Magnetism and electromagnetism

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Hassan has a bar magnet and an iron nail. When he holds the nail near the magnet, the nail picks up some steel paper clips. When he moves the magnet away, the paper clips fall off the nail.

Compare the bar magnet and the iron nail as magnets. Include how each one behaves with other magnets and materials.

(6 marks)

Model answer

While the nail is near the magnet, both behave as magnets. Each has a magnetic field with a north and a south pole, and each can attract magnetic materials such as iron, steel, nickel and cobalt. For both, the field is strongest at the poles, which is why the clips gather at the ends.

The difference is that the bar magnet is a permanent magnet, so it produces its own magnetic field all the time. The iron nail is an induced magnet. It only becomes a magnet because it has been placed in the bar magnet's field. When the bar magnet is moved away, the nail loses most or all of its magnetism quickly, so the paper clips drop off. The bar magnet would keep holding clips.

The force between an induced magnet and the magnet causing it is always attraction. The bar magnet, however, can attract or repel another magnet: like poles repel and unlike poles attract. Since repulsion only happens between two magnets, it can be used to show that the bar magnet is permanent.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Both have a magnetic field with a north pole and a south pole while they are magnetised
- Both can attract magnetic materials such as iron, steel, nickel and cobalt
- The bar magnet is a permanent magnet: it produces its own magnetic field all the time
- The nail is an induced magnet: it only becomes a magnet when it is placed in a magnetic field
- The nail loses most or all of its magnetism quickly when the magnet is removed, so the clips fall off
- The force between an induced magnet and the magnet that induces it is always attraction
- The bar magnet can attract or repel another magnet: like poles repel, unlike poles attract
- Repulsion only happens between two magnets, so it is a test for a permanent magnet
- The field of both is strongest at the poles, shown by the clips clustering at the ends

How it is marked

- 5-6 marks: makes several clear point-by-point comparisons, including permanent versus induced, attraction only versus attraction and repulsion, and why the clips fall off.
- 3-4 marks: correctly identifies the bar magnet as permanent and the nail as induced and makes some comparisons, but misses the idea that induced magnetism always attracts or is lost.
- 1-2 marks: gives simple statements about one of the objects, or says both are magnets, with little comparison.

What loses marks

- Saying the nail stays magnetised after the magnet is removed
- Saying induced magnets can repel
- Describing the magnet and the nail separately without comparing them

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2 A flat has an electric door lock. A coil of wire is wrapped around an iron core inside the door frame. A small iron bolt sits next to the core on a spring. When a resident presses a button in the flat, a current flows in the coil, the bolt is pulled towards the core and the door can be opened. When the button is released, the spring pushes the bolt back and the door is locked again.

Explain how the lock works, and explain two changes that would make the pull on the bolt stronger. (6 marks)

Model answer

When the resident presses the button, a current flows through the coil. A current in a wire produces a magnetic field around it, and winding the wire into a coil makes the field inside much stronger, with a shape like a bar magnet's field. The iron core becomes an induced magnet, which makes the field stronger still.

The bolt is made of iron, which is a magnetic material, so it is attracted towards the electromagnet. This pulls the bolt out of the locking position and the door can be opened.

When the button is released, the current stops and the magnetic field disappears. Iron loses its induced magnetism quickly, so the bolt is no longer attracted and the spring pushes it back to lock the door. This is why an electromagnet is used: it can be switched on and off, which a permanent magnet cannot.

To make the pull on the bolt stronger, the current in the coil could be increased, for example by using a higher voltage. Another way is to wind more turns of wire on the coil. Both changes make the magnetic field stronger.

Marking points (credit any 6 relevant points, linked in a sensible order)

- A current in a wire produces a magnetic field around the wire
- Wrapping the wire into a coil (solenoid) makes the field inside stronger and similar to a bar magnet's
- The iron core becomes an induced magnet, which makes the field much stronger
- The iron bolt is a magnetic material, so it is attracted to the electromagnet and pulled away from the locking position
- When the button is released the current stops, so the magnetic field disappears
- The iron core loses its magnetism quickly, so the spring can push the bolt back
- Increasing the current makes the magnetic field stronger, so the pull is greater
- Increasing the number of turns on the coil makes the magnetic field stronger
- An electromagnet is useful here because it can be switched on and off, unlike a permanent magnet

How it is marked

- 5-6 marks: explains the chain from current to magnetic field to induced magnetism in the core and bolt, explains why it releases when switched off, and gives two correct ways to strengthen it.
- 3-4 marks: explains that current makes the coil a magnet that attracts the bolt, and gives at least one correct change, but the role of the iron core or switching off is unclear.
- 1-2 marks: states that the coil becomes a magnet or gives one way to make it stronger, with little explanation.

What loses marks

- Saying the bolt is pulled because it has an electric charge
- Suggesting a thicker iron bolt or a bigger button as a way to strengthen the field
- Not explaining why the bolt is released when the current stops

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3 **Higher tier**

Grace places a straight horizontal wire between the poles of a horseshoe magnet. The wire runs at right angles to the magnetic field and 0.050 m of it is inside the field. She passes different currents through the wire and measures the force on it.

Current in A	Force in N
1.0	0.004
2.0	0.008
3.0	0.012
4.0	0.016

Use the data to describe the relationship between current and force, calculate the magnetic flux density of the magnet, and explain how Grace could work out the direction of the force and make it reverse.

(6 marks)

Model answer

The force is directly proportional to the current. When the current doubles from 1.0 A to 2.0 A, the force doubles from 0.004 N to 0.008 N, and at 4.0 A the force is four times bigger, 0.016 N. This is the motor effect: the magnetic field around the current-carrying wire interacts with the field of the magnet, producing a force.

F = B x I x l, so B = F / (I x l). Using the first row, B = 0.004 / (1.0 x 0.050) = 0.08 T. Checking with 4.0 A gives 0.016 / (4.0 x 0.050) = 0.08 T, so every result gives the same flux density.

Grace can find the direction of the force using Fleming's left-hand rule. She holds her thumb, first finger and second finger at right angles. The first finger points along the field from north to south, the second finger points along the current, and the thumb shows the direction of the force, which is at right angles to both.

To reverse the force she could reverse the current or turn the magnet round to reverse the field. Reversing both together would leave the force in the same direction.

Marking points (credit any 6 relevant points, linked in a sensible order)

- The force is directly proportional to the current: doubling the current from 1.0 A to 2.0 A doubles the force from 0.004 N to 0.008 N
- This happens because the magnetic field of the current in the wire interacts with the field of the magnet (the motor effect)
- F = B x I x l, so B = F / (I x l)
- Using 1.0 A: B = 0.004 / (1.0 x 0.050) = 0.08 T
- Every row gives the same value, 0.08 tesla, which supports the relationship
- The direction of the force is found using Fleming's left-hand rule
- First finger points along the field (north to south), second finger along the current, thumb gives the direction of the force
- The force is at right angles to both the field and the current
- Reversing the current or turning the magnet round to reverse the field makes the force act in the opposite direction
- Reversing both at once would leave the force in the same direction

How it is marked

- 5-6 marks: uses data to show direct proportionality, rearranges F = BIl correctly to get 0.08 T with a check, and explains Fleming's left-hand rule and how to reverse the force.
- 3-4 marks: describes the relationship and either calculates B correctly or explains the left-hand rule clearly, with the other part incomplete.
- 1-2 marks: states that more current gives more force or names the left-hand rule, with no correct calculation.

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What loses marks

- Using the length in centimetres instead of metres
- Using the right hand, or mixing up which finger is current and which is field
- Saying reversing both current and field reverses the force

4 **Higher tier**

A simple model motor has a rectangular coil of wire that can spin on an axle between the poles of two magnets. A direct current is fed into the coil through a split-ring commutator and two carbon brushes.

Explain why the coil starts to turn when the current is switched on, and why it keeps turning in the same direction.

(6 marks)

Model answer

When the current is switched on, it creates a magnetic field around the wires of the coil. This field interacts with the field of the magnets, so each side of the coil feels a force at right angles to the field. This is the motor effect.

The current flows one way along one side of the coil and the opposite way along the other side. By Fleming's left-hand rule, this means one side is pushed up and the other side is pushed down. These two forces in opposite directions make a turning effect about the axle, so the coil starts to rotate.

If nothing else happened, after half a turn the sides would swap places but the current would still flow the same way in each wire, so the forces would push the coil back. The split-ring commutator stops this. It turns with the coil and swaps the connections to the brushes every half turn, which reverses the current in the coil. The side near each magnet pole always carries current in the same direction, so it is always pushed the same way. The coil's momentum carries it past the vertical position, so it keeps spinning in one direction.

Marking points (credit any 6 relevant points, linked in a sensible order)

- The current in the coil creates its own magnetic field, which interacts with the field of the magnets
- This produces a force on each side of the coil that is at right angles to the field (the motor effect)
- The current flows in opposite directions along the two sides of the coil
- So one side is pushed up and the other side is pushed down, using Fleming's left-hand rule
- These two forces form a turning effect (moment) about the axle, so the coil rotates
- Without a commutator, after half a turn the forces would push the coil back the other way
- The split-ring commutator swaps the connections to the brushes every half turn
- This reverses the current in the coil every half turn, so the side next to each pole always has current in the same direction
- The forces therefore keep turning the coil the same way, so it rotates continuously
- The coil's momentum carries it past the vertical position where the forces have no turning effect

How it is marked

- 5-6 marks: explains the forces on opposite sides of the coil as a turning effect, and explains how the commutator reverses the current every half turn to keep rotation in one direction.
- 3-4 marks: explains that forces on the coil make it turn and that the commutator is needed, but how the commutator works is unclear.
- 1-2 marks: states that the magnet and current make the coil spin, with little explanation of the forces or commutator.

What loses marks

- Saying the commutator reverses the direction of the magnetic field of the magnets
- Saying both sides of the coil are pushed in the same direction
- Not explaining what would go wrong without the commutator

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5 **Higher tier | Separate science only**

Nadia sings into a moving-coil microphone at a school concert. Inside the microphone, a light diaphragm is attached to a small coil of wire. The coil sits around one pole of a permanent magnet, and its ends are connected to an amplifier.

Describe how the microphone turns the sound of Nadia's voice into an electrical signal that matches the sound.

(6 marks)

Model answer

Sound waves are pressure variations in the air. When they reach the microphone, they push and pull on the light diaphragm, making it vibrate backwards and forwards. The coil is fixed to the diaphragm, so the coil vibrates as well.

As the coil moves, it moves relative to the magnetic field of the permanent magnet and cuts through the field lines. This induces a potential difference across the ends of the coil. This is called the generator effect. Because the coil is connected to the amplifier in a complete circuit, an induced current flows. When the coil moves one way and then the other, the induced current changes direction, so the signal is alternating.

The signal matches the sound. When Nadia sings louder, the diaphragm moves further and faster, so a larger potential difference is induced. When she sings a higher note, the coil vibrates more times per second, so the signal has a higher frequency. The signal is small, so the amplifier makes it bigger before it is sent to the loudspeakers.

Marking points (credit any 6 relevant points, linked in a sensible order)

- Sound waves are pressure variations in the air
- The pressure variations hit the diaphragm and make it vibrate backwards and forwards
- The coil is attached to the diaphragm, so the coil vibrates too
- The coil moves relative to the magnetic field of the permanent magnet, cutting the field lines
- This induces a potential difference across the ends of the coil (the generator effect)
- Because the coil is part of a complete circuit, an induced current flows
- As the coil moves one way then the other, the direction of the induced current changes, so it is alternating
- A louder sound makes the diaphragm move further and faster, giving a larger potential difference
- A higher pitched sound makes the coil vibrate more often, giving a signal with a higher frequency
- The amplifier makes the small signal bigger so it can drive the loudspeakers

How it is marked

- 5-6 marks: describes the full sequence from pressure variations to vibrating coil to induced potential difference, and explains how loudness and pitch are matched in the signal.
- 3-4 marks: describes the diaphragm and coil vibrating in the magnetic field to induce a current, but does not explain how the signal matches the sound.
- 1-2 marks: states that sound makes something vibrate or that the microphone makes electricity, with little detail.

What loses marks

- Saying the magnet vibrates or that sound itself travels along the wire
- Describing a loudspeaker (current making the cone move) instead of a microphone
- Not explaining how loudness and pitch show up in the signal

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