Get started

AO2/AO3

4 Electromagnetism

This unit will help you to understand how electricity and magnetism interact.

In the exam you will be asked to answer questions such as the one below.

Exam-style question

1 A student investigated what happens to a wire in a magnetic field. Figure 1 shows the apparatus the student used. The wire XY is connected to a switch and battery. When the switch is closed, a force acts on the wire.

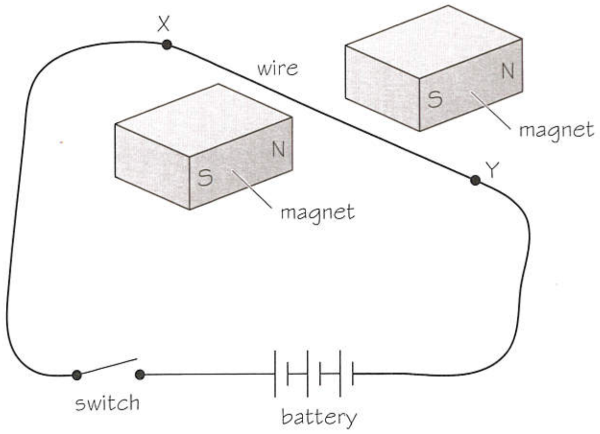


Figure 1

(a) Explain why a force acts on the wire XY when the switch is closed. **(3 marks)**

....

(b) Draw an arrow to show the direction of the force acting on the wire XY. **(1 mark)**

(c) Use an equation from the equation sheet that links the force acting on a wire carrying an electric current with magnetic flux density and current size. **(1 mark)**

....

(d) Describe **three** ways in which the force on the wire can be **increased**. **(2 marks)**

....

You will already have done some work on electromagnetism. Before starting the **skills boosts**, rate your confidence in each area. Colour in the bars.

1 How do I relate electricity to magnetism?

2 What causes a force to act on a current-carrying conductor?

3 How do I calculate the force on a wire?

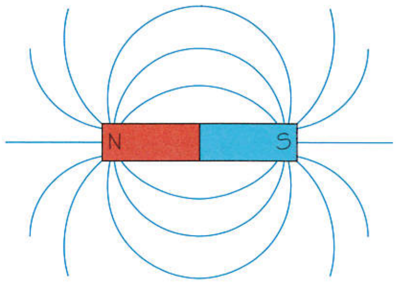
Physics

Get started

Magnetic field lines are a model used to represent the strength and the direction of magnetic fields. We can investigate magnetic fields using iron filings or plotting compasses. Magnetic field diagrams follow some simple rules:

- Field lines point from north (N) to south (S).
- Field lines cannot touch or cross each other.
- The closer the field lines are to each other, the higher the magnetic flux density (field strength).
- Straight, equally spaced field lines show a uniform field.

1 The diagram represents the magnetic field around a bar magnet.

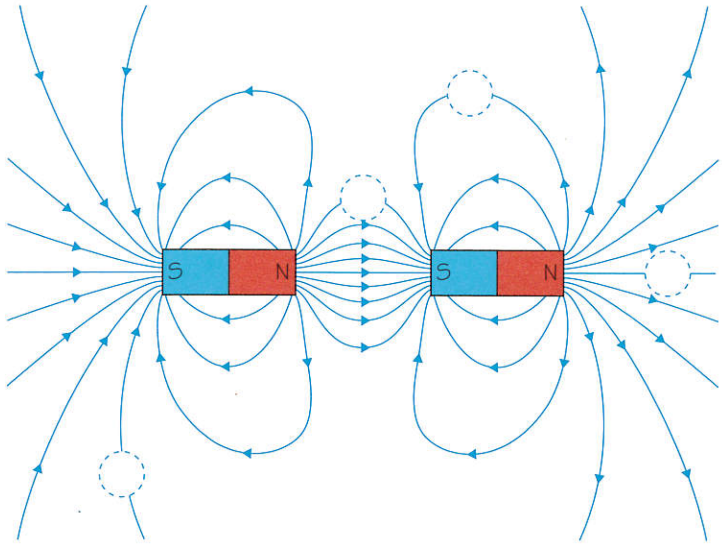


a Draw an arrow on each field line to show the direction of the magnetic field.

b Write a letter 'X' in a region of high magnetic flux density.

c Write a letter 'Y' in a region of low magnetic flux density.

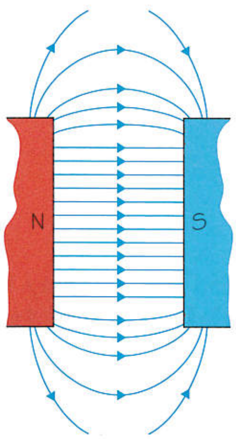
If we place two magnets with unlike poles facing, we get a field diagram between the poles as shown in the diagram.



The magnetic fields of the two magnets interact so that there are some field lines between the two magnets.

2 The four circles represent plotting compasses. Add a compass needle to each to show the direction that it would point.

If we have two magnets with wide poles placed close together, the magnetic field between them looks like the diagram on the right.



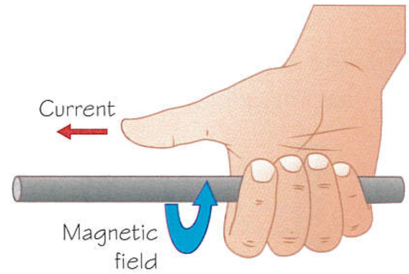
3 How would you describe the magnetic field between the magnets on the right? Tick **two** boxes.

- [ ] weak
- [ ] strong
- [ ] random
- [ ] irregular
- [ ] uniform

1 How do I relate electricity to magnetism?

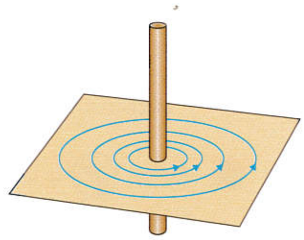
A wire carrying an electric current produces a circular magnetic field around itself. We can predict the direction of the magnetic field using the right-hand grip rule.

1 The diagram shows the right-hand grip rule. Complete the sentence.



> If you were to grip a wire with your right hand, your thumb would point in the direction of the .... and your fingers would point in the direction of the ....

2 The diagram shows the field around a current-carrying wire. The arrows on the field lines show the direction of the magnetic field. Draw an arrow on the diagram to show the direction of the current.



The strength of the magnetic field depends on its distance from the wire and the size of the current.

Imagine a right hand gripped around the wire.

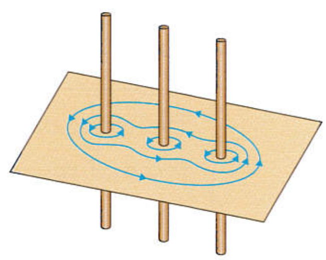
3 Circle the correct words in **bold** to complete the sentences.

Look at the spacing of the field lines.

> The magnetic field is **weakest** / **strongest** closer to the wire and gets **stronger** / **weaker** as the distance from the wire increases.
>
> The higher the current the **weaker** / **stronger** the magnetic field.

Magnetic fields can interact with each other.

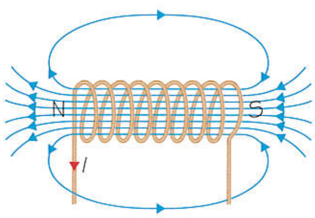
- If the magnetic fields are in the same direction, the fields add to each other and become stronger.
- If the fields are in the opposite direction, they cancel each other and become weaker.



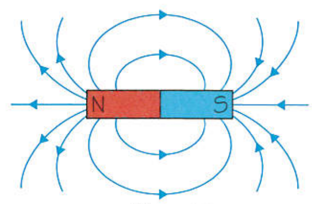
4 The diagram shows how the magnetic fields from three parallel wires interact. Use the right-hand grip rule to predict the direction of current flow in each wire. Label each wire with an arrow to show the direction.

5 The diagram shows the magnetic fields around a solenoid and a bar magnet. Tick the correct boxes to show which statements are true and which are false.

Remember that the closer the field lines, the stronger the magnetic flux density (field strength).



Solenoid



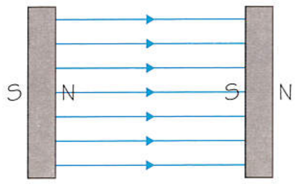
Magnet

	True	False
a The magnetic fields have the same basic shape.	☐	☐
b The magnetic flux density (field strength) at the poles of the magnet is greater than the magnetic flux density at the poles of the solenoid.	☐	☐
c The magnetic flux density (field strength) at the sides of the magnet is greater than the magnetic flux density at the sides of the solenoid.	☐	☐

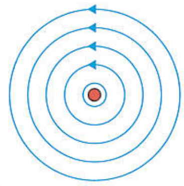
2 What causes a force to act on a current-carrying conductor?

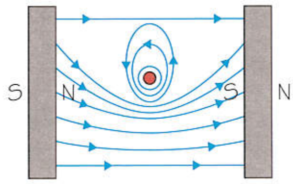
The magnetic field around a wire carrying an electric current can interact with other magnetic fields. For example, it can interact with the magnetic field produced by a permanent magnet. These interactions produce forces that may cause the wire or magnet to move.

1 The diagram shows the magnetic field produced when a current-carrying wire is put between two magnets.



Two flat magnets produce a uniform magnetic field between them.


A magnetic field goes around a wire carrying a current.



When the wire carrying a current is put between the magnets, the two fields interact to produce a force.

a Write a letter 'X' on the right-hand diagram where the magnetic field is strongest.

b Write a letter 'Y' on the right-hand diagram where the field is weakest.

c Draw an arrow on the diagram to show the direction of the force on the wire.

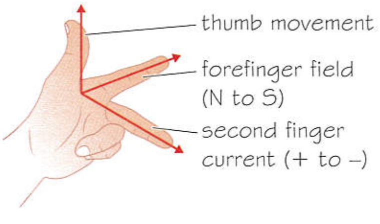
> To predict the direction of the force on the wire, visualise the field lines as elastic bands. Imagine the elastic bands are trying to straighten by catapulting the wire away.

The wire also exerts a force on the magnets (Newton's third law).

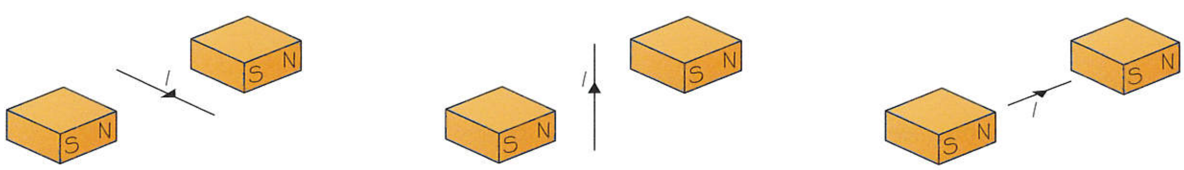
d Circle the correct words in **bold** to complete the sentences.

> The force of the wire acting on the magnets is in the **same / opposite** direction to the force of the magnets acting on the wire.
>
> The size of the force of the wire acting on the magnets is **the same as / different to** the size of the force of the magnets acting on the wire.

To create the greatest force, the magnetic field from the magnets must be at right angles to the current in the wire. Fleming's left-hand rule (shown in the diagram) gives us an easy way to predict the force (and so direction of movement) of a wire carrying an electric current.



2 The diagram shows three wires in three different magnetic fields. The arrows show the direction of the current flowing in each wire.



Draw arrows to show the direction of the force acting on each wire. If no force is acting, label the wire with the words 'no force'.

3 How do I calculate the force on a wire?

The force acting on a wire in a magnetic field depends on the strength of the magnetic field, the size of the current and the length of the wire carrying the current. Remember that the force is greatest when the magnetic field and wire are at right angles to each other.

We can calculate the size of the force acting on a wire using the following equation:

force on a conductor at right angles to a magnetic field carrying a current (N) = magnetic flux density (tesla, T) × current (A) × length (m)

$$F = B \times I \times l$$

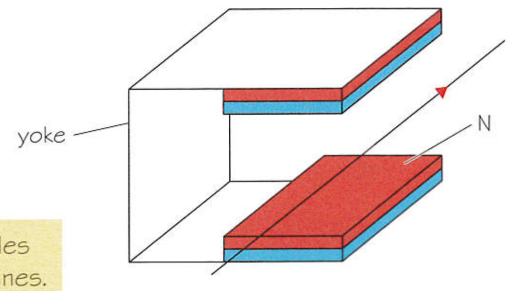
You don't need to learn this equation, but you do need to use it correctly. You need to learn the physical quantities, their symbols and their units.

1. Draw lines to link each physical quantity to its symbol and unit. One has been done for you.

Physical quantity	Symbol	Unit
force	I	volt
magnetic flux density	F	ampere
length	V	newton
current	B	metre
potential difference	L	tesla

Remember, not all physical quantities have symbols that match the first letter of the physical quantity.

2. The diagram shows two magnets producing a strong uniform magnetic field. The north pole of each magnet is shown in red. The yoke is a metal frame which holds the two magnets.



a. Draw an arrow to show the direction of the magnetic field and label it 'B'.

Remember the rules for magnetic field lines.

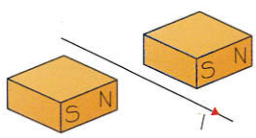
b. Draw an arrow from the wire to show the direction of the force acting on the wire.

Remember to use Fleming's left-hand rule to predict the direction of the force acting on the wire.

c. Draw an arrow from the yoke to show the direction of the force acting on the yoke.

Remember to apply Newton's third law here.

3. The diagram shows a current-carrying wire in a magnetic field. A 12 cm length of wire in a magnetic field of flux density 0.2 T carries a current of 1.5 A. Calculate the force acting on the wire using the equation: $F = B \times I \times l$



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Remember to convert the length of the wire from centimetres to metres.

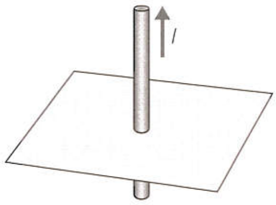
Physics

Sample response

Look at these exam-style questions and answers given by a student.

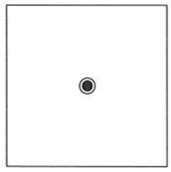
Exam-style question

1 The diagram on the left shows a vertical wire passing through a hole in a card. The wire is carrying an electric current in the direction shown by the arrow labelled *I*.



The diagram on the right shows the same card as viewed from above. Use your knowledge of electromagnetism to draw the magnetic field around the wire. **(3 marks)**

1 **a** The student's answer is shown in the diagram above. The student only gained 1 mark. How could the student have gained full marks? Draw an improved answer on the diagram on the right.



b Explain why your diagram is better than the student's diagram.

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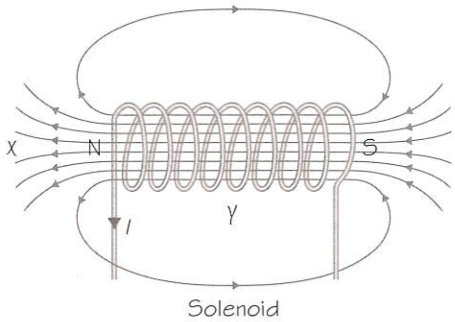
Exam-style question

2 The diagram shows the magnetic field around a solenoid.



(a) Write a letter 'X' in a region of high magnetic flux density. **(1 mark)**

(b) Write a letter 'Y' in a region of low magnetic flux density. **(1 mark)**

(c) Describe **two** features of the magnetic field **inside** the solenoid. **(2 marks)**

The field lines are close together so the magnetic field is strong.

2 **a** The student has put a letter 'X' at the north pole of the solenoid to show a region of high magnetic flux density but the field lines are diverging (spreading out). Where would be a better place for the student to put the letter 'X' and why?

....

....

b There are other regions of low magnetic flux density where the student could have placed a letter 'Y'. Add a letter 'Y' to **three** more places of low magnetic flux density.

c For their answer to part **(c)**, the student only gained 1 mark. Write an improved answer which includes two features.

....

....

Your turn!

It is now time to use what you have learned to answer the exam-style question from page 137. Remember to read the question thoroughly, looking for information that may help you. Make good use of your knowledge from other areas of physics.

Remember to use Fleming's left-hand rule when answering this question.

Exam-style question

1 A student investigated what happens to a wire in a magnetic field. Figure 1 shows the apparatus the student used. The wire XY is connected to a switch and battery. When the switch is closed, a force acts on the wire.

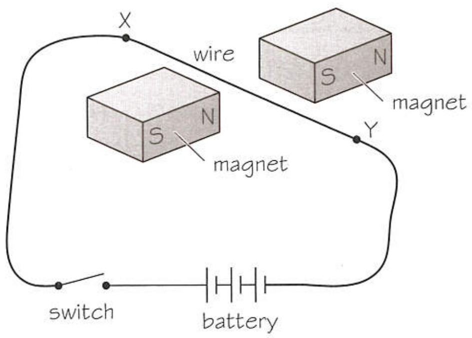


Figure 1

(a) Explain why a force acts on the wire XY when the switch is closed. **(3 marks)**

....

....

....

There are 3 marks available for part **(a)**. Think about three important points to write about – use the figure to help you.

(b) Draw an arrow to show the direction of the force acting on the wire XY. **(1 mark)**

Work out the direction of the force acting on the wire using Fleming's left-hand rule.

(c) Use an equation from the equation sheet that links the force acting on a wire carrying an electric current with magnetic flux density and current size. **(1 mark)**

....

....

(d) Describe **three** ways in which the force on the wire can be **increased**. **(2 marks)**

....

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....

Use the equation to help you. Think about which factors on the right side of the equation could increase the force acting on the wire.

Physics

Need more practice?

Exam questions may ask about different parts of a topic, or parts of more than one topic.

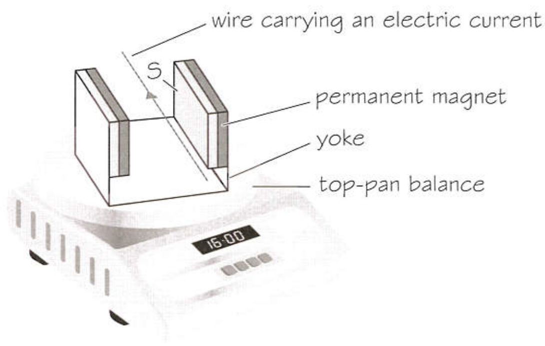
Questions about electromagnetism could occur as:

- questions about that topic only
- part of a question about an experiment or investigation about devices that rely on an electromagnet to work.

Have a go at this exam-style question.

Exam-style question

1 A student wanted to measure the magnetic flux density produced by two magnets. She placed the two magnets on a top-pan balance. The top-pan balance reading changed by 16.0 g when she passed a current of 3.2 A through the wire and placed it in the magnetic field.



(a) Calculate the force acting on the balance. Use gravitational field strength (*g*) = 10 N/kg. **(2 marks)**

....

....

Remember that weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg), $W = m \times g$.

(b) Calculate the magnetic flux density produced by the two magnets, assuming that 0.10 m of wire is in the magnetic field. Use an equation from the equation sheet. **(4 marks)**

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Boost your grade

Make sure you can use select and apply the equation: force on a conductor at right angles to a magnetic field carrying a current (newton, N) = magnetic flux density (tesla, T) × current (ampere, A) × length (metre, m), $F = B \times I \times l$.

Make sure you learn and can apply the right-hand grip rule and Fleming's left-hand rule.

How confident do you feel about each of these **skills**? Colour in the bars.

1 **How do I relate electricity to magnetism?**

2 **What causes a force to act on a current-carrying conductor?**

3 **How do I calculate the force on a wire?**