EECS16A DIS 4C

Topics for today

[1] Charge conservation and when and where it applies → useful for analyzing switch capacitor ckts
(Definition of floating nodes)

[2] Charge sharing algorithm
(algorithm for analyzing voltages in a switch capacitor ckt)

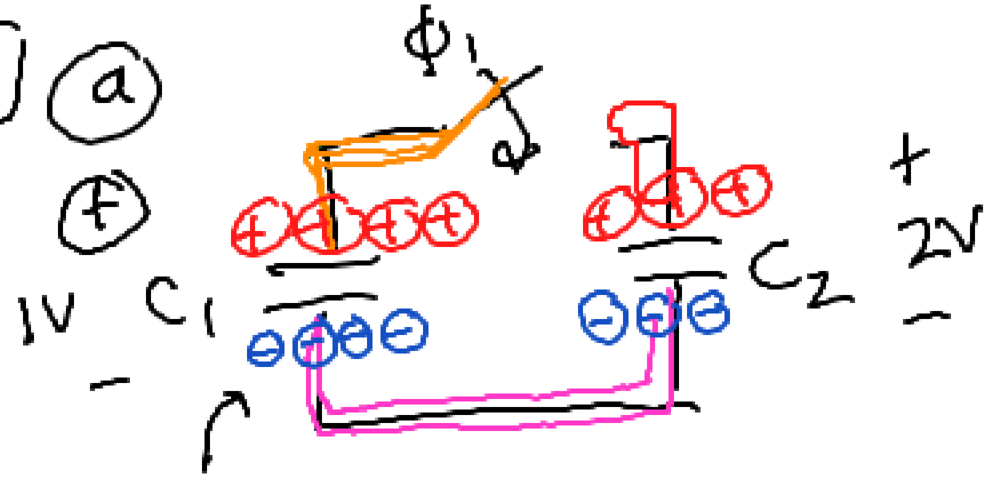
In circuits we have positive charges (+)
negative charges (−)

physics - can't destroy
- energy
- mass
- charge

Charge is only conserved when we have a closed system where it can't leave
↳ nodes from which charge can't leave
→ there are no conductive paths from this node to elsewhere
→ no resistors, no wires to other nodes
→ no Batteries / voltages, no current sources

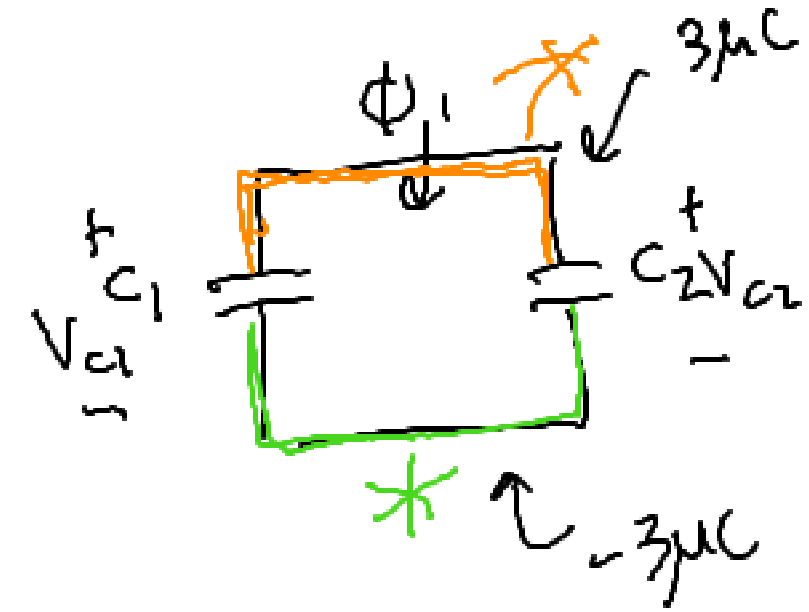
this is what is called a Floating node

1 (a)



ϕ_1 open

→



ϕ_1 closed
Has 2 nodes
Has 2 floating nodes

$C_1 = C_2 = 1\mu F$

Q: What is the charge on C_1, C_2

Q: What nodes do we have before ϕ_1 closed?
3 nodes, they are floating nodes

$Q = CV$

$Q_1 = (1\mu F)(1V) = \boxed{1\mu C}$

↳ Positive top left charge (⊕⊕⊕⊕)

Negative bottom left charge (⊖⊖⊖⊖)

↳ $-1\mu C$

$Q_2 = 1\mu F \cdot 2V = \boxed{2\mu C}$

↳ Positive top right (⊕⊕⊕)

(b) When ϕ_1 Closed
what is V_{c1} and V_{c2}?

$V_{c1} = V_{c2}$

$Q_{top} = Q_1 + Q_2 = 3\mu C$

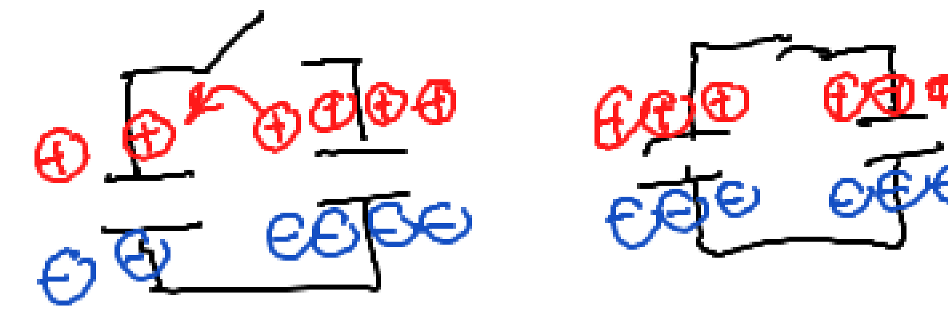
$Q_{bottom} = -(Q_1 + Q_2) = -3\mu C$

What does Q top & Q bottom tell us about V_{C1}, V_{C2} and Q_1 & Q_2 (on each cap when the switch is closed?)

$Q_{top} = 3\mu C$, $Q_{bot} = -3\mu C$

$Q_1^{\phi_1} = C_1 V_{C_1} = C_1 V$

$Q_2^{\phi_1} = C_2 V_{C_2} = C_2 V$



$Q_{top} = Q_1^{\phi_1} + Q_2^{\phi_1}$

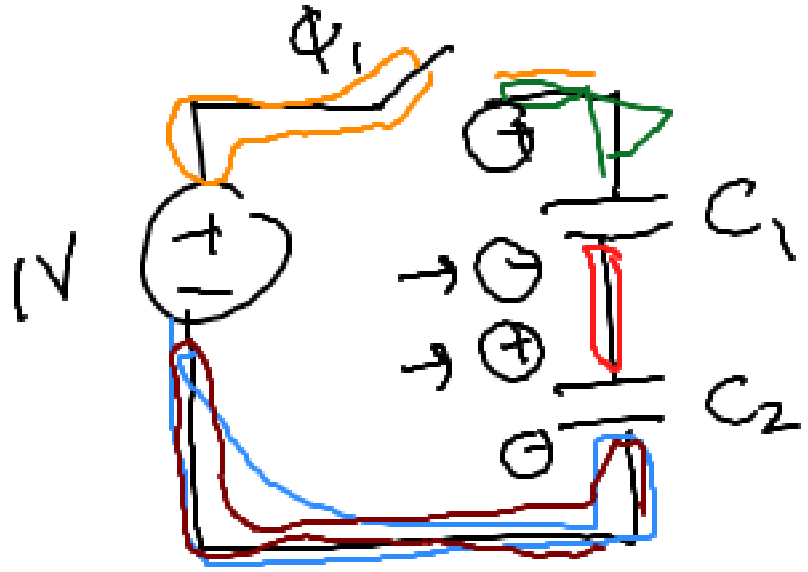
$3\mu C = C_1 V + C_2 V \rightarrow$

$3\mu C = (1\mu F + 1\mu F) V \Rightarrow V = \frac{3\mu C}{2\mu F} = \boxed{1.5V}$

$Q_1^{\phi_1} = \underline{C_1} V = 1\mu F \cdot 1.5V = \boxed{1.5\mu C}$

$Q_2^{\phi_2} = \underline{C_2} V = 1\mu F \cdot 1.5V = \boxed{1.5\mu C}$

1 (c)



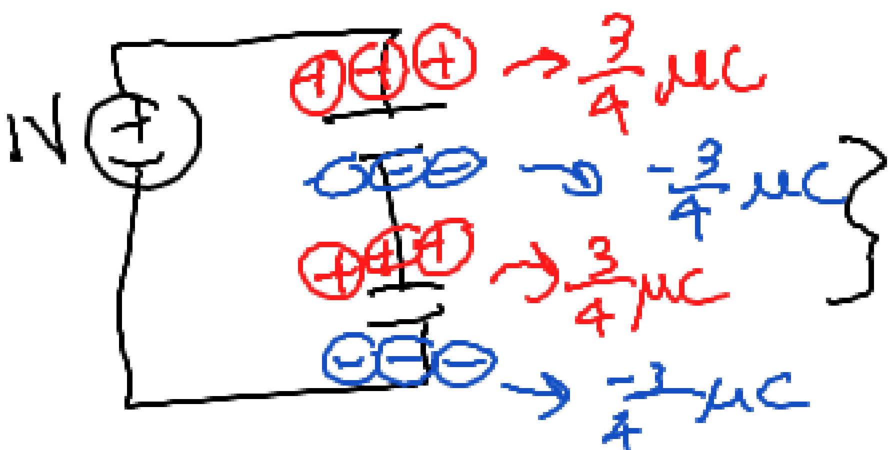
$C_1 = 1\mu F$
$C_2 = 3\mu F$

$V_{C_1}(\phi_1 \text{ open}) = 0V$ (No charge on plates)

"time"

$V_{C_2}(\phi_1 \text{ open}) = 0V$ (No charge on plates)

But when ϕ_1 closes



Q: Which are floating nodes? (when ϕ_1 is open) A: [green], [red] (also, 4 nodes total)

Q: How much charge is on red node? 0μC (charge is conserved here)

ϕ_1 closed

Q: Which are floating nodes? (when ϕ_1 is closed) A: [green]

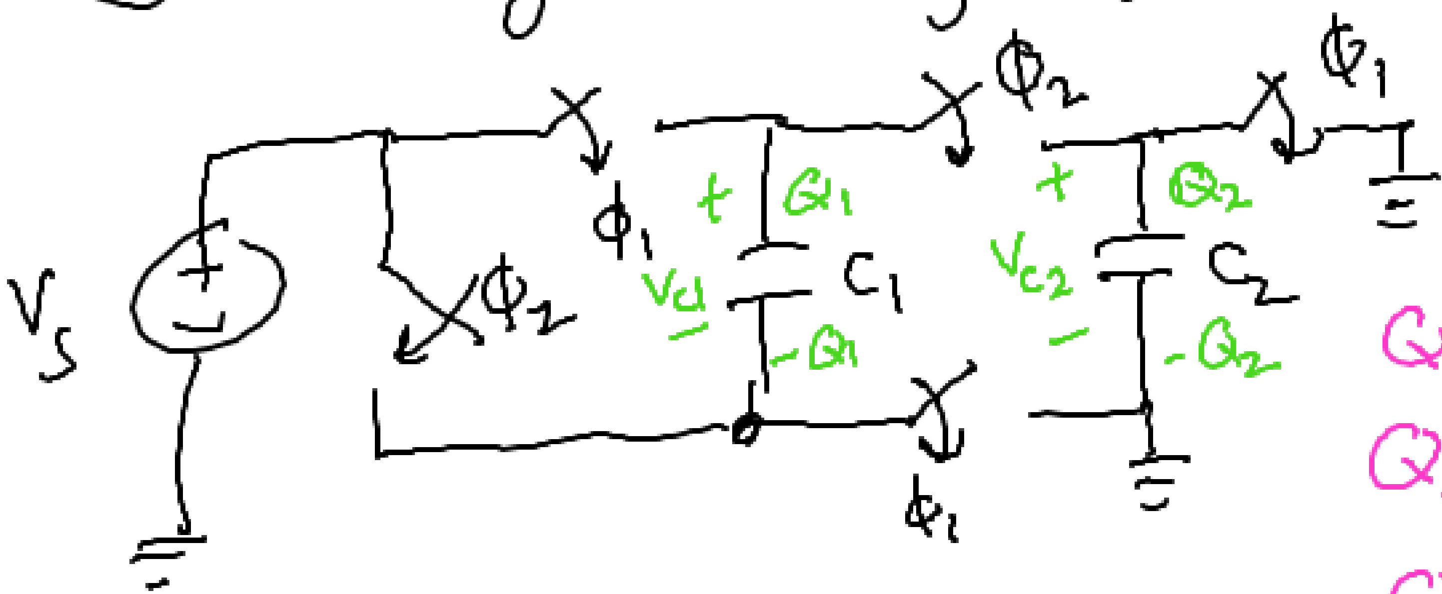
→ 3 nodes [yellow/cyan] [green] [purple]

→ 1 floating node

$\frac{3}{4}\mu C - \frac{3}{4}\mu C$ ↓

Q: How much charge is on green node? 0μC (charge is conserved here)

2 Charge Sharing Algo.



Q: Calculate all node voltages at the end of phase 2 as a function of V_s, C_1, C_2

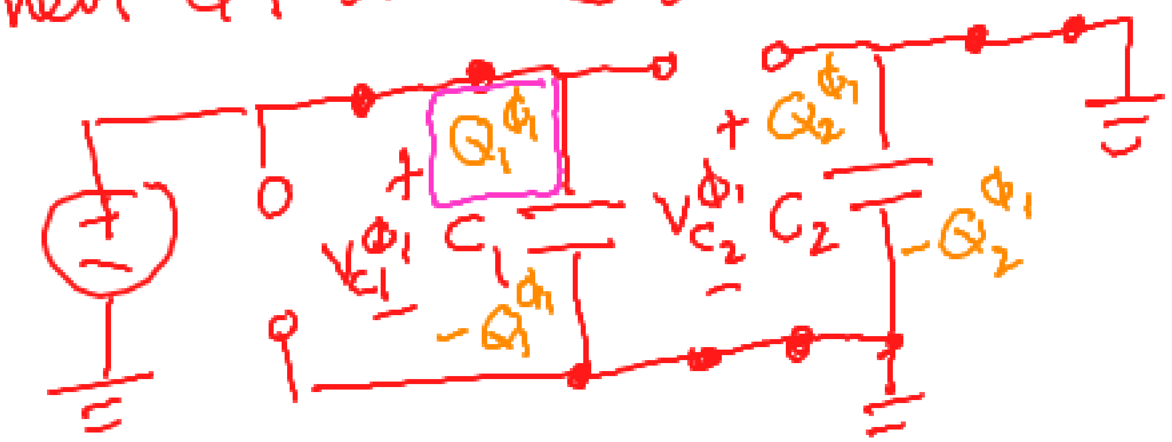
$Q_1^{\phi_1} = C_1 V_s$

$Q_2^{\phi_1} = C_2 \cdot 0$

$Q_1^{\phi_2} = C_1(u - V_s)$

$Q_2^{\phi_2} = C_2(u - 0)$

When ϕ_1 switches are closed (when ϕ_2 open)



Charge Sharing Algo.

1. Label voltages + charges in circuit
2. Draw equivalent circuits for each phase (label voltages + charges)
3. Identify floating nodes in second phase
4. Apply charge conservation at each floating node

$Q_1^{\phi_1} + Q_2^{\phi_1} = Q_1^{\phi_2} + Q_2^{\phi_2}$

$C_1 V_s + 0 = C_1(u - V_s) + C_2 u$ → solve for u

$u = \frac{2C_1}{C_1 + C_2} V_s$

When ϕ_2 switches are closed (and ϕ_1 open)

this is the only floating node

3 nodes in brown