2008년 국가직 7급 회로이론 봉책형 해설

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1.【정답】①

$$Z_{TH}=\frac{6(-j2)}{6-j2}=\frac{-j6}{3-j}=\frac{-j6(3+j)}{10}=0.6-j1.8\,[\Omega]$$

$$V_{TH}=20\angle 0^\circ\times\frac{-j2}{6-j2}=20\times\frac{-j}{3-j}=20\times\frac{-j(3+j)}{10}=-2j(3+j)$$

$$V_{TH}=2-j6\,[\mathrm{V}]$$

2.【정답】④

$$\frac{V_1}{3}+\frac{V_2}{3}+\cdots+\frac{V_{100}}{3}=\frac{0-V_o}{2}$$

$$\frac{1}{3}(V_1+V_2+\cdots V_{100})=-\frac{V_o}{2}$$

$$V_o=-\frac{2}{3}\times\frac{100\times 101}{2}=-\frac{10100}{3}\,[\mathrm{mV}]$$

3.【정답】①

$$Z_{11}=\frac{V_1}{I_1}\bigg|_{I_2=0}=\frac{4I_1}{I_1}=4,\ Z_{12}=\frac{V_1}{I_2}\bigg|_{I_1=0}=\frac{I_2}{I_2}=1$$

$$Z_{21}=\frac{V_2}{I_1}\bigg|_{I_2=0}=\frac{I_1}{I_1}=1,\ Z_{22}=\frac{V_2}{I_2}\bigg|_{I_1=0}=\frac{(s+1)I_2}{I_2}=s+1$$

$$\begin{bmatrix}V_1\\V_2\end{bmatrix}=\begin{bmatrix}4 & 1\\1 & (s+1)\end{bmatrix}\begin{bmatrix}I_1\\I_2\end{bmatrix}$$

4.【정답】③

$10u(t)=\dfrac{dI}{dt}+V_c+3I$, 라플라스 변환하면 $\dfrac{10}{s}=sI(s)+V_c(s)+3I(s)$

$I=\dfrac{1}{2}\dfrac{dV_c}{dt}$, 라플라스 변환하면 $I(s)=\dfrac{1}{2}\left(sV_c(s)-5\right)$, $V_c(s)=\dfrac{2I(s)+5}{s}$

$$\frac{10}{s}=(s+3)I(s)+\frac{2I(s)+5}{s}$$

$$I(s)=\frac{\frac{5}{s}}{s+3+\frac{2}{s}}=\frac{5}{s^2+3s+2}=\frac{5}{(s+1)(s+2)}=5\left(\frac{1}{s+1}-\frac{1}{s+2}\right)$$

역변환하면 $I(t)=5e^{-t}-5e^{-2t},\ t\geq 0$

5. 【정답】 ②

$$V_2(s)=-4sI_1(s)$$

$$I_1(s)=\frac{V_1(s)}{6+2s}$$

$$\frac{V_2(s)}{V_1(s)}=\frac{-4s}{2s+6}$$

6. 【정답】 ②

$$\frac{V_1}{R_1}+g_mV_1+\frac{V_{\text{in}}}{R_{\text{in}}}=\frac{V_{\text{in}}}{R_2}$$

$$V_1=-V_{\text{in}}$$

$$\frac{-V_{\text{in}}}{R_1}-g_mV_{\text{in}}+\frac{V_{\text{in}}}{R_{\text{in}}}=+\frac{V_{\text{in}}}{R_2}$$

$$-\frac{1}{R_1}-g_m+\frac{1}{R_{\text{in}}}=\frac{1}{R_2},\ \frac{1}{R_{\text{in}}}=\frac{1}{R_1}+\frac{1}{R_2}+g_m$$

$$R_{\text{in}}=\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+g_m}=\frac{R_1R_2}{R_1+R_2+g_mR_1R_2}$$

7. 【정답】 ②

$V_a=0\,[\mathrm{V}]$로 놓으면 $V_c=4\times 3=12\,[\mathrm{V}]$

$$\frac{12-4}{8}=\frac{4-0}{R_1},\ R_1=4\,[\mathrm{k\Omega}]$$

8. 【정답】 ③

$$V(t)=u(t)-u(t-0.1)$$

$$V(s)=\frac{1}{s}\left(1-e^{-0.1s}\right)$$

$$I(s)=\frac{V(s)}{R+\frac{1}{sC}}=\frac{sC}{sCR+1}V(s)$$

$CR = 0.1 \times 10^{-6} \times 3 \times 10^{6} = 0.3$

$I(s) = \frac{10^{-7}s}{0.3s+1} \cdot \frac{1}{s}\left(1-e^{-0.1s}\right) = \frac{10^{-7}}{0.3s+1}\left(1-e^{-0.1s}\right)$

$I(s) = \frac{\frac{10^{-7}}{0.3}}{s+\frac{10}{3}}\left(1-e^{-0.1s}\right) = \frac{1}{3}\frac{1}{s+\frac{10}{3}}\left(1-e^{-0.1s}\right)10^{-6}$

$I(t) = \frac{1}{3}\left(e^{-\frac{10}{3}t} - e^{-\frac{10}{3}(t-0.1)}u(t-0.1)\right) = \frac{1}{3}e^{-\frac{10}{3}t}\left(1-e^{\frac{1}{3}}u(t-0.1)\right)$ [μA]

$I(0.2) = \frac{1}{3}e^{-\frac{2}{3}}\left(1-e^{\frac{1}{3}}\right) = -\frac{1}{3}e^{-\frac{2}{3}}\left(e^{\frac{1}{3}}-1\right) = -\frac{1}{3}\left(1-e^{-\frac{1}{3}}\right)e^{-\frac{1}{3}}$ [μA]

다른 풀이

$0 \le t < 0.1$에서 $V(s) = \frac{1}{s}$이므로

$I_1(s) = \frac{C}{sCR+1} = \frac{10^{-7}}{0.3s+1} = \frac{1}{3}\frac{1}{s+\frac{10}{3}}10^{-6}$

$I_1(t) = \frac{1}{3}e^{-\frac{10}{3}t}$ [μA]

$t \ge 0.1$일 때는 $-u(t-0.1)$의 입력이 추가된 것으로 볼 수 있으므로

$I_2(t) = -\frac{1}{3}e^{-\frac{10}{3}(t-0.1)}$ [μA]

$I(t) = I_1(t) + I_2(t) = \frac{1}{3}e^{-\frac{10}{3}t} - \frac{1}{3}e^{-\frac{10}{3}(t-0.1)}$ [μA]

$I(0.2) = \frac{1}{3}e^{-\frac{2}{3}} - \frac{1}{3}e^{-\frac{1}{3}} = -\frac{1}{3}\left(1-e^{-\frac{1}{3}}\right)e^{-\frac{1}{3}}$ [μA]

9. **【정답】** ①

$v_L = L\frac{di}{dt}$에서 라플라스 변환하면 $V_L(s) = LsI(s) - LI(0)$

$i = C\frac{dV}{dt}$에서 라플라스 변환하면 $I(s) = CsV(s) - CV(0)$, $V(s)$에 관하여 정리하면

$V(s) = \frac{I(s)}{sC} + \frac{V(0)}{s}$

따라서 변환회로로 옳은 것은 ①번이다.

10. 【정답】 ②

문제의 신호는 기함수이므로 푸리에 계수 중 b_n만 구하면 된다.

$$b_n = \frac{2}{T_0}\left[\int_{-T_0/2}^{T_0/2} \frac{2\pi}{T_0} t \sin n \frac{2\pi}{T_0} t dt\right]$$

$+$	$\frac{2\pi}{T_0}t$	$\sin\frac{2n\pi}{T_0}t$
$-$	$\frac{2\pi}{T_0}$	$-\frac{T_0}{2n\pi}\cos\frac{2n\pi}{T_0}t$
$+$	0	$-\left(\frac{T_0}{2n\pi}\right)^2\sin\frac{2n\pi}{T_0}t$

$$b_n = \frac{2}{T_0}\left[-\frac{t}{n}\cos\frac{2n\pi}{T_0}t + \frac{T_0}{2n^2\pi}\sin\frac{2n\pi}{T_0}t\right]_{-T_0/2}^{T_0/2}$$

$$b_n = \frac{2}{T_0}\left(-\frac{T_0}{2n}\cos n\pi - \left(\frac{T_0}{2n}\cos n\pi\right)\right) = -\frac{2}{n}\cos n\pi$$

$$b_1 = 2,\ b_2 = -1,\ b_3 = \frac{2}{3},\ b_4 = -\frac{1}{2},\ \cdots$$

$$V_i(t) = 2\sin\frac{2\pi}{T_0}t - \sin\frac{4\pi}{T_0}t + \frac{2}{3}\sin\frac{6\pi}{T_0}t - \frac{1}{2}\sin\frac{8\pi}{T_0}t + \cdots$$

차단 각주파수가 $\frac{7\pi}{T_0}$인 이상적인 저역통과 필터이므로 $\frac{7\pi}{T_0}$보다 작은 주파수만 통과시킨다.

따라서 $V_o(t) = 2\sin\frac{2\pi}{T_0}t - \sin\frac{4\pi}{T_0}t + \frac{2}{3}\sin\frac{6\pi}{T_0}t$

실효값은 $\sqrt{\left(\frac{2}{\sqrt{2}}\right)^2 + \left(\frac{1}{\sqrt{2}}\right)^2 + \left(\frac{2}{3\sqrt{2}}\right)^2} = \sqrt{2 + \frac{1}{2} + \frac{2}{9}} = \sqrt{\frac{49}{18}} = \frac{7}{3\sqrt{2}} = \frac{7}{6}\sqrt{2}$

11. 【정답】 ③

③ 대역통과필터 : $N(s) = a_1 s$

12. 【정답】 ④

$$A = \left.\frac{V_1}{V_2}\right|_{I_2 = 0} = \frac{2 + \frac{1}{j\omega}}{\frac{1}{j\omega}} = 1 + 2j\omega$$

13. **【정답】** ④

무손실 전송선로에서 $Z_{\text{in}} = Z_0 \dfrac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l}$

종단이 단락되었으므로 부하 임피던스 $Z_L = 0$이고, $\beta = \dfrac{2\pi}{\lambda}$, $l = \dfrac{\lambda}{6}$이다.

$$j40\sqrt{3} = jZ_0 \tan\left(\frac{2\pi}{\lambda} \times \frac{\lambda}{6}\right) = jZ_0 \tan\frac{\pi}{3}$$

$$Z_0 = 40\,[\Omega]$$

14. **【정답】** ①

왼쪽 그림에서 $V_1 - KV_1 = \dfrac{I}{Y}$

오른쪽 그림에서 $V_1 = \dfrac{I}{Y_1}$, $KV_1 = -\dfrac{I}{Y_2}$

$V_1 = \dfrac{I}{Y(1-K)}$이므로 $\dfrac{I}{Y(1-K)} = \dfrac{I}{Y_1}$, $\dfrac{KI}{Y(1-K)} = -\dfrac{I}{Y_2}$

$$Y_1 = (1-K)\,Y,\ \ Y_2 = \left(\frac{K-1}{K}\right)Y = \left(1 - \frac{1}{K}\right)Y$$

15. **【정답】** ③

① 전달함수는 $\dfrac{V_1 - 0}{R_1} = \dfrac{0 - V_2}{R_2 + \dfrac{1}{sC}}$에서 $\dfrac{V_2}{V_1} = -\left(\dfrac{R_2}{R_1} + \dfrac{1}{sCR_1}\right)$이다.

② $V_2(s) = -\dfrac{R_2}{R_1} V_1(s) - \dfrac{1}{sCR_1} V_1(s)$에서 역변환하면

$V_2(t) = -\dfrac{R_2}{R_1} V_1(t) - \dfrac{1}{CR_1} \displaystyle\int_0^{t_1} V_1(\tau)d\tau$ 이다.(단, C의 초기전압은 0으로 가정한다.)

③ $\dfrac{V_2}{V_1} = -\dfrac{sCR_2 + 1}{sCR_1}$이므로 극점(pole)은 $s = 0$, 영점(zero)은 $s = -\dfrac{1}{CR_2}$이다.

극점(pole)과 영점(zero)은 각각 한 개가 있다.

④ 직류에서 커패시터는 개방회로로 작동하므로 저항이 무한대(∞)이다.

$\dfrac{V_1 - 0}{R_1} = \dfrac{0 - V_2}{\infty}$에서 $\dfrac{V_2}{V_1} = -\dfrac{\infty}{R_2} = -\infty$이므로 전압이득은 무한대이다.

16. 【정답】 ②

$$\frac{V_s(t)-V(t)}{3}+0.2\frac{d\left(V_s(t)-V(t)\right)}{dt}=0.3\frac{dV(t)}{dt}+I(t)$$

$$V(t)=2I(t)+0.2\frac{dI(t)}{dt}$$

$$\frac{dI(t)}{dt}=-10I(t)+5V(t)$$

$$0.5\frac{dV(t)}{dt}=-I(t)-\frac{1}{3}V(t)+\frac{1}{3}V_s(t)+0.2\frac{dV_s(t)}{dt}$$

$\frac{dV_s(t)}{dt}=-10e^{-2t}=-2V_s(t)$이므로

$$\frac{dV(t)}{dt}=-2I(t)-\frac{2}{3}V(t)+\frac{2}{3}V_s(t)+0.4\left(-2V_s(t)\right)=-2I(t)-\frac{2}{3}V(t)-\frac{2}{15}V_s(t)$$

$$\begin{bmatrix}\frac{dI(t)}{dt}\\ \frac{dV(t)}{dt}\end{bmatrix}=\begin{bmatrix}-10 & 5\\ -2 & -\frac{2}{3}\end{bmatrix}\begin{bmatrix}I(t)\\ V(t)\end{bmatrix}+\begin{bmatrix}0\\ -\frac{2}{15}V_s(t)\end{bmatrix}$$

17. 【정답】 ②

특성 임피던스 $Z_0=\sqrt{\frac{1\times10^{-6}}{400\times10^{-12}}}=\sqrt{\frac{10^6}{400}}=\sqrt{2500}=50\,[\Omega]$

반사계수 $\rho=\frac{150-50}{150+50}=\frac{100}{200}=0.5$

반사파 $V^{-}=\rho\times150=75\,[\mathrm{V}]$

18. 【정답】 ④

1) $t<0$

$50-60I(t)-200I(t)=0,\ I(t)=\frac{5}{26}\fallingdotseq0.19\,[\mathrm{A}]$

2) $t\geq0$

$t<0$에서 $\frac{120-\mathrm{V_a}}{10}=\frac{\mathrm{V_a}}{50}$, $\mathrm{V_a}=100\,[\mathrm{V}]$이므로

$$I(0^+)=\frac{100}{200}=0.5\,[\mathrm{A}]$$

$$I(\infty)=\frac{50}{60+\frac{200\times50}{200+50}}\times\frac{50}{200+50}=\frac{1}{2}\times\frac{1}{5}=0.1\,[\mathrm{A}]$$

따라서 $I(t)$로 가장 알맞은 것은 ④번이다.

19. 【정답】 ④

$$R + j\omega L = \overline{R - \frac{j}{\omega C}} = R + \frac{j}{\omega C}$$

$$\omega L = \frac{1}{\omega C},\ L = \frac{1}{\omega^2 C}$$

이때 최대 전력은 $\left(\dfrac{\dfrac{V_m}{\sqrt{2}}}{2R}\right)^2 R = \dfrac{V_m^2}{8R}$

20. 【정답】 ①

전류를 $I(t)$라 하면 $I(t) = C\dfrac{dV_o}{dt}$

$$E(t) = RI(t) + V_o(t) = RC\frac{dV_o}{dt} + V_o(t)$$

라플라스 변환하면

$$\frac{A}{s} = RC(sV_o(s) - V_c(0)) + V_o(s)$$

$$(sRC+1)V_o(s) = \frac{A}{s} + RCV_c(0)$$

$$V_o(s) = \frac{\dfrac{A}{s} + RCV_c(0)}{sRC+1} = \frac{A}{s(sRC+1)} + \frac{RCV_c(0)}{sRC+1}$$

$$V_o(s) = A\left(\frac{1}{s} - \frac{1}{s + \dfrac{1}{RC}}\right) + \frac{V_c(0)}{s + \dfrac{1}{RC}}$$

$$V_o(t) = A\left(1 - e^{-\frac{t}{RC}}\right)u(t) + V_c(0)e^{-\frac{t}{RC}}u(t)$$

$$V_o(t) = Au(t) + \left(-A + V_c(0)\right)e^{-\frac{t}{RC}}u(t)$$

① Transient response는 $\left(-A + V_c(0)\right)e^{-\frac{t}{RC}}u(t)$이다.

② Zero-input response는 $V_c(0)e^{-\frac{t}{RC}}u(t)$이다.

③ Steady-state response는 $Au(t)$이다.

④ Zero-state response는 $A\left(1 - e^{-\frac{t}{RC}}\right)u(t)$이다.