회로이론 I

12년 중간고사

07 명동주

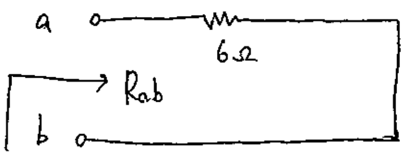
① 저항값. 오차

저항값	0	1	2	3	4	5	6	7	8	9
	검	갈	빨	주	노	초	파	보	회	흰

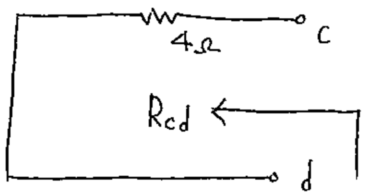
오차	±5%	±10%
	금	은

$25 \times 10^3 [\Omega]$ ±5%

② 등가저항 R_{ab}, R_{cd}

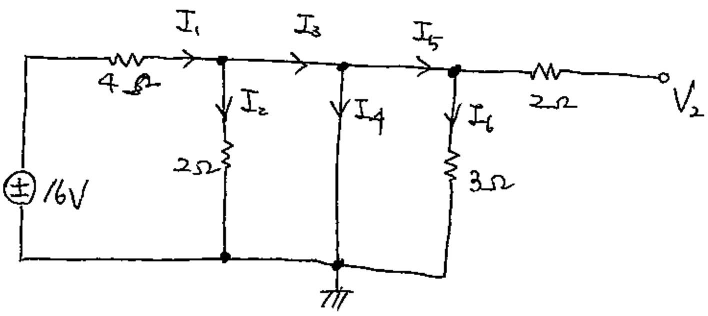


$R_{ab} = 6\Omega$



$R_{cd} = 4\Omega$

* ③~④



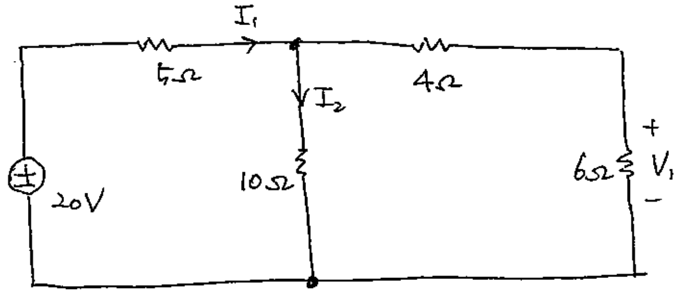
③ $I_1 = \frac{16}{4} = 4A$.　　$I_4 = 4A$

$I_2 = 0A$　　$I_5 = 0A$

$I_3 = 4A$　　$I_6 = 0A$

④ $V_1 = 0V$, $V_2 = 0V$

* ⑤~⑨



⑤ $R_{eq} = 5 + (10 // (4+6))$

$= 5 + (10 // 10)$

$= 5 + 5$

$= 10$

$I_1 = \frac{20}{R_{eq}} = \frac{20}{10} = 2A$.

⑥ $I_2 = I_1 \times \frac{(4+6)}{10 + (4+6)} = 2 \times \frac{1}{2} = 1A$

⑦ $V_1 = (I_1 - I_2) \times 6\Omega$

$= (2-1) \times 6 = 6V$

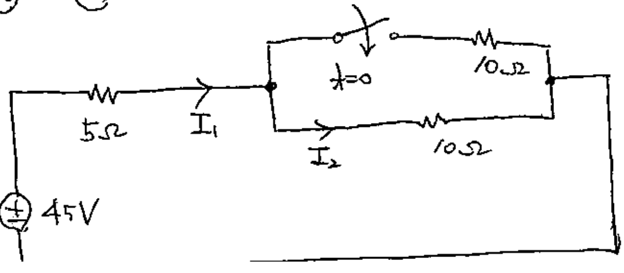
⑧ $\boxed{P = I^2 R}$ 전력

$= 1^2 \times 10 = 10$ [W]

⑨ $\boxed{W = P \cdot t}$ 에너지

$= 10 \times 10 = 100$ [J]

* ⑩~⑫



⑩ $t<0$ 에서 $I_1 = \dfrac{45}{5+10} = 3[A]$

$t>0$ 에서 $I_1 = \dfrac{45}{5+(10/\!/10)} = \dfrac{9}{2}[A]$

$I_{1\,t<0} : I_{2\,t>0} = 2:3$

⑪ $t<0$ 에서 $I_2 = I_1 = 3A$

$t>0$ 에서 $I_2 = I_1 \times \dfrac{10}{10+10} = \dfrac{9}{2} \times \dfrac{1}{2} = \dfrac{9}{4}[A]$

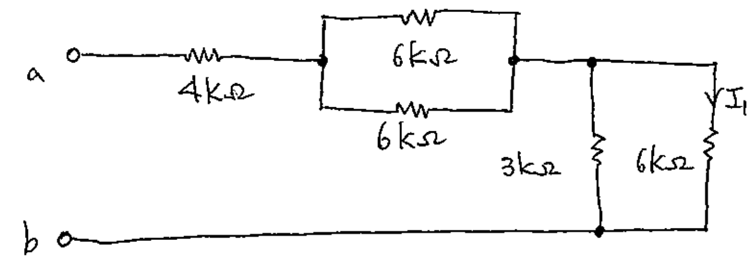
$I_{2\,t<0} : I_{2\,t>0} = 4:3$

⑫ $t<0$ 에서 $P = I^2R = 3^2 \times 5 = 45[W]$

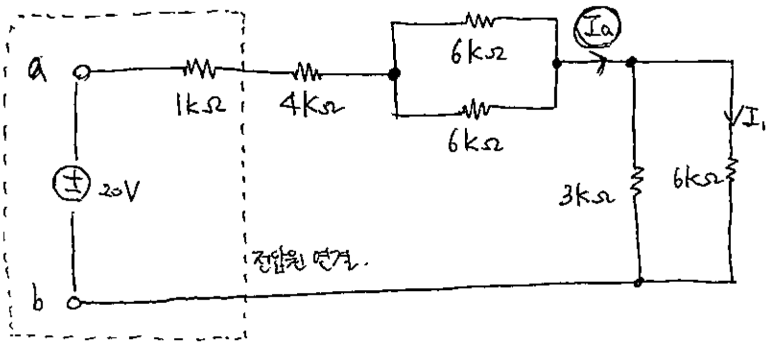
$t>0$ 에서 $P = I^2R = \left(\dfrac{9}{2}\right)^2 \times 5 = \dfrac{405}{4}[W]$

$P_{t<0} : P_{t>0} = 4:9$

* ⑬ ~ ⑭



⑬ 전압원 연결. → 직렬



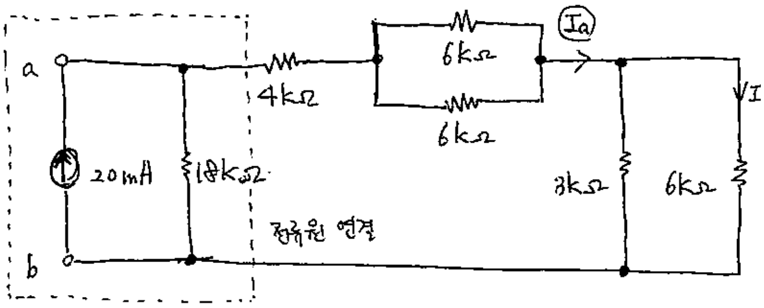
$Req = 1 + 4 + (6/\!/6) + (3/\!/6)$

$= 10[k\Omega]$

$I_a = \dfrac{20}{10k} = 2[mA]$

$\therefore I_1 = I_a \times \dfrac{3k}{3k+6k} = 2\,mA \times \dfrac{1}{3} = \dfrac{2}{3}[mA]$

⑭ 전류원 연결 → 병렬.

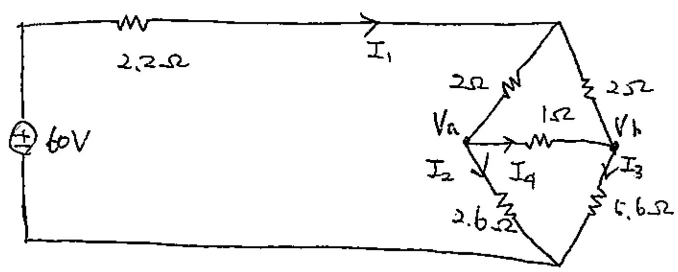


$I_a = 20\,mA \times \dfrac{18k}{18k+9k} = \dfrac{40}{3}[mA]$

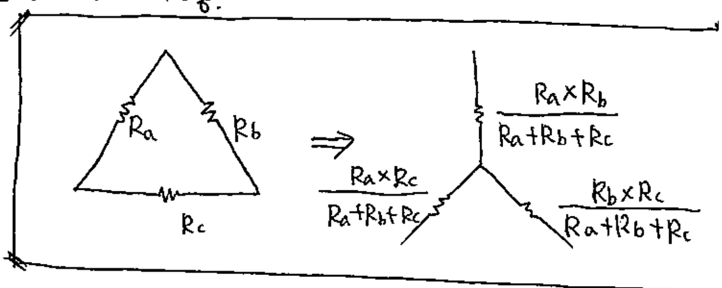
$\because 9k = 4k + (6k/\!/6k) + (3k/\!/6k)$

$\therefore I_1 = I_a \times \dfrac{3k}{3k+6k} = \dfrac{40}{3}\,mA \times \dfrac{1}{3} = \dfrac{40}{9}[mA]$

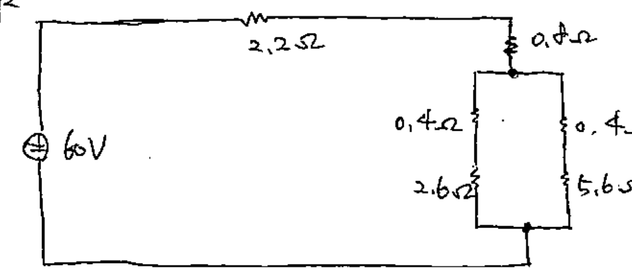
* ⑮ ~ ⑰



⑮ 등가저항 Req.



등가회로



$$\therefore R_{eq} = 2.2 + 0.8 + \left((0.4+2.6) // (0.4+5.6)\right)$$

$$= 3 + (3 // 6)$$

$$= 5\,[\Omega]$$

⑯ $I_1 = \dfrac{60V}{R_{eq}} = \dfrac{60}{5} = 12[A]$

$I_2 = 12 \times \dfrac{6}{3+6} = 12 \times \dfrac{2}{3} = 8[A]$

$I_3 = 12 \times \dfrac{3}{3+6} = 12 \times \dfrac{1}{3} = 4[A]$

⑰ (1Ω의 양단을 V_a, V_b라 잡았을 때)

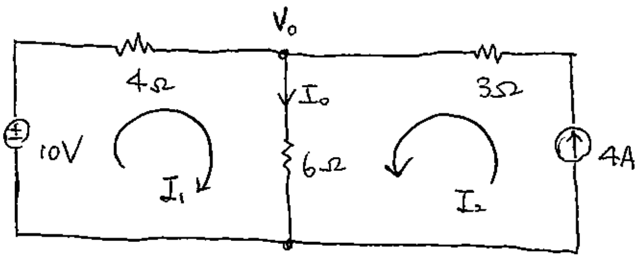
$I_4 = \dfrac{V_a - V_b}{R}$

여기서 $V_a = I_2 \times 2.6 = 8 \times 2.6 = \dfrac{104}{5}\,[V]$

$V_b = I_3 \times 5.6 = 4 \times 5.6 = \dfrac{112}{5}\,[V]$

$\therefore I_4 = \dfrac{\frac{104}{5} - \frac{112}{5}}{1\Omega} = -\dfrac{8}{5}\,[A]$

* ⑱ ~ ㉒



⑱ 마디 해석법.

$I_0 = \dfrac{V_0}{6}$

KCL 적용

$\dfrac{10 - V_0}{4} + 4 = \dfrac{V_0}{6}$

$30 - 3V_0 + 48 = 2V_0$

$5V_0 = 78$

$V_0 = \dfrac{78}{5}$

$\therefore I_0 = V_0 \times \dfrac{1}{6} = \dfrac{78}{5} \times \dfrac{1}{6}$

$= \dfrac{13}{5}\,[A]$

⑲ 루프 해석법

$I_0 = I_1 + I_2 = I_1 + 4$

$(\because I_2 = 4A)$

KVL 적용.

$10 = 4I_1 + 6(I_1 + 4)$

$10I_1 + 24 = 10$

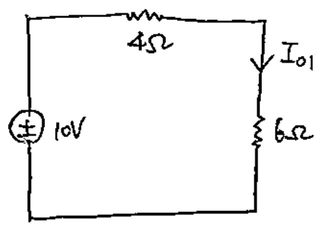
$10I_1 = -14$

$I_1 = -\dfrac{7}{5}\,A$

$\therefore I_0 = I_1 + 4 = -\dfrac{7}{5} + \dfrac{20}{5} = \dfrac{13}{5}\,[A]$

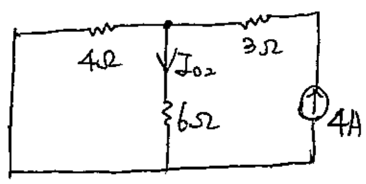
⑳ 중첩의 원리

i) 전압원만 있을 때. (전류원 open)



$I_{01} = \dfrac{10}{10} = 1A$

ii) 전류원만 있을 때 (전압원 close)



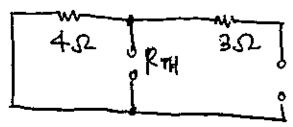
$I_{02} = 4 \times \dfrac{4}{6+4}$

$= \dfrac{8}{5}\,A$

$\therefore I_0 = I_{01} + I_{02} = 1 + \dfrac{8}{5} = \dfrac{13}{5}\,[A]$

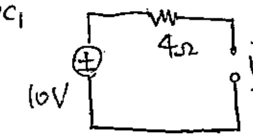
㉑ 테브난의 정리.

i) R_{TH}



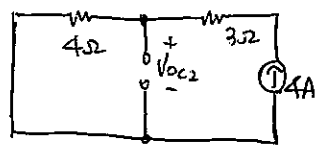
$R_{TH} = 4\Omega$.

ii) V_{OC_1}



$V_{oc1} = 10\ V$

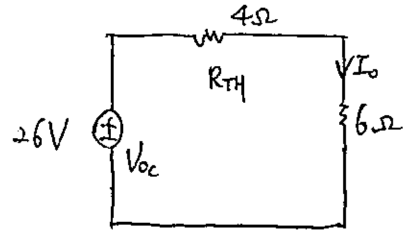
iii) V_{oc2}



$V_{oc_2} = 4 \times 4 = 16V$

$\therefore V_{oc} = 10 + 16 = 26V$

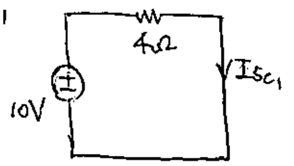
◦ 테브난의 등가회로.



$\therefore I_o = \dfrac{26}{10} = \dfrac{13}{5}[A]$

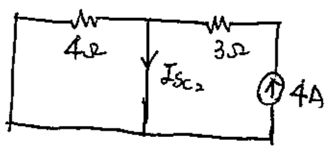
㉒ 노튼의 정리

i) I_{sc_1}



$I_{sc_1} = \dfrac{10}{4} = \dfrac{5}{2} A$

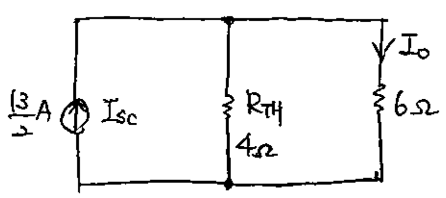
ii) I_{sc_2}



$I_{sc_2} = 4\ A$

$\therefore I_{sc} = \dfrac{5}{2} + 4 = \dfrac{13}{2} A$

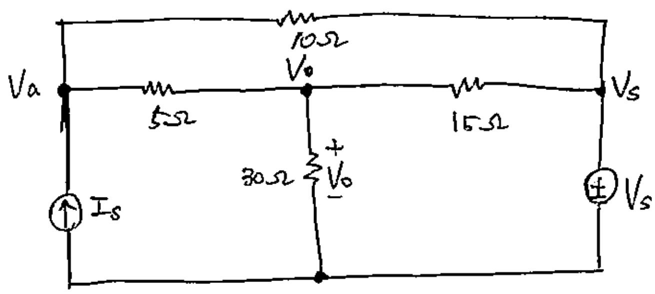
◦ 노튼의 등가회로



$\therefore I_o = \dfrac{13}{2} \times \dfrac{4}{4+6}$

$= \dfrac{13}{5}[A]$

* ㉓ ~ ㉙



㉓ 마디 해석법

V_o 에서 KCL 적용.

$$\frac{V_a - V_o}{5} + \frac{V_s - V_o}{15} = \frac{V_o}{30}$$

$$6V_a - 6V_o + 2V_s - 2V_o = V_o$$

$$9V_o = 6V_a + 2V_s \quad \cdots ①$$

V_a 에서 KCL 적용

$$I_s = \frac{V_a - V_o}{5} + \frac{V_a - V_s}{10}$$

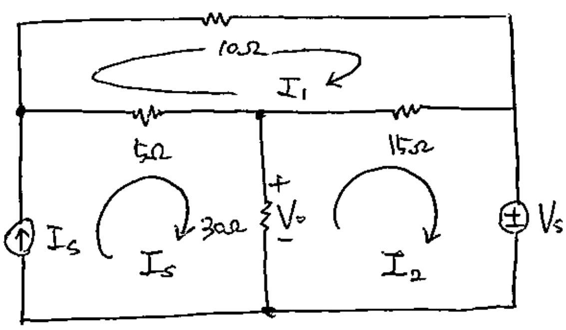
$$10I_s = 2V_a - 2V_o + V_a - V_s$$

$$2V_o = 3V_a - V_s - 10I_s \quad \cdots ②$$

① − ② × 2. 를 하면

$$\begin{array}{rl} & 9V_o = \cancel{6V_a} + 2V_s \\ - & 4V_o = \cancel{6V_a} - 2V_s - 20I_s \\ \hline & 5V_o = 4V_s + 20I_s \end{array}$$

$$\therefore V_o = \frac{4}{5}V_s + 4I_s$$



㉔ 루프해석법

$$V_o = 30(I_s - I_2)$$

I_1 에서 KVL 적용

$$5(I_1 - I_s) + 10I_1 + 15(I_1 - I_2) = 0.$$

$$30I_1 - 15I_2 = 5I_s \quad \cdots ①$$

I_2에서 KVL 적용

$$30(I_2 - I_s) + 15(I_2 - I_1) + V_s = 0$$

$$-15I_1 + 45I_2 = -V_s + 30I_s \quad \cdots ②$$

① + ② × 2 를 하면

$$\begin{array}{rrcl} & 30I_1 - 15I_2 & = & 5I_s \\ + & -30I_1 + 90I_2 & = & -2V_s + 60I_s \\ \hline & 75I_2 & = & -2V_s + 65I_s \end{array}$$

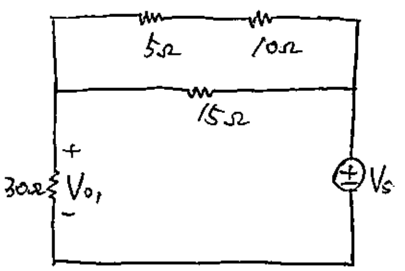
$$I_2 = -\frac{2}{75}V_s + \frac{13}{15}I_s$$

$$\therefore V_o = 30\left(I_s + \frac{2}{75}V_s - \frac{13}{15}I_s\right)$$

$$= \frac{4}{5}V_s + 4I_s$$

㉕ 중첩의 원리

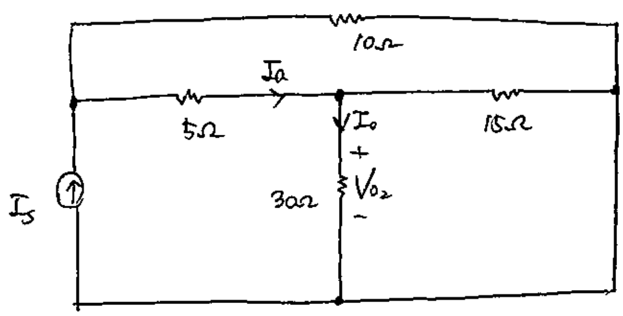
i) 전압원만 있을 때



$$V_{o1} = V_s \times \frac{30}{30 + \frac{15}{2}}$$

$$= \frac{4}{5}V_s$$

ii) 전류원만 있을 때



$$V_{o2} = 30I_o$$

$$I_a = I_s \times \frac{10}{10 + (5 + (30 /\!/ 15))} = \frac{2}{5}I_s$$

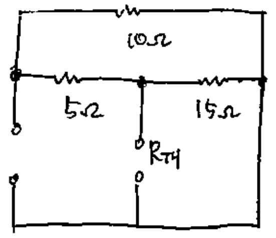
$$I_o = \frac{2}{5}I_s \times \frac{15}{30+15} = \frac{2}{15}I_s$$

$$V_{o2} = 30 \times \frac{2}{15}I_s = 4I_s$$

$$\therefore V_o = V_{o1} + V_{o2} = \frac{4}{5}V_s + 4I_s.$$

㉖ 테브난의 정리.

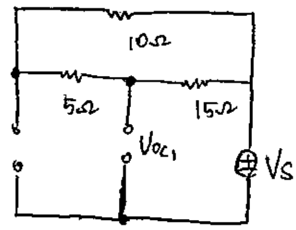
i) R_{TH}



$$R_{TH} = (5+10) /\!/ 15$$

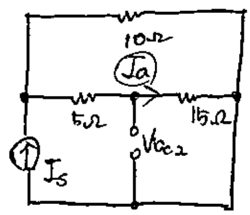
$$= \frac{15}{2}\,\Omega$$

ii) V_{oc1}



$$V_{oc1} = V_s.$$

iii) V_{oc2}



$$V_{oc2} = I_a \times 15$$

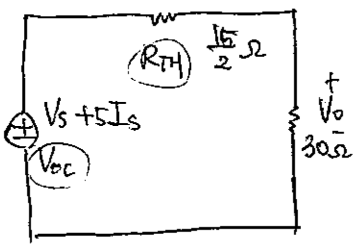
$$I_a = I_s \times \frac{10}{10 + (5+15)}$$

$$= \frac{1}{3}I_s$$

$$V_{oc2} = 5I_s$$

$$\therefore V_{oc} = V_{oc1} + V_{oc2} = V_s + 5I_s$$

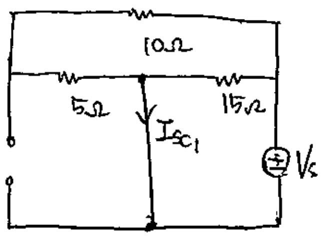
◦ 테브난의 등가회로



$$\therefore V_o = (V_s + 5I_s) \times \frac{30}{\frac{15}{2} + 30} = \frac{4}{5}V_s + 4I_s$$

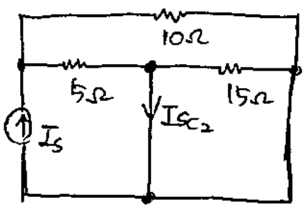
㉗ 노튼의 정리

i) I_{sc_1}



$$I_{sc_1} = \frac{V_s}{\frac{15}{2}} = \frac{2}{15}V_s$$

ii) I_{sc2}

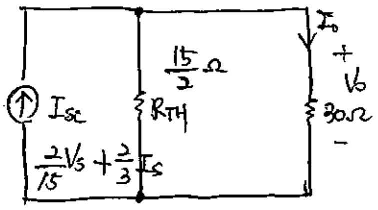


$$I_{sc2} = I_s \times \frac{10}{5+10} = \frac{2}{3}I_s$$

☆ $\boxed{\text{15Ω의 저항으로 전류 흐르지 X}}$

$$\therefore I_{sc} = \frac{2}{15}V_s + \frac{2}{3}I_s$$

∘ 노튼의 등가회로.

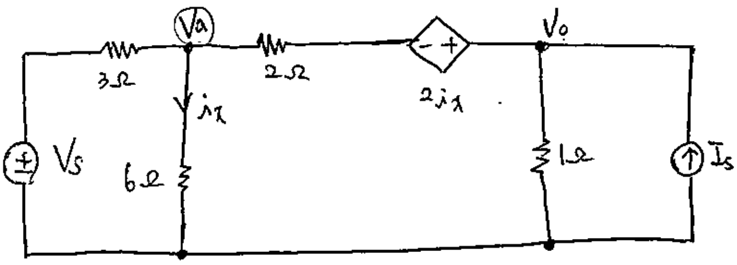


$$V_o = 30 I_o$$

$$I_o = I_{sc} \times \frac{\frac{15}{2}}{\frac{15}{2}+30}$$

$$\therefore V_o = 30 \times \left(\frac{2}{15}V_s + \frac{2}{3}I_s\right) \times \frac{\frac{15}{2}}{\frac{15}{2}+30} = \frac{4}{5}V_s + 4I_s$$

* ㉘ ~ ㉜



㉘ 마디해석법

$$i_x = \frac{V_a}{6}$$

V_a에서 KCL 적용

$$\frac{V_s - V_a}{3} = \frac{V_a}{6} + \frac{V_a - (V_o - 2i_x)}{2}$$

$$2V_s - 2V_a = V_a + 3V_a - 3V_o + V_a$$

$$7V_a - 3V_o = 2V_s \quad \cdots ①$$

V_o에서 KCL 적용

$$\frac{V_a - (V_o - 2i_x)}{2} + I_s = \frac{V_o}{1}$$

$$V_a - V_o + \frac{1}{3}V_a + 2I_s = 2V_o$$

$$\frac{4}{3}V_a - 3V_o = -2I_s$$

$$4V_a - 9V_o = -6I_s \quad \cdots ②$$

$$(① \times 4) - (② \times 7)$$

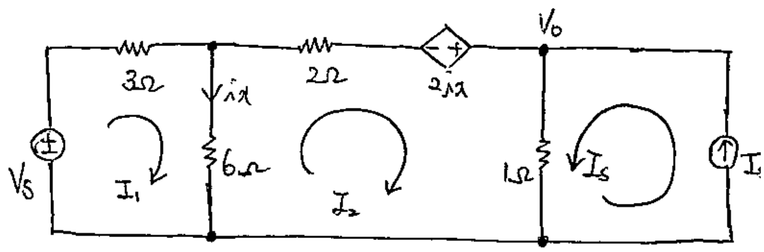
$$28V_a - 12V_o = 8V_s$$

$$-\ \underline{28V_a - 63V_o = -42I_s}$$

$$51V_o = 8V_s + 42I_s$$

$$\therefore V_o = \frac{8}{51}V_s + \frac{14}{17}I_s$$

㉙ 루프 해석법



$$i_x = I_1 - I_2, \quad V_o = 1 \times (I_2 + I_s)$$

I_1에서 KVL 적용

$$V_s = 3I_1 + 6(I_1 - I_2)$$

$$9I_1 - 6I_2 = V_s \quad \cdots ①$$

$$6(I_2 - I_1) + 2I_2 - 2i_x + I_2 + I_s = 0$$

$$6I_2 - 6I_1 + 2I_2 - 2I_1 + 2I_2 + I_2 + I_s = 0$$

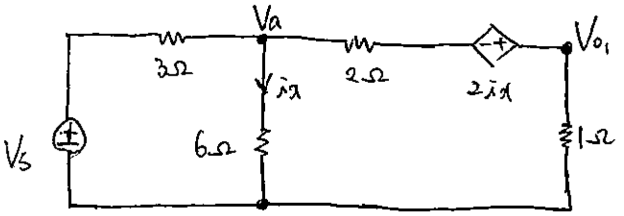
$$-8I_1 + 11I_2 = -I_s \quad \cdots ②$$

(①×8) + (②×9) 을 할 때

$$72I_1 - 48I_2 = 8V_s$$
$$+\ \ -72I_1 + 99I_2 = -9I_s$$
$$51I_2 = 8V_s - 9I_s$$
$$I_2 = \frac{8}{51}V_s - \frac{9}{51}I_s$$
$$\therefore V_o = \frac{8}{51}V_s - \frac{9}{51}I_s + I_s$$
$$= \frac{8}{51}V_s + \frac{14}{17}I_s$$

(30) 중첩의 원리.

i) 전압원만 있을 때



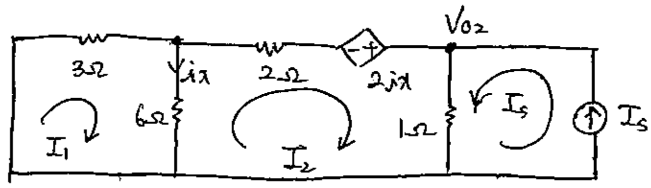
Va에서 KCL 적용

$$\frac{V_s - V_a}{3} = \frac{V_a}{6} + \frac{V_a - (V_{o1} - 2i_x)}{2}$$
$$2V_s - 2V_a = V_a + 3V_a - 3V_{o1} + V_a$$
$$(\because i_x = \tfrac{1}{6}V_a)$$
$$7V_a - 3V_{o1} = 2V_s \cdots ①$$
$$\frac{V_a - (V_{o1} - 2i_x)}{2} = \frac{V_{o1}}{1}$$
$$V_a - V_{o1} + \frac{1}{3}V_a = 2V_{o1}$$
$$\frac{4}{3}V_a - 3V_{o1} = 0$$
$$4V_a - 9V_{o1} = 0 \cdots ②$$

(①×4) − (②×7)을 할 때

$$28V_a - 12V_{o1} = 8V_s$$
$$-\ \ 28V_a - 63V_{o1} = 0$$
$$51V_{o1} = 8V_s$$
$$\therefore V_{o1} = \frac{8}{51}V_s$$

ii) 전류원만 있을 때



$$i_x = I_1 - I_2, \quad V_{o2} = 1 \times (I_2 + I_s)$$

I1에서 KVL 적용.

$$3I_1 + 6(I_1 - I_2) = 0.$$
$$9I_1 - 6I_2 = 0 \cdots ①$$

I2에서 KVL 적용.

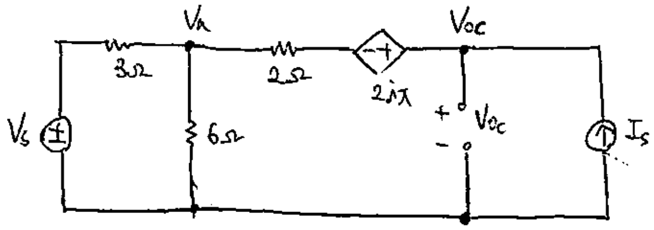
$$6(I_2 - I_1) + 2I_2 - 2i_x + I_2 + I_s = 0.$$
$$6I_2 - 6I_1 + 2I_2 - 2I_1 + 2I_2 + I_2 + I_s = 0$$
$$-8I_1 + 11I_2 = -I_s \cdots ②$$

(①×8) + (②×9)를 할 때

$$72I_1 - 48I_2 = 0$$
$$+\ \ -72I_1 + 99I_2 = -9I_s$$
$$51I_2 = -9I_s$$
$$I_2 = -\frac{9}{51}I_s$$
$$V_{o2} = -\frac{9}{51}I_s + I_s = \frac{14}{17}I_s$$
$$\therefore V_o = V_{o1} + V_{o2} = \frac{8}{51}V_s + \frac{14}{17}I_s$$

③ ~ ③ V_{oc}, I_{sc}, R_{TH} 구하기.

- V_{oc} 구하기.



V_a에서 KCL 적용

$$\frac{V_s - V_a}{3} = \frac{V_a}{6} + \frac{V_a - (V_{oc} - 2i_x)}{2}$$

$$2V_s - 2V_a = V_a + 3V_a - 3V_{oc} + V_a$$

$$(\because i_x = \frac{1}{6}V_a)$$

$$7V_a - 3V_{oc} = 2V_s \quad \cdots ①$$

V_{oc} 에서 KCL 적용

$$\frac{V_a - (V_{oc} - 2i_x)}{2} + I_s = 0.$$

$$V_a - V_{oc} + \frac{1}{3}V_a = -2I_s$$

$$\frac{4}{3}V_a - V_{oc} = -2I_s$$

$$4V_a - 3V_{oc} = -6I_s \quad \cdots ②$$

$(①\times 4) - (②\times 7)$ 을 할 때

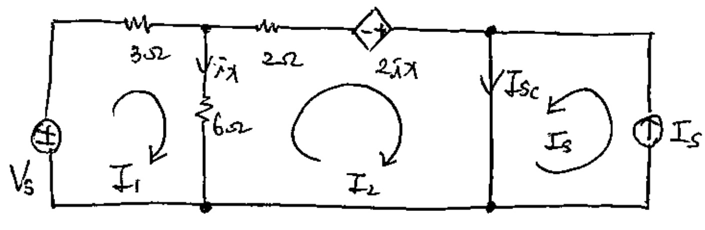
$$28V_a - 12V_{oc} = 8V_s$$

$$-\quad 28V_a - 21V_{oc} = -42I_s$$

$$9V_{oc} = 42I_s + 8V_s$$

$$\therefore V_{oc} = \frac{8}{9}V_s + \frac{14}{3}I_s.$$

- I_{sc} 구하기



$$i_x = I_1 - I_2 \quad , \quad I_{sc} = I_2 + I_s$$

I_1 에서 KVL 적용

$$V_s = 3I_1 + 6(I_1 - I_2)$$

$$9I_1 - 6I_2 = V_s \quad \cdots ①$$

I_2 에서 KVL 적용

$$6(I_2 - I_1) + 2I_2 - 2i_x = 0$$

$$6I_2 - 6I_1 + 2I_2 - 2I_1 + 2I_2 = 0$$

$$-8I_1 + 10I_2 = 0 \quad \cdots ②$$

$(①\times 8) + (②\times 9)$ 를 할 때

$$72I_1 - 48I_2 = 8V_s$$

$$+\quad -72I_1 + 90I_2 = 0$$

$$42I_2 = 8V_s$$

$$I_2 = \frac{4}{21}V_s$$

$$\therefore I_{sc} = \frac{4}{21}V_s + I_s.$$

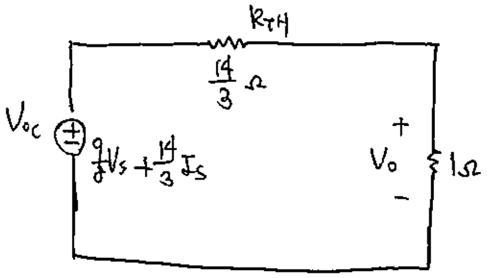
- R_{TH} 구하기

$$R_{TH} = \frac{V_{oc}}{I_{sc}} = \frac{\frac{8}{9}V_s + \frac{14}{3}I_s}{\frac{4}{21}V_s + I_s}$$

$$= \frac{\frac{14}{3}\left(\frac{\cancel{8}^{4}}{\cancel{9}_{3}} \times \frac{\cancel{3}}{\cancel{14}_{7}}V_s + I_s\right)}{\left(\frac{4}{21}V_s + I_s\right)} = \frac{14}{3}\,\Omega$$

31 테브난의 정리

◦ 테브난의 등가회로.

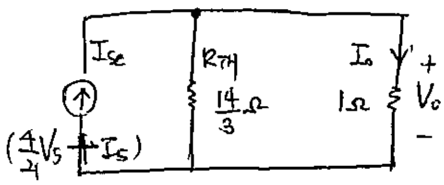


$$V_o = \left(\frac{9}{8}V_s + \frac{14}{3}I_s\right) \times \frac{1}{\frac{14}{3}+1}$$

$$= \frac{8}{51}V_s + \frac{14}{17}I_s$$

32 노튼의 정리

◦ 노튼의 등가회로.



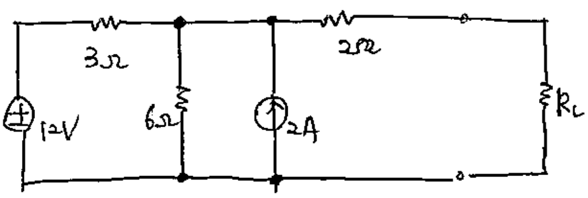
$$V_o = 1 \times I_o = I_o$$

$$I_o = I_{sc} \times \frac{\frac{14}{3}}{\frac{14}{3}+1}$$

$$\therefore V_o = \left(\frac{4}{21}V_s + I_s\right) \times \frac{\frac{14}{3}}{\frac{14}{3}+1}$$

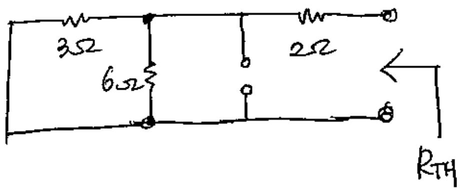
$$= \frac{8}{51}V_s + \frac{14}{17}I_s$$

※ 33 ~ 34



33 최대전력 위한 R_L 값

$\boxed{R_{TH} = R_L \text{ 일때 최대전력이 전달 됨.}}$



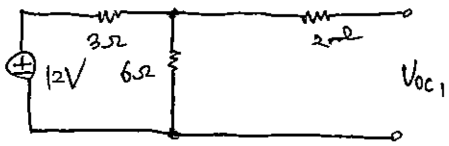
$$R_{TH} = 2 + (3 /\!/ 6) = 2 + 2 = 4\Omega.$$

$\therefore R_L = 4\Omega$ 일때 최대전력.

34 R_L에 최대전력.

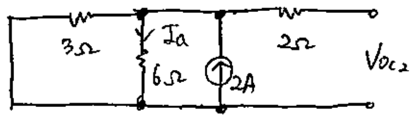
$$\boxed{P_{L/max} = \frac{V_{oc}^2}{4R_{TH}}}$$

i) V_{oc1}



$$V_{oc1} = 12 \times \frac{6}{3+6} = 8V$$

ii) V_{oc2}



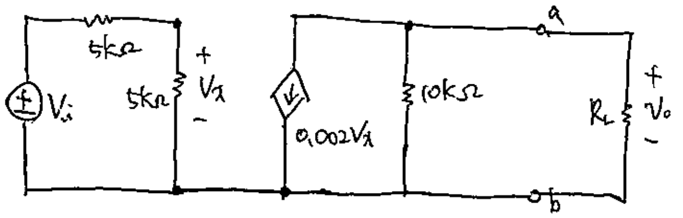
$$V_{oc2} = 6 \times I_a$$

$$= 6 \times 2 \times \frac{3}{3+6} = 4V$$

$$\therefore V_{oc} = 8 + 4 = 12V$$

$$\therefore P_{L/max} = \frac{12^2}{4 \times 4} = 9\ [W]$$

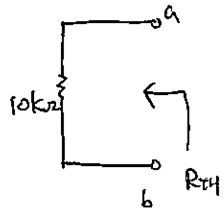
* ㉟ ~ ㊳



∴ 전압이득 $A_v = \frac{v_o}{V_i} = \frac{-5V_i}{v_i} = -5$

수고하셨습니다. 좋은 결과 있으시길 ... ^^

㉟ i) R_{TH}



$R_{TH} = 10k\Omega$

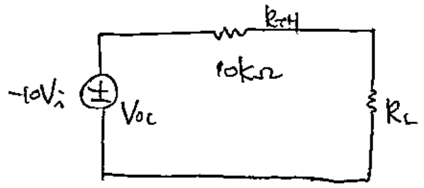
ii) V_{oc}

$$V_{oc} = -0.002V_x \times 10k. = -20V_x$$

$$= -20 \times \frac{5k}{5k+5k} V_i$$

$$= -10V_i$$

◦ 테브난의 등가회로



㊱ 최대전력 전달을 위해선 $R_L = R_{TH}$ 이어야 하므로.

$$R_L = 10[k\Omega]$$

㊲ 최대전력

$$P_{L/max} = \frac{V_{oc}^2}{4 \cdot R_{TH}} = \frac{(-10V_i)^2}{4 \times 10k} = 2.5V_i^2 [mW]$$

㊳ 전압이득

$$V_o = -10V_i \times \frac{\overset{R_L}{10k}}{\underbrace{10k}_{R_{TH}} + \underbrace{10k}_{R_L}} = -5V_i$$

회로 이론 I

12년 기말고사

07 명동수

① 저항값 . 오차.

저항값	0	1	2	3	4	5	6	7	8	9
	검	갈	빨	주	노	초	파	보	회	흰

오차 ±5% ±10%

금 은

25×10^4 [Ω] ± 5%

② capacitor 용량. 오차.

22×10^2 [pF] ± 5%

1H : 50 V (정격전압을 나타냄)

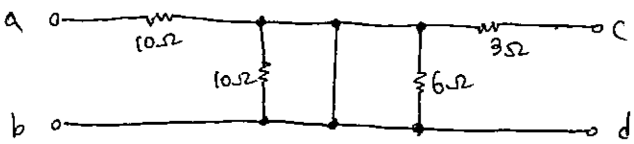
222 : $\boxed{22} \times 10^{\boxed{2}}$ [pF]

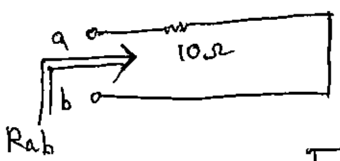
22: 앞 두자리수, 2: 셋째자리수

J : 오차 ±5% ±10% ±20%

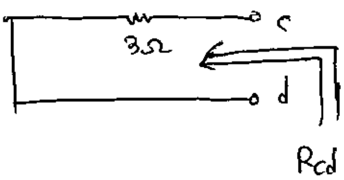
J K M

③ 등가저항 Rab . Rcd



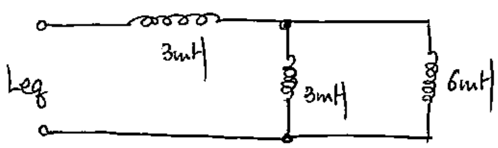


$R_{ab} = 10\Omega$.



$R_{cd} = 3\Omega$

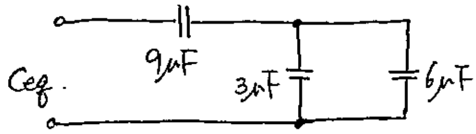
④ 등가 인덕턴스 Leq 는?



$L_{eq} = 3\text{ mH} + (3\text{ mH} \parallel 6\text{ mH})$

$= 3\text{mH} + 2\text{mH} = 5[\text{mH}]$

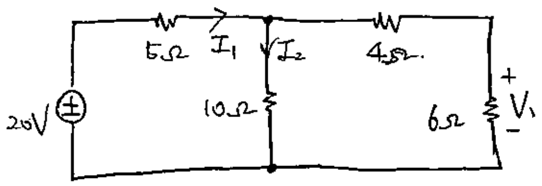
⑤ 등가 capacitance. Ceq 는?



$C_{eq} = 9\mu F \parallel (3\mu F + 6\mu F)$

$= 9\mu F \parallel 9\mu F = \frac{9}{2}[\mu F]$

* ⑥~⑦



⑥ I_1과 I_2 및 V_1을 구하시오.

$R_{eq} = 5 + (10 \parallel (6+4)) = 10\Omega$.

$I_1 = \frac{V}{R_{eq}} = \frac{20}{10} = 2[A]$

$I_2 = 2A \times \frac{10}{10+10} = 1[A]$

$V_1 = 6 \times 1 = 6[V]$

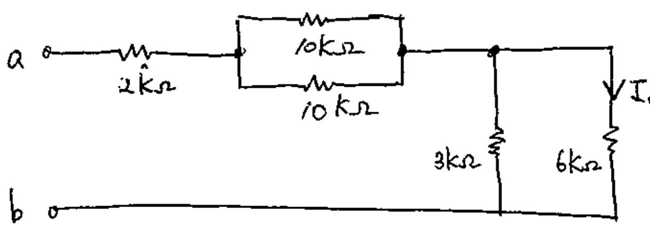
⑦ $\boxed{P = I^2 R}$ 전력

$\boxed{W = P \cdot t}$ 에너지.

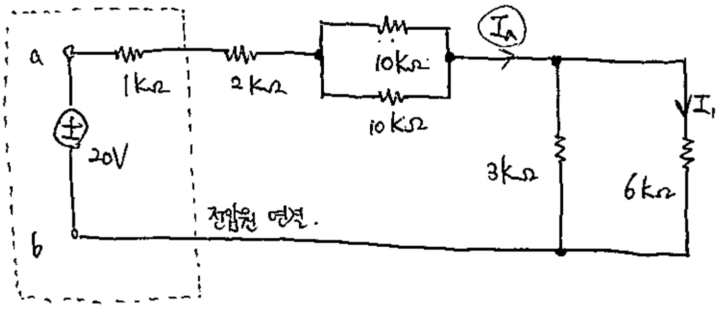
$P = 1^2 \times 10 = 10$ [W]

$W = 10 \times 10 = 100$ [J]

* ⑧



⑧ 전압원 연결.



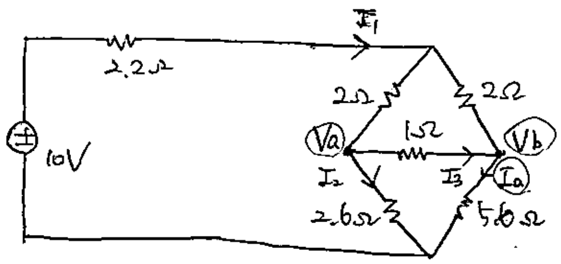
$$R_{eq} = 1k + 2k + (10k /\!/ 10k) + (3k /\!/ 6k)$$

$$= 10k\Omega.$$

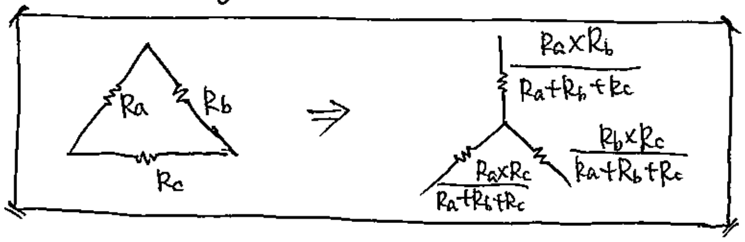
$$I_a = \frac{20}{10k} = 2\,mA$$

$$I_1 = 2mA \times \frac{3k}{3k + 6k} = \frac{2}{3}\,[mA]$$

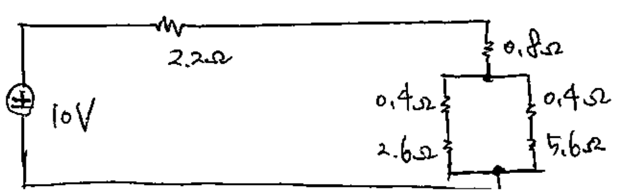
* ⑨ ~ ⑪



⑨ 등가저항 R_{eq}



등가회로



$$R_{eq} = 2.2 + 0.8 + \left((0.4+2.6) /\!/ (0.4+5.6)\right)$$

$$= 3 + (3 /\!/ 6)$$

$$= 5\,[\Omega]$$

⑩ I_1, I_2

$$I_1 = \frac{V}{R_{eq}} = \frac{10}{5} = 2\,[A]$$

$$I_2 = 2A \times \frac{6}{3+6} = \frac{4}{3}\,[A]$$

⑪ I_3.

$$I_a = 2A \times \frac{3}{3+6} = \frac{2}{3}\,A.$$

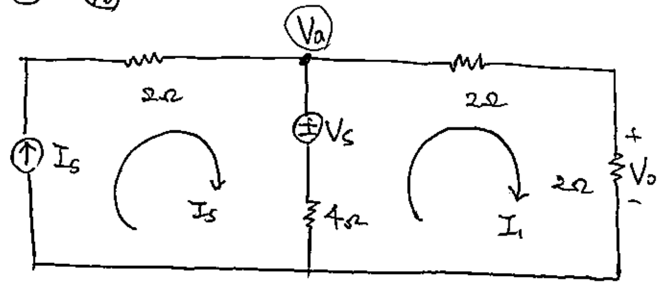
$$I_3 = \frac{V_a - V_b}{R}$$

여기서 $V_a = I_2 \times 2.6 = \frac{4}{3} \times \frac{13}{5} = \frac{52}{15}\,V$

$V_b = I_a \times 5.6 = \frac{2}{3} \times \frac{28}{5} = \frac{56}{15}\,V$

$$I_3 = \frac{\frac{52}{15} - \frac{56}{15}}{1\Omega} = -\frac{4}{15}\,[A]$$

* ⑫ ~ ⑯



⑫ 마디해석법

$$V_o = \frac{2}{2+2} V_a. = \frac{1}{2} V_a$$

V_a에서 KCL 적용

$$I_s = \frac{V_a - V_s}{4} + \frac{V_a}{4}$$

$$4I_s = V_a - V_s + V_a$$

$$V_a = 2I_s + \frac{1}{2} V_s$$

$$\therefore V_0 = \frac{1}{2}V_a = \frac{1}{2}\left(2I_s + \frac{1}{2}V_s\right)$$

$$= I_s + \frac{1}{4}V_s$$

⑬ 루프 해석법

I_1 에서 KVL 적용

$$V_s = 4(I_1 - I_s) + 2I_1 + 2I_1$$

$$V_s = 8I_1 - 4I_s.$$

$$I_1 = \frac{1}{2}I_s + \frac{1}{8}V_s \quad \cdots ①$$

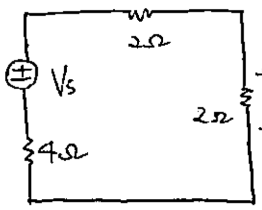
구하려는 V_0 는

$V_0 = 2I_1 \quad \cdots ②$ 이므로 대입하면

$$\therefore V_0 = 2\left(\frac{1}{2}I_s + \frac{1}{8}V_s\right) = I_s + \frac{1}{4}V_s$$

⑭ 중첩의 원리

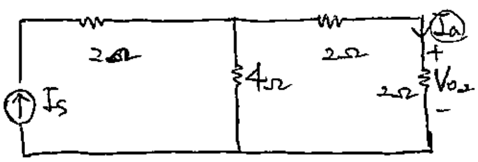
i) 전압원만 있을 때 (전류원 open)



$$V_{01} = \frac{2}{4+2+2} \times V_s$$

$$= \frac{1}{4}V_s$$

ii) 전류원만 있을 때 (전압원 close)



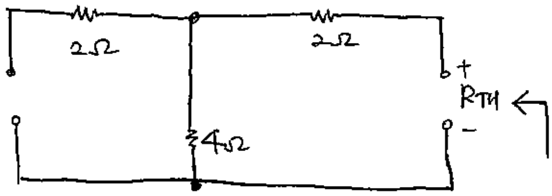
$$I_a = I_s \times \frac{4}{4+(2+2)} = \frac{1}{2}I_s$$

$$V_{02} = 2 \cdot I_a = 2 \times \frac{1}{2}I_s = I_s$$

$$\therefore V_0 = V_{01} + V_{02} = I_s + \frac{1}{4}V_s$$

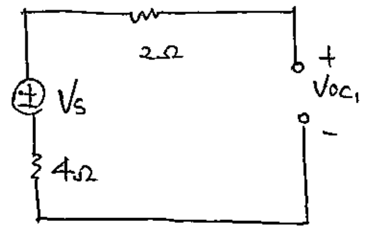
⑮ 테브난의 정리

i) R_{TH}



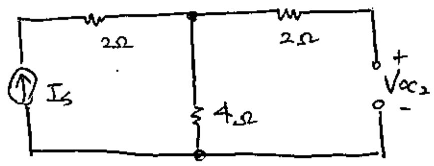
$R_{TH} = 6\Omega.$

ii) V_{oc_1}



$V_{oc_1} = V_s$

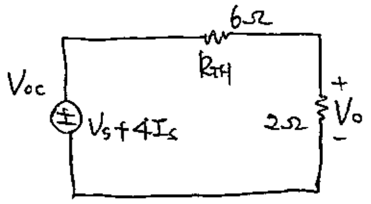
iii) V_{oc_2}



$V_{oc_2} = 4I_s$

$$\therefore V_{oc} = V_s + 4I_s$$

• 테브난의 등가회로



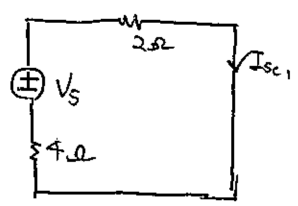
$$V_0 = V_{oc} \times \frac{2}{R_{TH}+2}$$

$$\therefore V_0 = (V_s + 4I_s) \times \frac{2}{6+2}$$

$$= I_s + \frac{1}{4}V_s$$

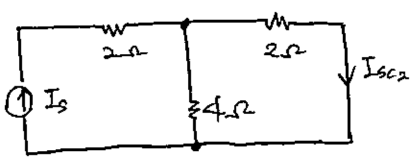
⑯ 노튼의 정리

i) I_{sc_1}



$$I_{sc_1} = \frac{1}{6}V_s$$

ii) I_{sc_2}

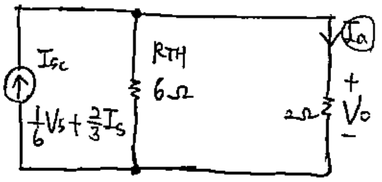


$$I_{sc_2} = I_s \times \frac{4}{4+2}$$

$$= \frac{2}{3}I_s$$

$$\therefore I_{sc} = \frac{1}{6}V_s + \frac{2}{3}I_s$$

o노튼의 등가회로

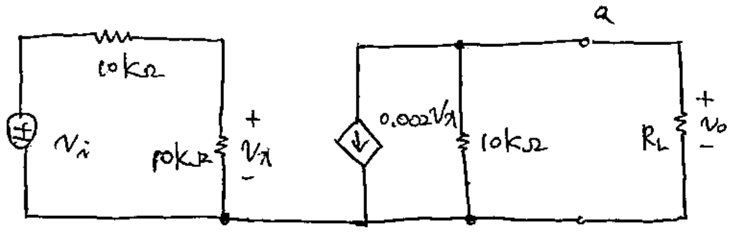


$$V_o = 2 \times I_a$$

$$I_a = I_{sc} \times \frac{6}{6+2} = \frac{3}{4}I_{sc}$$

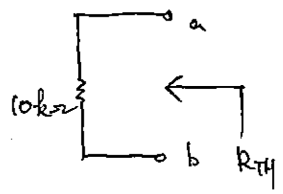
$$\therefore V_o = 2 \times \frac{3}{4} \times \left(\frac{1}{6}V_s + \frac{2}{3}I_s\right) = I_s + \frac{1}{4}V_s$$

* ⑰ ~ ⑳



⑰ 등가회로

i) R_{TH}



$$R_{TH} = 10k\Omega$$

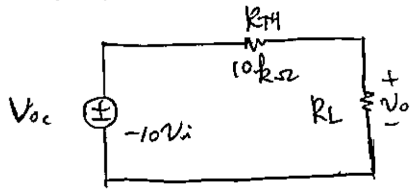
ii) V_{oc}

$$V_{oc} = -0.002V_x \times 10k = -20V_x$$

$$= -20 \times \frac{10k}{10k+10k} V_i$$

$$= -10V_i$$

o 등가회로



⑱ 최대 전력 전달을 위해선 $R_L = R_{TH}$ 이어야 하므로

$$R_L = 10[k\Omega]$$

⑲ 최대전력

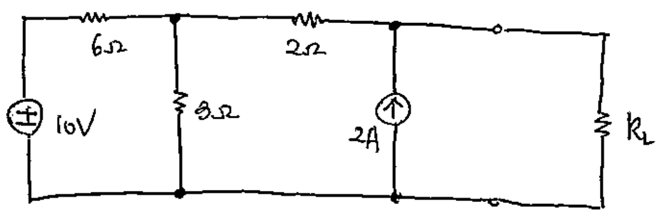
$$P_{L/max} = \frac{V_{oc}^2}{4 \cdot R_{TH}} = \frac{(-10V_i)^2}{4 \times 10k} = 2.5V_i^2[m]$$

⑳ 전압이득

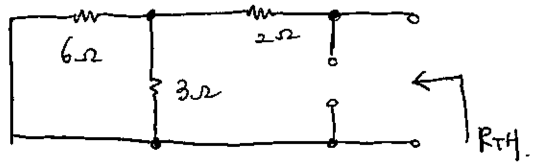
$$V_o = -10V_i \times \frac{\overbrace{10k}^{R_L}}{\underbrace{10k}_{R_{TH}} + \underbrace{10k}_{R_L}} = -5V_i$$

$$\therefore \text{전압이득} \quad A_v = \frac{v_o}{v_i} = \frac{-5V_i}{V_i} = -5$$

※ ㉑ ~ ㉒



㉑ 최대전력 전달 위한 R_L.

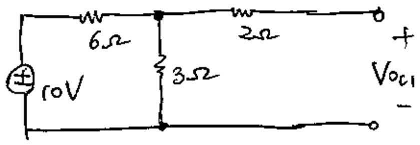


$$R_{TH} = 2 + (6 /\!/ 3) = 2+2 = 4[\Omega]$$

$R_L = 4[\Omega]$ 일때 최대 전력.

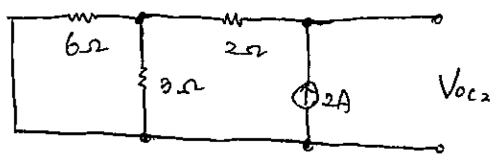
㉒ 최대전력.

i) V_{oc1}



$$V_{oc1} = 10 \times \frac{3}{6+3} = \frac{10}{3} V$$

ii) V_{oc2}

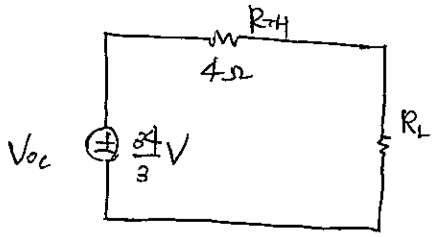


$$V_{oc2} = 2A \times (2 + (3/\!/6))$$

$$= 8V$$

$$\therefore V_{oc} = V_{oc1} + V_{oc2} = \frac{10}{3}V + 8V = \frac{34}{3}[V]$$

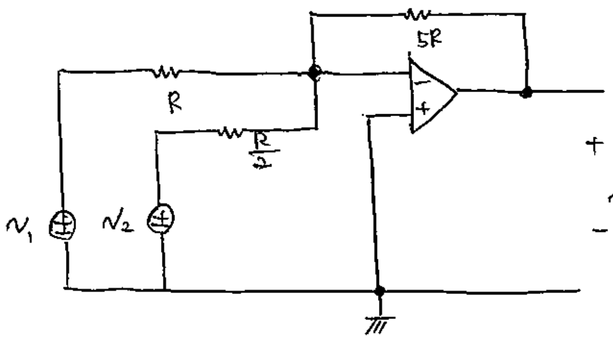
∘ 테브난의 등가회로



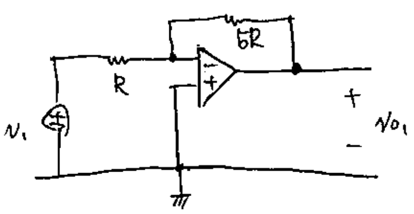
$$\therefore P_{L max} = \frac{V_{oc}^2}{4 \cdot R_{TH}} = \frac{(\frac{34}{3})^2}{4 \times 4} = 8.03$$

$$\doteqdot 8\ [W]$$

* ㉓



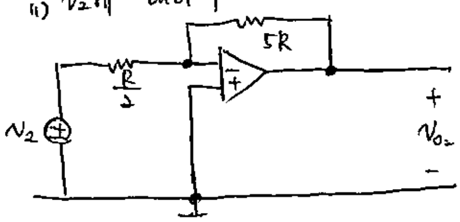
i) v_1에 대하여



$$v_{o1} = -\frac{5R}{R}v_1$$

$$= -5v_1$$

ii) v_2에 대하여

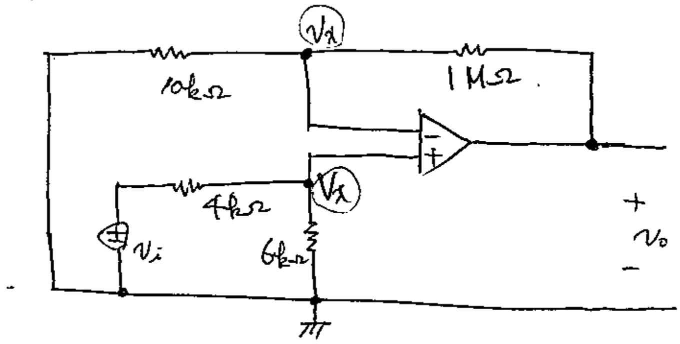


$$v_{o2} = -\frac{5R}{\frac{R}{2}}v_2$$

$$= -10v_2$$

$$\therefore v_o = v_{o1} + v_{o2} = -5v_1 - 10v_2.$$

* ㉔



⊕단자에서

$$v_x = \frac{6k}{4k+6k}v_i = \frac{3}{5}v_i \cdots ①$$

⊖단자에서

$$\frac{v_o - v_x}{1M} = \frac{v_x}{10k}$$

$$v_o = \frac{1M}{10k}v_x + v_x = 101\,v_x \cdots ②$$

①을 ②에 대입.

$$v_o = 101 \times \frac{3}{5}v_i$$

$$\therefore \frac{v_o}{v_i} = \frac{303}{5}$$

* ㉕ ~ ㉘ Laplace 변환

㉕ $\ddot{v}(t) + 3\dot{v}(t) + 2v(t) = 4u_s(t)$. $v(0) = \dot{v}(0) =$

$$\xrightarrow{\mathcal{L}} s^2V(s) + 3sV(s) + 2V(s) = \frac{4}{s}$$

$$V(s) = \frac{4}{s(s^2+3s+2)} = \frac{4}{s(s+1)(s+2)}$$

$$= \frac{A}{s} + \frac{B}{s+1} + \frac{C}{s+2}$$

$$A = V(s) \times s\Big|_{s=0} = 2$$

$$B = V(s) \times (s+1)\Big|_{s=-1} = -4$$

$$C = V(s) \times (s+2)\Big|_{s=-2} = 2$$

$$\therefore V(s) = \frac{2}{s} + \frac{-4}{s+1} + \frac{2}{s+2}$$

$$\xrightarrow{\mathcal{L}^{-1}} v(t) = 2 - 4e^{-t} + 2e^{-2t} \quad , t \geq 0$$

(26) $\ddot{v}(t) + 4\dot{v}(t) + 4v(t) = 8u_s(t)$, $v(0) = \dot{v}(0) = 0$

$$\xrightarrow{\mathcal{L}} s^2V(s) + 4sV(s) + 4V(s) = \frac{8}{s}$$

$$V(s) = \frac{8}{s(s^2+4s+4)} = \frac{8}{s(s+2)^2}$$

$$= \frac{A}{s} + \frac{B}{(s+2)^2} + \frac{C}{s+2}$$

$$A = \frac{8}{s(s+2)^2} \times s \Big|_{s=0} = 2$$

$$B = \frac{8}{s(s+2)^2} \times (s+2)^2 \Big|_{s=-2} = -4$$

$$C = \frac{d}{ds}\left[\frac{8}{s(s+2)^2} \times (s+2)^2\right]\Big|_{s=-2}$$

$$= \frac{d}{ds}\left[\frac{8}{s}\right]\Big|_{s=-2}$$

$$= \frac{-8}{s^2}\Big|_{s=-2} = -2$$

$$\therefore V(s) = \frac{2}{s} + \frac{-4}{(s+2)^2} + \frac{-2}{s+2}$$

$$\xrightarrow{\mathcal{L}^{-1}} \underline{v(t) = 2 - 4t\cdot e^{-2t} - 2e^{-2t}, \quad t \geq 0}$$

(27) $\ddot{v}(t) + 4\dot{v}(t) + 13v(t) = 26u_s(t)$, $v(0) = \dot{v}(0) = 0$

$$\xrightarrow{\mathcal{L}} s^2V(s) + 4sV(s) + 13V(s) = \frac{26}{s}$$

$$V(s) = \frac{26}{s(s^2+4s+13)}$$

$$= \frac{A}{s} + \frac{Bs+C}{s^2+4s+13}$$

$$A = \frac{26}{s(s^2+4s+13)} \times s \Big|_{s=0} = 2$$

$B = ?$ $\quad C = ?$

$$2(s^2+4s+13) + Bs^2 + Cs = 26$$

$$(2+B)s^2 + (8+C)s = 0$$

$$B = -2, \quad C = -8$$

$$\therefore V(s) = \frac{2}{s} + \frac{-2s-8}{s^2+4s+13}$$

$$= \frac{2}{s} + \frac{-2s-8}{(s+2)^2+3^2}$$

$$= \frac{2}{s} + \frac{-2(s+2)}{(s+2)^2+3^2} + \frac{-\frac{4}{3} \times 3}{(s+2)^2+3^2}$$

$$\xrightarrow{\mathcal{L}^{-1}} \underline{v(t) = 2 - 2e^{-2t}\cos 3t - \frac{4}{3}e^{-2t}\sin 3t, \quad t \geq 0.}$$

(28) $\ddot{v}(t) + 9v(t) = 9u_s(t)$, $v(0) = \dot{v}(0) = 0$

$$\xrightarrow{\mathcal{L}} s^2V(s) + 9V(s) = \frac{9}{s}$$

$$V(s) = \frac{9}{s(s^2+9)}$$

$$= \frac{A}{s} + \frac{Bs+C}{s^2+9}$$

$$A = \frac{9}{s(s^2+9)} \times s \Big|_{s=0} = 1$$

$B = ?$ $\quad C = ?$

$$s^2 + 9 + Bs^2 + Cs = 9$$

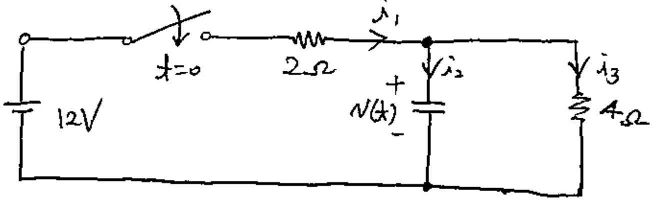
$$(1+B)s^2 + Cs = 0$$

$$B = -1, \quad C = 0.$$

$$\therefore V(s) = \frac{1}{s} + \frac{-s}{s^2+3^2}$$

$$\xrightarrow{\mathcal{L}^{-1}} \underline{v(t) = 1 - \cos 3t, \quad t \geq 0}$$

* (29) v(31)

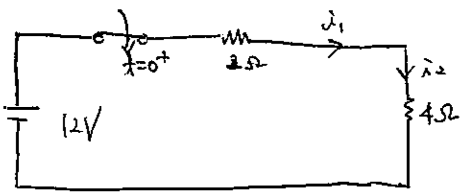


(29) $t = 0^-$ 에서

$$i_1(0^-) = i_2(0^-) = i_3(0^-) = 0[A]$$

$$v(0^-) = 0[V]$$

30 $t=0^+$ 에서

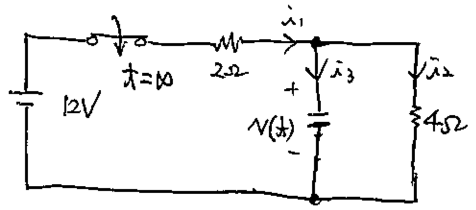


$i_1(0^+) = i_2(0^+) = \frac{12}{2} = 6$ [A]

$i_3(0^+) = 0$ [A]

$v_o(0^-) = v(0^+) = 0$[V]

31 $t=\infty$ 에서

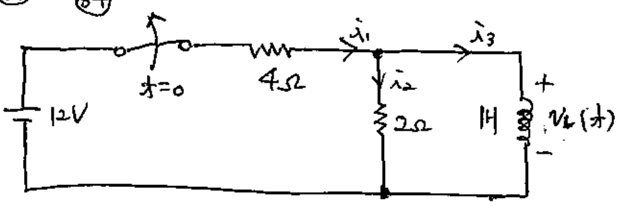


$i_1(\infty) = i_3(\infty) = \frac{12}{2+4} = 2$ [A]

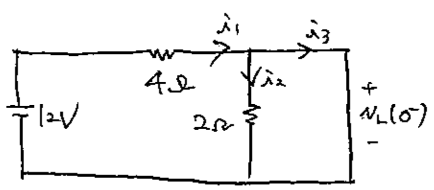
$i_2(\infty) = 0$ [A]

$v(\infty) = 12 \times \frac{4}{2+4} = 8$ [V]

* 32 ~ 34



32 $t=0^-$ 에서

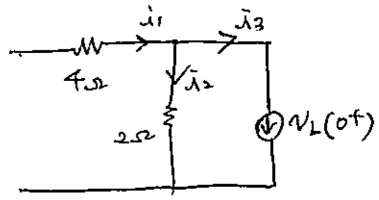


$i_1(0^-) = i_3(0^-) = \frac{12}{4} = 3$ [A]

$i_2(0^-) = 0$[A]

$v_L(0^-) = 0$ [V]

33 $t=0^+$ 에서



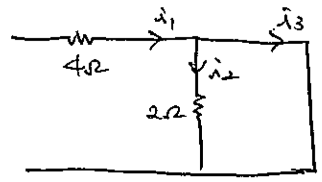
$i_1(0^+) = 0$[A]

$i_3(0^+) = i_3(0^-) = 3$ [A]

$i_2(0^+) = -3$ [A]

$v_L(0^+) = -3 \times 2 = -6$ [V]

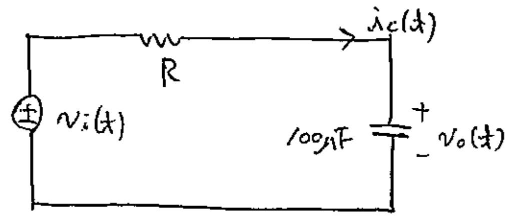
34 $t=\infty$ 에서



$i_1(\infty) = i_2(\infty) = i_3(\infty) = 0$ [A]

$v_L(\infty) = 0$ [V]

* 35 ~ 39



35 v_i 와 v_o 관계식

$v_i(t) = R \cdot i_c(t) + v_o(t)$

* $i_c(t) = 100\mu F \cdot \frac{d v_o(t)}{dt}$

$\therefore v_i(t) = R \cdot 100\mu \cdot \frac{d v_o(t)}{dt} + v_o(t)$

36 선형임을 보여라

$\boxed{\text{★ 비례성과 중첩성을 만족해야 선형}}$

i) 비례성

$\alpha v_i(t) = \alpha\left(R \cdot 100\mu F \cdot \frac{d}{dt} v_o(t) + v_o(t)\right)$

$= R \cdot 100\mu F \cdot \frac{d}{dt} \alpha v_o(t) + \alpha v_o(t)$

입력 $\alpha v_i(t)$에 대한 출력 $\alpha v_o(t)$ 성립 ⇒ 비례성

ii) 중첩성

입력을 $v_i = v_{i1} + v_{i2}$ 로 줄때

$$v_{i1} = R \cdot 100\mu \cdot \frac{d}{dt} v_{o1}(t) + v_{o1}(t)$$

$$v_{i2} = R \cdot 100\mu \cdot \frac{d}{dt} v_{o2}(t) + v_{o2}(t)$$

$$\Rightarrow v_{i1} + v_{i2} = R \cdot 100\mu \cdot \frac{d}{dt}\left(v_{o1}(t) + v_{o2}(t)\right) + \left(v_{o1}(t) + v_{o2}(t)\right)$$

가 성립. ⇒ 중첩성.

즉, 중첩성과 비례성 모두 만족하므로 선형.

(37) 시정수

$$\boxed{\tau = RC}$$

$$\tau = R \times 100\mu$$

$$= R \times 100 \times 10^{-6} = \underline{R \times 10^{-4}\ [s]}$$

(38).(39) $v_o(t)$ 파형 그리기

시정수와 정상상태 시간.

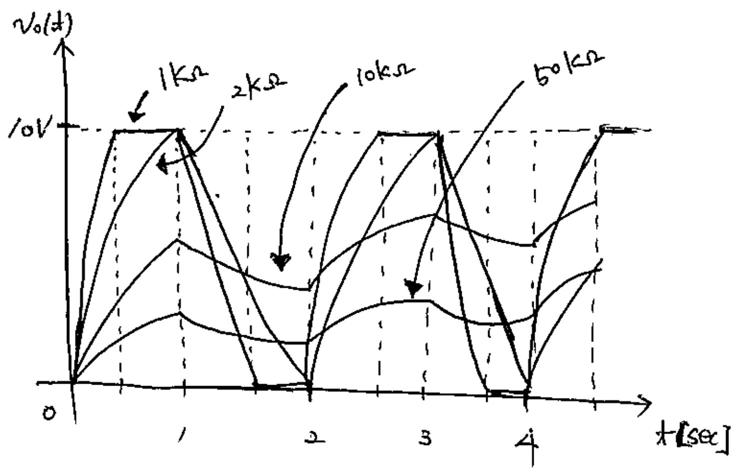
정상상태 (5τ 일때)

$R = 1k\Omega \rightarrow \tau = 0.1s$, $5\tau = 0.5s$

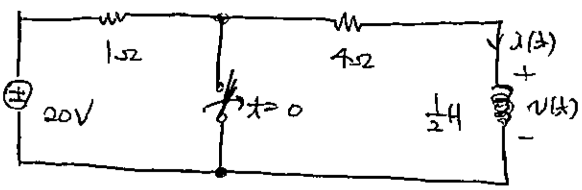
$R = 2k\Omega \rightarrow \tau = 0.2s$, $5\tau = 1s$

$R = 10k\Omega \rightarrow \tau = 1s$, $5\tau = 5s$

$R = 50k\Omega \rightarrow \tau = 5s$, $5\tau = 25s$

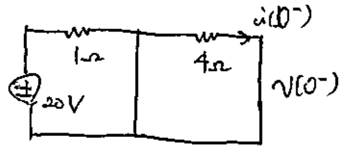


※ (40) ~ (42)



(40) (41)

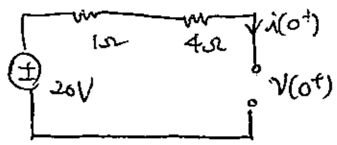
i) $t = 0^-$ 일때



$i(0^-) = 0\ [A]$

$v(0^-) = 0\ [V]$

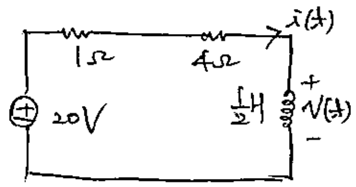
ii) $t = 0^+$ 일때



$i(0^+) = i(0^-) = 0\ [A]$

$v(0^+) = 20\ [V]$

iii) $t > 0$



$$20 = 5\,i(t) + v(t)$$

$$※ \boxed{v(t) = H \cdot \frac{d\,i(t)}{dt}} \text{ 이므로.}$$

$$v(t) = \frac{1}{2} \cdot \frac{d}{dt} i(t)$$

$$20 = 5\,i(t) + \frac{1}{2} \cdot \frac{d}{dt} i(t)$$

$$40 = 10\,i(t) + \frac{d}{dt} i(t)$$

$$\xrightarrow{\mathcal{L}} sI(s) + 10I(s) = \frac{40}{s} \quad (\because i(0) = 0 \text{ 이므로}$$

$$I(s) = \frac{40}{s(s+10)}$$

$$= \frac{A}{s} + \frac{B}{s+10}$$

$$A = \frac{40}{s(s+10)} \times s \Big|_{s=0} = 4$$

$$B = \frac{40}{s(s+10)} \times (s+10) \Big|_{s=-10} = -4$$

$$\therefore I(s) = \frac{4}{s} + \frac{-4}{s+10}$$

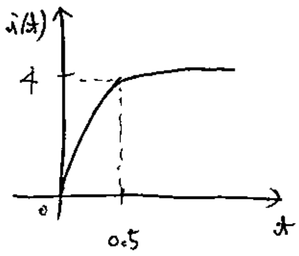
$$\xrightarrow{\mathcal{L}^{-1}} i(t) = 4 - 4e^{-10t} \ [A], \ t \geq 0$$

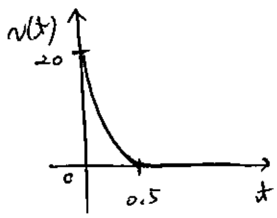
또한, $v(t) = H \cdot \frac{d}{dt} i(t)$ 이므로

$$= \frac{1}{2} \times \frac{d}{dt}\left(4 - 4e^{-10t}\right)$$

$$v(t) = 20e^{-10t} \ [V], \ t \geq 0$$

graph. (개형)

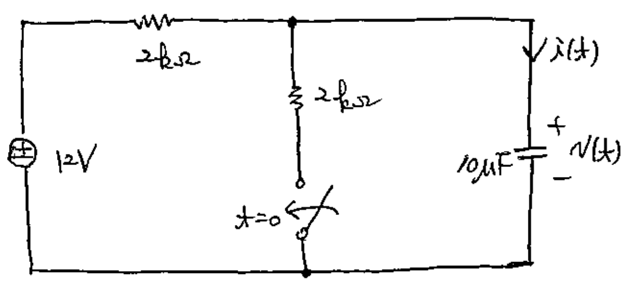




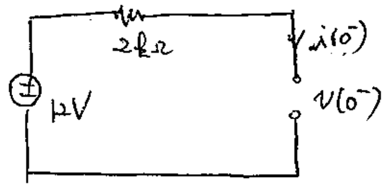
㊷ $t>0$ 에서 시정수

$$\tau = \frac{L}{R} = \frac{\frac{1}{2}}{5} = \frac{1}{10} = 0.1 \ [sec]$$

* ㊸ ~ ㊽

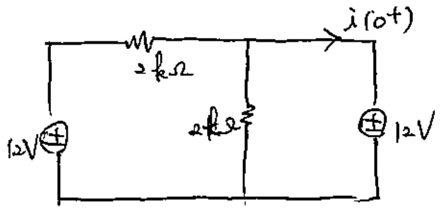


㊸ $t=0^-$ 일 때



$$i(0^-) = 0 \ [A] \quad v(0^-) = 12[V]$$

㊹ $t=0^+$ 일때



$$v(0^+) = v(0^-) = 12 \ [V]$$

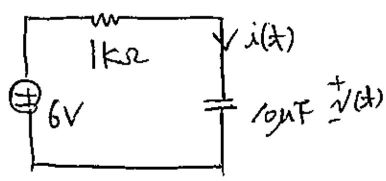
$$i(0^+) = \frac{-12}{2k} = -6 \ [mA]$$

㊺ $t>0$ 일때

테브난의 등가회로로 바꾸면

$$R_{TH} = 2k\Omega \,//\, 2k\Omega = 1k\Omega$$

$$V_{oc} = 12 \times \frac{2k}{2k+2k} = 6V$$



$$6 = 1k \cdot i(t) + v(t)$$

* $\boxed{i(t) = C \cdot \frac{dv(t)}{dt}}$ 이므로

$$i(t) = 10\mu \cdot \frac{d}{dt} v(t)$$

$$6 = 1k \cdot 10\mu \cdot \frac{d}{dt} v(t) + v(t)$$

$$600 = \frac{d}{dt} v(t) + 100\, v(t)$$

$\xrightarrow{\mathcal{L}}$ $sV(s) - V(0^+) + 100V(s) = \frac{600}{s}$

$(v(0^+) = 12[V]$ 이므로$)$

$(s+100)V(s) = \frac{600}{s} + 12$

$V(s) = \frac{12s + 600}{s(s+100)}$

$= \frac{A}{s} + \frac{B}{s+100}$

$A = \frac{12s+600}{s(s+100)} \times s \Big|_{s=0} = 6$

$B = \frac{12s+600}{s(s+100)} \times (s+100) \Big|_{s=-100} = 6$

$\therefore V(s) = \frac{6}{s} + \frac{6}{s+100}$

$\xrightarrow{\mathcal{L}^{-1}}$ $v(t) = 6 + 6e^{-100t}$ [V], $t \geq 0$

$i(t) = C \cdot \frac{d}{dt} v(t)$ 이므로

$= 10\mu \cdot \frac{d}{dt}(6 + 6e^{-100t})$

$i(t) = -6e^{-100t}$ [mA], $t \geq 0$

(45) $v(\infty) = \lim_{t\to\infty}(6 + 6e^{-100t}) = 6$ [V]

$i(\infty) = \lim_{t\to\infty}(-6e^{-100t}) = 0$ [A]

(46) $v(t) = 6 + 6 \cdot e^{-100t}$ [V], $t \geq 0$

$i(t) = -6e^{-100t}$ [mA], $t \geq 0$

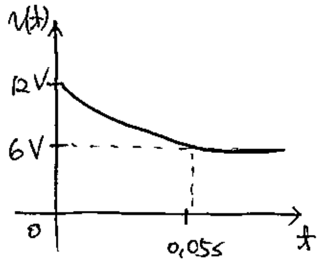
(47) $t>0$ 에서 정상상태 시간

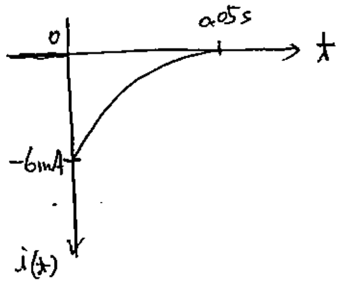
$\tau = R \cdot C = 1k\Omega \times 10\mu F$

$= 0.01$ [S]

정상상태 시간 $5\tau = 0.05$ [S] 에서 정상상태 도달

(48) $v(t)$, $i(t)$ 파형. graph





수고하셨습니다. 좋은 결과 있으시길 ... ^^