Capacitors

Basic Problems

1. When a voltage of 3 kV is applied to the two conductors of a capacitor, they carry a charge of ± 60 nC respectively. What is the capacitor's capacitance?
2. A variable capacitor's capacitance is increased by 10 % without changing the charge. How does the applied voltage change?
3. The distance between the plates of a parallel plate capacitor is increased by 50 %. How does its capacitance change?
4. Calculate the capacitance of an air filled parallel plate capacitor with area 1 m² and gap size 1 mm.
5. When a dielectric is introduced between the plates of a parallel plate capacitor, the potential difference decreases (at constant charge) from 600 V to 150 V. What material could the dielectric plate be made of?
6. A capacitor with capacitance 220 nF is connected to two capacitors in parallel with capacitances 220 nF and 330 nF. Calculate the total capacitance of the circuit.
7. The potential difference applied to a capacitor decreases by 10 %. How does the energy stored in the capacitor change?
8. How does the charge in a capacitor change when the stored energy increases by 50 %?
9. The energy densities at two points in an electric field vary by a factor of 3. What is the ratio of the electric field vector's magnitudes in these points?

Additional Problems

10. A spherical capacitor consists of two concentric spherical conducting shells.
    a) Show that the capacitance of a spherical capacitor is
    $$C = 4\pi \cdot \kappa \cdot \varepsilon_0 \cdot \left(\frac{1}{r_i} - \frac{1}{r_o} \right)^{-1} .$$
    r_i and r_o are the inner and outer shell's radii.
    (Hint: Potential difference in the field of a point charge.)
    b) Calculate the capacitance of a spherical capacitor filled with paraffin, whose inner and outer radius are 1 cm and 5 cm respectively.
    c) Derive the formula for the capacitance of a sphere with respect to a point at infinity. Use the result to calculate the capacitance of the earth.
11. A dielectric plate with dielectric constant κ is inserted between the plates of a parallel plate capacitor. The thickness of the plate is two third of the distance between the plates. How does the capacitance change?
12. An *electrostatic voltmeter* is basically a capacitor with a hand to indicate the charge on the device.
    With a first voltmeter (capacitance 15 pF) a potential difference of 275 V is measured on a capacitor. With a second voltmeter (25 pF) only 248 V are measured. Explain this phenomenon and calculate the correct potential difference.
13. An insulating foil often used to build capacitors has a dielectric constant 2.2, a thickness of 5 µm and a density of 910 kg/m³. It is covered on both sides with a very thin layer of metal.
    a) Calculate the volume and the mass of the foil in a 1.5 µF capacitor.
    b) What is the energy stored in the capacitor at an applied voltage of 3.5 kV?

Solutions to basic problems: 1. 20 pF; 2. −9 %; 3. −33 %; 4. 8.8 nF; 5. quartz glass; 6. 160 nF; 7. −19 %; 8. +22 %; 9. $\sqrt{3}:1$