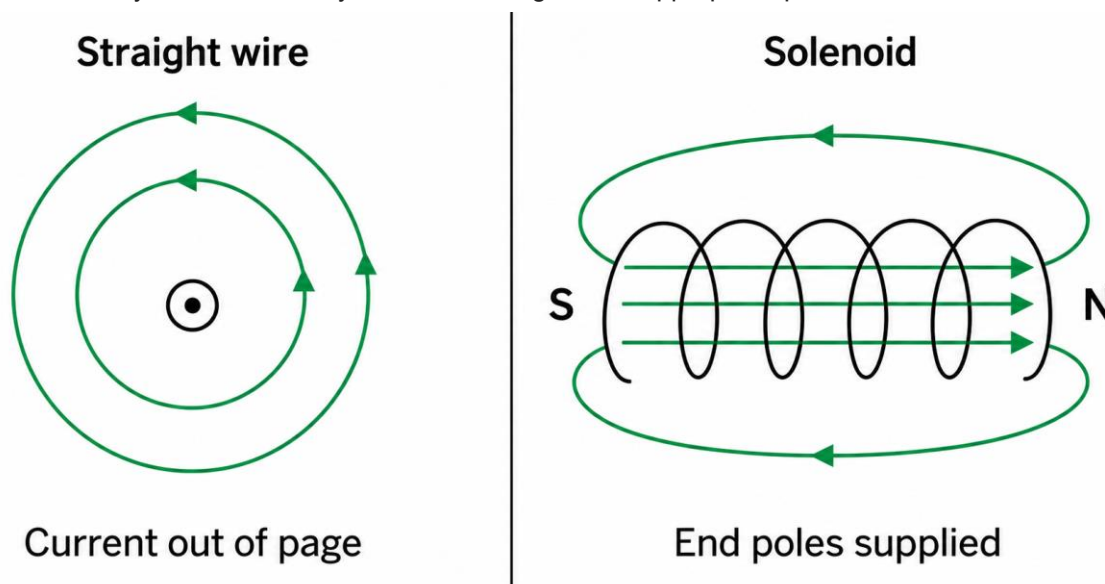


Figure 2

3(a) On the straight-wire panel of Figure 2, draw two field lines centred on the wire and add arrows for the current shown. **[2 marks]**

Answer / mark points: Two concentric circles centred on the wire. [1]

Arrows anticlockwise as viewed on the page for current out of the page. [1]

Teacher prompt: Use the right-hand grip rule: thumb out of the page, curled fingers anticlockwise.

3(b) On the solenoid panel, draw three field lines in its central interior and at least one return line outside. Show the directions. **[2 marks]**

Answer / mark points: Central interior lines are straight, parallel and evenly spaced. [1]

Inside arrows point right from S to N; outside return arrows point from the right N end back towards the left S end. [1]



3 Comparing wire and solenoid fields continued

3(c) Consider two separate changes to the straight-wire test. State what happens to the field direction if the current reverses, and to the field strength at the same point if the current is increased. **[2 marks]**

Answer / mark points: Reversing the current reverses the field direction to clockwise. [1]
Increasing the current increases the field strength at the same point. [1]

3(d) What do straight, parallel and evenly spaced field lines tell you about the central field inside a long solenoid? **[1 mark]**

Answer / mark points: It is uniform: its strength and direction are the same throughout that central region. [1]

3(e) For the same current, explain why winding the wire into a solenoid makes a stronger field in its interior than using one straight wire. **[1 mark]**

Answer / mark points: The magnetic fields from the turns reinforce each other inside the solenoid. [1]

3(f) The coil's plastic support is replaced by an iron core without changing the current or turns. State the effect on the field strength. **[1 mark]**

Answer / mark points: The field becomes stronger. [1] The iron becomes an induced magnet and reinforces the coil field.

4 Using the coil test results

The team measures the force needed to pull the same steel test piece away from a coil's iron core. They keep the coil, contact area, starting position, pull direction and test piece unchanged while varying current. The force meter is zeroed before use. Table 1 gives three pull-off measurements at each current.

Table 1

Current / A	Force 1 / N	Force 2 / N	Force 3 / N
0.20	0.18	0.20	0.22
0.40	0.78	0.80	0.82
0.60	1.78	1.80	1.82
0.80	3.18	3.20	3.22

4(a) Calculate the mean pull-off force at 0.60 A in Table 1. **[1 mark]**

Answer / mark points: Mean = $(1.78 + 1.80 + 1.82) / 3 = 1.80$ N. [1]

4(b) Calculate the range of the three force readings at 0.60 A. **[1 mark]**

Answer / mark points: Range = $1.82 - 1.78 = 0.04$ N. [1]

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4 Using the coil test results continued

4(c) A test requires a mean holding force of at least 1.50 N. Choose the smallest tested current that meets this requirement and justify it using the neighbouring test results. **[2 marks]**

Answer / mark points: Choose 0.60 A, with mean 1.80 N, above 1.50 N. [1]
The next lower tested current, 0.40 A, gives mean 0.80 N, below the requirement. [1]

4(d) A trainee claims the mean holding force exactly doubles when the current changes from 0.20 A to 0.40 A. Test the claim using Table 1. **[2 marks]**

Answer / mark points: The means are 0.20 N and 0.80 N. [1 for both]
The mean force increases by a factor of four in these data, not two, so the claim is not supported. [1]

Teacher prompt: Describe this measured relationship; do not infer a universal law for every electromagnet or current range.

4(e) Plan a fair investigation of how the number of turns affects the pull-off force. State what you would change, measure, control and repeat, and how you would compare the results. **[4 marks]**

Answer / mark points: Use coils with different measured numbers of turns on the same iron core. [1]
For each coil, pull the same steel test piece away in the same direction and record the maximum force immediately before separation, using a zeroed force meter. [1]
Keep current the same using an ammeter and adjustable supply, and keep the core, test piece and initial contact area/position unchanged. [1]
Repeat each setting at least three times, calculate mean pull-off forces and compare them for the different turn numbers. [1]

Teacher prompt: A coherent comparison is needed. Use a low-voltage supply within its rating, switch off between tests and avoid hot coils; do not suspend heavy loads over pupils.

4(f) Two coils tested at the same supply voltage carry 0.30 A and 0.45 A. Explain why this does not isolate the effect of turn number, and how the test should be adjusted. **[2 marks]**

Answer / mark points: Current differs as well as turn number, and current also affects magnetic strength. [1]
Measure current with an ammeter and adjust the supply so the same current flows in each coil. [1]

4(g) At fixed current, the test piece is moved farther from the core. State what happens to the strength of the magnetic attraction. **[1 mark]**

Answer / mark points: The attraction decreases as the distance increases. [1]



5 Higher only calculating motor effect forces

Q5 and Q6 are Higher only for both routes. Use $F = B I \ell$ for a wire perpendicular to a uniform magnetic field. F is force in N, B is magnetic flux density in T, I is current in A and ℓ is the length in the field in m. These are separate conductor tests, not the resultant force on the whole motor.

5(a) Higher only: a perpendicular test wire has $B = 0.25 \text{ T}$, $I = 0.60 \text{ A}$ and $\ell = 0.080 \text{ m}$. Calculate the force on it. **[1 mark]**

Answer / mark points: $F = B I \ell = 0.25 \times 0.60 \times 0.080 = 0.012 \text{ N}$. [1]

5(b) Higher only: a second wire has 12 cm in a 0.40 T field and carries 250 mA, perpendicular to the field. Calculate the force. **[2 marks]**

Answer / mark points: $\ell = 0.12 \text{ m}$; $I = 0.250 \text{ A}$. [1 for both conversions]
 $F = 0.40 \times 0.250 \times 0.12 = 0.012 \text{ N}$. [1]

5(c) Higher only: a force of 0.018 N acts on 0.060 m of perpendicular wire in a 0.30 T field. Calculate the current. **[2 marks]**

Answer / mark points: $I = F / (B\ell)$. [1]
 $I = 0.018 / (0.30 \times 0.060) = 1.0 \text{ A}$. [1]



5 Higher only calculating motor effect forces continued

5(d) Higher only: a perpendicular wire carries 0.80 A. Its active length is 0.10 m and the force is 0.024 N. Calculate the magnetic flux density. **[2 marks]**

Answer / mark points: $B = F / (I\ell)$. [1]

$B = 0.024 / (0.80 \times 0.10) = 0.30 \text{ T}$. [1]

5(e) Higher only: a circuit contains 80 cm of wire, but only 5.0 cm is inside the uniform 0.20 T field. The current is 2.0 A and that segment is perpendicular to the field. Calculate its magnetic force; ignore the field elsewhere.

[2 marks]

Answer / mark points: Use $\ell = 5.0 \text{ cm} = 0.050 \text{ m}$, not the full circuit length. [1]

$F = 0.20 \times 2.0 \times 0.050 = 0.020 \text{ N}$. [1]

Teacher prompt: The equation uses the wire length inside the specified field, not the entire wire supplied.

5(f) Higher only: a test rig needs 0.030 N on a perpendicular 0.050 m wire in a 0.20 T field. The supply is rated for at most 2.0 A. Calculate the required current and decide whether the rig can meet the target within that rating.

[2 marks]

Answer / mark points: $I = F / (B\ell) = 0.030 / (0.20 \times 0.050) = 3.0 \text{ A}$. [1]

No: 3.0 A exceeds the 2.0 A rating. Do not exceed the rating to obtain the target force. [1]



6 Higher only explaining motor rotation

Figure 3 is an end view of the two long sides A and B of a rectangular coil. The connecting ends are not shown. The coil turns about axis O, midway between the sides. A carries current out of the page and B into the page; both are perpendicular to the field.

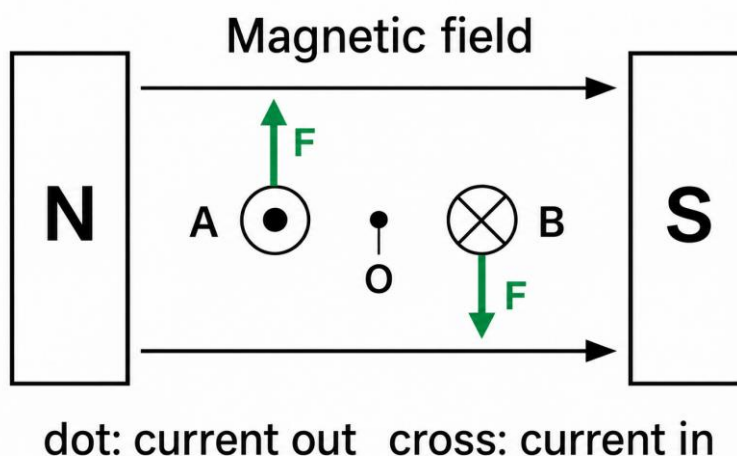


Figure 3

6(a) Higher only: use Fleming's left-hand rule to draw and label a magnetic force arrow on each side A and B in Figure 3. **[2 marks]**

Answer / mark points: Force on A is vertically upwards. [1]
Force on B is vertically downwards. [1] The green arrows show the two forces.

Teacher prompt: First finger: field right; second finger: conventional current. A is out of the page, B is into the page. Thumb gives force.

6(b) Higher only: explain why these forces turn the coil about O and state its initial direction of rotation in this view. **[2 marks]**

Answer / mark points: The opposite forces act on opposite sides of O along different lines, producing a turning effect rather than a resultant vertical push. [1]
Both give clockwise rotation in this view: left side up and right side down. [1]

6(c) Higher only: the motor reverses the current in the coil every half-turn while keeping the magnetic poles fixed. Explain why this helps it continue rotating in the same direction. **[2 marks]**

Answer / mark points: Reversing the coil current reverses the magnetic forces on its sides. [1]
After the sides exchange positions, these reversed forces maintain the same sense of turning instead of turning the coil back. [1]

Review and improve

An unmagnetised magnetic material can be attracted without being a permanent magnet. Outside a magnet the field runs from N to S; inside the central region of a solenoid it returns from S to N. Dot and cross show conventional current out of and into the page. Current direction, field direction and force direction are different quantities. Use only the active wire length in $F = B I \ell$.

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