MAGNETISM DAY 2: CIRCULAR MOTION & THE CYCLOTRON

WARMUP **A Force That Only Turns…**

…makes a circle. A constant-magnitude force always ⊥ v is exactly the centripetal recipe from Unit 2. Set $qvB = mv^2/r$ and solve for r before reading further: r = _____.

THE CYCLOTRON FORMULAS

$$r = mv/qB \qquad T = 2\pi m/qB$$

The period has NO v in it — fast particles ride bigger circles in the same lap time. That v-independence is the working principle of cyclotrons and mass spectrometers.

Velocity selector: crossed E and B fields; only v = E/B passes straight (qE balances qvB).

WE DO **Exercise 1: Proton Numbers**

A proton ($m = 1.67\times10^{-27}$ kg, $q = 1.6\times10^{-19}$ C) moves at 1.0×10^{6} m/s ⊥ to B = 0.5 T. **(a)** r = mv/qB = _____ m. **(b)** T = 2πm/qB = _____ (nanoseconds!).

WE DO Exercise 2: The Velocity Selector

Crossed fields: $E = 3.0\times10^{5}$ V/m and $B = 0.5$ T. **(a)** The speed that passes undeflected: $v = E/B =$ _____. **(b)** A FASTER ion enters — which force grows, which doesn't, and toward which force's side does it bend?

YOU DO Exercise 3: Weigh the Ion

An ion with $q = 1.6\times10^{-19}$ C enters a 0.5 T field at 6.0×10^{5} m/s and rides a circle of radius $r = 0.25$ m. Find its mass $m = qBr/v$.

CALC Exercise 4: Why T Doesn't Care About v

Derive it: $T =$ (circumference)/(speed) $= 2\pi r/v$. Substitute $r = mv/qB$ and show v cancels. Then the physical sentence: WHY does a faster particle take exactly as long per lap?

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Radius

An electron ($m = 9.11\times10^{-31}$ kg) at 2.0×10^{7} m/s $\perp$ to B = 0.01 T: find r.

P2 Period

For P1's electron, find T — and confirm it wouldn't change at double the speed.

P3 Selector

A velocity selector passes 4.0×10^{5} m/s with B = 0.25 T. What E does it need?

P4 Isotope Split

Two singly-charged ions at the same speed enter the same field. Ion A rides r = 0.20 m; ion B (heavier isotope) rides r = 0.22 m. Find the mass ratio m_B/m_A — and explain why the spectrometer needs the velocity selector FIRST.