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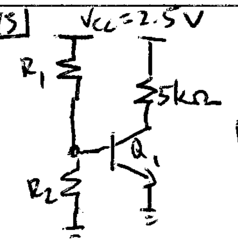
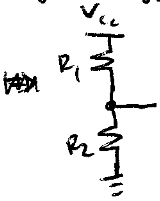
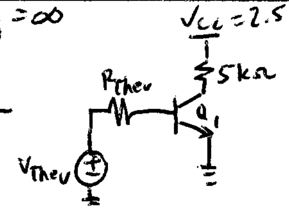
5.13 $V_{CC} = 2.5V$ $g_m \geq \frac{1}{260}$ $\beta = 100$ $I_S = 2 \times 10^{-17} A$ $V_A = \infty$



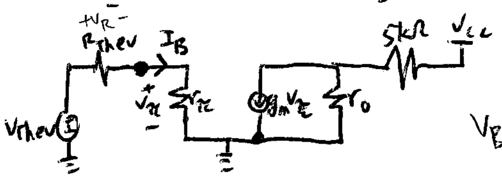


$V_{Thev} = V_{CC} \cdot \frac{R_2}{R_1 + R_2} = \frac{2.5 R_2}{R_1 + R_2}$

$R_{Thev} = R_1 \| R_2$



$R_{in} > 10k$



$R_{in} = R_1 \| R_2 \| r_\pi$

$I_C = g_m V_T = 100 \mu A$

$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right) = 0.026 \ln\left(\frac{100\mu A}{2E-17A}\right) = 0.760 V$

$I_B = \frac{I_C}{\beta} = 1\mu A$

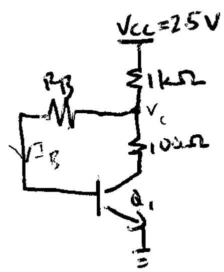
$\frac{V_{CC} - V_{BE}}{R_1} - \frac{V_{BE}}{R_2} = I_B$ $\quad \frac{2.5 - 0.76}{R_1} - \frac{2.5}{R_2} = 1E-6$

$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{r_\pi} = \frac{1}{R_{in}}$ $\quad \frac{1}{1/R_1 + 1/R_2 + 1/r_\pi} > 10k$ $\quad \frac{1}{1/R_1 + 1/R_2 + 1/26k} = 10k$

$r_\pi = \frac{\beta}{g_m} = 26k$

$\boxed{\begin{array}{l} R_1 > 27382\,\Omega \\ R_2 > 39971\,\Omega \end{array}}$

5.20 $I_C = 1mA$ $I_S = 3 \times 10^{-16}$ $\beta = 100$ $V_A = \infty$



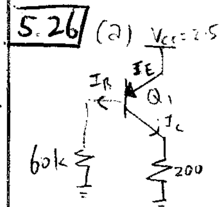
$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right) = 0.026 \ln\left(\frac{0.001}{3E-16}\right) = 0.74971 V$

$V_C = V_{BE} + I_B R_B$ $\quad I_B = \frac{I_C}{\beta} = \frac{0.001}{100} = 0.00001$

$V_C = V_{CC} - I_C 1k = 2.5 - (0.001)(1k) = 1.5V$

$R_B = \frac{V_C - V_{BE}}{I_B} = \frac{1.5 - 0.74971}{0.00001} = \boxed{75k\Omega}$

5.26 (a) $V_{CC} = 2.5$



$\beta_{pnp} = 50$ $I_S = 9 \times 10^{-16} A$ $V_A = \infty$

$2.5 - 60k I_B = V_{EB}$ $\quad V_{EB} = 2.5 - \frac{60k}{50} I_C$

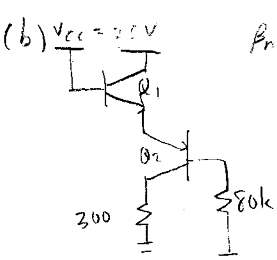
$I_B = \frac{I_C}{\beta}$

$I_C = I_S e^{V_{EB}/V_T}$

$V_{EB} = 2.5 - 60k \frac{I_C}{50}$

$I_C = 1.474 mA$ $\quad V_{EB} = 731.233 mV$

(b) $V_{CC} = 2.5V$



$\beta_{npn} = 100$ $\beta_{pnp} = 50$ $I_S = 9 \times 10^{-16} A$

$V_{BE_1} = V_T \ln\left(\frac{I_C}{I_S}\right)$

$V_{CC} - V_{BE_1} - I_{B_2}(80k) = V_{EB_2}$

$I_{E_1} = I_{E_2}$ $\quad I_{C_1} = \frac{\beta_{npn}}{1+\beta_{npn}} I_{E_1} = \frac{\beta_{npn}}{1+\beta_{npn}} I_{E_2}$

$= \frac{\beta_{npn}}{1+\beta_{npn}} \cdot \left(I_{C_2} + \frac{I_{C_2}}{\beta_{pnp}}\right)$

$= \frac{\beta_{npn}}{1+\beta_{npn}} \cdot \left(\frac{\beta_{pnp}+1}{\beta_{pnp}}\right) I_{C_2}$

$V_{CC} - V_T \ln\left(\frac{I_{C_1}}{I_S}\right) - \frac{I_{C_2}}{\beta_{pnp}}(80k) = V_T \ln\left(\frac{I_{C_2}}{I_S}\right)$

$I_{C_1} = \frac{\beta_{npn}}{1+\beta_{npn}} \left(\frac{\beta_{pnp}+1}{\beta_{pnp}}\right) I_{C_2}$

$\boxed{\begin{array}{l} I_{C_1} = 680\mu A \quad I_{C_2} = 674\mu A \\ V_{BE_1} = 0.71 V \quad V_{EB_2} = 0.71 V \end{array}}$

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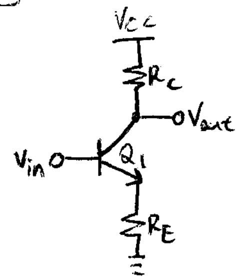
$\boxed{5.41}$



$V_{out} = -g_m V_\pi R_C \qquad V_\pi + I_C R_E = V_{in}$

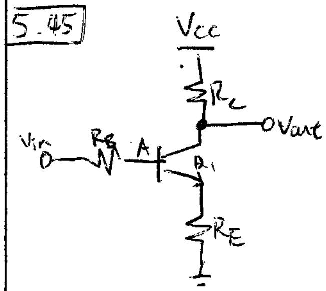
Assume β is large so $I_C \approx I_E$

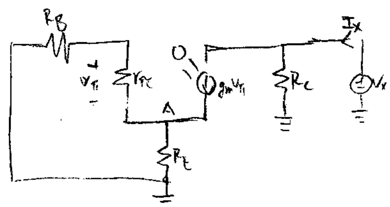
$$\frac{V_{out}}{V_{in}} = \frac{-g_m V_\pi R_C}{V_\pi + I_C R_E} = \frac{g_m I_E r_\pi R_C}{I_E r_\pi + I_C R_E} = \frac{-\beta I_C R_C}{V_T + I_C R_E} = \frac{R_C I_C}{R_E I_C + V_T}$$

$R_C = 20V_T \quad R_E = 5V_T$

$$\text{Gain} \quad \frac{20V_T I_C}{5V_T I_C + V_T} \approx \frac{20V_T}{6V_T} = \boxed{3.33}$$

$\boxed{5.45}$



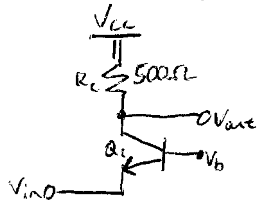


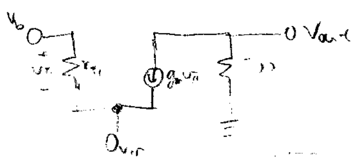
$V_x = I_x R_C \qquad I_x =$

$$\frac{V_x}{I_x} = R_C$$

$R_{out} = R_C$.

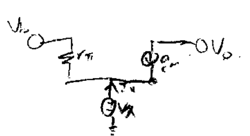
$\boxed{5.54}$ $\beta = ?? \quad I_C = 0.002 \quad V_A = \infty \quad V_{out} = g_m V_\pi R_C \quad \frac{V_{out}}{V_{in}} = g_m R_C = 500 g_m$





$$g_m = \frac{I_C}{V_T} = \frac{0.002}{0.026} = 0.076923$$

$\text{Gain} = 500 \cdot 0.076923 = 38.4615$



$\frac{1}{g_m} \| r_\pi = R_{in} \qquad r_\pi = \frac{\beta}{g_m} = \frac{100}{0.0769} = 1300 \qquad 13 \| 1300 = R_{in}$

$R_{in} = 12.87\Omega \qquad R_{out} = R_C = 500\Omega$

(b) Since Gain $= g_m R_C$ Gain $\propto R_C$ So the larger the R_C, the higher the gain

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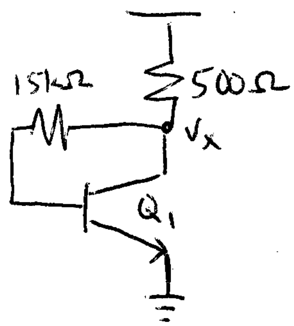
Homework 5

Benjamin Bergeson

Create A Problem

$V_{cc} = 2.5\text{ V}$



$\beta = 100 \quad V_X = 1\text{V} \quad V_A = \infty$

What is I_S?

$I_C + I_B = \frac{2.5-1}{500} \quad I_C + I_B = 0.003 \quad I_C + \frac{I_C}{\beta} = 0.003 \quad I_C = 0.00297\text{ A}$

$V_{BE} = 1 - 15k \cdot I_B = 1 - 15k \cdot \frac{I_C}{\beta} \quad V_{BE} = 0.554455\text{ V}$

$I_S = \frac{I_C}{e^{(V_{BE}/V_T)}} = \boxed{1.627 \times 10^{-12}\text{ A}}$

A) 1.627×10^{-12} A

B) 6.975×10^{-22} A

C) 2.126×10^{-27} A

D) 8.135 E -12