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Spring 2019

Electromagnetism

Cause of Magnetism

A stationary electric charge . . . is surrounded by an electric field

A moving electric charge . . . generates a magnetic field

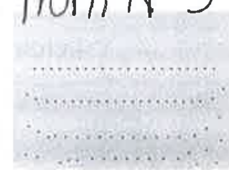
What causes magnetism? motion of charged particles - spin + rotation of electrons (magnetic moment)

$\vec{B}$ Magnetic Field runs from N - S

Non-magnetic material

Examples: wood, plastic, most metals

Reason: individual atoms cannot be made to align to produce an overall magnetic field



Non-magnetic material

Magnetic material

Examples: iron, nickel, cobalt

Reason: composed of domains that will align

Domain: region within a substance where all the magnetic fields are aligned

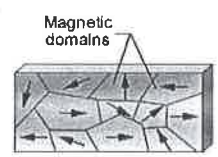
Unmagnetized magnetic material

Magnetized magnetic material

Magnetized material

Reason: many domains align to produce an overall magnetic field

Induced Magnetism: A magnetic material is magnetized by the application of an external magnetic field causing many of its magnetic domains to align.

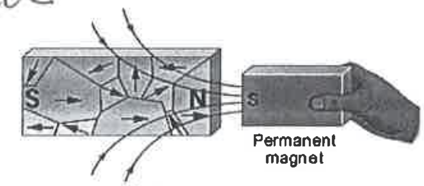


(a) Unmagnetized iron

1. What does the strength of a magnet depend on? how many domains are aligned

Hard (permanent) magnet: (ferromagnet) domains remain aligned for a long time

Soft (temporary) magnet: (paramagnet) domains quickly return to random alignment



(b) Induced magnetism

2. How does a magnet become weak or lose its magnetism?

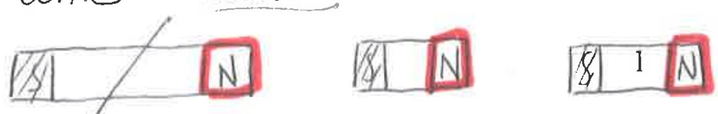
i) heat

ii) vibrations, hitting, dropping

iii) Over time, standing still - influenced by Earth's $\vec{B}$

iv) other $\vec{B}$ that magnets come in contact with

3. What will happen if you break a magnet in half?



No mono-pole exists.

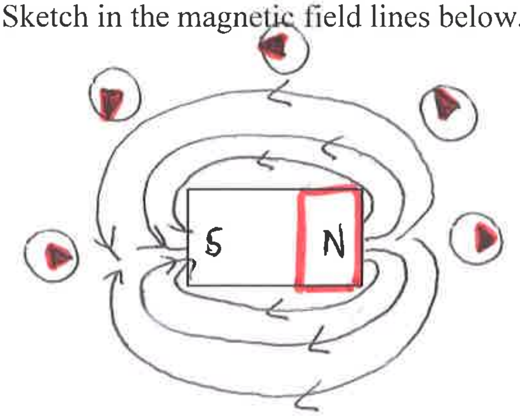
Magnetic Fields

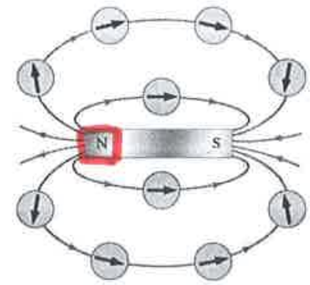
The Compass

1. small magnet that is free to rotate
2. used to map magnetic field lines N→S
3. responds to Earth's magnetic field and all other magnetic fields

Sketch in the magnetic field lines below.

a)



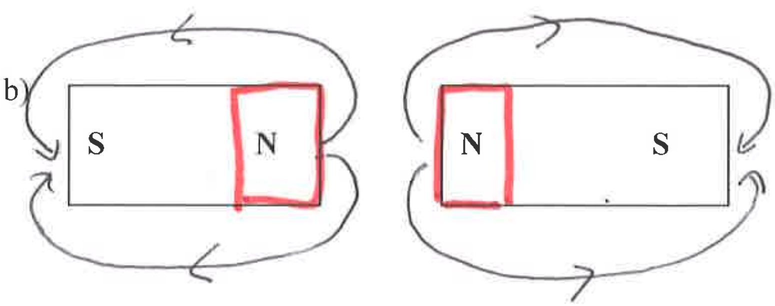


Mapping magnetic field lines using a compass

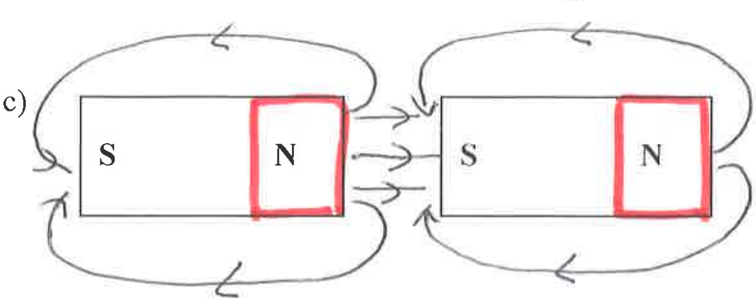
Magnetic Field Lines

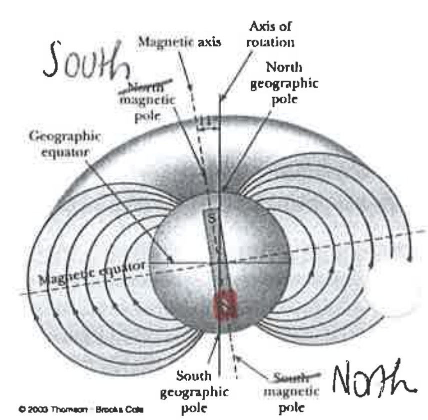
1. Field lines never cross.
2. Field lines run N→S
3. Direction of $\vec{B}$ is tangent to field lines.
4. Test field direction with a small compass.
5. $\vec{B}$ is most intense where field lines are most dense.

b)



c)





Why does the Earth have a magnetic field?

Spinning of iron rich molten outer core

~~The north magnetic pole of the Earth acts like~~ . . .

The Earth's geographic North pole is the magnetic South pole.

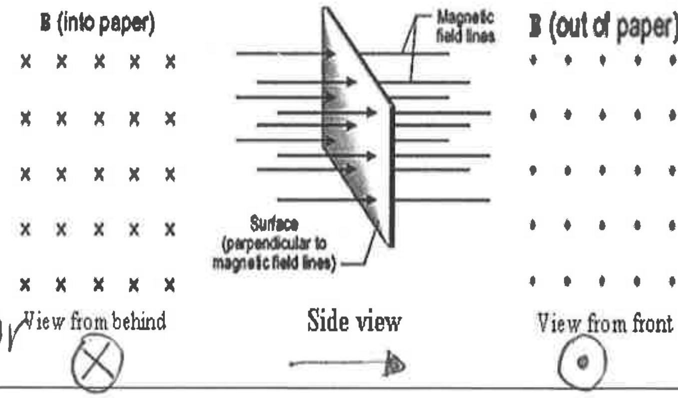
Field Strengths: units: $\vec{F}_g = \frac{N}{Kg}$ $\vec{E} = \frac{N}{C}$ $\vec{B} = \frac{N}{C \cdot m/s}$ (moving charge)

Magnetic Fields in Three Dimensions

Magnetic Flux: lines of magnetic field

Magnetic Field Strength, Magnetic Field Intensity, Magnetic Flux Density: (all same terms)
strength of magnetic field measured by density of field lines

Symbol: $\vec{B}$ Units: $\frac{N}{A \cdot m} = \frac{N}{C \cdot \frac{m}{s}}$ [T] tesla Type: vector



Electromagnetism

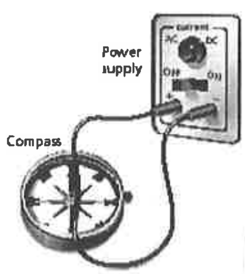
moving electric charge

Hans Christian Oersted
(Denmark, 1777 – 1851)

1. In 1819, Danish physicist and chemist Hans Christian Oersted was the first to notice
a connection between electricity + magnetism
2. He noticed that
a compass needle deflected when held near a wire with current running through it
3. This demonstrated the principle that
a current generates its own magnetic field

Not only was this astounding and unexpected, but further investigation showed that the magnetic field produced by the current in the wire had an unusual shape.

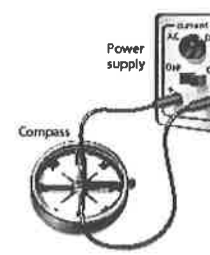
Current off



Oersted placed a compass beneath a wire with no current.

Direction of Compass Needle:
parallel to Earth's $\vec{B}$ + parallel to wire

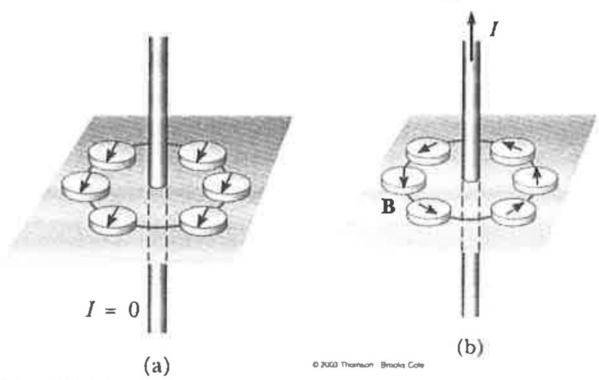
Current on



When the current was turned on, the compass needle deflected.

Direction of Compass Needle:
deflected the compass needle 90° or ⊥ to Earth's $\vec{B}$ and ⊥ to the wire

Iron filings sprinkled around a wire with current show a very different magnetic field from those of bar magnets



Current off **Current on**

Direction of Compass Needle when current is on:
tangent to a circle around the wire

Direction of magnetic field around wire:
right-hand thumb in direction of current then fingers are circled in direction of $\vec{B}$