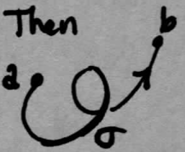
7/16/2009

Voltmeters and How To Use Them

opening remarks

In direct analogy with gravitational potential energy at the surface of the earth, we define the electrostatic potential fcn φ by $E = -\nabla\varphi$ E electrostatic field.

Then

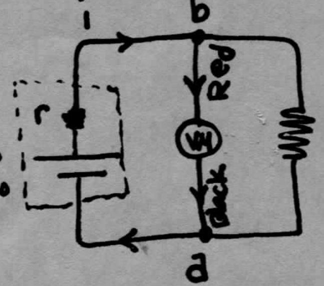


$$V_{a\to b} = \int_\sigma -E\cdot ds = \int_a^b \nabla\varphi\cdot ds = \varphi(b) - \varphi(a)$$

Voltage

work done, per unit charge, by an external agent to move charge along σ against field E.

Now put a voltmeter in a circuit:



(★)

$$\mathcal{E} - iR = 0$$

$$\mathcal{E}(i) = \mathcal{E}_0 - ir$$

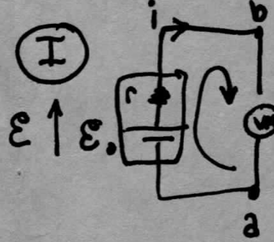
Voltage as "height above ground"

This actually defines 2 loops, so we'd better get a consistent answer no matter which one we choose!

RULES to orient VM

1. Pos charge flows In the Red lead, out the black.
2. Thus when we write $V_{a\to b} = \varphi(b) - \varphi(a)$ Path is in original circuit.
   "a" is the black lead (ground)
   "b" is the red lead
   (would have been nice to have 'b' for 'black')
3. Rule 1 defines orientation of the VM segment of a KVL mathematical loop. Thus the rest of the loop is also oriented by this (hence we may end up crossing resistors against the flow of pos charge current).

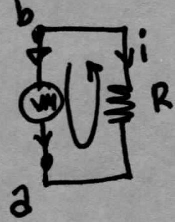
I



Here we cross the battery with the current so the VM displays $+\mathcal{E}$ reasoning from $\boxed{\text{Kirchhoff's Voltage Law (KVL)}}$

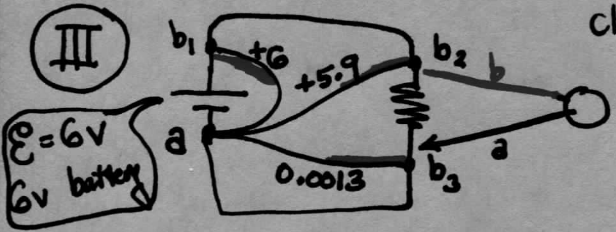
$\boxed{\text{The voltmeter actually measures a tiny current going through an accurately known resistance;}}$

II



Here we cross the resistor against the current, so voltmeter reads $+iR$ and from (★) above $+iR = \mathcal{E}$.

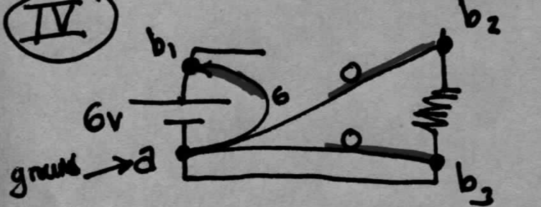
III



Closed circuit

voltage drop across resistor

IV



Open circuit

both branches are charged to battery terminals

no current flows, no drop across resistor

V