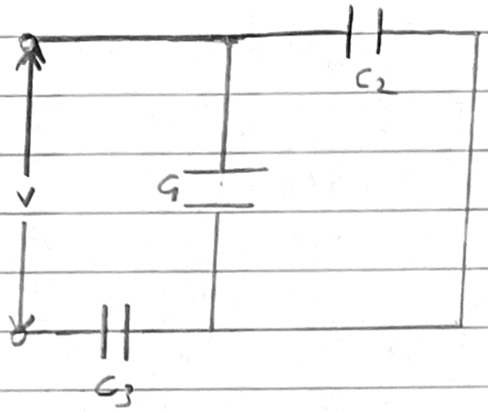
سارة جبار

Principles of physics (10th eddition)
phy 132
CH 25: capacitance
Problems: 2, 10, 17, 18, 37, 39, 53, 60

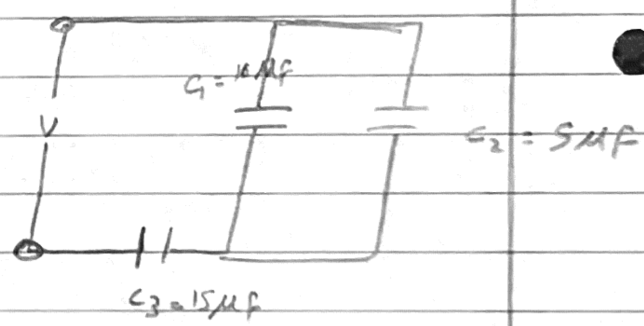
P_2: In Fig 25-18, a potential difference $V = 75.0\,V$ is applied across a capacitor arrangement with capacitance $C_1 = 10.0\,\mu F$, $C_2 = 5.00\,\mu F$ and $C_3 = 15.0\,\mu F$. What are (a) charge q_3, (b) potential difference V_3 and (c) stored energy U_3 for capacitor 3, (d) q_1, (e) V_1 and (f) U_1 for capacitor 1 and (g) q_2 (h) V_2 and (i) U_2 for capacitor 2?



Sol: C_1, C_2 parallel

$C = C_1 + C_2 = 10 + 5$

$C = 15\,\mu F$

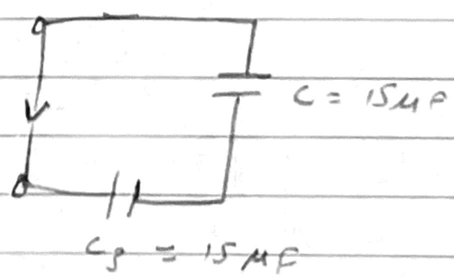


C, C_3 series

$C_{eq} = \frac{C C_3}{C + C_3} = \frac{15 \times 15}{15 + 15}$

$C_{eq} = \frac{225}{30}$

$C_{eq} = 7.5\,\mu F$



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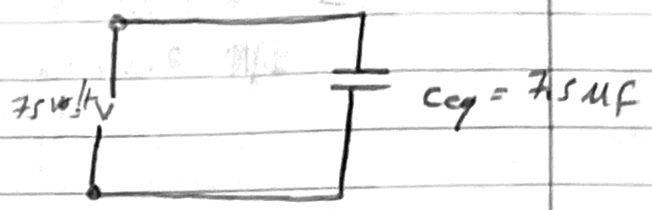
$Q_{eq} = C_{eq} V$

$= 7.5 \times 10^{-6} \times 75$

$Q_{eq} = 562.5\ \mu C$



$Q_{eq} = Q_{c_3} = Q_c$ in series

a) $q_3 = Q_{c_3} = 562.5\ \mu C$

b) $V_3 = \frac{q_3}{C_3} = \frac{562.5\ \mu C}{15\ \mu F} = 37.5$ volt

c) $U_3 = \frac{1}{2} C_3 V_3^2 = \frac{1}{2} \times 15 \times 10^{-6} \times (37.5)^2 = 1.05 \times 10^{-2}$ J

d) $q_1 = C_1 V_1$

$V_1 = V - V_3 = 75 - 37.5 = 37.5$ volt

$\Rightarrow q_1 = 10\ \mu F \times 37.5$

$= 375\ \mu C$

e) $V_1 = \frac{q_1}{C_1} = \frac{375\ \mu C}{10\ \mu F} = 37.5$ volt

or $V_1 = V - V_3 = 37.5$ volt

f) $U_1 = \frac{1}{2} C_1 V_1^2 = \frac{1}{2} \times 10 \times 10^{-6} \times (37.5)^2 = 7.03 \times 10^{-3}$ J

g) $q_2 = C_2 V_2$

$V_2 = V_1 = V - V_3 = 75 - 37.5$ volt

$q_2 = 5 \times 10^{-6} \times 37.5 = 187.5\ \mu C$

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h) $V_2 = V_1 = 37.5$ volt

i) $u_2 = \frac{1}{2} C_2 V_2^2 = \frac{1}{2} \times 5 \times 10^{-6} \times (37.5)^2$

$= 3.5 \times 10^{-3}$ J

P10: A parallel-plate air-filled capacitor having area 40 cm² and plate spacing 1.0 mm is charged to a potential difference of 500 V. Find (a) the capacitance, (b) the magnitude of the charge on each plate, (c) the stored energy, (d) the electric field between the plates and (e) the energy density between the plates

Sol:

a) $A = 40\ cm^2 = 40\ cm^2 \left(\frac{1m}{100cm}\right)^2$

$= \frac{40}{10000}$

$= 0.004\ m^2$

$= 4 \times 10^{-3}\ m^2$

$d = 1\ mm = 1 \times 10^{-3}$

$C = \frac{\epsilon_0 A}{d} = \frac{8.85 \times 10^{-12} \times 4 \times 10^{-3}}{1 \times 10^{-3}} = 3.54 \times 10^{-11}$ F

≈ 35 pF

b) $q = CV$

$= 3.54 \times 10^{-11} \times 500$

$= 1.77 \times 10^{-8}$ C

$\simeq 18$ nC

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c) $U = \frac{1}{2} C V^2 = \frac{1}{2} \times 3.54 \times 10^{-11} \times (500)^2$

$= 4.425 \times 10^{-6}$ J

$\simeq 4.425 \ \mu J$

d) $E = \frac{V}{d} = \frac{500}{1 \times 10^{-3}} = 5 \times 10^5$ V/m

e) $u = \frac{U}{\text{Volume}} = \frac{U}{A.d} = \frac{4.425 \times 10^{-6}}{4 \times 10^{-3} \times 1 \times 10^{-3}} = 1.10625$ J/m²

or $u = \frac{1}{2} \epsilon_0 E^2 = \frac{1}{2} \times 8.85 \times 10^{-12} \times (5 \times 10^5)^2 = 1.10625$ J/m²

P17: The parallel plates in a capacitor, with a plate area of 8.50 cm² and an air-filled separation of 8.00 mm are charged by a 16.0 V bettery. They are then disconnected from the battery and pushed together (without discharge) to a separation of 3.00 mm. Neglecting fringing, find (a) the potential difference between the plates (b) the initial stored energy (c) the final stored energy and (d) the (negative) work in pushing them together

sol:

a) $C = \frac{\epsilon_0 A}{d}$, $d = 8$ mm $d' = 3$ mm

$Q = CV$ Q same

$\frac{\epsilon_0 A}{d} V = \frac{\epsilon_0 A}{d'} V'$

$\frac{V}{d} = \frac{V'}{d'} \Rightarrow V' = \frac{V}{d} d' = \frac{16}{8 \times 10^{-3}} \times 3 \times 10^{-3}$

$\Rightarrow V' = 6$ volt

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b) $U_i = \frac{1}{2} C V^2$, $C = \frac{\epsilon_0 A}{d} = \frac{8.85\times10^{-12} \times 8.5\times10^{-9}}{8\times10^{-3}} = 9.4\times10^{-13}\ F$

$U = \frac{1}{2}(9.4\times10^{-13})(16)^2 = 1.2\times10^{-10}\ J$

$= 120\times10^{-12}\ J$

$= 120\ pJ$

c) $U_f = \frac{1}{2} C' V'^2$, $C' = \frac{\epsilon_0 A}{d'} = \frac{8.85\times10^{-12} \times 8.5\times10^{-4}}{3\times10^{-3}} = 2.5\times10^{-12}\ F$

$U_f = \frac{1}{2}(2.5\times10^{-12})(6)^2 = 4.5135\times10^{-11}\ J$

$= 45.135\times10^{-12}\ J$

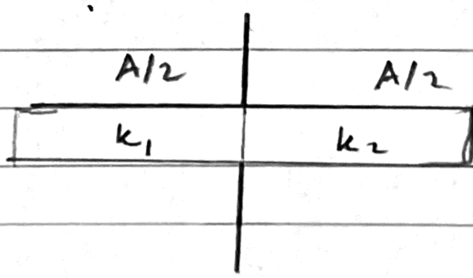
$\simeq 45\ pJ$

d) $W = \Delta U = U_f - U_i = 45\ pJ - 120\ pJ$

$\simeq$ [redacted] $75\ J$

P18: Figure 25-23 shows a parallel plate capacitor with a plate area $A = 5.56\ cm^2$ and separation $d = 5.56\ mm$ the left half of the gap is filled with material of dielectric constant $k_1 = 7.00$, the right half is filled with material of dielectric constant $k_2 = 10.0$ what is the capacitance?

$A = 5.56\times10^{-4}\ m^2$



sol:

$C_1 = \frac{k_1 \epsilon_0 A_1}{d_1} = \frac{k_1 \epsilon_0 A/2}{d} = \frac{7\times8.85\times10^{-12} \times \frac{5.56\times10^{-4}}{2}}{5.56\times10^{-3}} = 3.0975\times10^{-12}\ F$

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$$C_2 = \frac{k_2 \epsilon_0 A_2}{d_2} = \frac{k_2 \epsilon_0 A/2}{d} = \frac{10 \times 8.85\times10^{-12}\ 5.56\times10^{-4}}{(5.56\times10^{-3})\ (2)}$$

$$= 4.425\times10^{-12}$$

C_1, C_2 parallel plate

$$\Rightarrow C = C_1 + C_2 = 3.0975\times10^{-12} + 4.425\times10^{-12}$$

$$= 7.5225\times10^{-12} F$$

$$= 7.52 pF$$

or $C = C_1 + C_2$

$$\frac{k_1 \epsilon_0 A/2}{d} + \frac{k_2 \epsilon_0 A/2}{d}$$

$$= \frac{\epsilon_0 A}{2d}(k_1 + k_2)$$

$$= \frac{8.85\times10^{-12} \times 5.56\times10^{-4}}{2 \times 5.56\times10^{-3}}(7+10)$$

$$= 7.5225\times10^{-12} F$$

$$= 7.5225 pf$$

سارو بكا

P37: A certain substance has a dielectric constant of 5.6 and a dielectric strength of 18 MV/m. If it is used as the dielectric material in a parallel-plate capacitor What minimum area should the plates of the capacitor have to obtain a capacitance of 3.9×10^{-2} μF and to ensure that the capacitor will able to withstand a potential difference of 4.0 kV ?

Sol:

$k = 5.6$, $E = 18$ MV/m , $c' = 3.9 \times 10^{-2}$ μF , $V = 4.0$ kV $= 4 \times 10^{3}$ V

minimum Area A = ??

$$c = \frac{\epsilon_0 A}{d}$$ (if air between the plates)

* $$c' = \frac{k \epsilon_0 A}{d}$$ (if there is a material between plates)

* potintial difference between the plates

$$V = Ed \Rightarrow d = \frac{V}{E}$$

$$\Rightarrow c' = \frac{k \epsilon_0 A}{V/E}$$

$$c' = \frac{k \epsilon_0 A E}{V}$$

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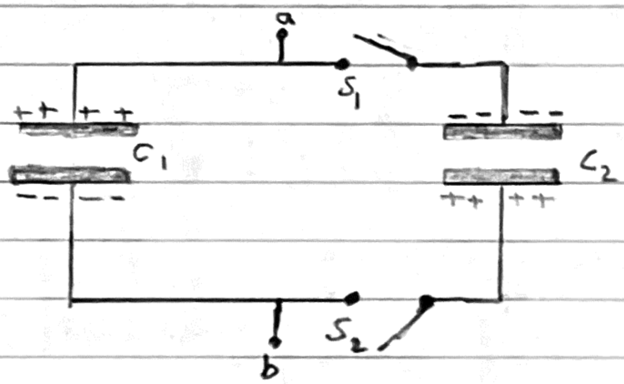
$$A = \frac{c' V}{k \epsilon_0 E}$$

$$\Rightarrow A = \frac{3.9 \times 10^{-2} \times 10^{-6} \times 4 \times 10^{3}}{5.6 \times 8.85 \times 10^{-12} \times 18 \times 10^{6}}$$

$$= 0.1748 \ m^2$$

$$\simeq 0.17 \ m^2$$

P39: In Fig 25-35, the capacitances are $C_1 = 1.0 \mu F$ and $C_2 = 3.0 \mu F$ and both capacitors are charged to a potential difference of $V = 200$ V but with opposite polarity as shown. Switches S_1 and S_2 are now closed. (a) What is now the potential difference between points a and b? What now is the charge on capacitor (b) 1 and (c) 2



Sol : $C_1 = 1 \mu F$, $C_2 = 3 \mu F$, $V = 200$ volt

a) * the switches are closed $\Rightarrow$ the potential difference across the capacitors are the same and they are in parallel

$$V_{ab} = \frac{Q_{tot}}{C_{eq}}$$

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$C_{eq} = C_1 + C_2 = 1\,\mu F + 3\,\mu F = 4\,\mu F$

befor the switches is closed

$q_1 = C_1 V = 1\times10^{-6} \times 200 = 200\times10^{-6}\,c$
$= 2\times10^{-4}\,c$

$q_2 = C_2 V = 3\times10^{-6} \times 200 = 600\times10^{-6}\,c$
$= 6\times10^{-4}\,c$

becouse the polarity is opposite $\Rightarrow Q_{tot} = q_2 - q_1$

$Q_{tot} = 6\times10^{-4} - 2\times10^{-4} = 4\times10^{-4}\,c$

$V_{ab} = \frac{Q_{tot}}{C_{eq}} = \frac{4\times10^{-4}}{4\times10^{-6}} = 100$ volt

b) $q_1 = C_1 V_{ab}$ after switches is closed

$= 1\times10^{-6}\times100$
$= 1\times10^{-4}$
$= 0.1\times10^{-3}$
$= 0.10\,mc$

c) $q_2 = C_2 V_{ab}$
$= 3\times10^{-6}\times100$
$= 3\times10^{-4}$
$= 0.3\times10^{-3}$
$= 0.30\,mc$

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P53: A 100 pF capacitor is charged to a potential difference of 80.0 V and the charging bettery is disconnected. The capacitor is then connected in parallel with a second (initially uncharged) capacitor. If the potential difference across the first capacitor drops to 35.0 V, what is the capacitance of this second capacitor?

Sol: $Q = CV$

q_i : before the charging bettery is disconnected

$q_i = C_1 V = 100\,pF \times 80\,v = 8000\,pc$

q_F : aftere the charging bettery is disconnected and connected in parallel with C_2

$q_f = C_2 V = 100\,pF \times 35 = 3500\,pc$

q_2 : the charge on capacitor 2

$q_2 = q_i - q_f$

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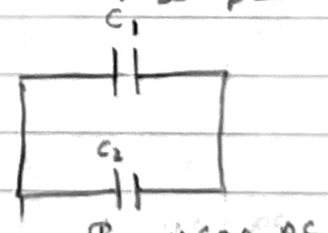
هي مجموعهم

$= 8000\,pc - 3500\,pc$

$q_2 = 4500\,pc$



$q_2 = C_2 V$

$C_2 = \dfrac{q_2}{V}$

$= \dfrac{4500 \times 10^{-9}}{35}$

$= 128.57 \times 10^{-9}$

$\simeq 129\,pF$