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4.19 $\Delta I_C = g_m \Delta V_{BE}$ $\quad g_m = \frac{I_C}{V_T}$ $\quad \Delta I_C = \frac{I_C}{V_T}\Delta V_{BE}$

$V_T \frac{\Delta I_C}{I_C} = \Delta V_{BE}$ $\quad \frac{\Delta I_C}{I_C} < 0.1$ $\quad V_T \cdot 0.1 > \Delta V_{BE}$ ✓

$\Delta V_{BE} \leq 2.6\,mV$

4.25 $\Delta V_{BE} = 0$ $\quad I_C = I_S e^{V_{BE}/V_T}\left(1 + \frac{1}{V_A}\right)$ $\quad \frac{\Delta I_C}{I_C} < 0.05$

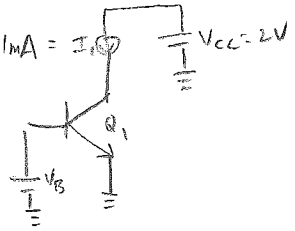
Approximation: $\frac{dI_C}{dV_{CE}} \simeq \frac{I_C}{V_A}$ $\quad \frac{\frac{I_C}{V_A}\Delta V_{CE}}{I_C} < 0.05$

$\frac{\Delta V_{CE}}{V_A} < 0.05$ $\quad V_A > \frac{2}{0.05}$ $\quad \boxed{V_A > 40\,V}$

4.31 $I_S = 3\times10^{-17}\,A$ (a) $I_C = 1mA$

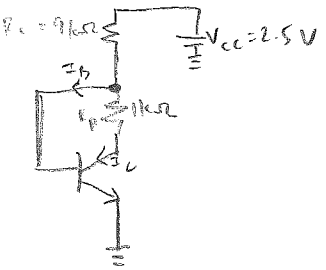
$I_C = I_S e^{V_{BE}/V_T}$

$\boxed{V_{BE} = 0.8096\,V}$



(b) $I_C = I_S e^{V_{BE}/V_T}\left(1 + \frac{V_{CE}}{V_A}\right)$ $\quad V_j = V_{BE} = \ln\left(\frac{I_C}{I_S\left(1+\frac{V_{CC}}{V_A}\right)}\right)$ $\quad \boxed{0.8028\,V}$

4.36



$\beta = 100$ $\quad V_A = \infty$ $\quad$ Find I_S

$V_{RC} = 0.2$

$R_B I_C = 0.2$ $\quad I_C = \frac{0.2}{1000} = 0.0002$

$V_{BE} = V_{CC} - (I_B + I_C)R_C = V_{CC} - \left(\frac{I_C}{\beta} + I_C\right)R_C = V_{CC} - R_C I_C \frac{\beta+1}{\beta} = 0.682$

$I_S = I_C e^{-V_{BE}/V_T} = 0.0002\, e^{-0.682/0.026} \approx \boxed{8.11\times10^{-16}}$

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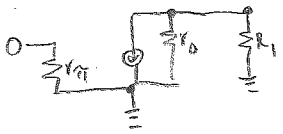
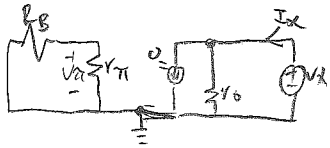
5.4

(a)



$R_{out} = r_o \| R_1$

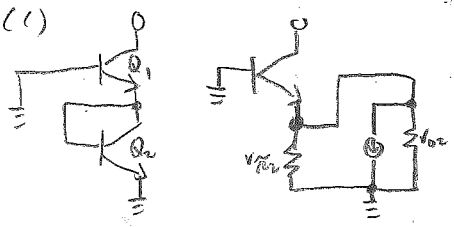
(b)



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

$\frac{V_x}{I_x} = \frac{V_x}{V_x/r_o} = r_o$

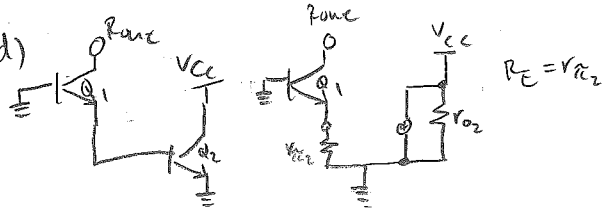
(c)



$Z_{Q_2} = r_{\pi_2} \| \frac{1}{g_{m2}} \| r_{o_2}$

$R_{out} = (1 + g_{m_1} r_{o_1})(r_{\pi_2} \| \frac{1}{g_{m2}} \| r_{o_2} \| r_{\pi_1}) + r_{o_1}$

(d)

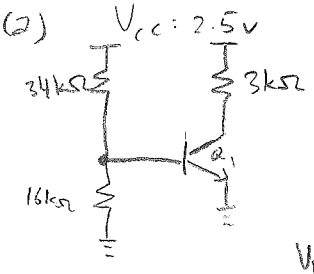


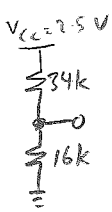
$R_E = r_{\pi_2}$

$R_{out} = (1 + g_{m_1} r_{o_1})(r_{\pi_2} \| r_{\pi_1}) + r_{o_1}$

5.9 $\beta = 100$ $I_S = 5 \times 10^{-16} A$ $V_A = \infty$

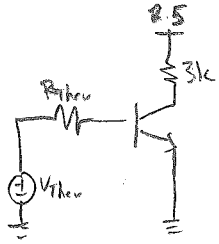
(a) $V_{cc} = 2.5V$





$V_{Thev} = 2.5 \cdot \left(\frac{34k}{34k+16k}\right) = 1.7V$

$R_{Thev} = 34k \| 16k = 10.88k$

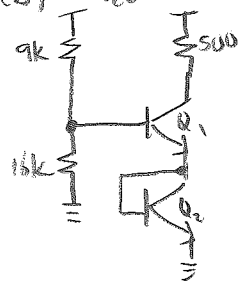


$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right)$ ① $\quad I_C = \beta I_B = \beta \frac{V_{Thev} - V_{BE}}{R_{Thev}}$

Guess $V_{BE} = 0.8V$ $I_C = 0.008272$ $V_{BE} = 0.791363$

Guess $V_{BE} = 0.79V$ $I_C = 0.008364$ $V_{BE} = 0.791651$

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



$V_{Thev} = 2.5\left(\frac{9k}{9k+16k}\right) = 0.9V$

$R_{Thev} = 9k \| 16k = 5760\Omega$

$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right)$ $\quad I_C = \beta I_B = \beta \frac{V_{Thev} - V_{BE} + V_{CE_2}}{R_{Thev}}$ $\quad V_{CE_2} = V_{BE_2} = V_{BE_1}$

$I_C = \beta \frac{V_{Thev} - 2V_{BE}}{R_{Thev}}$

Guess $V_{BE} = 0.8V$ $I_C = -0.012153$ $V_{BE} =$ undefined

Guess $V_{BE} = 0.4V$ $I_C = 0.001736$ $V_{BE} = 0.756771$

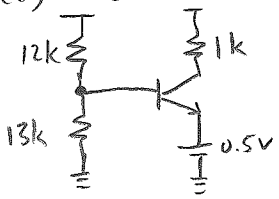
Guess $V_{BE} = 0.44V$ $I_C = 0.000347$ $V_{BE} = 0.708926$

Guess $V_{BE} = 0.4499V$ $I_C = 0.000003$ $V_{BE} = 0.589191$

Guess $V_{BE} = 0.449999V$ $I_C = 3.477277 \times 10^{-8}$ $V_{BE} = 0.469457$

Guess $V_{BE} = 0.44999995V$ $I_C = 1.736 \times 10^{-8}$ $V_{BE} = 0.451435$

(c)



$V_{Thev} = 2.5 \cdot \frac{12k}{13k+12k} = 1.2\,V$

$R_{Thev} = 12k \parallel 13k = 6240\,\Omega$

$V_{BE} = V_T \ln\left(\frac{I_C}{I_S}\right)$ $\quad I_C = \beta I_B = \beta \frac{V_{Thev} - 0.5 - V_{BE}}{R_{Thev}}$

Guess	$V_{BE} = 0.8V$	$I_C = -0.001603$	V_{BE} = undefined
Guess	$V_{BE} = 0.5V$	$I_C = 0.003205$	$V_{BE} = 0.766712$
Guess	$V_{BE} = 0.6V$	$I_C = 0.001603$	$V_{BE} = 0.74869$
Guess	$V_{BE} = 0.69V$	$I_C = 0.00016$	$V_{BE} = 0.688823$
Guess	$V_{BE} = 0.689V$	$I_C = 0.000176$	$V_{BE} = 0.691301$