7.7.1 Electric Potential Energy

A charged object in an electric field has potential energy. Potential energy is a scalar quantity. If we move a positively charged object towards another positively charged object, they repel. Work is done in bringing one charge towards another. The work that is done is stored as electric potential energy. The potential energy is defined to be zero when the objects are infinitely far apart and increasingly positive as they are brought together.

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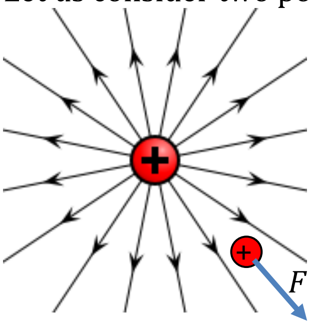
Let us consider two positive, point charges:



The first point positive charge Q creates a radial electric field E which varies according to the expression we saw in the previous unit (7.8):

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

The second point positive charge q, feels a repulsive force F in this field:

$$F = qE = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$$

Look away now if you don't like tricky maths! Note: not in syllabus.

work done = force x distance = $\int_r^\infty F dr = \frac{Qq}{4\pi\varepsilon_0}\int_r^\infty \frac{1}{r^2} dr = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r}$

So, the potential energy (E_{pot}) of q at a distance r from Q is given by:

$$E_{pot} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r}$$

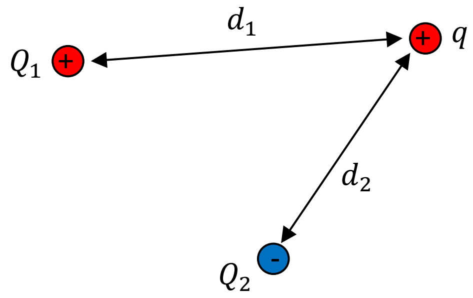
(1)✎Calculate the electric potential energy of a point charge $q = +3.0 \times 10^{-6}C$ at a distance of 0.40m from a point charge $Q = +10.0 \times 10^{-6}C$.

Unlike gravitational potential energy, which is negative everywhere, electrical potential energy can be positive or negative. A negative potential energy occurs for unlike charges.

(2)✎Calculate the electric potential energy of a point charge $q = -1.0 \times 10^{-6}C$ at a distance of 0.20m from a point charge $Q = +5.0 \times 10^{-6}C$.

Electric potential energy is additive. This means that when we have more than one charge producing electric fields, you just numerically add together the different contributions.

Consider the following situation:



If we want to work out the potential energy of q located at a distance d_1 from Q_1 and distance d_2 from Q_2, we just work out the individual contributions and add them together. Note, that Q_2 is a negative charge, so will produce a negative potential energy.

(3)✐Calculate the electric potential energy for a charge $q = +2.0 \times 10^{-6} C$ *in the diagram above, where* $Q_1 = +5.0 \times 10^{-6} C$, $Q_2 = -10 \times 10^{-6} C$, $d_1 = 10cm$, $d_2 = 8cm$.