3-5-14

Preface to capacitors in CH24.
CH23 review

$$\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$$

$$= \left(-\frac{\partial V}{\partial x}, -\frac{\partial V}{\partial y}, -\frac{\partial V}{\partial z}\right)$$

$$\vec{E}\cdot\vec{dl} = E_x dx + E_y dy + E_z dz$$

$$\vec{dl} = (dx, dy, dz)$$

$$= dx\hat{i} + dy\hat{j} + dz\hat{k}$$

$$\Delta V = V_B - V_A = -\int_A^B \vec{E}\cdot\vec{dl} \ *$$

WORK by field

$$* \ W = -\Delta U$$

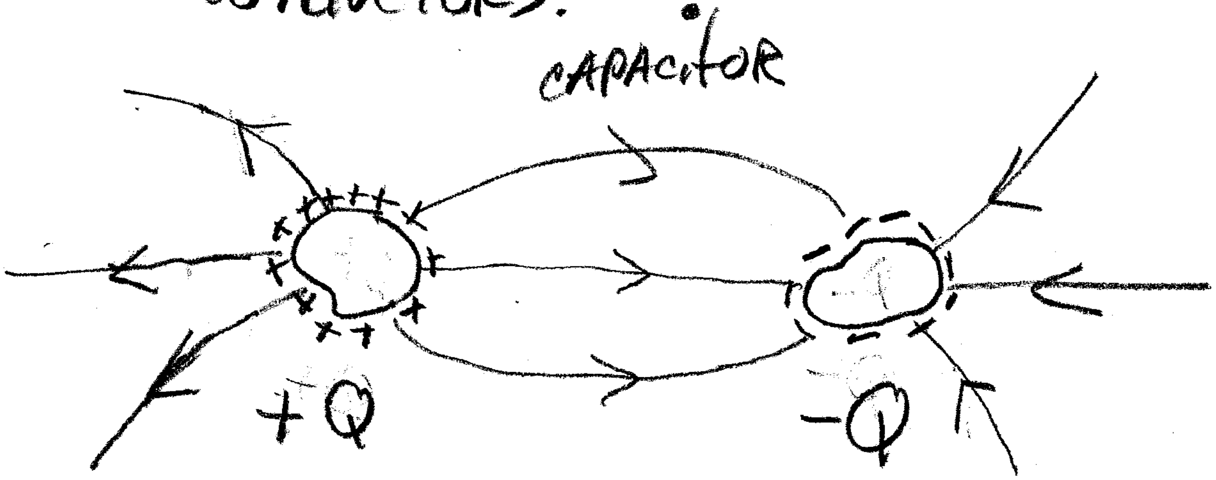
$W = q\int_A^B \vec{E}\cdot\vec{dl}$. If $\Delta U = -W$:

$$\Delta U = -q\int_A^B \vec{E}\cdot\vec{dl} \Rightarrow \Delta V = \frac{\Delta U}{q} = -\int_A^B \vec{E}\cdot\vec{dl}$$

3-5-14

CAPACITORS ch 24

any 2 oppositely charged conductors.



note: $|+Q| = |-Q| = |Q|$: same magnitude

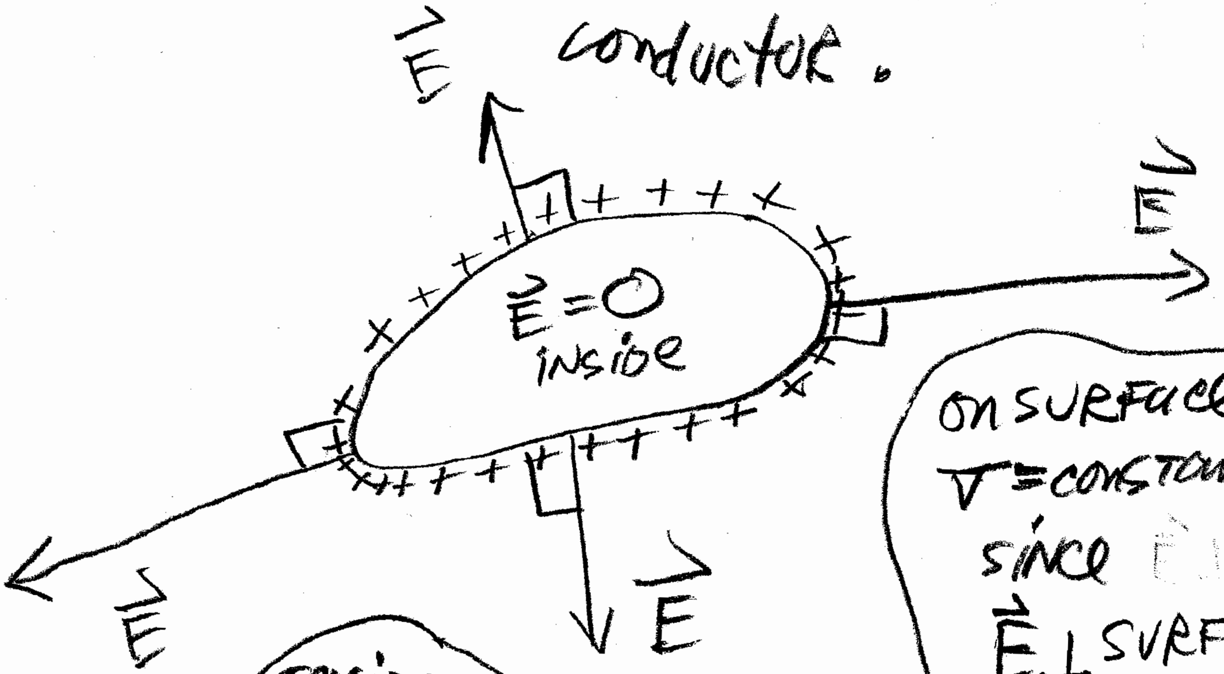
$$\text{capacitance} = C \equiv \frac{Q}{\Delta V} = \frac{Q}{V_+ - V_-}$$

V_+ = potential of positive conductor.
V_- = potential of negative conductor.

NOTE:

a conductor IS an EQUIPOTENTIAL object.

V = constant on conductor.



on surface:
V = constant
since
$\vec{E} \perp$ surface.

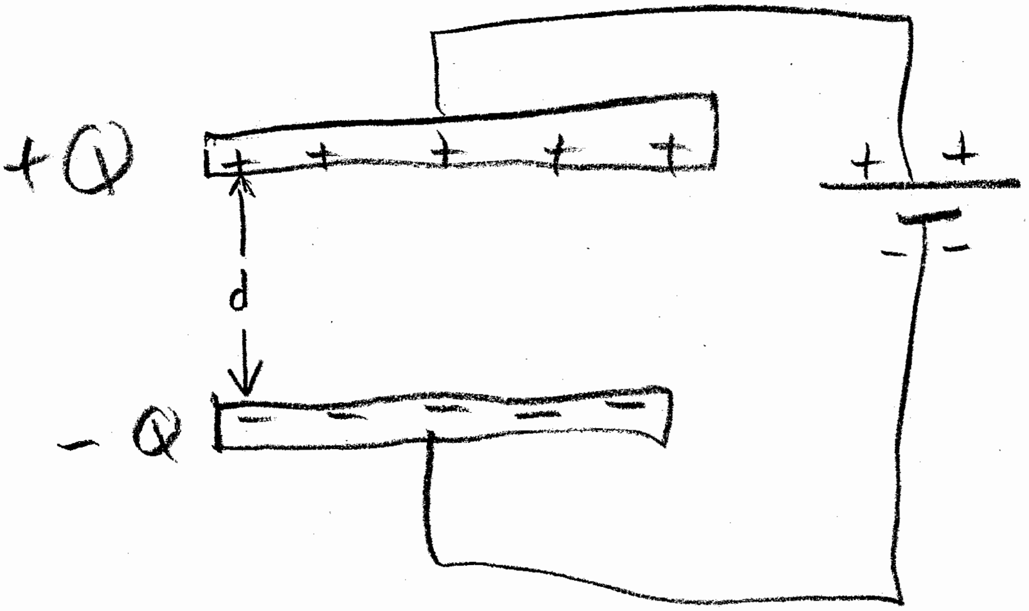
Inside:
V = constant,
since $\vec{E} = 0$.

$\Delta V = 0$ since $E_s = 0$

* see page 775's discussion of gradient: $E_s = -\frac{\Delta V}{\Delta S}$
$\Rightarrow \Delta V = -E_s \cdot \Delta S$.

$$C = \frac{Q}{E \cdot d}, \text{ where } E = \frac{Q}{A\varepsilon_0}$$

$$\Rightarrow C = \frac{Q}{\left(\frac{Q}{A\varepsilon_0}\right) \cdot d} = \boxed{\frac{A\varepsilon_0}{d}}$$

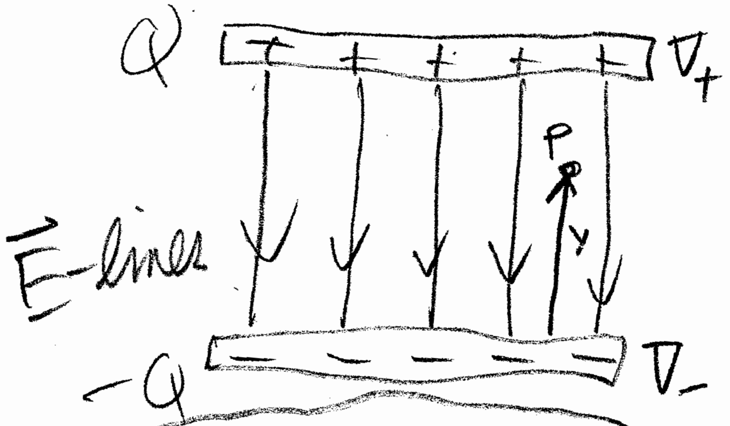


note: C is independent of Q.
It's ONLY a function geometry.

3-5-14

Capacitors

Example



ⓐ FIND C.

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

$$= \frac{(2m^2)(8.85\times10^{-12}\,\frac{F}{m})}{5\times10^{-3}\,(m)}$$

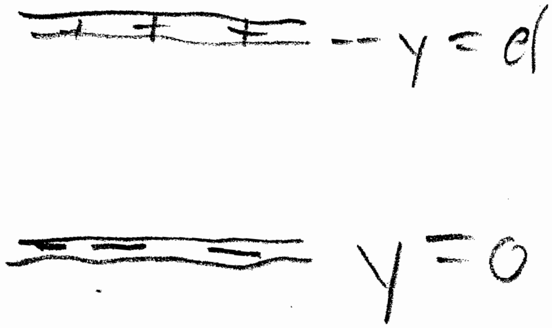
$$= 3.54\,nF$$

$$\boxed{C = \frac{Q}{V_+ - V_-}\ (F)\ \text{FARAD}}$$

V at $P = E \cdot y$

$V_- \equiv 0$

$V_+ = E \cdot d$
$(y = d)$



(b) FIND charge on each plate.

TOP plate: Q

bottom ″ : $-Q$

$$\Delta V = V_+ - V_- = 10.0 \times 10^3 (V)$$

$$kV = 10^3 (V)$$

$$Q = C \cdot \Delta V = 3.54 \times 10^{-9} F \cdot (\underbrace{10.0 \times 10^3}_{10^4} V)$$

$$= \boxed{3.54 \times 10^{-5} (F)}$$

$$= 35.4 \times 10^{-6} (F)$$

$$= 35.4 \mu F$$

(c) $E = |\vec{E}| \Rightarrow$

$$\Delta V = V_+ - V_- = E \cdot d - E \cdot 0$$

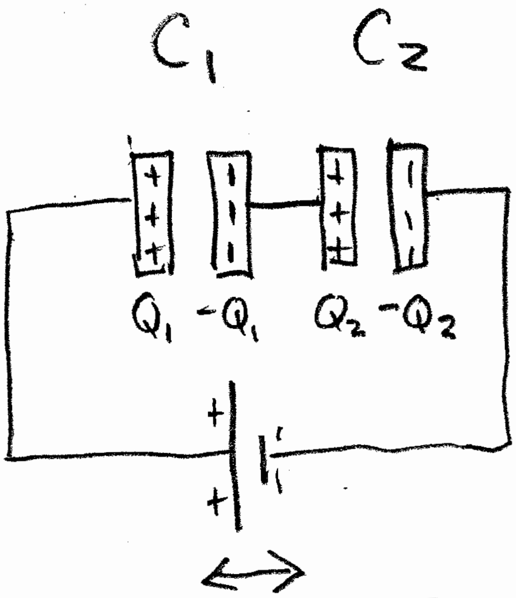
$$10.0 \times 10^3 V = E \cdot d$$

$$E = \frac{10.0 \times 10^{3} (V)}{5 \times 10^{-3} (m)}$$

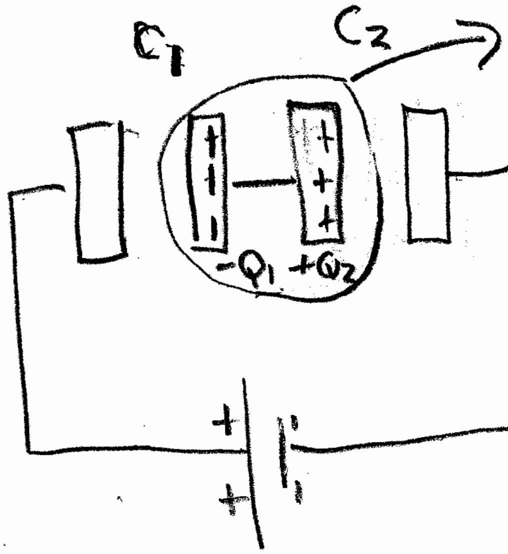
$$= 2 \times 10^{6} \left(\frac{V}{m}\right)$$

Sec. 24.2

series



$\Delta V = V_+ - V_-$



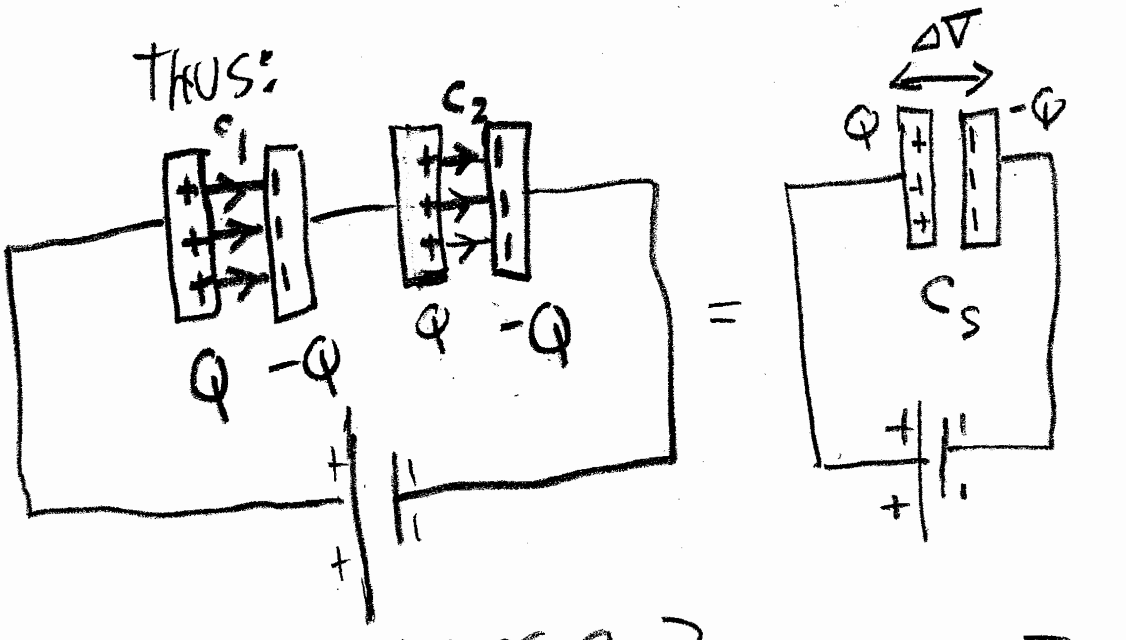
METAL SECTION WAS NEUTRAL Before Battery:

THUS,

$$|-Q_1| = |Q_2|$$

$$|-Q_1| = |Q_2| = Q$$

THUS:



ΔV_1 = VOLTAGE ACROSS C_1

ΔV_2 = " " C_2

$$\Delta V = \Delta V_1 + \Delta V_2$$

$$\frac{Q}{C_s} = \frac{Q_1}{C_1} + \frac{Q_2}{C_2}$$

$$Q_1 = Q_2 = Q$$

$$\frac{Q}{C_S} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\boxed{\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2}}$$

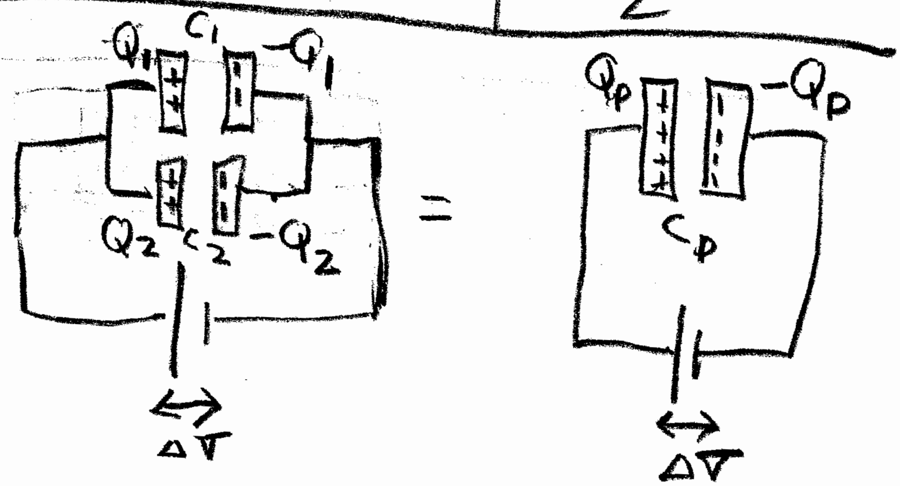
Series:

$$\rightarrow C_S = \frac{C_1 \cdot C_2}{C_1 + C_2} < C_2$$

$$C_S = \frac{C_1 \cdot C_2}{C_1 + C_2} < C_1$$

---

parallel



$\Delta V_1 = \Delta V_2$ and $Q_p = Q_1 + Q_2$

$$Q_p = Q_1 + Q_2$$

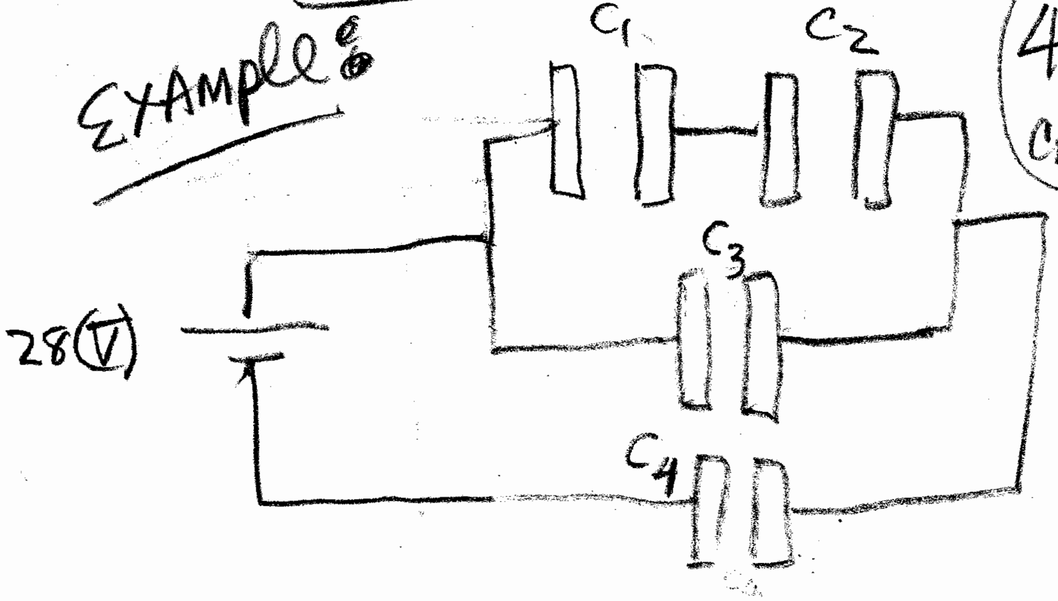
$$C_p \cdot \Delta V = C_1 \cdot \Delta V_1 + C_2 \cdot \Delta V_2$$

$$\Delta V_1 = \Delta V_2 = \Delta V$$

$$C_p \cdot \cancel{\Delta V} = C_1 \cdot \cancel{\Delta V} + C_2 \cdot \cancel{\Delta V}$$

$$\boxed{C_p = C_1 + C_2}$$

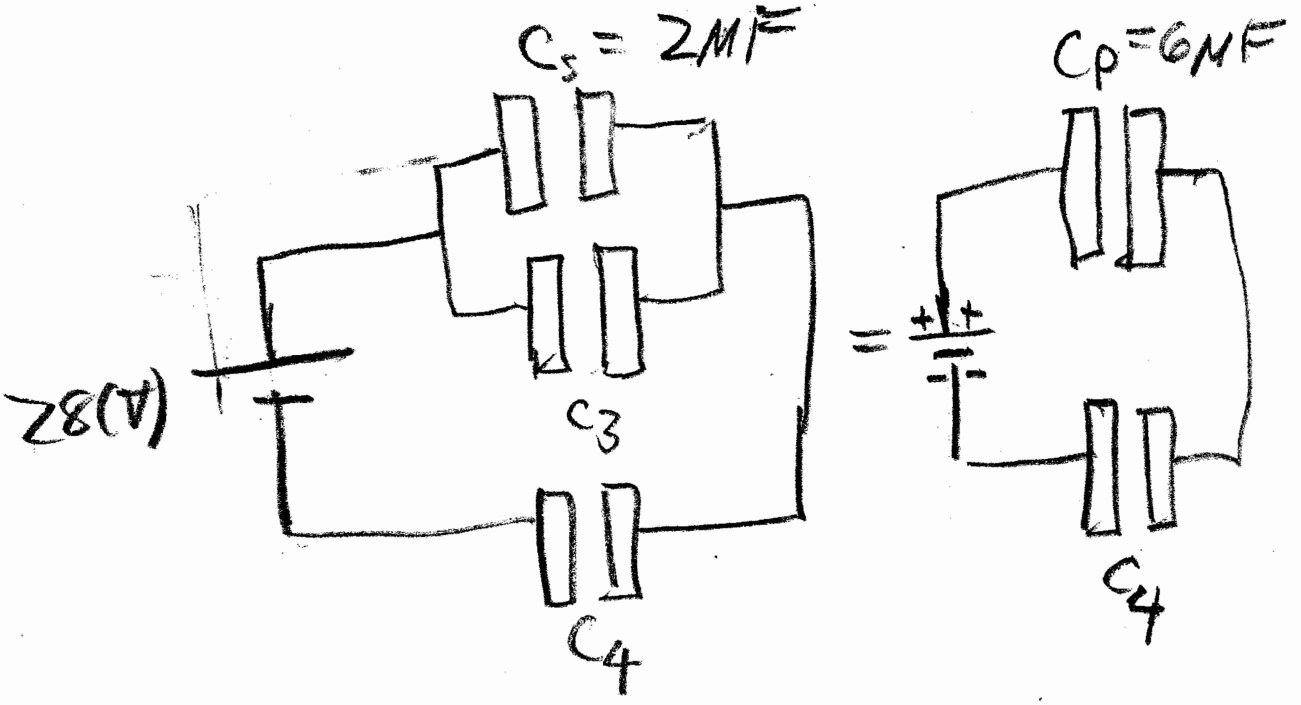
EXAMPLE:



4 identical capacitors

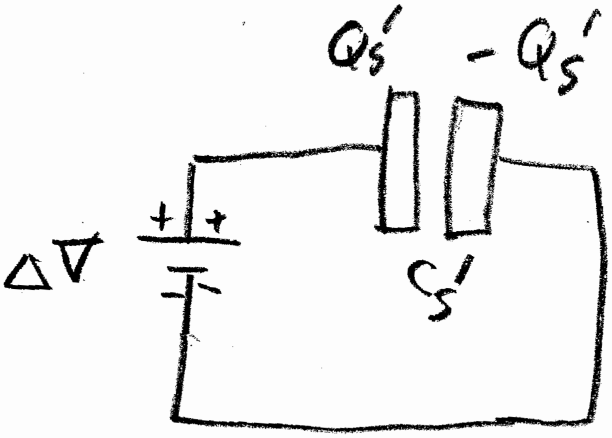
C7

$C_1 = C_2 = C_3 = C_4 = 4 \mu F$



$$C_s = \frac{C_1 \cdot C_2}{C_1 + C_2} = \frac{(4 \cdot 4)}{4+4} = \frac{16}{8} = 2 \mu F$$

$$C_p = C_s + C_3 = (2+4) \mu F$$
$$= 6 \mu F$$



$$C_s' = \frac{C_p \cdot C_4}{C_p + C_4}$$

$$C_s' = \frac{(6)\cdot(4)}{6+4} = \frac{24}{10}\,\mu F$$

$$C_s' = 2.4\,\mu F$$

units

$$\boxed{F \cdot V = C}$$

FARAD volts coulomb

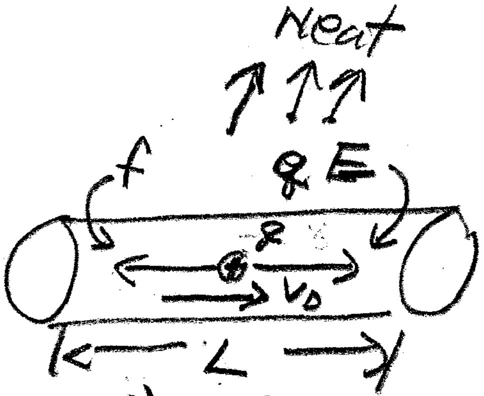
$$\Longrightarrow Q_s' = C_s \cdot \Delta V$$

$$= (\underset{F}{2.4 \times 10^{-6}})(\underset{V}{28})(C)$$

$$= 67.5\,\mu C$$

Note: $\mu C = 10^{-6} C$

3-5-14



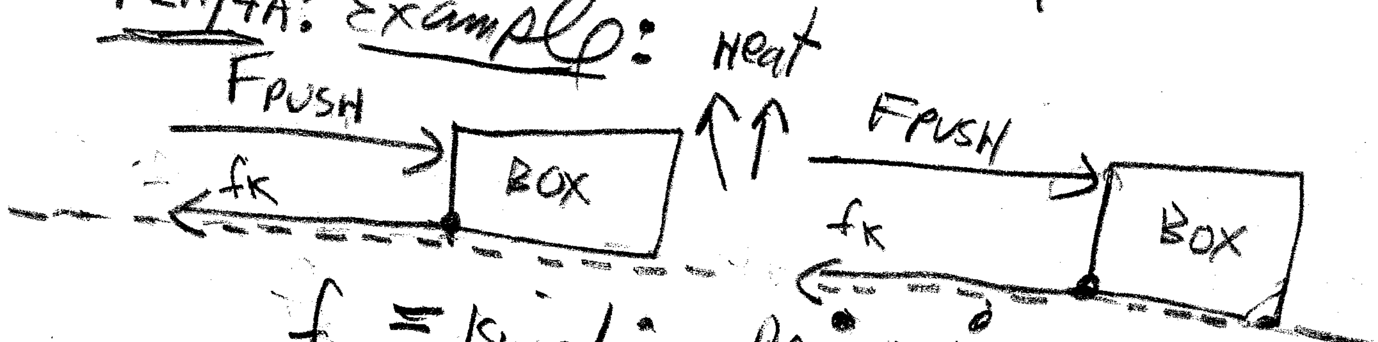
V_D = drift speed

f = "friction" force.

$W_f = -f \cdot L$ = friction work

P2A/4A: heat $= f \cdot L = -W_f$

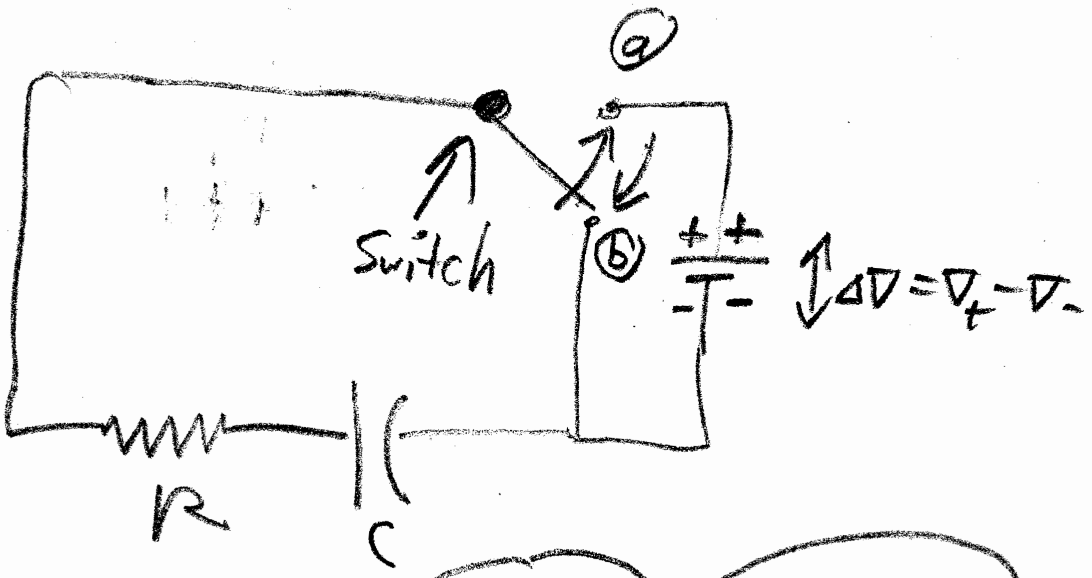
P2A/4A: Example:



f_K = kinetic friction force.

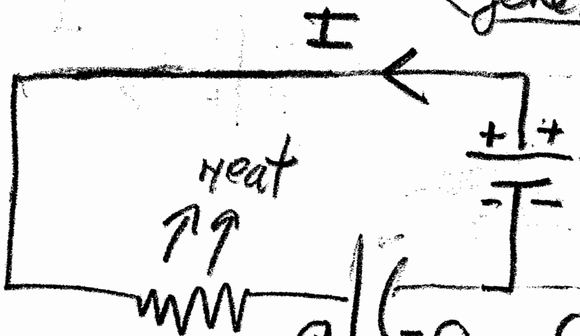
HEAT = $f_K \cdot$ DISTANCE

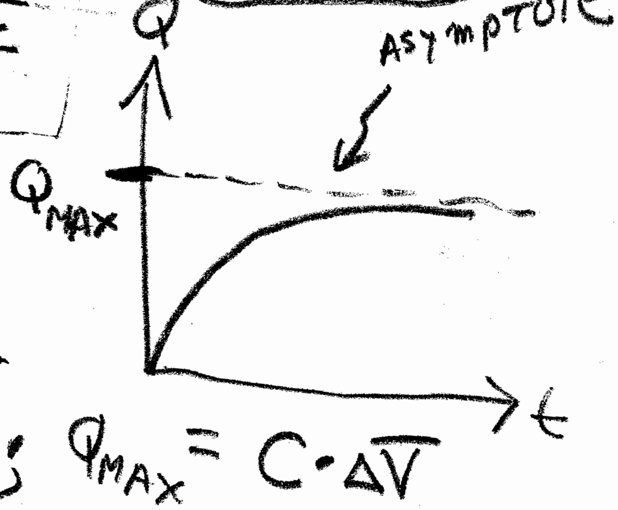
RC circuits



switch at ⓐ: I FLOWS; heat is generated and Q increases.

ASSUME $Q=0$ at $t=0$





AT $Q = Q_{MAX}$, $t \Rightarrow \infty$.

AT $Q = Q_{MAX}$, $I = 0$; $Q_{MAX} = C \cdot \Delta V$

charging circuit:

$$Q = Q_{MAX} \cdot \left(1 - e^{-t/RC}\right)$$

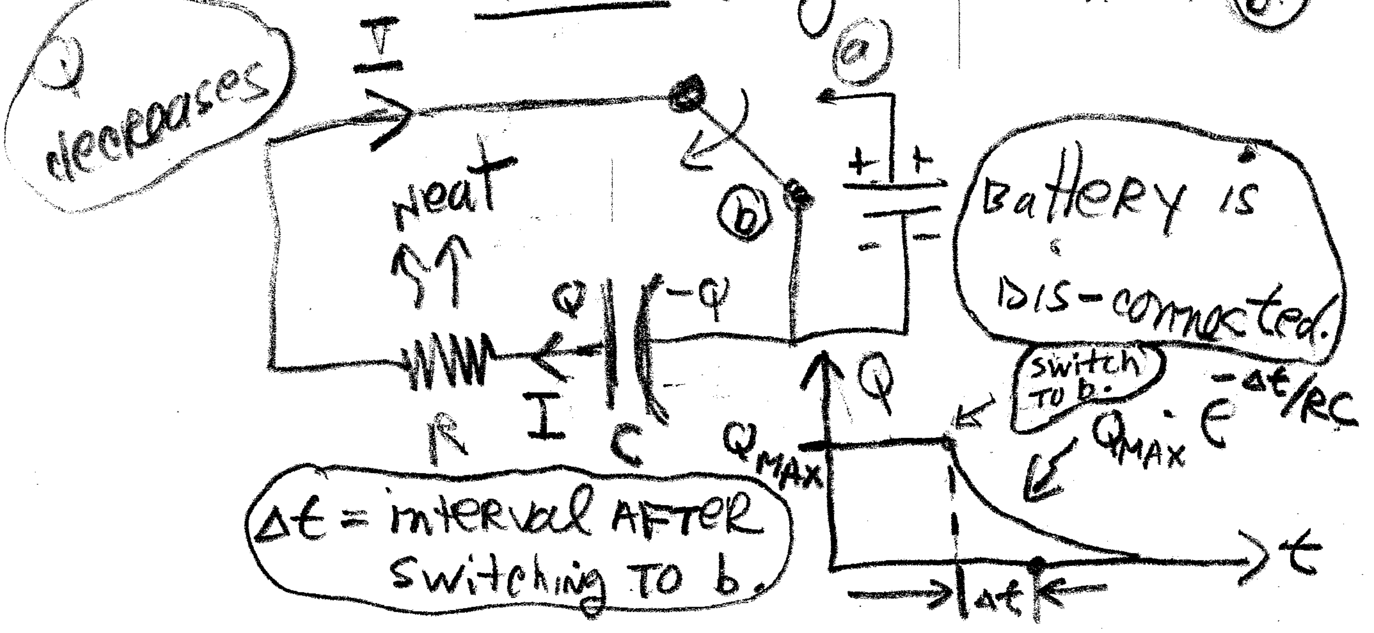
at $t=0$: $e^{-0} = 1 = e^{0}$

$$Q = Q_{MAX} \cdot (1-1) = 0$$

at $t=\infty$: $e^{-\infty} = 0$

$$Q = Q_{MAX} \cdot (1-0) = Q_{MAX}$$

DIS-CHARGING: switch at ⓑ.



Battery is DIS-connected.

Δt = interval AFTER switching to b.

GLOBAL EXAM schedule

2B March 21 = Test 2

Review: MAR 17

CH 18, 19, 20

↑ ↑

end ONLY assigned

4B March 21

CH 23, 24