Announcements

- Homework
  - You have VHW4 due tonight
  - I'm hoping to have everything for Test 1 graded by the end of tomorrow
  - Webwork due on Wednesday, but *not* test material
- You have a test on Friday!
  - Bring your writing tools, your calculator, and your notecard
  - You'll have an hour to complete the test. I try to write to take me sub 12 minutes
  - Study materials posted!
- Polling: `rembold-class.ddns.net`

Review Question

A solid plastic ball with radius of 5 cm has an excess 20 μC spread evenly throughout its volume. What is the magnitude of the electric field at a distance of 4 cm from the ball's center?

A) $0\,\mathrm{N/C}$

B) $2.88 \times 10^{6}\,\mathrm{N/C}$

C) $5.76 \times 10^{7}\,\mathrm{N/C}$

D) $1.44 \times 10^{9}\,\mathrm{N/C}$

Solution: $5.76 \times 10^{7}\,\mathrm{N/C}$

Upcoming:

Recalling Energy

Some Energy Review

- Following the same path as in Phys 221: Forces $\rightarrow$ Energy
- Energy of a single particle:
$$E = mc^2 + K$$
where K is the kinetic energy, m the mass and c the speed of light
- For slow speeds:
$$K \approx \frac{1}{2}mv^2$$
where v is the velocity
- A single, lonesome particle does not have potential energy!

Energy and Work

- For a single particle without a change in rest mass, we then could say that

$$\Delta K_{sys} = W_{surr}$$

where W is the work done by surroundings.

- We defined work as:

$$\begin{aligned} W &= \vec{\mathbf{F}} \cdot \Delta\vec{\mathbf{r}} \\ &= F_x \Delta x + F_y \Delta y + F_z \Delta z \\ &= \left|\vec{\mathbf{F}}\right| \left|\Delta\vec{\mathbf{r}}\right| \cos\theta \end{aligned}$$

- Despite being defined in terms of vectors, work is a scalar quantity!

An Electrifying Example

Suppose an electron is traveling at $4000\,\text{m/s}$ in the positive x-direction. It enters an area where there is electric field of $\langle -500, 500, 0 \rangle\,\text{N/C}$. If the electron travels purely horizontally through this field for a distance of $10\,\text{m}$, what is it's speed afterwards?

Solution: 4.19×10^7 m/s – Probably need to adjust these numbers!

Potential Energy

- When we have two or more objects in our system we have a choice:

$$\Delta K = W_{surr} + W_{int}$$

- We define the negative change in potential energy to be equal to any work done by the internal forces in the system:

$$-\Delta U = W_{int}$$

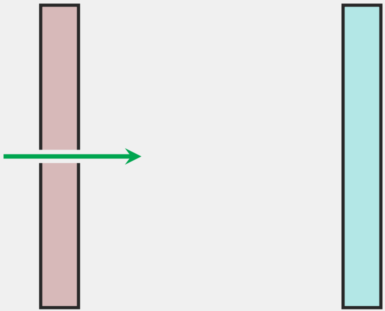
  where U is the potential energy
- If little heat transferred:

$$\Delta K_{sys} + \Delta U = W_{surr} + \cancelto{0}{Q}$$

- In most cases in electricity and magnetism:

$$\Delta K_{sys} + \Delta U = 0$$

Understanding Check



A proton enters the region between two charged plates through a tiny hole (as shown to the left). When the proton arrives at the rightmost plate, what is true about its change in potential energy from the left plate to the right?

A) $\Delta U > 0$

B) $\Delta U < 0$

C) $\Delta U = 0$

D) Impossible to tell

Solution: $\Delta U < 0$

Change in Potential Energy due to Constant E-Field

- We know that the electric field inside a capacitor is approximately constant
- Can use that to determine an expression for $\Delta U_{electric}$:

$$\begin{aligned}
\Delta U_{electric} &= -W_{int} \\
&= -\left(F_x \Delta x + F_y \Delta y + F_z \Delta z\right) \\
&= -\left(eE_x \Delta x + eE_y \Delta y + eE_z \Delta z\right) \\
&= -eE_x \Delta x
\end{aligned}$$

- Note that this depends on the amount of charge (and sign) of the test charge, which is maybe not the most convenient...

Deja Q

- Want to remove the charge dependence, just like we did with the force

$$E = \frac{F}{q}$$

- Define the potential difference:

$$\Delta V = \frac{\Delta U_{electric}}{q}$$

- Units:

$$1 \frac{\text{joule}}{\text{coulomb}} = 1 \text{ volt} = 1\,\text{V}$$

Potential Difference from Electric Field

- Keep it distinct in your mind from potential energy!
- We know that

$$
\begin{aligned}
\Delta V = \frac{\Delta U}{q} &= -\frac{W_{int}}{q} \\
&= -\frac{(F_x\Delta x + F_y\Delta y + F_z\Delta z)}{q} \\
&= -(E_x\Delta x + E_y\Delta y + E_z\Delta z) \\
&= -\vec{\mathbf{E}}\cdot\Delta\vec{\ell}
\end{aligned}
$$

where $\Delta\vec{\ell} = \langle \Delta x, \Delta y, \Delta z\rangle$.

Slippery Slopes

- Some rearranging gives us

$$E_x = -\frac{\Delta V}{\Delta x}, \quad E_y = -\frac{\Delta V}{\Delta y}, \quad E_z = -\frac{\Delta V}{\Delta z}$$

- Or, for tiny displacements:

$$E_x = -\frac{\partial V}{\partial x}, \quad E_y = -\frac{\partial V}{\partial y}, \quad E_z = -\frac{\partial V}{\partial z}$$

- So the electric field in any direction is the negative slope of the potential in that direction!
- Alternative units for electric field: V/m

Finding ΔV

Suppose we have an electric field with a magnitude of $100\,\mathrm{N/C}$ pointing 40° above the positive x axis. What would be the change in potential moving from $\vec{\mathbf{r}}_i = \langle 1, 0, 0\rangle$ to $\vec{\mathbf{r}}_f = \langle 4, -2, 0\rangle$?

Solution: $-101.256\,\mathrm{V}$