ENGR 65 Circuit Theory

Lecture 3: Voltage/Current Sources, Resistance, and Ohm's Law

Topics

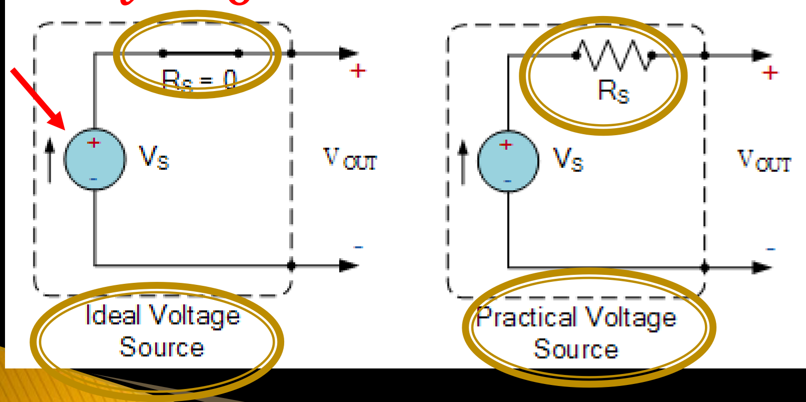
- Voltage/current sources
- Dependent/independent sources
- Resistance/conductance
- Ohm's Law

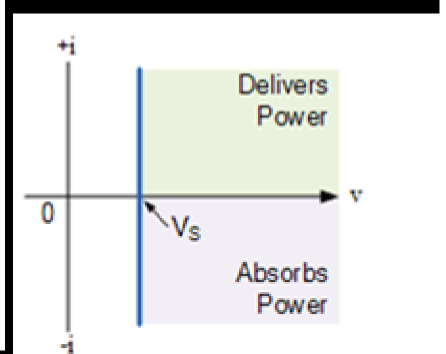
Covered in Sections 2.1 and 2.2

Voltage Sources

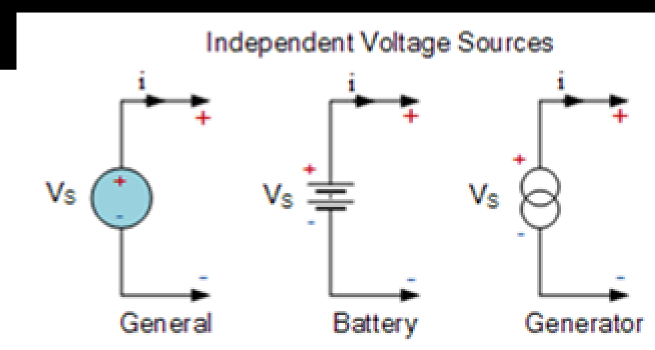
- An ideal voltage source is a circuit element that maintains a prescribed voltage across its terminals no matter what and how the current flows through it.
- An ideal voltage source has zero internal resistance. It cannot be shorted. The “+” and “–” indicate the reference polarity of the voltage.
- The current in an ideal voltage source can be zero if no loads are connected to the source.

$i = 0$





Ideal DC voltage sources

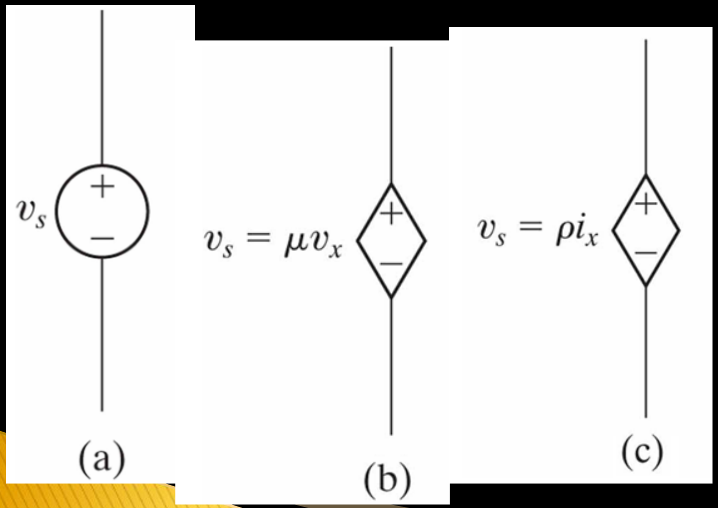


http://www.electronics-tutorials.ws/dccircuits/voltage-source.html

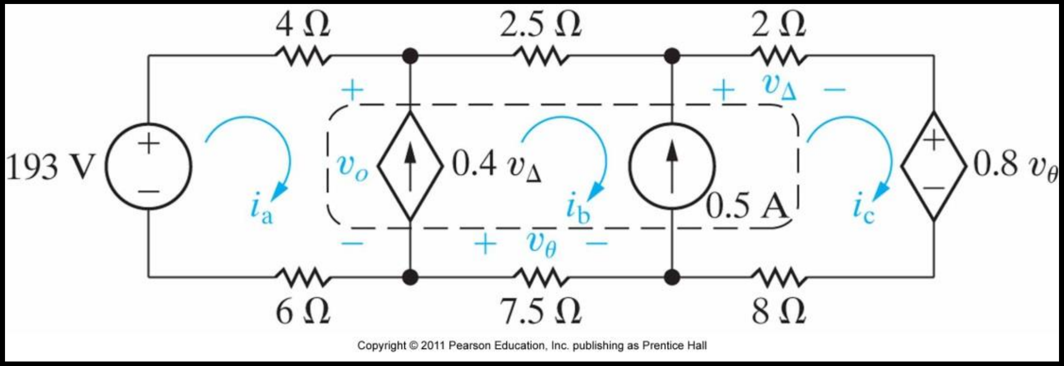
Voltage Sources

There are two types of voltage sources:

1. Independent voltage sources (a)
2. Dependent voltage sources (controlled voltage sources) (b) (c)
    1. Voltage controlled voltage sources or VCVS (b)
    2. Current controlled voltage sources or CCVS (c)

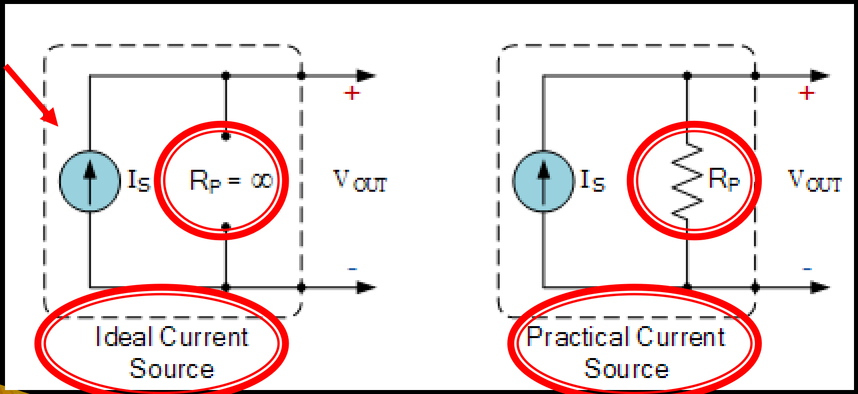


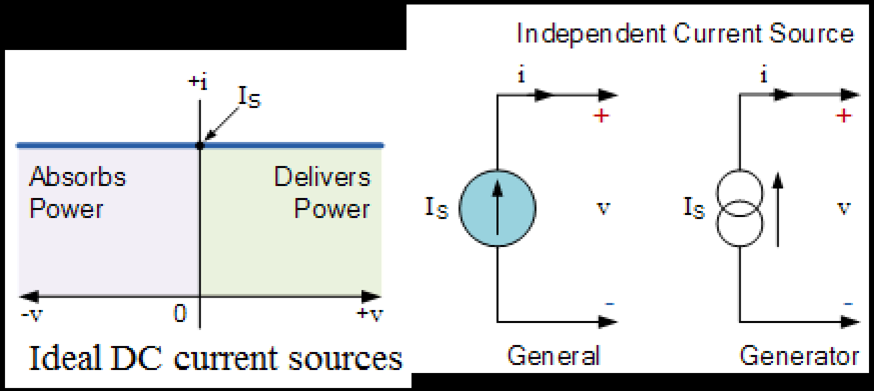
The coefficient μ is dimensionless and the ρ has a unit of ohms.



Current Sources

- An ideal current source is a circuit element with a prescribed current flowing through its terminals no matter what the voltage across these terminals is.
- In theory, an ideal current source has infinite internal resistance.
- The arrow in the circle shows the reference direction of the current in the source .



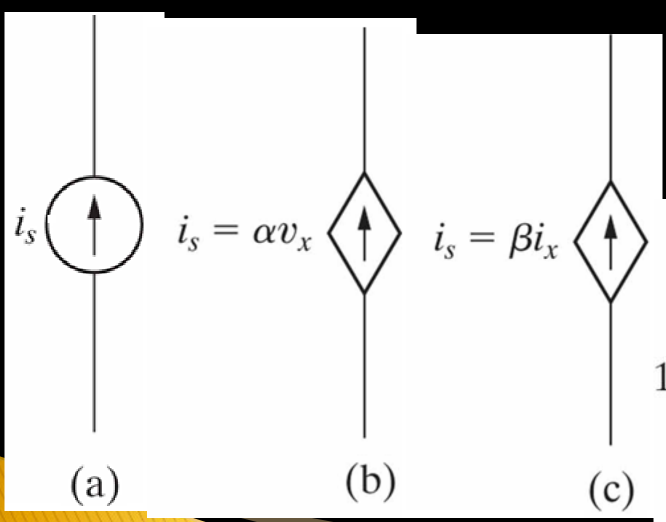


http://www.electronics-tutorials.ws/dccircuits/current-source.html

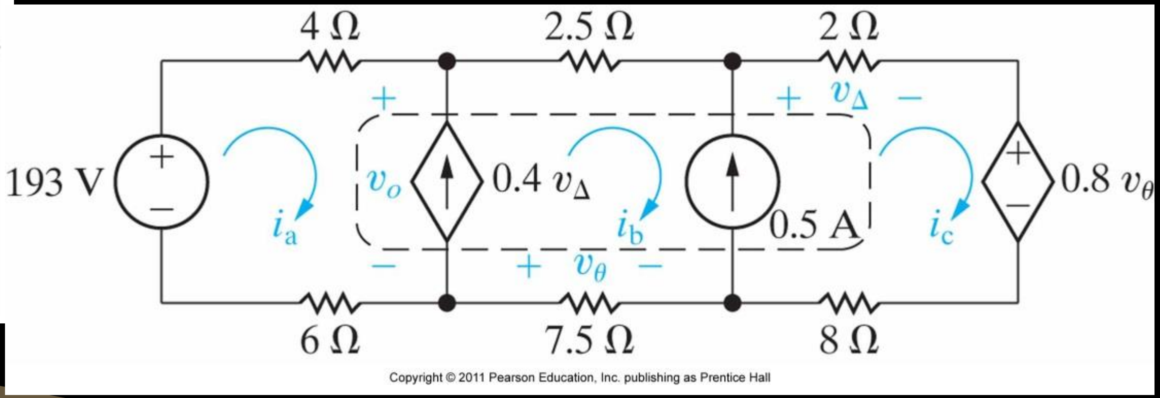
Current Sources

There are two types of current sources

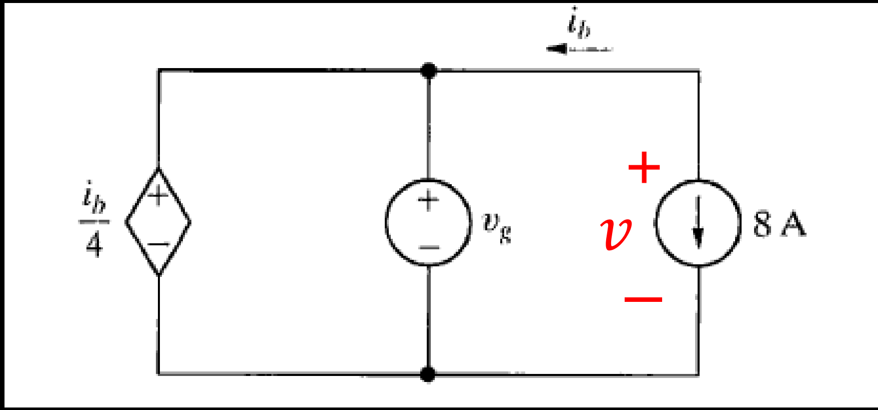
- Independent current sources (a)
- Dependent current sources (controlled current sources) (b) (c)
  1. Voltage controlled current sources or VCCS (b)
  2. Current controlled current sources or CCCS (c)



The coefficient β is dimensionless and the α has a unit of Siemens.



Example #1



(This is a fake circuit. It is used to explain the reference directions and the passive sign convention)

1. Find i_b.
2. Find v_g.
3. Calculate the power associated with the independent current source.

$$1.\ i_b = -8\ A$$

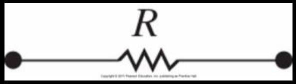
$$2.\ v_g = \frac{i_b}{4} = \frac{-8}{4} = -2\ V$$

$$3.\ p = 8v = 8(-2) = -16\ W$$

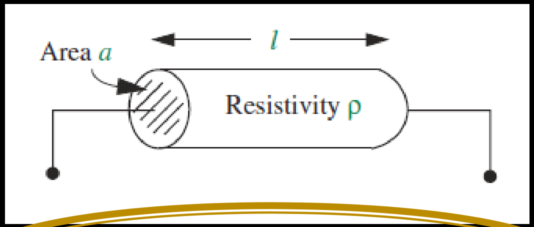
$$or\ \ p = -v i_b = -(-2)(-8) = -16\ W$$

Electrical Resistance

- Resistance is the capability of materials to impede the flow of current, or the flow of electric charge.
- The circuit element used to model the resistance is called the resistor, R. the unit is ohms. Ω is the standard symbol for an ohm.



- In this course, the resistance of wires is assumed to be zero.



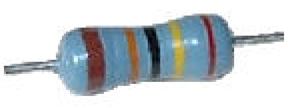
$R = \rho \frac{l}{a}$, ρ: resistivity (Ω.m)

Silver: $\rho = 1.59 \times 10^{-8}$

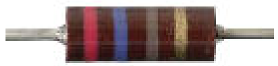
Copper: $\rho = 1.68 \times 10^{-8}$

Carbon: $\rho = 1{\sim}60 \times 10^{-5}$

Hard Rubber: $1{\sim}100 \times 10^{13}$



Film Resistor



Carbon Resistor

Wirewound Resistor

https://www.youtube.com/watch?v=Gc1wVdbVI0E

http://www.electronics-tutorials.ws/resistor/res_1.html

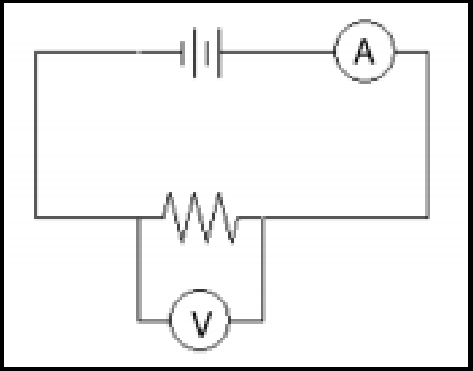
Ohm's Law

Georg Ohm

The voltage across a conductor is proportional to the current through the conductor.

$$v = iR \quad \text{(Ohm's Law)}$$

The constant of proportionality is called the resistance.



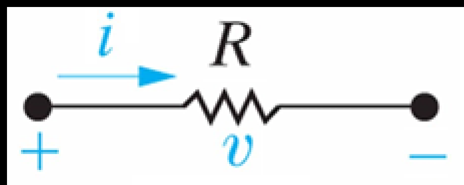
where *v:* the voltage in volts(V),

i: the current in amperes(A),

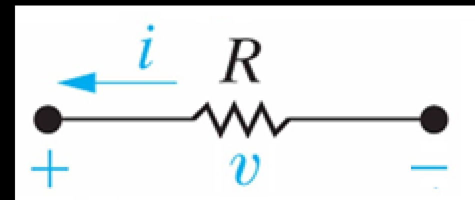
R: the resistance in ohms(Ω).

Ohm's Law

With the passive sign convention, Ohm's law has two forms.

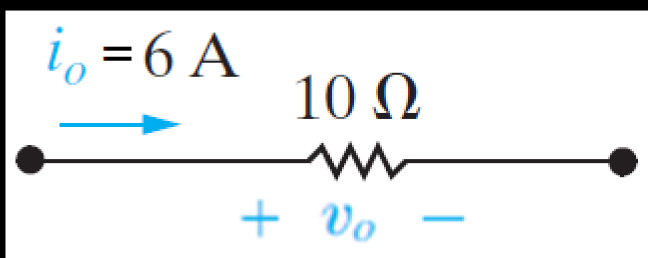


$v = iR$

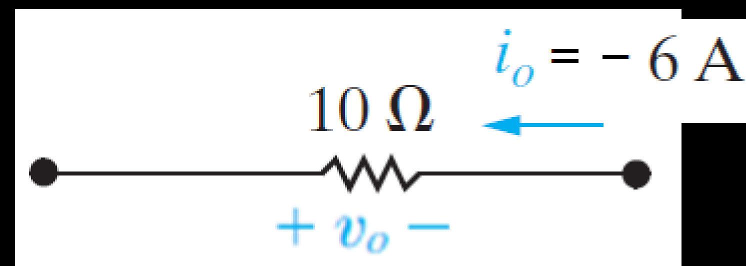


$v = -iR$

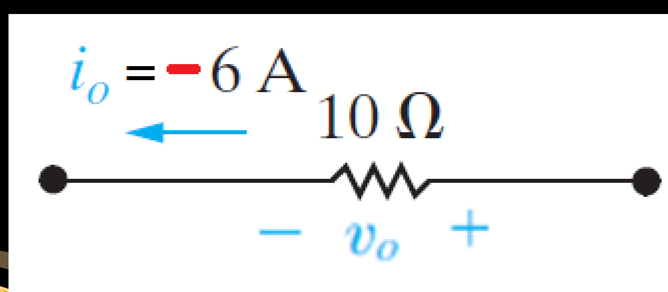
For Example:



$$v_0 = (i_0)(10) = 60\ V$$



$$v_0 = -(i_0)(10) = 60\ V$$



$$v_0 = +(i_0)(10) = -60\ V$$

Conductance

If the current is written as the function of the voltage, we have:

$$i = \frac{v}{R} \ or \ i = -\frac{v}{R}$$

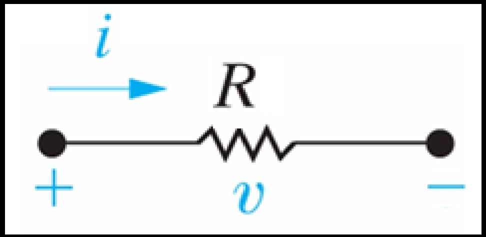
We define $G = \frac{1}{R}$, the above expressions can be written as:

$$i = vG \ or \ i = -vG$$

G is called conductance with a unit of siemens (S). It reflects the ability that an object conducts electricity.

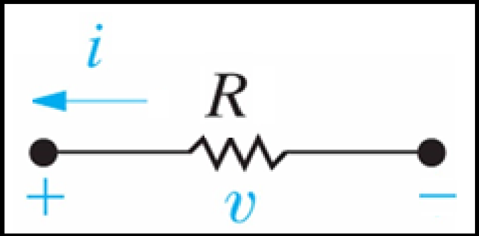
Power of Resistors

- With this reference assignments, $v = iR$ and the power of the resistor can be expressed as:



1. $p = vi$
2. $p = (iR)i = i^2R = \frac{i^2}{G}$
3. $p = v\frac{v}{R} = \frac{v^2}{R} = Gv^2$

- With this reference assignments, $v = -iR$ and the power of the resistor can be expressed as:

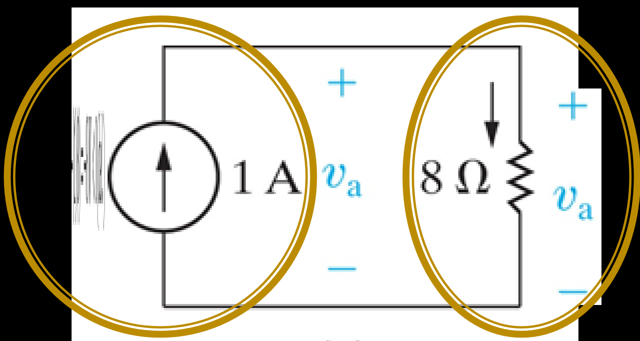


1. $p = -vi$
2. $p = -(-iR)i = i^2R = \frac{i^2}{G}$
3. $or\ p = (-v)\left(-\frac{v}{R}\right) = \frac{v^2}{R} = Gv^2$

- No matter how the references are assigned, the power associated with resistors is always positive, which means resistors always absorb power from circuits.

Example #2

1. Calculate the values of v and i in the circuits below
2. Find the power associated with each source and resistor.



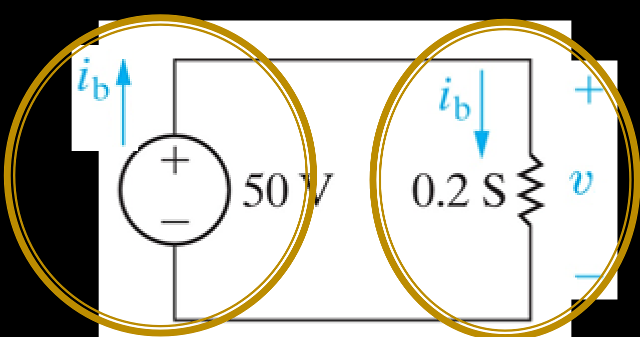
(a)

$$v_a = +(1)(8) = 8\ V$$

$$p_{8\Omega} = +(1)(v_a) = \left(1^2\right)(8) = 8\ W\ > 0(Abs.)$$

$$p_{1A} = -(1)v_a = -(1)(8) = -8\ W\ < 0\ (del.)$$

$$|p_{8\Omega}| = |p_{1A}|\quad verified!$$



(b)

$$v = 50\ V$$

$$i_b = Gv = (0.2)(50) = 10\ A$$

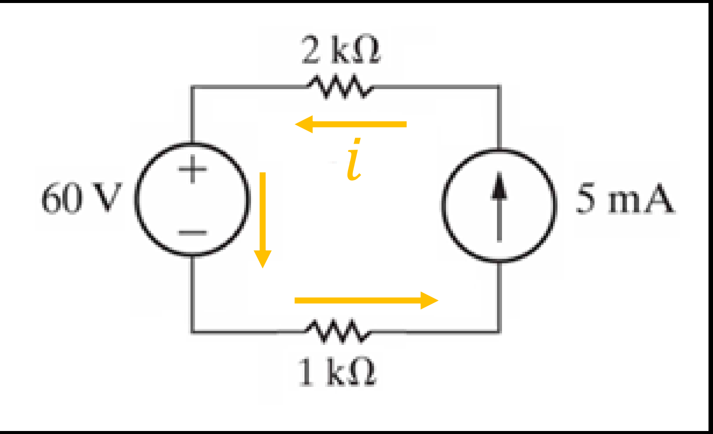
$$p_{0.2S} = (i_b)(v) = (10)(50)$$
$$= 500\ W > 0\ (absorbing)$$

$$p_{50V} = -i_b(50) = -(10)(50)$$
$$= -500\ W\ < 0\ (delivering)$$

$$|p_{0.2S}| = |p_{50V}|$$ verified!

Example #3

Find the power associated with two resistors and the voltage source.



1. For sources: $p = \pm vi$
2. For resistors: $p = \pm vi = i^2 R = \frac{v^2}{R}$
3. Assign the reference direction of the current for each element, $i = 5\ mA$
4. Find the powers

$$p_{2k} = i^2(2000) = (0.005)^2(2000) = 50\ mW$$

$$p_{1k} = i^2(1000) = (0.005)^2(1000) = 25\ mW$$

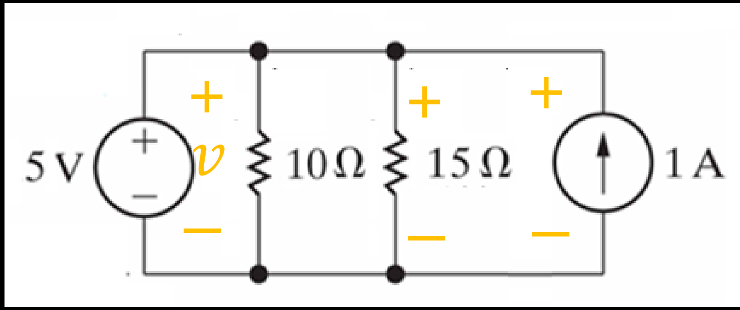
$$p_{60V} = +60i = (60)(0.005) = 300\ mW$$

$p_{5mA} =?$

Kirchhoff's Voltage Law

Example #4

Find the power associated with the two resistors and the current source.



1. For sources: $p = \pm vi$
2. For resistors: $p = \pm vi = i^2 R = \frac{v^2}{R}$
3. Assign the reference polarity of the voltage for each element, $v = 5\ V$
4. Find the powers

$$p_{10} = \frac{v^2}{10} = \frac{5^2}{10} = 2.5\ W$$

$$p_{15} = \frac{v^2}{15} = \frac{5^2}{15} = 1.67\ W$$

$$p_{1A} = -v(1) = -(5)(1) = -5\ W$$

$p_{5V} = ?$ Kirchhoff's Current Law

Summary

- There are two independent sources: current sources and voltage sources.
- There are four dependent sources: the current controlled current sources (CCCS), the current controlled voltage source (CCVS), the voltage controlled voltage source (VCVS), and the voltage controlled current source (VCCS).
- Resistors can be used to control the current in a circuit.
- Ohm's law indicates the relationship among the resistance of a resistor, the voltage across the resistor, and the current flowing through the resistor.

- In next class, we are going to discuss:
- Kirchhoff's current and voltage laws (KCL, KVL)
- Applications of Ohm's law, KCL, and KVL.