PHYS 1441 – Section 002
Lecture #10

Wednesday, Oct. 3, 2018

Dr. Jaehoon Yu

- Chapter 24 Capacitance etc..
  - Capacitors
  - Capacitors in Series or Parallel
  - Electric Energy Storage
  - Effect of Dielectric
  - Molecular description of Dielectric Material

Announcements

- Mid Term Exam
  - In class Wednesday, Oct. 17
  - Covers CH21.1 through what we cover in class Monday, Oct. 15 + appendix
  - Bring your calculator but DO NOT input formula into it!
    - Cell phones or any types of computers cannot replace a calculator!
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants
  - No derivations, word definitions or solutions of any kind!
  - No additional formulae or values of constants will be provided!
- Colloquium 4pm today in SH101
  - Dr. Xi Zhang of U.C. Santa Cruz

Physic Department
The University of Texas at Arlington
COLLOQUIUM

Physics of Hazes and Clouds in Cold and Hot Planetary Atmospheres

Xi Zhang
University of California Santa Cruz

Wednesday October 3, 2018
4:00 p.m. Room 100 Science Hall

Abstract

Hazes and clouds are ubiquitous in all substantial atmospheres in the solar system. Abundant condensed particles are also inferred from the transmission observations in the warm and hot (500-2200 K) atmospheres of extra-solar planets which are hundreds to thousands of degrees warmer than the solar system planets. These exotic clouds could result from condensation of salts, silicates and metals, and/or hydrocarbons produced by atmospheric photochemistry and ion chemistry. In this presentation, I will first talk about the thin, cold and hazy atmospheres in the outer solar system such as on Saturn's moon Titan, Neptune's moon Triton, and Pluto. I will present how these atmospheres regulate themselves such that the chemical-produced hydrocarbon haze particles significantly dominate the radiative energy balance over the gas volatiles. In particular, the haze particles could explain the colder-than-expected temperature on Pluto observed by the New Horizons mission recently. Then I will talk about the thick, hot and cloudy atmospheres of hot Jupiters and brown dwarf stars. I will show how to form clouds of salts, silicates and metals in this regime, highlighting the important physical processes such as seed formation, nucleation, coagulation, condensation, gravitational settling as well as atmospheric particle transport. I will also emphasize the importance of particle size distribution on interpreting the observed transmission spectra of extra-solar planets and how to predict it from first principles in a self-consistent microphysical cloud formation model.

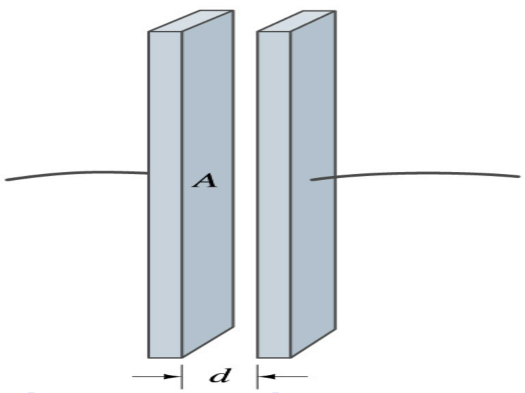
Refreshments will be served at 3:30 in Physics Lounge.

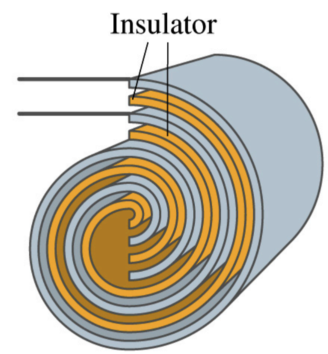
Capacitors (or Condensers)

- What is a capacitor?
  - A device that can store electric charge
  - But does not let them flow through
- What does a capacitor consist of?
  - Usually consists of two conducting objects (plates or sheets) placed near each other without touching
  - Why can't they touch each other?
    - The charge will neutralize…
- Can you give some examples?
  - Camera flash, Surge protectors, binary circuits, memory, etc…
- How is the capacitor different than the battery?
  - Battery provides potential difference by storing energy (usually chemical energy) while the capacitor stores charges but very little energy.

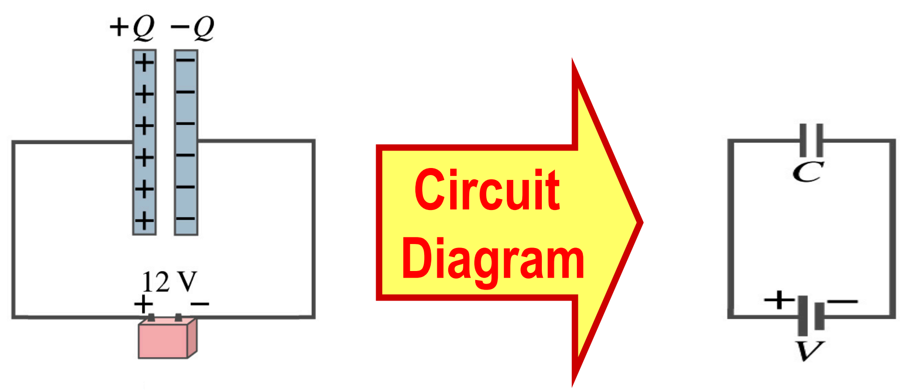
Capacitors

- A simple capacitor consists of a pair of parallel plates of area A separated by a distance d.
  - A cylindrical capacitor is essentially parallel plates wrapped around as a cylinder.



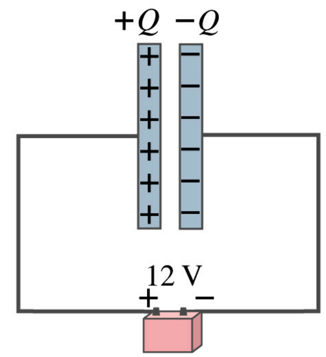


- How do you draw symbols for a capacitor and a battery in a circuit diagram?
  - Capacitor -||-
  - Battery (+) -|i- (-)



Capacitors

- What do you think will happen if a battery is connected (or the voltage is applied) to a capacitor?
  - The capacitor gets charged quickly, one plate positive and the other negative in equal amount.



- The battery terminals, the wires and the plates are conductors. What does this mean?
  - All conductors are at the same potential. And?
  - So the full battery voltage is applied across the capacitor plates.
- So for a given capacitor, the amount of charge stored on each capacitor plate is proportional to the potential difference V_{ba} between the plates. How would you write this formula?

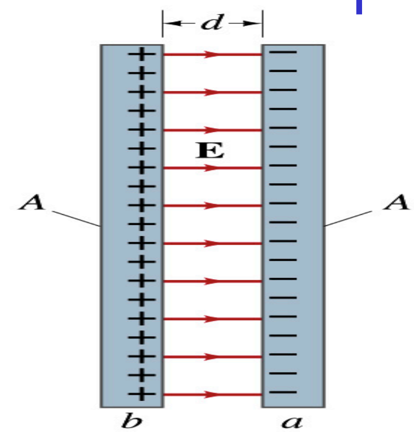
$$\boxed{Q = CV_{ba}}$$

C is the property of a capacitor so does not depend on Q or V.

  - C is a proportionality constant, called the capacitance of the device.
  - What is the unit? C/V or Farad (F) Normally use µF or pF.

Determination of Capacitance

- C can be determined analytically for a capacitor with a simple geometry and air in between.



- Let's consider a parallel plate capacitor.
  - Plates have area A each and separated by d.
    - d is smaller than the length, and so E is uniform.
  - E for parallel plates is $E=\sigma/\varepsilon_0$, $\sigma=Q/A$ is the surface charge density.
- E and V are related $V_{ba}=-\int_a^b \vec{E}\cdot d\vec{l}$
- Since we take the integral from the lower potential (a) to the higher potential (b) along the field line, we obtain
- $V_{ba}=V_b-V_a=-\int_a^b E\,dl\cos 180^\circ=+\int_a^b Edl=\int_a^b \frac{\sigma}{\varepsilon_0}dl=\int_a^b \frac{Q}{\varepsilon_0 A}dl=\frac{Q}{\varepsilon_0 A}\int_a^b dl=\frac{Q}{\varepsilon_0 A}(b-a)=\frac{Qd}{\varepsilon_0 A}$
- So from the formula:
  - What do you notice?

$$\boxed{C=\frac{Q}{V_{ba}}=\frac{Q}{Qd/\varepsilon_0 A}=\frac{\varepsilon_0 A}{d}}$$

C only depends on the area and the distance of the plates and the permittivity of the medium between them.

Example 24 – 1

Capacitor calculations: (a) Calculate the capacitance of a capacitor whose plates are 20cmx3.0cm and are separated by a 1.0mm air gap. (b) What is the charge on each plate if the capacitor is connected to a 12-V battery? (c) What is the electric field between the plates? (d) Estimate the area of the plates needed to achieve a capacitance of 1F, given the same air gap.

(a) Using the formula for a parallel plate capacitor, we obtain

$$C = \frac{\varepsilon_0 A}{d} =$$

$$= \left(8.85\times 10^{-12}\, C^2/N\cdot m^2\right)\frac{0.2\times 0.03m^2}{1\times 10^{-3}\,m} = 53\times 10^{-12}\, C^2/N\cdot m = 53\,pF$$

(b) From Q=CV, the charge on each plate is

$$Q = CV = \left(53\times 10^{-12}\, C^2/N\cdot m\right)\left(12V\right) = 6.4\times 10^{-10}\,C = 640\,pC$$

Example 24 – 1

(C) Using the formula for the electric field in two parallel plates

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0} = \frac{6.4\times10^{-10}C}{6.0\times10^{-3}m^2\times8.85\times10^{-12}C^2/N\cdot m^2} = 1.2\times10^4 N/C = 1.2\times10^4 V/m$$

Or, since $V = Ed$ we can obtain $E = \frac{V}{d} = \frac{12V}{1.0\times10^{-3}m} = 1.2\times10^4 V/m$

(d) Solving the capacitance formula for A, we obtain

$$C = \frac{\varepsilon_0 A}{d}$$

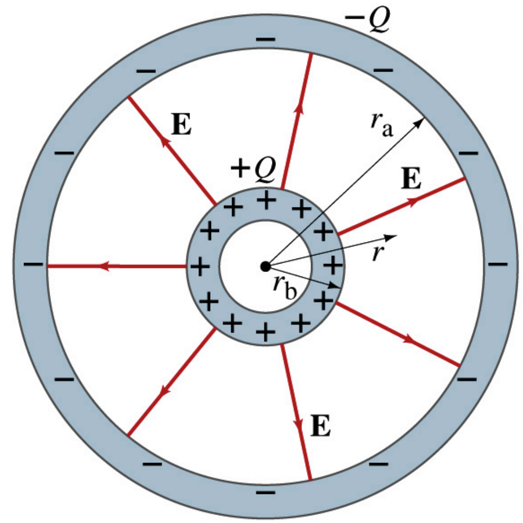
Solve for A

$$A = \frac{Cd}{\varepsilon_0} = \frac{1F\cdot1\times10^{-3}m}{\left(9\times10^{-12}C^2/N\cdot m^2\right)} \approx 10^8 m^2 \approx 100km^2$$

About 40% the area of Arlington (256km^2).

Example 24 – 3

Spherical capacitor: A spherical capacitor consists of two thin concentric spherical conducting shells, of radius r_a and r_b, as in the figure. The inner shell carries a uniformly distributed charge Q on its surface and the outer shell an equal but opposite charge –Q. Determine the capacitance of the two shells.



Using Gauss' law, the electric field outside a uniformly charged conducting sphere is

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

So the potential difference between a and b is

$$V_{ba} = -\int_a^b \vec{E}\cdot d\vec{l} =$$

$$= -\int_a^b E\cdot dr = -\int_a^b \frac{Q}{4\pi\varepsilon_0 r^2}dr = -\frac{Q}{4\pi\varepsilon_0}\int_a^b \frac{dr}{r^2} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r}\right)_{r_a}^{r_b} = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_b}-\frac{1}{r_a}\right) = \frac{Q}{4\pi\varepsilon_0}\left(\frac{r_a - r_b}{r_b r_a}\right)$$

Thus capacitance is

$$C = \frac{Q}{V} = \frac{Q}{\frac{Q}{4\pi\varepsilon_0}\left(\frac{r_a - r_b}{r_b r_a}\right)} = \frac{4\pi\varepsilon_0 r_b r_a}{r_a - r_b}$$

Capacitor Cont'd

- A single isolated conductor can be said to have a capacitance, C.
- C can still be defined as the ratio of the charge to the absolute potential V on the conductor.
  - So Q=CV.
- The potential of a single conducting sphere of radius r_b can be obtained as

$$V = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{r_b} - \frac{1}{r_a}\right) = \frac{Q}{4\pi\varepsilon_0 r_b} \quad \text{where} \quad r_a \to \infty$$

- So its capacitance is $\boxed{C = \frac{Q}{V} = 4\pi\varepsilon_0 r_b}$