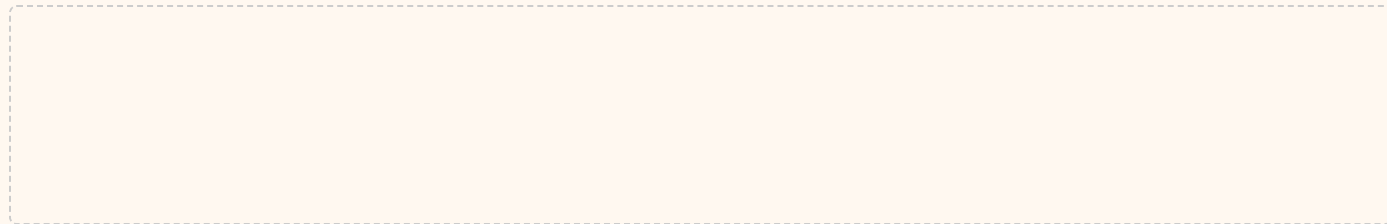


MAGNETISM DAY 6: THE MASS SPECTROMETER

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

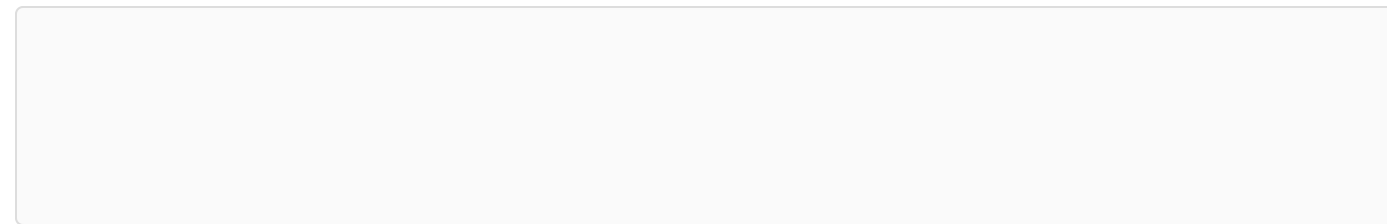
Stage 1 — accelerate: $q\Delta V = \frac{1}{2}mv^2$ sets the speed from rest.

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

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

WE DO Exercise 1: Run the Pipeline

A singly-charged ion ($q = 1.6 \times 10^{-19}$ C) exits the selector at $v = 6.0 \times 10^5$ 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.



WE DO Exercise 2: Trap in Your Own Field

Your solenoid ($n = 2000$ turns/m, $I = 1.5$ A) produces $B = \rule{1cm}{0.4pt}$ mT (Day 5). A proton circles inside it $\perp$ 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, $\Delta V = 2000$ V measures $r = 0.0129$ m — verify $m \approx 1.67 \times 10^{-27}$ 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

$q = 1.6 \times 10^{-19}$ C, $v = 5.0 \times 10^5$ 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 $m_{12} = 1.99 \times 10^{-26}$ kg and $m_{13} = 2.16 \times 10^{-26}$ kg, find both radii and the separation $2(r_{13} - r_{12})$ between where they land (they land a full diameter out).