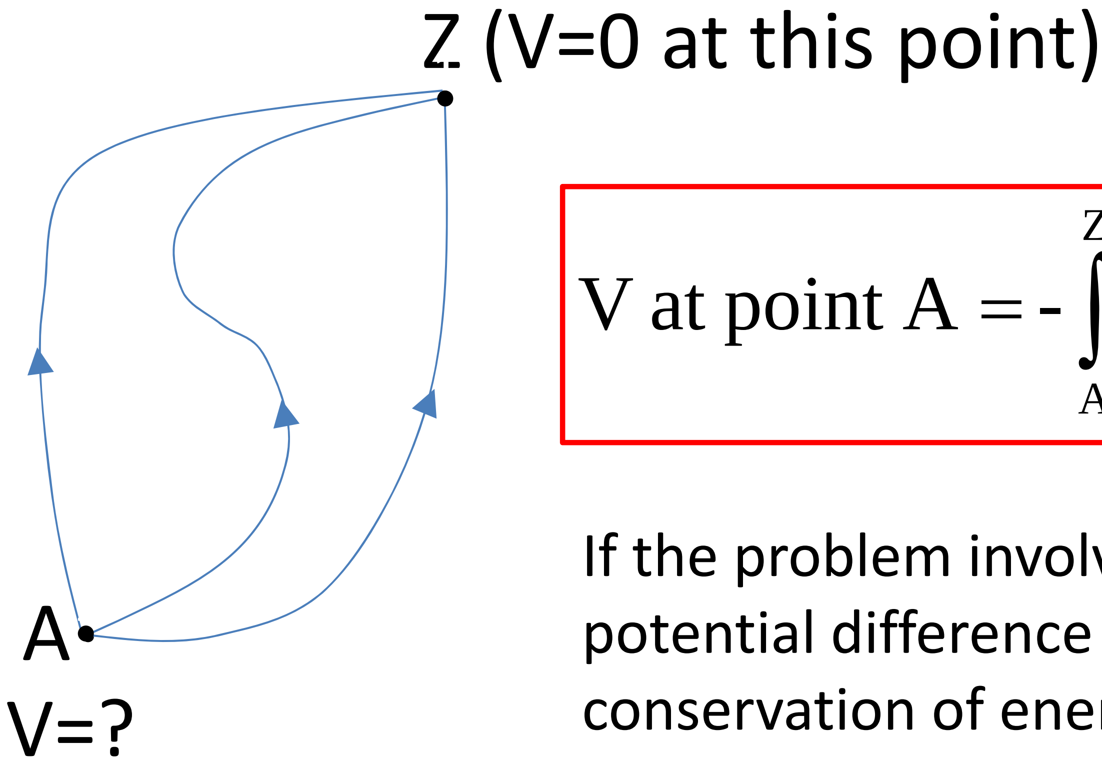
Class 11: More Electric potential

Potential Difference and Potential

If we can define a point Z in space as a point with zero potential, then the potential of all other points in space is defined.

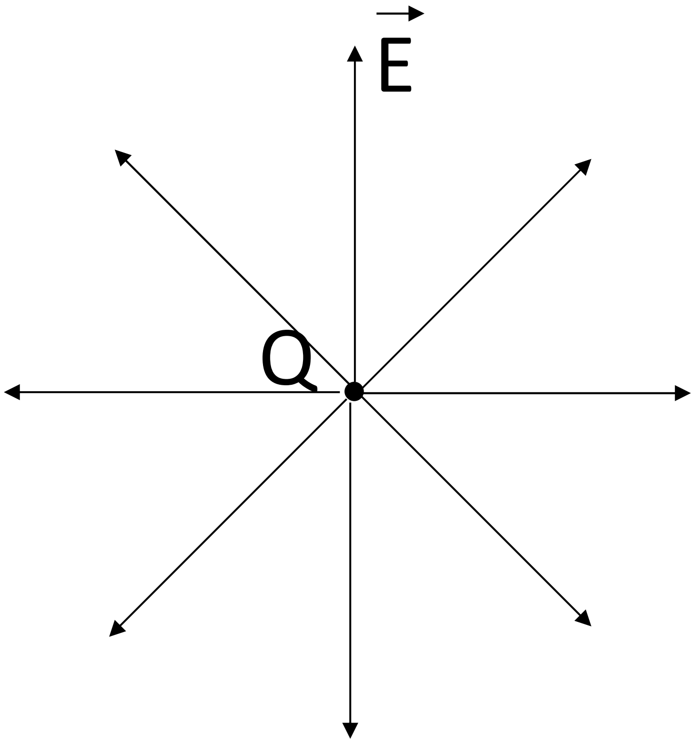


$$\text{V at point A} = -\int_{A}^{Z} \vec{E}(\vec{r}) \cdot d\vec{r}$$

If the problem involves only potential difference (e.g. conservation of energy), the choice of this zero point is not important.

Potential of a Point Charge

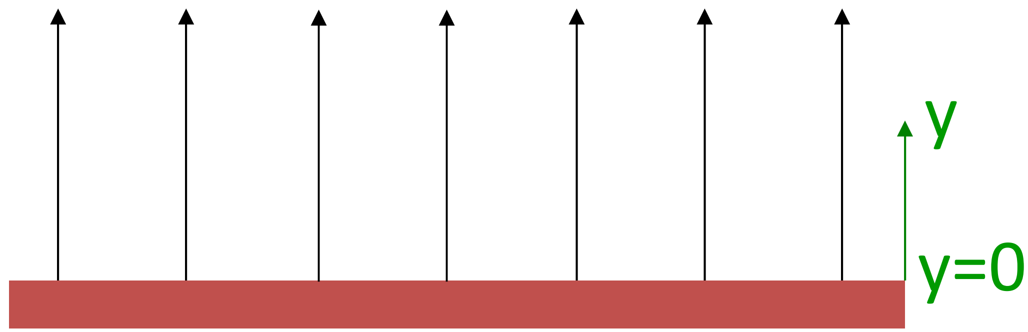
This is important because from this we can calculate the potential of any source charge assembly.



$$V = \frac{Q}{4\pi\varepsilon_0\, r}$$

V=0 at r=∞

Potential of a Constant Field



$$V = -Ey = -\frac{\sigma}{2\varepsilon_0}y$$

V=0 at the sheet of source charges (y=0)

General Observations

1. Electric field tends to point from a high potential point to a low potential point.

2. If you release a test charge particle from rest and let it go along the field line for a short time, the particle will go from a high potential point to a low potential point if it is positive in charge. In reverse, it will go from a low potential point to a high potential point if it is negative in charge.

Calculating Electric Field from Electric Potential

Given an electric field, we can calculate the corresponding potential

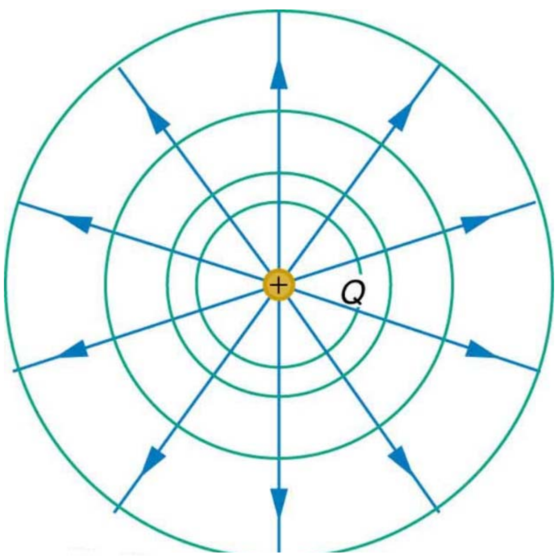
$$\text{V at point A} = -\int_{A}^{Z} \vec{E}(\vec{r}) \cdot d\vec{r}$$

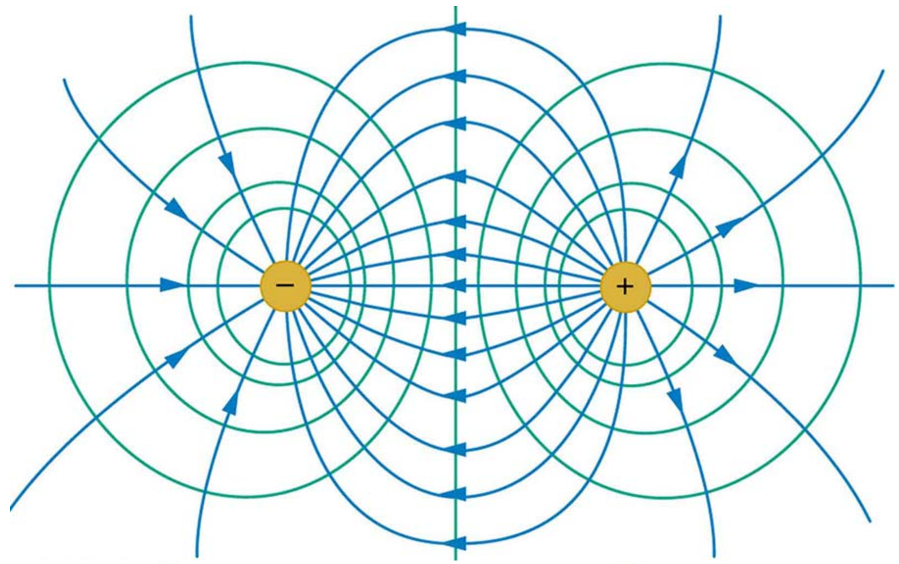
In reverse, given an electric potential, we can calculate the corresponding field:

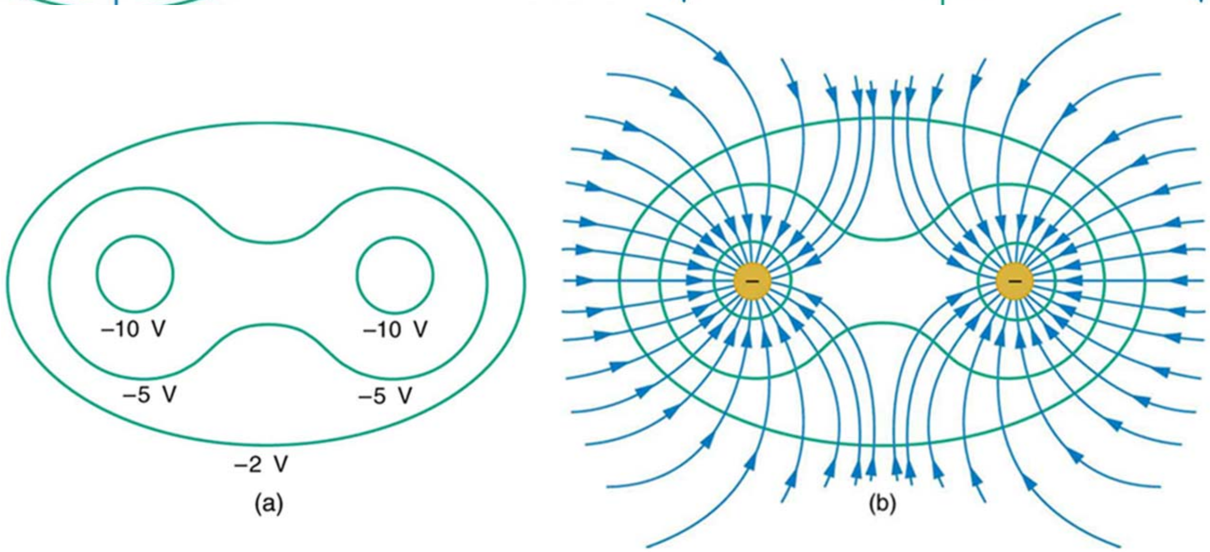
$$\vec{E} = -\nabla V = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$$

Equipotential Lines (Surfaces)

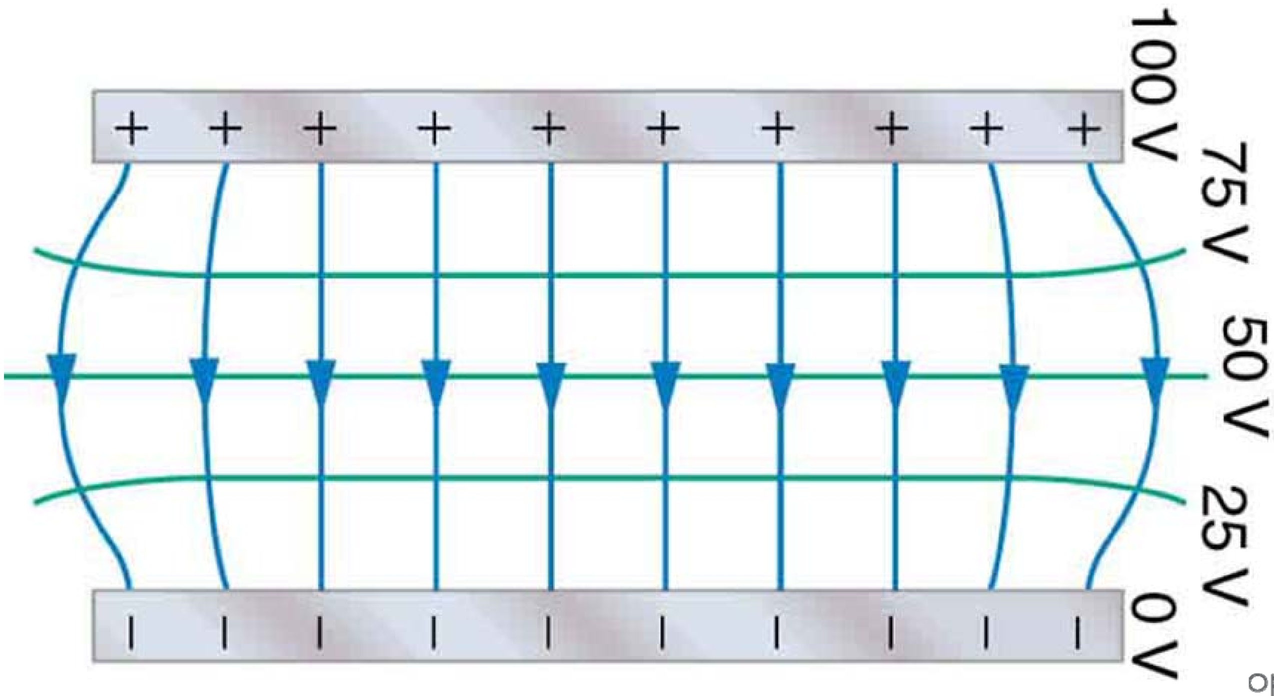
Equipotential lines (surfaces) are lines (surfaces) on which the electric potential is a constant.







Equipotential Lines (Surfaces) II



Properties of equipotential lines (surfaces):

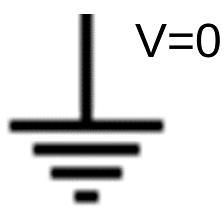
1. No work is required to move a test charge along an equipotential.
2. The electric field always perpendicular to the equipotential.
3. A conductor is an equipotential in static situations.

Zero Potential

One has the freedom to choose an equipotential and define its potential as 0V. The potential of all other equipotentials are determined after this.

For most practical purposes, the Earth is defined to have zero potential.

A conductor can be fixed at zero volts by connecting it to the earth with a good conductor—a process called grounding.



Two ways to solve electrostatic problems

$$E \Leftrightarrow V$$

1. Calculate E first (Coulomb's Law or Gauss's Law), then V:

$$\Delta V = \frac{\Delta U}{q} = -\int_i^f \vec{E}(\vec{r}) \cdot d\vec{r}$$

(this is more difficult unless you can use Gauss's Law)

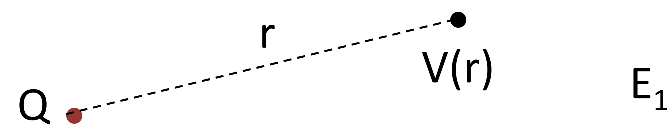
2. Calculate V first, then E:

$$\vec{E} = -\nabla V = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$$

Calculation of electric potential

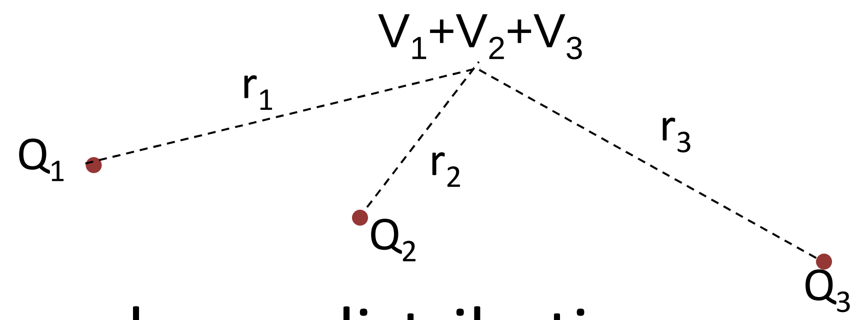
Electric potential due to a point charge:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$



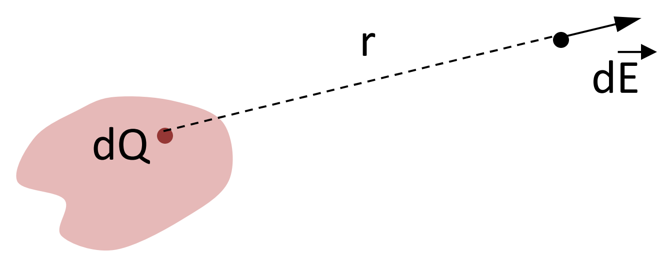
Electric potential due to several point charges:

$$\vec{E} = \sum_i \frac{1}{4\pi\varepsilon_0}\frac{Q_i}{r_i}$$



Electric field due to continuous charge distribution:

$$V = \int dV = \int \frac{1}{4\pi\varepsilon_0}\frac{dQ}{r}$$



Note that electric potential is a scalar, it is easier to calculate than electric field (vector).

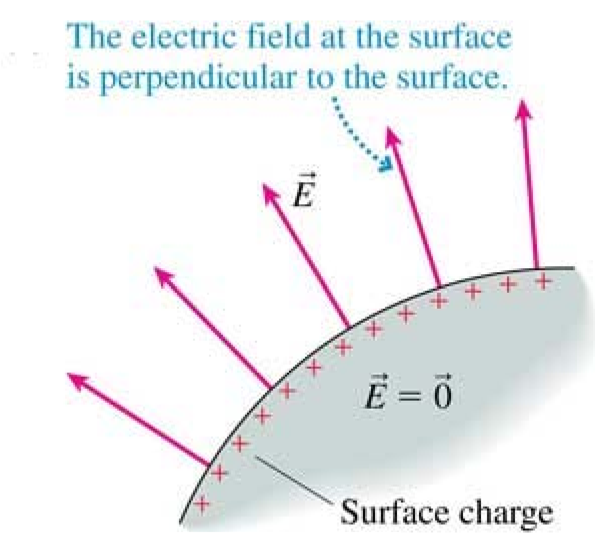
All on Conductors (as a Source of Electric Field)

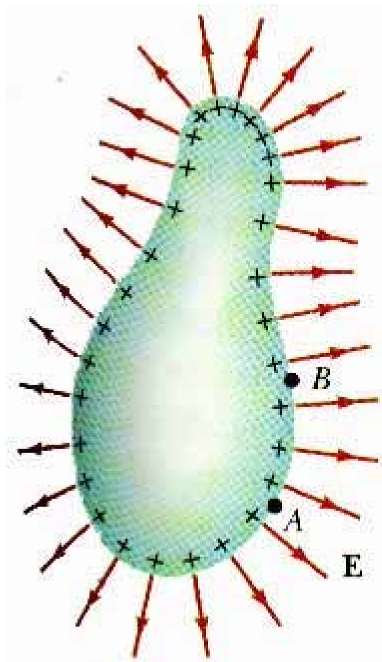
The following are true for any shape of a conductor, including the ones with cavities inside it (but assume there is no charge inside the cavities).

1.If the conductor has a net charge, all charges will stay on the outer surface of the conductor.

2.There is no electric field inside the conductor.

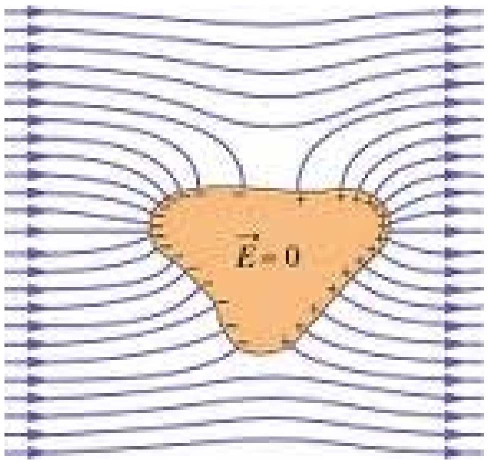
3.The electric field outside the outer surface always perpendicular to the surface in the proximity of the conductor.

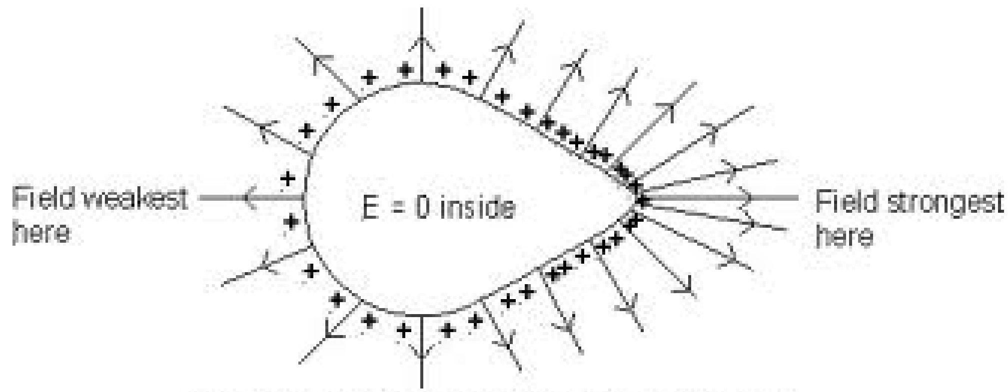




All on Conductors (as a Source of Electric Field) (Con't)

4. Electric field is stronger at the sharper part (smaller radius of curvature) of the outer surface.





(d) Electric field & charge distribution around a pear-shaped conductor

5. The conductor has the same potential, including the cavities (unless there are charges inside the cavities) and surfaces, through out the whole body.