Full resolution photo on my Instagram @feenafoto

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ECOR1043: Circuits

Resistive Circuits

Ohm's Law and Kirchhoff's Laws

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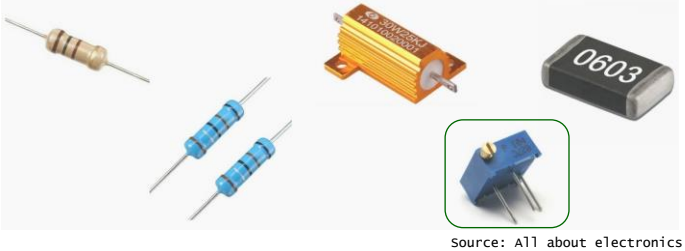
Ohm's Law

- Resistance R
  - The resistance R of an element denotes its ability to resist the flow of electric current
  - Resistance is measured in ohms Ω
  - An element with this property is called a *resistor*
  - Resistor could also be variable



Source: All about electronics

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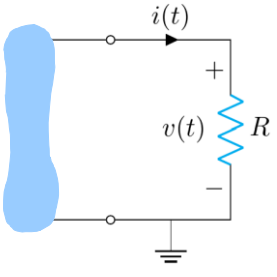
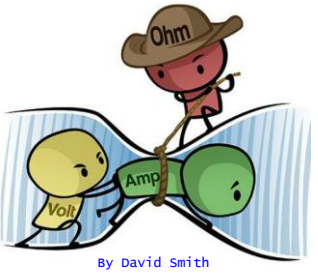
Ohm's Law

- Ohm's law
  - The voltage across a resistance is directly proportional to the current flowing through it

$$v(t) = i(t)R$$
$$V = IR$$





By David Smith

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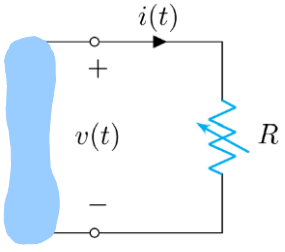
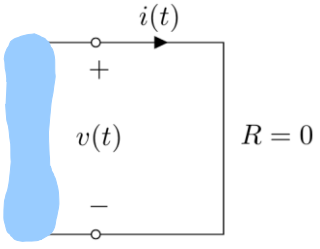
Ohm's Law

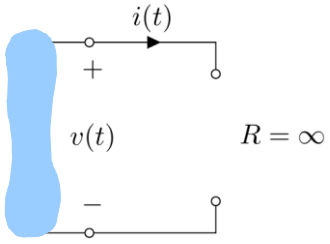
- Special Cases of Resistance



Variable Resistor



Short-Circuit



Open-Circuit

- What about the current?

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Ohm's Law

- Typical problems and how to solve them using Ohm's Law

$v = iR$

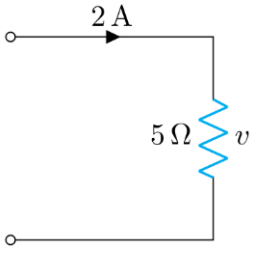
One equation and three variables.
Given ANY two we solve for the third.

- Ex. 1: Given current and resistance, find the voltage across the resistor

Hint: Use PSC to determine voltage polarity

$v = iR$

$v = iR = (2\ A)(5\ \Omega) = 10V$



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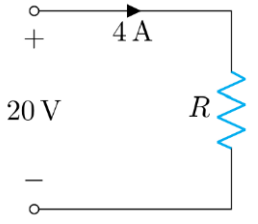
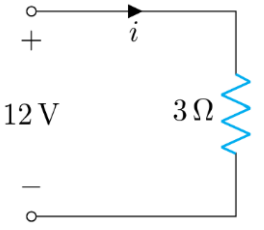
Ohm's Law

- Ex. 2: Given the current and voltage, find the resistance of the resistor



- Ex. 3: Given the voltage and resistance, find the current through the resistor



$R = \frac{v}{i} = \frac{20\ V}{4\ A} = 5\ \Omega$

$i = \frac{v}{R} = \frac{12\ V}{3\ \Omega} = 4\ A$

Ohm's Law

- Resistors and electric power
  - Combining Ohm's law and the expressions for power we can derive several useful expressions

$V = IR$ → A

$P = VI$ → B

  - Therefore, substituting V from eq. A into eq. B, we get

$P = I^2R$

  - And substituting I from eq. A into eq. B, we get

$P = \frac{V^2}{R}$

  - So, we have three equations to compute power

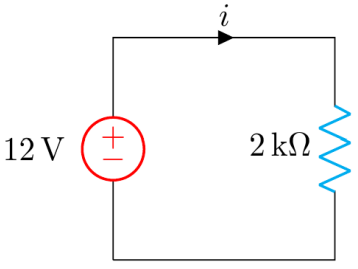
$P = VI$ $P = I^2R$ $P = \frac{V^2}{R}$

Ohm's Law

- Ex. 4: Determine the current and the power associated with the resistor

i=? $v = iR$ $v = 12V$ $R = 2k\Omega$

$$i = \frac{v}{R} = \frac{12\ V}{2\ k\Omega} = 6\ mA$$



P=? $P = vi$

$$P = (12\ V)(6\ mA) = 72\ mW$$

Can you we use any other formula to compute P?

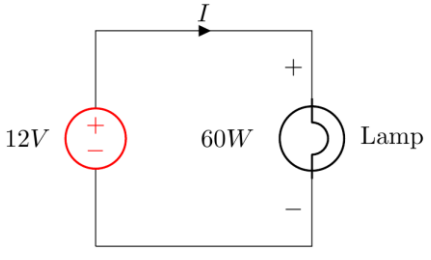
$P = I^2R$ $P = \frac{V^2}{R}$

Ohm's Law

- Ex. 5: Find the resistance of the lamp and the current through the lamp. $V = 12$V $P = 60W$

R=? $P = VI$ $P = I^2R$ $P = V^2/R$

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{(12\ V)^2}{60\ W} = 2.4\ \Omega$$



I=? $V = 12$V $P = 60W$ $R = 2.4\Omega$

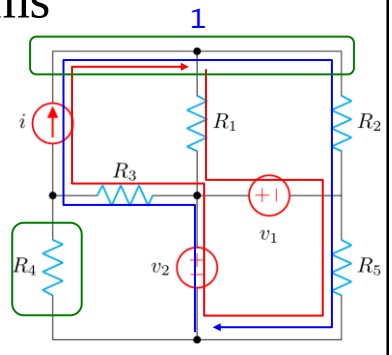
$V = IR$ $P = VI$ $P = I^2R$

$V = IR$

$$I = \frac{V}{R} = \frac{12\ V}{2.4\ \Omega} = 5\ A$$

Equivalently, we could have used P=VI or P=I²R to find I

Circuit Concepts and Terms



- Branch *b*
  - A branch represents a single element such as a voltage source or a resistor. (e.g., component R4)
- Node *n*
  - A node is the point of connection between two or more branches (e.g., big node 1)
- Loop *l*
  - A closed path that never goes twice over a node (e.g., the blue line)
  - The red path is not a loop
  - A loop is said to be *independent* if it contains at least one branch which is not a part of any other independent loop

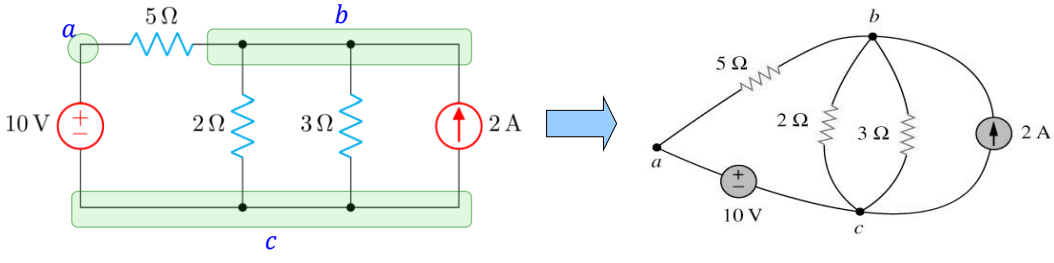
$$l = b - n + 1$$

Where *l* is the maximum number of independent loops

Circuit Concepts and Terms

- Ex. 6: Determine number of branches (*b*), number of nodes (*n*) and maximum number of independent loops (*l*) for the following circuit:

$$l = b - n + 1$$



Branches? $b = 5$

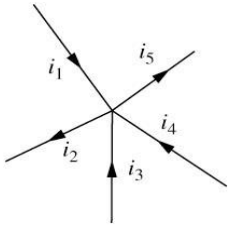
Nodes $n = 3$

$l = b\text{-}n+1$
$=5\text{-}3+1=3$

Kirchhoff's Current Law (KCL)

- *The algebraic sum of the currents entering (or leaving) any node is zero*

$$\sum_{n=1}^{N} i_n = 0$$



- *The sum of the currents entering a node is equal to the sum of the currents leaving the node*
- Kirchhoff's current law is based on the principle of conservation of charge
- We assume signs of the currents and stay consistent

Kirchhoff's Current Law (KCL)

- Ex 7: Find the missing current i_x

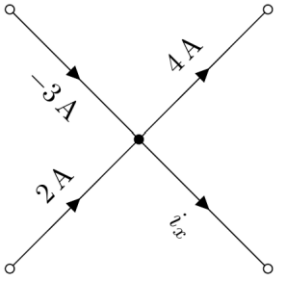
Algebraic sum of currents into Node is zero

Assuming the currents exiting the node are +ve

$i_x + 4\ A - (-3\ A) - 2A = 0$

$i_x + 4\ A + 3A - 2A = 0$

$i_x = -5A$



Kirchhoff's Current Law (KCL)

- Ex 8: Find the missing current i

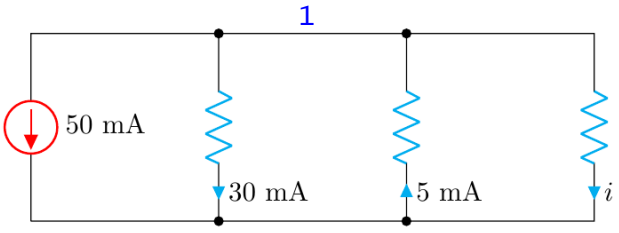
Algebraic sum of currents into Node 1 is zero

Assuming the currents exiting the node are +ve

$50m + 30m - 5m + i = 0$

$75 + i = 0$

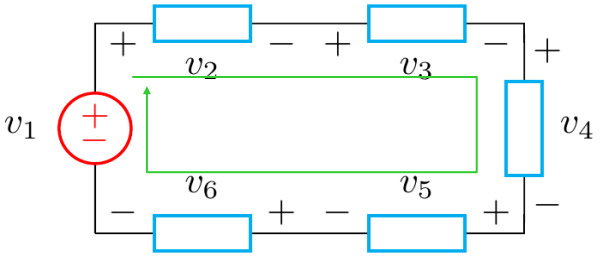
$i = -75mA$



Kirchhoff's Voltage Law (KVL)

- *The algebraic sum of the voltages around any loop is zero*

$$\sum_{m=1}^{M} v_m = 0$$



- To apply KVL, we must traverse any loop in the circuit and sum to zero the increases and decreases in energy level
- As we move around a loop, we encounter the plus sign first for a decrease in energy level and a negative sign first for an increase in energy level
- Kirchhoff's voltage law is based on the conservation of energy

Kirchhoff's Voltage Law (KVL)

- Ex. 9: Given V_{R1} and V_{R2}, find V_{R3} using KVL and $P_{2k\Omega}$

$V_{R1} = 18\ V$

$V_{R2} = 12\ V$

For V_{R3}

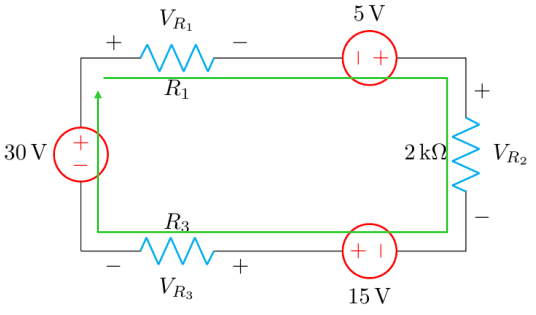
$V_{R1} - 5\ V + V_{R2} - 15\ V + V_{R3} - 30\ V = 0$

$18 - 5\ V + 12 - 15\ V + V_{R3} - 30\ V = 0$

$V_{R3} = 20\ V$

For power $P_{2k\Omega}$

$$P_{2k\Omega} = \frac{V_{R2}^2}{R_2} = \frac{(12)^2}{2k} = 72\ mW$$



Kirchhoff's Voltage Law (KVL)

- Ex. 10: Find the number of branches, nodes, maximum independent loops, and write the KVL equations for all loops.

b? $b=7$ n? $n=6$

l? $l = b - n + 1$

$l = 7 - 6 + 1 = 2$

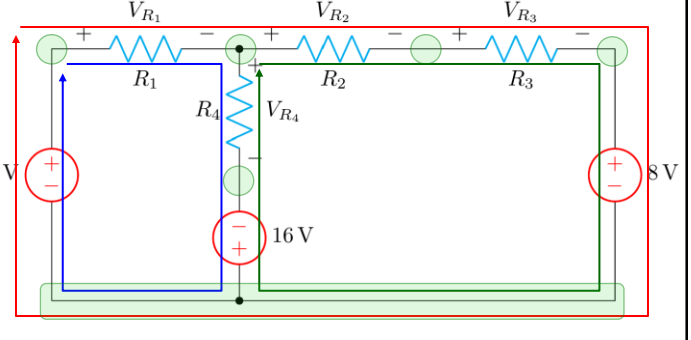
Hence there are only 2 independent KVL equations

$V_{R1} + V_{R4} - 16\ V - 24\ V = 0$

$V_{R2} + V_{R3} + 8\ V + 16\ V - V_{R4} = 0$

$V_{R1} + V_{R2} + V_{R3} + 8\ V - 24\ V = 0$

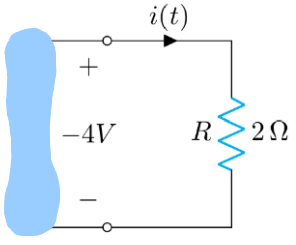
The third equation is the sum of the Other two!!



Practice Problems

Ohm's Law

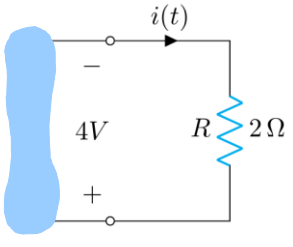
- Prob. 1: Determine $i(t)$



OHM'S LAW $v(t) = Ri(t)$

$-4[V] = (2\Omega)i(t) \Rightarrow i(t) = -2[A]$

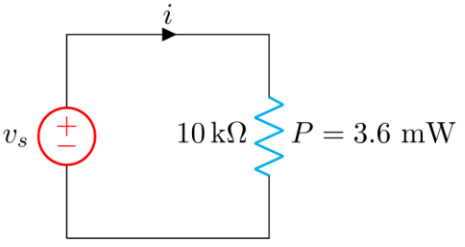
This problem could be given like this



OHM'S LAW $v(t) = -Ri(t)$

Ohm's Law

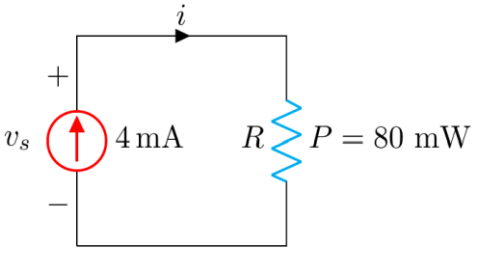
- Prob. 2
  - Determine current and voltage



  - Ans: $v = 6\text{V}$, $i = 0.6\text{mA}$

Ohm's Law

- Prob. 3
  - Determine R and v_s



  - Ans: R=5kΩ, v_s=20V

Kirchhoff's Current Law (KCL)

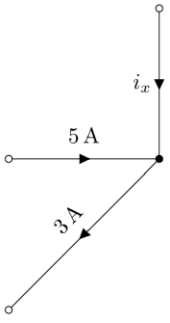
- Prob. 4: Find the missing current i_x

Sum of currents into Node is zero

Assuming the currents entering the node are +ve

$5\ A + i_x - 3\ A = 0$

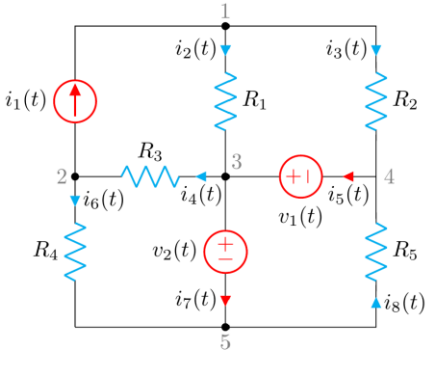
$i_x = -2\ A$



Do the same calculation, assuming current leaving the node are +ve, what happens?

Kirchhoff's Current Law (KCL)

- Prob. 5: Write KCL for node 3
  - Assuming currents entering the node are +



Ans: $i_2(t) + i_5(t) - i_7(t) - i_4(t) = 0$

Kirchhoff's Current Law (KCL)

- Prob. 6: Find the missing currents, I_1, I_4, I_5 and I_6

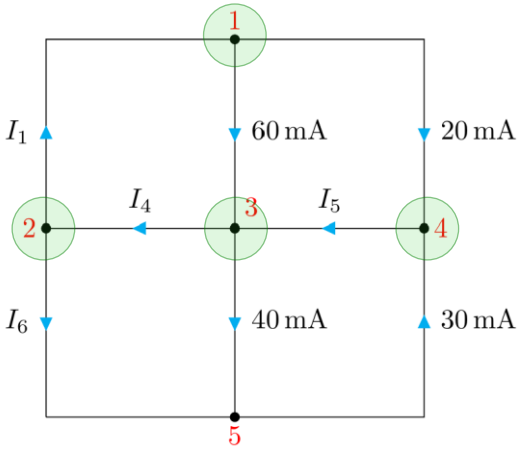
Assuming the currents exiting the nodes are +ve, Write KCL for each node

(1) $-I_1 + 60\ mA + 20mA = 0$

(2) $I_1 - I_4 + I_6 = 0$

(3) $-60\ mA + I_4 - I_5 + 40\ mA = 0$

(4) $-20\ mA + I_5 - 30\ mA = 0$



Kirchhoff's Current Law (KCL)

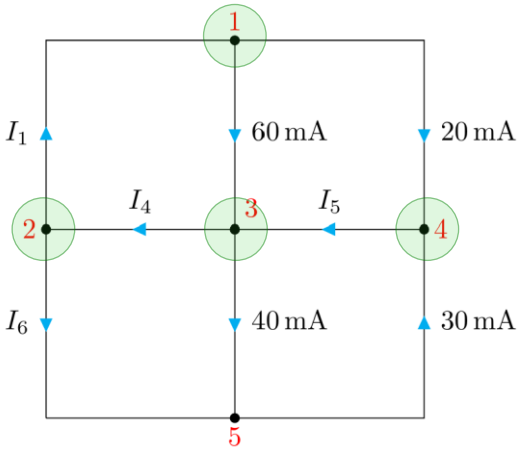
- Prob. 6 (cont.): Find the missing currents, I_1, I_4, I_5 and I_6

For I_1 (1) $-I_1 + 60\ mA + 20mA = 0$

For I_5 (4) $-20\ mA + I_5 - 30\ mA = 0$

For I_4 (3) $-60\ mA + I_4 - I_5 + 40\ mA = 0$

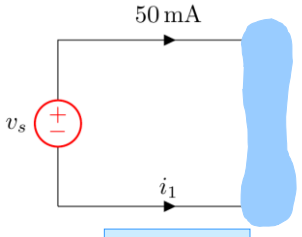
For I_6 (2) $I_1 - I_4 + I_6 = 0$



$I_1 = 80\ mA$ $I_5 = 50\ mA$ $I_4 = 70\ mA$ $I_6 = -10\ mA$

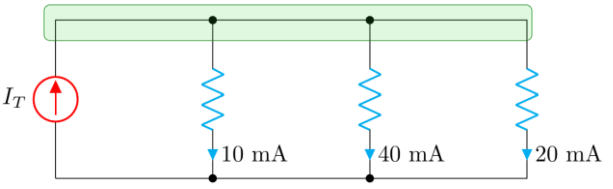
Kirchhoff's Current Law (KCL)

- Prob. 7: Find i_1



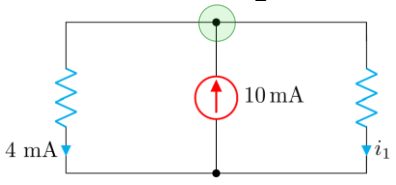
$i_1 = -50mA$

- Prob. 8 : Find I_T



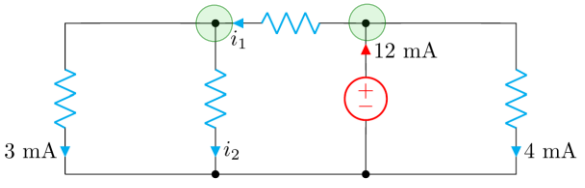
$I_T = 10mA + 40mA + 20mA$

- Prob. 9 : Find i_1



$10mA - 4mA - i_1 = 0$

- Prob. 10 : Find i_1 and i_2

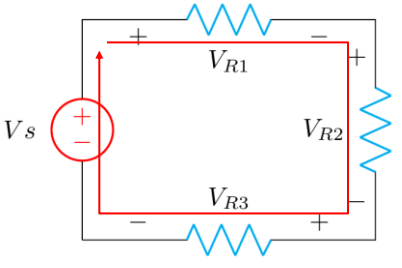


$i_2 + 3mA - i_1 = 0$ $\quad$ $i_1 + 4mA - 12mA = 0$

Kirchhoff's Voltage Law (KVL)

- Prob. 11: Write the KVL equation

$V_{R1} + V_{R2} + V_{R3} - V_S = 0$



Kirchhoff's Voltage Law (KVL)

- Prob. 12: Given V_2, find V_x, and $P_{2k\Omega}$

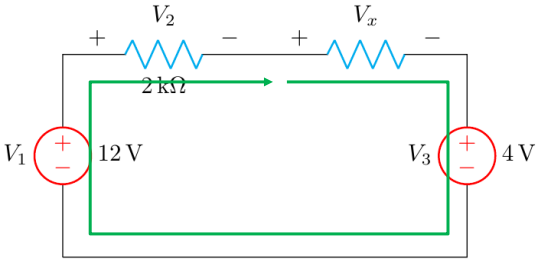
We need to find a closed path where only one voltage is unknown

To find V_x $V_2 = 4\ V$

$V_x + V_3 - V_1 + V_2 = 0$

$V_x + 4V - 12V + 4V = 0$

$V_x = 4\ V$



Kirchhoff's Voltage Law (KVL)

- Prob. 12 (cont.): Given V_2, find V_x, and $P_{2k\Omega}$

To find $P_{2k\Omega}$ $V_2 = 4\ V$

$P_{2k\Omega} = \frac{V_2^2}{R_2}$

$P_{2k\Omega} = \frac{(4\ \mathrm{V})^2}{2\ k\Omega}$

$P_{2k\Omega} = 8\ mW$

$V_2 = 4\ V$

White Board