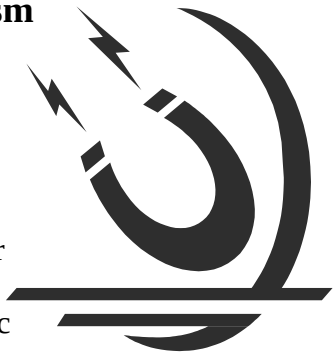
Electricity, Energy and Magnetism



A. What's a Magnet?

A magnet is a substance with two opposite poles: North and South. Like opposite charges, opposite poles attract, so the north pole of one magnet will stick to the south pole of another magnet. Similar poles, like similar charges, repel. In addition, magnets attract certain materials known as ferromagnetic materials.

B. Nonmagnetic, Ferromagnetic and Permanent Magnets

Example: Complete the following table

Classification of Materials		
Types of Materials	**Examples**	**Characteristics**
Nonmagnetic		• Will not attract a magnet or a ferromagnetic substance • domains do not form; although electron spins create magnetic fields, they cancel out.
Ferromagnetic		• can only attract a ferromagnetic substance if stuck to a permanent magnet; otherwise only attracts another magnet • domains form as electron spin are aligned, but the domains themselves are scrambled until they're placed in a magnetic field.
Permanent Magnets		• can attract another magnet(if properly aligned)and a ferromagnetic substance • domains are locked into place by impurities

Nonmagnetic materials do not stick to a magnet. Examples are given in the table above. Those materials that are attracted to magnets are known as *ferromagnetic* materials. Note that not all metals are ferromagnetic. Copper, zinc and aluminum will not stick to a magnet, but Fe, Co, Ni , Nd, and Sm will.

What is a temporary magnet?

Magnetism

C. Domains: Why Magnetism Exists

There are four basic forces in nature:

(1) ***gravity***, which attracts matter to itself and acts over large distances
(2) the ***strong*** force, which is much more powerful than gravity but which acts only over miniscule distances. It is what keeps quarks (the basic particles of neutrons and protons) bonded together.
(3) the ***electroweak*** force which controls a radioactive process in which a neutron breaks down into a proton and a fast moving electron (beta particle)
(4) the ***electromagnetic*** force which is what makes ferromagnetic material stick to a permanent magnet and what also keeps positive ions attracted to negative ions.

Now notice we mention the electric force and magnetic force in the same breath. That's because electricity and magnetism go hand in hand. If the current in a wire is strong enough it can deflect the magnetic needle of a compass. A generator of electricity consists of rotating magnets.

Electrons not only go around the nucleus, but each spins on its own axis. In doing so, every spinning electron creates a tiny magnetic field. (a magnetic field is a 3D area where the magnetic force acts) But if a neighboring electron from within the atom or from another atom spins in the opposite direction, the magnetic fields cancel out. This happens in most materials, which explains why most materials are not magnetic. But in *ferromagnetic atoms*, two things are going on:
(1) there are unpaired electrons whose magnetic fields point in the same direction and
(2) these electrons are "shielded" from other unpaired electrons in neighboring atoms. No canceling occurs.

The above two conditions lead to the formation of **domains**. A domain is a small group of about 10 000 atoms whose magnetic fields strengthen each other because they act in the same direction. Each arrow in the diagram below represents 1 domain.

<u>Example:</u> Draw the domains for each of the following:

Domains in a ferromagnetic material	Domains in a temporary magnet	Domains in a permanent magnet

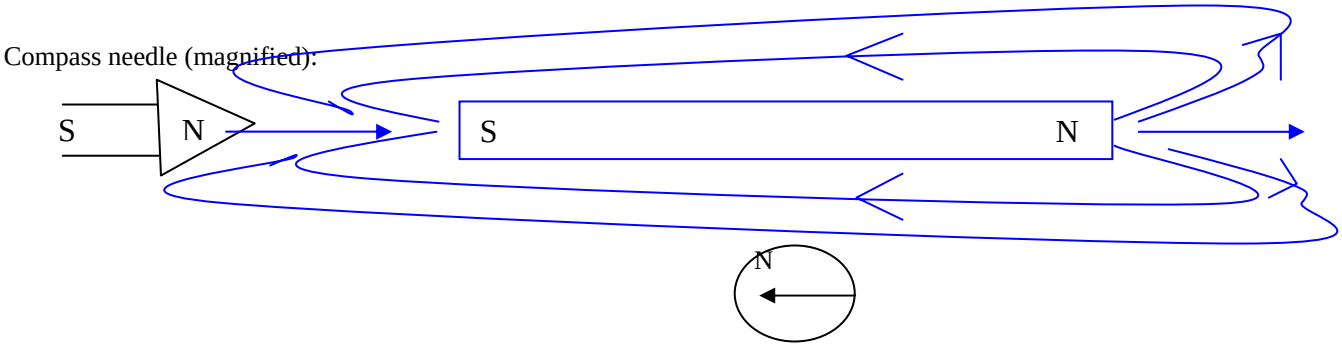
If you place a piece of iron near a magnet, the domains of the iron align themselves with the external magnetic field. The "north pole" of each domain will attract the south pole of the external magnet. The alignment is so perfect, that while a paper clip is stuck to a magnet, it can act as a temporary magnet and attract another clip. But unless there are impurities in the temporary magnet to lock the domains into place, it will lose its "power" once taken away from the permanent magnet.

Permanent magnets then have impurities like Al in Alnico magnets to lock the domains into place.

Example: How can a permanent magnet lose its magnetism?

D. Magnetic Field Lines

These are obtained by placing a compass in the vicinity of a magnet and moving it around while taking note of the compass *direction*. According to the direction of the compass we place the arrows on the magnetic lines accordingly. (Keep in mind that the compass needle itself is a magnetic needle with the pointy part being the North. North repels north which accounts for the direction they are pointing in.) If we do that around a bar magnet we obtain the following:



The more lines there are, then the stronger the magnet.

Example Draw the magnetic field lines around the following magnet. Assume it is stronger than the one drawn above.

Magnetism

Exercises

1. State whether there is repulsion, attraction or neither.

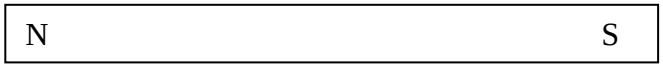
A. N and S ends of two magnets
B. S and S ends of a magnet
C. S end of magnet and ferromagnetic material
D. N end of a magnet and Cu
E. Two ferromagnetic materials; neither is a permanent or temporary magnet

2. Draw the domains, if any, for each of the following:

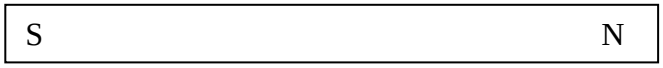
a. Cu	b. Fe not near a magnet	c. pure Fe near a magnet	d. Fe with impurities. It sticks to another iron nail.

3. a. In #2, which one was non-magnetic?
   b. a permanent magnet?
   c. A temporary magnet

4. Draw the magnetic field lines around the following bar magnet.

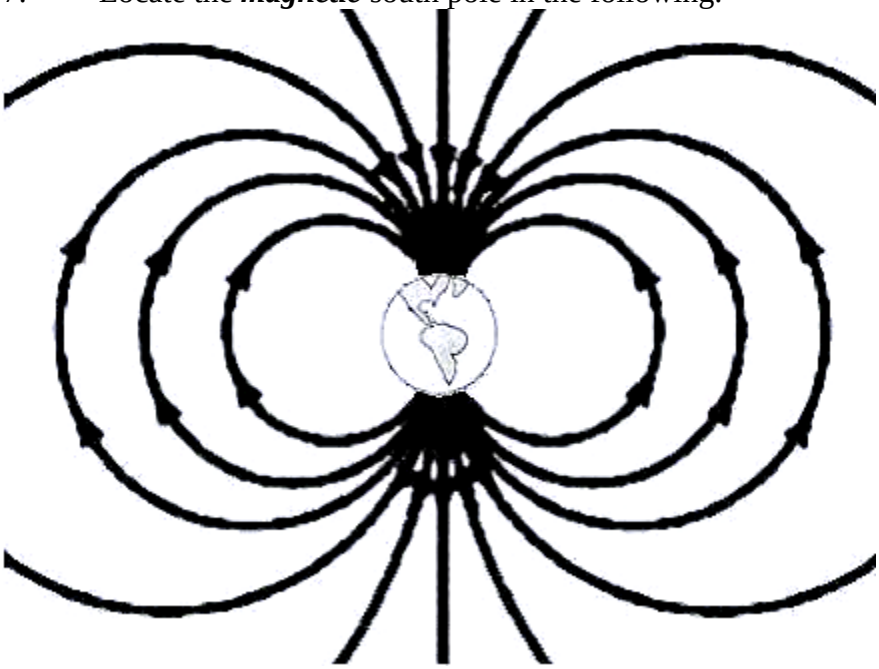


5. Now here is a stronger bar magnet. Draw the field lines again.



6. Explain how we obtain magnetic field lines. How do we know they really exist? What experiment can be performed to reveal their existence?

7. Locate the ***magnetic*** south pole in the following.



8. How can a permanent magnet be ruined? List two ways and explain what happens.

9. Neodymium magnets are actually made up of Nd, B and Fe, while many cheaper magnets consist of Al, Ni and Co.

a. Pick out the non magnetic material from each trio.
b. Explain why it is included.

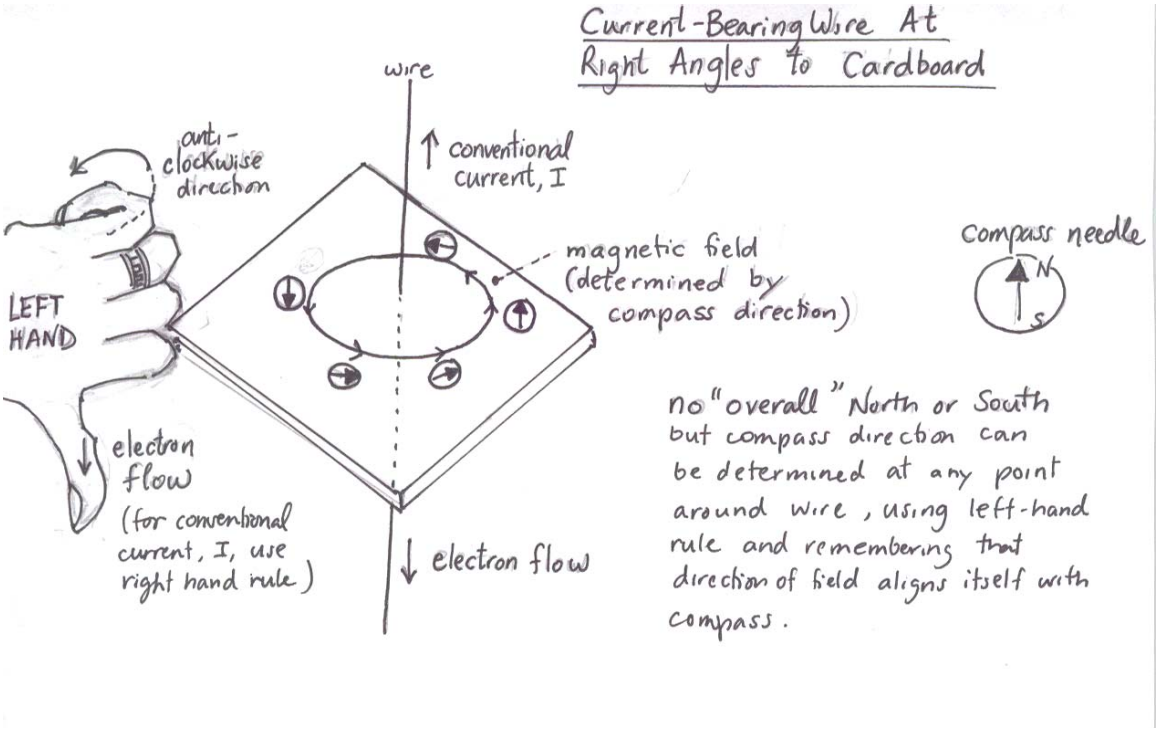
10. TRUE? Or FALSE?

a. When an electron spins around the nucleus, it creates a magnetic field._____
b. An electron spinning in a direction opposite to that of another electron will create a magnetic field pointing in the opposite direction, canceling the first field._____
c. A group of atoms with magnetic field lines that strengthen each other is known as a *domain*._____
d. Aluminum, lithium and gallium form domains_____
e. Ferromagnetic elements include iron, cobalt, nickel and neodymium.____
f. In a strong magnetic field, the domains of a ferromagnetic element get scrambled in all directions._____
g. If impurities lock domains into an aligned state, we have a permanent magnet_____
h. Lodestone, compasses and horseshoe magnets are examples of temporary magnets.

Magnetism

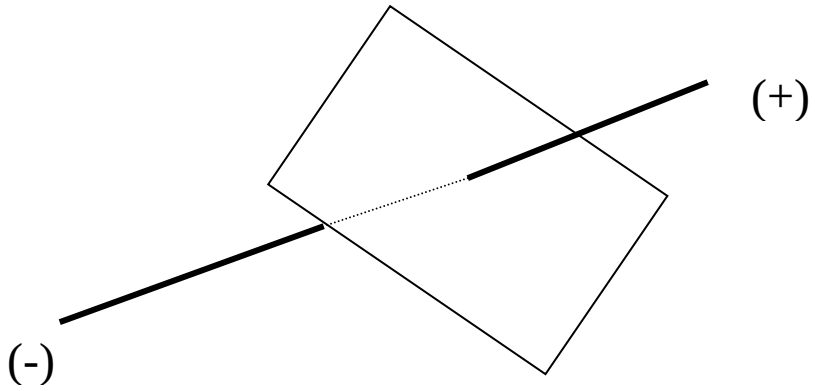
E. Magnetic Field Induced By a Current

If a strong enough current moves through a straight wire it will create a magnetic field perpendicular to the direction of the current. The **first left hand rule** reveals whether the compass direction along the circle would be clockwise or counter clockwise. Notice that the thumb points in the direction of the electron flow.

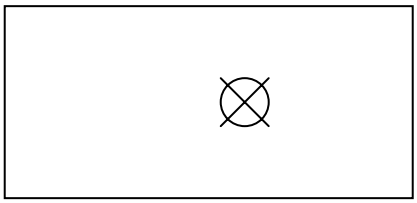


Example 1 Draw the magnetic field in each case.

a.



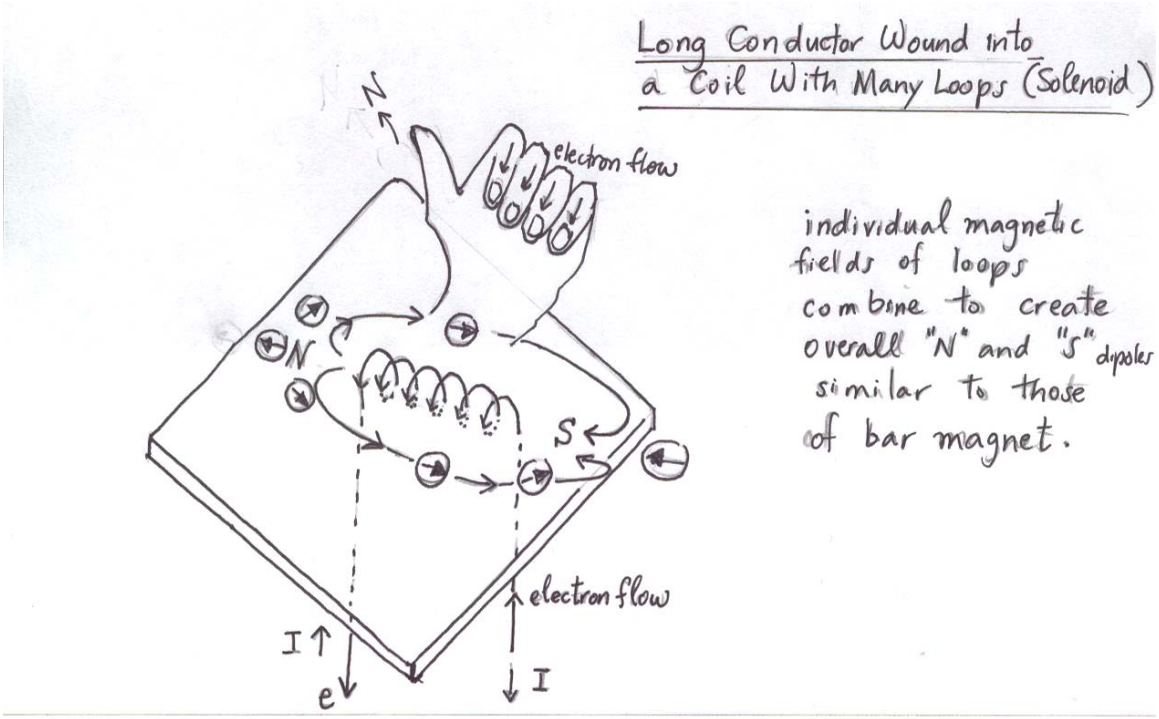
b.



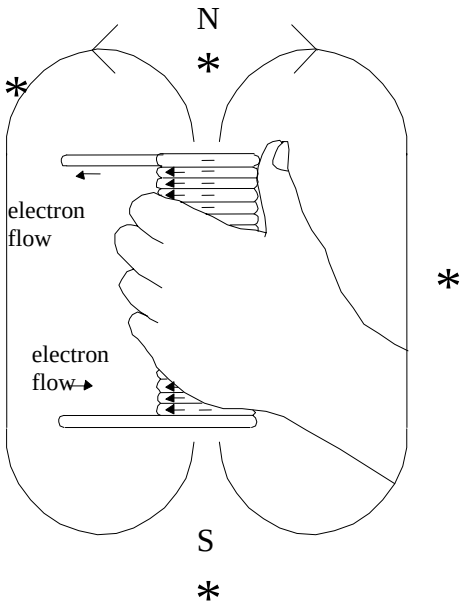
The X represents electrons moving into the paper.

F. Magnetic Field Induced By a Current in a Solenoid

When a solenoid is attached to a strong voltage source, an electromagnet can be created. Each of the circular magnetic field loops combine to create one overall field that resembles that of a bar magnet. The **second left-hand rule** reveals the North end of the magnetic field. Notice that the finger nails are pointing in the same direction as the electrons

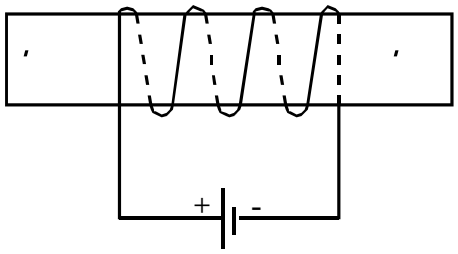


Example 1 Draw what a compass would be behave like all along the magnetic field shown in the diagram. Draw a compass at each position marked by a *

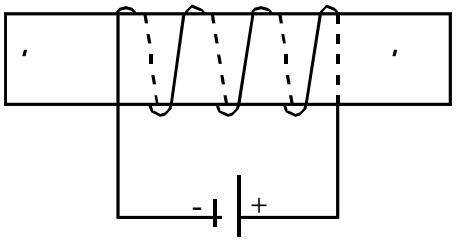


Example 2 Draw the magnetic field around the following electromagnets.

a.



b.



c. Draw a solenoid in which the wire from the (-) end first slips under teh coil, and then draw the magnetic field.

G. Factors Affecting Electromagnets

The magnet's strength increases by

(1) increasing the current
(2) increasing the number of loops
(3) and by placing a ferromagnetic material inside the coil.

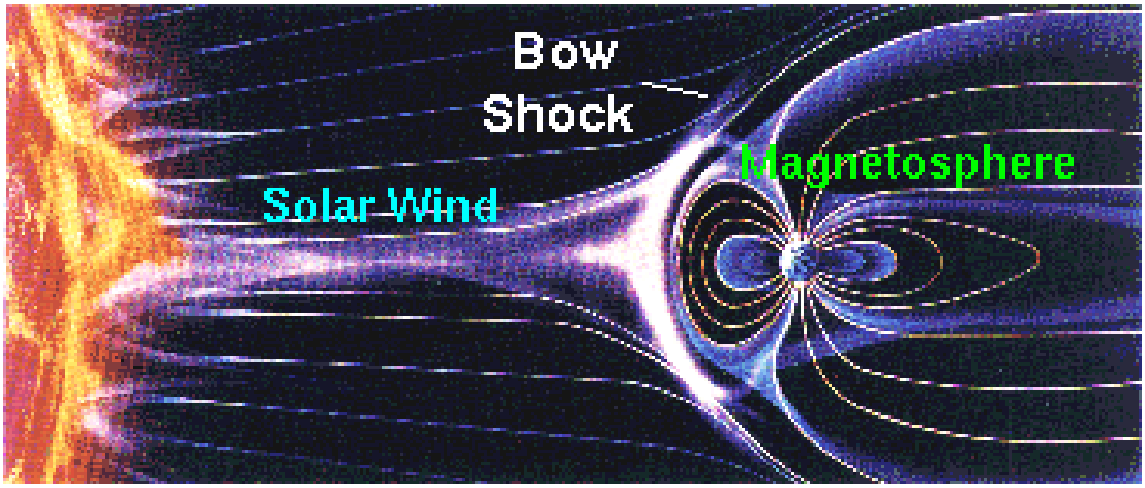
Example: Elaborate on each of the above 3 factors.

H. The Earth's Magnetic Field

The earth acts like a giant magnet. The origin of this magnetic field is not completely understood, but it could be caused by the earth's spinning liquid metallic inner core of iron and nickel.

Since the North end of a compass is attracted to an area in the northern part of the globe, technically, that part of the earth is the magnetic ***south***, even though it's in the Canadian Arctic. Similarly the magnetic ***north*** of the earth is found in Antarctica, the home of the geographic south pole.

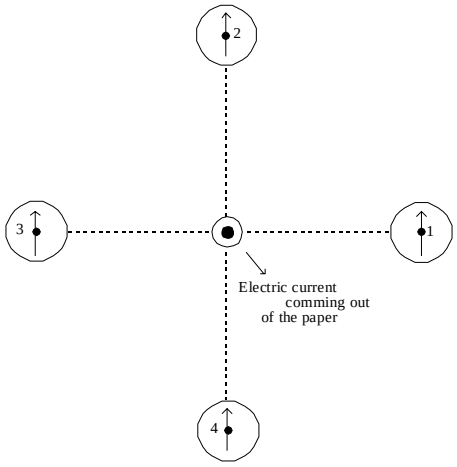
The earth's magnetic field shields us from fast-moving solar wind particles. These have been known to cause major power shortages when the sun emits large amounts of protons.



Magnetism

Exercises (exact or varied forms of ministry exam questions)

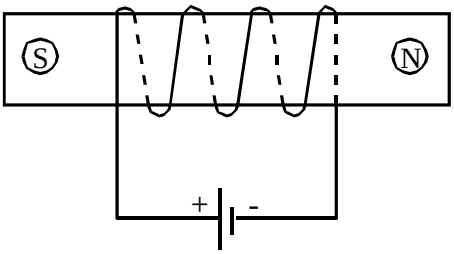
1. An electric current in a straight wire comes up through a sheet of paper. Four compasses are placed on the paper at different points around the wire.



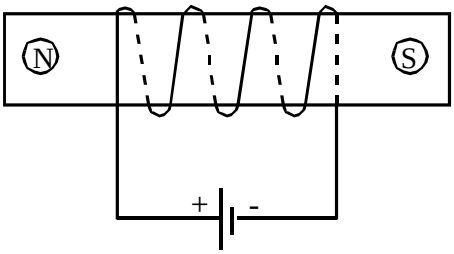
Which arrow on the diagram correctly shows the direction of the needle of the compass at the location where it is placed?

2. The four diagrams below represent electromagnets connected to the terminals of a battery.

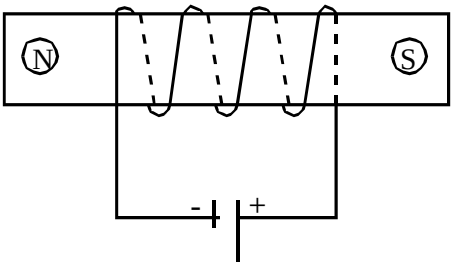
A.



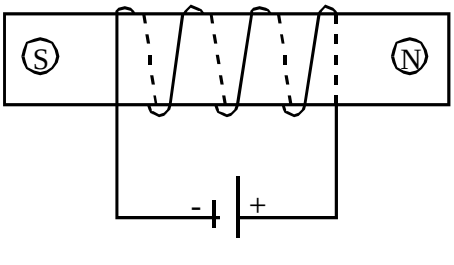
3.



B.



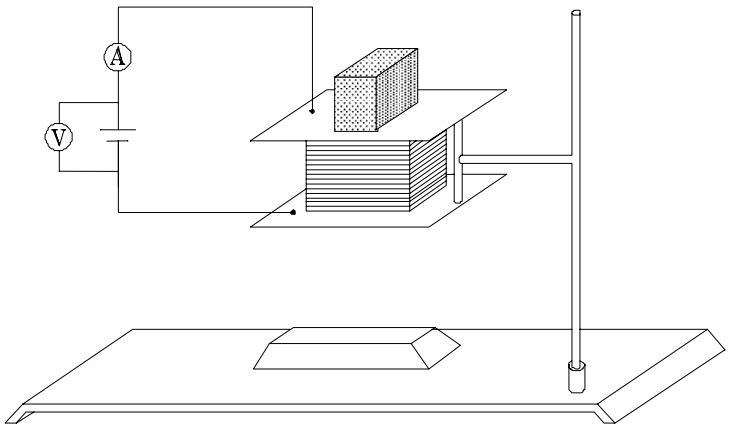
4.



a. In which diagrams are the magnetic poles of the electromagnet correctly indicated? ____ and _____

b. Redraw diagram (A) with a correct magnetic field.

3. Electro-magnets are used in industry to attract metallic objects.

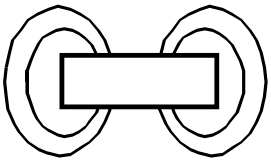


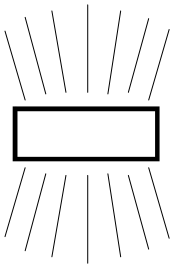
The diagram shows an electro-magnet with an iron core.

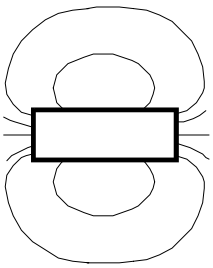
Which of the following changes would increase the strength of the electro-magnet? (yes or no)

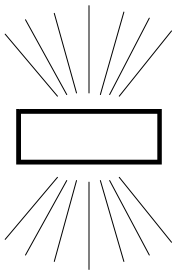
a. Increase the potential difference of the power supply.____
b. Increase the temperature of the core._____
c. Use a core made of copper instead of iron._____
d. Increase the number of turns._____

4. What does the magnetic field around a solenoid look like?

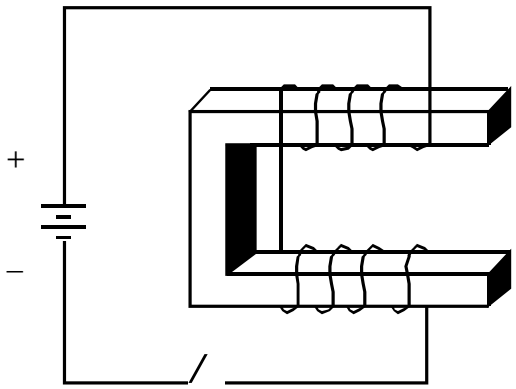
A) 

C) 

B) 

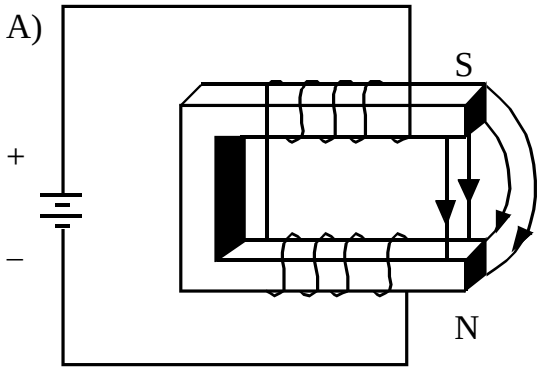
D) 

5. The magnet in the diagram is constructed from an iron core and a coil of wire connected to a battery. When the switch is turned off, an electric current circulates through the wire.

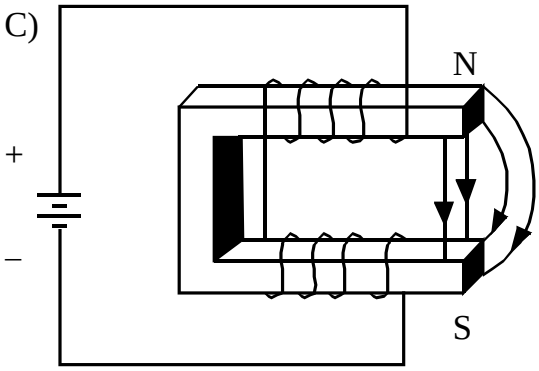


Which of the following diagrams correctly shows the magnetic field of this electromagnet?

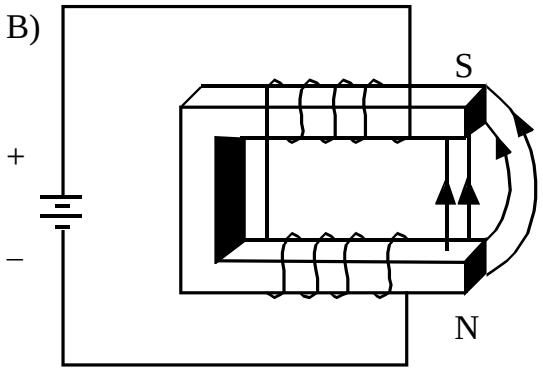
A)



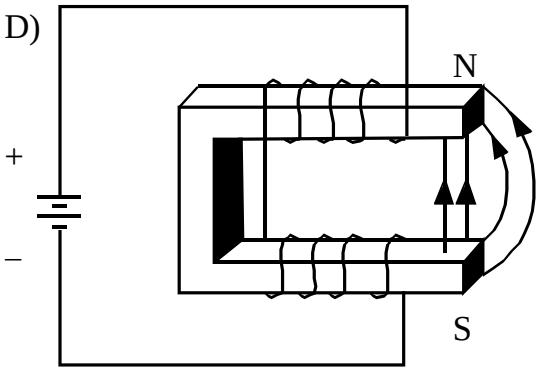
C)



B)



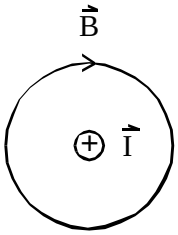
D)



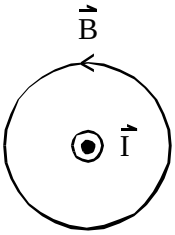
6. Study the five diagrams below.

Which diagram(s) correctly show the relationship between a magnetic field and the electric current producing it?

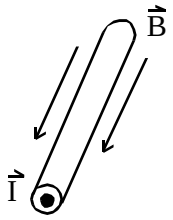
1.



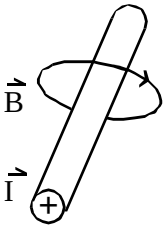
2.



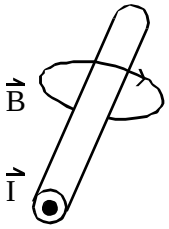
3.



4.



5.



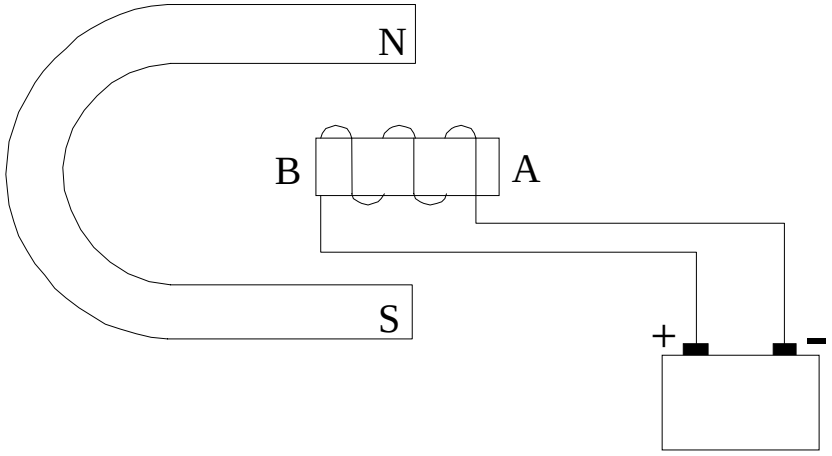
Legend :

⊙ electron flow "out of the paper"

⊕ electron flow "into the paper"

Magnetism

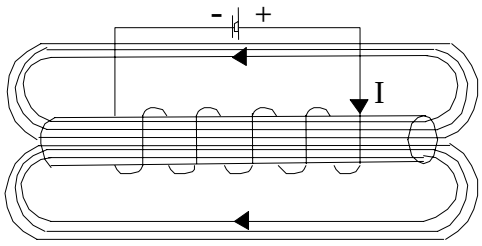
7. A solenoid connected to a battery is placed between the north pole and the south pole of a U-shaped magnet.



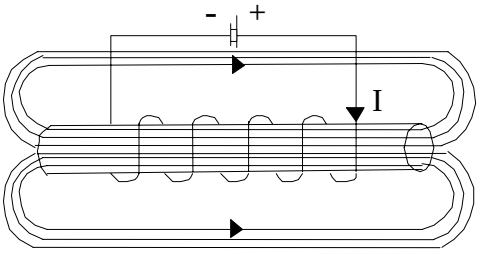
What effect does the magnet have on the solenoid?

8. Two of the following diagrams correctly represent the magnetic field created by an electric current flowing through a solenoid. *(careful: the diagrams' arrows are not representing electron flow but conventional current which ran in the opposite direction)*

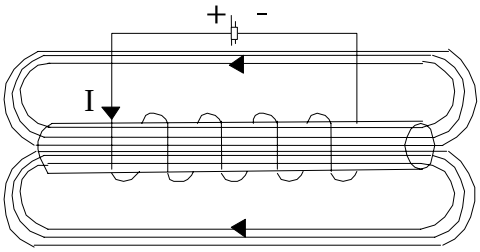
1.



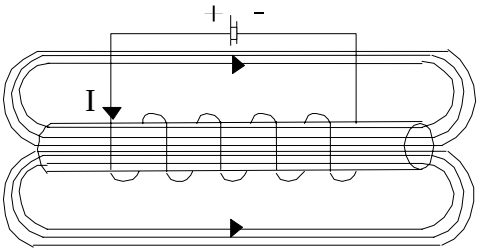
3.



2.

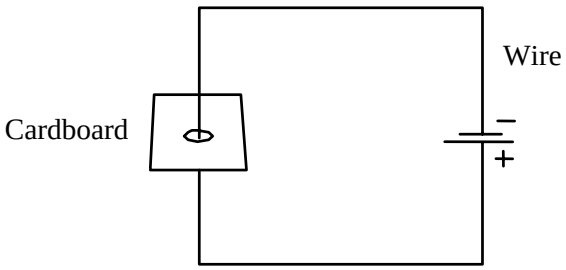


4.



Which two diagrams are they?

9. A copper wire with a current flowing through it passes through a piece of cardboard as shown in the diagram to the right.

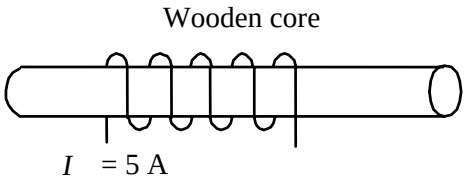


A magnetic compass is placed on the piece of cardboard near the wire. Draw where the compass would be pointing if it was placed at the

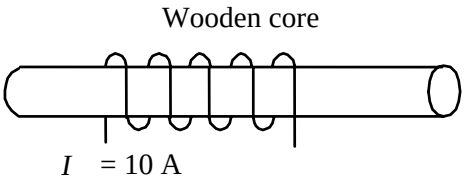
a. 12 o clock position on top of the cardboard
b. 3 o clock position on top of the cardboard

10. Which of the following electromagnets produces the strongest magnetic field?

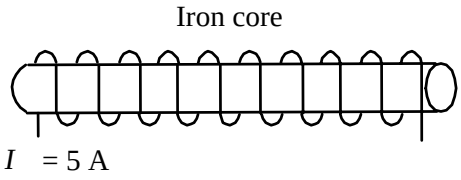
A)



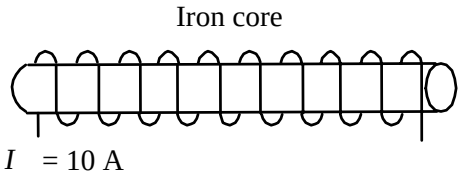
C)



B)



D)

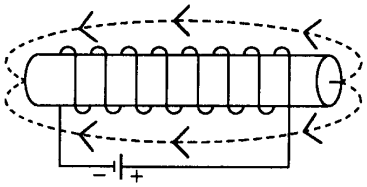


Magnetism

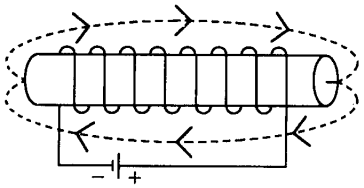
11. An electric current flows through a solenoid.

Which diagram correctly illustrates the magnetic field produced by this solenoid?

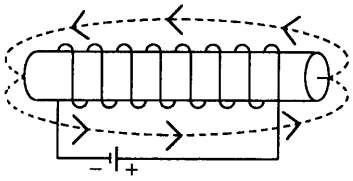
A)



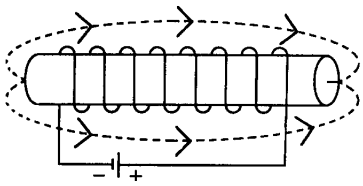
C)



B)



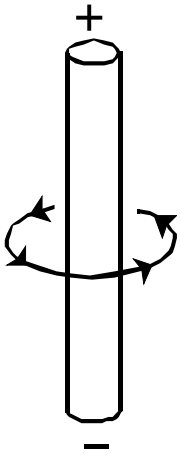
D)



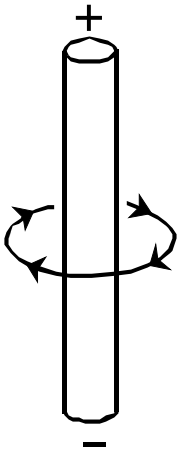
12. An electric current flows through a *straight wire* and produces a magnetic field.

Which of the following diagrams correctly represents this magnetic field?

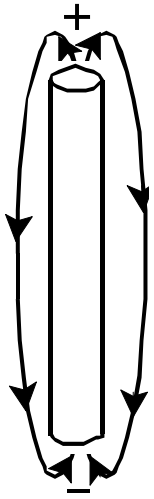
A)



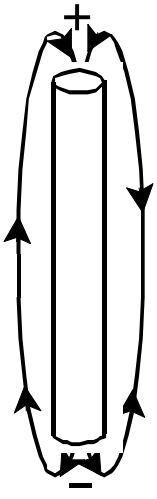
B)



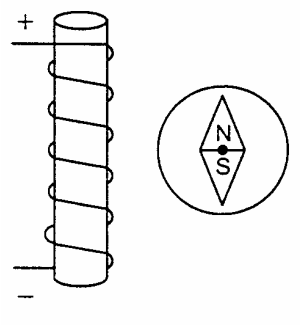
C)

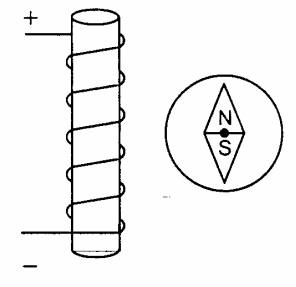


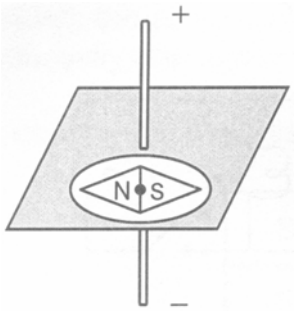
D)

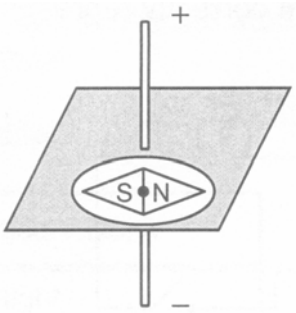


13. The diagrams below illustrate a compass placed in magnetic field.

1) 

3) 

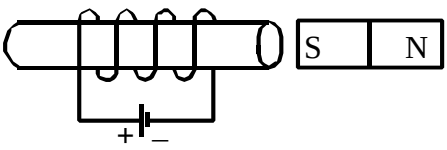
2) 

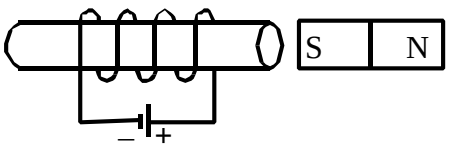
4) 

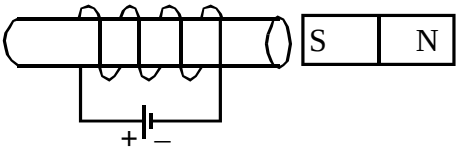
Which diagrams show the compass needle pointing in the correct direction?
____ and _____

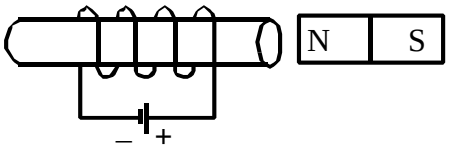
14. A bar magnet is brought close to a current-bearing solenoid.

In which one of the following situations will there be repulsion?

A) 

C) 

B) 

D) 

Magnetism

Phys Sc 430
Extra Magnetism Questions

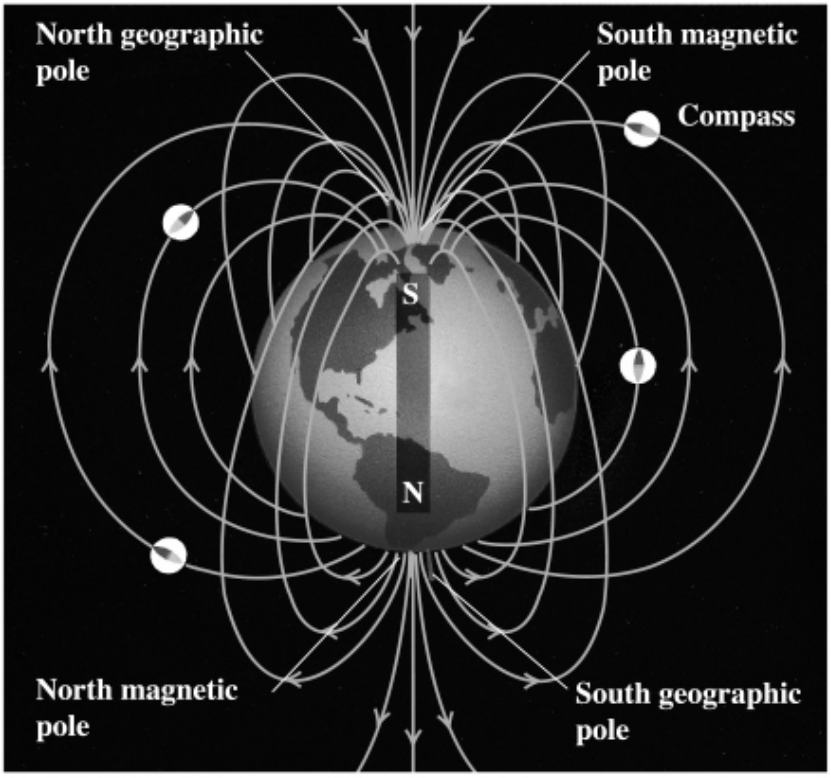
1. List three ways by which a solenoid can be turned into a powerful electromagnet.

2. If you place a pure iron bar inside a solenoid and let a strong current flow through the solenoid, will the bar remain magnetic after the power has been switched off?
Explain.

3.

If you are holding a compass in Venezuela, does your compass needle point towards Canada or towards Chile (found at the "bottom" of South America)?

4. If you are in an airplane, what country would you have to be flying over, if your special 3D compass was pointing directly to the center of the earth?



5. What is it about the interior of the earth that leads to the formation of a magnetic field, and what feature is related to why its poles reverse, on average, every 250 000 years?