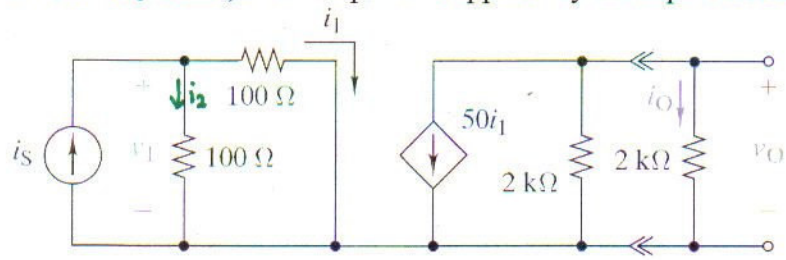
Problem#1: Problem 4-2 textbook

Find the voltage gain vo/v1 and the current gain i_o/i_s for the given circuit. If the input current is i_s=2mA, find the power supplied by the input current source.



$$i_1 = \frac{100}{100+100} i_s = \frac{i_s}{2} = i_2$$

$$V_1 = 100\, i_2 = 50\, i_s$$

$$i_s = \frac{V_1}{50}$$

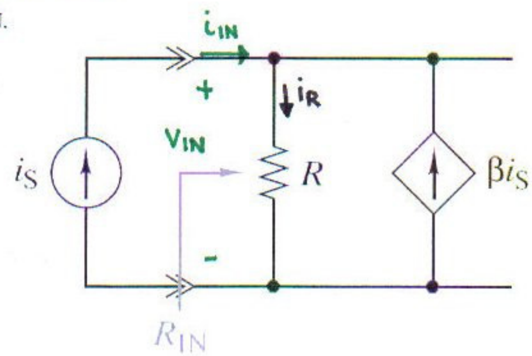
$$i_o = -\frac{2}{2+2}(50\, i_1) = -25\, i_1 = -12.5\, i_s \Rightarrow \boxed{\frac{i_o}{i_s} = -12.5}$$

$$V_o = 2\cdot 10^3 i_o = 2\cdot 10^3(-12.5\, i_s) = -25\cdot 10^3\, i_s = -\frac{25\cdot 10^3}{50} V_1 \Rightarrow \boxed{\frac{V_o}{V_1} = -500}$$

POWER SUPPLIED $p = |-V_1 \cdot i_s| = 50(2\cdot 10^{-3})\cdot 2\cdot 10^{-3} = 200\cdot 10^{-6} = \boxed{0.2\ mW}$

Problem#3: Problem 4-13 textbook

Find the input resistance R_{IN}.



$$R_{IN} = \frac{V_{IN}}{i_{IN}}$$

$$i_{IN} = i_s$$

$$i_R = i_{IN} + \beta i_s = (1+\beta)\, i_s$$

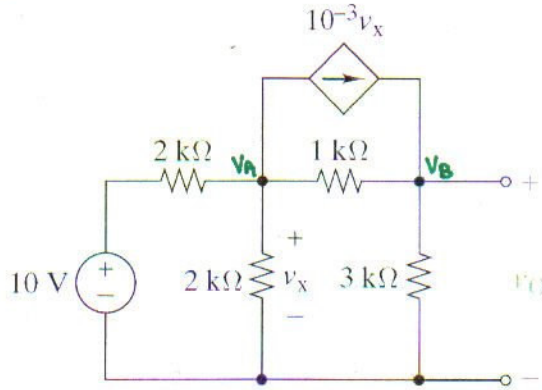
$$V_{IN} = R\, i_R = R(1+\beta)\, i_s$$

$$\boxed{R_{IN}} = \frac{V_{IN}}{i_{IN}} = \frac{R(1+\beta) i_s}{i_s} = \boxed{R(1+\beta)}$$

Problem#2: Problem 4-7 textbook
Find the output voltage.

$V_A = V_x$

$V_B = V_o$



NODE A $$\frac{V_A - 10}{2K} + \frac{V_A}{2K} + \frac{V_A - V_B}{1K} + 10^{-3} V_x = 0$$

$$V_A - 10 + V_A + 2V_A - 2V_B + 2V_A = 0$$

$$6V_A - 2V_B = 10 \qquad (1)$$

NODE B $$\frac{V_B - V_A}{1K} + \frac{V_B}{3K} = 10^{-3} V_x$$

$$3V_B - 3V_A + V_B = 3V_A$$

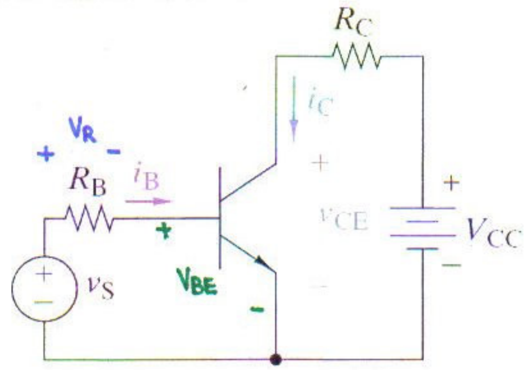
$$-6V_A + 4V_B = 0 \qquad (2)$$

(1) + (2) ⇨ $2V_B = 10$ ⇨ $V_B = 5V$ ⇨ $\boxed{V_o = 5V}$

substituting in (2) ⇨ $6V_A = 20$ ⇨ $V_A = \frac{10}{3}V$ ⇨ $V_x = 3.33\,V$

Problem#4: Problem 4-16 textbook

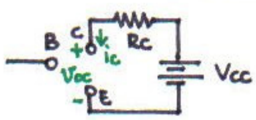
The circuit parameters are R_B=50 k Ω, R_C=3 k Ω, β=100, V_γ=0.7 V, and V_{CC}=15 V. Find the collector current i_C and V_{CE} for v_s=2 V.



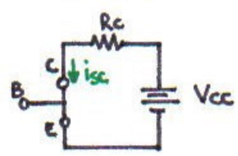
$$V_R = V_S - V_{BE}$$

$$i_B = \frac{V_R}{R_B} = \frac{V_S - V_{BE}}{R_B}$$

(1) COMPUTE THE OPEN-CIRCUIT VOLTAGE AND SHORT-CIRCUIT CURRENT



$i_c = 0 \Rightarrow V_{oc} = V_{cc} = 15V$



$$i_{sc} = \frac{V_{cc}}{R_c} = \frac{15}{3K} = 5mA$$

(2) ASSUME THAT THE BJT OPERATES IN ACTIVE MODE AND SOLVE THE CIRCUIT

when the BJT is in active mode $\begin{cases} i_c = \beta i_B \\ V_{BE} = V_\gamma \end{cases}$

$$i_c = \beta i_B = \beta \left(\frac{V_S - V_{BE}}{R_B} \right) = 100 \left(\frac{2 - 0.7}{50 \cdot 10^3} \right) = 2.6 \text{ mA}$$

$$V_{CE} = 15 - R_c i_c = 15 - 3 \cdot 10^3 \, (2.6 \cdot 10^{-3}) = 7.2 \text{ V}$$

(3) since

$0 < i_c < i_{sc} = 5mA$
$0 < V_{CE} < V_{oc} = 15V$

the BJT is indeed operating in ACTIVE MODE

Thus the analysis carried in step (2) is correct and

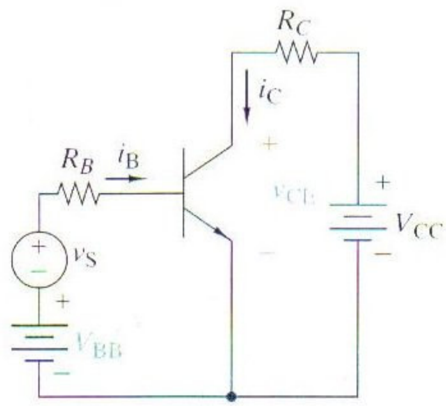
$i_c = 2.6mA$
$V_{CE} = 7.2V$

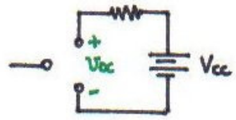
Problem#5: MATLAB Program

The input to the circuit is a series connection of a dc source and signal source v_s. The parameters of the circuit are R_B=500 k Ω, R_C=5 k Ω, β=100, V_γ=0.7 V, and V_{CC}=15 V.

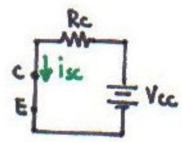
a) With v_s=0 select the value of V_{BB} so that the circuit is in active mode when v_{CE}= $V_{CC}/2$.

b) Using the same value of V_{BB} plot the characteristics of v_{CE} versus v_s as the signal voltage changes from -10V to +10V.



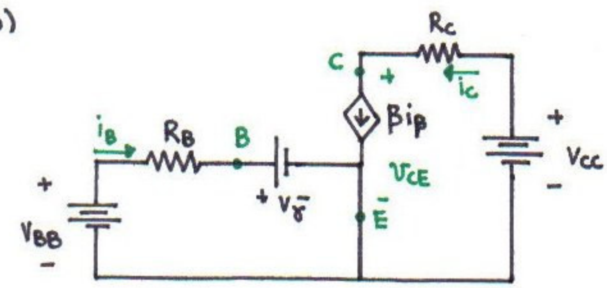


$\underline{V_{oc} = V_{cc} = 15\,V}$



$i_{sc} = \frac{V_{cc}}{R_c} = 3mA$

(a)



ACTIVE MODE

$$\begin{cases} V_{CE} + R_c i_c = V_{cc} \\ V_\gamma + R_B i_B = V_{BB} \end{cases}$$

$i_c = \beta i_B$

$V_{CE} = \frac{V_{cc}}{2}$

$$\begin{cases} \frac{V_{cc}}{2} + R_c \beta i_B = V_{cc} & (1) \\ i_B = \frac{V_{BB} - V_\gamma}{R_B} & (2) \end{cases}$$

substituting (2) into (1)

$$R_c \beta \left(\frac{V_{BB} - V_\gamma}{R_B}\right) = \frac{V_{cc}}{2} \quad \Rightarrow \quad 5K \cdot 100 \left(\frac{V_{BB} - 0.7}{500\,K}\right) = 7.5 \quad \Rightarrow \quad \boxed{V_{BB} = 8.2\,V}$$

(b) the BJT remains in ACTIVE MODE IF

$$\boxed{\begin{array}{l} 0 < V_{CE} < V_{oc} = 15V \quad (*) \\ 0 < i_c < i_{sc} = 3mA \quad (+) \end{array}}$$

$$V_{CE} = V_{cc} - R_c \beta i_B = V_{cc} - \overset{=1}{\frac{R_c \beta}{R_B}} (V_{BB} + V_s - V_\gamma) = V_{cc} - V_{BB} - V_s - V_\gamma = 7.5 - V_s$$

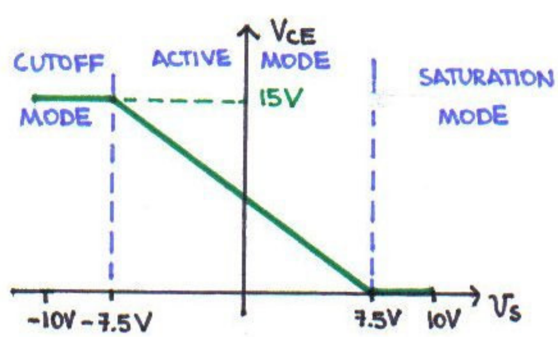
(*) $0 < 7.5 - V_s < 15 \quad \Rightarrow \quad \boxed{-7.5V < V_s < 7.5V}$

$$i_c = \beta \left(\frac{V_{BB} + V_s - V_\gamma}{R_B}\right) = 0.2\,(7.5 + V_s) \cdot 10^{-3}$$

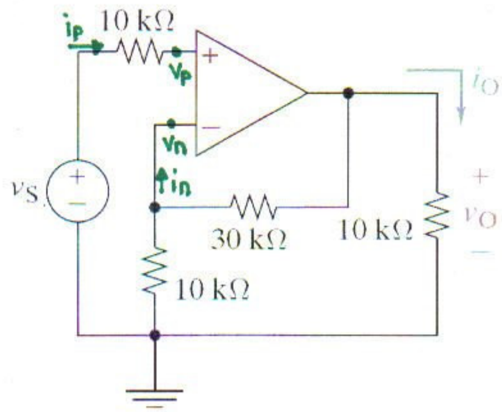
$V_s = -7.5V \Rightarrow i_c = 0$

$V_s = 7.5V \Rightarrow i_c = 3mA$

$\Rightarrow$ (+) is satisfied



Problem#6: Problem 4-23 textbook
Find v_O in terms of v_s.



OP AMP ⇨

$$V_p = V_n$$
$$i_p = i_n = 0$$

$i_p = 0$ ⇨ $V_p = V_s$

$V_n = V_p = V_s$

$i_n = 0$ ⇨ $\dfrac{V_n}{10K} + \dfrac{V_n - V_o}{30K} = 0$

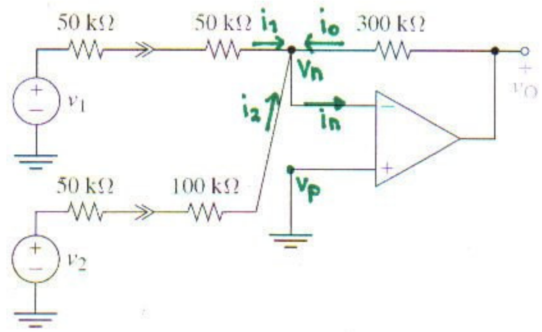
$3V_n + V_n - V_o = 0$

$4V_n = V_o$

$$\boxed{V_o = 4V_s}$$

Problem#7: Problem 4-26 textbook

Find v_O in terms of inputs v_1 and v_2.



OP AMP ⇨ $v_p = v_n$, $i_p = i_n = 0$

$v_p = 0 \Rightarrow v_n = 0$

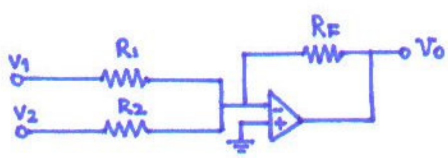
$i_n = 0 \Rightarrow i_o + i_1 + i_2 = 0$

$$\frac{V_o - V_n^{=0}}{300K} + \frac{V_1 - V_n^{=0}}{100K} + \frac{V_2 - V_n^{=0}}{150K} = 0$$

$$2V_2 + 3V_1 + V_o = 0$$

$$\boxed{V_o = -3V_1 - 2V_2}$$

NOTE



SUMMER $\boxed{V_o = K_1V_1 + K_2V_2}$

$K_1 = -\frac{R_F}{R_1}$

$K_2 = -\frac{R_F}{R_2}$

IN OUR CASE $R_1 = 100\,k\Omega$

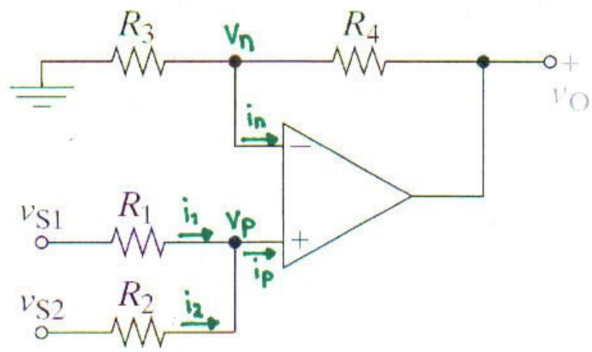
$R_2 = 150\,k\Omega$

$R_F = 300\,k\Omega$

HENCE $K_1 = -3$

$K_2 = -2$

Problem#8: Problem 4-30 textbook
Find vo in terms of vs1 and vs2.



$i_n = i_p = 0$

$V_n = V_p$

since $i_n = 0$ by voltage division rule $V_n = \frac{R_3}{R_3 + R_4} V_o = V_p$

$i_p = 0 \Rightarrow i_1 + i_2 = 0$

$$\frac{V_{s1} - V_p}{R_1} + \frac{V_{s2} - V_p}{R_2} = 0$$

$$R_2 \left(V_{s1} - \frac{R_3 V_o}{R_3 + R_4} \right) + R_1 \left(V_{s2} - \frac{R_3 V_o}{R_3 + R_4} \right) = 0$$

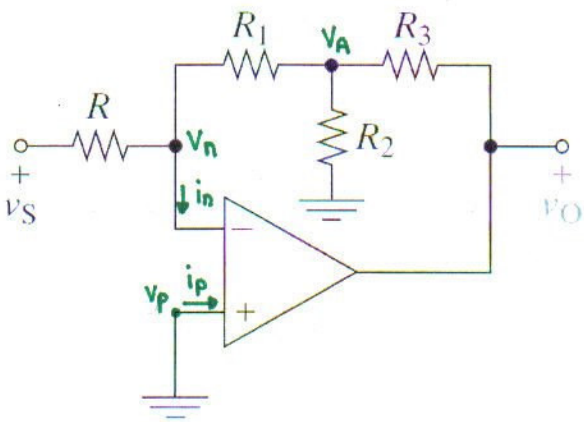
$$R_2 V_{s1} + R_1 V_{s2} = \frac{R_3 (R_1 + R_2)}{R_3 + R_4} V_o$$

$$\boxed{V_o = \frac{R_3 + R_4}{R_3 (R_1 + R_2)} \left[R_2 V_{s1} + R_1 V_{s2} \right]}$$

NON INVERTING
SUMMER AMPLIFIER

Problem#9: Problem 4-33 textbook

Using node voltage analysis, find the input- output relationship.



$V_n = V_p$

$i_n = i_p = 0$

$V_p = 0 \Rightarrow V_n = V_p = 0$

$i_n = 0 \Rightarrow \frac{\overset{=0}{\cancel{V_n}} - V_s}{R} + \frac{\overset{=0}{\cancel{V_n}} - V_A}{R_1} = 0$

$R_1 V_s = -R V_A$

$V_A = -\frac{R_1}{R} V_s$

KCL @ NODE A $\Rightarrow \frac{V_A - \overset{=0}{\cancel{V_n}}}{R_1} + \frac{V_A}{R_2} + \frac{V_A - V_o}{R_3} = 0$

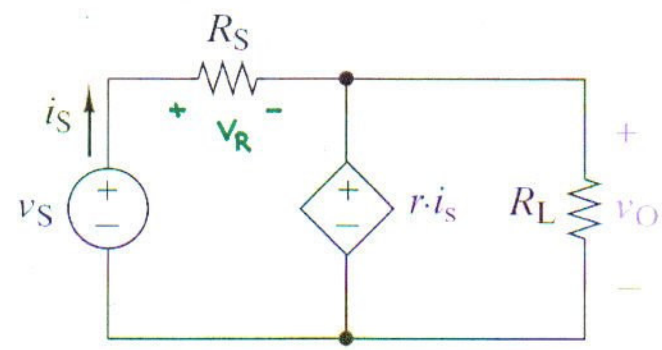
$\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right) V_A = \frac{V_o}{R_3}$

$\frac{R_1R_2 + R_1R_3 + R_2R_3}{\cancel{R_1}R_2\cancel{R_3}} \left(-\frac{\cancel{R_1}}{R} V_s\right) = \frac{V_o}{\cancel{R_3}}$

$$V_o = -\frac{R_1R_2 + R_1R_3 + R_2R_3}{RR_2} V_s$$

Problem#10: Problem 4-11 textbook

Find an expression for vo/vs.



$$V_R = R_s i_s = v_s - r i_s$$

$$(R_s + r)\, i_s = v_s$$

$$i_s = \frac{v_s}{R_s + r}$$

$$V_o = r i_s = \frac{r}{R_s + r} V_s$$

$$\boxed{\frac{V_o}{V_s} = \frac{r}{r + R_s}}$$