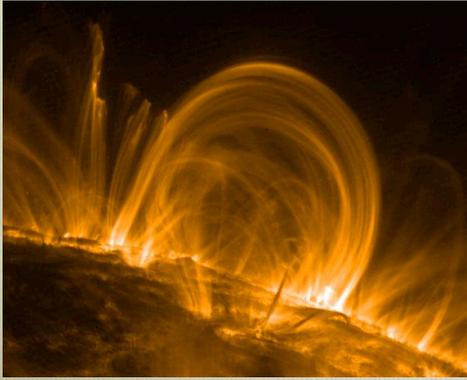


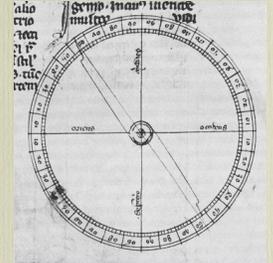
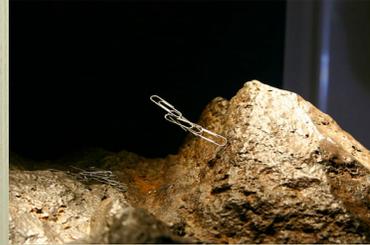
Magnetism

Peter Watson



Coronal loop in sun (NASA)

- First observed as "lodestones": lumps of magnetic iron-ore (magnetite, or Fe_3O_4).
- Can be suspended from a string and will point North. Used by Vikings.
- Letter on the Magnet by Petrus Peregrinus written in 1269.



Wikisource

The good news

- Much easier to study than electrostatics (even lodestones give strong fields)

The bad news

- Much harder to understand than electrostatics (no elementary charge like the electron)

Text

Basic Observations

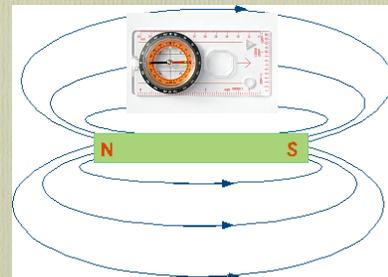
- Some materials act as if they contain magnetic charges, or poles.
- Like poles (NN, SS) repel, unlike (NS, SN) attract
- Iron filings will map out "magnetic field"



Text

This is how we can see the field

- Can map out magnetic field with a compass

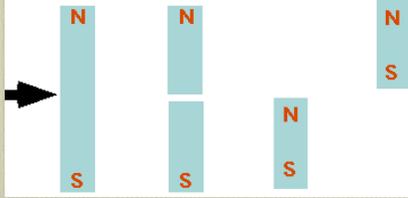


PW, Wikipedia

Text

Basic Observations

- Poles cannot be separated
- You just get smaller magnets



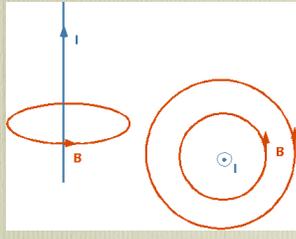
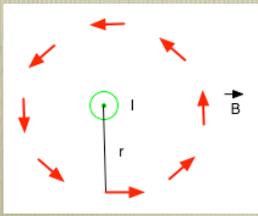
Text

Basic Observations

- Electric currents produce mag. fields
- Magnetic fields produce forces on currents

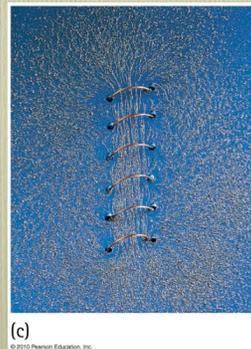
Currents can produce a magnetic field

- mag field is circle round wire
- Direction given by right-hand rule
- thumb along current, fingers go in direction of field



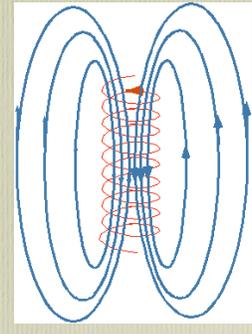
PW

- Can wrap wire to make a helix (solenoid)
- Gives field just like bar magnet
- almost constant in centre



(c)

© 2010 Pearson Education, Inc.



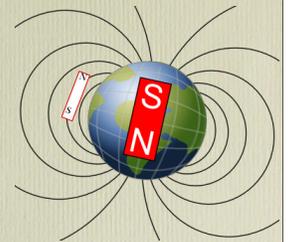
PW

- Unit is the Tesla (T) though Gauss are still common $1\text{G} = 0.0001\text{T}$
- Smallest detectable field $\sim 10^{-12}\text{G}$
- Fields produced by currents in brain $\sim 10^{-9}\text{G}$
- Earth's field $\sim 1/2\text{G}$
- Permanent magnets $\sim 1000\text{G}$
- MRI machines $\sim 50000\text{G} = 5\text{T}$

Text

Earth's Magnetic Field

- Acts as if giant dipole is embedded in earth
- Angle and direction vary over earth's surface
- Compass is short mag dipole.
- North pole on magnet is attracted to a south pole
- so the magnetic pole in the north of Canada is a south magnetic pole.....



Wikisource

Note many animals exploit this

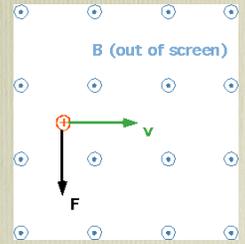
- Magnetotactic bacteria: can orientate themselves in local magnetic field so as to find sediment.
- These are ferrite crystals
- Also (maybe) Homing pigeons
- Honeybees
- Sea turtles
- Dolphins



Text

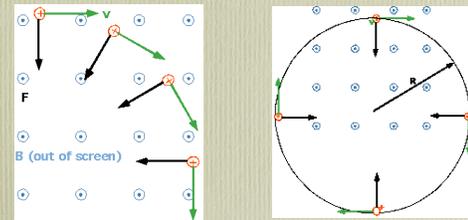
Force on a single Particle

- No force if charge $q = 0$
- No force if vel. of charge $v = 0$
- Force perpendicular to field B
- Force perpendicular to velocity v



PW

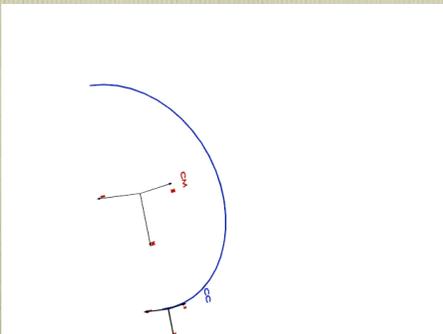
This is how it works in practice



Text

PW

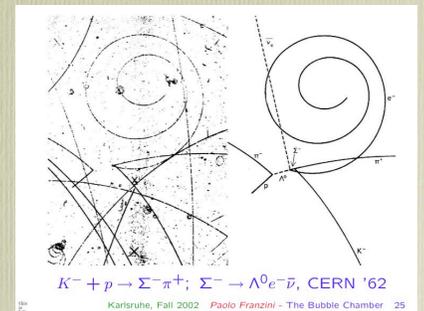
Or if it is moving, can go in helix around the field



By Juan Barandiaran Balzola

Used to analyse particle properties

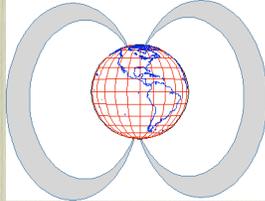
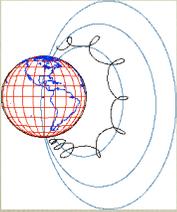
- Bubble chamber allows tracking of charged particles
- liquid hydrogen will "boil" if hit by a charged particle
- mag field bends them



CERN

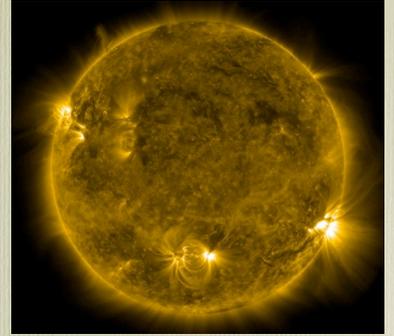
Van Allen belts

- Electrons (and Protons) reflected from North to South Pole
- Hence “belts” of particles form near earth of particles.



PW

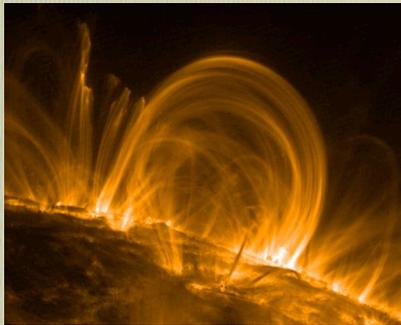
- Sunspots are magnetic storms on the sun
- Occur in pairs linked to N & S poles of mag field



Text

Close up view:

- magnetic field is traced out by hot plasma
- Loop of hot gas extends into the corona:
- About 50000 km high.



Text

1. Casey Corrigan

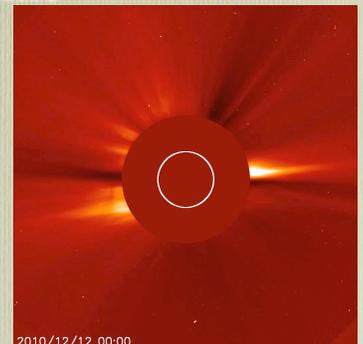
1. What is the Aurora borealis?
2. Why does it occur? Does it only occur in arctic regions? Can it happen in other areas?
3. I'm sure the professor would be able to explain it.

1. Julieth Beltran

1. A question that I think would be really interesting to answer in class is: “How are the colors in the Aurora Borealis created and why does it occur at the poles?”
2. The Aurora Borealis has always been of my interest, and this past week I just thought it would be nice to know the reason behind such an amazing show.
3. The question is not too hard but I consider that this is not something everyone has knowledge

But magnetic fields are dynamic

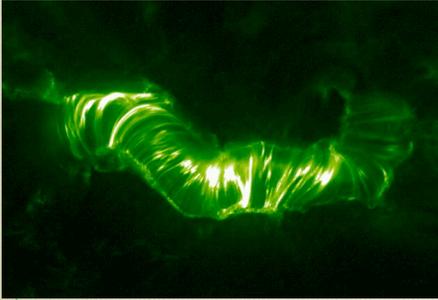
- They can expand and squirt out gases
- or collapse and spray out high energy particles
- Solar & Heliospheric Observatory



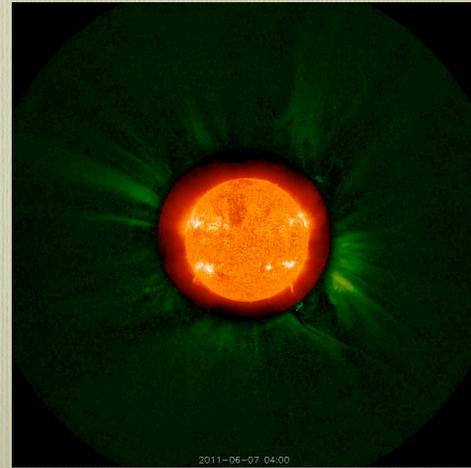
2010/12/12 00:00

SOHO

- This is a tube of magnetic flux on the sun: it confines particles.
- When it collapses, it squirts out the particles (false colour)



Text



2011-06-07 04:00

Text

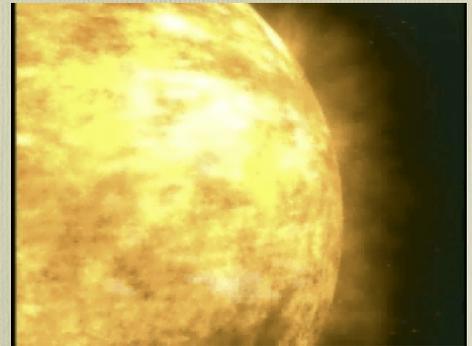
Which travel towards the earth



- So particles get filtered down to the poles

Text

Like this



Text

And become auroras



Text

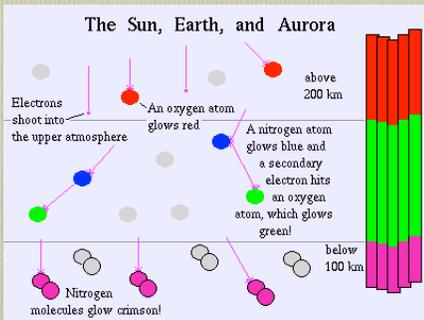
SNO picture

Which we can even see from space!



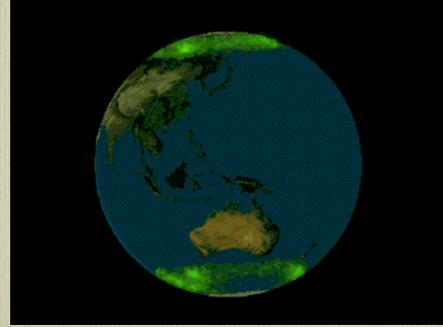
Text

The colours:



University of Alaska
Geophysical Institute

- Note we always get simultaneous aurora at N & S poles



Text

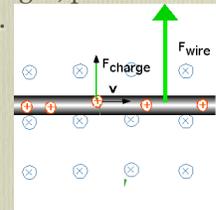
- And we can even see them on other planets



Text

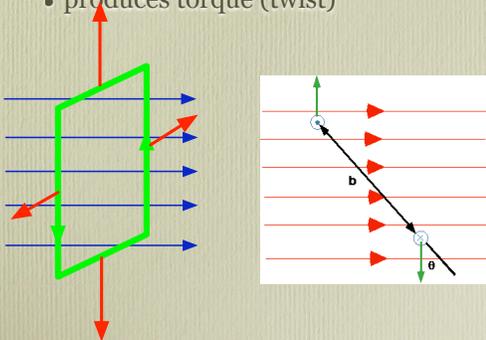
Force on Wire

- How does the force on a charge turn into a force on a wire?
- Each charged particle will feel force due to mag field, but charges are confined to wire, so force is applied to wire.
- Force = Field x current x length, provided everything is at right angles).



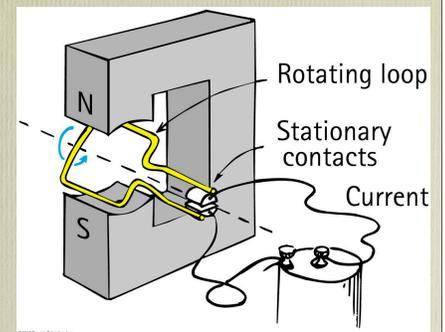
PW

- Usually more interested in loop of current
- Forces on all 4 sides
- produces torque (twist)



Text

- Becomes electric motor



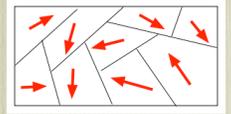
Text

This is a very simple motor

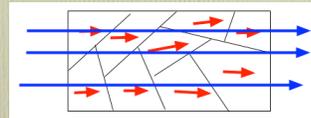
Text

Permanent Magnets

- Iron is normally non-magnetic
- Consists of randomly oriented "domains"



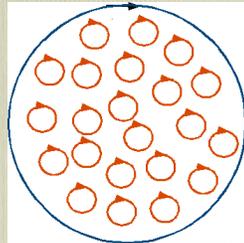
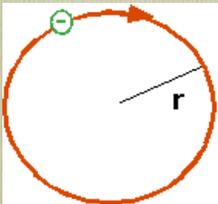
These can be lined up by an external field



Text

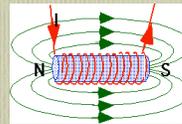
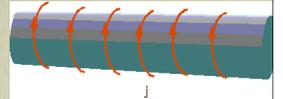
Where does the magnetism come from?

- Ampere argued that if there were no magnetic poles, there would have to be current loops in atoms
- and these would add up



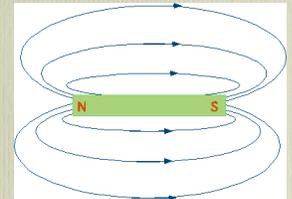
Text

- to give a surface current



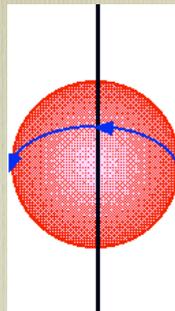
- to give a fields like a solenoid

Which is what we see



PW

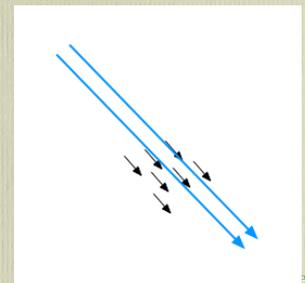
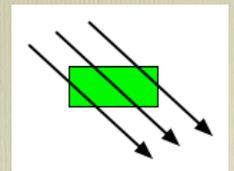
- Currents in atoms are actually Electron spins
- A model is a spinning ball of negative charge, so acts as tiny magnet
- Electron in a magnetic field can spin up or down: i.e. aligned or opposing the field



Text

Magnetism

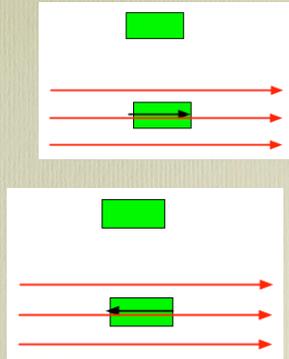
- In practice materials divide into 3:
- Ferromagnets: field exists in absence of external field
- Electron spins are aligned



ext

Magnetism

- Paramagnetic: increases external field
- Diamagnetic: oppose an external magnetic field
- e.g. water is (weakly) diamagnetic



Text

The 2000 Ig Nobel Prize Winners

- **PHYSICS:** [Andre Geim](#) of the University of Nijmegen (the Netherlands) and [Sir Michael Berry](#) of Bristol University (UK), for using [magnets](#) to [levitate a frog](#).



Text

Nobel Prize for Physics 2007



Albert Fert



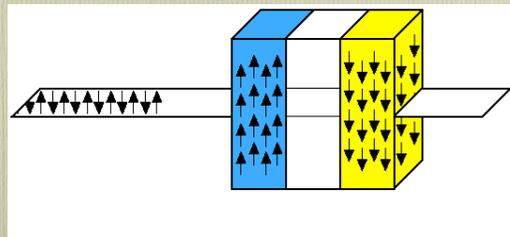
Peter Grünberg

Giant Magneto-Resistance: Why you own it!

Text

Sandwich magnetic and non-magnetic materials together.

- Resistivity changes abruptly (giantly) according to alignment of successive layers
- So current changes very rapidly



Text

Which can be used to store information at huge density on a hard drive

- Ipod would be impossible without it (B\$1.9 in 2007!)



Text

Oh, and Peter Grünberg worked at Carleton ([in chemistry](#)) for 3 years.

Text