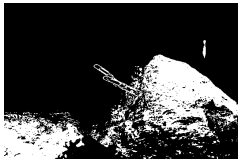
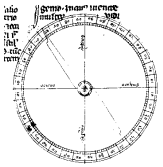
Magnetism

Peter Watson

- 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.





The good news

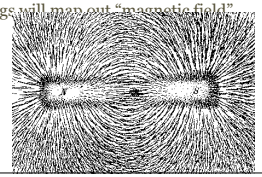
- Much easier to study than electrostatics (even lodestones give strong fields)

The bad news

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

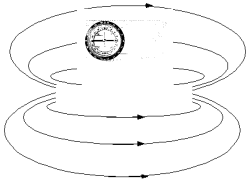
Basic Observations

- 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"



This is how we can see the field

- Can map out magnetic field with a compass
-



Basic Observations

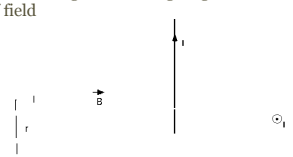
- Poles cannot be separated
- You just get smaller magnets

Basic Observations

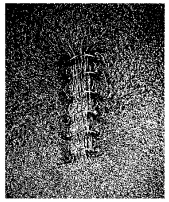
- Electric currents produce mag. fields
- Magnetic fields produce forces on currents

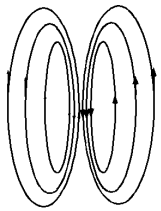
Currents can produce a magnetic field

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



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

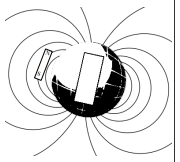




- Unit is the Tesla (T) though Gauss are still common 1G = 0.0001T
- Smallest detectable field ~ 10^{-12} G
- Fields produced by currents in brain ~ 10^{-9} G
- Earths field ~ 1/2 G
- Permanent magnets ~ 1000 G
- MRI machines ~ 50000 G = 5 T

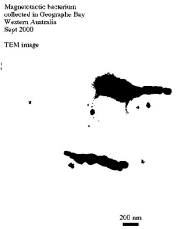
Earth's Magnetic Field

- 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.....



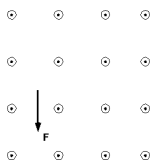
Note many animals exploit this

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



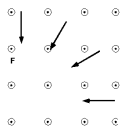
Force on a single Particle

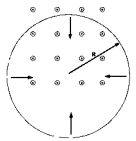
- No force if charge q = 0
- No force if vel. of charge v = 0
- Force perpendicular to field B
- Force perpendicular to velocity v



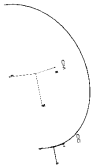
This is how it works in practice

Means particle can be trapped into a circle



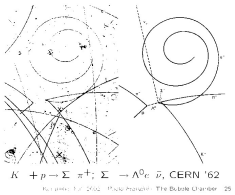


Or if it is moving, can go in helix around the field



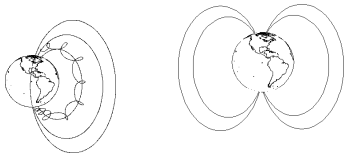
Used to analyse particle properties

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

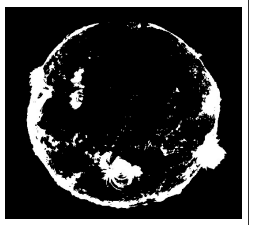


Van Allen belts

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



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



Close up view:

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

1. Casey Corrigall

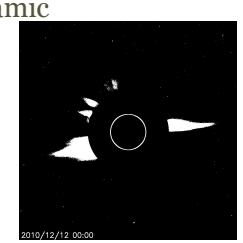
1. What is the Aurora borealis?
2. Why does it occur? Does it only occur in artic regions? Can it happen in other areas?
3. I'm sure the professor would be able to explain it.

1. Julieth Beltran

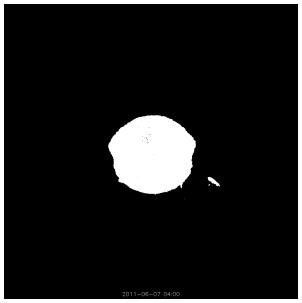
1. A question that I think would be really interesting to answer in class is:"How are the colors in the Aurora Borealis created and why does it occur at the poles?"
2. The Aurora Borealis has always been of my interest, and this past week I just thought it would be nice to know the reason behind such an amazing show.
3. The question in 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



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

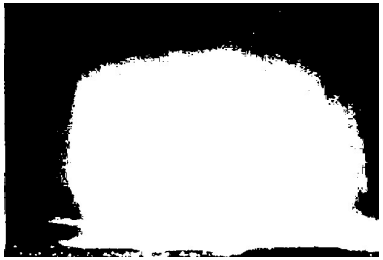


Which travel towards the earth

- So particles get filtered down to the poles

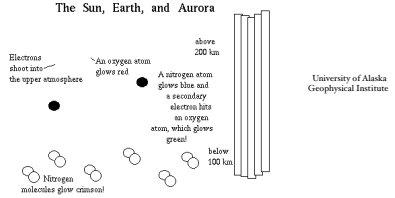
Like this

And become auroras



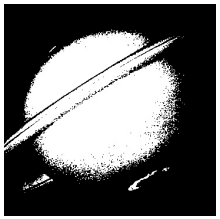
Which we can even see from space!

The colours:



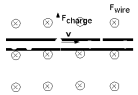
- Note we always get simultaneous aurora at N & S poles

- And we can even see them on other planets

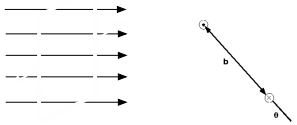


Force on Wire

- 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).



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



- Becomes electric motor
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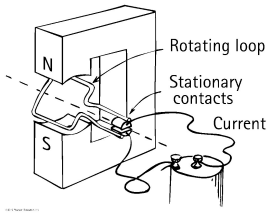
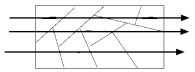


This is a very simple motor

Permanent Magnets

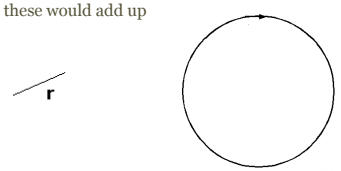
- Iron is normally non-magnetic
- Consists of randomly oriented "domains"

These can be lined up by an external field

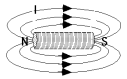


Where does the magnetism come from?

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

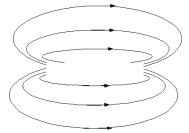


- to give a surface current

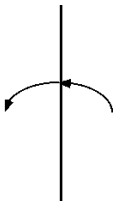


- to give a fields like a solenoid

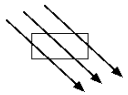
Which is what we see



- 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



Magnetism



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

Magnetism

- Paramagnetic: increases external field

- Diamagnetic: oppose an external magnetic field

- e.g. water is (weakly) diamagnetic

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.

Nobel Prize for Physics 2007

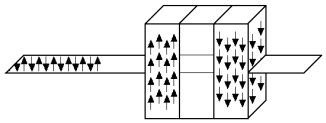
Albert Fert

Peter Grünberg

Giant Magneto-Resistance: Why you own it!

Sandwich magnetic and non-magnetic materials together.

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



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!)

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