

L 27 Electricity & Magnetism [5]

Magnetism

- Magnets
 - permanent magnets
 - electromagnets
 - the Earth's magnetic field
- magnetic forces
- applications

1

Magnetism

- two sources of magnetism
 - permanent magnets
 - Electromagnets (currents in wires)
- the earth's magnetic field
 - how does a compass work
 - the north pole is really a south pole!
 - Van Allen radiation belts

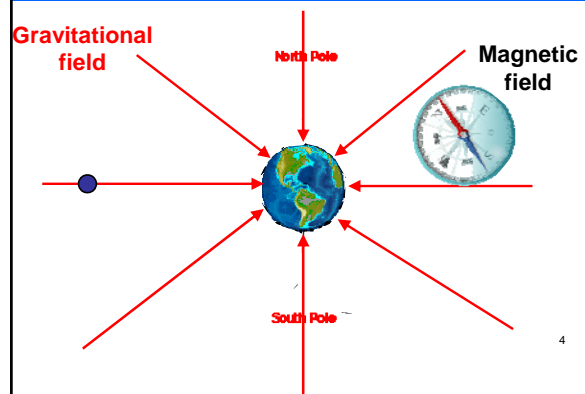
2

Permanent magnetism

- certain minerals (magnetite, Fe_3O_4) are naturally magnetic
- These minerals will attract bits of iron
- a magnet produces a magnetic field in the space around it, just like the Sun has a gravitational field that holds the planets in their orbits
- the magnetic field can be visualized with iron filings

3

Earth's magnetic and gravitational force fields



4

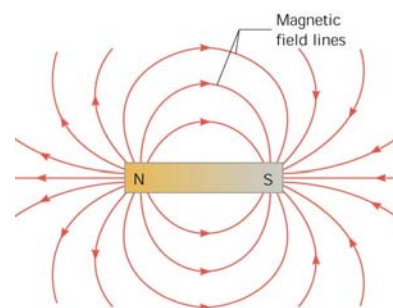
Permanent magnets

- Are made from alloys of some of the rare earth elements like neodymium, samarium, and cobalt.
- Always have a north and a south pole
- like poles repel and unlike poles attract
- if you break a magnet in half you get 2 magnets → cannot have just a north or just a south pole



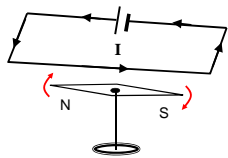
5

Magnetic field of a bar magnet



6

ELECTROMAGNETISM



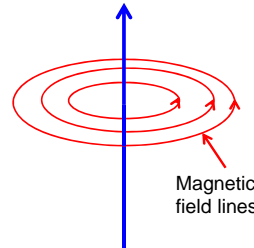
Hans Christian Oersted in 1820 observed that current flowing in a wire near a compass caused the compass needle to move.

André-Marie Ampère in 1820, discovered the law relating the magnetic field and the current.

7

Magnetic field of a wire

Long straight wire with current I

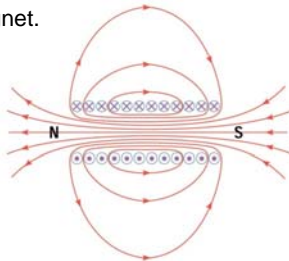
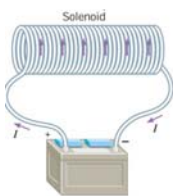


- The magnetic field lines form a set of concentric circles surrounding the wire
- The magnetic field is stronger close to the wire, and gets weaker away from the wire

8

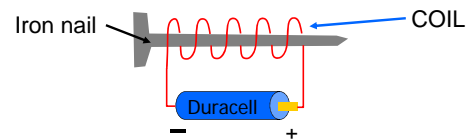
Magnetic field of a solenoid

A solenoid is a set of circular coils wound on a cylindrical form. The field is similar to the field of a bar magnet.



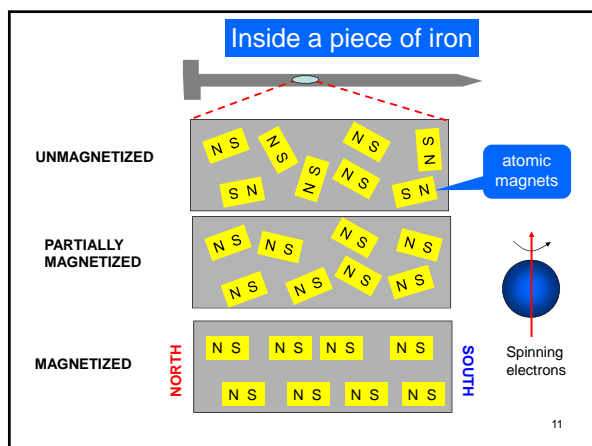
9

Homemade magnets



You can think of the nail as a collection of little magnets that are randomly aligned. The magnetic field of the coil aligns these little magnets giving a larger field than that of the coil alone. We say that the nail becomes "magnetized", but the effect is not permanent.

10



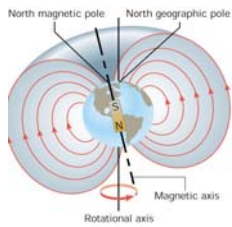
11

Magnetic materials

- some materials are naturally magnetic or can be magnetized and retain their magnetism → **ferromagnetic materials**
- other materials (iron) can be magnetized temporarily by placing them near magnets
- some materials have essentially no magnetic properties → copper, aluminum, plastics...
- heat can destroy magnetism (Curie effect)
- Permanent magnetism is due to the **electron's spin**

12

The earth is a big magnet

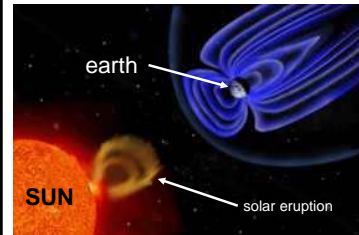


The magnetic north pole is inclined about 14° from the geographic north pole, or by about 600 miles.

- The earth's north geographic pole is the south pole of a big magnet.
- A compass needle is attracted to the earth's north geographic pole
- The earth's magnetism is due to currents flowing in its molten core (not entirely understood!)

13

Sun – Earth Connection: space weather



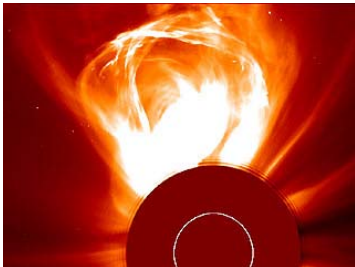
Space weather can have a large effect on communications, and it can cause damage to orbiting satellites and the power grid.



Northern Lights (aurora)

14

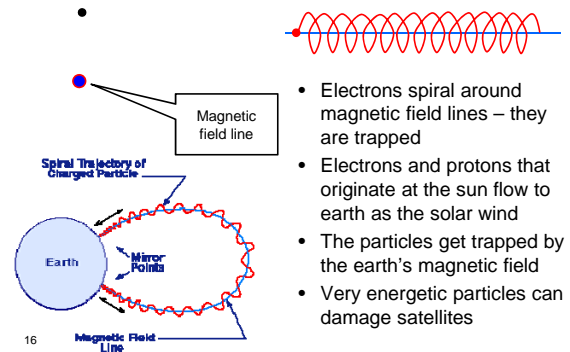
Solar eruptions – CMEs (solar coronal mass ejections)



CMEs put out roughly 10^{12} kg of mass

15

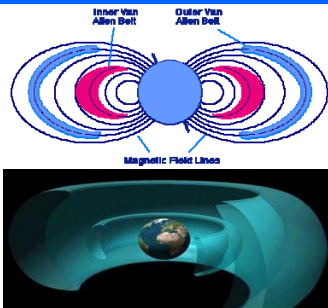
Charges stay on magnetic field lines



16

Van Allen Radiation Belts

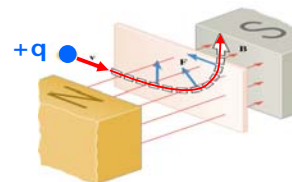
2 regions around the earth where charged particles are trapped in the earth's Magnetic field



17

Magnetic forces

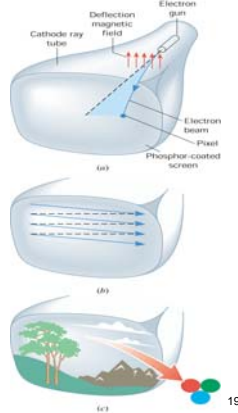
- Magnetic fields exert sideways forces on charges
- A charge is turned around by the magnetic force
- There is NO magnetic force if the charge is not moving



18

Application:

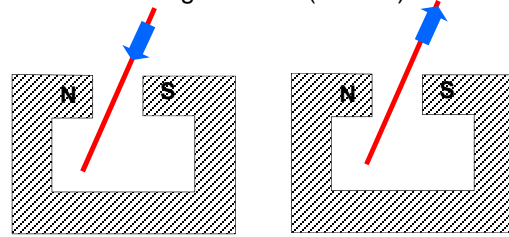
Magnetic deflection of electrons in a TV tube.



19

Magnetic forces on wires

Magnetic fields exert forces on the electrons moving in a wire (current)



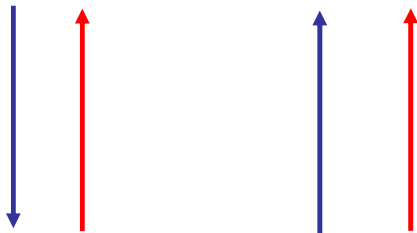
Wire pushed OUT

Wire pulled IN

20

Forces on current carrying wires

The current in one wire makes a magnetic field that exerts a magnetic force on the current in the other wire

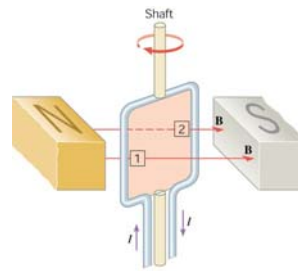


Opposites repel

Likes attract

21

Torque on a current loop in a magnetic field

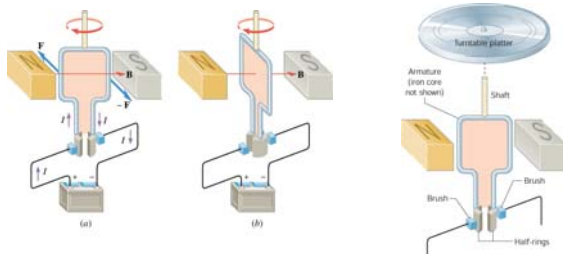


A loop of wire (coil) carrying current experiences a torque when placed in a magnetic field.

The torque makes the loop rotate.

22

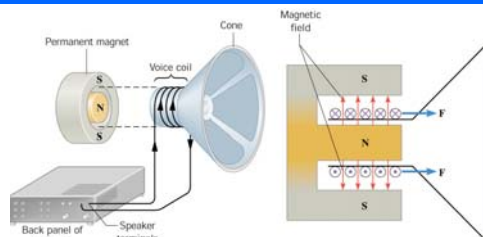
Application: The electric motor



When a current is present in a coil, it experiences a torque and rotates.

23

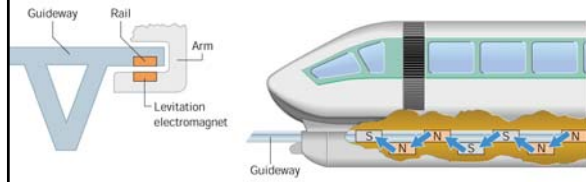
Application: Magnetic force in a speaker



The force between the permanent magnet and the voice coil moves the speaker cone

24

Application: MAGLEV Trains



Magnetic levitation can be used to keep the cars on the track, and to propel them without touching

25