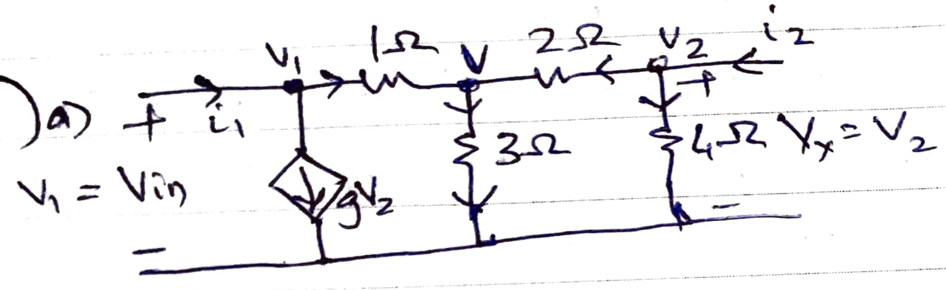
Analog Circuits
Assignment-1

1) (a)



From the above circuit, by using KCL,

$$\frac{V_1 - V}{1} + \frac{V_2 - V}{2} = \frac{V}{3} \Rightarrow V_1 + \frac{V_2}{2} = V\left[\frac{11}{6}\right]$$

$$\Rightarrow \boxed{V = \frac{3}{11}\left[2V_1 + V_2\right]} = \frac{6V_1}{11} + \frac{3V_2}{11}$$

$$\Rightarrow i_1 = gV_2 + \frac{V_1 - V}{1} = gV_2 + V_1 - \frac{6V_1}{11} - \frac{3}{11}V_2$$

$$\boxed{i_1 = \frac{5}{11}V_1 + \left(g - \frac{3}{11}\right)V_2}$$

And $i_2 = \dfrac{V_2}{4} + \dfrac{V_2 - V}{2} = \dfrac{V_2}{4} + \dfrac{V_2}{2} - \dfrac{1}{2}\left[\dfrac{6V_1}{11} + \dfrac{3V_2}{11}\right]$

$$= \frac{3V_2}{4} - \frac{3V_1}{11} - \frac{3V_2}{22} = \frac{33V_2 - 6V_2}{44} - \frac{3V_1}{11}$$

$$= \frac{27}{44}V_2 - \frac{3V_1}{11} \Rightarrow \boxed{i_2 = -\frac{3V_1}{11} + \frac{27}{44}V_2}$$

$$\Rightarrow \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \underbrace{\begin{bmatrix} 5/11 & g - 3/11 \\ -3/11 & 27/44 \end{bmatrix}}_{\text{Y-parameters}} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

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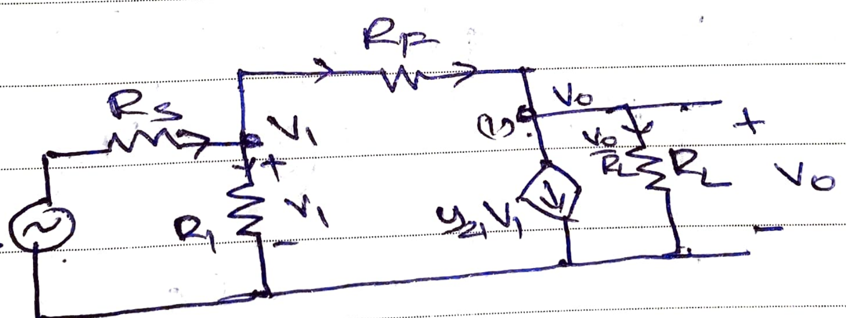
b) A unilateral network is a circuit network in which the affect of change in input parameter is traversed to the other port but is not affected in the other way round. Hence, for admittance circuit, y_{21} or y_{12} is zero. (anyone)

Hence in the found Y matrix,

$$y = \begin{bmatrix} 5/11 & g-3/11 \\ -3/11 & 27/44 \end{bmatrix}, \text{ Here } y_{12} \text{ must be zero}$$

$$\Rightarrow g - \frac{3}{11} = 0 \Rightarrow \boxed{g = \frac{3}{11}}$$

2)



By applying Nodal analysis:

(1) $\Rightarrow$ $$V_1 - V_o = R_F\left[y_{21}V_1 + \frac{V_o}{R_L}\right]$$

$$V_1\left[1 - R_F y_{21}\right] = V_o\left[1 + \frac{R_F}{R_L}\right]$$

$$\boxed{V_1 = \frac{V_o\left(1 + R_F/R_L\right)}{1 - R_F y_{21}}}$$

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(a) $$V_s - V_1 = R_s\left[\frac{V_1}{R_1} + \underbrace{y_{21}V_1 + \frac{V_o}{R_L}}_{\frac{V_1 - V_o}{R_F}}\right] = \left(\frac{R_s}{R_1} + \frac{R_s}{R_F}\right)V_1 - \frac{R_s}{R_F}V_o$$

$$\Rightarrow V_s = V_1\left(\frac{R_s}{R_1} + \frac{R_s}{R_F} + 1\right) - \frac{R_s}{R_F}V_o$$

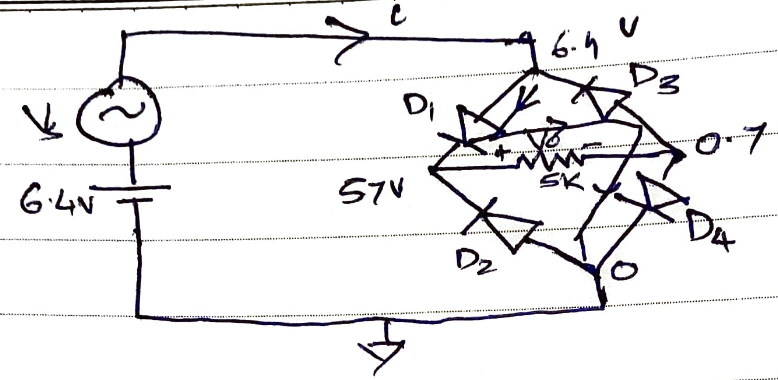
$$= V_o\left[\frac{(1 + R_F/R_L)}{(1 - R_F y_{21})}\left(1 + \frac{R_s}{R_1} + \frac{R_s}{R_F}\right) - \frac{R_s}{R_F}\right]$$

$$\Rightarrow \boxed{\frac{V_o}{V_s} = \frac{1}{\left(\frac{1 + R_F/R_L}{1 - R_F y_{21}}\right)\left(1 + \frac{R_s(R_1 + R_F)}{R_1 R_F}\right) - \left(\frac{R_s}{R_F}\right)}}$$

(b) When $y_{21} \to \infty$, the term in denominator converges to zero, which gives

$$\frac{V_o}{V_s} = \frac{1}{0 - \frac{R_s}{R_F}} = -\frac{R_F}{R_s}$$

3)



$i = \frac{5}{5k} = 1mA$

a) As we can see D_1 and D_4 will be in forward bias and D_2 and D_3 will be in reverse bias. Assuming the cut-in voltage of diodes be 0.7V, we get

$$V_o = 5.7V - 0.7V = 5V$$

And correspondingly the D.C operating point are

	V_D	I_D
D_1	0.7V	1mA
D_2	-5.7V	~0A
D_3	-5.7V	~0A
D_4	0.7V	1mA

b) The D.C current through the 5k resistor is $= \frac{5V}{5k} = 1mA$.

c) Now applying a small input gain voltage of V_s, we see the voltage across resistor

$$V_o' = (5.7 + V_s) - 0.7 = 5 + V_s$$

$$\Rightarrow V_o' - V_o = (5+V_s) - (5) = V_s \Rightarrow \boxed{\frac{\Delta V_o}{V_s} \approx 1}$$

$\therefore$ Small signal gain $\approx 1 = \frac{V_o}{V_s}$

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4) Given input-output characteristics of 2 non-linear networks:

$N_1 : V_o = \frac{V_{in}^2}{V_A}$ | $N_2 : V_o = V_A \exp\left(\frac{V_{in}}{V_A}\right)$

a) i) For N_1 : $V_o = \frac{V_{in}^2}{V_A} \Rightarrow \left.\frac{\partial V_o}{\partial V_{in}}\right|_{V_{in}=V} = \left.\frac{2V_{in}}{V_A}\right|_V$

$\Rightarrow \frac{2V}{V_A} = 10 \Rightarrow \boxed{V = 5V_A}$

Hence, $V_{in} = 5V_A$ for incremental gain to be 10.

ii) For N_2 : $V_o = V_A \exp\left(\frac{V_{in}}{V_A}\right)$

$\Rightarrow \left.\frac{\partial V_o}{\partial V_{in}}\right|_{V_{in}=V} = \left.\cancel{V_A} \cdot \left(\frac{1}{\cancel{V_A}} \exp\left(\frac{V_{in}}{V_A}\right)\right)\right|_{V_{in}=V} = 10$

$\Rightarrow \boxed{V_{in} = V_A \ln 10}$ for incremental gain to be 10.

b) To find which network is more linear, we can find the second derivative and observe which is more closer to zero.

For N_1 : $\left.\frac{\partial^2 V_o}{\partial V_{in}^2}\right|_{V_{in}=V_A \times 5} = \frac{2}{V_A}$

N_2 : $\left.\frac{\partial^2 V_o}{\partial V_{in}^2}\right|_{V_{in}=V_A \ln 10} = \frac{1}{V_A} \exp\left(\frac{\cancel{V_A} \ln 10}{\cancel{V_A}}\right) = \frac{10}{V_A}$

As $\frac{2}{V_A} < \frac{10}{V_A}$, N_1 network is more linear than N_2