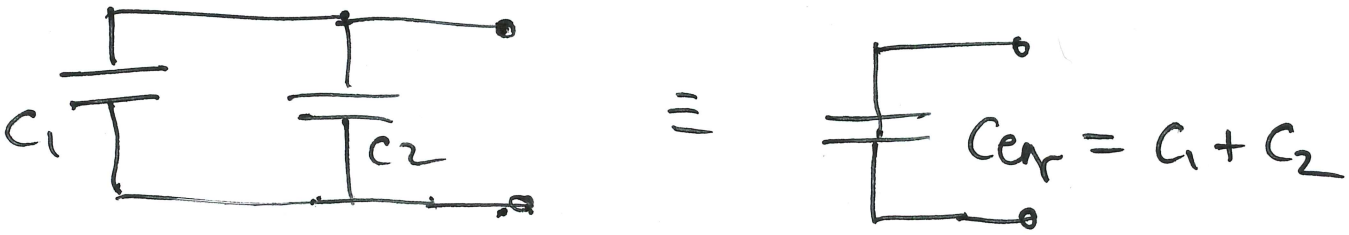
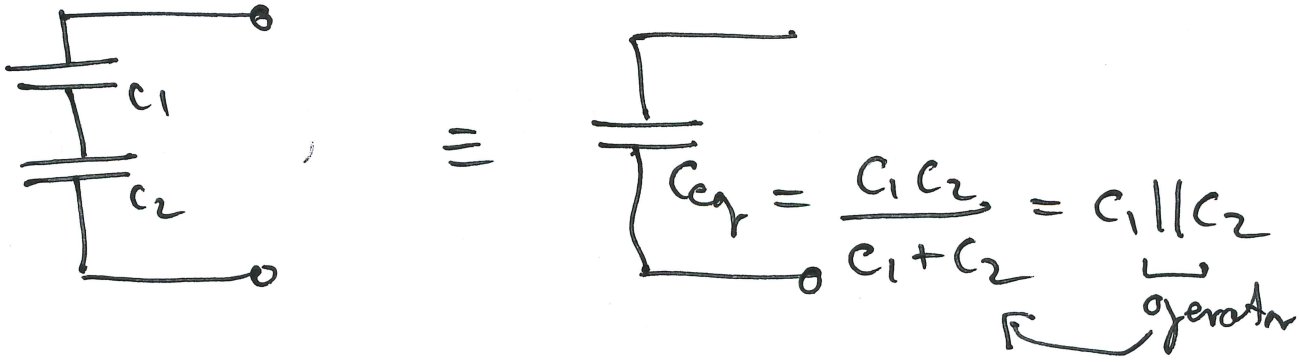
EE16A – Module 2 – Lecture #6

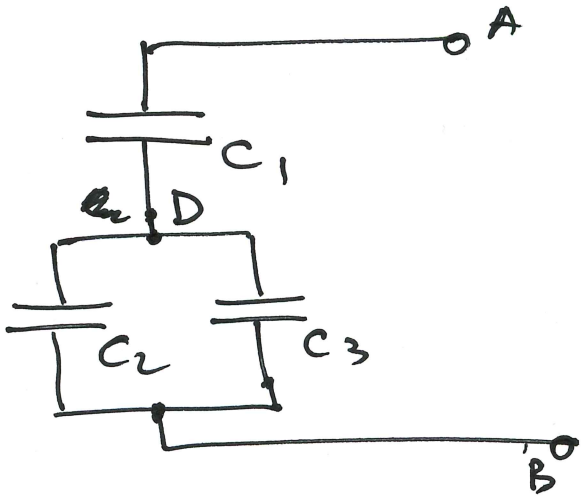
* Cap. Equivalence example
* Capacitor physics
* 2D – touch
* cap measurements (sensor)



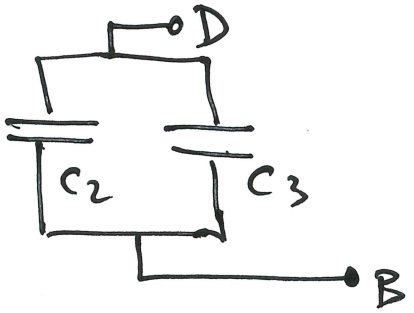


$$C_{eq} = \frac{I_{test}}{\frac{dV_{test}}{dt}}$$

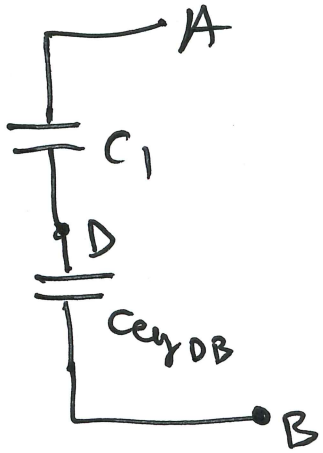
example #3 :



$\equiv$ $C_{eq} = C_1 \,||\, (C_2 + C_3)$



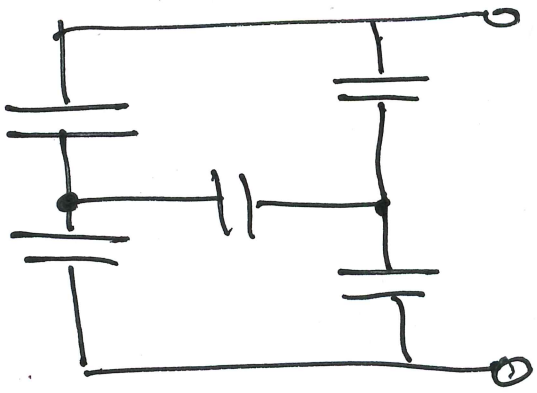
$\equiv$ $C_{eq\,DB} = C_2 + C_3$



$\equiv$ $C_{eq} = C_1 \,||\, C_{eq\,DB}$

$= C_1 \,||\, (C_2 + C_3)$

(l3)



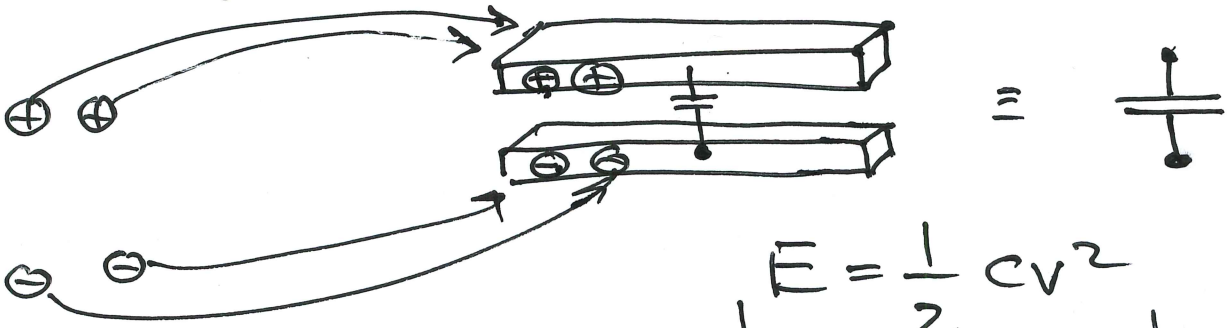
do for practice

16# Capacitor physics

* Any two conductors separated by an insulator => capacitor

cannot carry current

$$Q = C \cdot V$$



$$E = \frac{1}{2} C V^2$$

"capacitor" is a "bucket" for charge

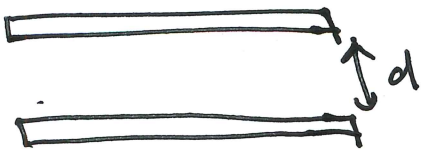
Capacitance depends on: 1) geometry of the conductors

2) material properties of the insulator

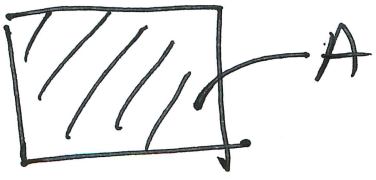
- ε - permitivity $\left[\frac{F}{m}\right]$

$\varepsilon_0 = 8.85 \frac{pF}{m}$

side view:



top view:

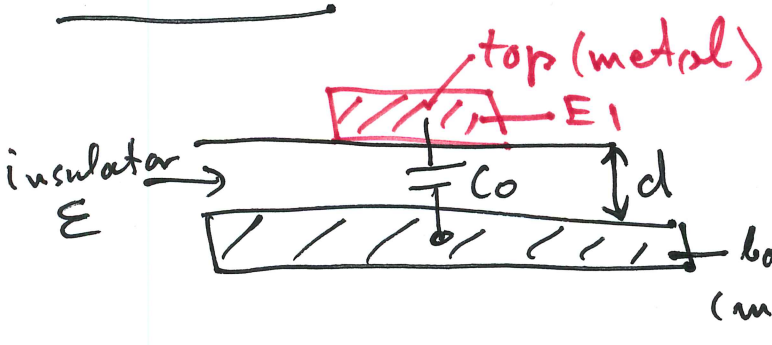


$$C = \varepsilon \frac{A}{d} =$$

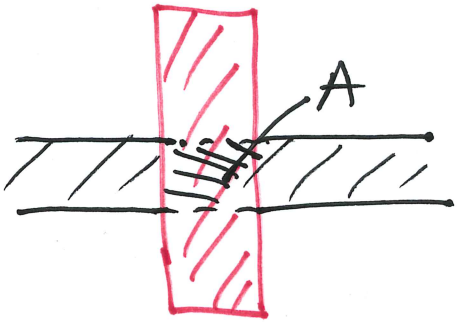
$[F]$ $\left[\frac{F}{m}\right]$ $\left[\frac{m^2}{m}\right]$

Touchscreen:

Side view:

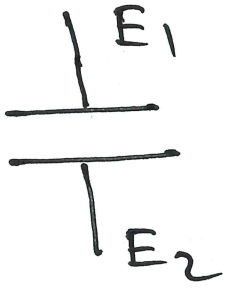


Top view:



Model:

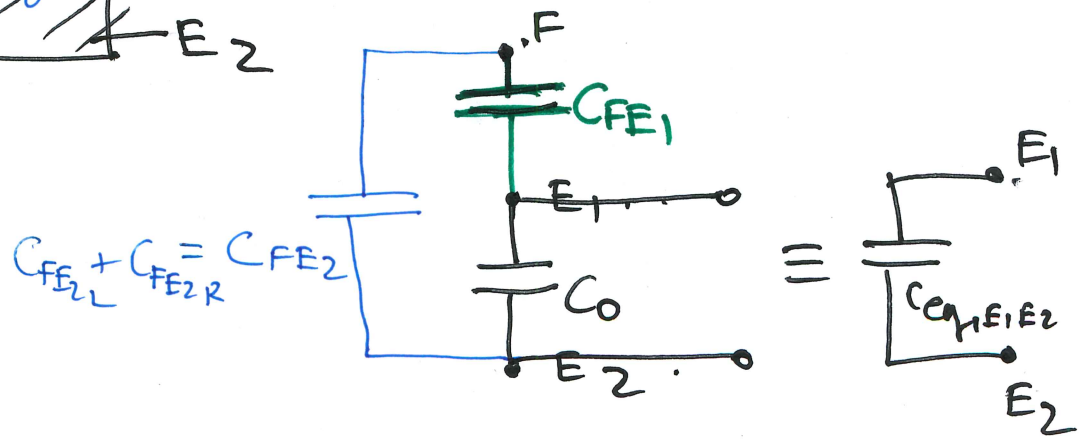
w/o touch



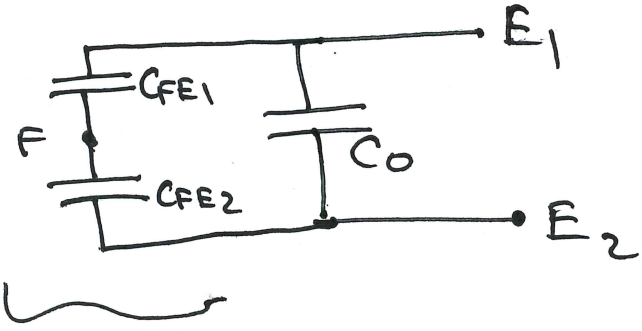
$$C_o = \varepsilon \cdot \frac{A}{d}$$

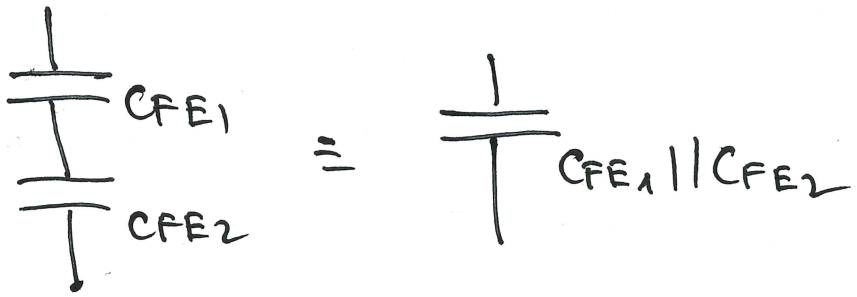
Model:

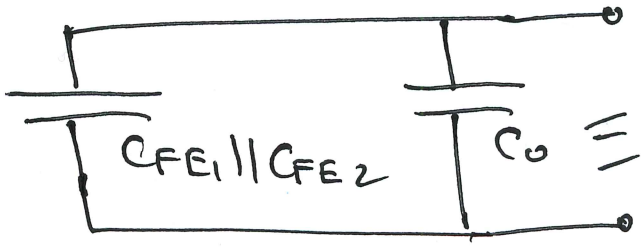
with touch



$$C_{eq,E1E2} = C_o + \underbrace{C_{FE1} \,||\, C_{FE2}}_{\Delta C > 0}$$

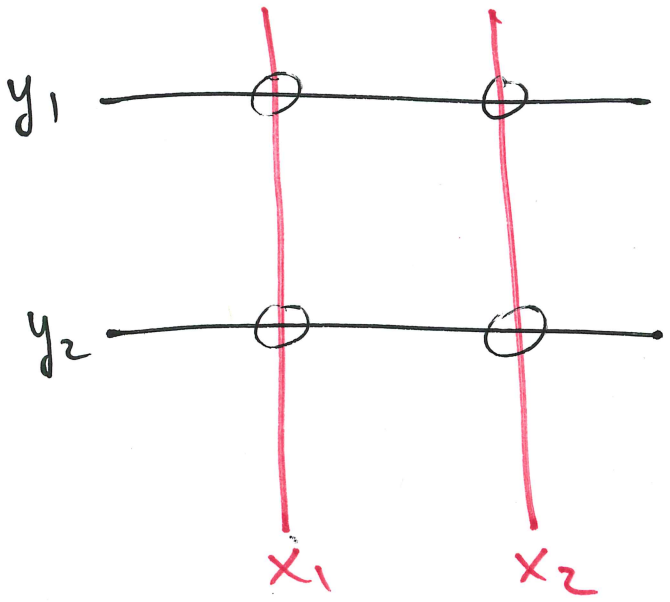

E1
CFE1
F
CO
CFE2
E2


CFE1
CFE2
≡
CFE1 || CFE2


CFE1 || CFE2
CO
≡

(17)

Expanding to 2D:



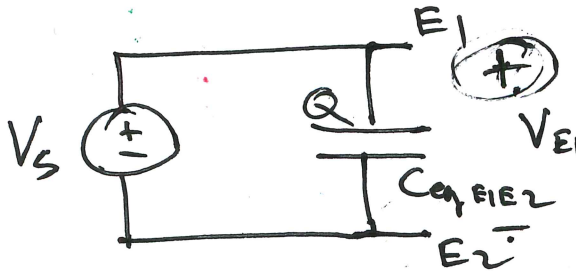
upper left: x_1, y_1

⋮

How do we measure capacitance?

$$Q = C \cdot V \quad \Rightarrow \quad V = \frac{Q}{C}$$

Attempt #1:

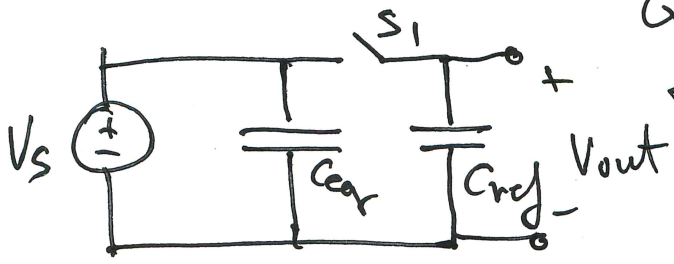


$V_{E1E2} = V_S$ ☹

Attempt #2:

$$Q_{E1E2} = C_{eq\,E1E2} \cdot V_S$$

Q_0 ← Q_{E1E2} → $Q_0 + \Delta Q$; C_0 ; $C_0 + \Delta C$



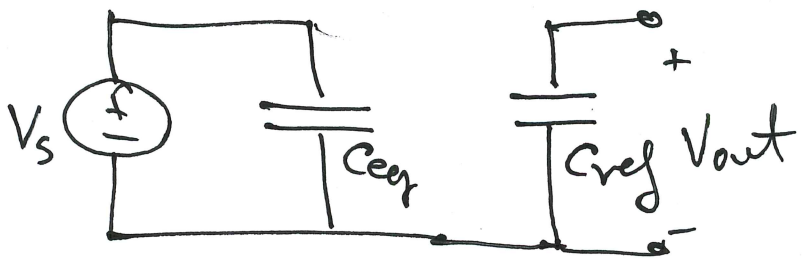
define a switch:

S_1: on: —— wire

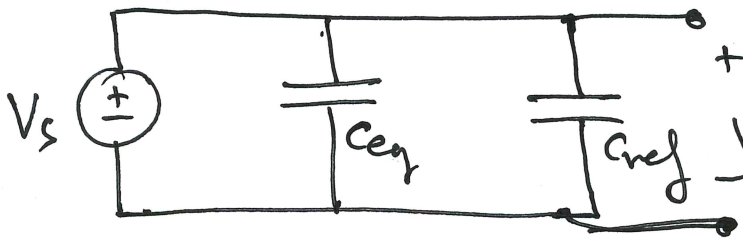
off: — o o — open ckt

Attempt #2 cont:

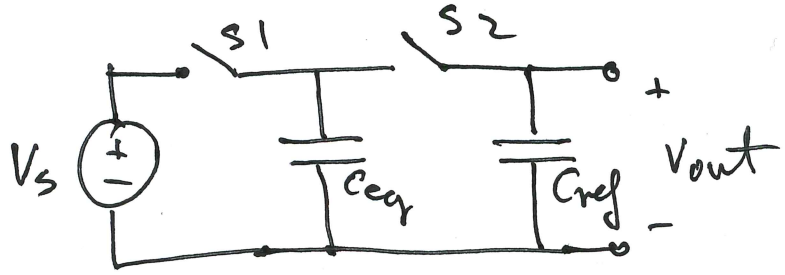
S1 off:



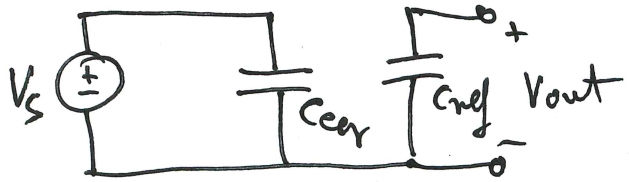
S1 on:



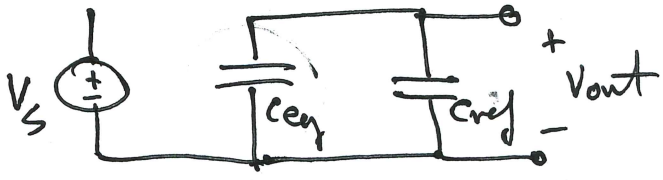
Attempt #3:



S1 on, S2 off:

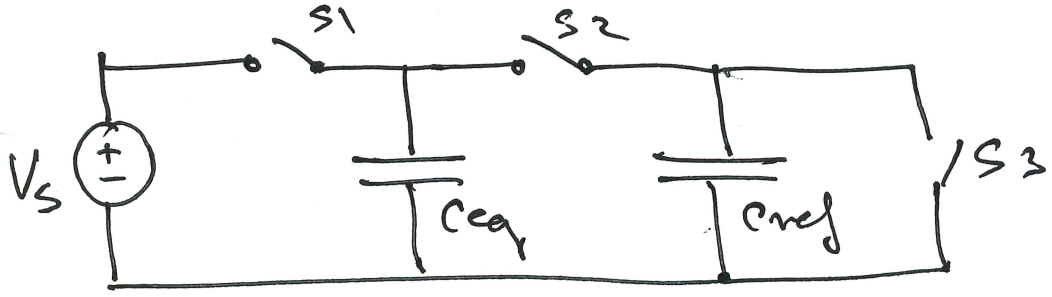


S1 off, S2 on:

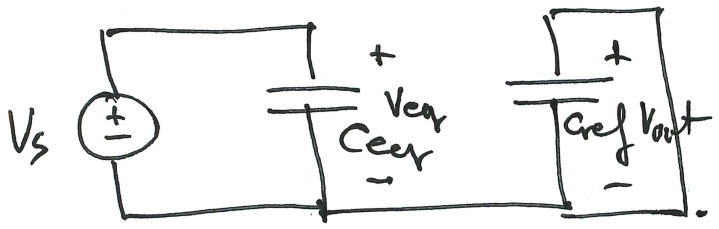


almost there.

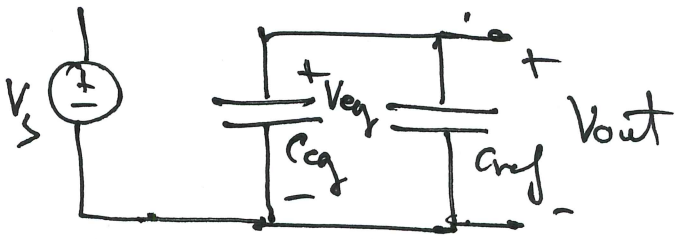
(19) Attempt #4:



phase 1
S1 on, S2 off, S3 on



phase 2:
S1 off, S2 on, S3 off



Charge needs to be conserved:

$$Q_{total,\,phase1} = Q_{total,\,phase2}$$

$$Q_{ceq,1} + Q_{cref,1} = Q_{ceq,2} + Q_{cref,2}$$

$$C_{eq} \cdot V_{eq,1} + C_{ref} \cdot V_{out,1} = C_{eq} \cdot V_{eq,2} + C_{ref} \cdot V_{out,2}$$

($V_{eq,1} = V_s$, $V_{out,1} = 0$, $V_{eq,2} = V_{out,2}$)

$$C_{eq} V_s = C_{eq} V_{out,2} + C_{ref} \cdot V_{out,2}$$

$$C_{eq} V_s = (C_{eq} + C_{ref}) V_{out,2}$$

$$V_{out,2} = \frac{C_{eq} V_s}{C_{eq} + C_{ref}}$$