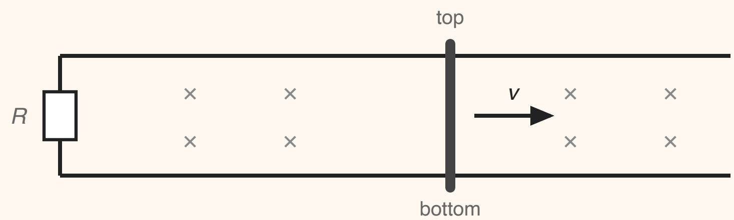
INDUCTION DAY 3: MOTIONAL EMF

WARMUP A Battery Made of Motion

Today's rig: a conducting bar slides RIGHT along two rails, through a field B pointing INTO the page. Every charge inside the bar rides along at v — so each feels $qv \times B$ directed along the bar. Which end of the bar — top or bottom — accumulates positive charge, and what has the bar become?



The bar-on-rails rig for the whole day. × = B into the page.

MOTIONAL EMF & THE ENERGY PIPELINE

$\varepsilon = BLv$ (bar ⊥ B, sliding ⊥ its length)

Close the circuit (resistance R) and the chain runs: $I = BLv/R$ → the current-carrying bar feels **$F = BIL = B^2L^2v/R$** opposing the motion (Lenz) → keeping the bar moving costs $P = Fv =$ **ε^2/R**, exactly the heat in R.

Faraday agrees: the enclosed area grows at rate Lv, so $d\Phi/dt = BLv$. Two derivations, one answer.

WE DO Exercise 1: The Full Chain

B = 0.4 T, L = 0.5 m, v = 3.0 m/s, R = 0.2 Ω. **(a)** $\varepsilon = BLv =$ ________. **(b)** I = ________. **(c)** F on the bar = BIL = ________. **(d)** P = Fv = ________ = ε^2/R = ________.

VARIATIONS ON THE BAR

WE DO **Exercise 2: Terminal Velocity**

The same rails tipped vertical: the bar ($m = 0.1$ kg) falls, and the magnetic drag B^2L^2v/R grows with speed until it balances gravity. Set $B^2L^2v/R = mg$ and solve for the terminal speed ($B = 0.4$ T, $L = 0.5$ m, $R = 0.2\ \Omega$, $g = 9.8$ m/s²).

YOU DO **Exercise 3: Design the Bar**

You need 1.5 V from a rail generator with $B = 0.5$ T and $v = 2.0$ m/s. What bar length?

CALC **Exercise 4: Faraday Route**

Let $x(t)$ be the bar's position, so the enclosed area is $A = Lx$ and $\Phi = BLx$. Differentiate to show $\varepsilon = -d\Phi/dt$ has magnitude BLv — the flux derivation of the same law. State why the $qv\times B$ and $d\Phi/dt$ routes MUST agree.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 BLv

$B = 0.5$ T, $L = 0.8$ m, $v = 4.0$ m/s: find ε.

P2 Chain It

For P1 with $R = 0.4\ \Omega$: find I and the drag force on the bar.

P3 Power Balance

For P1-P2, show $P = Fv$ and $P = \varepsilon^2/R$ give the same number.

P4 The Free-Wheeling Bar

The pushing hand lets go. Describe the bar's subsequent motion qualitatively — what force acts, how it depends on v, and what KIND of decay that produces (you know this shape from RC circuits).