Physics 4B
Chapter 25: Capacitance

"The answers you receive depend upon the questions you ask." – Thomas Kuhn

"*Life is a mirror and will reflect back to the thinker what he thinks into it.****"*** **–** Ernest Holmes

"What we see depends mainly on what we look for." **–** John Lubbock

Reading: pages 656 – 674

Outline:

⇒ capacitors
- introduction
- definition of capacitance

⇒ calculating capacitance
- parallel-plate capacitor
- spherical capacitor (read on your own)
- cylindrical capacitor (read on your own)

⇒ combinations of capacitors
- series
- parallel

⇒ energy stored in an electric field

⇒ dielectrics
- capacitors with dielectrics
- atomic view of dielectrics (PowerPoint)
- Gauss' Law (read on your own)

Problem Solving Techniques

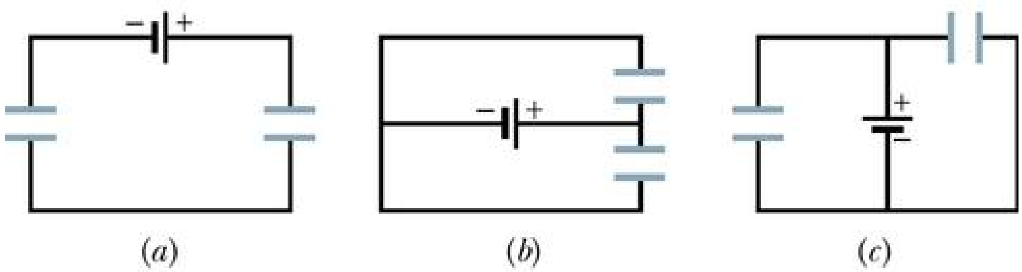
To solve many problems of this chapter, you should know the basic relationship between the magnitude q of the charge on either plate of a capacitor and the potential V difference across the plates: $q = CV$. You should also know how to calculate the capacitance of a parallel-plate capacitor, a cylindrical capacitor, and a spherical capacitor, all in terms of the geometry of the capacitor. You should also know that the capacitance of a capacitor that is filled with a dielectric of dielectric constant k is $C = \kappa C_0$, where C_0 is the capacitance of the capacitor without the dielectric.

Some problems deal with capacitors in series or parallel. In each case, you should know how to compute the equivalent capacitance, the charge on each capacitor, and the potential difference across each capacitor, given the potential difference across the combination.

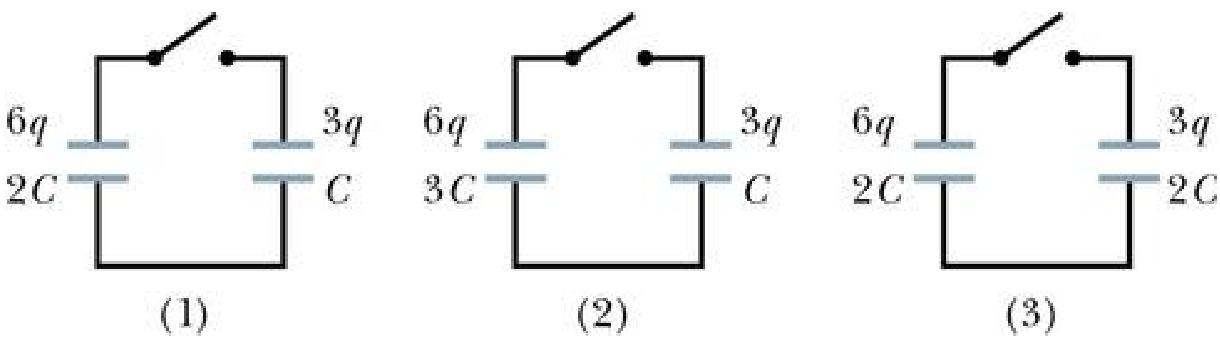
You should know how to compute the energy stored in a capacitor, given either its charge or potential difference. You should also know how to compute the energy density at points between the plates or, in general, at any point within a given electric field.

Questions and Example Problems from Chapter 25

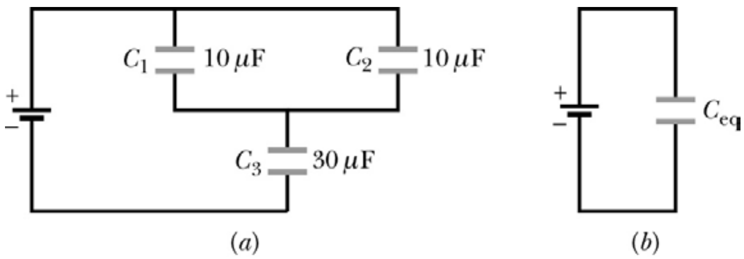
Question 1
For each circuit in the figure below, are the capacitors connected in series, in parallel, or in neither mode?



Question 2
The figure below shows three circuits, each consisting of a switch and two capacitors, initially charged as indicated. After the switches have been closed, in which circuit (if any) will the charge on the left-hand capacitor (a) increase, (b) decrease, and (c) remain the same?



Question 3
Figure a shows a circuit with three capacitors, and Fig. b shows the circuit with their equivalent capacitor, of capacitance C_{eq}, which has a charge of 60 μC. Without a calculator (and, if possible, without written calculation), find (a) the charge on and (b) the voltage across capacitor 3 and then (c) the charge on and (d) the voltage across capacitor 1.

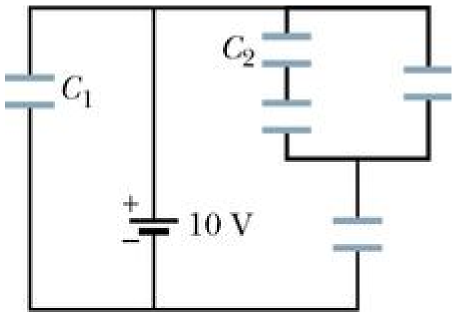


Problem 1
A parallel-plate capacitor has circular plates of 8.20 cm radius and 1.30 mm separation. (a) Calculate the capacitance. (b) Find the charge for a potential difference of 120 V.

Problem 2
Suppose that the two spherical shells of a spherical capacitor have approximately equal radii. Under these conditions, the device approximates a parallel-plate capacitor with b - a = d. Show that Eq. 25-17 ($C = 4\pi\varepsilon_0\, ab/(b - a)$) does indeed reduce to Eq. 25-9 ($C = \varepsilon_0 A/d$) in this case.

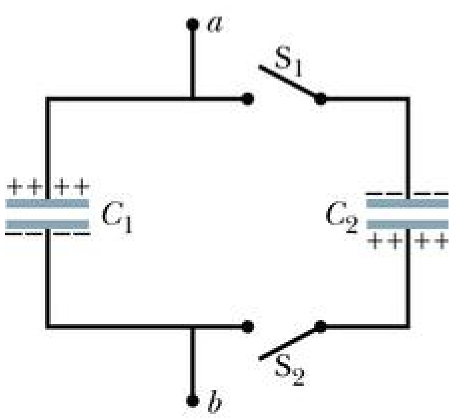
Problem 3

In the figure below, the battery has a potential difference of 10.0 V and the five capacitors each have a capacitance of 10.0 μF. What is the charge on (a) capacitor 1 and (b) capacitor 2?



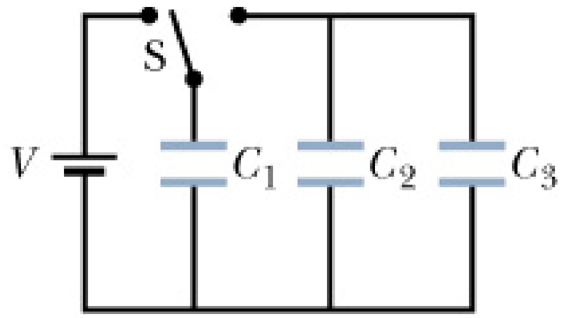
Problem 4
A 100 pF capacitor is charged to a potential difference of 50 V, and the charging battery is disconnected. The capacitor is then connected in parallel with a second (initially uncharged) capacitor. If the potential difference across the first capacitor drops to 35 V, what is the capacitance of this second capacitor?

Problem 5
In the figure below, the capacitances are C_1 = 1.0 μF and C_2 = 3.0 μF and both capacitors are charged to a potential difference of V = 100 V but with opposite polarity as shown. Switches S_1 and S_2 are now closed. (a) What is now the potential difference between points a and b? What are now the charges on capacitors (b) 1 and (c) 2?



Problem 6

In the figure below, V = 10 V, C_1 = 10 μF, and $C_2 = C_3$ = 20 μF. Switch S is first thrown to the left side until capacitor 1 reaches equilibrium. Then the switch is thrown to the right. When equilibrium is again reached, how much charge is on capacitor 1.



Problem 7
The parallel-plates in a capacitor, with a plate area of 8.50 cm^2 and an air-filled separation of 3.00 mm, are charged by a 6.00 V battery. They are then disconnected from the battery and pulled apart (without discharge) to a separation of 8.00 mm. Neglecting fringing, find (a) the potential difference between the plates (b) the initial stored energy, (c) the final stored energy and (d) the work required to separate the plates.

Problem 8
A parallel-plate air-filled capacitor has a capacitance of 50 pF. (a) If each of its plates has an area of 0.35 m^2, what is the separation? (b) If the region between the plates is now filled with material having $\kappa = 5.6$, what is the capacitance?

Problem 9

The space between two concentric conducting spherical shells of radii b = 1.70 cm and a = 1.20 cm is filled with a substance of dielectric constant $\kappa = 23.5$. A potential difference V = 73.0 V is applied across the inner and outer shells. Determine (a) the capacitance of the device, (b) the free charge q on the inner shell, and (c) the charge q' induced along the surface of the inner shell.

Problem 10

Two parallel plates of area 100 cm^2 are given charges of equal magnitudes 8.9×10^{-7} C but opposite signs. The electric field within the dielectric material filling the space between the plates is 1.4×10^6 V/m. (a) Calculate the dielectric constant of the material. (b) Determine the magnitude of the charge induced on each dielectric surface.