Capacitors & Dielectrics

Capacitance · 7 questions · step-by-step answers at the end

Name: Date: Score: / 7

USEFUL EQUATIONS

$C = Q/V$ $C = \kappa\varepsilon_0 A/d$ $U = \tfrac{1}{2}CV^2 = \tfrac{1}{2}QV$ $E = V/d = \sigma/(\kappa\varepsilon_0)$ $C_{\text{par}} = \Sigma C,\ 1/C_{\text{ser}} = \Sigma 1/C$

Questions

Show your working in the space under each question.

1. An isolated charged capacitor has its plate separation doubled. What happens to C, V and U?

2. Parallel plates of area 0.010 m² are 2.0 mm apart in air, connected to 12 V. Find C, Q and U. What happens to Q if a dielectric with κ = 4 is inserted while it is still connected?

3. 3.0 µF and 6.0 µF capacitors are in series across 12 V. Find C_{eq}, the charge, and each voltage.

4. 2.0 µF and 4.0 µF capacitors are in series, and that pair is in parallel with a 6.0 µF capacitor. Find the equivalent capacitance.

5. A $\kappa = 4$ dielectric is slid into a capacitor that stays connected to a battery. What happens to Q?

6. What is the energy density in a field of 1.0×10^5 V/m?

7. An isolated charged capacitor has a $\kappa = 3$ dielectric slid in. What happens to V and U?

Step-by-step answers

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1. C **halves**, Q is fixed, so V = Q/C **doubles**, and U = $Q^2/2C$ **doubles**. The extra energy comes from the work done pulling the plates apart.

2. 1. $C = \varepsilon_0 A/d = (8.85 \times 10^{-12})(0.010)/(0.0020) =$ **44 pF**.
2. $Q = CV = (44.3 \times 10^{-12})(12) =$ **0.53 nC**.
3. $U = \frac{1}{2}CV^2 = \frac{1}{2}(44.3 \times 10^{-12})(144) =$ **3.2 nJ**.
4. With the dielectric, C becomes 4 × 44 = 177 pF. V stays 12 V (battery), so Q = CV goes up **4×**, to 2.1 nC. More charge flows on from the battery.

Answer: C = 44 pF, Q = 0.53 nC, U = 3.2 nJ; Q goes up 4×

3. C_{eq} = **2.0 µF**; Q = **24 µC** on each; V = 24/3 = **8 V** and 24/6 = **4 V**.

4. Series: (2 × 4)/(2 + 4) = 1.33 µF. Adding 6 in parallel gives **7.33 µF**.

5. C ×4 with V fixed, so **Q ×4**.

6. $u = \frac{1}{2}\varepsilon_0 E^2 =$ **0.044 J/m³**.

7. Q is fixed and C triples, so V and U each drop to ⅓. The dielectric is pulled in.