Tutorial 3 (Covering Lectures 5-7)

QUESTIONS:

1. Define the *capacitance* of a capacitor.

2. A parallel-plate capacitor has a capacitance of 6×10^{-4} μF and is charged by 100 V battery.
   (a) Calculate the charge stored by this capacitor.
   (b) How much charge would be stored if the same capacitor was connected to a 50 V battery?

3. One plate of a parallel-plate capacitor is earthed and the other is at a potential V.
   (a) For the region between the plates, sketch a graph of the potential V against distance between the plates.
   (b) Write down an equation that relates the potential difference between the plates, the separation d of the plates, and the electric field strength E between the plates.
   (c) Give the expression for the capacitance of a parallel plate capacitor that has plates with area A whose separation is d. Derive this expression, given that Gauss' law applied to a large, charged, flat conducting plate gives for the electric field E close to the surface:
   $$E = \frac{\sigma}{\varepsilon}$$
   where σ is the surface charge density and ε is the permittivity in air.

4. A capacitor placed in air has plates of area 0.25 m^2, that are 2 mm apart and is connected to a 90 V battery.
   (a) Calculate the capacitance and the charge of the capacitor.
   (b) The capacitor is then disconnected from the battery and the plates are moved apart to twice the original distance. Calculate the potential between the plates under these conditions.

5. A film of plastic, having a thickness of 0.05 mm and a relative permittivity of 2.6, is sandwiched between two sheets of aluminium foil to make a 1.0 μF capacitor. Calculate the area of the film of plastic. (Assume that the areas of the foils and the plastic are the same, and that $\varepsilon_o = 8.85\times10^{-12}$ Fm^{-1}.)

6. A sheet of paper, having a width of 40 mm and a thickness of 0.015 mm, is sandwiched between metal foil to make a 2.0 μF capacitor. If the dielectric constant (relative permittivity) of the paper is 2.5, what is the length of paper required? . (Assume that the areas of the foils and the paper are the same, and that $\varepsilon_o = 8.85\times10^{-12}$ Fm^{-1}.)

7. Give an expression for the potential on the surface of an isolated, conducting sphere having a charge Q and a radius R. Hence, derive an expression for the capacitance of the sphere.

8. Multiple choice: Which of the following statements are *always true* for two capacitors that are connected in parallel:
   (i) the potential difference across each capacitor is the same;
   (ii) the charge stored on each capacitor is the same;
   (iii) the total capacitance is greater than the capacitance of each capacitor.

   A (i), (ii) and (ii); **B** (i) and (ii), only; **C** (i) and (iii) only; **D** (ii) and (iii), only; **E** (ii) only

9. Multiple choice: Which of the following statements are *always true* for two capacitors that are connected in series:
   (i) the potential difference across each capacitor is the same;
   (ii) the charge stored on each capacitor is the same;
   (iii) the total capacitance is greater than the capacitance of each capacitor.

   A (i), (ii) and (ii); **B** (i) and (ii), only; **C** (i) and (iii) only; **D** (ii) and (iii), only; **E** (ii) only

10. Two capacitors having capacitances of 8 μF and 12 μF, respectively, are connected:
    (i) in series; (ii) in parallel.
    Calculate the equivalent capacitance in each case.

11. Two capacitors having capacitances of 0.4 μF and 0.6 μF, respectively, are connected:
    (i) in series; (ii) in parallel.
    Calculate the equivalent capacitance in each case.

COURSEWORK (Questions 1. to 3.):

1. Two capacitors, each having a capacitance of 8 μF, are connected:
   (i) in series; (ii) in parallel.
   Calculate the equivalent capacitance in each case.

2. A capacitor placed in air has plates of area 0.5 m^2, that are 1 mm apart and is connected to a 100 V battery.
   (a) Calculate the capacitance and the charge of the capacitor.
   (b) The capacitor is then disconnected from the battery and the plates are moved apart to twice the original distance. Calculate the potential between the plates under these conditions.

3. A sheet of paper, having a width of 10 mm and a thickness of 0.01 mm, is sandwiched between metal foil to make a 2.0 μF capacitor. If the dielectric constant (relative permittivity) of the paper is 2.5, what is the length of paper required? . (Assume that the areas of the foils and the paper are the same, and that $\varepsilon_o = 8.85 \times 10^{-12}$ Fm^{-1}.)