Announcements:

1. HW will be due on Wednesday this week (check website for new version)
2. Graded midterms are for pickup from TAs

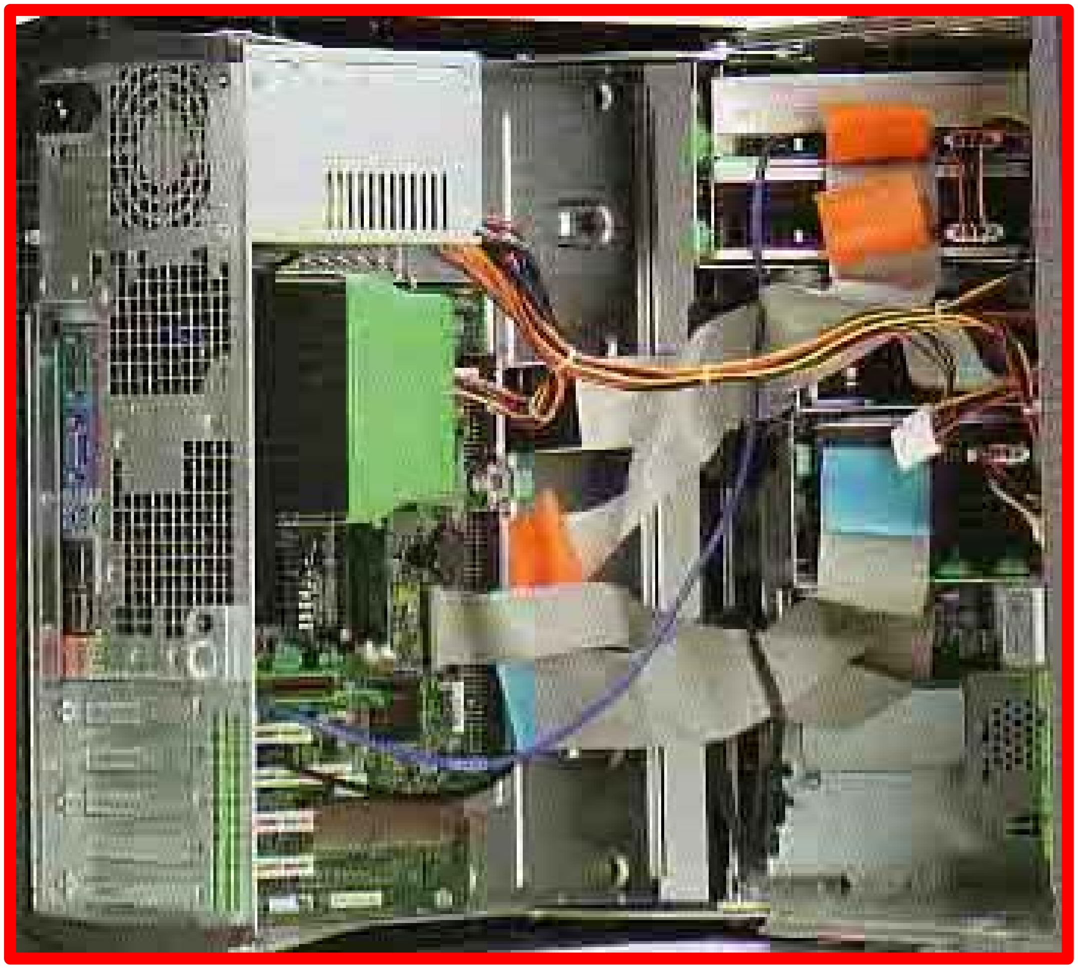
EECS 70A: Network Analysis

Lecture 9

Today's Agenda

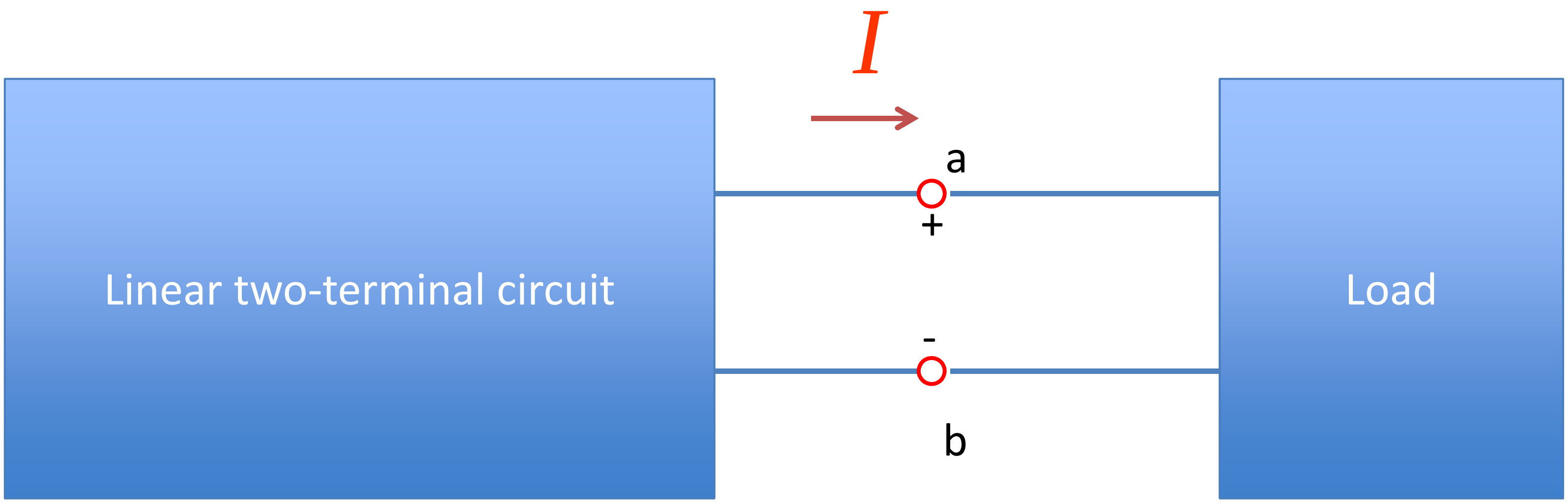
- Thevinin/Norton theorem
- Power transfer
- Capacitors
- Inductors

Compartmentalization: Need for simplicity

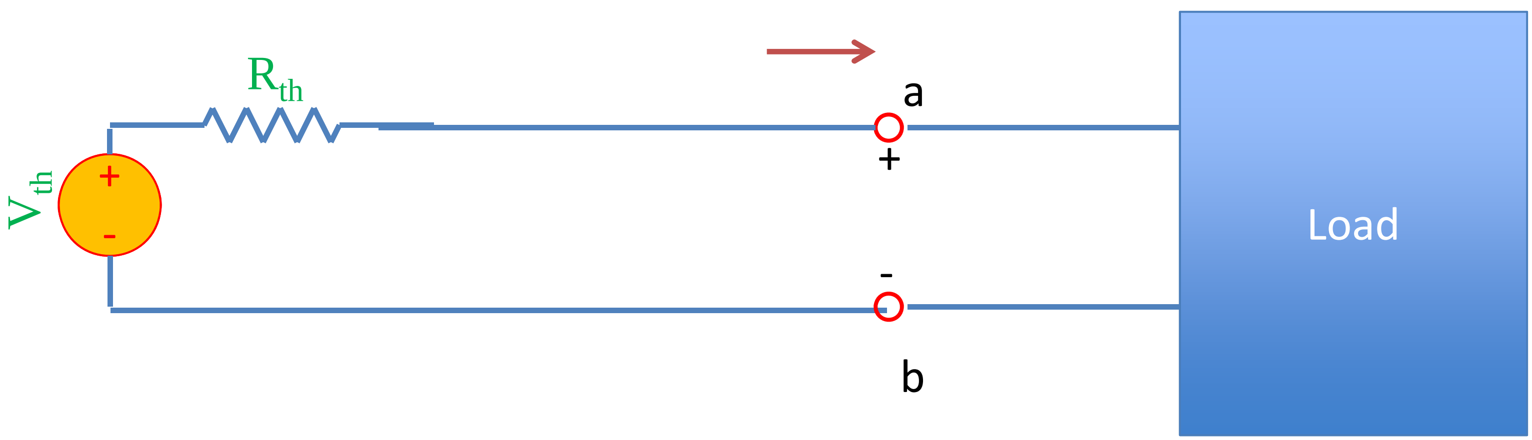


Power brick image.
And ask class to show their own…
Demo: Computer?

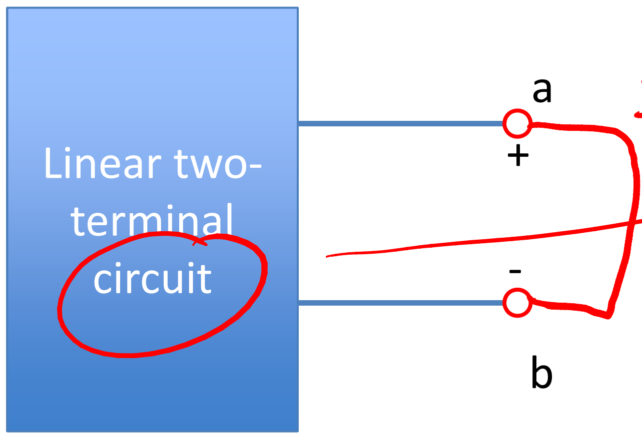
Thevenin's Theorem



Equivalent to:



Finding V_{th}, R_{th}



Goal: Find V_{th}, R_{th}:

Given: circuit

$I = \frac{V_{th}}{R_{th}}$

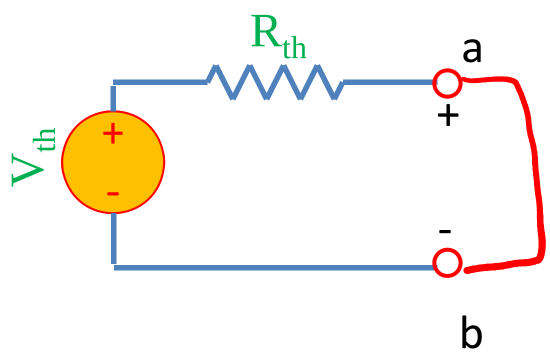
1) Find V_{th}:

Calculate V_{ab} (when no external circuit connected)

2) Find $I_{short\ circuit}$

Then $R_{th} = \frac{V_{th}}{I_{short\ circuit}}$

Equivalent to:

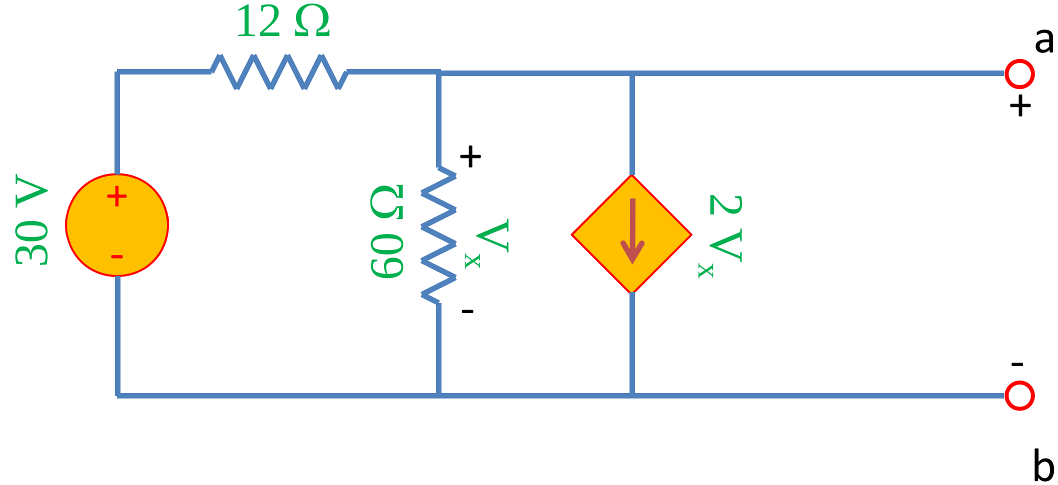


$I = \frac{V_{th}}{R_{th}}$

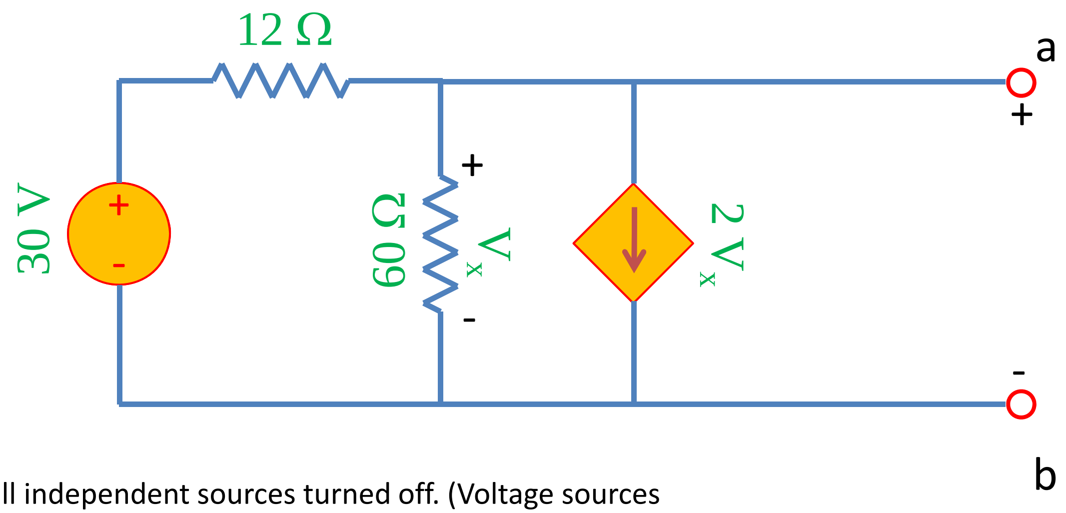
$\Leftrightarrow R_{th} = \frac{V_{th}}{I_{short\ circuit}}$

Example

Find the Thevenin & Norton equivalent circuit of the circuit below with respect to terminals a and b:

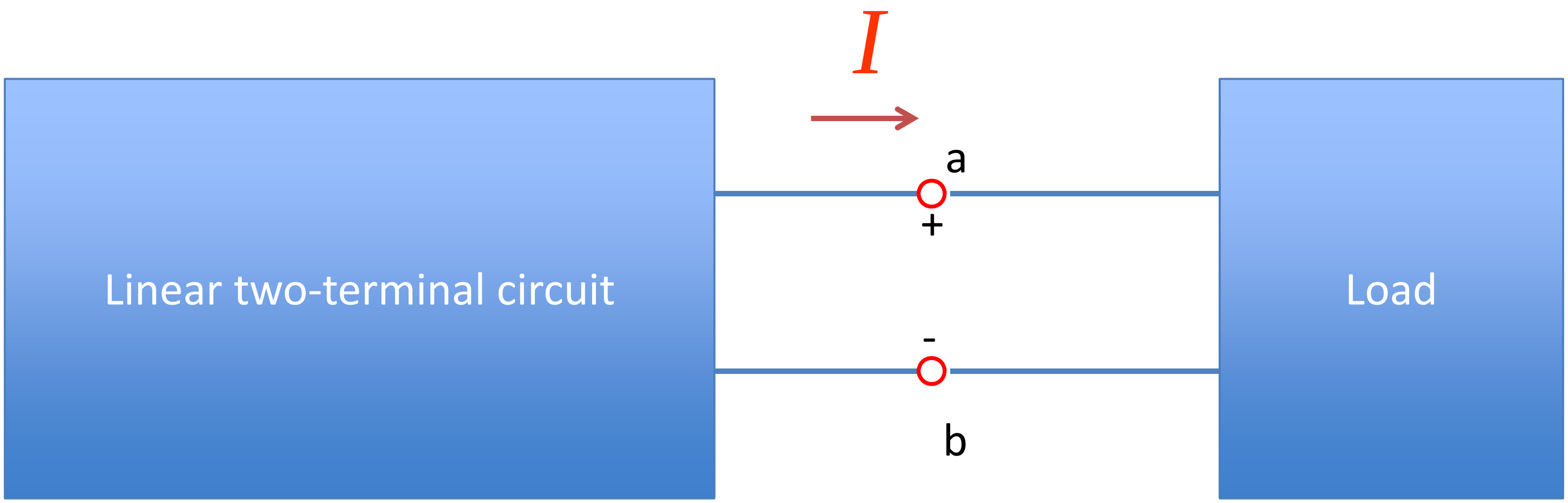


Alternate method to find R_{th}:

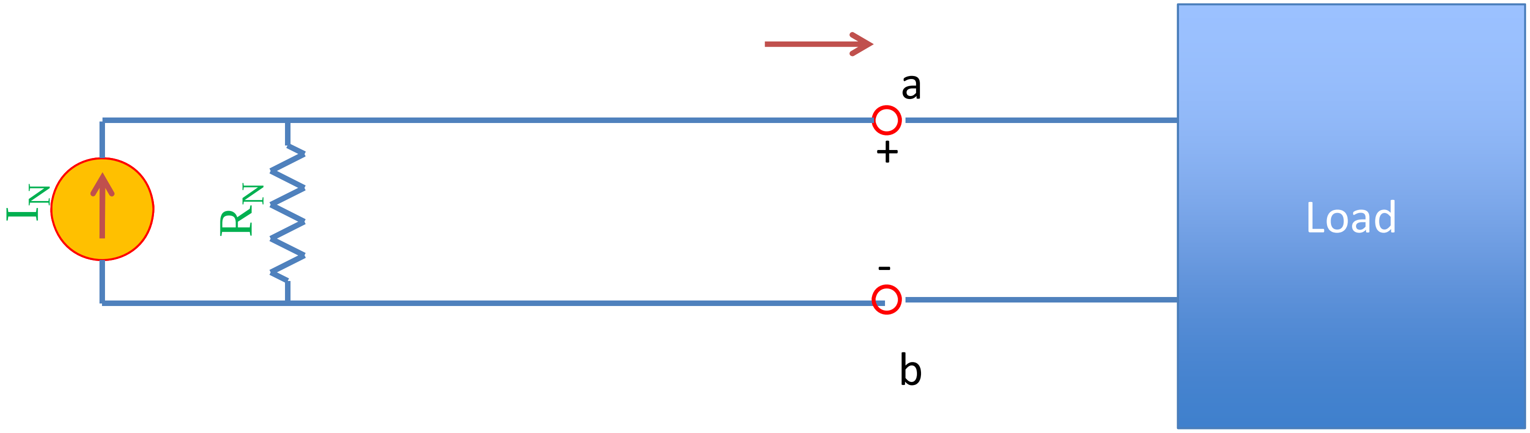


Find R_{ab} when all independent sources turned off. (Voltage sources become shorts, current sources become opens).

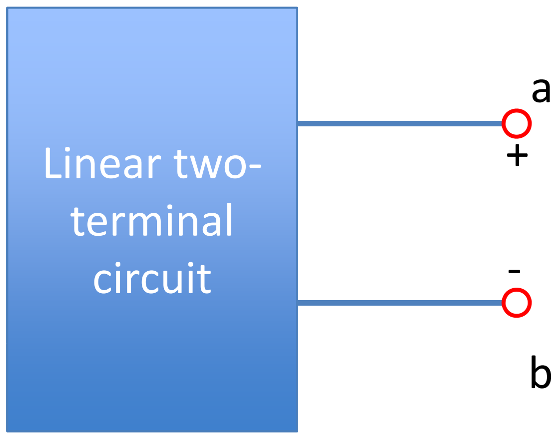
Norton’s Theorem



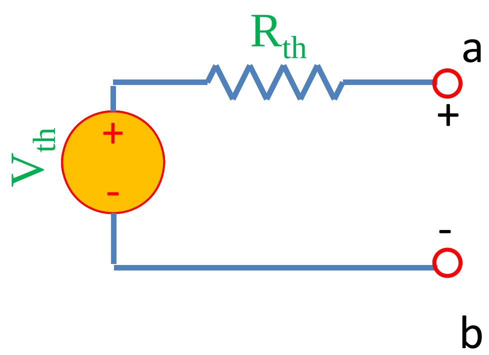
Equivalent to:



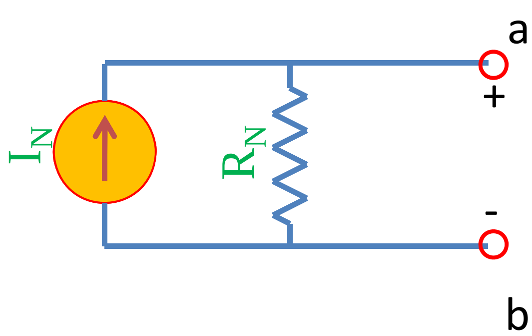
Finding V_{th}, R_{th}



Equivalent to:

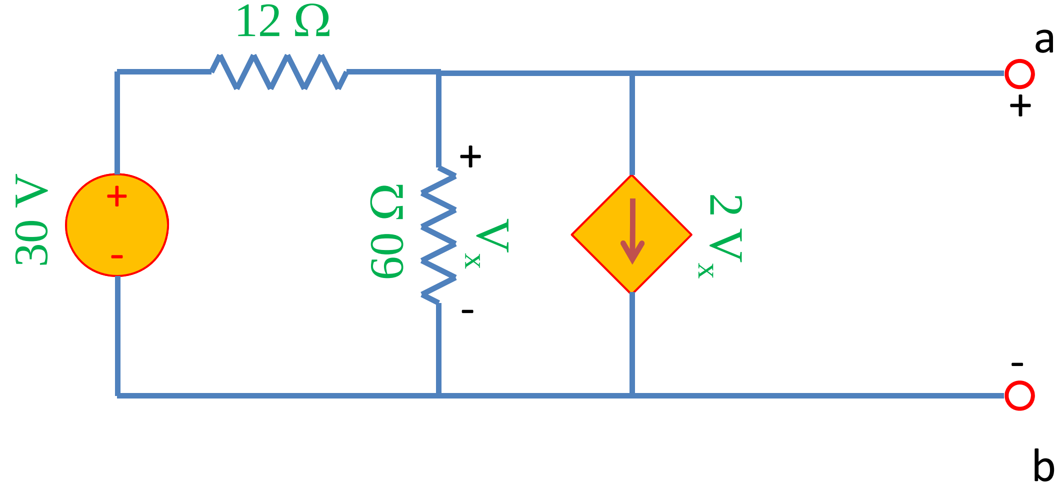


Equivalent to:



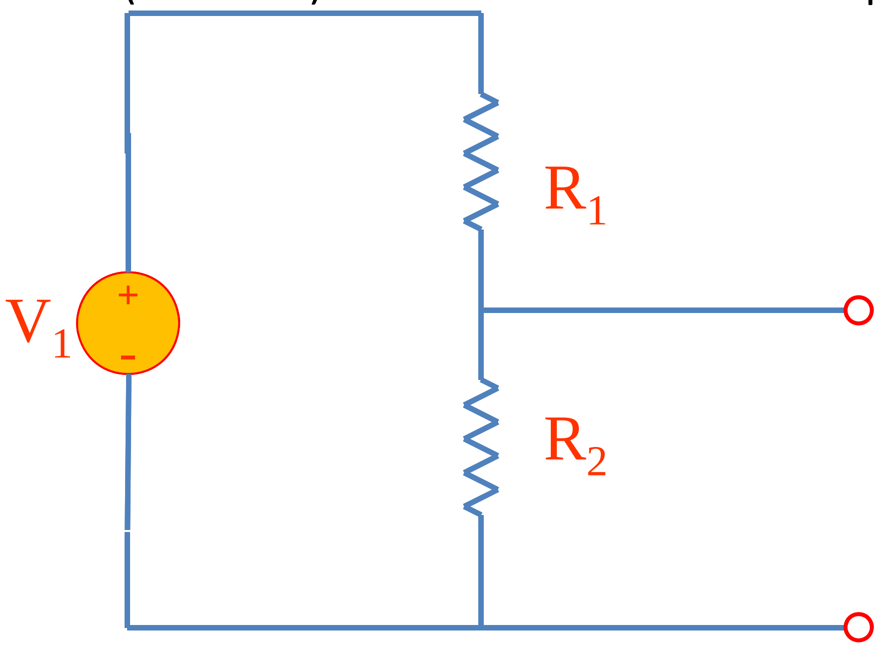
Example

Find the Thevenin & Norton equivalent circuit of the circuit below with respect to terminals a and b:

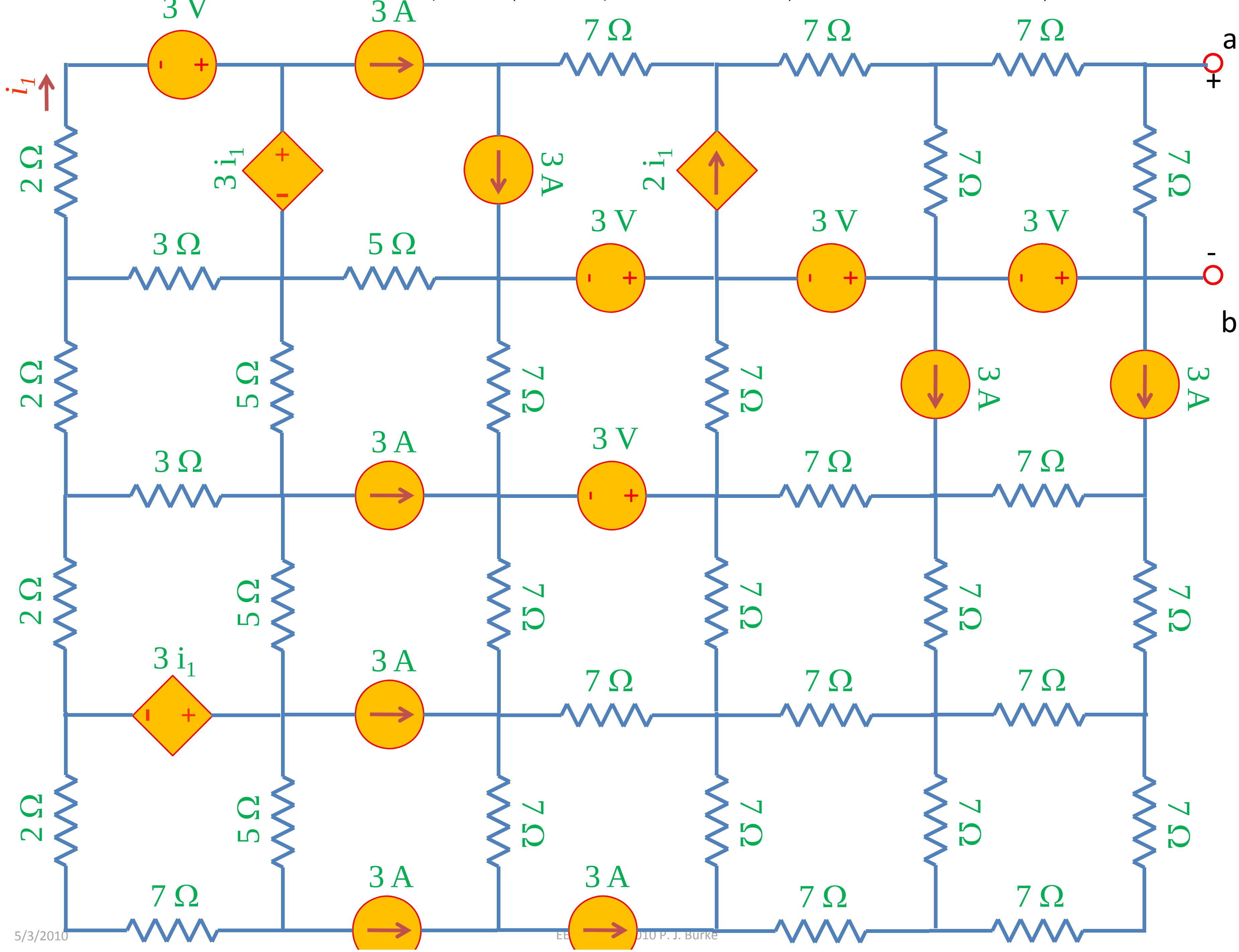


Example

(Students): Find Thevenin & Norton equivalent circuit:

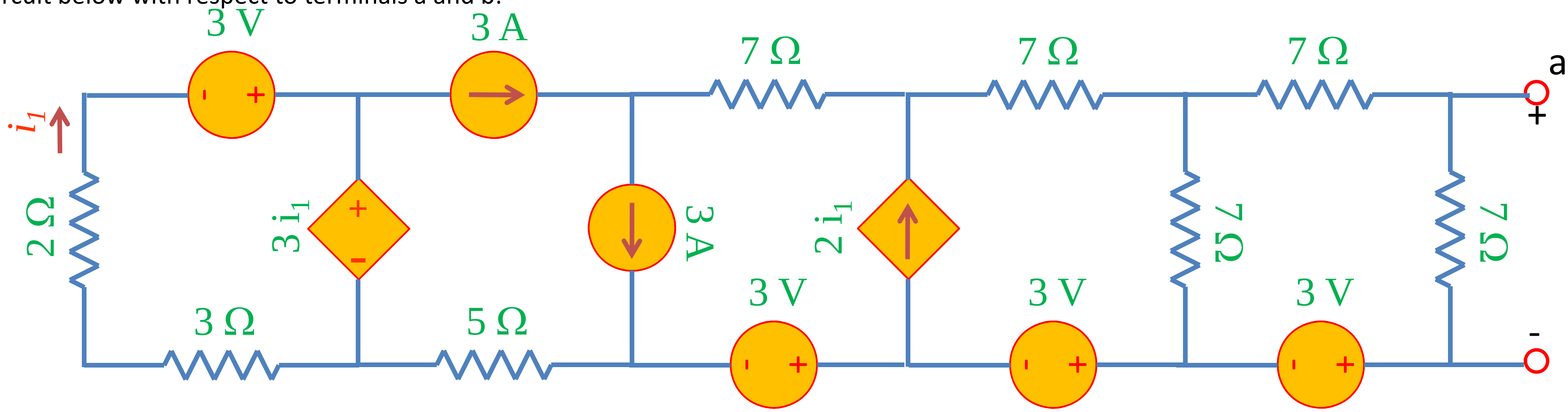


(Monster HW problem: Part 2):Find the Thevenin & Norton equivalent circuit of the circuit below with respect to terminals a and b:

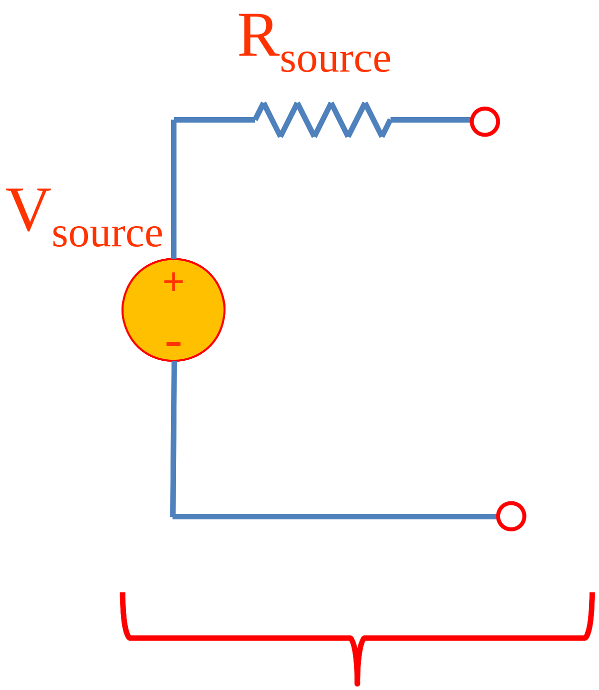


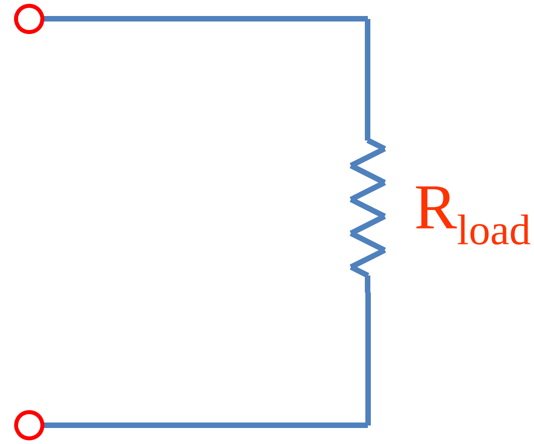
“Baby” monster problem

Find the Thevenin & Norton equivalent circuit of the circuit below with respect to terminals a and b:



Source/load





$$V_{load} = \frac{R_{load}}{R_{load} + R_{source}} V_{source}$$

Derivation:

Thevenin Thm:
Any circuit can be represented by this equivalent circuit.

Case 1:

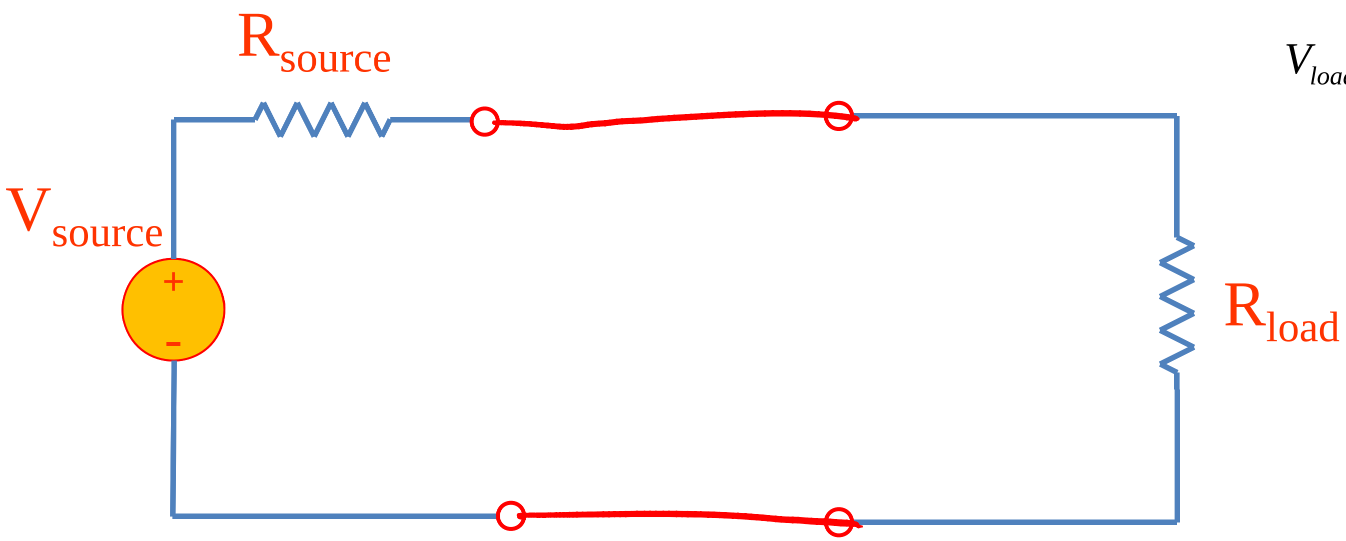
$$R_{load} >> R_{source}$$

Case 2:

$$R_{source} >> R_{load}$$

We say R_{load} "*loads down*" the source.

Source/load



$$V_{load} = \frac{R_{load}}{R_{load} + R_{source}} V_{source}$$

Derivation:

Thevenin Thm:
Any circuit can be represented by this equivalent circuit.

Case 1:

$$R_{load} >> R_{source}$$

$\Rightarrow V_{load} \approx V_{source}$

Case 2:

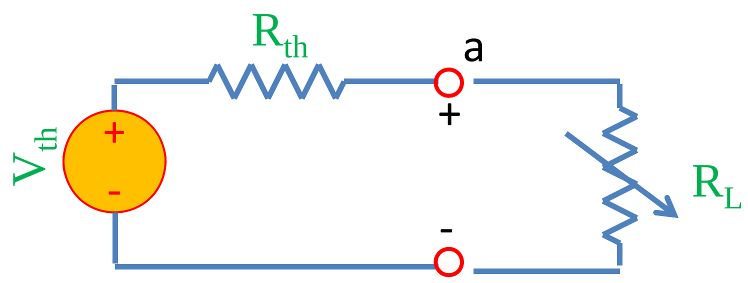
$$R_{source} >> R_{load}$$

$V_{load} \to 0$

$\approx \frac{R_{load}}{R_{source}} V_{source}$

We say R_{load} "*loads down*" the source.

Power

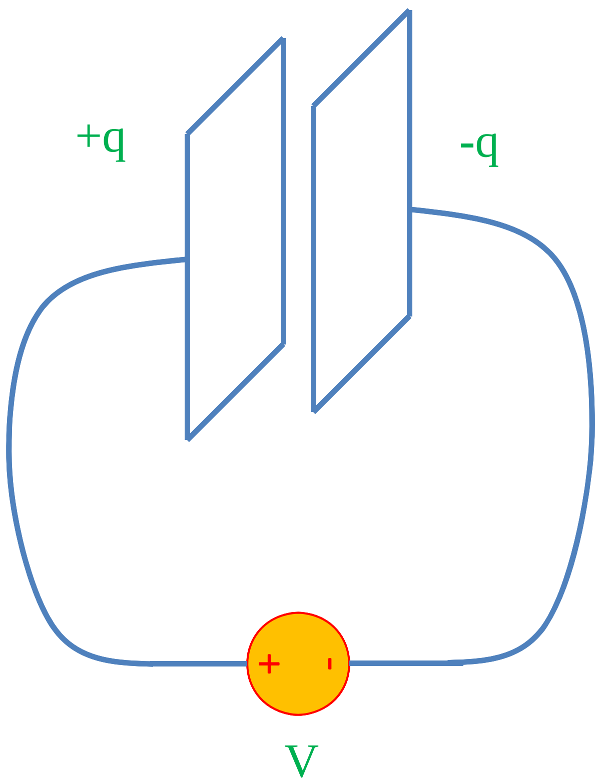


Arrow means R_L variable (e.g. by a knob)

Power delivered to load = ?

Questions?

Capacitors



$$q = CV$$

$$C = \frac{\varepsilon A}{d}$$

A=area
d=plate separation

Farads[F] = Coulombs/Volt [C]/[V]

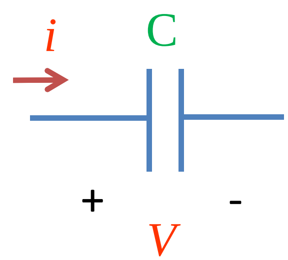
$$\varepsilon_0 = 8.85 \times 10^{-12} F/m$$

$$\varepsilon = \kappa \varepsilon_0$$

Dielectric constant:

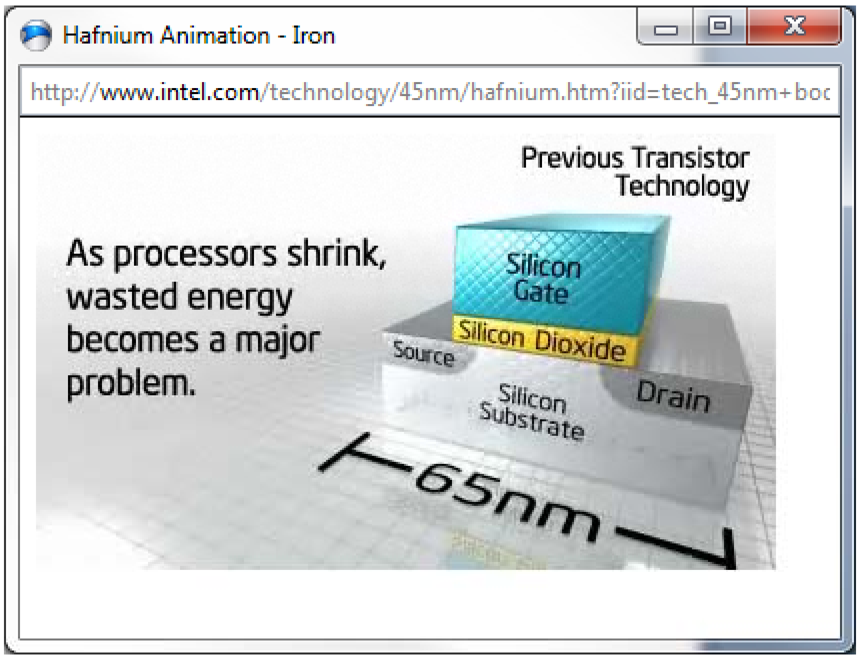
$\kappa = 3.9$ SiO_2

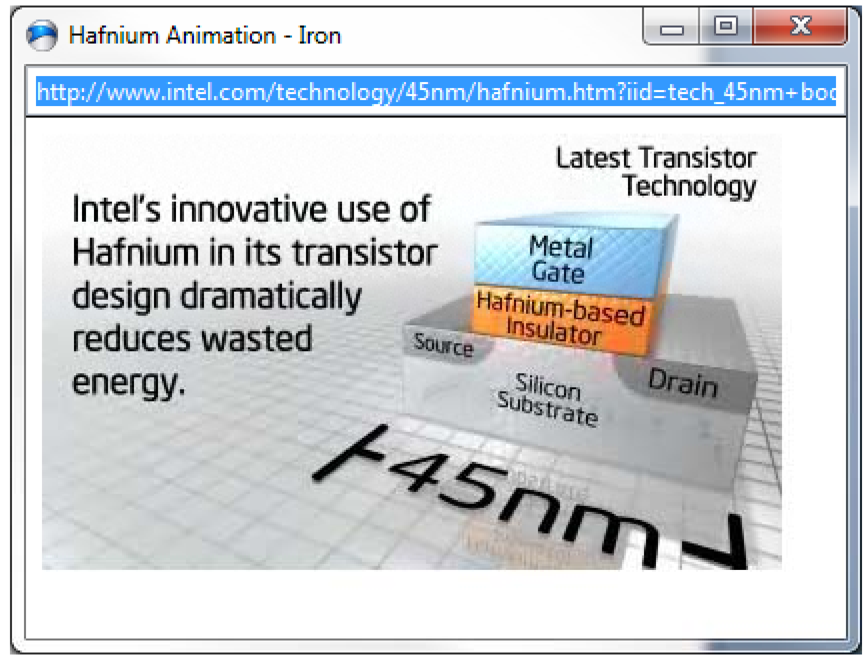
$\kappa = 25$ HfO_2



“High-K Dielectric”

http://www.intel.com/technology/45nm/hafnium.htm?iid=tech_45nm+body_animation_hafnium





Time dependence

$$q = CV \qquad i = \frac{dq}{dt} = C\frac{dV}{dt}$$

q, V, i can depend on time !

Implicit:

$$q(t) = CV(t) \qquad i(t) = \frac{dq(t)}{dt} = C\frac{dV(t)}{dt}$$

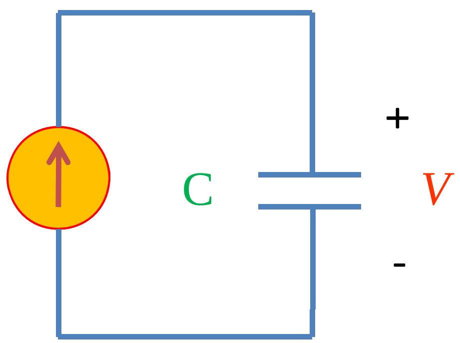
Will not always write (t), but it is assumed from now on.

$$i(t) = C\frac{dV(t)}{dt} \Rightarrow V(t) = \frac{1}{C}\int i(t)dt$$

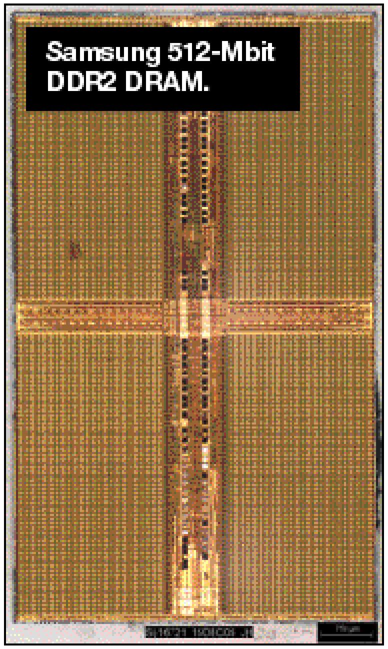
$$\Rightarrow q(t) = \int i(t)dt$$

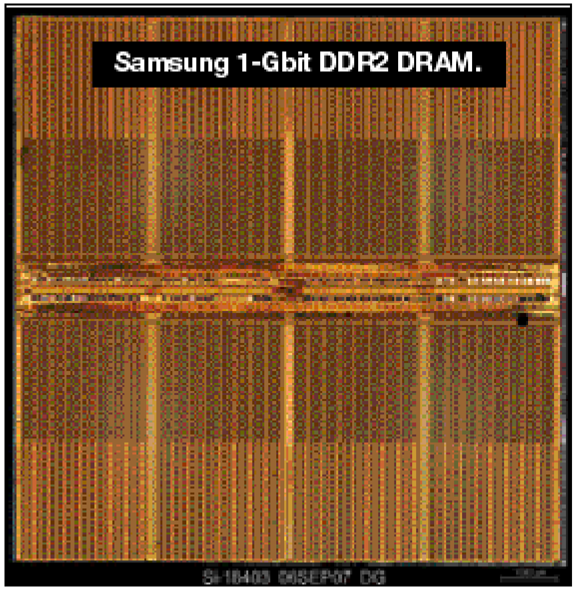
Example Capacitor Problem

Find V(t), q(t)



One-bit memory

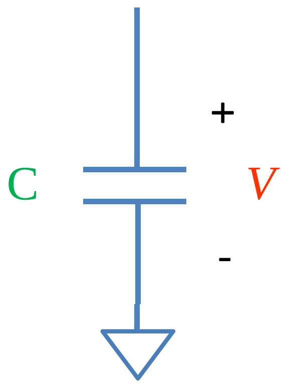




http://i.cmpnet.com/eet/news/07/11/DC1502_UTH_samsung.gif

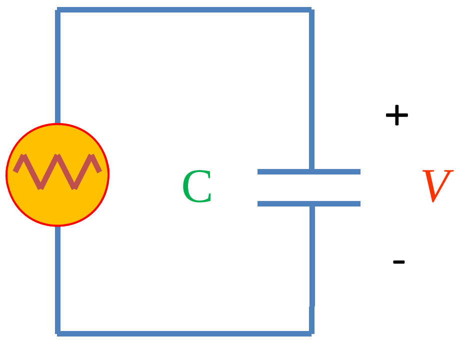
Typical dimensions:
0.1 micron x 0.1 micron area
10 nm thickness.
What is C?

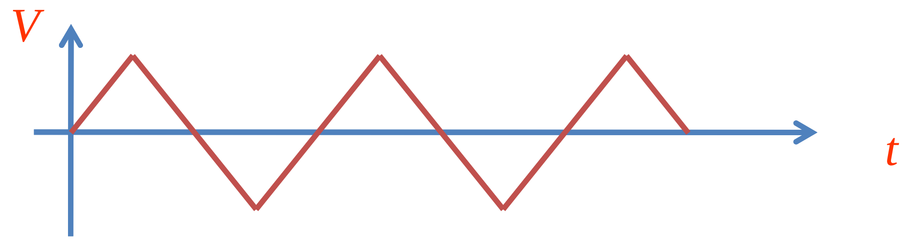
1 Bit Read/Write



Example Problem #2

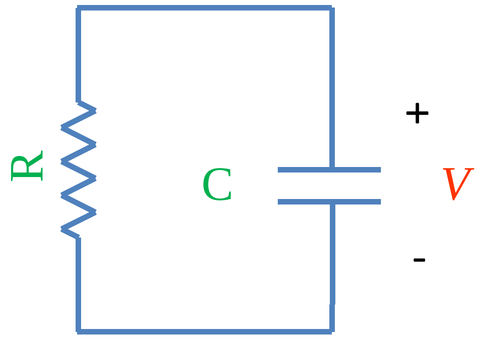
(Students): Find i(t), q(t)





RC circuit

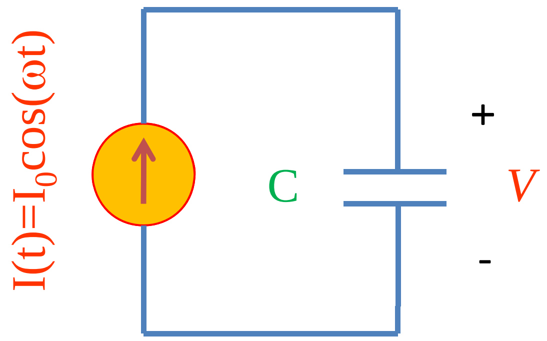
Find V(t), q(t), i(t)



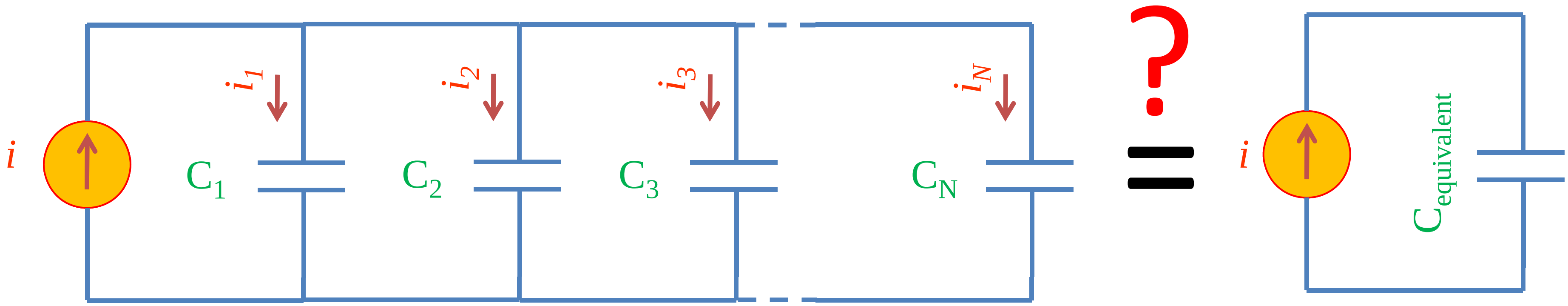
DRAM vs. SRAM

Example Capacitor Problem #2

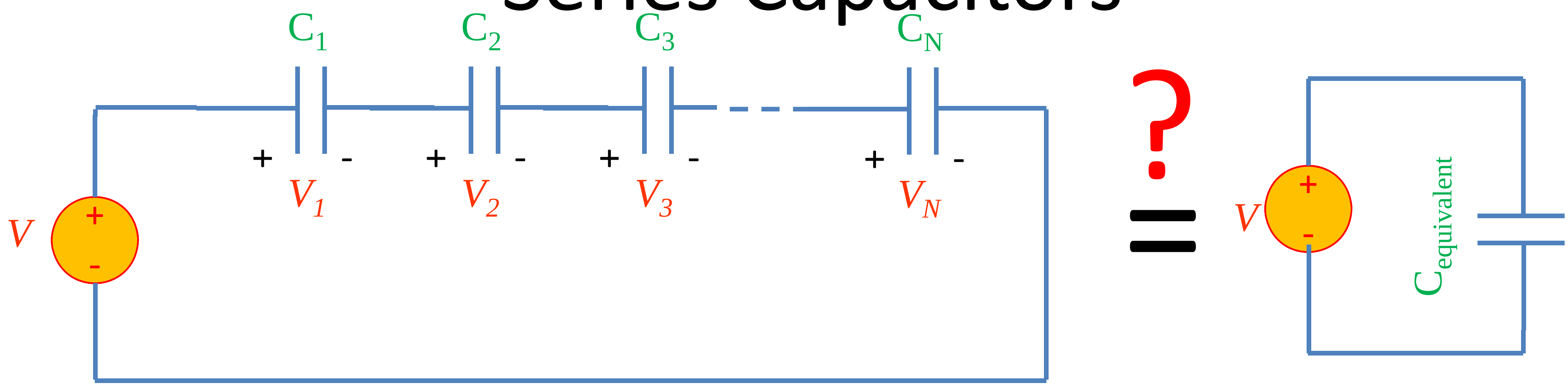
Find V(t), q(t)



Parallel Capacitors

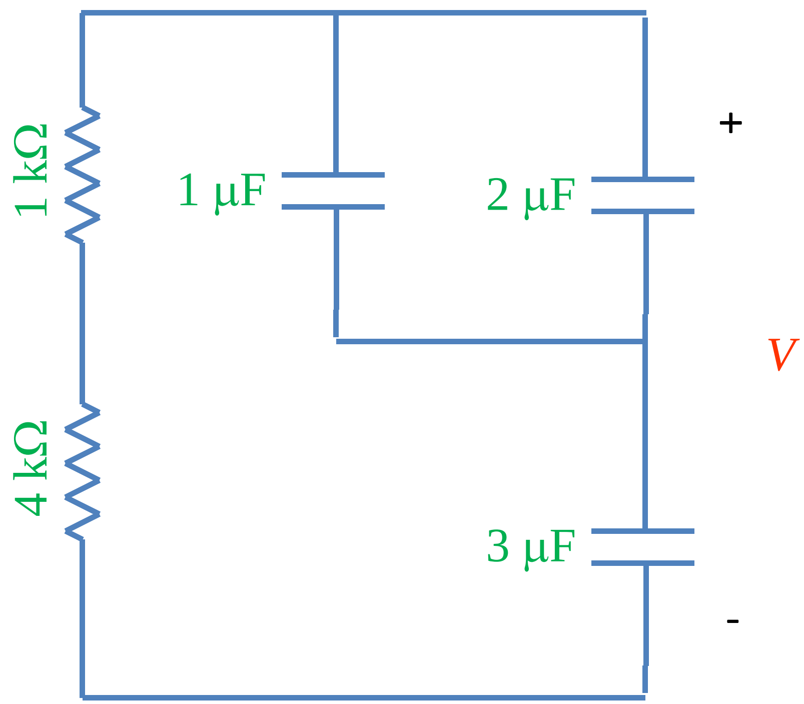


Series Capacitors

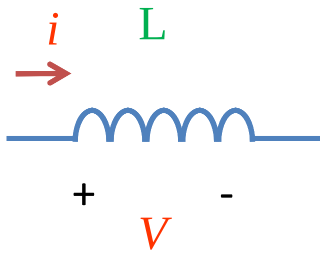


Example problem #4

(Students) Find V(t), given that V(t=0) = 5 Volts



Inductors



$$L = \frac{N^2 \mu A}{l}$$

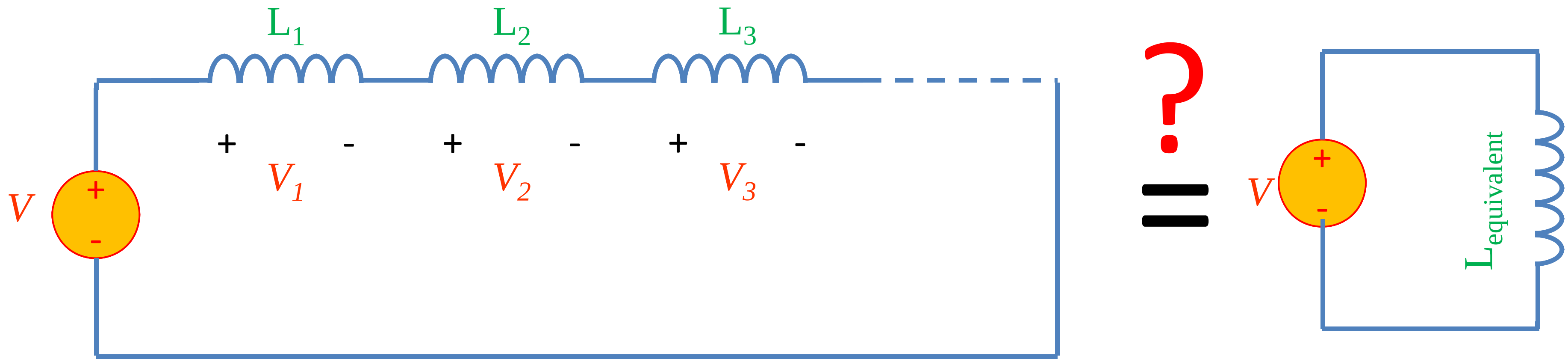
A=area
l=wire length
N = # of turns
$\mu = 4\,\pi\,10^{-6}$ H/m

$$V = L\frac{di}{dt}$$

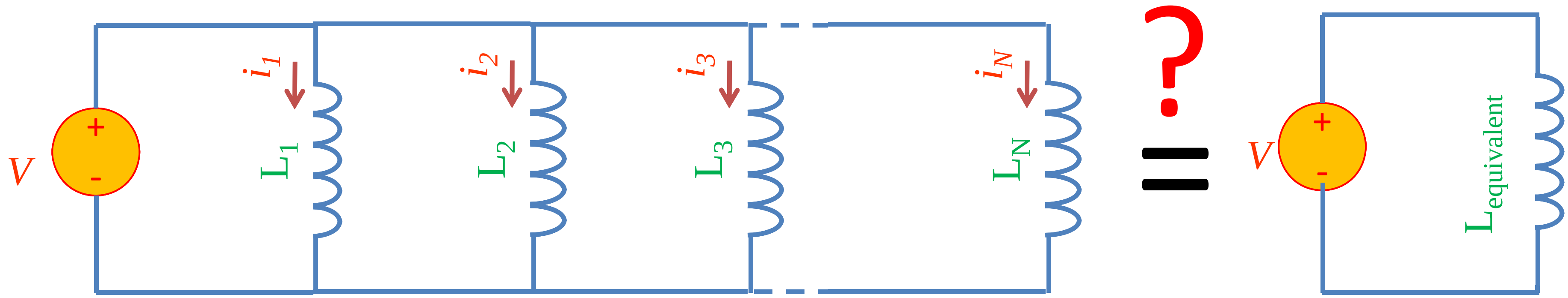
Henry[H]

$$V = L\frac{di}{dt} \Rightarrow i(t) = \frac{1}{L}\int V(t)dt$$

Series Inductors

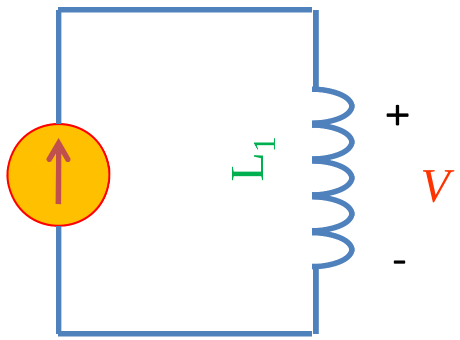


Parallel Inductors



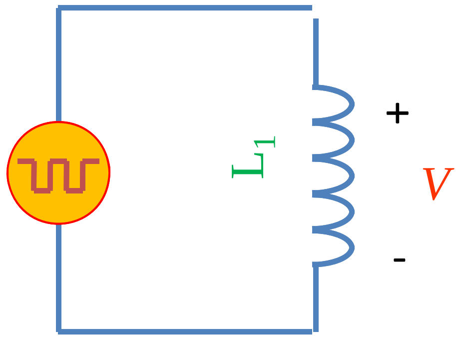
Example Inductor Problem

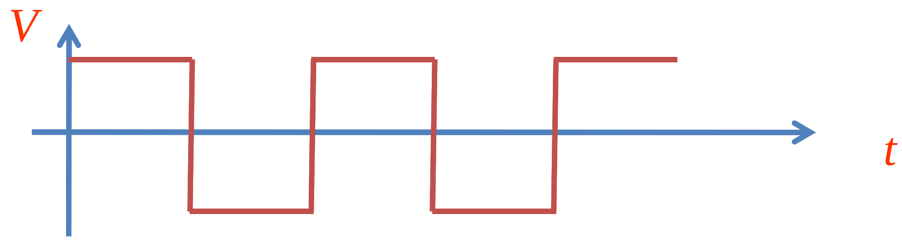
(Students): Find V(t).



Example Inductor Problem #2

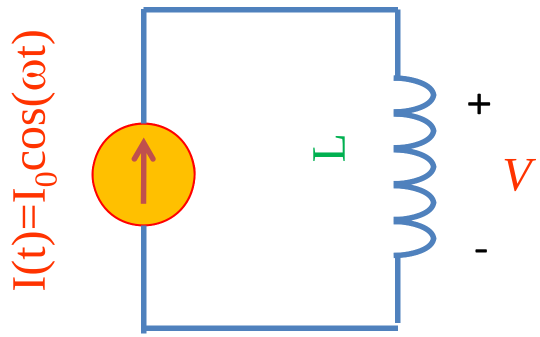
(Students): Find i(t)





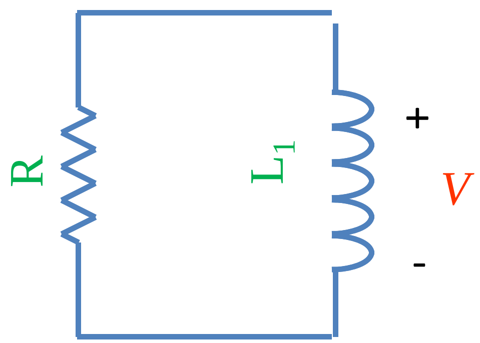
Example Inductor Problem #3

Find V(t)



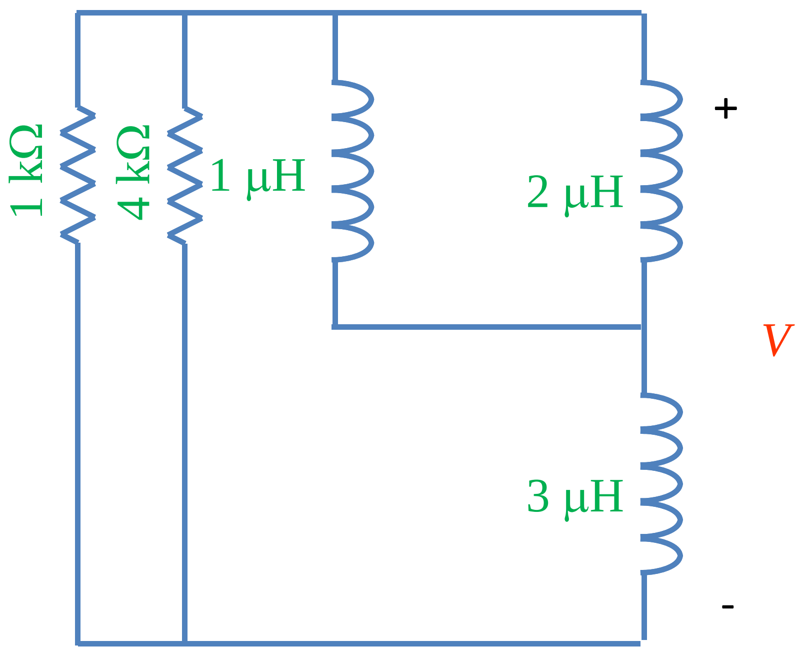
LR circuit

Find V(t), i(t)

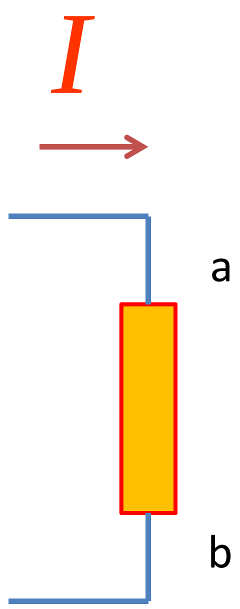


Example LR problem

(Students) Find V(t), given that V(t=0) = 5 Volts



Power



$$I \times V_{ab} = power$$

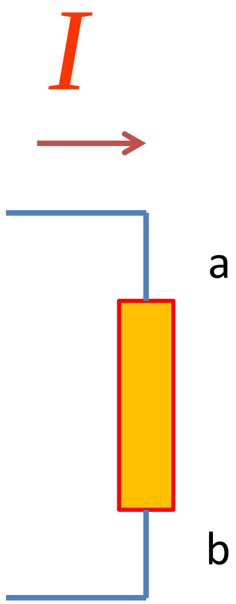
Watts [W] = Volt Amp [V-A]

Note: MKSA unit system:
Meters Kilogram Second Amp

Resistor:
Energy lost to heat…

Inductor or capacitor:
Energy *STORED* and can be recovered…

Energy stored



$$I \times V_{ab} = power$$

Energy:

$$W = \int P dt = \int I \cdot V dt$$

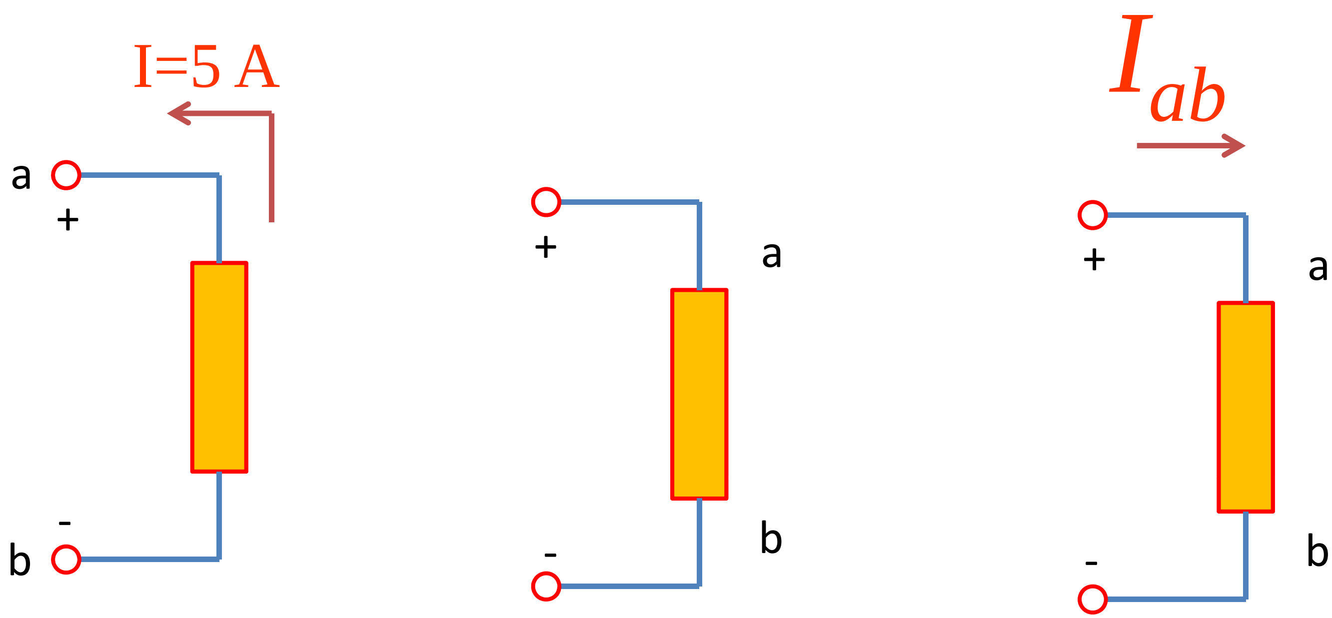
Capacitor stored energy:

$$\int I \cdot V dt = \int C \frac{dV}{dt} \cdot V dt = \frac{1}{2} C V^2 = \frac{Q^2}{2C}$$

Inductor stored energy:

$$\int I \cdot V dt = \int I \cdot L \frac{dI}{dt} dt = \frac{1}{2} L I^2$$

Symbol library



Symbol library