Mon: HW by 5pm

Ex 47, 48, 49, 51, 53, 54, 55, 57

Thurs: Seminar

Fri: SPS

Tues: Lecture

## ~~The~~ Electrostatic potential

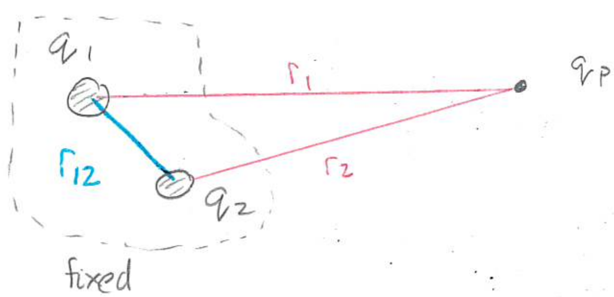
We have seen that, for point charges there exists an electrostatic potential energy $U_{elec}$ and if there are no other forces the total energy

$E_{mech} = K + U_{elec}$ is conserved.

| Thus, only electrostatic forces $\Rightarrow$ $\Delta K + \Delta U_{elec} = 0$ |
|---|

There is an explicit formula that describes the electrostatic potential energy. Consider a point probe charge with charge $q$ in the presence of fixed source charges $q_1, q_2, \ldots$ Then the electric potential energy of this arrangement is

$$U_{elec} = \underbrace{k\frac{q_1 q_2}{r_{12}}} + k\frac{q_p q_1}{r_1} + k\frac{q_p q_2}{r_2} + \cdots$$




The first term represents the energy internal to the source charge arrangement and in electrostatics this will stay constant. So it does not enter into energy conservation. The other terms represent the energy of the potentially mobile probe charge. These will change as the probe moves.

Quiz 1 40% - 70%

We can see that for the illustrated situation,

$$U_{elec} = \begin{matrix}\text{Internal, constant} \\ U_{elec} \text{ from} \\ \text{sources only}\end{matrix} + \overset{\text{probe}}{q_p} \times \underbrace{\left[ k\frac{q_1}{r_1} + k\frac{q_2}{r_2} + \dots \right]}_{\text{only depends on sources.}}$$

Since the internal part remains constant we get

$$\Delta U_{elec} = \underset{\text{probe}}{q} \times \underbrace{\text{term depending on sources}}_{\text{sources}}$$

This is similar in structure to the force law $\vec{F}_{elec} = \underset{\text{probe}}{q} \times \underset{\text{sources}}{\vec{E}}$. Thus general proportionality with respect to the probe charge motivates the definition of a new scalar quantity, the electric potential.

Electric potential

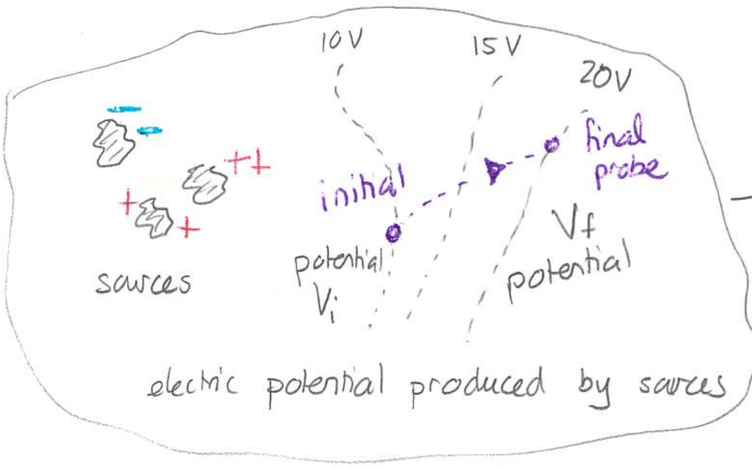
The electric / electrostatic potential is defined so that:

> The electric potential energy $U_{elec}$ of a probe in the presence of fixed sources is
>
> $$U_{elec} = q_p V$$
>
> where $q_p$ is the charge of the probe and $V$ is the electric potential produced by the sources at the probe location.

Notes:

1) V is a scalar quantity
2) V has units of Volts $V = J/C$
3) the electric potential only depends on the arrangement of the sources
4) the electric potential can vary from one location to another.

Now consider a probe that moves in the presence of fixed sources. This can be viewed as:




→ At each location probe "sees" electric potential. The change in electric potential energy is

$$\Delta U_{elec} = q_p \Delta V$$

where $q_p$ = charge probe

$$\Delta V = V_f - V_i$$

($V_f$: potential final probe location; $V_i$: potential initial probe location)

← From initial to final location

$$\Delta K + q \Delta V = 0$$

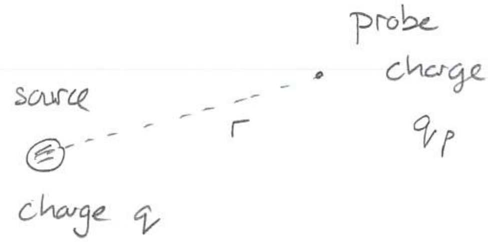
Warm Up 1

Quiz 2 30% - 90%

Quiz 3

# Electric potential produced by a point source/s

Consider a probe charge in the presence of a source charge $q$. Then




$$U_{elec} = k\frac{q_p q}{r}$$

$$= q_p \underbrace{\left(k\frac{q}{r}\right)}_{V}$$

$V$ produced by source.

Thus we get

> The electric potential produce by a point source is
>
> $$V = k\frac{q}{r} \Rightarrow V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$
>
> where $r$ is the distance from the source to the probe's potential location
>
> 
> 

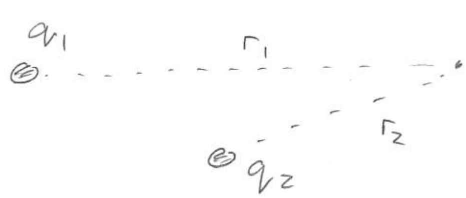
In this way the source sets up a "landscape" of electric potential values, one at each location

Demo: Khutoryansky video 0:27, 0:59 1:50

Demo: ophysics – manipulate charges into same location

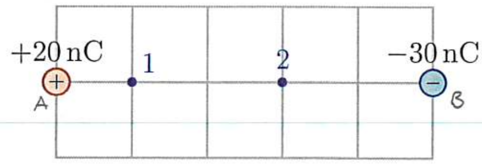
When there are multiple sources the potential is the scalar sum of the individual potentials

$$V = k\frac{q_1}{r_1} + k\frac{q_2}{r_2} + \ldots$$



**58 Electric potential difference produced by two point charges**

Two point charges are held at rest as illustrated. The grid units are 0.10 m. *(132S22 Class)*




a) Determine the electric potential at point 1 and also at point 2.

b) A $3.0 \times 10^{-4}$ kg probe charge with charge 800 nC is held at rest at point 1. Determine it's speed when it reaches point 2.

Answer: a) At either $V = k\frac{q_A}{r_A} + k\frac{q_B}{r_B} = k\left(\frac{q_A}{r_A} + \frac{q_B}{r_B}\right)$

At 1 $r_A = 0.10\,m$, $r_B = 0.40\,m$

$$V_1 = 9\times10^9\,\frac{Nm^2}{C^2}\left(\frac{20\times10^{-9}C}{0.10\,m} - \frac{30\times10^{-9}}{0.40\,m}\right)$$

$$V_1 = 1125\,V$$

At 2 $r_A = 0.30\,m$, $r_B = 0.20\,m$

$$V_2 = 9\times10^9\,\frac{Nm^2}{C^2}\left(\frac{20\times10^{-9}C}{0.30\,m} - \frac{30\times10^{-9}C}{0.20\,m}\right)$$

$$V_2 = -750\,V$$

b) $\Delta K + q\Delta V = 0 \Rightarrow \Delta K = -q\Delta V$

$$\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = -q(V_2 - V_1) \quad (v_1 = 0)$$

$$v_2^2 = -\frac{2q}{m}(V_2 - V_1) = -\frac{2\times800\times10^{-9}C}{3.0\times10^{-4}kg}\left[-750\,V - 1125\,V\right]$$

$$= 10\,m^2/s^2$$

$$v_2 = \sqrt{10\,m^2/s^2} \Rightarrow v_2 = 3.2\,m/s$$