

Class Note 1: Definitions of V, I, P, and W & Polarity and Source Power Calculation**1. "Circuit" Theory**

Circuit: 1. Mathematical model
2. Approximation of actual electrical system

Assumptions: 1. Instantaneous System (or Lumped-Parameter System): "no time delay"
2. Zero Net Charge: "No collection of charge on every element"
3. Zero Coupling: "No magnetic coupling between components"

2. Alphabet Soup of Network Analysis I

Variable "bowl": V (voltage), I (current), and P (power)
Element "bowl": R (resistor), L (inductor), C (capacitor)
Source "bowl": V_s (voltage source) and I_s (current source)

3. Definitions of V, I, P, and W

a. Voltage [V]: "Separation of charge creates electric force (V)": $V = \frac{dw}{dq}$ (1)

w : Energy [J]
 q : electric charge

b. Current [A]: "Motion of charge creates an electric flow (current)": $I = \frac{dq}{dt}$ (2)

c. Power [W¹]: "Time rate of absorbing and delivering energy": $P = \frac{dw}{dt}$ (3)

Equation (3) can be rearranged to: $P = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = V \cdot I$ (4)

d. Energy [J]: "Time accumulation of power": $w = \int_0^t P d\tau$ (5)

4. Polarity and Source Power Calculation

Power calculation in a resistor is simple and straightforward without considering polarity and flow direction. However, when a source is involved the correct power calculation is sometimes confusing. Remember, though, the important convention: a negative power indicates it generates (or delivers) power; a positive, it consumes (or absorbs).

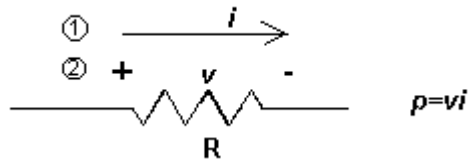
Polarity and Power Calculation in a Resistor ("passive convention")

Assume that a resistor (shown below) is connected in a circuit.

¹ **Symbol confusion and clarity:** lower case w indicates the symbol of energy while the upper case **W** (read as Watt), the unit of power. The symbol of power is the upper case **P**.



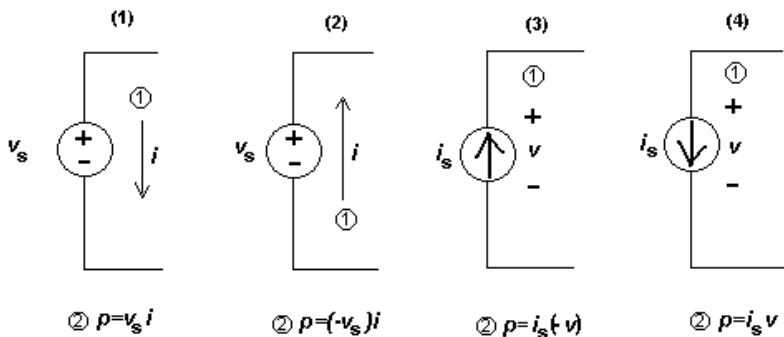
The first thing we do is to mark an assumed direction of current as indicated by (1) in the figure shown below. Then, we mark voltage polarity mark to indicate the "Right" direction (following so called "passive convention") of the voltage indicated by (2). It's simple: since current flows from *Positive* to *Negative*. Or, current flows in the *Direction of Voltage Drop*.



Then, the power in the resistor is: $p=vi$ or $p=(+v)(+i)=vi$

Polarity and Power Calculation in a Source

This part is most confusing to some students. Let's proceed while remembering the passive convention: **if current flows in the *Direction of Voltage Drop* then use positive polarity for both voltage and current in power calculation.** Otherwise, one of them must be negative. Here we have four different cases involving two voltage source cases and the other two with current source.



- (1) Voltage Source 1: a voltage source is present in a circuit and if the current flow is assumed to be downward, then, this combination gives you the positive polarity to the current.
- (2) Voltage Source 2: a voltage source is present in a circuit and if the current flow is assumed to be upward, then, this combination gives you the positive polarity to the voltage.
- (3) Current Source 1: an upward current source is present and if the voltage polarity is assumed to be + and - (top to bottom), then, voltage must be negative.
- (4) Current Source 2: a downward current source is present and if the voltage polarity is assumed to be + and - (top to bottom), then, voltage is well matched with the convention and thus has to be positive.