

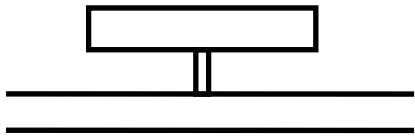
Lecture 17

Capacitance: $C = \frac{Q}{V}$

$$C = \frac{Q}{Ed} = \frac{Q}{\left(\frac{Q/A}{\epsilon_0}\right)d} = \frac{\epsilon_0 A}{d}$$

Units: $\frac{\text{Coulomb}}{\text{Volts}} = \text{Farad}$

Computer Key Button – Estimate Capacitance:


$$A \approx 1 \text{ cm}^2 \quad \epsilon_0 = \frac{1}{4\pi k} \approx 8.885 \times 10^{-12} \approx 10^{-11}$$
$$d \approx 1 \text{ mm}$$

Find: C Choices: $\approx 10^{-10} F$, $\approx 10^{-11} F$, or $\approx 10^{-12} F$

Ans: $10^{-12} F = 1 \text{ pF}$ Please verify.

Revisit: Energy stored in a capacitor, Q, A, D

$$U = F^{ext} d = Q E_Q^{1plate} d$$

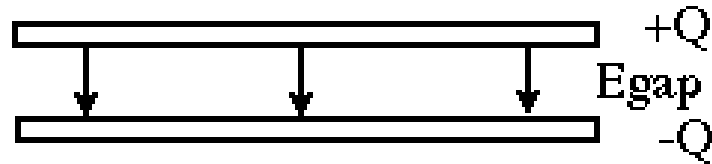
$$= Q \left(\frac{Q/A}{2\epsilon_0} \right) d$$

$$= \frac{Q^2}{2} \cdot \frac{1}{\frac{\epsilon_0 A}{d}}$$

$$U = \frac{Q^2}{2C}$$

Fig(clicker) 17-1

! Attraction between two plates



Given: a parallel plate system with plate charge Q and area A . Within the gap, $E_{gap} = (Q/A)/\epsilon_0$

What is the electric force that the bottom plate exerts on the top plate?

Choice	F
1	QE_{gap}
2	$0.5QE_{gap}$

Hint: In general, the force on exerted on q by a field E is given by “ $F = qE$ ”. Here, “ E ” is the field due to all source charges except q , since self-force (i.e. q on q) is 0.

Fig(clicker) 17-1 cont.

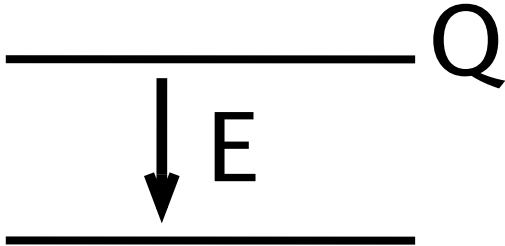
$$E = \frac{Q/A}{\epsilon_0}, \quad Q = \epsilon_0 E A$$

$$\therefore U = \frac{Q^2}{2C} = \frac{(\epsilon_0 E A)^2}{2} \cdot \frac{1}{\epsilon_0 A d} = \frac{d}{\epsilon_0 A} = \left(\frac{\epsilon_0}{2} E^2 \right) (A d)$$

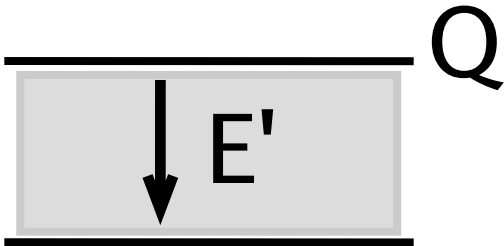
$$u = \frac{U}{A d} = \frac{\epsilon_0 E^2}{2}$$

When there is E there is electric energy

Dielectric Mediums



For fixed plate charge Q

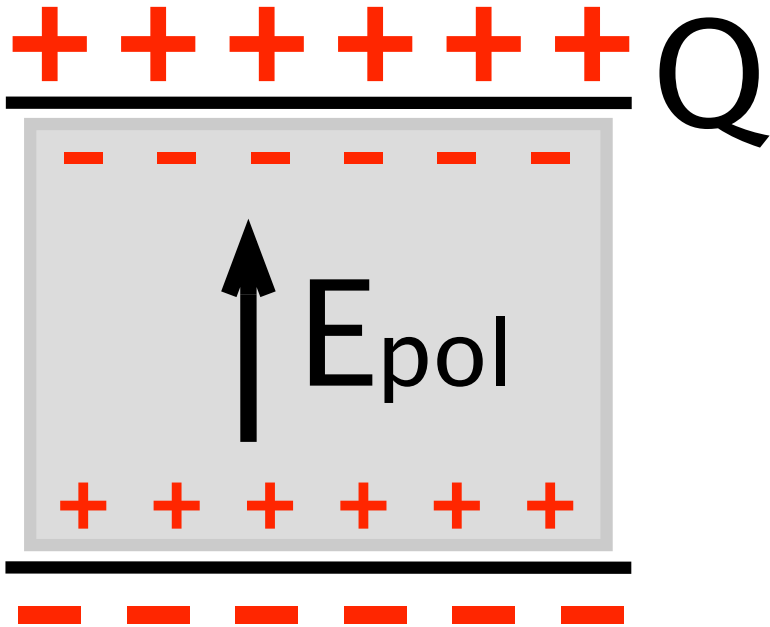


$$E' = \frac{E}{\kappa}$$

Examples of κ

	κ
Vacuum	1
Air	1.0006
Plastic	5
Water	80
Semi-conductor	300
Conductor	infinity

Microscopic Picture:



$$E' = E - E_{pol} = \frac{E}{\kappa}$$

Dielectric Mediums continued...

$$E' = E - E_{pol} = \frac{E}{\kappa}$$

$$\frac{Q/A}{\epsilon_0} - \frac{Q_{pol}/A}{\epsilon_0} = \frac{Q/A}{\kappa\epsilon_0}, \quad Q - Q_{pol} = \frac{Q}{\kappa}$$

$$Q_{pol} = Q \left[1 - \frac{1}{\kappa} \right]$$

2 limits: vacuum $k = 1 \Rightarrow Q_{pol} = Q \left[1 - \frac{1}{1} \right] = 0$

metal $k = \infty \Rightarrow Q_{pol} = Q \left[1 - \frac{1}{\infty} \right] = Q$

General κ and Q fixed: $1 < \kappa < \infty$ $E' = \frac{E}{\kappa}, \quad V' = \frac{V}{\kappa}$

$$C = \frac{Q}{V}, \quad C' = \frac{Q}{V'} = \kappa C, \quad U = \frac{Q^2}{2C}, \quad U' = \frac{Q^2}{2C'} \quad U' = \frac{U}{\kappa}$$

Fig(clicker) 17.2

Capacitance in the presence of a dielectric medium

The capacitance of a parallel plate capacitor in free space is given by $C = Q/V = (Q)/(\frac{(Q/A)d}{\epsilon_0}) = \epsilon_0 \frac{A}{d}$, where V is the potential difference across the gap.

When the gap is filled with a dielectric medium of dielectric constant κ , the electric field is reduced from the free space field E to $E' = E/\kappa$. Determine V' and C' — the potential difference and capacitance in the presence of the dielectric.

Choice	V'	C'
1	V/κ	κC
2	κV	κC
3	V/κ	C/κ
4	κV	C/κ

Fig(clicker) 17.3

Lec16-6 Energy stored in a capacitor filled with a dielectric medium

Given: a parallel plate capacitor with plate area A and gap width d .

Determine the energy stored in the capacitor for a plate charge Q when there is a dielectric within the gap with dielectric constant κ .

Hint: From Lecture 16-2, the energy stored in the capacitor in the absence of a dielectric is:

$$U = Fd = \left[\frac{1}{2} QE_{gap} \right] d = \frac{Q}{2} V = \frac{Q^2}{2C},$$

where $V = Ed$ and $V = Q/C$ were used. Also $C' = \kappa C$.

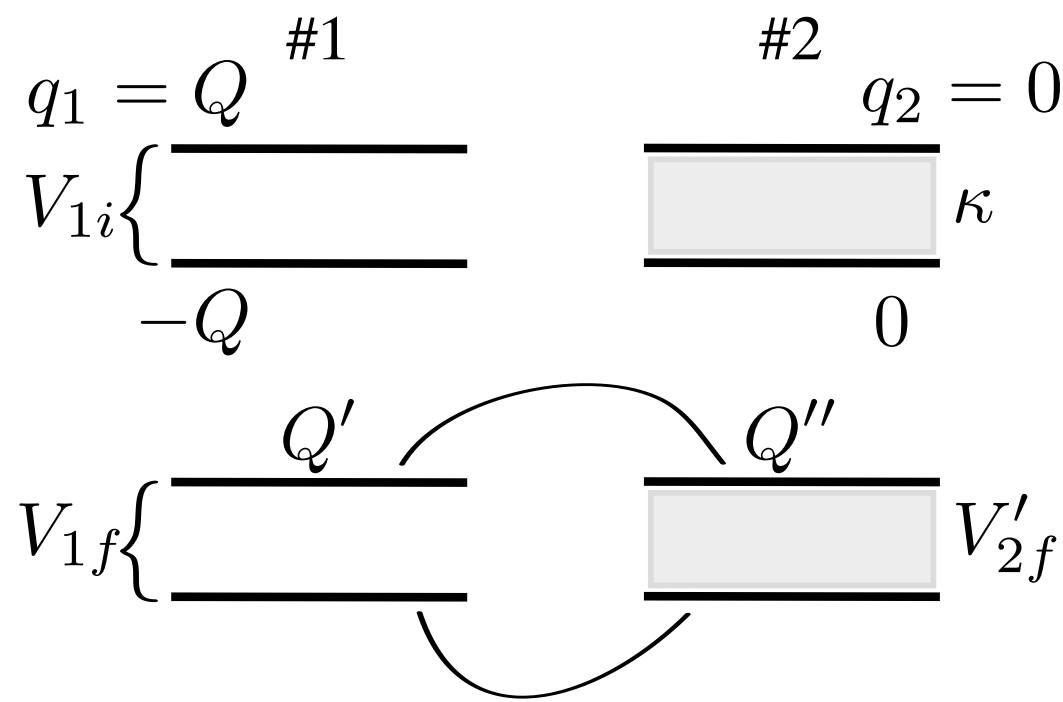
Choice	U'
1	κU
2	U
3	U/κ

Hint on HW17-3 : 005

005 (part 2 of 2) 10.0 points

For this part of the problem, we will simplify the problem assuming that the two capacitors have identical geometry, i.e. $A_1 = A_2 = A$ and $s_1 = s_2 = s$. There is still the dielectric slab with dielectric constant κ in capacitor 2.

Before the connection let the initial voltage of the first capacitor by V_{1i} . Denote the final potential differences of the first and the second capacitor to be ΔV_{1f} and ΔV_{2f} . After the connection, let the charge across the second capacitor be denoted by Q_2 .



Consider the following statements:

Ia. $\Delta V_{1f} = \Delta V_{2f}$

Ib. $\Delta V_{1f} > \Delta V_{2f}$

IIa. $E_{2f} = \frac{1}{\epsilon_0 \kappa} \frac{Q_2}{A}$

IIb. $E_{2f} = \frac{1}{2\epsilon_0 \kappa} \frac{Q_2}{A}$

IIIa. $\Delta V_{1f} = \frac{\kappa}{1 + \kappa} V_{1i}$

IIIb. $\Delta V_{2f} = \frac{1}{1 + \kappa} V_{1i}$

Find: $\frac{V_{1f}}{V_{1i}}$

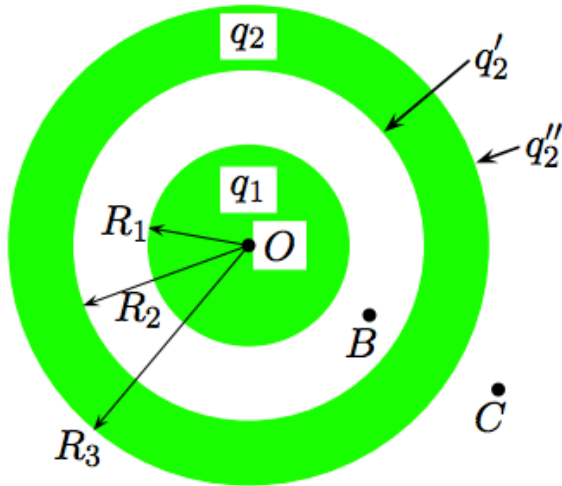
Hint:

$$\begin{aligned} \frac{V_{1f}}{V_{1i}} &= \frac{\frac{Q'/A}{\epsilon_0}}{\frac{Q/A}{\epsilon_0}} = \frac{Q'}{Q' + Q''} \\ &= \frac{1}{1 + \frac{Q''}{Q'}} \end{aligned}$$

Shell Game 06

010 (part 1 of 2) 10.0 points

Consider a system of a metallic ball with net charge q_1 and radius R_1 enclosed by a spherically symmetric metallic shell with net charge q_2 , inner radius R_2 and outer radius R_3 . If q_2'' is the charge on the outside surface of the shell and q_2' the charge on its inside surface, then $q_2'' + q_2' = q_2$.



Find the potential at C . $\overline{OB} = b$ and $\overline{OC} = c$.

Find: V at 0

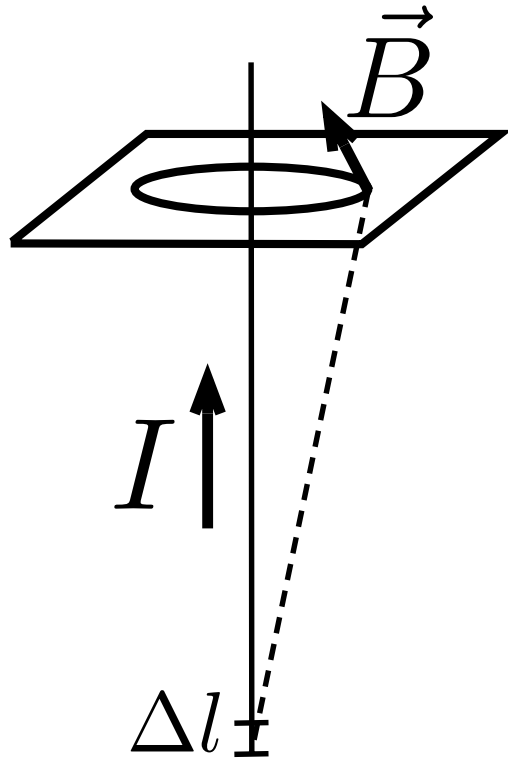
$$V_0 = V_0^{shell1} + V_0^{shell2} + V_0^{shell3}$$

Where charges are all at the surface of the three shells

with charges: q_1 , q_2' , q_2''

radii: R_1 , R_2 , R_3

Preview of Ch. 18: Magnetic Field due to a long wire



$$\Delta \vec{B} = \frac{\mu_0}{4\pi} \frac{I \Delta \vec{l} \times \hat{r}}{r^2}$$