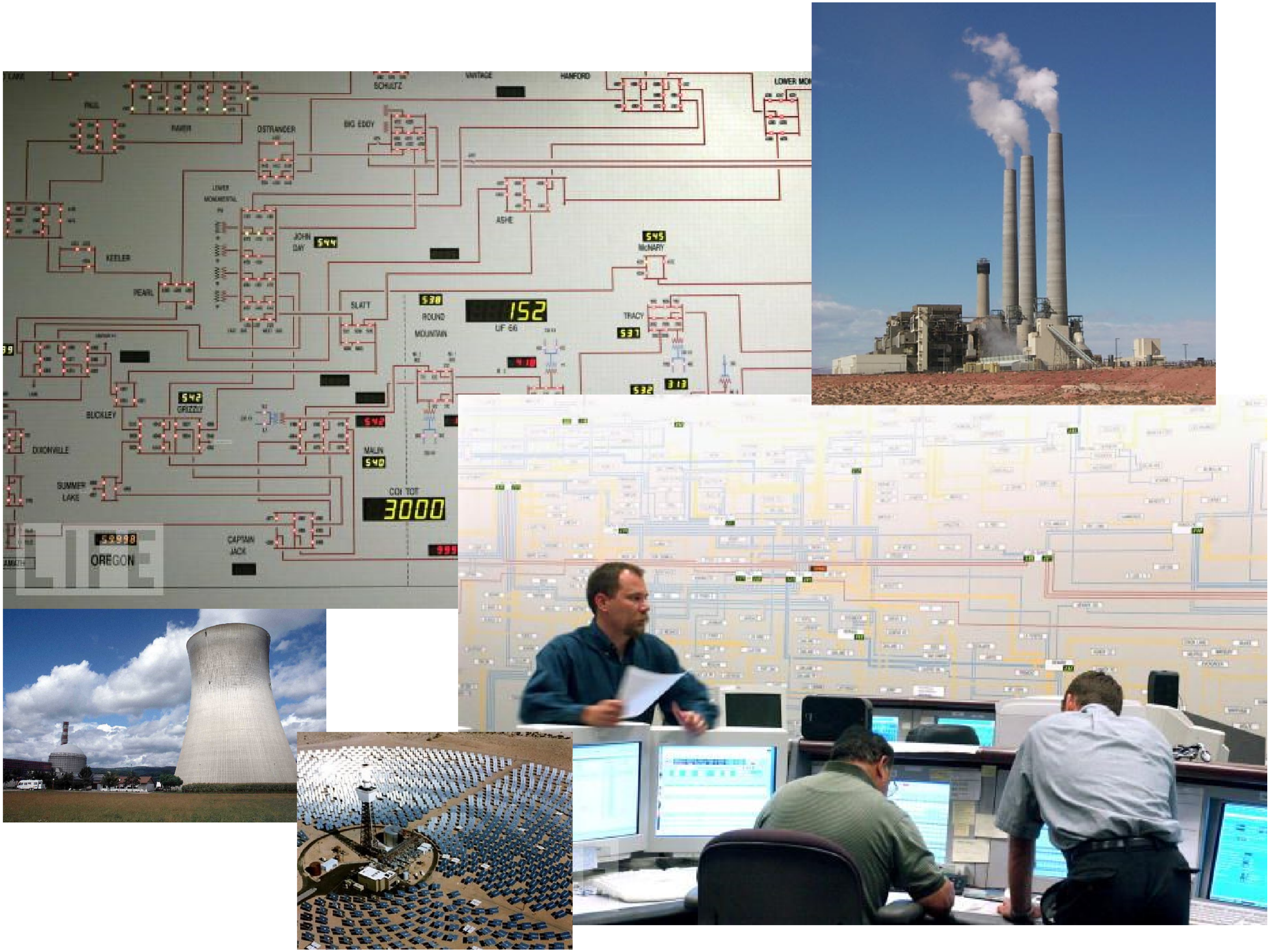
Announcements:

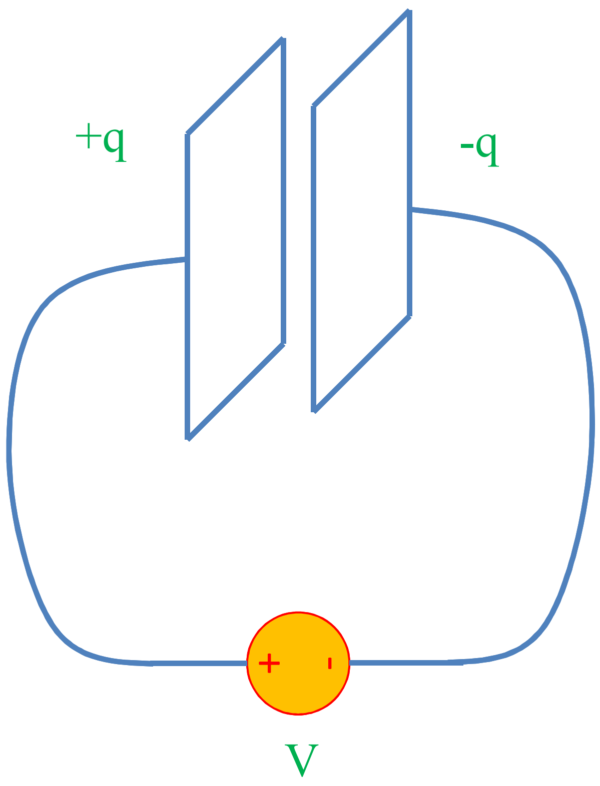
1. Etc etc etc

EECS 70A: Network Analysis

Lecture 10


SCHULTZ
VANTAGE
HANFORD
PAUL
RAVER
OSTRANDER
BIG EDDY
ASHE
JOHN DAY
544
McNARY
545
KEELER
PEARL
SLATT
538
ROUND MOUNTAIN
152
UF 66
TRACY
531
542
GRIZZLY
BUCKLEY
DIXONVILLE
MALIN
540
SUMMER LAKE
COI TOT
3000
CAPTAIN JACK
OREGON
LIFE

Capacitors



$$q = CV$$

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

A=area
d=plate separation

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

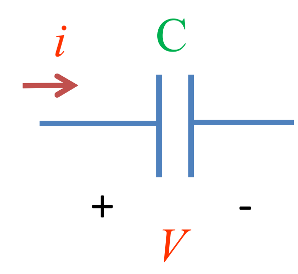
$$\varepsilon_0 = 8.85 \times 10^{-12} F/m$$

$$\varepsilon = \kappa \varepsilon_0$$

Dielectric constant:

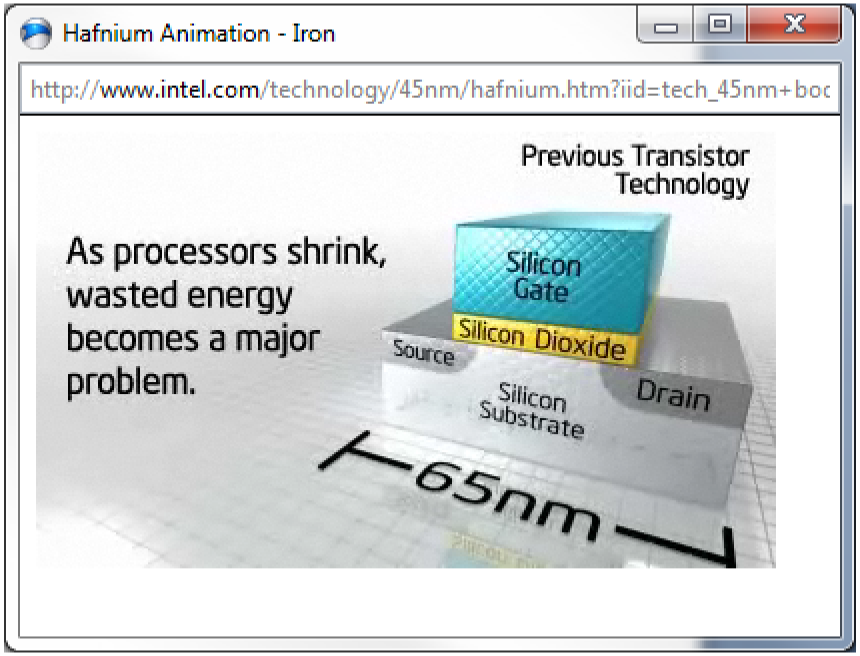
$\kappa = 3.9$ SiO_2

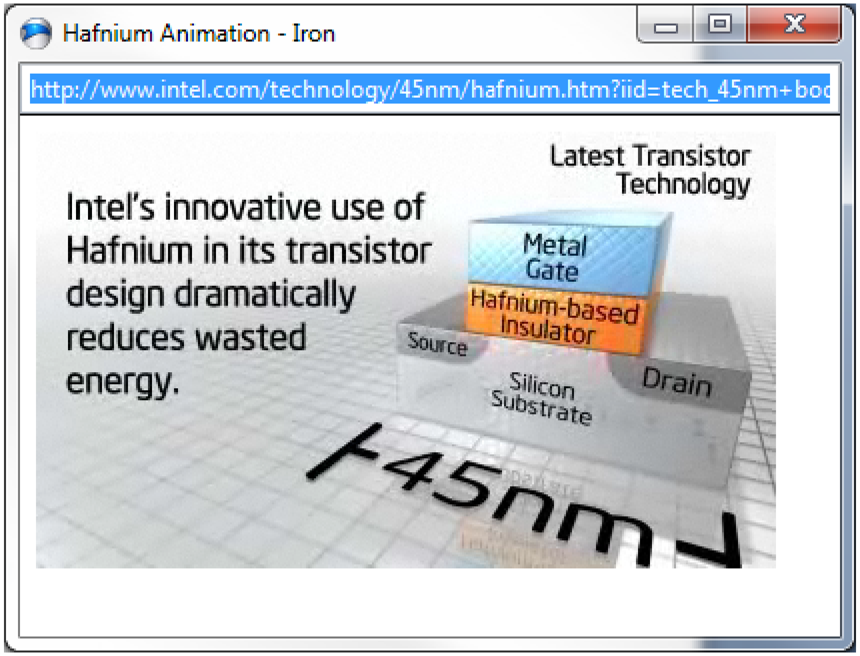
$\kappa = 25$ HfO_2



“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:

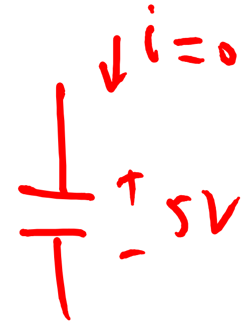
$$q(t) = CV(t) \qquad i(t) = \frac{dq(t)}{dt} = C\frac{dV(t)}{dt}$$

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

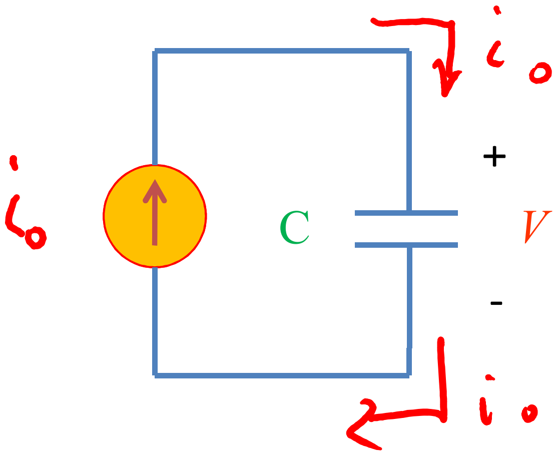
$$i(t) = C\frac{dV(t)}{dt} \Rightarrow V(t) = \frac{1}{C}\int i(t)dt$$

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

Example Capacitor Problem



Find V(t), q(t)

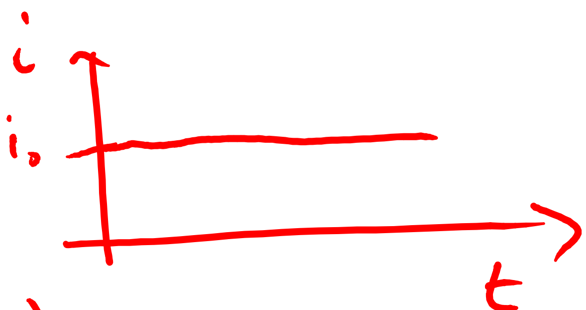


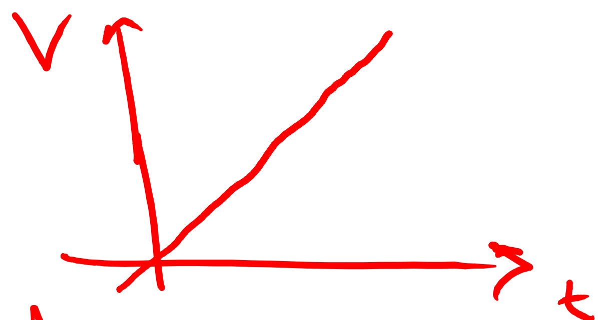
$q = CV$

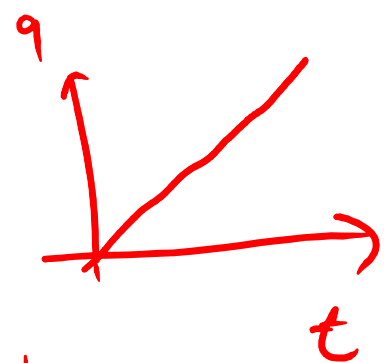
$i = C\frac{dV}{dt}$

$V = \frac{1}{C}\int_0^t i(t')\,dt' = \frac{1}{C} i_0 \int_0^t dt' = \frac{i_0}{C} t$

$V(t) = \frac{i_0}{C} t \qquad q(t) = i_0 t$



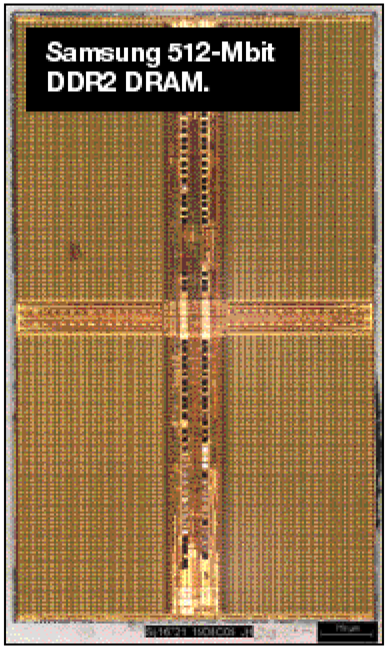


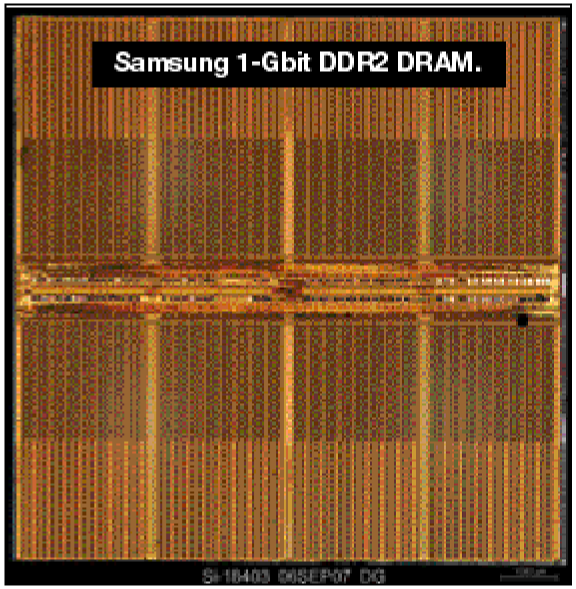


There is another kind of current "displacement current" between plates only

One-bit memory

ITRS Roadmap
"Technology Node"





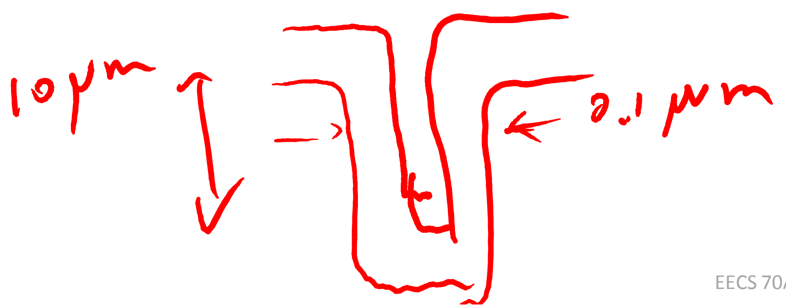
http://i.cmpnet.com/eet/news/07/11/DC1502_UTH_samsung.gif

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

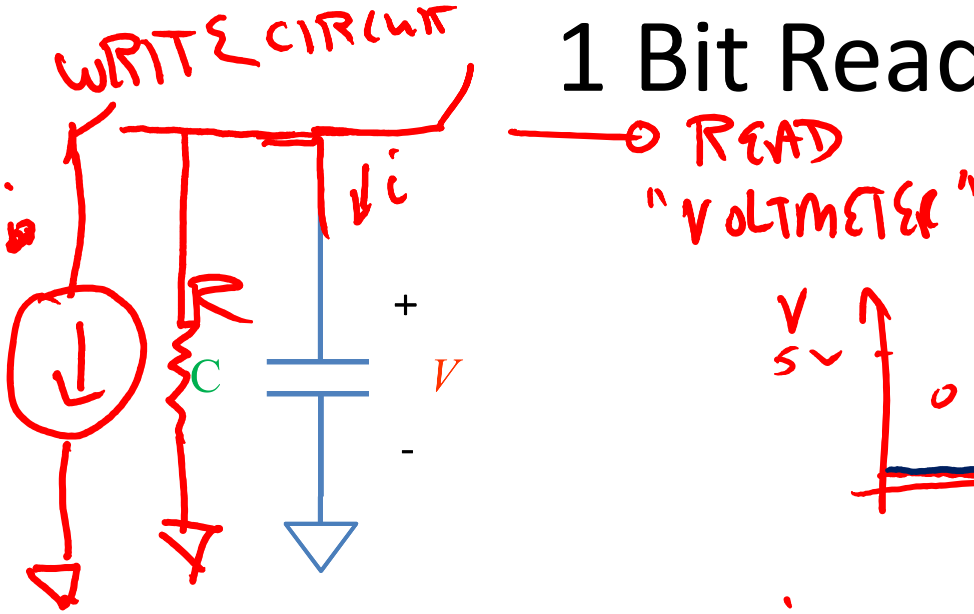
eg 65nm node
45 nm node

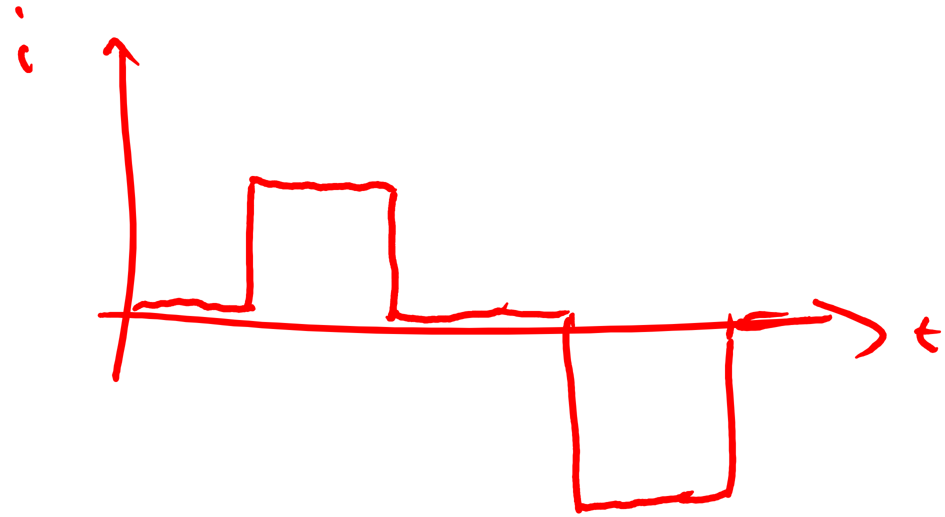
$$C = \frac{\varepsilon_0 K A}{d} = \frac{8.8\times10^{-12} F/m \cdot 10 \times 10^{-7} m \times 10^{-7} m}{10^{-8} m}$$

$= 10^{+1-12+1-7-7+8} F =$
$10^{+10-26} F = 10^{-16} F = 0.1 fF$ too small for practical



1 Bit Read/Write





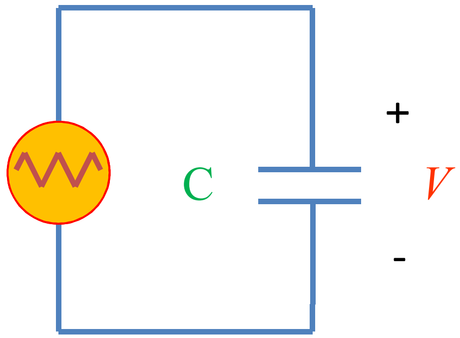
REFRESH
EVERY 10 ms TYPICAL

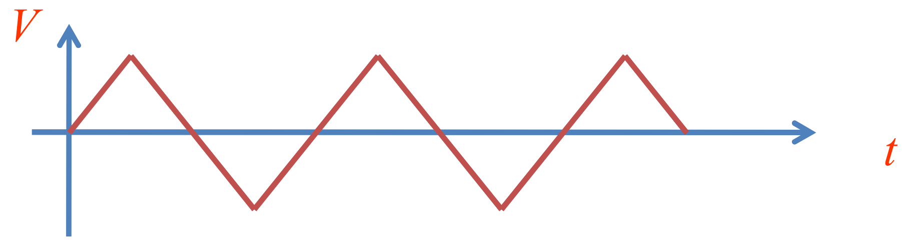
DRAM

L> dynamic

Example Problem #2

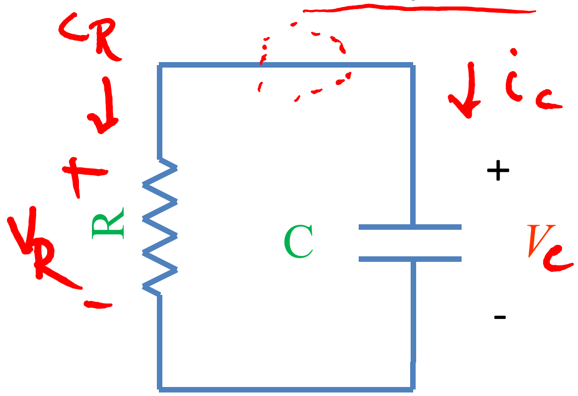
(Students): Find i(t), q(t)





RC circuit

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



Assume $V(t=0) = V_0$

KCL (IN = OUT): $0 = i_R + i_C$

$i_R = -i_C$

$V_C = V_R$

$\tau = RC$

$$q_c = C V_c \Rightarrow i_c = C \frac{dV_c}{dt}$$

$R i_R = V_R$ (ohm)

$$\frac{V_R}{R} = -C \frac{dV_c}{dt} \Rightarrow \boxed{\frac{dV}{dt} = -\frac{1}{RC} V}$$

soln: $V(t) = V(t=0)\, e^{-t/RC}$

proof: By substitution

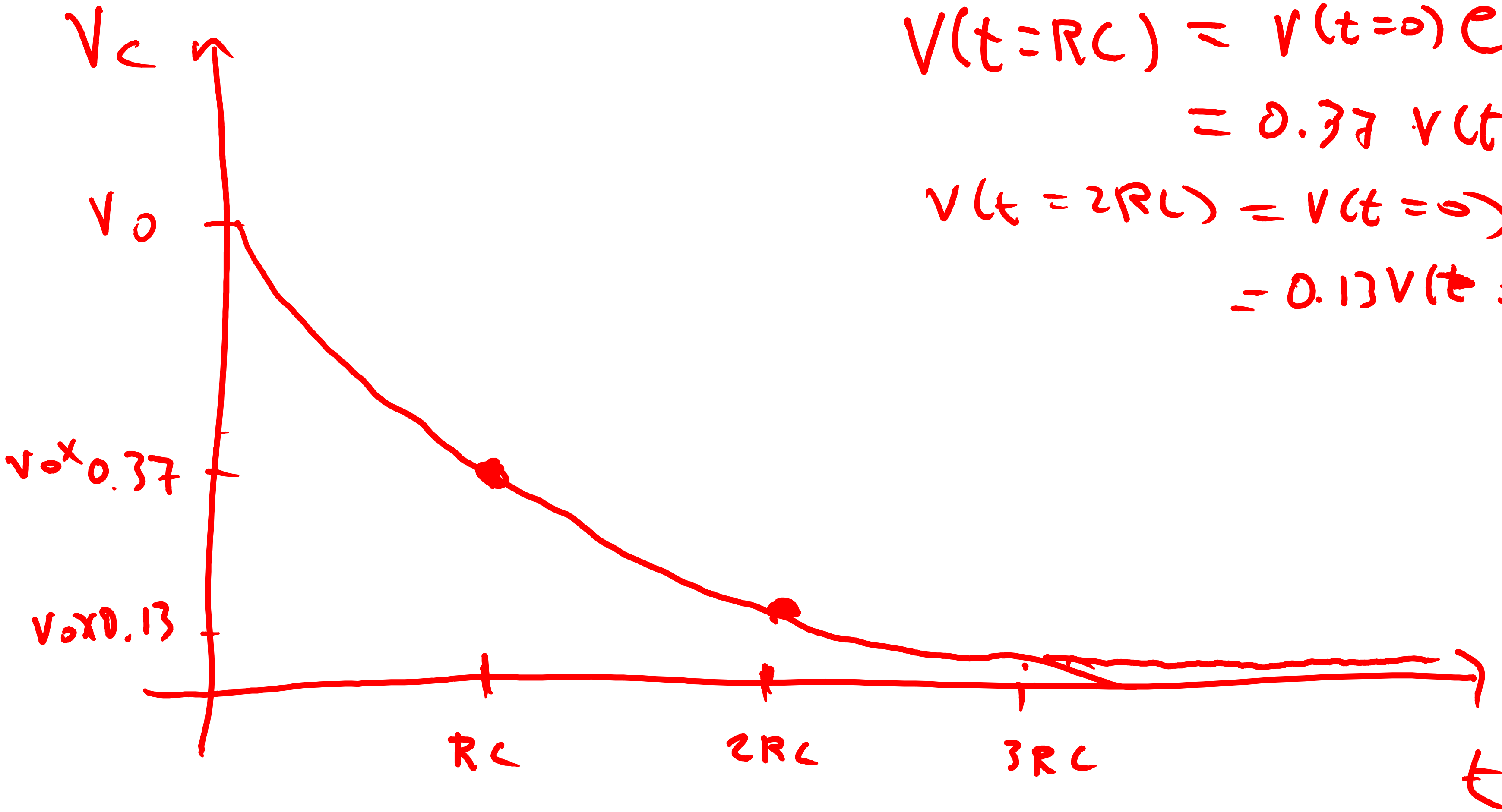
$$V(t) = V(t=0)\, e^{-t/RC}$$

$$V(t=RC) = V(t=0)\, e^{-1}$$

$$= 0.37\, V(t=0)$$

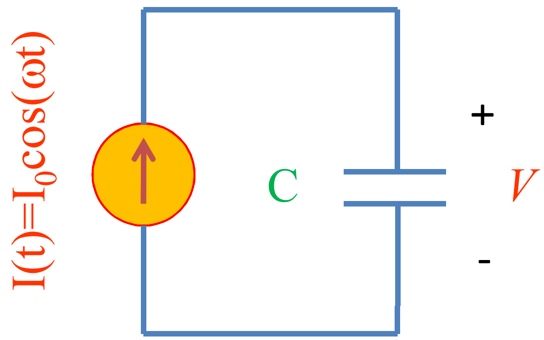
$$V(t=2RC) = V(t=0)\, e^{-2}$$

$$= 0.13\, V(t=0)$$



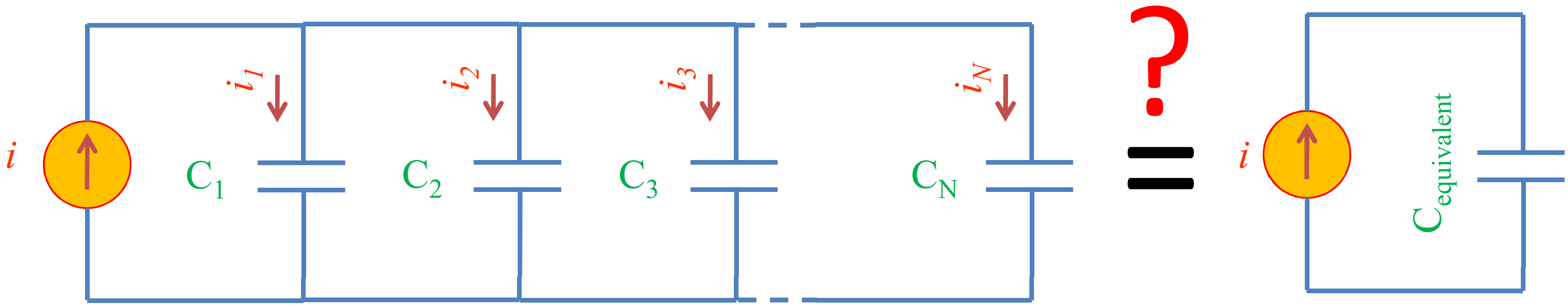
Example Capacitor Problem #2

Find V(t), q(t)

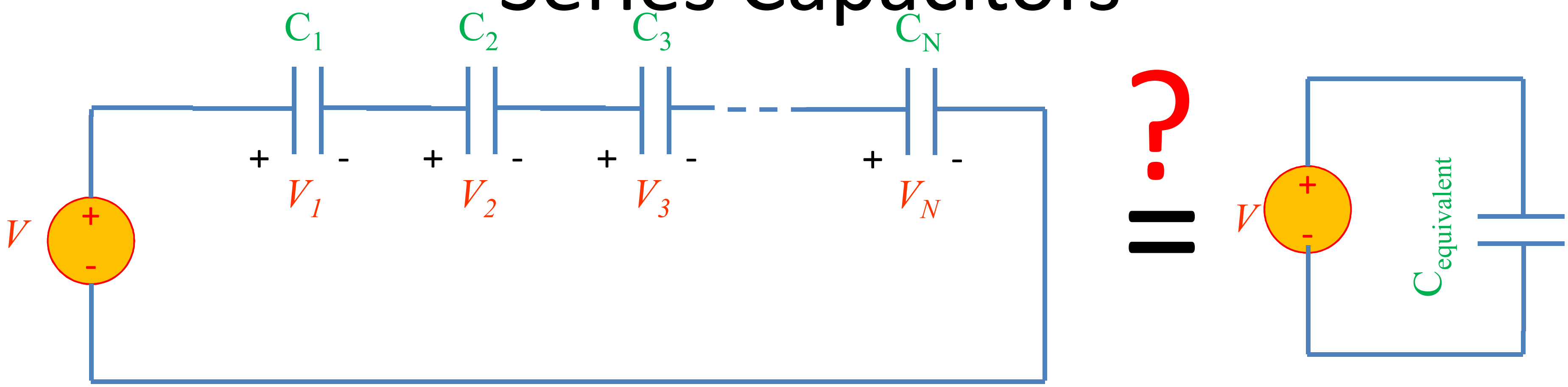


Phasors

Parallel Capacitors

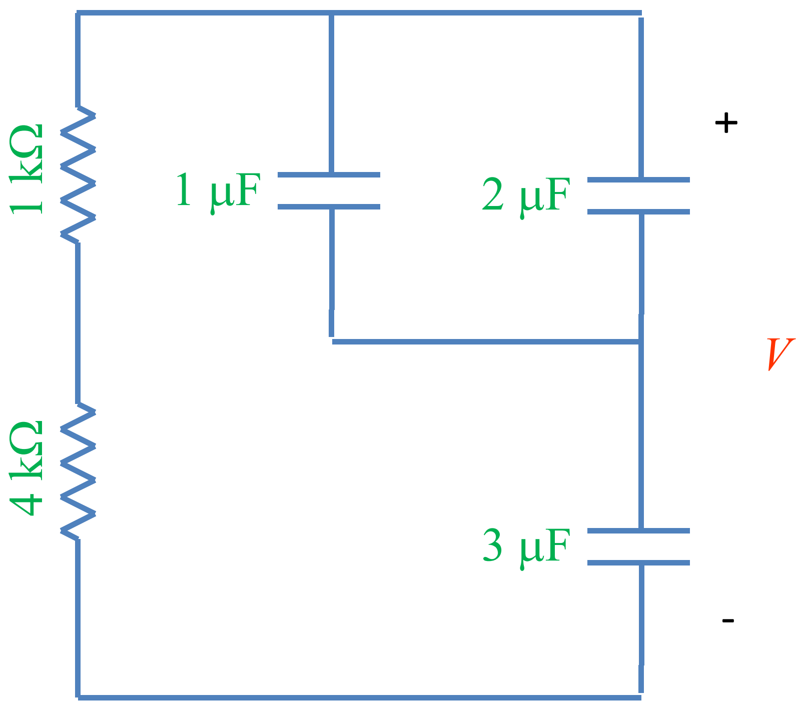


Series Capacitors

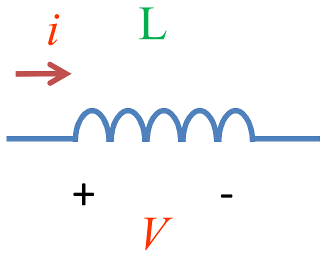


Example problem #4

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



Inductors

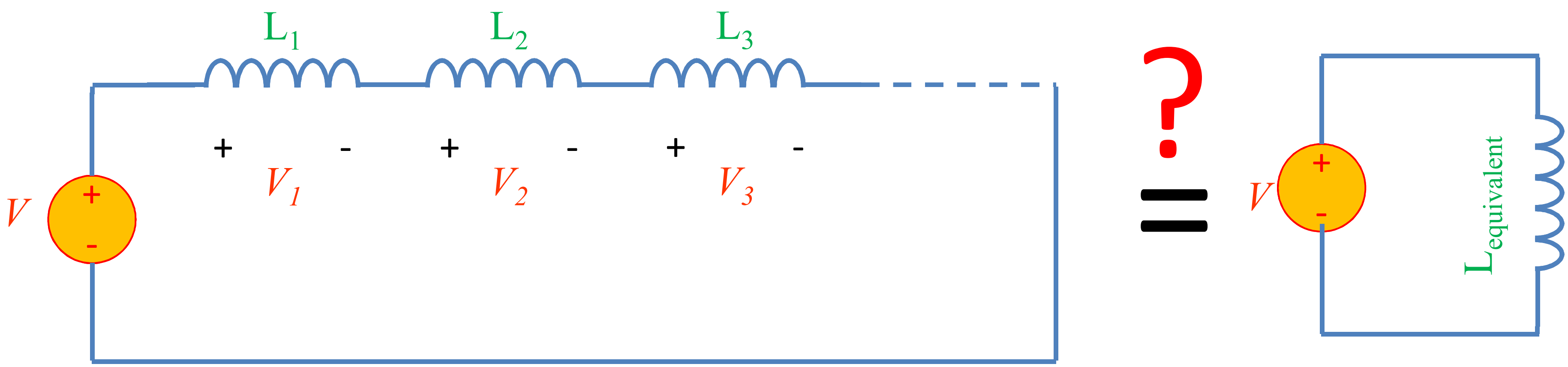


$$L = \frac{N^2 \mu A}{l}$$

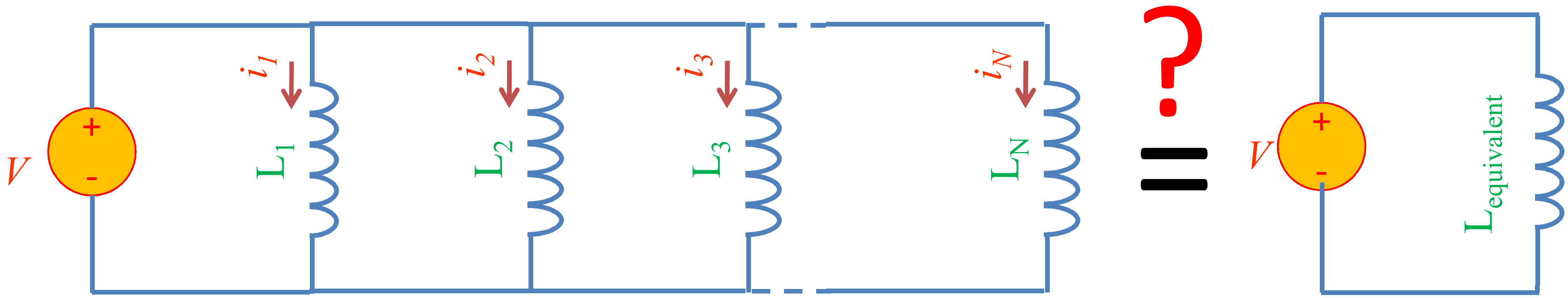
A=area
l=wire length
N = # of turns
$\mu = 4\ \pi\ 10^{-6}$ H/m

Henry[H]

Series Inductors

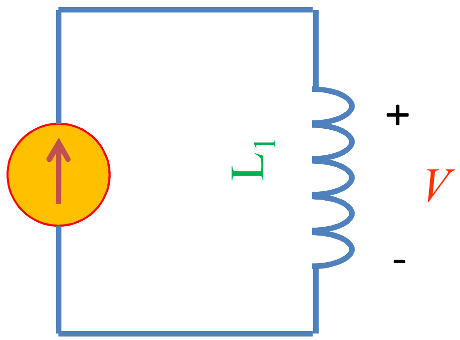


Parallel Inductors



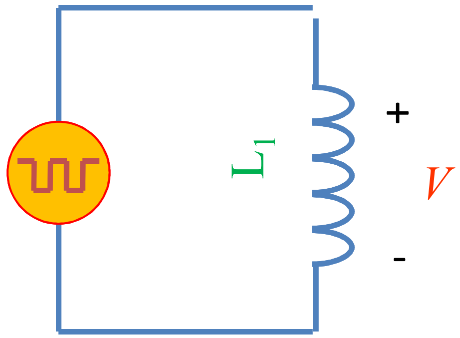
Example Inductor Problem

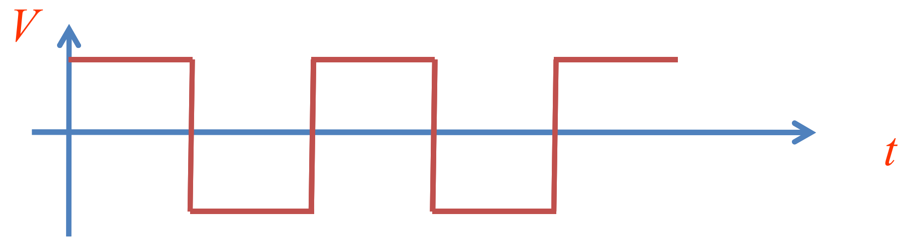
(Students): Find V(t).



Example Inductor Problem #2

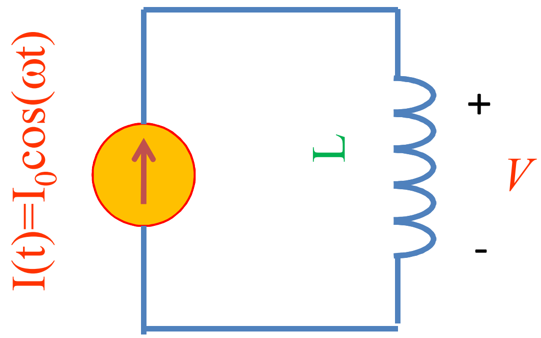
(Students): Find i(t)





Example Inductor Problem #3

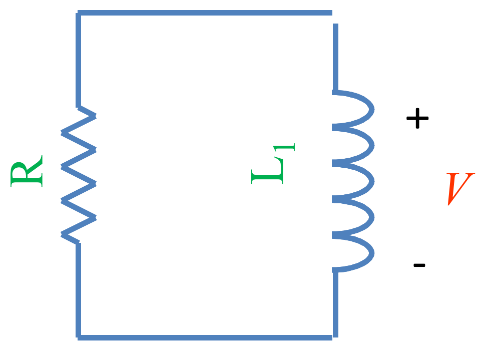
Find V(t)



Impedance

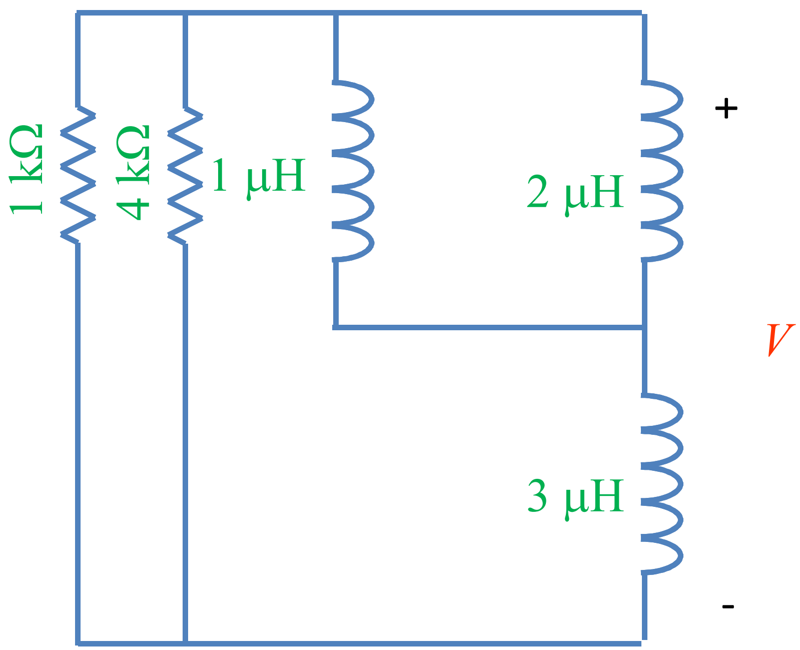
LR circuit

Find V(t), i(t)

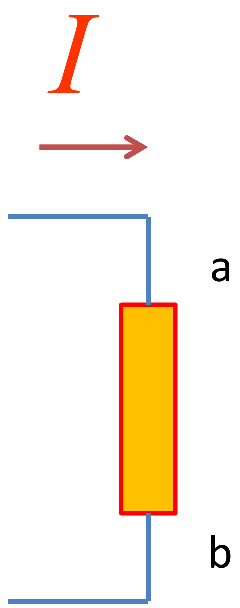


Example LR problem

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



Power



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

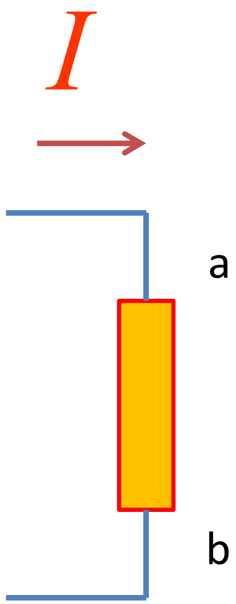
Watts [W] = Volt Amp [V-A]

Note: MKSA unit system:
Meters Kilogram Second Amp

Resistor:
Energy lost to heat…

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

Energy stored



$$I \, x \, V_{ab} = power$$

Energy:

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

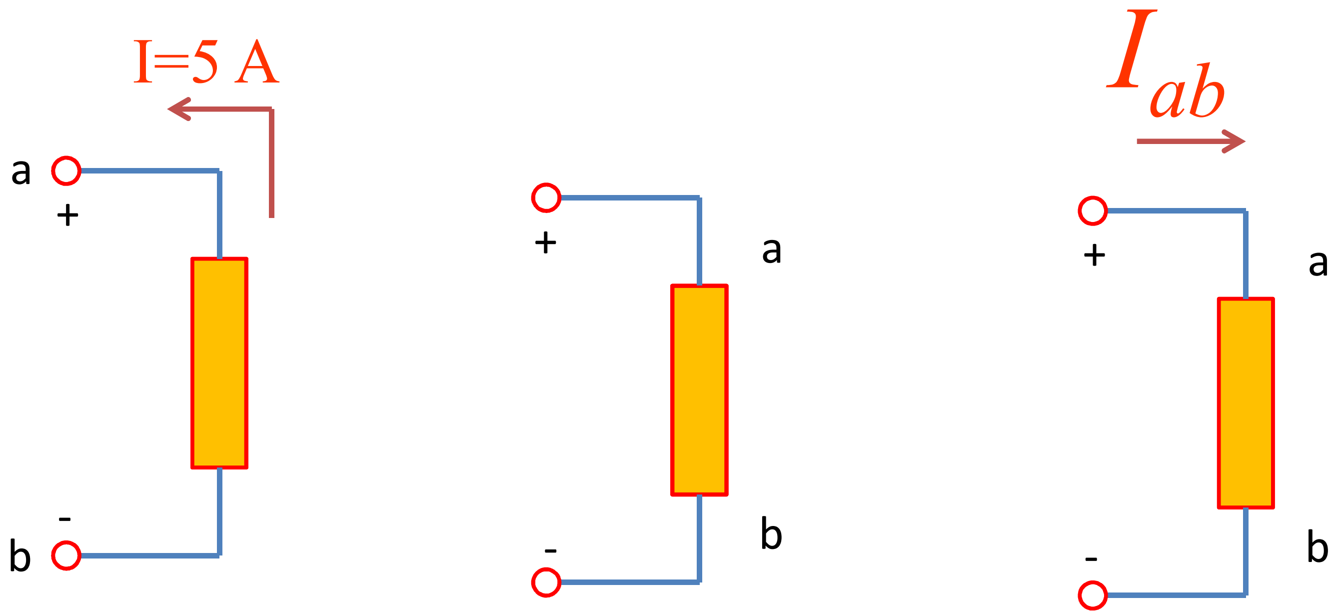
Capacitor stored energy:

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

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