MAGNETISM DAY 4: BIOT–SAVART

WARMUP Where Does B Come From?

Yesterday two parallel wires attracted each other — wire 1's current put a field at wire 2's location. The demo that discovered this: a compass beside a wire snaps sideways when the current switches on (Oersted, mid-lecture, 1820); carried around the wire, the needle traces CIRCLES. Sketch those circular field lines, right-hand grip rule (thumb along I, fingers curl along B) setting their direction.

BIOT–SAVART: THE DQ INTEGRAL OF MAGNETISM

$$\mathbf{dB = (\mu_0/4\pi)\, I\, d\mathbf{l} \times \hat{r} / r^2} \quad (\mu_0 = 4\pi\times10^{-7}\ \text{T·m/A, so } \mu_0/4\pi = 10^{-7})$$

Loop center: every $d\mathbf{l} \perp \hat{r}$ at constant $r = R \rightarrow \mathbf{B = \mu_0 I/2R}$ (N turns: multiply by N; an arc: multiply by its fraction of the circle).

Infinite straight wire (the other landmark): $\mathbf{B = \mu_0 I/2\pi d}$ — circles around the wire, right-hand grip rule.

WE DO Exercise 1: Loop Numbers

A single loop, R = 0.5 m, I = 5.0 A. **(a)** B at the center = $\mu_0 I/2R$ = _____ μT. **(b)** Wound as a 100-turn coil instead: B = _____ μT.

WIRES AND FRAGMENTS

WE DO Exercise 2: The Straight Wire

A power line carries 10 A. **(a)** B at d = 0.05 m: $\mu_0 I/2\pi d = (2\times10^{-7})(I)/d =$ _____ μT. **(b)** Compare to Earth's ~50 μT field — could a compass detect this wire?

YOU DO Exercise 3: The Half Loop

A wire is bent into a SEMICIRCLE of radius 0.2 m carrying 6.0 A. Find B at the center. (What fraction of the full loop's field survives, and why does the symmetry argument still hold?)

CALC Exercise 4: Set Up the Center Integral

For the full loop, write $B = \int(\mu_0/4\pi)(I\, dl \sin90°)/R^2$ around the circumference, pull the constants out, and evaluate $\int dl = 2\pi R$ to reach $\mu_0 I/2R$. Note where each simplification uses the geometry.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Loop Center

R = 0.25 m, I = 4.0 A, single loop: find B at the center in μT.

P2 Near a Wire

Find B at 0.02 m from a wire carrying 15 A, in μT.

P3 Coil Design

How many turns (radius 0.10 m, I = 2.0 A) are needed for B = 1.26 mT at the center?

P4 Quarter Arc

A quarter-circle arc (R = 0.1 m) carries 8.0 A. Find B at the center of curvature — and state why the two straight feed-in wires pointing RADIALLY at the center contribute nothing (look at $d\vec{l} \times \hat{r}$).