TEMASEK JUNIOR COLLEGE

TJC IP4 PHYSICS

Topic 15: Magnetism

Content

- Laws of magnetism
- Magnetic properties of matter
- Magnetic field

Learning Outcomes

Candidates should be able to:

(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)

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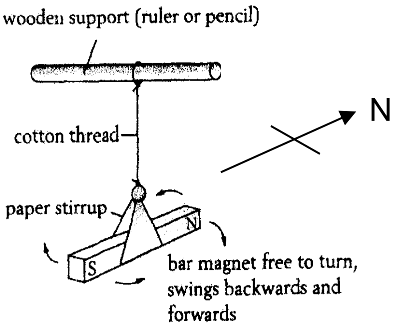
1 Introduction

We can observe that the magnets interact even when they are they are not in direct contact. In electrostatics, we used the idea of an electric field to account for the interaction between charges that were separated from one another. In the same way, we can use the idea of magnetic field to account for the magnetic interaction.
Every magnet has two poles. This is where most of its magnetic strength is most powerful. These poles are called north and south poles. The poles are called this as when a magnet is hung or suspended the magnet lines up in a north - south direction. Like poles repel each other while unlike poles attract. The attraction or repelling of two magnets depend on how close they are to each other and how strong the magnetic field of each magnet is.

1.1 Properties of Magnets *LO (a)*

All magnets have the following properties:

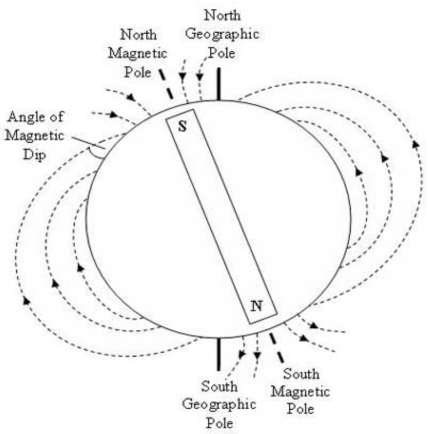
- <u>Magnetic poles</u>:
  Sprinkle iron filings onto a bar magnet and most of them attracted to the two ends of the bar magnet. These two ends are known as poles of the magnet. They are the locations where the magnetic effects are the strongest.
- <u>North and South poles</u>:
  When a bar magnet is suspended freely, it will come to rest in the North-South direction. The end of the bar magnet that points to the northern end of the Earth is called the north-seeking pole, North pole or N pole. The other end is known as the south-seeking pole, South pole or S pole.
- <u>Law of magnetism</u>: Like poles repel, unlike poles attract.
  [parallel to what has been taught in Static Electricity: Law of electrostatics]
- <u>Attracts **magnetic** materials :</u> **Co**balt,**I**ron, **N**ickel & **S**teel (Mnemonic: CoINS)



A freely suspended magnet rests along the N-S direction

1.2 The Earth's Magnetic Field

Because of Earth's magnetic field, a compass placed anywhere on Earth turns so that the "north pole" of the magnet inside the compass points roughly north, toward Earth's north magnetic pole in northern Canada. This is the traditional definition of the "north pole" of a magnet, although other equivalent definitions are also possible. One confusion that arises from this definition is that if Earth itself is considered as a magnet, the south pole of that magnet would be the one nearer the north magnetic pole, and vice-versa. (Opposite poles attract and the north pole of the compass magnet is attracted to the north magnetic pole.) The north magnetic pole is so named not because of the polarity of the field there but because of its geographical location.



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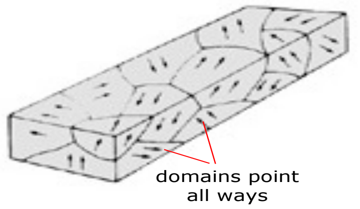
1.3 Magnetic and Non-magnetic Materials

	Magnetic materials **(with 'tiny' magnets or magnetic domains)**	Non-magnetic materials
Attraction by magnet	yes	no
Magnetism	can be magnetised, can be used to make magnets	cannot be magnetised, cannot be used to make magnets
Examples	Cobalt, Iron, Nickel & many alloys based on these metals e.g. Steel (alloy of iron and carbon) and alnico (alloy of almumium, nickel and cobalt)	wood, copper, paper, aluminium, brass and glass

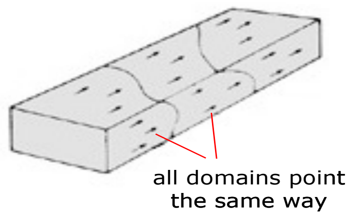
1.3.1 Magnetic Material



In an unmagnetised state, millions of atoms arrange themselves in groups (magnetic domains) each with its atomic magnets pointing in different directions. Their magnetic effects cancel out.

A group of atomic magnets pointing in the same direction is called a magnetic domain.

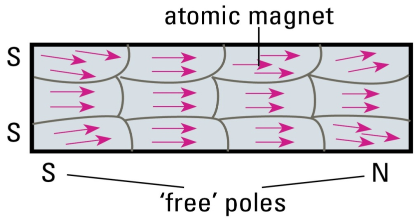
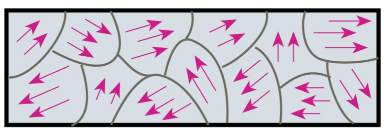
In a magnetised magnetic material, the magnetic domains are arranged so that they point in a certain direction.



Ferromagnetic materials consist of clusters of aligned atoms called magnetic domains, which behave like tiny magnets. When the material is unmagnetised, these domains are randomly oriented so that their magnetic fields cancel each other out. When the material is subject to a strong magnetic field, the magnetic domains line up and the material is said to be magnetised.

Ferromagnetic materials include such metals as steel, iron, nickel and cobalt. Examples of non-magnetic metals include copper, aluminium and lead.

Every magnet has a maximum strength. This happens when ALL the magnetic domains are pointing in the same direction. The magnet is said to be **magnetically saturated** and cannot be any stronger.

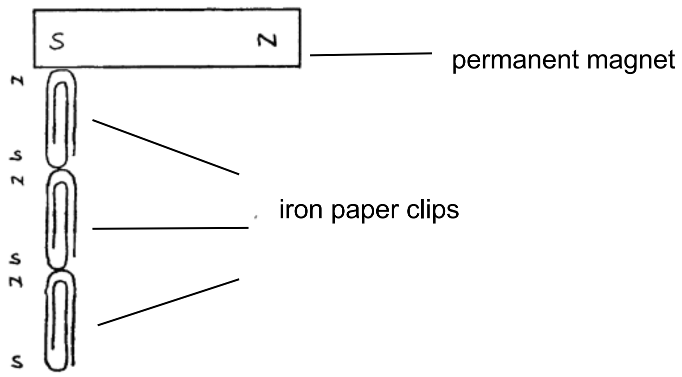
Magnetised Bar	**Unmagnetised Bar**
Magnetic domains are aligned	Magnetic domains point in random directions
Magnetic domains at the ends splay out due to the mutual repulsion between like poles	Resulting magnetic effect of all magnetic domains are cancelled out
Free poles at the end	No free pole
	 No magnetic effect

Question 1: When a bar magnet is broken into half, does each smaller piece still possess an N pole and an S pole? Does each smaller piece behave like a magnet?

How is a magnet identified?
Testing for evidence of magnetism: <u>Only repulsion</u> between a specimen and a magnet allows us to conclude that the specimen is a magnet.

Specimen	One end of specimen brought near to N pole	Other end of specimen brought near to N pole
bar magnet	repulsion	attraction
bar magnet	attraction	repulsion
soft iron rod (magnetic material)	attraction	attraction
wooden rod	stationary	stationary

2 Magnetic Induction (Induced Magnetism) ***LO (b)***
When a paper clip is attracted to a permanent magnet, we say the paper clip has become an induced magnet.



Magnetic induction is the process whereby an object of a magnetic material becomes a magnet when it is near (without contact) or in contact with a magnet.

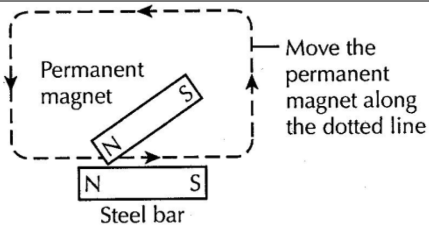
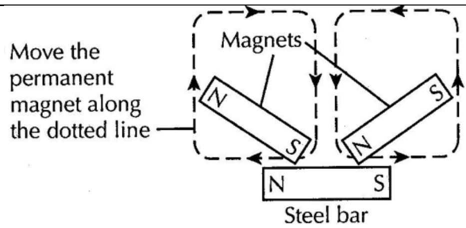
Worked Example 1: How does a magnet attract iron paper clips?
When 1 iron paper clip is brought near a permanent magnet, it is attracted to the magnet. The iron paper clip has become an induced magnet (temporary magnet). This induced magnet (iron paper clip) is able to attract other iron paper clips.

The S pole of the permanent magnet <u>induces</u> an N pole in the top end of the iron paper clip nearer to the magnet, while the further end of the iron paper clip becomes an <u>induced</u> S pole. Since opposite poles attract, the S pole of the permanent magnet attracts the induced N pole of the iron paper clip; and like poles repel, the S pole of permanent magnet repels the induced S pole of the iron paper clip. Since the magnetic strength/ force decreases with increase in distance, there is a net attractive force acting on the iron paper clip towards the magnet. Thus, the iron paper clip is <u>attracted upwards</u> to the permanent magnet.

Induction always precedes attraction

3 Magnetisation **LO (c)**

3.1 Stroking method of Magnetisation

<table>
<tr><th>Single Touch</th><th>Divided touch</th></tr>
<tr><td colspan="2">• Stroke continuously in the same direction.
• Polarity of each end of the induced magnet is opposite to the pole which leaves the end.</td></tr>
<tr><td>
</td><td>
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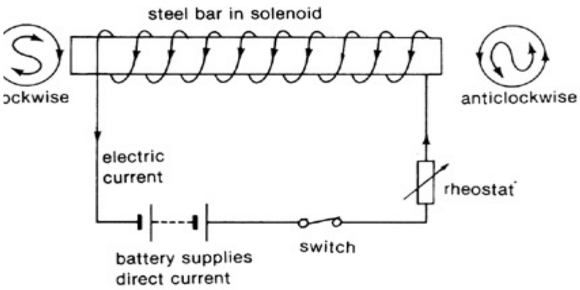
3.2 Electrical Method of Magnetisation

<u>Magnetisation using direct current:</u>

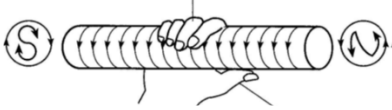
- A direct current passes through the solenoid produces a strong magnetic field (magnetic effect of a current, Topic 16).
- Place a steel bar inside the solenoid and it will be magnetized.
- Consider using the *<u>Right-hand grip rule</u>* to identify the polarity



3 ways for increasing magnetic field strength:

- **increase current (increase the emf of battery/ decrease the resistance of rheostat);**
- **increase the no. of turns (per unit length) of coil/solenoid**
- Use a soft-iron core (which concentrates magnetic field lines)

Curl fingers in the same direction as current



Thumb point to the North pole

4 Demagnetisation *LO (c)*

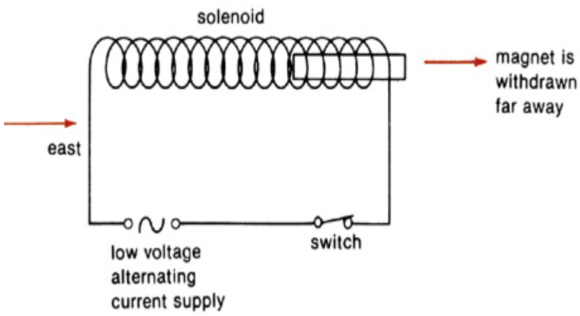
4.1 Demagnetisation by heating and hammering (Refer to Physics Matters)

4.2 Electrical Method of Demagnetisation

Demagnetisation is a process of removing magnetism from a magnet.

Demagnetisation using alternating current:

- Place a magnet inside a solenoid connected to an alternating current (a.c.) supply.
- Magnet is slowly withdrawn in the East-West direction far away from the solenoid while the alternating current is still flowing.
- The strong magnetic field produced in the solenoid by a.c., changes its direction many times a second.



Question 2 : Explain why the magnet will be demagnetised.
Hint: Explain what happens to the 'tiny magnets' or magnetic domains

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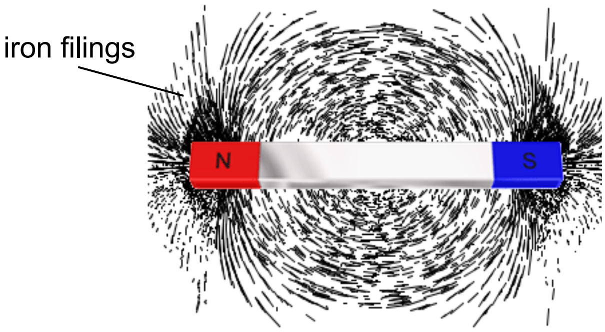
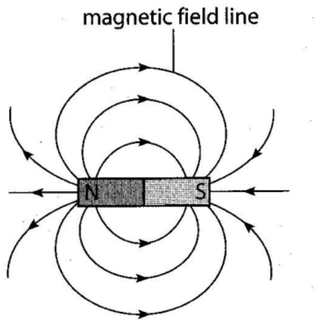
5 Magnetic Fields *LO (d), (e)*

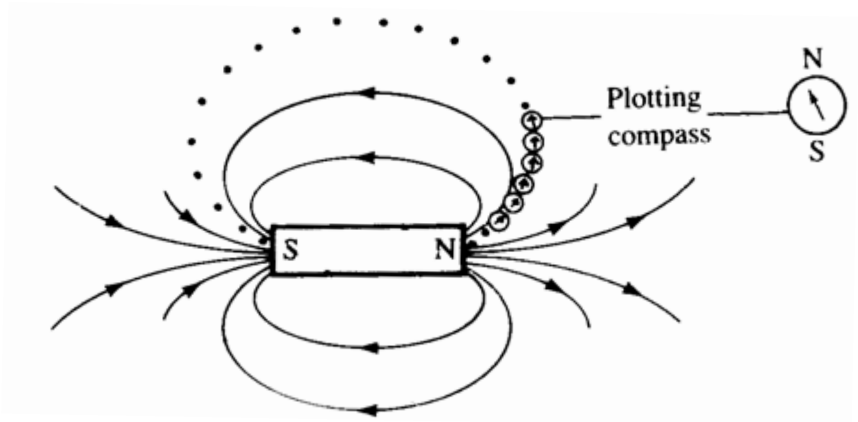
A **magnetic field** is a region in which a magnetic object, placed within the influence of the field, experiences a magnetic force. The magnetic field at any given point is specified by both a direction and a magnitude (or strength); as such it is a vector field.

Magnetic field patterns can be revealed by sprinkling iron-filings around a bar magnet that is placed on a piece of paper.

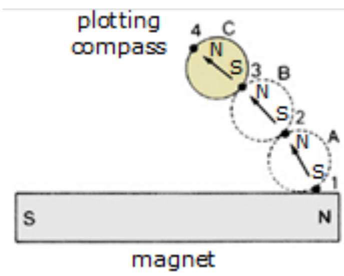




To find **direction of the magnetic field lines**, use a small plotting compass: Magnetic fields can be detected by the force they exert on small plotting compass.



Question 3:
Describe how to plot magnetic field lines with a plotting compass
Hint: Refer to Physics Matters
Write the procedure here



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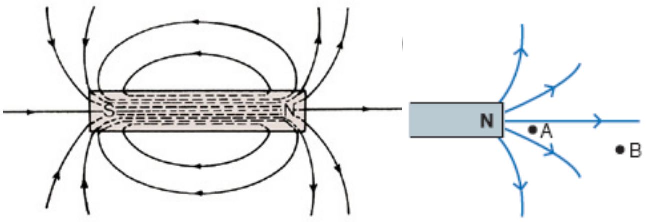
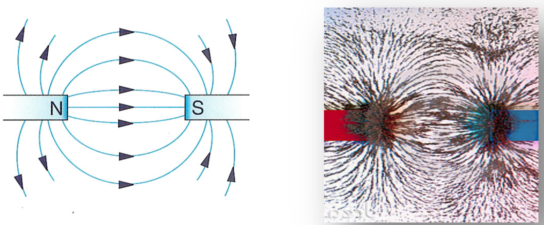
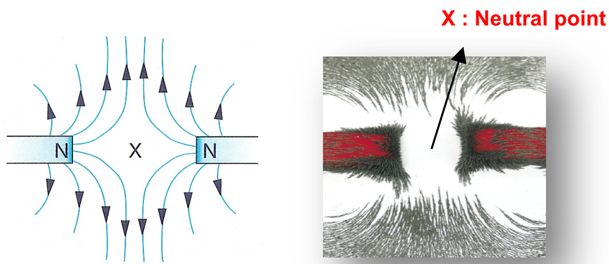
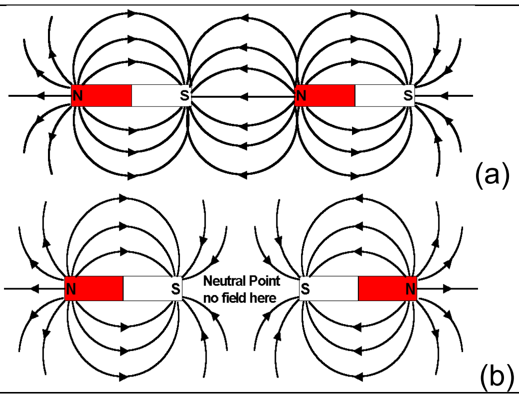
5.1 Properties of magnetic lines of force in all magnetic fields: *[compare with Electric fields]*

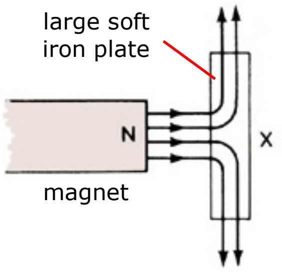
- Direction of field lines: Outside the magnet, the lines start from N pole and end at S pole. Within the magnet, lines continue from S pole to the N pole
- Field lines do not intersect/cross one another.
- The density of fields lines drawn indicate the strength of the magnetic field. Field lines are closer to each other in a stronger magnetic field
- pay attention to symmetry of field pattern

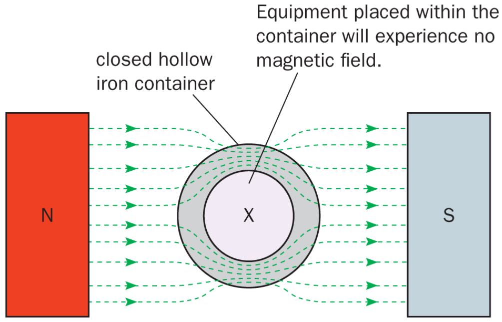
****The direction of the tangent to a magnetic field line at a point is the direction of the magnetic field and the direction in which a plotting compass needle would point.**

Magnetic field lines of a bar magnet (Non-uniform field)	**Uniform magnetic field is represented by straight parallel lines of force**
 The magnetic field is stronger at A than at B	
(a) Magnetic field pattern & lines between two opposite poles of two equally strong bar magnets (S-N poles)	**(b) similar poles of two equally strong bar magnets (S-S poles or N-N poles)**
By iron-filings:to see the magnetic field pattern  *Could this be the magnetic field pattern formed for a piece of bar magnet?*	By iron-filings:to see the magnetic field pattern 
	By plotting compass: to see the magnetic field lines (a) Magnetic field lines between two opposite poles of two bar magnets (b) Magnetic field lines between similar poles of two bar magnets (N-N poles). The point where there is no net magnetic effect is called the neutral point. There are no magnetic field lines at X.

5.2 Magnetic Shielding

Magnetic shielding prevents surrounding magnetic fields from reaching sensitive areas of a piece of equipment whose operation may be affected by the fields. Magnetic field lines tend to pass through a magnetic substance (e.g. iron) rather than through non-magnetic substances like the air, paper, aluminium. These magnetic substances work by diverting the magnetic fields.

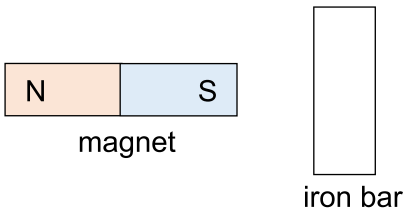




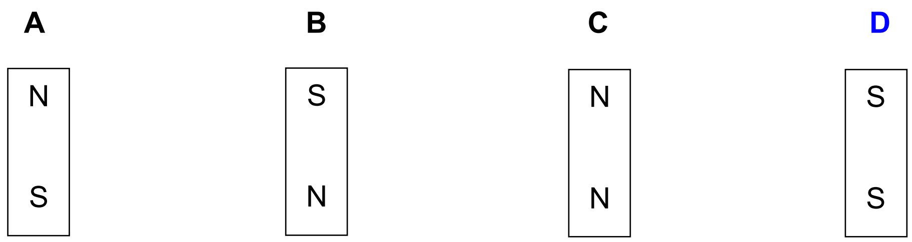
X: neutral points (regions where there is no magnetic field; shielded from magnetic field)

Worked Example 2:

An iron bar is placed near a magnet as shown below.



(a) Which diagram correctly shows the induced magnetism in the iron bar?



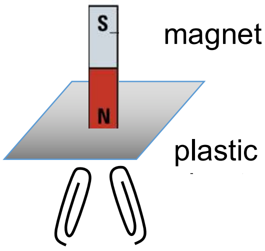
The magnetic field lines enter the iron bar from both ends and exit into the S-pole of the permanent magnet at the left side of the middle of the bar.

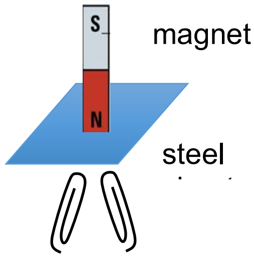
(b) Explain whether an iron paper clip placed on the right side of iron bar will be attracted to the iron bar.

By drawing magnetic field lines, the magnetic field lines of the magnet will travel through the length of the iron bar (magnetic object) and there will be no magnetic field lines exiting on the right hand side of the iron bar. That is, an iron paper clip placed on the right hand side of the iron bar will not be attracted to the iron bar. As such, iron paper clip has been shielded from the magnetism of the magnet.

Question 4:

In an experiment to test the properties of a bar magnet, 2 different objects are held between one pole of a magnet and two iron paper clips. **Predict**, **observe** and then **explain (POE)** whether the iron paper clips will be attracted to the objects.





(a) a plastic clip board	(b) a steel sheet (e.g, stainless steel bookend)
Prediction: attract / not attract	**P**rediction: attract / not attract
Observation: attract / not attract	**O**bservation: attract / not attract
Explanation:	**E**xplanation:

6 Properties & Uses of Temporary Magnets and Permanent Magnets ***LO (f)***

	Temporary magnet (e.g. Iron)	**Permanent magnet (e.g. Steel)**
Properties	Soft magnetic material • easier to magnetise • easier to demagnetize, loses its magnetism easily when removed from a magnetic field	Hard magnetic material • difficult to magnetise • difficult to demagnetize, retains its magnetism for a long time
Uses **(For more details, refer to Physics Matters)**	Magnetic effects required only for specific intervals of time: • electromagnets	• plotting compasses • magnetic door catches/ fridge door • loudspeakers* • electric moving-coil meters* (eg. ammeter) • motors*/ generators^ • hard disk • Maglev trains

**KIV; application of electromagnetism in Topic 16*
^ KIV; application of electromagnetic induction in Topic 17