- Last time I said you could use a potential difference to steer an electron onto a screen ①

⇒ here's a source of potential difference (battery, you guessed it, V is in volts)

⇒ & here's a device with plates

notice how the deflection changes when I change the source of potential difference

- we also talked about the Electric Potential for a point charge & mentioned it's still a potential difference, & we did a ust assume $V = 0$ @ ∞

assembly of charges.

0.1m away

① $q_1 = 10nC$ P_2

@ point P_2 $V = \frac{Kq_1}{r}$

$$= \frac{(9\times10^9 N\frac{m^2}{C^2})(10nC)}{0.1m} \quad 10^{-9}$$

$$= 900\frac{Nm}{C} \left(\frac{\text{Energy}}{C}\right)$$

• P_3 = $-10nC$

bring in a charge q_2 to point P_1

- changes the potential energy of the system from 0 (∞) to $V_f - V_I = -10nC\left(900\frac{Nm}{C}\right) = (9\times10^{-6}J)$ (q_2 is attracted)

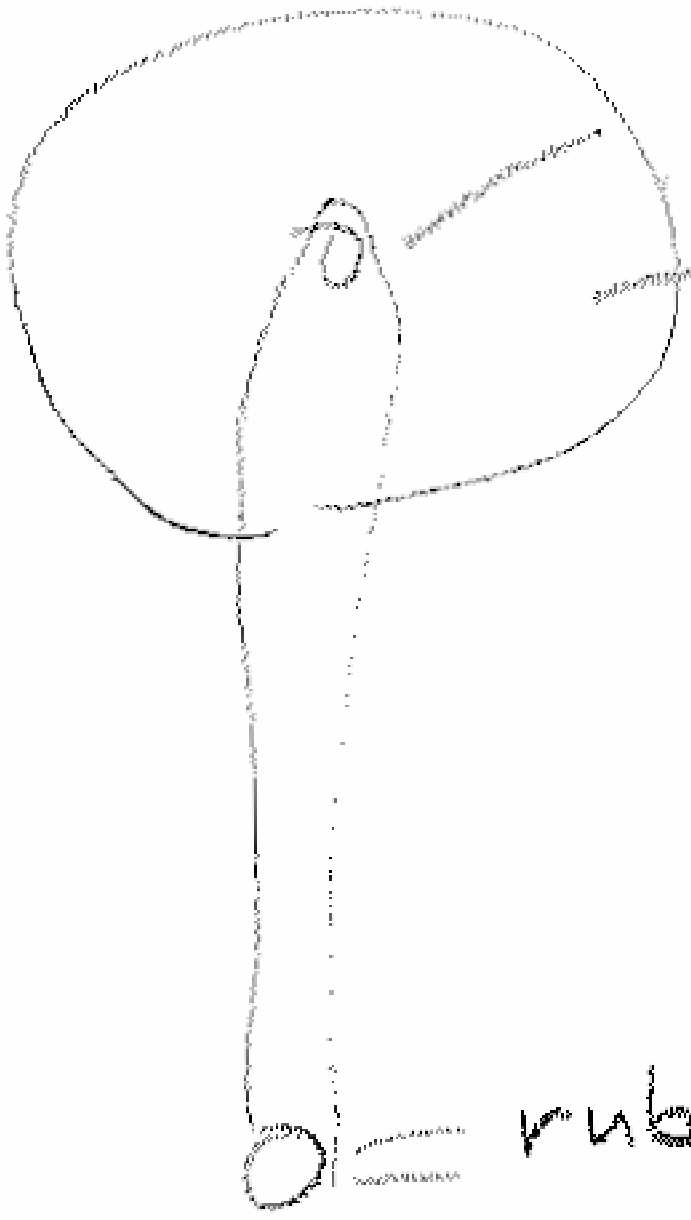
lets bring in a 3rd charge to point P_3 0.1m from P_2, 0.05m from q_1

$q_3 = 20nC$

$$V = \frac{Kq_2}{0.1m} + \frac{Kq_1}{0.05m} = -900V + 1800V$$

ΔU of system for q_3
$= 18\times10^{-6}J$

I've been frustrated this week by a lack of sleep, so I want to blow some stuff up. A good illustration of Gauss Law in action & potential diff is a Van De Graff Gen



puts charge on ball here

rubs here

outside sphere, acts like point charge

may continue to hold charge until sparks!

sparks become self generating at $E \approx 3\times10^6 \frac{V}{m}$

which means for our ~20 cm radius sphere

$$V = \frac{kq}{r} = Er = \sim 0.6\times10^6\,V \quad \text{wow!}$$

$$\& \quad q = \frac{Vr}{k} \sim \frac{\left(0.6\times10^6 \frac{Nm}{C}\right)(0.2m)}{9\times10^9 N \frac{m^2}{C^2}}$$

$$= 1.33\times10^{-5}\,C$$

(& remember once we're outside it looks like a point charge, even if $\rho(r)$ is wierd, as long as it's spherically symmetric just do $q_{inside} = 4\pi\int \rho r^2 dr$

notice: if belt not there $E=0$ inside sphere

consider

$$\Delta V = \int dV = \int -\vec{E}\cdot d\vec{r} = \int \underbrace{-E_x dx\,\hat{i} - E_y dy\,\hat{j} - E_z dz\,\hat{k}}_{dV}$$

E $\quad -\dfrac{\partial V}{\partial x} \quad -\dfrac{\partial V}{\partial y} \quad -\dfrac{\partial V}{\partial z}$

if V is <u>constant</u> $E=0$!

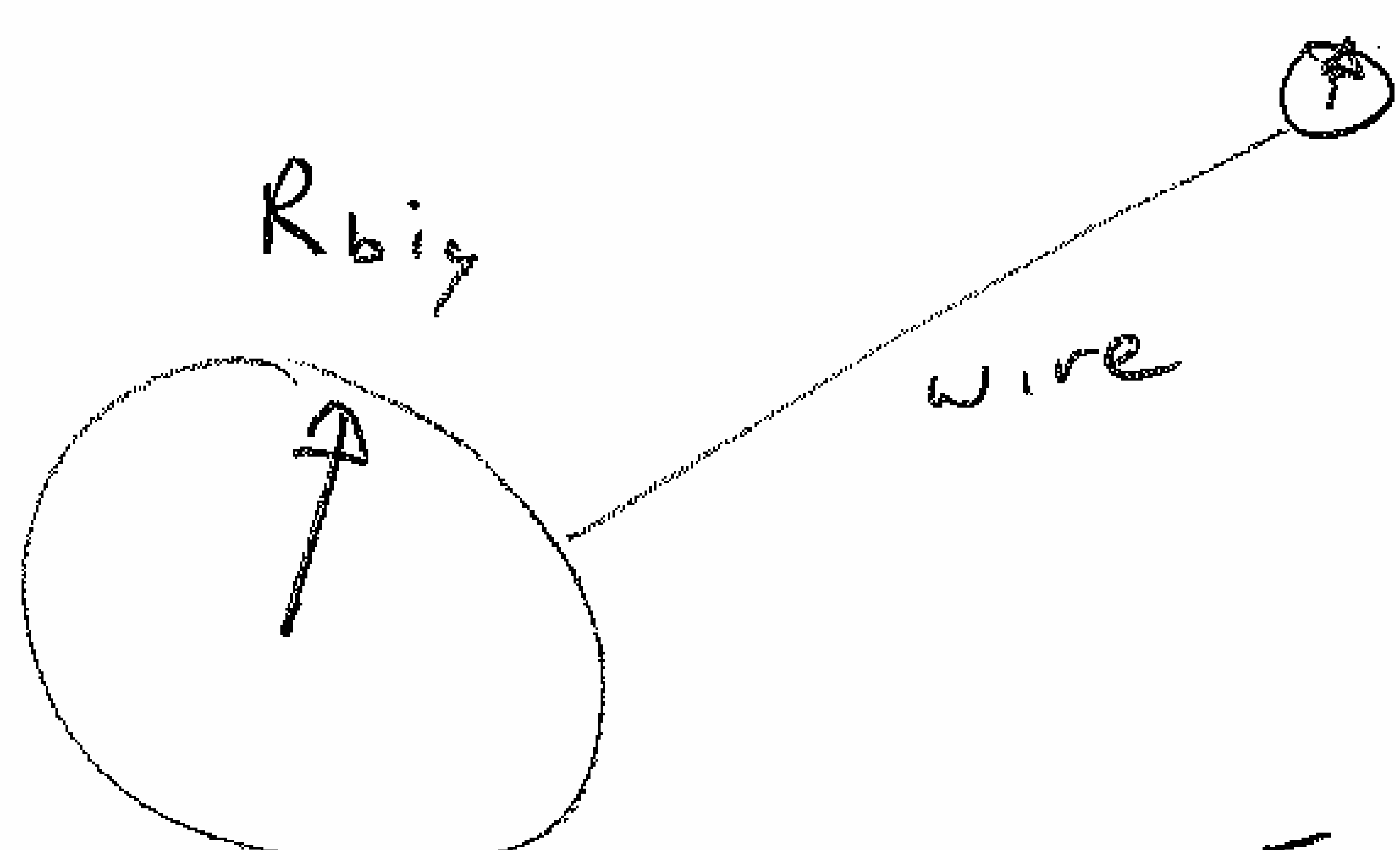
so V is constant @ surface & inside

conductor @ Equistatic Equip <u>Useful!</u>

I want more better sparks out of my Vandgraf

use lighting rod? Here's the idea

consider 2 spheres @ same V



r_{small}

@ surface & inside

$V_{Big} = V_{small}$

$$\frac{kQ_{big}}{R_{big}} = \frac{kq_{small}}{r_{small}}$$

so $E_{big} = \dfrac{kQ_{big}}{R_{big}^2} = \dfrac{V_{Big}}{R_{Big}}$

$E_{small} = \dfrac{V_{small}}{r_{small}} = \dfrac{V_{big}}{r_{small}}$

so $\dfrac{E_{small}}{E_{big}} = \dfrac{\frac{V_{big}}{r_{small}}}{\frac{V_{big}}{R_{big}}} = \dfrac{R_{big}}{r_{small}}$

smaller $\rightarrow$ more intense E, easier to get E_{Break}!

now lets destroy a clock!

consider a non-uniform $\rho(r) = hr$ spher sym

in a sphere radius = a

inside

$$q_{inside} = 4\pi \int \rho(r) r^2 dr = 4\pi \int_0^{r_0} hr (r^2 dr)$$

$$= 4\pi \frac{h r_0^4}{4} \qquad E_{out} = \frac{1}{\cancel{4\pi}\varepsilon_0} \left(\frac{\cancel{4\pi} h a_0^4}{4} \right) / r^2$$

inside

so

$$E \, 4\pi r_0^2 = \frac{4\pi}{\varepsilon_0} \frac{h r_0^4}{4} \Rightarrow \frac{h}{\varepsilon_0} \frac{r_0^2}{4} = E$$

inside potenial more trick! Consider going from $0 \to \infty$ in s/pp

$$\text{so} \quad \underbrace{V_{r_0} - V_0}_{\text{keep a diff!}} = \int_0^{r_0} -\frac{h}{\varepsilon_0} \frac{r_0^2}{4} dr_0 = -\frac{h}{\varepsilon_0} \frac{r^3}{12}$$

F I

set 0

$$\cancel{V_\infty} - V_a = \int_a^\infty -\frac{h}{4\varepsilon_0} \frac{a_0^4}{r^2} = \frac{h a_0^4}{4\varepsilon_0} \left(\frac{1}{\infty} - \frac{1}{a} \right) =$$

$$= -\frac{h a_0^4}{4\varepsilon_0}$$

add both @ a

$$-V_0 = -\frac{h}{\varepsilon_0} \frac{a_0^3}{12} - \frac{h}{\varepsilon_0} \frac{a_0^3}{4} = -\frac{h}{\varepsilon_0} \frac{a_0^3}{3}$$

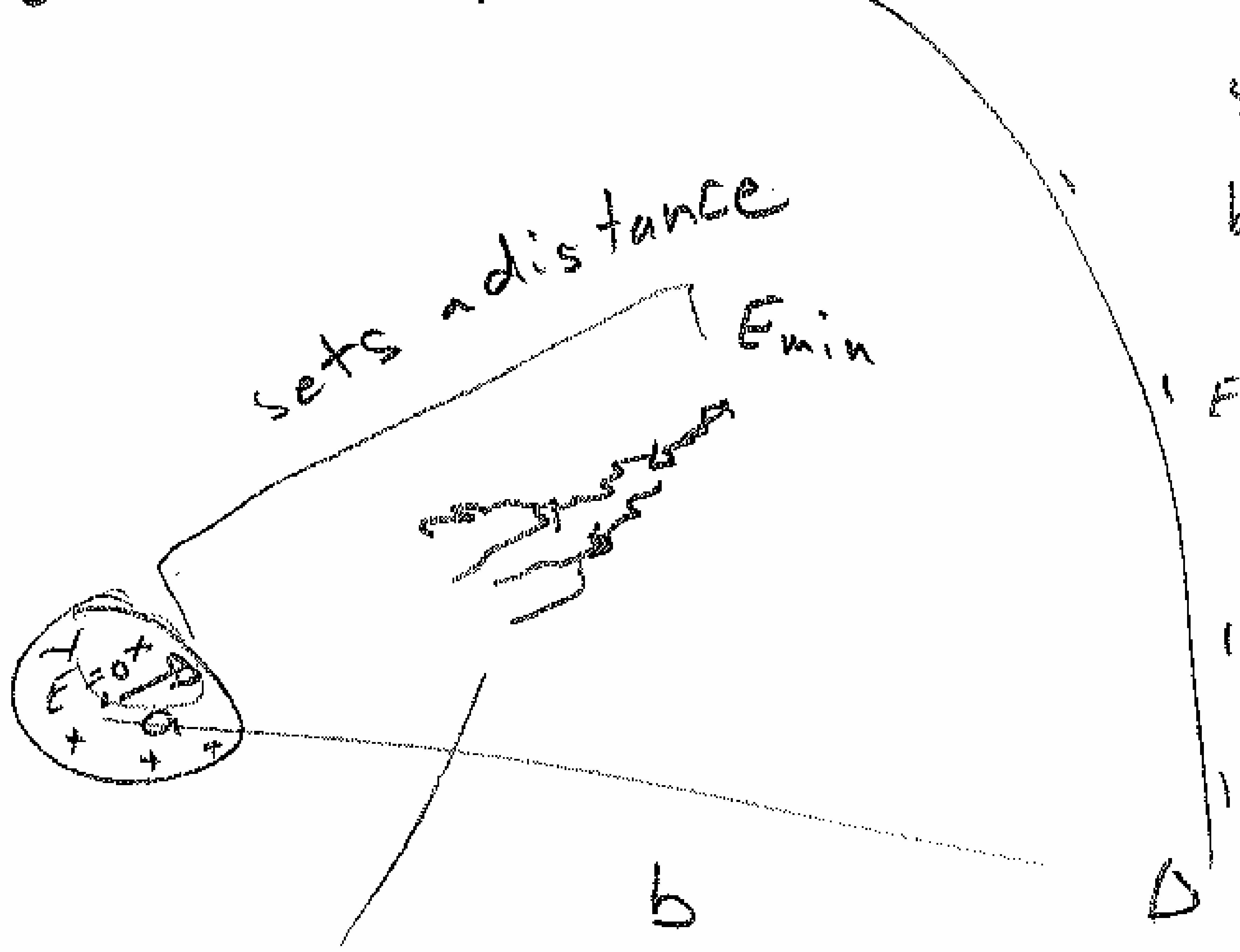
$$V_{r_0} \text{ inside} = V_0 - \frac{h}{\varepsilon_0} \frac{r^3}{12} = \frac{h}{\varepsilon_0} \frac{a_0^3}{3} - \frac{h}{\varepsilon_0} \frac{r^{3 \to a}}{12} = \frac{h a_0^4}{12\varepsilon_0}$$

Finally, we can use this breakdown crap to our advantage. Consider a breakdown an opportunity. 5

If we approach it quantitatively, each free electron will create 2 more every time it accel enough to bash one out (part of reason for Breakdown, you can have leakage w/o breakdown too!)

consider a tube w/a wire down the center

surrounded by a shield



recal

$= \frac{2k\lambda}{r}$

$E_{min} = \frac{2k\lambda}{s_{min}}$

↑ gas

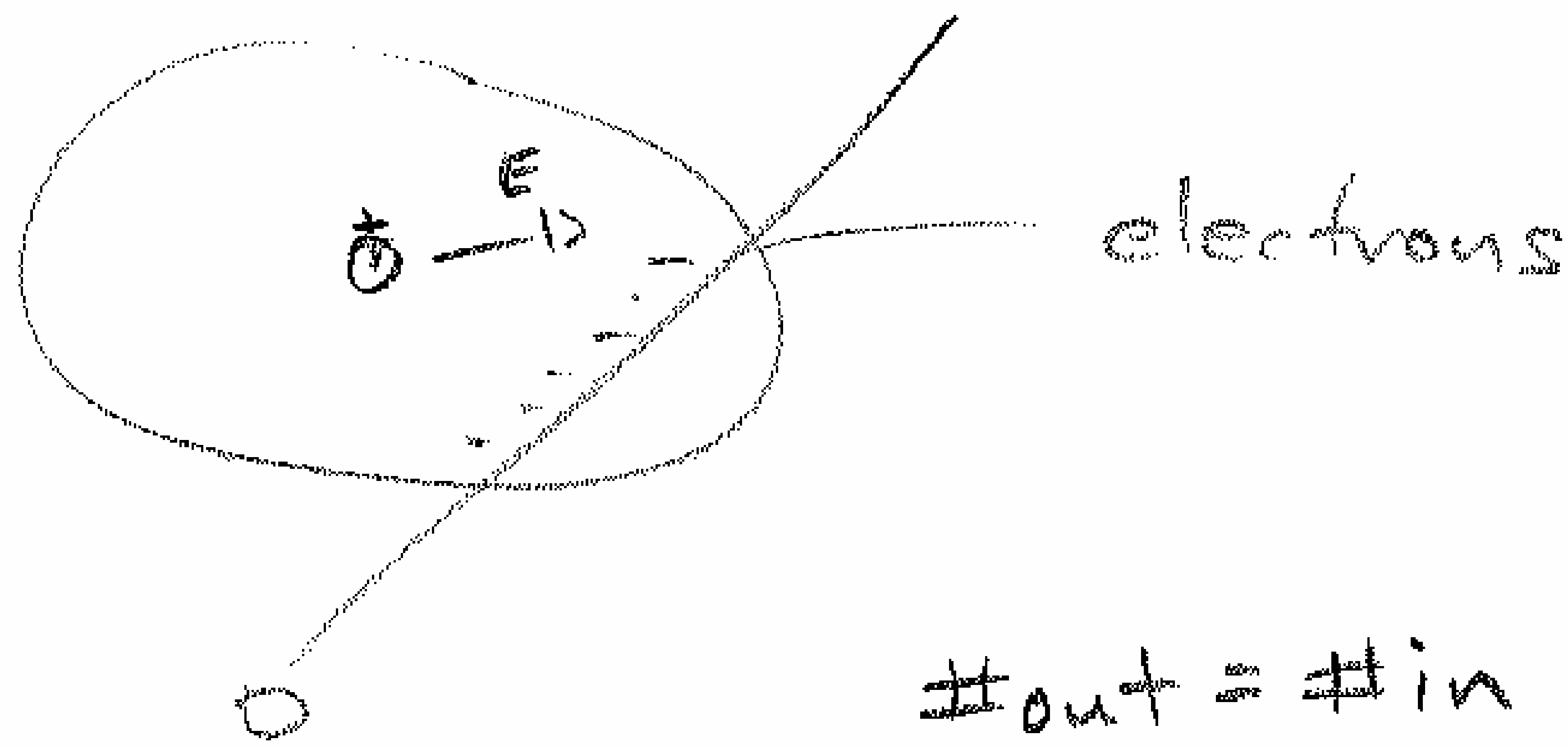
like a coax cable

Start getting an avalanche

So we just need to know how much ΔV between s_{min} & and how much energy it takes to knock out ΔV_{gas}

$\Delta V / \Delta V_{gas}$ = # of times electrons double so, if we have a cosmic ray going into the tube we can look for a signal From # electrons it makes when it goes in!

6



$$\#_{out} = \#_{in}\, 2^{\Delta V/\Delta V_{gas}}$$

(other stuff here with gas, not consider now)

use P10 $\quad E_{min} = 48\ kV/cm = 4.8\times10^{6}\ V/m$

(similar to air)

our tube $\quad b = 5\,cm\ (0.05\,m)$ $\quad \lambda = ?$
$\qquad\qquad a = 15\,\mu m\ (1\times10^{-5}\,m)$

goal $\frac{out}{in} = \sim 10^{4}$

put a potential diff across

check 1800V

consider

$$V_b - V_a = -\int_a^b \frac{2k\lambda}{r}\,dr = -2k\lambda(\ln(b)-\ln(a)) = -2k\lambda\ln(b/a)$$

convention $\cancel{V_b} \Rightarrow 0$

$$-V_a = 2k\lambda\ln(b/a) \Rightarrow 2k\lambda = \frac{V_a}{\ln(b/a)}$$

curious, $s_{air} = ?$

$$s_{min} = \frac{V_a/\ln(b/a)}{4.8\times10^{6}\,V/m} = \frac{1800V/\underbrace{\ln\left(\frac{0.05}{15\times10^{-6}}\right)}_{8.112}}{4.8\times10^{6}\,V/m} = 4.6\times10^{-5}m!$$

not to far out!

$\Delta V_{gas} = 23.6 \pm 5.4\,V$

↑not worry about! for now

$$\Delta V_{S_0\,a} = -\int_{S_0}^{a} \frac{2k\lambda}{r}\,dr = -\ln(S_0/a)(2k\lambda) = \frac{V_a}{\ln(b/a)}\ln(S_0/a)$$

$$\#\text{ of doublings} = \frac{\frac{V_a}{\ln(b/a)}\ln(S_0/a)}{\Delta V_{gas}} = \frac{\frac{1800V}{8.112}\ln\left(\frac{46}{15}\right)}{23.6V}$$

$= 10.54$

$2^{10.54} = 1500$ more Voltage!

@1900

$= 11.66$

$\Rightarrow 2^{11.66} = 3236$

@ 2000

$= 12.81$

$\Rightarrow 2^{12.81} = 7181$

somewhere between!

@2100

$= 13.98$

$\Rightarrow 2^{14} = 16384$