Laws of magnetism

Magnetic properties of matter

Electromagnetism

MAGNETISM AND ELECTROMAGNETISM

State the properties of magnets.

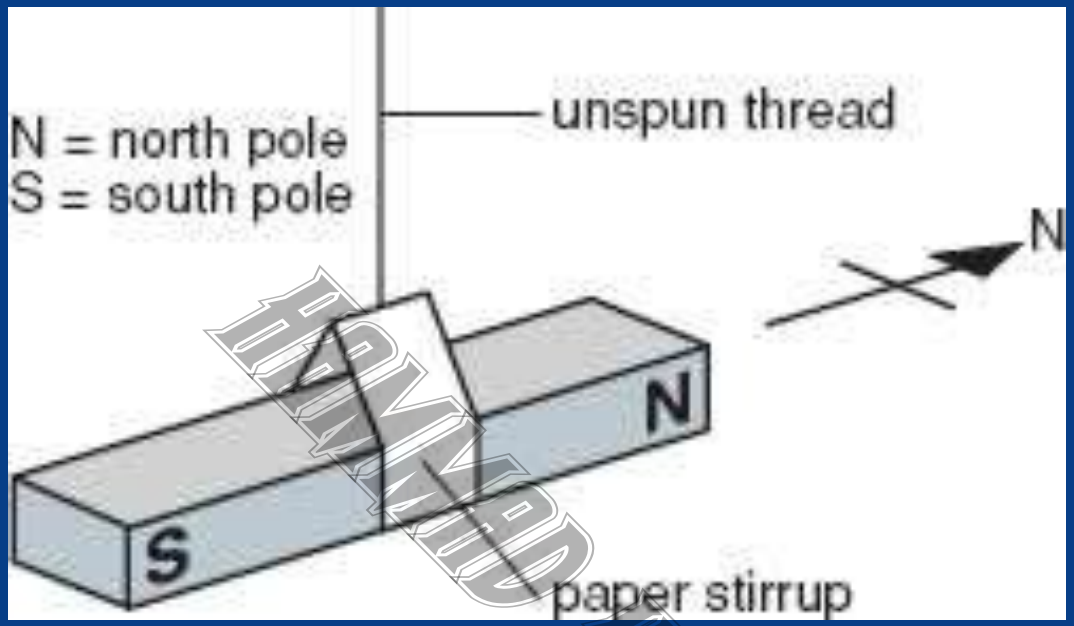
Laws of Magnetism

Magnetism

- The ancient Chinese discovered the magnetic property possessed by a certain type of natural iron ore called magnetite or lodestone in 2000 BC.
- When suspend freely, this magnetic ore always points in a north-south direction.
- The Chinese used this property to make a simple form of compass for navigational purposes.

Properties of Magnet

- A magnets;
  - Has a magnetic field around it
  - Has two opposite poles which exert forces on other magnet
  - Will attract magnetic materials by inducing magnetism in them.
  - Will exert little or no force on a non-magnetic material.



- When a bar magnet is suspended freely in a paper stirrup, it always comes to rest in a north-south direction.
- Its two points will always point in their respective fixed position, i.e. north pole pointed to the north and south pole pointed to the south.

Force Between Magnets

- If two magnets are brought close together, they exert forces on each other.
- If the north (N pole) of a bar magnet is brought near the N pole of another suspended magnet, the suspended magnet moves away.
- Repulsion also occurs when two south poles (S poles) are brought near each other.
- If the N pole is brought near a S pole, they are attracted to each other.

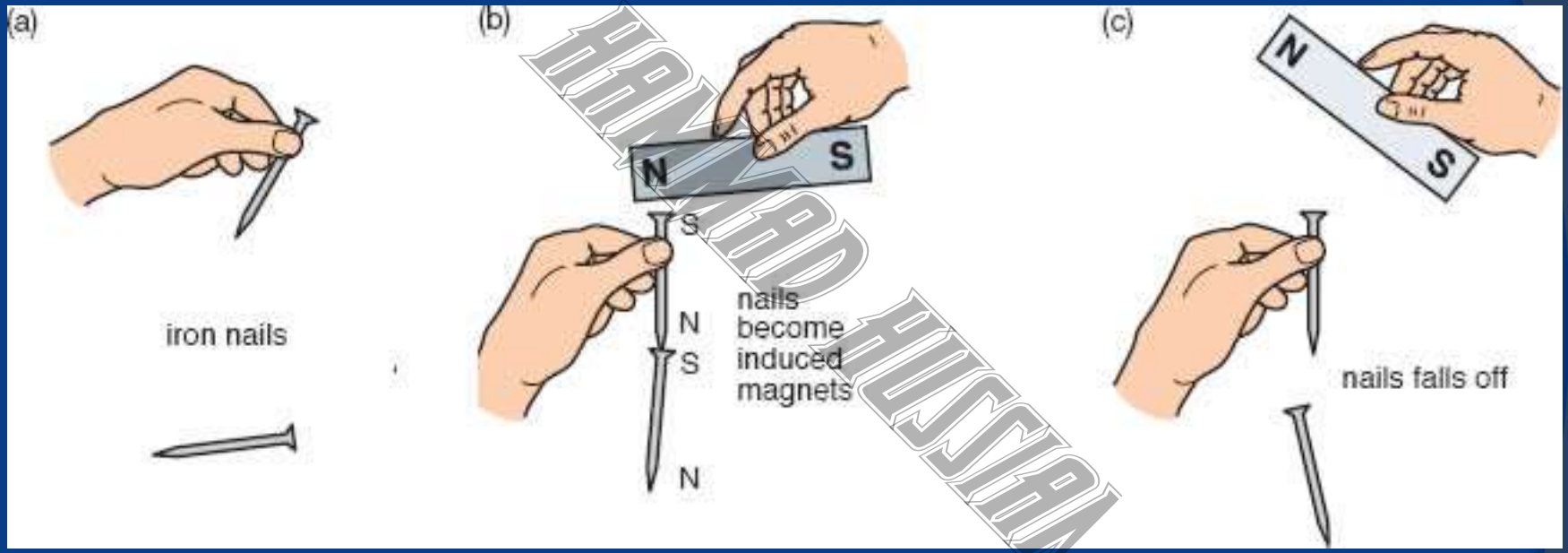
Law of Magnetism

- Hence we can summarised the laws of magnetism:
  - Like poles repel each other.
  - Unlike poles attract each other.

Describe induced magnetism.

Laws of Magnetism

Induced Magnetism



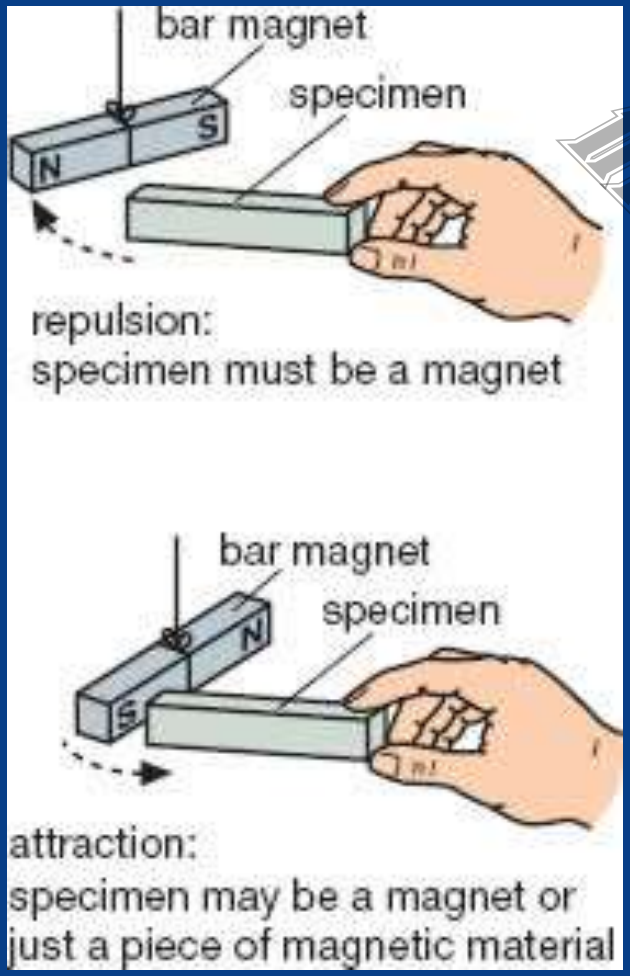
- Induced Magnetism is the magnetism of an object as a result of an external influence.

- When a magnet is brought near an iron rod, the rod becomes an induced magnet with one end nearer the magnet having opposite polarity to that of the magnet.
- Thus induction always precedes attraction.

State the differences between magnetic, non-magnetic and magnetised materials.

Laws of Magnetism

Testing for Evidence of Magnetism



- Only repulsion between a specimen and a magnet allows us to conclude that the specimen is a magnet.
- Attraction between a specimen and a magnet only suggests that the specimen may be a magnetic material or a magnet.

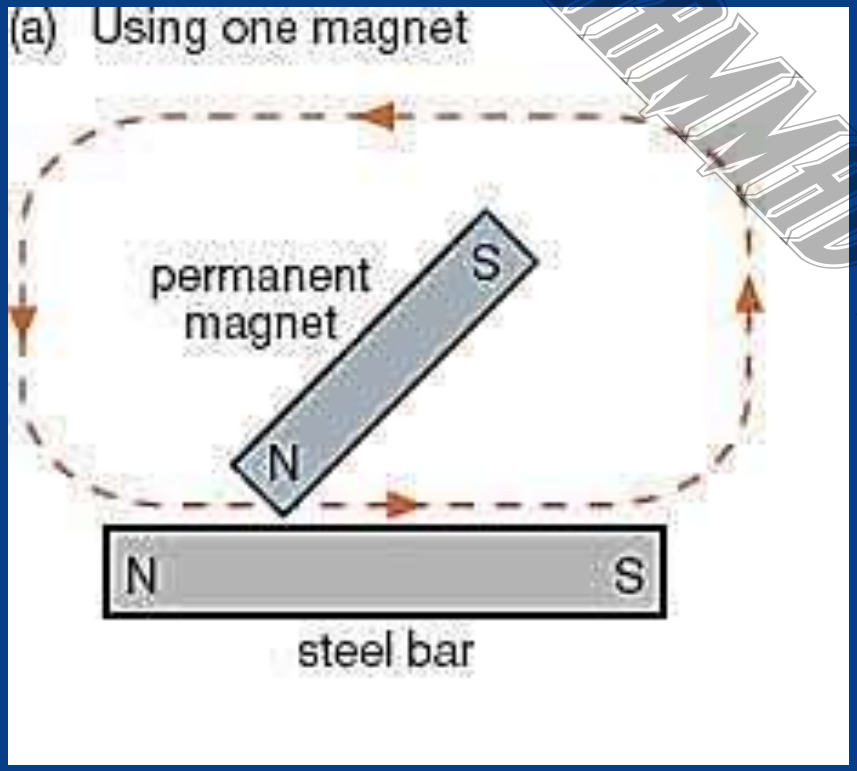
Specimen	One end of specimen brought near the N pole	The other end of specimen brought near to N pole
Bar magnet	N pole is repelled (or S pole is attracted)	S pole is attracted (or N pole is repelled)
Soft iron rod (magnetic material)	N pole is attracted	N pole is attracted
Wooden rod (non-magnetic material)	N pole remains stationary	N pole remains stationary

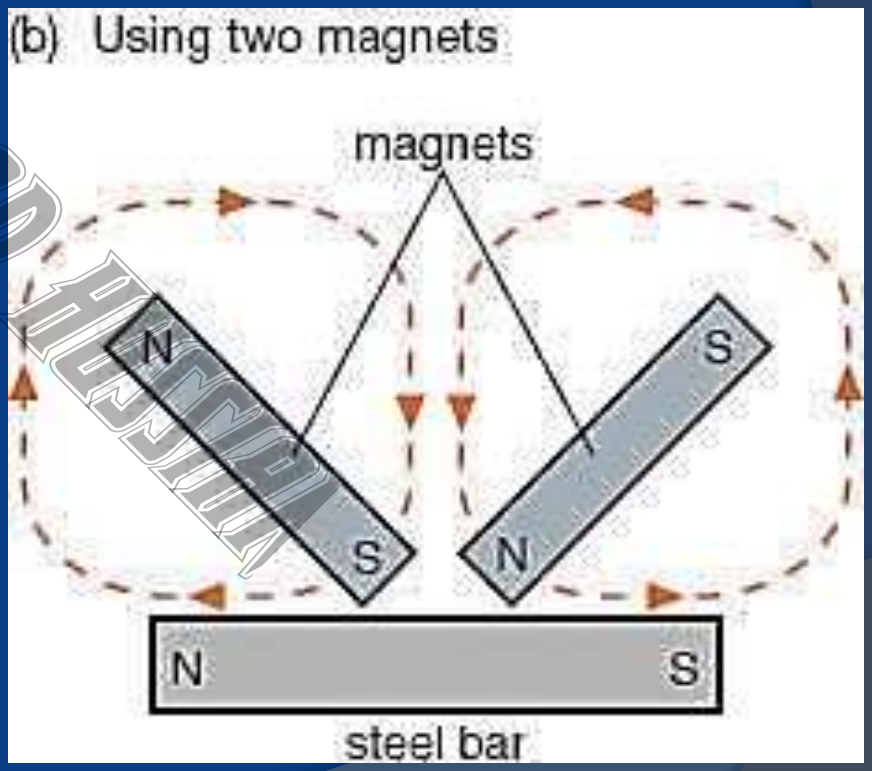
Describe electrical methods of magnetisation and demagnetisation.

Laws of Magnetism

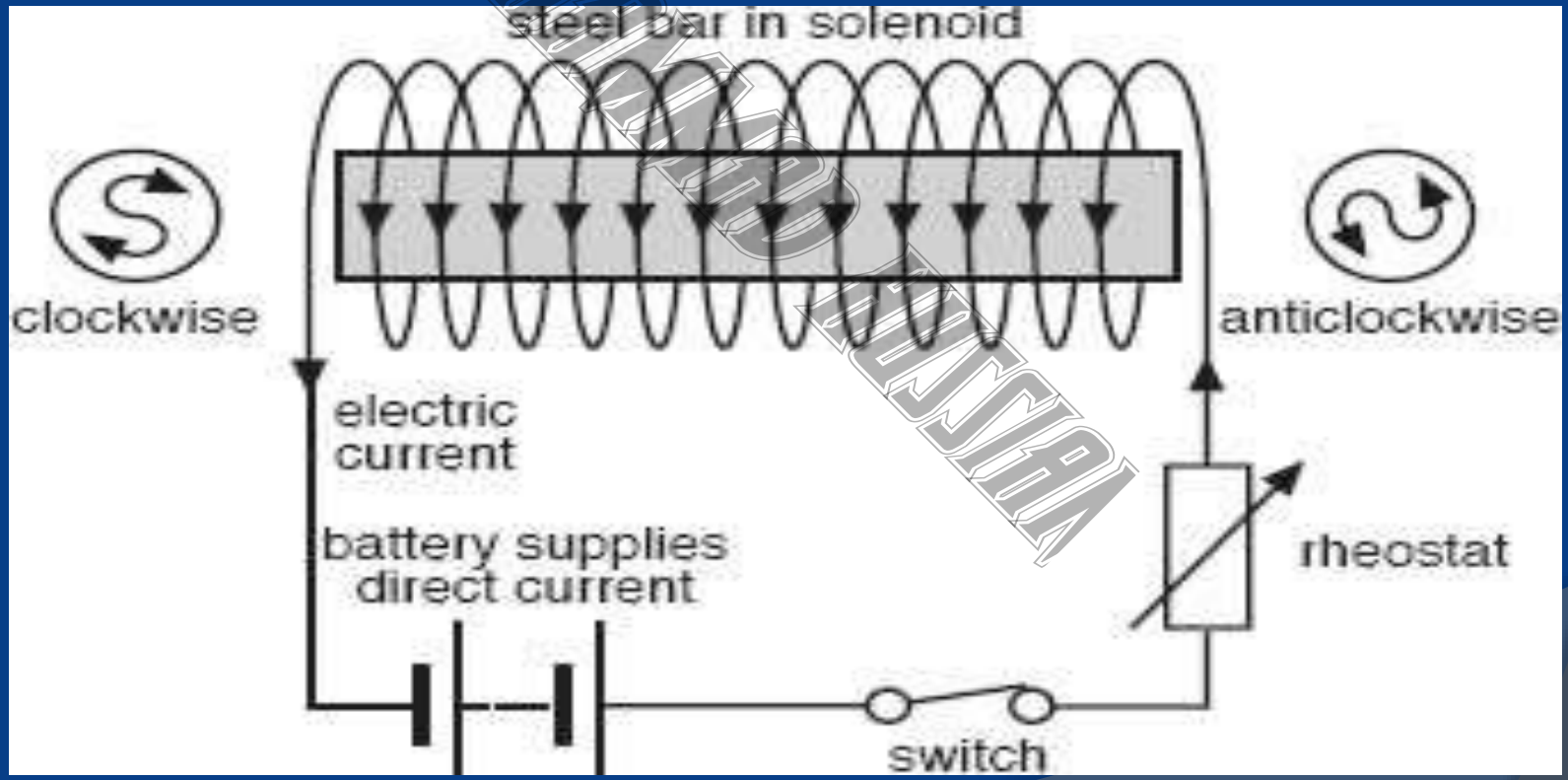
Magnetisation and Demagnetisation

- Magnetisation by Stroking

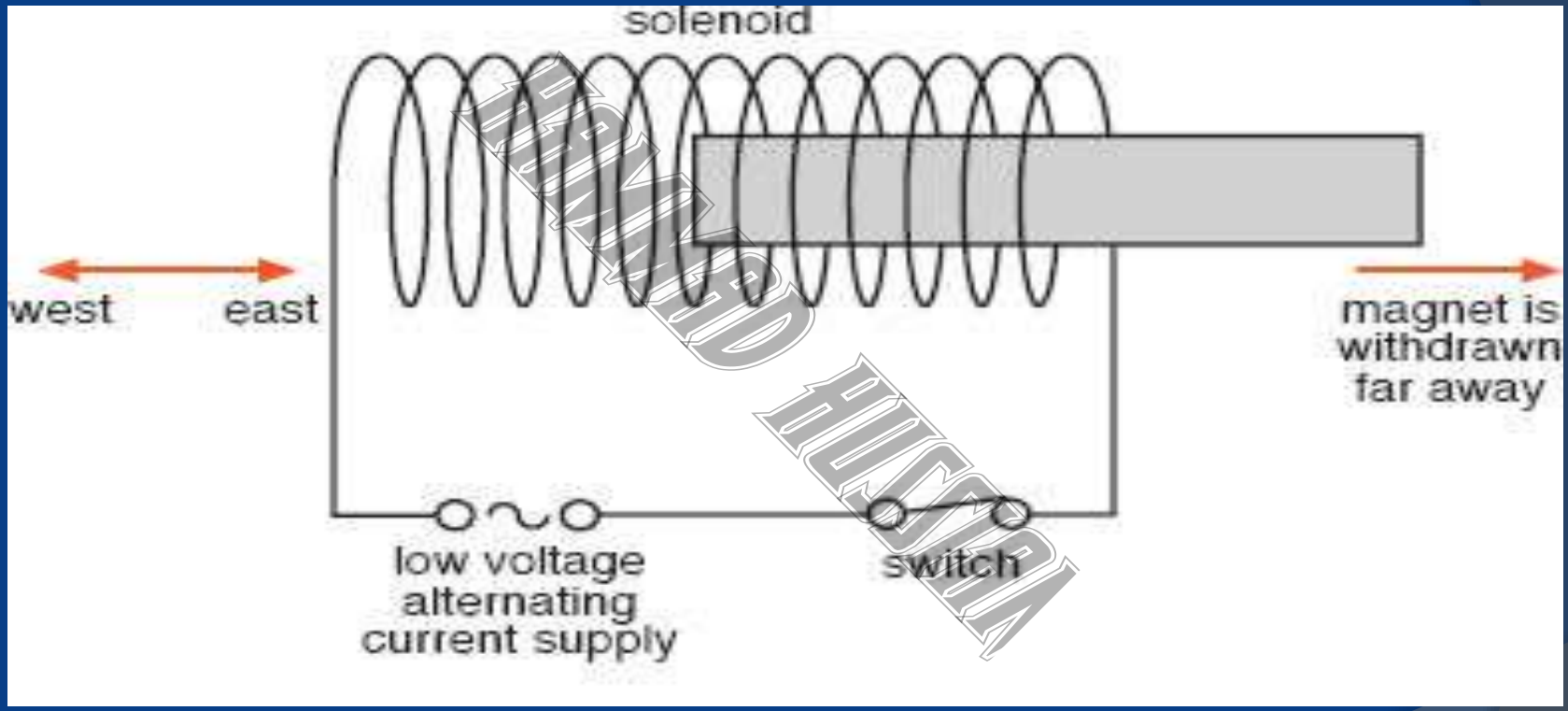




- Magnetisation Using Direct Current



- Demagnetisation Using Alternating Current



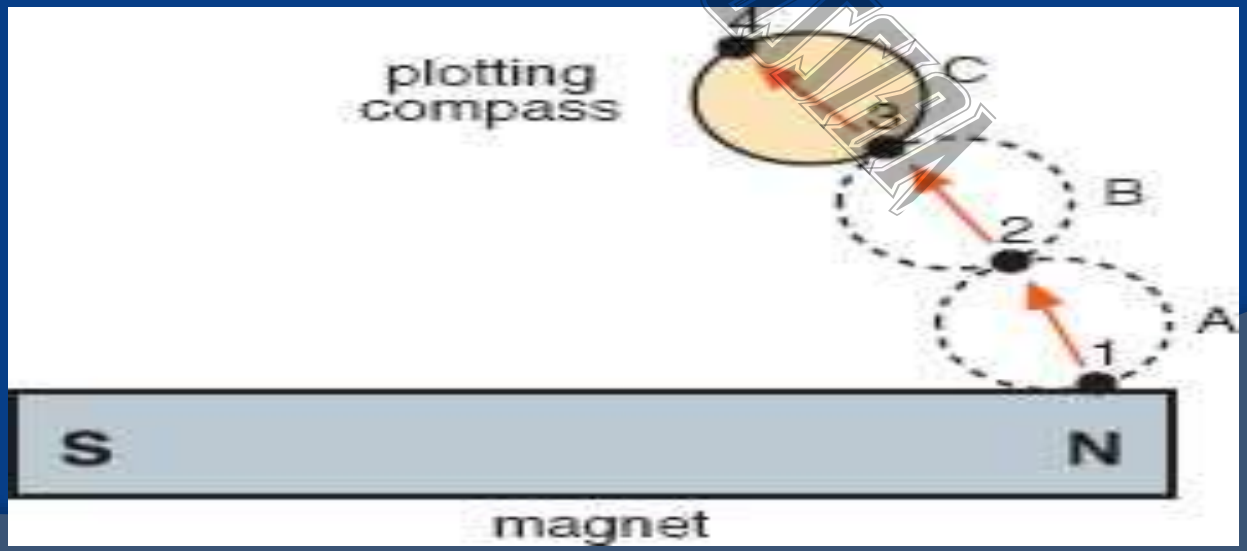
- Demagnetisation by Heating and Hammering

Describe the plotting of magnetic field lines with a compass.

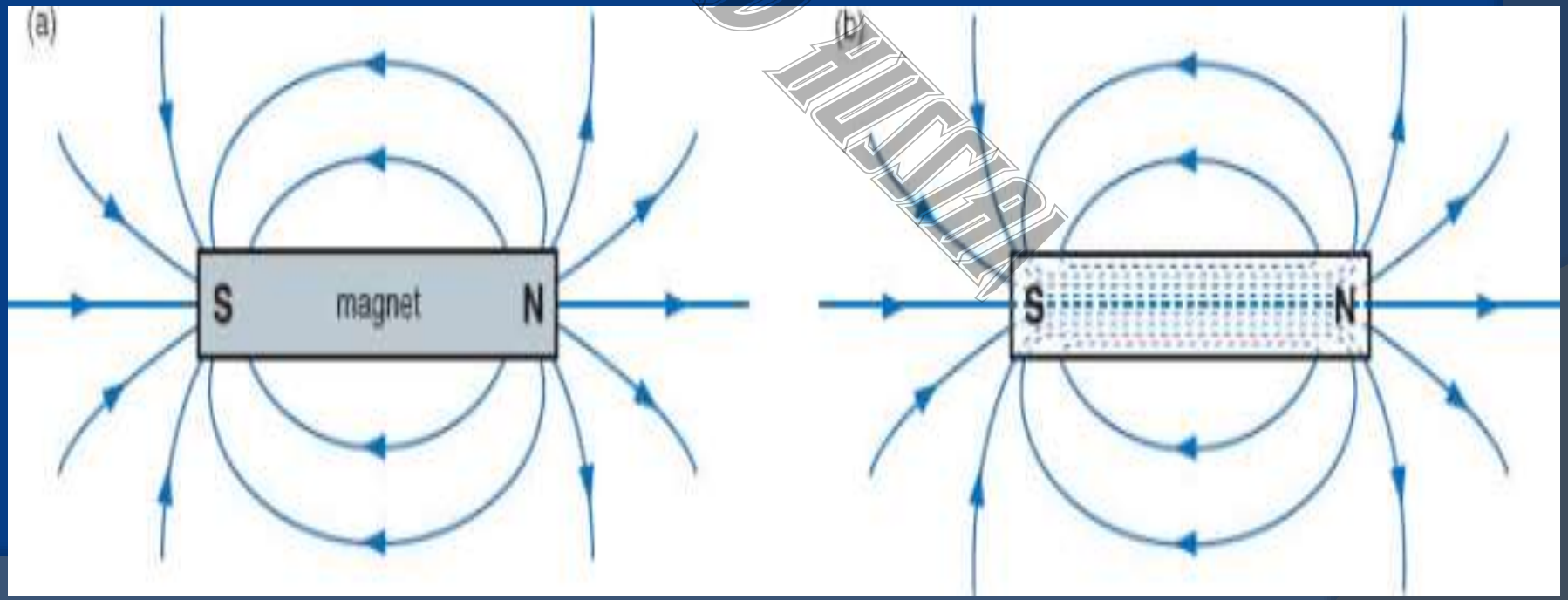
Laws of Magnetism

Magnetic Fields

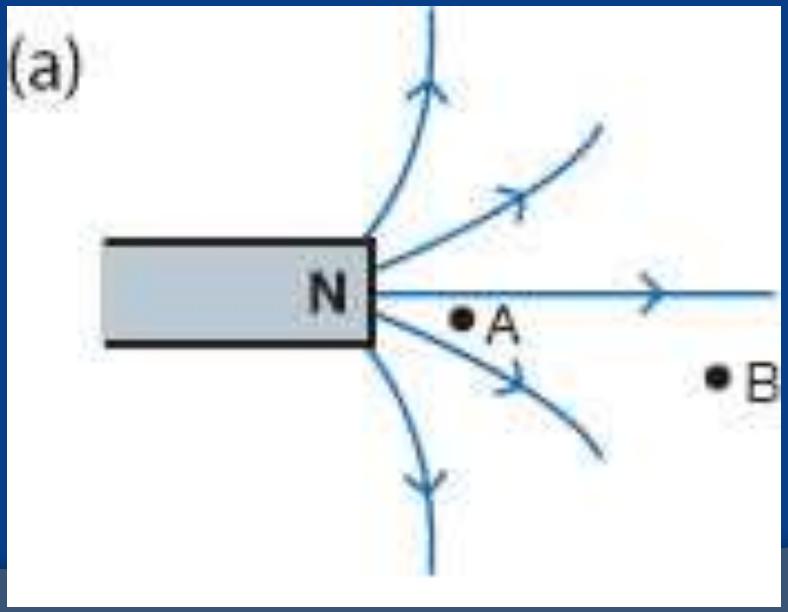
- The region around a magnet which magnetic effect can be detected is called a magnetic field.
- The pattern of a magnetic field can be plotted using a compass.

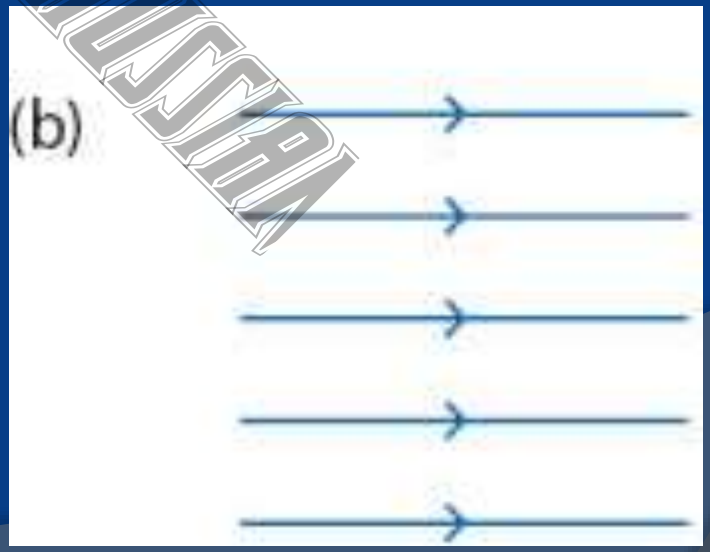


- All magnetic lines of forces show the following properties;
  - Outside the magnet, the lines start from the N pole and end at the S pole. Within the magnet, the lines continue from the S pole to the N pole. The magnetic lines are actually closed loops.



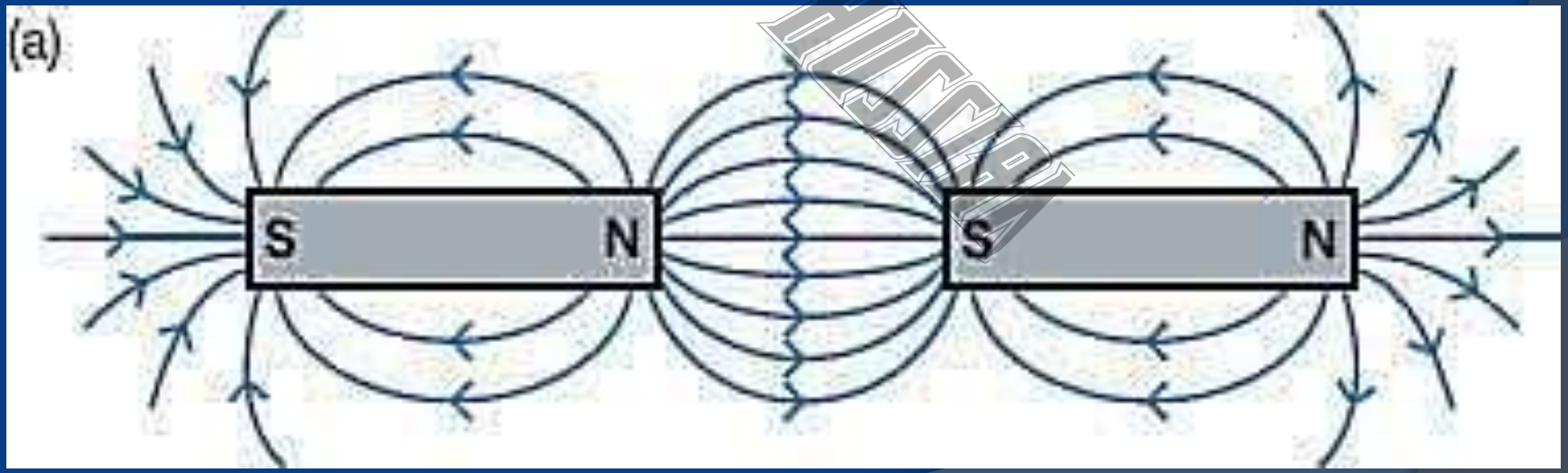
- The lines can never cross each other.
- The lines a closer to each other in a stronger magnetic field. A uniform magnetic field is represented by straight parallel lines of force.

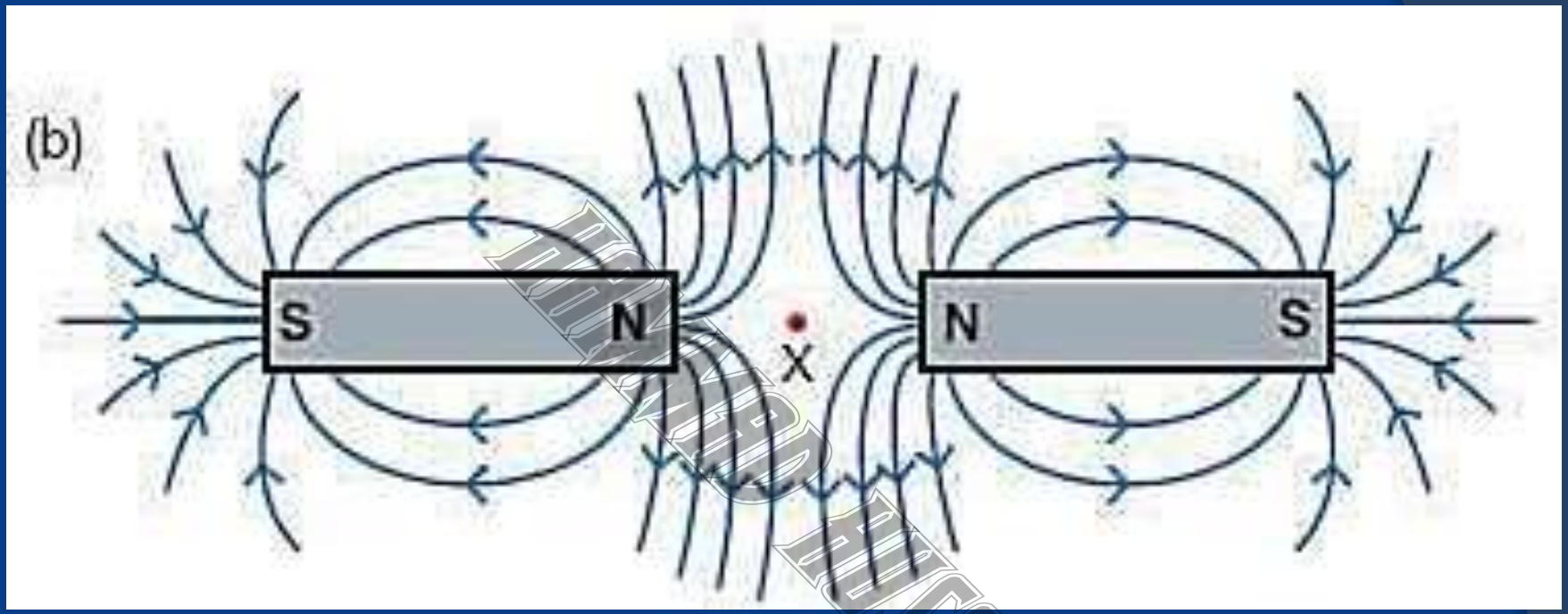




More Magnetic Field Patterns

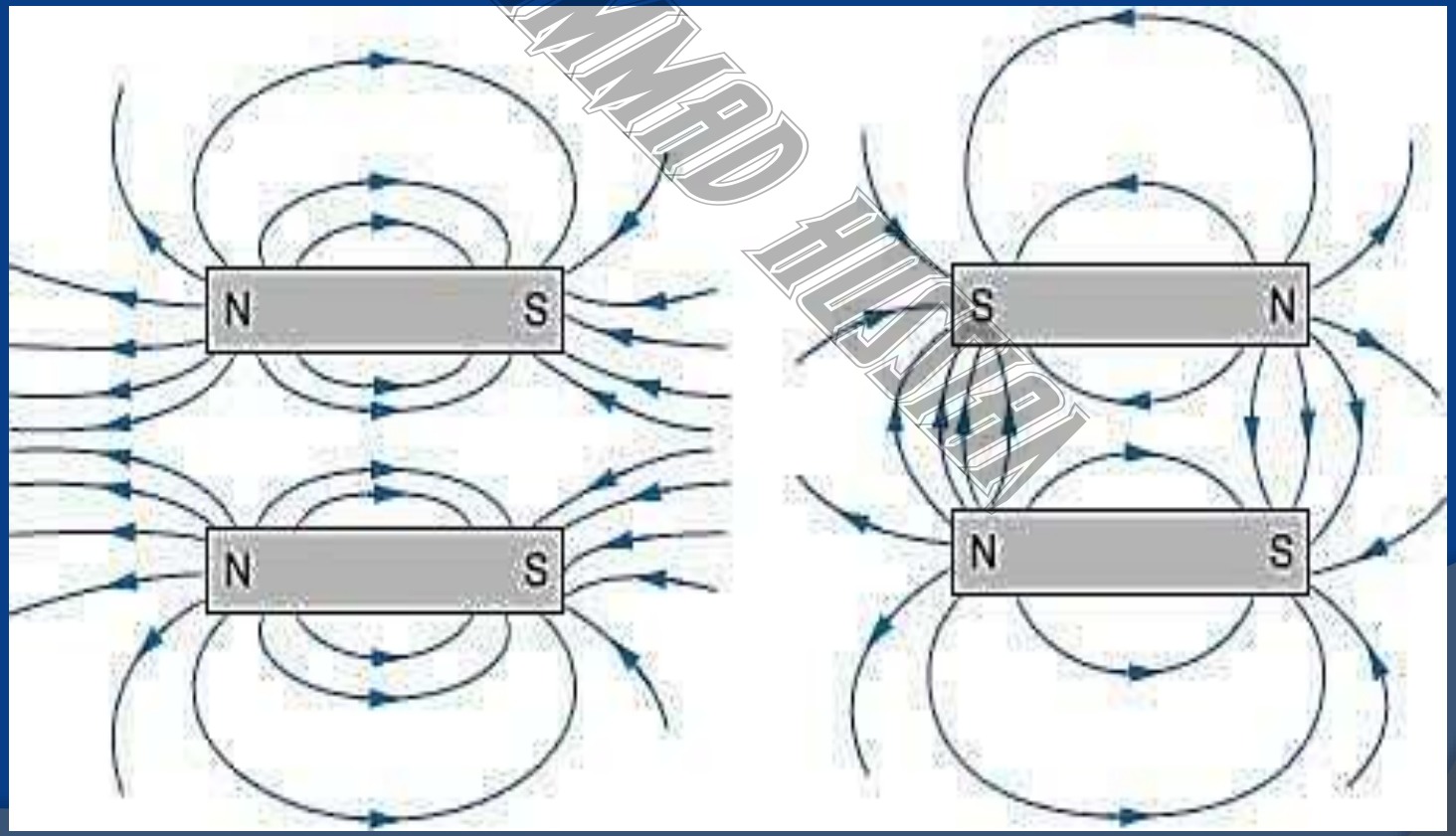
- If two magnets are placed close to each other, the field produced is the result of the combined effect of both of the magnets.





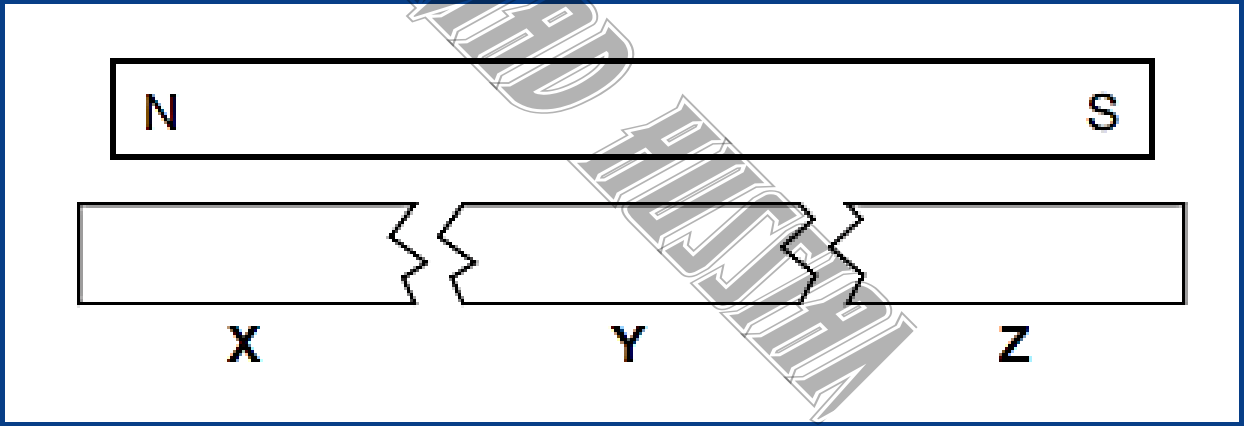
- The point in a combined magnetic field where there is no magnetic effect is called a **neutral point**.
- A compass needle placed at this point will not point to a specific direction.

- Magnetic field patterns between parallel bar magnets.

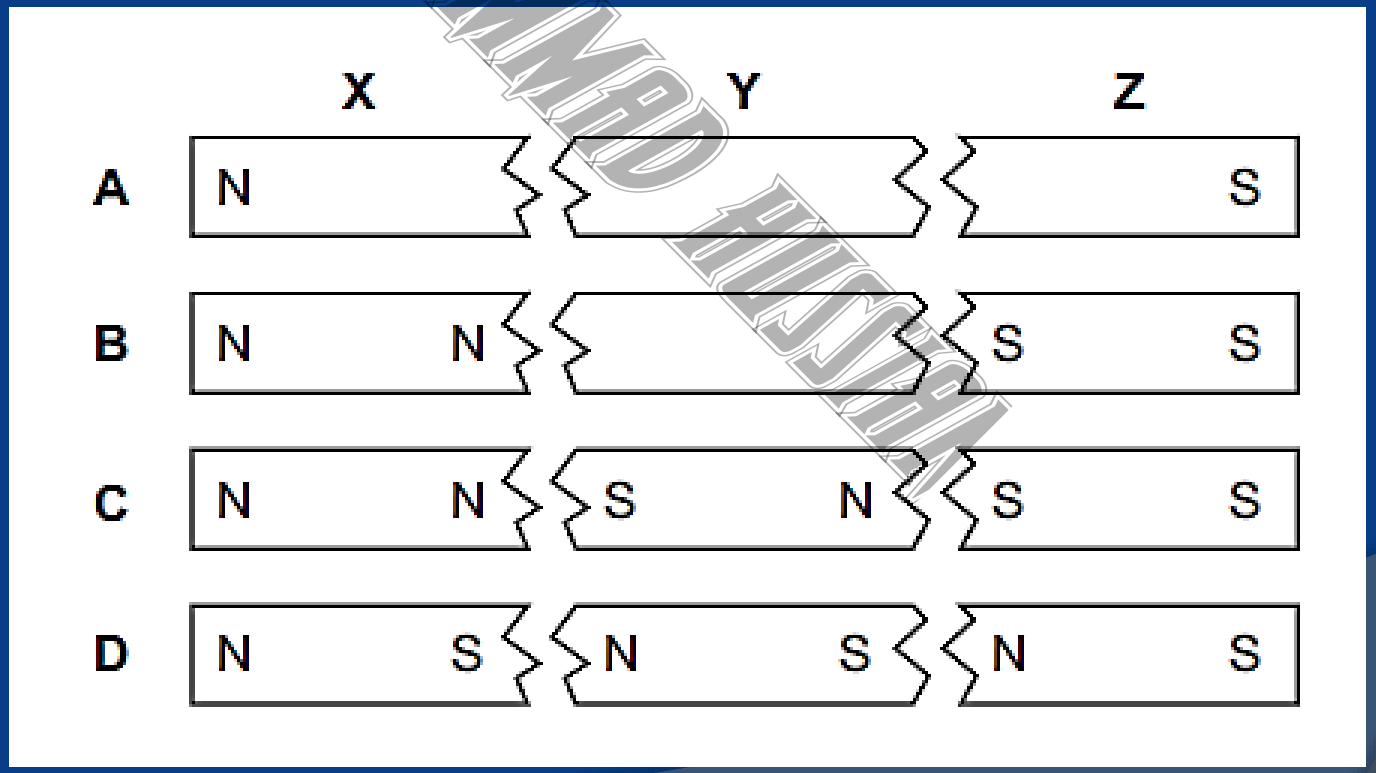


1. Which statement about a magnet is not correct?
   A. It can attract another magnet.
   B. It can attract an unmagnetised piece of iron.
   C. It can repel another magnet.
   D. It can repel an unmagnetised piece of iron.

2. A bar magnet is broken into three parts X, Y and Z.



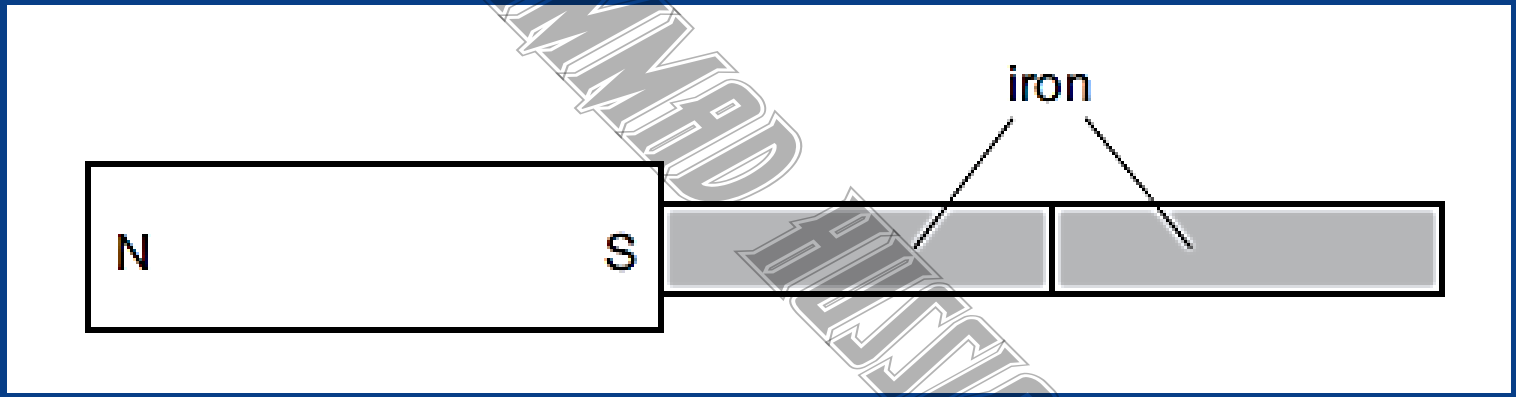
Which diagram shows the poles in X, Y and Z?



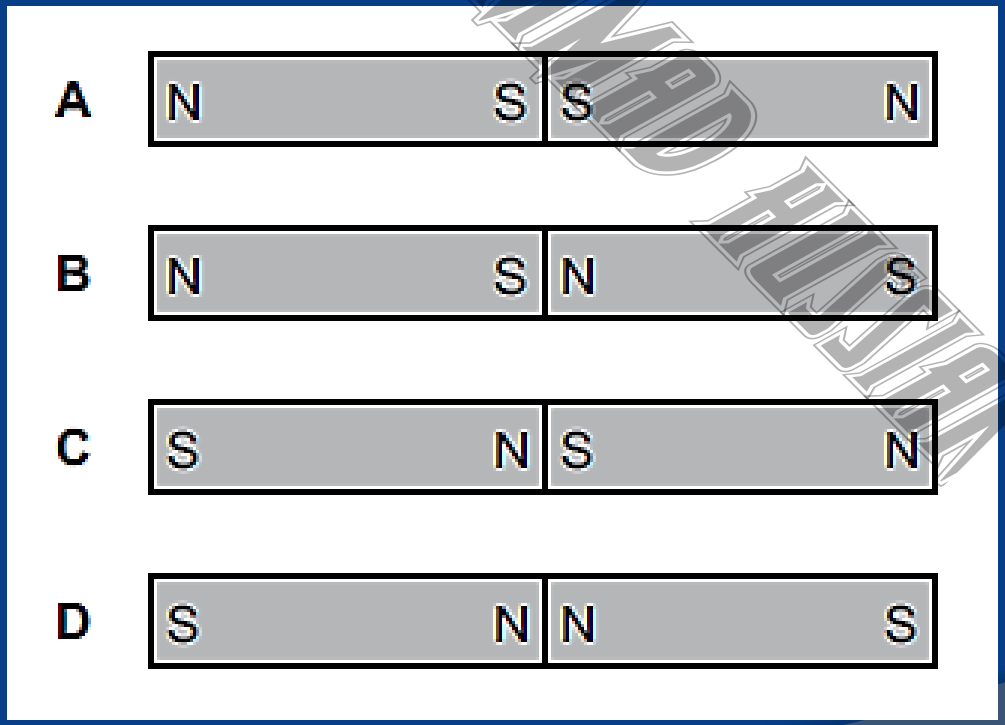
D

3. Which of the following is an example of induced magnetism?
   A. a compass needle pointing north
   B. a north pole attracting iron filings
   C. a north pole repelling a north pole
   D. the coil of a motor turning in a magnetic field

4. A magnet attracts two pieces of iron.

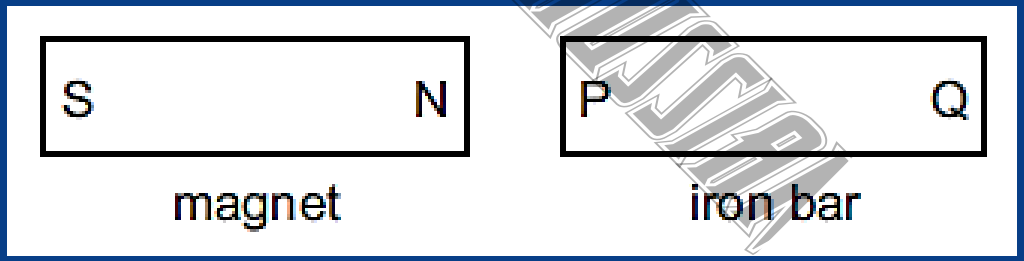


What is the arrangement of the induced poles in the pieces of iron?



B

5. The north pole of a bar magnet is placed next to end P of an iron bar PQ, as shown. As a result, magnetic poles are induced in the iron bar.

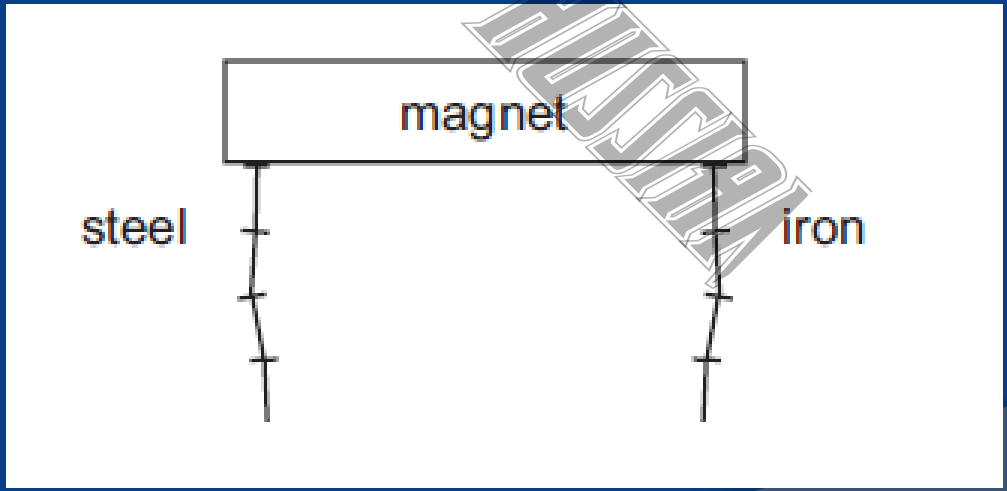


What are the magnetic poles induced at P and at Q?

	magnetic pole at P	magnetic pole at Q
A	north	north
B	north	south
C	south	north
D	south	south

C

6. A chain of steel nails and a chain of iron nails hang from a strong magnet. The chains are then carefully removed from the magnet.

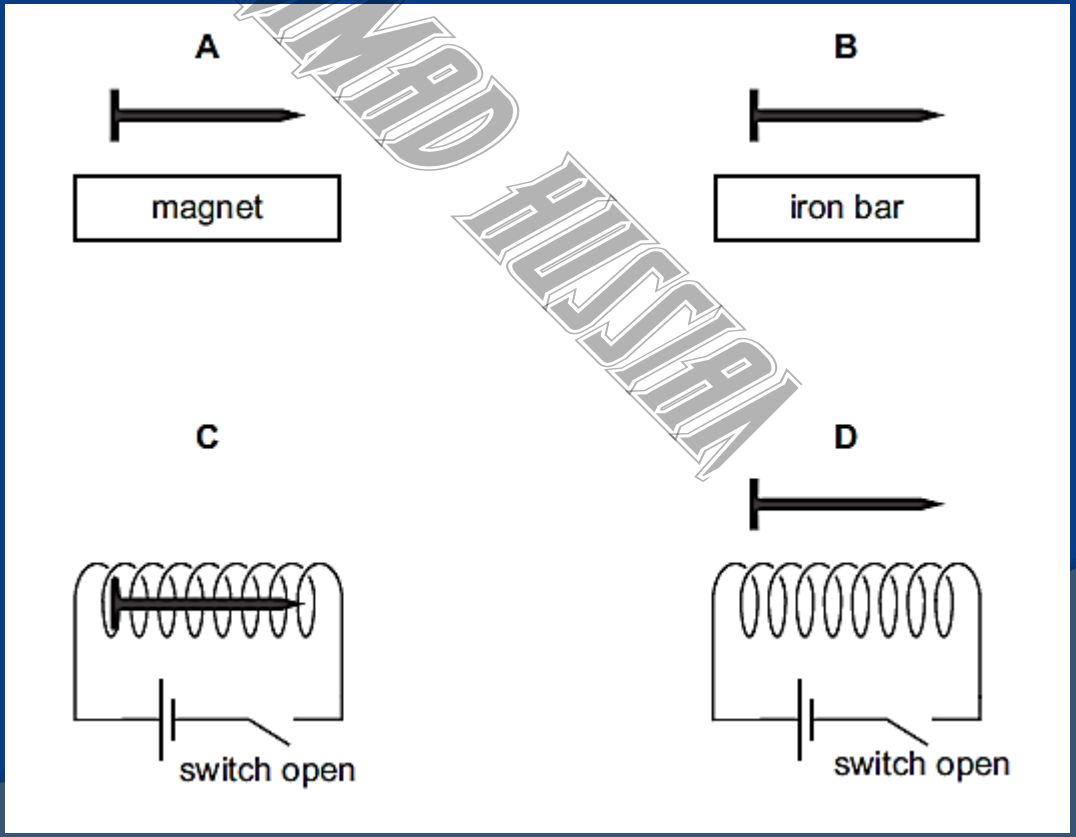


What happens to the chains?

A. Both chains fall apart.
B. Both chains stay together.
C. Only the chain of iron nails falls apart.
D. Only the chain of steel nails falls apart.

7. The diagrams show an iron nail in four different situations.

   In which diagram will the nail become an induced magnet?



A

8. End X of a metal rod attracts the N-pole of a compass needle.

   What does this show about the rod?

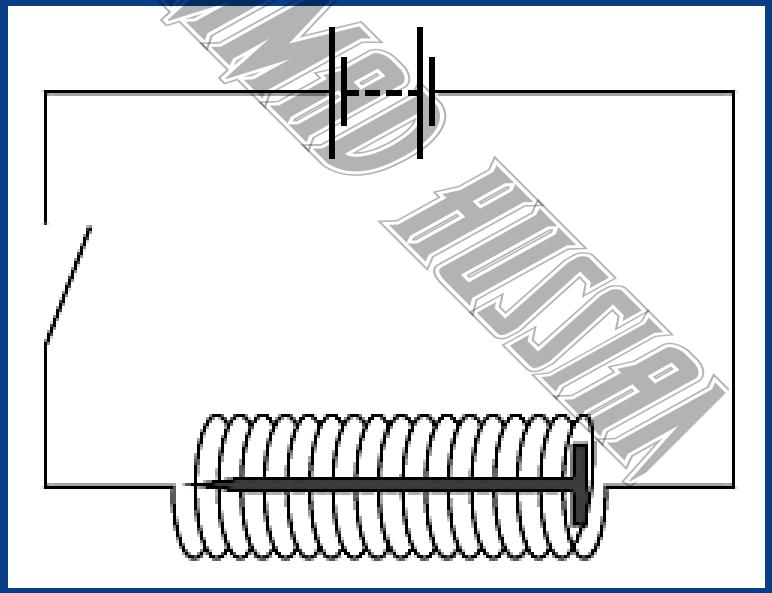
   A. It could be made of copper but is not permanently magnetised.
   B. It could be made of copper with a S-pole at X.
   C. It could be made of steel but is not permanently magnetised.
   D. It could be made of steel with a N-pole at X.

9. A student tries to magnetise a short steel rod.

   Which of these tests will show that he has been successful?

   A. both ends of a permanent magnet attract the rod
   B. one end of a permanent magnet repels the rod
   C. the rod picks up a small piece of paper
   D. when freely suspended, the rod points in any direction

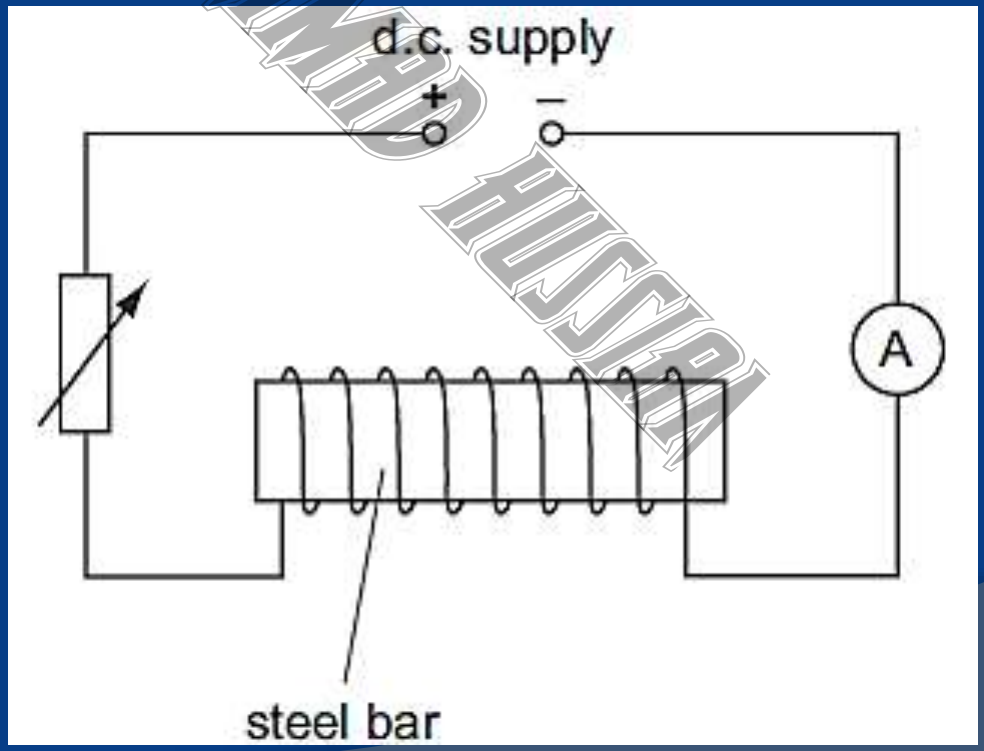
10. An iron nail can be magnetised using a coil.



How can the nail be demagnetised?

A. leaving the apparatus switched on for a long time
B. removing the nail from the coil while using an a.c. supply
C. using a coil with fewer turns
D. using more cells

11. The diagram shows how a steel bar can be magnetised.

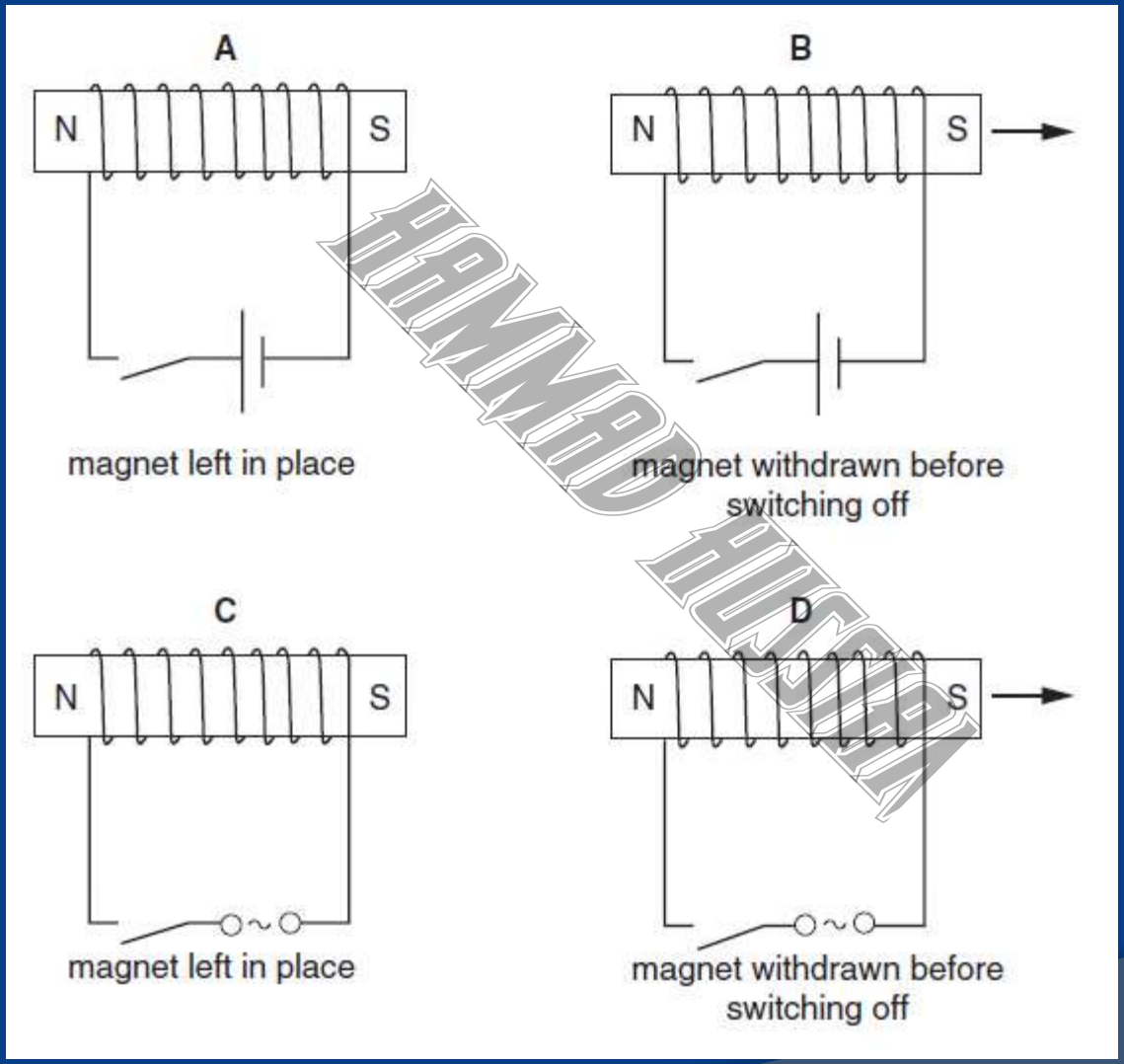


Which statement describes how the steel bar can be demagnetised?

A. Reverse the d.c. supply and gradually decrease the current in the circuit.
B. Reverse the d.c. supply and gradually increase the current in the circuit.
C. Use an a.c. supply and gradually decrease the current in the circuit.
D. Use an a.c. supply and gradually increase the current in the circuit.

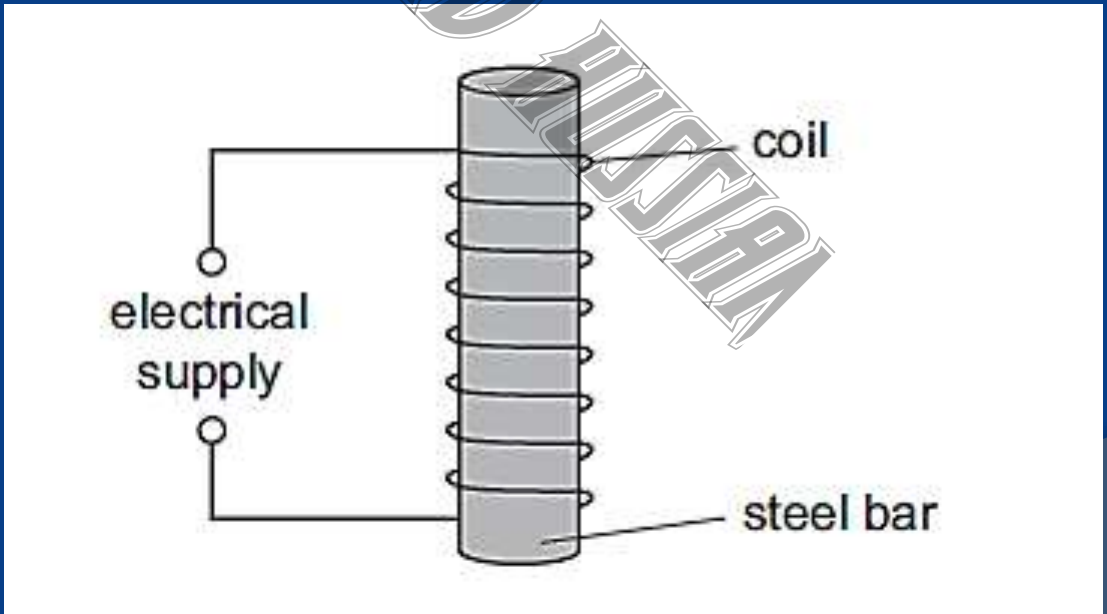
12. A permanent magnet can be demagnetised by using a solenoid and switching the current on then off.

    Which diagram shows the most effective method of producing demagnetisation?



D

13. A student wishes to demagnetise a steel bar. He uses the apparatus shown.



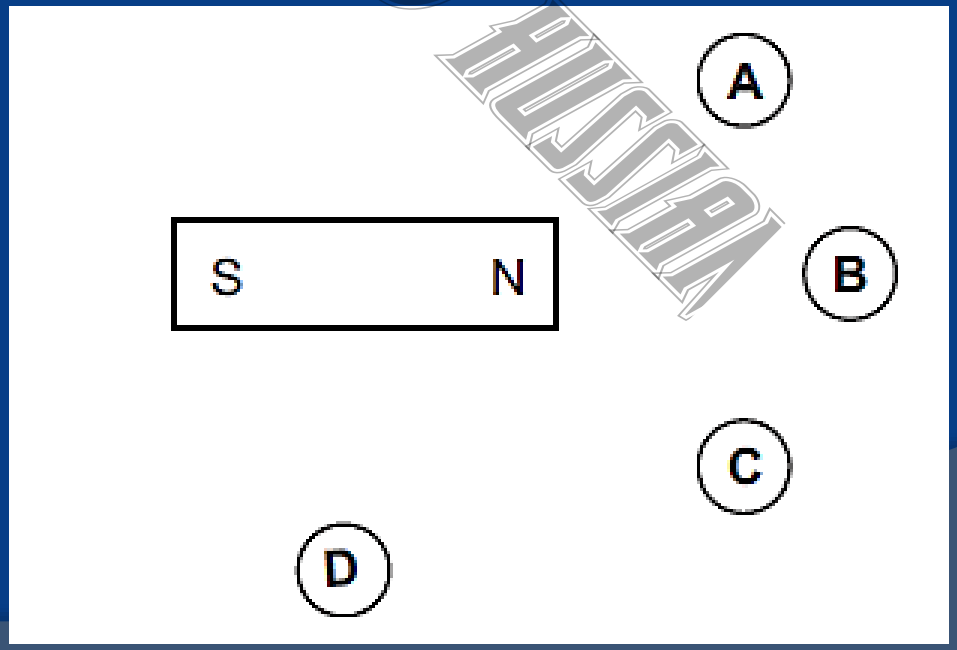
Which type of electrical supply should the student use and what should he do with the steel bar?

	supply	what to do with the steel bar
A	a.c.	keep it inside the coil
B	a.c.	slowly remove it from the coil
C	d.c.	keep it inside the coil
D	d.c.	slowly remove it from the coil

B

14. Four plotting compasses are placed near a bar magnet. You may ignore any effects of the Earth's magnetic field.

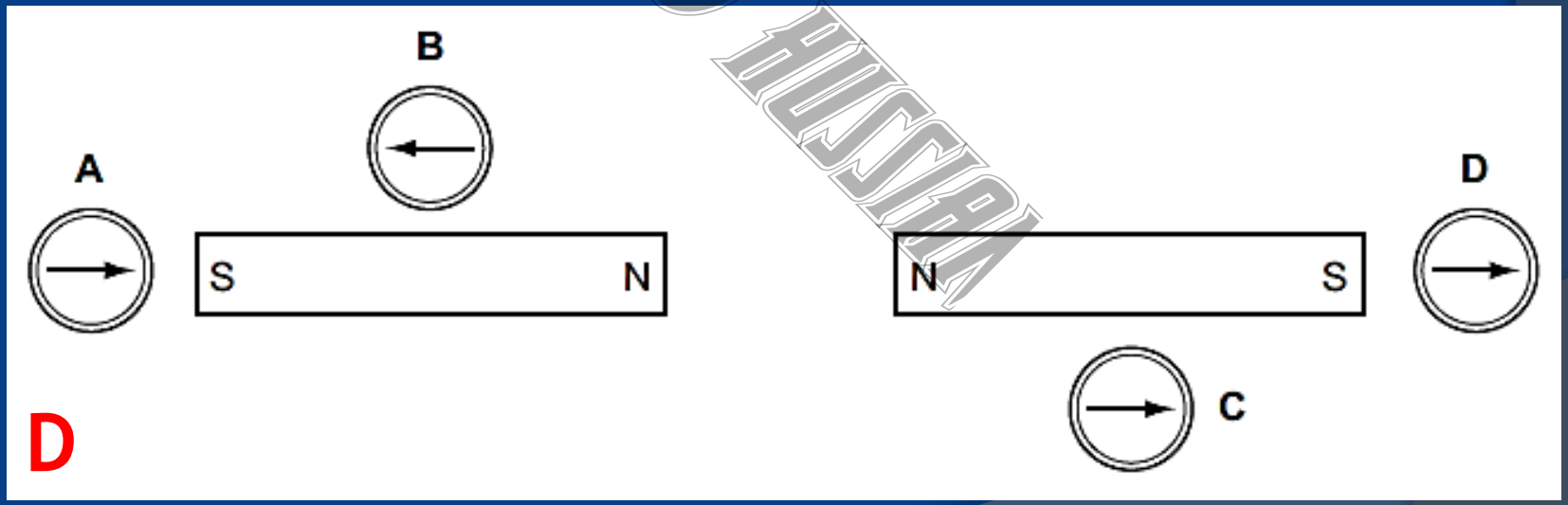
    In which position does the compass appear like this,  ?



C

15. Four plotting compasses are placed in the magnetic field of two identical bar magnets as shown in the diagram.

    Which compass is shown pointing in the wrong direction?



D

State the differences between the properties of temporary magnets (e.g. iron) and permanent magnets (e.g. steel).

Magnetic properties of Matter

Magnetic Materials

- Hard magnetic materials such as steel and alloys called Alcomax and Magnadur are difficult to magnetize but do not readily lose their magnetism.
- Soft magnetic materials such as iron and Mumetal are relatively easy to magnetize, but their magnetism is only temporary.

Describe uses of permanent magnets and electromagnets.

Magnetic properties of Matter

Uses of Permanent Magnets

Magnetic Compass

- A navigational device which uses a pivoted permanent magnet to point towards Magnetic North.

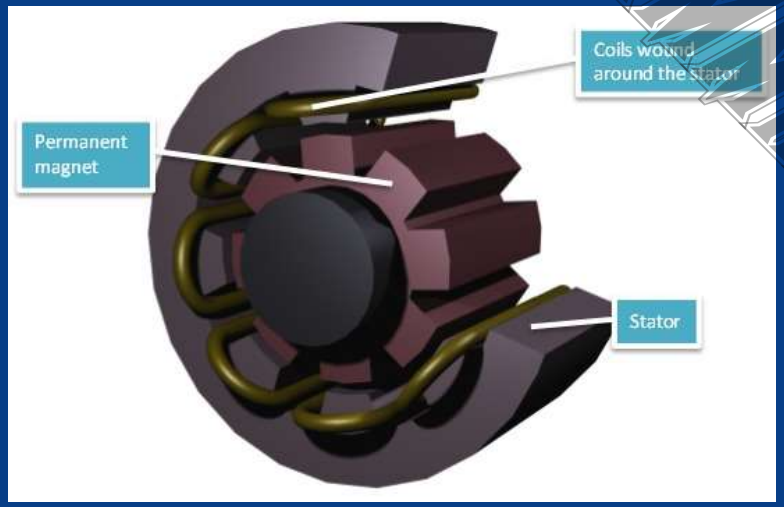
Apple’s MagSafe chargers

- The connector is held in place magnetically so that if it is tugged it will pull out of the socket without damaging the connector

Fridge Magnet

- Used to post items on a refrigerator door or serves as decoration

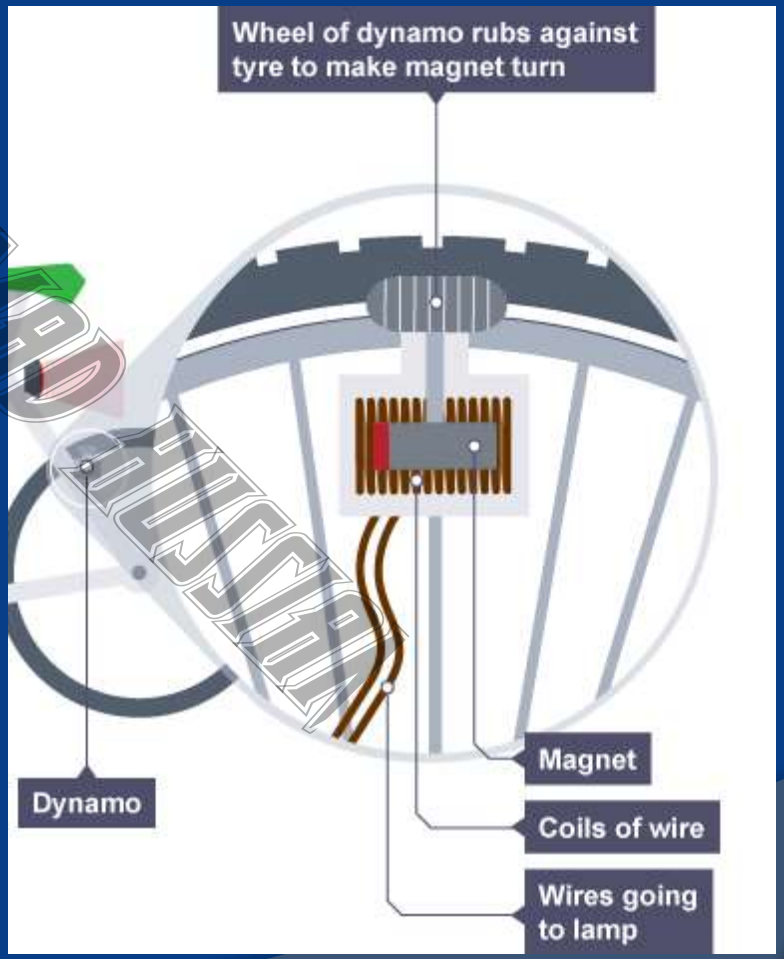
Permanent Magnet Generators



- It generate power without batteries. Use mostly in wind power.

Dynamos

- An electrical generator that produces direct current with the use of a commutator.



Use Permanent Magnet

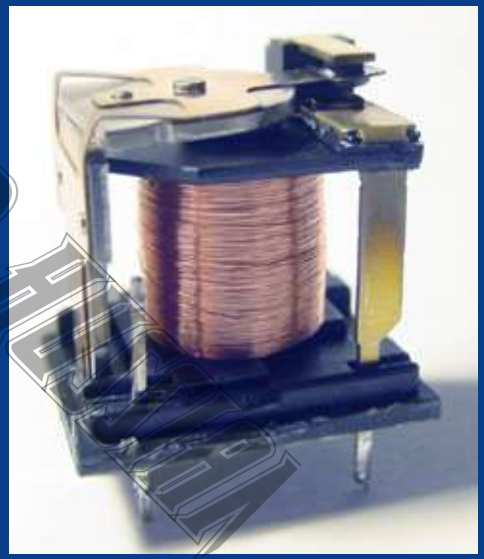
- Door Holders

- Magnetic Screwdriver

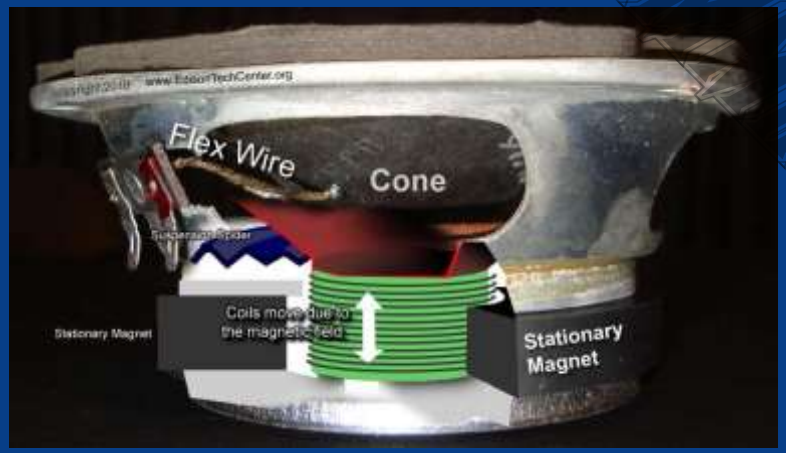
Uses of Electromagnets

A relay

- An electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current.



Speakers

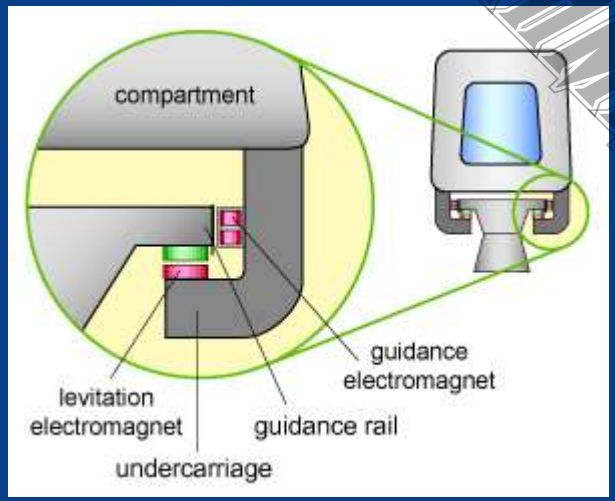


- Inside a speaker, an electromagnet is placed in front of a permanent magnet.
- The permanent magnet is fixed firmly into position whereas the electromagnet is mobile.
- As pulses of electricity pass through the coil of the electromagnet, the direction of its magnetic field is rapidly changed.

Doorbell

- It consists of an electromagnet that triggers some kind of noise (a buzzer, bell, or chime).
- When you press the button of a doorbell, you are completing the bell's circuit, activating the electromagnet.

Maglev Train

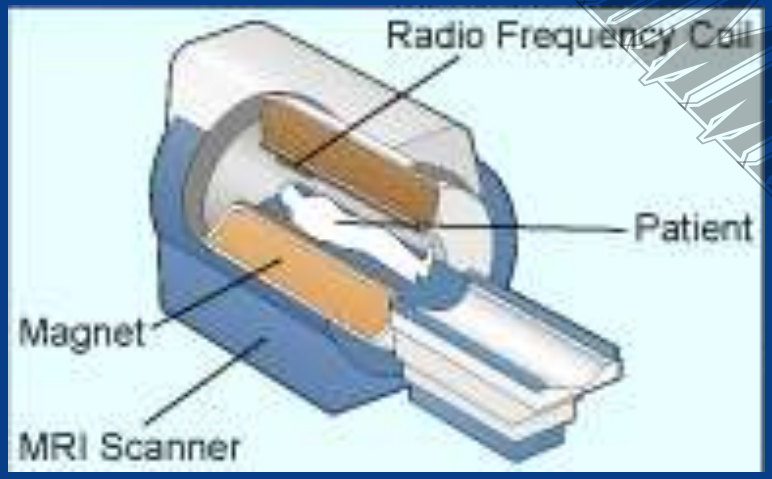


- **Maglev** (derived from magnetic levitation) is a transport method that uses magnetic levitation to move vehicles without touching the ground.
- With **maglev**, a vehicle travels along a guideway using magnets to create both lift and propulsion, thereby reducing friction and allowing higher speeds.

Scrap Metal Work

- The crane operator lowers the electromagnet into a pile of scrap steel and then switches on the electricity.
- This causes the steel disc to become a powerful magnet. Scrap steel is attracted to the disc.

Magnetic Resonance Imaging



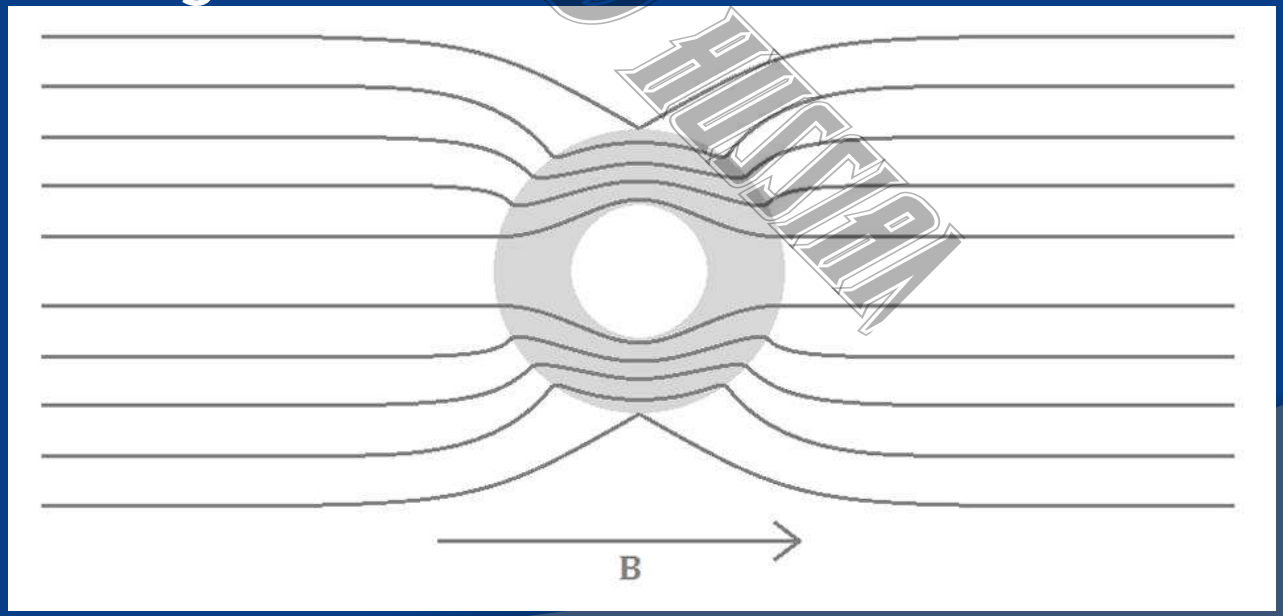
- If an atomic nucleus is exposed to a static magnetic field, it resonates when a varying electromagnetic field is applied at the proper frequency.
- An Image is computed from the resonance signals of which the frequency and phase (timing) contain space information.

Explain the choice of material for, and use of, magnetic screening.

Magnetic properties of Matter

Magnetic Screening

- Magnetic screening is a method of redirecting magnetic field lines so that magnetic flux flows through the walls of the shield itself.
- Most steels are used as its work well for a redirecting shield.



- The purpose is to prevent magnetic fields from interfering with electrical devices
  - Magnetic resonance imaging equipment that generate powerful magnetic flux.
  - Speaker magnets can distort a cathode ray tube (CRT) television picture.

Describe the use of magnetic materials in audio/video tapes.

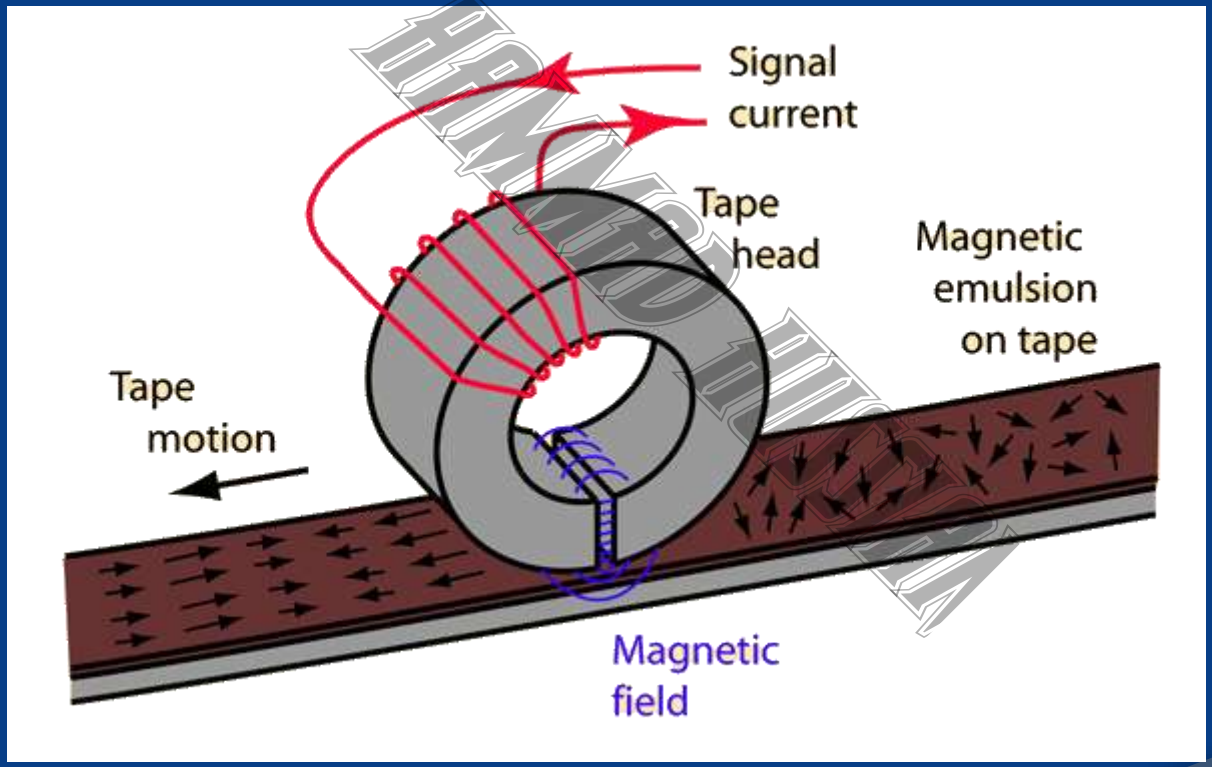
Magnetic properties of Matter

Magnetic Storage

- **Magnetic storage** or **magnetic recording** is the storage of data on a magnetised medium.
- Magnetic storage media includes hard disks, magnetic recording tape, and magnetic stripes on credit cards.

Magnetic Tape

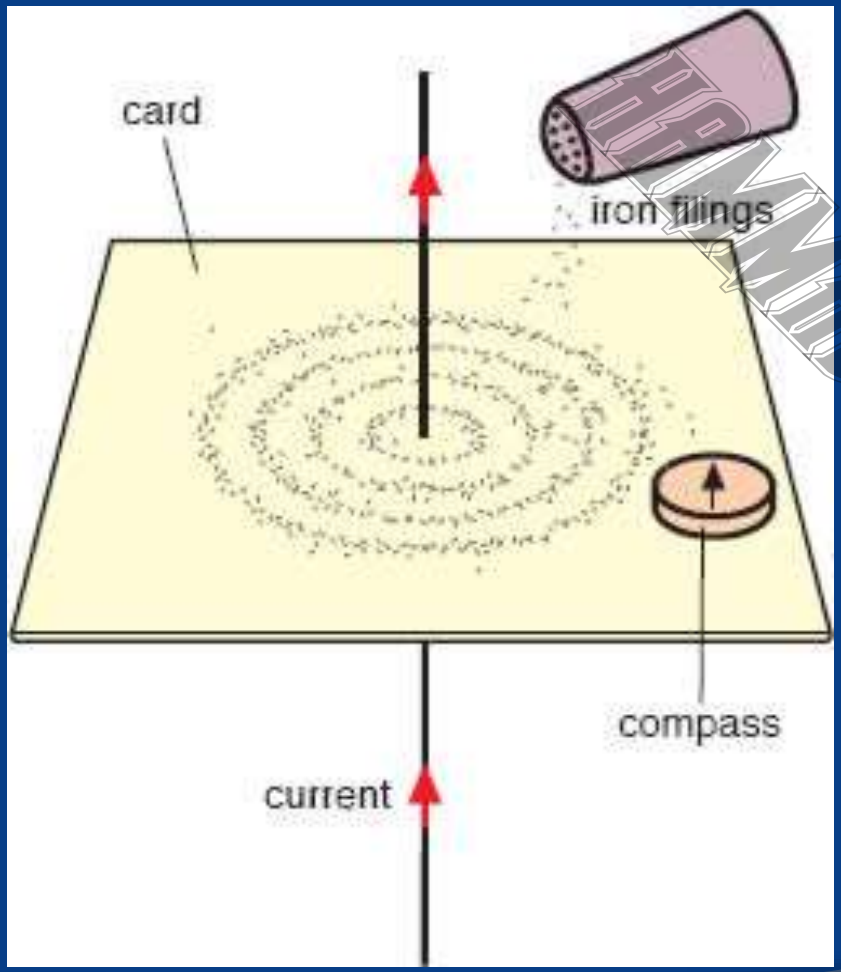
- The recording medium for the tape is typically made by embedding tiny magnetic oxide particles in a plastic binder on a polyester film tape.
- Tape heads are made from rings of ferromagnetic material with a gap where the tape contacts it so the magnetic field can fringe out to magnetize the emulsion on the tape.
- A coil of wire around the ring carries the current to produce a magnetic field proportional to the signal to be recorded.


Signal
current
Tape
head
Magnetic
emulsion
on tape
Tape
motion
Magnetic
field

Describe the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and direction of the current.

Electromagnetism

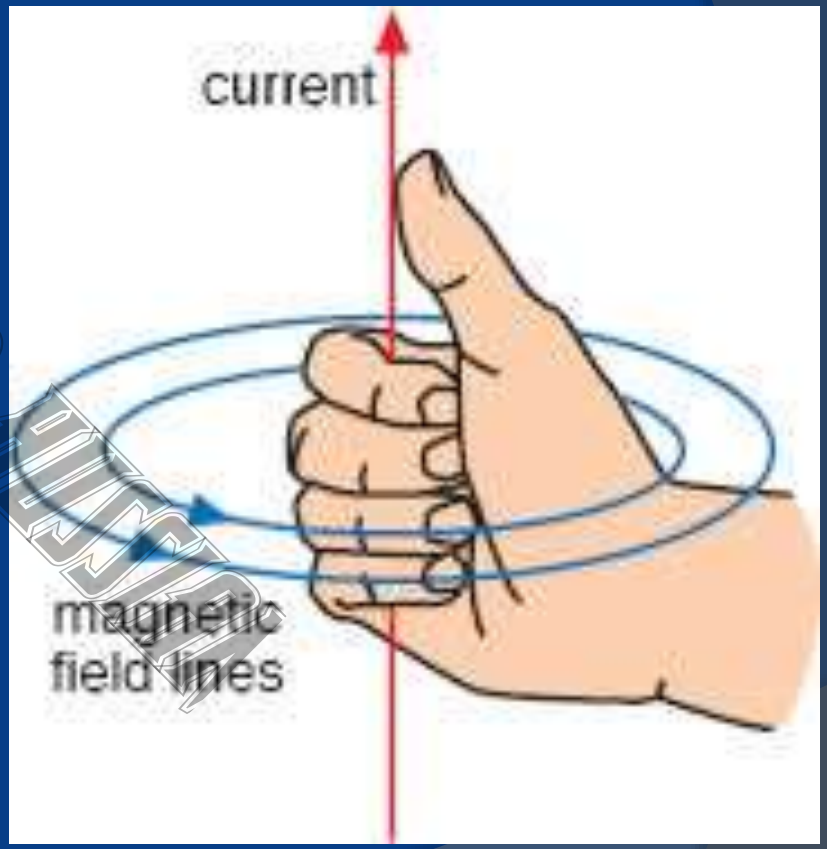
Magnetic Field Around a Long Straight Wire

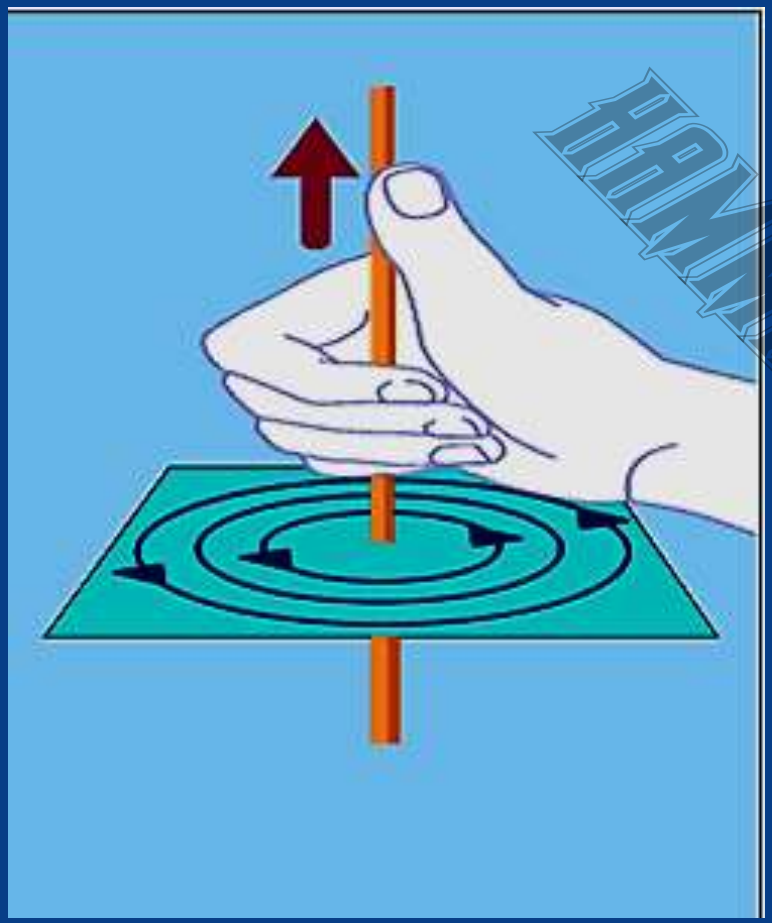


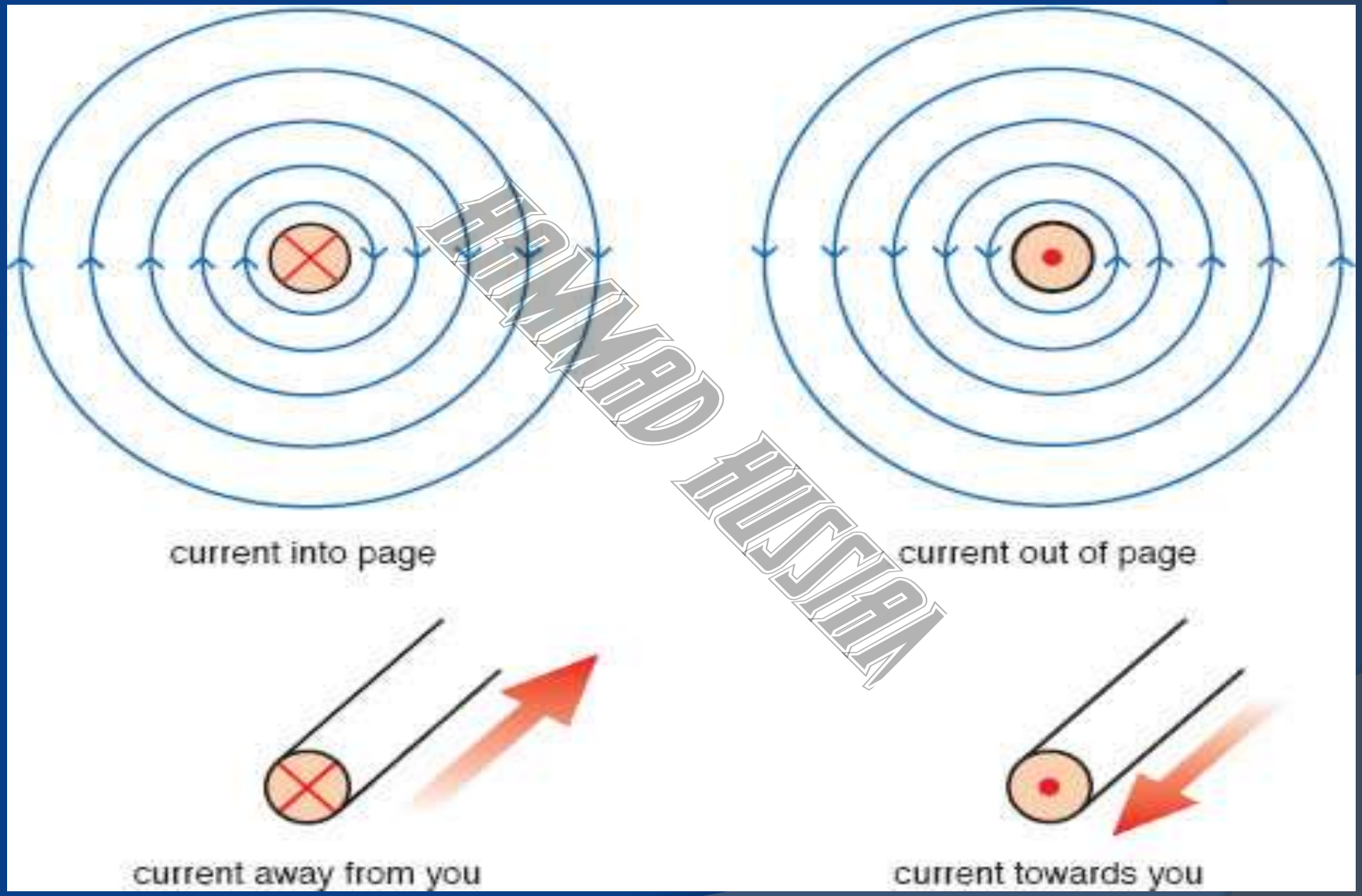
- If an electric current is passed through a wire, a weak magnetic field is produced. The field has these features:
  - The magnetic field lines are circles
  - The field is stronger close to the wire
  - Increasing the current increases the strength of the field

The Right-Hand Grip Rule

- Imagine gripping the wire using your right hand.
- The thumb points in the direction of the current and the fingers curl in the direction of the magnetic field.

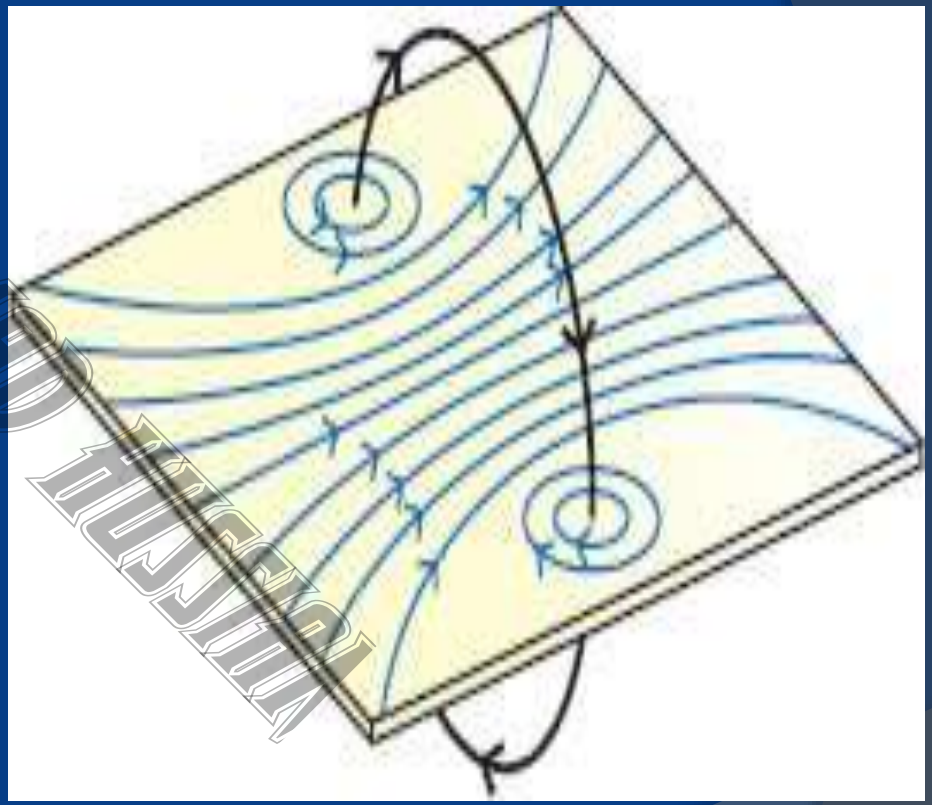






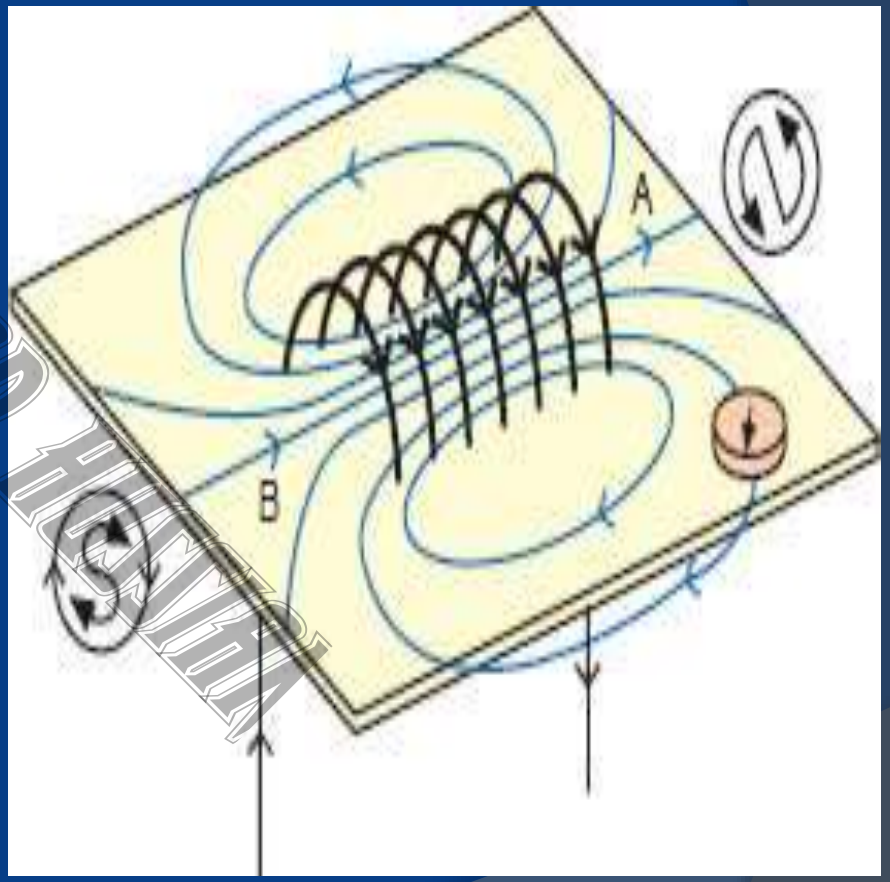
Magnetic Field of a Flat Coil

- The magnetic field due to a current in a flat coil is stronger in the region inside the coil.
- The fields from each part of the wire are in the same direction and confined to a small area.



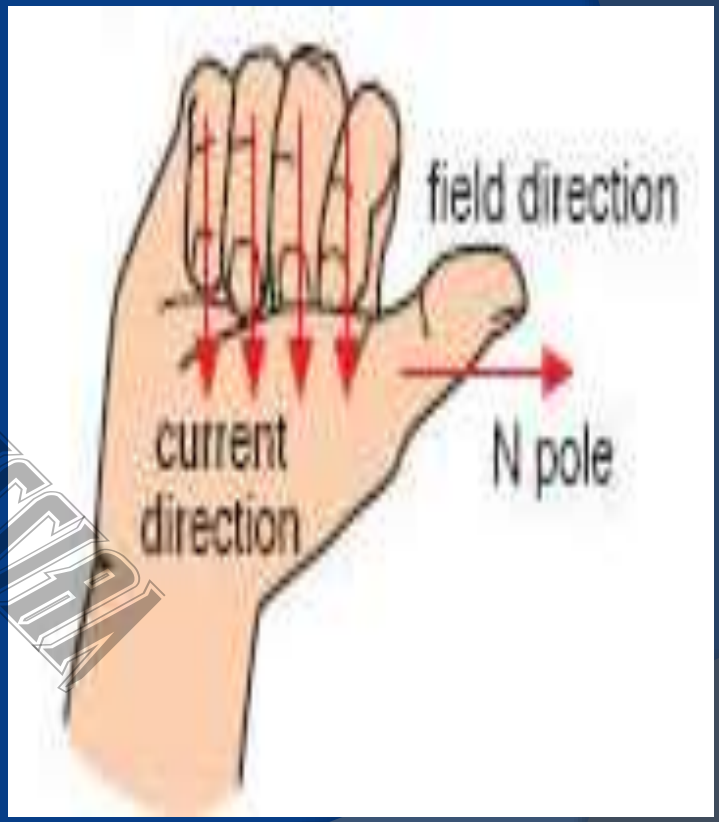
Magnetic Field of a Solenoid

- The magnetic field is stronger in the region of the solenoid.
- The field lines in this region are parallel to each other showing that the field has the same strength along most of the inner part of the solenoid.



- If the current in the solenoid is reversed, then the poles will also be reversed.
- The strength of the magnetic field produced by a solenoid can be increased by
  - increasing the magnitude of the current;
  - increasing the number of turns of the solenoid;
  - inserting a soft iron core into the solenoid.

- The right-hand grip rule can be used to remember the direction of the magnetic field.
- Curl the fingers of the right hand in the direction of the current.
- The thumb now points along the direction of the magnetic field. It points towards the end of the solenoid that behaves like a north pole.

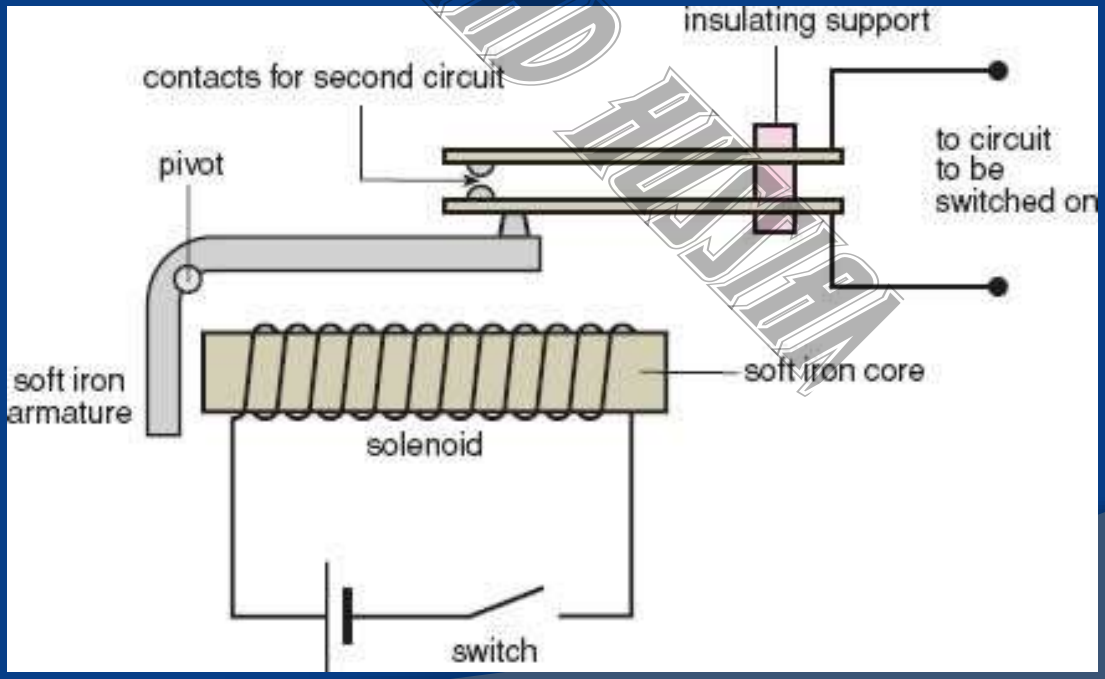


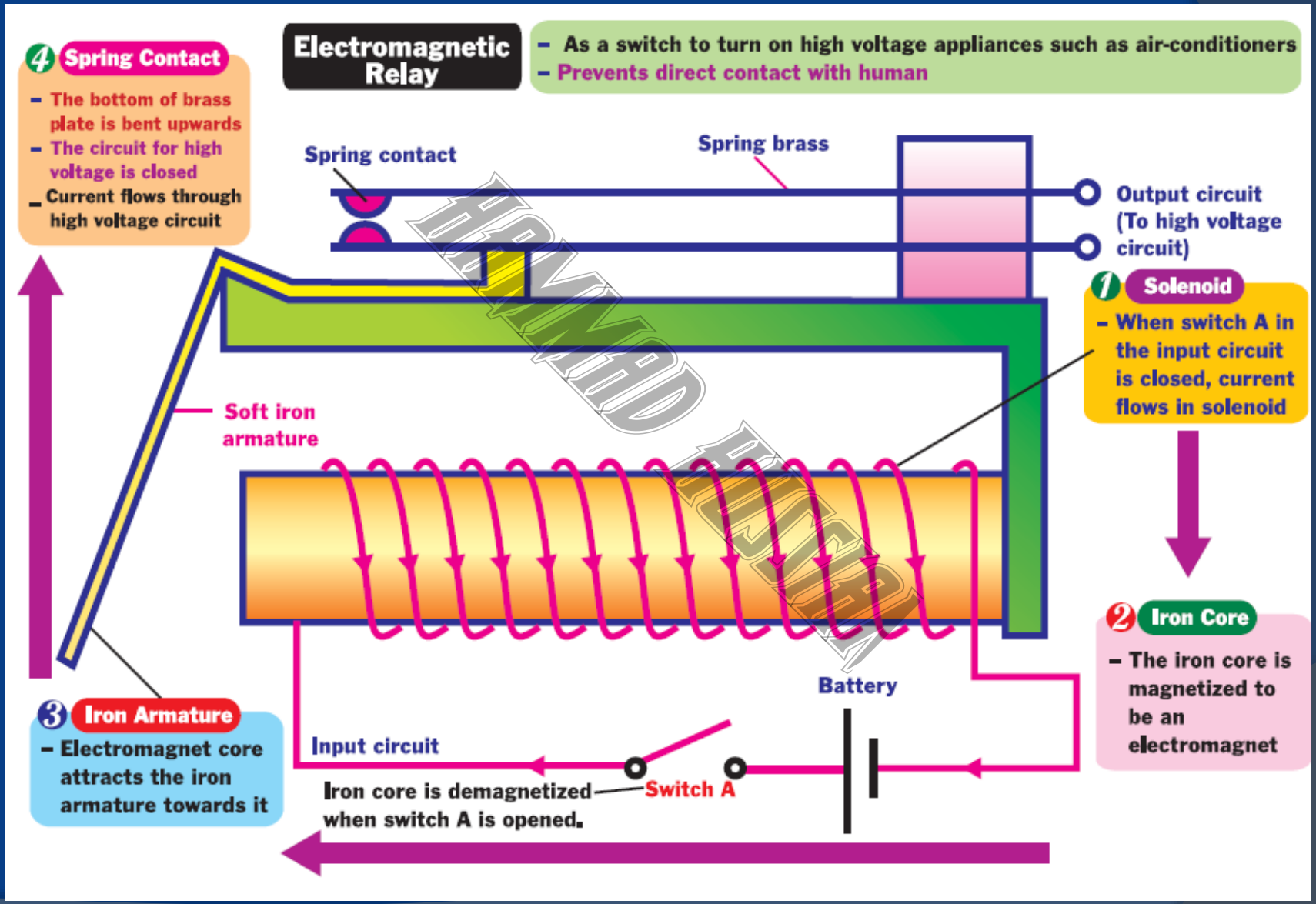
Describe applications of the magnetic effect of a current in relays, circuit-breakers and loudspeakers.

Electromagnetism

Magnetic Relay

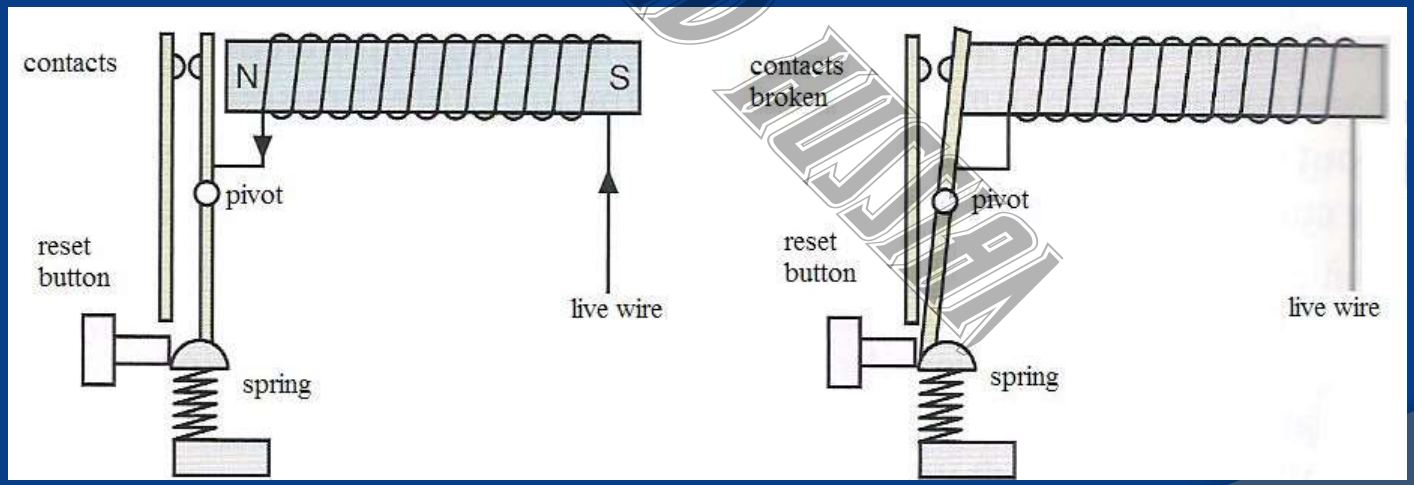
- The magnetic relay is a device using an electromagnet in one circuit to switch on another circuit.

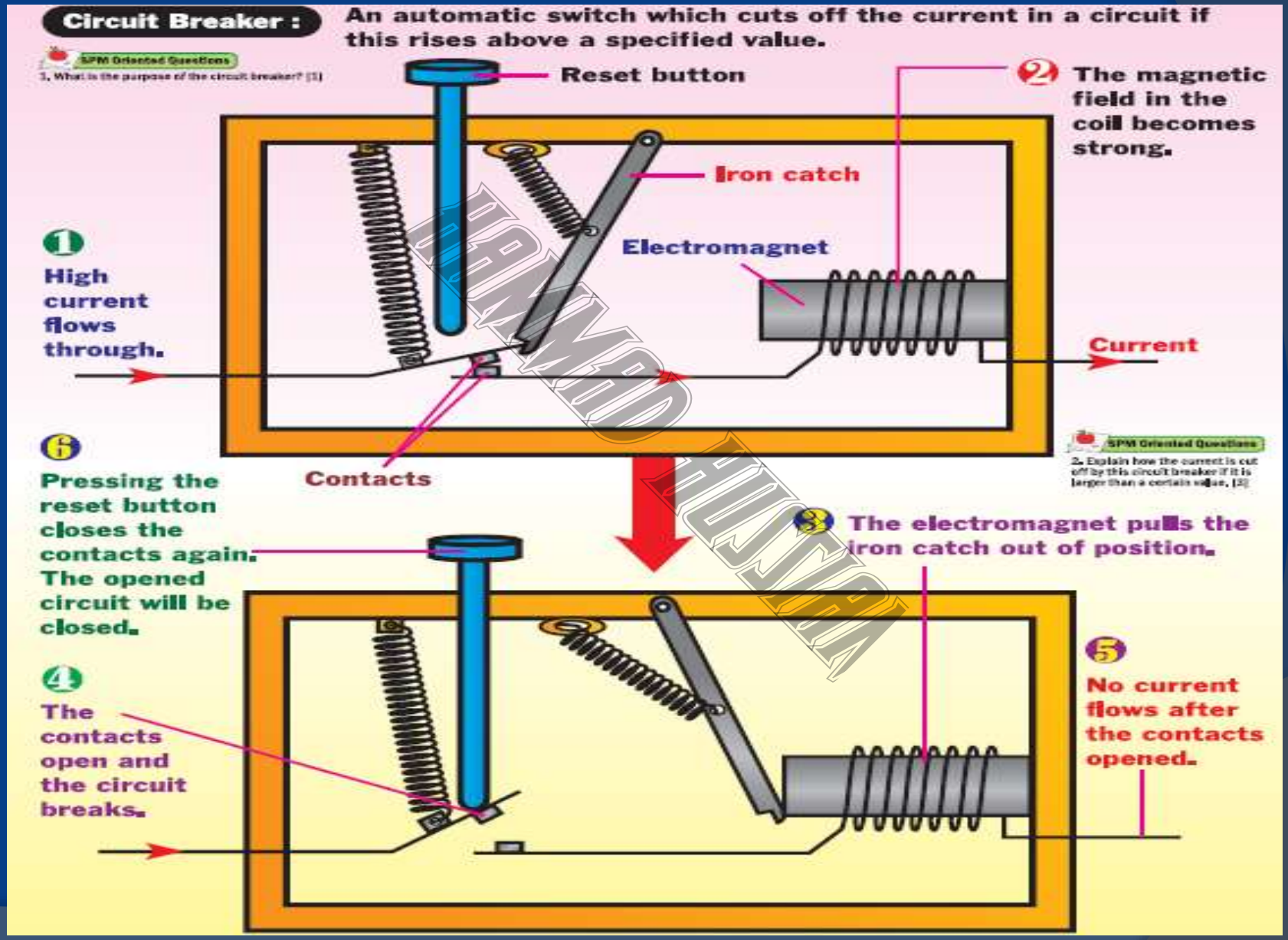



Electromagnetic Relay
– As a switch to turn on high voltage appliances such as air-conditioners
– Prevents direct contact with human
4 Spring Contact
– The bottom of brass plate is bent upwards
– The circuit for high voltage is closed
– Current flows through high voltage circuit
Spring contact
Spring brass
Output circuit (To high voltage circuit)
1 Solenoid
– When switch A in the input circuit is closed, current flows in solenoid
Soft iron armature
2 Iron Core
– The iron core is magnetized to be an electromagnet
Battery
3 Iron Armature
– Electromagnet core attracts the iron armature towards it
Input circuit
Iron core is demagnetized when switch A is opened.
Switch A

Circuit Breaker

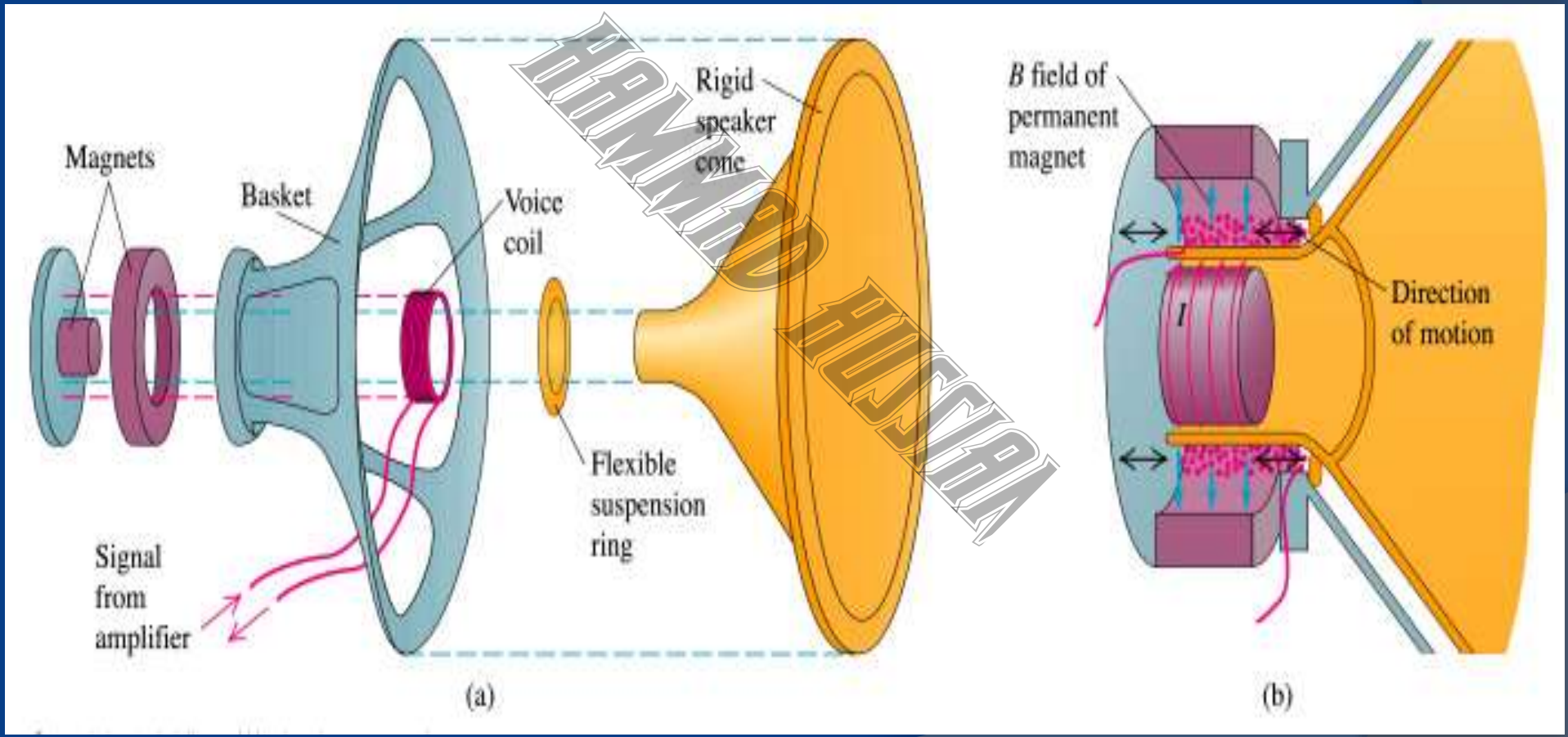
- Circuit breakers are designed to open a circuit when the current exceeds a certain value.




Circuit Breaker :
An automatic switch which cuts off the current in a circuit if this rises above a specified value.
SPM Oriented Questions
1. What is the purpose of the circuit breaker? [1]
Reset button
2 The magnetic field in the coil becomes strong.
Iron catch
Electromagnet
1 High current flows through.
Current
Contacts
6 Pressing the reset button closes the contacts again. The opened circuit will be closed.
SPM Oriented Questions
2. Explain how the current is cut off by this circuit breaker if it is larger than a certain value. [2]
3 The electromagnet pulls the iron catch out of position.
4 The contacts open and the circuit breaks.
5 No current flows after the contacts opened.

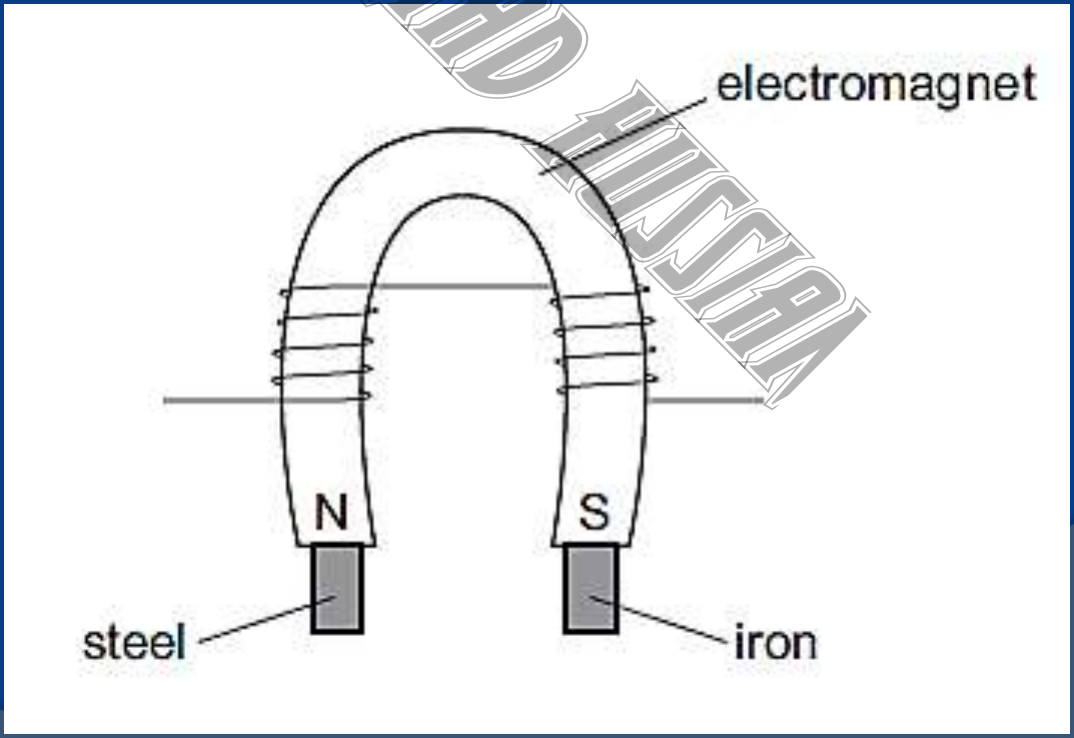
Loudspeaker

- A loudspeaker produces sound by converting electrical signals from an audio amplifier into mechanical motion.
- The electromagnet is positioned in a constant magnetic field created by a **permanent magnet**.
- As the alternating current constantly reverses the magnetic forces between the voice coil and the permanent magnet. This pushes the coil back and forth rapidly, like a piston.
- When the coil moves, it pushes and pulls on the speaker cone.
- This vibrates the air in front of the speaker, creating sound waves.


Magnets
Basket
Voice coil
Rigid speaker cone
Flexible suspension ring
Signal from amplifier
(a)
B field of permanent magnet
I
Direction of motion
(b)


from PHYSCLIPS

1. A piece of iron and a piece of steel are picked up by an electromagnet as shown.



The current to the electromagnet is switched off.

What happens?

A. Both the iron and the steel remain magnetised.
B. Neither the iron nor the steel remain magnetised.
C. Only the iron remains magnetised.
D. Only the steel remains magnetised.

2. Which row describes the ease with which iron or steel can be magnetised and demagnetised?

	metal	magnetised	demagnetised
A	iron	difficult	easy
B	iron	easy	difficult
C	steel	difficult	difficult
D	steel	easy	easy

D

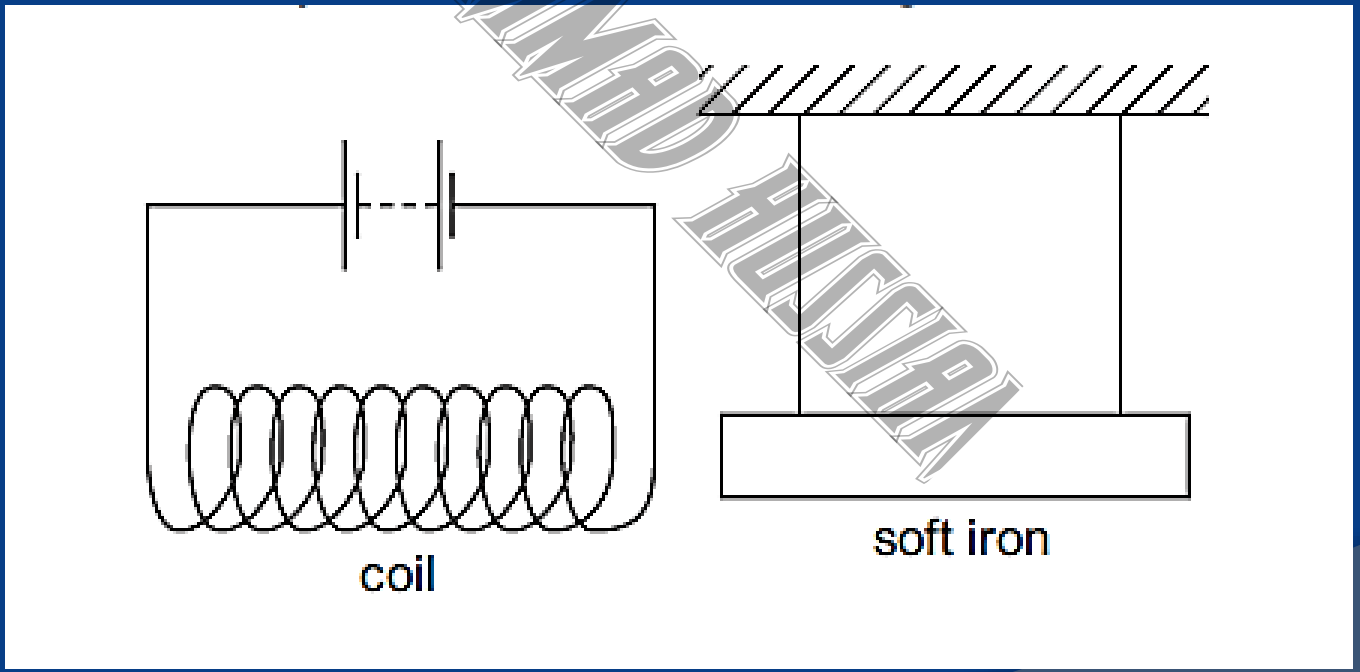
3. A permanent magnet is brought near to a piece of copper. The copper is not attracted by the magnet.

   Why is there no attraction?

   A. Copper is ferrous but is only attracted by an electromagnet.
   B. Copper is ferrous but is not attracted by any type of magnet.
   C. Copper is not ferrous and is only attracted by an electromagnet.
   D. Copper is not ferrous and is not attracted by any type of magnet.

4. Which part of a video tape recording system does not rely on magnetic material for its operation?
   A. the drive motor
   B. the power lead
   C. the transformer
   D. the video tape

5. A coil is connected to a battery and a soft iron bar is hung near to it.



The current is then reversed by reversing the battery connections.

How does the soft iron bar behave in the two cases?

	with the battery as shown	with the battery reversed
A	attracted to the coil	attracted to the coil
B	attracted to the coil	repelled from the coil
C	repelled from the coil	attracted to the coil
D	repelled from the coil	repelled from the coil

A

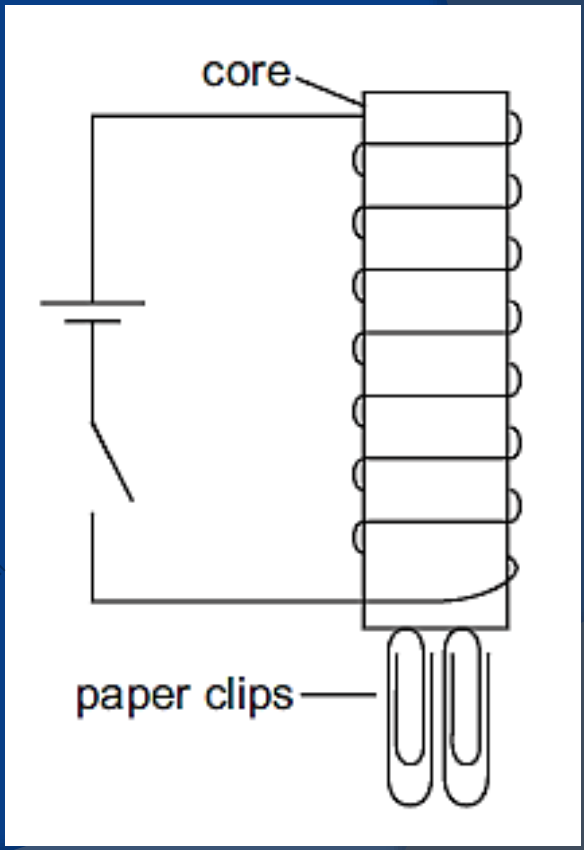
6. An electromagnet is used to separate magnetic metals from non-magnetic metals.

   Why is steel unsuitable as the core of the electromagnet?

   A. It forms a permanent magnet.
   B. It has a high density.
   C. It has a high thermal capacity.
   D. It is a good conductor of electricity.

7. Four different substances are tested by using each as the core of an electromagnet.

   The number of paper clips each holds is recorded when there is a current in the electromagnet and when the current is switched off.

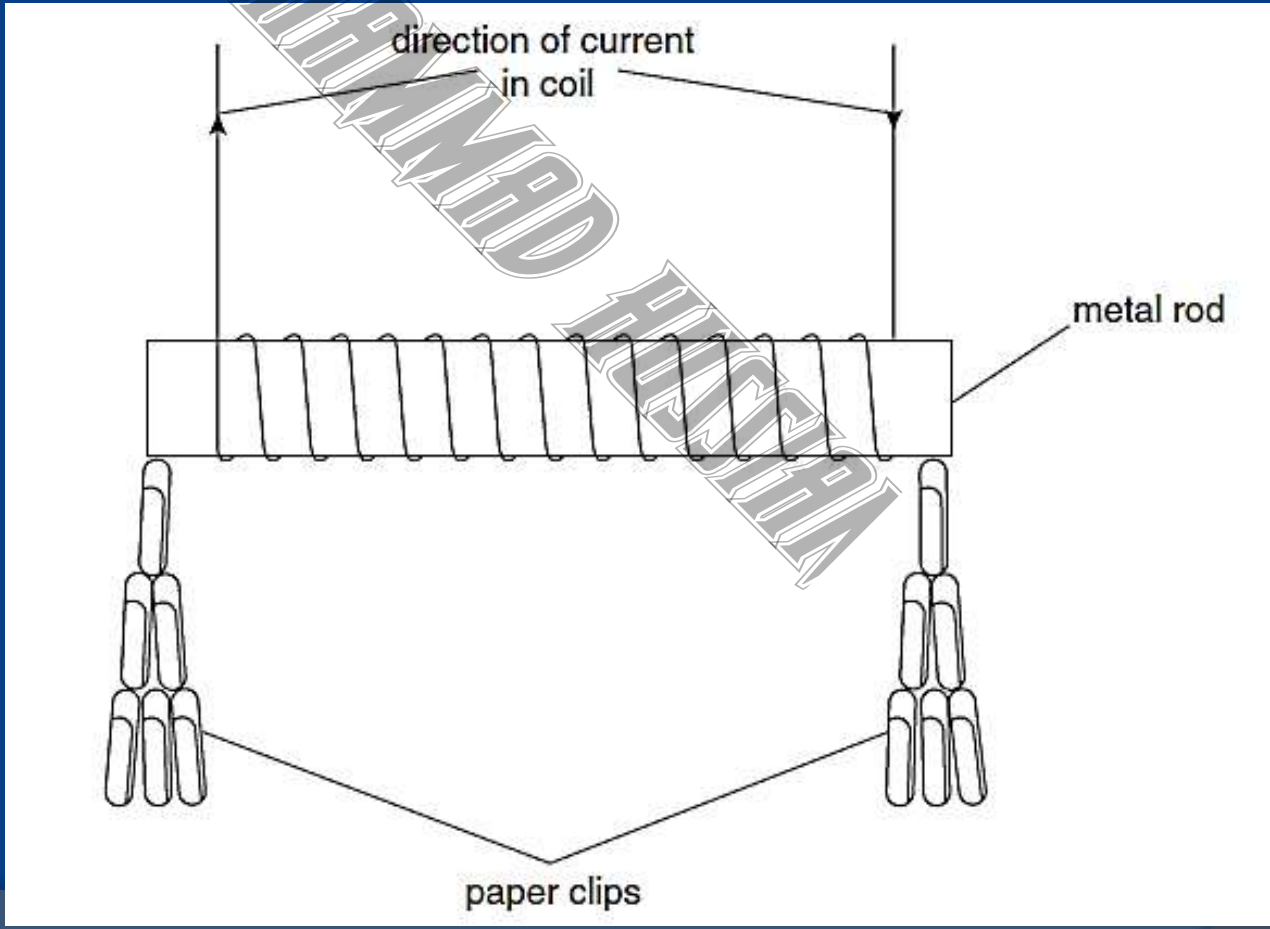


Which substance is the best for making the core of a transformer?

	number of paper clips held when there is a current in the electromagnet	number of paper clips held when current is switched off
A	8	4
B	6	0
C	5	1
D	4	0

B

8. Four metal rods are placed, in turn, inside a coil of copper wire.



The table below gives the results of the experiment.

Which rod would be the most suitable to use for the core of a coil in a circuit breaker?

metal rod	number of paper clips picked up when there is a current in the coil	number of paper clips still attracted when the current is switched off
A	1	0
B	20	2
C	35	0
D	35	30

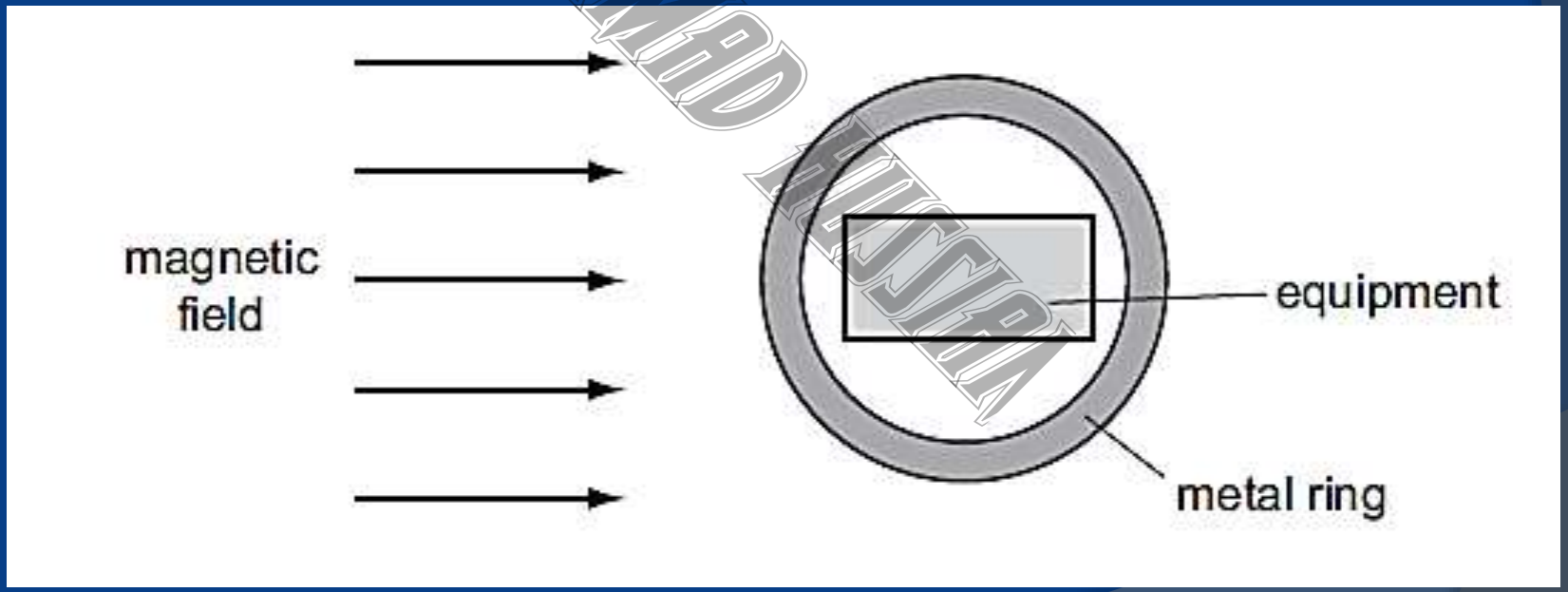
C

9. Delicate instruments are often placed in a ‘box’ to protect them from stray magnetic fields.

   What is the material used for the box and why is it chosen?

   A. Aluminium is used because it is a non-magnetic material.
   B. Copper is used because it has a low electrical resistance.
   C. Polythene is used because it is a good electrical insulator.
   D. Soft iron is used because it is a magnetic material.

10. A metal ring screens a piece of equipment from a magnetic field.



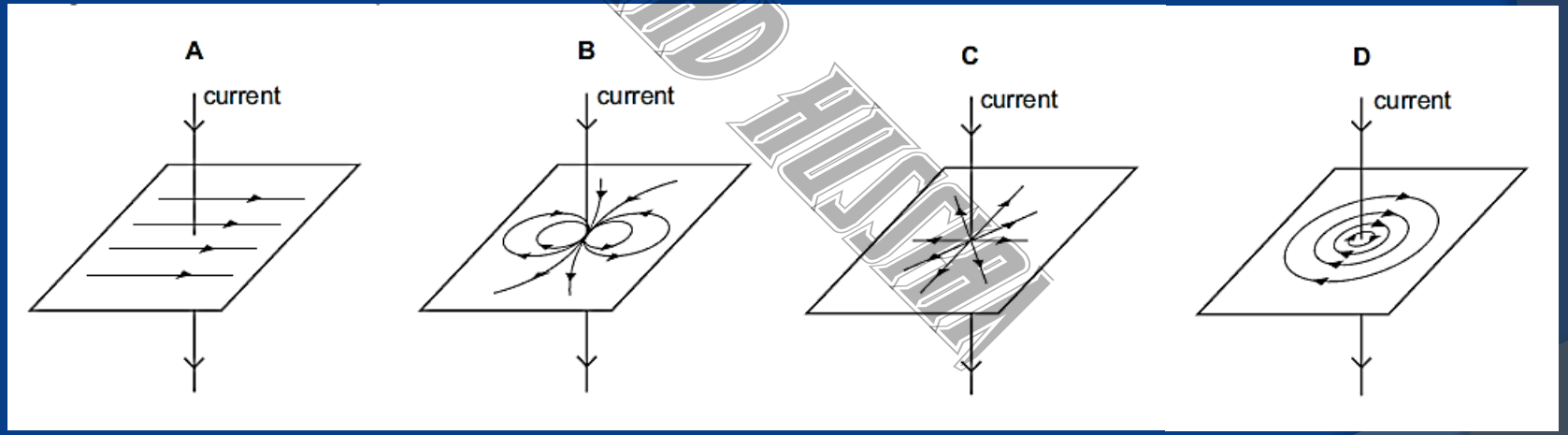
Which metal should be used for the ring, and why?

	metal	reason
A	copper	the metal carries the field lines around the equipment
B	copper	the metal is non-magnetic
C	iron	the metal carries the field lines around the equipment
D	iron	the metal is non-magnetic

C

11. A straight wire carrying a current produces a magnetic field.

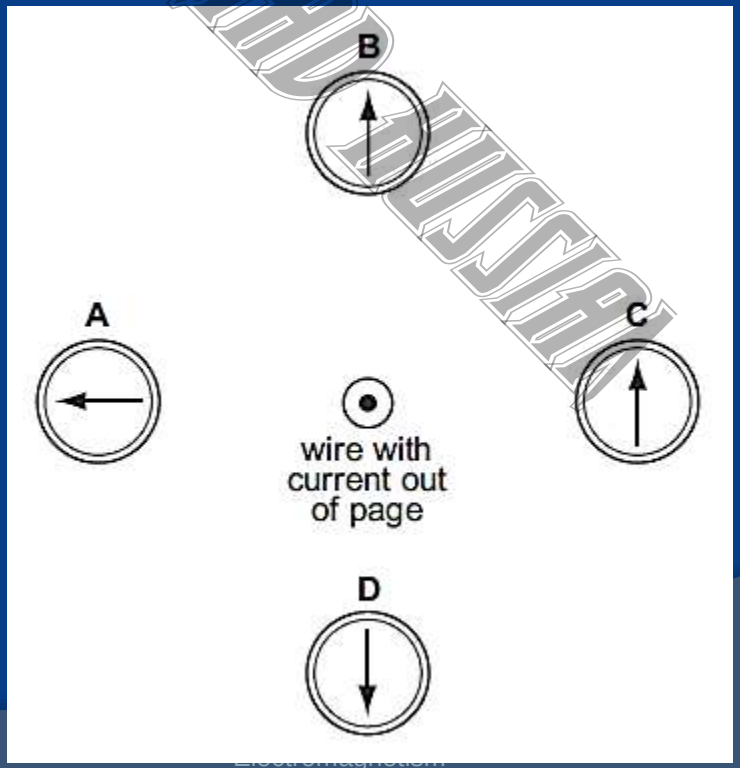
    Which diagram shows the correct shape of the field?



D

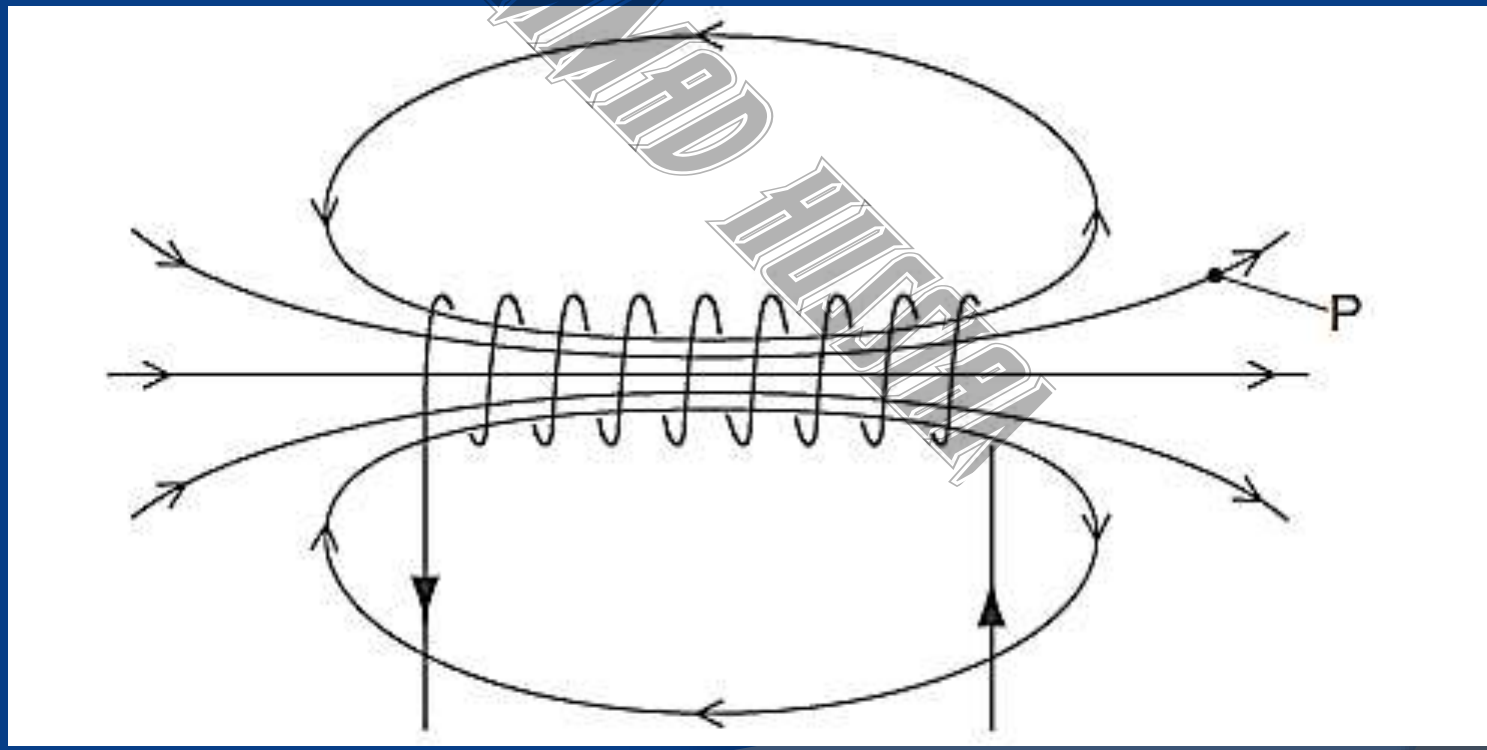
12. A wire perpendicular to the page carries an electric current in a direction out of the page. There are four compasses near the wire.

    Which compass shows the direction of the magnetic field caused by the current?



C

13. A current in a solenoid creates a magnetic field.



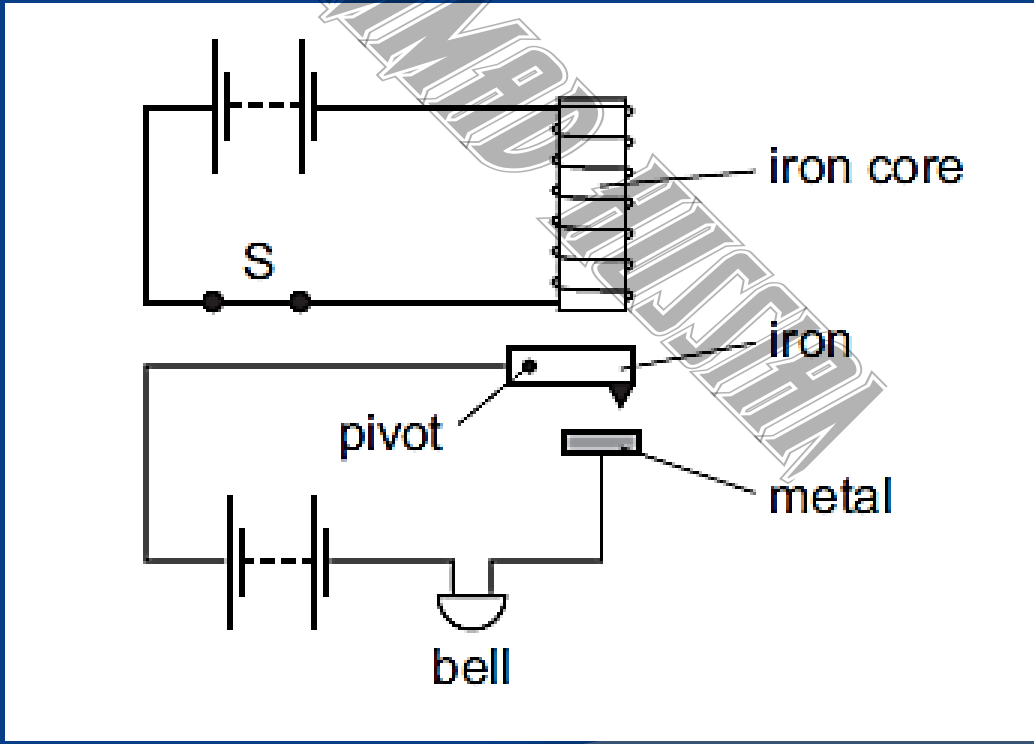
What is the effect on the magnetic field at the point P of using a larger current in the opposite direction?

	field strength	field direction
A	decreases	reverses
B	decreases	unchanged
C	increases	reverses
D	increases	unchanged

C

14. Which properties make materials suitable for use as a core in an electromagnet?
    A. difficult to magnetise and easy to demagnetise
    B. difficult to magnetise and retains magnetic strength
    C. easy to magnetise and retains magnetic strength
    D. easy to magnetise and easy to demagnetise

15. The diagram shows an alarm system in which the switch S is shown closed.

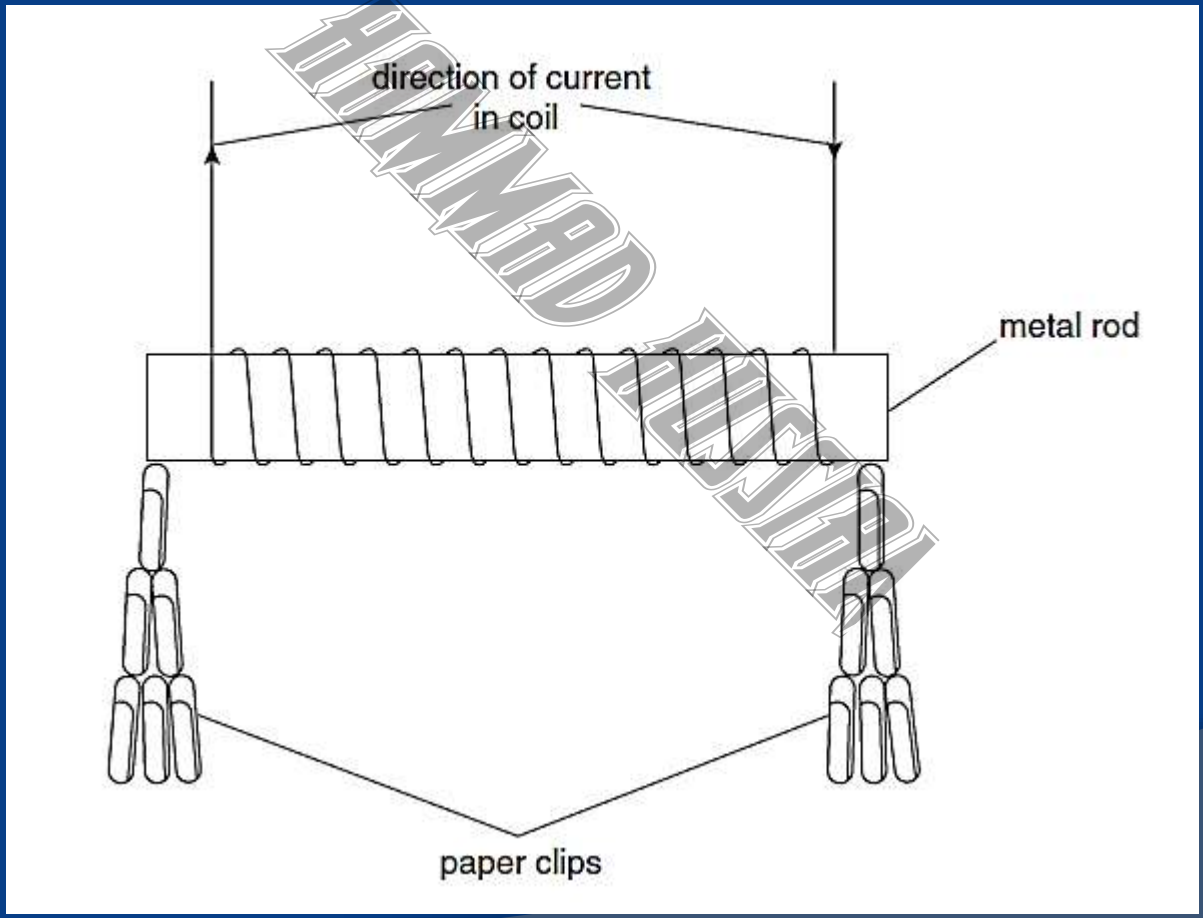


What happens when the switch S is opened?

	iron	bell
A	drops	rings
B	drops	stops ringing
C	moves up	rings
D	moves up	stops ringing

A

16. Four metal rods are placed, in turn, inside a coil of copper wire.



The table below gives the results of the experiment.

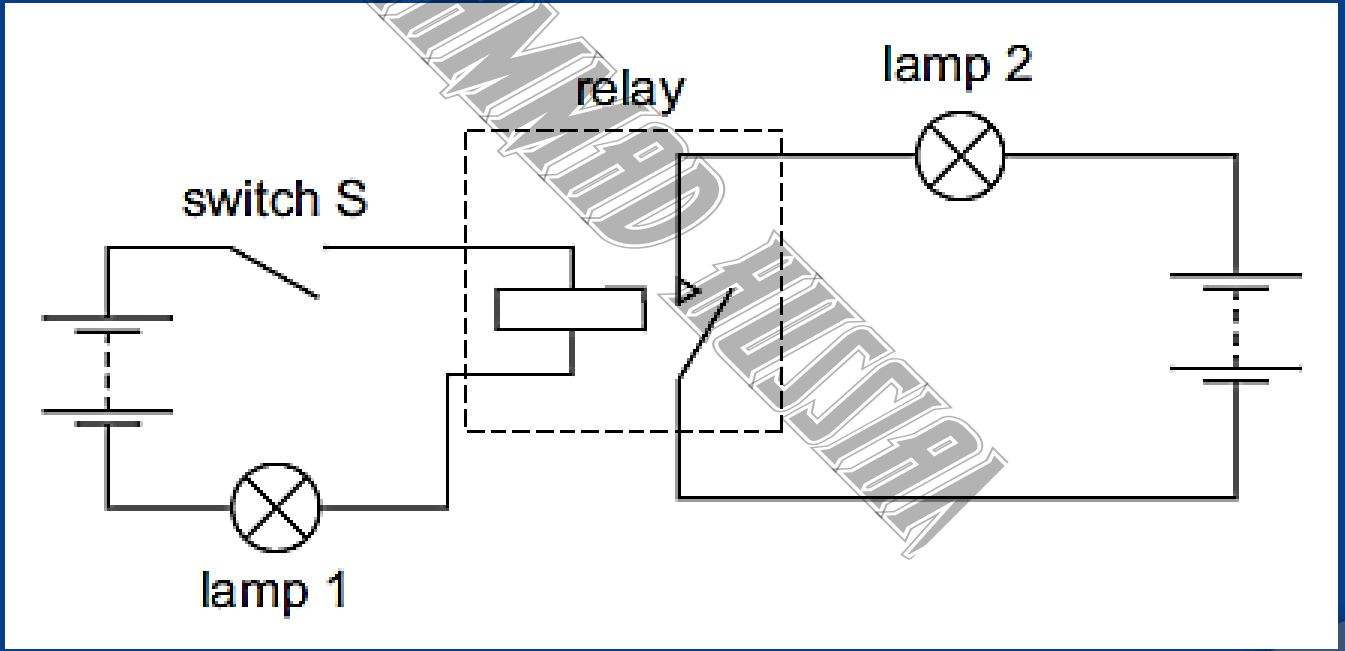
Which rod would be the most suitable to use for the core of a coil in a circuit breaker?

metal rod	number of paper clips picked up when there is a current in the coil	number of paper clips still attracted when the current is switched off
A	1	0
B	20	2
C	35	0
D	35	30

C

17. Which device is designed to allow a small direct current (d.c.) to control a large direct current (d.c.)?
    A. a generator
    B. a motor
    C. a relay
    D. a transformer

18. The circuit contains a relay.

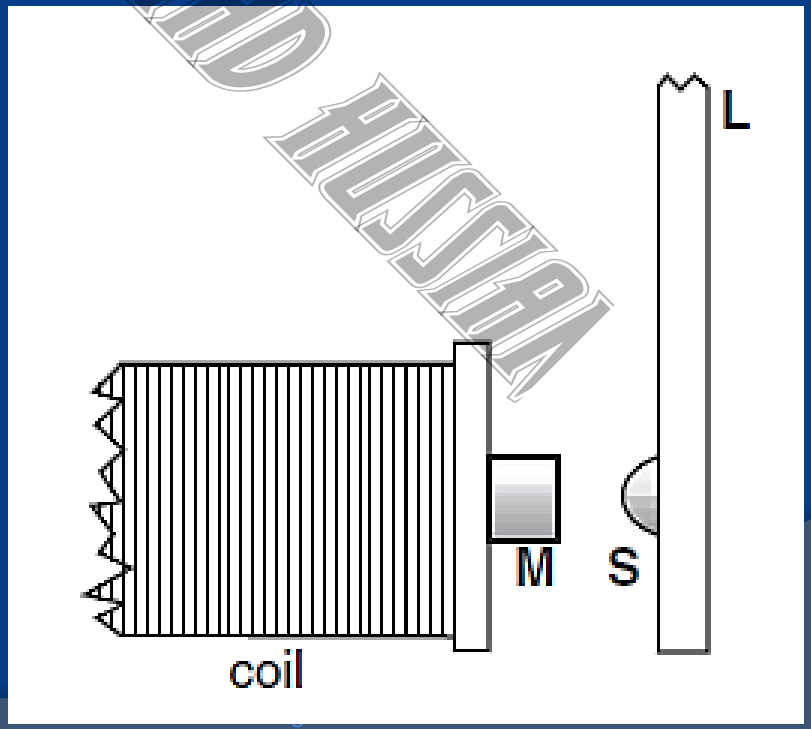


When switch S is closed, what is the state of the lamps?

	lamp 1	lamp 2
A	on	on
B	on	off
C	off	on
D	off	off

A

19. The diagram shows part of a magnetic relay. **M** is part of the core of the magnet. **L** is part of the armature which is attracted to the core when a current flows through the coil. **S** is a stud which stops the armature being attracted too strongly.

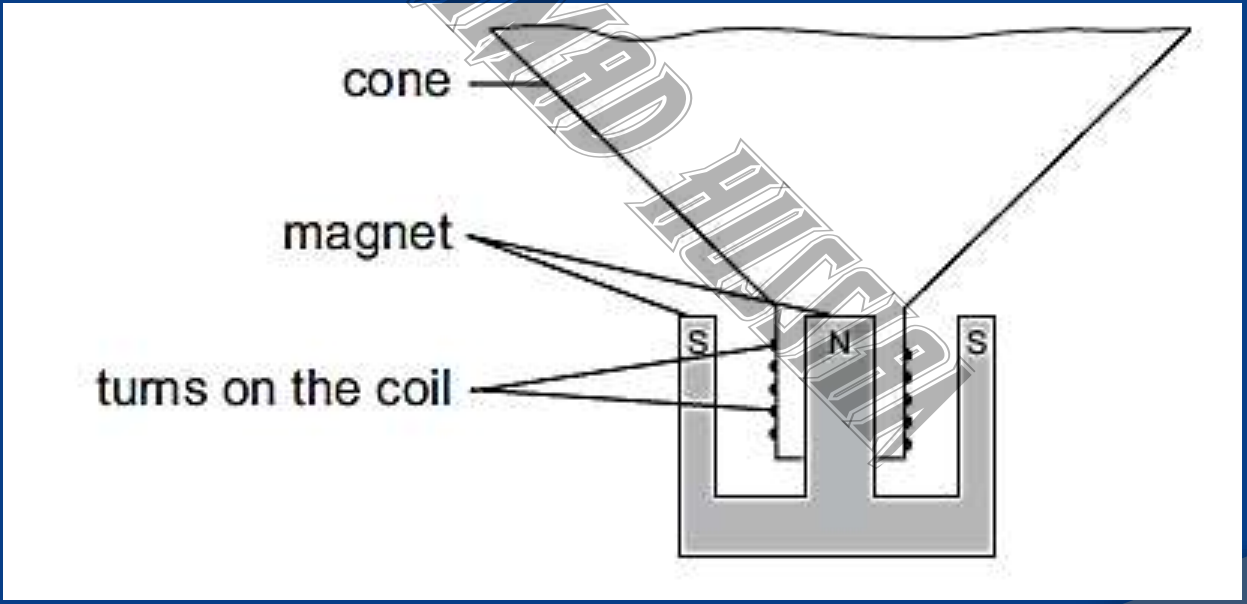


Which line of the table gives the best materials for M, L and S?

	M	L	S
A	iron	iron	iron
B	iron	iron	copper
C	iron	copper	copper
D	copper	copper	copper

B

20. The diagram shows parts of a loudspeaker.



Which type of current is passed through the coil and why?

	current passed through coil	reason why
A	alternating	to keep the magnetic field constant
B	alternating	to make the coil vibrate
C	direct	to keep the magnetic field constant
D	direct	to make the coil vibrate

B