Chapter 20 – Solutions to Problems 1, 5, 8, 11, 13, 17, 23, 25, 26, 30, 35, 37, 38, 39, 43, 47, 51

1. A capacitor is a device. The capacitance of this device defines how much charge +*Q* and –*Q*, is stored in separated form for a given voltage difference applied to it. The definition is $C = Q/V$. A capacitor that stores 1 Coulomb of +charge on its positive "plate" and 1 Coulomb of –charge on its negative "plate" when a 1-volt difference is applied to its "terminals," is said to have a capacitance of 1 Farad. For the device described in this problem, $Q = CV = (0.75 \times 10^{-6}$ F)(25 V) = 19 microC.

5. As described in problem 1), $C = Q/V$. Thus $C = 2 \times 10^{-6}$ C)/(1000 V) = 2×10^{-9} F.

8. If two concentric spheres have almost the same radii, then the gap between the two spheres is very small. The two spherical surfaces can be regarded as closely equivalent to a parallel plate capacitor having the same area as that of a sphere having an intermediate radius. This approximation becomes poor if the gap gets too large. For this problem, the gap is only 0.50 mm, whereas the radii of the spheres are about 10 cm, so that the gap is only 5% of the average radius. For a large gap you would need calculus, which is beyond expectation for this course. Recall that the surface of a sphere of radius *R* is 4(pi)R^2. Your book tells you that the capacitance of a parallel-plate capacitor is C = (epsilon$_0$)(A)/d. Thus *C* is approximately equal to (8.85×10^{-12} F/m)(4)(3.14)(0.105 m)^2/(0.0005 m) = 2.5×10^{-9} F.

11. In class, we discussed that the effective capacitance of three capacitors in parallel is found from the expression $C_{eff} = C_1 + C_2 + C_3$, and of three capacitors is series from the expression

$$\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}.$$

   a. Thus for the three capacitors in series $1/C_{eff}$ = (1/2 + 1/7 + 1/14) microF^{-1} = 10/14 microF^{-1}.

      C_{eff} = 1.4 microF.

   b. In parallel, the three capacitors are simply added to get the effective capacitance.

      C_{eff} = (2 + 7 + 14) microF = 23 microF.

13.
   a. Remember the important comments in class about various voltages across circuit elements in any circuit. When three capacitors are connected in parallel across a 12-volt battery, each capacitor has 12 volts across it. For each capacitor, $Q = CV$, so that

      Q_2 = (2 microF)(12 V) = 24 microC

      Q_6 = (6 microF)(12 V) = 72 microC

      Q_{12} = (12 microF)(12 V) = 144 microC

   b. The series configuration is not that simple, however. Refer to the diagram below. The important starting point is to know that each capacitor in the series has the same stored charge on their individual positive plates. Thus replace the series by its effective value using the series equation of problem 11. Since 1/2 + 1/6 + 1/12 = 9/12, we see that the effective capacitance if the series is C_{eff} = 4/3 microF. This effective capacitor, when charged by 12 volts, stores a charge of

      Q = (4/3 microF)(12 V) = 16 microC.

   A charge +*Q* resides on the positive plate, and a like amount –*Q* resides on the negative plate of each capacitor. This fact is all we need to determine the voltage across each capacitor.

      $V_{AB} = V_B - V_A$ = – (16 microC)/(2 microF) = –8 V.

      $V_{BC} = V_C - V_B$ = – (16 microF)/(6 microF) = –2.67 V

      $V_{CD} = V_D - V_C$ = – (16 microF)/(12 microF) = –1.33 V

17. The solution of this question is based on the concepts of Chapter 19. To begin with, the electric field between the plates of a parallel plate capacitor is uniform, except at the edges. In a uniform electric field, the voltage difference between any two points along the field is *Ed*. The imaginary plane perpendicular to the electric field is called an equipotential surface, because everywhere on this plane, the electrical potential is constant. Two such perpendicular planes 10 cm apart in a field of strength 30,000 V/m (remember it's also 30,000N/C) is assumed to have a potential difference of 10 V. Thus, the separation distance must be

      d = (10 V)/(30,000 V/m) = 3.33×10^{-4} m.