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Electronics and Modern Physics for Computers PHY 232

Lecture Note

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Lecture Overview

1. D.C. Circuits
2. Kirchhoff's Laws, sources of end and current,
3. network analysis and circuit theorems.
4. A.C. Circuits. Inductance, capacitance, the transformer, sinusoidal wave-forms runs and peak values,
5. power, impedance and admittance series RLC circuit, Q factor, resonance,
6. filters.
7. Electronics; Thermionic emission; vacuum tube, thermionic devices; valves and the CRT
8. semiconductors, the pn-junction,
9. Bipolar Transistors and Field Effect Transistors
10. Characteristics and equivalent circuits,
11. Amplifiers,
12. Feedback and oscillators.

13. Exercises

LESSON 2

Kirchhoff’s Laws, sources of end and current

Kirchhoff’s Laws

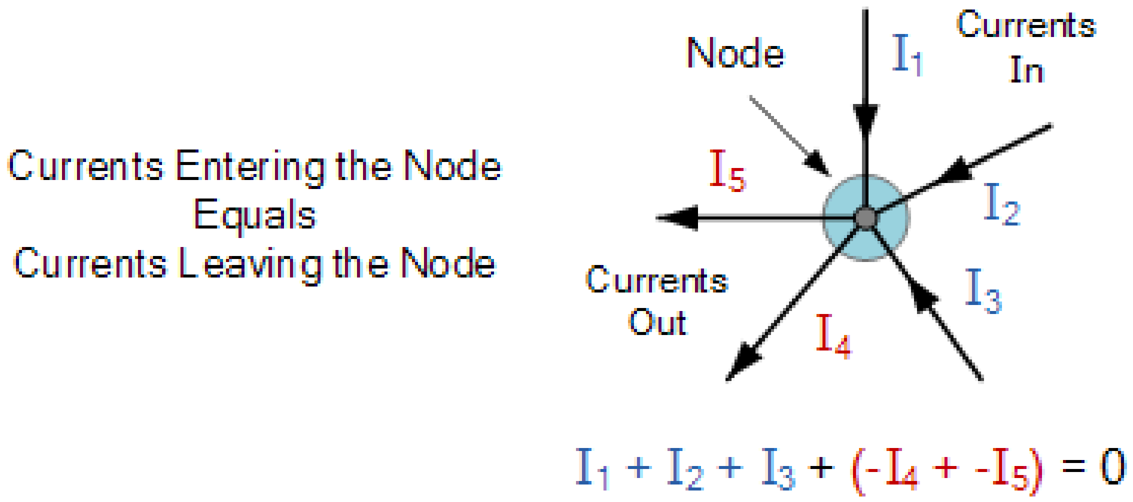
- In 1845, a German physicist, **Gustav Kirchhoff** developed a set of laws which deal with the conservation of current and energy within electrical circuits. They are

1. Kirchhoff’s first law or Point law or Current law (KCL). It states that “*total current or charge entering a junction or node is exactly equal to the charge leaving the node.*
2. Kirchhoff’s second law or Mesh law or Voltage law (KVL). It states that “*in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop” or the sum of the product of the current and resistance in a closed mesh plus the sum of the e.m.f in that mesh is zero*

Common DC Circuit Theory Terms:

- • Circuit – a circuit is a closed loop conducting path in which an electrical current flows.
- • Path – a single line of connecting elements or sources.
- • Node – a node is a junction, connection or terminal within a circuit were two or more circuit elements are connected or joined together giving a connection point between two or more branches. A node is indicated by a dot.
- • Branch – a branch is a single or group of components such as resistors or a source which are connected between two nodes.
- • Loop – a loop is a simple closed path in a circuit in which no circuit element or node is encountered more than once.
- • Mesh – a mesh is a single open loop that does not have a closed path. There are no components inside a mesh.

Kirchhoff’s first law or Point law or Current law (KCL)



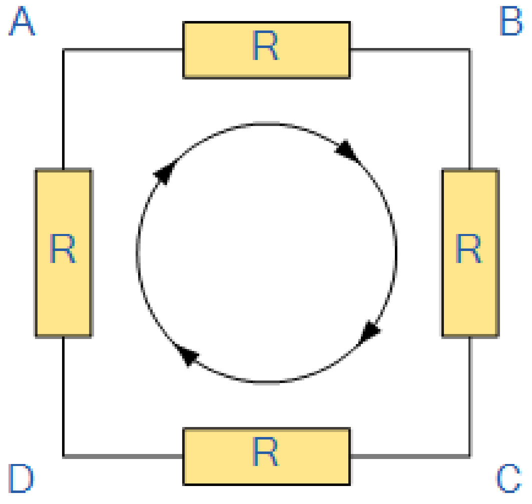
$$\sum I = 0$$

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

Kirchhoff’s second law or Mesh law or Voltage law (KVL).

$$\sum IR + \sum e.m.f = 0$$

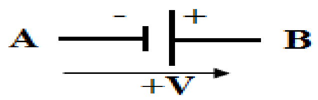
The sum of all the Voltage
Drops around the loop
is equal to Zero

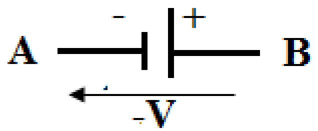


$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

Determination of Sign

- In applying Kirchhoff's laws to specific problems, particular attention should be given to the algebraic signs of voltage drops and e.m.f.s; otherwise the results will be wrong.
- 1. arise in voltage is +ve

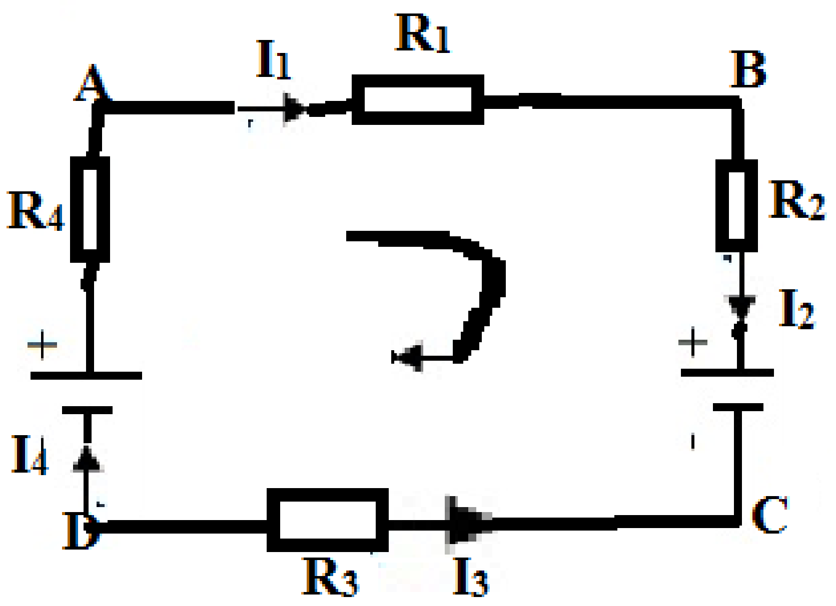




- 2. fall in voltage is -ve
- Note: the sign of the battery is independent of the direction of the current through the branch. Current flows from higher potential to lower potential.

Determination of Sign

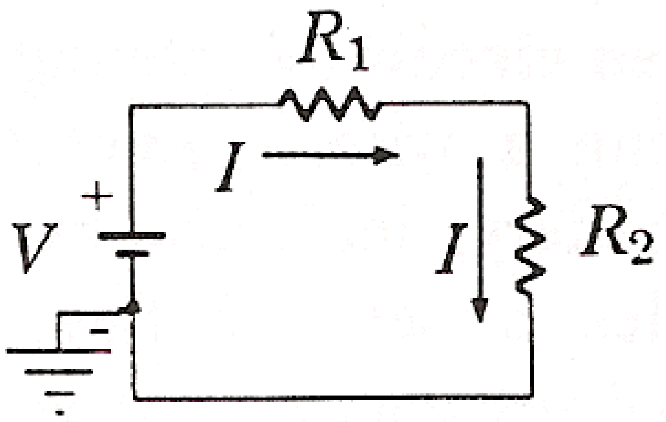
- Consider the closed path ABCDA in the figure below



- $-I_1R_1$
- $-I_2R_2$
- $+I_3R_3$
- $-I_4R_4$
- $+E_1$
- $-E_2$

$$-I_1R_1 - I_2R_2 + I_3R_3 - I_4R_4 - E_2 + E_1 = 0$$
$$I_1R_1 + I_2R_2 - I_3R_3 + I_4R_4 = E_1 - E_2$$

Kirchhoff's Voltage Law – Series Circuit



$$V_{Total} + (-IR_1) + (-IR_2) = 0$$

$$V_{Total} = IR_1 + IR_2, \quad V_{Total} = IR_{Total}$$

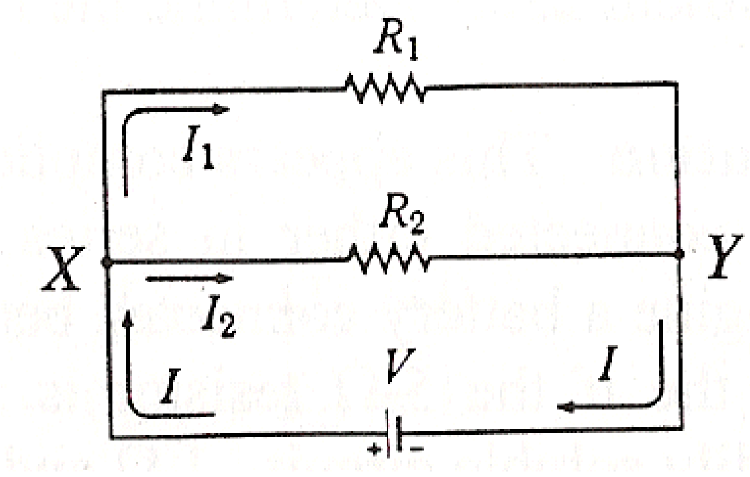
$$IR_{Total} = IR_1 + IR_2 \quad \text{("I" Cancels)}$$

$$R_{Total} = R_1 + R_2 \rightarrow R_{Total(series)} = \sum_{i}^{n} R_i$$

Here we see that applying Kirchhoff's Voltage Law to this loop produces the formula for the ***effective*** resistance in a series circuit. The word ***effective*** or ***equivalent*** means the same thing as the TOTAL.

Kirchhoff's Current Law

"The sum of the currents flowing into a junction is equal to the sum of the currents flowing out."



$$I_{Total} = I_1 + I_2$$

$$\frac{V_T}{R_T} = \frac{V_1}{R_1} + \frac{V_2}{R_2}$$

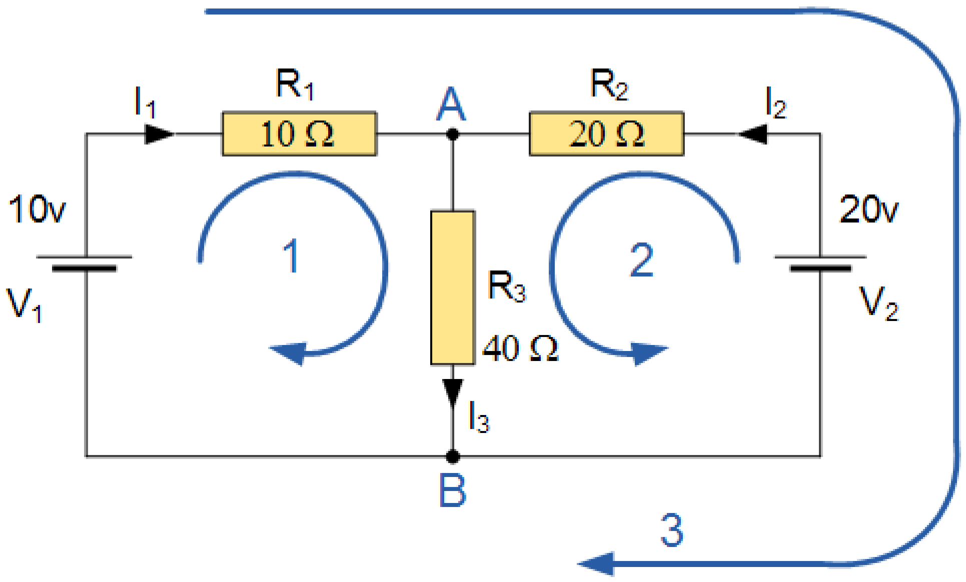
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_p} = \sum_{i}^{n} \frac{1}{R_i}$$

When two resistors have BOTH ends connected together, with nothing intervening, they are connected in PARALLEL. The drop in potential when you go from X to Y is the SAME no matter which way you go through the circuit. Thus resistors in parallel have the same potential drop.

Examples

- Find the current flowing in the R_3

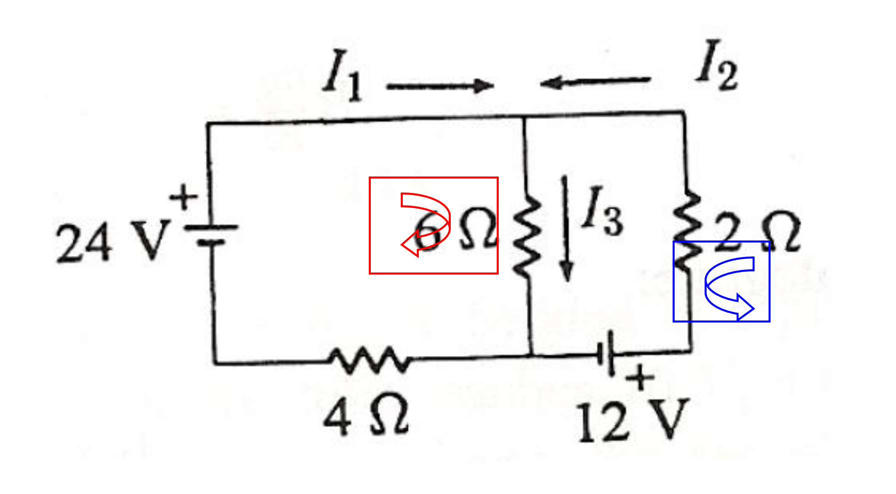


solution

- The circuit has 3 branches, 2 nodes (A and B) and 2 independent loops.
- Using **Kirchhoff's Current Law**, **KCL** the equations are given as:
- At node A : $I_1 + I_2 = I_3$
- At node B : $I_3 = I_1 + I_2$
- Using **Kirchhoff's Voltage Law**, **KVL** the equations are given as:
- Loop 1 is given as : $10 = R_1\, I_1 + R_3\, I_3 = 10I_1 + 40I_3$
- Loop 2 is given as : $20 = R_2\, I_2 + R_3\, I_3 = 20I_2 + 40I_3$
- Loop 3 is given as : $10 – 20 = 10I_1 – 20I_2$
- As I_3 is the sum of $I_1 + I_2$ we can rewrite the equations as;
- Eq. No 1 : $10 = 10I_1 + 40(I_1 + I_2) = 50I_1 + 40I_2$
- Eq. No 2 : $20 = 20I_2 + 40(I_1 + I_2) = 40I_1 + 60I_2$
- "**Simultaneous Equations**" can be reduced to give us the values of I_1 and I_2
- Substitution of I_1 in terms of I_2 gives us the value of I_1 as -0.143 Amps
- Substitution of I_2 in terms of I_1 gives us the value of I_2 as +0.429 Amps
- As : $I_3 = I_1 + I_2$
- The current flowing in resistor R_3 is given as : -0.143 + 0.429 = 0.286 Amps
- and the voltage across the resistor R_3 is given as : 0.286 x 40 = 11.44 volts

Applying Kirchhoff’s Laws

Goal: Find the three unknown currents.



First decide which way you think the current is traveling around the loop. It is OK to be incorrect.

$$\text{Red Loop} \rightarrow V + (-I_3 6) + (-I_1 4) = 0$$
$$24 = 6I_3 + 4I_1$$

Using Kirchhoff’s Voltage Law

$$\text{Blue Loop} \rightarrow V + (-I_2 2) + (-I_3 6) = 0$$
$$12 = 2I_2 + 6I_3$$

Using Kirchhoff’s Current Law

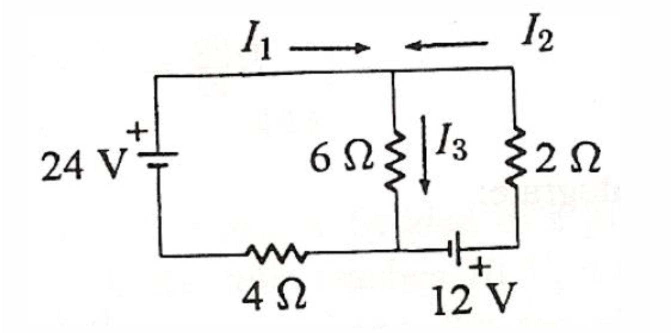
$$I_1 + I_2 = I_3$$

Applying Kirchhoff's Laws

$$24 = 6I_3 + 4I_1$$

$$12 = 2I_2 + 6I_3$$

$$I_3 = I_1 + I_2$$



$$\boxed{\begin{aligned}24 &= 6(I_1 + I_2) + 4I_1 = 6I_1 + 6I_2 + 4I_1 = 10I_1 + 6I_2 \\ 12 &= 2I_2 + 6(I_1 + I_2) = 2I_2 + 6I_1 + 6I_2 = 6I_1 + 8I_2\end{aligned}}$$

$$24 = 10I_1 + 6I_2 \rightarrow -6(24 = 10I_1 + 6I_2)$$

$$12 = 6I_1 + 8I_2 \rightarrow 10(12 = 6I_1 + 8I_2)$$

$$-144 = -60I_1 - 36I_2 \qquad 120 = 60I_1 + 80I_2$$

$$-24 = 44I_2$$

$I_2 =$ **-0.545 A**

A NEGATIVE current does NOT mean you are wrong. It means you chose your current to be in the wrong direction initially.

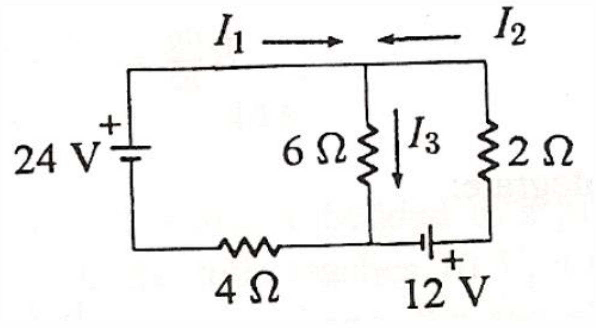
Applying Kirchhoff's Laws

$$12 = 2I_2 + 6I_3 \rightarrow 12 = 2(-0.545) + 6I_3$$

$I_3 =$ **2.18 A**

$$24 = 6I_3 + 4I_1 \rightarrow 24 = 6(?) + 4I_1$$

$I_1 =$ **2.73 A**



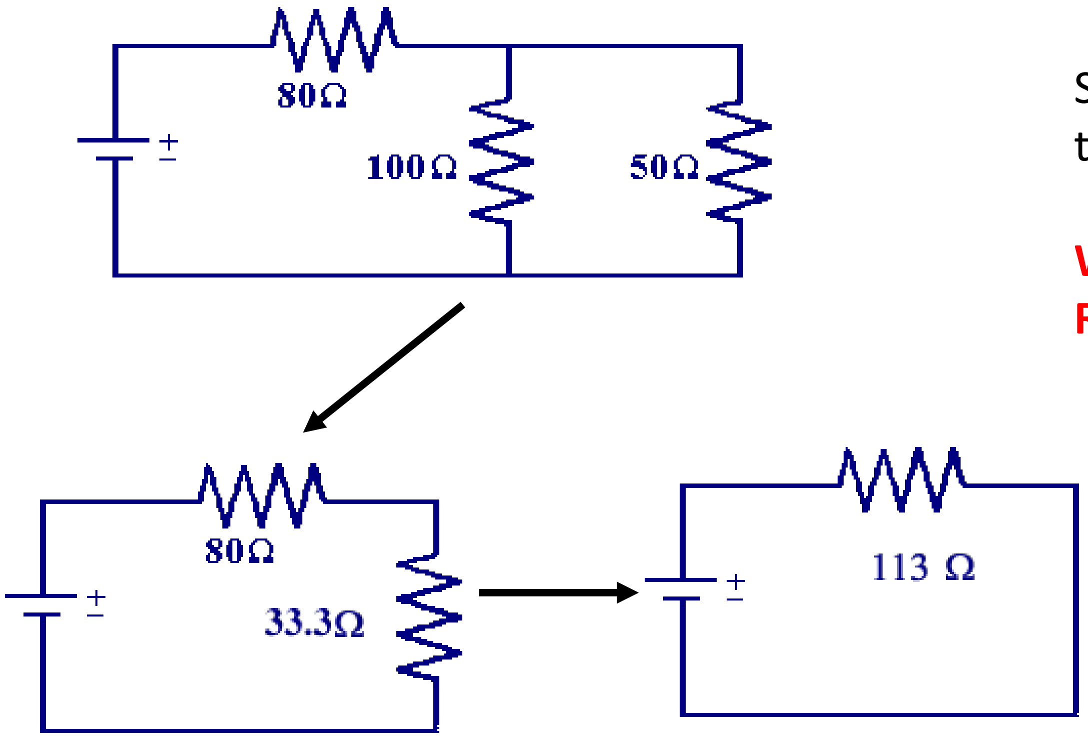
$$\text{Instead of :} \quad I_3 = I_1 + I_2$$

$$\text{It should have been :} I_1 = I_2 + I_3$$

$$2.73 = 2.18 + 0.545$$

Compound (Complex) Circuits

Many times you will have series and parallel in the SAME circuit.



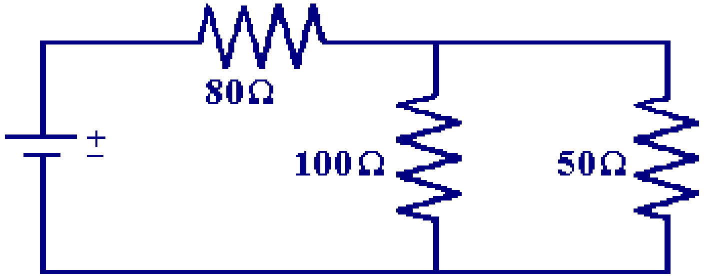
Solve this type of circuit from the inside out.

WHAT IS THE TOTAL RESISTANCE?

$$\frac{1}{R_P} = \frac{1}{100} + \frac{1}{50}; \quad R_P = 33.3\Omega$$

$$R_s = 80 + 33.3 = 113.3\Omega$$

Compound (Complex) Circuits



$$\frac{1}{R_P} = \frac{1}{100} + \frac{1}{50}; \quad R_P = 33.3\Omega$$

$$R_s = 80 + 33.3 = 113.3\Omega$$

Suppose the potential difference (voltage) is equal to **120V**. What is the total current?

$$\Delta V_T = I_T R_T$$

$$120 = I_T (113.3)$$

$$I_T = \quad \textbf{1.06 A}$$

What is the VOLTAGE DROP across the 80Ω resistor?

$$\Delta V_{80\Omega} = I_{80\Omega} R_{80\Omega}$$

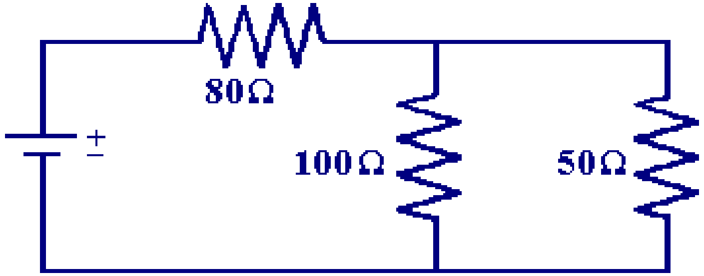
$$V_{80\Omega} = (1.06)(80)$$

$$V_{80\Omega} =$$

84.8 V

Compound (Complex) Circuits

$$R_T = 113.3\Omega$$
$$V_T = 120V$$
$$I_T = 1.06A$$
$$V_{80\Omega} = 84.8V$$
$$I_{80\Omega} = 1.06A$$



What is the VOLTAGE DROP across the 100Ω and 50Ω resistor?

$$V_{T(parallel)} = V_2 = V_3$$
$$V_{T(series)} = V_1 + V_{2\&3}$$
$$120 = 84.8 + V_{2\&3}$$
$$V_{2\&3} =$$ **35.2 V Each!**

What is the current across the 100Ω and 50Ω resistor?

$$I_{T(parallel)} = I_2 + I_3$$
$$I_{T(series)} = I_1 = I_{2\&3}$$
$$I_{100\Omega} = \frac{35.2}{100} = \text{0.352 A}$$
$$I_{50\Omega} = \frac{35.2}{50} = \text{0.704 A}$$

Add to 1.06A