EECS 42
Introduction to Electronics for Computer Science

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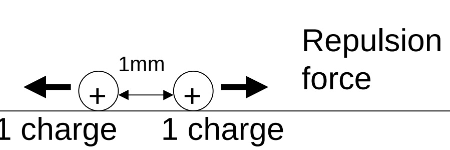
Charge

- Most matter are neutral (uncharged) most of the time… exceptions: clouds in thunderstorms; people on carpets in dry weather
- Unbalanced charge -> attracts charge of opposite sign; tendency to discharge.

Unit of Charge

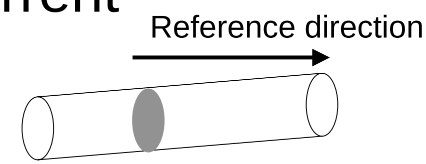
- Define unit of charge: 1 mm separation, 1 charge, F=14.4X10^{-3N}… determine that a single charge is 1.609X10^{-19} Coulombs
- Bits of information stored on a chips signify the presence or absence of charge!



Uses of Charge in Electronics

- Store it and detect it
  - Example: 64Mbit dynamics RAM(DRAM) Storage cell
  - Q = charge stored for "1"=10^{-13}C
  - Number of charges stored in Q/(unit charge) = 10^{-13}C/($1.609X10^{-19}$C/charge)
    = $6.25X10^{5}$.

Current



Definition

$I = \Delta q / \Delta t$

must pick a direction in order to assign a sign to the charge…

The choice is arbitrary but mandatory(!)

+ charge moving "with the directional array"$\rightarrow$ positive Δ q

- charge moving "opposite the directional array" $\rightarrow$ positive Δ q (not typo!)

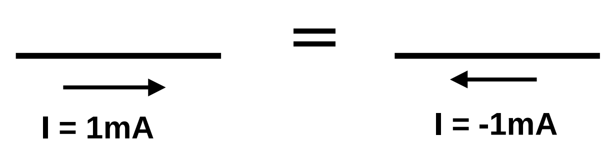
Conceptual Problems

- How does charge move through the wire?

Drift due to electric field in the medium

Conceptual Problems

- There is no need to guess the reference direction so that the answer comes out positive… your guess won't affect what the charge carriers are doing!

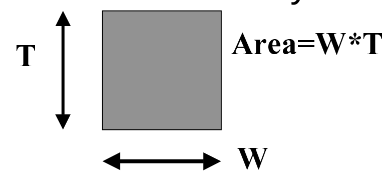


Unit of Current

- Coulombs/second = Amperes (Amps)
- Current magnitudes:
  - Household wiring … 1-20A (sinusoidal function of time)
  - Power transmission… up to kA (sinusoidal function of time)
  - Microelectronics: Currents in large integrated circuits such as microprocessors …nA to mA (10^{-9} A to 10^{-3} A)

Current vs. Current Density

- Tiny currents can lead to huge current densities (Think of Car tires pressure (32psi) vs Bicycle tires pressure (80psi), pressure is force density in pound per square inches)
- Current density is equal to current divided by cross sectional area



Example:

- Area = 1µmX1µm = 10^{-4} cmX10^{-4} cm
- I = 1mA => Current density =10^{8}A/cm^{2}

Charge Transport

- Charge carriers at room temperature: agitated motion
  - One carrier/atom in metals: around 10^{23} cm^{-3}.
  - Velocity=10^{5}m/s=100km/s
  - collide with atoms every 0.1ps=10^{-13}s

Carrier Motion

- Electric Field: carriers "feel" the force **F** = q**E** in between collisions…results in "drift". (**E** = electric field)
- Without electric field: carriers motion would be purely random.

Carrier Motion

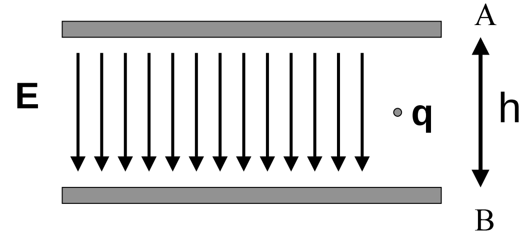
- With electric field

Remember: Electronics (negative charge) move opposite of **E**

Electric Potential Energy

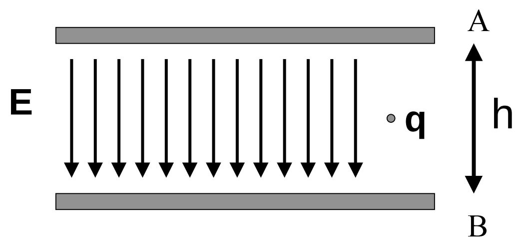
- Electric potential energy U:

U = q**E**h, q is the charge, **E** the electric field, h the distance electrodes A&B.



Electric Potential Energy

- Electric potential (voltage) difference or "drop" $V_A - V_B = \mathbf{E}\, h$



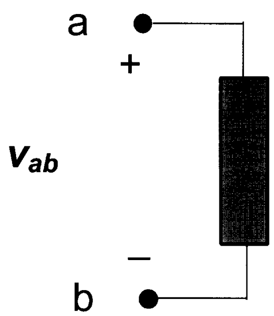
- Differences: positive & negative charge; direction of **E** can be up or down $\rightarrow$ we need to be systematic about signs.

Thinking about Voltage

- Potential is always referenced to some point (V_{AB} in the example; V_A is meaningless without an understood reference point)
- If a conducting path exists between A and B, charges will "drift" due to electric field $\rightarrow$ current flows
- Potential difference is present even without a conducting path.

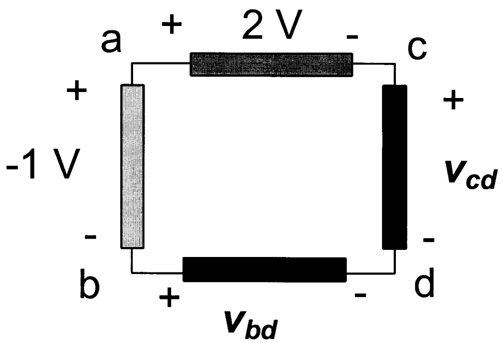
Voltage Across an Element

- Generalized circuit element with two terminals (wires) a and b, with a potential V_{ab}



Sign Conventions

- Using the sign conventions:



Power in Electric Circuits

- Power: transfer of energy per unit time

(Joules/second = watts)

 – Concept: potential energy change = q**E**h for each charge q
 – Rate is given by the # of charges/sec
- Power = P = **E**h(Δ q/ Δ t) = (**E**h)I = VI
- P = VI is the most common form

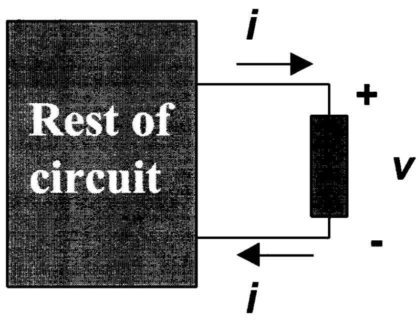
Power

- Circuit elements can "absorbs" or "release" power (that is, from or to the rest of the circuit)
- Power can be a function of time
  – Just as current or voltage can be function of time
- How to keep the signs straight for absorbing and releasing power?

Reference Directions

- It is convenient to define the current through a circuit element as positive when entering the terminal associated with the + reference for voltage

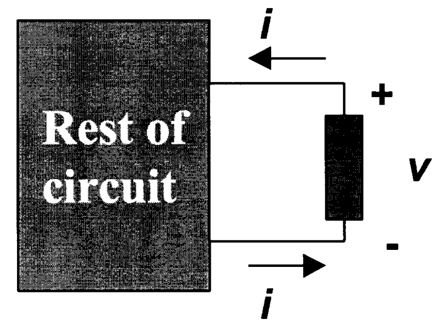
For positive current and positive voltage, positive charge “falls down” a potential “drop” in moving through the circuit element: it absorbs power.



Figuring out the Direction of Power Flow

- If the circuit element does not have a reference directions, care is needed

Try: to convert to the reference directional by reversing the reference direction for current (or voltage) Remembering to “flip” the sign at the same time.

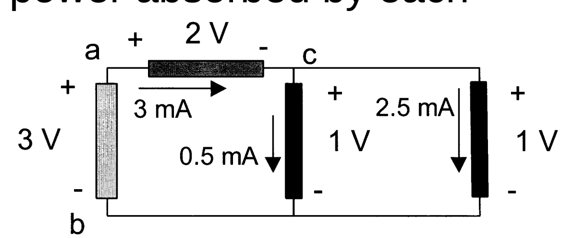


Power Definitions

- P = VI > 0 corresponds to the element absorbing power
  - How can a circuit element absorb power?
- By converting electrical energy into heat (resistors in toasters), light (light bulbs), acoustic energy (speakers); by storing energy (charging a battery)
- Negative power - releasing power to the rest of the circuit.

Calculating Power

- Find the power absorbed by each element



- Element a-b, flip current direction
- Elements a-c, c-b (left), and c-b (right): reference direction

Conservation of Power

- Sum of the power absorbed by all circuit element must be zero.
- Concept: circuit elements are used to model all modes of energy conversion (heat, sound, batteries, voltage generators, etc.)
- Simple example:

  Power released (VI <0) by the element on the left equals to the power absorbed by the element on the right.