Lecture 2 : Voltage, Ground, Power, Power Sources

Learning Objectives:

1. **Define Voltage**
2. **Write difference between two points in symbolic form**
3. **Define Ground and identify ground in a circuit**
4. **Compute Power absorbed/supplied by elements**
5. **Identify voltage and current sources**

1. Voltage:

The movement of charge in an can transfer energy. For example, in the circuit shown below the chemical energy stored in the battery is converted to light in the LED.

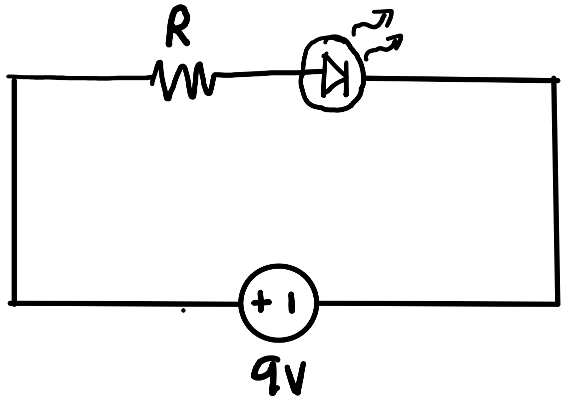


Fig 2.1: Chemical energy converted to light

Voltage represents the work done in moving charge from one point to another in an electric field. Consider the figure below where a charge "q" moves from point "a" to point "b" in an electric field.

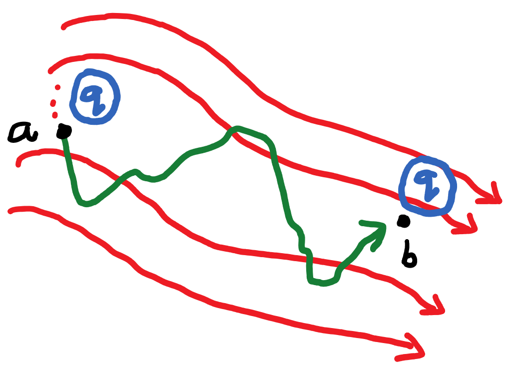


Fig 2.2: Charge movement in an electric field.

The voltage between point "a" and "b" is then given by,

$$V_{ab} = \frac{W_{ab}}{q},$$

Where W_{ab} denotes the work done in moving charge "q" from "a" to "b".

Unit of voltage: The unit of voltage is Volts (V) and $1V = \frac{1\ Joule}{1\ Coulomb}$.

Note that Voltage is always defined between two point while current is always through an element/wire.

The following figure illustrates a two terminal electrical element with voltage, V_{ab}, between its terminals and current i_{ab} through it.

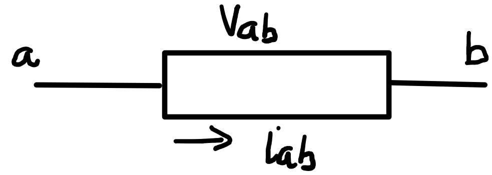


Fig. 2.3 Voltage and current notations

2. Ground

In circuit analysis it is useful to define a **reference point**. This is analogous to specifying the height of mass m with reference to a reference point called **ground**. The ground is said to be at height $h_g = 0$. Consider two masses m_1 and m_2 at heights h_a and h_b respectively with respect to the common reference (**ground)** as shown below.

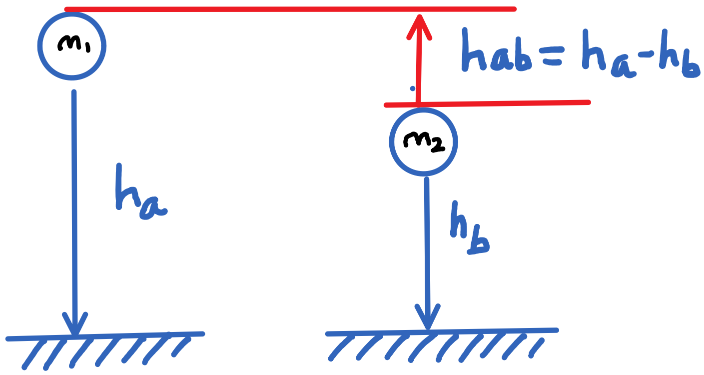


Fig. 2.4: Two masses at heights h_a and h_b.

Let $h_{xy} = h_x - h_y$ denote the difference in height between two points at heights h_x and h_y respectively with respect to ground. We then have the following relationships,

$$h_{ag} = h_a - h_g = h_a$$

$$h_{bg} = h_b - h_g = h_b$$

Height difference between m_1 and m_2,

$$h_{ab} = h_a - h_b$$

As an example, let $h_a = 10\ m$ and $h_b = 5\ m$, then,

$$h_{ab} = 10 - 5 = 5\ m.$$

We can then say that mass m_1 is $5\ m$ higher than mass m_2. Similarly we can say that mass m_2 is $-5m$ **higher** than mass m_2, i.e.,

$$h_{ba} = h_b - h_a = -5\ m.$$

Fig. 2.5 below illustrates the equivalence between height and voltage.

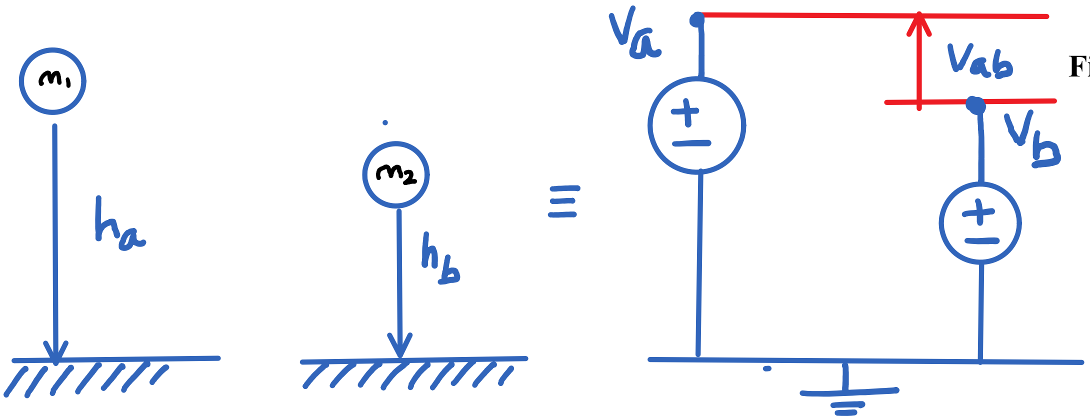


Fig. 2.5: Voltage - Height

Ground height, h_g =0 **Ground = 0 V**

<u>The reference for a circuit is also called</u> "<u>**ground**</u>".

Let $V_{xy} = V_x - V_y$ denote the difference in voltage between two points x and y. We then have the following relationships,

$$V_{ag} = V_a - V_g = V_a$$

$$V_{bg} = V_b - V_g = V_b$$

From Fig. 2.5, voltage difference between points "a" and "b" , is given by,

$$V_{ab} = V_a - V_b.$$

As an example, if $V_a = 10\ V$ and $V_b = 5\ V$, then

$$V_{ab} = V_a - V_b = 5V.$$

We then say point "a" is $5V$ higher than point "b" or point "b" is $-5\ V$ higher than "a". Table 2.1 below sunmarizes the equivalence between height and voltage.

<u>Table 2.1</u>

Height	Voltage
$\boldsymbol{h_{ag} = h_a - h_g = h_a = 10m}$	$\boldsymbol{V_{ag} = V_a - V_g = V_a = 10\ V}$
$\boldsymbol{h_{bg} = h_b - h_g = h_b = 5m}$	$\boldsymbol{V_{bg} = V_b - V_g = V_b = 5\ V}$
$\boldsymbol{h_{ab} = h_a - h_b = 5m}$	$\boldsymbol{V_{ab} = V_a - V_b = 5\ V}$
$\boldsymbol{h_{ba} = h_b - h_a = -5m}$	$\boldsymbol{V_{ba} = V_b - V_a = -5\ V}$

<u>Please Note:</u>

$\boldsymbol{V_{ab} \Rightarrow}$ ***Voltage between "a" and "b"***

$\boldsymbol{V_a \Rightarrow}$ ***Voltage between*** **"a" and ground.**

3. Power

Power is the rate at which work is dissipated (consumed) or delivered (supplied).

$$P = \frac{dW}{dq} = \frac{dW}{dq} \times \frac{dq}{dt}$$

$$\Rightarrow P = V \times I$$

Unit of Power: Watts (W)

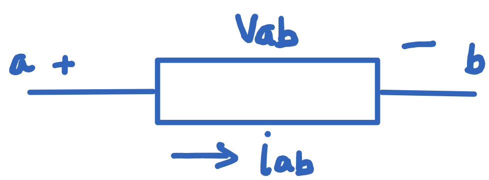
By convention:

$P > 0 \Rightarrow$ Power dissipated or consumed

$P < 0 \Rightarrow$ Power delivered or supplied

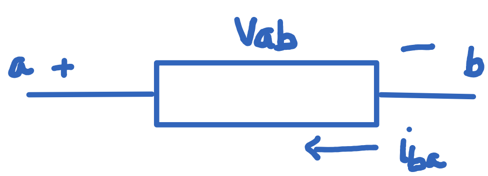
Power Sign Conventions:

1. If current enters the positive end of an element and leaves the negative end, then the element is dissipating power. The power is positive in this case.



$P = V_{ab} i_{ab} \Rightarrow$ Element is dissipating (consuming) power

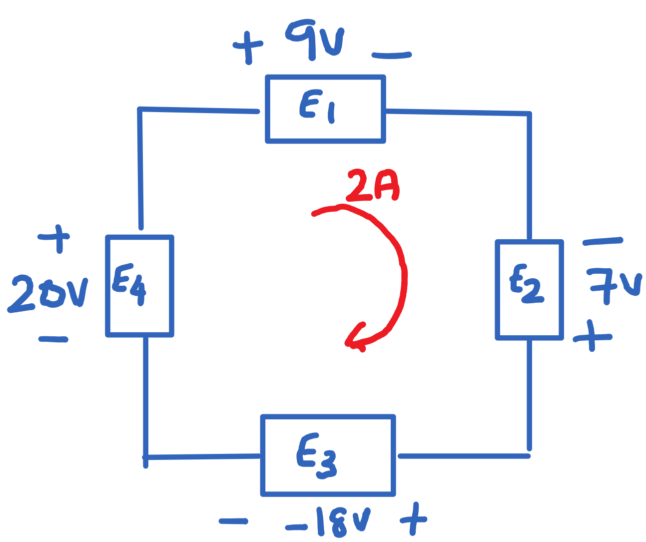
2. If current enters the negative end of an element and leaves the positive end the device is delivering (supplying) power. The power is negative in this case.



$P = V_{ab} i_{ba} = -V_{ab} i_{ab} \Rightarrow$ Element is delivering (supplying) power.

Examples:

1. Find the power consumed/supplied by elements E1, E2, E3, E4, in the circuit below.



Solution: Solved in class as part of worksheet

4. Circuit Elements Revisited:

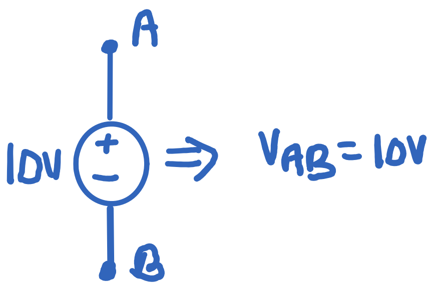
We will again look at some of the circuit elements we discussed earlier. We will classify these elements in two categories:

1. Passives:

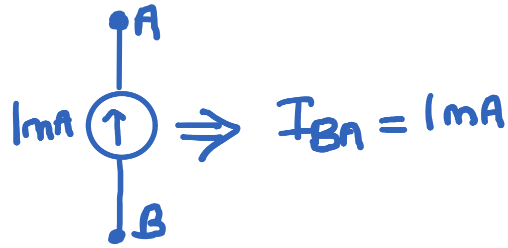
Resistor **Inductor** **Capacitor**

Passives can only consume power.

2. Sources:



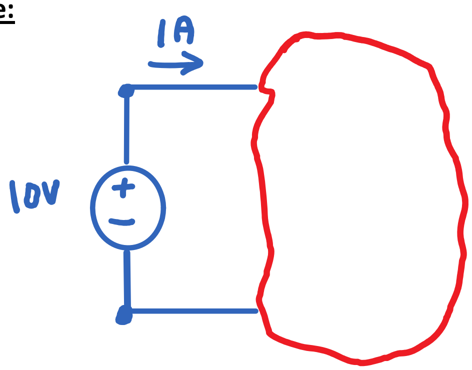
Voltage Source



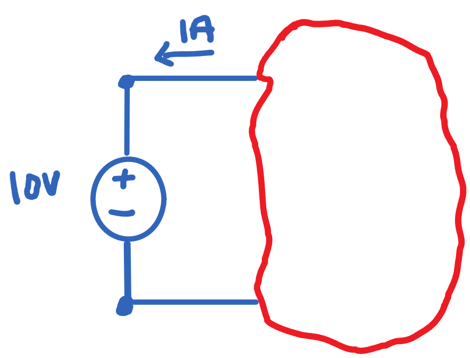
Current Source

Sources can supply/consume power.

Example:



$P = -10 \times 1 = -10\ W$



$P = 10 \times 1 = 10\ W$

Ideal Sources:

1. **Ideal Voltage Source:** An ideal voltage source can drive infinite current.

2. **Ideal Current Source**: An ideal current source can have infinite voltage across its terminals.

In this course we will assume that voltage and current sources are ideal. We will discuss more on the concept of ideal voltage and current sources in later lectures.