

Physics Mid-Term

* Electric Charge & Electric Fields *

1) a)

$$E = \frac{1}{4\pi\epsilon_0} \left(\frac{q}{r^2} \right)$$

$$2 \times 10^{-3} = \frac{1}{4\pi\epsilon_0} \frac{q}{(1 \times 10^{-3})^2}$$

$$(2 \times 10^{-3})(1 \times 10^{-3})^2 = \frac{q}{4\pi\epsilon_0}$$

$$E = 2 \times 10^{-3}$$

$$r = 1 \text{ mm}$$

at 5mm:

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{(5 \times 10^{-3})^2}$$

$$= 2 \times 10^{-3} \times 10^{-6} \left(\frac{1}{25 \times 10^{-6}} \right)$$

$$= 0.08 \times 10^{-3}$$

$$E = \boxed{8 \times 10^{-5} \frac{\text{V}}{\text{m}}}$$

b) $E = \frac{1}{4\pi\epsilon_0} \frac{3q}{r^2}$

$$E = 8 \times 10^3 \times 3q$$

$$\boxed{E = 24 \times 10^3 \frac{\text{V}}{\text{m}}}$$

Electric field is 3 times bigger and due to

scaling problem we multiply 8×10^3 by 3.

2) $m = 4 \times 10^{-16} \text{ kg}$

a) $E = 6131.25 \text{ N/C}$

$$q = \frac{mg}{E} = \frac{4 \times 10^{-16} \times 9.8}{6131.25}$$

$$= 6.39 \times 10^{-19}$$

$$q = ne \rightarrow n = \frac{q}{e}$$

$$\boxed{n = 4 \text{ electrons}}$$

b) $q' = \frac{mg}{E} = e \rightarrow \frac{(4 \times 10^{-16})(9.8)}{6131.25} + 1.6 \times 10^{-19} \rightarrow 4.79 \times 10^{-19}$ electrostatic force

$F_e \uparrow$

$F_g \downarrow$

$$F_e = q'E = (4.79 \times 10^{-19})(6131.2) \rightarrow 2.939 \times 10^{-15}$$

mass of drop = $4 \times 10^{-16} \text{ kg}$

$$F_g = mg \rightarrow (4 \times 10^{-16})(9.8) = \boxed{3.92 \times 10^{-15} \text{ N}}$$
 gravitational force

$$a = \frac{F_g - F_e}{m} \rightarrow \frac{3.92 \times 10^{-15} - 2.939 \times 10^{-15}}{4 \times 10^{-16}}$$

acceleration

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

downwards

★ Potential Energy and Voltage, Capacitors ★

1) a) $KE = qV$

$q = 1.6 \times 10^{-19} \text{ A}$

$KV = 4 \times 10^3 \rightarrow V = 4 \times 10^3$

$KE_{\text{hydrogens}} = (1.6 \times 10^{-19})(4 \times 10^3) \quad (\text{conversion})$
 $= 6.4 \times 10^{-16} \text{ J} \times 6.242 \times 10^{18}$
 $= \boxed{3994.5 \text{ eV}}$

$KE_{\text{He}} = 2 \times 10^{-19} \times (4 \times 10^3) \quad (\text{conversion})$
 $= 12.8 \times 10^{-16} \text{ J} \times 6.242 \times 10^{18}$
 $= \boxed{7990 \text{ eV}}$

$\rightarrow \boxed{\text{Total eV} = 11984.5}$

b) $E = -\frac{\Delta V}{\Delta x}$

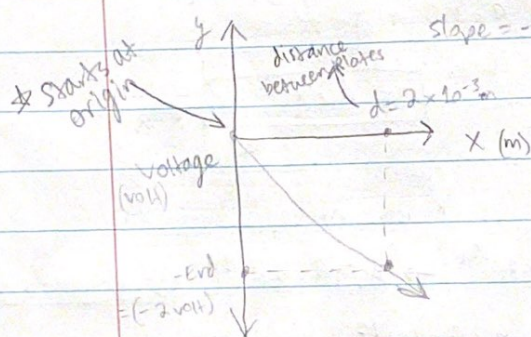
$\Delta x = 5 \text{ m} \rightarrow 5 \times 10^{-2} \text{ m}$

$\Delta V = 4 \times 10^3$

$E = \frac{4 \times 10^3}{5 \times 10^{-2}} = \boxed{8 \times 10^4 \text{ V/m}}$

2) $E = -\frac{dV}{dx} \text{ or } V = -E \times X$

$E = 1000 \text{ V/m}$



* when distance is zero \rightarrow voltage does not exist
 * can't divide by 0

3) a) $C = \frac{\epsilon_0 A}{d}$

$\epsilon_0 = 8.85 \times 10^{-12}$

$= 8.85 \times 10^{-12} \times 10^{-4}$
 2×10^{-3}

$A = \text{km}^2 = \frac{1 \text{ m}}{1000 \text{ m}} \times \frac{1 \text{ m}}{1000 \text{ m}} = 10^{-6} \text{ m}^2$

$= \boxed{4.425 \times 10^{-13} \text{ F}}$

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

$= \frac{1}{2} (4.425 \times 10^{-13}) (5^2)$

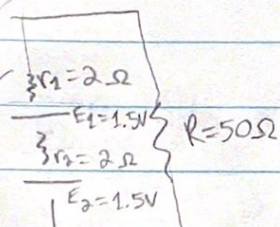
$= 2.2 \times 10^{-13} \text{ (25)}$

$= \boxed{5.53 \times 10^{-12} \text{ J}}$

A) We should connect the identical capacitor in parallel because it will allow a system to store more energy or have more capacitance by $C_{tot} = C_1 + C_2$ while in series is $C_{tot} = \frac{1}{C_1} + \frac{1}{C_2}$.

★ Current, Resistance, and DC circuits ★

1) a)
Series



$I = ?$

$$E_1 + E_2 + E_3 + \dots = 0$$

$$E_1 - I r_1 - I r_2 - I R + E_2 = 0$$

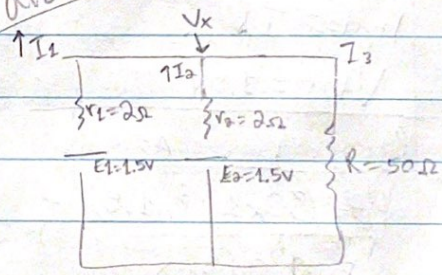
$$E_1 + E_2 = I(r_1 + r_2 + R)$$

$$I = \frac{E_1 + E_2}{r_1 + r_2 + R}$$

$$\frac{1.5 + 1.5}{2 + 2 + 50} = \frac{3}{54} = 0.055 \text{ A} \times 1000$$

$$\text{Series } I = 55.6 \text{ mA}$$

Parallel



batteries are parallel $E = 1.5 \text{ V}$

$$I = \frac{V}{R} \quad I = \frac{1.5}{50}$$

$$I = 30 \text{ mA}$$

1) b) Power Consumption \rightarrow Series

$$P = IV$$

$$V_{tot} = V_1 + V_2$$

$$= 1.5 + 1.5$$

$$V_{tot} = 3$$

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

$$= 0.1668 \times 1000$$

$$P = 166.8 \text{ mW}$$

Power Consumption \rightarrow Parallel

$$P = IV$$

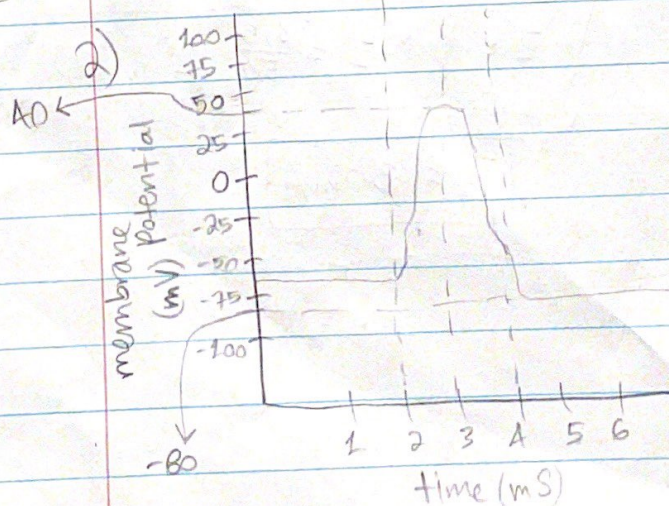
$$V_{tot} = 1.5V$$

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

$$= 0.045 \times 1000$$

$$P = 45 \text{ mW}$$

c) Checked on PhET DC ✓



a) Pulse width = 2ms

b) highest peak = 40mV

(lowest peak = -80mV)

$$40 - (-80)$$

$$40 + 80 = 120 \text{ mV}$$