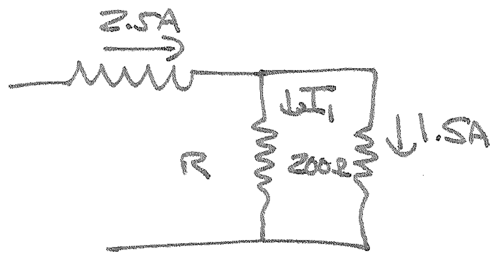
Physics 152, HW#5

Mastering Physics: 8 Questions
from Chapter 23

Two written Questions

23.19



WHAT is R?

By JUNCTION RULE: $I_1 + 1.5A = 2.5A$

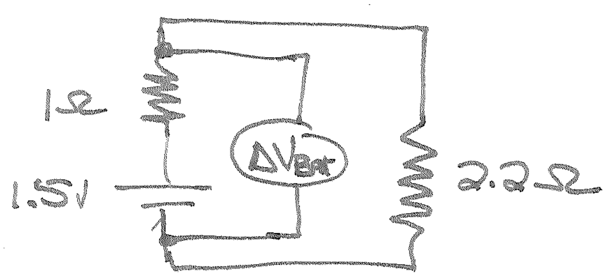
$\Rightarrow I_1 = 1A$

R AND 200Ω RESISTOR ARE IN parallel $\Rightarrow \Delta V_1 = \Delta V_2$

$\Delta V = IR \Rightarrow \Delta V_1 = (1.5A)(200\Omega) = 300V$

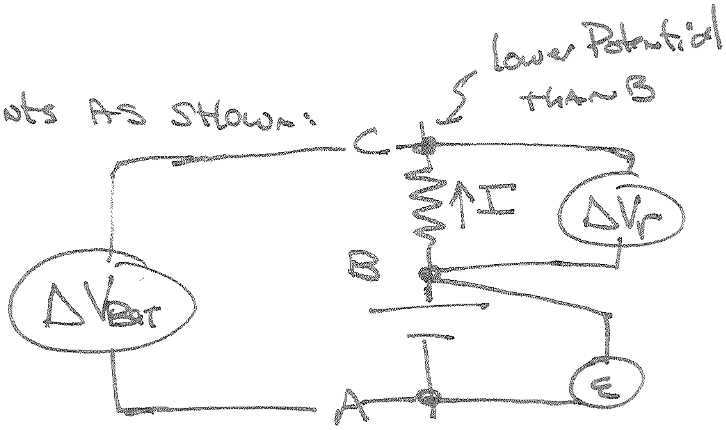
$$\Delta V_1 = I_1 R \Rightarrow R = \frac{\Delta V_1}{I_1} = \frac{300V}{1A} = 300\Omega$$

23.55



$\Delta V_{Bat} = ?$

Label Points as shown:



$\Delta V_{Bat} = V_C - V_A$

$\Delta V_r = V_B - V_C$

$\mathcal{E} = V_B - V_A$

$\Rightarrow \mathcal{E} - \Delta V_r = V_C - V_A$

$= \Delta V_{Bat}$

By Ohm's Law $\Delta V_r = Ir = I(1\Omega)$

$\Rightarrow \Delta V_{Bat} = \mathcal{E} - I(1\Omega)$

To Find I : $R_{EQ} = 1\Omega + 2.2\Omega = 3.2\Omega$

$\therefore I = \frac{\mathcal{E}}{R_{EQ}} = \frac{1.5V}{3.2\Omega} = 0.46875A$

$\therefore \Delta V_{Bat} = 1.5V - 0.46875A(1\Omega) = 1.03125\ V = 1.0V$

b) WHAT FRACTION Dissipated? $\frac{\Delta P}{P} = ?$

ΔP = Power used by INTERNAL Resistance

$P_R = I^2R \Rightarrow \Delta P = (0.46875A)^2(1\Omega) = 0.2197$ watt

P = Power supplied by EMF $\rightarrow P_{EMF} = I\mathcal{E} = (0.46875A)(1.5V)$

$= .703125$ watt

$$\therefore \quad \frac{\Delta P}{P} = \frac{0.2197 \text{ watt}}{0.703125 \text{ watt}} = 0.31246 \times 100\% = 31.246\%$$

$$= 31\%$$

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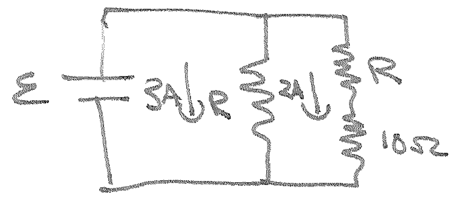


a) what is R?

THE Resistor R on the left AND THE R/10Ω Combo on the Right ARE in parallel with battery

$$\Rightarrow \Delta V_1 = \Delta V_2 = \mathcal{E}$$

$$\Delta V_\phi = IR \Rightarrow \Delta V_1 = (3A)R, \quad \Delta V_2 = (2A)\underbrace{(R+10\Omega)}_{\text{Series}} = (2A)R + 20V$$

$$\Rightarrow (3A)R = (2A)R + 20V \Rightarrow [(3A-2A)]R = 20V$$

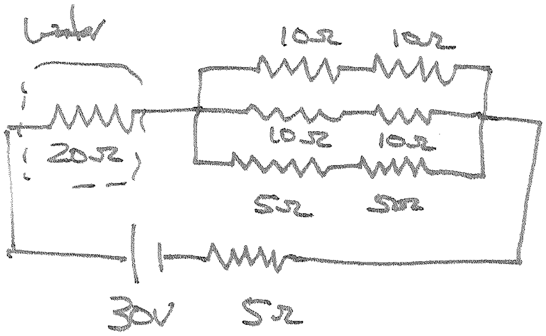
$$\Rightarrow (1A)R = 20V \Rightarrow R = \frac{20V}{1A} = 20\Omega$$

b) $\mathcal{E} = \Delta V_1 = (3A)R = (3A)(20\Omega) = 60V$

If you prefer: $\mathcal{E} = \Delta V_2 = (2A)(R+10\Omega) = (2A)(20\Omega+10\Omega)$

$$= (2A)(30\Omega) = 60V$$

Heating A Water Bath :



$m = 104g \times \frac{kg}{1000g} = 0.104\,kg$

Water at $T_i = 10.7°C$

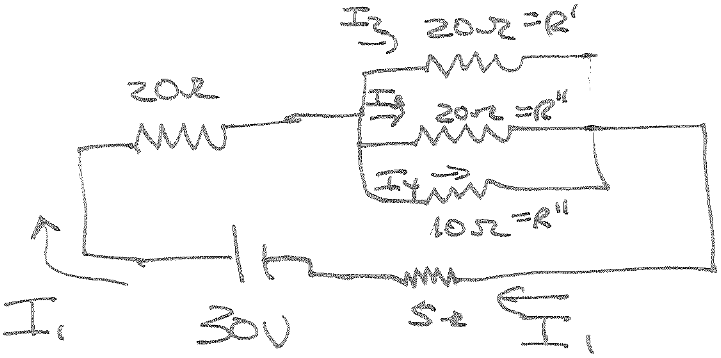
How long until $T_f = 58.7°C$

$Heat = mc\Delta T$

Heat Supplied by 20Ω Resistor

$P_R = I^2 R \Rightarrow$ Need Current through it

Luckily 20Ω Connected in Series to battery ⇒ Find R_{EQ}



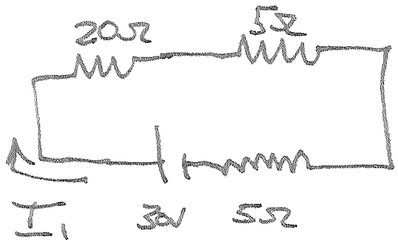
Notice I used Series Formulas to simplify

R', R'', R''' in ~~Series~~ Parallel

$$\Rightarrow \frac{1}{R^{(4)}} = \frac{1}{R'} + \frac{1}{R''} + \frac{1}{R'''}$$

$$\Rightarrow \frac{1}{R^{(4)}} = \frac{1}{20\Omega} + \frac{1}{20\Omega} + \frac{1}{10\Omega} = \frac{1}{20\Omega} + \frac{1}{20\Omega} + \frac{2}{20\Omega} = \frac{4}{20\Omega} = \frac{1}{5\Omega}$$

$$\Rightarrow R^{(4)} = 5\Omega$$



$R_{EQ} = 20\Omega + 5\Omega + 5\Omega = 30\Omega$

$$I_1 = \frac{\mathcal{E}}{R_{EQ}} = \frac{30V}{30\Omega} = 1A$$

$$P_R = I_1^2 R_1 = (1A)^2(20\Omega) = 20\,\text{watt} = 20\,J/s$$

$$P_R = \frac{Heat}{\Delta t} \qquad Heat = mc\,\Delta T = (0.104\,kg)(4190\,J/kg\cdot{}^\circ C)(58.7^\circ C - 10.7^\circ C)$$

$$= (0.104\,kg)(4190\,J/kg\cdot C^\circ)(48^\circ C) =$$

$$20916.48\,\cancel{watt}\ J$$

$$20\,J/s = \frac{20916.48\,J}{\Delta t} \Rightarrow \Delta t = \frac{20916.48\,J}{20\,J/s} = 1045.824\,s$$

$$= 1050\,s$$

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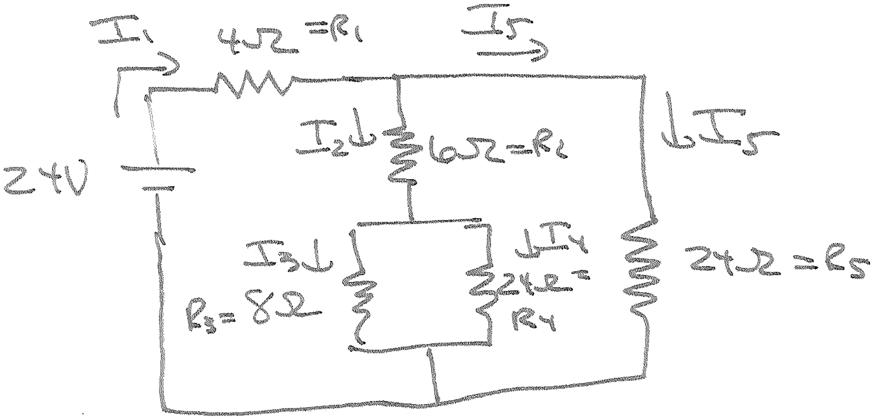
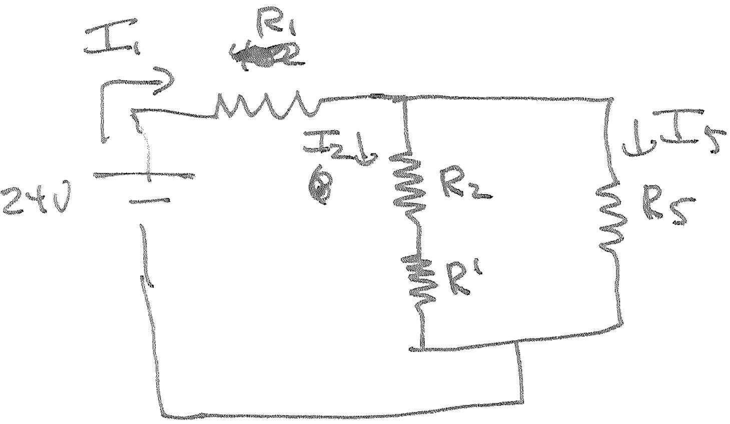


label Currents As Shown.

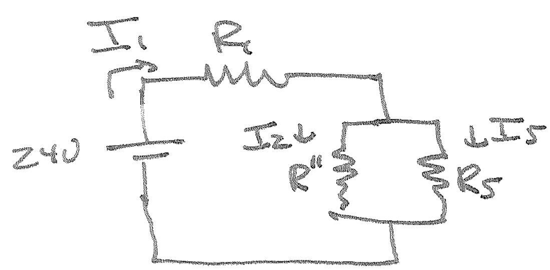
R_1 in Series with battery

R_3 & R_4 in parallel $\Rightarrow$ $R' = \frac{R_3 R_4}{R_3 + R_4} = \frac{(8\Omega)(24\Omega)}{(8\Omega + 24\Omega)} = \frac{192\,\Omega^2}{32\,\Omega} = 6\,\Omega$



R_2 & R' in Series

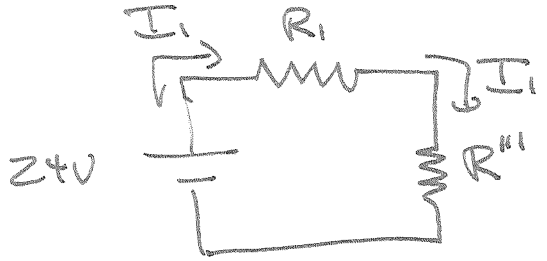
$\Rightarrow R'' = R_2 + R' = 6\Omega + 6\Omega = 12\Omega$



R'' & R_5 in Parallel $\Rightarrow$

$R''' = \frac{R'' R_5}{R'' + R_5} = \frac{(12\Omega)(24\Omega)}{(12\Omega + 24\Omega)} = \frac{288\,\Omega^2}{36\,\Omega}$

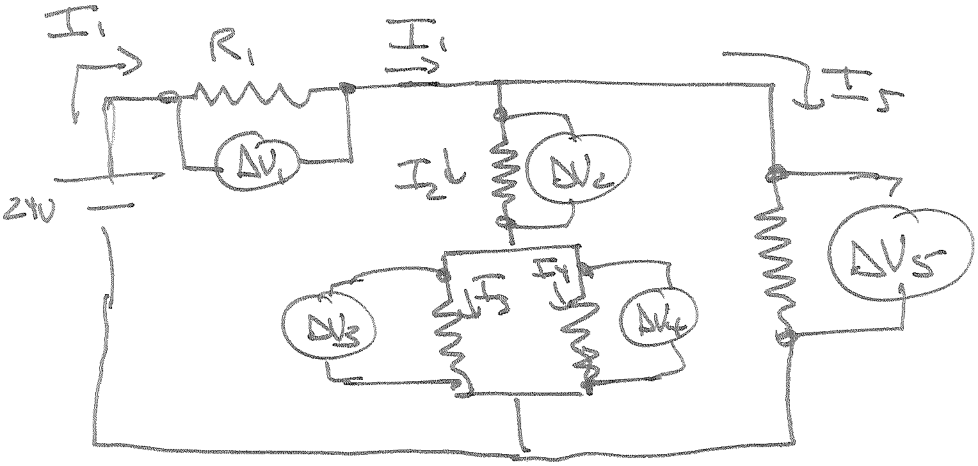
$= 8\,\Omega$



Series $\Rightarrow$

$R_{EQ} = R_1 + R''' = 4\Omega + 8\Omega = 12\Omega$

$$I_1 = \frac{\mathcal{E}}{R_{EQ}} = \frac{24V}{12\Omega} = 2A$$



$\Delta V_1 = I_1 R_1 = (2A)(4\Omega) = 8V$

A little checking shows $\Delta V_1 + \Delta V_5 = \mathcal{E} \Rightarrow \Delta V_5 = \mathcal{E} - \Delta V_1 = 24V - 8V$
$= 16V$

$$\Delta V_5 = I_5 R_5 \Rightarrow I_5 = \frac{\Delta V_5}{R_5} = \frac{\cancel{24\Omega}\ 16V}{24\Omega} = 0.6666..\ A = \tfrac{2}{3} A$$

Junction Rule: $I_1 = I_2 + I_5 \Rightarrow I_2 = I_1 - I_5 = 2A - \tfrac{2}{3}A =$
$\tfrac{4}{3}A = 1.333A$

$\Delta V_2 = I_2 R_2 = (\tfrac{4}{3}A)(6\Omega) = 8V$

A little more checking shows $\Delta V_1 + \Delta V_2 + \Delta V_3 = \mathcal{E}$

$$\Rightarrow \Delta V_3 = \mathcal{E} - \Delta V_1 - \Delta V_2 = 24V - 8V - 8V = 8V$$

$$\Delta V_3 = I_3 R_3 \Rightarrow I_3 = \frac{\Delta V_3}{R_3} = \frac{8V}{8\Omega} = 1A$$

$\Delta V_4 = \Delta V_3$ since Parallel, $I_4 = \frac{\Delta V_4}{R_4} = \frac{8V}{24\Omega} = \frac{1}{3}A = 0.333\ A$

So In summary:

	I_i	ΔV_i
R_1	2A	8V
R_2	$4/3$A = 1.3A	8V
R_3	1A	8V
R_4	$\frac{1}{3}$A = 0.33A	8V
R_5	$2/3$A = 0.67A	16V

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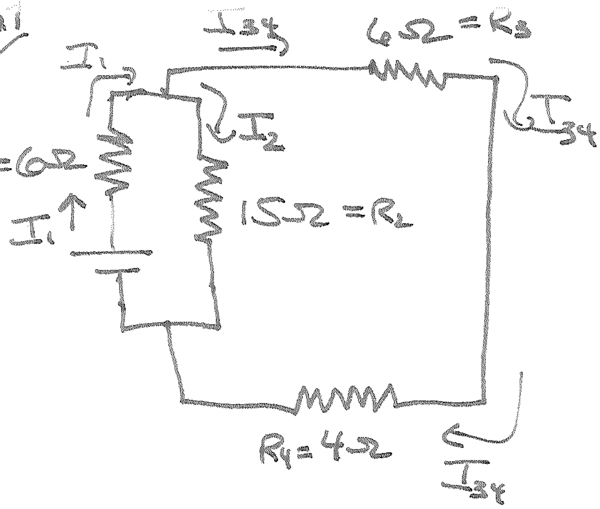


This is drawn strangely.

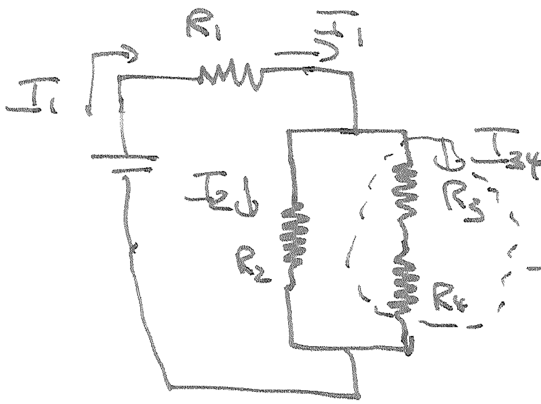
Labeling currents as shown helps

R_3 & R_4 are in series

R_1 in series with battery

Current then splits to go through R_2 and R_3/R_4. Finger test ⇒ R_2 in parallel with R_3/R_4

So a better picture is:

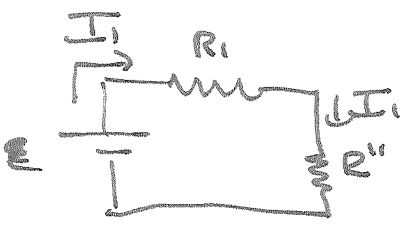


$R' = R_3 + R_4 = 6\Omega + 4\Omega$

$= 10\Omega$

$$R'' = \frac{R_2 R'}{R_2 + R'}$$

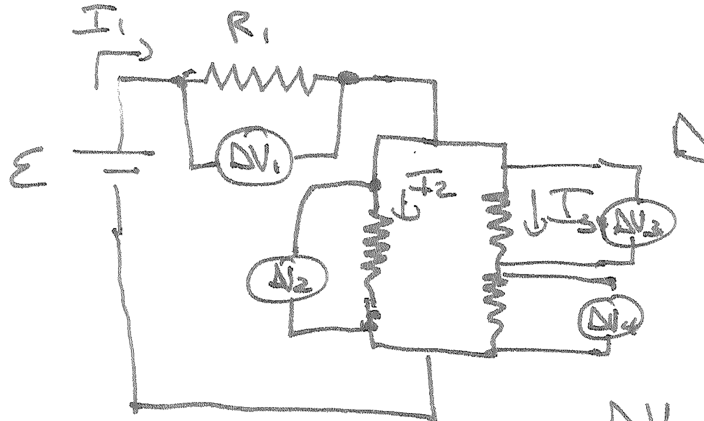
$$R'' = \frac{(15\Omega)(10\Omega)}{(15\Omega + 10\Omega)} = \frac{150\Omega^2}{25\Omega} = 6\Omega$$



$$R_{EQ} = R_1 + R'' = 6\Omega + 6\Omega = 12\Omega$$

$$I_1 = \frac{\mathcal{E}}{R_{EQ}} = \frac{24V}{12\Omega} = 2A$$

Now Find $\Delta V_1 = I_1 R_1$ $\quad \Delta V_1 = (2A)(6\Omega) = 12V$



$\Delta V_1 + \Delta V_2 = \varepsilon \Rightarrow \Delta V_2 = \varepsilon - \Delta V_1$

$\Delta V_2 = 24V - 12V = 12V$

$\Delta V_2 = I_2 R_2 \Rightarrow I_2 = \frac{\Delta V_2}{R_2} = \frac{12V}{15\Omega} = 0.8A$

Junction Rule: $I_1 = I_2 + I_{34} \Rightarrow I_{34} = I_1 - I_2 = 2A - 0.8A = 1.2A$

$\Delta V_3 = I_{34} R_3 = (1.2A)(6\Omega) = 7.2V$

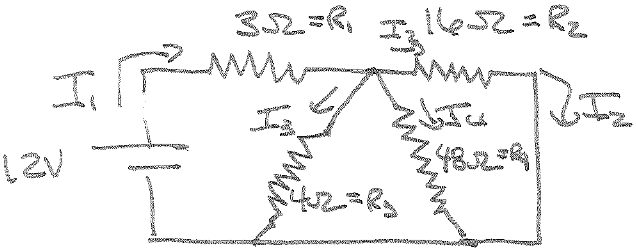
$\Delta V_4 = I_{34} R_4 = (1.2A)(4\Omega) = 4.8V$

Notice $\Delta V_3 + \Delta V_4 = 12V = \Delta V_2$
Since they're in Parallel

In summary:

	I_i	ΔV_i
R_1	2A	12V
R_2	0.8A	12V
R_3	1.2A	7.2V
R_4	1.2A	4.8V

23.29



Again, Strangely Drawn

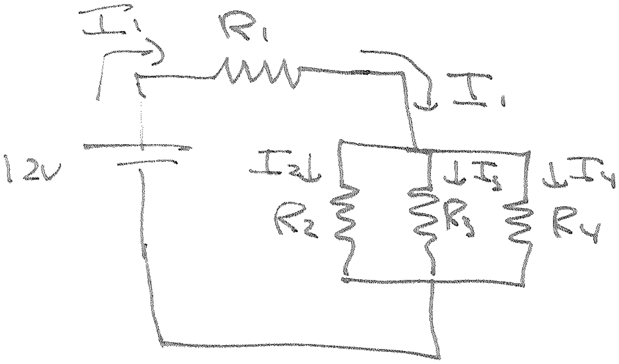
Label Currents As Shown

Current From Battery must go through R_1 ⇒ In Series.

I_1 then splits into 3

Finger test shows R_2, R_3 R_4 in Parallel

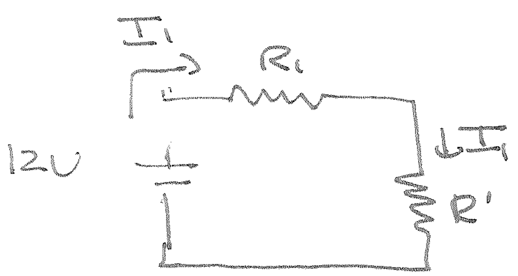
So A Better Drawing:



In Parallel ⇒ $\frac{1}{R'} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$

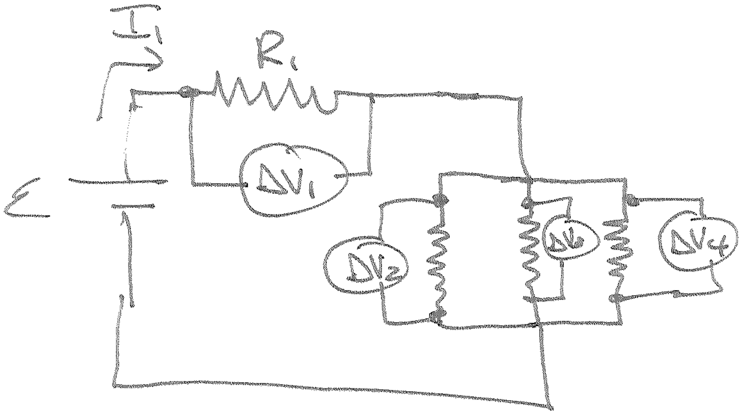
$$\Rightarrow \frac{1}{R'} = \frac{1}{16\Omega} + \frac{1}{4\Omega} + \frac{1}{48\Omega} = \frac{3}{48\Omega} + \frac{12}{48\Omega} + \frac{1}{48\Omega}$$

$$\Rightarrow \frac{1}{R'} = \frac{16}{48\Omega} = \frac{1}{3\Omega} \Rightarrow R' = 3\Omega$$



Series ⇒ $R_{EQ} = R_1 + R' = 3\Omega + 3\Omega = 6\Omega$

$$I_1 = \frac{\varepsilon}{R_{EQ}} = \frac{12V}{6\Omega} = 2A$$



$$\Delta V_1 = I_1 R_1 = (2A)(3\Omega) = 6V$$

Parallel $\Rightarrow \Delta V_2 = \Delta V_3 = \Delta V_4$

$$\Delta V_1 + \Delta V_2 = \varepsilon \Rightarrow \Delta V_2 = \varepsilon - \Delta V_1$$

$$\Rightarrow \Delta V_2 = 12V - 6V = 6V$$

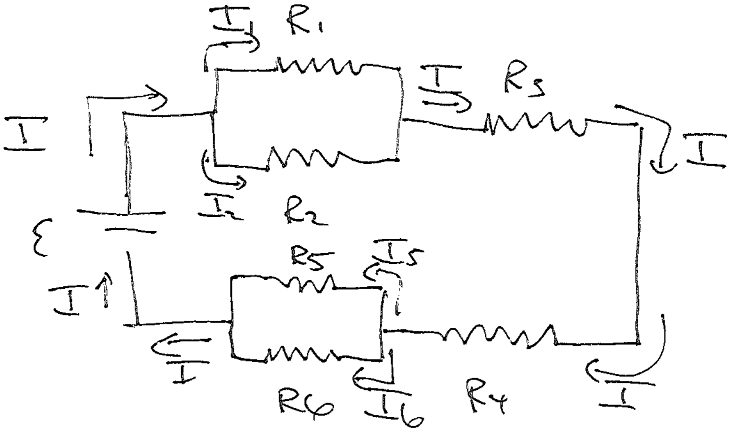
$$\Delta V_2 = I_2 R_2 \Rightarrow I_2 = \frac{\Delta V_2}{R_2} = \frac{6V}{16\Omega} = 0.375A = 0.38A$$

$$I_3 = \frac{\Delta V_3}{R_3} = \frac{6V}{4\Omega} = 1.5A$$

$$I_4 = \frac{\Delta V_4}{R_4} = \frac{6V}{48\Omega} = 0.125A = 0.13A$$

Notice How $I_2 + I_3 + I_4 = I_1$ As Junction Rule Requires

23.52



$R_1 = 50\Omega$

$R_2 = 35\Omega$

$R_3 = 45\Omega$

$R_4 = 70\Omega$

$R_5 = 25\Omega$

$R_6 = 35\Omega$

MAX power, $P_{max} = 0.6$ Watt

a.) Which Resistor uses the most power?

It's kind of tricky but R_3 & R_4 are in series with the battery.
The current entering the first junction is the same as the battery's.

Junction Rule $\Rightarrow I_1 + I_2 = I$ $\Rightarrow$ same current I going through R_3 and R_4.

At the other junction, we get $I_5 + I_6 = I$

$I_1 + I_2 = I \Rightarrow$ Current through R_1 & R_2 smaller than current through R_3 & R_4

$I_5 + I_6 = I \Rightarrow$ Current through R_5 & R_6 smaller than current through R_3 & R_4

$P = I^2R \Rightarrow$ Resistor with largest current and resistance value uses most power. $R_4 = 70\Omega$ is largest resistor and has the largest current $\Rightarrow$ uses most power.

b.) What is MAX Current From battery?.

Since R_4 is using the most power, if it's using the MAX then everybody else is using less.

$P = I^2 R \Rightarrow P_{MAX} = I_4^2 R_4$ but since R_4 in Series with battery $I_4 = I$

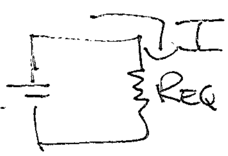
$\uparrow$ current through #4

$\Rightarrow P_{MAX} = I^2 R_4 \Rightarrow I^2 = \frac{P_{MAX}}{R_4} \Rightarrow I = \sqrt{\frac{P_{MAX}}{R_4}} = \sqrt{\frac{0.6\,\text{watt}}{70\,\Omega}}$

$\Rightarrow I = 0.0926\,A$ $\left(\text{Unit: } \frac{\text{Watt}}{\Omega} = \frac{J/s}{V/A} = \frac{J/s}{J/C} \cdot A = \frac{C}{s} \cdot A = A \cdot A = A^2 \qquad \sqrt{A^2} = A \right)$

c.) What is MAX emf?

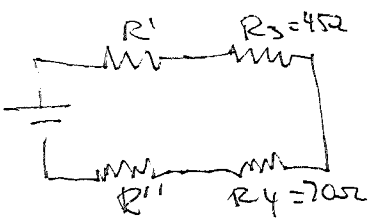
I = Current From battery $\Rightarrow$ Also Current in Equivalent Circuit



$\mathcal{E} = I R_{EQ}$ $\Rightarrow$ Find Equivalent Resistance

R_1 & R_2 in parallel $\Rightarrow R' = \frac{R_1 R_2}{R_1 + R_2} = \frac{(50\Omega)(35\Omega)}{(50\Omega + 35\Omega)} = 20.588\,\Omega$

R_5 & R_6 in parallel $\Rightarrow R'' = \frac{R_5 R_6}{R_5 + R_6} = \frac{(25\Omega)(35\Omega)}{(25\Omega + 35\Omega)} = 14.583\,\Omega$

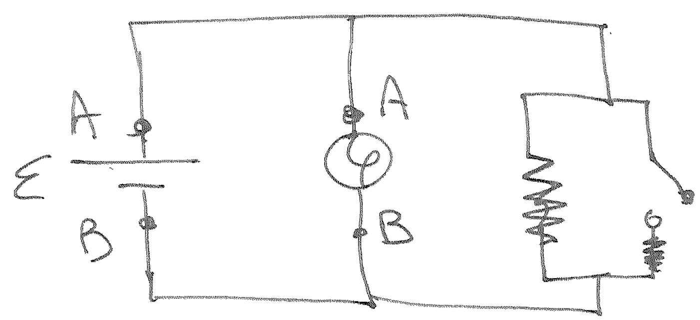


Series $\Rightarrow R_{EQ} = R' + R_3 + R_4 + R'' = 150.171\,\Omega$

$\Rightarrow \mathcal{E} = I R_{EQ} = (0.0926A)(150.171\Omega) = 13.9V$
$= \underline{14V}$

Written Question #1

a)



WHAT HAPPENS TO LIGHT BULB WHEN SWITCH CLOSED?

THE LIGHT BULB IS CONNECTED IN Parallel TO THE Battery. SINCE, AS SHOWN, $\Delta V_{LB} = V_A - V_B$ AND $\mathcal{E} = V_A - V_B$.

Light Bulb

CLOSING THE SWITCH HAS NO EFFECT ON THIS. SO

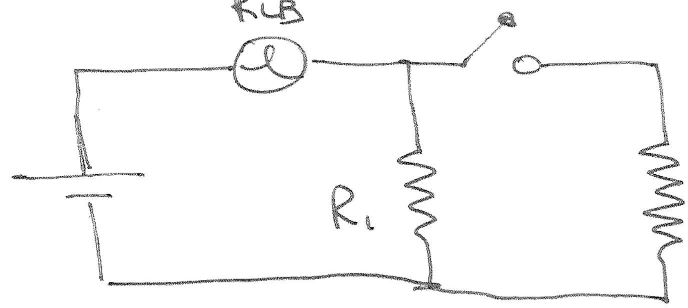
$P_{LB} = \frac{\Delta V_{LB}^2}{R_{LB}}$ tells us THAT THE power DISSIPATED By THE Light bulb stays THE SAME $\Rightarrow$ STAYS THE SAME Brightness

CONSTANT

$$P_{LB} = \frac{\mathcal{E}^2}{R_{LB}}$$

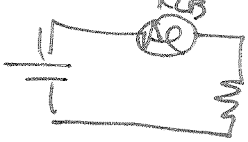
CONSTANT

b.)



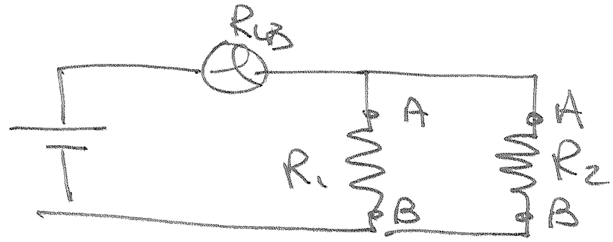
WHAT HAPPENS TO LIGHTBULB WHEN SWITCH CLOSED?

WITH SWITCH OPEN R_2 IS NOT IN CIRCUIT $\Rightarrow$



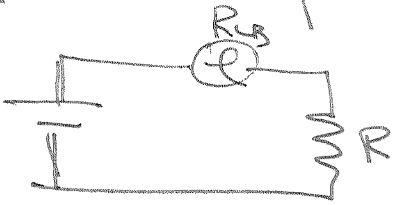
SERIES $\Rightarrow R_{EQ} = R_{LB} + R_1$

CLOSING THE SWITCH ADDS ~~A~~ RESISTOR R_2 IN PARALLEL TO R_1 SINCE



$\Delta V_1 = \Delta V_2 = V_A - V_B$

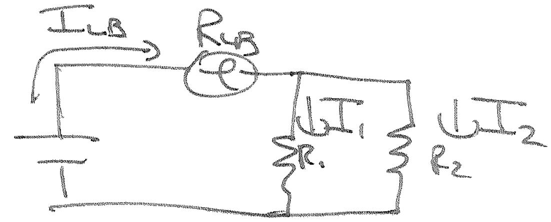
THE EQUIVALENT RESISTANCE OF RESISTORS IN PARALLEL IS SMALLER THAN INDIVIDUAL VALUES $\Rightarrow$



WHERE R' IS SMALLER THAN R_1

LIGHTBULB AND R' IN SERIES $\Rightarrow R_{EQ} = R_{LB} + R'$ SO SINCE R' SMALLER THAN R_1 THE CIRCUIT'S EQUIVALENT RESISTANCE IS SMALLER WITH SWITCH CLOSED. $\Rightarrow$ CURRENT FROM BATTERY INCREASES

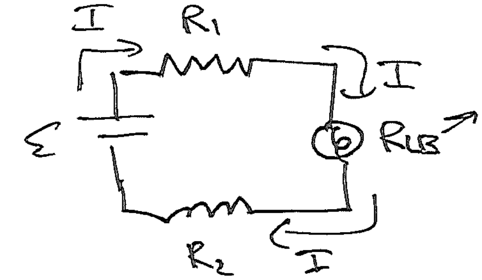
THE LIGHTBULB IS CONNECTED IN SERIES TO THE BATTERY (WITH SWITCH OPEN OR CLOSED) $\Rightarrow$ MUST HAVE SAME AMOUNT OF CURRENT THROUGH LIGHTBULB AND BATTERY.



SO MORE CURRENT FROM BATTERY $\Rightarrow$ MORE CURRENT THROUGH LIGHTBULB.

$P_{LB} = I^2 R_{LB} \Rightarrow$ MORE POWER $\Rightarrow$ BRIGHTER

#2 ~~#3~~



LB = LightBulB

a.) ADD ONE Resistor to Circuit to make lightbulb DIMMER.

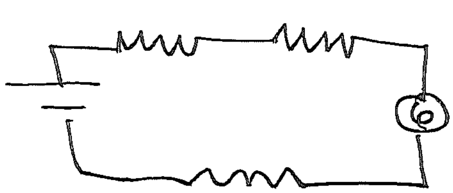
initially, All 3 are in Series ∴ $R_{EQ} = R_1 + R_{LB} + R_2$

AND $I = \frac{\mathcal{E}}{R_{EQ}}$

To make lightbulb Dimmer, we need to make R_{EQ} LARGER AND keep lightbulb in series with Battery so that the smaller current coming out of battery ⇒ smaller current through bulb.

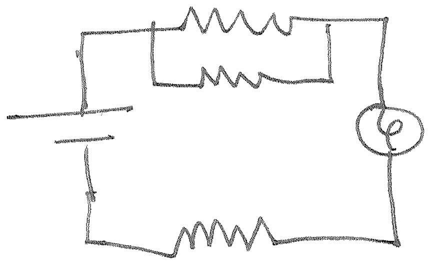
R_{EQ} Becomes LARGER by ADDING ANOTHER Resistor in series

⇒

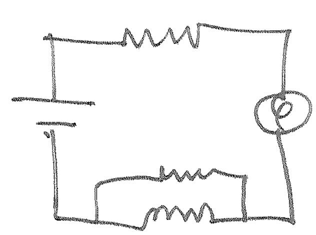


b.) MAKE Brighter → SAME BASIC IDEA but we want to make R_{EQ} smaller while keeping lightbulb in series with Battery. ∴ ADD Resistor in parallel to one of the resistors AND NOT the lightbulb.

(SEE next page)

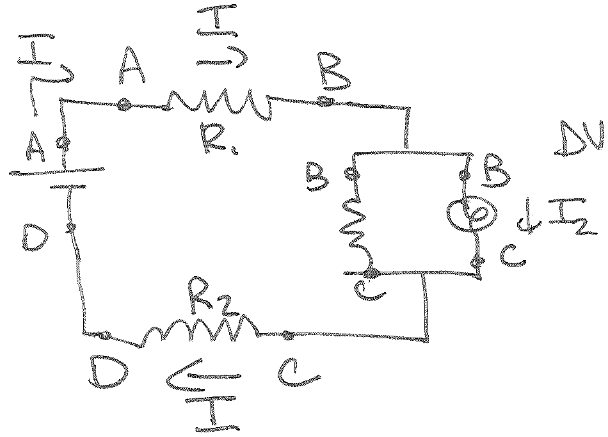


OR



Makes R_{EQ} smaller
AND light bulb in series with battery
$\Rightarrow$ More current through lightbulb $\Rightarrow$ brighter

But ADDING Resistor to lightBULB will make it dimmer!



$\Delta V_1 = V_A - V_B$, $\Delta V_2 = V_C - V_D$

While $\Delta V_{LB} = V_B - V_C$

LightBULB

Notice THAT $\Delta V_1 + \Delta V_{LB} + \Delta V_2 = V_A - \cancel{V_B} + \cancel{V_B} - \cancel{V_C} + V_C - V_D = \mathcal{E}$

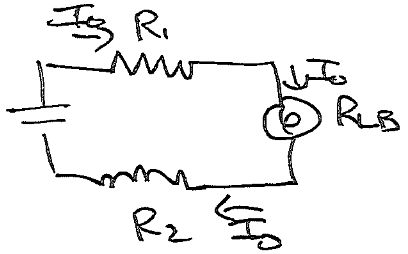
$\Rightarrow \Delta V_{LB} = \mathcal{E} - \Delta V_1 - \Delta V_2$

(Resistors R_1 & R_2 in series with battery $\Rightarrow$ current through them must also increase)

Ohm's LAW $\Rightarrow \Delta V_1 = IR_1$, $\Delta V_2 = IR_2$. When we ADD a Resistor in parallel, THE AMOUNT OF current (I) DOES INCREASE But so does ΔV_1 AND ΔV_2. ($\Delta V_1 = IR_1$, $\Delta V_2 = IR_2$) Since $\mathcal{E}$ is constant, increasing ΔV_1 AND ΔV_2 means that ΔV_{LB} must decrease since $\Delta V_{LB} = \mathcal{E} - \Delta V_1 - \Delta V_2$

$P_{LB} = \dfrac{\Delta V_{LB}^2}{R_{LB}} \Rightarrow$ Less power for light bulb $\Rightarrow$ DIMMER c.) Keep Brightness the same.

In order to keep lightbulb the same we need to keep the current flowing through it the same.



$R_{EQ} = R_1 + R_{LB} + R_2 \Rightarrow I_0 = \frac{\mathcal{E}}{R_1 + R_{LB} + R_2}$

$\Rightarrow$ we need to keep the voltage across the combination equal to the battery's EMF

$\Rightarrow$ Add new resistor in parallel to battery that way the voltage across the original combo stays the same.

$\Rightarrow$