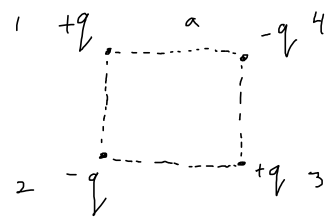
2-18-2019: Work and Ohm's Law

Monday, February 18, 2019 9:07 AM

$$E = -\frac{dV}{ds}, \quad -\frac{\Delta V}{\Delta d},$$

When calculating the energy of a system, we need to consider all of the pairs…



Required Work

$$W = ?$$

$$U_i - U_\infty = 0$$

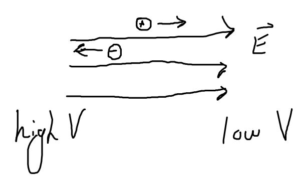
$$U_f = \sum_{\substack{\text{all} \\ \text{pairs}}} \frac{q_i q_j}{4\pi\varepsilon_0 r_{ij}}$$

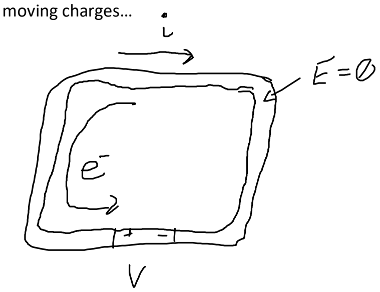
$$W = \Delta U$$
$$= U_f$$

$$= \frac{1}{4\pi\varepsilon_0}\left(\frac{(+q)(-q)}{a} + \frac{(+q)(+q)}{\sqrt{2}\,a} + \frac{(q)(-q)}{a} + \frac{(-q)(+q)}{a} + \frac{(-q)(-q)}{\sqrt{2}\,a} + \frac{(+q)(-q)}{a}\right)$$

$$= \frac{q^2}{4\pi\varepsilon_0}\left(\frac{2}{\sqrt{2}} - 2\right)$$

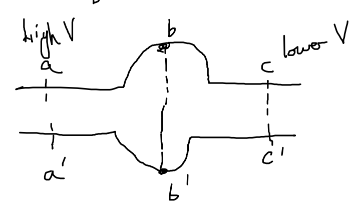
So far we have talked about fixed charges that are not moving. This field is called **electrostatics**. Now, we will talk about **electrodynamics**, the study of moving charges…





Electros move to a higher potential. But, by convention, current follows the flow of positive charge. So, the direction of the vector **i** will point from higher V to lower V.

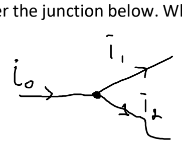
$$i\Big|_a^{a'} = i\Big|_{b'}^{b} = i\Big|_{c'}^{c}$$



$$i \equiv \frac{dq}{dt}, \quad q = \int_0^t i\,dt$$

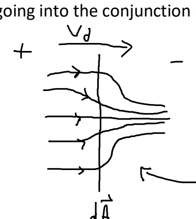
$$\text{Ampere (A)} = \frac{1\,C}{1\,S}$$

Consider the junction below. Whatever is going into the conjunction must also leave the conjunction…



$$i_0 = i_1 + i_2$$

$$i = \int \vec{j} \cdot d\vec{A}$$



STREAM-LINE (LIKE FIELD LINES)

- DENSITY' LINES/CURRENT
- DIRECTION' LINES/CURRENT

e^- SPEED >> DRIFT VELOCITY

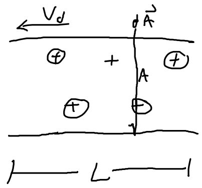
$$100^6\ m/s >> 10^{-5} \sim 10^{-4}\ m/s$$

Suppose we have a constant density…

$$i = \int \vec{j} \cdot d\vec{A} = J \int dA = JA \Rightarrow J = \frac{i}{A}$$

Let's now consider an example collection of charges. The drift velocity of the positive charges is to the left, and there is some **n**: # of charged particles per fixed unit of volume, some **L**: the length of the wire, and some **e**: charge of each particle. How can I calculate the current here?

Let's now consider an example collection of charges. The drift velocity of the positive charges is to the left, and there is some **n**: # of charged particles per fixed unit of volume, some **L**: the length of the wire, and some **e**: charge of each particle. How can I calculate the current here?



$$i = \frac{q}{t} = \frac{(n \times \cancel{L} A)\, e}{\cancel{L}/v_d} = nAev_d$$

$$i = nAev_d$$

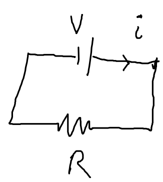
$$\vec{v}_d = \frac{i}{nAe} = \frac{\vec{J}}{ne}$$

positive e $\vec{v}_d \parallel \vec{E}$

neg e $\vec{v}_d \parallel -\vec{E}$

Let's next talk about two new things: resistivity (an intrinsic property to a material) and resistance (an extrinsic property of a resistor).

$R \equiv \frac{V}{i}$ (Ohm's law) $\frac{V}{A} = 1\Omega$ ohm



$$\rho = \frac{E}{J}$$

$$R = \frac{V}{i} = \frac{\vec{E}\cdot\vec{L}}{\vec{J}\cdot\vec{A}} = \frac{E}{J}\left(\frac{L}{A}\right)$$

$$\Rightarrow \boxed{R = \rho\left(\frac{L}{A}\right)}$$ UNIT: $(\Omega \cdot m)$

OHM-METER