MAGNETISM DAY 6: THE MASS SPECTROMETER

WARMUP **Assemble the Machine**

You now own every part of a mass spectrometer: an accelerating voltage (Unit 9), a velocity selector (Day 2), and a bending field (Day 2). Sketch the three stages in order and label what each one fixes.

THE SPECTROMETER PIPELINE

Stage 1 — accelerate: $q\Delta V = \frac{1}{2}mv^2$ sets the speed from rest.

Stage 2 — select: crossed fields pass only $v = E/B_1$.

Stage 3 — bend and weigh: $r = mv/qB_2 \rightarrow \mathbf{m = qB_2r/v}$. Measure r, read off m.

WE DO **Exercise 1: Run the Pipeline**

A singly-charged ion ($q = 1.6\times10^{-19}$ C) exits the selector at $v = 6.0\times10^{5}$ m/s and bends through r = 0.25 m in B = 0.5 T. **(a)** m = qBr/v = _____ kg. **(b)** Divide by 1.66×10^{-27} kg/u: about _____ atomic mass units.

SOLENOID + PARTICLE: FIELDS YOU BUILT

WE DO Exercise 2: Trap in Your Own Field

Your solenoid (n = 2000 turns/m, I = 1.5 A) produces B = _____ mT (Day 5). A proton circles inside it ⊥ to B at 2.0×10^{5} m/s. Find its orbit radius r = mv/qB.

YOU DO Exercise 3: Speed From Volts, Again

A proton accelerates from rest through 2000 V (stage 1). Find its speed $v = \sqrt{(2q\Delta V/m)}$ — the input to every later stage.

CALC Exercise 4: The Design Equation

Combine all three stages symbolically: eliminate v between $q\Delta V = \frac{1}{2}mv^2$ and r = mv/qB to show $m = qB^2r^2/(2\Delta V)$. A spectrometer with B = 0.5 T, ΔV = 2000 V measures r = 0.0129 m — verify $m \approx 1.67\times10^{-27}$ kg (a proton!).

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Selector Setting

Pass exactly 5.0×10^{5} m/s with B = 0.4 T: what E?

P2 Weigh It

q = 1.6×10^{-19} C, v = 5.0×10^{5} m/s, B = 0.4 T, measured r = 0.13 m: find m.

P3 Solenoid Spec

A lab needs 4.0 mT from a solenoid at 2.5 A. Find the required n (turns/m).

P4 Isotope Resolution

Carbon-12 and carbon-13 ions (same q, same selector speed 5.0×10^{5} m/s) bend in 0.4 T. Using m_{12} = 1.99×10^{-26} kg and m_{13} = 2.16×10^{-26} kg, find both radii and the separation $2(r_{13} - r_{12})$ between where they land (they land a full diameter out).