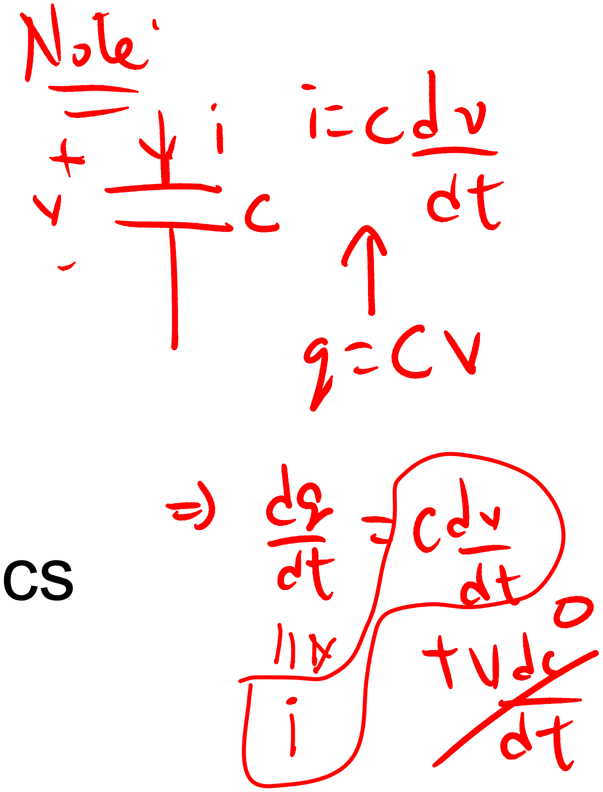
EE100Su08 Lecture #1 (June 23rd 2008)

- Outline
  - Electrical quantities
    - Charge, Current, Voltage, Power
  - The ideal basic circuit element
  - Sign conventions
  - Circuit element I-V characteristics
  - Construction of a circuit model
  - Kirchhoff's Current Law
  - Kirchhoff's Voltage Law



Electric Charge

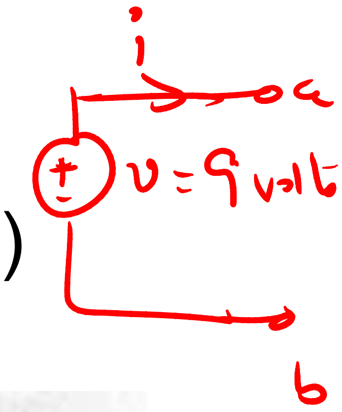
- Electrical effects are due to
  - separation of charge → electric force (voltage)
  - charges in motion → electric flow (current)
- Macroscopically, most matter is electrically neutral most of the time.
  - Exceptions: clouds in a thunderstorm, people on carpets in dry weather, plates of a charged capacitor, etc.
- Microscopically, matter is full of electric charges
  - Electric charge exists in discrete quantities, integral multiples of the electronic charge -1.6×10^{-19} *Coulomb*

Electric Current

<u>Definition</u>: rate of positive charge flow

<u>Symbol</u>: i

<u>Units</u>: Coulombs per second ≡ Amperes (A)



Note: Current has polarity.

$i = dq/dt$ where

q = charge (Coulombs)

t = time (in seconds)

André-Marie Ampère's

1775-1836

Electric Current Examples

1. 10^5 positively charged particles (each with charge 1.6×10^{-19} C) flow to the right ($+x$ direction) every nanosecond

$$I = \frac{Q}{t} = +\frac{10^5 \times 1.6\times10^{-19}}{10^{-9}} = 1.6\times10^{-5}\ \text{A}$$

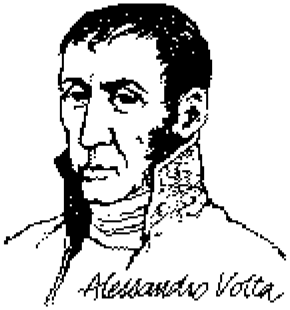
$$= \frac{1.6\times10^{-5}\times10}{10} = 16\times10^{-6} = 16\ \mu A$$

2. 10^5 electrons flow to the right ($+x$ direction) every nanosecond

$$I = \frac{Q}{t} = -\frac{10^5 \times 1.6\times10^{-19}}{10^{-9}} = -1.6\times10^{-5} A$$

Electric Potential (Voltage)

- **<u>Definition</u>:** energy per unit charge
- **<u>Symbol</u>:** v
- **<u>Units</u>:** Joules/Coulomb ≡ Volts (V)

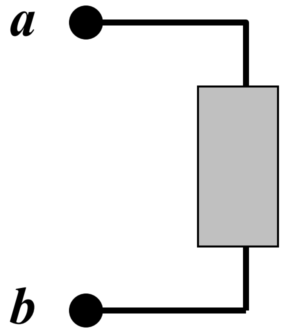


Alessandro Volta
(*1745–1827*)

$$v = dw/dq$$

where w = energy (in Joules), q = charge (in Coulombs)

Note: Potential is always referenced to some point.



<u>Subscript convention</u>:

v_{ab} means the potential at a minus the potential at b.

$$v_{ab} \equiv v_a - v_b$$

Electric Power

- **Definition:** transfer of energy per unit time
- **Symbol:** p
- **Units:** Joules per second ≡ Watts (W)

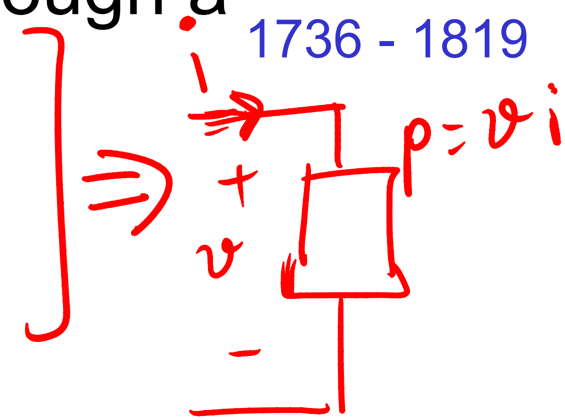
James Watt
1736 - 1819

$$p = dw/dt = (dw/dq)(dq/dt) = vi$$

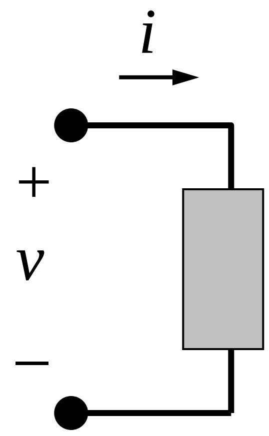
- **Concept:**

  As a positive charge q moves through a drop in voltage v, it loses energy

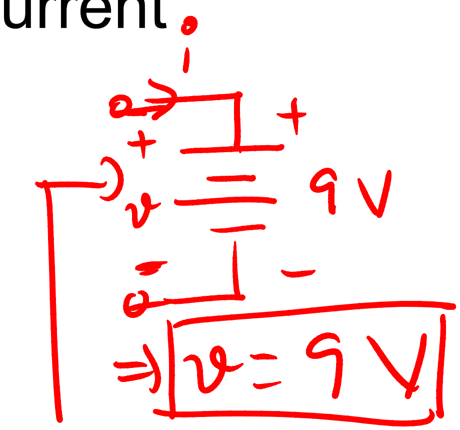
  - energy change = qv
  - rate is proportional to # charges/sec



The Ideal Basic Circuit Element

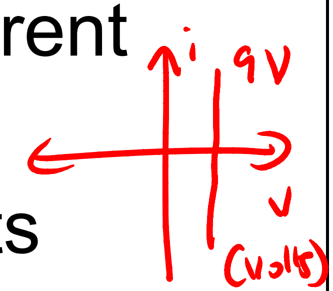


- Polarity reference for voltage can be indicated by plus and minus signs
- Reference direction for the current is indicated by an arrow



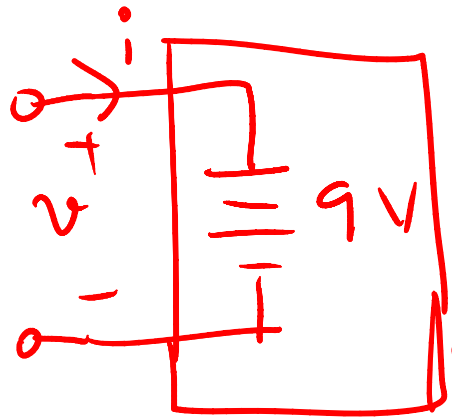
Attributes:

- Two terminals (points of connection)
- Mathematically described in terms of current and/or voltage
- Cannot be subdivided into other elements

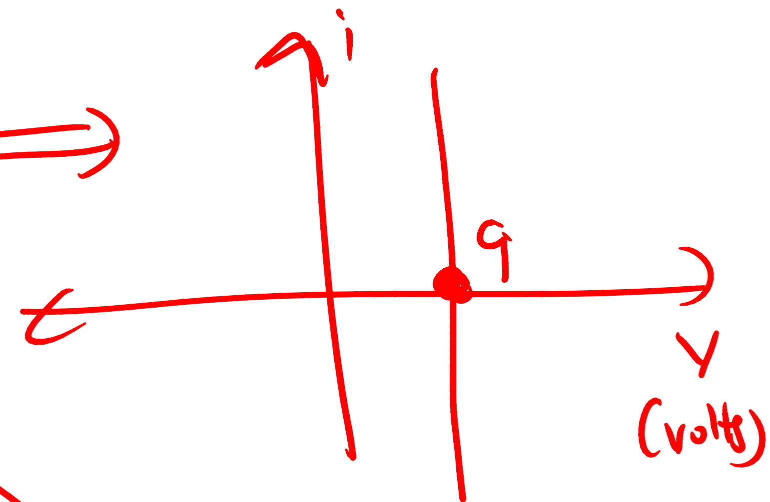


A note on sign conventions

ex:



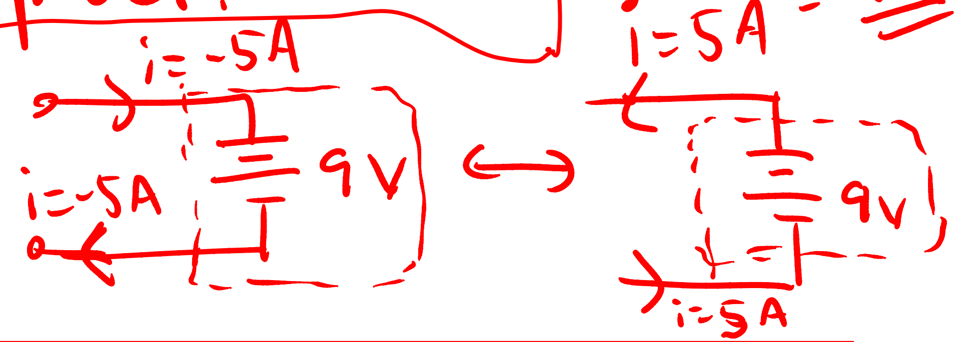
$v = 9\,V \iff$



(Q:) What if $i > 0$?

(A:) From the i-v relationship "picture", we see that the device is absorbing power.

(Q:) What if $i < 0$? $\Rightarrow$

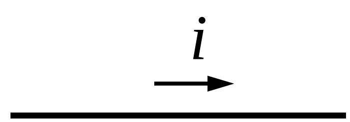


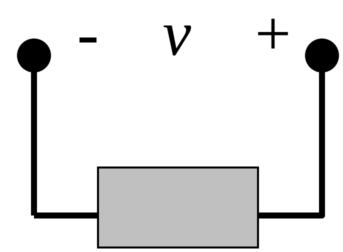
$p = -(9)(5)$

$i = 5\,A = -45\,W$

A Note about Reference Directions

- A problem like "Find the current" or "Find the voltage" is always accompanied by a definition of the direction:

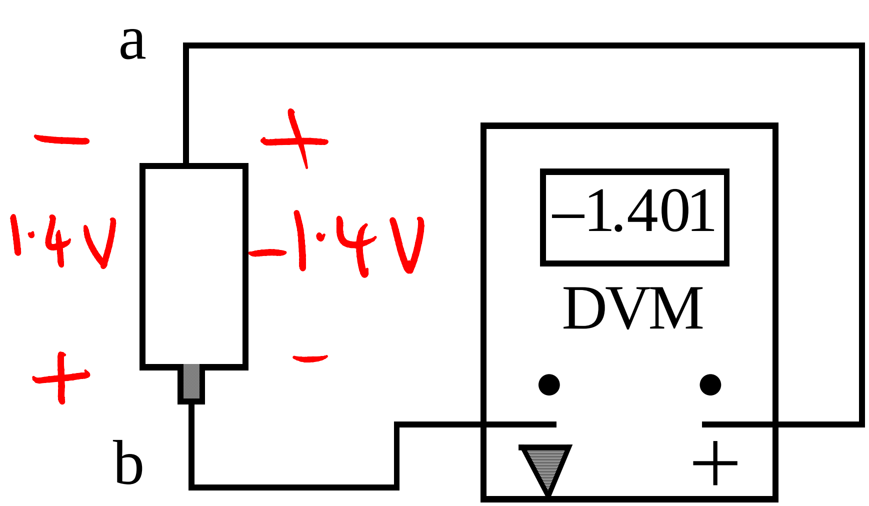




- In this case, if the current turns out to be 1 mA flowing to the left, we would say i = -1 mA.
- In order to perform circuit analysis to determine the voltages and currents in an electric circuit, you need to specify reference directions.
- There is no need to guess the reference direction so that the answers come out positive.

Sign Convention Example

Suppose you have an unlabelled battery and you measure its voltage with a digital voltmeter (DVM). It will tell you the **magnitude and sign** of the voltage.



With this circuit, you are measuring v_{ab}.

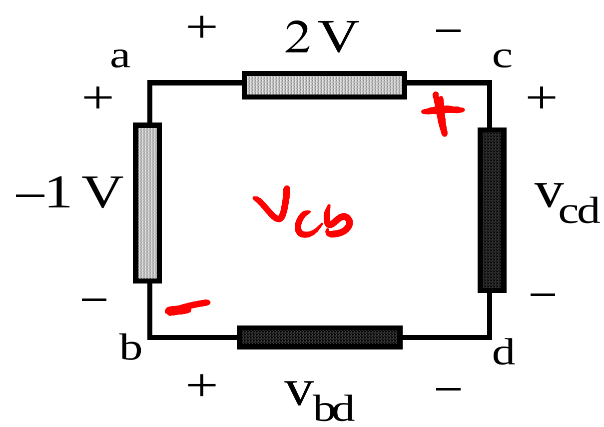
The DVM indicates –1.401, so v_a is lower than v_b by 1.401 V.

Which is the positive battery terminal?

Note that we have used the "ground" symbol (▽) for the reference node on the DVM. Often it is labeled "C" for "common."

Another Example

Find v_{ab}, v_{ca}, v_{cb}



$v_{cb} \triangleq v_c - v_b$.

$V_{ab} = -1\ V \iff V_{ba} = 1\ V$

$V_{ca} = -2\ V \iff V_{ac} = 2\ V$

$V_{cb} = -3\ V$

we actually use KVL (Kirchoff's voltage law) to find v_{cb}

Note that the labeling convention has nothing to do with whether or not v is positive or negative.