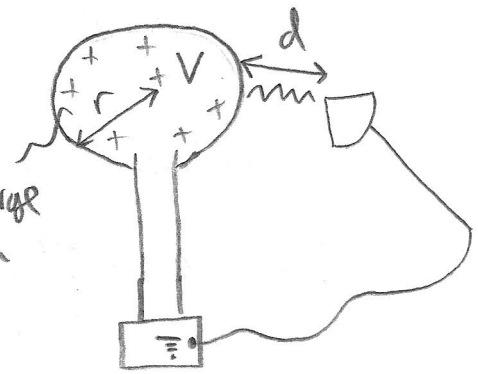
ELECTRIC FIELDS & CAPACITORS

1/ (i)



Van der Graaf generator

Spark when $\frac{V}{d} > 3.0\times10^{6}\,Vm^{-1}$ in air.

$\therefore V = 3.0\times10^{6}\,Vm^{-1} \times 0.15\,M$

$V = 450\,kV$

(ii) $r = 0.120\,m$. $C = 4\pi\varepsilon_0 r$ for a charged sphere.

$\therefore C = 4\pi \times 8.85\times10^{-12} \times 0.20 = 2.22\times10^{-11}\,F$

$Q = CV$ $\therefore$ $Q =$ above answer $\times 450\times10^{3}$ C

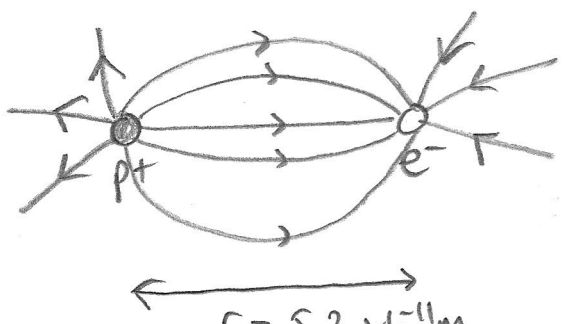
$= 1.00\times10^{-5}\,C$

$E = \frac{1}{2}CV^2$ $\therefore$ $E = \frac{1}{2}\times 2.2\times10^{-11}\times(450\times10^{3})^2$

$= 2.25\,J$

(which is why a Van der Graaf is impressively high voltage but not very dangerous, since actually very little charge is stored, and not much energy is discharged in a spark).

(iii)



$E(r) = \frac{e}{4\pi\varepsilon_0 r^2}$ Field strength at e^- caused by p^+.

$= \frac{1.602\times10^{-19}}{4\pi\times8.85\times10^{-12}\times(5.3\times10^{-11})^2}$

$= 5.13\times10^{11}\,V/m$

a huge!

Force on electron is $F = eE$

so above answer $\times 1.602\times10^{-19} = 8.22\times10^{-8}\,N$

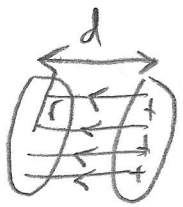
(iv) $\frac{f_E}{f_G} = \frac{\frac{e^2}{4\pi\varepsilon_0 r^2}}{\frac{GM_e^2}{r^2}} = \frac{e^2}{4\pi\varepsilon_0 G M_e^2}$

$= \frac{(1.602\times10^{-19})^2}{[4\pi\times8.85\times10^{-12}\times6.67\times10^{-11}\times(9.109\times10^{-31})^2]}$

$= \boxed{4.17\times10^{42}}$

So electric fores are Massively stronger than gravitational fores.

For a 'reasonable' 'human sized' gravitational fore, you need a planet-worth of mass.

(v) 

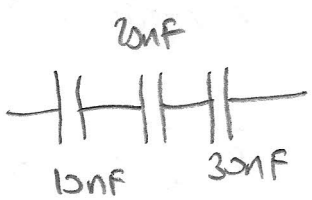
$\boxed{C = \frac{\varepsilon_0 \pi r^2}{d}} = 0.42\mu F$

$d \to d/2, \quad r \to 3r$

$\therefore C \to \frac{\varepsilon_0 \pi (3r)^2}{d/2} = \frac{18\varepsilon_0\pi r^2}{d}$

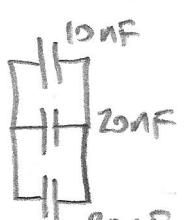
$= 18\times 0.42\,\mu F$

$= \boxed{7.56\,\mu F}$

(vii) a) 

$C = \frac{1}{\frac{1}{10}+\frac{1}{20}+\frac{1}{30}}$ nF

$C = \frac{60}{11} = \boxed{5\frac{5}{11}\,nF}$ $(5.45\,nF)$

b) 

$C = (10+20+30)\,nF$

$\boxed{C = 60\,nF}$