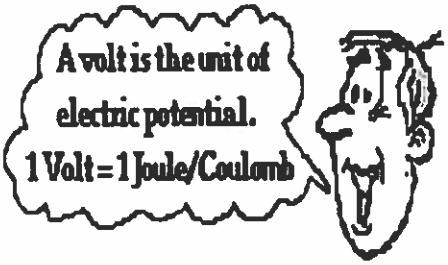
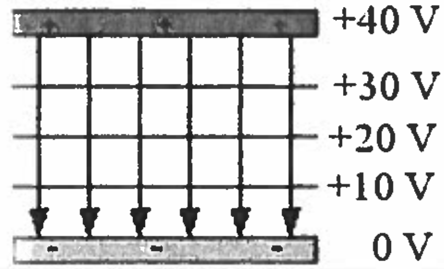
PHYSICS 12

Examples Connecting Electric force and Energy





Field and equipotential lines between plates

1. Recall that eV is a unit of energy and it is defined as work done by electric force on one electron by moving it through a potential difference equal to exactly 1 V.

$$v = \sqrt{\frac{2KE}{m}}$$

$1eV = 1.6x10^{-19}J$

a) Calculate the speed of a proton with 100eV of kinetic energy.

$100\ eV = (1.6 \times 10^{-19})(100)\ J$

$\therefore v = 1.4 \times 10^{5}\ m/s$

$$v = \sqrt{\frac{200(1.6\times10^{-19})}{1.67\times10^{-27}}}$$

$$v = \sqrt{1.9162 \times 10^{10}}$$

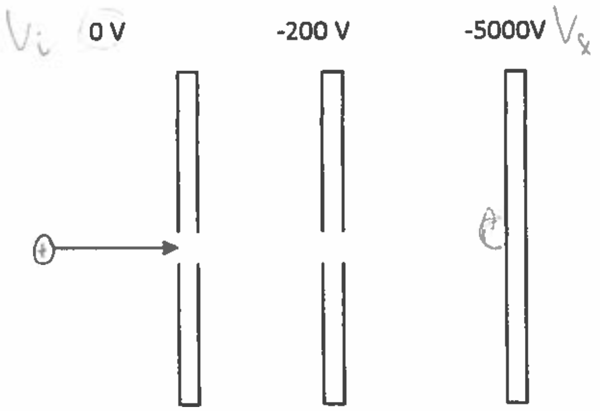
b) What would be the speed of an electron with the same amount of kinetic energy?

$$v = \sqrt{\frac{200(1.6\times10^{-19})}{9.11\times10^{-31}}}$$

$$v = \sqrt{3.5\times10^{13}}$$

$\therefore v = 5.9 \times 10^{6}\ m/s$

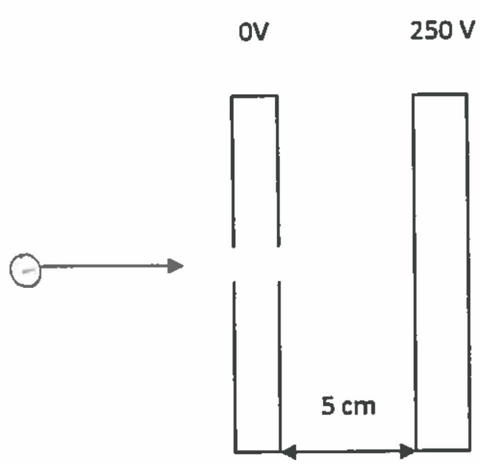
2. A proton moving at 5.0x10^{5}m/s enters a series of charged parallel plates as shown below. What is the impact speed on the last plate? **Note: this speed cannot exceed the speed of light in vacuum.**



$$EPE = q \cdot \Delta V$$
$$KE = \frac{1}{2} m v^2$$
$$\frac{1}{2} m v_i^2 = \frac{1}{2} m v_f^2 + q \Delta V$$
$$v_f = \sqrt{\frac{\left(\frac{1}{2} m v_i^2 - q \Delta V\right) \cdot 2}{m}}$$

$$KE_i + EPE_i + W_{in} = KE_f + EPE_f + W_{nc}$$
$$\frac{1}{2}(1.67 \times 10^{-27})(5.0 \times 10^5)^2 + 0 + 0 = \frac{1}{2}(1.67 \times 10^{-27}) v_f^2 + (1.6 \times 10^{-19})(-5000) + 0$$
$$2.0875 \times 10^{-16} = 8.35 \times 10^{-28} v_f^2 + (-8.0 \times 10^{-16})$$
$$v_f = \sqrt{1.20808 \times 10^{12}}$$
$$v_f = 1.1 \times 10^6 \text{ m/s}$$

3. An electron moving at 2.5x10^{6}m/s enters a region of electric field between parallel plates by passing through a small hole in the plates as shown. What is the impact speed of the electron on the second plate?



$$W_{in} + KE_i + EPE_i = KE_f + EPE_f + W_{nc}$$
$$0 + \frac{1}{2}(9.11 \times 10^{-31})(2.5 \times 10^6)^2 + 0 = \frac{1}{2}(9.11 \times 10^{-31}) v_f^2 + (-1.6 \times 10^{-19}) \cdot (250) + 0$$
$$2.847 \times 10^{-18} = 4.555 \times 10^{-31} v_f^2 - 4 \times 10^{-17}$$
$$v_f = \sqrt{9.407 \times 10^{13}}$$
$$v_f = 9.7 \times 10^6 \text{ m/s}$$

$$v = \sqrt{\frac{2\left(\frac{1}{2} m v_i^2 - q \Delta V\right)}{m}}$$

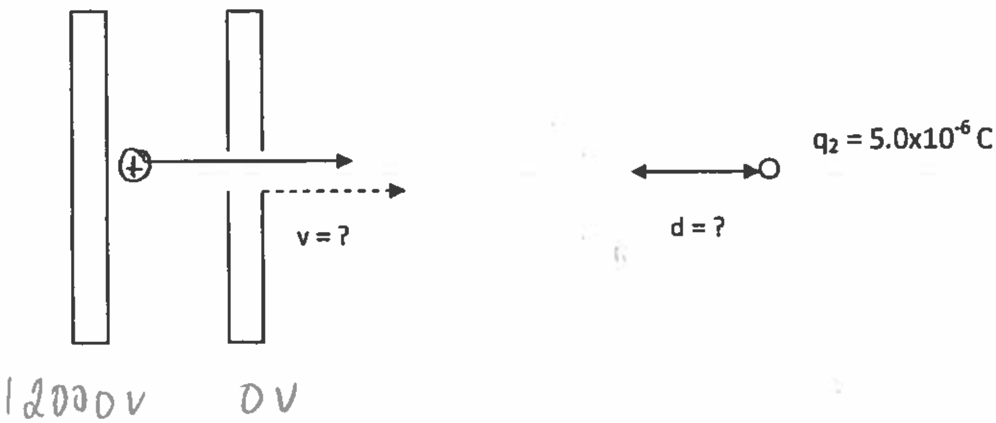
$KE_i = 0$

4. A proton is accelerated from rest through a potential difference of $1.2\text{x}10^4$V is directed at a fixed charge of $+5.0\text{x}10^{-6}$C.

$EPE_i = KE_f$

a) What is the speed of the proton as it leaves the last plate?

$(1.6\times10^{-19})(12000) = \frac{1}{2}(1.67\times10^{-27})v_f^2$



$$\therefore v_f = \sqrt{\frac{2 \cdot q \Delta V}{m}} = \sqrt{2.299\times10^{12}}$$

$$v_f = 1.5\times10^6 \text{ m/s}$$

b) What is the distance of the proton from q_2 when proton stops?

$= v_i$

$KE_f = 0$

$KE_i = \frac{1}{2}m(1.5\times10^6)^2$

$= 1.87\times10^{-15}$ J

should be 1.92×10^{-15} J

$$KE_i + EPE_i = KE_f + EPE_f$$

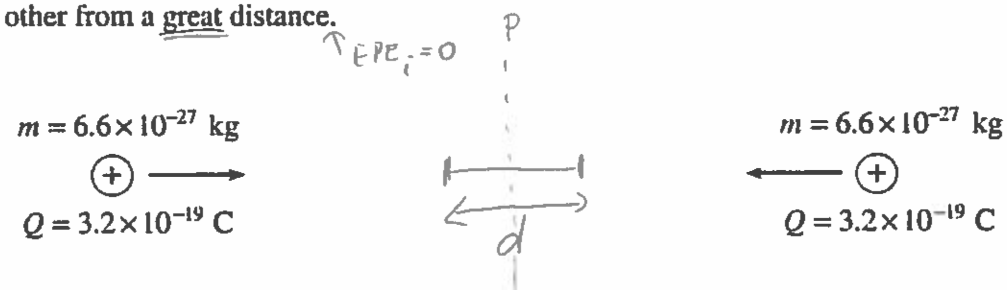
$$\frac{1}{2}mv_i^2 + 0 = 0 + \frac{k \cdot q_2 q_1}{r}$$

$$r = \frac{(kq_2q_1)2}{mv_i^2}$$

$$r = \frac{(9.0\times10^9)(5.0\times10^{-6})(1.6\times10^{-19})(2)}{(1.67\times10^{-27})(1.5\times10^6)^2}$$

$r = 3.75$ m

5. Alpha particles with a mass of 6.6×10^{-27} kg and a charge of 3.2×10^{-19} C are fired towards each other from a great distance.



a) If they each have a speed of 2.5×10^{6} m/s to start with, what will be their minimum separation distance? ($d = 2.2\times10^{-14}$ m)

$$EPE_i + KE_i = KE_f + EPE_f$$

$$0 + \frac{1}{2} m v_i^2 = 0 + \frac{k q_1 q_2}{r}$$

$$\frac{1}{2}(6.6\times10^{-27})(2.5\times10^{6})^2 = \frac{(9\times10^{9})(3.2\times10^{-19})^2}{r}$$

$$r = \frac{9.216\times10^{-28}}{2.0625\times10^{-14}}$$

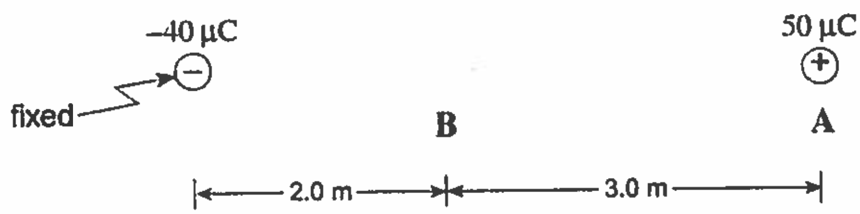
$$r = 4.47\times10^{-14}\ \text{m}$$

$$d = \frac{r}{2} = 2.2\times10^{-14}\ \text{m}$$

b) Using energy principles, explain why the particles do not come any closer than this minimum separation distance.

- KE is changing into EPE once all KE is changed, particle stops.
- For them to move any closer additional energy would have to be supplied.

6. A 1.0×10^{-3} kg styrofoam ball carrying 50 μC of charge is released from rest from position **A** as shown in the diagram below. ($1\,\mu C = 1 \times 10^{-6}$ C)



a) Determine the change in electric potential energy, ΔE_p, of the ball as it moves from position **A** to position **B**. $\Delta EPE = -5.4\ J$

$$\Delta EPE = EPE_f - EPE_i$$

$$= \frac{k(-40\times10^{-6})(50\times10^{-6})}{2} - \frac{k(-40\times10^{-6})(50\times10^{-6})}{5}$$

$$= -9 + 3.6$$

$$= -5.4\ J$$

b) What is the speed of the ball as it reaches position **B**? ($v_i = 0$ at **A**) $v_f = 1.0\times10^2\ m/s$

$$\Delta EPE = -\Delta KE$$

$$+5.4 = KE_f$$

$$5.4 = \frac{1}{2}(1.0\times10^{-3})(v_f)^2$$

$$v_f = 104\ m/s$$