MAGNETISM DAY 5: AMPÈRE'S LAW

WARMUP **Gauss, But for Loops**

Yesterday's straight wire: $B = \mu_0 I/2\pi d$. Multiply that field by the circumference of the circle it lives on: $B\cdot(2\pi d)$ = ________. Everything cancels except ________. That result — the product never depends on d — is today's law.

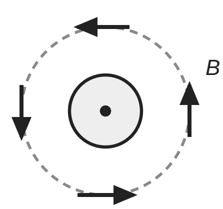
AMPÈRE'S LAW

$$\oint B\cdot dl = \mu_0 I_{enc}$$

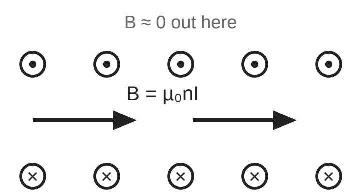
Wire (outside, r > a): $B\cdot 2\pi r = \mu_0 I \rightarrow B = \mu_0 I/2\pi r$. **Inside a uniform wire (r < a):** only the fraction r^2/a^2 is enclosed $\rightarrow B = \mu_0 I r/2\pi a^2$ — grows linearly, peaks at the surface.

Solenoid: a rectangular loop straddling the side gives $\mathbf{B = \mu_0 n I}$ inside (n = turns per meter), ≈ 0 outside — magnetism's uniform-field device.

Like Gauss: always true, only USEFUL when symmetry makes B constant on the path.



wire, I out of the page



solenoid, cut lengthwise (⊙ toward you, × away)

The two symmetry workhorses. Exercise 4 asks YOU to add the rectangular loop to the solenoid picture.

WE DO **Exercise 1: Outside the Wire**

A wire carries 10 A. **(a)** Write Ampère for a circle at r = 2.0 m and solve: B = ________ μT. **(b)** At r = 4.0 m: B = ________ μT (halved — 1/r, not $1/r^2$).

INSIDE, AND THE SOLENOID

WE DO Exercise 2: Inside the Wire

A thick wire (radius $a = 2.0$ mm) carries 10 A spread uniformly. At $r = 1.0$ mm: **(a)** enclosed current = $I\cdot(r^2/a^2)$ = ________. **(b)** $B = \mu_0 I_{enc}/2\pi r$ = ________ μT. **(c)** Where is B largest — center, surface, or far away?

YOU DO Exercise 3: Solenoid Numbers

A solenoid has 1000 turns per meter carrying 2.0 A. Find B inside (in mT), and state what happens to it just outside the coil.

CALC Exercise 4: Derive the Solenoid Field

Draw a rectangular Amperian loop of width w with one side inside the solenoid (parallel to B) and one side outside ($B \approx 0$). Show that $\oint B\cdot dl = Bw$, that $I_{enc} = nwI$, and conclude $B = \mu_0 nI$. Which two sides contribute nothing, and why?

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Outside

B at $r = 0.10$ m from a wire carrying 25 A, in μT?

P2 Solenoid

A solenoid with $n = 2000$ turns/m carries 1.5 A. Find B inside, in mT.

P3 Design

You need $B = 5.0$ mT inside a solenoid running at 2.0 A. How many turns per meter?

P4 The Full Profile

For a thick wire of radius a carrying I: write $B(r)$ for $r < a$ and $r > a$, verify both give the same value at $r = a$, and sketch B versus r from 0 to 4a.