Physics 1B
HW #3 Solutions
Chap 16 Conceptual Questions: 9, 11, 16, 18
For Questions or Errors please email Morgan at mjbrown@ucsd.edu

9. When a capacitor is charged up there is a voltage across the terminals even after the battery is taken away. If you touched it, you would give the stored-up charge a path to go from the high voltage side to the low voltage side and current would flow through you. In order to make it safe for handling, you could put some sort of insulator over the plus and minus leads so that even when you touch it, no charge can flow. You could also discharge the capacitor (with something besides your hand) before handling it.

11. Electric field lines cannot cross. If they did, they would be telling you that the force on a charge at that location would point in two different directions, which does not make any sense at all. Equipotential lines at different potentials can never cross either. This is because they are, by definition, a line of constant potential. The equipotential at a given point in space can only have a single value. If lines for two different values of the potential were to cross, then they would no longer represent equipotential lines. Note: It is possible for two lines representing the same potential to cross. See the book page A.18 for an example.

16. a) For capacitors connected in parallel, C(tot) = C1 + C2 + C3 + … so the net result is that the total capacitance is greater than the capacitance of any individual capacitor.
b) For capacitors in series, 1/C(tot) = 1/C1 + 1/C2 + 1/C3 + … so the net result is that the total capacitance is smaller than the capacitance of any individual capacitor. The first one is easy to see. If the second one does not seem clear, try putting in some numbers and attempt to come up with a configuration that breaks the rule.

18. The equation $V_B - V_A = -E_x\_x$ is only valid when the electric field is constant and the displacement is parallel to the E field (denoted here by the subscript x). b) The equation cannot be used for the field of a point charge because the electric field is decreasing as you move farther away. c) The equation is valid for a parallel plate capacitor because the field is taken to be constant in that region.

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HW3 : problems: 16, 19, 26, 39, 40,
(Chap 16) 42, 57, 63

16

$q_1 = 9.00\ nC$

How much work is done to bring in $q_2 = 3.00\ nC$ from infinity to distance $x = 0.300\ m$

$$V = \frac{kq_1}{r}$$

We first find the potential at a point 0.3 m away

$V = kq_1/r = 270V$

We next get work using $W = -PE = +q_2 \Delta V$

$W = +q_2(V_f - V_i) = +q_2(V - V_\infty) = +q_2 V = (+3nC)\,270\,V$

We must do work to bring the charge in from infinity. $\boxed{W = +81\ \mu J}$

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$q_1 = +2e$, $V_i = 2.00 \times 10^7\ m/s$, $m = 6.64 \times 10^{-27}\ kg$
$q_2 = +79e$

All energy starts out kinetic & converts to potential

$\underline{\text{Initial } E} = \underline{\text{Final } E}$

$\frac{1}{2} m V_i^2 = q\Delta V = Kq_1q_2/r$ → solve for r

$r = \left[\frac{2K\,q_1 q_2}{m V_i^2}\right] = \frac{2Ke^2(2)(79)}{mV_i^2}$ → plug in numbers

$$\boxed{r = 2.74 \times 10^{-14}\ m}$$

26 Capacitors: $A = 21.0 \times 10^{-12}\ m^2$ $\qquad$ <u>Assume // Plates</u>

$C = 60.0 \times 10^{-15}\ F$ $\qquad C = \frac{\varepsilon_0 A}{d}$

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$ $\qquad \Rightarrow d = \frac{\varepsilon_0 A}{C}$

$d = ?$

$$d = \frac{\varepsilon_0 A}{C} = 3.1 \times 10^{-9} m = 31 \times 10^{-10} m = \boxed{31\ \text{Å}}$$

(in Angstroms)

39 $C_1 = 1.00\ \mu F$, $V = 10.0 V$ $\Rightarrow Q = CV = 10\ \mu C$

Now connect to uncharged $2\mu F$ capacitor (C_2)

ΔV across each must be the same or charges would move. Thus $\Delta V_1 = \Delta V_2$

and $\Delta V = \frac{Q}{C} \Rightarrow \frac{Q_1}{C_1} = \frac{Q_2}{C_2}$ and the total charge from the first part is conserved.

so $Q_1 + Q_2 = 10\ \mu C$

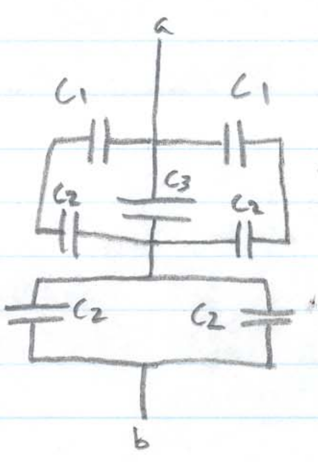
$\rightarrow Q_1 = 10\ \mu C - Q_2$

$$C_2\left(\frac{10\mu C - Q_2}{\cancel{C_1}}\right) = \frac{Q_2}{\cancel{C_2}}(C_1)$$

$$(10\mu C) C_2 = C_1 Q_2 + C_2 Q_2 \rightarrow Q_2 = \frac{(10\mu C) C_2}{C_1 + C_2} = \boxed{Q_2 = 6.67\ \mu C}$$

$$\boxed{Q_1 = 3.33\ \mu C}$$

40



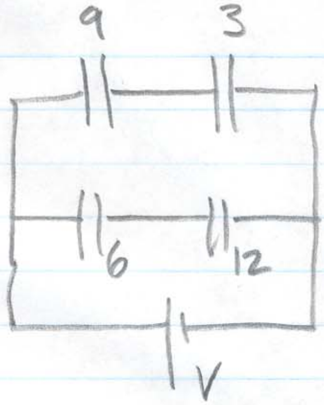
$C_1 = 5\mu F$

$C_2 = 10\mu F$

$C_3 = 2\mu F$

First combine C_1 and C_2 on the left and right top in series

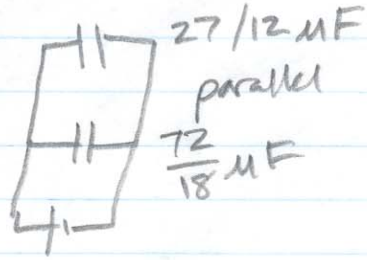
$$\left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1} = \left(\frac{1}{5} + \frac{1}{10}\right)^{-1} = \frac{10}{3}\mu F \rightarrow \text{redraw}$$



$$\left(\frac{1}{9}+\frac{1}{3}\right)^{-1} = \frac{27}{12}\,\mu F$$

$$\left(\frac{1}{6}+\frac{1}{12}\right)^{-1} = \frac{72}{18}\,\mu F$$

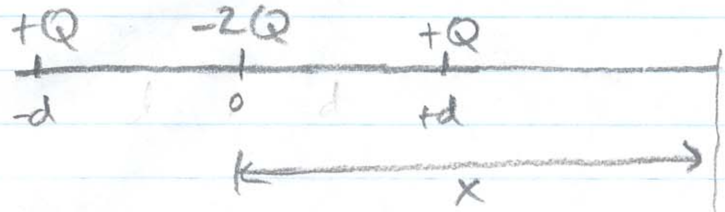
$\Longrightarrow$



$$C_T = \left(\frac{27}{12}+\frac{72}{18}\right)\mu F \rightarrow \boxed{C_T = 6.25\,\mu F}$$

$\boxed{63}$

(a)



Add up the 3 pieces of voltage $V_1 + V_2 + V_3$

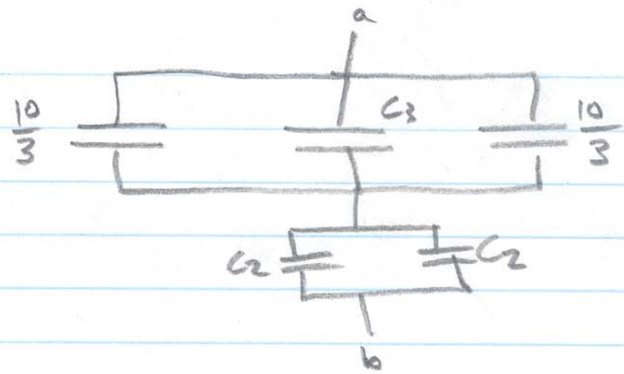
$$V = \frac{kQ}{x+d} - \frac{2kQ}{x} + \frac{kQ}{x-d} = kQ\left[\frac{x(x-d) - 2(x+d)(x-d) + x(x+d)}{x(x+d)(x-d)}\right]$$

$$= kQ\left[x^2 - xd - 2x^2 + 2d^2 + x^2 + xd\right] / x(x^2-d^2)$$

$$\boxed{V = \frac{kQ(+2d^2)}{x^3 - xd^2}}$$

(b) For $x \gg d$ $\quad x^3 \gg \frac{x}{d^2}$ so we drop that term

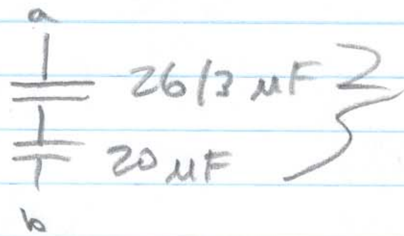
$$\boxed{V(x \gg d) = \frac{kQ(2d^2)}{x^3}}$$



Top 3 parallel $= \frac{20}{3} + 2$

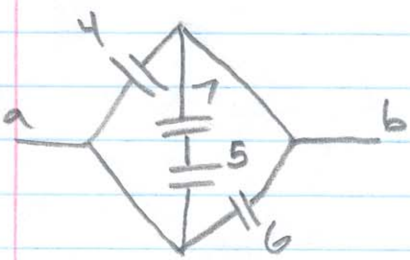
Bottom 2 parallel $= 10 + 10$

Redraw



$\left(\frac{3}{26} + \frac{1}{20}\right)^{-1} = \boxed{6.05\,\mu F}$

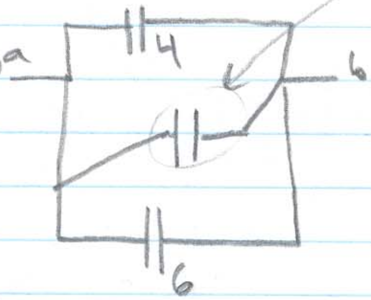
42



① combine 7 & 5 in series

$\left(\frac{1}{7} + \frac{1}{5}\right)^{-1} = \frac{35}{12}\,\mu F$

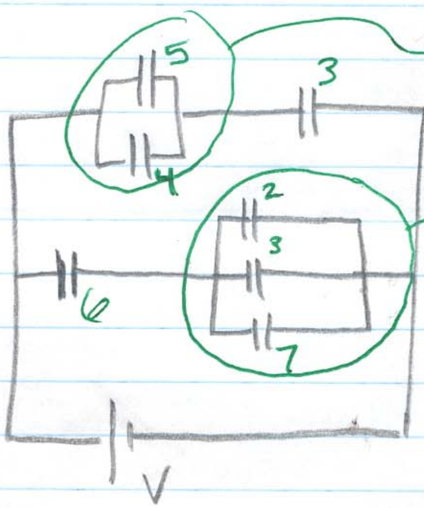
② [Redraw]



Note, even though it looks odd, these 3 are now in parallel

$C_T = \left(4 + 6 + \frac{35}{12}\right)\mu F \rightarrow \boxed{C_T = 12.9\,\mu F}$

57



→ parallel ⇒ 5+4 = 9μF

parallel
2+3+7 = 12μF

→ Redraw now

→