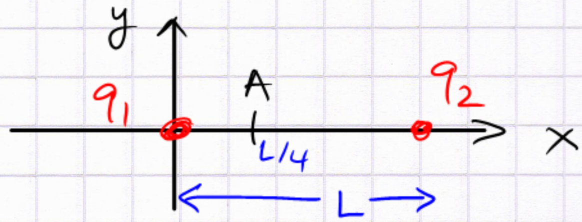
Week 15 18.35

Two point particles, charges q_1, q_2 are separated by L.
Electric potential $= 0$ @ $x = A$, $y = 0$
where $A = L/4$. Determine q_1/q_2



Solution.

Point charge potential: $V = \frac{kq}{r}$

At $x = A = \frac{L}{4}$, $y = 0$: $r_L = \frac{L}{4}$, $r_R = \frac{3}{4}L$

$$\therefore \quad V_A = K\left(\frac{q_1}{(L/4)} + \frac{q_2}{(3L/4)}\right) = 0 \quad \leftarrow \text{by demand}$$

$\therefore$ L drops out (multiply eqn by it)

$$4q_1 + \frac{4}{3}q_2 = 0 \qquad \therefore \quad q_1 = -\frac{q_2}{3}$$

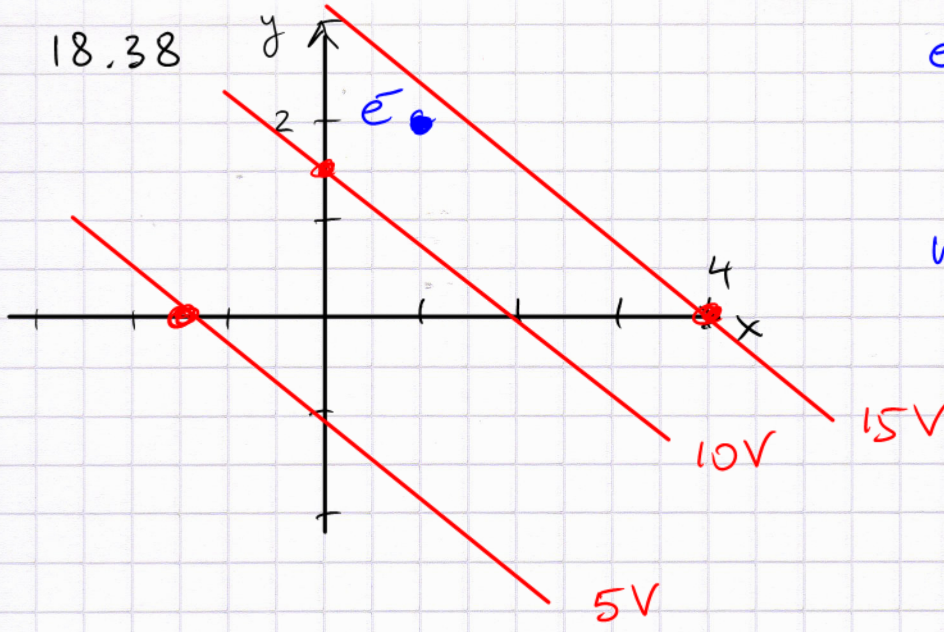
makes sense?

1) q_2 is three times as far from A as q_1

2) for the potential to vanish in between at some place: $q_1 q_2 < 0$ (opposite charges)

3) q_2 is further away $\therefore$ $q_2 >> q_1$

18.38



e^- is released from (1.0, 2.0)

Which direction does it move in?

Solution

1) An e^- will go from low to high potential.

2) It starts from rest ∴ it will accelerate + move in the direction of $q\vec{E}$ [if it was moving it would accelerate along $q\vec{E}$, but $\vec{v}_{fin} = \vec{v}_{in} + \vec{a}\,\Delta t$

3) find $\vec{E}$ @ (1.0, 2.0) m → $\vec{E}$ is ⊥ to equipot'l

4) ↗ is the direction of $q\vec{E}$ ($q=-e$).

$E_x = -\dfrac{\Delta V}{\Delta x}$ $\quad E_y = -\dfrac{\Delta V}{\Delta y}$ → we could do those derivatives approximately from the 10V + 5V lines

but we use geometry:

5) use the 15 V line: slope $m = \dfrac{0-3.5}{4-0} = -\dfrac{7}{8}$

$\vec{E}$ is ⊥ to that; geometry $m_\perp = -\dfrac{1}{m} = \dfrac{8}{7}$

Q: $7\hat{i} + 8\hat{j}$ gives the direction of e^- acc.?

$\vartheta = \tan^{-1}(8/7)$ ∴ $\vartheta = 49°$

18.44 Design a parallel-plate capacitor, $C = 5.0\ F$ (huge!)
use realistic d

Solution.

$$C = \frac{\varepsilon_0 A}{d}$$

$A = L^2$ ← plate area

d = separation

start with $d = 0.1\ mm$ (= $100\ \mu m$)

$$A = \frac{Cd}{\varepsilon_0} = \frac{5.0 \times 0.1 \times 10^{-3}}{8.85 \times 10^{-12}} = 5.65 \times 10^{7}\ m^2$$

Suppose $A = L \times L$ (square): $L = 7.5 \times 10^{3}\ m$

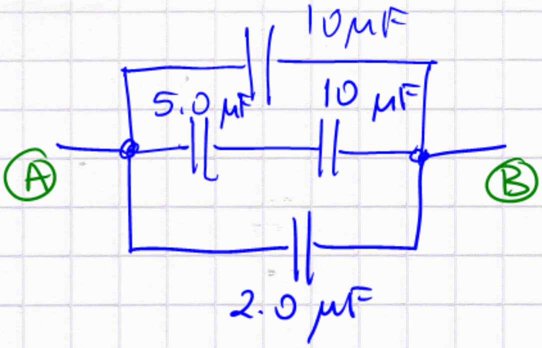
A 7.5-by 7.5 km large pair of plates separated by only 0.1 mm would do the trick

→ highly impractical

→ need a dielectric effect

→ actually, electrolytic capacitors can do this, and still they are big.

18.51



$C_{eq} = ?$

Solution.

We see three parallel pathways: the potential difference ΔV_{AB} applies equally to:

1) top $= 10\ \mu F$, 2) bottom $= 2.0\ \mu F$

3) middle $= ?$ 5.0 μF and 10 μF in series

$$\therefore \quad C_{eq} = C_1 + C_2 + C^{eq}_{middle} = 12.0\,\mu F + C^{eq}_{middle}$$

$$\frac{1}{C_{middle}} = \frac{1}{5.0\ \mu F} + \frac{1}{10.\ \mu F}$$

$$\therefore \quad C_{middle} = \frac{C_L C_R}{C_L + C_R} = \frac{5.0 \times 10}{5.0 + 10}\ \mu F$$

$$= \frac{50}{15.}\ \mu F = 3.33\ \mu F$$

$$\therefore \quad C_{eq} = 12.0 + 3.33 = 15.33\,\mu F$$

$$= 15\ \mu F \quad \text{(2 sign. digits)}$$

19.4 Electrons move from A to B, rate: $\frac{15 e^-}{sec}$.

$I = ?$

Solution.

$I = \frac{\Delta q}{\Delta t}$ $|\Delta q| = Ne$

for electrons $\Delta q = -Ne$

we are given the particle current $N = 15$, $\Delta t = 1 sec.$

direction: current goes from B to A!

$\Delta t = 1 sec$, $|\Delta q| = 15 \times 1.6 \times 10^{-19} C = 24 \times 10^{-19} C$

$I = 2.4 \times 10^{-18} A$

Significance:

a < \$ 100 multimeter (The Source, Canadian Tire)

can certainly measure $\mu A = 10^{-6} A$

• "macroscopic" current → $\sim 10^{13} e^- / sec$

effects from quantization of charge!

a \$ 150 multimeter can measure $nA = 10^{-9} A$

$10^{10} e^-/s$.

10,000 instrument → pA .. fA

$fA = 10^{-15} A$ → $\sim 10{,}000 e^- / sec$ → eventually: shot noise

19.8 $14.4\,V$ battery, $I = 2.0\ A$

a) $\Delta t = 5$ min $\rightarrow \Delta q = ?$ b) $W_{tot} = ?$

Solution.

a) $I = \frac{\Delta q}{\Delta t}$ $\therefore$ $\Delta q = I\,\Delta t = 2.0\,A \times 5 \times 60\,s$

$= 600\ As = 6.0 \times 10^2\ C$

b) $|W| = |q\,\Delta V|$

$= 6.0 \times 10^2 \cdot 14.4\ VAs$ VA = Watt (power unit)

$= 8.6 \times 10^3\ Ws$ $1\ Ws = 1\ Nm = 1\,J$

$= 8.6\ kJ$