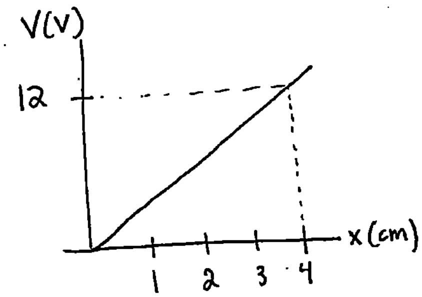
MIDTERM EXAM
PHYSICS 5C (WINTER 2022, LECTURE 2)

Problem 1 (12 points). The following plot shows the electric potential along the x-axis in a certain region. The potential is constant along the y-direction. An electric dipole with dipole moment of magnitude 7×10^{-9} C m is placed at rest in this region, with the dipole moment directed 60° counterclockwise from the positive x-axis.



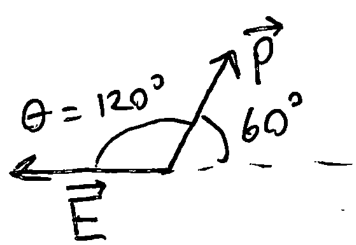
(a) (6 points) What are the magnitude and direction of the electric field?

(b) (6 points) What is the magnitude of the initial torque on the dipole? Will it initially rotate clockwise or counterclockwise?

(a) $E_x = -\frac{\Delta V}{\Delta x} = -\frac{12V}{4cm} = -300\frac{V}{m}$

So $E = 300\frac{V}{m}$ & $\vec{E}$ points **left**

(b)

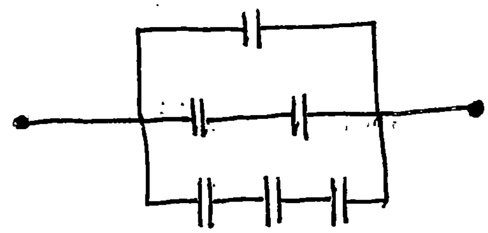


$\tau = pE\sin\theta$

$= 1.8 \times 10^{-6}$ N·m

& dipole will rotate **counterclockwise** to align w/ $\vec{E}$

Problem 2 (16 points). All of the capacitors in the network shown below have identical capacitance 3 nF.



(a) (8 points) What is the equivalent capacitance of this network?

(b) (4 points) If the entire network is connected across a 9 V source, what total energy is stored all of the capacitors?

(c) (4 points) If the entire network is connected across a 9 V source, what is the charge on the topmost capacitor?

(a) $$C_{eq} = \frac{1}{\frac{1}{C}+\frac{1}{C}+\frac{1}{C}} + \frac{1}{\frac{1}{C}+\frac{1}{C}} + C$$

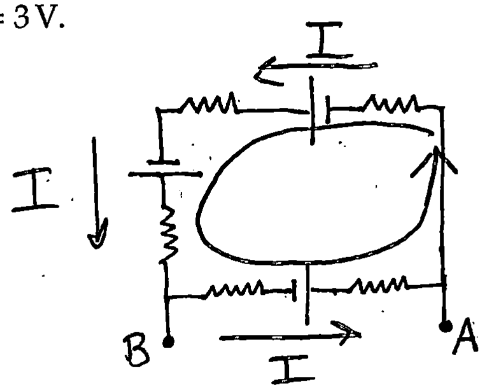
$$= \frac{C}{3} + \frac{C}{2} + C = \frac{11C}{6} = \boxed{5.5\,\text{nF}}$$

(b) $$U = \frac{1}{2} C_{eq} \Delta V^2 = \boxed{2.2 \times 10^{-7}\ \text{J}}$$

(c) Top capacitor in parallel w/ source, $\Delta V = 9V$

$$Q = C\Delta V = \boxed{2.7 \times 10^{-8}\ \text{C}}$$

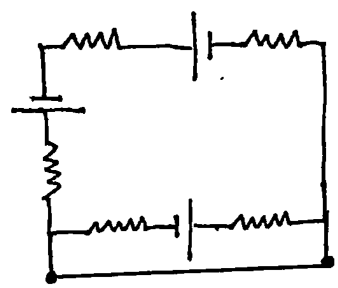
Problem 3 (18 points). In the circuit below, all of the resistors are identical and have resistance $R = 2.2\,\Omega$. The batteries all have emf $\mathcal{E} = 3\,\text{V}$.



(a) (6 points) Find the current that flows in this circuit. (You can treat the circuit as a single loop, since no current will flow in the open wires at the bottom.)

(b) (6 points) Find the voltage $V_B - V_A$ from point A to point B shown on the circuit diagram.

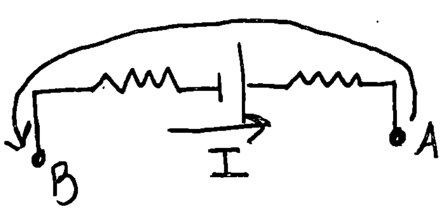
(c) (6 points) Now suppose an additional ideal wire is added connecting A and B directly, as shown below. Use the loop and junction rules to find the current that flows in the wire connecting A and B.

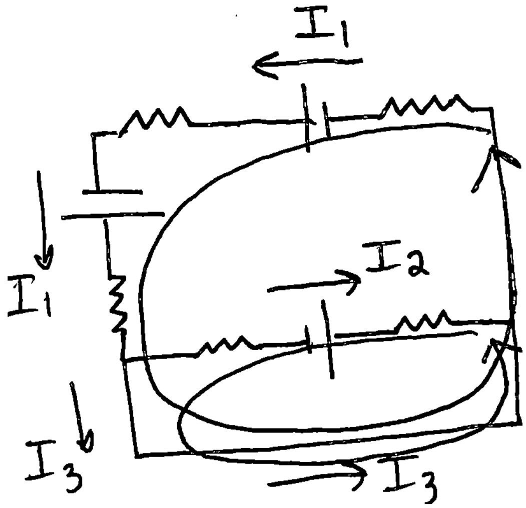


(a) $\Delta V_{loop} = -IR + \varepsilon - IR + \varepsilon - IR - IR + \varepsilon - IR = 3\varepsilon - 5IR = 0$

$\rightarrow I = \dfrac{3\varepsilon}{5R} = \boxed{0.82\text{ A}}$ $\boxed{\text{counterclockwise}}$

(b) $V_B - V_A = +IR - \varepsilon + IR = 2IR - \varepsilon = \boxed{0.6\text{ V}}$





Junction rule:

$$I_1 = I_2 + I_3$$

Loop rule:

$$\Delta V_{loop} = -3I_1R + 2\mathcal{E} = 0 \quad \text{(big loop)}$$

$$\Delta V_{loop} = +2I_2R - \mathcal{E} = 0 \quad \text{(small loop)}$$

So

$$I_1 = \frac{2\mathcal{E}}{3R} = 0.91\text{ A},$$

$$I_2 = \frac{\mathcal{E}}{2R} = 0.68\text{ A},$$

$$I_3 = I_1 - I_2 = \boxed{0.23\text{ A}}$$ & flows **right** in the wire