PURDUE UNIVERSITY DEPARTMENT OF PHYSICS

Physics 21900

General Physics II

Electricity, Magnetism and Optics

Lecture 10 – Chapter 17.1-2

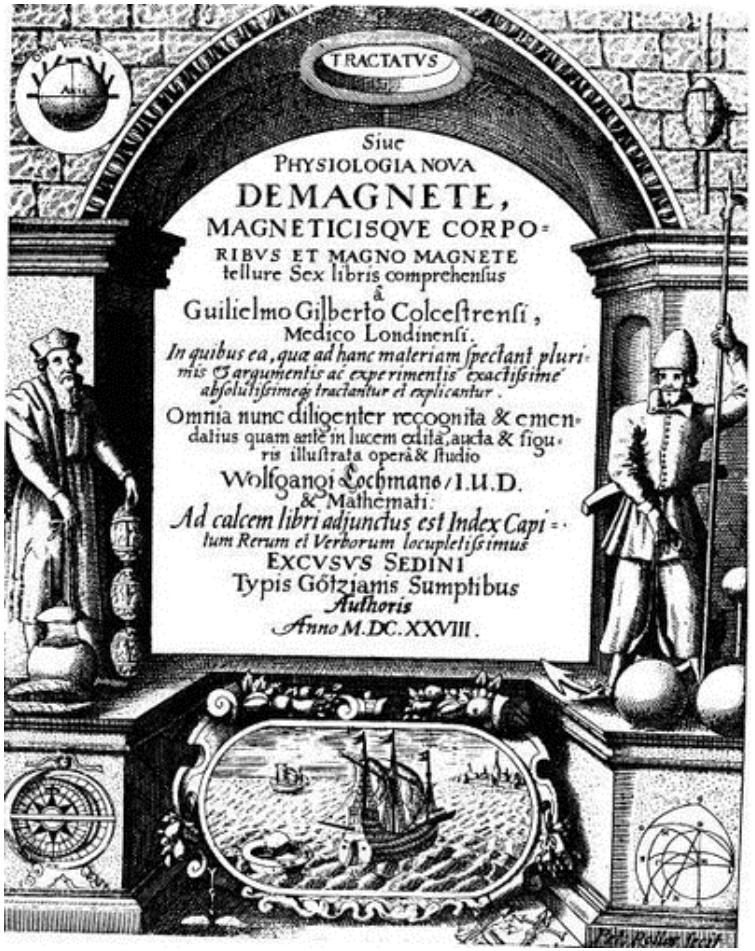
Introduction to Magnetism

Fall 2015 Semester

Prof. Matthew Jones

Magnetism

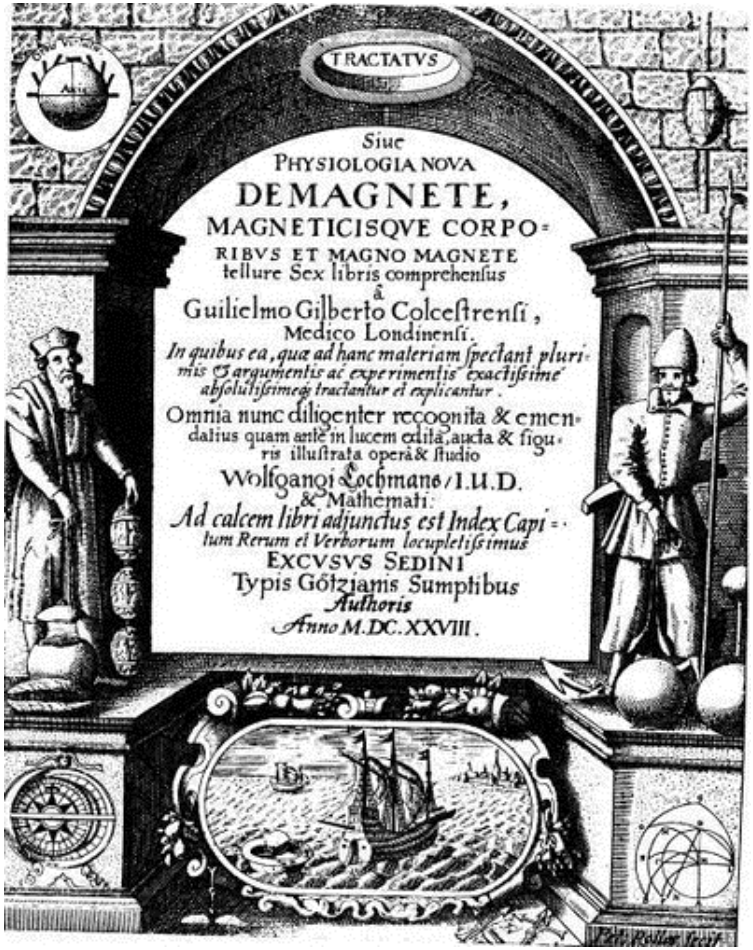
Shen Kuo (1031-1091)



William Gilbert (1600)

The Sad Decline in Quality of Scientific Publications

Which publication would you want to read?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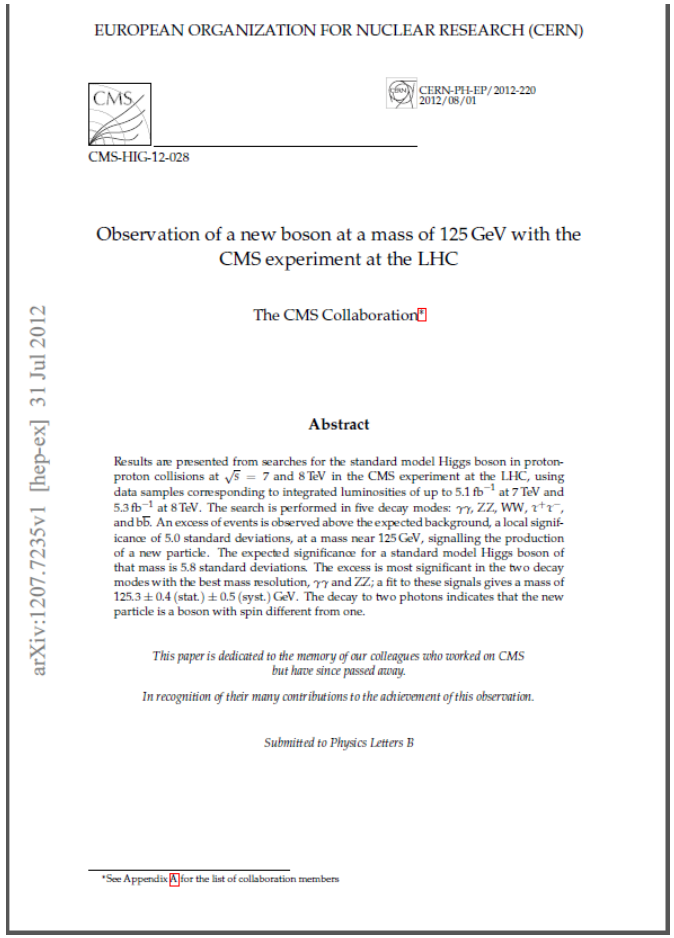

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CMS

CERN-PH-EP/2012-220
2012/08/01

CMS-HIG-12-028

Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC

The CMS Collaboration*

arXiv:1207.7235v1 [hep-ex] 31 Jul 2012

Abstract

Results are presented from searches for the standard model Higgs boson in proton-proton collisions at $\sqrt{s} = 7$ and 8 TeV in the CMS experiment at the LHC, using data samples corresponding to integrated luminosities of up to 5.1 fb^{-1} at 7 TeV and 5.3 fb^{-1} at 8 TeV. The search is performed in five decay modes: $\gamma\gamma$, ZZ, WW, $\tau^+\tau^-$, and $b\bar{b}$. An excess of events is observed above the expected background, a local significance of 5.0 standard deviations, at a mass near 125 GeV, signalling the production of a new particle. The expected significance for a standard model Higgs boson of that mass is 5.8 standard deviations. The excess is most significant in the two decay modes with the best mass resolution, $\gamma\gamma$ and ZZ; a fit to these signals gives a mass of $125.3 \pm 0.4\,(\text{stat.}) \pm 0.5\,(\text{syst.})$ GeV. The decay to two photons indicates that the new particle is a boson with spin different from one.

This paper is dedicated to the memory of our colleagues who worked on CMS but have since passed away.

In recognition of their many contributions to the achievement of this observation.

Submitted to Physics Letters B

*See Appendix A for the list of collaboration members

Magnetism in History

Name derived from rocks (lodestones – naturally magnetized pieces of iron ore) found in the province of Magnesia in Greece, near Turkey.

First reports – 2500 BC

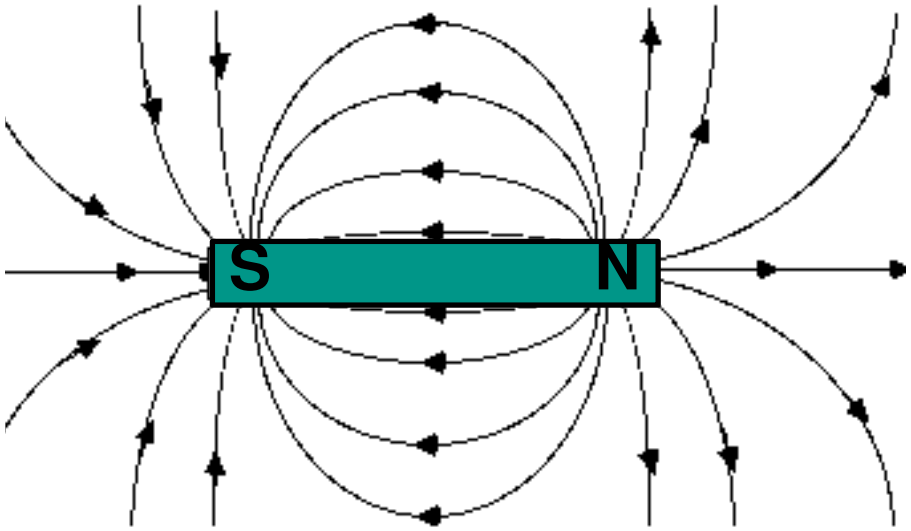
Historically, more interesting than electricity due to importance in early navigation applications.

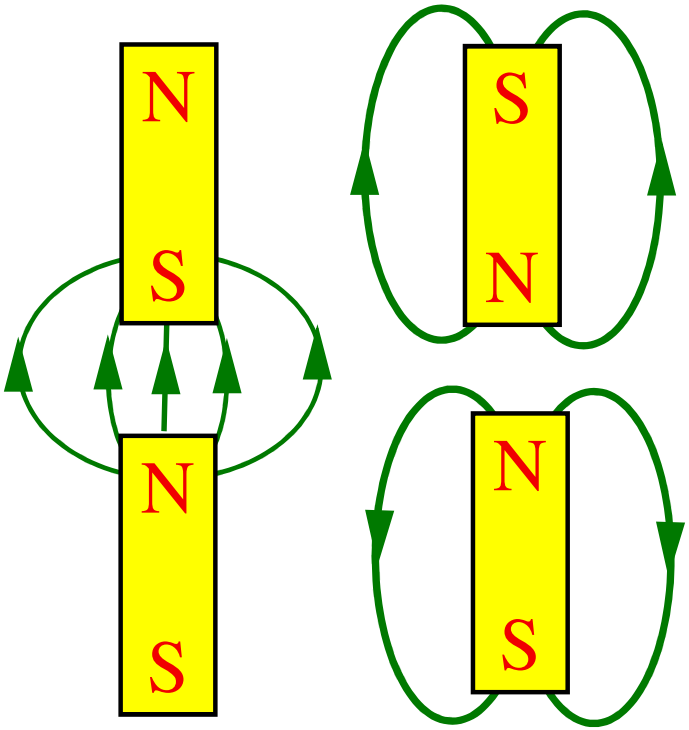
Originally thought to be a separate topic from electricity/electrostatics.

Today: unified subject – electromagnetism.

Fundamental Property of Magnets

- Bar magnets always two opposite poles
  - The ‘N’ pole is feels an attractive force towards the northern hemisphere
  - Like poles repel, unlike poles attract
  - We can describe the magnetic field the same way we talked about electric fields.



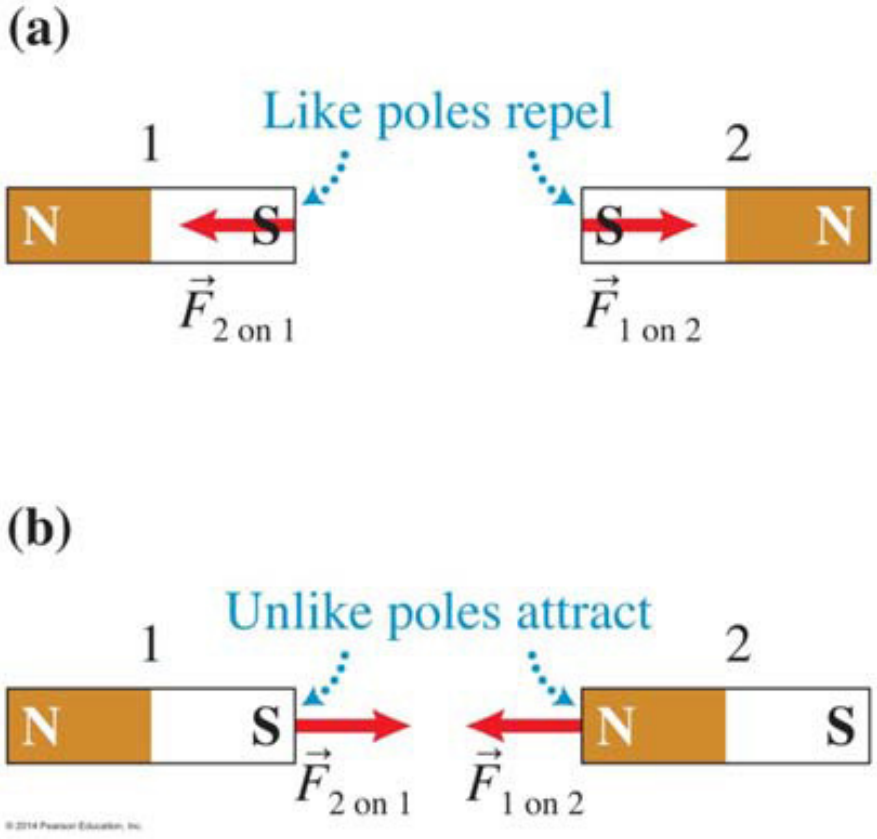


Magnetic Monopoles

- Can you cut the end off a magnet to get just the North or South poles?

- Most elementary particles behave like little bar magnets: they have a north end and a south end.
  - Although they are point-like we can still talk about which way their magnetic field is pointing
- In principle, a fundamental particle with a magnetic charge ***could*** exist, but we haven't found any evidence that they do.

Magnetic Poles – Forces Between Magnets



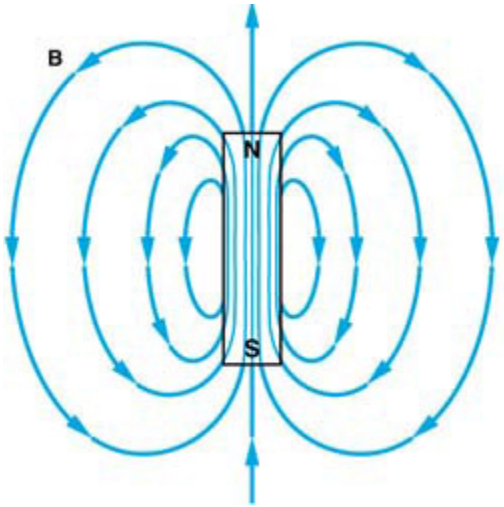
Just like gravity and the electrostatic force, magnetic forces are non-contact forces – they act on objects that are not touching each other.

The magnitude of the force depends on the “pole strength” and the separation between the poles.

Dipole magnetic field/Electric field

Magnetic field lines $\vec{B}$

MKS units: Tesla

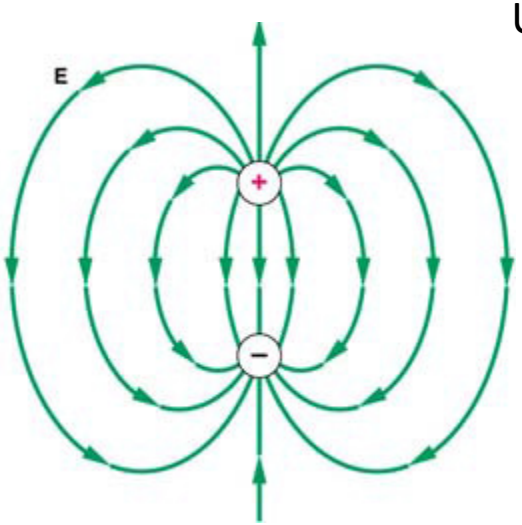


$\vec{B}$ is a vector.

$\vec{B}$ lines are continuous.

Electric field lines $\vec{E}$

Units: N/C or V/m.



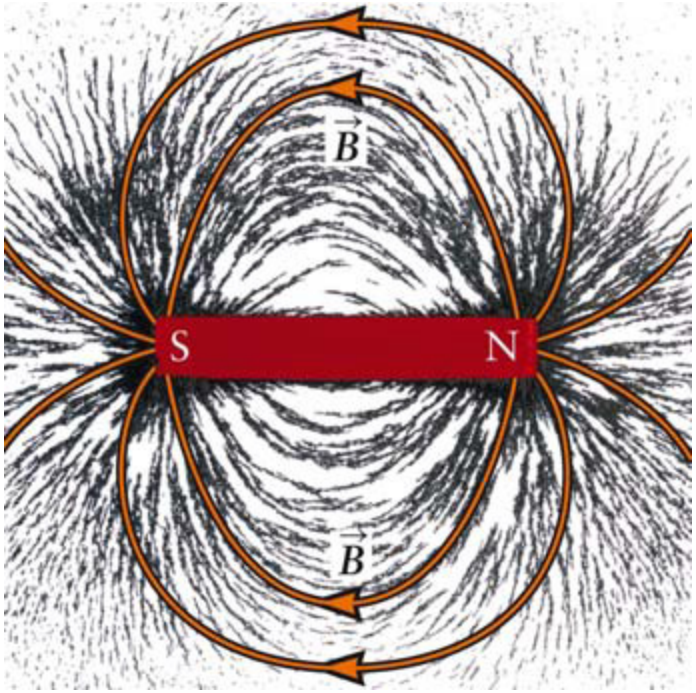
$\vec{E}$ is a vector.

$\vec{E}$ lines begin/end on positive/negative charges.

- Key point: *there are no "magnetic charges"!*
- MKS units for magnetic field is the Tesla (T).

Visualizing magnetic fields

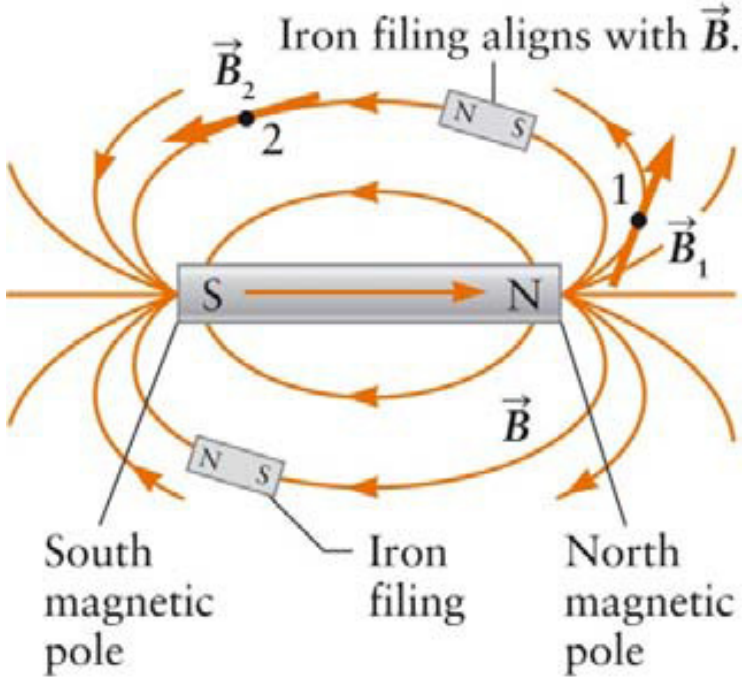
- A bar magnet is a permanent magnet in the shape of a bar.
- The iron filings are small, needle-shaped, permanent magnets.
- The magnetic field lines can be deduced from the pattern of the iron filings.



Important Points to Remember

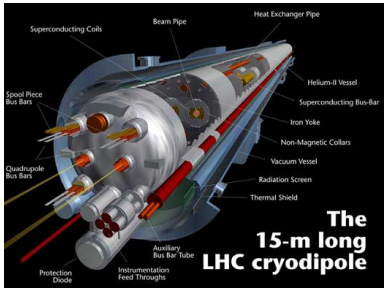
- The MKS/SI unit for magnetic field is the Tesla (T).
- The CGS unit for magnetic field is the Gauss.

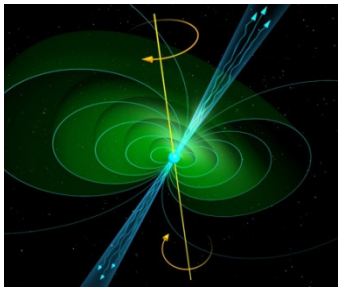
  1 Tesla = 10,000 Gauss.
- The magnetic field lines go from the north pole towards the south pole.
- The magnitude of the B-field lines decreases as you move farther from a pole.
- The magnetic field lines form closed loops – a general property of ALL magnetic field lines, not just for bar magnets.



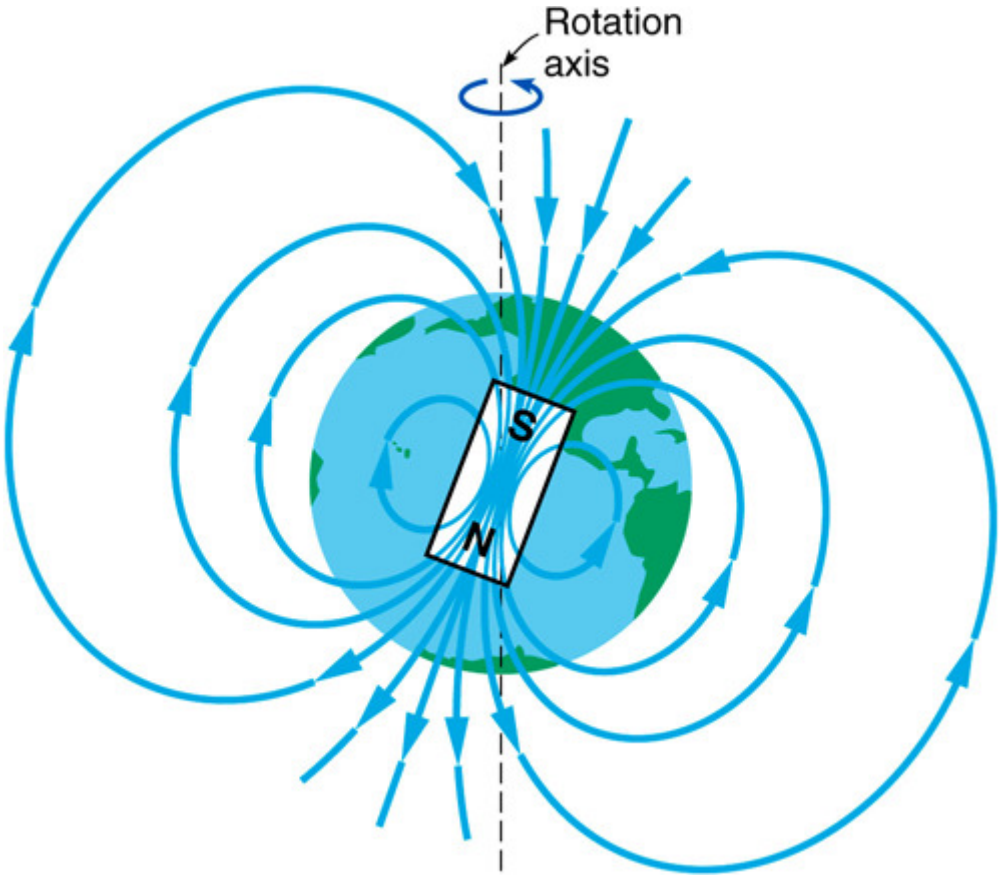
Magnetic Field Strength

Source	Typical B field (Tesla)
Interstellar magnetic field	10^{-9}
Earth's magnetic field	5×10^{-5}
Fridge magnet	5×10^{-3}
Electromagnet	10^{-2}
Rare earth magnet	1
Magnetic Resonance Imaging (MRI) machine	2
Superconducting magnets	10
Neutron star	10^{6}





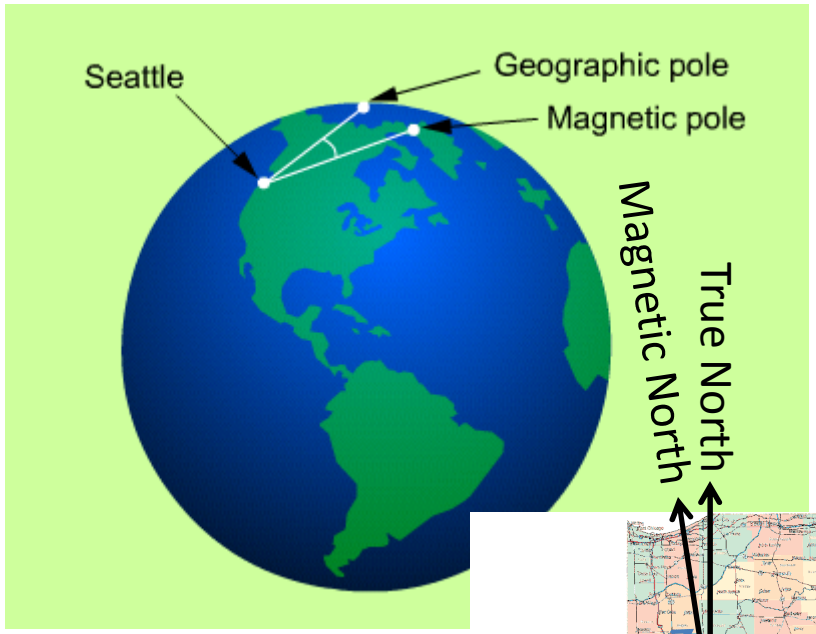
The Earth acts like a large magnet



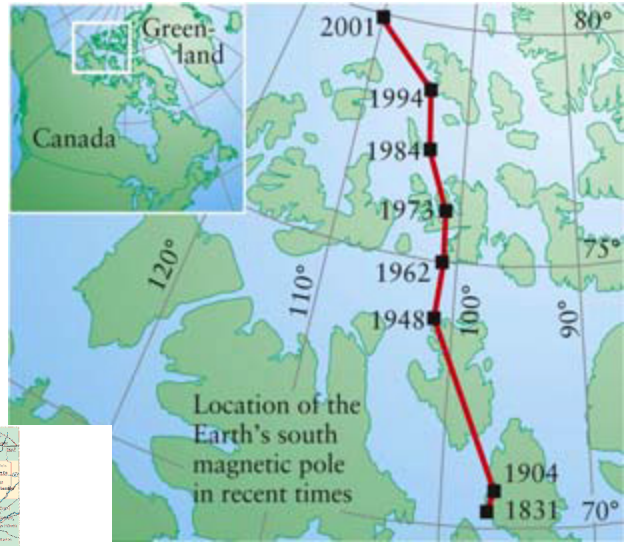
Geographic north pole of the earth roughly corresponds to the geomagnetic south pole of the earth.

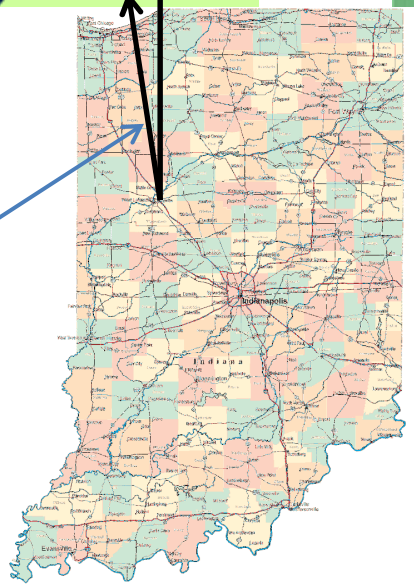
The north pole of a bar magnet on the earth's surface will be attracted towards the Northern hemisphere.

Earth's Magnetic Field



Earth's geomagnetic pole wanders over time





Magnetic declination in Indiana is about 4° West.

Magnetic Declination in the US