Schedule…

Date	Day	Class No.	Title	Chapters	HW Due date	Lab Due date	Exam
10 Sept	Wed	3	Power	2.4 – 2.5			
11 Sept	Thu						
12 Sept	Fri		Recitation		HW1		
13 Sept	Sat						
14 Sept	Sun						
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			

True Power – The Book of Mormon

Alma 37:14, 16, 18

14 And now remember, my son, that God has entrusted you with these things, which are sacred, which he has kept sacred, and also which he will keep and preserve for a wise purpose in him, that he may show forth his **power** unto future generations.

16 But if ye keep the commandments of God, and do with these things which are sacred according to that which the Lord doth command you, (for you must appeal unto the Lord for all things whatsoever ye must do with them) behold, no **power** of earth or hell can take them from you, for God is **powerful** to the fulfilling of all his words.

18 For he promised unto them that he would preserve these things for a wise purpose in him, that he might show forth his **power** unto future generations.

Mormon 8:15, 16, 22, 26, 28

15 For none can have **power** to bring it to light save it be given him of God; for God wills that it shall be done with an eye single to his glory, or the welfare of the ancient and long dispersed covenant people of the Lord.

16 And blessed be he that shall bring this thing to light; for it shall be brought out of darkness unto light, according to the word of God; yea, it shall be brought out of the earth, and it shall shine forth out of darkness, and come unto the knowledge of the people; and it shall be done by the **power** of God.

22 For the eternal purposes of the Lord shall roll on, until all his promises shall be fulfilled.

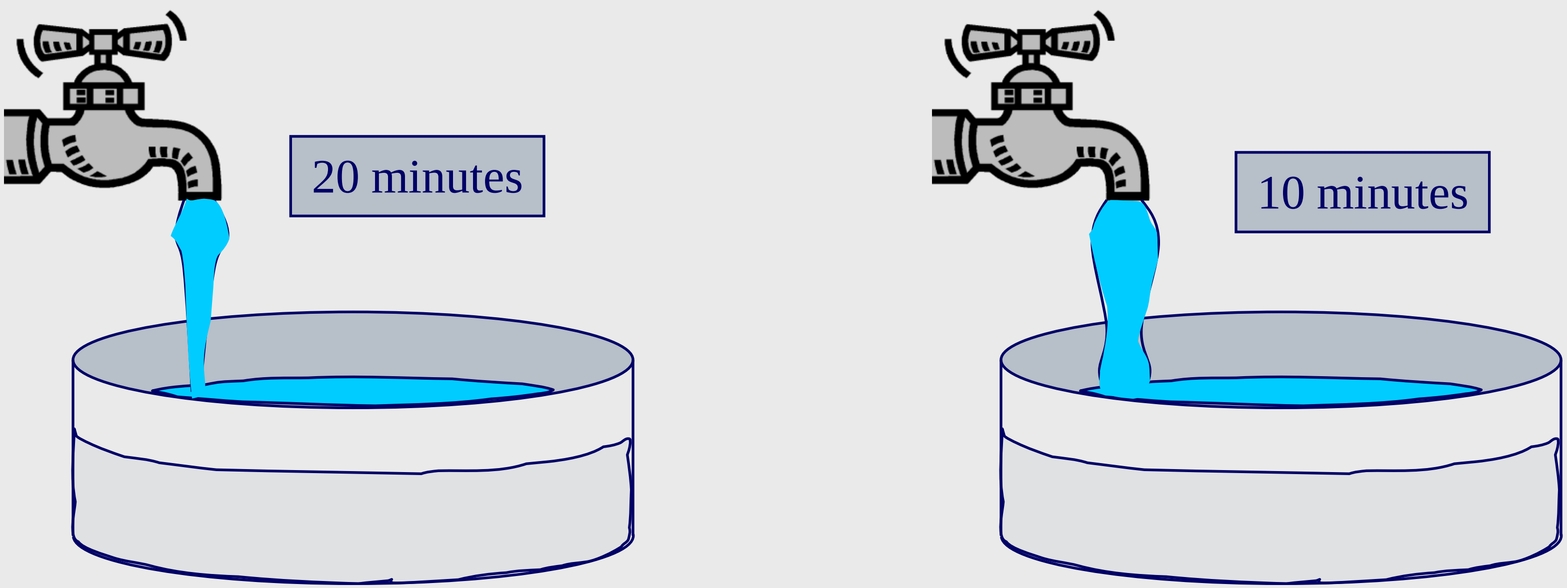
26 And no one need say they shall not come, for they surely shall, for the Lord hath spoken it; for out of the earth shall they come, by the hand of the Lord, and none can stay it; and it shall come in a day when it shall be said that miracles are done away; and it shall come even as if one should speak from the dead.

28 Yea, it shall come in a day when the **power** of God shall be denied…

Lecture 3 – Electric Power

Energy vs. Power

- Consider filling a pool of water
  - The **rate** (**power**) at which the water comes out determines how long it will take to fill the pool
  - The water that has filled the pool represents **energy**
  - Both pools have the same amount of water (**energy**) – the rate at which they were filled (**power**) was different



Energy vs. Power

- **<u>Power</u>**: the **rate** at which energy (electricity) is consumed
  - How fast energy can be generated/delivered to/from an electrical device
- **<u>Energy</u>**: the ability to do work
  - EX: a battery, a capacitor, a fuel cell

$$Energy = Power \cdot Duration\ of\ \ Use$$

<u>joule (J)</u>: electric energy unit.

1 J = the work required to move an electrical charge of 1C through 1V
1 J = the energy required to lift a small apple (102 g) one meter against Earth's gravity.
1 J = the energy required to heat one gram of dry, cool air by 1 degree Celsius.
1 J = 6.241506363091018 eV (electron-volts)
1 J = 2.7778 $\times 10^{-7}$ kilowatt-hour

<u>kilowatt-hour (kWh)</u>: electric energy unit.

Electric Power

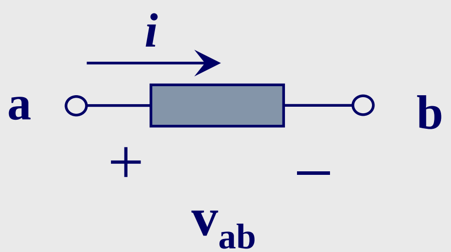
- **Electric Power**: the power generated by an *active* element, or dissipated by a *passive* element is equal to the product of: **voltage** across the element and **current** flowing through it

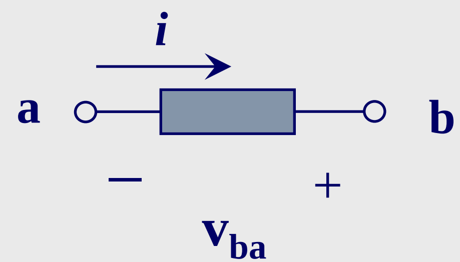
$$P = i \cdot v$$

Watt (W): electric power unit.
1 Watt = 1 joule/second (J/s)
1 Watt = 1 volt-amp (VA)

Electric Power

- **<u>Passive sign convention</u>**: power ***dissipated by a load*** is a positive quantity – the power ***generated by a source*** is positive





Passive Element (load)
- power dissipated = **v*i***
- power generated = **-v*i***

Positive voltage

Active Element (source)
- power dissipated = **-v*i***
- power generated = **v*i***

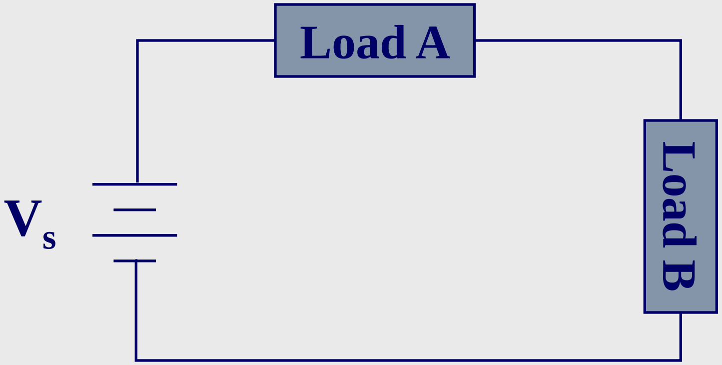
Negative voltage

Passive Sign Convention

1. Choose an arbitrary direction for current flow
2. Label polarities of all active elements (sources) based on direction of current flow
3. Label polarities of all passive elements (loads) based on direction of current flow
4. Compute the power dissipated by each element based on:
    a) If current flows into the positive terminal of the element, the power dissipated is positive (power is absorbed)
    b) If current flows into the negative terminal of the element the power dissipated is negative (power is delivered)

Electric Power

- **Example1**: find the power **dissipated** by each element.
  - $\mathbf{v_a}$ = 8V, $\mathbf{v_b}$ = 4V, $\boldsymbol{i}$ = 0.1A



Electric Power

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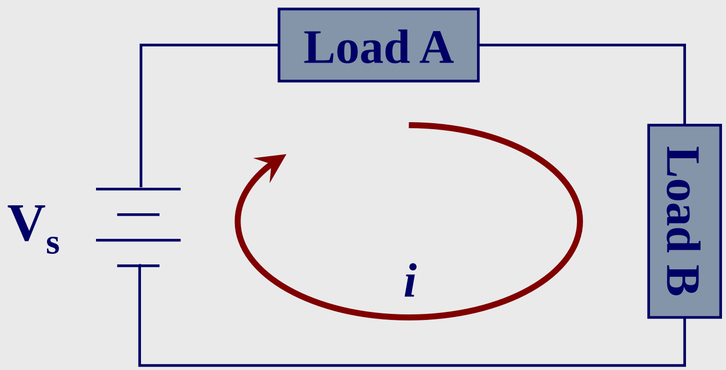
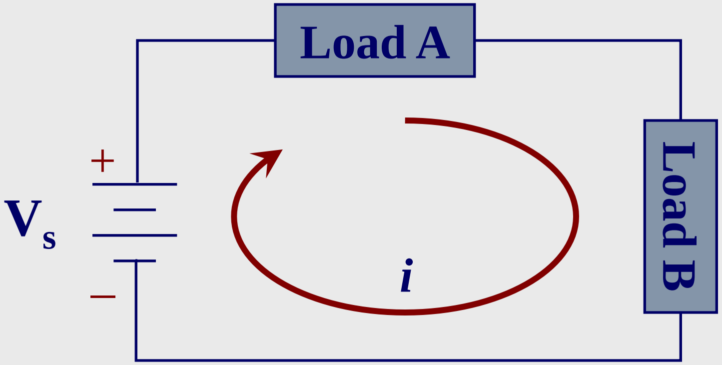


1. Assume a **clockwise** direction of current flow

Electric Power

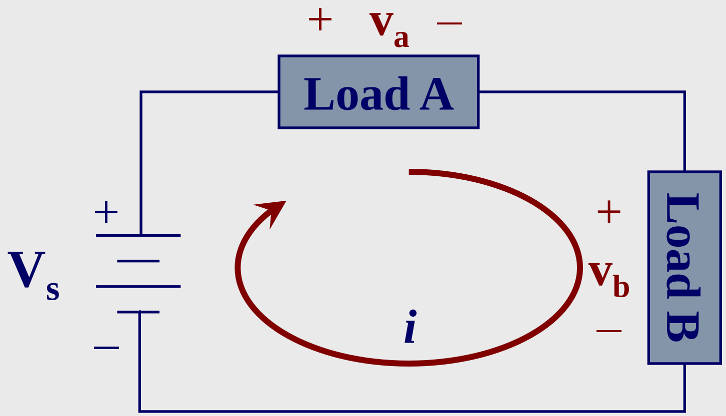
- **<u>Example1</u>**: find the power **dissipated** by each element.
  - $\mathbf{v_a} = 8V$, $\mathbf{v_b} = 4V$, $\boldsymbol{i} = 0.1A$



1. Assume a **clockwise** direction of current flow
2. Label polarity of sources according to current flow

Electric Power

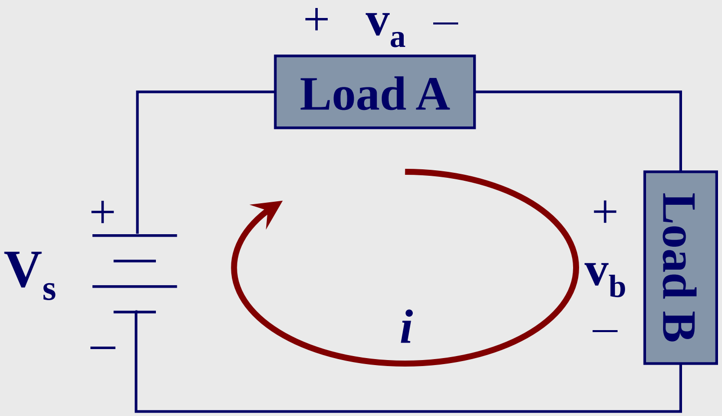
- **<u>Example1</u>**: find the power **dissipated** by each element.
  - $\mathbf{v_a} = 8V$, $\mathbf{v_b} = 4V$, $\boldsymbol{i} = 0.1A$



1. Assume a **clockwise** direction of current flow
2. Label polarity of sources according to current flow
3. Label polarity of loads according to current flow

Electric Power

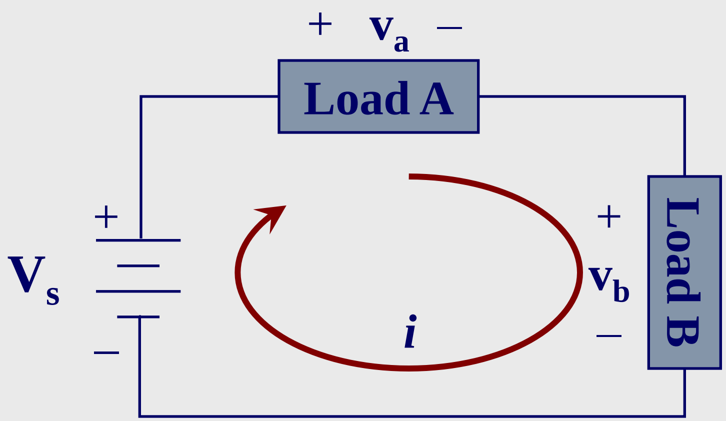
- **Example1**: find the power **dissipated** by each element.
  - $\mathbf{v_a} = 8V$, $\mathbf{v_b} = 4V$, $\boldsymbol{i} = 0.1A$



1. Assume a **clockwise** direction of current flow
2. Label polarity of sources according to current flow
3. Label polarity of loads according to current flow
4. Calculate power dissipated in each element

Electric Power

- **Example1**: find the power **dissipated** by each element.
  - $\mathbf{v_a} = 8V$, $\mathbf{v_b} = 4V$, $\boldsymbol{i} = 0.1A$



1. Assume a **clockwise** direction of current flow
2. Label polarity of sources according to current flow
3. Label polarity of loads according to current flow
4. Calculate power dissipated in each element

Using KVL:

$$-v_s + v_a + v_b = 0$$

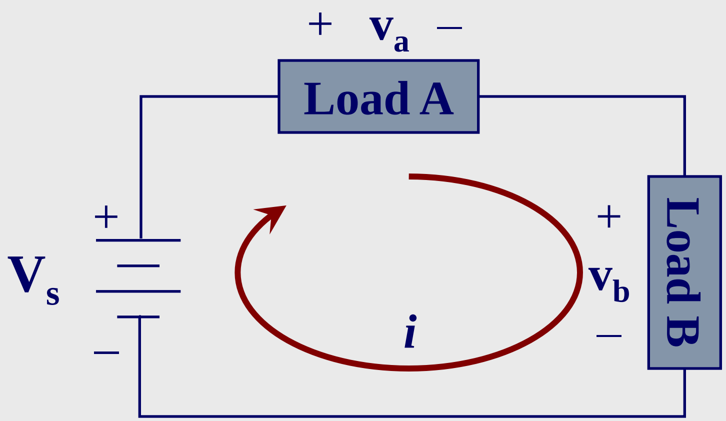
$$v_s = v_a + v_b$$

$$= 8 + 4$$

$$= 12V$$

Electric Power

- **Example1**: find the power **dissipated** by each element.
  - $\mathbf{v_a}$ = 8V, $\mathbf{v_b}$ = 4V, $\boldsymbol{i}$ = 0.1A



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4. Calculate power dissipated in each element

Using KVL:

$$-v_s + v_a + v_b = 0$$
$$v_s = v_a + v_b$$
$$= 8 + 4$$
$$= 12V$$

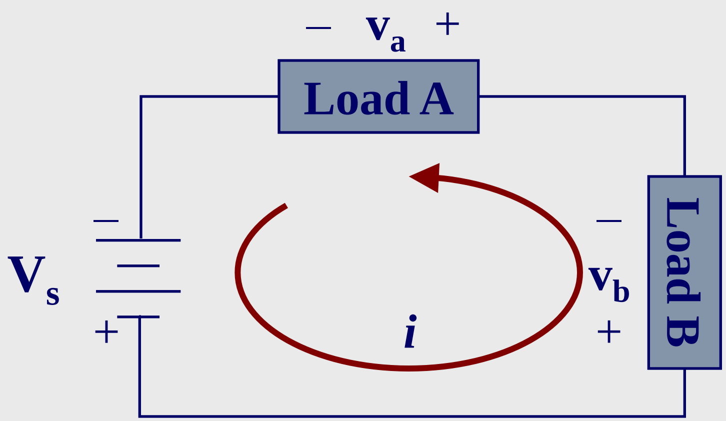
$$P_s = -v_s \times i = (-12V)\times(0.1A) = -1.2W$$

$$P_a = v_a \times i = (8V)\times(0.1A) = 0.8W$$

$$P_b = v_b \times i = (4V)\times(0.1A) = 0.4W$$

Electric Power

- **Example1**: find the power **dissipated** by each element.
  - $\mathbf{v_a} = 8V$, $\mathbf{v_b} = 4V$, $\boldsymbol{i} = 0.1A$



1. Assume a **counter-clockwise** direction of current flow
2. Label polarity of sources according to current flow
3. Label polarity of loads according to current flow
4. Calculate power dissipated in each element

Using KVL:

$$-v_s + v_a + v_b = 0$$

$$v_s = v_a + v_b = 8 + 4 = 12V$$

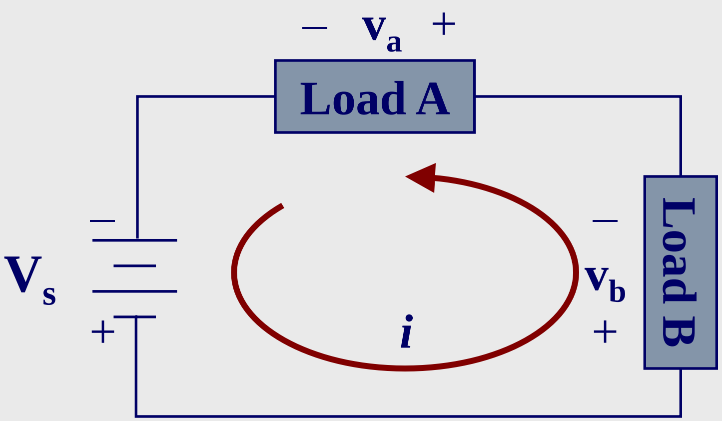
$$P_s = -v_s \times i = (-12V) \times (0.1A) = -1.2W$$

$$P_a = v_a \times i = (8V) \times (0.1A) = 0.8W$$

$$P_b = v_b \times i = (4V) \times (0.1A) = 0.4W$$

Electric Power

- **<u>Example1</u>**: find the power **dissipated** by each element.
  - $\mathbf{v_a} = 8V$, $\mathbf{v_b} = 4V$, $\boldsymbol{i} = 0.1A$



NB: Power is conserved (power supplied always equals power consumed):

$$P_s + P_a + P_b = 0$$

Using KVL:

$$
\begin{aligned}
-v_s + v_a + v_b &= 0 \\
v_s &= v_a + v_b \\
&= 8 + 4 \\
&= 12V
\end{aligned}
$$

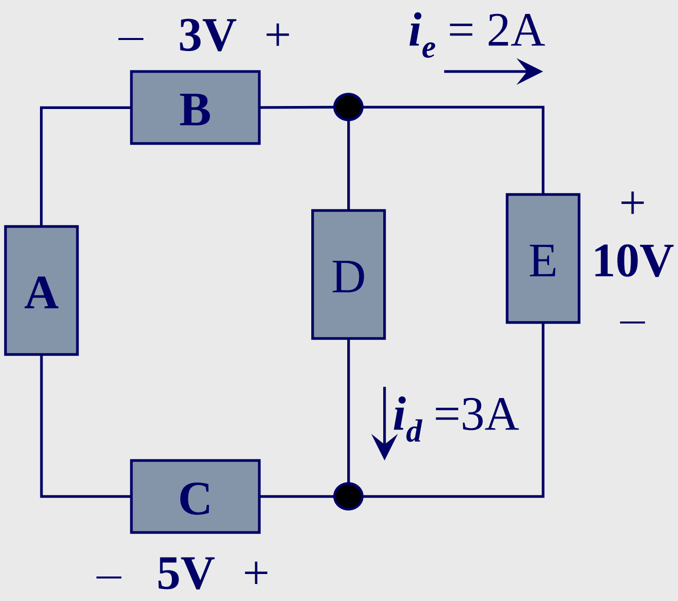
$$
\begin{aligned}
P_s &= -v_s \times i \\
&= (-12V) \times (0.1A) \\
&= -1.2W
\end{aligned}
$$

$$
\begin{aligned}
P_a &= v_a \times i \\
&= (8V) \times (0.1A) \\
&= 0.8W
\end{aligned}
$$

$$
\begin{aligned}
P_b &= v_b \times i \\
&= (4V) \times (0.1A) \\
&= 0.4W
\end{aligned}
$$

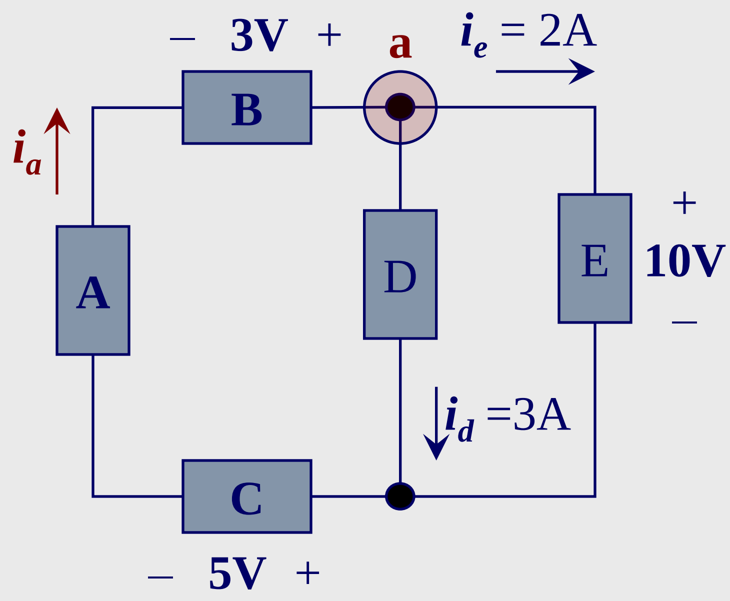
Electric Power

- **Example2**: find the power **dissipated** by each element.



Electric Power

- **Example2**: find the power **dissipated** by each element.



KCL at node a:

$$i_a - i_d - i_e = 0$$

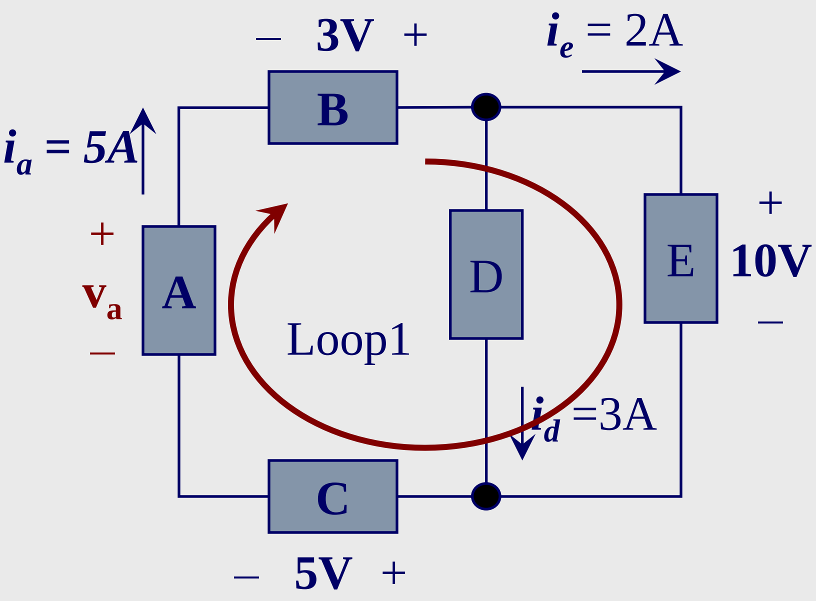
$$i_a = i_d + i_e$$

$$= 3 + 2$$

$$= 5A$$

Electric Power

- **<u>Example2</u>**: find the power **dissipated** by each element.



KVL at Loop1 :

$$-v_a - v_b + v_e + v_c = 0$$

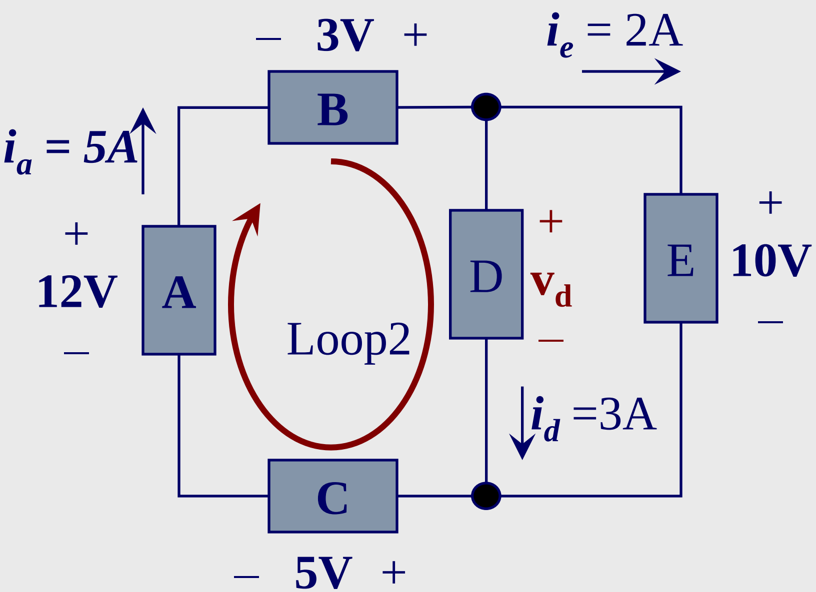
$$v_a = v_e + v_c - v_b$$

$$= 10 + 5 - 3$$

$$= 12V$$

Electric Power

- **Example2**: find the power **dissipated** by each element.



KVL at Loop2 :

$$-v_a - v_b + v_d + v_c = 0$$

$$v_d = v_a + v_b - v_c$$

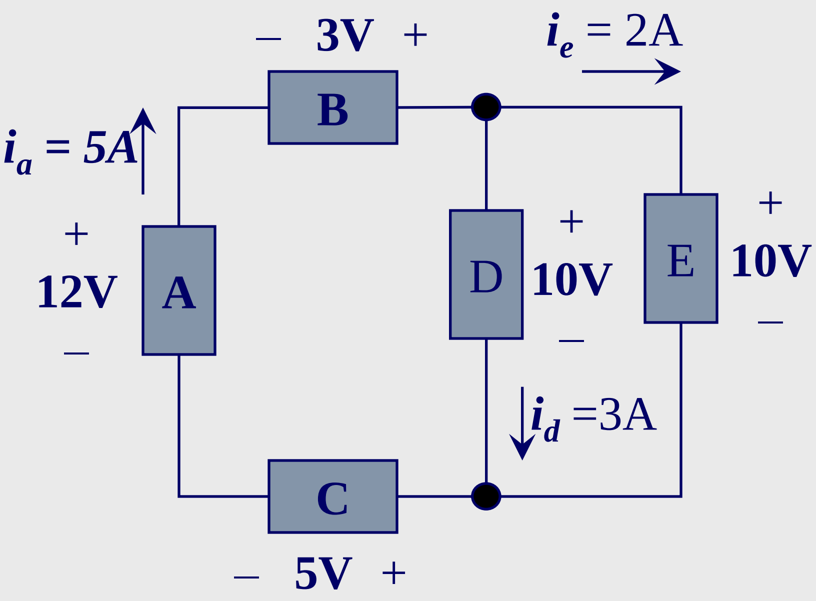
$$= 12 + 3 - 5$$

$$= 10V$$

NB: since **load D** and **load E** share the same node their voltages will be the same

Electric Power

- **<u>Example2</u>**: find the power **dissipated** by each element.



$$P_a = -12V \times 5A = -60W$$
A supplies $60W$

$$P_b = -3V \times 5A = -15W$$
B supplies $15W$

$$P_c = 5V \times 5A = 25W$$
C absorbs $25W$

$$P_d = 10V \times 3A = 30W$$
D absorbs $30W$

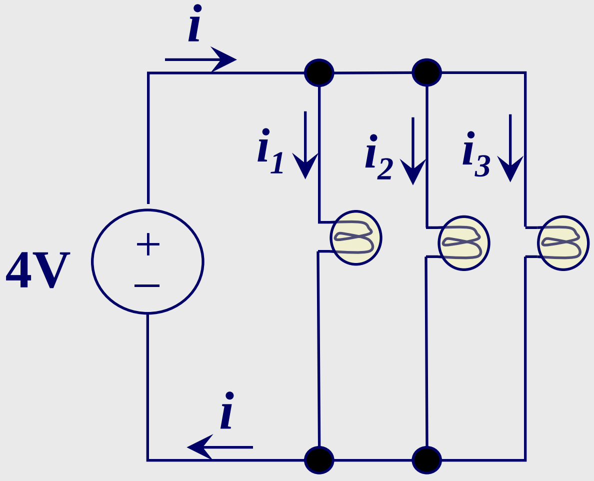
$$P_e = 10V \times 2A = 20W$$
E absorbs $20W$

Total Power Supplied :
$$P_a + P_b = 60W + 15W = 75W$$

Total Power Absorbed :
$$P_c + P_d + P_e = 25W + 30W + 20W = 75W$$

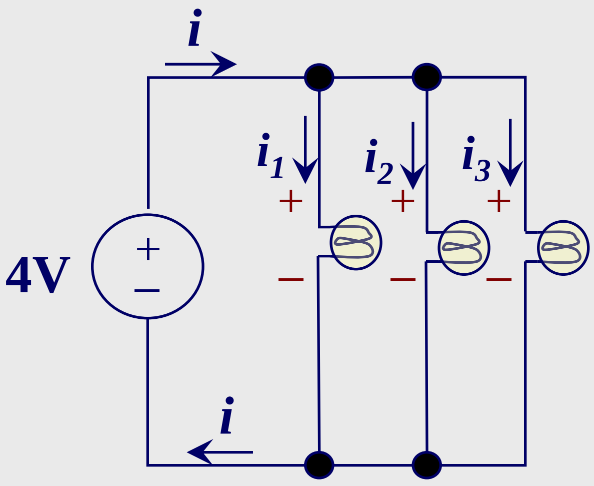
Electric Power

- **Example3**: The battery supplies a total of 10mW. What is $\boldsymbol{i_3}$?
  - $\boldsymbol{i_1}$ = 1mA, $\boldsymbol{i_2}$ = 1.5mA



Electric Power

- **Example3**: The battery supplies a total of 10mW. What is $\boldsymbol{i_3}$?
  - $\boldsymbol{i_1}$ = 1mA, $\boldsymbol{i_2}$ = 1.5mA



$$P_s = i \times v$$

$$i = \frac{P_s}{v} = \frac{10mW}{4V} = \frac{0.01W}{4V} = 0.0025\,A = 2.5mA$$

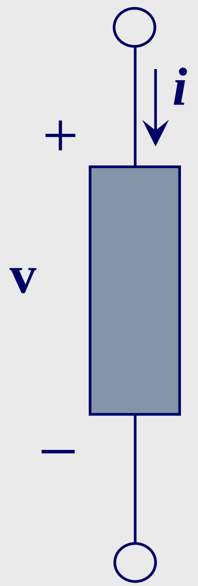
Using KCL:

$$i - i_1 - i_2 - i_3 = 0$$

$$i_3 = i - i_1 - i_2 = 2.5 - 2 - 1.5 = 1.0mA$$

i–v Element Characteristics

- The relationship between current (***i***) and voltage (**v**) at the terminals of a circuit element defines the behaviour of that element within the circuit



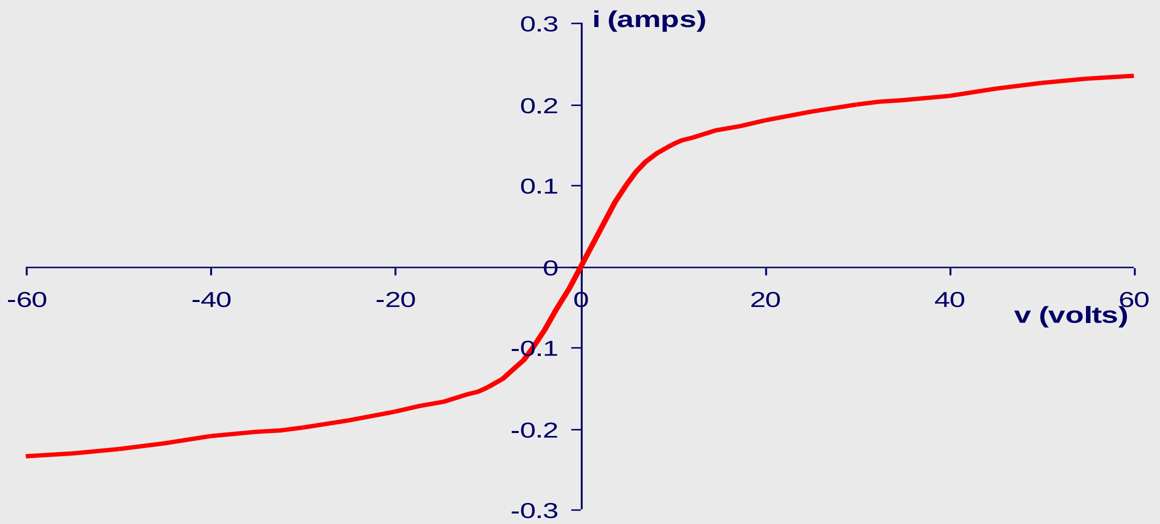
- If a voltage is imposed across the terminals of the element the voltage itself (**v**) and the current that will flow (***i***) form a unique pair of values.
  - measuring the current while the voltage varies is known as the ***i*–v characteristic**
  - with the ***i*–v** characteristic voltage (current) can be determined from a given current (voltage)
  - power can also be determined

***i*–v** Element Characteristics

- ***i*–v** characteristic can be given as:
  - **a function**

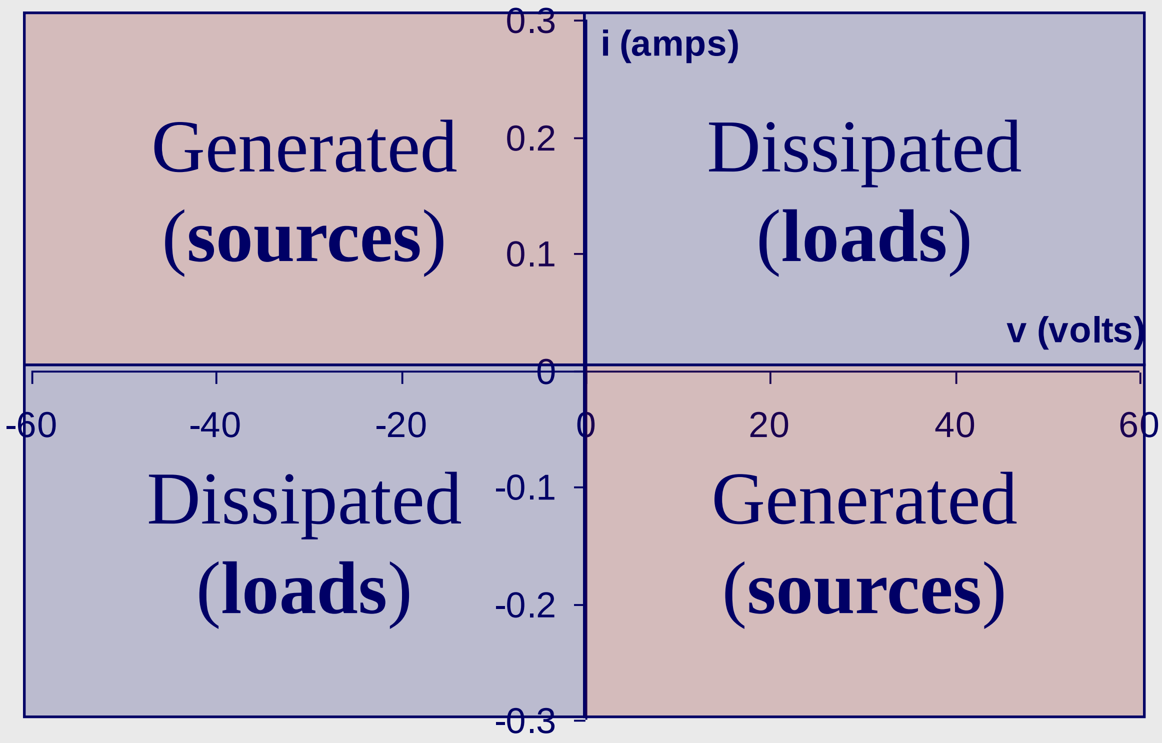
$$i = f(v) \qquad\qquad v = g(i)$$

  - **a graph**



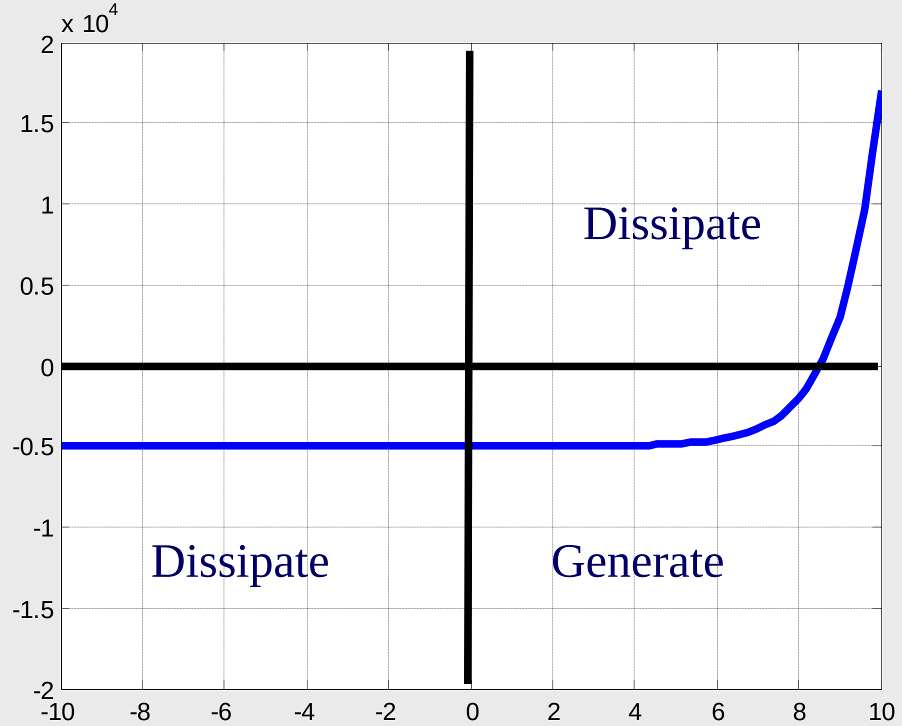
i–v Element Characteristics

- Power generated vs. power dissipated quadrants



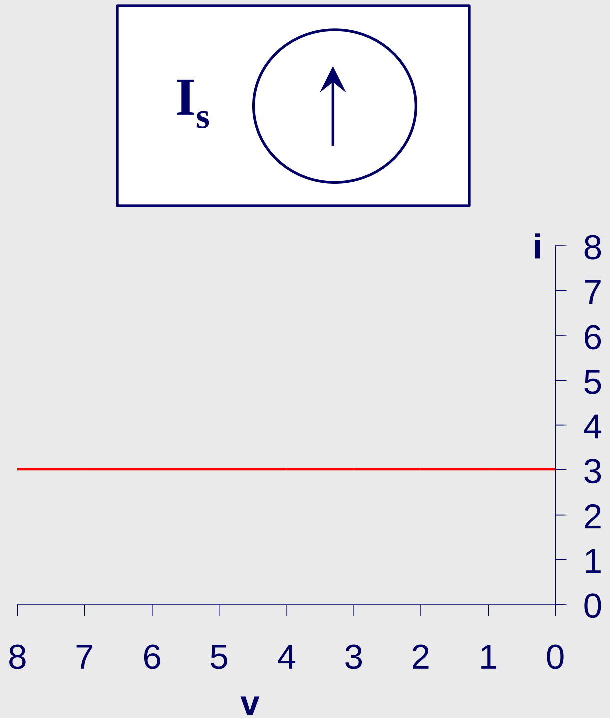
i–v Element Characteristics

- Elements that source and dissipate power
  - Photovoltaic – solar cells, photodiodes, photodetectors



i–v Element Characteristics

- Ideal DC current source
  - 3A source



- Ideal DC voltage source
  - 6V source