Phys 132 2022

Lecture 10

Mon: HW by 5pm

Tues:

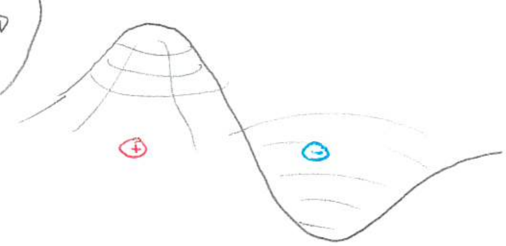
Weds: Discussion/quiz

Electric potential and electric potential energy

In electrostatics the scheme for energy is:

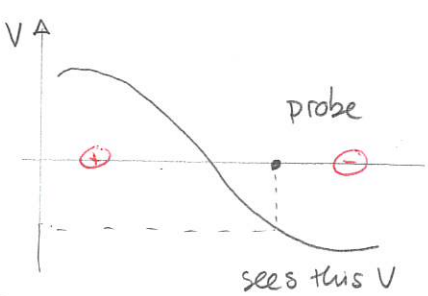
Fixed sources produce electric potential
≡ one number at each location

Electric potential, V (in Volts)



gives an energy "landscape"

Another "probe" charge is placed in the vicinity of the sources. It "feels the energy landscape"



The electric potential energy of the probe is

$$U_{elec} = q_{probe} V$$ at probe location.

Subsequent motion of probe satisfies energy conservation

$$\Delta K + \Delta U_{elec} = 0 \quad \text{or} \quad \Delta K + q\Delta V = 0$$

Then for any collection of point sources the electric potential is

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

Warm Up 1

Demo: Show oPhysics page

Now we can use $\Delta K + q\Delta V = 0$

$$\Rightarrow \Delta K = -q\Delta V$$

to understand aspects of probe charge motion under a potential

Quiz 1 50% - 100%

So we have

Probe charge	Electric potential	Charge motion
+	increases	slows down
+	decreases	speeds up
−	increases	speeds up
−	decreases	slows down

Quiz 2 80%

Equipotentials

A plot of electric potential would require four axes – three for the spatial dimensions and one for the potential. This is not feasible to draw. Even a plot of potential in a two dimensional surface would require difficult three dimensional images.

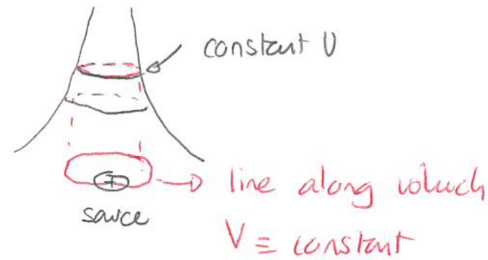
Other possibilities include:

- "heat maps"
- "equipotentials"

Demo: PhET Charges + Fields

- single source → display voltage
- two sources → " "
- multiple " → " "

We could envisage the potential landscape by drawing contours along which the potential is constant. This results in the concept



An equipotential is a line (of locations) along which all values of the electric potential are the same

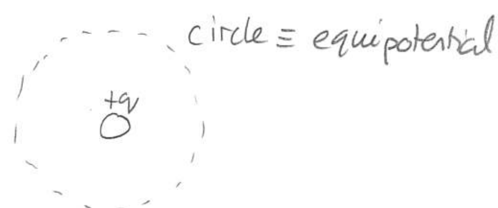
Demo: Show use PhET Charges + Fields

Demo: Show oPhysics Equipotentials of two charges.
- show equipotential view

We can chart the equipotentials for a single point source. Here

$$V = k\frac{q}{r} = \text{constant}$$

$$\Rightarrow \quad \frac{kq}{\text{constant}} = r \quad \Rightarrow \quad r = \text{constant}$$



These are circles.

Quiz 3 50%

Quiz 4

Electric potential from electric field

In general we have that the work done by a force on an object is

$$W = \int_{\text{initial}}^{\text{final}} \vec{F} \cdot d\vec{r}$$

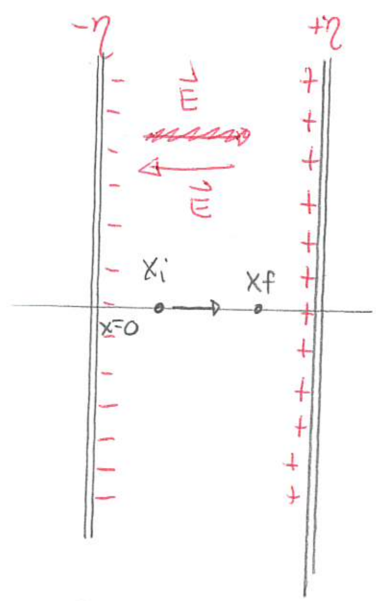
Now if the force is electrostatic then $\vec{F} = q_{probe} \vec{E}$ and $W = -\Delta U_{elec}$. So

$$-\Delta U_{elec} = q_{probe} \int_{\text{initial}}^{\text{final}} \vec{E} \cdot d\vec{r} \quad \Rightarrow \quad \Delta U_{elec} = q \, \Delta V$$

where

$$\Delta V = -\int_{\text{initial}}^{\text{final}} \vec{E} \cdot d\vec{r}$$

We apply this to the region between a parallel plate capacitor. Previous results give



$$\vec{E} = -\frac{\eta}{\epsilon_0} \hat{\imath}$$

for the illustrated configuration. Consider a trajectory as illustrated. Then

$$d\vec{r} = dx \, \hat{\imath}$$

and $\vec{E} \cdot d\vec{r} = -\frac{\eta}{\epsilon_0} dx$

So

$$\Delta V = + \int_{x_i}^{x_f} \frac{\eta}{\epsilon_0} dx \quad \Rightarrow \quad \Delta V = + \frac{\eta}{\epsilon_0} \Delta x$$

This gives the electric potential difference between any two locations. We can fix this via:

1) set $V = V_0$ at $x=0$

2) follow path from 0 to x $\Rightarrow$ $\Delta x = 0$. Thus

$$V(x) - V_0 = \frac{\eta}{\epsilon_0} x \quad \Rightarrow \quad V = V_0 + \frac{\eta}{\epsilon_0} x$$

3) for convenience set $V_0 = 0$. Then

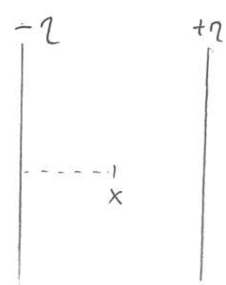
$$V = \frac{\eta}{\epsilon_0} x$$

So we arrive at.

If $V = 0$ at left (negative) plate then

$$V = \frac{\eta}{\epsilon_0} x$$

between.



A plot gives a straight line between the plates.