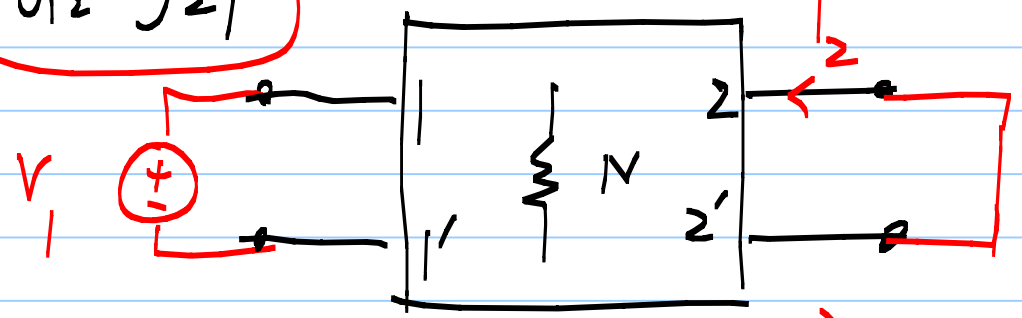
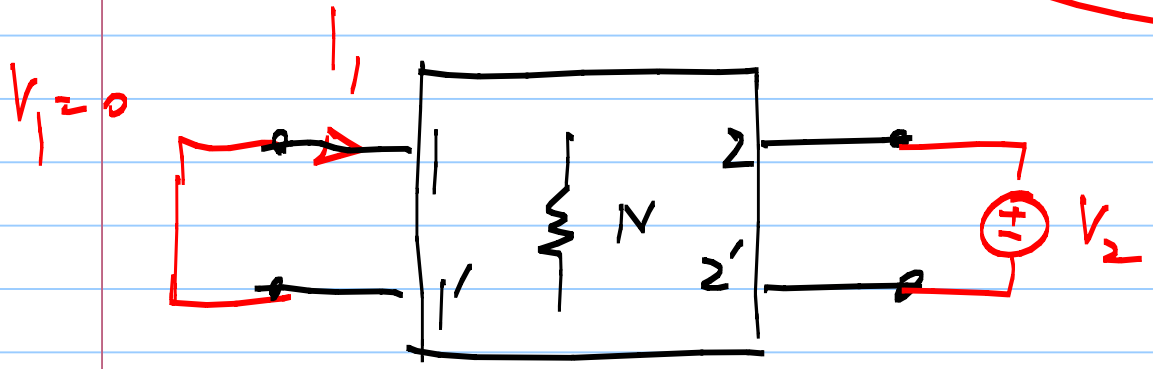
EE 2015 — Reciprocity & two-ports — 5/9/2017

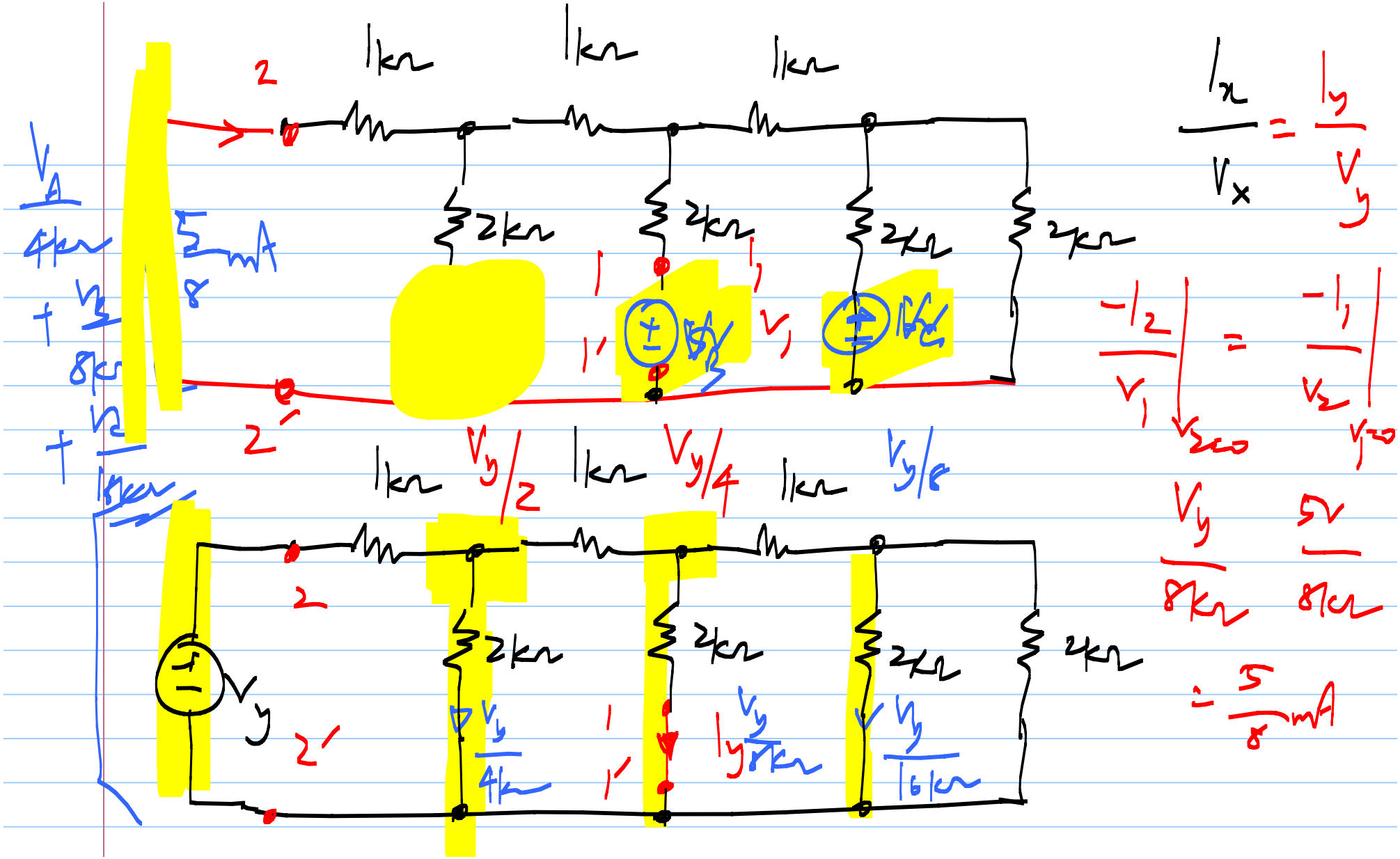
$y_{12} = y_{21}$



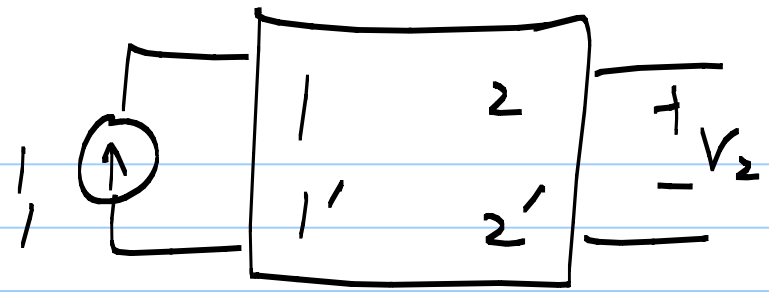
$$\left.\frac{I_1}{V_2}\right|_{V_1=0} = \left.\frac{I_2}{V_1}\right|_{V_2=0}$$

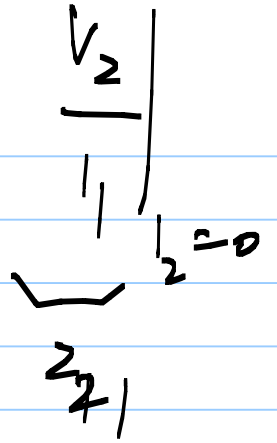
$$y_{12} = y_{21}$$



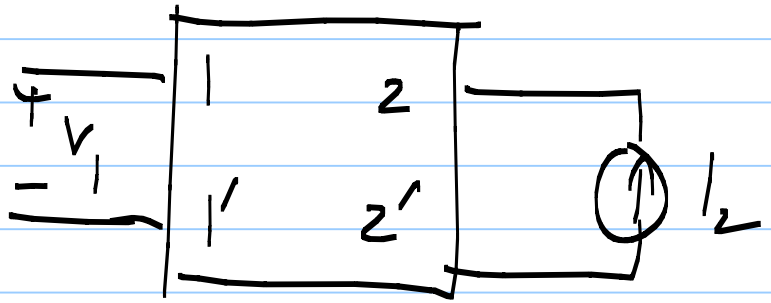

1kΩ
1kΩ
1kΩ
2kΩ
2kΩ
2kΩ
2kΩ
2
2'
1
1'
I_1
V_1
$V_y/2$
$V_y/4$
$V_y/6$
V_y
$\frac{V_y}{4k\Omega}$
I_y
$\frac{V_y}{8k\Omega}$
$\frac{V_y}{16k\Omega}$
$\frac{V_A}{4k\Omega}$
5 mA
8
$\frac{V_2}{8k\Omega}$
$\frac{V_2}{16k\Omega}$
$\frac{I_x}{V_x} = \frac{I_y}{V_y}$
$\left|\frac{-I_2}{V_1}\right|_{V_{2=0}} = \left|\frac{-I_1}{V_2}\right|_{V_{1=0}}$
$\frac{V_y}{8k\Omega} = \frac{5V}{8k\Omega}$
$= \frac{5}{8}$ mA

$Z_{12} = Z_{21}$:

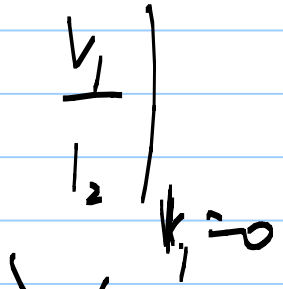




Z_{21}

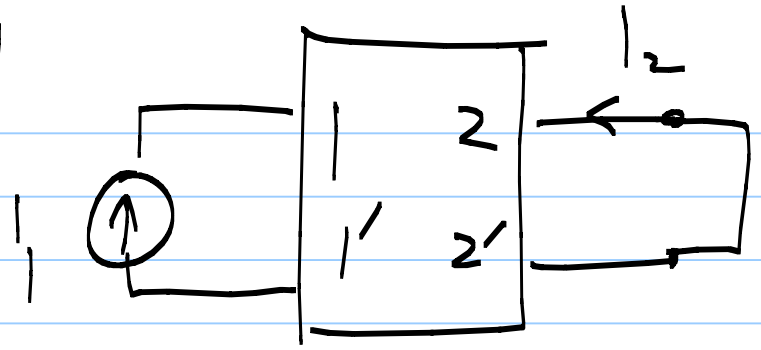


$=$



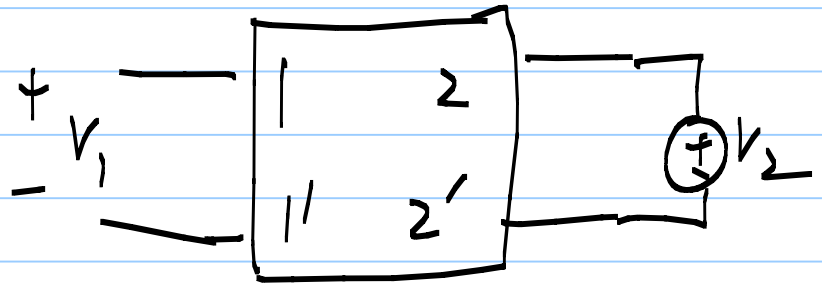
Z_{12}

$h_{12} = -h_{21}$



$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2 = 0}$$

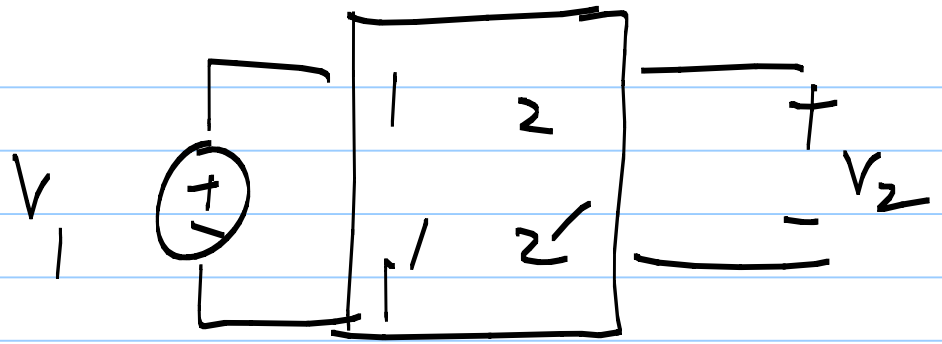
short ckt current gain from 1 → 2



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

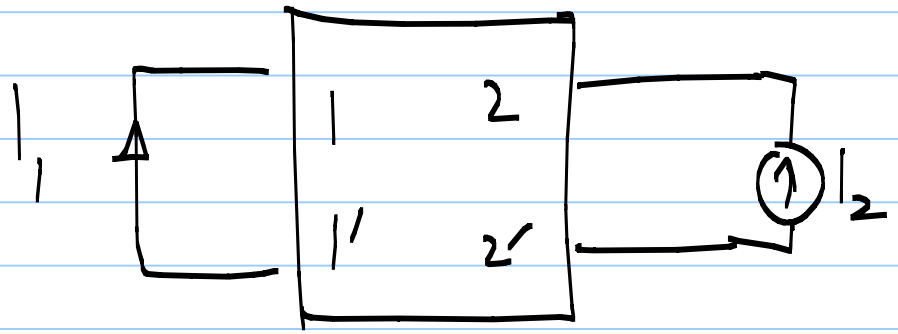
open circuit voltage gain from 2 → 1

$g_{12} = -g_{21}$



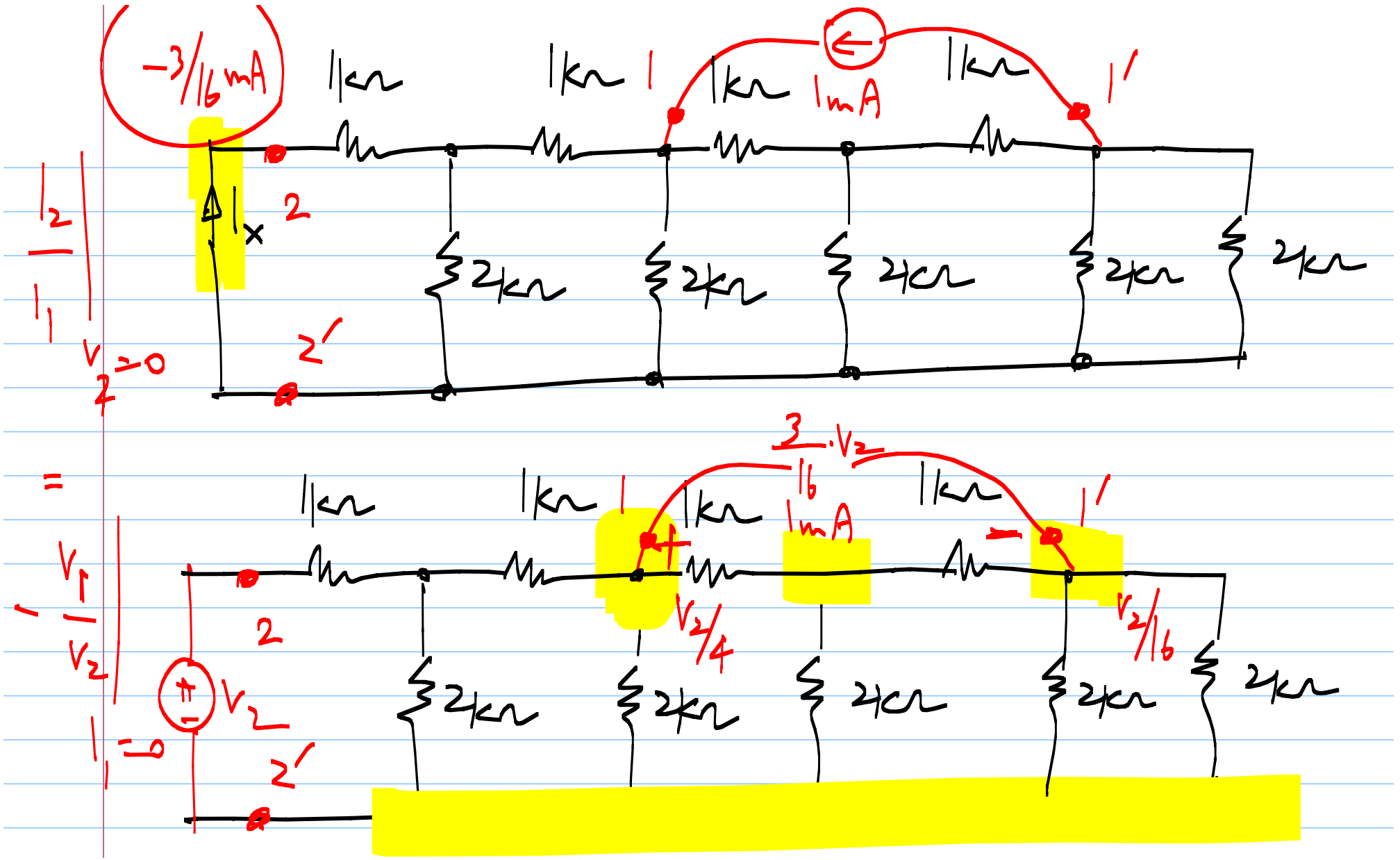
$$\left.\frac{V_2}{V_1}\right|_{I_2=0}$$

open circuit-
voltage gain
from $1 \rightarrow 2$



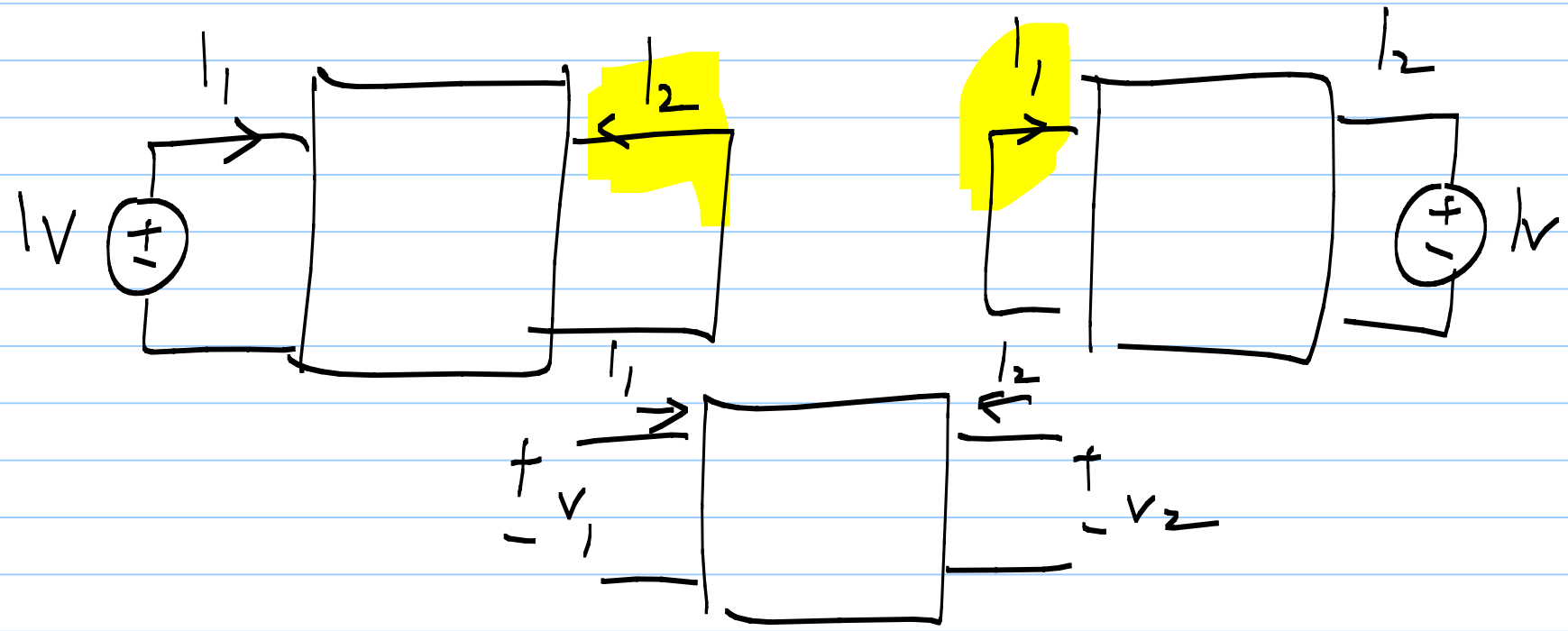
$$\left.\frac{I_1}{I_2}\right|_{V_1=0}$$

S.C. current
gain from $2 \rightarrow 1$

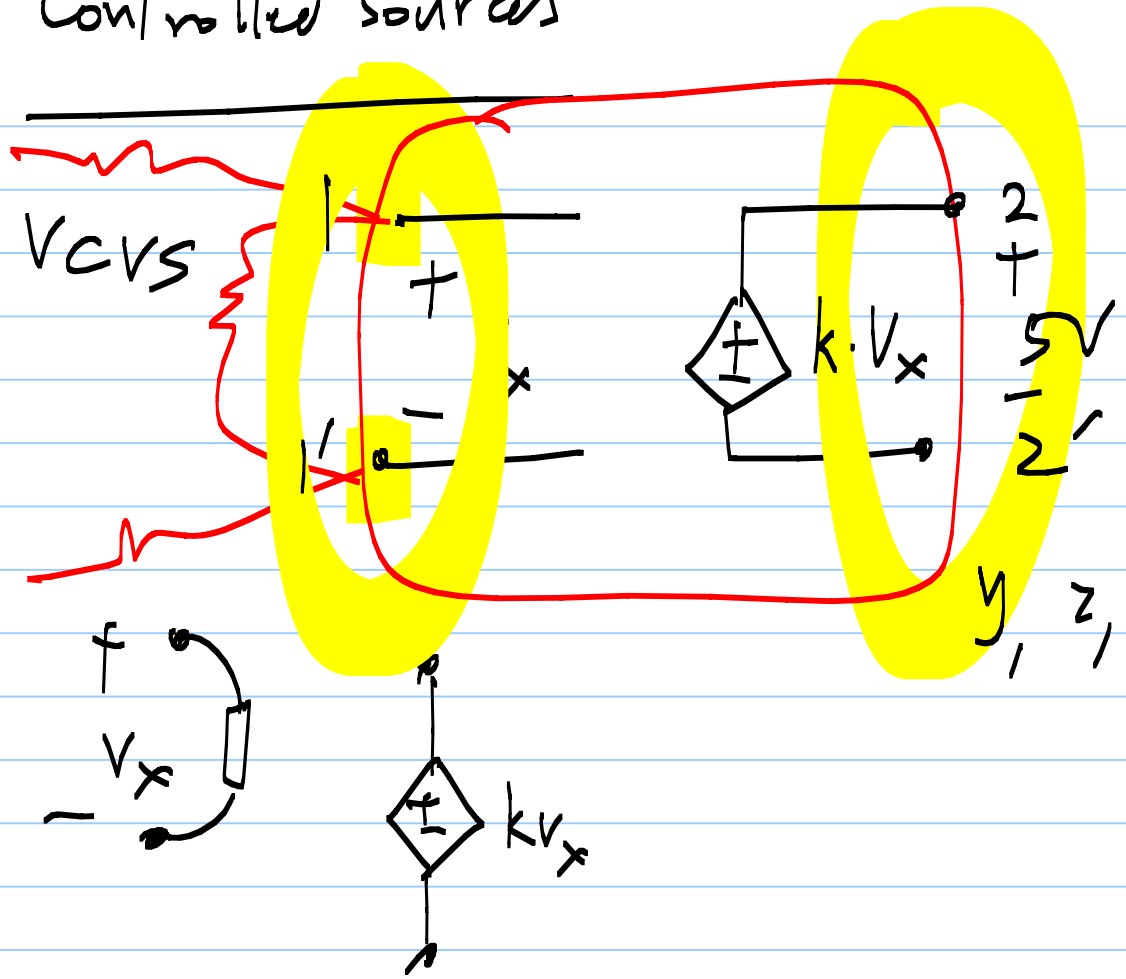

-3/16 mA
1kΩ
1kΩ
1
1kΩ
1mA
1kΩ
1'
2
x
2kΩ
2kΩ
2kΩ
2kΩ
2kΩ
I2/I1
V2=0
2'
=
3/16 V2
1mA
V1/V2
V2/4
V2/16
V2
I1=0

Resistive 2-ports are reciprocal

$$y_{12} = y_{21} \; ; \quad z_{12} = z_{21} \; ; \quad h_{12} = -h_{21} \; ; \quad g_{12} = -g_{21}$$



Controlled sources

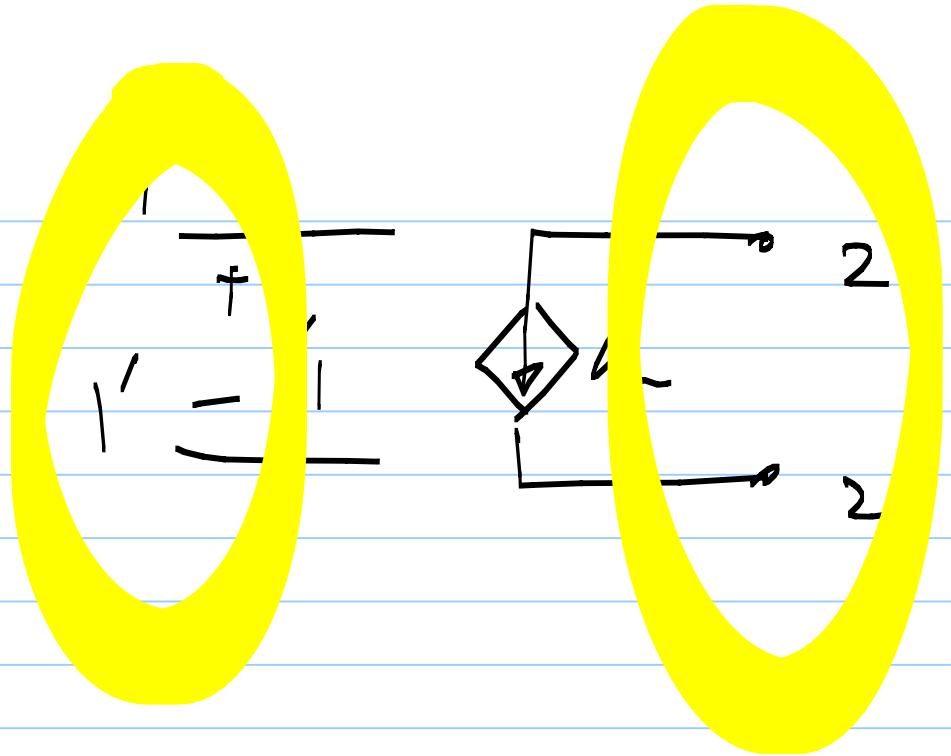


$V_2 = k \cdot V_1$

$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ k & 0 \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

y, z, h

VCCS :



$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ G_m & 0 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$