Physics 6C
Introduction to Physics III
Electricity and Magnetism

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Electric Potential Energy

- Because the force is conservative, we usually don’t have to do the nasty line integral.
- Instead, we define a potential energy $U$ at each point in space and just subtract to find the work.

$$W_{\vec{a}\rightarrow\vec{b}} = U(\vec{a}) - U(\vec{b}) = -(U(\vec{b}) - U(\vec{a})) \equiv -\Delta U$$

$U(a)$ = the potential energy of our test charge $q$ at the point $a$.

$$\Delta U = -W_{\vec{a}\rightarrow\vec{b}} = -q\int_{\vec{a}}^{\vec{b}} \vec{E} \cdot d\vec{l}$$
**PE: Gravity vs. Electricity**

Simplest examples: uniform field

The location where we call $U=0$ is arbitrary!
These equations assume that the potential energy is zero when the two objects are infinitely far apart ($r \rightarrow \infty$).
Change of Electric Potential Energy

Will $\Delta U$ be positive, negative, or zero when a charge $+q$ moves from $a$ to $b$?
Change of Electric Potential Energy

Will $\Delta U$ be positive, negative, or zero when a charge $+q$ moves from $a$ to $b$?
Change of Electric Potential Energy

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PE of a Dipole in a Uniform E Field

\[ U_{\text{dipole}} = -pE \cos \phi = -\vec{p} \cdot \vec{E} \quad \text{ } \quad p \equiv qd \]

Minimum PE
\[
\begin{align*}
E & \quad \phi=0 \\
- & \quad +
\end{align*}
\]

\[ U=0 \]

Maximum PE
\[
\begin{align*}
E & \quad \phi=180^\circ \\
+ & \quad -
\end{align*}
\]

Note: this does not include the constant PE stored in the dipole itself:
\[ -K \frac{q^2}{d} \]
Electric Potential

Electric field = force on test charge per unit charge:
\[ \vec{E}(\vec{r}) = \vec{F}(\vec{r}) / q = k \frac{Q}{r^2} \hat{r} \]
Vector! Includes direction.

Electric potential = potential energy of test charge per unit charge:
\[ V(\vec{r}) = U(\vec{r}) / q = k \frac{Q}{r} \]
Scalar! No direction.

(units: J/C=volt)