전기회로 (가, 나)

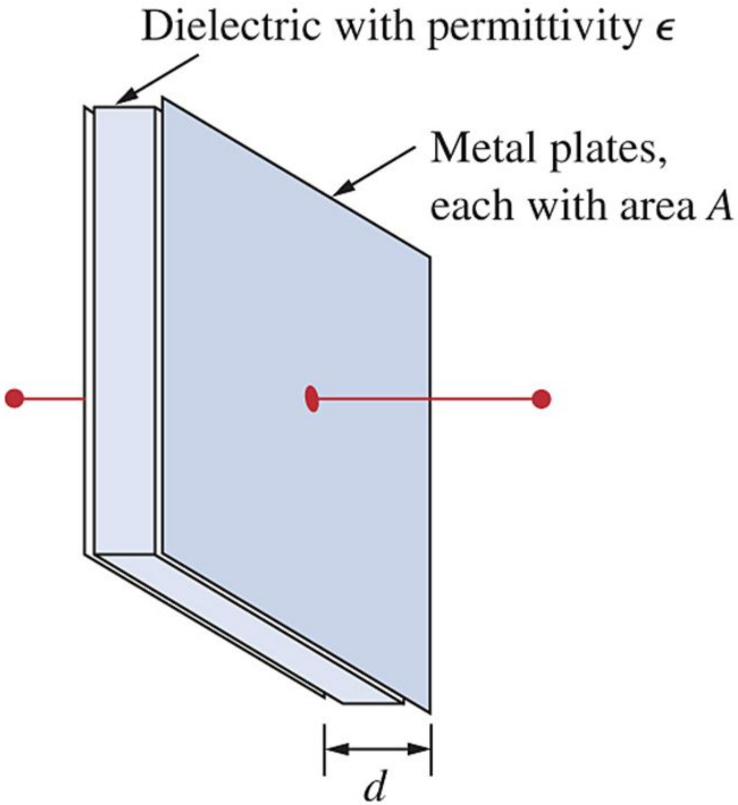
Chapter 6 : Capacitors & Inductors

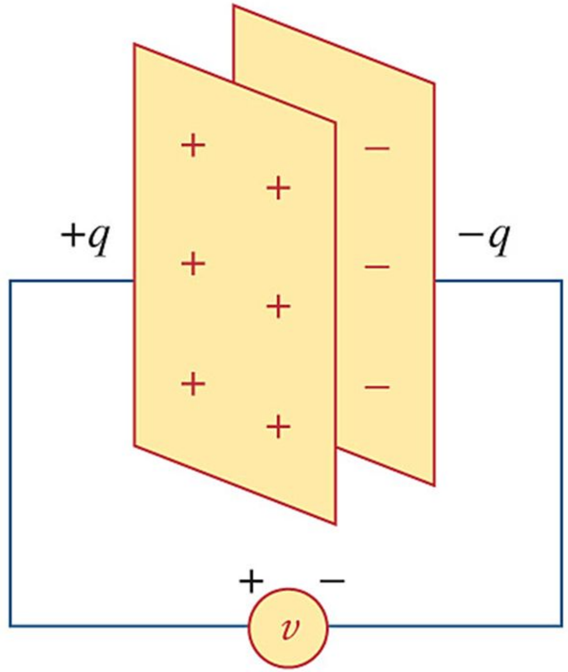
2017. 1학기

윤영식 교수
글로벌브레인홀 204호
ysyoun@ssu.ac.kr

6.2 Capacitors (캐패시터)

- Capacitor
  - 전기장(electric field)에 에너지를 저장하는 수동소자
  - 절연체(또는 유전체)를 사이에 두고 2장의 전도판으로 구성





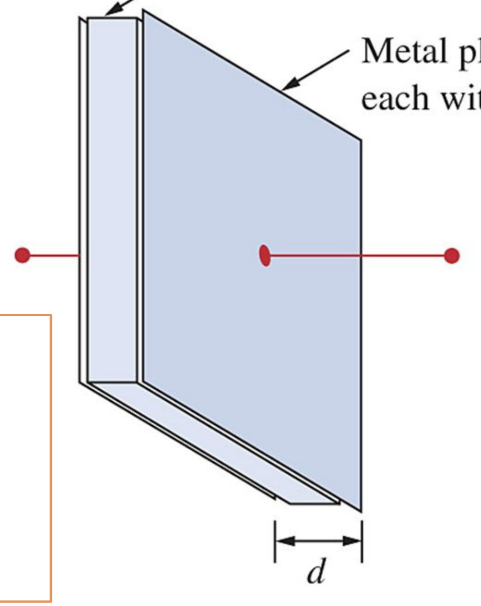
6.2 Capacitor : capacitance

- 전하(electric charge)를 저장 ➔ 충전
- 저장되는 전하의 양은 두 판 사이에 걸리는 전압에 비례

$$\boxed{q = Cv}$$

C : 비례상수 (farad, F) → capacitance

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

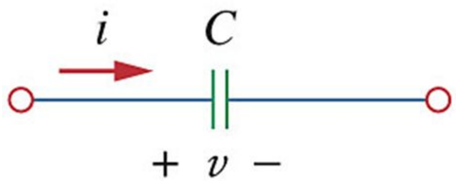


C (capacitance) 증가
- 판의 표면적이 넓을수록
- 판 사이의 거리가 가까울수록
- 절연체의 유전율이 높아질수록

6.2 Capacitor

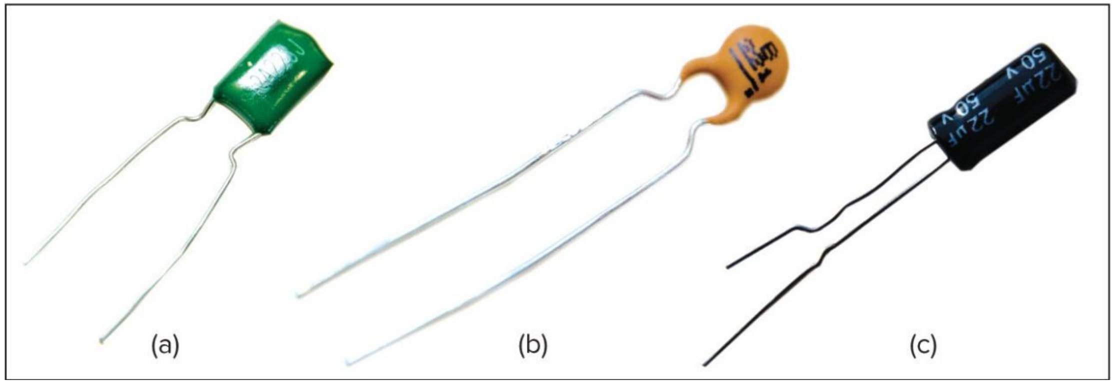
충전과 방전

- 충전(charging) : 전류의 방향과 전압강하의 방향이 일치
- 방전(discharging) : 전류의 방향과 전압강하의 방향이 반대



용도

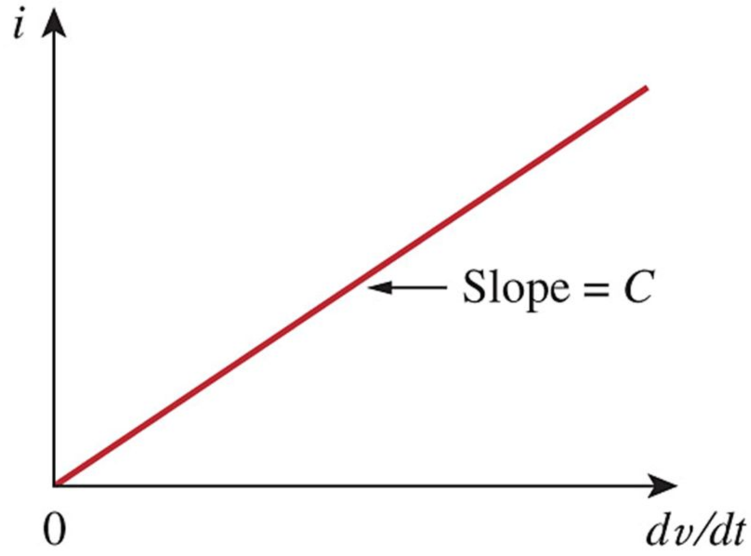
- DC(직류) 차단
- 위상 변화, 주파수 변화
- 에너지 저장/방전
- 잡음 제거
- 라디오 튜너
- 메모리



6.2 Capacitors : i-v relationship

$$q = Cv \quad \& \quad i = \frac{dq}{dt}$$

$$\boxed{i = C\frac{dv}{dt}} \qquad \boxed{v = \frac{1}{C}\int_{-\infty}^{t} i\,dt \quad \text{or} \quad v = \frac{1}{C}\int_{t_0}^{t} i\,dt + v(t_0)} \qquad v(t_0) = q(t_0)/C$$



시간(t)에 따라 변함.

cf) 저항(R) : $v = iR \quad i = \frac{v}{R}$

6.2 Capacitors : Capacitor Energy

- 순간전력 p(t) : $\boxed{p(t) = v(t)i(t) = Cv\frac{dv}{dt}}$

- capacitor에 저장된 에너지 w :

$$w(t) = \int_{-\infty}^{t} p(t)dt = C\int_{-\infty}^{t} v(t)\frac{dv(t)}{dt}dt = C\int_{v(-\infty)}^{v(t)} vdv = \frac{1}{2}Cv^2$$

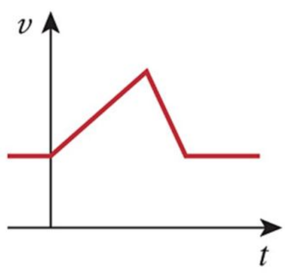
$$\boxed{w = \frac{1}{2}Cv^2}$$

6.2 Capacitors

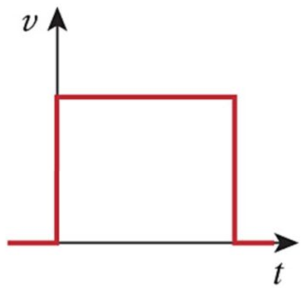
- Capacitor의 주요 성질
  - **직류 차단** (직류 전류는 C 통과 불가)

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

    - DC에 대하여 C는 open circuit
    - DC 전압에 의하여 충전은 가능
  - **Capacitor 전압은 급하게 변하지 못한다.**
    - **전압의 변화를 방해**

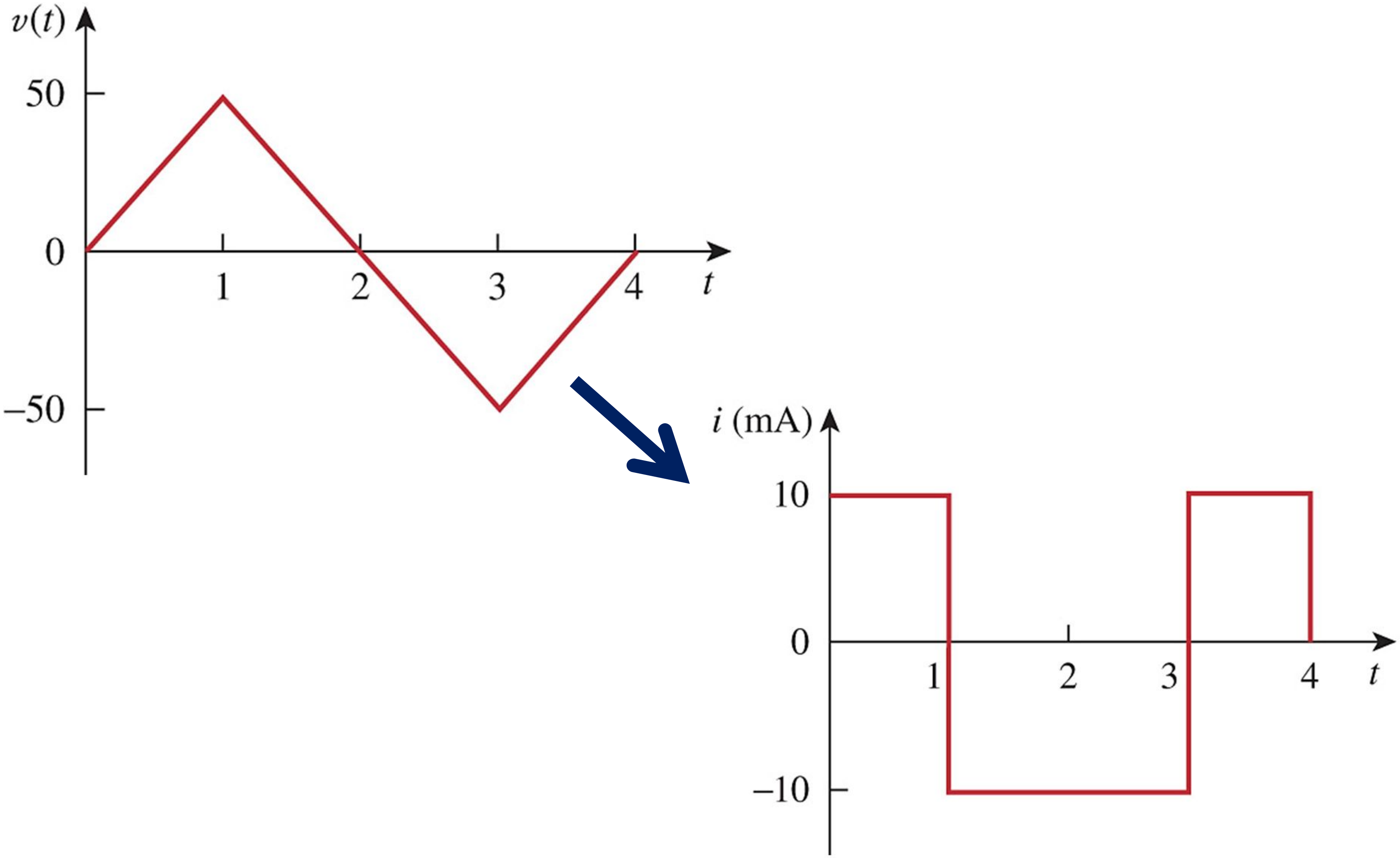


(O)

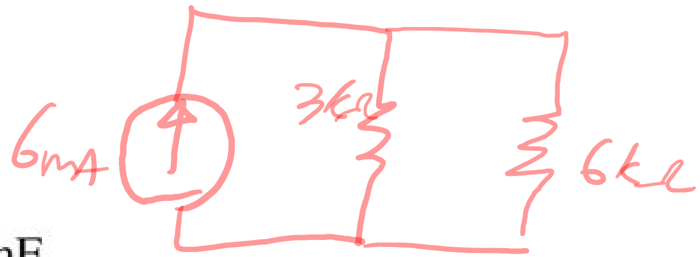


(X)

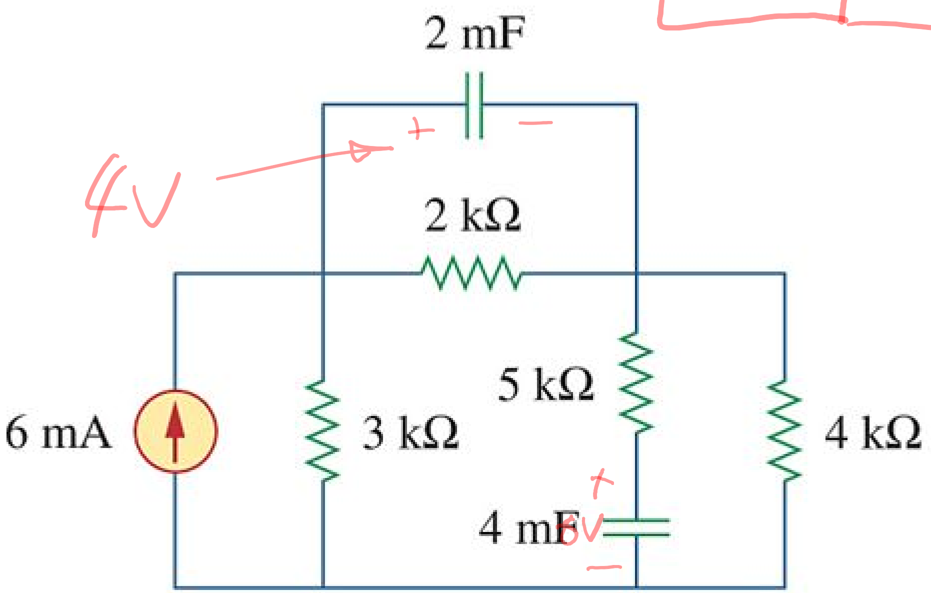
Example 6.4

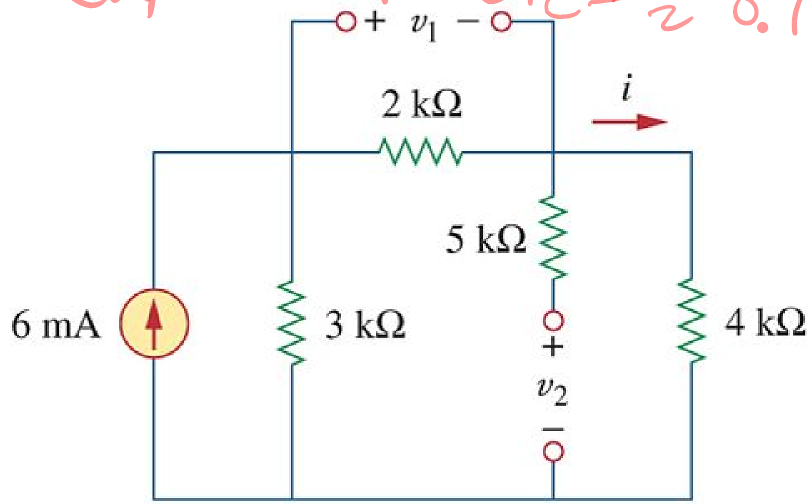


Example 6.5



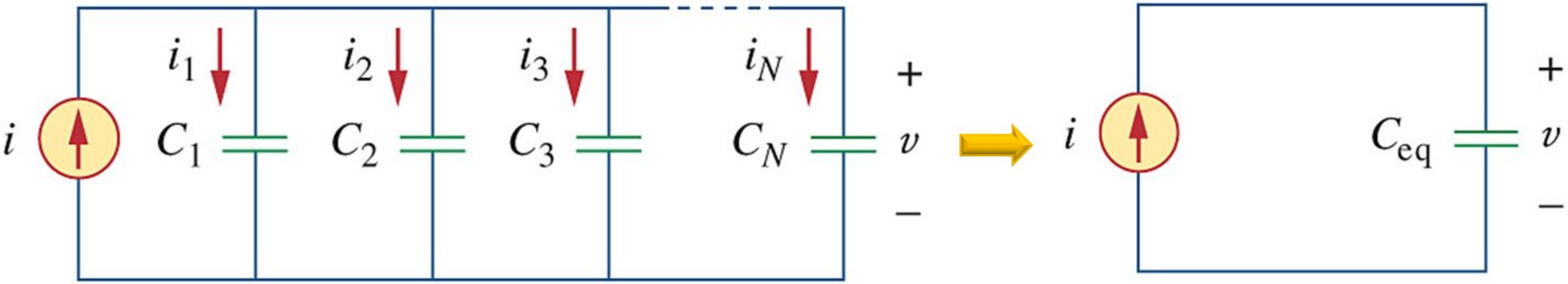
Capasitor에 충전이 완료될 경우





6.3 Series & Parallel Capacitors

- Capacitor의 병렬연결



KCL 적용 :

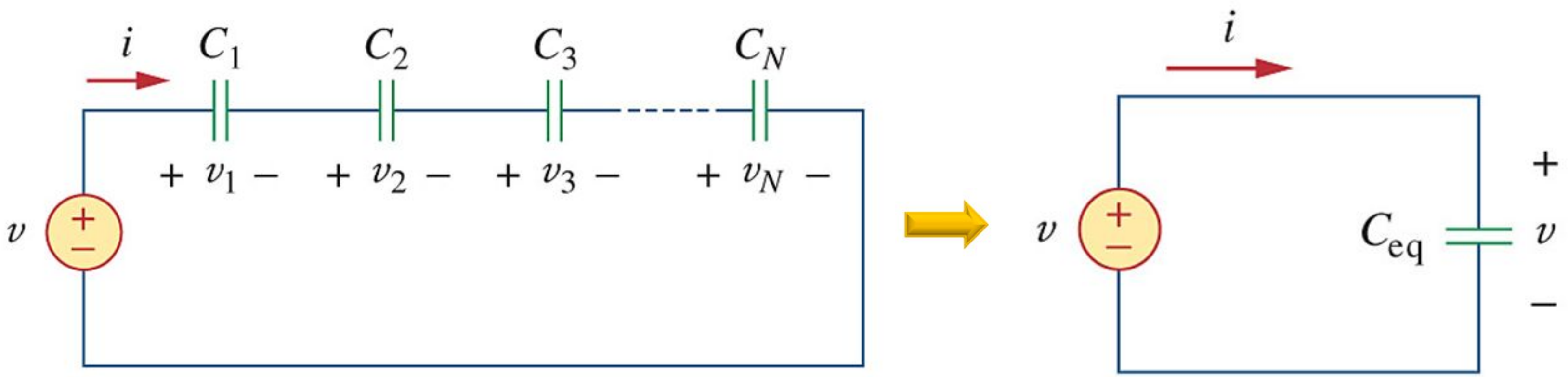
$$i = i_1 + i_2 + i_3 + \cdots + i_N$$

$$C_{eq}\frac{dv}{dt} = C_1\frac{dv}{dt} + C_2\frac{dv}{dt} + C_3\frac{dv}{dt} + \cdots + C_N\frac{dv}{dt}$$

$$\boxed{C_{eq} = C_1 + C_2 + C_3 + \cdots + C_N}$$

6.3 Series & Parallel Capacitors

- Capacitor의 직렬연결



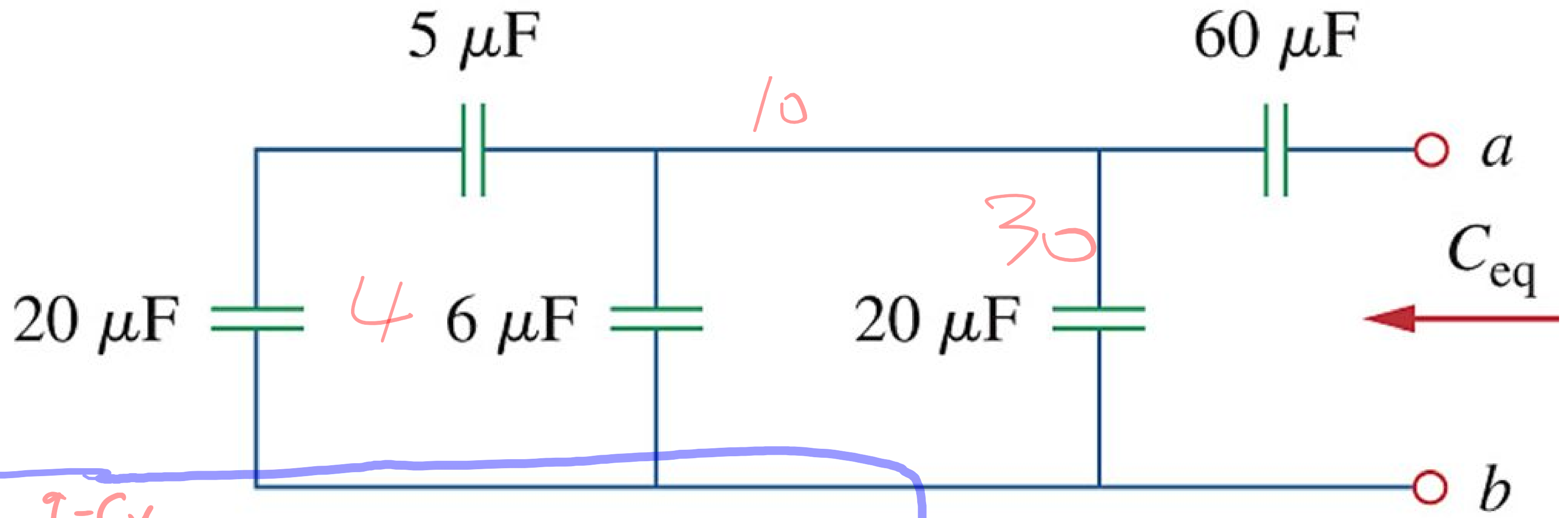
KVL 적용 :

$$v = v_1 + v_2 + v_3 + \cdots + v_N$$

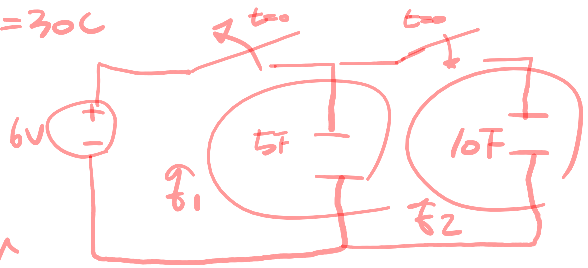
$$\frac{1}{C_{eq}}\int_{-\infty}^{t} i(t)dt = \frac{1}{C_1}\int_{-\infty}^{t} i(t)dt + \frac{1}{C_2}\int_{-\infty}^{t} i(t)dt + \frac{1}{C_3}\int_{-\infty}^{t} i(t)dt + \cdots + \frac{1}{C_N}\int_{-\infty}^{t} i(t)dt$$

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots + \frac{1}{C_N}}$$

Example 6.6



$q = Cv$
$= 5F \times 6V = 30C$



$q_1 = 5F \times v = 5v$

$q_2 = 10F \times v = 10v$

$30 = 5v + 10v = 15v$ $\therefore 2V$

20 μF

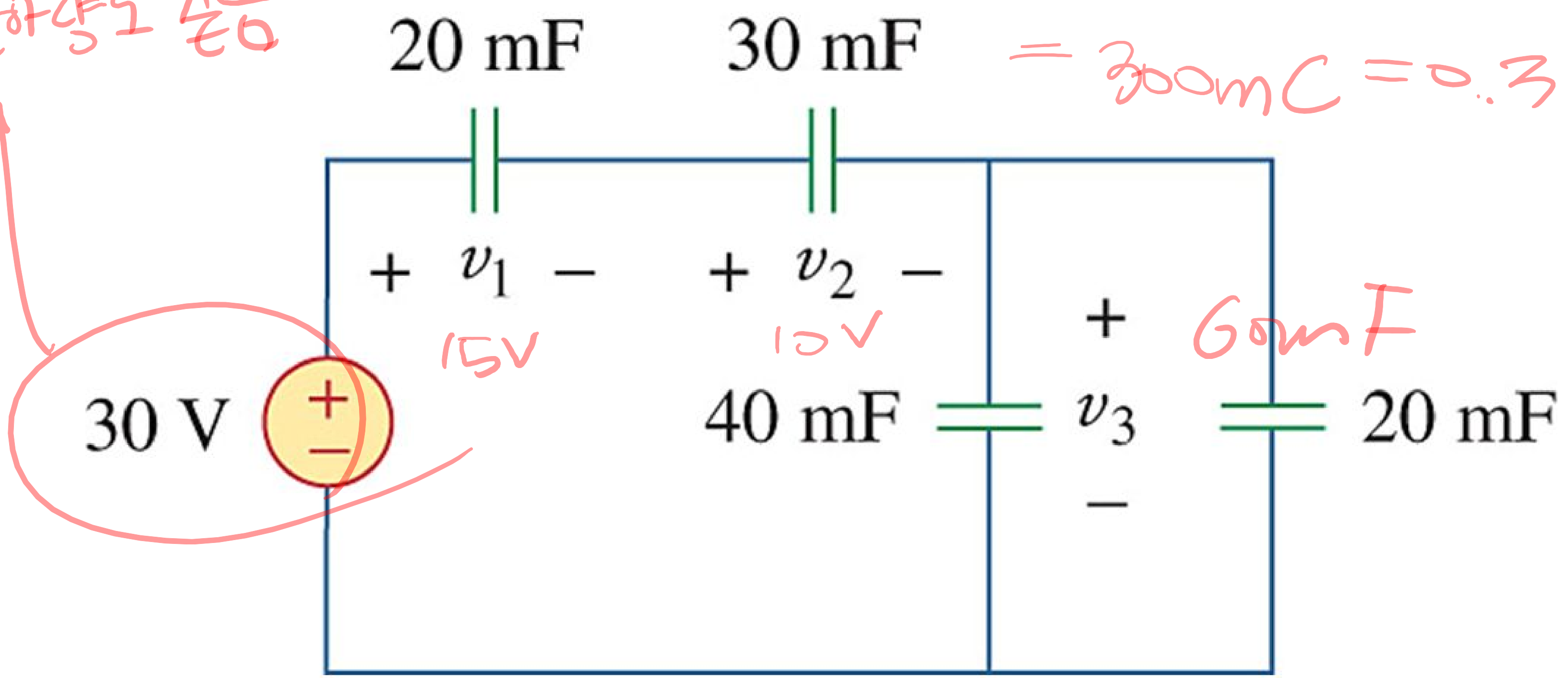
Example 6.7

전류가 같으므로

충전된 전하량도 같음

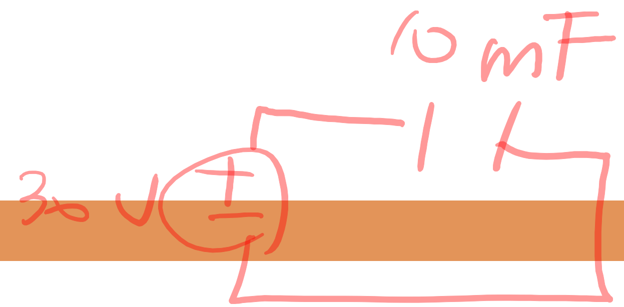
$q = Cv = 10mF \times 30V$

$= 300mC = 0.3C$



$q_1 = 300mC = 20mF \times V_1$

$V_1 = 15V$

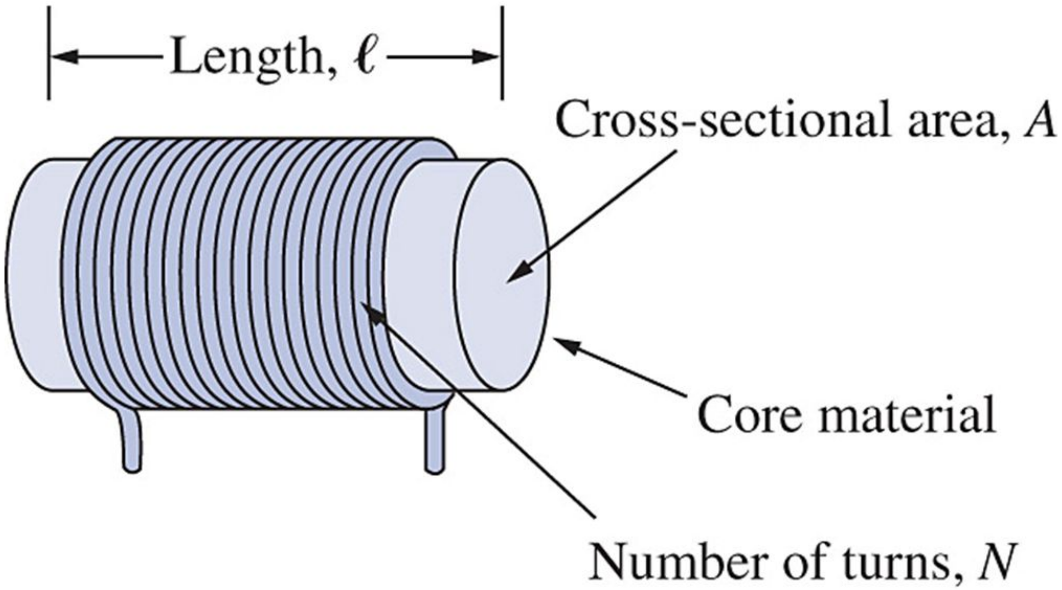


$q_2 = 300mC = 30mF \times V_2$

$V_2 = 10V$

6.4 Inductor

- Inductor란? $q = CV,\ i = C\frac{dv}{dt}$
  - 자기장(Magnetic Field)에 에너지를 저장하는 수동 소자
  - 모든 금속은 자체적으로 인덕턴스가 존재 함
  - 인덕턴스 값을 증가 시키기 위하여 주로 코일의 형태로 구현



6.4 Inductors : Inductance

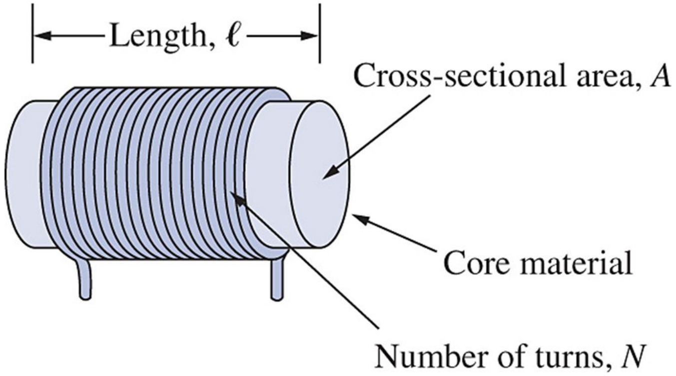
- 인덕터에 걸리는 전압은 전류의 시간적 변화량에 비례

전류↑ : 전류흐름을 방해

$$\boxed{v = L\frac{di}{dt}}$$

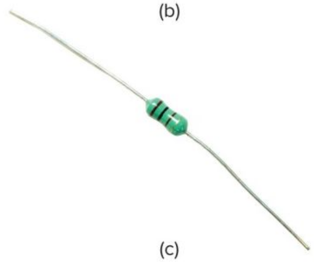
L : 비례상수 (inductance, henry(H))

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



(a)

(b)



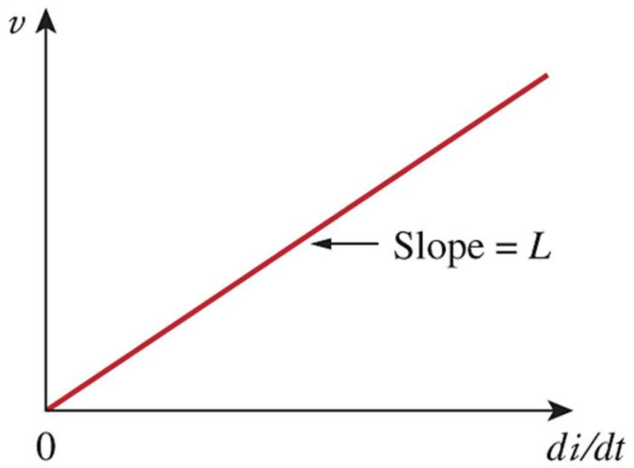
(c)

μ : permeability(투자율, 透磁率)

6.4 Inductors : i-v relationship

$$\boxed{v = L\frac{di}{dt}}$$

$$\boxed{i = \frac{1}{L}\int_{-\infty}^{t} v(t)dt} \quad \text{or} \quad \boxed{i = \frac{1}{L}\int_{t_0}^{t} v(t)dt + i(t_0)}$$



6.4 Inductors : Power & Energy

- 인덕터의 전력(power) : $p = vi = \left(L\dfrac{di}{dt} \right) i$

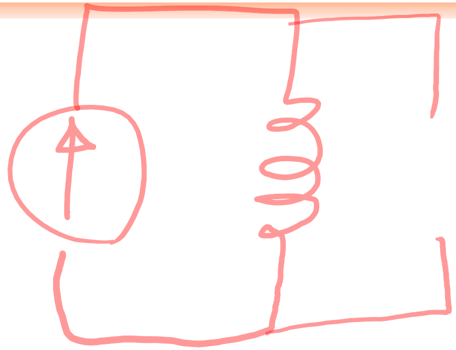
- 인덕터에 저장되는 에너지 :

$$w = \int_{-\infty}^{t} p\,dt = \int_{-\infty}^{t} \left(L\frac{di}{dt} \right) i\,dt = L\int_{-\infty}^{t} i\,di = \frac{1}{2}Li^2(t)$$

$$\boxed{w = \frac{1}{2}Li^2}$$

6.4 Inductors

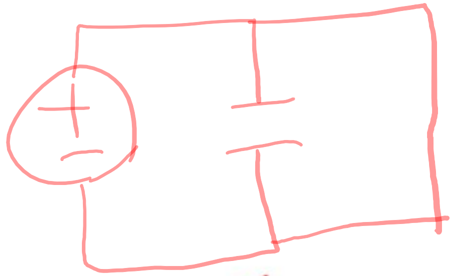
- Inductor의 주요 성질
  - **직류 전류에 대하여 저항 0 ➔ short circuit로 동작**

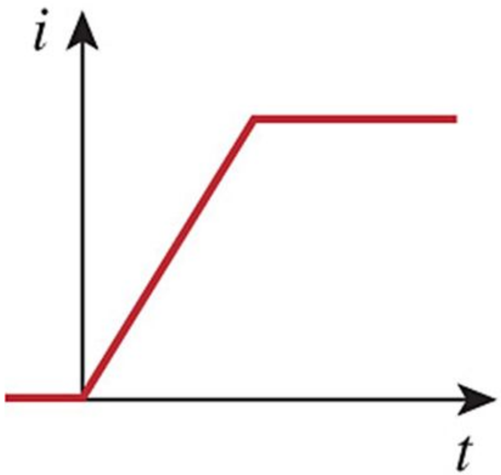


  - **인덕터를 통하여 흐르는 전류는 급격하게 변하지 못한다.**

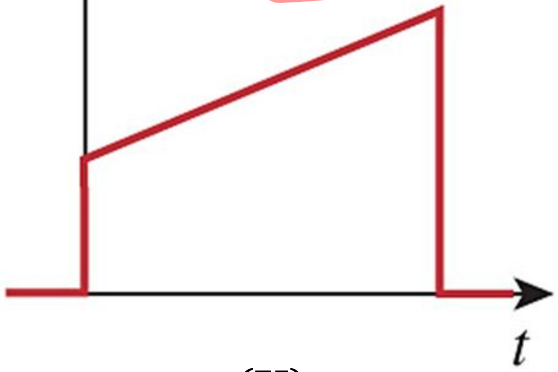
전력소모 X

    - **전류의 변화를 방해**



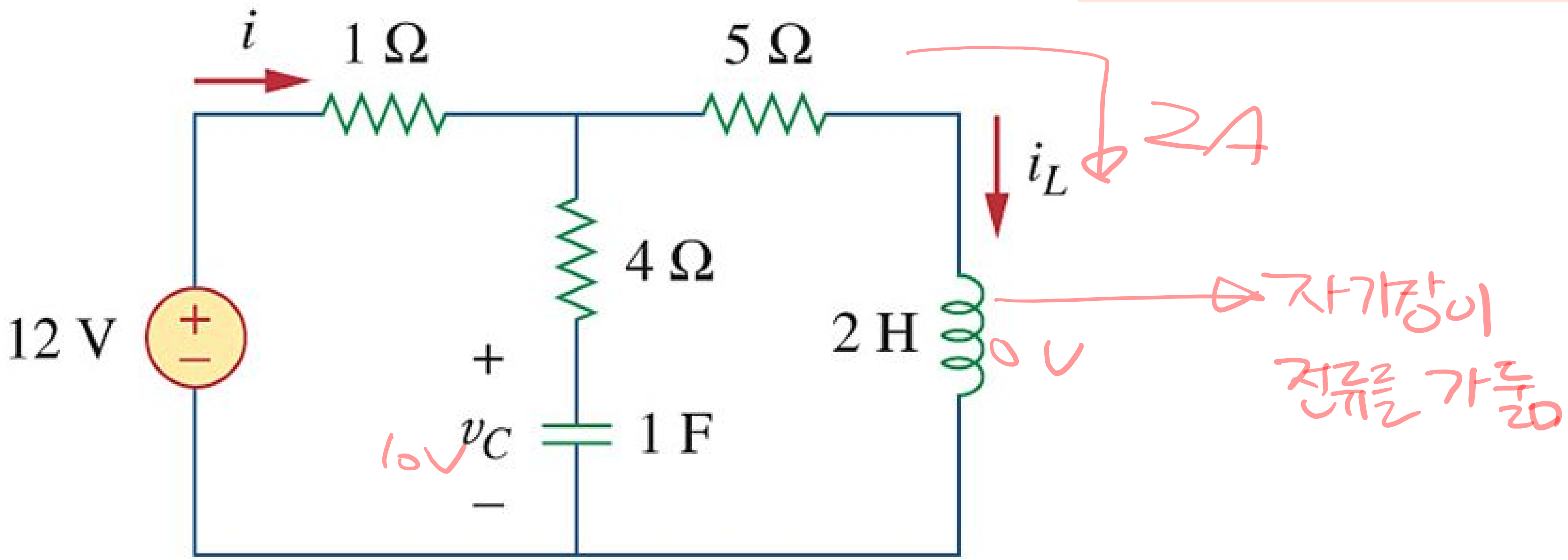


(O)

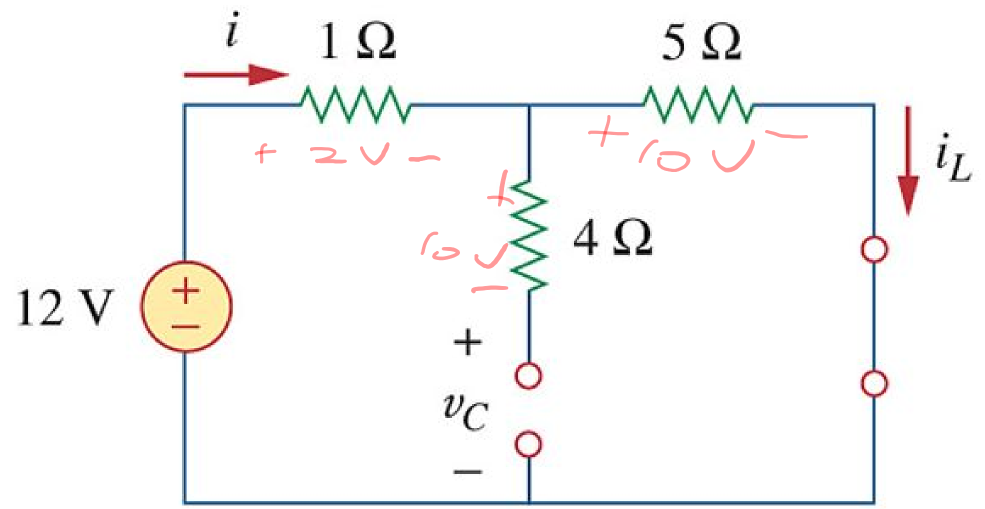


(X)

Example 6.10

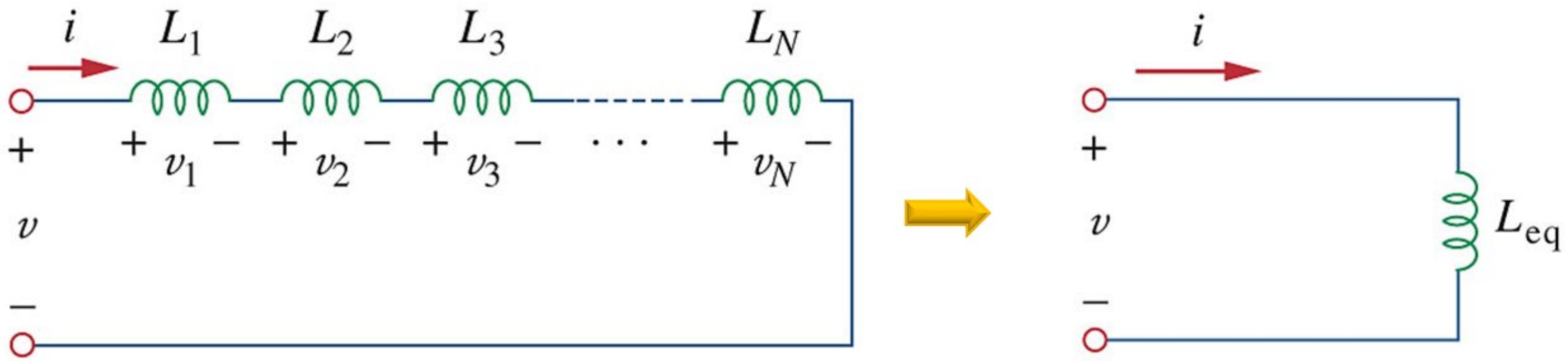


t=∞



6.5 Series & Parallel Inductors

- Inductor의 직렬연결



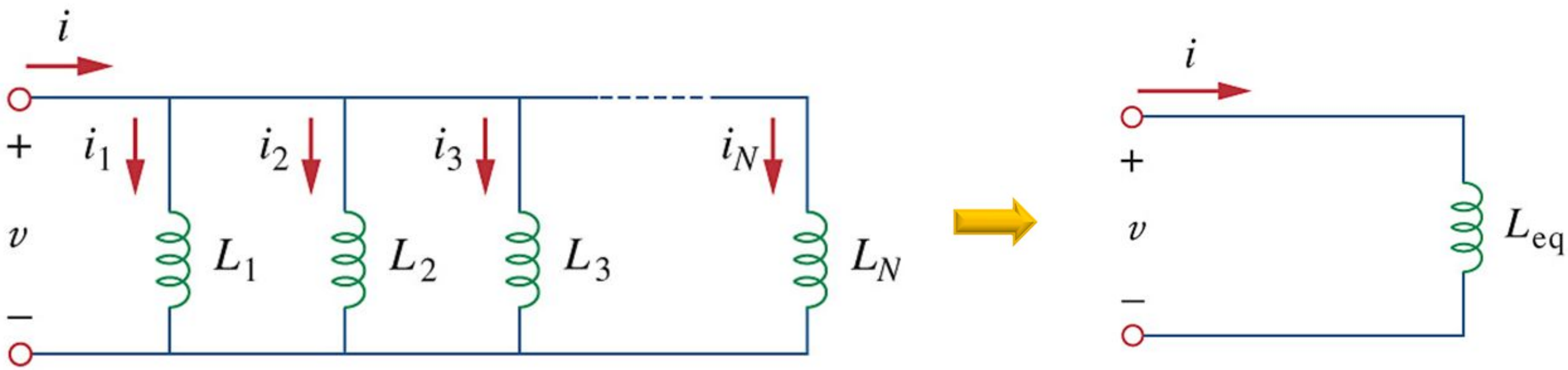
KVL 적용 : $$v = v_1 + v_2 + v_3 + \cdots + v_N$$

$$L_{eq}\frac{di}{dt} = L_1\frac{di}{dt} + L_2\frac{di}{dt} + L_3\frac{di}{dt} + \cdots + L_N\frac{di}{dt}$$

$$\boxed{L_{eq} = L_1 + L_2 + L_3 + \cdots + L_N}$$

6.5 Series & Parallel Inductors

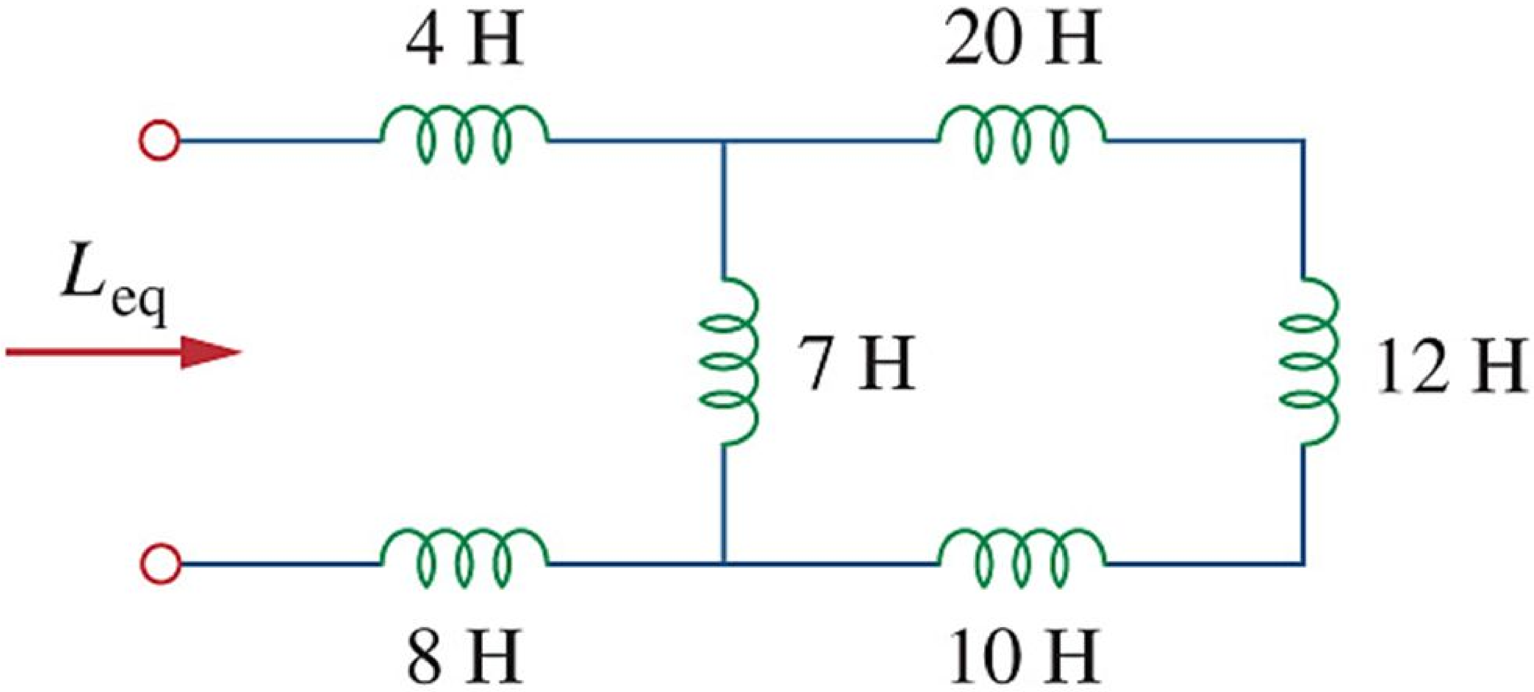
- Inductor의 병렬연결



KCL 적용 :

$$\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots + \frac{1}{L_N}}$$

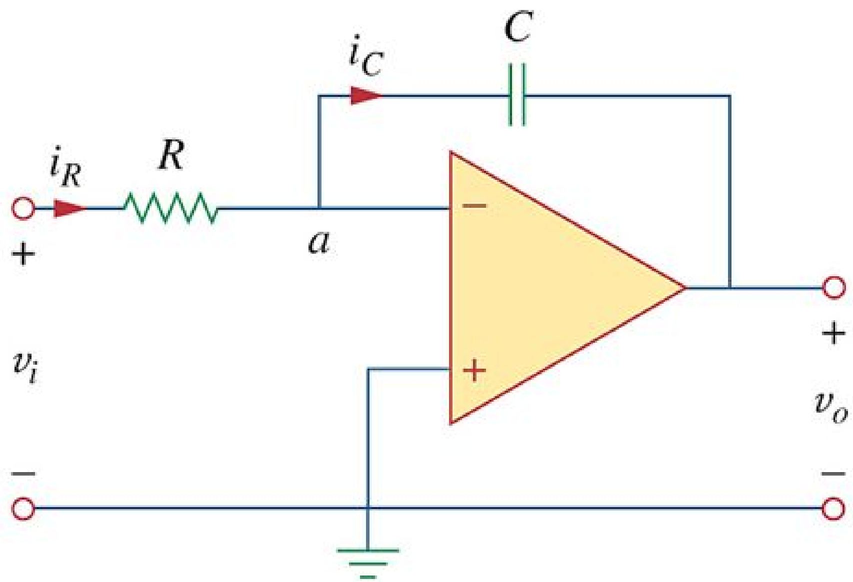
Example 6.11



Summary

Relation	Resistor (R)	Capacitor (C)	Inductor (L)
v-i	$v = iR$	$v = \frac{1}{C}\int i dt$	$v = L\frac{di}{dt}$
i-v	$i = \frac{v}{R}$	$i = C\frac{dv}{dt}$	$i = \frac{1}{L}\int v dt$
전력(p), 에너지(w)	$p = i^2 R = \frac{v^2}{R}$	$w = \frac{1}{2}Cv^2$	$w = \frac{1}{2}Li^2$
직렬연결	$R_{eq} = R_1 + R_2$	$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$	$L_{eq} = L_1 + L_2$
병렬연결	$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$	$C_{eq} = C_1 + C_2$	$L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$
@ 직류	-	open circuit	short circuit
방해 요소	전류의 흐름	전압의 변화	전류의 변화

6.6.1 Integrator (적분기)



Node a에서 KCL 적용 :

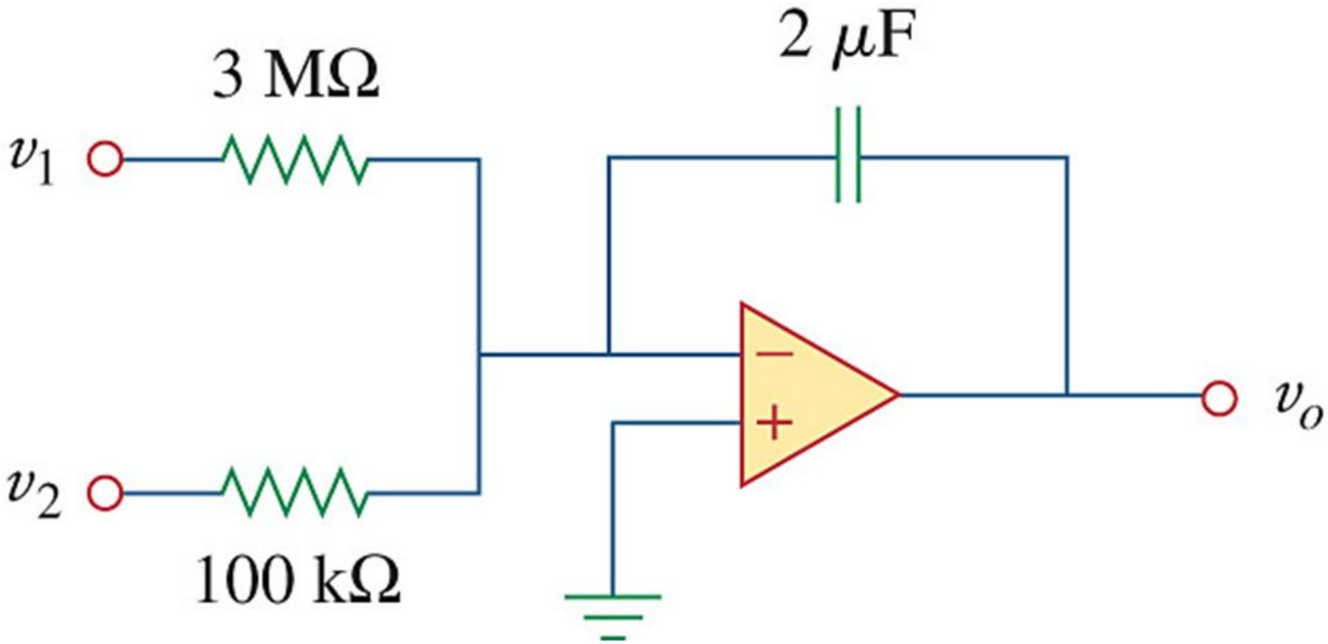
$$i_R = i_C$$

$$\frac{v_i}{R} = -C\frac{dv_o}{dt}$$

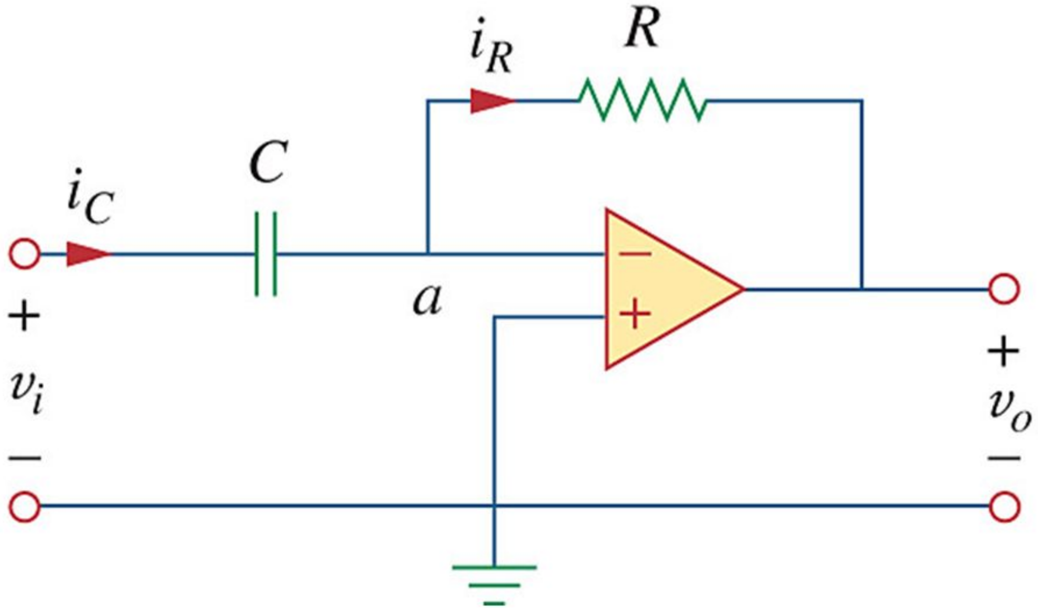
$$\boxed{v_o = -\frac{1}{RC}\int_0^t v_i(t)dt}$$

Example 6.13

- $v_1 = 10cos2t$ mV, $v_2 = 0.5t$ mV



6.6.2 Differentiator (미분기)

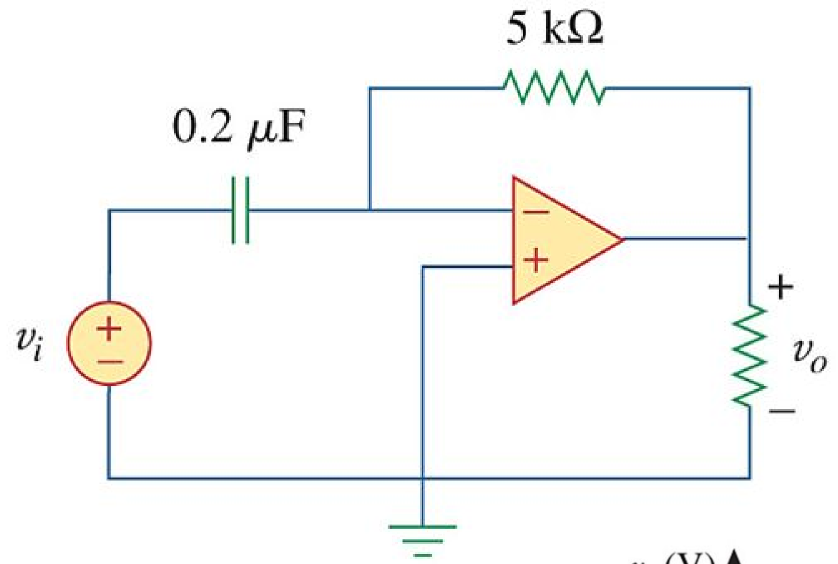


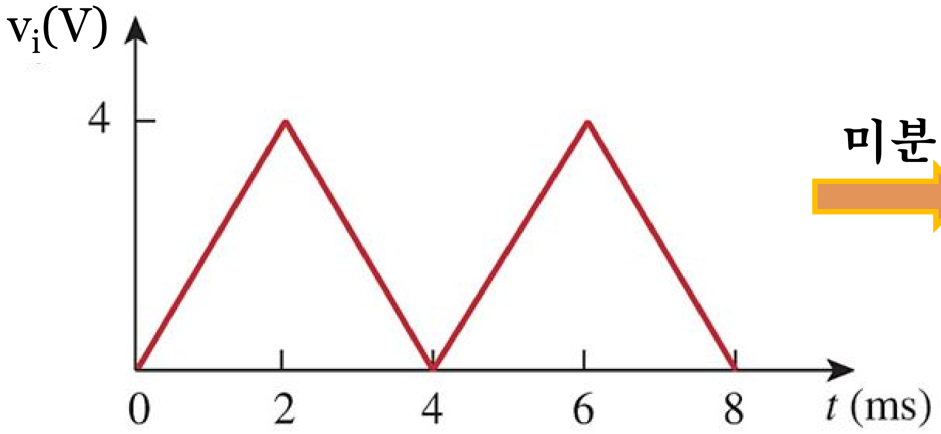
$$i_R = i_C$$

$$-\frac{v_o}{R} = C\frac{dv_i}{dt}$$

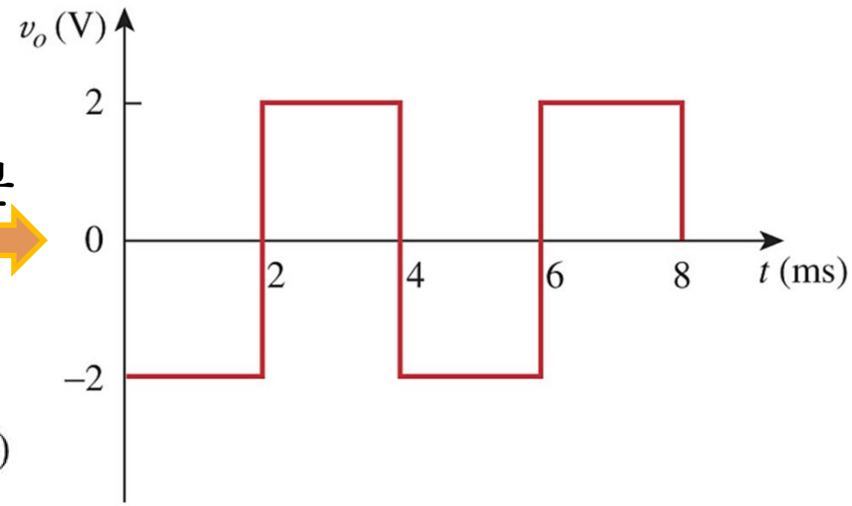
$$\boxed{v_o = -\frac{1}{RC}\frac{dv_i}{dt}}$$

Example 6.14

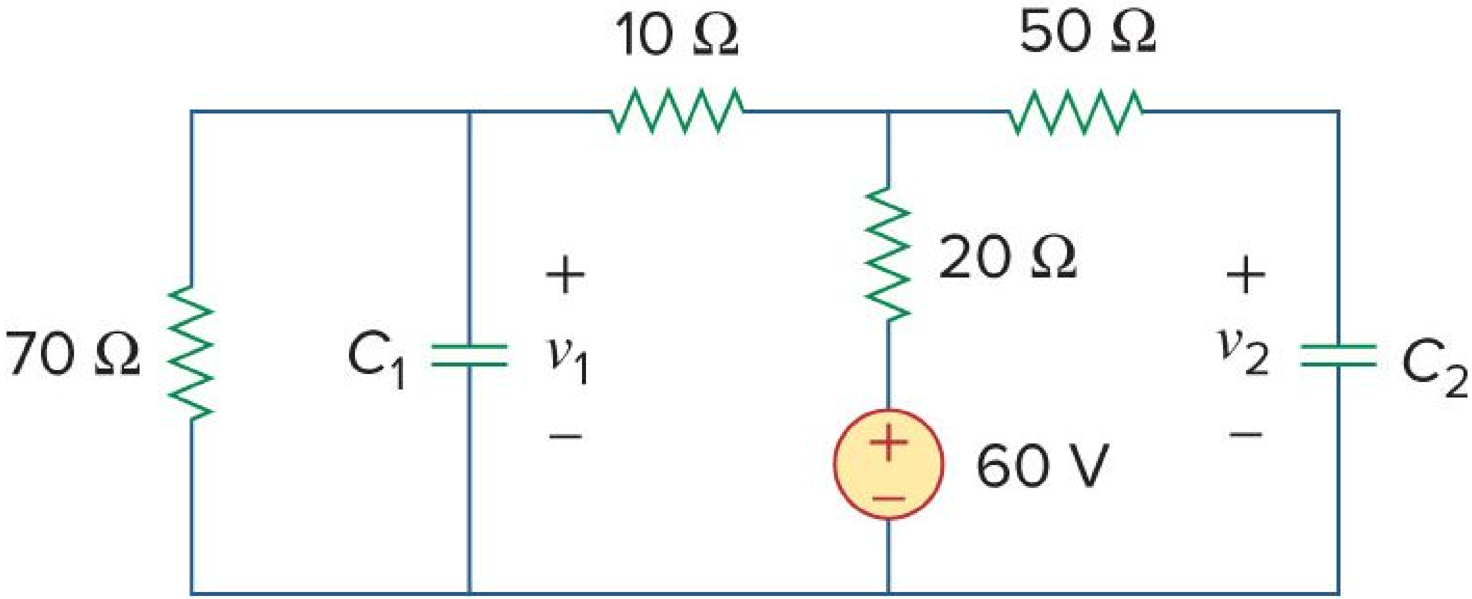




미분

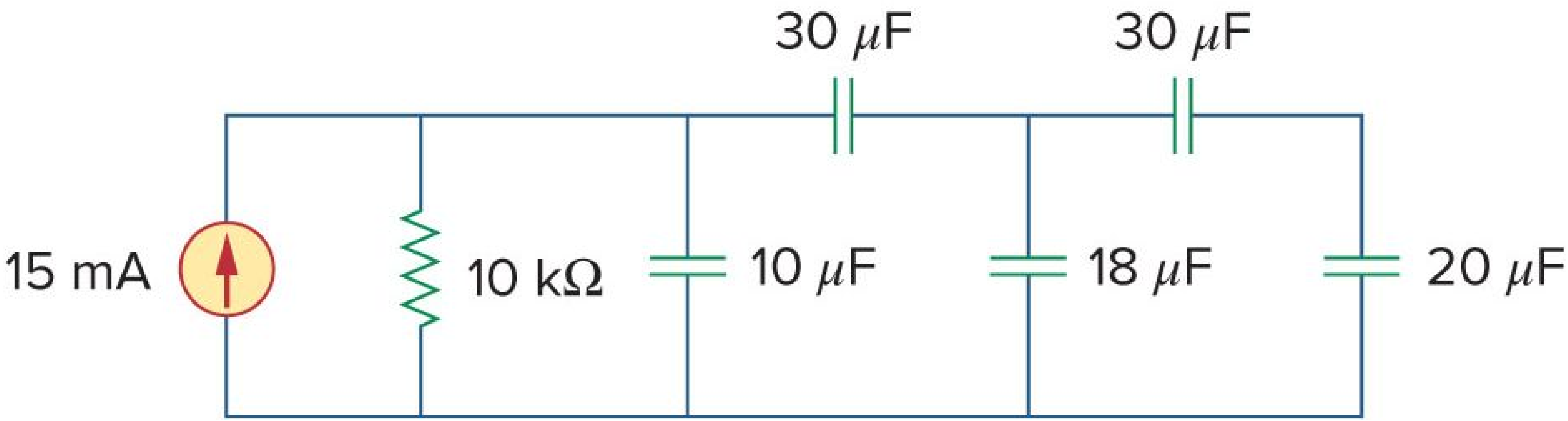


Problem 6.13



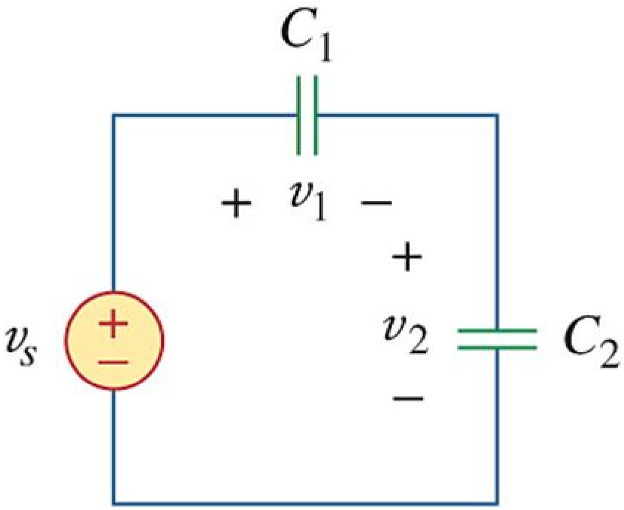
Problem 6.24

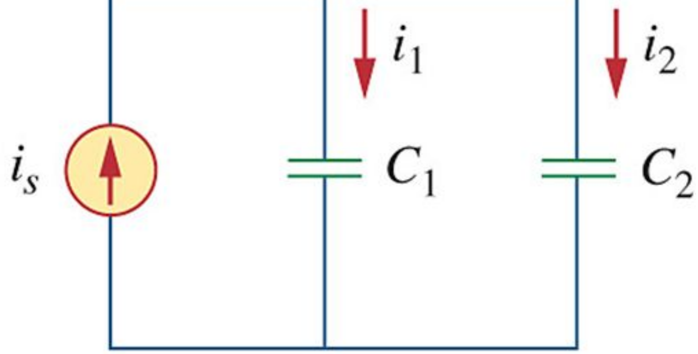
- 각 capacitor에 걸리는 전압은?

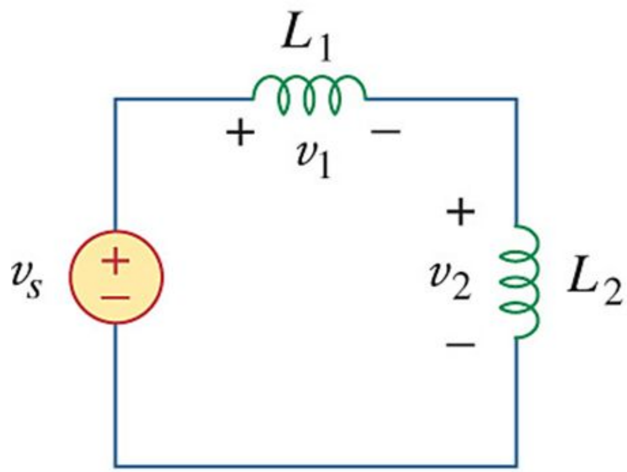


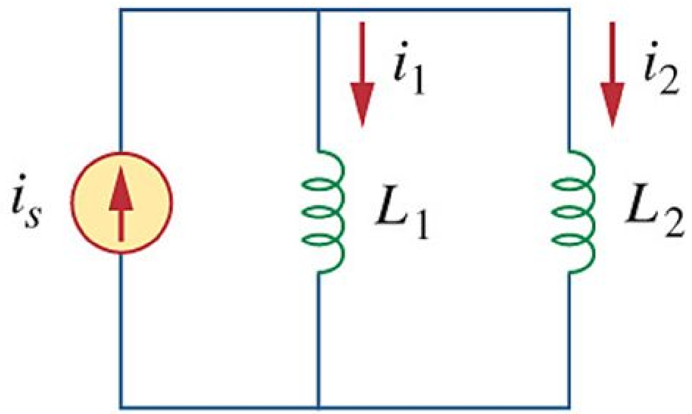
Problem 6.25 & 6.59

- 전압분배 & 전류분배

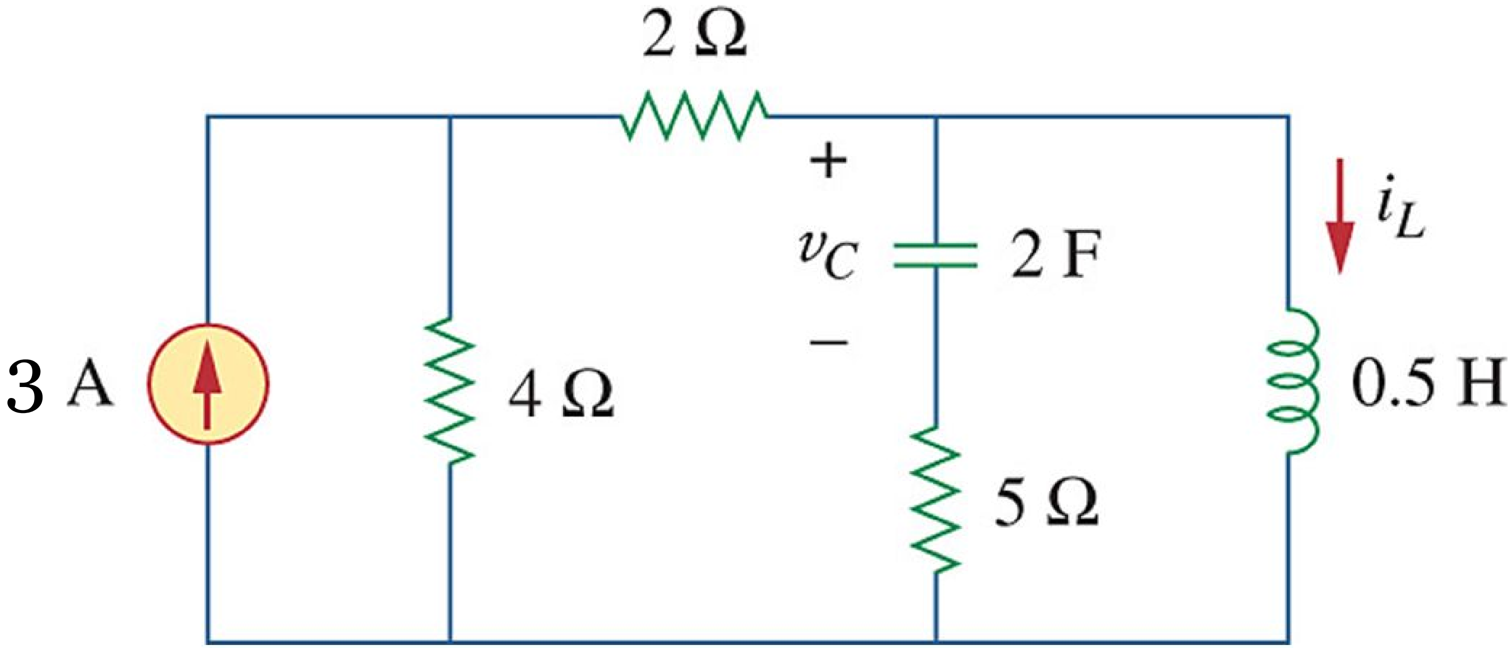








Problem 6.46

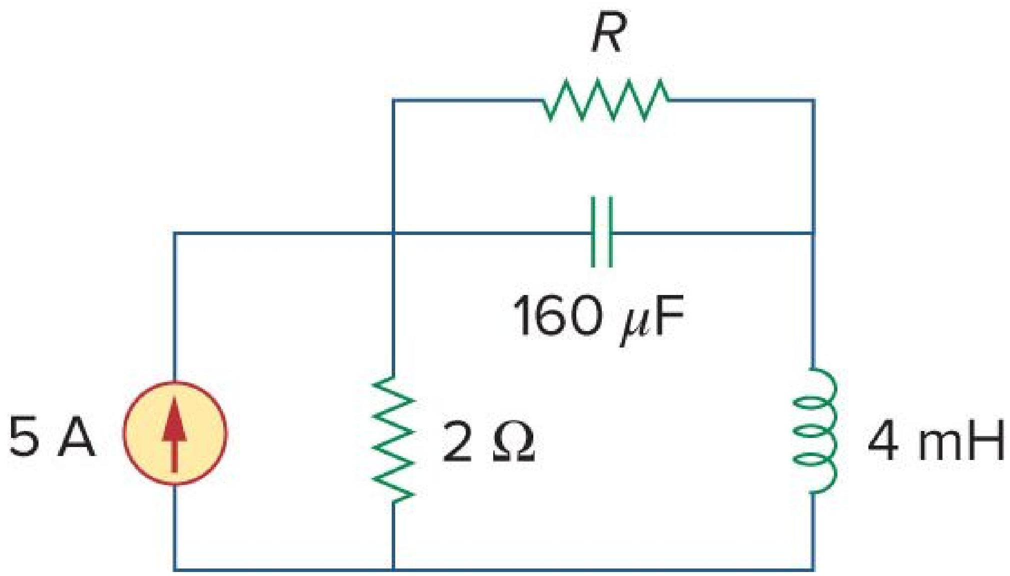


Homework #8

#1. Problem 6.47

커패시터에 저장된 에너지와 인덕터에 저장된 에너지가 같도록

R 값을 구하라.

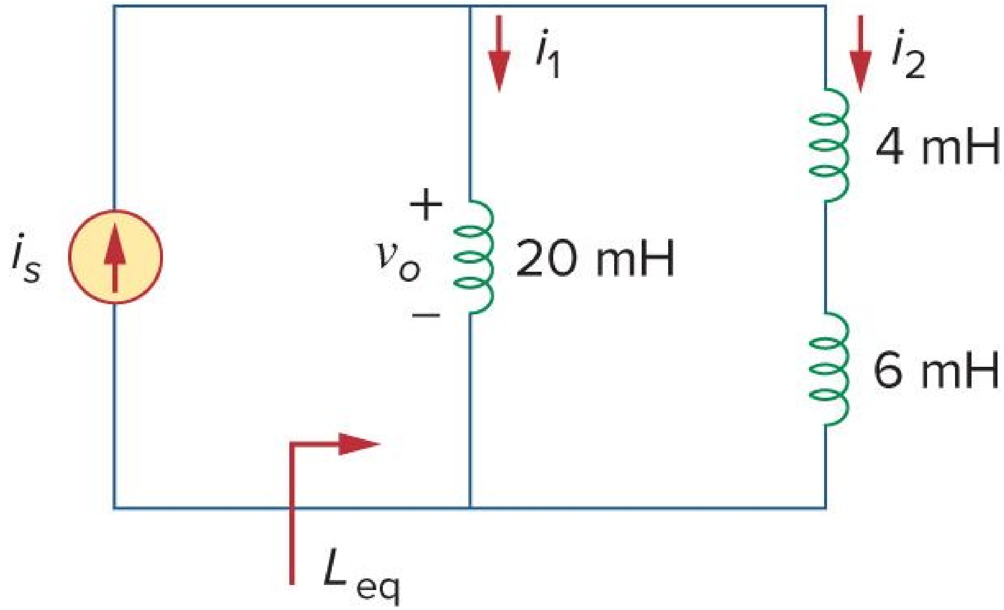


Homework #8

#2. Problem 6.61

(a) $i_s = 3e^{-t}mA$ 일 때, $L_{eq}, i_1(t), i_2(t), v_0(t)$

(b) $t = 1$ 일 때, 인덕터에 저장된 에너지를 구하라.

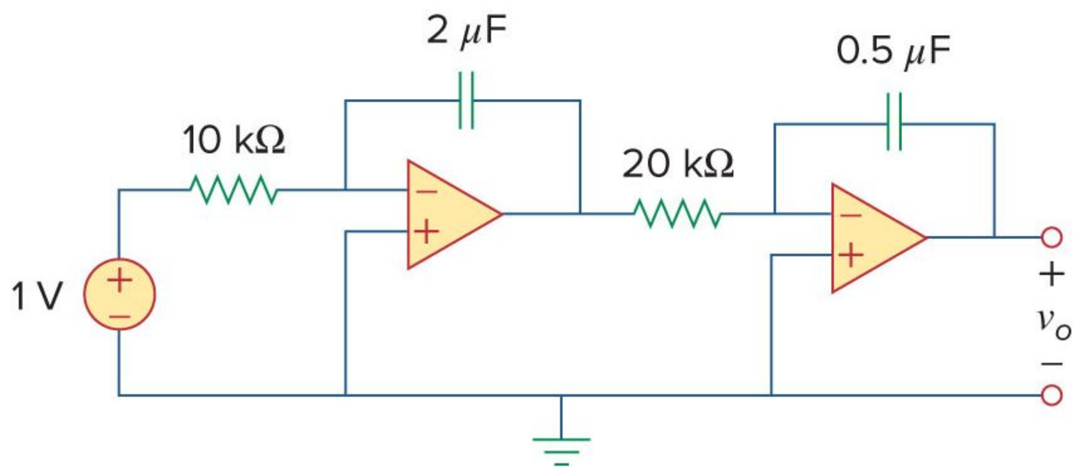


Homework #8

#3. Problem 6.72

아래의 중첩 적분기에 서 $t = 1.5ms$ 일 때 v_o를 구하라.

($t = 0$ 에서 0 V로 초기화 되었다고 가정한다.)



Homework #8

#4. Problem 6.73

다음 회로가 비반전 적분기라는 것을 보여라.