Schedule…

Date	Day	Class No.	Title	Chapters	HW Due date	Lab Due date	Exam
15 Sept	Mon	4	Ohm's Law	2.5 – 2.6		LAB 1	
16 Sept	Tue						
17 Sept	Wed	5	Ohm's Law	2.6			
18 Sept	Thu					LAB 1	
29 Sept	Fri		Recitation		HW 2		
20 Sept	Sat						
21 Sept	Sun						
22 Sept	Mon	6	Practical Sources	2.6 – 2.8		LAB 2	
23 Sept	Tue						

High Resistance to Evil, Low Resistance to Good

James 4:7

7 Submit yourselves therefore to God. **Resist** the devil, and he will flee from you.

Alma 61:14

14 Therefore, my beloved brother, Moroni, let us **resist** evil, and whatsoever evil we cannot **resist** with our words, yea, such as rebellions and dissensions, let us **resist** them with our swords, that we may retain our freedom, that we may rejoice in the great privilege of our church, and in the cause of our Redeemer and our God.

Lecture 4 – Resistance & Ohm's Law

Resistance

- **Resistance (R)**: opposition to the flow of current
  - Magnitude depends on electrical properties of the material
  - All circuit elements exhibit some resistance
  - May be undesirable
  - Causes electric energy to be transformed into heat
  - Element symbols:

Ohm (Ω): electric resistance unit.
1 Ohm = 1 Volt/Ampere (V/A)

Conductance

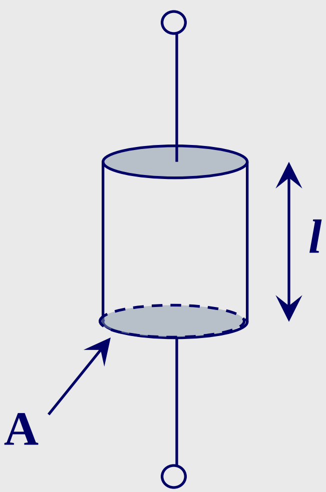
- **Conductance (G)**: the inverse of resistance

$$G = \frac{1}{R}$$

siemens (S): electric conductance unit.
1 siemens = 1 Ampere/Volt (A/V)

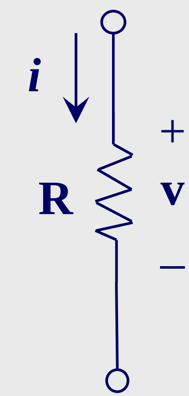
Resistance

- **<u>Resistivity (ρ)</u>**: a materials property which determines resistance
- **<u>Conductivity (σ)</u>**: the inverse of resistivity (determines conductance)



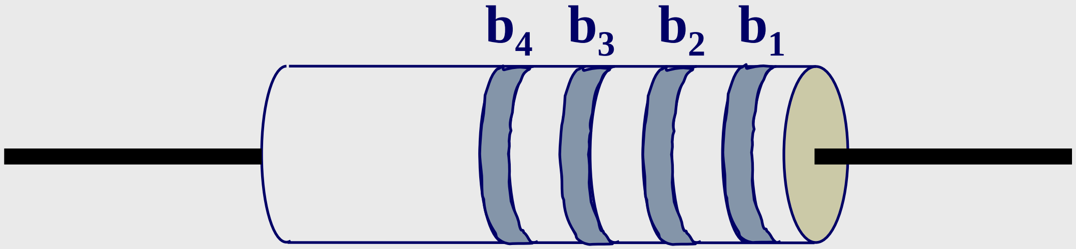
Cylindrical Resistance:

$$R = \frac{l}{\sigma A}$$



Resistance

- Common resistors are made of cylindrical sections of carbon (resistivity **ρ** = 3.5x10^{-5}**Ω-m**)



$$\text{Resistor Value} = (b_1 b_2) \times 10^{b_3}$$

$$b_4 = \%\ \text{tolerance in actual value}$$

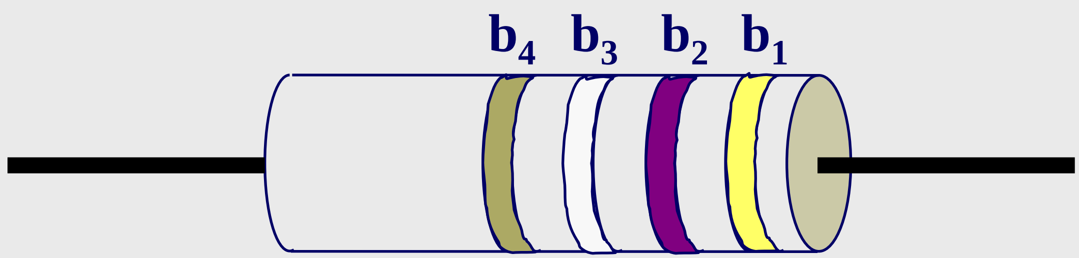
black	**0**	Blue	**6**
brown	**1 (1%)**	violet	**7**
red	**2 (2%)**	gray	**8**
orange	**3**	white	**9**
yellow	**4**	silver	**-2 (10%)**
green	**5**	gold	**-1 (5%)**
		None	**(20%)**

Resistance

Code	Ω	Mult	Ω	Mult	k Ω	Mult	k Ω	Mult	k Ω	Mult
Brn-blk	10	Black	100	Brown	1.0	Red	10	Orange	100	Yellow
Brn-red	12	Black	120	Brown	1.2	Red	12	Orange	120	Yellow
Brn-grn	15	Black	150	Brown	1.5	Red	15	Orange	150	Yellow
Brn-gry	18	Black	180	Brown	1.8	Red	18	Orange	180	Yellow
Red-red	22	Black	220	Brown	2.2	Red	22	Orange	220	Yellow
Red-vlt	27	Black	270	Brown	2.7	Red	27	Orange	270	Yellow
Org-org	33	Black	330	Brown	3.3	Red	33	Orange	330	Yellow
Org-wht	39	Black	390	Brown	3.9	Red	39	Orange	390	Yellow
Ylw-vlt	47	Black	470	Brown	4.7	Red	4.7	Orange	470	Yellow
Grn-blu	56	Black	560	Brown	5.6	Red	5.6	Orange	560	Yellow
Blu-gry	68	Black	680	Brown	6.8	Red	6.8	Orange	680	Yellow
Gry-red	82	Black	820	Brown	8.2	Red	8.2	Orange	820	Yellow

Resistance

- **<u>Example1</u>**: what is the value of the resistor?



black	**0**	Blue	**6**
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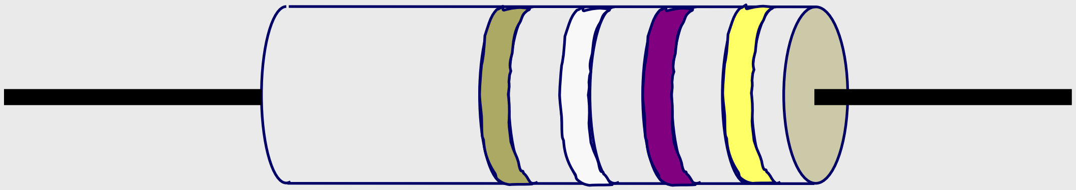
Resistance

- **Example1**: what is the value of the resistor?

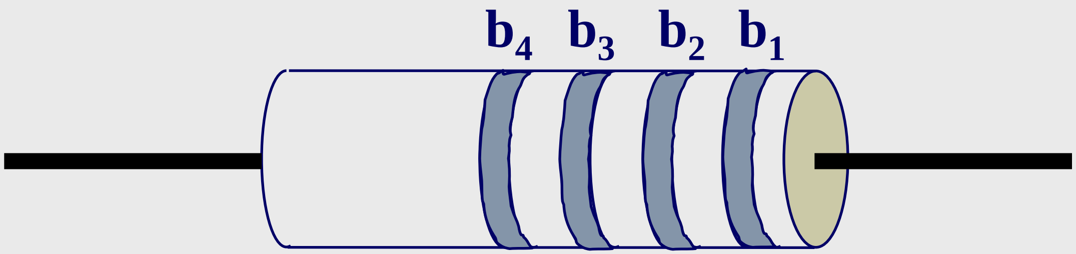


$$\text{Resistor Value} = (b_1 b_2) \times 10^{b_3}$$
$$= (yellow\ \ violet) \times 10^{white}$$
$$= 47 \times 10^{9}$$
$$= 47 G\Omega \pm 5\%$$

black	**0**	Blue	**6**
brown	**1 (1%)**	violet	**7**
red	**2 (2%)**	gray	**8**
orange	**3**	white	**9**
yellow	**4**	silver	**-2 (10%)**
green	**5**	gold	**-1 (5%)**
		None	**(20%)**

Resistance

- **Example2**: what resistor has a value of 6.2M **Ω**?



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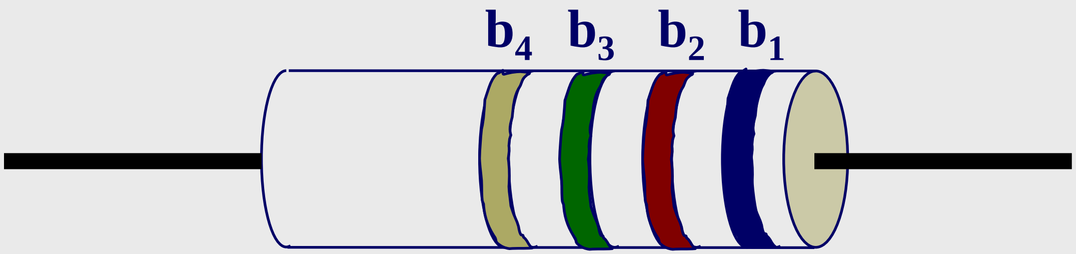
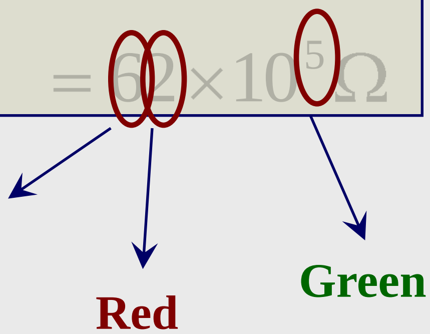
Resistance

- **Example2**: what resistor has a value of 6.2M **Ω**?



$$6.2M\Omega = 6.2\times10^{6}\Omega$$
$$= 62\times10^{5}\Omega$$
$$= 62\times10^{5}\Omega$$



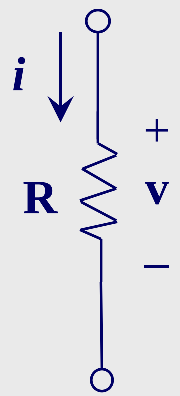
black	**0**
brown	**1 (1%)**
red	**2 (2%)**
orange	**3**
yellow	**4**
green	**5**

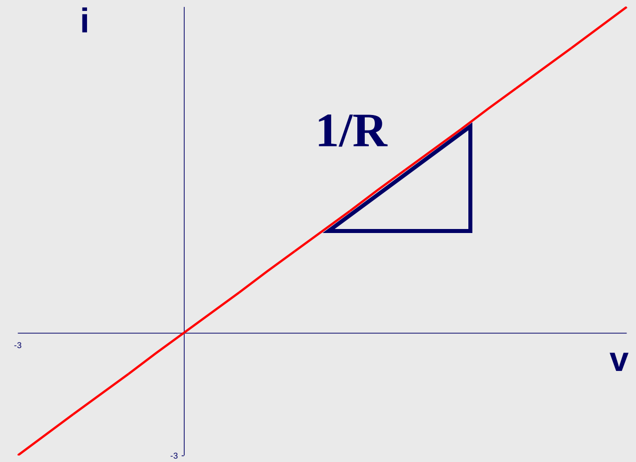
Blue	**6**
violet	**7**
gray	**8**
white	**9**
silver	**-2 (10%)**
gold	**-1 (5%)**
None	**(20%)**

Ohm's Law

- The voltage across an element is directly proportional to the current flow through it

$$V = IR \quad \text{OR} \quad I = GV$$





Ohm’s Law

- Ohm’s law is only a **simplification**
  - Ohm’s law is not applicable:
    - At high voltages or currents
    - At high frequencies
    - Over long distances
    - For some materials

Maxwell's Equations

$$\oint_S D \cdot dA = \int_V \rho dV$$

$$\oint_S B \cdot dA = 0$$

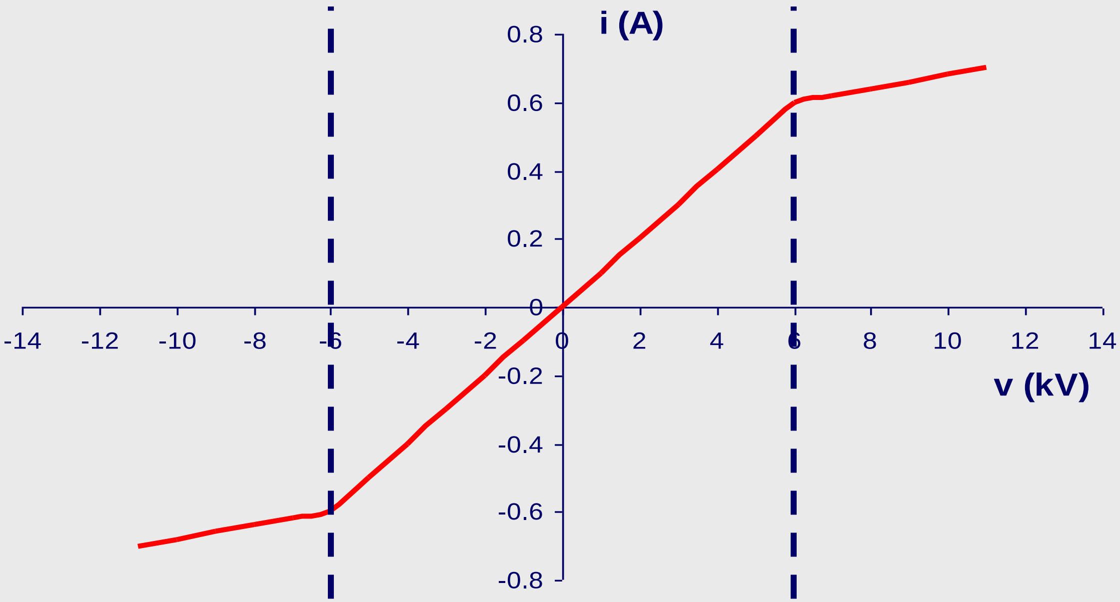
$$\oint_C E \cdot dl - \oint_C B \times v \cdot dl = -\frac{d}{dt} \int_S B \cdot dA$$

$$\oint_C H \cdot dl = \int_S J \cdot dA + \int_S \frac{\partial D}{\partial t} \cdot dA$$

For our class **Ohm’s law** will apply!

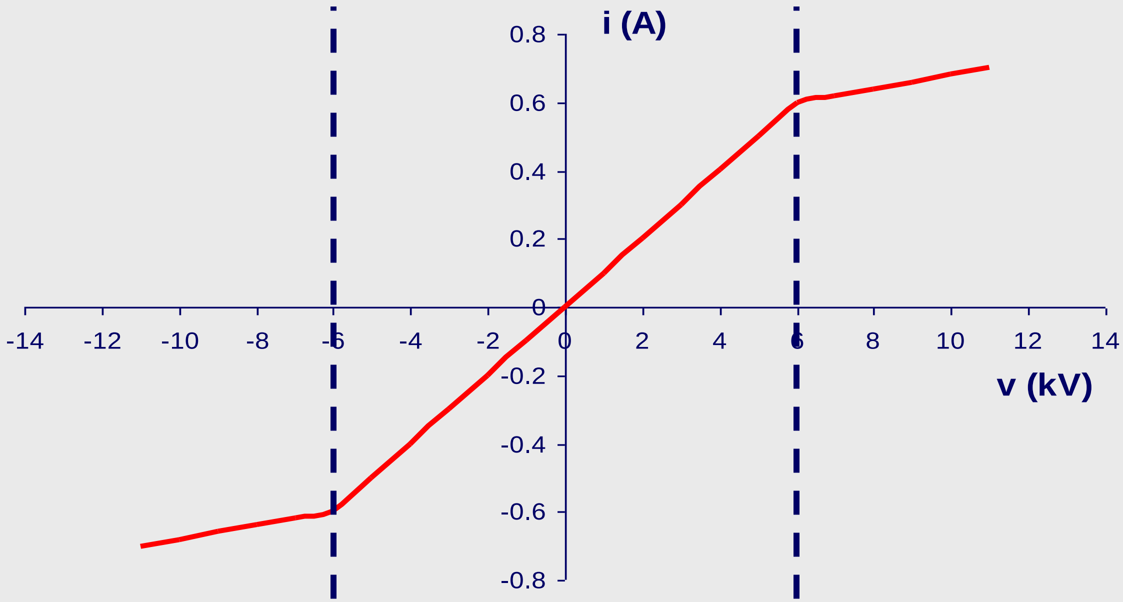
Ohm’s Law

- Ohm’s Law only applies to a portion of an electrical element’s the ***i*–v** graph



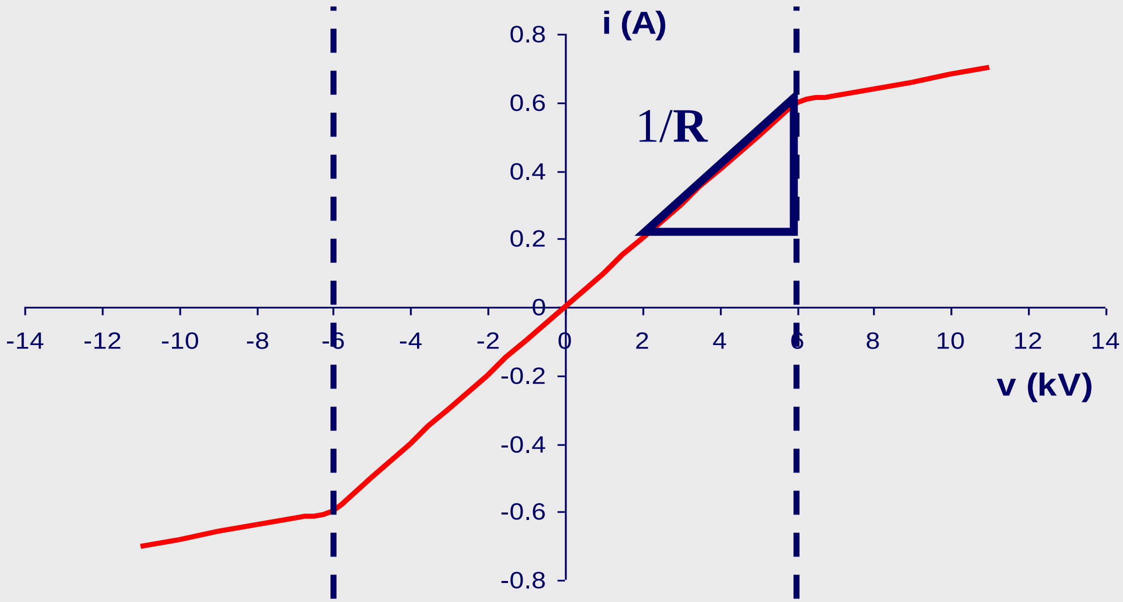
Ohm's Law

- **Example3**: What is the resistance of the element with the following ***i*–v** characteristic?



Ohm's Law

- **<u>Example3</u>**: What is the resistance of the element with the following ***i*–v** characteristic?



$$\frac{1}{R} = i - v\ Slope$$

$$= \frac{\Delta i}{\Delta v}$$

$$= \frac{(0.6 - 0.2)A}{(6 - 2)kV}$$

$$= \frac{0.4}{4 \times 10^3} S$$

$$= 0.1 \times 10^{-3} S$$

$$R = 10k\Omega$$

Power Rating

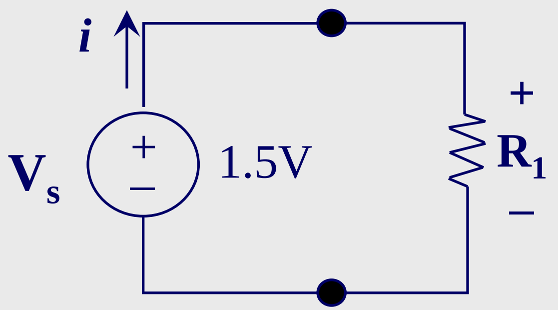
- **power rating**: maximum allowable power dissipation
  - Common power rating is ¼ W

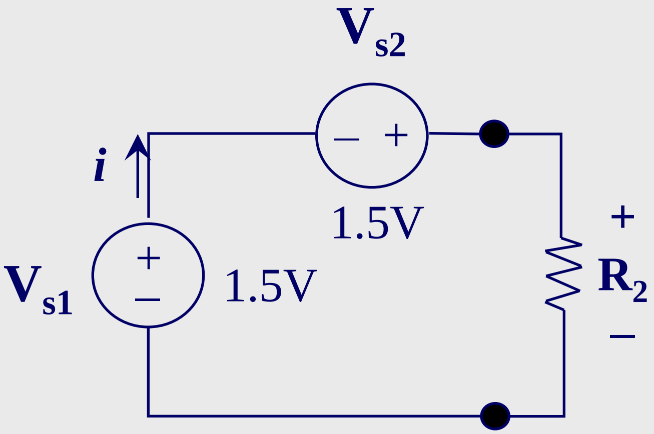
$$P = i \cdot v$$
$$= i^2 \cdot R$$
$$= \frac{v^2}{R}$$

- Exceeding the power rating for an electrical element will cause the element to **burn up**!
  - Always consider power ratings!!

Power Rating

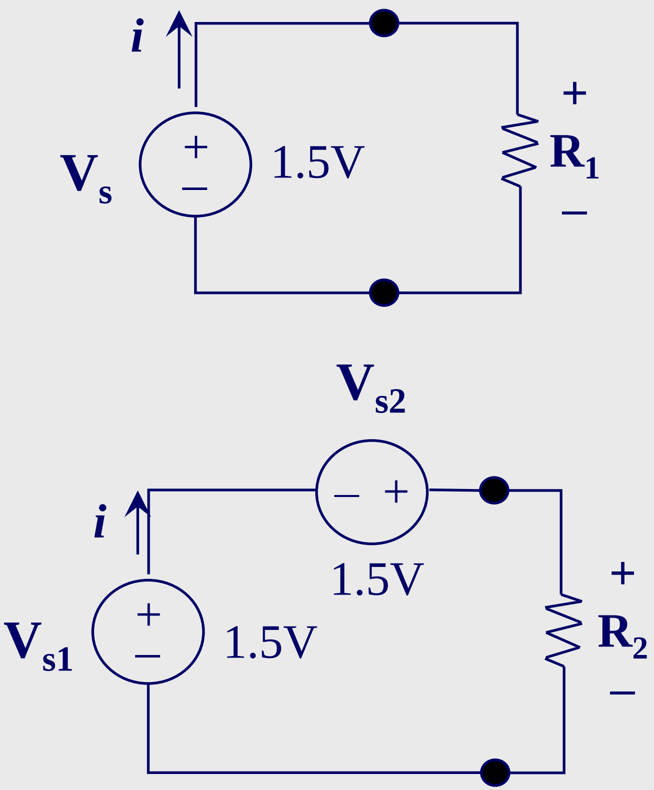
- **<u>Example4</u>**: With a ¼ W rating, what is the minimum resistor size (**R**) that can be used in the following:





Power Rating

- **<u>Example4</u>**: With a ¼ W rating, what is the minimum resistor size (**R**) that can be used in the following:

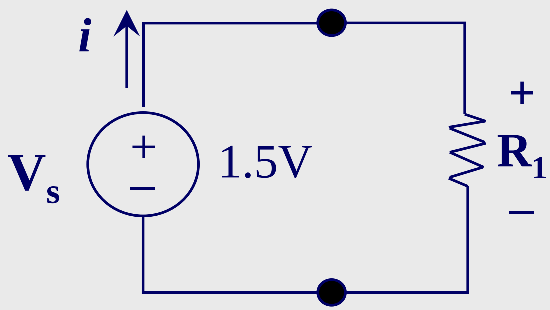


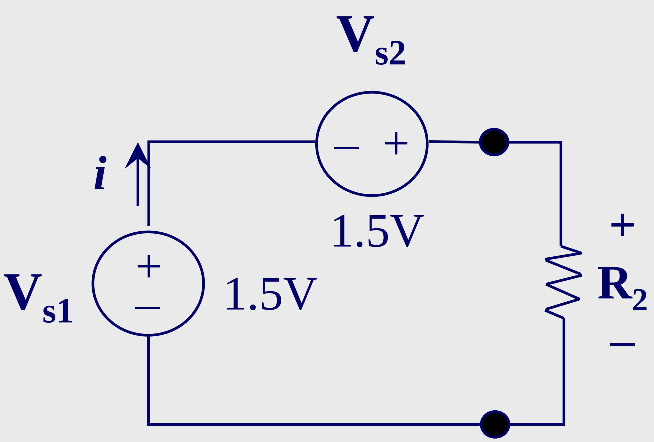
$$P_{R1} = v \cdot i = v \cdot \left(\frac{v}{R_1} \right) = \frac{v^2}{R_1}$$

$$R_1 = \frac{v^2}{P_{R1}} = \frac{1.5^2}{0.25} = 9\Omega$$

Power Rating

- **Example4**: With a ¼ W rating, what is the minimum resistor size (**R**) that can be used in the following:





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$$R_1 = \frac{v^2}{P_{R1}} = \frac{1.5^2}{0.25} = 9\Omega$$

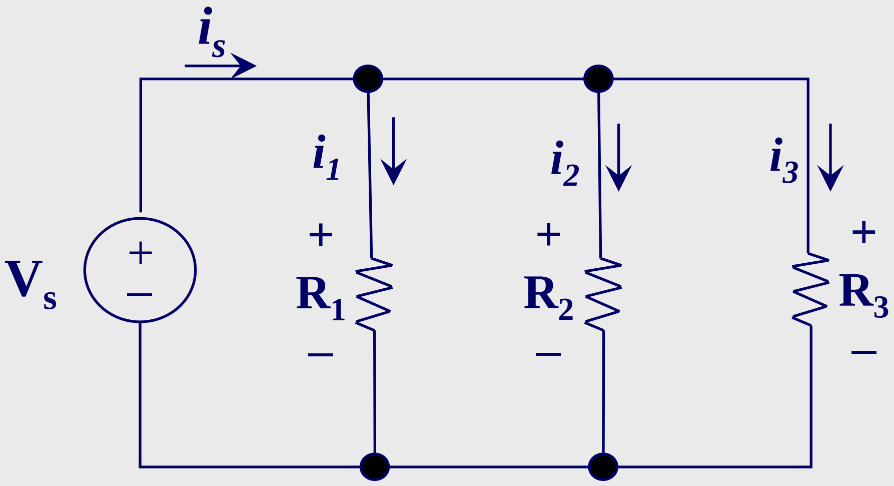
$$P_{R2} = v \cdot i = v \cdot \left(\frac{v}{R_2} \right) = \frac{v^2}{R_2}$$

$$R_2 = \frac{v^2}{P_{R2}} = \frac{3^2}{0.25} = 36\Omega$$

NB: Doubling the amount of voltage has a quadratic effect on minimum resistor size

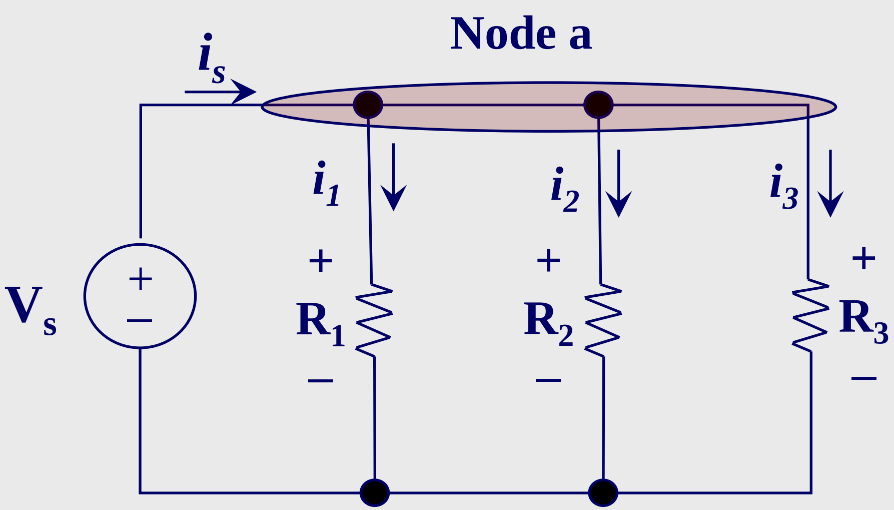
Power Rating

- **Example5**: find the power supplied by the battery
  - $V_s = 3V$, $i_1 = 0.2mA$, $i_2 = 0.4mA$, $i_3 = 1.2mA$



Power Rating

- **<u>Example5</u>**: find the power supplied by the battery
  - $\mathbf{V_s} = 3V$, $\boldsymbol{i_1} = 0.2mA$, $\boldsymbol{i_2} = 0.4mA$, $\boldsymbol{i_3} = 1.2mA$



KCL at Node a :

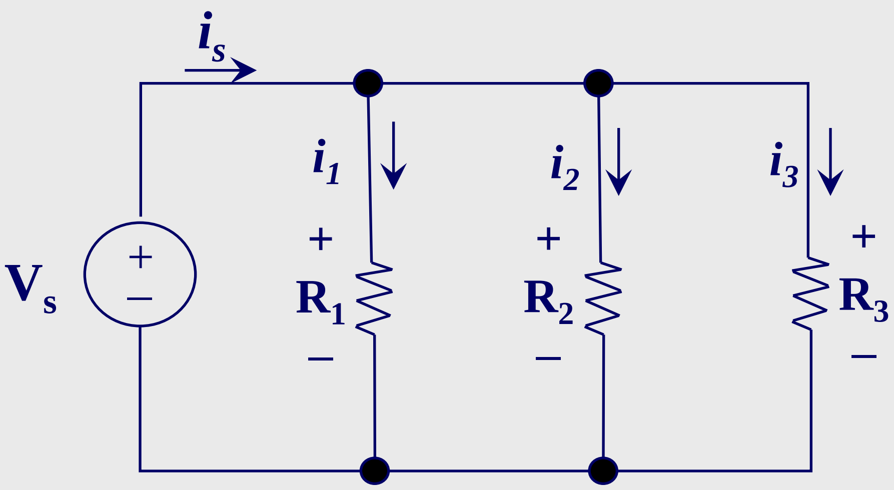
$$i_s - i_1 - i_2 - i_3 = 0$$

$$\begin{aligned} i_s &= i_1 + i_2 + i_3 \\ &= 0.2 + 0.4 + 1.2 \\ &= 1.8mA \end{aligned}$$

$$\begin{aligned} P_s &= i_s \cdot V_s \\ &= 1.8mA(3V) \\ &= 5.4mW \end{aligned}$$

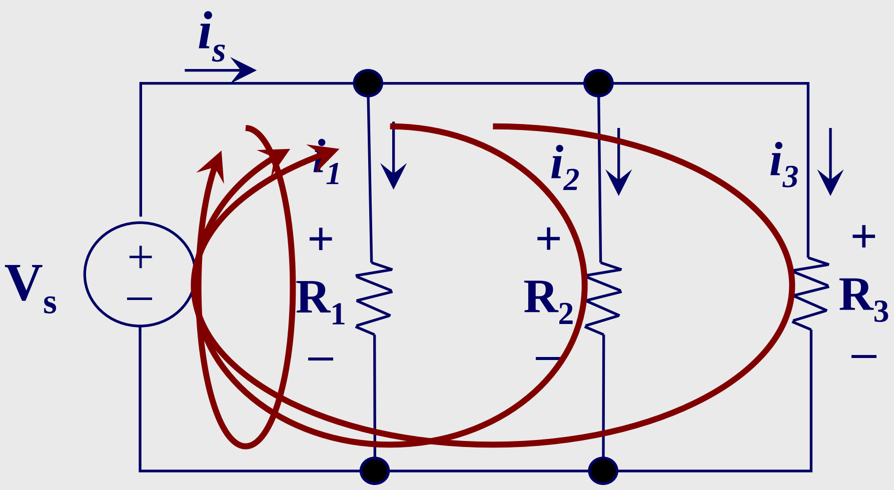
Power Rating

- **<u>Example6</u>**: find the voltages and resistances of $\mathbf{R_1}$, $\mathbf{R_2}$, $\mathbf{R_3}$
  - $\mathbf{V_s} = 3V$, $\boldsymbol{i_1} = 0.2mA$, $\boldsymbol{i_2} = 0.4mA$, $\boldsymbol{i_3} = 1.2mA$



Power Rating

- **Example6**: find the voltages and resistances of $\mathbf{R_1}$, $\mathbf{R_2}$, $\mathbf{R_3}$
  - $V_s = 3V$, $i_1 = 0.2mA$, $i_2 = 0.4mA$, $i_3 = 1.2mA$



Using KVL:

$$-V_s + v_1 = 0$$

$$v_1 = V_s$$

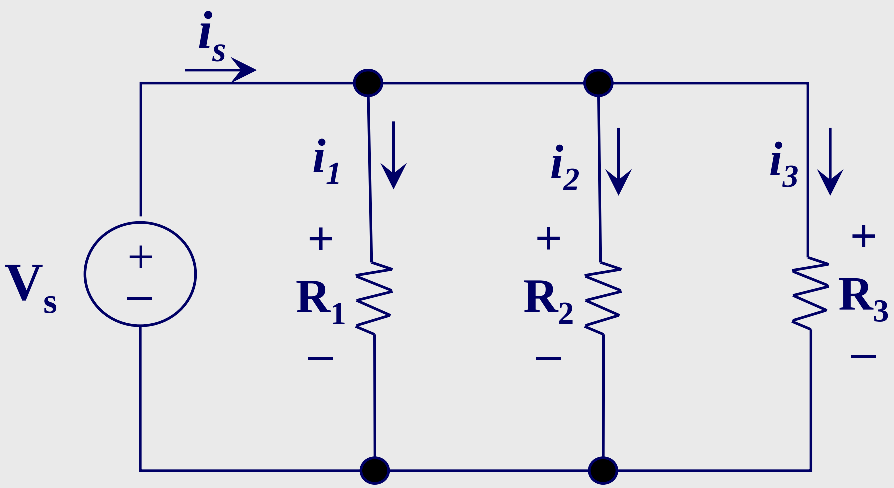
$$= 3V$$

$$v_2 = 3V$$

$$v_3 = 3V$$

Power Rating

- **<u>Example6</u>**: find the voltages and resistances of $\mathbf{R_1}$, $\mathbf{R_2}$, $\mathbf{R_3}$
  - $\mathbf{V_s} = 3V$, $\boldsymbol{i_1} = 0.2mA$, $\boldsymbol{i_2} = 0.4mA$, $\boldsymbol{i_3} = 1.2mA$



$$v_1 = i_1 \cdot R_1$$

$$R_1 = \frac{v_1}{i_1} = \frac{3V}{0.2mA} = \frac{3V}{0.2 \times 10^{-3} A} = 15 \times 10^3 \Omega = 15k\Omega$$

$$v_2 = i_2 \cdot R_2$$

$$R_2 = \frac{v_2}{i_2} = \frac{3V}{0.4mA} = 7.5k\Omega$$

$$v_3 = i_3 \cdot R_3$$

$$R_3 = \frac{v_3}{i_3} = \frac{3V}{1.2mA} = 2.5k\Omega$$