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Physics Midterm

20/20

yay!

1. a) at $r = 1mm$ $\quad \mathcal{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

$E = 2\times10^{-3}$ $\quad 2\times10^{-3} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(1\times10^{-3})^2}$

$(2\times10^{-3})(1\times10^{-6}) = \frac{q}{4\pi\varepsilon_0}$

Value at $r = 5mm$

$\mathcal{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(5\times10^{-3})^2}$

$\mathcal{E} = 2\times10^{-3}\times10^{-6}\cdot\frac{1}{25\times10^{-6}}$

$\mathcal{E} = 0.08\times10^{-3} \Rightarrow \boxed{8\times10^{-5}\ V/m}$

b) $1\mu C$ charge $\mathcal{E}_c = 8.00\times10^{-5}\ V/m$

in this the electric field is 3X bigger so we need to multiply $(8\times10^{-5} V/m)$ 3 times 3 because it is a scaling problem

$\hookrightarrow \boxed{= 24\times10^{-3}\ V/m}$

2. a) mass $= 4\times10^{-16}$ kg $\quad$ Electric field $= 6131.25$ N/C

let Charge $= q$

$qE = mg$

$q = \frac{mg}{E} \rightarrow q = \frac{4\times10^{-16}\times9.8}{6131.25} \Rightarrow q = 6.39\times10^{-19}$

We know $q = ne$

$\frac{q}{e} = n \rightarrow n = \frac{6.39\times10^{-19}}{1.6\times10^{-19}} \approx 3.99 \Rightarrow \boxed{n = 4 \text{ electrons}}$

b) If one electron removed...

$q' = q - e = 4.793\times10^{-19}$

* Find the forces with an electron removed, find the mass with an electron removed, then find acceleration

Electrostatic Force $= qE$ (Fe)

$Fe = q'E \rightarrow Fe = (4.7934\times10^{-19})(6131.25) = 29\times10^{-5}$

mass of drop is

$m' = m - m_e \approx 4.0\times10^{-16}$ kg

Gravitational Force

$Fg = m'g$

$= 4.0\times10^{-16}\times9.8 \Rightarrow \boxed{Fg = 3.92\times10^{-15} N}$

Acceleration

$a = \frac{Fg - Fe}{m} \rightarrow \frac{3.92\times10^{-15} - 2.939\times10^{-15}}{4\times10^{-16}}$

$\boxed{a = 2.45\ m/s^2}$

Potential Energy & Voltage, Capacitors

1. a) $KE = qV$

$KE_{hydrogens} = (1.6\times10^{-19})(4\times10^{3})$

$= 6.4\times10^{-16}\,J$ $\boxed{\Rightarrow 3995 \text{ electron-volts}}$

$1J = 6.242\times10^{18}$ $(6.4\times10^{-16})(6.242\times10^{18}) = 3994.88$

$\boxed{\text{Total}: 11985 \text{ electron-volts}}$

$KE_{Helium} = (2\times10^{-19})(4\times10^{3})$

$= 12.8\times10^{-16}\,J$ $\boxed{\Rightarrow 7990 \text{ electron-volts}}$

$1J = 6.242\times10^{18}$ $(12.8\times10^{-16})(6.242\times10^{18}) = 7989.76$

you can just say 4 keV, 8 keV 12 keV etc.

b) $E = -\frac{\Delta V}{\Delta x} \rightarrow -\frac{4\times10^{3}}{5\times10^{-2}}$ $\boxed{= -8\times10^{4}\ V/m}$

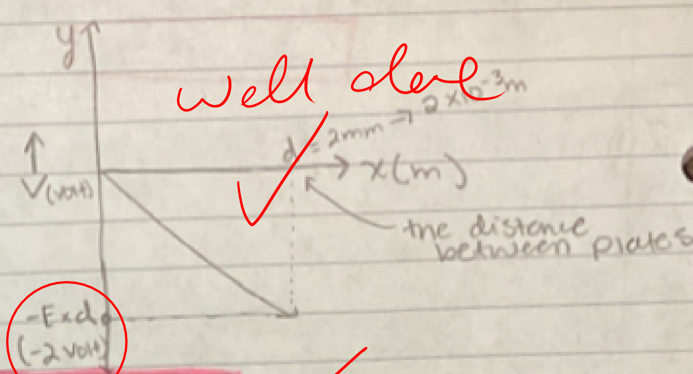
($5cm \rightarrow 5\times10^{-2}m$)

2. $\mathcal{E} = 1000\ V/m$

$\rightarrow \mathcal{E} = \frac{-dV}{dx}$ or $V = -\mathcal{E}\times x$

Slope $= -1000\ V/m$

$\boxed{\text{- y intercept is zero}}$



well done

*graph is between V & x is straight line w/ -ve slope

3. a) $C = \frac{\varepsilon_0 A}{d} = \frac{8.85\times10^{-12}\times10^{-4}}{2\times10^{-3}}$ $\boxed{= 4.425\times10^{-13}F}$

b) Energy $= \frac{1}{2}CV^2$

$= \frac{1}{2}(4.425\times10^{-13})(5)^2$

$\boxed{= 5.5\times10^{-12}\,J}$

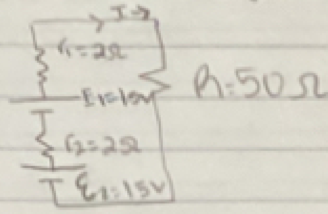
4. To get a system with more capacitance, we should connect the identical capacitors in parallel because in parallel combination capacitance gets added up in parallel combination

$C_{net} = C_1 + C_2 = 2C$

but in series C_{net} becomes $C/2$ so the inverse

Current, Resistance, and DC circuits

1. a) Serial case (3V)



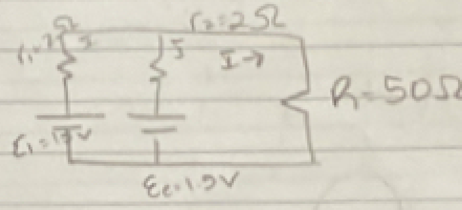
Kirchoff's rule

$-\mathcal{E}_2 + Ir_2 + Ir_1 - E_1 + IR = 0$

$I = \frac{3V}{r_1+r_2+R} = \frac{3}{2+2+50} = \frac{3}{54}$

$= 0.0555\,A \rightarrow \boxed{55.6mA}$

Parallel case



$I = I_1 + I_2$

$\mathcal{E} = 1.5V$ the system is in Parallel

$I = \frac{V}{R}$

$I = \frac{1.5}{50} \rightarrow 0.03 \Rightarrow \boxed{30mA}$

b) Power consumption series

$P = IV$

$V_{tot} = V_1 + V_2$

$P = (55.6 \times 10^{-3})(3) = 0.1668W$

$\boxed{= 166.8mW}$

Power consumption Parallel

$P = IV$

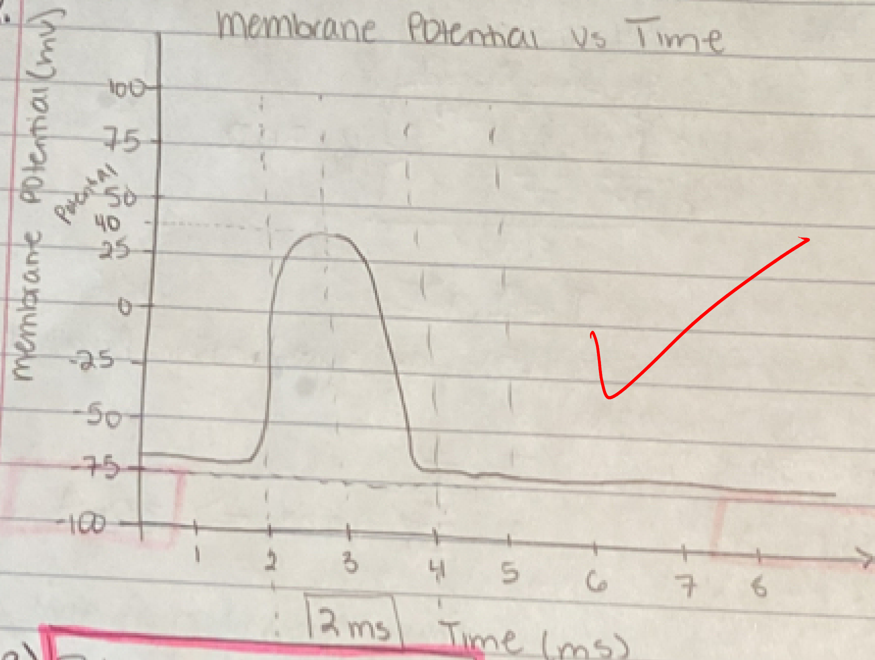
$V_{tot} = 1.5V$

$P = (30 \times 10^{-3})(1.5) = 0.045$

$\boxed{= 45mW}$

c) Checked on PhET ✓ correct

2.



a) $\boxed{\text{Pulse width is } 2\text{ ms}}$

b) Peak to Peak voltage

$= 40 - (-75)$

$= 40 + 75$

$\boxed{V_{peak\,peak} = 115\text{ mV}}$