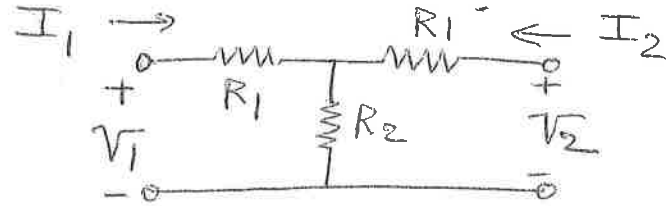
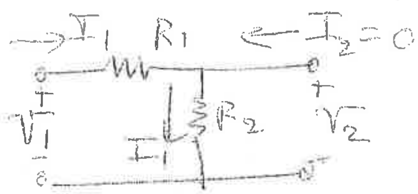
III.(90pts): **Two port feedback network**

Consider the feedback network below and calculate its **FOUR** z-parameters. Draw explicitly each of the small circuit diagram needed to calculate each of the four z-parameters. Also, calculate the explicit values of the four parameters z_{11}, z_{12}, z_{21}, and z_{22} and give their **UNITS** if $R_1 = 1M\Omega$ and $R_2 = 100k\Omega$.



$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$z_{11} = \left.\dfrac{V_1}{I_1}\right|_{I_2=0}$

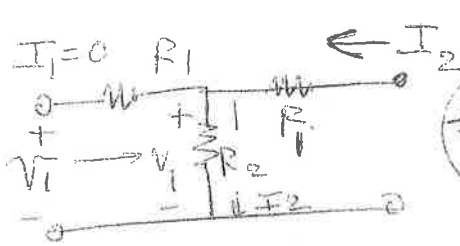


+5.0

$V_1 = (R_1 + R_2) I_1$

$\rightarrow z_{11} = R_1 + R_2 = 1.1 M\Omega$

$z_{12} = \left.\dfrac{V_1}{I_2}\right|_{I_1=0}$



+5.0

$V_1 = R_2 I_2 \rightarrow z_{12} = R_2 = 100 k\Omega$

$z_{22} = \left.\dfrac{V_2}{I_2}\right|_{I_1=0} = z_{11}$ by symmetry $= 1.1 M\Omega$ +5.0

$z_{21} = \left.\dfrac{V_2}{I_1}\right|_{I_2=0} = z_{12} =$ By by symmetry $= R_2 = 100 k\Omega$

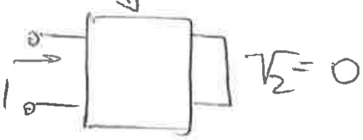
+5.0

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

$$y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0}$$

(Siemens)

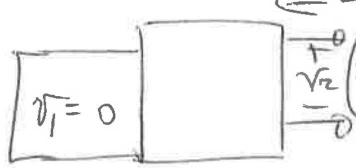
$$y_{11} = R_{11}^{-1}$$



$$R_{11} = R_1 + (R_1 /\!/ R_2) \simeq 1.1\,M\Omega$$

$$\boxed{y_{11} = 0.91\,\mu S}$$

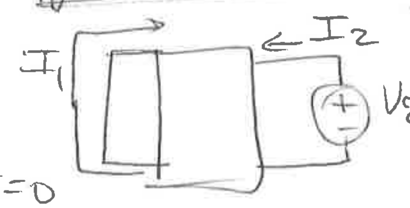
$$y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1=0}$$

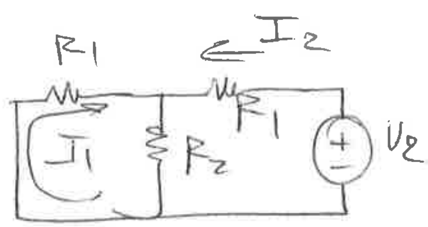


$$R_{22} = y_{22}^{-1} \underset{\text{by symmetry}}{=} R_{11} = R_1 + (R_1 /\!/ R_2) = 1.1\,M\Omega$$

$$\boxed{y_{22} = 0.91\,\mu S}$$

$$y_{12} = \beta f = \left.\frac{I_1}{V_2}\right|_{V_1=0}$$





$$I_1 = \frac{-R_2}{R_1 + R_2} I_2$$

$$V_2 = [R_1 + (R_1 /\!/ R_2)] I_2$$

$$\rightarrow y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1} = \left(\frac{-R_2}{R_1 + R_2}\right) \frac{1}{[R_1 + (R_1 /\!/ R_2)]}$$

$$\beta f = -\frac{100k\Omega}{1.1M\Omega} \cdot \frac{1}{1M\Omega + (1M /\!/ 100k)}$$

$$\rightarrow \boxed{y_{12} = -8.33\,10^{-8}\,S = -83.3\,nS}$$

$$y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2=0} = y_{12} \text{ (by symmetry)}$$

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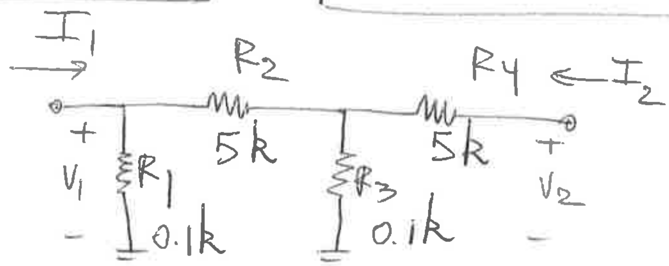
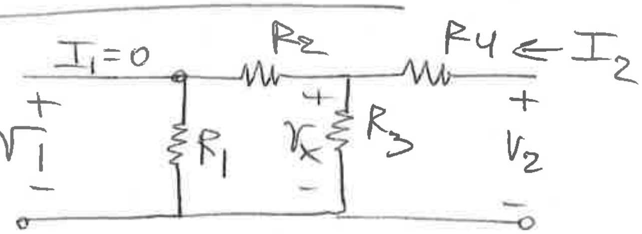


$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

$$\boxed{h_{11} = \frac{V_1}{I_1}\bigg|_{V_2=0} = \left\{R_1 // \left[R_2 + (R_3 // R_4)\right]\right\}} \quad +4.5$$

$$= \left\{0.1 // \left[5 + (0.1 // 5)\right]\right\} \simeq \boxed{98\,\Omega = h_{11}} \quad +0.5$$

$$h_{12} = \frac{V_1}{V_2}\bigg|_{I_1=0}$$



$$V_x = V_2 \left[\frac{(R_1+R_2)//R_3}{(R_1+R_2)//R_3 + R_4}\right] \quad \& \quad V_1 = \frac{R_1}{R_1+R_2} V_x$$

$$\rightarrow V_1 = \frac{\left[(R_1+R_2)//R_3\right]}{\left\{\left[(R_1+R_2)//R_3\right] + R_4\right\}} \cdot \frac{R_1}{R_1+R_2} \, V_2 \qquad = h_{12} \quad +4.5$$

$$\rightarrow \boxed{h_{12} = 1.88 \cdot 10^{-2}\ V/V} \quad +0.5$$