INDUCTION DAY 5: INDUCTANCE & LR CIRCUITS

WARMUP A Coil Fights Its Own Current

A coil's current makes flux through the coil ITSELF — so changing the current changes its own flux, inducing an EMF in itself that (Lenz!) opposes the change. What everyday mechanics concept does "opposes changes to its own motion-quantity" sound like?

INDUCTANCE: CURRENT INERTIA

$\varepsilon_L = -L\cdot dI/dt$ (L in henries; solenoid: $L = \mu_0 n^2\cdot$(volume))

LR decay (switch the battery out): $I(t) = I_0 e^{-t/\tau}$ with **$\tau = L/R$**. **LR rise:** $I(t) = (\varepsilon/R)(1 - e^{-t/\tau})$ — the inductor starts as an OPEN switch, ends as a bare wire (the capacitor's exact opposite).

Stored energy: $U = \frac{1}{2}LI^2$ — in the magnetic field, the twin of $\frac{1}{2}CV^2$.

WE DO Exercise 1: Clock, Bank, and Flow

L = 5.0 H carrying 2.0 A discharges through R = 10 Ω. **(a)** $\tau = L/R$ = ________. **(b)** Stored energy $\frac{1}{2}LI^2$ = ________. **(c)** Total charge that flows: $I_0\tau$ = ________.

SELF-EMF AND THE RISE

WE DO **Exercise 2: Back-EMF**

A 0.2 H inductor's current is ramped at dI/dt = 50 A/s. **(a)** $|\varepsilon_L|$ = L·dI/dt = _________. **(b)** The ramp doubles to 100 A/s: ε_L = _________. **(c)** The current is large but CONSTANT: ε_L = _________.

YOU DO **Exercise 3: The Rise**

A 12 V battery, R = 10 Ω, L = 5.0 H (τ = 0.5 s). Find the FINAL current (t ≫ τ, inductor = bare wire), the current at t = 0 (inductor = open switch), and the current at t = τ (63% of the way).

CALC **Exercise 4: Derive the Decay**

After the switch: the loop rule reads –L·dI/dt – IR = 0. Separate variables and integrate to reach I(t) = I_0e^(–Rt/L). Compare line-by-line with the RC derivation — same mathematics, new letters.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 **The Clock**

$L = 2.0$ H, $R = 8.0\ \Omega$: find τ.

P2 **Back-EMF**

A 0.5 H inductor with current ramping at 20 A/s: find $|\varepsilon_L|$.

P3 **Stored Energy**

A 2.0 H inductor carries 3.0 A. Find $U = \frac{1}{2}LI^2$.

P4 **Why Switches Spark**

Opening a switch on an inductive circuit forces dI/dt to be huge (current to zero, fast). Use $\varepsilon = -L\cdot dI/dt$ to explain the spark that jumps the gap — and why the ENERGY for the spark was already sitting in the circuit before the switch moved.