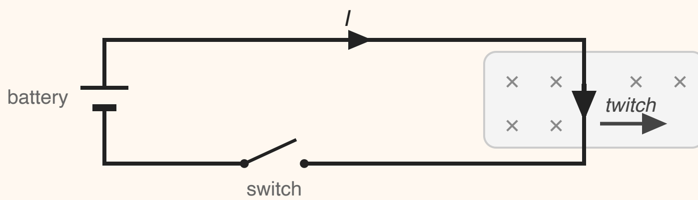
MAGNETISM DAY 1: THE MAGNETIC FORCE

WARMUP A New Kind of Force

A straight wire sits between the poles of a strong magnet. With the switch open, nothing moves. When the teacher briefly closes the circuit, the wire twitches sideways; reverse the battery and the twitch reverses. Electric fields can push charges at rest. This new force appears only when charge is moving through a magnetic field. What TWO things does the twitch tell you about the magnetic force?



The demo circuit. × marks the magnet's field B pointing into the page — the pole faces sit in front of and behind the paper.

THE CROSS-PRODUCT FORCE

The wire twitches because every charge drifting inside it feels a sideways shove. Per charge, the law is:

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}, \text{ magnitude } F = qvB\sin\theta \text{ — B in tesla (T).}$$

Direction: right hand — fingers along v, curl to B, thumb gives F (flip it for negative charges).

The consequence: $F \perp v$ always, so $F \cdot v = 0$ — magnetic forces do NO WORK. They can turn a motion sideways; they cannot speed it up or slow it down.

WE DO Exercise 1: Magnitude Reps

A +5.0 μC charge moves at 2000 m/s perpendicular to a 0.5 T field. **(a)** $F = qvB$ = ________. **(b)** If v makes a 30° angle with B instead: $F = qvB \sin 30°$ = ________.

DIRECTION DISCIPLINE

WE DO **Exercise 2: Axes, Then Cross**

Set up axes (east = $\hat{x}$, north = $\hat{y}$, up = $\hat{z}$ — or your own choice, but WRITE it down first). A proton moves EAST through a field pointing UP. **(a)** Direction of F? **(b)** Same proton, B now points NORTH (horizontal): direction of F? **(c)** An ELECTRON moving east, B up: direction of F?

YOU DO **Exercise 3: The No-Work Argument**

A 500 eV electron enters a strong magnetic field, circles for an hour, and exits. What is its kinetic energy on exit, and what is the one-line justification?

CALC **Exercise 4: Zero Force Cases**

$F = qvB \sin\theta$ vanishes in three distinct physical situations. Name all three (one involves q, one involves v, one involves θ) — and explain why a charge moving PARALLEL to B sails straight through.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Straight Multiply

A $+2.0\ \mu C$ charge at 4000 m/s $\perp$ to a 0.25 T field: find F.

P2 With the Angle

The same charge and field, but v makes 37° with B ($\sin 37° = 0.6$): find F.

P3 Solve for B

A $+4.0\ \mu C$ charge at 5000 m/s ($\perp$) feels 0.01 N. Find B.

P4 Electric vs Magnetic

A charge sits at REST in a region with both E = 2000 V/m and B = 0.5 T. Which field exerts a force on it, how big (per μC), and what must the charge do before the other field can touch it?