PHY132H1F Introduction to Physics II
Class 12 : Half-way through the semester!

– **Today:**
- Electric Potential of Many Charges
- Finding Electric Field from the Potential
- Batteries, EMF

| CRAZY PHENOMENON | IF IT WORKED, COMPANIES WOULD BE USING IT TO MAKE A KILLING IN... | ARE THEY? |
|---|---|---|
| REMOTE VIEWING | OIL PROSPECTING | |
| DOWSING | | |
| AURAS | HEALTH CARE COST REDUCTION | |
| HOMEOPATHY | | |
| REMOTE PRAYER | | |
| ASTROLOGY | FINANCIAL/BUSINESS PLANNING | |
| TAROT | | |
| CRYSTAL ENERGY | REGULAR ENERGY | |
| CURSES, HEXES | THE MILITARY | |
| RELATIVITY | GPS DEVICES | ✓ |
| QUANTUM ELECTRODYNAMICS | SEMICONDUCTOR CIRCUIT DESIGN | ✓ |

EVENTUALLY, ARGUING THAT THESE THINGS WORK MEANS ARGUING THAT MODERN CAPITALISM ISN'T *THAT* RUTHLESSLY PROFIT-FOCUSED.

## Quick Ch. 26,27,29,30 reading quiz.. [1/4]

The magnitude of the force, in Newtons, on a point charge that is near another point charge is:

A. $K\frac{q}{r}$ C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$ D. $K\frac{q_1 q_2}{r^2}$

$K = \frac{1}{4\pi\varepsilon_0}$

## Quick Ch. 26,27,29,30 reading quiz.. [2/4]

The magnitude of the Electric Field, in Newtons per Coulomb, near a point charge is:

A. $K\frac{q}{r}$ C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$ D. $K\frac{q_1 q_2}{r^2}$

$K = \frac{1}{4\pi\varepsilon_0}$

## Quick Ch. 26,27,29,30 reading quiz.. [3/4]

The electric potential energy, in Joules, of two point charges is:

A. $K\frac{q}{r}$ C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$ D. $K\frac{q_1 q_2}{r^2}$

$K = \frac{1}{4\pi\varepsilon_0}$

## Quick Ch. 26,27,29,30 reading quiz.. [4/4]

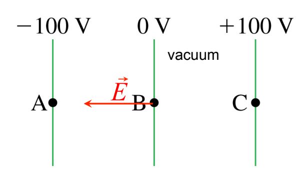
The electric potential, in Volts, near a point charge is:

A. $K\frac{q}{r}$ C. $K\frac{q_1 q_2}{r}$

B. $K\frac{q}{r^2}$ D. $K\frac{q_1 q_2}{r^2}$

$K = \frac{1}{4\pi\varepsilon_0}$

**Last week: A proton is released from rest at point B, where the potential is 0 V. Afterward, the proton**




Zero-point of electric potential is arbitrary. – only potential *difference* matters.

A. moves toward A with a steady speed.
B. moves toward A with an increasing speed.
C. moves toward C with a steady speed.
D. moves toward C with an increasing speed.
E. remains at rest at B.

**Fundamental Principle in Physics:** If a system, when perturbed, can reduce its potential energy, it will tend to do this.

## The Potential Energy of a Dipole

The potential energy of an electric dipole $p$ in a uniform electric field $E$ is

$$U_{\text{dipole}} = -pE\cos\phi = -\vec{p}\cdot E$$

The potential energy is minimum at $\Phi = 0°$ where the dipole is aligned with the electric field.

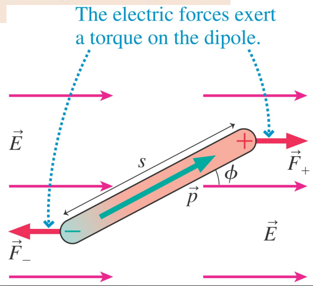
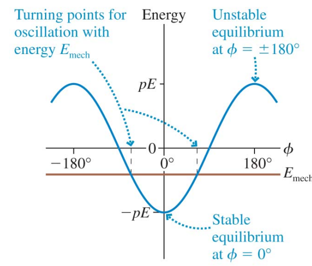



FIGURE 29.16 The energy of a dipole in an electric field.




## EXAMPLE 29.5 Rotating a molecule

**QUESTION:**

**EXAMPLE 29.5 Rotating a molecule**
The water molecule is a permanent electric dipole with dipole moment $6.2 \times 10^{-30}$ Cm. A water molecule is aligned in an electric field with field strength $1.0 \times 10^{7}$ N/C. How much energy is needed to rotate the molecule 90°?

## Review of electric potential..

- For the space surrounding a point charge, $q$, the electric potential due to this charge is:

$$V = \frac{Kq}{r}$$

- where $V$ is electric potential [V], $K = 8.99\times10^{9}$ Nm$^2$/C$^2$, $q$ is the charge [C] (including +/- sign), and $r$ is the distance from $q$ (always positive).
- Potential has an arbitrary zero point. We could have just as correctly written:

$$V = \frac{Kq}{r} + V_0$$

- where $V_0$ is some constant.
- By convention, we choose $V$=0 when $r\to\infty$. So $V_0 = 0$ in the first equation.

## Review of electric potential..

- For the space surrounding a point charge, $q$, the electric potential due to this charge is:

$$V = \frac{Kq}{r}$$

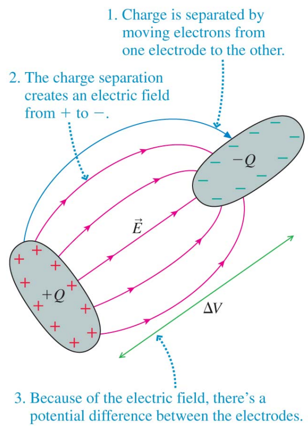
- where $V$ is electric potential [V], $K = 8.99\times10^{9}$ Nm$^2$/C$^2$, $q$ is the charge [C] (including +/- sign), and $r$ is the distance from $q$ (always positive).
- When two or more charges are present, the total potential is the sum of the potentials of the individual charges.
- A positive test charge tends to accelerate from high $V$ to low $V$. It gains kinetic energy as it does this, and we say that this energy comes from the electric potential.

In Class Discussion Question

### The electric field

A. is always perpendicular to an equipotential surface.
B. is always tangent to an equipotential surface.
C. always bisects an equipotential surface.
D. makes an angle to an equipotential surface that depends on the amount of charge.

A charge separation creates a potential difference.




## Finding the Electric Field from the Potential

In terms of the potential, the component of the electric field in the $s$-direction is

$$E_s = -\frac{dV}{ds}$$

What if we want to find the electric potential from the Electric field?
… the opposite function of differentiation is integration.

## Finding the Potential from the Electric Field

The potential difference between two points in space is

$$\Delta V = V_f - V_i = -\int_{s_i}^{s_f} E_s\, ds = -\int_{i}^{f} \vec{E} \cdot d\vec{s}$$

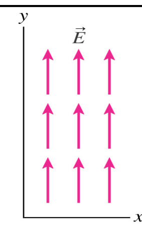
where $s$ is the position along a line from point i to point f. That is, we can find the potential difference between two points if we know the electric field.

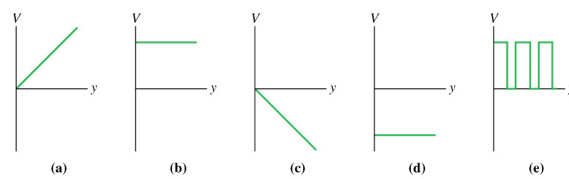
We can think of an integral as an area under a curve. Thus a graphical interpretation of the equation above is

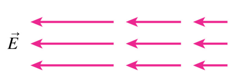
$V_f = V_i -$ (area under the $E_s$-versus-$s$ curve between $s_i$ and $s_f$)

In class discussion question.

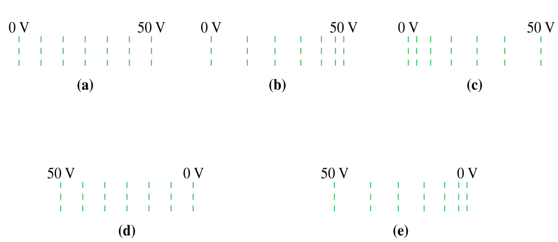
**Which potential-energy graph describes this electric field?**




**Which set of equipotential surfaces matches this electric field?**




## Batteries and emf

The potential difference between the terminals of an ideal battery is

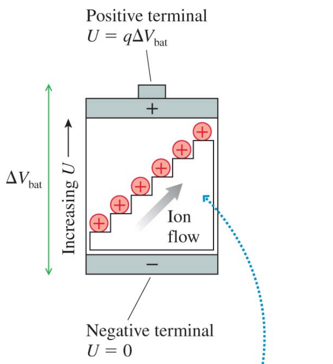
$$\Delta V_{bat} = \frac{W_{chem}}{q} = \mathcal{E} \qquad \text{(ideal battery)}$$

In other words, a battery constructed to have an emf of 1.5V creates a 1.5 V potential difference between its positive and negative terminals.

The total potential difference of batteries in series is the sum of their individual terminal voltages:

$$\Delta V_{series} = \Delta V_1 + \Delta V_2 + \cdots \qquad \text{(batteries in series)}$$

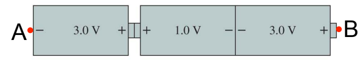
Knight's "charge escalator model". It is just a cartoon! Nothing get's "lifted" in real life!




The charge escalator "lifts" charge from the negative side to the positive side. Charge $q$ gains energy $\Delta U = q\Delta V_{bat}$.

In class discussion question

**What total potential difference ($V_B - V_A$) is created by these three batteries?**




A. 1.0 V
B. 2.0 V
C. 5.0 V
D. 6.0 V
E. 7.0 V

## Before Next Class:

- Please finish reading Chapter 30 on "Potential and Field" before Wednesday's class. We will be talking about capacitors.

- MasteringPhysics Problem Set 5, due Wednesday evening, only has 3 problems, but they aren't easy. They test your understanding of Chapter 29.

*See you Wednesday!*