What is a field?
→ a representation of the force exerted in a region

The direction of the electric field is the direction of the net electric force on a positive charge.

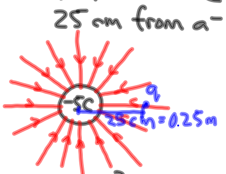
Electric Field Strength

$\vec{E}$ → the force on a test charge at a specific location

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\frac{\vec{F_g}}{m} = \vec{g}$$

Ex. Determine $\vec{E}$ at a point 25 cm from a -5C charge.



$$F_e = \frac{kq_1q_2}{r^2}$$
$$= \frac{(9\times10^9)(5)q}{(0.25)^2}$$
$$= 7.2\times10^{11}q$$

$$\frac{mv^2}{r} = \frac{kq_1q_2}{r^2}$$
$$v = \sqrt{\frac{kq_1q_2}{mr}}$$

$$E = \frac{F_e}{q}$$
$$= \frac{7.2\times10^{11}\cancel{q}}{\cancel{q}}$$
$$\vec{E} = 7.2\times10^{11}\ \frac{N}{C}$$
[towards the charge]

$$E = \frac{F_e}{q}$$
$$= \frac{\frac{kq_1\cancel{q}}{r^2}}{\cancel{q}}$$
$$E = \frac{kq_1}{r^2}$$

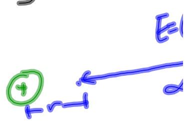
$$\cancel{m}a = \cancel{m}g$$
$$ma = Eq$$

Electric Potential

Electrical potential energy..

E_e between 2 charges is

$$E_e = \frac{kq_1q_2}{r}$$



The amount of electrical energy per unit of charge is called electrical potential.

$$V = \frac{E_e}{q}$$

For point charges...

$$V = \frac{\frac{kq_1\cancel{q}}{r}}{\cancel{q}}$$

$$V = \frac{kq}{r}$$

~~Example~~

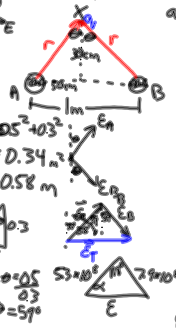
Example: A 20 mC and -30 mC charge are placed as shown. For position X, determine (if you can) each of these...

a) electric field strength

~~b)~~ electric force

c) electrical potential

~~d)~~ electrical potential energy



$r^2 = 0.5^2 + 0.3^2$

$r^2 = 0.34\ m^2$

$r = 0.58\ m$

$\tan\theta = \frac{0.5}{0.3}$

$\theta = 59°$

a) $\mathcal{E} = \frac{F}{q}$

$\mathcal{E}_A = \frac{F_A}{q} = \frac{\frac{kq_A \cancel{q}}{r^2}}{\cancel{q}}$

$\mathcal{E}_A = \frac{kq_A}{r^2}$

$\mathcal{E}_B = \frac{kq_B}{r^2}$

$\mathcal{E}_A = \frac{(9\times10^9)(2\times10^{-2})}{0.34} = 5.3\times10^8\ \frac{N}{C}$

$\mathcal{E}_B = \frac{(9\times10^9)(3\times10^{-2})}{0.34} = 7.9\times10^8\ \frac{N}{C}$

$\mathcal{E}^2 = 5.3^2 + 7.9^2 - 2(5.3)(7.8)\cos 118°$

$\mathcal{E} = 11.4\times10^8\ \frac{N}{C}$

$= 1.14\times10^9\ \frac{N}{C}$

$\frac{\sin\alpha}{7.9} = \frac{\sin 118}{11.4}$

$\alpha = 38°$

$\vec{\mathcal{E}} = 1.14\times10^9\ \frac{N}{C}$ [E 7° S]

$V = \frac{E}{q} = \frac{\frac{kq\cancel{q}}{r}}{\cancel{q}} = \frac{kq}{r}$

$V_A = \frac{kq_A}{r} = \frac{(9\times10^9)(2\times10^{-2})}{0.58} = 3.1\times10^8\ V$

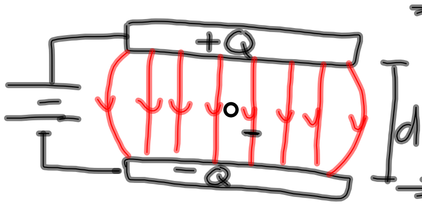
$V_B = \frac{(9\times10^9)(-3\times10^{-2})}{0.58} = -4.7\times10^8\ V$

$V_T = V_A + V_B$

$= (3.1 + (-4.7))\times10^8$

$= -1.6\times10^8\ V$

Charged Plates (parallel)



→ $\vec{\mathcal{E}}$ inside the plates is uniform (except near the edges)

→ $\mathcal{E} \propto Q$ only

We know $\mathcal{E} = \frac{F}{q}$ but $W = Fd$

$\Delta E_e = F_e d$

$F_e = \mathcal{E}q$

also $V = \frac{E_e}{q}$

$Vq = F_e d$

$\therefore E_e = Vq$

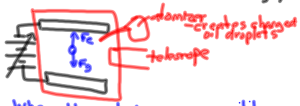
$\therefore V\cancel{q} = \mathcal{E}\cancel{q}d$

$V = \mathcal{E}d$

$$\boxed{\mathcal{E} = \frac{V}{d}}$$

Millikan's Oil Drop Experiment

Purpose: to determine the fundamental charge, e



When the oil drop is in equilibrium

$F_e = F_g$

$\varepsilon q = mg$

$\therefore \frac{Vq}{d} = mg$

$q = \frac{mgd}{V}$

To get m we need volume

∴ " " r

To get r, measure terminal velocity of the drop by setting $V = 0$.

$m = \frac{4}{3}\pi\rho\left(\frac{9\eta v_0}{2g(\rho - \rho_0)}\right)^{3/2}$

Obtain 1 value for q

$q = Ne$ → need more q since we don't know what N is

(N = integer) → look for smallest common factor

Eg. $ 1.26, 96¢, 27¢, 54, 1.02, 18, 3.00

possible cost/candy ($)

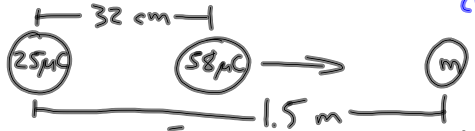
1, 2, 3, 6, 9, 14, 18, ...

In the end . . . . $e = 1.602 \times 10^{-19}$ C

There are ~ 6.25×10^{18} e^- in 1 C

Motion of Charged Particles

A 25 μC charge is anchored in place. A 58 μC charge is set 32 cm away. How fast is the charge moving when it is 1.5 m from the anchored charge?



$m = 1 \times 10^{-4}$

$E_i = E_f$

$E_{e_i} = E_{e_f} + E_K$

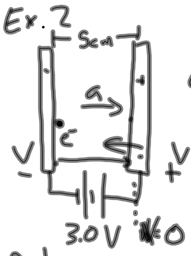
$\frac{kq_1q_2}{r_i} = \frac{kq_1q_2}{r_f} + \frac{1}{2}(1\times10^{-4})v^2$

$kq_1q_2\left(\frac{1}{r_i} - \frac{1}{r_f}\right) = 5\times10^{-5}v^2$

$(9\times10^{9})(2.5\times10^{-5})(5.8\times10^{-5})\left(\frac{1}{0.32} - \frac{1}{1.5}\right) = 5\times10^{-5}v^2$

$v = 801 \ \frac{m}{s}$

Ex. 2



$q_e = -e = -1.602 \times 10^{-19}$ C

$\Delta V = 3.0$ V

$d = 0.05$ m

$m_e = 9.11 \times 10^{-31}$ kg

$\mathcal{E} = \frac{F}{q}$

Determine v when it hits the other plate.

$F_e = \mathcal{E} q$

$F_e = \frac{V}{d} q$

$ma = \frac{Vq}{d}$

$a = \frac{Vq}{md}$

$= \frac{(3)(1.602\times ...)}{(9.11\times10^{-31})(...)}$

$= 1.05 \times 10^{13}$ m/s²

$V_f^2 = V_i^2 + 2ad$

$V_f^2 = 2(1.05\times10^{13})(0.05)$

$= 1.05 \times 10^{12}$

$V_f = 1 \times 10^6 \frac{m}{s}$

OR

Energy...

$E_i = E_f$

$-\Delta E_e = \Delta E_k$

$E_{e_i} + E_{k_i} = \Delta E_{k_f} + E_f$

$qV = E_{k_f}$

$(1.602\times10^{-19})(3)$

$= \frac{1}{2}(9.11\times10^{-31})v^2$

$- E_{ef} + E_{ei} = \Delta E_k$

$-(E_{ef} - E_{ei})$

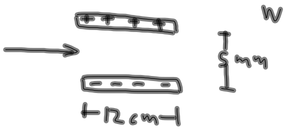
$-\Delta E_e = \Delta E_k$

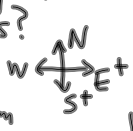
$-q\Delta V = \Delta E_k$

$V_i \quad V_f$

$\Delta V = ...$

A proton ($m = 1.67\times10^{-27}$ kg) enters the region between two charged plate heading east at 350 km/s. The plates are 5 mm apart, 12 cm long, and have a potential differen... of 2.5 kV between them. With what velocity does the proton exit the regi... between the plates?





~~Hor.~~ E-W

$V = 350$ k...

~~Vert.~~ N-S

$V_i = 0$

$a =$

$V_f = ?$

$t = T$

$= 3.4\times1...$

In E-W

$d = 0.12$ m

$V = 3.5\times10^5 \frac{m}{s}$

$t = \frac{d}{V} = 3.4\times10^{-7}$ s

$ma = \mathcal{E} q$

$ma = \frac{Vq}{d}$

$a = \frac{Vq}{md}$

$= \frac{(2500)(1.60...)}{(1.67\times10^{-27})(...)}$

$= 4.8\times10^{13}$ m/s²

N-S

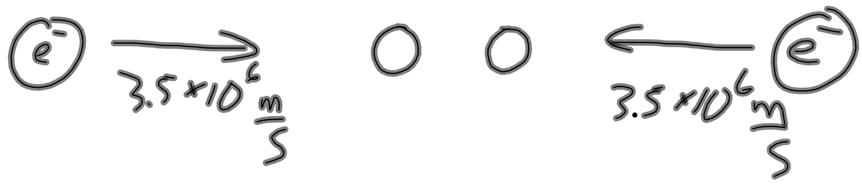
$V_f = V_i + at$

$= 0 + (4.8\times10^{13})(3.4\times10^{-7})$

$= 1.6\times10^7 \frac{m}{s}$ [S]

3.5×10^5

7.6 #3



$$E_i = E_f$$

$$2E_k = E_e$$

$$\cancel{2}\left(\frac{1}{\cancel{2}}\right)(9.11\times10^{-31})(3.5\times10^{6})^2 = \frac{(9\times10^{9})(1.602\times10^{-19})^2}{r}$$

$$1.12\times10^{-17} = \frac{2.31\times10^{-28}}{r}$$

$$r = \frac{2.31\times10^{-28}}{1.12\times10^{-17}}$$

$$= 2.06\times10^{-11}\ \text{m}$$

7.6 #5

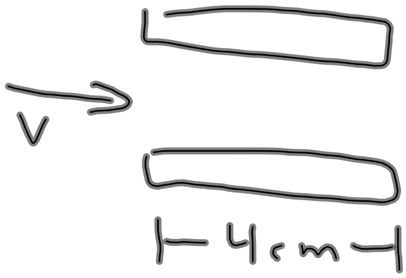
$\varepsilon = 120\ \frac{N}{C}$

$\varepsilon = \frac{F}{q}$

$F = \varepsilon q$

$ma = \varepsilon q$

$a = \frac{\varepsilon q}{m}$



Hor.

$v =$ ✓

$a =$ ✓

$t =$ calc.

Vert.

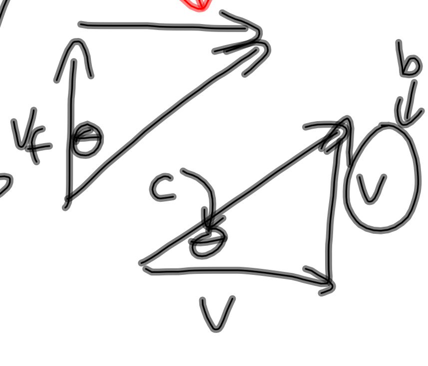
t

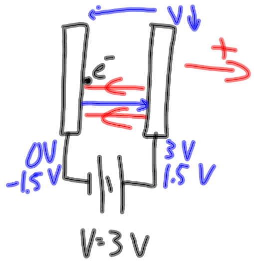
$v_i = 0$

$a =$

$v_f = v$

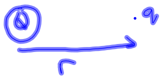
$\boxed{a)\ d =}$





$E = qV$

$ma = \mathcal{E}q$



$E_i = E_f$

$V = \frac{E_e}{q} = \frac{\frac{kQ\cancel{q}}{r}}{\cancel{q}} = \frac{kQ}{r}$

$V_i q + 0 = V_f q + \frac{1}{2}mv^2$

$0 = \underline{(3)(-1.6\times10^{-19})} + \underline{\frac{1}{2}mv^2}$

$E_e = E_k$

$(3)(1.6\times10^{-19}) = \frac{1}{2}mv^2$

$-\Delta E_e = \Delta E_k$

$Q_{gain} = -Q_{lost}$

$Q_g + Q_l = 0$

$E_{e_i} + E_{k_i} = E_{e_f} + E_{k_f}$

$E_{e_i} - E_{e_f} = \underline{E_{k_f} - E_{k_i}}$

$-(-E_{e_i} + E_{e_f})$

$-\Delta E_e$