PHY 316M

Marc Matvienko

October 17, 2017

1 Capacitors

$C = |\frac{Q}{V}|$

2 Current

Is the flow of charge in on direction. Current:

$$I = \frac{\Delta Q}{\Delta t} = \frac{\delta Q}{\delta t}$$

Current Density (current per unit area): $J = \frac{I}{A}$
n = charge carriere density, q = charge per carrier, v_d = drift velocity This can give us, $\boxed{J = nqv_d}$

2.1 Ohm's Law

Usually we see Ohm's law in different forms, i.e. for a particular chunk.
Consinder some block with volume $A \cdot l$, some source of energy(battery) forces current thorugh by applying an electric field.
For a uniform electric field: $\boxed{V = E \cdot l}$

$$\begin{aligned} J &= \frac{I}{A} \\ &= \sigma E \\ &= \sigma \frac{V}{l} \end{aligned}$$

$$\boxed{\frac{V}{I} = \frac{1}{\sigma}\frac{l}{A} = \rho\frac{l}{A} = R = \text{resistance}}$$

$\boxed{\frac{V}{I} = R}$ Resistance is not resistivity (opisiton of current flow of a particular material[ρ]) Ohmic material is a material that has a constant slope on Voltage to Current graph. Most common materials like copper behave like this.

Example The resistivity of nichrome wire(heaters, toasters) is $1.5 \times 10^{-6}\Omega m$. If a household voltage of $115V$ is applied acros a $0.2mm$ radius write, $1.0m$ long, what current flows?

$R = \rho \frac{l}{A} = \rho \frac{l}{\pi r^2} = \frac{1.5\times 10^{-6}\Omega m \cdot 1.0m}{(\pi(2\times 10^{-4}m)^2))} = 11.9\Omega$

2.2 Model for electric conduction

- electron unergo many rapid ocllision when $E = 0$
- when $E \neq 0$, the electrons accelrate between collisions
- $F = ma = qE => a = \frac{qE}{m}$
- $v = v_0 + at = v_0 + \frac{qE}{m}t$

Let τ = average collision time
the $v_d = v_{avg} =< v_0 > + \frac{qE}{m}\tau$
so, $J = nqv_d = nq = \frac{qE}{m}\tau = \sigma E$
so conducitvity $\sigma = \frac{nq^2\tau}{m}$
Called the Drude model or free electron mode

$$\boxed{\sigma = \frac{nq^2\tau}{m}}$$

$$\boxed{\frac{1}{\sigma} = \rho}$$

Example Assume for copper that each atom donates one free electron. What is the average time between collision for electrons in copper.?
Given:

- Density$= 8.98\frac{g}{cm^3}$
- Atomic Weight $= 63.54\frac{g}{mole}$
- $\rho = 1.7 \times 10 -^{-8}\,\Omega \cdot m$

$\tau = \frac{m}{nq^2\rho} = \frac{9.14\times 10^{-31}kg}{(8.5\times 10^{2}2)(1.6\times 10^{-19})^2 1.7\times 10^{-8}\Omega m} = 2.5 \times 10^{-14}s$

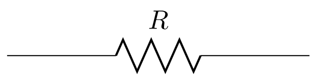
2.3 Temerature Dependence of resistivity

- resistivities tabulated for 20 °celsius
- for metals, ρ is higher and T is higher
- α = linear temprature coefficient
- over some range, $\boxed{\rho = \rho_0(1 + \alpha(T - T_0))}$

As T increases, the scattering time decreases due to collisions with vibrating atoms
At higher temperatures the ρ to temprature graph is linear. But at the beginning there is residual resistvity due to impurities.

Semiconductors The number of carriers decreases as the temperature decreases, this means that all the electrons are sticking to their atoms.

3 Resistors in Series and Parallel

Circuit symbol: 

3.1 Resistors in series

For resistors in series the resistivities add

$$R_{tot} = R_1 + R_2 + ...$$

$$R_{tot} = \frac{V}{I} = \frac{V_1}{I_1} + \frac{V_2}{I_2} = R_1 + R_2$$

The current (I) is the same everywhere too. **Resistors don't add in parallel. Capacitors do.**

$$V = V_1 + V_2$$

The voltage divider

$$V_1 = I \cdot R_1 = \frac{V}{R_1 + R_2} \cdot R_1$$

3.2 Resistors in parallel

For resisitors in parallel halve the resistance if two exact resistors are put in parallel

- In parallel have the same voltage across each element
- In parallel also the current divides among branches

$$I = I_1 + I_2 = \frac{V}{R_1} + \frac{V}{R_2} => R_{tot} = \frac{V}{I} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Superconductors Electrons pair up and when electron jumps to the lattice another electrons pulls it right back.

3.3 Resistors Disipate Energy

Electrons undergo collisions, and give up energy as heat. A steady release of current (I) causes a steady realease of energy.

$$\Delta U = \Delta Q V$$

Better to discess the rate, which is really known as:

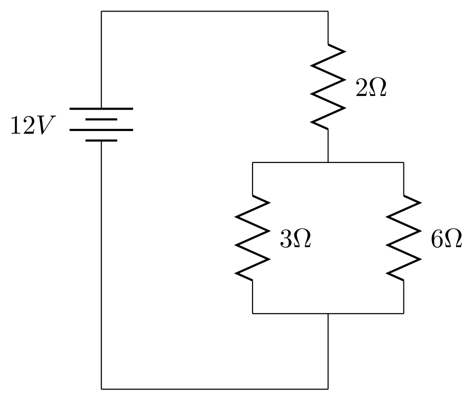
$$\text{Power} = P = \frac{\Delta U}{\Delta t} = \frac{\Delta U}{\Delta t} V = IV$$

$$\boxed{P = IV = I^2 R = \frac{V^2}{R}}$$

This power is also known as Joule heating.

Putting this into practice: many circuits can be analyzed with just Ohm's Law and Resistance.

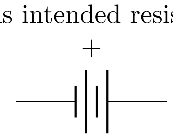
- What is the total power delivered?
- What is the power dissipated in each R?



$$P_{\text{dissapated in } 3\Omega} = \frac{V_3^2}{R} = \frac{(6V)^2}{3\Omega} = 12W$$

3.4 Direct Current Circuits

Real battery is an ideal $\mathscr{E}$MF plus intended resistance

Batteries are a source of voltage 

Source of voltage = "electromotive force" = $\mathscr{E}$MF= $\mathscr{E}$

$$\boxed{V = \mathscr{E} - Ir}$$

"Open-circuit voltage", where $I = 0$

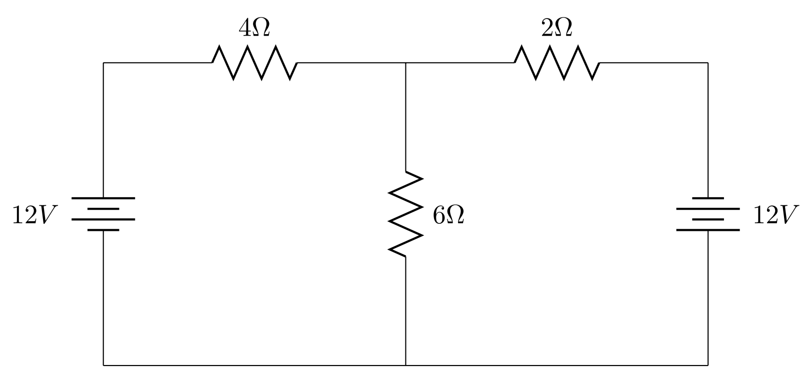
Analysis of circuits Any circuit can be analyzed with Kirchhoffs Rules:

- Junction Rule, algebraic sum of currents into a junction = sum of currents $\Sigma i_{in} = \Sigma i_{out}$
- Loop Rule, algebraic sum of voltages around any closed loop is zero. Where coltage rises are positive (- to +) and votlage drops are negative (+ to -)

For resistors the current directino determines voltage drop(negative)

Example

- What is the current in the 6Ω resisitor?
- Is it flowing up or down?



(I) Junction at A: $i_1 = i_2 + i_3$

(II) Loop A: $12V - i_1(4\Omega)0i_3(6\Omega) = 0$

(III) Loop B: $I_3(6\Omega) - i_2(2\Omega) + 12V = 0$

$i_3 = \frac{-12V}{22\Omega} = -\frac{6}{11}A$

2 other techniques:

i) same, except use ficticious "loop currents"

ii) Source suppressing - can look at effects of sources seperately

Next: Circuits with Capacitors will see time-depedent behavior Before "transient phenomena", look at *Steady-state*: "after a long time". The capacitor starts acting like the current is 0.