INDUCTION DAY 6: THE AC GENERATOR

WARMUP **The 90° Shift**

On Day 1 you sketched the flux cosine for a spinning loop; on Day 2 you marked where its derivative peaks. Faraday says ε = –dΦ/dt. So at which points of the rotation does the EMF peak — and what is the EMF at the instant the flux itself is largest?

THE AC GENERATOR

Spin a coil at ω in a field: Φ = NBA·cos(ωt), so

$$\varepsilon = NBA\omega \cdot \sin(\omega t), \text{ peak } \varepsilon_0 = NBA\omega$$

Alternating by construction — rotation cannot help but make AC. All four knobs (N, B, A, ω) scale the peak linearly, but ω also sets the frequency (f = ω/2π; the grid pins f = 60 Hz, so ω = 377 rad/s).

Motors run backward: a spinning motor is also a generator whose back-EMF opposes the supply — why motors draw huge current at startup (no back-EMF yet).

WE DO **Exercise 1: Classroom Loop, Then Grid Machine**

(a) A demonstration loop: N = 1, B = 0.5 T, A = 1.0 m², ω = 2.0 rad/s: ε_0 = _____. **(b)** Grid generator: N = 100, B = 0.5 T, A = 0.01 m², ω = 377 rad/s: ε_0 = _____.

DESIGN AND BACK-EMF

WE DO Exercise 2: Hit a Spec

A generator must peak at 170 V (household AC) at $\omega = 377$ rad/s with $B = 0.4$ T and $A = 0.02$ m². How many turns?

YOU DO Exercise 3: The Startup Surge

A motor (armature resistance 2.0 Ω) runs on 120 V. Spinning at speed, its back-EMF is 110 V. Find the running current — and the current at the instant of startup (back-EMF = 0). Which one is more likely to heat/melt copper wire?

CALC Exercise 4: Differentiate the Flux

Start from $\Phi = NBA\cdot\cos(\omega t)$ and differentiate to derive $\varepsilon = NBA\omega\cdot\sin(\omega t)$. Mark where the chain rule deposits the ω — that factor is why faster spinning means more volts, not just more cycles.

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Peak EMF

N = 50, B = 0.2 T, A = 0.05 m², ω = 100 rad/s: find ε_0.

P2 Solve for ω

The same coil must peak at 100 V. What ω?

P3 Frequency

At ω = 377 rad/s, find the AC frequency f = ω/2π — and recognize the number.

P4 The Energy Honest-Broker

A generator delivering electrical power gets HARDER to turn as the load draws more current. Chain the argument (current → force on the spinning coil → Lenz) and state why a frictionless, load-free generator would spin forever but power nothing.