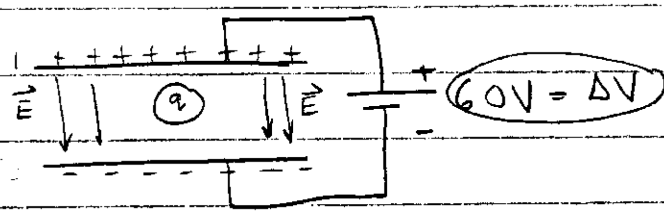
HW#2 SOL^N - ADAM COHEN

Chapter 16 — Electric Energy

(4)



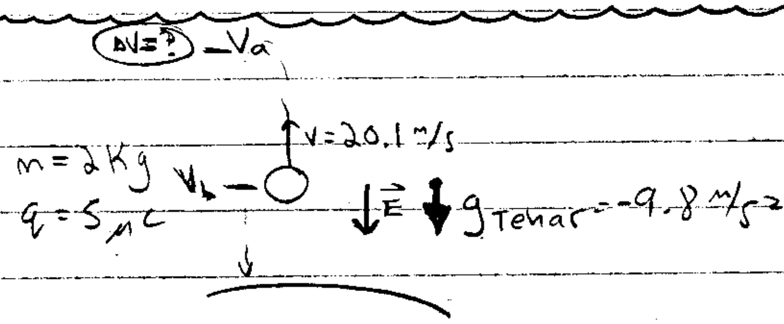
potential difference : $\Delta V = \dfrac{\Delta PE}{q}$

$$\Rightarrow \quad q = \frac{\Delta PE}{\Delta V} = \frac{-1.92\times10^{-17}\,J}{60\,V}$$

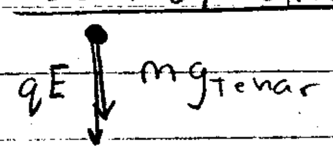
$$= -3.2\times10^{-19}\ C$$

$$\boxed{q \approx -2e}$$

(10) $(\Delta t = 4.1\,s)$



FREE-BODY DIAGRAM



- want to ΔV from $y_{initial} \longrightarrow y_{top}$
- this is a uniform electric field so, it holds that:

$$|\Delta V| = E\,\Delta y = E\,(y_{top} - y_{initial})$$

- So, we need to know the magnitude of the electric field and the change in height.

(I) Use Kinematics to get Δy:

- first get acceleration on Tehar due to gravity (mass) and due to electricity (charge)

recall: $\Delta y = V_o t + \frac{1}{2} a t^2$

- for the entire flight $\Delta y = 0$ since the mass returns to its initial position

$$\Rightarrow \frac{0}{t} = \frac{V_o t + \frac{1}{2} a t^2}{t}$$

$$0 = V_o + \frac{1}{2} a t$$

$$\frac{\cancel{\frac{1}{2}} a \cancel{t}}{\cancel{\frac{1}{2} t}} = \frac{-V_o}{\frac{1}{2} t}$$

$$a = \frac{-2V_o}{t} = \frac{(-2)(20.1\,m/s)}{4.1s} \approx -9.8\,m/s^2 \approx g_{Tehar}$$

recall: $V_f^2 = V_i^2 + 2a\Delta y$

- apply this only to the upward part of the flight

$\Rightarrow V_f = 0$

so, $0 = V_i^2 + 2a\Delta y$

con't →

• now solve for Δy

$$\Delta y = \frac{-v_i^2}{2a} = \left(\frac{-(20.1)^2}{2(-9.8)}\right)m = 20.6\,m$$

So $\Delta y = 20.6\,m$ = change in height from top to bottom of path ✓

(II) get E from Newton's 2ND Law:

$$\left(\sum F = ma\right)_y$$

$$-F_{grav} - F_{elec} = ma$$

$$-mg - qE = ma$$

solve for E: $-qE = ma + mg$

$$E = -\frac{m}{q}(a+g)$$

BUT here that small difference between a and g is important, so re-use $a = -2v_0/t$, $g = 9.80\,m/s^2$

$$\Rightarrow \quad E = \frac{m}{q}\left(\frac{2v_0}{t} - g\right) = \cdots = 1.95 \times 10^3\,N/C$$

✓

FINALLY! have E & Δy

So: $\Delta V = E\,\Delta y$

$$= (20.6\text{ m})(1.95\times10^{3}\text{ N/C})$$

$$\boxed{\Delta V = 4.02\times10^{4}\text{ V}}$$

* try using energy conservation:
$E_i = E_f$

(11) (a) the electric potential due to a point charge:

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

here $\begin{cases} K = \text{Coulomb's constant} \\ q = +e = \text{charge of proton} \\ r = 1\text{cm} = 0.01\text{ m} \end{cases}$

$$\Rightarrow \boxed{V = 1.44\times10^{-7}\text{ V}}$$

(b) $\Delta V = V_{(1cm)} - V_{(2cm)} = \dfrac{Kq}{(0.01)\text{m}} - \dfrac{Kq}{(0.02)\text{m}}$

$$\boxed{\Delta V = 7.19\times10^{-8}\text{ V}}$$

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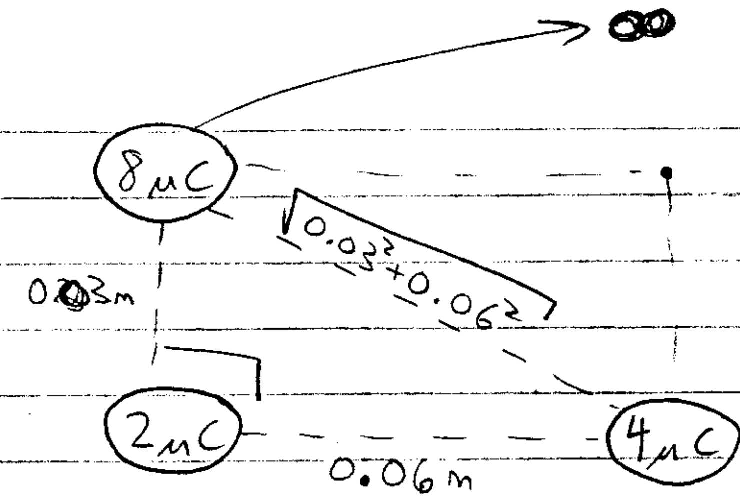


- the work to move the 8μC from its current location to ∞ is:

$$W = q\,\Delta V = q(V_\infty - V_i)$$

- at ∞, $V_\infty = 0$, since the charge is far away . . . .

$$\left(V = \frac{Kq}{r},\ \text{as } r \to \infty,\ V \to 0 \right)$$

- V_i is electric potential due to 2μC and 4μC charges
- recall, potential can be superimposed

$$\Rightarrow \quad V_i = V_{\text{due to } 2\mu C} + V_{\text{due to } 4\mu C}$$

$$= \frac{K(2\mu C)}{r_{2\to 8}} + \frac{K(4\mu C)}{r_{4\to 8}}$$

$r_{2\to 8} = 0.03\text{m}$

$r_{4\to 8} = \sqrt{0.03^2 + 0.06^2}$ by Pythagorus

$= 0.067\text{ m}$

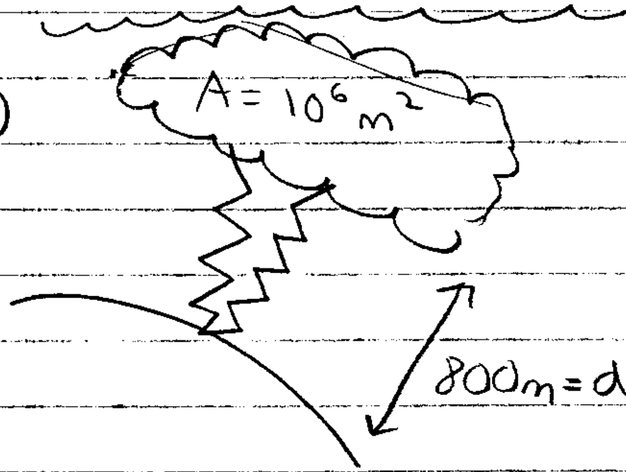
$V_i = \cdots = 1.135 \times 10^6$ V

plugging & chugging

so $W = -q V_i = -(8\,\mu C)(\quad)$

$$\boxed{W = -9.08\ J}$$

(23)



$$C = \frac{\epsilon_0 A}{d}$$

(a)

$$\boxed{C = 1.1 \times 10^{-8}\ F}$$

capacitance is defined as: $C \equiv \frac{Q}{\Delta V}$

so $Q_{max} = C\,\Delta V_{max} = C\,(E_{max}\, d)$

for infinite plates

- use C from (a)
- $E_{max} = 3 \times 10^6$ N/C

$\Rightarrow$ $\boxed{Q_{max} = 27\ C}$

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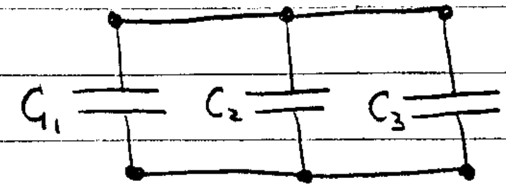
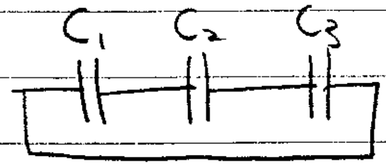


in parallel: $C_{eq} = C_1 + C_2 + C_3$

$$= (5 + 4 + 9)\mu F$$

$$= 18\,\mu F$$



in series: $\dfrac{1}{C_{eq}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$

$$\frac{1}{C_{eq}} = \frac{1}{5\mu F} + \frac{1}{4\mu F} + \frac{1}{9\mu F}$$

$$\frac{1}{C_{eq}} = 0.2 + 0.25 + 0.\overline{11111}$$

$$C_{eq} = \frac{1}{0.56} = 1.78\,\mu F$$

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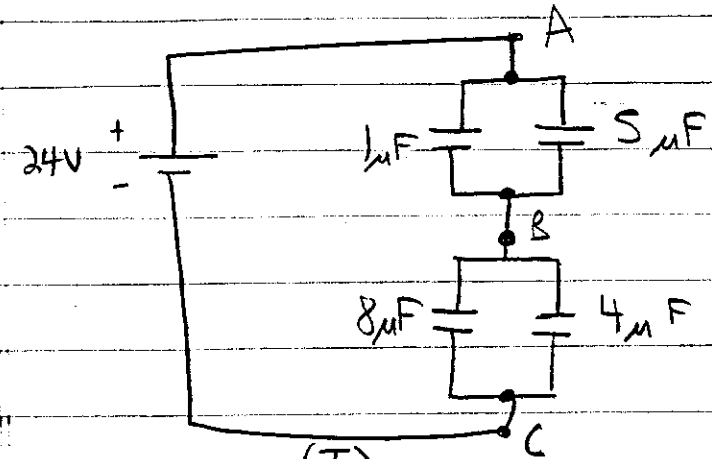


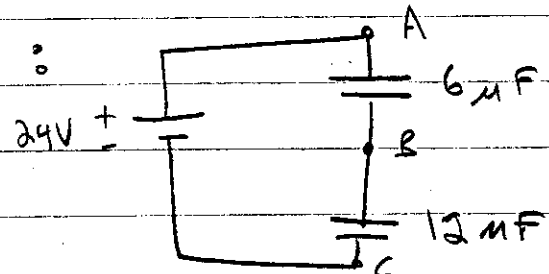
(I)

This circuit seems like a mess!
Let's clean it up by making equivalent circuits!
We can combine C_1 and C_5 (they are in parallel.)

by $C_{15} = C_1 + C_5 = 6\,\mu F$

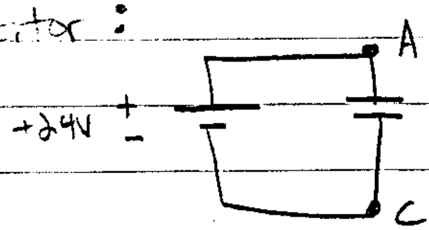
Similarly: $C_{84} = C_8 + C_4 = 12\,\mu F$

Now:



II

Further, we can make 1 equivalent capacitor:



$$\frac{1}{C_{eq}} = \frac{1}{6\,\mu F} + \frac{1}{12\,\mu F} \quad \text{(in series)}$$

$$\Rightarrow C_{eq} = 4\,\mu F$$

So the charge accross our simplest capacitor is:

$$Q_{AC} = C\,\Delta V = (4\,\mu F)(24\,V)$$
$$= 96\,\mu C$$

*FACT: Series capacitors have the same charge, so:

$Q_{AC} = Q_{AB} = Q_{BC}$ (from our 2^{nd} diagram)

$$\Delta V_{AB} = \frac{Q_{AB}}{C_{AB}} = \frac{Q_{AC}}{C_{AB}} = \frac{96\,\mu C}{6\,\mu F} = 16\,V$$

and

$$\Delta V_{BC} = \frac{Q_{AC}}{C_{BC}} = \frac{96\,\mu C}{12\,\mu F} = 8\,V$$

and $16\,V + 8\,V = 24\,V$ = the voltage accross the battery, so the loop rule holds!

Finally, move back to our original circuit

con^{t} ⟶

* FACT : parallel capacitors have the same voltage drop.

so,

① $\Delta V_{AB} = \Delta V_1 = \Delta V_5 = 16\,V$

so $Q_1 = C_1 \Delta V_1 = (1\,\mu F)(16\,V)$

$Q_1 = 16\,\mu C$

$Q_5 = (5\,\mu F)(16\,V)$

$Q_5 = 80\,\mu C$

② $\Delta V_{BC} = \Delta V_8 = \Delta V_4 = 8\,V$

$Q_8 = (8\,\mu F)(8\,V)$

$Q_8 = 64\,\mu C$

$Q_4 = (4\,\mu F)(8\,V)$

$Q_4 = 32\,\mu C$

(a) in parallel:

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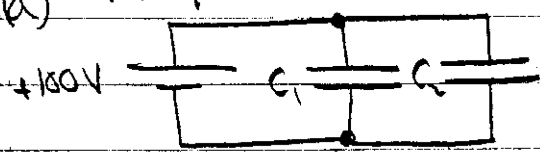
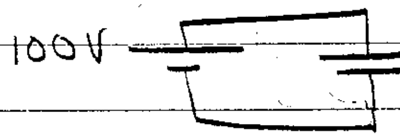


$$\begin{cases} C_1 = 25\,\mu F \\ C_2 = 5\,\mu F \end{cases}$$

$\Updownarrow$



$C_{12} = C_1 + C_2 = 30\,\mu F$

energy stored $= \frac{1}{2} C (\Delta V)^2$

$= \frac{1}{2}(30\,\mu F)(100\,V)^2$

$= \frac{1}{2}(30 \times 10^{-6}\,F)(100\,V)^2$

$= 0.15\,J$

(b) in series:

again, build equivalent circuit

$$\frac{1}{C_{12}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{25} + \frac{1}{5}$$

$\Rightarrow C_{12} = 4.17\,\mu F$

energy stored $= E = \frac{1}{2} C \Delta V^2$

solve for ΔV : $\Delta V = \sqrt{\frac{2E}{C}}$

to get $E = 0.15\,J$ from $4.17\,\mu F$,

$$\boxed{\Delta V = 268\,V}$$