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Electronic Circuits

- Obiquitous is just about every aspect of modern day life (i.e. most 'techonology' has a circuit at its foundation in some form)

- Circuits also provide a very useful means to describe and understand complex systems. Some examples include:
  - modeling the middle ear
  - synchronizing chaos
  - neural networks

  ] see course webpage for some references along these lines

→ Circuits form the backbone of 'future' technologies too, such as 'bionic implants' (e.g. cochlear implants)

- Circuits tend to get complicated quickly, so we will stick to some of the basics, our chief focus being the underlying physical principles. Some key topics we'll address include:
  - current
  - resistance → draw power from electrical potential en
  - batteries
  - inductors (which introduces magnetism)
  - circuit topology
  - dynamics of simple circuits (alluding to their practicality) → will need some basic calculus here

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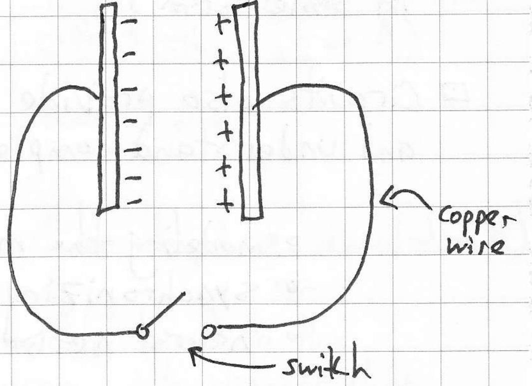
Electric Circuits (a gentle introduction)

☐ Consider a charged parallel-plate capacitor, whose plates are connected via a copper **wire** (a good conductor!) with a **switch** along the way



- Leave the switch 'open' and the plates stay charged indefinitely
- 'Close' the switch and electrons will move from the left plate through the wire and get pushed onto the right plate
- Thus $Q(t) \rightarrow 0$ with time (where Q is the charge on either plate). During this process, the wire actually warms up a bit.

☐ A couple key ideas/questions emerge here:

- The notion of charge moving through the wire → **current**
- A change in the electrical potential energy stored in the capacitor, the wire warming up
  → **discharge**, **resistance**
- How does charge move along the wire?
  → wire acts as a conductor
  → electrons move from the plate and interact w/ electrons in the wire, so electrons are the **charge carriers**
  (however convention dictates the movement of positive charge!)

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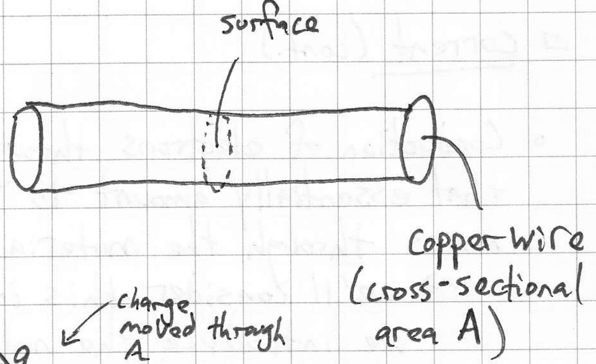
Current (thru a conducting wire)



- Consider the wire to the right. How many 'charged particles' move through the surface (w/ area A) per unit time?

- We define the current as $I = \frac{\Delta q}{\Delta t}$

  charge moved through A

  amount of time considered

  ⤳ current has units of C/s (which we call an **ampère**, denoted as A)

- Convention has current as being positive with regard to the direction positive charge moves. However, the charges that are actually moving in an electric wire are **electrons** (i.e. they are negative!). Put another way for reference:

  positive charge moving R to L = negative charge moving L to R

  these two are equivalent!

  ⤳ we will typically consider the flow of 'positive charge' (i.e. that will be our reference choice)

<u>NOTE</u>: Once you have chosen a reference, you need to stick with it. This is because current can be negative (and that physically is important!)

- In metals, electrons carry the charge. But in ionic solutions (i.e. the fluids in your body!), ions (e.g. Na^+, Cl^-) move due to electric fields and thereby carry the current

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☐ Current (cont.)

- Conduction of electrons through a wire involves a number of factors that essentially amount to how a 'swarm' of electrons moves through the material
  - ⇝ we'll consider this in more detail come ch. 19.3 once we introduce the notion of resistance)

- Note that in Giordano ex. 19.1 ('How many electrons does it take to light a lightbulb?'), draws a current of 0.5 A (60 W and 120 V → $60\,{}^{J}/_{s} / 120\,{}^{J}/_{C} = 0.5\,{}^{C}/_{s} = 0.5\,A$)

$$\Rightarrow \quad N = 10^{22} \text{ electrons}/\text{hr}$$

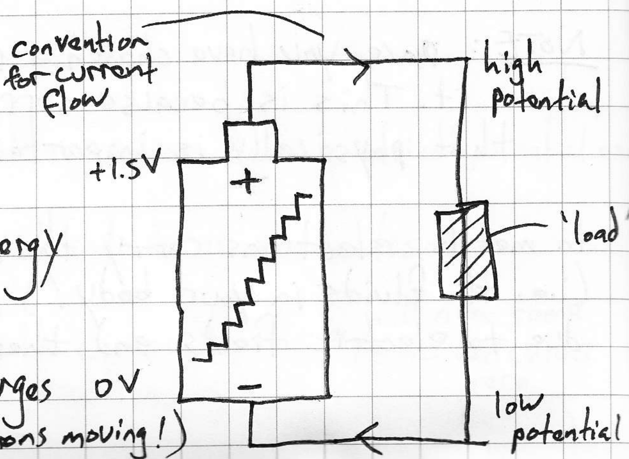
- Ideally, current can be held const. (so to be able to uniformly draw power), motivating the notion of a battery....

⊛ **NOTE** current requires some sort of '**closed**' path to follow

☐ Battery

- A battery provides energy so to maintain an electrical potential difference across its '**leads**' (this relates to the notion of a closed path in the circuit)

- Think of the battery like an **escalator** (see Giordano fig. 19.3) ⊛
  - → battery does work to provide electrical potential energy



- Note the sign convention: positive current is the direction positive charges would move (but in reality, it's electrons moving!)