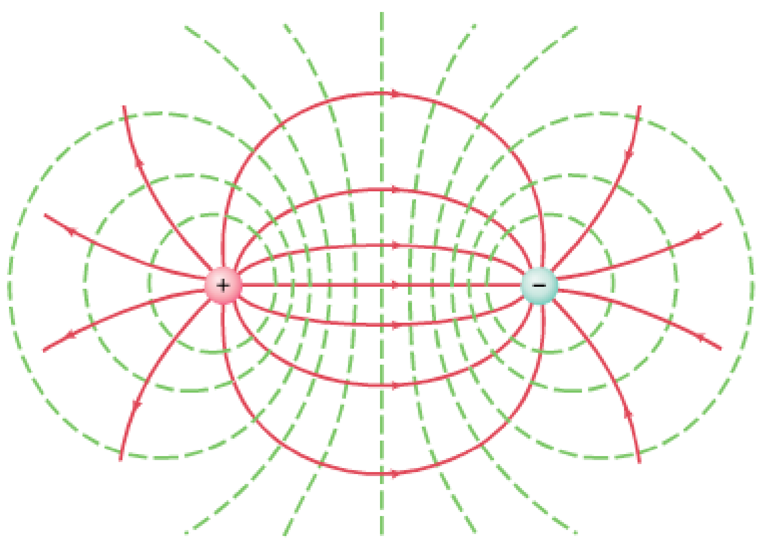
Notes

Physics Tool box

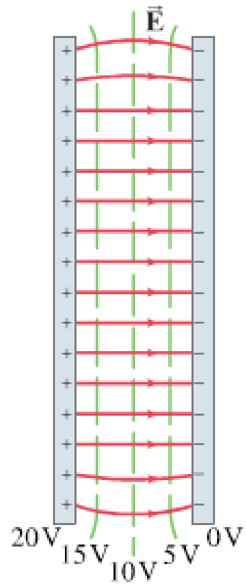
- **Work done by Electric Field** – in moving a positive charge, q, from a to b is equal to the negative of the change in potential energy.
  - $W = -q(V_b - V_a) = -qVba$
    $= Fd = qEd$
- $V_{ba} = -Ed$
- $E = -\frac{V_{ba}}{d}$ (the negative sign just indicates that the field is a vector pointing in the direction of decrease of electric potential.)

We have seen that electric potential can be represented diagrammatically by drawing lines of potential. An equipotential line (or surface on a 3D drawing) represents those points that are at the same potential. This means that the potential difference between any two points on the line (or surface) is zero, and therefore NO WORK is required to move a charge from one point to another on that line (or surface).



The red lines on the above diagram represent the electric field lines (pointing from positive to negative), the green dashed lines represent some equipotential lines. Notice that the equipotential lines are always perpendicular to the electric field lines.

For parallel conducting plates, like those in a capacitor, the electric field lines are perpendicular to the plates and the equipotential lines are parallel to the plates.

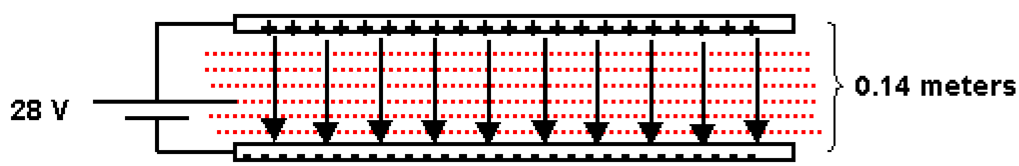


Note: equipotential lines cannot cross (this would indicate that we have two different potentials at the same location).

Example

Two parallel plates are connected to a 28V battery. If the two plates are 0.14 metres apart, and a 2 nC positive particle (m= 2.0×10^{-10} kg) is placed exactly in between the two plates:

a) Determine the magnitude of the uniform field.
b) Determine the force be on the particle.
c) Determine the change in electric potential as the particle moves to bottom plate.
d) Determine the change in electric potential energy.
e) Determine the speed of the charge as it's the bottom plate.



Solution

a) Since the top plate is positive and the bottom plate is negative, the field points down with a magnitude of :

$$\begin{aligned} E &= \frac{V}{d} \\ &= \frac{28V}{0.14m} \\ &= 200\ V/m \end{aligned}$$

Therefore the field strength is ***200 V/m***.

b) The force would be toward the negative end of the terminal, given by:

$$\begin{aligned} F &= qE \\ &= q\left(-\frac{\Delta V}{d}\right) \\ &= \left(2\times10^{-9}C\right)\left(-\frac{0V-28V}{0.14m}\right) \\ &= 4.0\times10^{-7}N \end{aligned}$$

Notice that this force is the same no latter where the particle is placed between the plates.

c) From $V_{ba} = -Ed$, we have:

$$\begin{aligned} V_{ba} &= -Ed \\ &= -\left(200\frac{V}{m}\right)(0.07m) \\ &= -14V \end{aligned}$$

Therefore the potential decreases by ***14 Volts***.

d) We use $\Delta U_E = q\Delta V$ to determine the change in electric potential energy.

$$\begin{aligned} \Delta U_E &= q\Delta V \\ &= \left(2\times10^{-9}C\right)\left(-14V\right) \\ &= -2.8\times10^{-8}J \end{aligned}$$

Therefore the particle looses ***$2.8x10^{-8}$ J*** of potential energy when it reaches the bottom plate.

f) We will use the conservation of energy rules to determine the kinetic energy and thus the speed.

$$\begin{aligned} K_i + U_i &= K_f + U_f \\ U_i &= K_f \\ K_f &= U_i \\ \frac{1}{2}mv^2 &= 2.8\times10^{-8}J \\ v &= \sqrt{\frac{2\left(2.8\times10^{-8}J\right)}{2\times10^{-10}kg}} \\ &= 16.7\frac{m}{s} \end{aligned}$$

Therefore the particle end up moving at ***16.7 m/s*** when it reaches the bottom plate.

Extra Notes and Comments