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(1) Phys 1402 2015-09-22 Lec 8

Exam 1 Tue 9/29

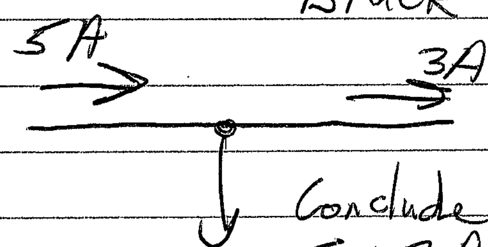
Kirchoff's Laws

- Cons. Charge - Kirchoff's Current Law

$$\sum I_{in} = 0 \quad \text{(outward is } \ominus\text{)}$$

$$\sum I_{in} = \sum I_{out}$$

Applies to: Junction, Component, Black Box



Conclude
$I = 2A$

$$I_5 = I_3 + I_2$$

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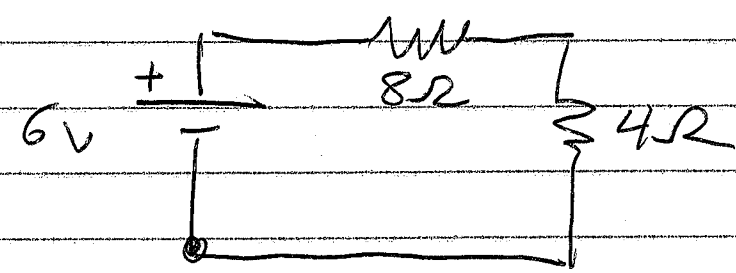
- Cons. Energy per Charge (Voltage)

$$\sum \Delta V = 0$$

$$\sum V_{rises} = \sum V_{drops}$$

Applies to: Any "closed" loop.

Ex: Series Circuit



Start @ Lower Left, go CW.

Battery	$V_{rise} = 6\,V$	$\Delta V = +6\,V$
8Ω	$V_{drop} = I(8\Omega)$	$\Delta V = -(8\Omega)I$
4Ω	$V_{drop} = I(4\Omega)$	$\Delta V = -(4\Omega)I$

$$(6V) = I(8\Omega) + I(4\Omega) \rightarrow I = 0.5A$$

$$(6V) - (8\Omega)I - (4\Omega)I = 0 \nearrow$$

Follow the currents and R's are "drops".
Batteries are rises if you go ⊖ to ⊕.

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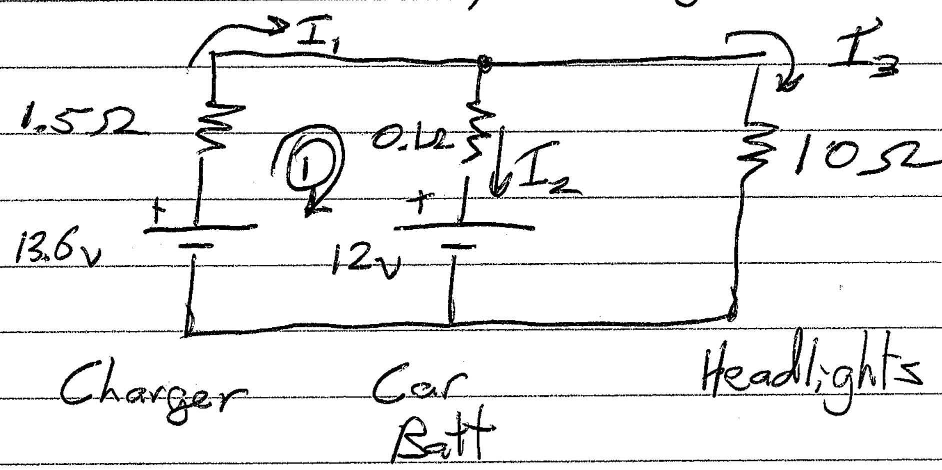
Why use Kirchoff's Laws?

- Two Batteries
- Complicated meshes.

Ex: Car Battery Charger



Method: Mesh Currents - avoid
Node Voltages - ok, but not covered
Currents - typical method

- Choose measurable currents.
- Build current Eqn.

$$I_1 = I_2 + I_3$$

- Build voltage eqns.

(1) $+(13.6V) - (12V) = 1.5 I_1 + 0.1 I_2$

(Outside) $+13.6 = 1.5 I_1 + 10 I_3$

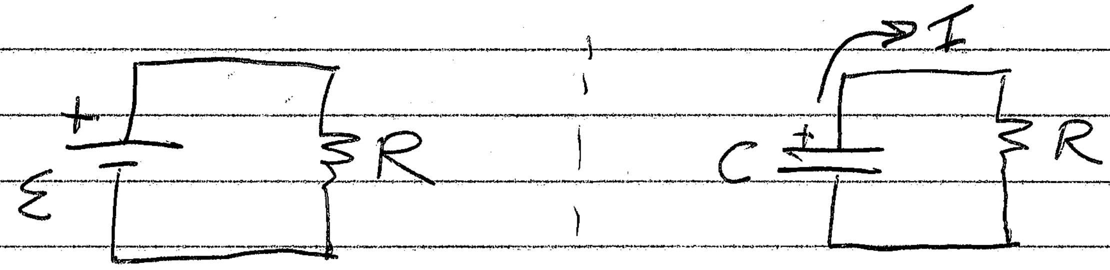
simultaneous eqns
linear eqns

$I_1 = 1.07$ A
$I_2 = -0.12$ A
$I_3 = 1.20$ A

Capacitors and RC Circuits

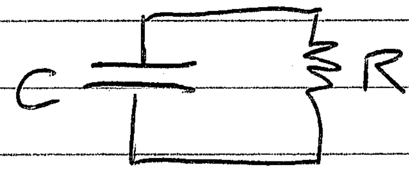
So far: Steady state is $I = 0$,
Charge is $Q = CV$

Compare a battery to a charged cap:



Battery	Charged cap
$V_R = \mathcal{E}$ = const	$V_R = V_C$ = not const
$I = \frac{V_R}{R}$ = const	$I = \frac{V_R}{R}$ drains cap
Battery provides steady voltage.	$Q = CV$ decreases
	Cap still drains, but more slowly.
	Eventually, $I \approx 0$
Like a faucet.	Like a bucket/tank.
Steady Pressure.	Pressure depends on fullness.

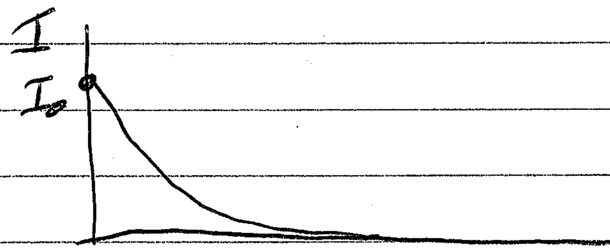
Math of Discharging Capacitor



$V_R = IR$

$V_C = Q/C$

All Quantities decrease exponentially.



$$I = I_0 e^{-t/\tau}$$

I = current at any moment in time

I_0 = initial current

$\tau = RC$ = time constant

e = Euler's constant ≈ 2.718

$e^{-t/\tau}$ = fraction of process remaining

0.5 means halfway done

$e^x = 0.5$

$x = \ln(0.5) = -0.693$

$-t/\tau = -0.693$

$t = 0.693\,\tau$

Time needed to get halfway done.

Called "half-life".

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Ex 18.6, but discharging

$V_0 = 12.0\ V$
$C = 5.0\ \mu F$
$R = 800\ k\Omega$

Initial Current $I_0 = \frac{V_0}{R} = 0.000\,015\ A$
$= 15\ \mu A$

Initial Charge $Q_0 = CV_0 = (5\times10^{-6} F)(12.0 V)$
$= 0.00006\ C$
$= 60\ \mu C$

Time Const $\tau = RC = (5\times10^{-6} F)(800\times10^{3}\Omega)$
$= 4.0\ s$

Time to get down to 1.0 V:

$$V = V_0\, e^{-t/\tau}$$
$$(1.0) = (12)\, e^{-t/\tau}$$

$$\frac{1}{12} = 0.0833 = e^{-t/\tau}$$
$$-2.48 = -t/\tau \quad (\ln \text{both})$$
$$t = (4)(2.48) = 9.94\ s$$