General Physics - E&M (PHY 1308) Lecture Notes

Lecture 008: Capacitors

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no tags

Goals of this Lecture

- Discuss how to store energy in a simple configuration: the parallel plate capacitor
- Discuss the properties of capacitors

Capacitors

So we can store energy in an electric field. A device that does this is called a *capacitor*. Specifically,

- A **capacitor** is a pair of electrical conductors that carry equal but opposite charges

The two conductors are thus attracted to one another, and it takes work to keep them apart. The easiest to analyze capactor is the **parallel-plate capacitor**, although capacitors come in many configurations. Understanding the parallel-plate capacitor will give us insight into electrostatic energy and the electric field.

Parallel plate capacitor

A device with two parallel thin sheets of conductor. Charge is removed from one plate and added to the other (e.g. a battery can do this). Thus we have equal but opposite charges on the two plates, and close to the center of the plates we can understand the electric field by modeling the system with two infinite thin sheets of opposite charge. The field lines are perpendicular to the sheets and go from positive to negative.

Closer to the ends, the field becomes nonuniform. But we can neglect this and still get tremendously far in understanding these devices.

Tthe electric field at the surface of the conductor is given by $|E| = \sigma/\epsilon_0$. If we've spread out charge uniformly over the two plates, then for either plate $\sigma = Q/A$, where A is the area of the plate. Thus the uniform field between the two is:

$$E = Q/\epsilon_0 A$$

Remember, these are conductors and the opposite charges accumulate on the faces closest between the two plates.

The potential difference between the two plates is

$$V = Ed = Qd/\epsilon_0 A$$

since the field is uniform.

Capacitance

We can rewrite our relationship between charge and potential to solve for charge in terms of potential:

$$Q = (\epsilon_0 A/d)V$$

- Charge is linearly proportional to the potential difference
- the proportionality depends on the geometry of the capacitor and the constant ϵ_0.

This geometric factor is called the **CAPACITANCE** of a capacitor, and basically tells you how the geometry contributes to the amount of charge accumulated per volt of potential difference applied:

$$C \equiv \epsilon_0 A/d = Q/V$$

For *any* capacitor, we have:

$$Q = CV$$

and specifically for the parallel plate capacitor we have the above. You can imagine, then, using potential difference and charge to determine the capacitance of a difference geometry, something other than a parallel plate system.

The units of capacitance are Coulombs/Volt, known as the "Farad" (F) in honor of Michael Faraday, who introduced the concept of an electric field - of a force per unit electric charge.

The Farad is a LARGE unit of capacitance. Typical capacitors you find in electronics are measured in micro-Farads, μF, or even pico-Farads (pF). Releasing the energy of a 1F capacitor - say, but shorting across the leads of the capacitor with a screwdriver - is sufficient to weld the metal of the screwdriver to the leads of the capacitor.