Capacitors

Basic Problems

1. When a voltage of 3 kV is applied to a capacitor, it carries a charge of 60 nC. Calculate the 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 with initial capacitance 7.8 pF is increased from 1.4 mm to 2.1 mm. Calculate the new capacitance.
4. Calculate the capacitance of an air filled parallel plate capacitor with area 1.5 m^2 and gap size 1.2 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. Calculate the total capacitance of a 220 nF capacitor in series to a 220 nF and a 330 nF capacitor in parallel.
7. A 47 µF capacitor stores 2.4 J of electric energy. Calculate the potential difference at the capacitor.
8. The potential difference applied to a capacitor is decreased from 320 V to 280 V. Calculate the percentage change of the energy stored in the capacitor.
9. How does the charge on the capacitor plates change when the stored energy increases by 35 %?
10. The energy density in a laser beam is 35 µJ/m^3. Calculate the magnitude of the electric field vector at this position.

Additional Problems

11. A spherical capacitor consists of two concentric spherical conducting shells.
    a) Show that the capacitance of a spherical capacitor is given by the expression
    $$C = 4\pi\,\kappa\,\varepsilon_0 \cdot \left(\frac{1}{r_\mathrm{i}} - \frac{1}{r_\mathrm{o}}\right)^{-1},$$
    where r_i and r_o are the inner and outer shell's radii.
    Hint: Potential 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.
12. A dielectric plate with dielectric constant κ is inserted between the plates of a parallel plate capacitor. The thickness of the plate is two thirds of the distance between the plates. How does the capacitance change?
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/m^3. 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?
14. 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.

Solutions: 1. 20 pF; 2. − 9 %; 3. 5.2 pF; 4. 8.8 nF; 5. quartz glass; 6. 160 nF; 7. 320 V; 8. − 23 %; 9. +16 %; 10. 2.8 kV/m; 11. 3.1 pF; 12. factor 3 κ/(2+κ); 13. 1.9 mm^3, 9.2 J; 14. 77 pF