

# 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.



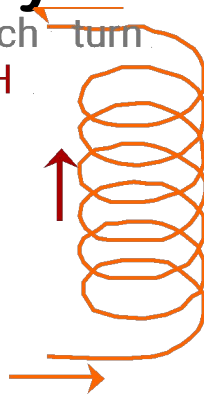


# APPLIED MAGNETIC FIELD

- Created by current through a

coil.

Applying total magnetic field H



- Relation for the applied magnetic field,

**H:**

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

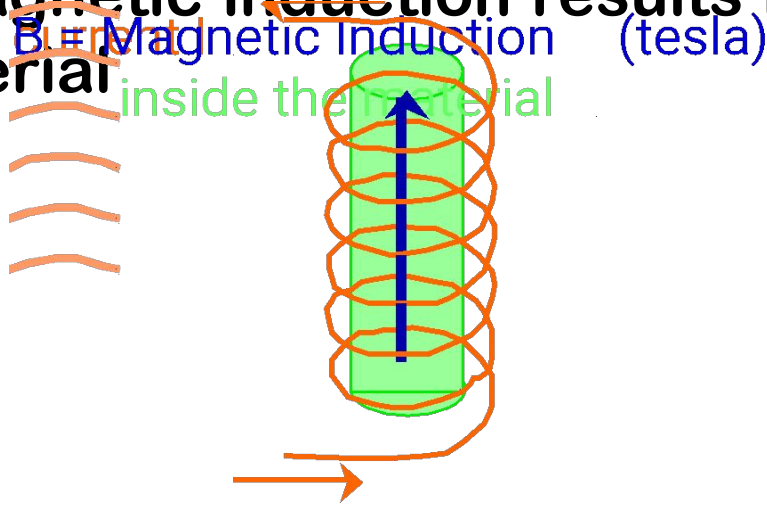
current

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

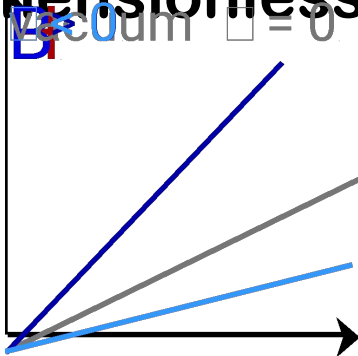


# RESPONSE TO A MAGNETIC FIELD

- Magnetic induction results in the material



- Magnetic susceptibility,  $\chi$  (dimensionless)

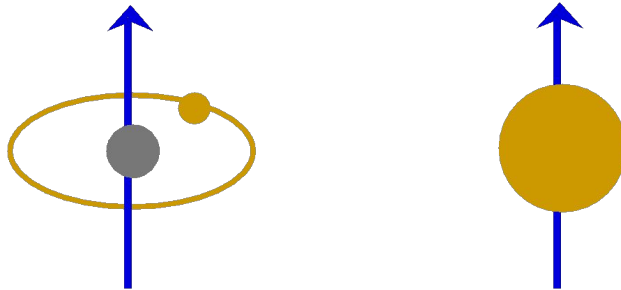


$\chi$  measures the material response relative to a vacuum.



# 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...



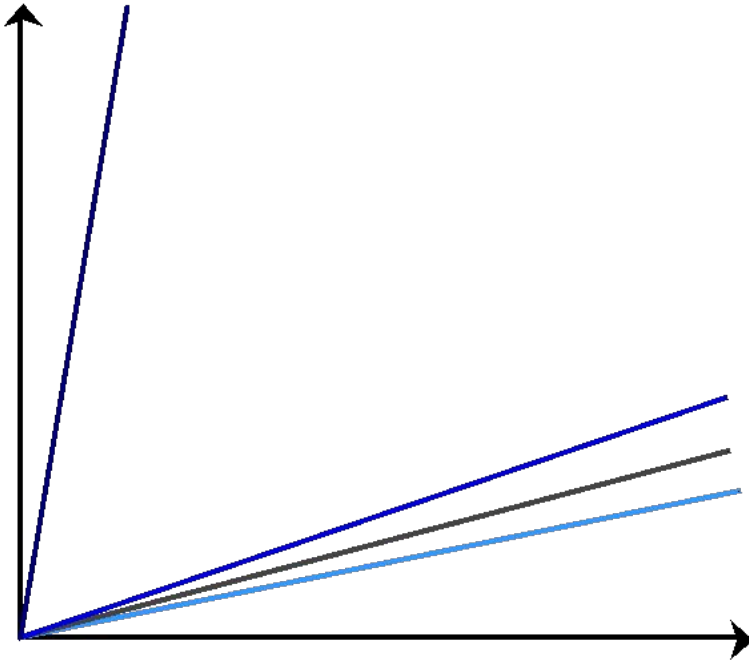
# 3 TYPES OF MAGNETISM

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

permeability of a

material (ampere-turns/m)  $\mu_0$  (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  $H$ .

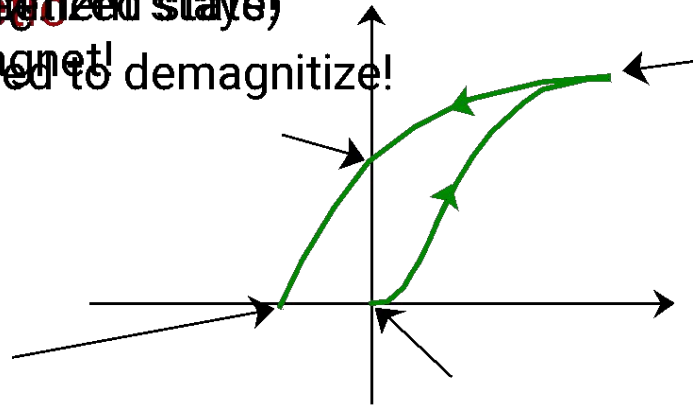
Adapted from Fig.  
20.13, *Callister 6e*.  
(Fig. 20.13 adapted  
from O.H. Wyatt and  
D. Dew-Hughes,  
*Metals, Ceramics, and  
Polymers*, Cambridge  
University Press,  
1974.)





# PERMANENT MAGNETS

- **Progressive magnet!**  
 (initially magnetized 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:

$H_c = 5900$  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.)



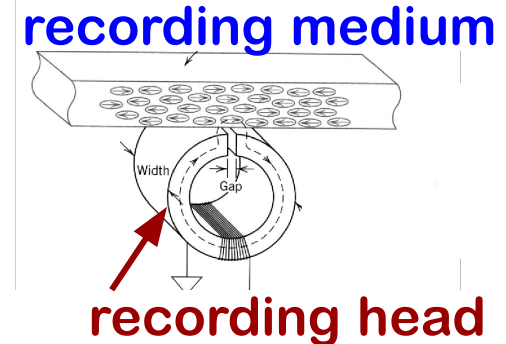
# MAGNETIC STORAGE

- 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.

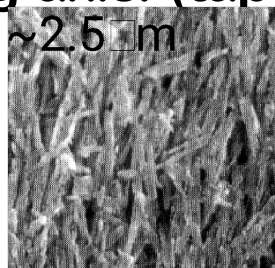


Adapted from Fig. 20.18, *Callister 6e*. (Fig. 20.18 from J.U. Lemke, *MRS Bulletin*, Vol. XV, No. 3, p. 31, 1990.)

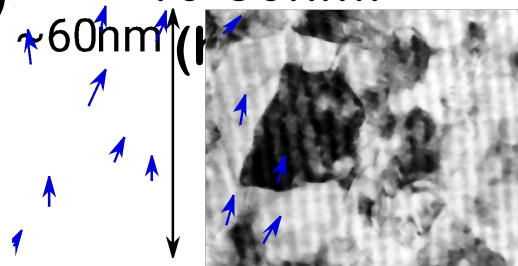
- detect a change in the magnetization of the medium.
- Two media types**

**Particulate: needle-shaped**  
 $\gamma\text{-Fe}_2\text{O}_3$ . +/- mag. moment along axis. (tape, floppy)

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



**--Thin film: CoPtCr or CoCrTa alloy. Domains are ~10-30nm!**



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:

