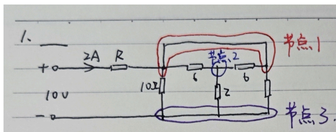
一、填空题

感谢 2ALA 与群友指正！

Ver 23.8.27.02

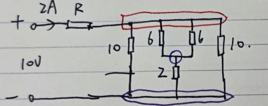
1. ——

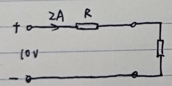


复杂电路化简为等效电路

方法：~~等效电路~~ 找广义节点.

在不改变连接关系的基础上整理电路





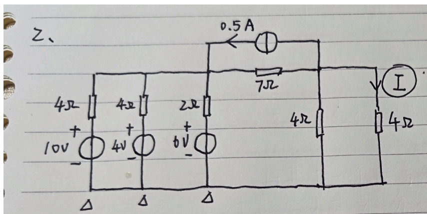
$Req = 10 // (6//6+2) // 10$

$= 10 // (5) // 10$

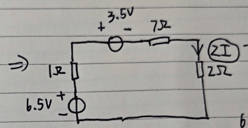
$= \frac{5}{2}\Omega.$

故 $R = \frac{10}{2} - Req = \frac{5}{2}\Omega.$

2、



⇒

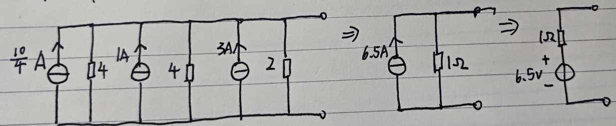


$2I = \frac{6.5-3.5}{10}$

$= 0.3$

$I = 0.15A.$

戴维南支路变为诺顿支路



$4+\frac{5}{2}$

3、$u_i(t) = 10\sin(4t+59^\circ)$

$= 10\cos(4t+31^\circ)$

且为零状态，则稳态响应就是正弦稳态响应

故稳态响应的相量

（将 $H(s) = \frac{U_o(s)}{U_i(s)}$）

（变换为 $H(j\omega) = \frac{U_o(j\omega)}{U_i(j\omega)}$）

即为 $\dot{U}_i$ 相量.

即 $H(j\omega) = \frac{\dot{U}_o}{\dot{U}_i}$

$\dot{U}_o = H(j\omega)\dot{U}_i$.

$= \frac{17.5}{(4j+1)(4j+2)} \times \frac{10}{\sqrt{2}} \angle 31^\circ$

有效值相量.

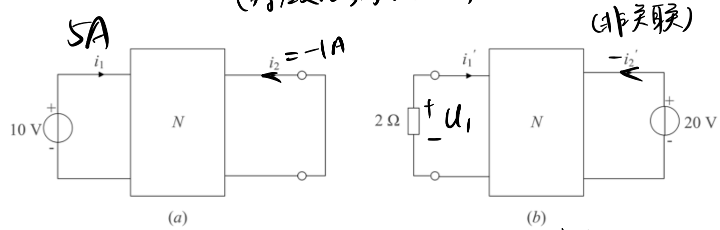
用卡西欧计算器计算可得. $6.71\angle -108.40^\circ$

故 $u_o(t) = \overset{\text{// } 6.71\sqrt{2}}{9.5}\cos(4t-108.4^\circ)$. V.

4.

（对应支路参考方向一致）

（非关联）



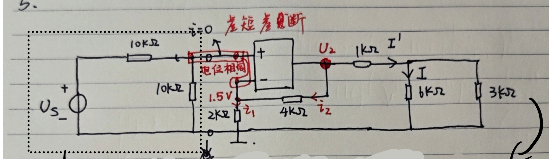
各条支路上电压电流参考方向一致且均取非关联参考方向、

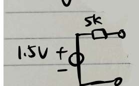
则有 $10i_1' + 0\times(-i_2') = U_1 \times i_1 + 20 \times i_2$

又 $U_1 = -2i_1'$（非关联！）

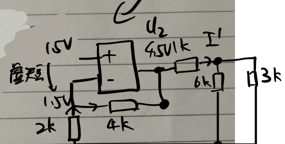
$\Rightarrow 20i_1' = 20i_2 \quad i_1' = -1A.$

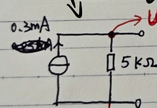
5.





（由于虚断，等效的5k电阻上无压降，则此点电位即为1.5V）





$U_1 = 1.5V.$

故 $U_2 = \frac{1.5}{2K} \times 6K = 4.5V$ $(i_1 = i_2)$.

$I' = \frac{4.5}{1+6//3}$ mA $= 1.5$ mA

$I = \frac{3}{6+3} \times I' = 0.5$ mA

二、计算题

6. 由于 U_{n1} 电压已知，无需对节点①列方程

~~② $U_{n1}\times(-\frac{1}{4})+U_{n2}(\frac{1}{4}$~~

节点②与③所求量相关，故有

~~② $-\frac{1}{4}U_{n1}+U_{n2}(\frac{1}{8}$~~

②: $-\overset{12V}{U_{n1}}\cdot(\frac{1}{4})+\overset{20}{U_{n2}}(\frac{1}{8}+\frac{1}{4}+\frac{1}{5})-U_{n3}(\frac{1}{5})=-\frac{U_s}{8}+2$

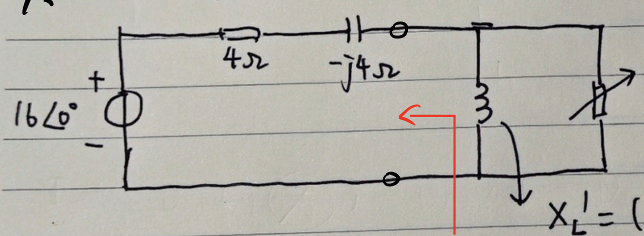
③: $0-\overset{20}{U_{n2}}(\frac{1}{5})+U_{n3}(\frac{1}{5}+\frac{1}{10})=2I.$

由欧姆关系知 $\frac{\overset{20}{U_{n2}}-(-U_s)}{8}=I.$

(整理由卡西欧可算)

$U_{n3}=40V$ $\underline{U_s=12V}$ $\underline{I=4A}.$

7. 将二次侧等效到一次侧上



$Z_L'=(\frac{2}{1})^2\cdot Z_L=4Z_L$

$X_L'=(\frac{2}{1})^2\cdot j2=j8\ \Omega.$

Z_L 功率最大也即 Z_L' 功率最大，又由于电感没有有功，所以可以将它和 Z_L 放在一块考虑，即考虑它们整体功率何时最大。

从上图红色处看进去，等效电源电压有效值 $U_{eq}=16V$，内阻 $(4-j4)\Omega$

电感与 Z_L 并联阻抗 $\frac{j8\cdot Z_L'}{j8+Z_L'}$

由最大功率传输定理应有 $\frac{j8\cdot Z_L'}{j8+Z_L'}=4+j4 \Rightarrow Z_L'=8\Omega \Rightarrow Z_L=2\Omega$

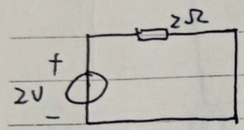
则取 $Z_L=2\Omega$

$P_{max}=\frac{U_{eq}^2}{4\times4}=\frac{256}{4\times4}=16W.$

8、 $u_s(t) = 2 + 3\sqrt{2}\cos t + 3\sqrt{2}\cos 2t$

① $\omega=0$

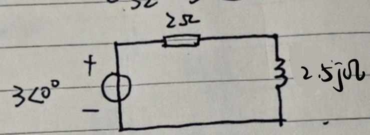
$U_{s1} = 2\ V$



$P_1 = \frac{U^2}{R} = 2W$

② $\omega=1$

$U_{s2} = 3\angle 0^\circ$



$j\omega L$

$= j\cdot 1\cdot(0.5+1+0.5\times 2)$

同名端串联（正串）

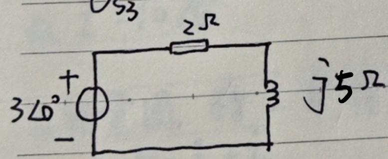
试卷上箭头应指向同名端

$P_2 = \left(\frac{3}{\sqrt{2^2+2.5^2}}\right)^2 \times 2$

$= 1.76W$

③ $\omega = 2$

$U_{s3} = 3\angle 0^\circ$



$j\omega L = j\cdot 2\cdot(0.5+1+0.5\times 2)$

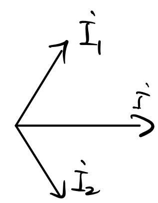
$P_3 = \left(\frac{3}{\sqrt{2^2+5^2}}\right)^2 \times 2 = 0.62W$

$P_{总} = 4.38\ W$.

9. 解：设端口总电压相量为参考相量、

端口总电流 $I = \frac{P}{U} = 10A$（因电压电流没有相位差） $\dot{I} = 10\angle 0^\circ$

则 R两端电压为 $\dot{U}_R = 120\angle 0^\circ\ V$ 则 R_1与C、R_2与L 两端电压均为 $\dot{U}_1 = 100\angle 0^\circ\ V$



由 $\dot{I}_1 + \dot{I}_2 = \dot{I}$ 且 I_1超前于I，I_2滞后于I（均小于90°）

画出相量图可知，$\dot{I}_1$与$\dot{I}_2$超前/落后 $\dot{I}$ 的角度应一致，不妨设为θ，再结合 $I_1\cos\theta + I_2\cos\theta = I$

$\Rightarrow \theta = 60^\circ$ 则 $\dot{I}_1 = 10\angle 60^\circ\ A$，$\dot{I}_2 = 10\angle -60^\circ\ A$ 由 $\frac{\dot{U}_1}{\dot{I}_1} = R_1 + \frac{1}{j\omega C}$ $\frac{\dot{U}_2}{\dot{I}_2} = R_2 + j\omega L$

得 $10\angle -60^\circ = R_1 + \frac{1}{j\omega C}$，$10\angle 60^\circ = R_2 + j\omega L$

$\Rightarrow R_1 = R_2 = 5\Omega$ （工频为50Hz）

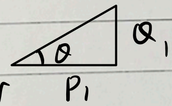
$C = \frac{1}{5\sqrt{3}\omega} = \frac{1}{500\sqrt{3}\pi}$ (F)

$L = \frac{5\sqrt{3}}{\omega} = \frac{\sqrt{3}}{20\pi}$ (H)

设 $\dot{U} = 220\angle 0°$ $I =$ (2) Q'

10.

$P = P_1 + P_2 = 400\ \text{W}$



$Q_1 = P_1 \tan\theta_1 = P_1 \times \frac{4}{3} = 400\ \text{var}$

$\theta = \arccos(\lambda)$

$Q_2 = P_2 \tan\theta_2 = P_2 \times 1 = 100\ \text{var}$

故 $Q = 400 + 100 = 500\ \text{var}$.

$S = P + jQ$

$S_{总} = 640.31\ \text{VA} = \sqrt{P^2 + Q^2}$

$I = \frac{S_{总}}{U} = \frac{640.31}{220} = 2.91\ \text{A}$.

$\arccos(0.95) = 18.19°$.

$\sin(\arccos(0.95)) = 0.31$.

$\tan(\arccos(0.95)) = 0.326$.

故 $Q' = \tan(\arccos(0.95)) \times 400$

$= 131.47\ \text{var}$.

$\Delta Q = 368.53\ \text{var}$.

$= \frac{U^2}{\left|\frac{1}{j\omega C}\right|}$ (电容补偿的无功)

$C = \frac{368.53}{U^2 \cdot \omega} = 2.424 \times 10^{-5}\ \text{F}$

11. 解： $t<0$ 时，当直流 U_{S2} 单独作用时,电感相当于短路，电容相当于开路。

$$I_{L(0)} = \frac{U_{S2}}{R_2} = \frac{20}{5} = 4\text{A}, U_{C(0)} = 0$$

当交流 u_{S1} 单独作用时, $\omega L = 1/\omega C = 10\Omega$, L 和 C 发生并联谐振,相当于开路

$$\dot{U}_{C(1)} = \frac{R_2}{R_1 + R_2}\dot{U}_{S1} = \frac{5}{10+5} \times 30\angle 45° = 10\angle 45°\text{V}$$

$$\dot{I}_{L(1)} = \frac{\dot{U}_{C(1)}}{j\omega L} = \frac{10\angle 45°}{j10} = 1\angle -45°\text{A}$$

所以 $t<0$ 时， $u_C(t) = 10\sqrt{2}\cos(100t+45°)\text{V}$, $i_L(t) = 4 + \sqrt{2}\cos(100t-45°)\text{A}$

换路后,变为两个一阶电路,电感电流和电容电压不能跃变,即

$u_C(0_+) = u_C(0_-) = 10\sqrt{2}\cos 45° = 10\text{V}$, $i_L(0_+) = i_L(0_-) = 4 + \sqrt{2}\cos(-45°) = 5\text{A}$

当换路后电路达到稳态时

$$u_C(\infty) = U_{S2} = 20\text{V}$$

$$\dot{I}_L = \frac{\dot{U}_{S1}}{R_1 + j\omega L} = \frac{30\angle 45°}{10 + j10} = 1.5\sqrt{2}\angle 0°\text{A}$$

特解 $i_{LP}(t) = 3\cos 100t\text{A}$,特解初值 $i_{LP}(0_+) = 3\text{A}$

时间常数 $\tau_L = L/R_1 = 0.01\text{s}$, $\tau_C = R_2 C = 0.005\text{s}$

由三要素公式可得

$$u_C(t) = 20 - 10e^{-200t}\ \text{V},\ t \ge 0,\ i_L(t) = 3\cos 100t + 2e^{-100t}\ \text{A},\ t \ge 0$$

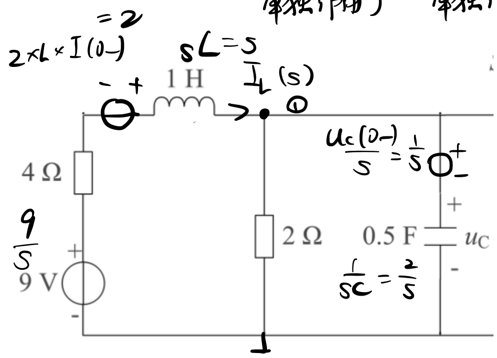
典型的伪二阶电路、即看似有多个储能元件，但换路后两储能元件独立地分属于两一阶电路中。

12、解：换路前，对直流电源，电感相当于短路，电容相当于开路，

$I_L(0-) = 2.25A - \frac{1V}{4\Omega} = 2A$ （9V电源单独作用）（1V电源单独作用）

$u_C(0-) = 0 + 1V = 1V$ （9V电源单独作用）（1V电源单独作用）

则换路后运算电路为



[注：$U_C(s) = \frac{u_C(0+)}{s} + \frac{1}{sC} I_C(s)$

$U_L(s) = sL I_L(s) - L I(0-)$]

则对①节点列节点电压方程

有 $\left(\frac{9}{s}+2\right)\left(\frac{1}{4+s}\right) + \frac{1/s}{2/s}$

$= U_{n1}\left(\frac{1}{2} + \frac{s}{2} + \frac{1}{4+s}\right)$

解得 $U_{n1}(s) = \dfrac{\frac{9+2s}{s(4+s)} + \frac{1}{2}}{\frac{1}{2}+\frac{s}{2}+\frac{1}{4+s}}$

$= \dfrac{\frac{18+4s}{s} + s+4}{(s+1)(s+4)+2} = \dfrac{s^2+8s+18}{s(s+2)(s+3)} = -\frac{3}{s+2} + \frac{1}{s+3} + \frac{3}{s}$

则 $I_L(s) = \dfrac{\frac{9}{s}+2-U_{n1}(s)}{s+4} = \dfrac{\frac{6}{s}+2+\frac{3}{s+2}-\frac{1}{s+3}}{s+4}$

$= \frac{2}{s+4} + \frac{6}{s(s+4)} + \frac{3}{(s+2)(s+4)} - \frac{1}{(s+3)(s+4)}$

$= \frac{2}{s+4} + \frac{1.5}{s} - \frac{1.5}{s+4} - \frac{1.5}{s+4} + \frac{1.5}{s+2} - \frac{1}{s+3} + \frac{1}{s+4}$

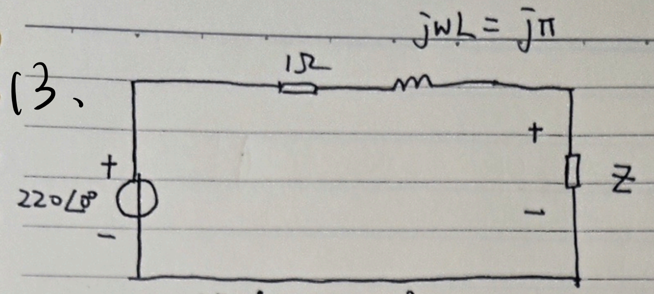
$= \frac{1.5}{s} + \frac{1.5}{s+2} - \frac{1}{s+3}$

作拉普拉斯反变换可得

$u_C(t) = 3 - 3e^{-2t} + e^{-3t}$ (V)

$i_L(t) = 1.5 + 1.5e^{-2t} - e^{-3t}$ (A)

13、



记 $\dot{U}_A = 220\angle 0°$

$\bar{S}_1 = 4000 - 3000j$　　　　$5000 = 220 \cdot I$

$P = 4000\ W = \sqrt{3} V_L I_L \cos\theta$

$Q = 3000\ var = \sqrt{3} V_L I_L \sin\theta$

$I_{LA} = 7.6A$　$\theta = 36.9°$　$\dot{I}_{LA} = 7.6\angle -36.9°$

$\dot{U}_{AZ} = \dot{U}_A - \dot{I}_L(1 + j\pi)$

$= 200.1\angle -4.16°$

$\bar{S}_Z = 3\dot{U}_{AZ}\dot{I}_{LA}^*$

$= 3(1146.70 - 999.0j)$

$= 3440.1 - 2996.7j$

则 $P_L = 3440.1\ W$　$Q = 2996.7\ var$.

$U_L = 346.6\angle -4.16°$