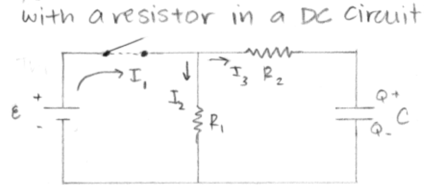
**Physical Sciences 3**
Lectures 7 and 8 – February 27, 2008 – Kirchhoff's Rules and RC Circuits
*Reading for Understanding: Chapter 26 s1-3, 5*

## DC CIRCUITS

- characterized by constant current, both in magnitude and direction
- only resistors and emfs matter

add ⊣⊢

what happens when you now put a capacitor in series with a resistor in a DC circuit?




call this an "RC CIRCUIT"

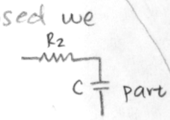
Consider the circuit above with an open switch first. (i.e. nothing flowing)

we know that capacitors store charge not current ∴ a capacitor cannot conduct current. A capacitor also cannot store charge forever - it dissipates over time.

$Q(t) = \int_0^t \frac{dQ}{dt}\,dt = Q_0 \quad \therefore I_c = 0$

definition of current I

initially, when the switch is first closed we are under CHARGING CONDITIONS




at $t=0$, C has charge $Q_0$ $\quad \Delta V = \frac{Q}{C}$

$I = \frac{\Delta V}{R} = \frac{Q}{RC}$

due to resistor being in circuit

time constant: time it takes for the (to 63%) capacitor to charge or discharge. The larger the R the longer it takes to charge. The larger the C the more storage there is.

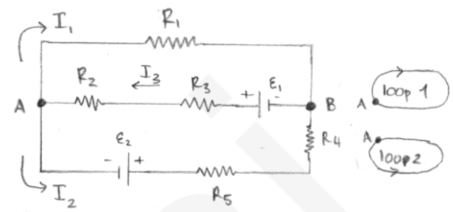
so current is flowing through the Resistor - it is dissipating through the resistor until $I_c = 0$, point at which the capacitor is fully charged.

$I = -\frac{dQ}{dt} = \frac{Q}{RC} \rightarrow -\frac{1}{RC}dt = \frac{1}{Q}dQ \rightarrow \ln Q = -\frac{1}{RC}t + \text{constant}$

$Q(t) = Q_0(e^{-t/RC})$ $\quad \therefore \quad$ $I(t) = \frac{Q_0}{RC}(e^{-t/RC})$

method → KIRCHHOFF'S RULES

Specifically for solving emf/resistor circuits.




① IDENTIFY THE CURRENTS:

The emf ε is positive if current is flowing like so: $+\varepsilon$ ⊣⊢ →I $\quad$ a little later... →I ⁺∿∿∿⁻ means $-RI$

It doesn't matter which direction you ultimately choose; if you have the sign wrong, you know it'll be going in the opposite direction if it's negative.

② JUNCTION RULE: (NODES •A •B)

The sum of all the currents entering a junction equals the sum of all the currents leaving that junction.

look at •A $\quad I_3 = I_1 + I_2 \qquad$ •B $\quad I_1 + I_2 = I_3$

③ LOOP RULE:

The sum of changes in potential around any closed path is zero

look at loop 1: (top half of circuit)

$-R_1 I_1 + \varepsilon_1 - R_3 I_3 - R_2 I_3 = 0$

look at loop 2: (bottom half of circuit)

$\varepsilon_2 - R_5 I_2 - R_4 I_2 + \varepsilon_1 - R_3 I_3 - R_2 I_3 = 0$

* YOU NOW HAVE 3 EQUATIONS & 3 UNKNOWNS! SOLVE! *

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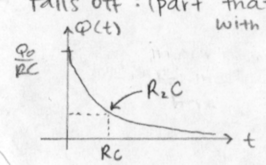
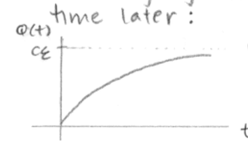
So the resistor's current ($I_3$) falls off: (part that in series with ⊣⊢)



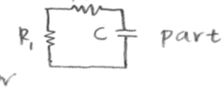

as $I_3$ dissipates, the capacitor is charging up, until $\Delta V = \varepsilon$ some time later:



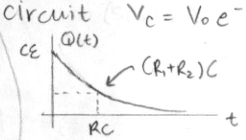

$V_c = \varepsilon(1 - e^{-t/RC})$

at $t \gg 0$ goes to ∅.

Now, after the capacitor has been fully charged, let's open the switch momentarily... then let's close it; we are under DISCHARGING CONDITIONS:




now all the charge in the capacitor discharges (dissipates) via both the resistors in the circuit $\quad V_c = V_0 e^{-t/RC}$ and $Q = Q_0 e^{-t/RC}$




So Kirchhoff for left and right loops? $I_1 = I_2 + I_3$

LHS: $\varepsilon - R_1 I_2 = 0$

RHS: $I_3 = \frac{dQ}{dt}$ so $R_1 I_2 - R_2 I_3 + \frac{Q}{C} = 0$

$\therefore \varepsilon - R_2 \frac{dQ}{dt} + \frac{Q}{C} = 0$

solve differential...