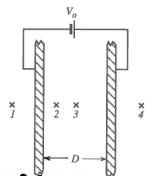
4. Write expressions for the following quantities in terms of σ_o and d (the new distance between the plates).
   - the magnitude of the electric field between the plates
   - the potential difference between the plates

5. Find $\frac{Q}{\Delta V}$ (the ratio of the net charge on one plate to the potential difference between the plates).

   How, if at all, would this ratio change if the charge densities on the plates were $+2\sigma_o$ and $-2\sigma_o$?

➪ Check your results for part A with a tutorial instructor before you continue.

B. Suppose the plates are discharged, then held a distance D apart and connected to a battery. (Ignore the fringing fields near the plate edges.)



1. Write expressions for the following quantities in terms of the given variables. Explain your reasoning in each case.
   - the potential difference ΔV between the plates

     V_o

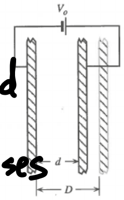
   - the electric field at points *1, 2, 3,* and *4*

     $E_1 = E_4 = 0 \quad \vec{E}_2 = \vec{E}_3 = \frac{V_o}{D}(-\hat{i})$

   - the charge density on each plate

     $E = \sigma/\epsilon_0 \rightarrow \sigma = \frac{V_o}{D}\epsilon_0$

2. The right plate is moved to the left. Describe how each of the following quantities changes (if at all). Explain.



   - the potential difference ΔV between the plates

     V_o unchanged

   - the electric field both outside and between the plates

     $E = \frac{V_o}{d}$ increases

   - the charge density on each plate

     $\sigma = E\epsilon_0$ increases

3. Write expressions for the following quantities in terms of V_o and d (the new distance between the plates).
   - the magnitude of the electric field between the plates

     V_o/d

   - the charge density on each plate

     $\frac{V_o}{d}\epsilon_0$

4. Find $\frac{Q}{\Delta V}$ (the ratio of the net charge on one plate to the potential difference between the plates).

   $C = \frac{Q}{\Delta V} = \frac{\sigma A}{V_o} = \frac{E\epsilon_0 A}{V_o} = \frac{\frac{V_o \epsilon_0 A}{d}}{V_o} = \frac{\epsilon_0 A}{d}$

   How, if at all, would this ratio change if the voltage of the battery was $2V_o$?

   unchanged

➪ Check your results for part B with a tutorial instructor before you continue.

C. Compare the ratio $\frac{Q}{\Delta V}$ that you calculated for two insulated plates (part A) to the same ratio for two plates connected to a battery (part B).

1. Does the ratio $\frac{Q}{\Delta V}$ depend on whether or not the plates are connected to a battery?

   No! C is an intrinsic

2. Does the ratio $\frac{Q}{\Delta V}$ depend on the distance between the plates?

   Yes $C = \frac{k\epsilon_0 A}{d}$

The potential difference ΔV between two isolated conductors depends on their net charges and their physical arrangement. If the conductors have charge $+Q$ and $-Q$, the ratio $\frac{Q}{\Delta V}$ is called the *capacitance (C)* of the particular arrangement of conductors.

D. For the following cases, state whether each of the quantities q, σ, E, ΔV, and C changes or remains fixed:

1. two insulated conducting plates are moved farther apart

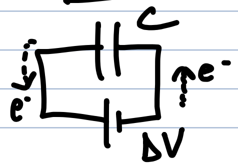
   E, σ, q unchanged
   ΔV increases
   C drops

   $E = \frac{\Delta V}{\Delta x}$

2. two conducting plates connected to a battery are moved farther apart

   q drops
   σ drops
   E drops
   ΔV unchanged
   C drops

Energy storage in capacitors



Q: How much energy can we extract from a charged capacitor?

A: The same amount it took to charge it up!

At some time t, the charge is $q(t)$

To transfer another dq to the plates requires

$$W = \int dW = \int V\,dq = \int \frac{q}{C}\,dq = \frac{1}{C}\int_0^Q q\,dq = \frac{1}{2}\frac{Q^2}{C}$$

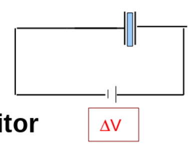
example Portable heart defibrillator

$C = 70\,\mu F$ with $\Delta V = 5000\,V$ $U = \frac{1}{2}CV^2 = 875\,J$

$\sim 200\,J$ of this energy is sent in a $\sim 2\,ms$ pulse

$\rightarrow$ Power $= \dfrac{\text{energy}}{\text{time}} = 100\,kW$ much greater than a simple battery could provide

Suppose a dielectric placed between two plates of a capacitor increases the overall capacitance by a factor of two.



$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

The amount of stored energy in the capacitor

a) doubles
b) halves
c) quadruples
d) is four times smaller

Concept Q #5

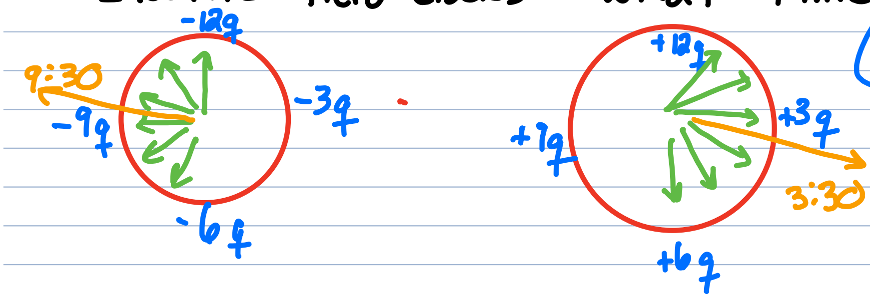
Q1 E increases potential since $E = \text{constant} = \sigma/\epsilon_0$ and $\Delta V = E\,\Delta x$

Q2 A and C

We reviewed ch 8 tutorials $\rightarrow$ 24.06.png

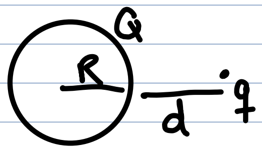
We did 24.14 & 24.16

Electric field clocks — what time is it?



(what are the directions for the net $\vec{E}$ at clock centers?)

23.29 in ch8 tutorials



$\Delta K + \Delta U = 0$

$(\cancel{K_f}^{\,0} - K_i) + (U_f - \cancel{U_i}^{\,0}) = 0$

$K_i = U_f$ $\quad \frac{1}{2} m v_i^2 = k \frac{qQ}{R+d} \Rightarrow v = \sqrt{\frac{2kqQ}{m(R+d)}}$

≈ 150 m/s