Capacitance and Dielectric

PHY 104

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1 Capacitor

- When two opposite charges of $+q$ and $-q$ are kept at some distance apart, there will be an electric field E between them.

  With electric field, there will be potential difference ΔV between two charges (see previous lecture note).

$$\Delta V = -\int_i^f \vec{E} \cdot d\vec{s}$$

  The ratio of charge q and the potential difference ΔV is called capacitance.

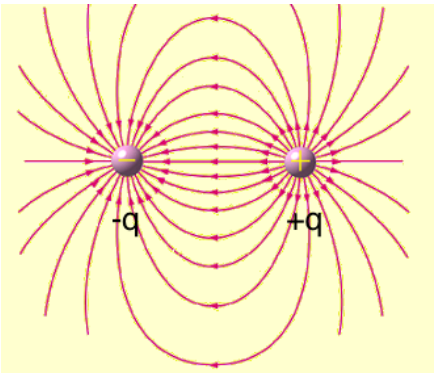


Figure 1.1: https://upload.wikimedia.org/wikipedia/commons/8/8f/Camposcargas.PNG

Definition 1.1. Capacitance

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

Note that Δ is dropped by historical reasons and to simplify the notation but the potential difference is assumed

- The unit of C is in _____ (from Faraday) or Coulomb per Volt, but since Coulomb is high, so normally we would have micro or picofarad capacitors.
- Capacitance depends only on geometry of a capacitor (not the voltage or charge).
- $C = \epsilon_0 \mathcal{L}$, where $\mathcal{L}$ is anything in the unit of _____.
- The most important is the parallel plate.

  Example 1.1. A parallel plate capacitor

2 Calculating Capacitance

- Identify the two plates
- Put charges of $+q$ and $-q$ onto two plates (does not matter in what order)
- Calculate E field
- Calculate potential difference
- Take the ratio of q and V

Example 2.1. A cylindrical capacitor

3 Capacitors in Series and Parallel

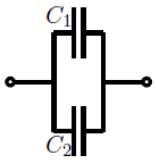
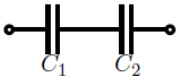
PARALLEL		$C_p = C_1 + C_2$
SERIES		$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$

Figure 3.1: http://mysite.avemaria.edu/jcdaly/phys223/lab/Lab3RCcircuits/fig4.png

4 Energy Consideration

- You need energy to maintain the charges $+q$ and $-q$ of the capacitor since work must be done move the charges apart.
- energy stored in capacitor

- Who did this work? _____

5 Dielectric

- Dielectric material is an insulator that could be polarized by an electric field.
- "To be polarized is to create a dipole moment and align them against the field.
- $U = -\vec{p} \cdot \vec{E}$
- When filling the space with dielectric, the electric field is "shielded by the dielectric polarization.
- ϵ_0 in vacuum is replaced by a _____; κ is a dielectric constant (or relative permitivity), which is normally > 1

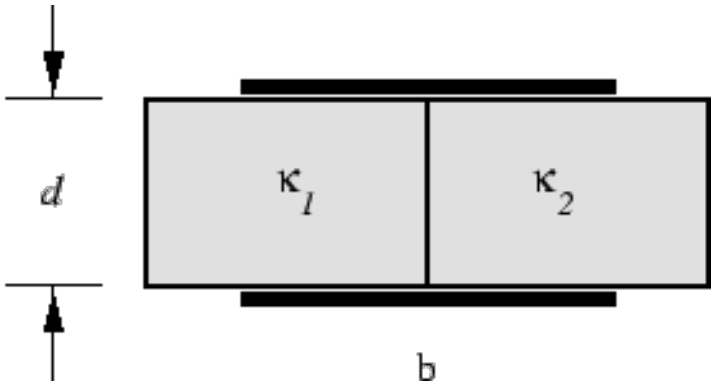


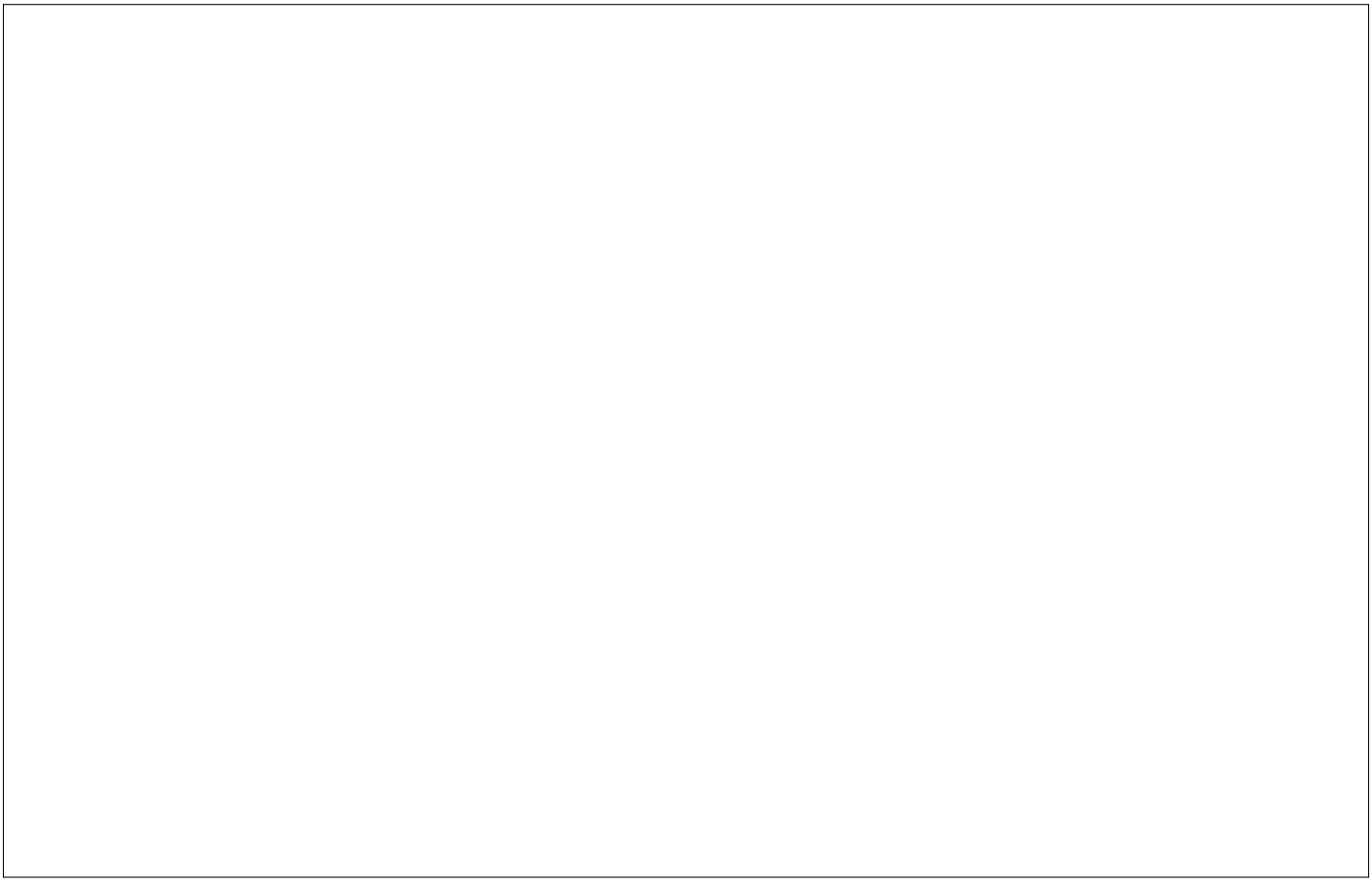
Figure 6.1: http://www.theory.caltech.edu/people/politzer/syllabus/img98.png

- a point charge insjide a dielectric produces an electric field of $E =$ _____
- Given a parallel plate capacitor with charges $\pm q$, if the dielectric is inserte, the field is reduced to $\frac{q}{A\kappa\epsilon_0}$. Therefore, the potential difference V is reduced by a factor κ as well.

6 A Classic Problem

A parallel-plate capacitor of plate area A is filled with two dielectrics (Fig. 7.1). Show that the capacitance is

$$C = \frac{\epsilon_0 A}{d}\frac{\kappa_1 + \kappa_2}{2}$$



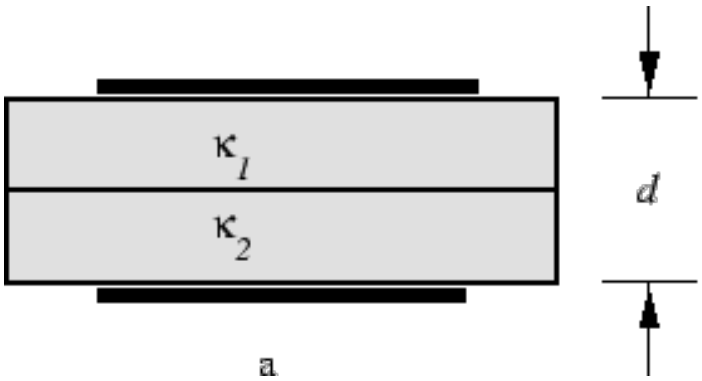


Figure 7.1: http://www.theory.caltech.edu/people/politzer/syllabus/img98.png

7 Homework

Homework 1 (Another classic problem)**.** Find the capacitance of the configuration below.

Hint: The electric field inside the dielectrics are $\frac{q}{\epsilon_0 \kappa_1 A}$ and $\frac{q}{\epsilon_0 \kappa_2 A}$. Use these to identify the potential difference between top and bottom plate.