Physics 2113

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Physics 2102
Lecture 12: WED 22 SEP

Electric Potential I

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Danger!
<table>
<thead>
<tr>
<th>Volume [m$^3$]</th>
<th>Area [m$^2$]</th>
<th>Circumference [m]</th>
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<td>$\frac{4\pi}{3} R^3$</td>
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**Sphere**

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<th>Volume [m$^3$]</th>
<th>Area [m$^2$]</th>
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<tr>
<td>$\pi R^2 L$</td>
<td>$2\pi RL$</td>
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<td>$\frac{d}{dR}$</td>
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**Circle**

<table>
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<th>Volume [m$^3$]</th>
<th>Area [m$^2$]</th>
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<td>$L \times L$</td>
<td>$L \times L$</td>
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<td>$\frac{d}{dR}$</td>
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Electric Potential Energy

Electric Potential Energy $U$ is **negative** of the Work $W$ to bring charges in from infinity:

$$U = -W_{\infty}$$

The change in potential energy $\Delta U$ between an initial and final configuration is negative the work $W$ done by the electrostatic forces:

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

- What is the potential energy of a single charge?
- What is the potential energy of a dipole?
- A proton moves from point $i$ to point $f$ in a uniform electric field, as shown.
  - Does the electric field do positive or negative work on the proton?
  - Does the electric potential energy of the proton increase or decrease?
Electric potential difference between two points = \text{work per unit charge needed to move a charge between the two points:}

$$\Delta V = V_f - V_i = -\frac{W}{q} = \frac{\Delta U}{q}$$

\[dW = \vec{F} \cdot d\vec{s}\]

\[dW = q_0 \vec{E} \cdot d\vec{s}\]

\[W = \int_{i}^{f} dW = \int_{i}^{f} q_0 \vec{E} \cdot d\vec{s}\]

\[\Delta V = V_f - V_i = -\frac{W}{q_0} = -\int_{i}^{f} \vec{E} \cdot d\vec{s}\]
Electric Potential Energy, Electric Potential

**Units**

Potential Energy = $U = [J] = $ Joules

Electric Potential = $V = U/q = [J/C] = [Nm/C] = [V] = Volts

Electric Field = $E = [N/C] = [V/m] =$ Volts per meter

Electron Volt = $1eV = Work Needed to Move an Electron$ Through a Potential Difference of 1V:

$W = q\Delta V = e \times 1V = 1.60 \times 10^{-19} \text{ C} \times 1\text{J/C} = 1.60 \times 10^{-19} \text{ J}$
Electric Potential and Electric Potential Energy

The change in potential energy of a charge $q$ moving from point $i$ to point $f$ is equal to the work done by the applied force, which is equal to minus the work done by the electric field, which is related to the difference in electric potential:

$$\Delta U = U_f - U_i = W_{\text{app}} = -W = q\Delta V$$

We move a proton from point $i$ to point $f$ in a uniform electric field, as shown.

- Does the electric field do positive or negative work on the proton?
- Does the electric potential energy of the proton increase or decrease?
- Does our force do positive or negative work?
- Does the proton move to a higher or lower potential?
Positive Work

$+Q \quad a \quad +Q$

Negative Work

$+Q \quad a \quad -Q$
Positive Work

Charge Moves Uphill

Negative Work

Charge Moves Downhill
CHECKPOINT 1

In the figure, a proton moves from point $i$ to point $f$ in a uniform electric field directed as shown. (a) Does the electric field do positive or negative work on the proton? (b) Does the electric potential energy of the proton increase or decrease?

(a) E-field does:  
+ work?  
− work? ✔

(b) Potential Energy:  
increase? ✔  
decrease?

(c) Proton Does:  
+ work? ✔  
− work?

$+V_{\text{high}} = ++++++++$

$-V_{\text{low}} = ------------$
ICPP:
Consider a positive and a negative charge, freely moving in a uniform electric field. True or false?
(a) Positive charge moves to points with lower potential.
(b) Negative charge moves to points with lower potential.
(c) Positive charge moves to a lower potential energy.
(d) Negative charge moves to a lower potential energy.

(a) True
(b) False
(c) True
(d) True
CHECKPOINT 2
In the figure of Checkpoint 1, we move the proton from point $i$ to point $f$ in a uniform electric field directed as shown. (a) Does our force do positive or negative work? (b) Does the proton move to a point of higher or lower potential?

(a) Force Does:  $+\text{ work?}$ ✓  $-\text{ work?}$

(b) Proton Moves to:  Higher Potential? ✓  Lower Potential?

(c) Proton Moves to:  Higher Potential Energy? ✓  Lower Potential Energy?

What if this was an electron???
In the figure of Checkpoint 1, we move the electron from point $i$ to point $f$ in a uniform electric field directed as shown. (a) Does our force do positive or negative work? (b) Does the proton move to a point of higher or lower potential?

(a) Force Does: + work? ✔

(b) Electron Moves to: Higher Potential? ✔

(c) Electron Moves to: Higher Potential Energy? ✔

- $V_{\text{low}} = \ldots$

+ $V_{\text{high}} =$
Summary:

- **Electric potential**: work needed to bring +1C from infinity; units $V = \text{Volt}$

- Electric potential uniquely defined for every point in space -- independent of path!

- Electric potential is a **scalar** — add contributions from individual point charges

- We calculated the electric potential produced by a single charge: $V = kq/r$, and by continuous charge distributions: $dV = kdq/r$

- **Electric potential energy**: work used to build the system, charge by charge. Use $W = qV$ for each charge.
"It's unified and it's a theory, but it's not the unified theory we've all been looking for."
Midterm Exam #1

- Dowling Section No. 2: AVG = 73; STDV=12
- Pullin Section No. 3: Avg. = 70
- **A:** 90-100%
- **B:** 75-89%
- **C:** 60-74%
- **D:** 50-59%
- **F:** 49-0%