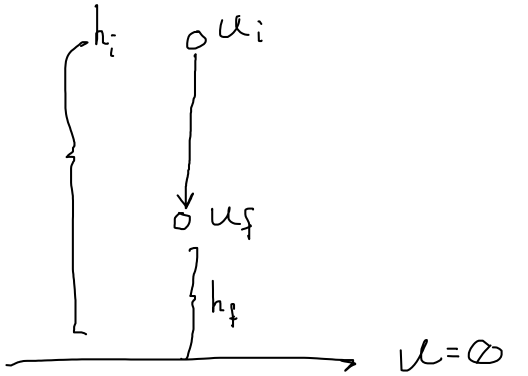
2-11-2019: Electric Potential Energy and Electric Potential

Monday, February 11, 2019 9:22 AM

We know that gravitational and electrical forces are analogous, so let's start by looking at gravitational potential energy to get a look at what electric potential energy would be…



$$\vec{F}_G = \frac{G m_1 m_2}{r^2}\hat{r}$$

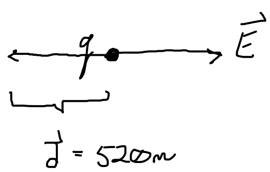
$$U = mgh$$

$$\Delta U = U_f - U_i = -W_G$$

$$mgh_f - mgh_i = -mg(h_i - h_f)$$

$$W_F = -W_G = \Delta U$$

Now let's turn to the coulombic interaction! Suppose we have an electron exposed to some electric field. Suppose it moves to the left a distance of 520m. How much work is done by the electric force?



$$E = 15\varnothing \ N/C$$

$$q_e = -1.6\times10^{-19}\ C$$

MAGNITUDES

$$W_E = \vec{F}\cdot\vec{d} = (q\vec{E})\cdot\vec{d} = qEd = (1.6\times10^{-19}\,C)(15\varnothing\ N/C)(52\varnothing m) = 1.2\times10^{-14}\ J$$

Notice that this force will actually point opposite to the field because we are talking about an electron. So actually, F is parallel to d!

$$\Delta U = -W_E = -1.2\times10^{-14}\ J$$

Remember that the force direction and the displacement direction will tell you what the work's sign will be. Also, the direction of the force will depend on both the charge and the electric field.

Because potential energy can be defined with some reference point, in electric potential energy we define the potential energy at a radius of infinity as zero.

$$U_\infty = \varnothing$$

$$\Delta U = U_p - \cancelto{\varnothing}{U_\infty} = -W_\infty \Rightarrow U_p = \boxed{-W_\infty}$$

potential energy at some point p

work done by electric force from infinity to p.

potential energy at some point p work done by electric force from infinity to p.

Let's define a new quantity: the electric potential (or sometimes just potential), which is a ratio of the potential energy divided by the charge.

$$V = \frac{U}{q} \quad \leftarrow \text{electric potential}$$

Remember that electric potential is a scalar.

$$\Delta V = \frac{\Delta U}{q} \iff \Delta V = V_f - V_i = \frac{U_f}{q} - \frac{U_i}{q}$$

$$V_p = \frac{-W_\infty}{q}$$

UNIT: $1\ J/C$, 1 VOLTAGE (VOLT) V $\quad (1\ V = 1\ J/C)$

Electric field, $\frac{N}{C} = \frac{J/m}{C} = (1\ J/C)\frac{1}{m} = 1\ \frac{V}{m}$

Alternative expression for electric field (as opposed to N/C).

Recall from our gravitational example that…

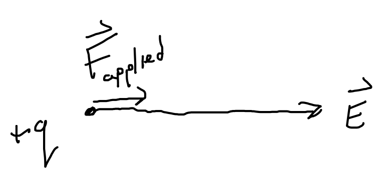
$$W_F = -W_G = \Delta U$$

This comes from saying that our kinetic energy change is zero, as such

$$\Delta K = W_F + W_G = 0$$

Similarly, with electric field we can also use this behavior to describe the work done by some applied force…

$$W_{app} = -W_E = -(-\Delta U) = \Delta U = q\,\Delta V.$$



$$W_{app} = q\,\Delta V$$

positive q $\begin{cases} W_{app} > 0 & \Delta V > 0 \\ W_{app} < 0 & \Delta V < 0 \end{cases}$