INDUCTION DAY 7: UNIT REVIEW & MAXWELL

BIG IDEAS TO REMEMBER

- **$\Phi = BA\cos\theta$** (Wb); closed surfaces always net zero (no monopoles).
- **$\varepsilon = -N \cdot d\Phi/dt$**; Lenz's minus = energy conservation. Change B, A, or θ — one law covers all three.
- **Motional:** $\varepsilon = BLv$; drag $F = B^2L^2v/R$; $P = Fv = \varepsilon^2/R$ exactly.
- **Curly E:** $\oint E \cdot dl = -d\Phi/dt$ — no potential map; $(r/2)dB/dt$ inside a ramping solenoid.
- **Inductors:** $\varepsilon_L = -L \cdot dI/dt$; $\tau = L/R$; $U = \frac{1}{2}LI^2$; open-switch → bare-wire over ~5τ.
- **Generator:** $\varepsilon = NBA\omega \cdot \sin(\omega t)$ — the flux cosine, differentiated by rotation.

A Direction & Concept Rapid-Fire

One line each: **(a)** magnet's N pole pulled AWAY from a loop (viewed from the magnet's side) — induced current direction? **(b)** at t = 0, a charging inductor acts like what element? A charging capacitor? **(c)** why does $\tau = L/R$ SHRINK when R grows, while $\tau = RC$ grows? **(d)** where does a generator's electrical energy come from?

MIXED PRACTICE

B Faraday Chain

A 300-turn coil ($A = 0.02\ m^2$, $R = 6.0\ \Omega$) sits in a field ramping at 0.5 T/s. Find ε, then I, then the power dissipated.

C Rails Chain

$B = 0.5$ T, $L = 0.8$ m, $v = 4.0$ m/s, $R = 0.4\ \Omega$. Find ε, I, the drag force, and verify $Fv = \varepsilon^2/R$.

D LR Chain

$L = 2.0$ H carrying 3.0 A ($U = \frac{1}{2}LI^2$ — compute it) discharges through $R = 8.0\ \Omega$. Find τ, the current at $t = \tau$, and where the stored joules end up.

THE COURSE IN FOUR EQUATIONS

MAXWELL'S EQUATIONS — YOU NOW OWN ALL FOUR

- **Gauss (E):** $\oint E\cdot dA = q_{enc}/\varepsilon_0$ — charges source E (Unit 8).
- **Gauss (B):** $\oint B\cdot dA = 0$ — no monopoles; B-lines close (Unit 13, Day 1).
- **Faraday:** $\oint E\cdot dl = -d\Phi_B/dt$ — changing B curls E (Unit 13).
- **Ampère(–Maxwell):** $\oint B\cdot dl = \mu_0 I_{enc}$ $(+\ \mu_0\varepsilon_0\cdot d\Phi_E/dt)$ — currents (and changing E) curl B (Unit 12).

Chase Faraday and Ampère–Maxwell into empty space and they feed each other: a wave of E and B, traveling at $1/\sqrt{\mu_0\varepsilon_0} = 3\times10^8$ m/s. Light. That's the whole course's punchline.

E Short FRQ: Derive the LR Rise

A battery ε, resistor R, and inductor L are switched on at t = 0.

a. **Write** the loop rule: $\varepsilon - IR - L\cdot dI/dt = 0$.

b. **Verify** by substitution that $I(t) = (\varepsilon/R)(1 - e^{-Rt/L})$ satisfies it, with $I(0) = 0$.

c. **Explain** physically why I starts at zero and ends at ε/R.

F Reflection

Which of these can you least reliably do on your own — Lenz directions, motional-EMF chains, induced electric fields, or LR exponentials? Name it, and write your plan to fix it before the test:

Test Reminder: induction responds to CHANGE, never amount; Lenz before algebra on every direction question; τ = L/R (R below!); and the generator's ω appears twice — amplitude AND frequency.