1.2 THE LUMPED CIRCUIT ABSTRACTION

1. Capped a set of lumped elements that obey the lumped matter discipline using ideal wires to form an assembly that performs a specific function results in the lumped circuit abstraction.

1.3 THE LUMPED MATTER DISCIPLINE

a. Once we adhere to the lumped matter discipline, we can make several simplifications in our circuit analysis and work with the lumped circuit abstraction. Thus, the lumped matter discipline provides the foundation for the lumped circuit abstraction, and is the fundamental mechanism by which we are able to move from the domain of physics to the domain of electrical engineering.

1. Choose lumped element boundaries such that the rate of change of magnetic flux linked with any closed loop outside an element must be zero for all time.

∂B/∂t = 0

* Voltage is the work involved to move a particle with a unit of charge from one point to another against the e- field force.
* Voltage value is independent of path taken – this can be true if there is no time-varying magnetic flux outside the element.

1. Choose lumped element boundaries so that there is no total time varying charge within the element for all time. In other words, choose element boundaries such that

∂q/∂t = 0

* We can define a unique value for current is there is not charge build up or depletion.
* Both 1 and 2 require that magnetic flux outside the element and charge within the element must be 0 at all times. It also is required that the magnetic flux and electric field are 0 at all times. No field (e- or magnetic) can exert over each other. This allows elements to be independently analyzed: 🡪 V=IR

1. Operate in the regime in which signal time scales of interest are much larger than the propagation delay of electromagnetic waves across the lumped elements.

* The third constraint says that the circuit must be much smaller in all its dimensions than the wavelength of light at the highest operating frequency of interest
* The third postulate of the lumped matter discipline requires us to limit ourselves to signal speeds that are significantly lower than the speed of electromagnetic waves.
* A **transmission line** is a specialized cable or other structure designed to carry [alternating current](https://en.wikipedia.org/wiki/Alternating_current) of [**radio frequency**](https://en.wikipedia.org/wiki/Radio_frequency)**,** that is, currents with a [**frequency**](https://en.wikipedia.org/wiki/Frequency)**high enough that their**[**wave**](https://en.wikipedia.org/wiki/Wave)**nature must be taken into account.**
* Radio frequency currents also tend to reflect from discontinuities in the cable such as [connectors](https://en.wikipedia.org/wiki/Electrical_connector) and joints, and travel back down the cable toward the source.[[1]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-Jackman-1)[[2]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-Oklobdzija-2) **These reflections act as bottlenecks,** preventing the signal power from reaching the destination. Transmission lines use specialized construction, and [impedance matching](https://en.wikipedia.org/wiki/Impedance_matching), to carry electromagnetic signals with minimal reflections and power losses.

1.5 PRACTICAL TWO-TERMINAL ELEMENTS

1.5.1 BATTERIES

a. The power delivered **by** the battery is the product of the voltage and the current:

p = VI

b. Power is delivered by the battery when the current I flowing out of the positive voltage terminal of the battery is positive.

c. If a constant amount of power p is delivered over an interval T , the energy w supplied is:

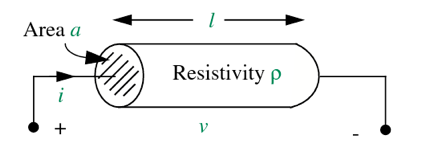
w = pT

d. If you want to increase the battery’s capacity **without increasing the voltage**, connect the battery in **parallel**.

If you want to keep the **current the same** in a cell, connect the batteries in **series**.

1.5.2 LINEAR RESISTORS

a. R = ρ\*l/a if the cylindrical piece satisifies the LMD.



b. Similarly, the resistance of a cuboid shaped resistor with length l , width w , and height h is given by R = ρ\*l/wh

c. Limiting cases for linear resistors:

**open circuits**: R 🡪 infinity (no current can flow through a circuit.)

**close circuits**: aka. Short circuit: R 🡪 0 (tons of current can flow through)

1.5.3 ASSOCIATED VARIABLES CONVENTION

a. Energy that is pumped into an element is considered (+) when a positive current i is directed into the voltage terminal marked positive.

b. When current goes away from the positive terminal, energy is (-).

c. Current is defined as entering the + and exiting – terminal.

d. Power supplied into an element:

p=vi units = watts.

p= i^2r

p= v^2/r

e.