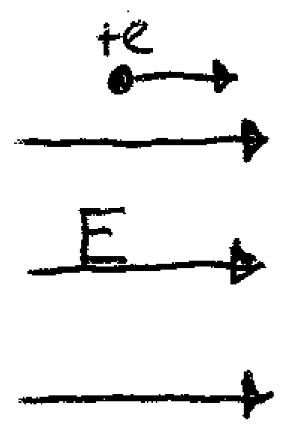
# Week 2 CH16

Phys 1B
Solutions
Summer 2010

1 a)



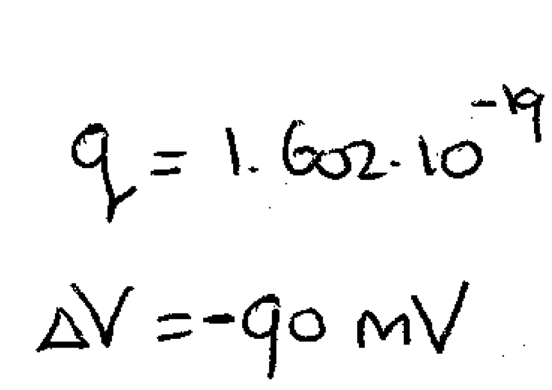

$$\left.\begin{array}{l} E = 200\ N/C \\ q = 1.602\cdot 10^{-19}\,C \\ \Delta x = 2.00\,cm = 2\cdot 10^{-2}\,m. \end{array}\right\} W = qE\Delta x = 6.41\cdot 10^{-19}\,J$$

b) $W = -\Delta PE \Rightarrow \Delta PE = -6.41\cdot 10^{-19}\,J$

c) $\Delta V = \Delta PE/q = -4.00\,V.$

note: An electron would lose 4V if it did the same motion. The proton looses potential energy going along the electric field lines, therefore $\Delta PE$ is negative and $q$ is positive. Hence $\Delta V$ is negative. The electron would gain potential energy but $q$ is negative; Hence $\Delta V$ is still negative.

3)




$$\left.\begin{array}{l} \Delta PE = -W \\ \Delta PE = q\Delta V \end{array}\right\} W = -q\Delta V$$

$$\left.\begin{array}{l} q = 1.602\cdot 10^{-19}\,C \\ \Delta V = -90\,mV \end{array}\right\} 1.4\cdot 10^{-20}\,J$$

note: $q = 1.602\cdot 10^{-19}\,C$, because the net charge of a sodium ion is $+1e$.

$\Delta V$ is negative, because the ion moves from negative to positive, against the field lines.

6) $W = -q\,\Delta V$

$q = 3.6\cdot10^{5}\,C$

$\Delta V = -12\,V$

$W = 4.3\cdot10^{6}\,J$

see problem 3 for why $\Delta V$ is negative

8a) $W = -q\,\Delta V$

$q = 1.602\cdot10^{-19}\,C$

$\Delta V = 120\,V$

$W = -1.92\cdot10^{-17}\,J$

By the work/energy theorem $W = -\Delta KE$ Hence

$\Delta KE = 1.92\cdot10^{-17}\,J$

$\Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2$ but $v_o = 0$ thus

$m = 1.67\cdot10^{-27}\,kg$

$\Delta KE = 1.92\cdot10^{-17}\,J$

$\Delta KE = \frac{1}{2}mv_f^2$ $\quad v_f = \sqrt{\frac{2\Delta KE}{m}} = 1.52\cdot10^{5}\,m/s$

b) to be precise, the electron will accelerate in the opposite direction and $\Delta V$ should be $-120V$, but this is still considered a difference of 120V.

$q$ and $\Delta V$ are equal and thus $\Delta KE$ stays the same: $\Delta KE = 1.92\cdot10^{-17}\,J$

The only thing that changes is $m$ $\quad m = 9.11\cdot10^{-31}\,kg$ Hence

$v_f = \sqrt{\frac{2\Delta KE}{m}} = 6.49\cdot10^{6}\,m/s$

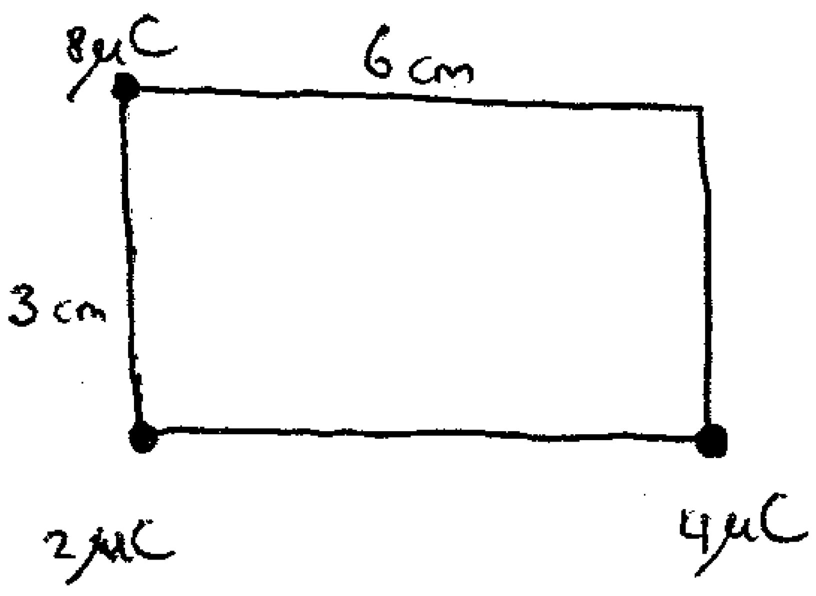
5) $\Delta V = -E\,\Delta x$

$\Delta V = 2.5\cdot10^{4}\,V$

$\Delta x = 1.5\cdot10^{-2}\,m$

$E = \frac{-\Delta V}{\Delta x} = -1.67\cdot10^{6}\,V/m$ since we only need the magnitude:

$|E| = 1.7\cdot10^{6}\,V/m = 1.7\cdot10^{6}\,N/C$ (note the two units are the same).

13a) 

$V_\phi = k_e \, q/r$ since $V$ is a scalar, the three individual voltages can just be added:

$V_1$: $q_1 = 8 \cdot 10^{-6}\,C$, $r = 0.06\,m$ $\Big\}$ $V_1 = 1.20 \cdot 10^6\,V$

$V_2$: $q_2 = 4 \cdot 10^{-6}\,C$, $r = 0.03\,m$ $\Big\}$ $V_2 = 1.20 \cdot 10^6\,V$

$V_3$: $q_3 = 2 \cdot 10^{-6}\,C$, $r = \sqrt{3^2+6^2} = 0.0671\,m$ $\Big\}$ $V_3 = 2.68 \cdot 10^5\,V$

$V = V_1 + V_2 + V_3 = 2.67 \cdot 10^6\,V$

b) If $2\mu C$ is replaced with $-2\mu C$ then $V_3 = -2.68 \cdot 10^5\,V$ Hence

$V = V_1 + V_2 + V_3 = 1.20 \cdot 10^6\,V + 1.20 \cdot 10^6\,V + (-2.68 \cdot 10^5\,V) = 2.13 \cdot 10^6\,V$

15 a) 

Halfway in between, $r = 17.5\,cm$. Hence,

$V_1 = k_e \, q/r$, $q = 5 \cdot 10^{-9}\,C$, $r = 0.175\,m$ $\Big\}$ $V_1 = 257\,V$

$V_2 = k_e \, q/r$, $q = -3 \cdot 10^{-9}\,C$, $r = 0.175\,m$ $\Big\}$ $V_2 = -154\,V$

$V = V_1 + V_2 = 257 + (-154) = 103\,V.$

b) $\Delta PE = k_e \, q_1 q_2 / r$

$q_1 = 5 \cdot 10^{-9}\,C$

$q_2 = -3 \cdot 10^{-9}\,C$

$r = 0.35\,m$

$\Big\}$ $\Delta PE = -3.85 \cdot 10^{-7}\,J$

Since PE is $-$ $W = -\Delta PE$ is positive. Hence, work needs to be done to seperate the two charges. If the charges had the <u>same</u> sign, then no work needs to be done (the two charges would repel).

16) $V = k_e\, q/r$ $\quad k_e = 8.99 \cdot 10^{9}\ \mathrm{N\,m^2/C^2}$

$$\left.\begin{array}{ll} q = 9 \cdot 10^{-9}\,\mathrm{C} & r = 0.3\,\mathrm{m} \end{array}\right\} V = 270\,\mathrm{V}$$

The voltage at x=30cm from the origin due to the charge there is 270V
at infinity the voltage is 0V. Therefore:

$\Delta PE = -W \Rightarrow W = q(V_{30cm} - V_{\infty})$.

$$\left.\begin{array}{l} q = 3 \cdot 10^{-9}\,\mathrm{C} \\ V_{30cm} = 270\,\mathrm{V} \end{array}\right\} W = 3 \cdot 10^{-9}\,\mathrm{C} \cdot (270 - 0) = 8.10 \cdot 10^{-7}\,\mathrm{J}$$

The work is positive, you need to do work to bring two positive charges together
because they repel each other.

21) $V = k_e\, q/r$ $\quad r = k_e\, q/V$

$$\left.\begin{array}{l} q = 8 \cdot 10^{-9}\,\mathrm{C} \\ V = \cancel{215}\ 100\,\mathrm{V} \end{array}\right\} r = 0.719\,\mathrm{m}$$

similarly for $V = 50\,\mathrm{V}$ $r = 1.44\,\mathrm{m}$ $V = 25\,\mathrm{V}$ $r = 2.88\,\mathrm{m}$

In a table:

| V(v) | r(m) |
|---|---|
| 100 | 0.719m |
| 50 | 1.44m |
| 25 | 2.88 m |

Clearly when V halves, r doubles, V and r are inversely proportional
as can be seen from the equation $r = k_e\, q/V$.

22 a) $C = Q/\Delta V$

$\Delta V = 12.0V$

$C = 4.00\mu F$

$\left.\right\}$ $Q = C\Delta V = 4.80 \cdot 10^{-5} C$

b) Now $\Delta V = 1.50V \Rightarrow Q = C\Delta V = 6.00 \cdot 10^{-6} C$

23 a) $C = \epsilon_0 A/d$

$A = 1 \cdot 10^6 m^2$

$d = 800 m$

$\epsilon_0 = 8.85 \cdot 10^{-12} C^2/N \cdot m^2$

$\left.\right\}$ $C = 1.1 \cdot 10^{-8} F$

b) First find $\Delta V$ from $\Delta V = E \cdot \Delta x$

$E = 3 \cdot 10^6 N/C$

$\Delta x = 800 m$

$\left.\right\}$ $\Delta V = 2.4 \cdot 10^9 V$ therefore

$C = Q/\Delta V \Rightarrow Q = C\Delta V$

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

$\Delta V = 2.4 \cdot 10^9 V$

$\left.\right\}$ $Q = 26 C$

25 a) $\Delta V = -E \cdot \Delta x$

$\Delta V = 20.0V$

$\Delta x = 1.80 \cdot 10^{-3} m$

$\left.\right\}$ $E = \frac{-\Delta V}{\Delta x} = 1.11 \cdot 10^4 V/m$ E always points from positive to negative

b) $C = \epsilon_0 A/d$

$A = 7.6 \cdot 10^{-4} m^2$

$d = 1.8 \cdot 10^{-3} m$

$\left.\right\}$ $C = 3.74 \cdot 10^{-12} F$

c) $C = Q/\Delta V \Rightarrow Q = C\Delta V$

$C = 3.74 \cdot 10^{-12} F$

$\Delta V = 20.0V$

$\left.\right\}$ $Q = 7.48 \cdot 10^{-11} C$ note that this is the charge on one plate

the other plate will have an equal but opposite charge $Q = -7.48 \cdot 10^{-11} C$

30a) for parallel: $C_{eq} = C_1 + C_2 + C_3$

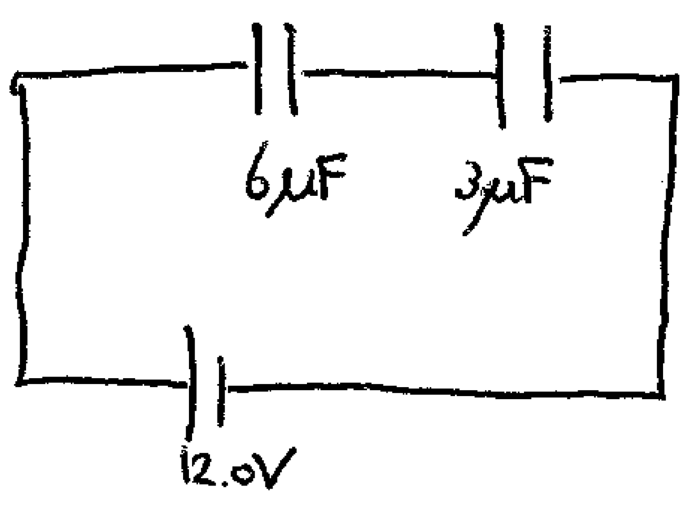
$C_1 = 5\mu F$ $C_2 = 4\mu F$ $C_3 = 9\mu F$ $C_{eq} = 5+4+9 = 18\mu F$

b) for series: $1/C_{eq} = 1/C_1 + 1/C_2 + 1/C_3$

$$C_{eq} = \left(1/5\mu F + 1/4\mu F + 1/9\mu F\right)^{-1} = 1.78\mu F$$

31a) Note that the $2\mu F$ and $4\mu F$ are in parallel Hence $C_{eq} = 2\mu F + 4\mu F = 6\mu F$

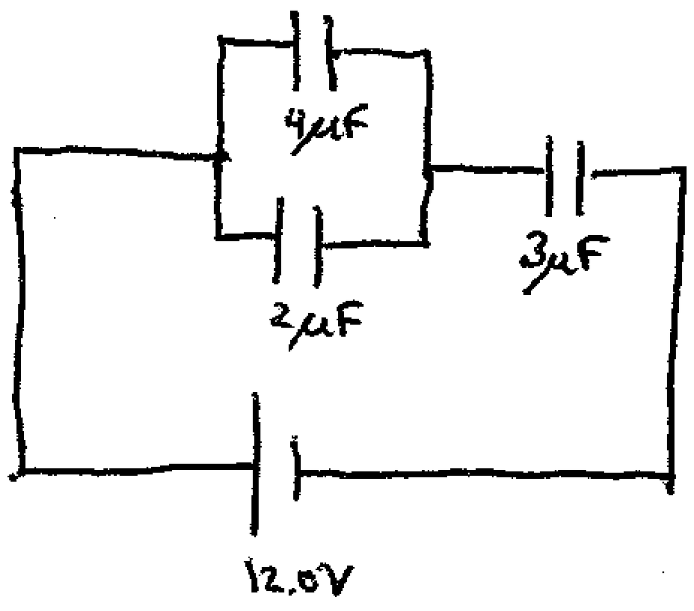
Redraw the new circuit will be:

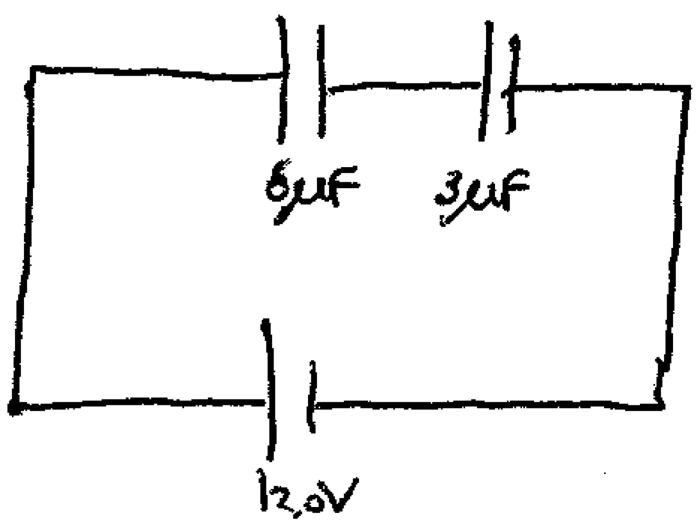


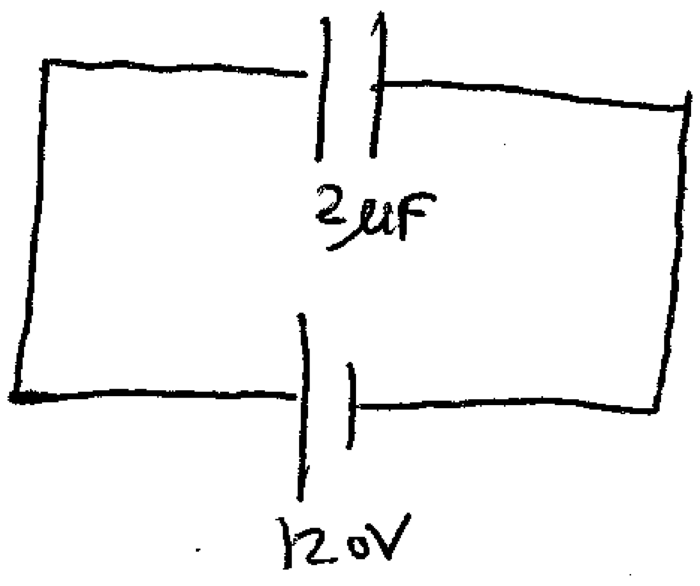

These are of course in series therefore

$$C_{eq} = \left(1/6\mu F + 1/3\mu F\right)^{-1} = 2\mu F$$

b) The best strategy is redrawing each step and work backwards:




From the last picture $C = Q/\Delta V$ $\Delta V = 12.0V$ $C = 2\mu F \Rightarrow Q = 2.4 \cdot 10^{-5} C$

going to the previous picture: the two capacitors are in <u>series</u> and <u>must</u> have the <u>same</u> <u>charge</u> on them $Q = 2.4 \cdot 10^{-5} C$ on each. Therefore

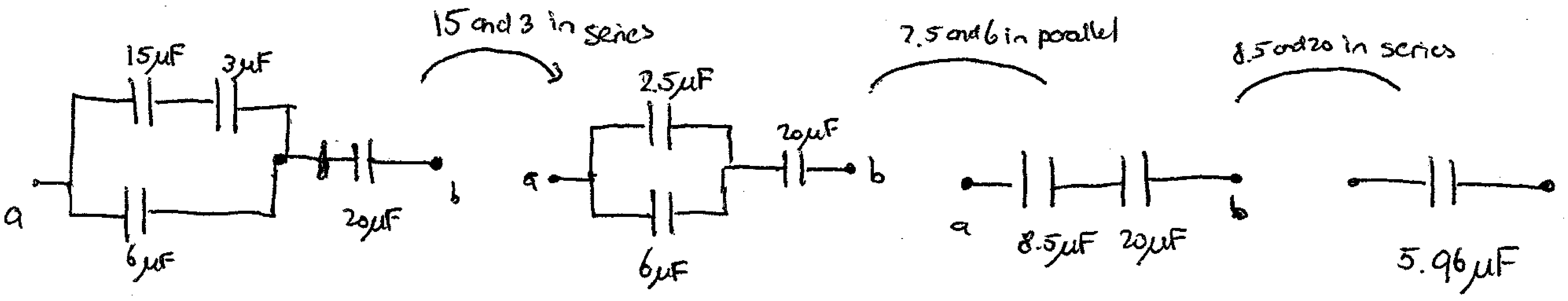
$\Delta V = Q/C = 8V$ for $3\mu F$ and $\Delta V = Q/C = 4V$ for $6\mu F$.

going to the first picture: the two capacitors in <u>parallel</u> <u>must</u> have the <u>same</u> <u>voltage</u>: $\Delta V = 4V$ for both the $2\mu F$ and $4\mu F$ capacitor

$Q = C\Delta V = 8 \cdot 10^{-6} C$ for $2\mu F$ and $Q = C\Delta V = 1.6 \cdot 10^{-5} C$ for $4\mu F$ results:

$$\boxed{2\mu F: \Delta V = 4V \; Q = 8 \cdot 10^{-6} C \quad 4\mu F: \Delta V = 4V \; Q = 1.6 \cdot 10^{-5} C \quad 3\mu F: \Delta V = 8V \; Q = 2.4 \cdot 10^{-5} C}$$

33a)




$C_{eq} = 5.96\mu F$ for this circuit

b) Working backwards again: Using $C = Q/\Delta V$ over and over again:

with two facts: 1) Capacitors in parallel have equal voltage

2) Capacitors in series have equal charge

$Q_{5.96} = 8.9\cancel{6}4 \cdot 10^{-5}C$    $\Delta V_{5.96} = 15.0V$

$Q_{8.5} = 8.94 \cdot 10^{-5}C$    $\Delta V_{8.5} = 10.5V$

$\boxed{Q_{20} = 8.94 \cdot 10^{-5}C \quad \Delta V_{20} = 4.47V}$

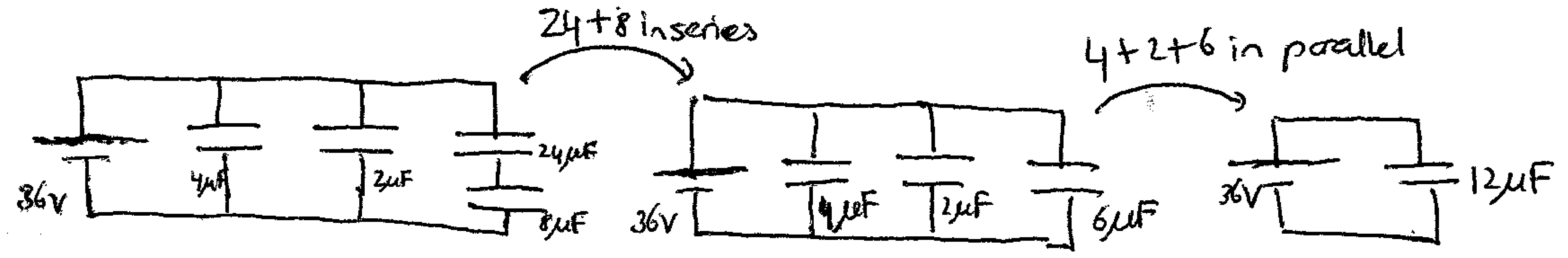
$Q_{2.5} = 2.63 \cdot 10^{-5}C$    $\Delta V_{2.5} = 10.5V$

$\boxed{Q_6 = 6.30 \cdot 10^{-5}C \quad \Delta V_6 = 10.5V}$

$\boxed{Q_3 = 2.63 \cdot 10^{-5}C \quad \Delta V_3 = 8.77V}$

$\boxed{Q_{15} = 2.63 \cdot 10^{-5}C \quad \Delta V_{15} = 1.75V}$

34 a)




$C_{eq} = 12\mu F$ for this circuit.

b) $Q_{12} = 4.32 \cdot 10^{-4}C$    $\Delta V_{12} = 36.0V$

$\boxed{Q_4 = 1.44 \cdot 10^{-4}C}$    $\Delta V_4 = 36.0V$

$\boxed{Q_2 = 7.20 \cdot 10^{-5}C}$    $\Delta V_2 = 36.0V$

$Q_6 = 2.16 \cdot 10^{-4}C$    $\Delta V_6 = 36.0V$

$\boxed{Q_{24} = 2.16 \cdot 10^{-4}C}$    $\Delta V_{24} = 9.00V$

$\boxed{Q_8 = 2.16 \cdot 10^{-4}C}$    $\Delta V_8 = 27.0V$

37 a) $Q = C\Delta V$

$C = 25 \cdot 10^{-6}\,F$

$\Delta V = 50\,V$

$\left.\right\} Q_{25} = 1.25 \cdot 10^{-3}\,C$

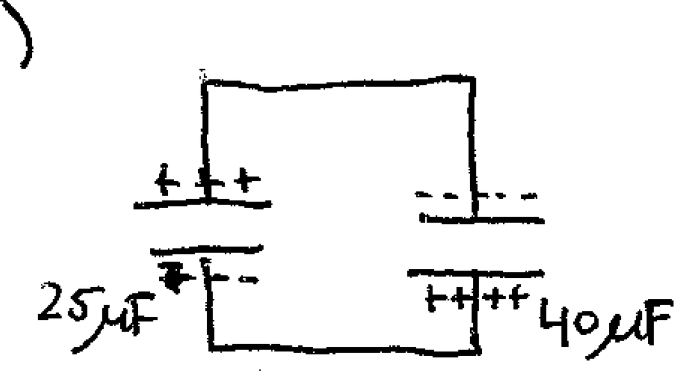
$Q = C\Delta V$

$C = 40\mu F$

$\Delta V = 50V$

$\left.\right\} Q_{40} = 2.00 \cdot 10^{-3}\,C$

b)




The first thing that happens is that the charge on the 25μF capacitor gets cancelled. this leaves:

$2 \cdot 10^{-3} - 1.25 \cdot 10^{-3} = 7.5 \cdot 10^{-4}\,C$ of charge in the system

This charge gets divided over the two capacitors until the voltage across the two ~~plat~~ capacitors is the same.

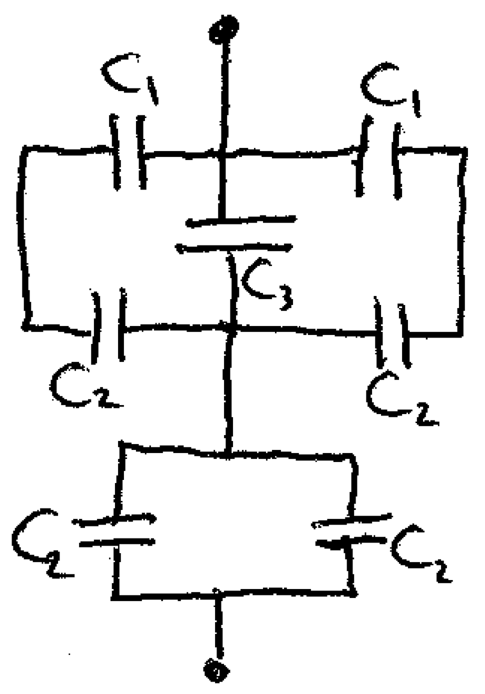
$\frac{Q_{25}}{\cancel{2}C_{25}} = V = \frac{Q_{40}}{C_{40}}$ $\quad \frac{Q_{25}}{Q_{40}} = \frac{25\mu F}{40\mu F} = \frac{5}{8}$ $\quad Q_{25} = \frac{5}{8} Q_{40}$

$Q_{25} + Q_{40} = 7.5 \cdot 10^{-4}\,C \Rightarrow \frac{5}{8} Q_{40} + Q_{40} = 7.5 \cdot 10^{-4} \Rightarrow \frac{13}{8} Q_{40} = 7.5 \cdot 10^{-4}$

$\boxed{Q_{40} = 4.62 \cdot 10^{-4}\,C}$ $\quad \boxed{Q_{25} = 7.5 \cdot 10^{-4} - 4.62 \cdot 10^{-4} = 2.88 \cdot 10^{-4}\,C}$

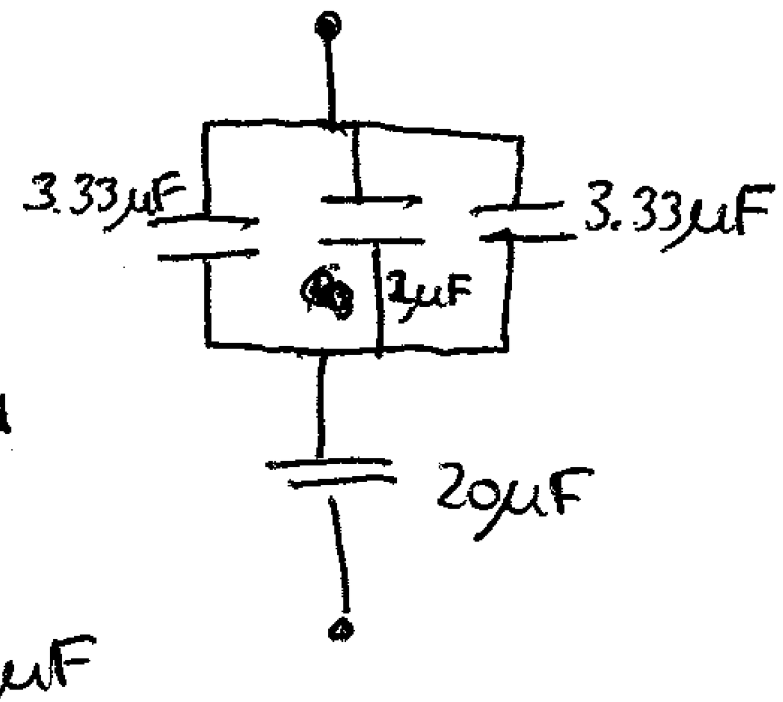
$\Delta V_{40} = Q_{40}/C_{40} = \boxed{11.6\,V}$

40)

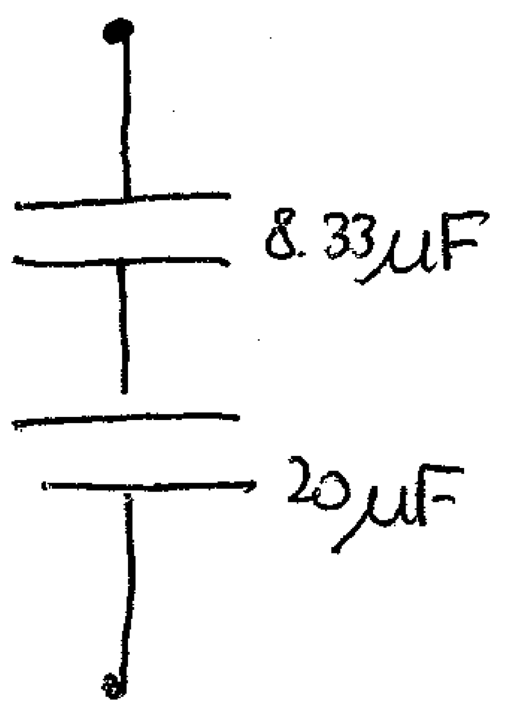



$C_1$ and $C_2$ are in series ~~...~~ and $C_2$ and $C_2$ at the bottom are in parallel -

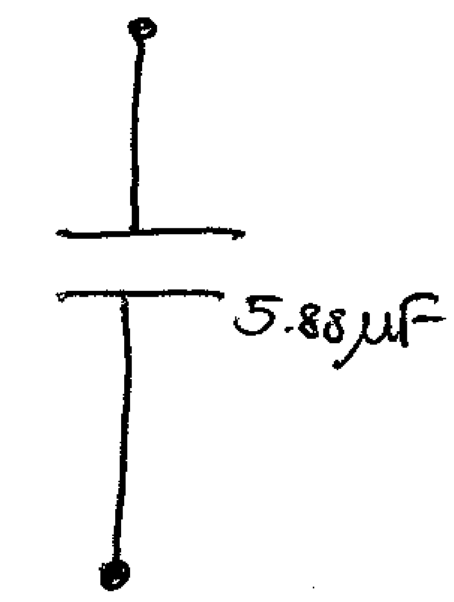
$C_1 = 5\mu F$ $C_2 = 10\mu F$ $C_3 = 2\mu F$




the three capacitors on the top are in parallel:




→ these are obviously in series




$C_{eq} = 5.88\mu F$

43) first find $C = \epsilon_0 A/d$

$$\left.\begin{array}{l} \epsilon_0 = 8.85 \cdot 10^{-12}\ C^2/N{\cdot}m^2 \\ A = 2.00 \cdot 10^{-4}\ m^2 \\ d = 5 \cdot 10^{-3}\ m \end{array}\right\} C = 3.54 \cdot 10^{-13}\ F$$

$$\left.\begin{array}{l} E = \frac{1}{2} C (\Delta V)^2 \\ C = 3.54 \cdot 10^{-13} F \\ \Delta V = 12.0 V \end{array}\right\} E = 2.55 \cdot 10^{-11}\ J$$

45) See problem 23) $C = 1.1 \cdot 10^{-8} F$

$\Delta V = 2.4 \cdot 10^{9} V$

$$E = \frac{1}{2} C (\Delta V)^2 = 3.2 \cdot 10^{10}\ J$$

59) $E = \frac{1}{2} C (\Delta V)^2$

$$\left.\begin{array}{l} E = 300\ W \cdot s \overset{!}{=} 300 J \\ C = 3 \cdot 10^{-5} F \end{array}\right\} \Delta V = \sqrt{\frac{2E}{C}} = 4.47 \cdot 10^{3} V$$

47) $\Delta V = \frac{\Delta V_0}{K}$

$$\left.\begin{array}{l} \Delta V_0 = 100 V \\ \Delta V = 25 V \end{array}\right\} K = \frac{\Delta V_0}{\Delta V} = 4.0$$

49a) $C = K\epsilon_0 A/d$

$$\left.\begin{array}{l} \epsilon_0 = 8.85 \cdot 10^{-12}\ C^2/Nm^2 \\ K = 2.1 \\ A = 175\ cm^2 = 1.75 \cdot 10^{-2} m \\ d = 4.00 \cdot 10^{-5} m \end{array}\right\} C = 8.1 \cdot 10^{-9} F$$

b) $E_{max} = 60 \cdot 10^6\ V/m$

$$\left.\begin{array}{l} \Delta V_{max} = E_{max} \cdot d \\ d = 4.00 \cdot 10^{-5} m \end{array}\right\} \Delta V_{max} = 2400 V$$

51a) $\rho = m/V$

$$\left.\begin{array}{l} \rho = \text{density} = 1100\ kg/m^3 \\ m = 1 \cdot 10^{-12}\ kg \end{array}\right\} V = m/\rho = 9.09 \cdot 10^{-16} m^3$$

a sphere has volume formula: $V = \frac{4}{3}\pi r^3$

$r = \sqrt[3]{\frac{3V}{4\pi}} = 6.01 \cdot 10^{-6} m$ is the radius of the blood cell.

$A = 4\pi r^2 = 4.534 \cdot 10^{-10}\ m^2$

b) $C = K\epsilon_0 A/d$

$$\left.\begin{array}{l} K = 5.00 \\ \epsilon_0 = 8.85 \cdot 10^{-12}\ C^2/N \cdot m^2 \\ A = 4.54 \cdot 10^{-10} m^2 \\ d = 1.00 \cdot 10^{-7} m \end{array}\right\} C = 2.01 \cdot 10^{-13} F$$

c) $C = Q/\Delta V$

$$\left.\begin{array}{l} C = 2.01 \cdot 10^{-13} F \\ \Delta V = 0.1 V \end{array}\right\} Q = C\Delta V = 2.01 \cdot 10^{-14} C \Rightarrow 2.01 \cdot 10^{-14} C \times \frac{1\ e}{1.602 \cdot 10^{-19} C} = 1.25 \cdot 10^5 e.$$