

CHAPTER 20: MAGNETIC PROPERTIES

ISSUES TO ADDRESS...

- How do we measure magnetic properties?
- What are the atomic reasons for magnetism?
- How are magnetic material classified?
- Materials design for magnetic storage.

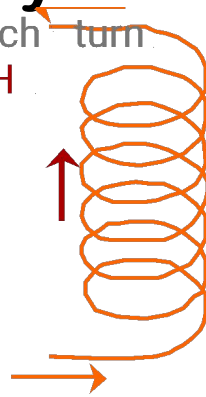


APPLIED MAGNETIC FIELD

- Created by current through a

coil.

Applied field of each turn magnetic field H



- Relation for the applied magnetic field,

H:

$$H = \frac{NI}{L}$$

current

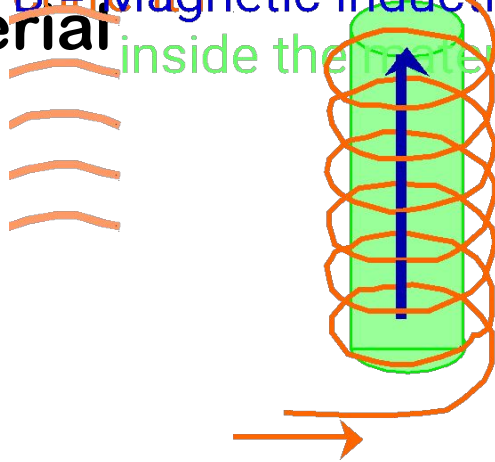
applied magnetic field
units =
(ampere-turns/m)



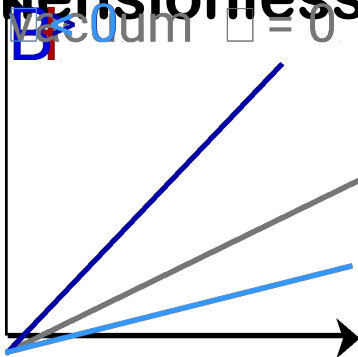
RESPONSE TO A MAGNETIC FIELD

- Magnetic induction results in the material

$B = \mu$ Magnetic Induction (tesla)
inside the material



- Magnetic susceptibility, χ (dimensionless)

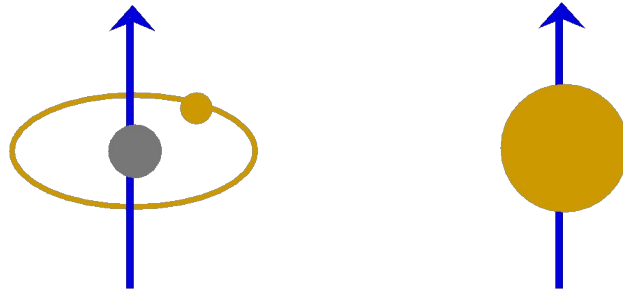


χ measures the material response relative to a vacuum.



MAGNETIC SUSCEPTIBILITY

- Measures the response of electrons to a magnetic field.
- Electrons produce magnetic moments.



Adapted from Fig. 20.4, Callister 6e.

- Net magnetic moment:
 - sum of moments from all electrons.
- Three types of response...

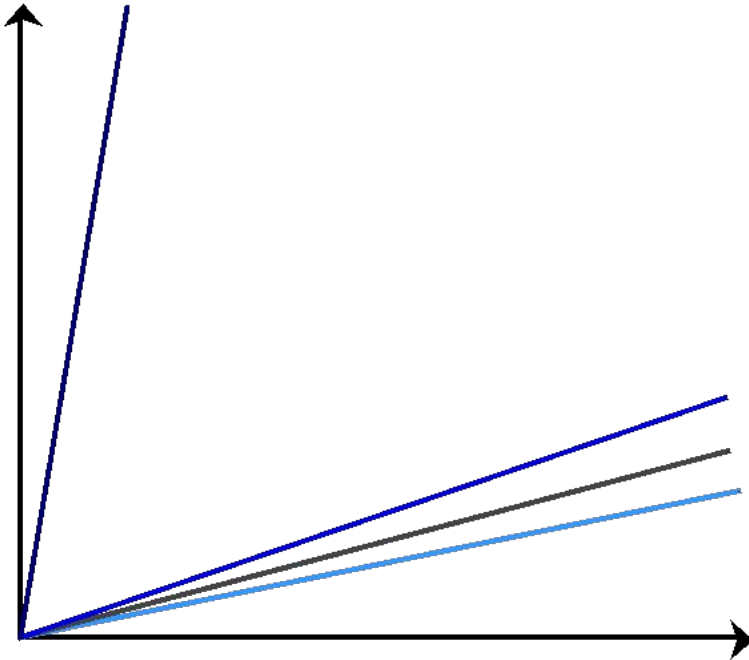
3 TYPES OF MAGNETISM

$$B = (1 + c)\mu_0 H$$

permeability of a

(ampere-turns/m) μ_0 (Henries/m) c (dimensionless)

$(1.26 \times 10^{-6} \text{ Henries/m})$



Plot adapted from Fig. 20.6, *Callister 6e*. Values and materials from Table 20.2 and discussion in Section 20.4, *Callister 6e*.



MAGNETIC MOMENTS FOR 3 TYPES

Adapted from Fig.
20.5(a), *Callister 6e*.

Adapted from Fig.
20.5(b), *Callister 6e*.

Adapted from Fig.
20.7, *Callister 6e*.



FERRO- & FERRI-MAGNETIC MATERIALS

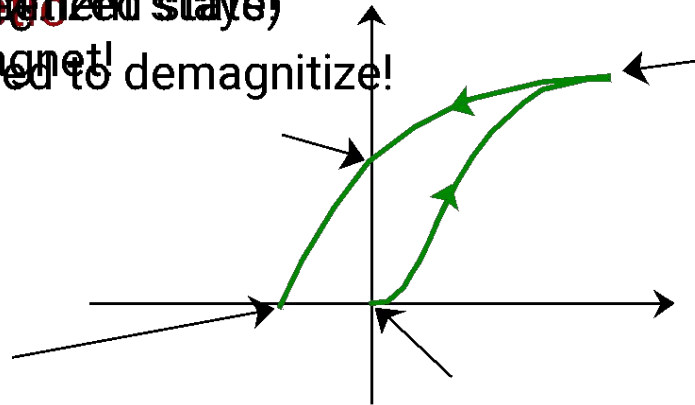
- As the applied field (H) increases...
--the magnetic moment aligns with H .

Adapted from Fig. 20.13, *Callister 6e*.
(Fig. 20.13 adapted from O.H. Wyatt and D. Dew-Hughes, *Metals, Ceramics, and Polymers*, Cambridge University Press, 1974.)



PERMANENT MAGNETS

- **Progressive magnet!**
 (demagnetized state)
 Negative H needed to demagnetize!



Adapted from Fig. 20.14, *Callister 6e*.

• Hard vs Soft Ma

large coercivity →

--good for perm magnets

--add particles/voids to make domain walls hard to move (e.g., tungsten steel:

$$H_c = 5900 \text{ amp-turn/m}$$

↑
 small coercivity--good for elec. motors (e.g., commercial iron 99.95 Fe)

Adapted from Fig. 20.16, *Callister 6e*. (Fig. 20.16 from K.M. Ralls, T.H. Courtney, and J. Wulff, *Introduction to Materials Science and Engineering*, John Wiley and Sons, Inc., 1976.)



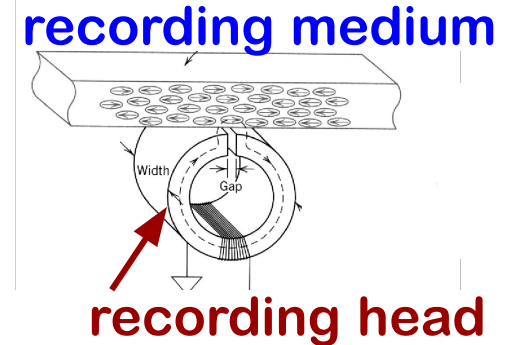
MAGNETIC STORAGE

- Information is stored by magnetizing material can...

- apply magnetic field H & align domains (i.e., magnetize the medium).



Simulation of hard drive courtesy Martin Chen. Reprinted with permission from International Business Machines Corporation.

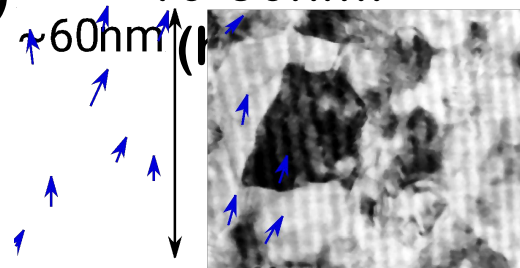
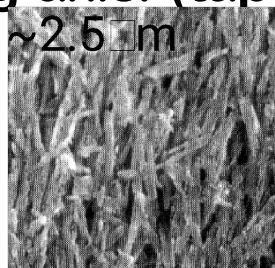


Adapted from Fig. 20.18, *Callister 6e*. (Fig. 20.18 from J.U. Lemke, *MRS Bulletin*, Vol. XV, No. 3, p. 31, 1990.)

- detect a change in the magnetization of the medium.

- Two media types:
 - Particulate: needle-shaped $\gamma\text{-Fe}_2\text{O}_3$. +/- mag. moment along axis. (tape, floppy)
 - Thin film: CoPtCr or CoCrTa alloy. Domains are ~ 10-30nm!

Adapted from Fig. 20.19, *Callister 6e*. (Fig. 20.19 courtesy P. Rayner and N.L. Head, IBM Corporation.)



Adapted from Fig. 20.20(a), *Callister 6e*. (Fig. 20.20(a) from M.R. Kim, S. Guruswamy, and K.E. Johnson, *J. Appl. Phys.*, Vol. 74 (7), p. 4646, 1993.)



SUMMARY

- A magnetic field can be produced by:
 - putting a current through a coil.
 - **Magnetic induction:**
 - occurs when a material is subjected to a magnetic field.
 - is a change in magnetic moment from electrons.
 - Types of material response to a field are:
 - ferri- or ferro-magnetic (large magnetic induction)
 - paramagnetic (poor magnetic induction)
 - diamagnetic (opposing magnetic moment)
 - **Hard magnets:** large **coercivity**.
 - **Soft magnets:** small coercivity.
 - **Magnetic storage media:**
 - particulate $\gamma\text{-Fe}_2\text{O}_3$ in polymeric film (tape or floppy)
 - thin film CoPtCr or CoCrTa on glass disk (hard drive)
- Note: For materials selection cases related to a magnet coil, see slides 22-11 to 22-15.



ANNOUNCEMENTS

Reading:

Core
Problems:

Self-help
Problems:

