ECC 203 : Electromagnetics and Radiating Systems

Magnetostatics

Gowrish Basavarajappa

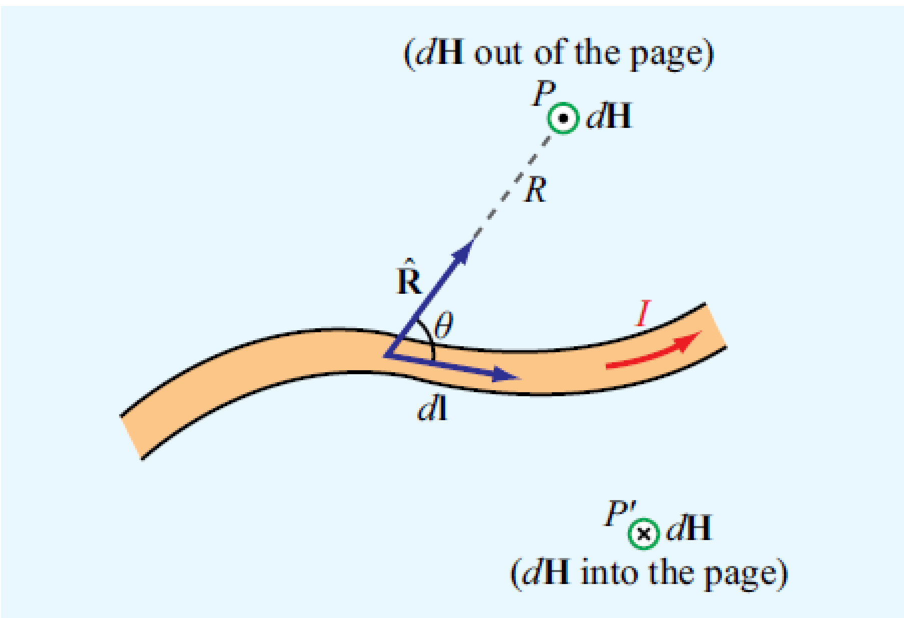
Asst. Professor, ECE Dept., IIT Roorkee

gowrish.b@ece.iitr.ac.in

www.gowrish.in

Biot–Savart Law

$$d\mathbf{H} = \frac{I}{4\pi} \frac{d\mathbf{l} \times \hat{\mathbf{R}}}{R^2} \qquad \text{(A/m)}$$



$$\mathbf{H} = \frac{I}{4\pi} \int_l \frac{d\mathbf{l} \times \hat{\mathbf{R}}}{R^2} \qquad \text{(A/m)}$$

$$\mathbf{H} = \frac{1}{4\pi} \int_S \frac{\mathbf{J}_s \times \hat{\mathbf{R}}}{R^2}\, ds,$$

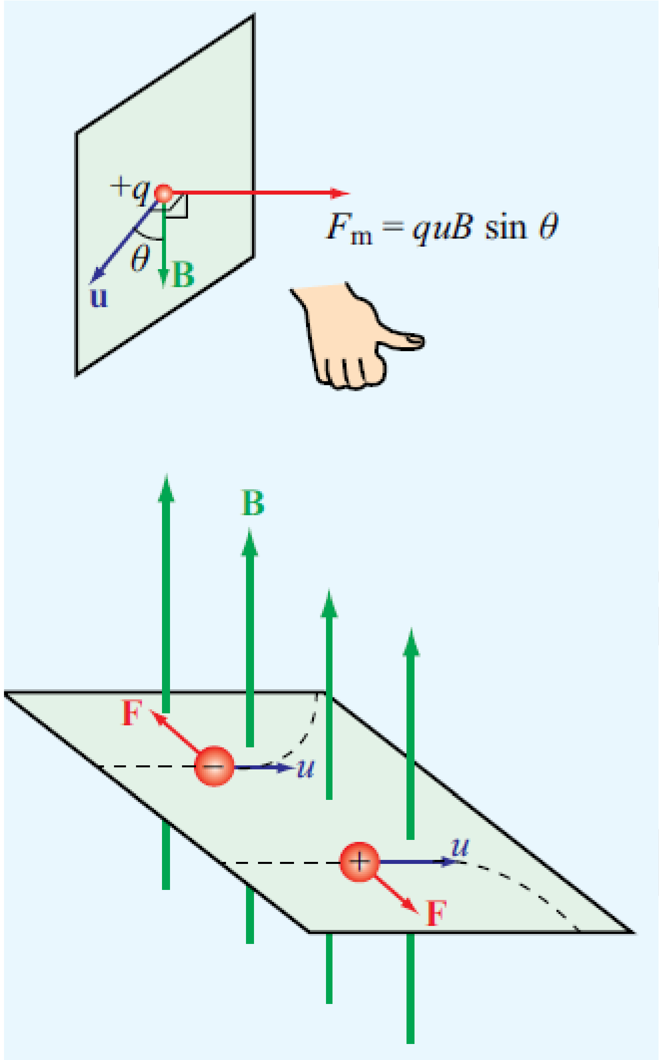
(surface current)

$$\mathbf{H} = \frac{1}{4\pi} \int_v \frac{\mathbf{J} \times \hat{\mathbf{R}}}{R^2}\, dv.$$

(volume current)

$$B = \mu \mathrm{H}$$

Biot–Savart Law



$$\mathbf{F}_m = q\mathbf{u} \times \mathbf{B}$$

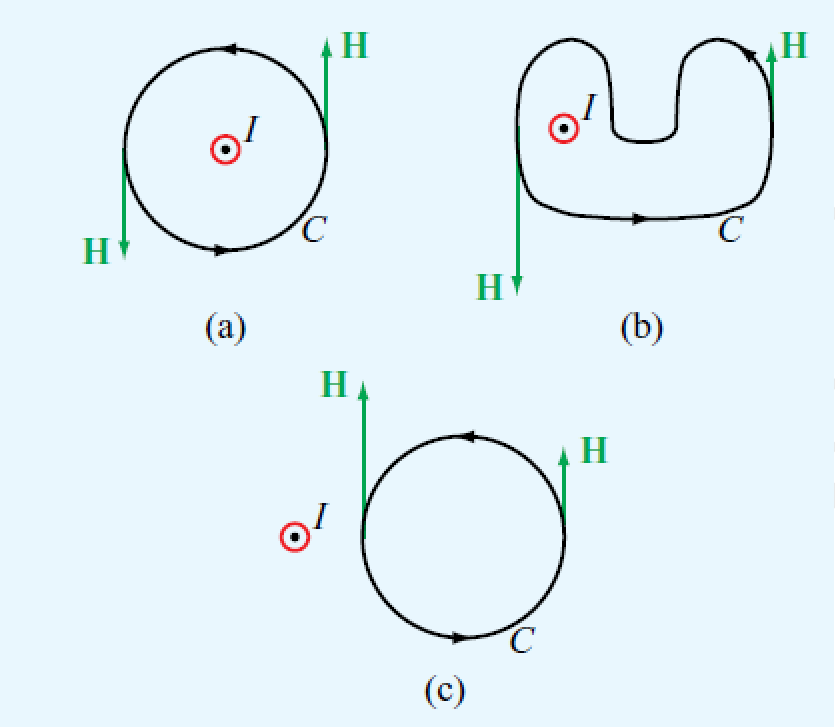
$$\mathbf{F} = \mathbf{F}_e + \mathbf{F}_m$$
$$= q\mathbf{E} + q\mathbf{u} \times \mathbf{B} = q(\mathbf{E} + \mathbf{u} \times \mathbf{B})$$

Lorentz force

Ampere' Law

$$\nabla \times \mathbf{H} = \mathbf{J} \longleftrightarrow \oint_C \mathbf{H} \cdot d\boldsymbol{\ell} = I,$$

*Ampere's law states that the line integral of **H** around a closed path is equal to the current traversing the surface bounded by that path*



Gauss’s Law for Magnetism

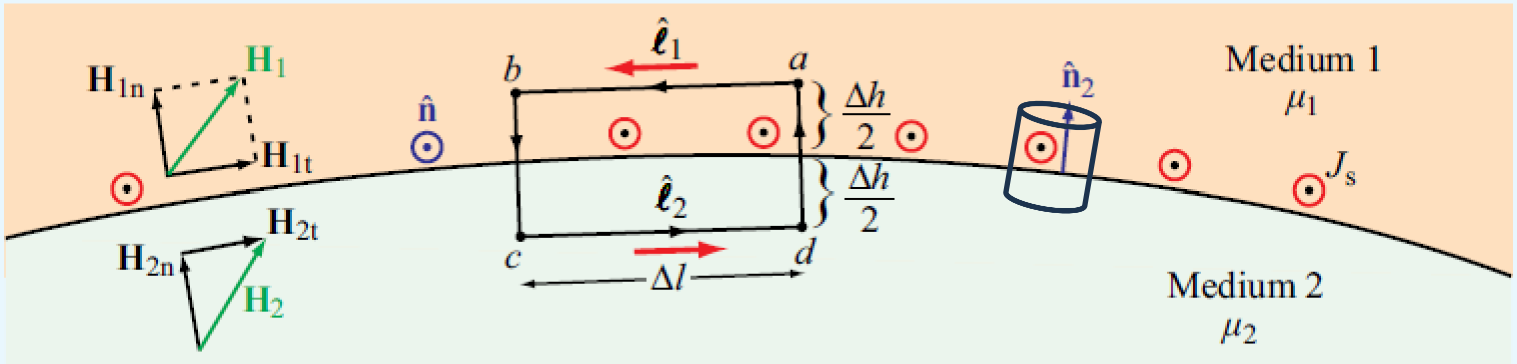
$$\nabla \cdot \mathbf{B} = 0 \quad \longleftrightarrow \quad \oint_S \mathbf{B} \cdot d\mathbf{s} = 0$$

Note that the right-hand side of Gauss’s law for magnetism is zero, reflecting the fact that the magnetic equivalence of an electric point charge does not exist in nature → NO MAGNETIC MONOPOLE in NATURE (YET !!!)

Magnetic Field Intensity / Magnetic Flux Density always form closed loop.

https://em8e.eecs.umich.edu/jsmodules/ulaby_modules.html

Magnetic Boundary Condition : Normal

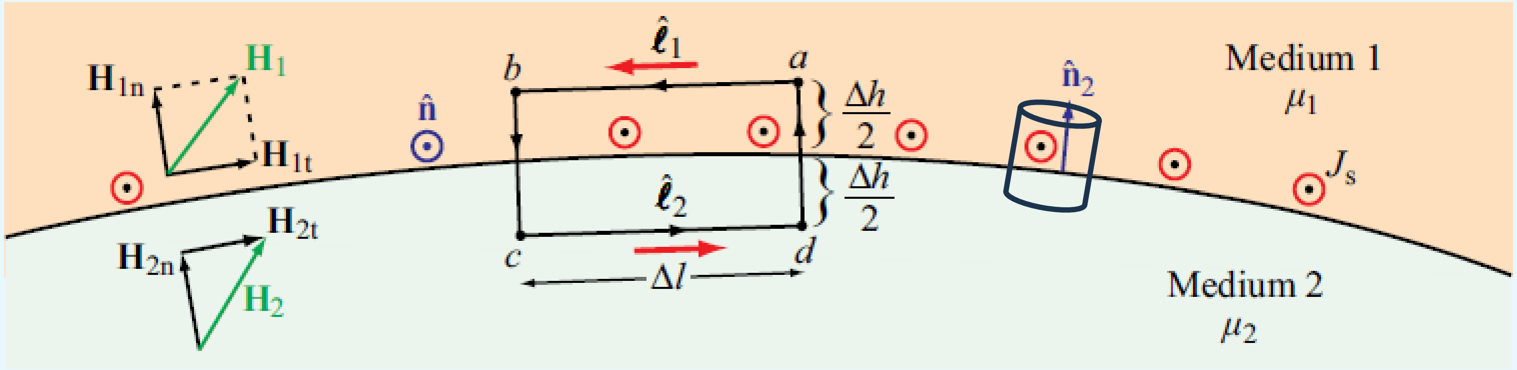


$$\oint_S \mathbf{B} \cdot d\mathbf{s} = 0 \quad \Rightarrow \quad B_{1n} = B_{2n}.$$

▶ Thus the normal component of **B** is continuous across the boundary between two adjacent media. ◀

$$\mu_1 H_{1n} = \mu_2 H_{2n}$$

Magnetic Boundary Condition : Tangential



$$\oint_C \mathbf{H} \cdot d\mathbf{l} = \int_a^b \mathbf{H}_1 \cdot \hat{\boldsymbol{\ell}}_1 \, d\ell + \int_c^d \mathbf{H}_2 \cdot \hat{\boldsymbol{\ell}}_2 \, d\ell = I$$

$$(\mathbf{H}_1 - \mathbf{H}_2) \cdot \hat{\boldsymbol{\ell}}_1 \, \Delta l = \mathbf{J}_s \cdot \hat{\mathbf{n}} \, \Delta l.$$

$$\hat{\mathbf{n}}_2 \times (\mathbf{H}_1 - \mathbf{H}_2) = \mathbf{J}_s$$

Thank You

Questions?