Mon Feb 27, 2017

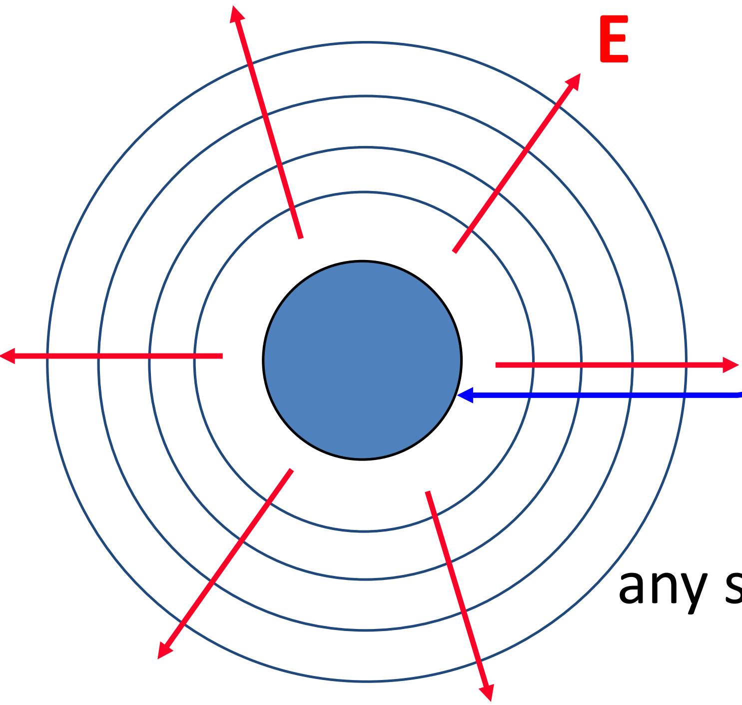
Last time:

- Electric potential energy and electric force
- Electric potential and electric field
- Electric potential of a dipole (along its axis)

Today:

- Equipotential surfaces: visualizing electric potential
- Conductors and electric potential
- Interpreting equipotential surfaces

Equipotentials



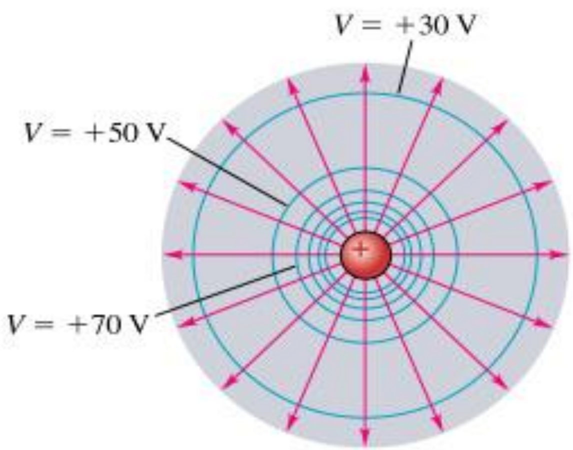
Consider equipotential lines
(or surfaces, actually, in 3-D):

eg --for uniform spherical charge,
$V(r) = k\,Q/r$ is constant over
any sphere concentric with the charged sphere.

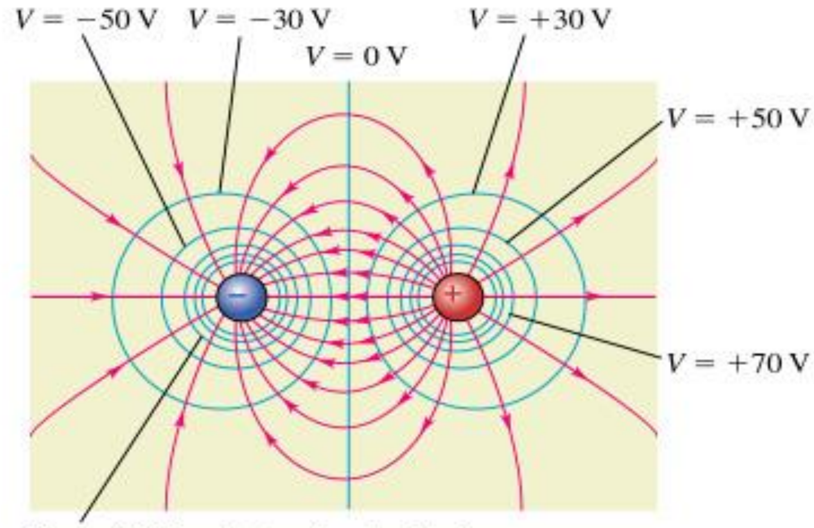
Note that if move along equipotential surface, by definition $\Delta V = 0$
but this $= -\vec{E}\cdot\Delta\vec{r} \Rightarrow \vec{E}$ is $\perp$ equipotential surface

http://www.falstad.com/vector3de/

Equipotential Surfaces



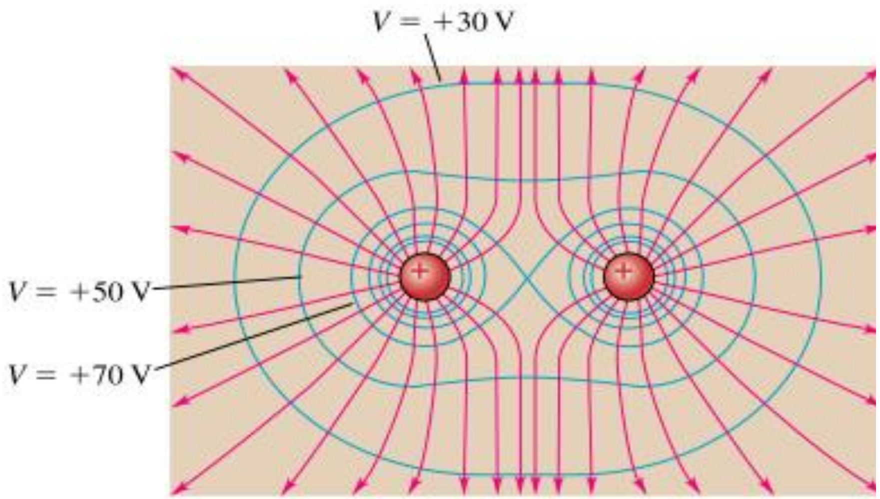
(a) A single positive charge



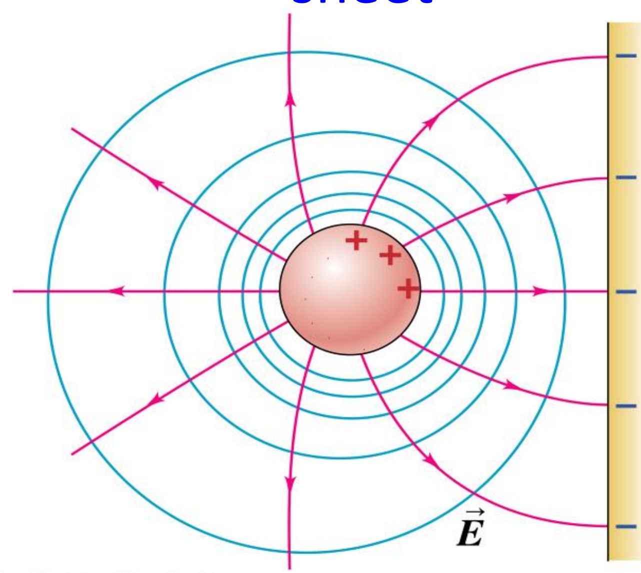
(b) An electric dipole

Note – E is always ⊥ V !!

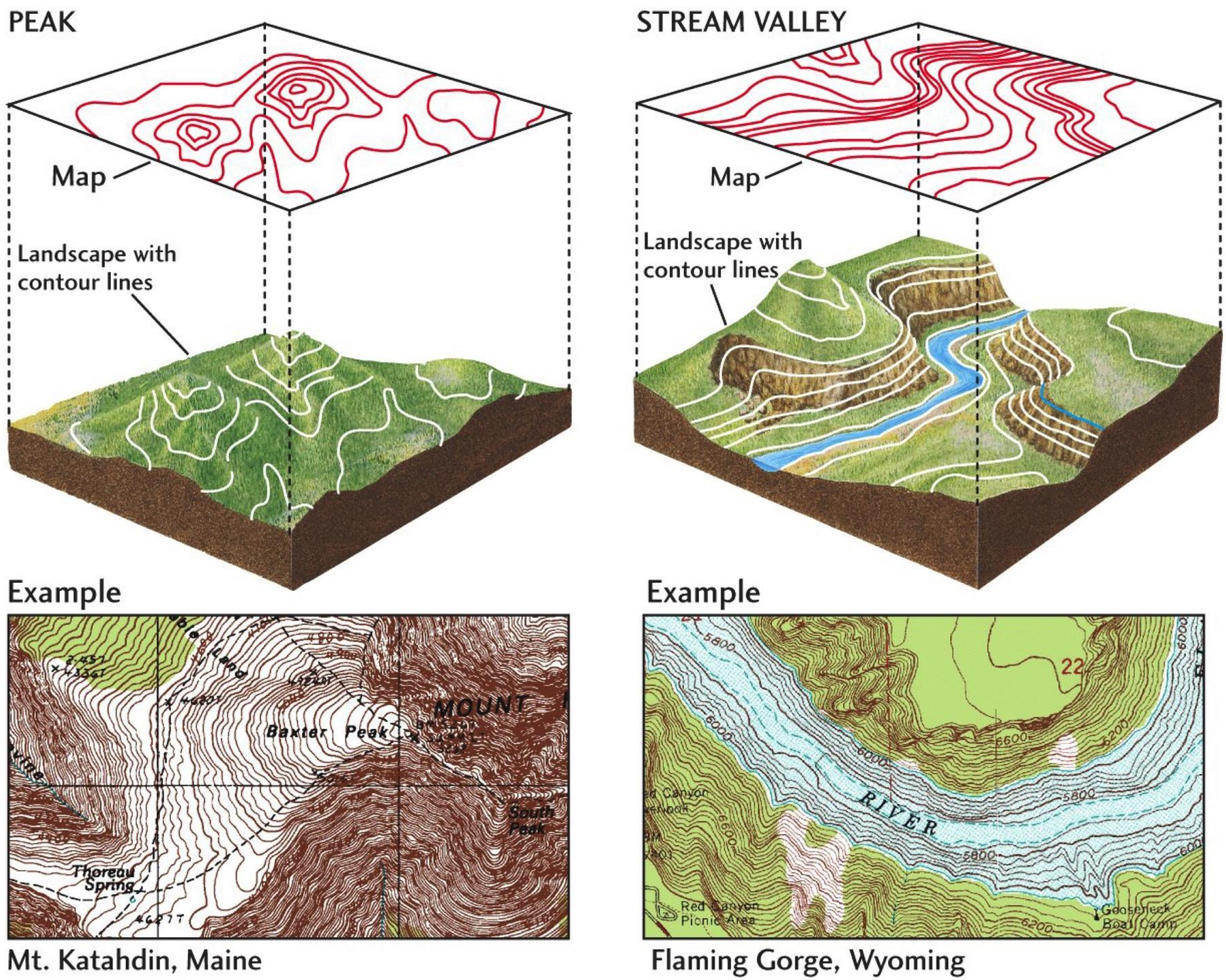
Conducting sphere
+ sheet



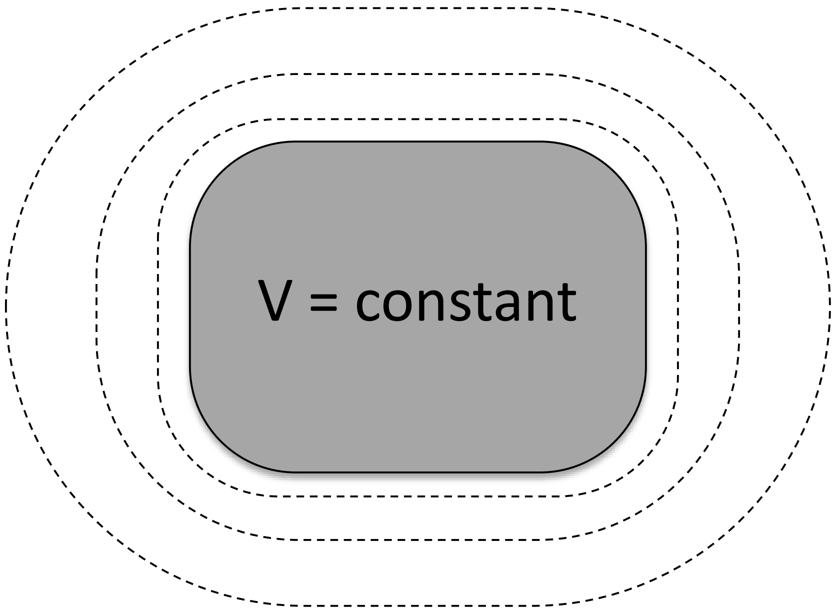
(c) Two equal positive charges



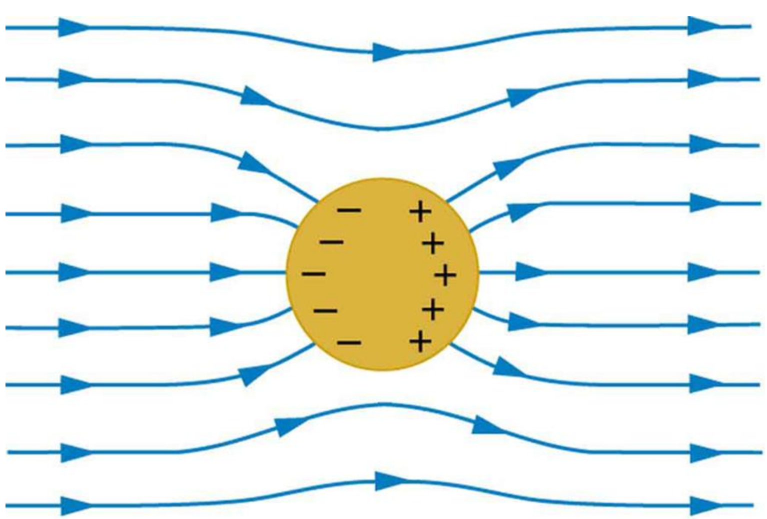
Where have you seen equipotentials before?



Conductors and E-fields



The surface of a conductor is an equipotential. If there was a potential difference across the surface of a conductor, the freely moving charges would move around until the potential is constant.



https://cnx.org/contents/Ax2o07Ul@8.8:a8tWDdDr@3/Conductors-and-Electric-Fields

This means that electric field lines ALWAYS must meet a conducting surface at right angles (any tangential component would imply a tangential force on the free charges).

Potential Gradient (E and V)

Note: E is always $\perp$ equipotential lines

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

In 3 dimensions we must take 3 derivatives, then add them **VECTORIALLY**

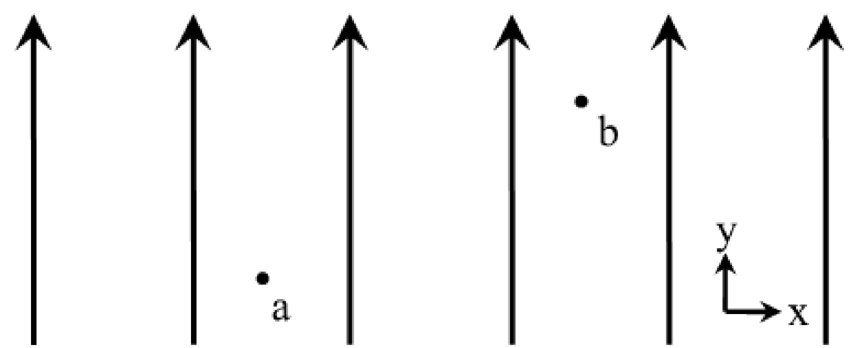
Alternatively, the potential is found from the electric field integrated along any path connecting points A and B

$$\boxed{\Delta V = -\int_A^B \vec{E} \cdot \overrightarrow{dl}}$$

TopHat question

- The diagram below shows a uniform electric field, with a field strength of 6000 V/m. Point *a* is at (x, y) = (3 cm, 4 cm) and point *b* is at (7 cm,7 cm). What is the potential difference V_{ab}?

A. 240 V
B. 30 000 V
C. 300 V
D. 180 V
E. 18 000 V



TopHat question

- The electric potential in a particular region of space is given by $V = 5x^2 - 3y^2$. What is the direction of the **electric field** at the point (x, y) = (3 m, 3m)?

A. 59^{o} above the –*x* direction

B. 31^{o} above the +*x* direction

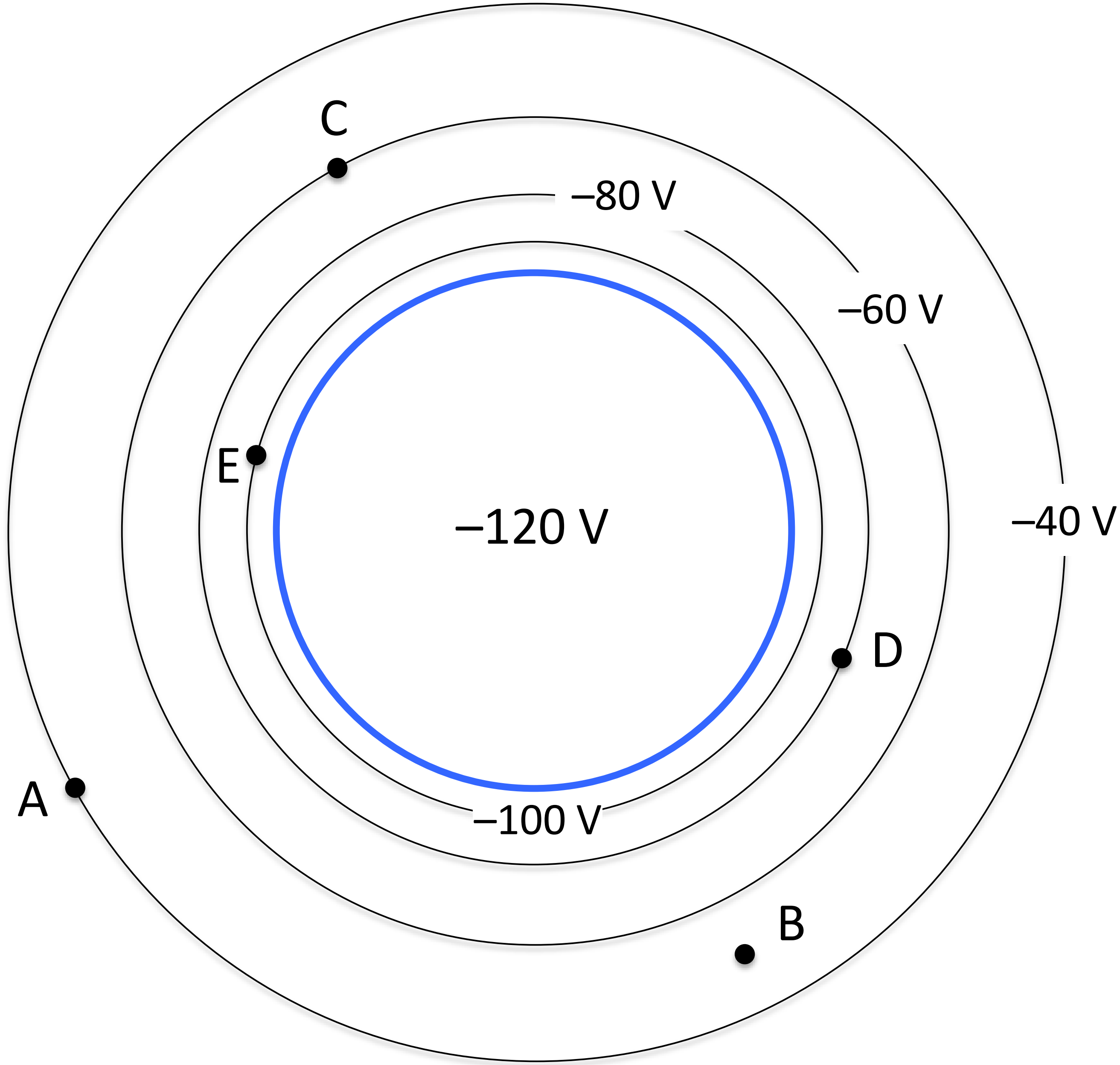
C. 59^{o} below the +*x* direction

D. 31^{o} below the +*x* direction

E. 31^{o} above the –*x* direction

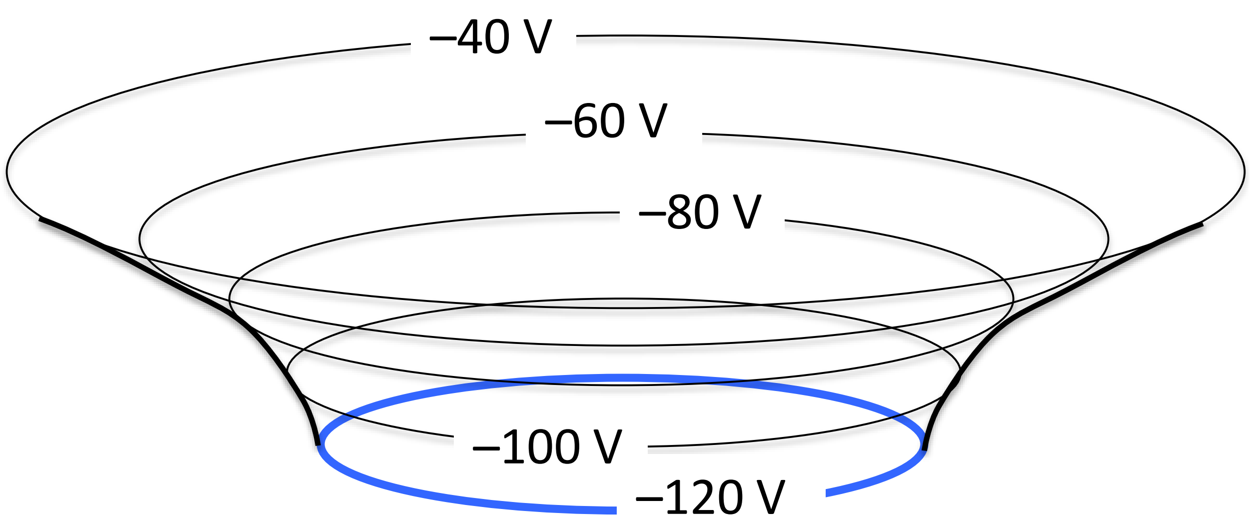
Equipotential surfaces for charged shell

Equipotential surfaces give you information about the potential energy that charged particles would have, the direction of the electric field, the strength of the electric field, and where a charged particle is allowed to go, based on its energy.



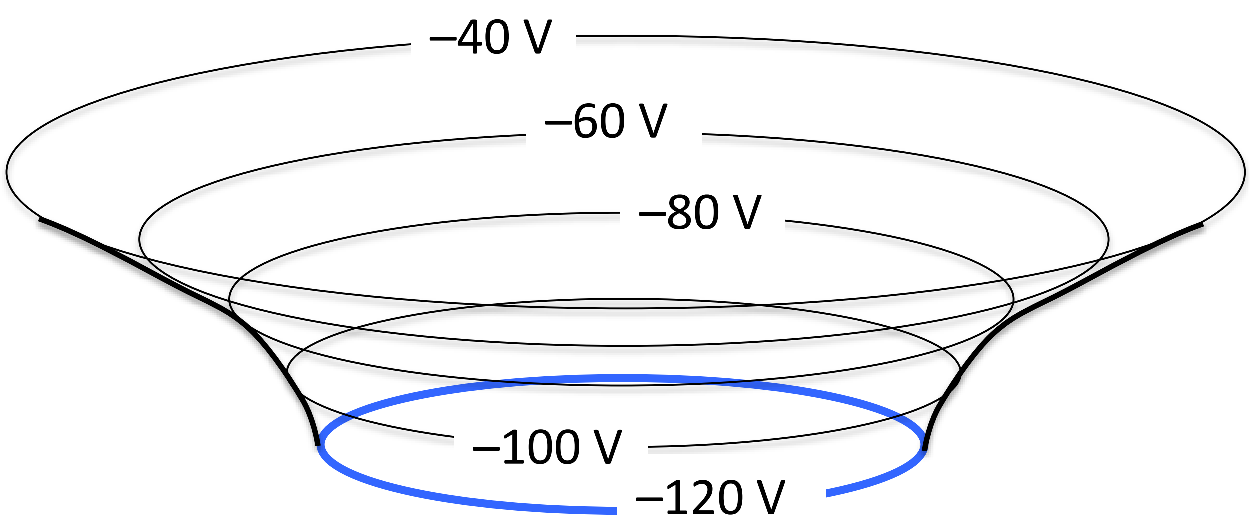
Equipotential surfaces for charged shell

Equipotential surfaces give you information about **the potential energy that charged particles would have**: Think of the electric potential (V) the same way that gravitational potential (gh) is an altitude above sea level. The potential energy of a charge q is then just U = qV, while the potential energy of a mass is U = mgh.



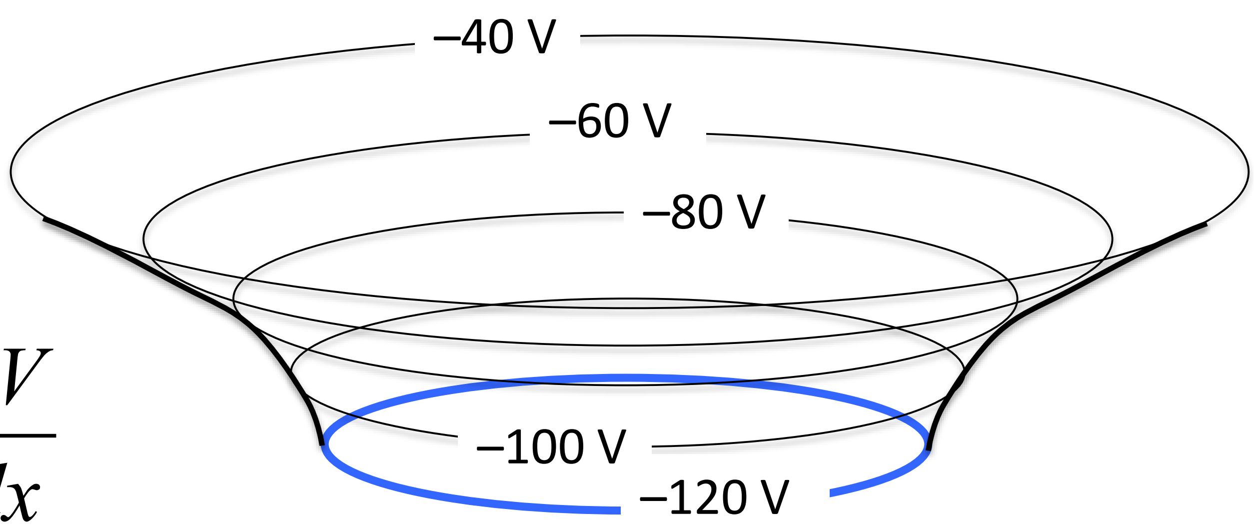
Equipotential surfaces for charged shell

Equipotential surfaces give you information about **the direction of the electric field**. Just like in the gravitational analogy, objects roll downhill (to lower gravitational potential), positive charges move "downhill" to lower electric potential; the electric field always points "downhill".



Equipotential surfaces for charged shell

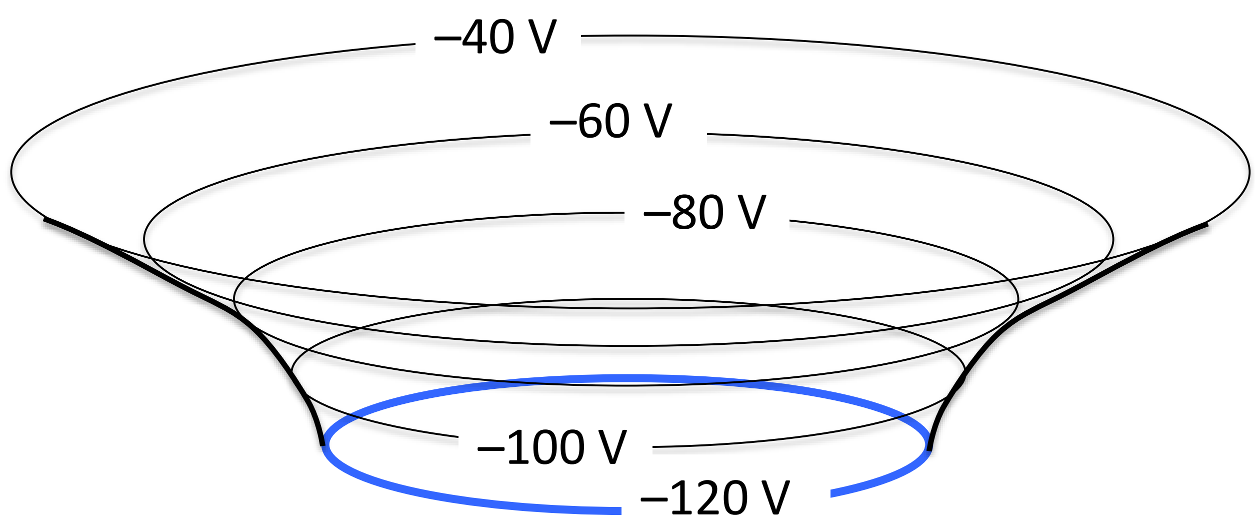
Equipotential surfaces give you information about **the strength of the electric field**. We know that the in the gravitational case, objects on steeper slopes will accelerate faster. Similarly here, the strength of the electric field is related to the slope of V(x). The more bunched together the equipotential lines, the steeper the slope, the stronger the field.



$$E = -\frac{dV}{dx}$$

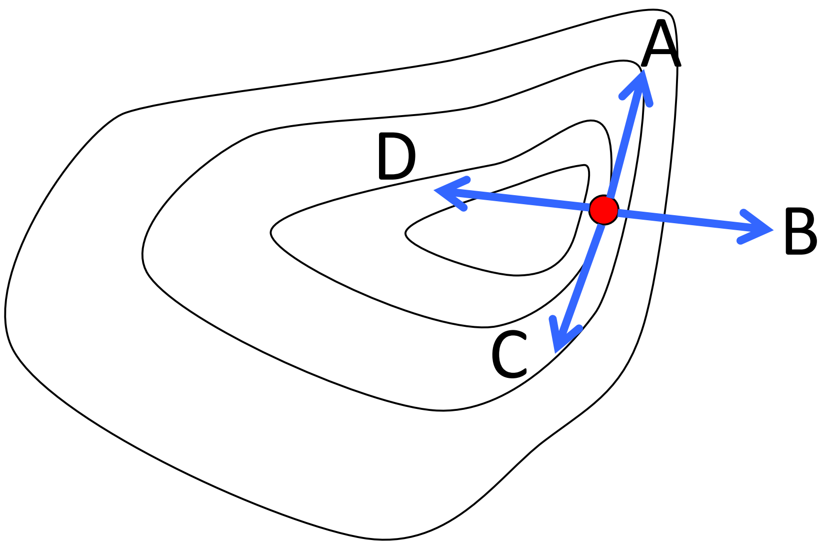
Equipotential surfaces for charged shell

Equipotential surfaces give you information about **where a charged particle is allowed to go, based on its energy**. If you release a marble in a bowl at some height *h*, it will never be able to reach a higher height. Similarly, if you release a positive charge from some potential, it can never reach a higher potential unless supplied with extra energy.



TopHat Question

Equipotential surfaces are shown below. If a positively charged particle were released from rest at the point indicated, in which direction would the particle begin to move?



A.

B.

C.

D.

E. Not enough info