# Lect. 3: Magnetic Fields (Chap. 6 in Cheng)

- Current produces magnetic fields

Ampere's Law: $\nabla \times \bar{H} = \bar{J}$

$\bar{J}$ : Current density (A/m$^2$)  $\bar{H}$ : Magnetic field (A/m)

Integral form?



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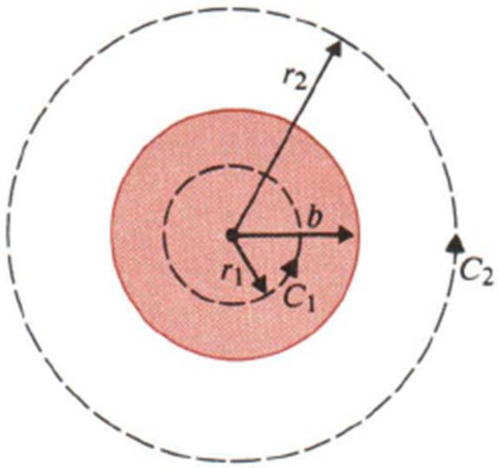
- Example 6-1 in Cheng. Determine H when uniform current I is flowing out.



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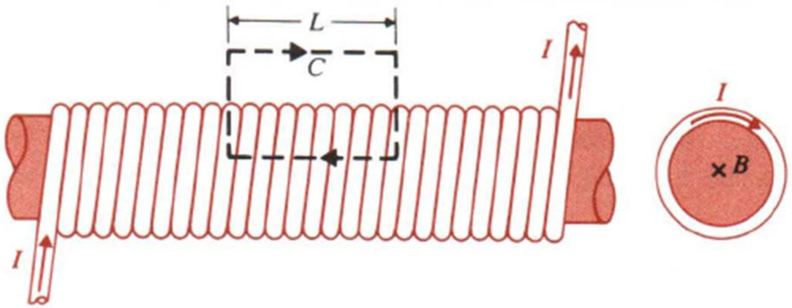
- Example 6-3 in Cheng:
  Determine H when the conductor is infinitely long and there are n turns for unit length



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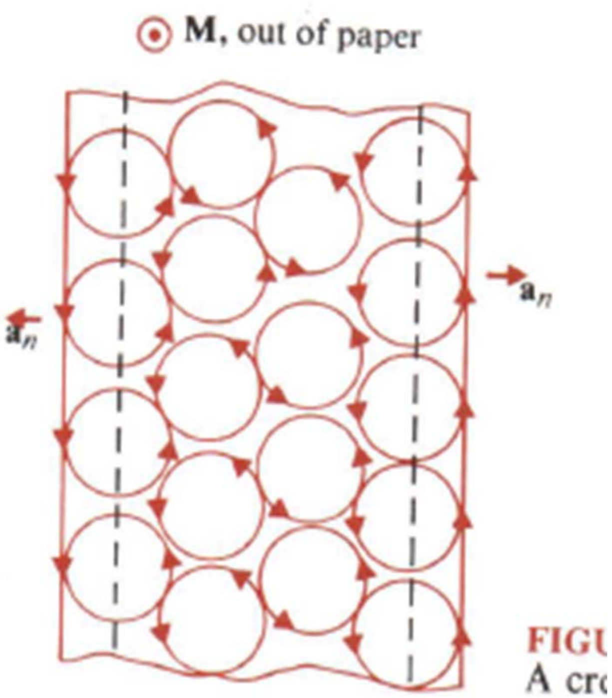
- How does magnetic field affect materials?

Magnetization: Microscopic current loops inside the material (magnetic dipole)




$$\bar{M} = \chi_m \bar{H}$$ $\chi_m$: Magnetic susceptibility

$\bar{B}$: Magnetic flux density

$$\bar{B} = \mu_0 \bar{H} + \mu_0 \bar{M} = \mu_0 \bar{H} + \mu_0 \chi_m \bar{H}$$
$$= (1 + \chi_m)\mu_0 \bar{H} = \mu_r \mu_0 \bar{H} = \mu \bar{H}$$

$\mu$: Permeability

- Diamagnetic: $\mu_r < 1$
- Paramagnetic: $\mu_r > 1$
- Ferromagnetic: $\mu_r >> 1$

In this course, we assume $\mu = \mu_0$ (EM waves in non-magnetic materials)

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# Lect. 3: Magnetic Fields

Correspondence between Electric and Magnetic Fields

| | |
|---|---|
| $\overline{E}$ | $\overline{H}$ |
| $\overline{D}$ | $\overline{B}$ |
| $\overline{D} = \varepsilon \overline{E}$ | $\overline{B} = \mu \overline{H}$ |
| $\nabla \cdot \overline{D} = \rho$ | $\nabla \cdot \overline{B} = 0$ |
| $\nabla \times \overline{E} = 0$ | $\nabla \times \overline{H} = \overline{J}$ |

Static Maxwell Equations