ELECTRICITY DAY 14: CAPACITORS - CAPACITANCE, ENERGY & DIELECTRICS

CED 10.6–10.7 · Skill 2.B · FRQ: MR · target: capacitance is set by geometry and material, not by applied voltage

PREDICT BEFORE OBSERVING

A charged capacitor is disconnected from its source and connected across a small bulb. Predict: **steady light / brief flash / no light**. State where the delivered energy was stored.

Observation source: a low-voltage capacitor and bulb/LED with appropriate resistor; projected circuit simulation; or the printed sequence: charged capacitor → connect bulb → flash → uncharged capacitor.

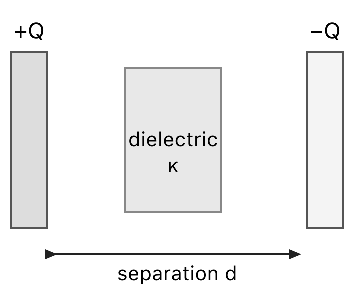
CAPACITANCE

$$C = Q/\Delta V \qquad Q = C\Delta V$$

For an ideal linear capacitor, C is a device property. Changing the applied voltage changes Q in the same ratio, so Q/ΔV remains constant.

QUICK A 0.40 μF capacitor is connected first to 10 V and then to 20 V. Compare Q and C in the two cases.

PARALLEL-PLATE CAPACITOR MODEL



$C = \varepsilon_0 \kappa A/d$

larger A → larger C

larger d → smaller C

larger κ → larger C

PARALLEL-PLATE GEOMETRY

$$C = \varepsilon_0 \kappa A/d \qquad \varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F/m}$$

Use plate overlap area A in m² and separation d in m. For vacuum/air, $\kappa \approx 1$.

WE DO A capacitor has plate area $150\ \mathrm{cm}^2$, separation $1.5\ \mathrm{mm}$, and dielectric constant $\kappa = 2.5$. Find C in pF.

YOU DO For the same capacitor, find Q when connected to 90 V.

Geometry prediction: doubling A doubles C; doubling d halves C; inserting a dielectric multiplies C by κ.

STORED ENERGY

$$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2 = \frac{Q^2}{2C}$$

WE DO Find the stored energy of the 221 pF capacitor at 90 V. Report J and µJ.

ENERGY THROUGH A POTENTIAL DIFFERENCE

For a charge moving through a potential difference:

$$\Delta U = q\Delta V \qquad W_{\text{field}} = -\Delta U$$

YOU DO A $+2.0\mu\text{C}$ charge moves from 150 V to 0 V through a circuit element. Find ΔU and the energy delivered by the electric field.

REPRESENT Draw before/after energy bars for the capacitor-bulb flash. Include stored electric energy, light/thermal transfer, and final capacitor energy.

PRACTICE

1. A capacitor stores 6.0 μC at 24 V. Find C.

2. Vacuum plates have A = 180 cm^2 and d = 2.0 mm. Find C in pF.

3. A 120 μF capacitor is charged to 15 V. Find stored energy in mJ.

4. Plate area doubles, separation triples, and κ becomes four times larger. Find the C factor.

5. A dielectric is inserted. Compare Q, V, C, and U for (a) a capacitor still connected to an ideal battery and (b) an isolated charged capacitor. State what is conserved in each case.