Chapter 20 – Magnetism

Subject content

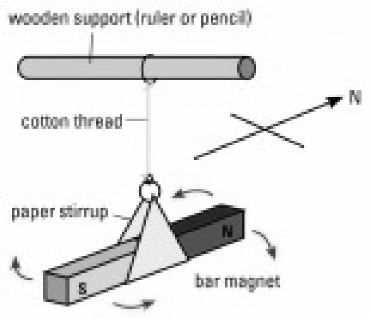
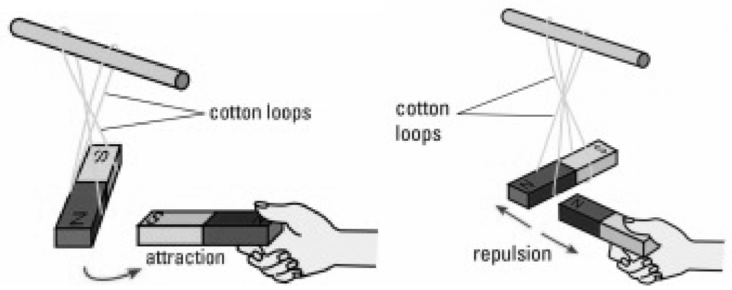
Content ● Laws of magnetism ● Magnetic properties of matter ● Magnetic field Learning outcomes (a) state the properties of magnets (b) describe induced magnetism (c) describe electrical methods of magnetisation and demagnetisation (d) draw the magnetic field pattern around a bar magnet and between the poles of two bar magnets (e) describe the plotting of magnetic field lines with a compass (f) distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)

Definitions

Term	Definition
Magnetic materials	Materials that can be attracted to a magnet
Non-magnetic materials	Materials that cannot be attracted to a magnet
Magnetic induction	Process where object made of magnetic material becomes magnet when it is near / in contact with a magnet
Magnetic field	Region surrounding magnet in which a body of magnetic material experiences magnetic force

20.1 Magnets and Magnetic Materials

Properties of magnets

<table>
<tr><th>Property</th><th>Explanation</th></tr>
<tr><td>1. Attract magnetic materials</td><td>Materials
<table>
<tr><th>Magnetic materials</th><th>Non-magnetic materials</th></tr>
<tr><td>Iron
Cobalt
Nickel
Steel
Lodestone (natural)</td><td>Copper
Aluminium
Wood
Plastic
Brass</td></tr>
</table></td></tr>
<tr><td>2. Have 2 poles</td><td>Magnetic effects are strongest at poles</td></tr>
<tr><td>3. Freely suspended: come to rest in N-S direction</td><td>N pole: end that points to North Pole of Earth
S pole: end that points to South Pole of Earth

</td></tr>
<tr><td>4. Like poles repel
Unlike poles attract</td><td>
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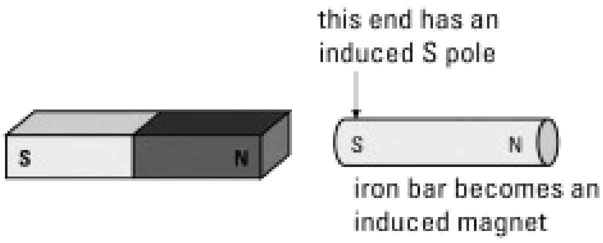
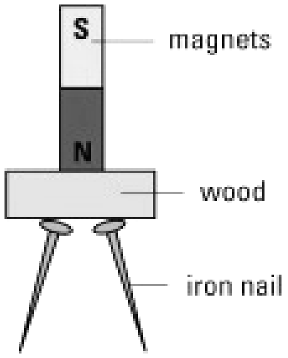
Identify magnets

Attraction	**Repulsion**
magnet ⇔ magnet magnet ⇔ unmagnetised magnetic material	magnet ⇔ magnet

20.2 Magnetic Induction





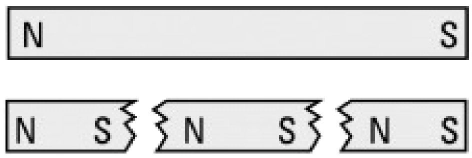
Iron rod is magnetically induced → become induced magnet

Permanent magnet	Iron rod
N pole	S pole induced
S pole	N pole induced

20.3 Magnetisation and Demagnetisation

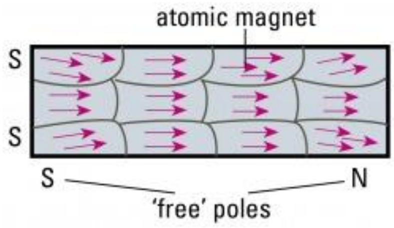
<u>Theory of magnetism</u>

Magnet is made up of many 'tiny magnets' (magnetic domains)

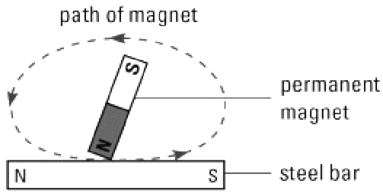
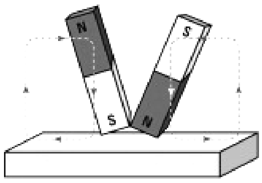
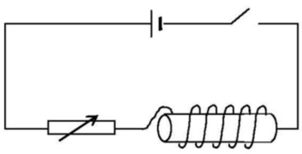
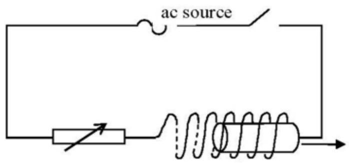


Magnetic domain: group of atomic magnets pointing in same direction

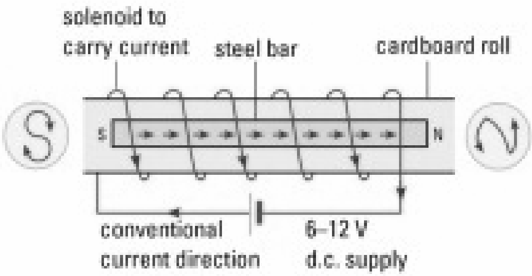
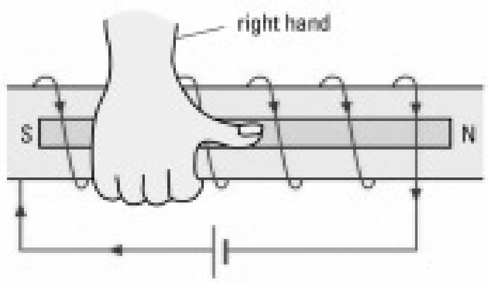
Magnetisation

	
Magnetic domains: random directions	Magnetic domains: same direction
Domains point in opposite directions → cancel one another out → no net magnetisation	Each arrow directly behind arrow in front of it → N poles cancel out adjacent S poles → net magnetisation (N/S poles at the ends)

Magnetise and demagnetise magnetic materials

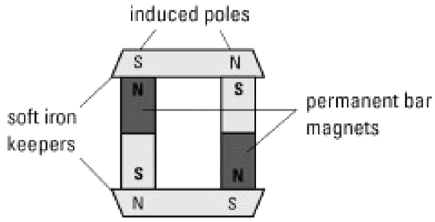
Magnetise	Demagnetise
Magnetic domains aligned	Magnetic domains disaligned
1. Stroking • Stroke steel bar with one pole of permanent magnet several times from one end to the other • Lift stroking magnet sufficiently high above steel bar b/w successive strokes • Pole at end of steel bar: opposite to stroking pole used 	1. Heating • Strongly heat • Cool in E-W direction  2. Hammering • Hammer in E-W direction 
2. Electrical (d.c.) • Place in solenoid • Pass large d.c. through solenoid  Make electromagnet stronger 1) increase current (more cells) 2) increase no. of turns in coils	3. Electrical (a.c.) • Place in solenoid in E-W direction • Pass a.c. through solenoid • Withdraw slowly until far away 

Determine poles of electromagnet

1. Direction of current at ends	2. Right-hand grip rule
	

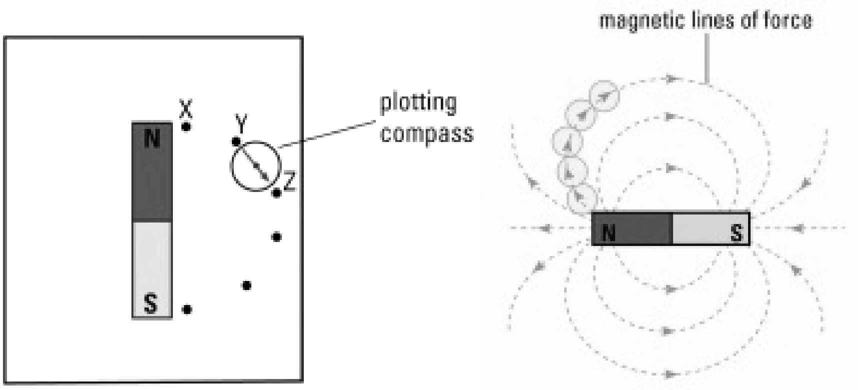
<u>Storage of bar magnets</u>

- Permanent magnets lose magnetism: free poles at ends repel each other → alter magnetic domains
- Store in pairs + soft iron keepers across ends
  - poles of atomic magnets in closed loops, no ‘free’ poles
  - lock alignment of magnetic domains

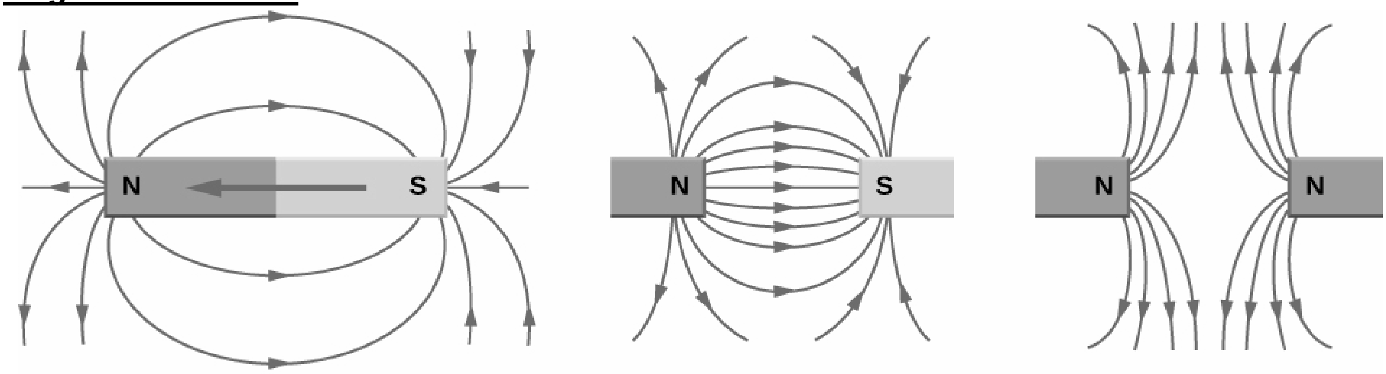


20.4 Magnetic Fields

Plotting magnetic field lines (using compass)



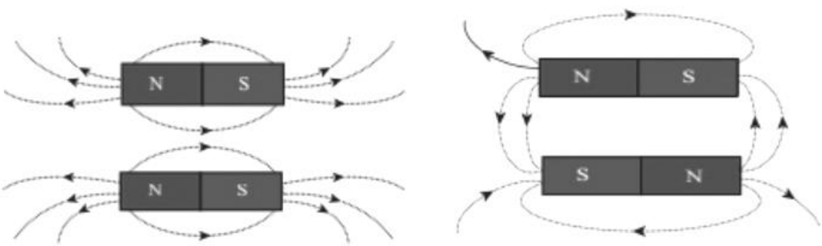
<u>Magnetic field lines</u>

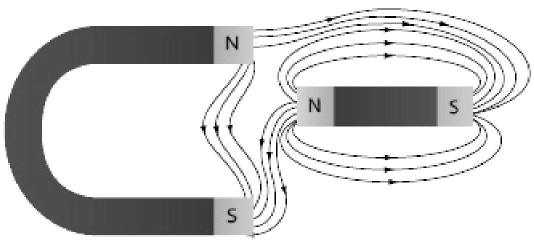


Magnetic field lines of a bar magnet

Magnetic field lines between unlike poles

Magnetic field lines between like poles

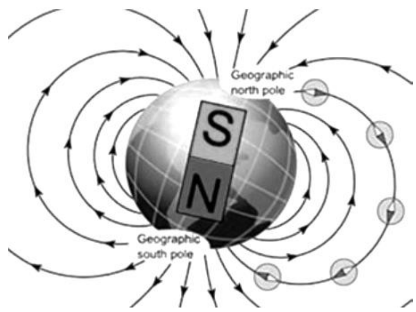




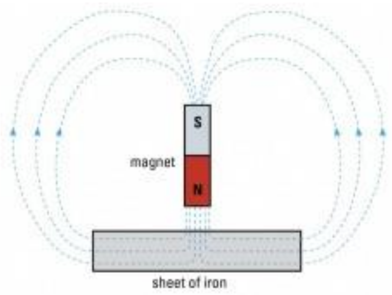
two pairs of parallel bar magnets

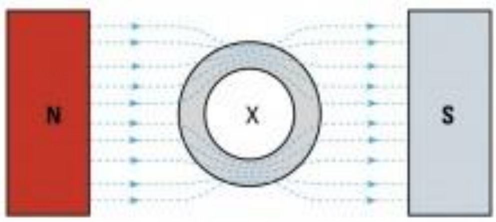
Note:

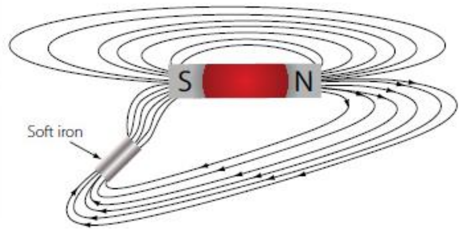
- Magnetic field lines: N → S pole
- Magnetic field lines: X cross / intersect one another
- Magnetic field lines closer → stronger magnetic field



<u>Magnetic shielding</u>



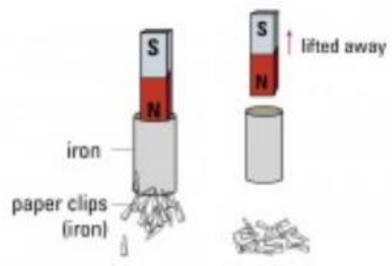
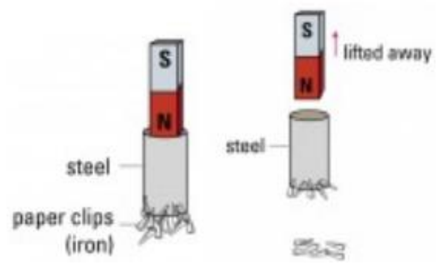




Magnetic shielding

- Prevent surrounding magnetic fields from affecting proper functioning of equipment
  - magnetic resonance imaging (MRI) equipment
  - computer hard drives
- Use thin sheets of <u>soft magnetic material</u> (iron / MuMetal)
  → <u>divert</u> magnetic field lines (tend to pass through them)

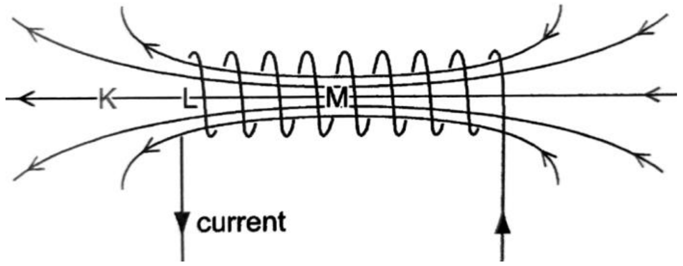
20.5 Temporary and Permanent Magnets

Magnetic material	**Soft**	**Hard**
Figure		
Ease of magnetising & demagnetising	easy	difficult
Magnetic strength when magnetised	stronger	weaker
Retain magnetism	easy	difficult
Example	iron	steel
Applications	**<u>Temporary</u> magnets** • electromagnet • electric bell • circuit breaker	**<u>Permanent</u> magnets** • magnetic door catches • activate reed switches • loudspeaker • ammeter • compass

<u>Typical questions</u>

Multiple choice questions

1 The diagram shows the magnetic field pattern due to a current in a solenoid.



Which statement is correct? (2012 P1 Q27)

A The strength of the field is greater at K than it is at L.
B The strength of the field is greater at M than it is at L.
C The strength of the field is the same at K as it is at M.
D The strength of the field is the same at L as it is at M.

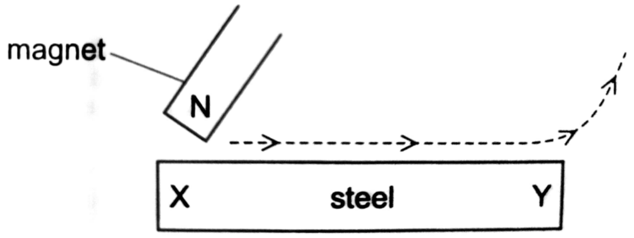
2 An electromagnet is produced by passing an electric current through a coil of copper wire wrapped around a core made from a suitable material.
Which material produces the strongest electromagnet? (2013 P1 Q36)

A aluminium
B copper
C iron
D steel

3 What correctly describes the field produced in the region surrounding a solenoid that carries a current? (2014 P1 Q27)

A a region where stationary electric charges experience a force
B a region where electric charges gain energy
C a region where magnetic poles experience a force
D a region where magnetic poles gain energy

4 A piece of steel can be magnetised by stroking it with a magnet.



When the magnet is moved in the direction shown, which poles are produced at X and at Y?
(2014 P1 Q33)

	X	Y

A	N-pole	N-pole
B	N-pole	S-pole
C	S-pole	N-pole
D	S-pole	S-pole

5 Which metals are used for temporary and for permanent magnets? (2014 P1 Q34)

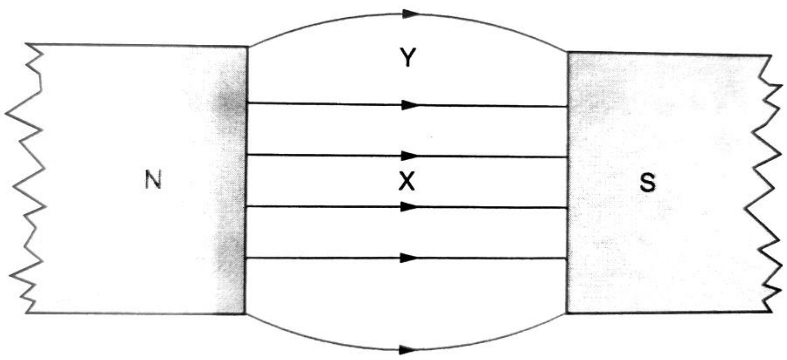
	temporary	permanent
A	iron	iron
B	iron	steel
C	steel	iron
D	steel	steel

6 A current-carrying solenoid is used to demagnetise a bar magnet.
What must be part of the procedure for demagnetising the bar magnet? (2017 P1 Q29)

A Alternating current (a.c.) is used.
B Direct current (d.c.) is used.
C The magnet is inserted slowly into the solenoid.
D The magnet is withdrawn quickly from the solenoid.

Structured questions

1 The figure below shows the magnetic field between an N-pole and an S-pole on two bar magnets.



(2013 P2A Q8)

(a) The lines near X are parallel and evenly spaced.
State what this shows about the magnetic field at X. [1]

uniform

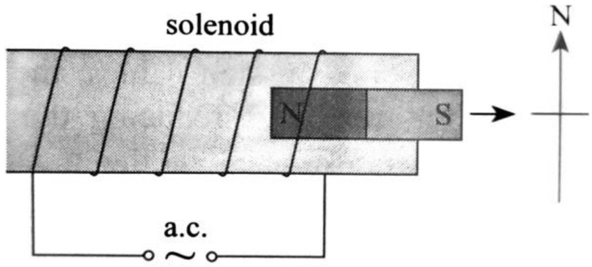
(b) The lines near Y are further apart.
State what this shows about the magnetic field at Y. [1]

weaker

(c) State what is meant by the N-pole (north pole) of a bar magnet. [1]

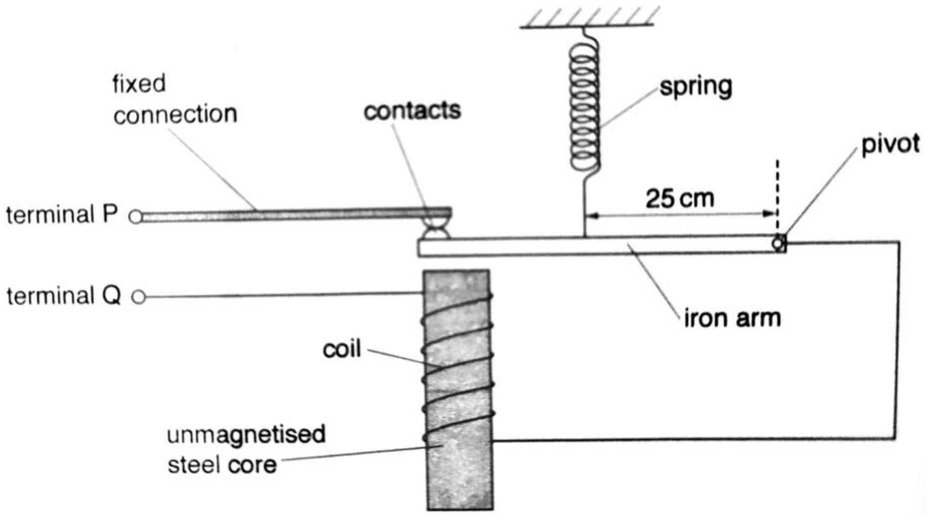
When suspended freely, the N-pole of a bar magnet is the end which points to the North pole of the Earth.

(d) Describe an electrical method to demagnetise a bar magnet.
You may include a diagram in your answer. [2]



1. Place the bar magnet in the E-W direction in the middle of a solenoid carrying an alternating current (a.c.).
2. With the a.c. flowing, withdraw the magnet out of the solenoid slowly.
3. The bar magnet will be demagnetised.

2 A student constructs a model of a circuit breaker using an unmagnetised steel core, as shown in the figure below.



(2016 P2A Q8b,c)

(a) The circuit breaker is connected in series with a circuit using terminals P and Q. A current in the circuit causes the contacts to separate. Explain why. [1]

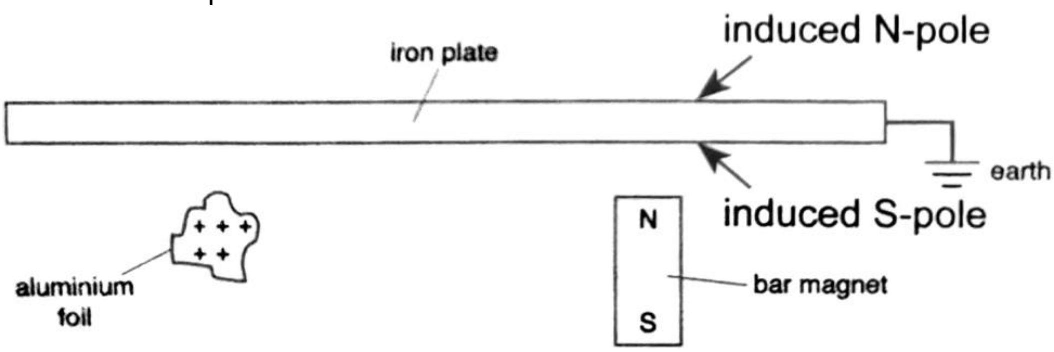
- When a larger current flows in the circuit, the steel core becomes a stronger electromagnet.

- It exerts a greater force on the iron arm, causing the contacts to separate.

(b) Circuit breakers have advantages when compared with fuses. One advantage is that they can normally be used more than once.
The student finds that his model can only be used once.
Suggest and explain **one** reason why. [2]

- The core used is steel, which is a hard magnetic material. Once magnetised, steel tends to retain its magnetism, unlike soft iron.
- As such, even if the fault in the circuit is fixed, the steel core that is still a strong magnet does not allow the iron arm to return to its original position to complete the circuit.

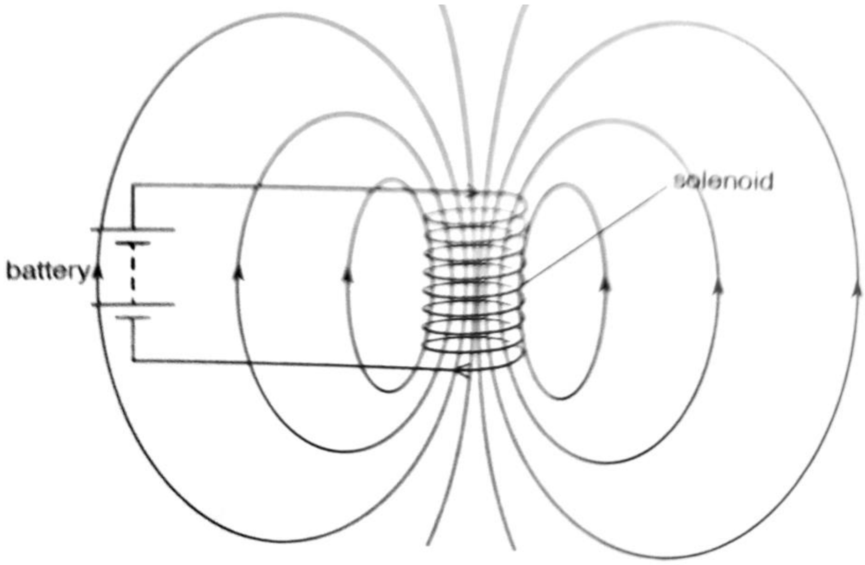
3 The figure below shows a very small piece of aluminium foil and a small bar magnet placed just beneath an earthed iron plate.



The aluminium foil has a positive electric charge.
Both the foil and the magnet are attached to the iron plate and move upwards.
Explain why the magnet is attracted to the iron plate. You may draw on the figure above. [2]
(2018 P2A Q5a)

- Due to magnetic induction, the side of the iron plate nearest to the bar magnet becomes an induced S-pole, while the side further from the bar magnet becomes an induced N-pole.
- The force of attraction between the unlike poles that are closer is stronger than the force of repulsion between the like poles, hence the bar magnet moves upwards.

4 The figure shows a battery connected to a solenoid. The arrows show the direction of the current at the top and at the bottom of the solenoid.



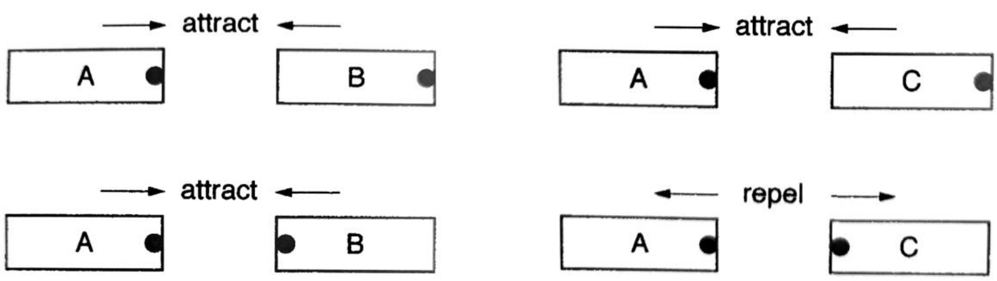
(2019 P2A Q8)

(a) On the figure above, draw the pattern of the magnetic field due to the current inside and around the solenoid. [3]

(b) State the effect on the magnetic field lines of having a larger current in the solenoid. [1]

The magnetic field lines would be closer together.

(c) Each of the three metal bars A, B and C has a dot marked on one end, as shown in the figure below.
Each bar is either a magnet with a pole at each end, or a piece of unmagnetised iron.
The forces that act between A and B and between A and C are shown by the arrows in the figure below.



(i) State whether each bar is a magnet or a piece of unmagnetised iron. [1]

A: magnet

B: unmagnetised iron

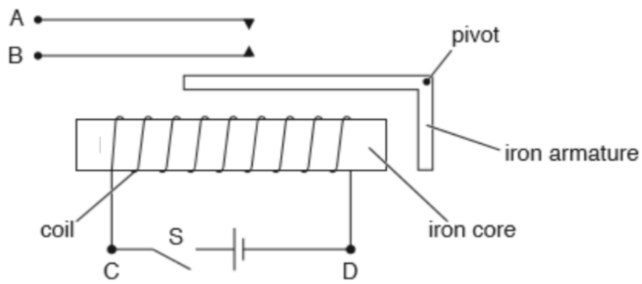
C: magnet

(ii) Explain how you decided on your answer to (c)(i). [2]

- Both ends of B are attracted to the same side A, which is only possible for induced magnetism, such that the end closer to A becomes an induced magnet with an unlike pole from the end at A.

- One end of C is repelled from A, as in the fourth case, showing that the like poles are facing each other, as like poles repel.

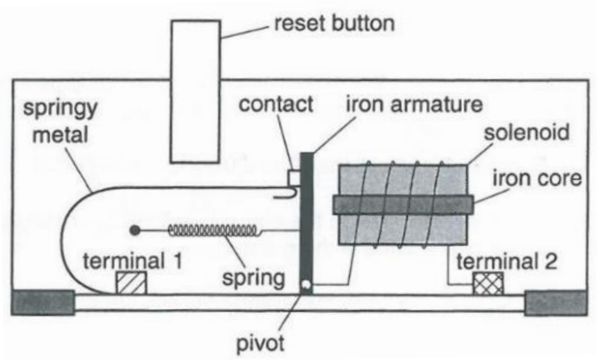
5 The figure shows a relay connected to a cell and a switch.



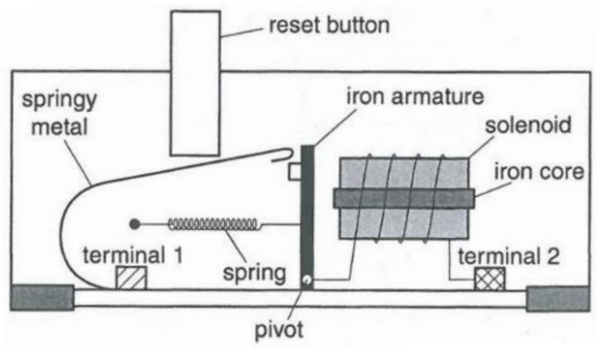
Explain how closing the switch S causes the contact AB to close.

- When the switch is closed, iron core becomes magnetised, thus armature is attracted to magnetised iron core.
- This causes armature to rotate clockwise about pivot and close contact AB.

6 A circuit breaker is a device designed to switch off the current in a circuit when the current exceeds a certain value. The figure below shows a circuit breaker with the contacts closed.



The figure below shows the circuit breaker after a large current has passed through the circuit.



Describe how the circuit breaker is able to stop the current from flowing in the circuit when a fault causes the current to become too large.

- When current in circuit becomes very large, the solenoid becomes a very strong electromagnet. This causes the iron armature to be attracted and move towards the electromagnet.

- The springy metal loses contact with the armature and touches the reset button.
- There is an open circuit between terminal 1 and 2 (no current flowing through), which can only be reset when button is pressed down.