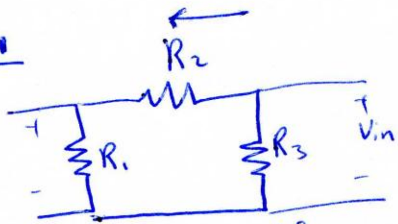
EE 230
HW 4 Solutions

Problem 1

a)

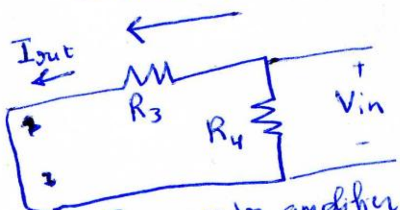


Voltage Amplifier

$$\beta = \frac{V_{out}}{V_{in}}$$

$$V_{out} = \frac{R_1}{R_1 + R_2} V_{in} \implies \beta = \frac{R_1}{R_1 + R_2}$$

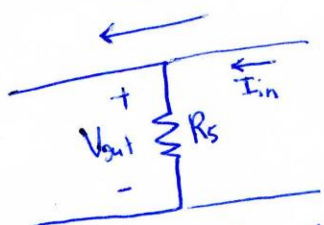
b)



Transresistor amplifier

$$\beta = \frac{I_{out}}{V_{in}} \implies \beta = \frac{\left(\frac{V_{in}}{R_3}\right)}{V_{in}} = \frac{1}{R_3}$$

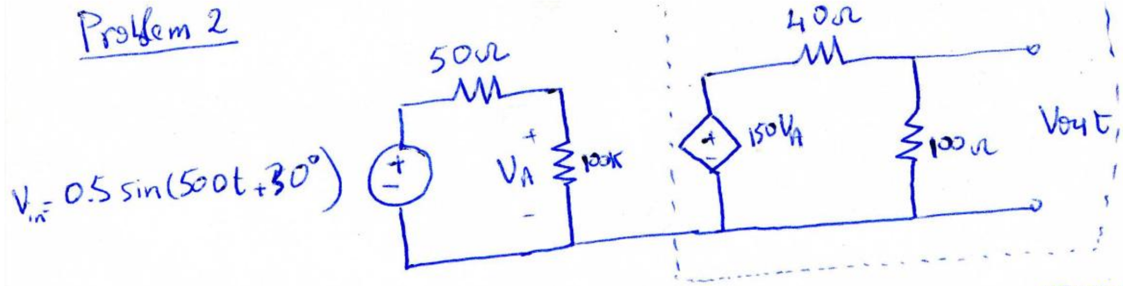
c)



Transconductance Amplifier

$$\beta = \frac{V_{out}}{I_{in}} \implies \beta = \frac{R_5 I_{in}}{I_{in}} = R_5$$

Problem 2



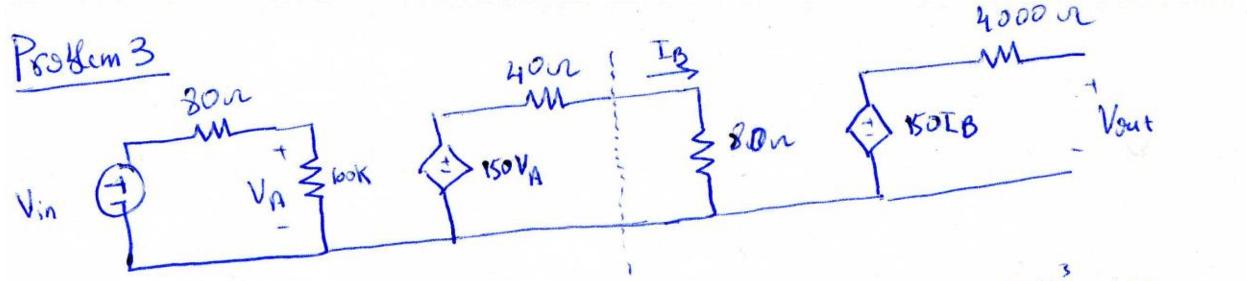
From the second port (dotted box) : $V_{out} = \dfrac{150 V_A \times 100}{40+100} = \dfrac{15000 V_A}{140} = \dfrac{1500}{1}$

From the first port : $V_A = \dfrac{100\times10^3 \times V_{in}}{100\times10^3 + 50}$ (2)

Replace (2) in (1) $\Rightarrow V_{out} = \dfrac{1500\left(\dfrac{10^5 V_{in}}{10^5+50}\right)}{14} = 107.089\, V_{in}$

$\Rightarrow \boxed{V_{out} = 53.54\sin(500t+30°)}$

Problem 3

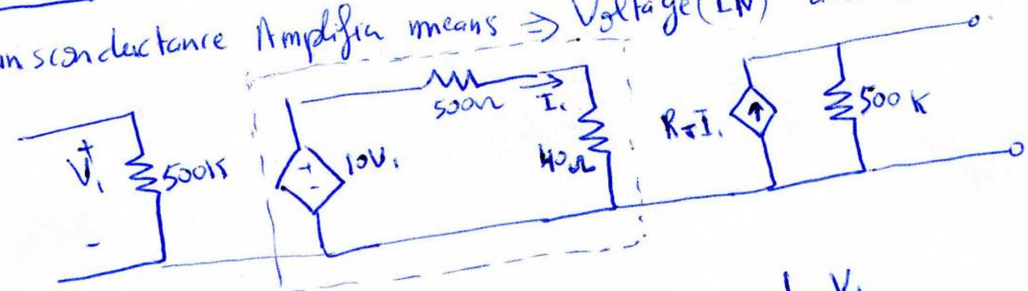


$$\begin{cases} V_{out} = 150 I_B \\ I_B = \dfrac{150\ V_A}{40+80} \\ V_A = \dfrac{100\times10^3 \times V_{in}}{80+100\times10^3} \end{cases} \Rightarrow V_{out} = 150 \times \frac{150}{40+80} \times \frac{100\times10^3}{80+100\times10^3} V_{in}$$

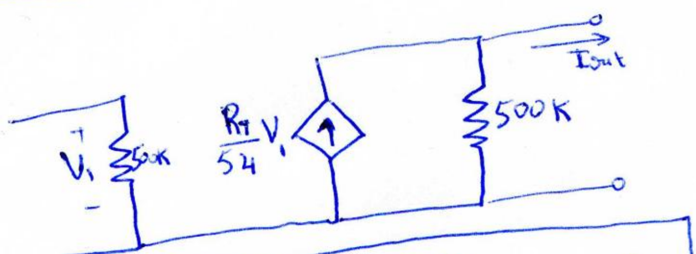
$$\Rightarrow \boxed{Gain = \frac{V_{out}}{V_{in}} = 187.35}$$

Problem 4

Transconductance Amplifier means ⇒ Voltage (IN) and Current (OUT)

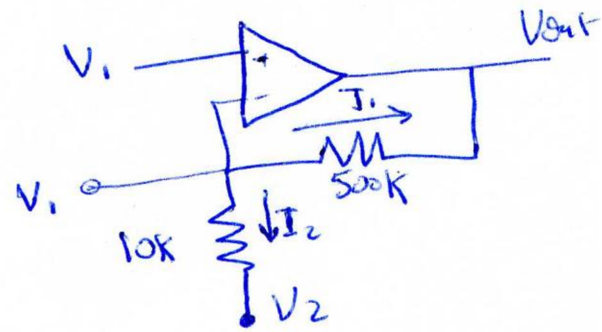


Based on the dotted box: $I_1 = \dfrac{10 V_1}{500+40} = \dfrac{1}{54} V_1$



$$\boxed{G_M = \frac{I_{out}}{V_1} = \frac{\frac{R_T V_1}{54}}{V_1} = \frac{R_T}{54}}$$

Problem 5



$V^+ = V^- = V_1$

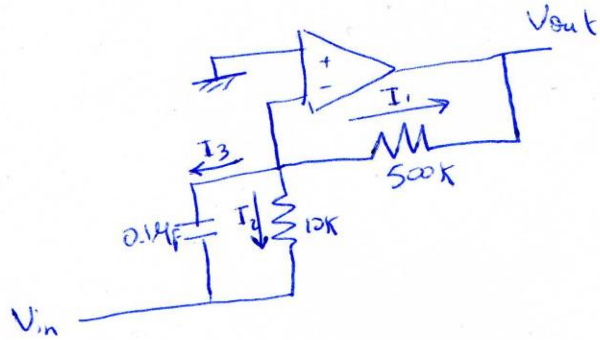
KCL $\quad I_1 + I_2 = 0$

$$\left(\frac{V_1 - V_{out}}{500K}\right) + \left(\frac{V_1 - V_2}{10K}\right) = 0$$

$$\Rightarrow V_{out} = V_1 + 50(V_1 - V_2)$$

$$\boxed{V_{out} = 51V_1 - 50V_2}$$

Problem 6



$V^+ = V^- = 0V$

* KCL $\quad I_1 + I_2 + I_3 = 0$

$$\left(-\frac{V_{out}}{500K}\right) + \left(-\frac{V_{in}}{10K}\right) + \left(-V_{in}\, sC\right) = 0$$

$$\Rightarrow V_{out} = -50V_{in} - 500\times10^3\, s.C\, V_{in}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = -50 - 500\times10^3 \times 0.1\times10^{-6} \cdot s$$

$$\Rightarrow \boxed{T(s) = \frac{V_{out}}{V_{in}} = -50 - 0.05s}$$

* $V_{in} = 2u(t) \Rightarrow V_{in}(s) = \frac{2}{s}$

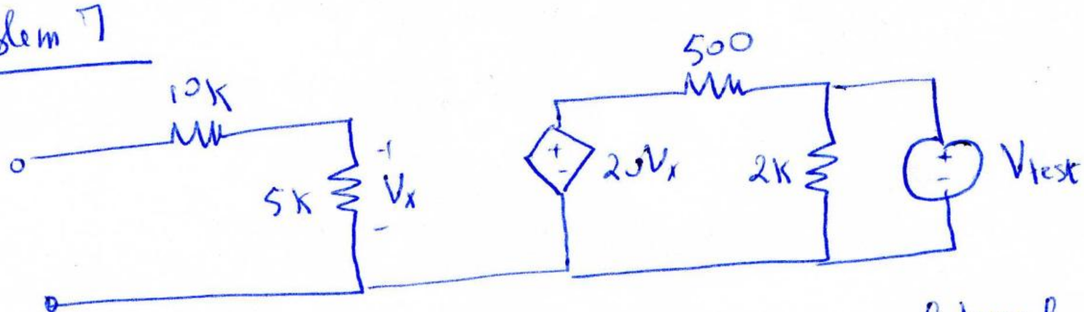
$$V_{out}(s) = V_{in}(s) \cdot T(s) = \frac{2}{s}\left(-50 - 0.05s\right) = \frac{-100}{s} - 0.05\times$$

$$V_{out}(t) = \mathcal{L}^{-1}\left(V_{out}(s)\right) = -100u(t) - 0.1\,\delta(t)$$

$$\boxed{V_{out}(t) = -\left(0.1\delta(t) + 100u(t)\right)}$$

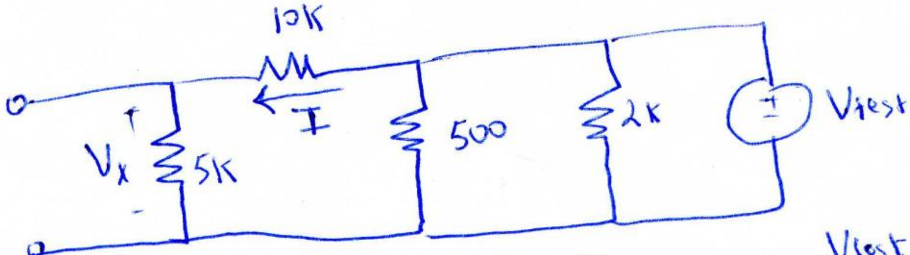
Problem 7

a)



$V_x = 0$ $\qquad A_{v_R} = \dfrac{V_x}{V_{test}} = \dfrac{0}{V_{test}} = 0 \Rightarrow$ unilateral

b)

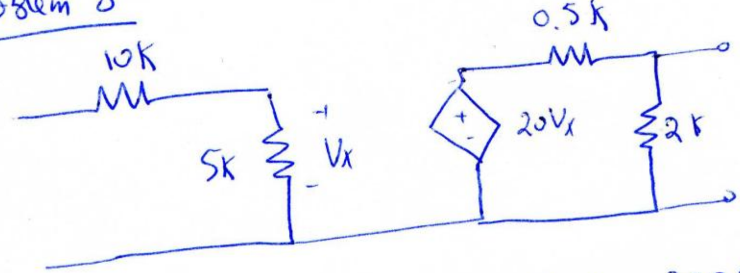


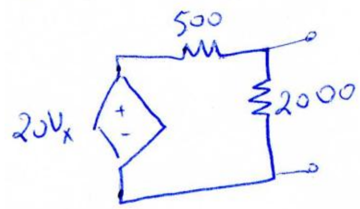
we have $\quad I = \dfrac{V_{test}}{10K + 5K} = \dfrac{V_{test}}{15K}$

and $\quad V_x = 5K \cdot I = \dfrac{5K\, V_{test}}{15K} = \dfrac{1}{3} V_{test}$

$\Rightarrow \boxed{\dfrac{V_x}{V_{test}} = \dfrac{1}{3}} \Rightarrow$ Not unilateral

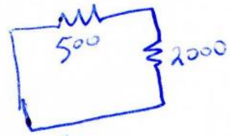
Problem 8



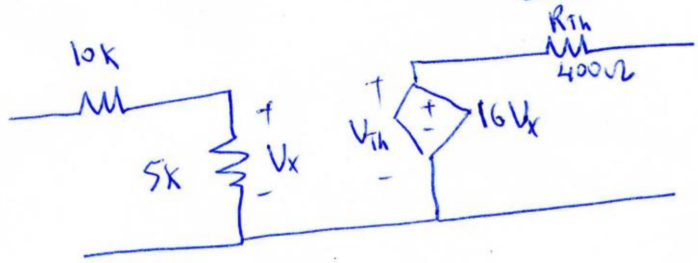


$\Longleftrightarrow$ $V_{th} = \dfrac{20V_x \cdot 2000}{2000+500} = 16\,V_x$

$\Longleftrightarrow$ $R_{Th} =$

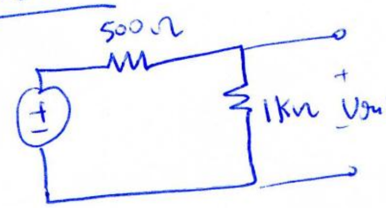


$= 50 \,//\, 2000 = 400\,\Omega$



Problem 9

a)



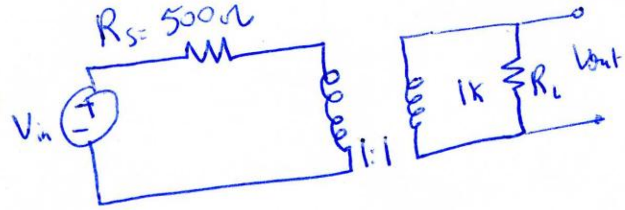
$$V_{out} = \frac{V_{in} \cdot 1K}{1K + 0.5K} = \frac{2}{3} V_{in}$$

$$P_L = \frac{V_{out}^2}{R_L} = \frac{\left(\frac{2}{3}V_{in}\right)^2}{R_L} = \frac{4}{9R_L} V_{in}^2$$

$$P_{source} = \frac{V_{in}^2}{1K + 0.5K} = \left(\frac{2}{3K}\right) V_{in}^2$$

$$\eta = \frac{P_L}{P_{source}} = \frac{\left(\frac{4}{9K}\right)V_{in}^2}{\left(\frac{2}{3K}\right)V_{in}^2} = \frac{4}{9} \times \frac{3}{2} = \frac{2}{3} = ($$

b)



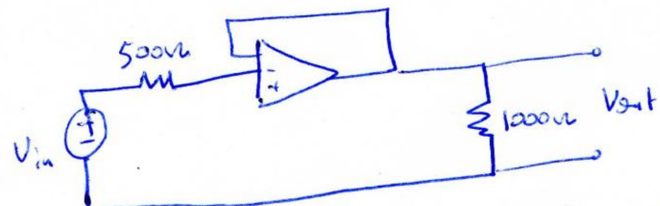
$$\eta = \frac{P_{Load}}{P_{Vin}} = \frac{R_L/r^2}{R_S + R_L/r^2}$$

$r = 1$ $\quad R_S = 500\Omega$ $\quad R_L = 1000\Omega$

$$\eta = \frac{1000}{1500} = \frac{2}{3} = 66\%$$

See lecture 8 pg 24

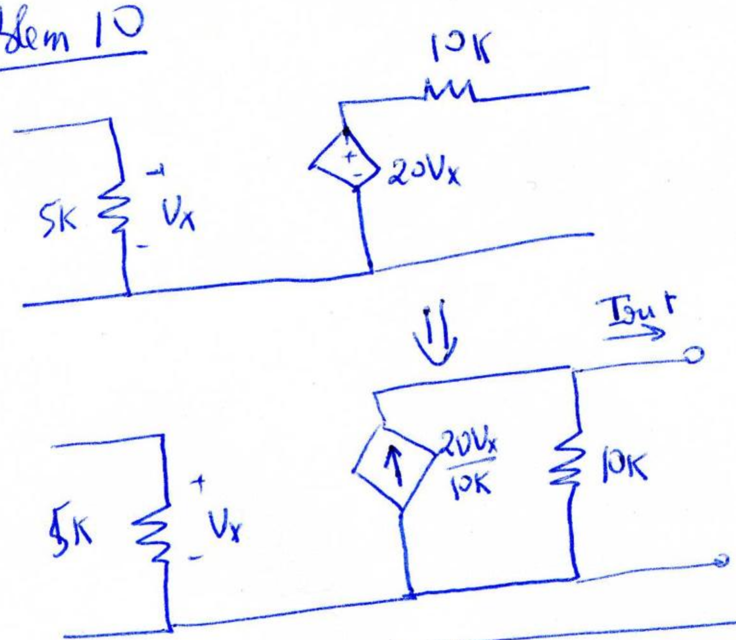
c)



The op-amp acts as a buffer $\Rightarrow V_{in} = V_{out} \Rightarrow \eta = 100\%$

$$P_L = \frac{V_{out}^2}{1000\Omega} = \frac{V_{in}^2}{1000} = \frac{1}{1000} = 1mW$$

Problem 10



$$G_m = \frac{20}{10 \times 1000} = 0.002$$