中南大学

2004 年研究生入学考试试题

考试科目：电路理论　　　　考试科目代码：43340

注意：所有答案（含选择题、填空题、判断题、作图题等）一律答在中南大学答题纸上；写在试题纸上或其他地点一律不给分。作图题可以在原试题图上作答，然后将“图”撕下来贴在答题纸上相应位置。

1．已知如图 1 所示电路中，电流 $I=1A$，求电阻 R。(10 分)

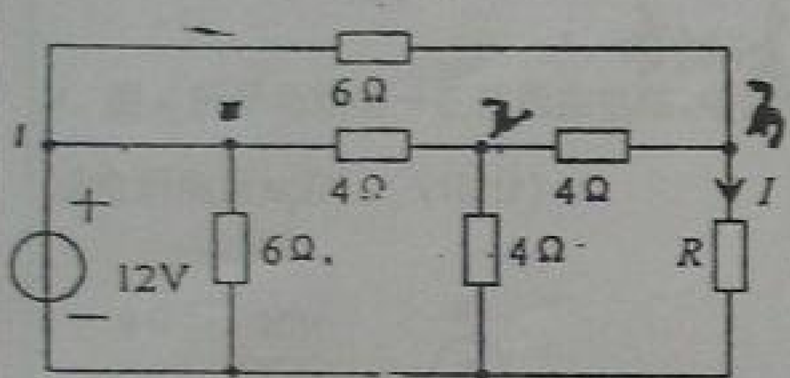


图 1

解：用节点法

$U_{n1}=12$

$-\frac{1}{4}U_{n1}+(\frac{1}{4}+\frac{1}{4}+\frac{1}{4})U_{n2}-\frac{1}{4}U_{n3}=0$

$-\frac{1}{6}U_{n1}-\frac{1}{4}U_{n2}+(\frac{1}{6}+\frac{1}{4}+\frac{1}{R})U_{n3}=0$

$U_{n3}=R\times I=R\times 1=R$

联立方程解之得 $R=6\Omega$.

2．如图 2 所示电路，N_0 为线性无源电阻网络。对图 2(a)，当输入电压为 20V 时，输入电流为 5A，而输出端的短路电流为 1A。如果把电源移到输出端，同时在输入端接上 4Ω 的电阻，如图 2(b)所示，求 4Ω 电阻的电压 U。(10 分)

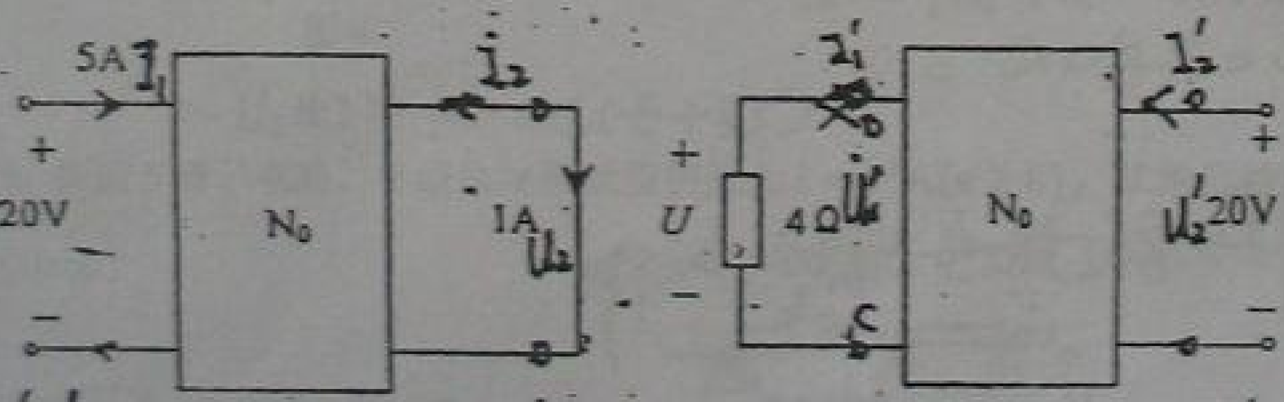


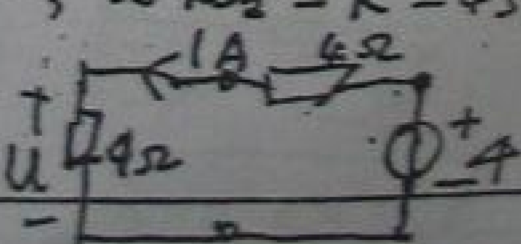
图 2(a)　　图 2(b)

图 2

解：由图 a 知，N_0 网络电阻 $R'=\frac{20V}{5A}=4\Omega$

用戴维南定理求 oc 间短路时，由互易定理得 $\therefore i_{sc}=1A$，又 $R_{eq}=R'=4\Omega$ $\therefore U_{oc}=4V$

$\therefore$ b 图可表为



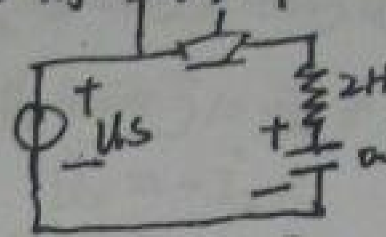
$U=\frac{4}{4+4}\times 4=2V$

3. 电路如图3所示，已知 $u_s = 4\sqrt{2}\cos t$ V，$i_s = 2$A（直流），求电容上电压 $u_C(t)$ 的有效值 U_C。（10分）

解：当电流源单独作用时，电容处于开路状态，此时 $U_C = 1\times 2 = 2V$

当电压源单独作用时：

有



$j\omega L = j\times 1\times 2 = j2$

$\frac{1}{j\omega C} = -j2$

∴ L与C处于串联谐振，

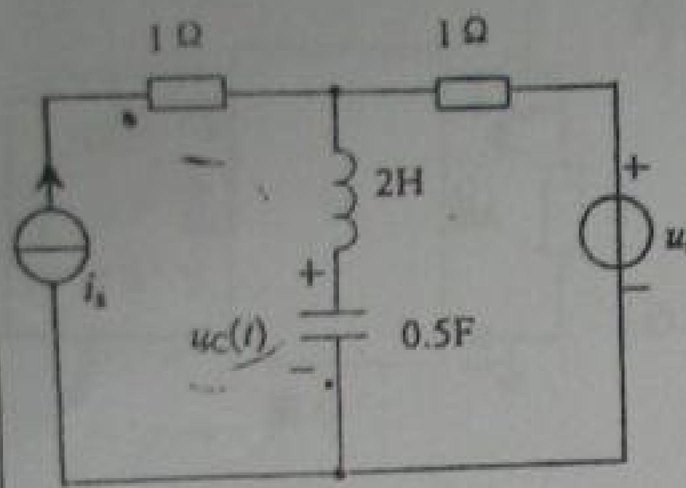


图 3

此时有 $U_C = 4V$

∴ 有效值 $U_C = \sqrt{4^2+2^2} = 2\sqrt{5}\,V = 4.47V$

4. 图4所示电路为一正弦稳态电路，电流表A的读数为零，电流表 A_1 的读数为1A(有效值)。求电源电压 $u_s(t)$。（10分）

电流表读数为0，而 A_1 为1A。

解：故1F，与1H处于并联谐振

此时有 $\frac{1}{\omega C} = \omega L$，故有 $\omega = 1$

因为 A_1 读数为1，故1H上电压有效值为1V，故1Ω上电压有效值为1V

∴ $I = 1A$　又 $Z = 9+1+j\omega L = 10+j10$

∴ $U = |Z|\cdot|I| = 10\sqrt{2}V$

$\varphi = \arctan\frac{10}{10} = 45°$

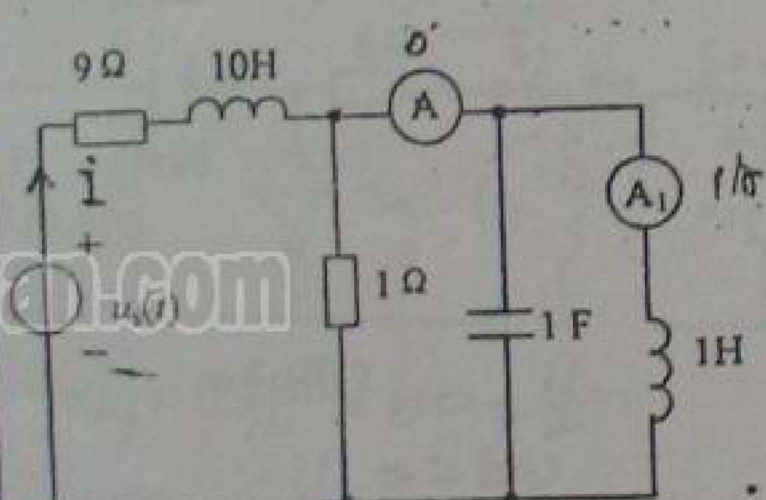
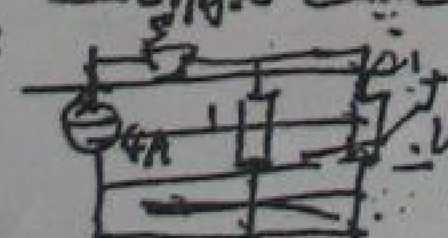


图 4

∴ $u_S(t) = 20\cos(t+45°)$

5. 如图5所示电路，非线性电阻伏安特性为 $i = u^2$A$(u \geq 0)$，试求非线性电阻中的电流 i。(10分)

解：~~电压源与电流源分别作用~~



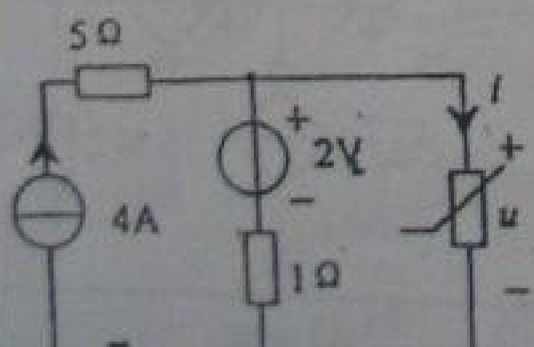
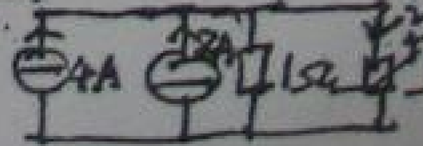
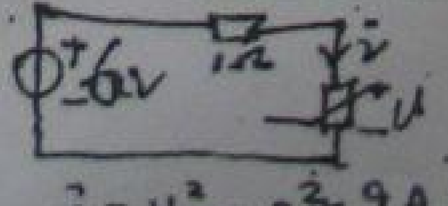


图 5

原图可变为



⇒



∴ $6 = 1\times i + u$

$6 = u^2 + u$

$u = 3$ or $u = -2$（舍）

∴ $i = u^2 = 3^2 = 9A$

∴ 电流 i 为9A

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6. 已知图 6 所示二端口网络 N 的 Y 参数矩阵为 $Y=\begin{bmatrix}0.2 & -0.1\\ -0.5 & 0.5\end{bmatrix}$S，负载 R 为纯电阻。问当负载 R 为何值时，它消耗的平均功率为最大，并求此最大功率。(12 分)

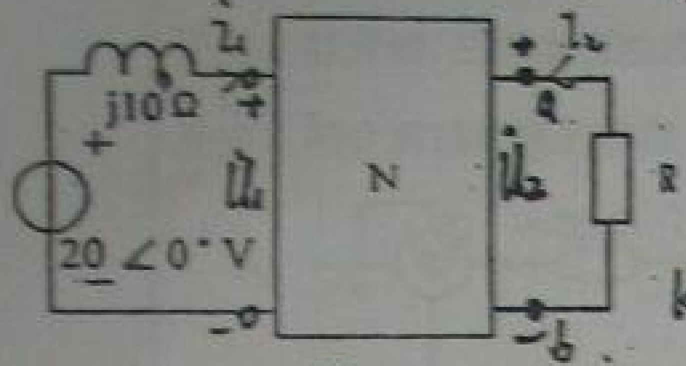


图 6

解：由已知 $\begin{cases}\dot I_1 = 0.2\dot U_1 - 0.1\dot U_2\\ \dot I_2 = -0.5\dot U_1 + 0.5\dot U_2\end{cases}$

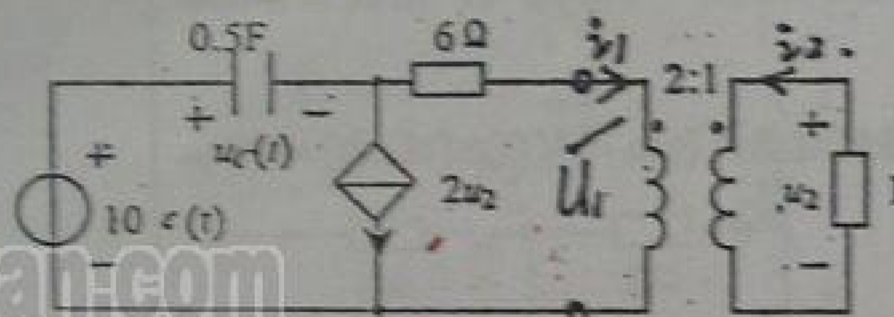
由左图可得 $\begin{cases}20 = j10\dot I_1 + \dot U_1\\ \dot U_2 = -\dot I_2 R\end{cases}$

由戴维南定理.

7. 如图 7 所示电路中含有理想变压器，电容 C 有初始电压 $u_C(0_-)=6\text{V}$，$\varepsilon(t)$ 为阶跃函数。求电容上电压 $u_C(t)$。(12 分)

解：由变比，二次侧 $=1\times 2^2=4\Omega$.

原图等效为



$\because i_1 = -\frac{1}{2}i_2 = -\frac{1}{2}\times\left(-\frac{u_2}{1}\right) = \frac{u_2}{2}$

由戴维南定理求得.

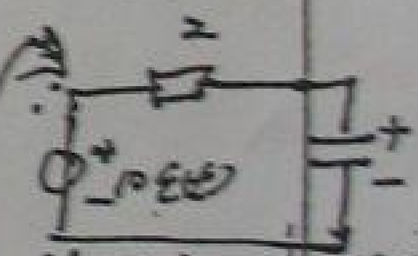
$U_{oc} = 10\varepsilon(t)$.

求OC间短路电流

$\therefore i_1 = \frac{10\varepsilon(t)}{10} = \varepsilon(t) = \frac{u_2}{2}$. 图 7

$\therefore u_2 = 2\varepsilon(t)$

$\therefore i_{sc} = i_1 + 2u_2 = 5\varepsilon(t)$ $\therefore R_{eq} = \frac{u_{oc}}{i_{sc}} = 2\Omega$.



$u_C(\infty) = 10\varepsilon(t)$

$\tau = RC = 2\times0.5 = 1\text{s}$.

$u_C(t) = u_C(\infty) + [u_C(0_+) - u_C(\infty)]e^{-t}$

$= [10 + (6-10)e^{-t}]\varepsilon(t)$

$= (10 - 4e^{-t})\varepsilon(t)$ V

8. 如图 8 所示的直流电路，求电压 U、电流 I 及两个受控源的功率。(18 分)

解：

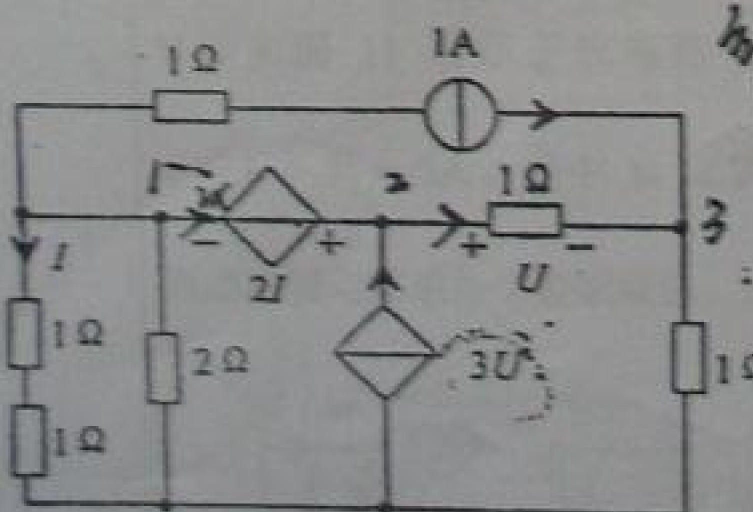


图 8

9. 三相电路如图 9 所示，已知正序对称三相电源线电压为 400V，$Z=20+j40\Omega$。(1) 开关 S 打开时，三相电源的线电流 $\dot{I}_A, \dot{I}_B, \dot{I}_C$；(2) 求开关 S 闭合后阻抗 Z 中的电流 $\dot{I}$；(3) 开关 S 闭合后功率表的读数，并问该功率表的读数有无意义，为什么？(20 分)

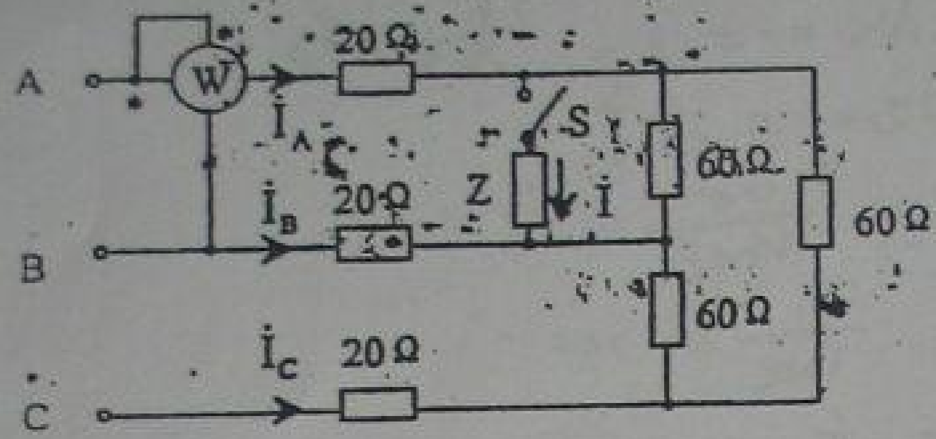


图 9

10. 电路如图 10 所示。(1)求网络函数 $H(s)=\dfrac{U_2(s)}{U_s(s)}$ 和单位冲激响应 $h(t)$；(2)若 $u_s(t)=(\sin 2t)\varepsilon(t)$ V，$\varepsilon(t)$ 为阶跃函数，求零状态响应 $u_2(t)$。(18 分)

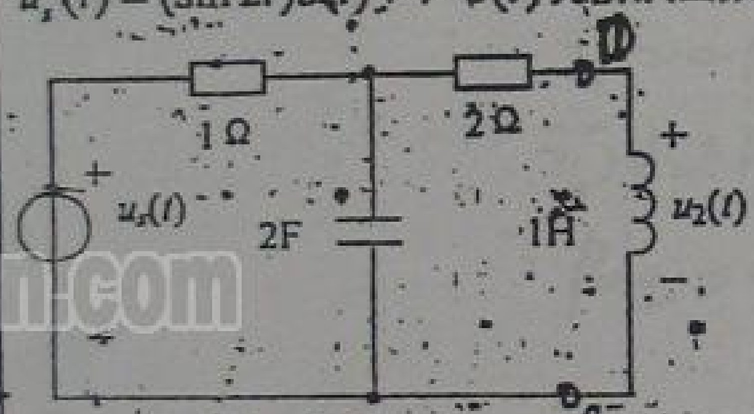


图 10

11. 如图 11 所示正弦电路中，已知 $R_1=10\Omega$，$R_2=1.34\Omega$，三个电流有效值 $I=I_1=I_2=5$A，图中 b、c 两点右侧电路处于并联谐振（即 $\dot{U}_{bc}$ 与 $\dot{I}$ 同相位），且 a、c 两点右侧电路也处于谐振状态。求 $\dfrac{1}{\omega C}, \omega M, \omega L_1, \omega L_2, U_{bc}$ 及 U_s。(20 分)

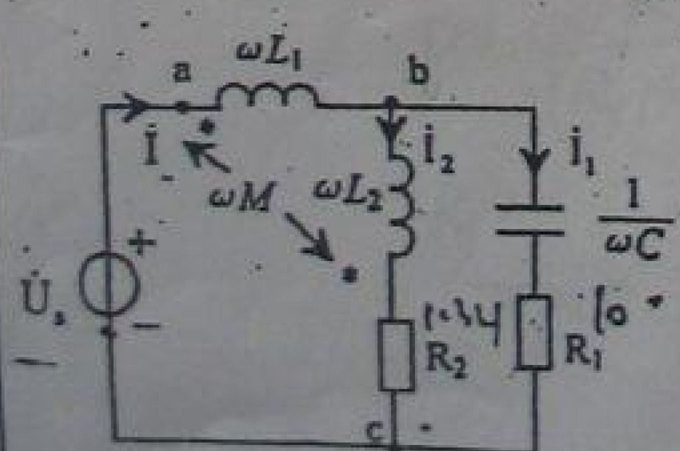


图 11

6. 解: 由已知 $\dot I_1 = 0.2\dot U_1 - 0.1\dot U_2$

$\dot I_2 = -0.5\dot U_1 + 0.5\dot U_2$

由右图可得 $\begin{cases} 20 = j10\dot I_1 + \dot U_1 \\ \dot U_2 = -\dot I_2 R \end{cases}$

由戴维南定理.

当 a, b 间短路时. $\dot U_2 = 0$. $\dot I_{sc} = -\dot I_2$

代入上式: $\begin{cases} \dot I_1 = -0.2\dot U_1 \\ \dot I_2 = -0.5\dot U_1 \end{cases} \Rightarrow 20 = j2\dot U_1 + \dot U_1$

$\therefore \dot U_1 = \dfrac{20}{j2+1}$ $\therefore \dot I_2 = \dfrac{-10}{j2+1}$

$\therefore \dot I_{sc} = \dfrac{10}{j2+1}$

当 a, b 间开路时. $\dot I_2 = 0$:

$\dot I_1 = 0.2\dot U_1 - 0.1\dot U_2$

$0 = -0.5\dot U_1 + 0.5\dot U_2$

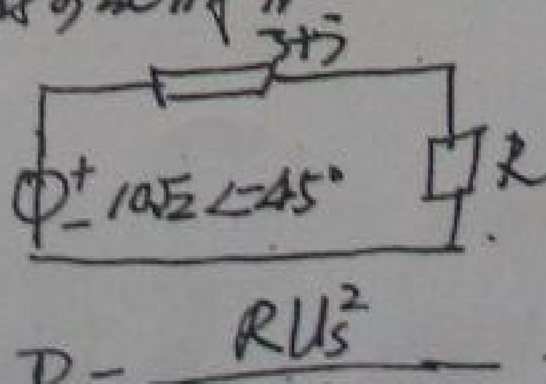
$\therefore \dot U_1 = \dot U_2$

$\therefore \dot I_1 = 0.1\dot U_1$

$\therefore 20 = j\dot U_1 + \dot U_1$ $\therefore \dot U_1 = \dfrac{20}{1+j} = U_{oc} = 10(1-j)$

$\therefore R_{eq} = \dfrac{U_{oc}}{I_{sc}} = \dfrac{\frac{20}{1+j}}{\frac{10}{1+j2}} = \dfrac{2(1+j2)}{1+j} = 3+j$.

$\therefore$ 原图可以简化为



$$P = \frac{RU_s^2}{(R_1+R)^2+X^2} = \frac{R\times 200}{(3+R)^2+1} = \frac{200}{R+\frac{10}{R}+6}$$

$\because R > 0$. 所以当 $R = \frac{10}{R}$ 时. $P = P_{max}$

即 $R = \sqrt{10}\,\Omega$ 时. $= 3.16\Omega$. $P_{max} = \dfrac{200}{6+2\sqrt{10}} = 16.23W$

8. 解：用节点法解题.

$$\begin{cases} (\frac{1}{2}+\frac{1}{2})U_{n1} = -1 - i_x \\ U_{n2} - U_{n3} = i_x + 3U \\ -U_{n2} + U_{n3} = 1 \\ U_{n2} = U_{n1} + 2I \\ i_x + 3U = \text{[illegible]} \end{cases} \Rightarrow \begin{cases} U = -1V \\ i_x = 2A \\ U_{n1} = -1-2 = -3V \end{cases}$$

$\because U_{n1} = I \times 2 \quad \therefore I = -\frac{3}{2}A, \quad U_{n2} = -3 + 2\times(-\frac{3}{2}) = -6V$

$\therefore$ 2I 受控源的功率为 ~~$P = UI = 2I$~~ $P = U_{21} I_{x2} = 2I \cdot i_x$

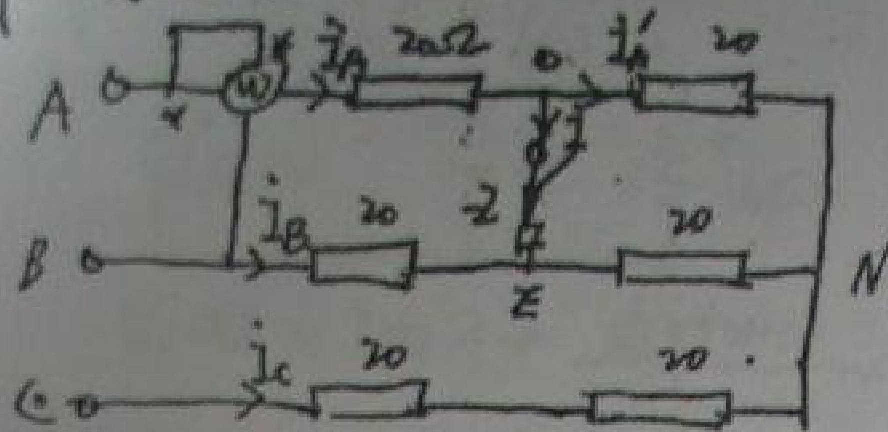
$\therefore P = 2\times(-\frac{3}{2})\times 2 = -6W.$

即发出功率.

3U 电流源的功率 $P = U_{n2} \times 3U = -6\times 3\times(-1) = 18W.$

~~二解~~.

9. 解：原图可表示为



(1). S打开后，令 $\dot U_A = \frac{400}{\sqrt3}\angle 0^\circ$

$$\therefore \dot I_A = \frac{\dot U_A}{20+20} = \frac{10}{3}\sqrt3\angle 0^\circ$$

$$\dot I_B = \frac{\dot U_B}{20+20} = \frac{400\angle -120^\circ}{40\sqrt3} = \frac{10}{3}\sqrt3\angle -120^\circ$$

$$\dot I_C = \frac{10}{3}\sqrt3\angle 120^\circ$$

(2) S闭合后，$\dot U_D = \frac12 \dot U_A = \frac{200}{\sqrt3}\angle 0^\circ$.

$$\dot U_E = \frac12 \dot U_B = \frac{200}{\sqrt3}\angle -120^\circ$$

$$\therefore \dot I = \frac{\dot U_{DE}}{Z} = \frac{\dot U_D - \dot U_E}{Z} = \frac{\frac{200}{\sqrt3}\left(1+\frac12 - j\frac{\sqrt3}{2}\right)}{20+j40} = \frac{200\left(\frac{\sqrt3}{2}-\frac{j}{2}\right)}{20(1+j2)} = \sqrt3-2-j$$

(3). $P = R_e[\dot U_{AB}\cdot \dot I_A^*]$

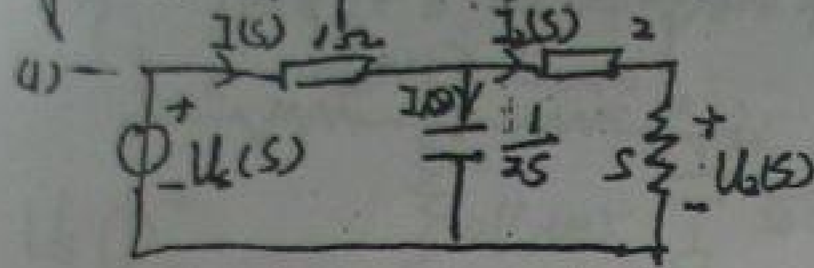
$$\because \dot U_A = \frac{\dot U_{AB}}{\sqrt3}\angle -30^\circ \quad \therefore \dot U_{AB} = \dot U_A\cdot\sqrt3\cdot\angle 30^\circ = 400\angle 30^\circ$$

$$\therefore P = 400\cos30^\circ \times \frac{10}{3}\sqrt3 = 4000\times\frac{\sqrt3}{2}\times\frac{\sqrt3}{3} = 2000W.$$

在一定条件下，两个功率表之一的读数可能为负，求代数和时该读数亦应取负值，一般说来，一个功率表的读数是没有意义的.

10、解：原图作拉斯变换

(1)



$$U_s(s) = I(s)\times 1 + \frac{\frac{1}{2s}\times(2+s)}{\frac{1}{2s}+2+s}\times I(s)$$

$$U_s(s) = I(s) + \frac{2+s}{(2+s)\cdot 2s+1} I(s).$$

$$U_2(s) = I_2(s)\cdot s = s\cdot \frac{\frac{1}{2s}}{2+s+\frac{1}{2s}}\cdot I(s).$$

$$\therefore H(s) = \frac{U_2(s)}{U(s)} = \frac{\frac{\frac{1}{2}}{2+s+\frac{1}{2s}}}{1+\frac{2+s}{(2+s)\times 2s+1}} = \frac{\frac{1}{2}\times 2s}{2s^2+4s+1+2+s} = \frac{s}{2s^2+5s+3}$$

$$H(s) = \frac{s}{(2s+3)(s+1)}.$$

令 $D(s) = (2s+3)(s+1)=0$ $\therefore s_1=-1,\ s_2=-\frac{3}{2}$

$$K_1 = \frac{N(s)}{D'(s)}\Big|_{s_1=-1} = \frac{s}{4s+5}\Big|_{s=-1} = \frac{-1}{-4+5} = -1$$

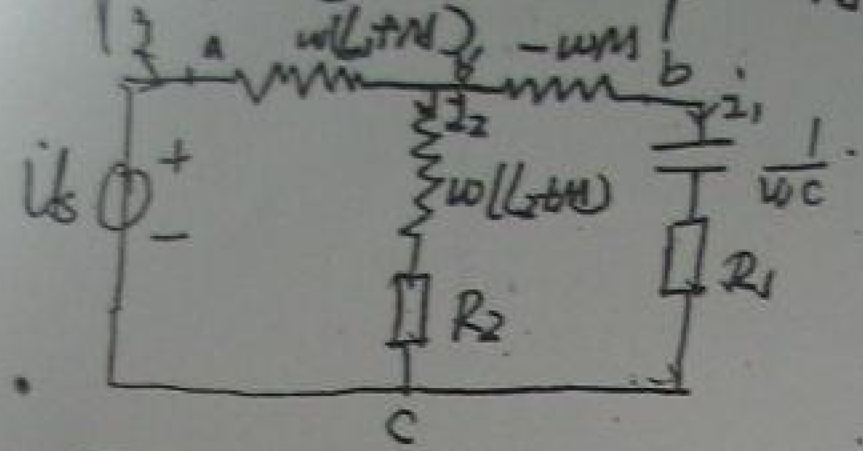
$$K_2 = \frac{N(s)}{D'(s)}\Big|_{s_2=-\frac{3}{2}} = \frac{-\frac{3}{2}}{4\times(-\frac{3}{2})+5} = \frac{3}{2}$$

$$h(t) = -e^{-t} + \frac{3}{2}e^{-\frac{3}{2}t}$$

(2). $\cancel{U_2(s) = \frac{\omega^2}{s^2+\omega^2} = \frac{2}{s^2+4}}\cdot\frac{1}{s}$..

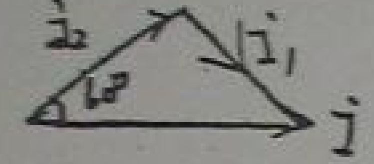
~~[illegible]~~.

八、解：原电路图去耦合得．



由已知．$\dot I = \dot I_1 + \dot I_2$ 且 $I = I_1 = I_2$

相量图为



∵ $\dot U_{bc}$ 与 $\dot I$ 同相位．故有

$$\dot U_{bc} = \dot I_1 \left(R_1 - \frac{j}{\omega C}\right) = \dot I \left(R_1 - \frac{j}{\omega C}\right)\cdot \angle 60^\circ$$

$$\therefore \frac{\dot U_{bc}}{\dot I} = \frac{R_1}{2} - \frac{j}{\omega C} - j\frac{\sqrt3}{2}R - \frac{\sqrt3}{2\omega C}$$

故 $\frac{R_1}{2} = \frac{\sqrt3}{2\omega C}$．∴ $\frac{1}{\omega C} = \frac{R_1}{\sqrt3} = \frac{10\sqrt3}{3}\Omega$．

$\dot U_{ac}$ 与 $\dot I$ 同相位．有 $\dot U_{ac} = \dot I \cdot j\omega L_1 + \dot I_2 [R_2 + j\omega(L_2+M)]$

$$\therefore \dot U_{ac} = \dot I \cdot j\omega(L_1+M) + \dot I \angle 60^\circ [R_2 + j\omega(L_2+M)]$$

$$\therefore \frac{\dot U_{ac}}{\dot I} = j\omega(L_1+M) + \frac{R_2}{2} + \frac{j\omega(L_2+M)}{2} + j\frac{\sqrt3}{2}R_2 - \frac{\sqrt3}{2}\omega(L_2+M)$$

$$\therefore \frac{R_2}{2} = \frac{\sqrt3}{2}\omega(L_2+M).$$

$$\therefore \omega(L_2+M) = \frac{R_2}{\sqrt3}\Omega = 0.773\Omega.$$

又．$\dot I_2 [R_2 + j\omega(L_2+M)] = \dot I_1 \left(R_1 - j\omega M - \frac{j}{\omega C}\right)$．

$$\therefore \dot I_1 \angle 120^\circ [R_2 + j\omega(L_2+M)] = \dot I_1 \left(R_1 - j\omega M - \frac{j}{\omega C}\right).$$

$$\therefore -\frac{R_2}{2} - \frac{j\omega(L_2+M)}{2} + j\frac{\sqrt3}{2}R_2 - \frac{\sqrt3\omega(L_2+M)}{2} = R_1 - j\omega M - \frac{j}{\omega C}$$

$$\frac{\sqrt3}{2}R_2 - \frac{\omega}{2}(L_2+M) = -\omega M - \frac{1}{\omega C}$$

$$\therefore \frac{\sqrt3}{2}R_2 - \frac{\sqrt3}{6}R_2 = -\omega M - \frac{10}{3}\sqrt3.$$

$$\therefore \frac{\sqrt3}{3}\times 1.338 + \frac{10}{3}\sqrt3 = -\omega M$$

$$\omega M = -6.5471$$

$$\therefore \omega L_2 = 6.5471 + 0.7732 = 7.32$$