Tutorial 4 (Covering Lectures 5-8)

QUESTIONS:

1. Give an expression for the energy stored in a charged capacitor. A capacitor is connected to a battery of 12 V and has a charge of 10 μC. What is the energy stored in the capacitor?

2. Calculate the energy stored in a capacitor of capacitance 10 μF that has a charge of 20 μC.

3. Calculate the energy stored in a capacitor of capacitance $C = 100$ μF that is charged to a potential $V = 100$ V.

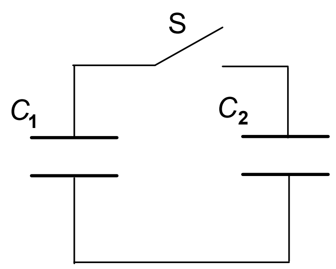
4. The capacitance of an isolated conducting sphere in air is approximately given by:

$$C = 4\pi\varepsilon_0 R \ ,$$

where R is the radius of the sphere and ε_0 is the permittivity of free space.
Two conducting spheres, at a considerable distance apart, are connected by a conducting wire. How will a total charge of 1 μC distribute itself in the cases when:

(a) the two spheres have the same radius;
(b) the radii of the spheres are 60 mm and 20 mm, respectively?

5.



A capacitor of capacitance $C_1 = 10$ μF is charged so that the potential difference between its terminals is $V_1 = 50$ V. The terminals of an uncharged capacitor, with capacitance $C_2 = 2.5$ μF , are then connected to those of the charged capacitor (see the above diagram).

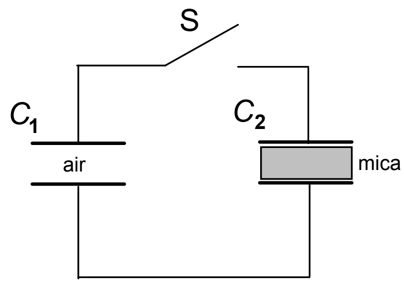
Calculate:

(a) the energy stored in C_1 before it is connected to C_2 ;
(b) the potential difference across the parallel combination of capacitors (after connection);
(c) the total energy stored in the two capacitors after they are connected to one another.

How do you account for the difference between (a) and (c)?

6. Explain the meaning of the term *relative permittivity.*

7.



Consider two parallel plate capacitors of identical dimensions, one of which has air as the dielectric and the other mica. The air capacitor is charged to 400 V, isolated and then connected (via a switch S) across the mica capacitor, which is initially uncharged (see the above diagram). Once the switch is closed, the potential difference across this parallel combination of capacitors becomes 50 V.

(a) Show that the total charge stored Q, before and after switch S is closed, is given by:

$$Q = 50(1+\varepsilon_r)C_1 \ ,$$

where ε_r is the relative permittivity of mica, and the relative permittivity of air to taken to be equal to 1.

(b) Hence, calculate the value of ε_r.

(c) Calculate the energy stored in the single air gap capacitor before the connection and compare this with the energy stored in the parallel combination. Comment on the difference.

8. Calculate the *time constant* for a circuit containing a capacitor with $C = 2\ \mu$F and a resistor with $R = 500\ k\Omega$.

9. Calculate the *time constant* for a circuit containing a resistance of $R = 50\ k\Omega$ and a capacitance of $C = 20\ \mu$F.

10. For a circuit containing a charged capacitor, $C = 5\ \mu$F, and a resistor, $R = 500\ k\Omega$, in series, after what time has the charge on the capacitor dropped to $\frac{1}{e}$ of its original value?

COURSEWORK (Questions 1. to 3.):

1. Repeat Question 3. with $C = 50\ \mu$F and $V = 50$ V.
2. Repeat Question 5. with $C_1 = 50\ \mu$F , $C_2 = 10\ \mu$F and $V_1 = 10$ V.
3. Repeat Question 10. with $C = 2\ \mu$F and $R = 5\ M\Omega$