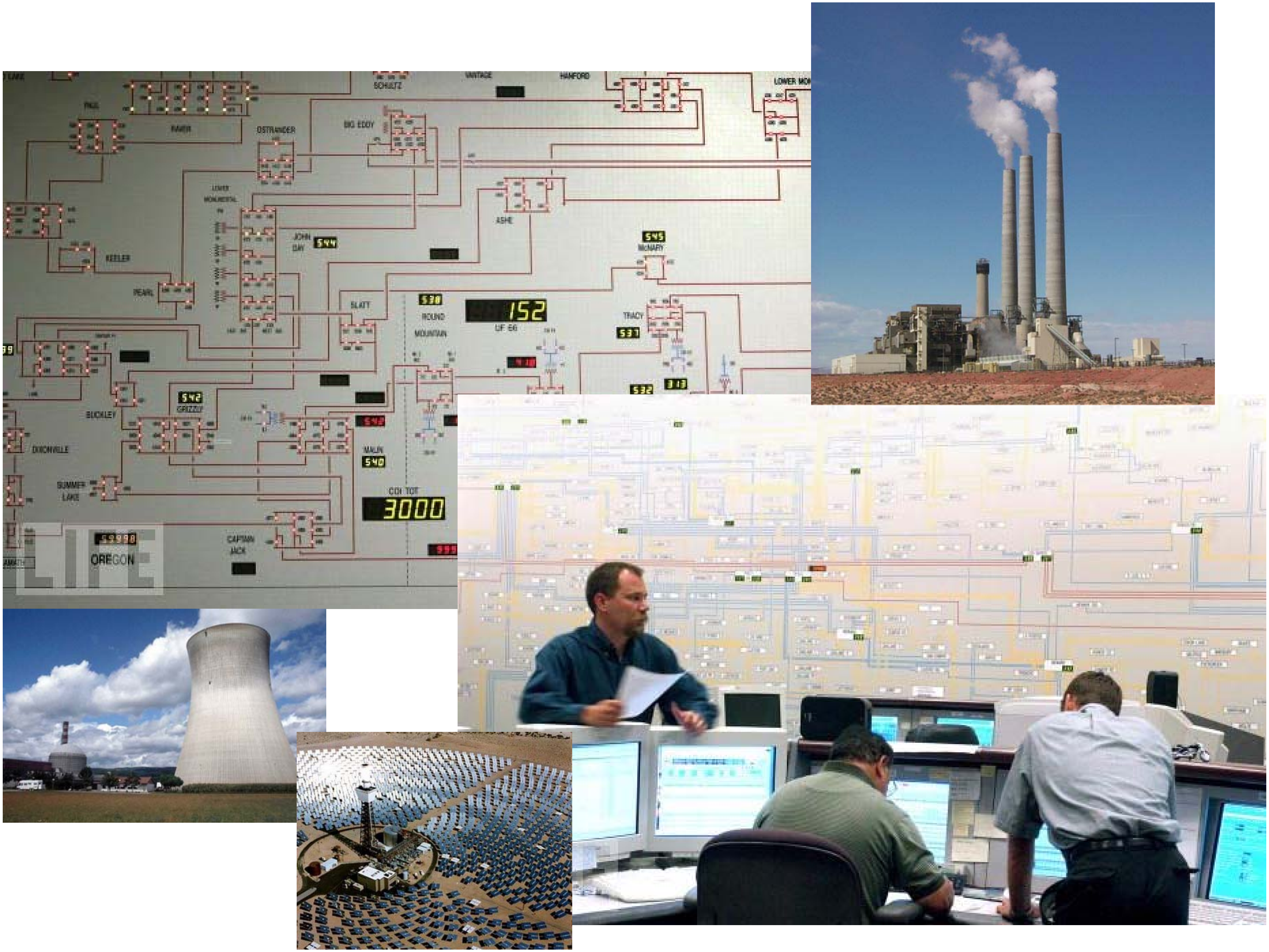
Announcements:

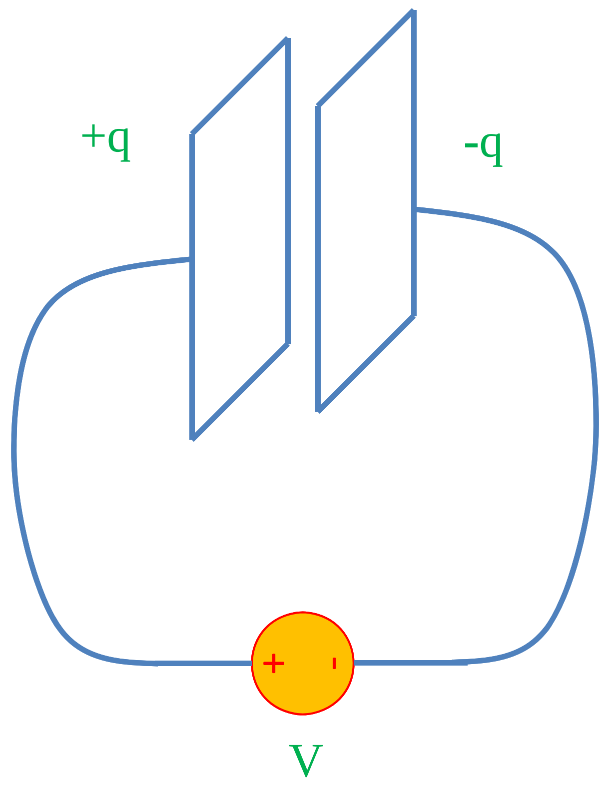
1. PSpice is installed in ECT 123 and EH 1131.
   (Not required but you may use for HWs if you like.)
2. Next quiz (#4) will be due Monday night
3. HW4 due Wed next week (to be posted soon)
4. MT2 2 weeks from today (ch 1-6, part of 9)

EECS 70A: Network Analysis

Lecture 10


SCHULTZ
VANTAGE
HANFORD
RAVER
OSTRANDER
BIG EDDY
ASHE
JOHN DAY
KEELER
PEARL
McNARY
SLATT
ROUND MOUNTAIN
152
TRACY
GRIZZLY
BUCKLEY
DIXONVILLE
MALIN
SUMMER LAKE
COI TOT
3000
CAPTAIN JACK
OREGON
LIFE

Capacitors



κ usually > 1

$$q = CV$$

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

A=area
d=plate separation

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

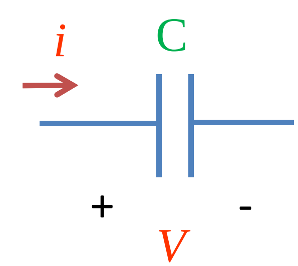
$$\varepsilon_0 = 8.85 \times 10^{-12} F/m$$

$$\varepsilon = \kappa \varepsilon_0$$

Dielectric constant:

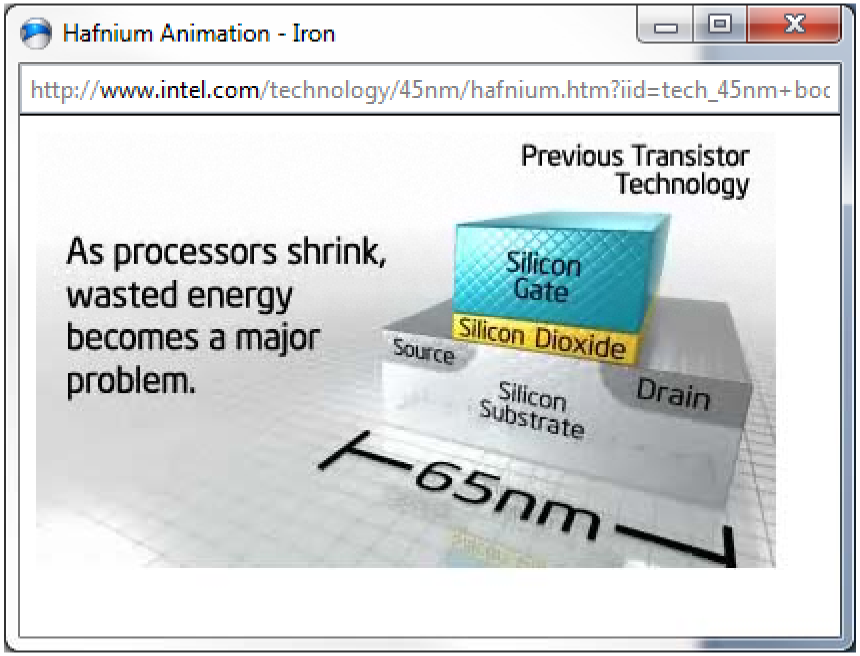
$\kappa = 3.9$ SiO_2

$\kappa = 25$ 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:

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

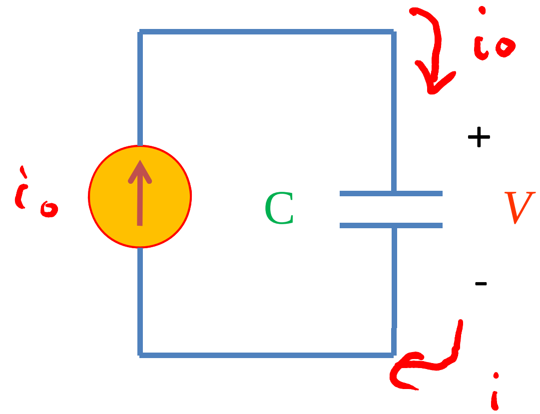
Will not always write (t), but it is assumed from now on.

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

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

Example Capacitor Problem

Find V(t), q(t)



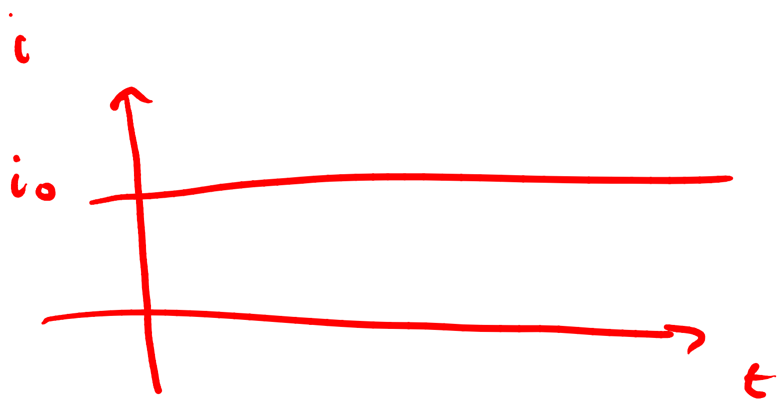
There is Another physical kind of current! Displacement current.

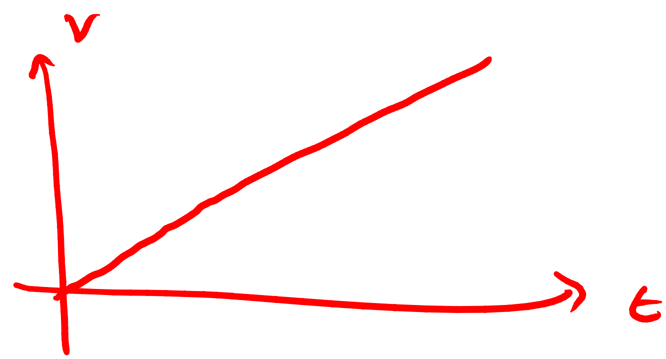
$$q = CV$$

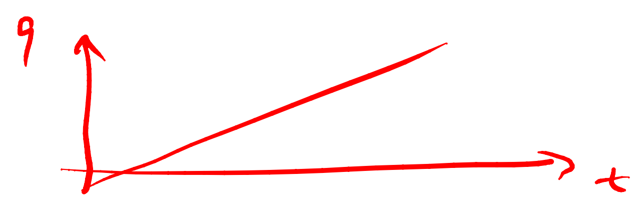
$$i = C\frac{dv}{dt}$$

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

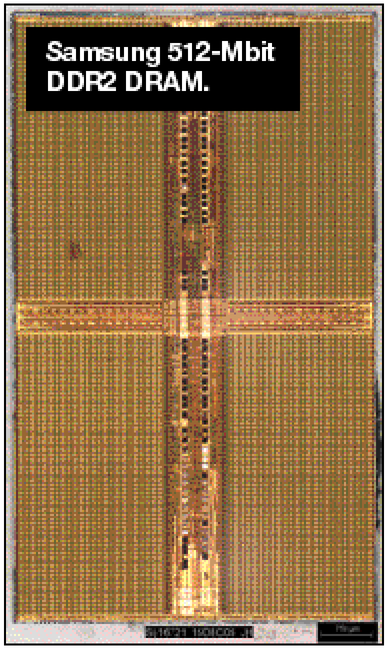
$$= \frac{1}{C}\, i_o \int dt = \frac{i_o}{C}\, t$$

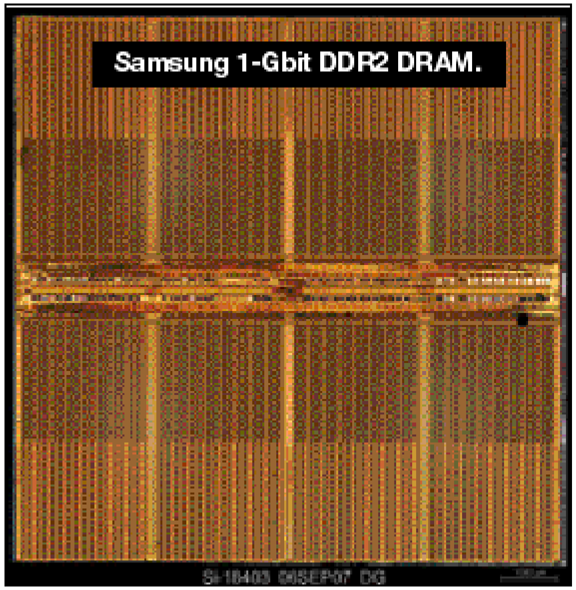






One-bit memory





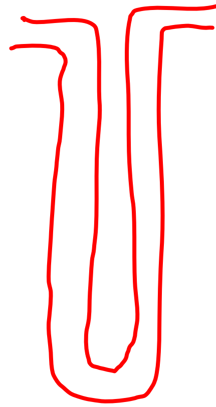
http://i.cmpnet.com/eet/news/07/11/DC1502_UTH_samsung.gif

ITRS Roadmap

0.1 μm "Technology Node"

eg 65 nm node

45 nm node



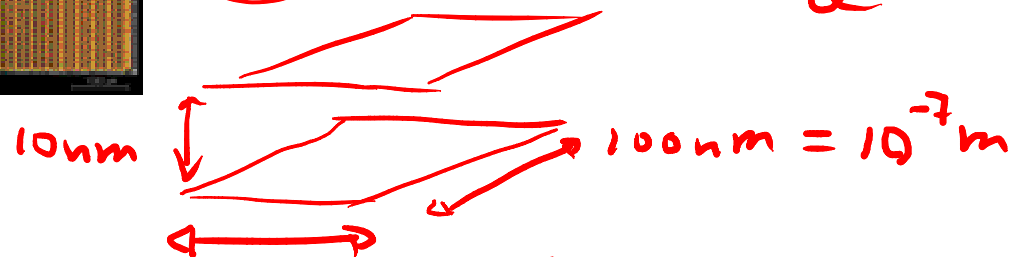
Typical dimensions:

0.1 micron x 0.1 micron area

10 nm thickness.

What is C?

$C = \frac{\varepsilon_0 k A}{d}$



Q = 0 bit 0

Q ≠ 0 bit 1

$C = \frac{\varepsilon A}{d} = \frac{10 \cdot 8.85 \times 10^{-12} \frac{F}{m} [10^{-7} m]^2}{10 \cdot 10^{-9} m}$

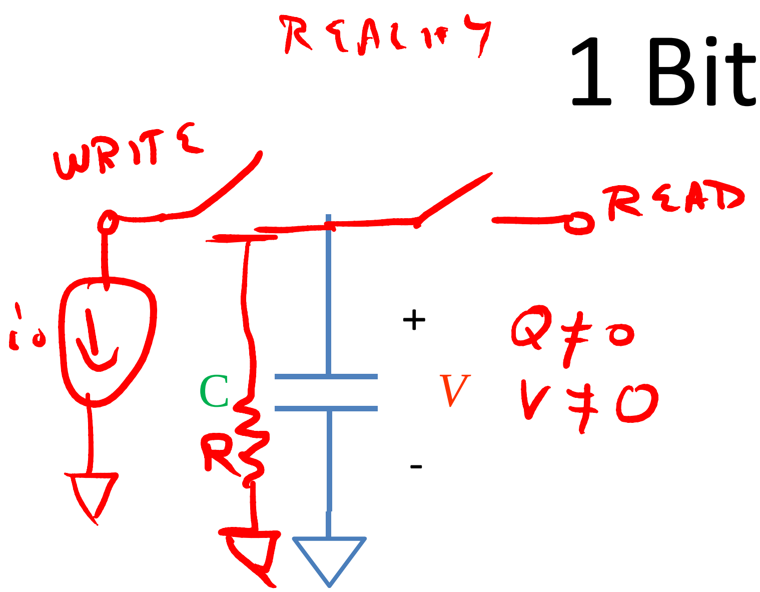
$= 10^{1+1-12-14-1+9} F = 10^{-16} F = 0.1 fF$ too small

$-27+11$

F Femto 10^{-15}

Need 10 fF

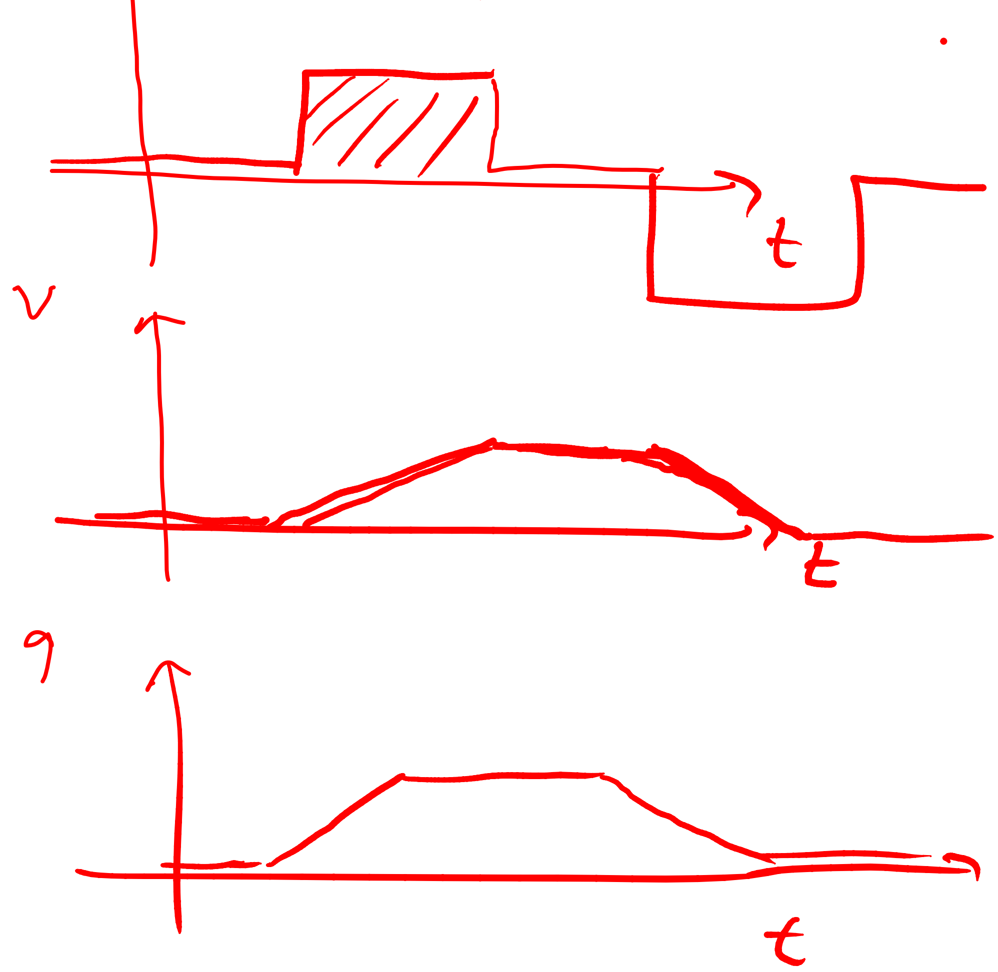
1 Bit Read/Write



$Q = CV$

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

$q = \int i\, dt$



TO READ, CONNECT TO VOLTMETER

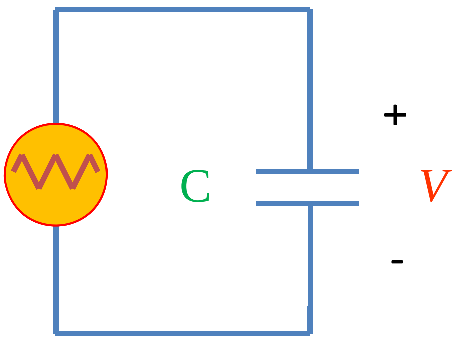
REFRESH RATE every 10ms

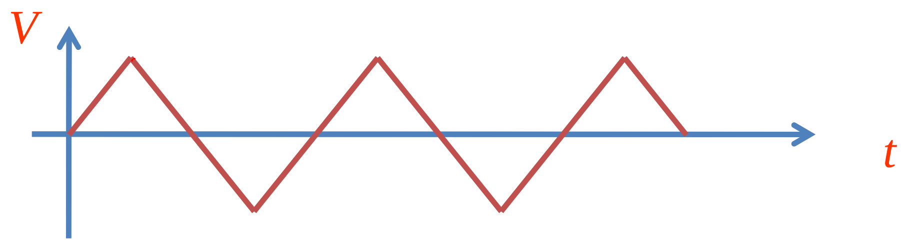
DRAM

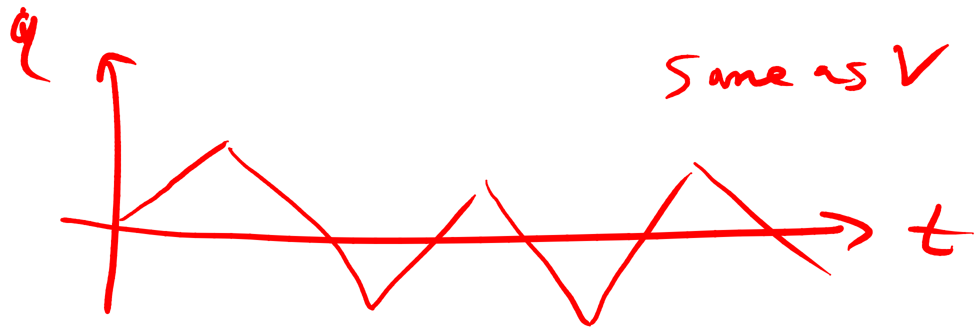
↳ dynamic

Example Problem #2

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



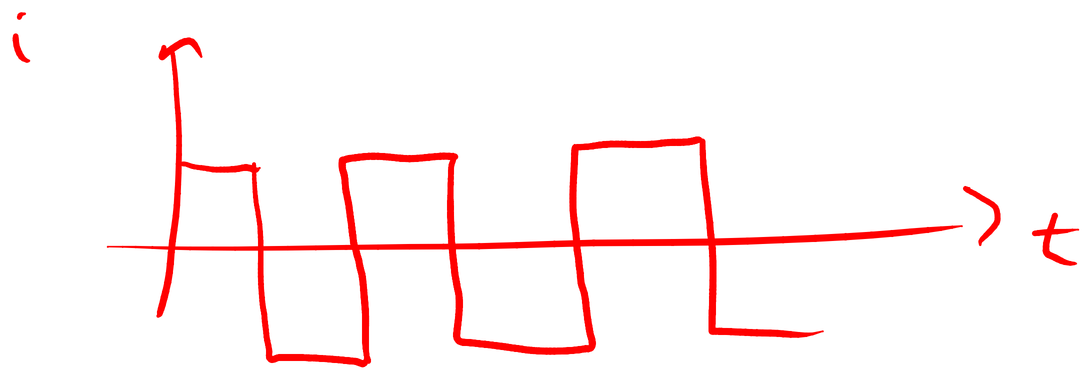




$$q = CV$$

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

$$V = \frac{1}{C}\int i\,dt$$



RC circuit

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

RESISTOR

$$i_R R = V_R = V_c = (-i_c)R$$

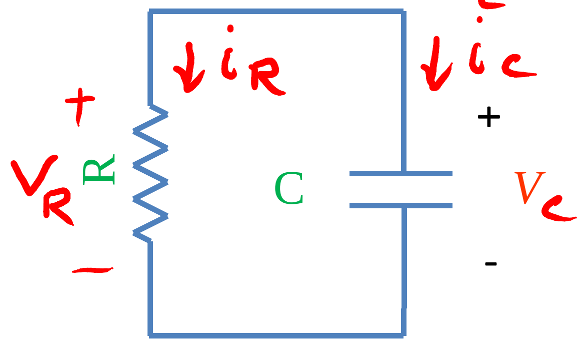
$$KVL \Rightarrow V_R = V_c$$

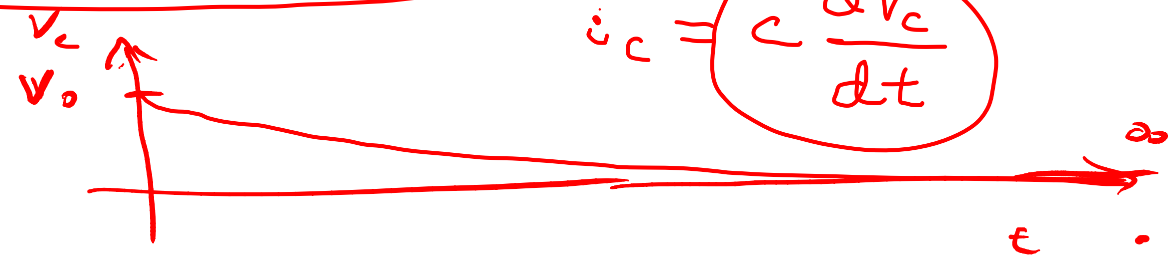
$$KCL \Rightarrow i_R = -i_c$$

CAPACITOR

$$q = C V_c$$

$$i_c = C\frac{dV_c}{dt}$$





$$\frac{V_c}{R} = -C\frac{dV_c}{dt} \qquad \tau \equiv RC$$

$$\frac{dV(t)}{dt} = -\frac{1}{RC} V(t) \quad \text{why?}$$

Soln:

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

Proof:

$$\frac{dV(t)}{dt} = \frac{d}{dt}\left[V(t=0)\, e^{-t/RC}\right]$$

$$= V(t=0)\frac{d}{dt}\left[e^{-t/RC}\right] = -\frac{1}{RC}\, V(t=0)\, e^{-t/RC}$$

$$= -\frac{1}{RC} V(t)$$

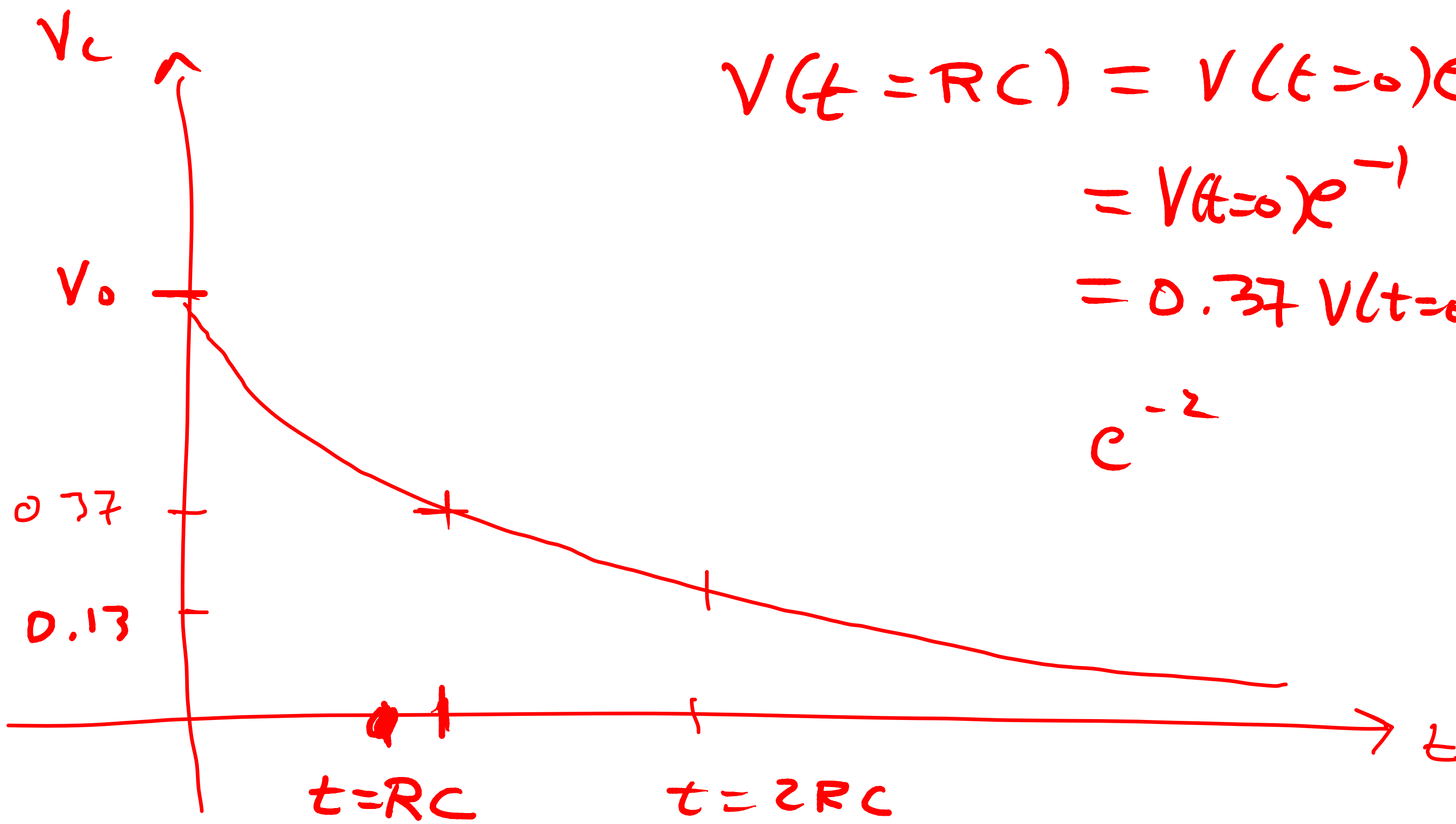
$$V(t) = V(t=0)\, e^{-t/RC}$$

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

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

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

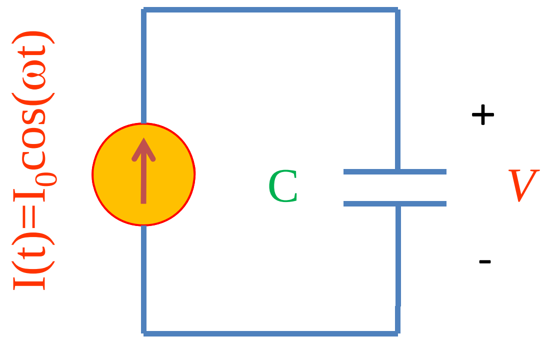
$$e^{-2}$$



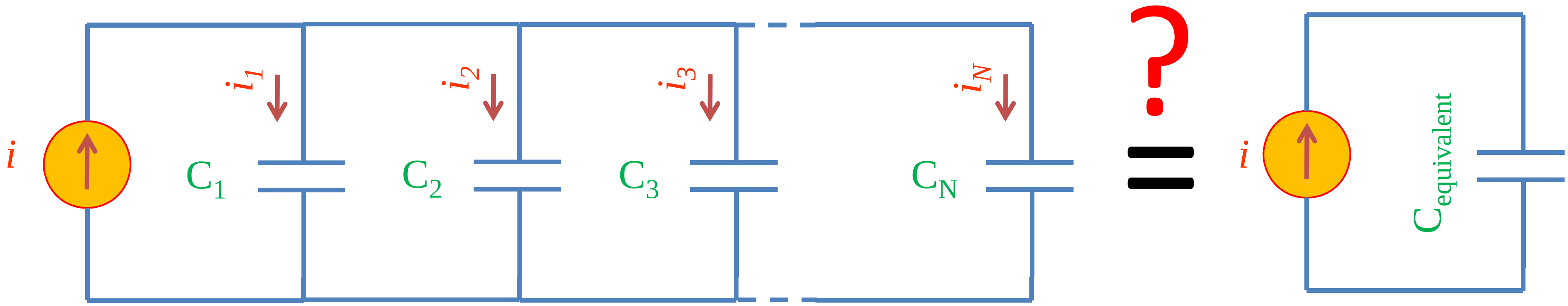
DRAM vs. SRAM

Example Capacitor Problem #2

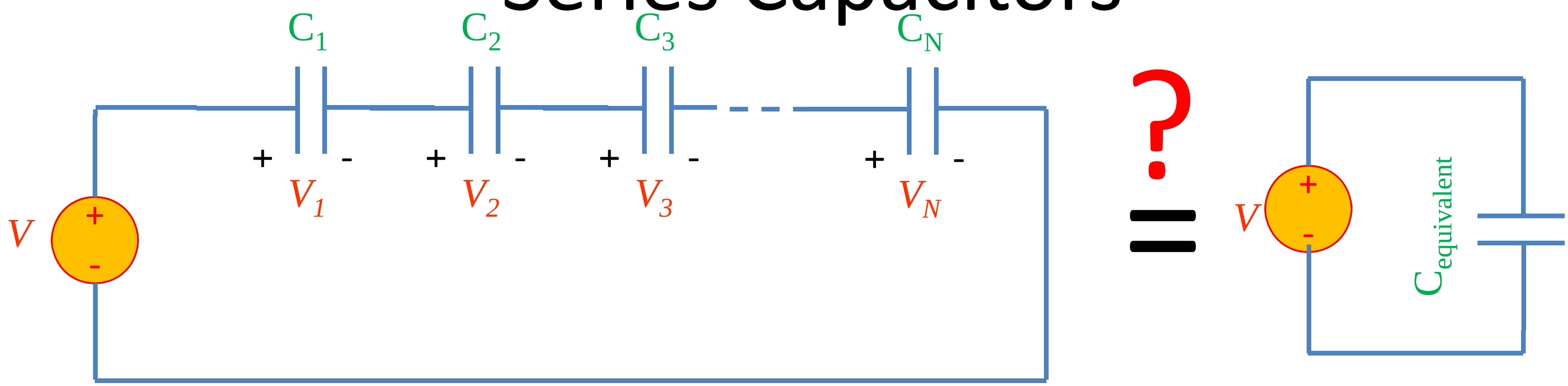
Find V(t), q(t)



Parallel Capacitors

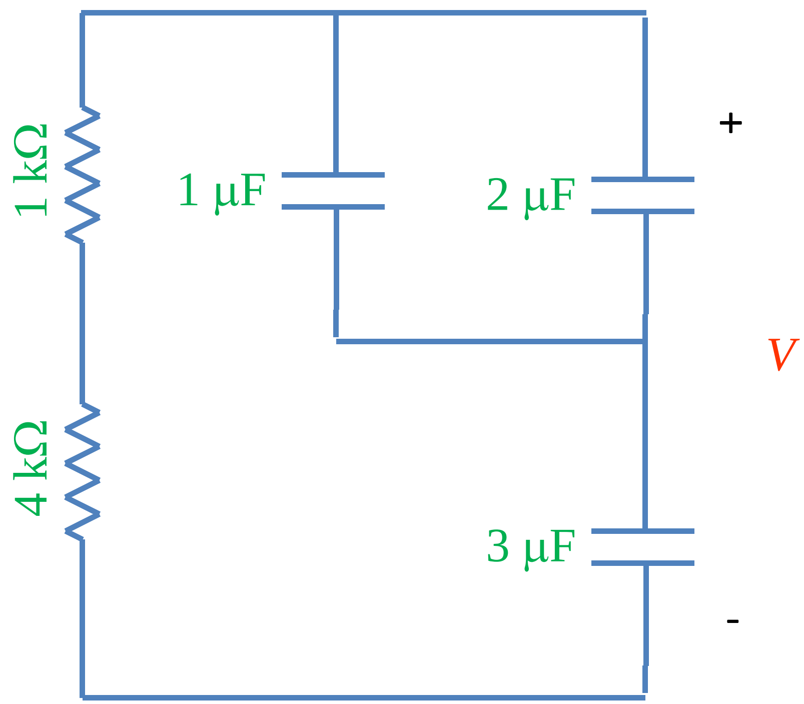


Series Capacitors

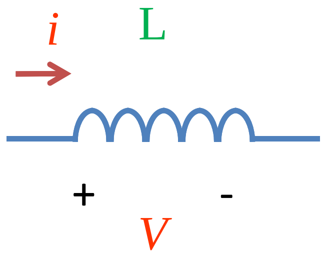


Example problem #4

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



Inductors



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

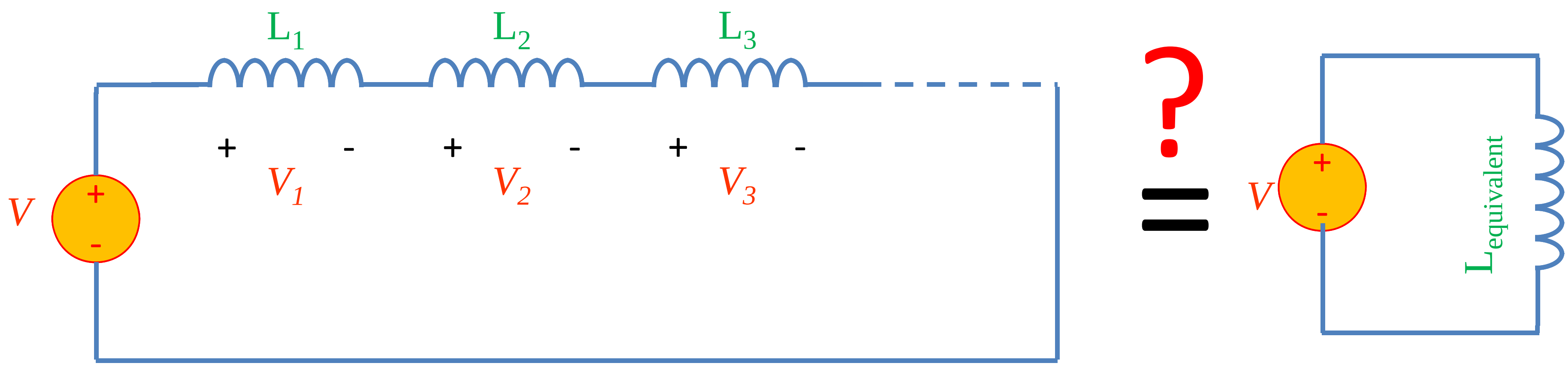
A=area
l=wire length
N = # of turns
$\mu = 4\,\pi\,10^{-6}$ H/m

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

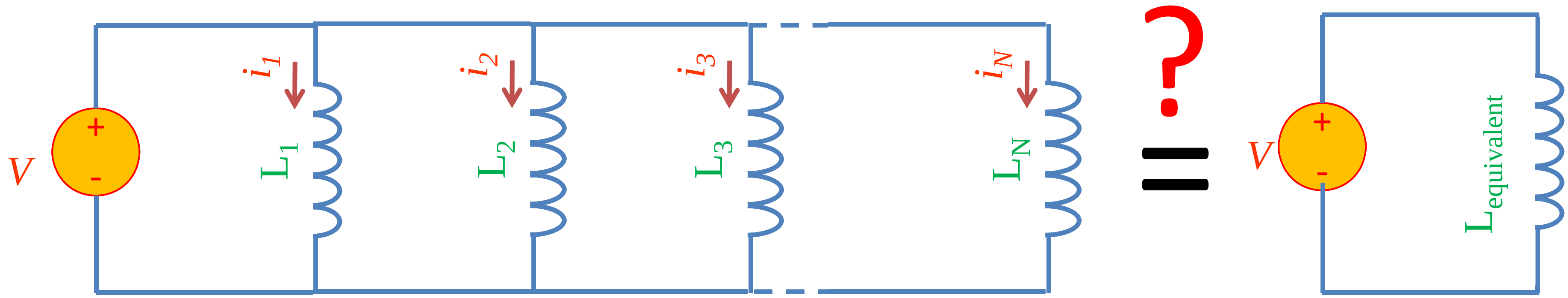
Henry[H]

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

Series Inductors

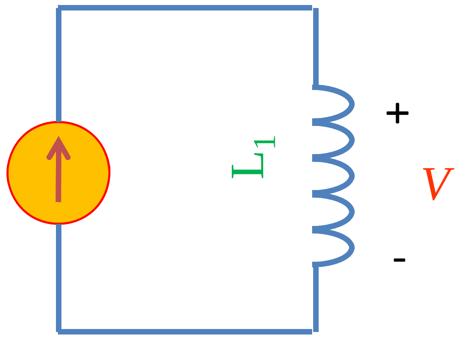


Parallel Inductors



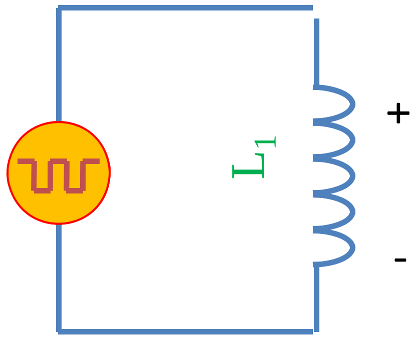
Example Inductor Problem

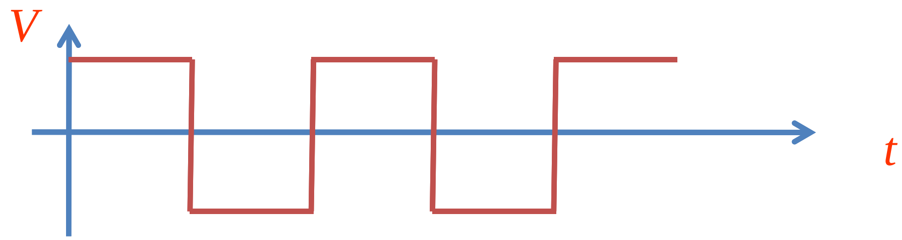
(Students): Find V(t).



Example Inductor Problem #2

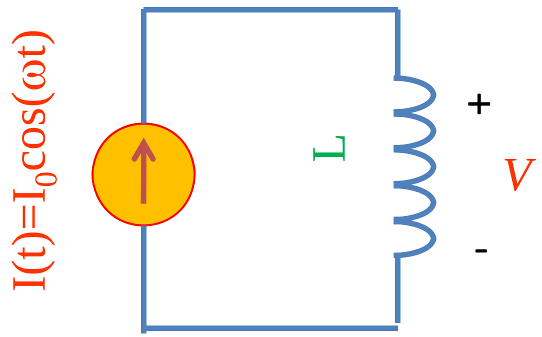
(Students): Find i(t)





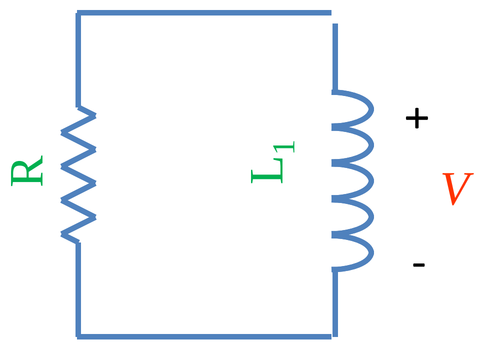
Example Inductor Problem #3

Find V(t)



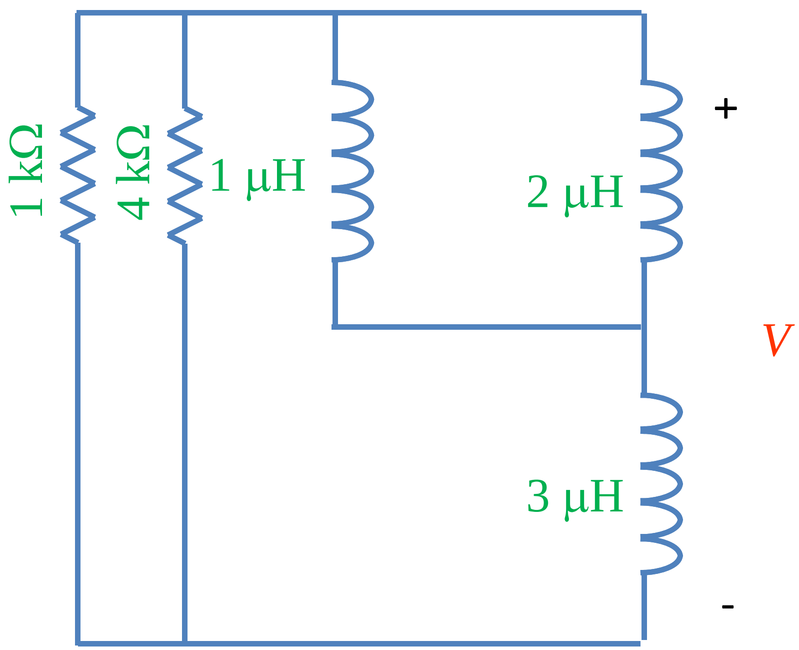
LR circuit

Find V(t), i(t)

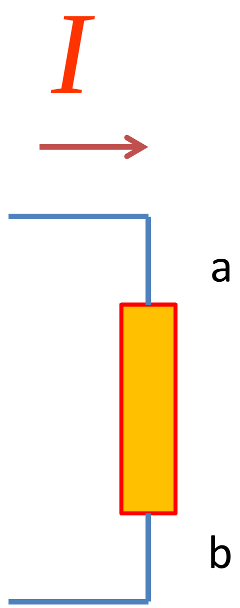


Example LR problem

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



Power



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

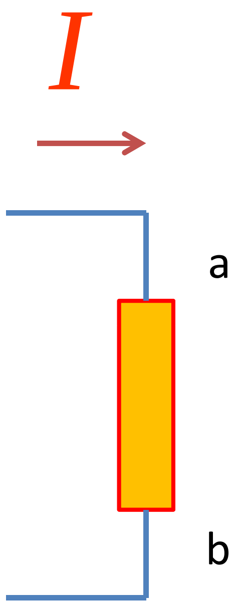
Watts [W] = Volt Amp [V-A]

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:

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

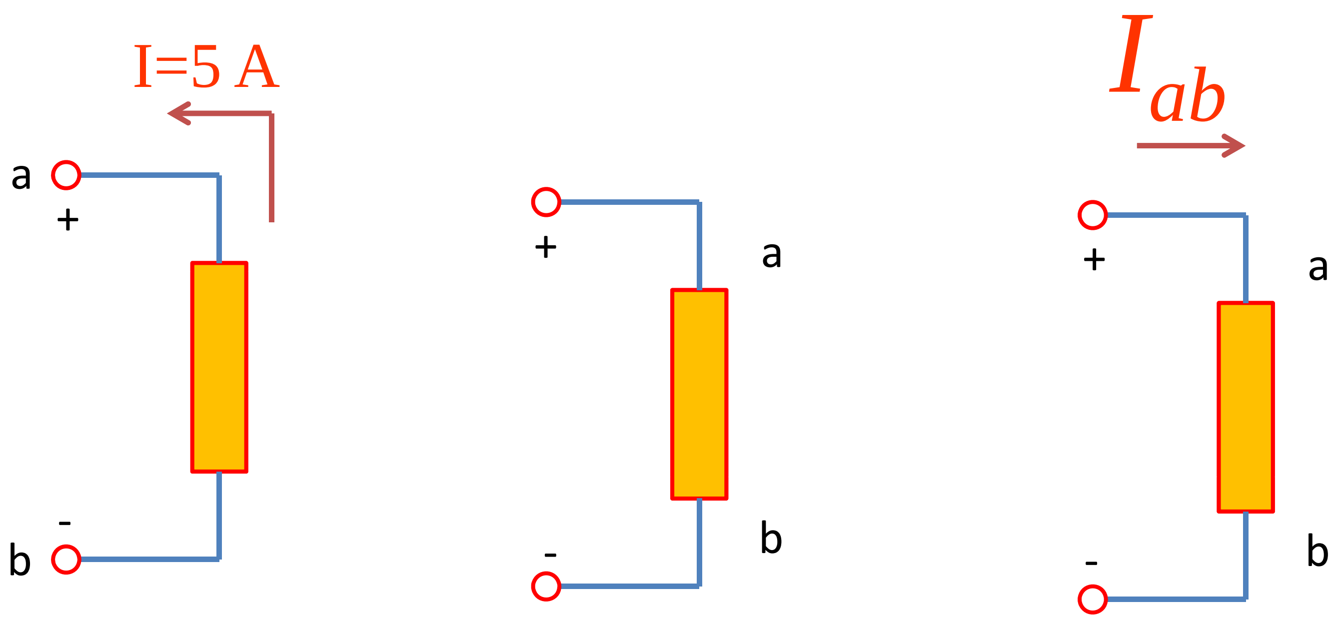
Capacitor stored energy:

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

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