PHYS 2212

Look over
Chapter 25 section 1-8
examples 1, 2, 3, 5, 6

PHYS 1112

Look over
Chapter 17 section 7-9
Examples 8, 11
Chapter 19 section 5
Example 10, 11

Things to Know

1) How to find the charge on a Capacitor.
2) How to find the Capacitance of a Capacitor.
3) How to find the equivalent Capacitance for Capacitors in circuits.
4) Understand how dielectrics change the Capacitance.

Capacitors

Whenever two close conductors of any size or shape carry equal and opposite charges, the combination of these conducting bodies is called a **Capacitor**.

There are 3 basic Capacitor shapes.

The Main Rule for Capacitors

When a Capacitor is "charged" the plates have equal but opposite charges of +q and -q. However, we refer to charge of a Capacitor as being q.

There is a potential difference between the two plates which we will refer to as just .

The charge q and the potential difference are proportional to each other.

$$q \propto V \text{ or } q = CV$$

Where **C** is the **Capacitance** of the capacitor

Units of Capacitance

The SI unit of Capacitance is the Coulomb per Volt. This combination of units is named the **Farad** (F) after Michael Faraday.

$$1\,farad = 1F = 1\frac{C}{V}$$

A farad is a very large unit so most of the time we will deal with sub-units such as $\mu F = 1\times10^{-6}\ F$ or $pF = 1\times10^{-12}\ F$.

Circuits

One way of charging up a Capacitor is to place it in an electric circuit with a battery.

An **Electric Circuit** is a path through which charge can flow.
A **Battery** is a device that maintains a certain potential difference between its terminals

The battery maintains a potential difference V between its terminals. The terminals of higher potential is labeled **(+)** positive.
The terminal of lower potential is labeled **(-)** negative.

Charging a Capacitor

When the circuit shown is complete, electrons are driven through the wires by an electric field that the battery sets up in the wire.

When the potential difference of the capacitor plates reaches the potential difference of the battery, then there is no more electric field in the wire and charge stops flowing.

The capacitor is then said to be fully charged with a charge $q=CV$

Calculating the Capacitance

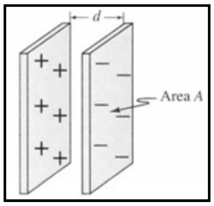
We can use Gauss' Law and our definition of the potential difference to calculate the capacitance of a capacitor.

From Gauss law we get:

$$q = \varepsilon_0 EA$$

Where we are assuming that E and A are parallel.

Example 1



1)What is the Capacitance of a Parallel-plate capacitor which has an area *A* and a separation distance *d* (Assuming the plates are large and are close together)?

Dielectrics and Electrostatics

In a region completely filled by a dielectric material of dielectric constant κ, all electrostatic equations containing the permittivity constant ε_0 are to be modified by replacing ε_0 with $\kappa\,\varepsilon_0$.

Capacitors in Circuits

When there is a combination of capacitors in a circuit, we can sometimes replace that combination of capacitors with an equivalent capacitor that has the same capacitance as the actual combination of capacitors. With the replacement we make it much easier to find unknown quantities in the circuit.

There are two ways that a capacitors can be combined in a circuit:

❶Parallel
❷Series

Capacitors in Parallel

Connected Capacitors are said to be in parallel when a potential difference that is applied across there combination results in the same potential difference across each capacitor.

$$C_{eq} = C_1 + C_2 + C_3$$

or

$$C_{eq} = \sum_{i=1}^{n} C_i$$

Capacitors in Series

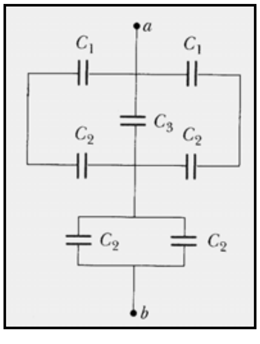
Connected capacitors are said to be in series when a potential difference that is applied across there combination is the sum of the resulting potential differences across each capacitor.

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

or

$$\frac{1}{C_{eq}} = \sum_{i=1}^{n} \frac{1}{C_i}$$

Example 2



2a) Find the equivalent capacitance between points *a* and *b* if $C_1=5.00\ \mu F$, $C_2=10.0\ \mu F$, and $C_3=2.00\ \mu F$.
b) If the potential difference between *a* and *b* is *60 V* what is the charge stored on C_3.

Storing Energy in an Electric Field

Work must be done by external agent to charge a capacitor.

We visualize the work required to charge a capacitor as being stored in the form of electrical potential energy U.

We can look at the work done in transferring a small amount of charge to the capacitor:

$$\Delta W = V\Delta q = \frac{q}{C}\Delta q$$

Energy Stored in a Capacitor

The total work is then: $W = \int_0^{q_f} \frac{q}{C}\,dq = \frac{q_f^2}{2C}$

So the work stored as the potential energy U in the capacitor is:

$$U = \frac{q^2}{2C} = \tfrac{1}{2}CV^2$$

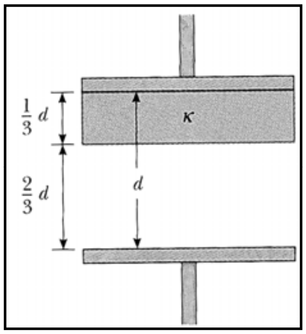
The energy density is given by: $U = \tfrac{1}{2}\varepsilon_0 E^2$

Capacitor with a Dielectric

So far we have only considered capacitors with nothing between the plates. Now we want to see what affect placing insulating material (called a **Dielectric)** between the capacitor plates will have.

In 1837 Michael Faraday found that the effect of the dielectric material is to increase the capacitance of the device by a factor κ which is known as the dielectric constant for the material.

Example 3



3) A parallel–plate capacitor with a plate separation *d* has a capacitance C_0 in the absence of a dielectric. What is the capacitance when a slab of dielectric material of dielectric constant κ and thickness ⅓*d* is inserted between the plates.