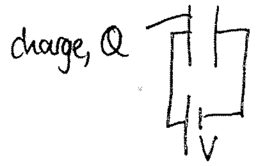
① $\boxed{1.1}$ parallel plate capacitor $C = \varepsilon_0 A/d$

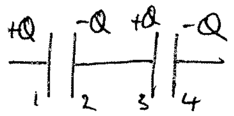


(a) d increases ⇒ C decreases $\boxed{B}$

(b) $Q = CV$, V is fixed, C decreases ⇒ Q decreases $\boxed{B.}$

(c) energy $U = \frac{1}{2}CV^2$, V is fixed, C decreases ⇒ U decreases $\boxed{B.}$

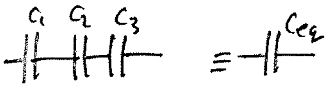
$\boxed{1.2}$ (a)



to remain overall neutral, plate 2 must have a charge $-Q$.

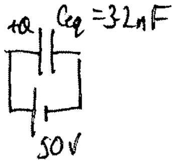
(b) all charge "pushed off" plate 2 must end up on plate 3 ⇒ charge on plate 3 is $+Q$

(c) in series $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

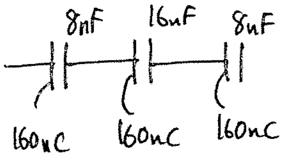


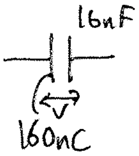
$$1/C_{eq} = \frac{1}{8nF} + \frac{1}{16nF} + \frac{1}{8nF} = \frac{2}{16nF} + \frac{1}{16nF} + \frac{2}{16nF} = 5/16nF \Rightarrow C_{eq} = \frac{16}{5}nF \underline{= 3.2nF}$$

(d)



$Q = C_{eq}V = \underline{160nC}$





$Q = CV$

$V = Q/C = \frac{160nC}{16nF} = \underline{10V}$

$\boxed{1.3}$ (a) energy stored $U = \frac{1}{2}CV^2$

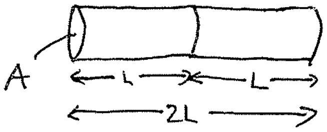
$$\Rightarrow C = 2U/V^2 = 2 \times \frac{1.0 \times 10^{-6} J}{(2.0V)^2} = \underline{0.5 \times 10^{-6} F}$$

(b) $Q = CV = (0.5 \times 10^{-6} F)(10V) = \underline{5 \times 10^{-6} C}$

the rightmost sphere is at lower potential ⇒ $q = \underline{-5.0 \times 10^{-6} C}$

② $\boxed{2.1}$ (a) resistivity is independent of the dimensions of the resistor $\Rightarrow \boxed{B}$

(b)

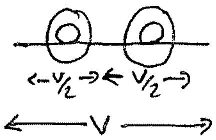


$R = \rho \frac{(2L)}{A}$ $\boxed{A}$

$\boxed{2.2}$ voltage across bulb 1 $= V$

power output of bulb 1 $= V^2/R = 200\,W$

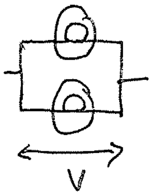
(a)



each bulb puts out $\left(\frac{V}{2}\right)^2/R = V^2/4R$

$\Rightarrow$ total power $= 2 \times V^2/4R = \frac{1}{2} V^2/R = \frac{1}{2} 200\,W = \underline{100\,W}$

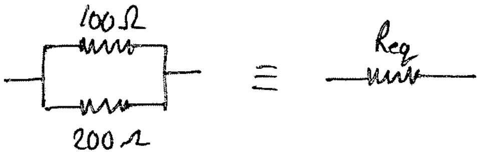
(b)



each bulb puts out V^2/R =

$\Rightarrow$ total power $= 2 \times V^2/R = 2 \times 200\,W = \underline{400\,W}$

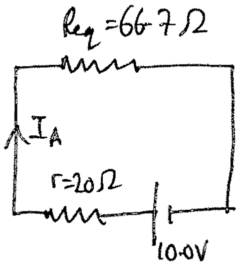
$\boxed{2.3}$ (a)



$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{100\,\Omega} + \frac{1}{200\,\Omega} = \frac{3}{200\,\Omega}$

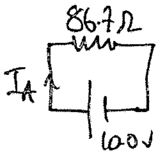
$R_{eq} = \frac{200}{3}\,\Omega = \underline{66.7\,\Omega}$

(b)



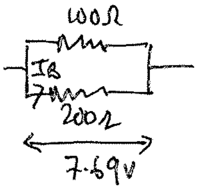
total resistance $= R_{eq} + r = 66.7\,\Omega + 20\,\Omega = 86.7\,\Omega$

≡



$V = I_A R \Rightarrow \underline{I_A} = V/R = \frac{10.0\,V}{86.7\,\Omega} = \underline{0.115\,A}$

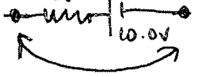
Voltage drop across the Req resistance, $V = I_A R_{eq} = (0.115\,A)(66.7\,\Omega)$
$= 7.69\,V$



$V = I_B R$

$\underline{I_B} = V/R = \frac{7.69\,V}{200\,\Omega} = \underline{0.0385\,A}$

(c) voltage drop across r : $V = I_A r = (0.115\,A)(20\,\Omega) = 2.3\,V$



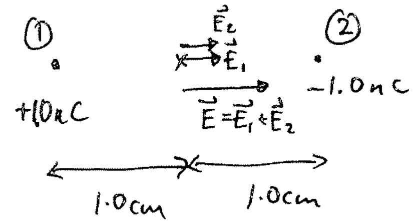
$10.0\,V - 2.3\,V = \underline{7.7\,V}$

(d) power lost in a resistor $\underline{P} = I^2 r = (0.115\,A)^2 (20\,\Omega) = \underline{0.265\,W}$

③ $\boxed{3.1}$ (a) field lines leave positive charges & arrive at negative charges $\}$ ⇒ q_1 is positive, q_2 is negative

(b) density of field lines indicates field strength, lines are most dense at A.

(c)



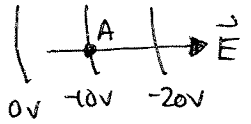
$$|\vec{E}_1| = \frac{k|q_1|}{r^2} = \frac{(8.99\times10^{9}\ \mathrm{Nm^2/C^2})(1.0\times10^{-9}\ \mathrm{C})}{(1.0\times10^{-2}\ \mathrm{m})^2}$$

$$= \underline{8.99\times10^{4}\ \mathrm{N/C}}$$

$$|\vec{E}_2| = \frac{k|q_2|}{r^2} = 8.99\times10^{4}\ \mathrm{N/C}$$

$$E_{tot} = E_1 + E_2 = \underline{1.80\times10^{5}\ \mathrm{N/C}}$$

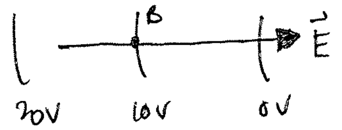
$\boxed{3.2}$ (a)



$\vec{F}=q\vec{E}$ ⇒ electric force points to the right $\boxed{B}$

q_{proton} is positive

(b)



$\vec{F}=q\vec{E}$, $q_{electron}$ is negative

⇒ electric force points to the left $\boxed{A}$

(c) $\boxed{A}$ acceleration at A is larger − electric field at A is larger & (hence so is the force) since the equipotentials are more closely spaced ($E=-\Delta V/\Delta s$)

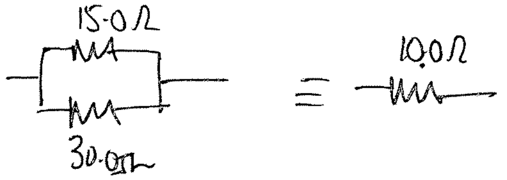
(d) in moving from point B to A the potential energy of the 10C charge

$U=qV$ decreases from (10C)(10V) = 100 J to (10C)(−10V) = −100 J,

a <u>decrease</u> of energy of 200 J

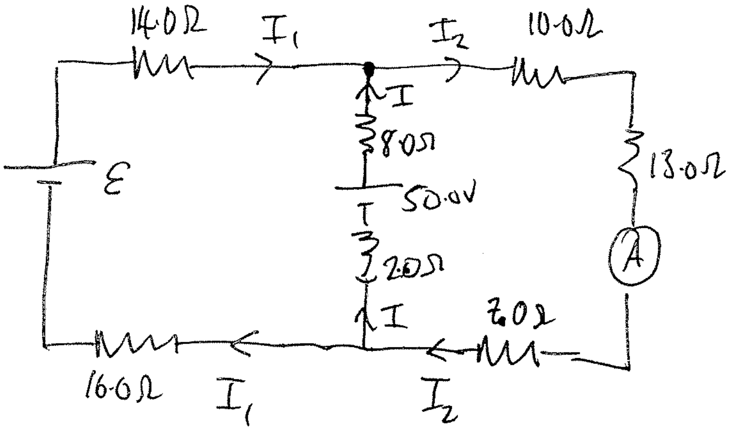
(e) C is on the same equipotential as B ⇒ change in potential energy is zero & <u>no work</u> is done by the electric field.

Extra Credit 15



$\frac{1}{R} = \frac{1}{30.0\Omega} + \frac{1}{15.0\Omega} = \frac{1}{30.0\Omega} + \frac{2}{30.0\Omega} = \frac{3}{30.0\Omega} = \frac{1}{10.0\Omega}$

$\underline{R = 10.0\Omega}$



$P = I^2R \Rightarrow I = \sqrt{\frac{P}{R}}$

$I = \sqrt{\frac{11.52W}{8.0\Omega}} = \underline{1.2A}$

- right most loop, clockwise $0 = -I_2(10.0\Omega) - I_2(13.0\Omega) - I_2(7.0\Omega)$

$- I(2.0\Omega) + 50.0V - I(8.0\Omega)$

$0 = -I_2(30.0\Omega) - I(10.0\Omega) + 50.0V$

$= -I_2(30.0\Omega) - (1.2A)(10.0\Omega) + 50.0V$

$= -I_2(30.0\Omega) - 12.0V + 50.0V$

$= -I_2(30.0\Omega) + 38.0V$

$I_2 = \frac{-38.0V}{-30.0\Omega} = 1.27A$

current in the ammeter is $\underline{1.27A}$
in the direction shown in the diagram

- leftmost loop, clockwise $0 = \mathcal{E} - I_1(14.0\Omega) + I(8.0\Omega) - 50.0V + I(2.0\Omega)$

$- I_1(16.0\Omega)$

$0 = \mathcal{E} - I_1(30.0\Omega) + I(10.0\Omega) - 50.0V$

at the upper junction $I_1 + I = I_2 \Rightarrow I_1 = I_2 - I = (1.2667 - 1.2)A = \underline{0.0667A}$

$0 = \mathcal{E} - (0.0667A)(30.0\Omega) + (1.2A)(10.0\Omega) - 50.0V$

$= \mathcal{E} - 2.0V + 12.0V - 50.0V = \mathcal{E} - 40.0V$

$\Rightarrow \underline{\mathcal{E} = 40.0V}$