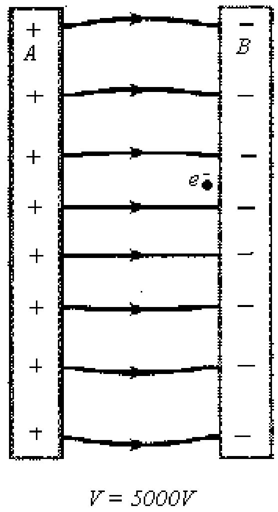
Example: Electron in a TV tube



Suppose an electron in the picture tube of a television set is accelerated from rest through a potential difference (voltage) of 5000V.

a. What is the change in potential energy of the electron?

b. What is the speed of the electron as a result of this acceleration?

The charge on an electron is $e = -1.60 \times 10^{-19}$ C.

The electron is at high potential at B and low potential at A. For the electron, the potential difference is +5000V.

$$V_{BA} = \frac{PE_A - PE_B}{q} = \frac{\Delta PE_{BA}}{e}$$

$$\Delta PE_{BA} = e \cdot V_{BA} = (-1.6 \times 10^{-19})(5000) = -8.0 \times 10^{-16} J$$

The negative sign indicates that the potential energy decreases as the electron changes positions.

This decrease in potential becomes an increase in kinetic energy, based on the conservation of energy: ΔKE + ΔPE = 0.

$$\Delta KE_{BA} = -\Delta PE_{BA}$$

$$KE_A - KE_B = -(-8.0 \times 10^{-16})$$

$$\frac{1}{2}mv^2 - 0 = 8.0 \times 10^{-16}$$

$$v = \sqrt{\frac{2(8.0 \times 10^{-16} J)}{9.1 \times 10^{-31} kg}} = 4.2 \times 10^7 ms^{-1}$$

c. Repeat for a positive charge moving from A to B.

The charge on a proton is $e = 1.60 \times 10^{-19}$ C.

The proton is at high potential at A and low potential at B. For the proton, the potential difference is -5000V.

$$V_{AB} = \frac{PE_B - PE_A}{q} = \frac{\Delta PE_{AB}}{e}$$

$$\Delta PE_{AB} = e \cdot V_{AB} = (1.6 \times 10^{-19})(-5000) = -8.0 \times 10^{-16} J$$

This is the same answer as for the electron.

The velocity will be different because a proton is more massive than an electron.

$$\Delta KE_{AB} = -\Delta PE_{AB}$$

$$KE_B - KE_A = -(-8.0 \times 10^{-16})$$

$$\frac{1}{2}mv^2 - 0 = 8.0 \times 10^{-16}$$

$$v = \sqrt{\frac{2(8.0 \times 10^{-16} J)}{1.67 \times 10^{-27} kg}} = 9.8 \times 10^5 ms^{-1}$$

Example: Accelerated particle

Two horizontal parallel plates are 0.0300*m* apart and the electric potential difference between them is 100.0V. A deuterium nucleus is initially at rest near the positive plate. Determine

a. the work done by the electric force on the particle as it passes between the plates

b. the particle's kinetic energy just before it strikes the negative plate.

Note: the mass of the nucleus is 3.34 x 10^{-27}*kg* and the charge is +1.60 x 10^{-19}*C*.

The nucleus is moving from an area of high to low potential. The loss of potential energy is equal to the work done by the electrical force, based on the work-energy theorem: $W = -\Delta PE$

A positive charge is moving from high (A) to low(B) potential, so the voltage will be –100.0V.
The change in potential energy is found from the equation

$$V = \frac{\Delta PE}{q}$$

$$\Delta PE = \frac{V}{q} = \frac{-100.0V}{1.60 \times 10^{-19} C} = -1.60 \times 10^{-17} J$$

$$W = -\Delta PE = +1.60 \times 10^{-17} J$$

If energy is conserved, then all the work is turned into kinetic energy. $W = \Delta KE$.

$$W = \Delta KE = KE_B - KE_A$$

$$W = KE_B - 0$$

$$KE_B = 1.60 \times 10^{-17} J$$

$$KE_B = \frac{1}{2} m {v_B}^2$$

$$v_B = \sqrt{\frac{2(KE_B)}{m}} = \sqrt{\frac{2(1.60 \times 10^{-17})}{3.34 \times 10^{-27}}} = 9.79 \times 10^4 ms^{-1}$$

Example: from infinity

a. **Determine the potential at a point *p* to a point charge of magnitude 3.00µC if point *p* is 0.400*m* from the charge.**
b. **Determine the work which must be done in order to move a 0.100µC from infinity to point *p*.**

$$V = k\frac{Q}{r}$$

$$V = (8.99\times10^{9})\frac{3.00\times10^{-6}}{0.400} = 66750V$$

The work that must be done on the object (against the electric force) is equal to the charge in potential energy. Assume that the potential energy is zero at infinity.

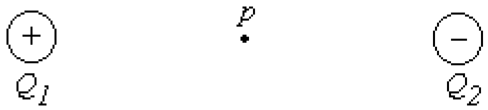
$$W = qV$$

$$W = (0.100\times10^{-6}C)(6750V)$$

$$W = 6.75\times10^{-4}J$$

Example: Addition of potentials

Two point charges ($Q_1 = 3.00\mu C$, $Q_2 = -2.50\mu C$) are placed 0.050*m* apart, as shown in the diagram. Determine the potential at the point *p* halfway between the two charges.



Electric potential is a scalar quantity. The total potential at point *p* equals the arithmetic sum of the potentials due to the individual charges.

$$V = V_1 + V_2$$

$$V = k\frac{Q_1}{r} + k\frac{Q_2}{r}$$

$$V = 8.99\times10^9\left(\frac{3.00\times10^{-6}}{0.0250}\right) + 8.99\times10^9\left(\frac{-2.50\times10^{-6}}{0.0250}\right)$$

$$V = 1.08\times10^6 + (-9.10\times10^5) = 1.70\times10^5 V$$