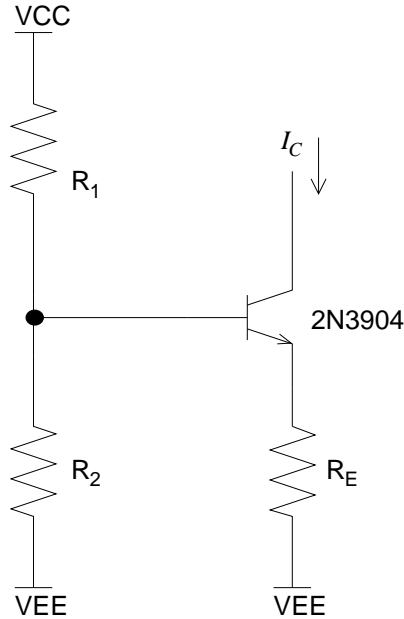


Physics 536 - Assignment #7

1. Consider the following circuit, designed to sink a current of 10 mA into the collector of the transistor.



(a) If $V_{CC} = 5$ V, $V_{EE} = -5$ V and assuming $V_{be} = 0.7$ V, calculate values for R_1 , R_2 and R_E that will yield $I_C = 10$ mA. Constrain R_1 and R_2 such that the base is held at $V_b = -2$ V and the current through the voltage divider is 5 mA. Ignore the current flowing into the base.

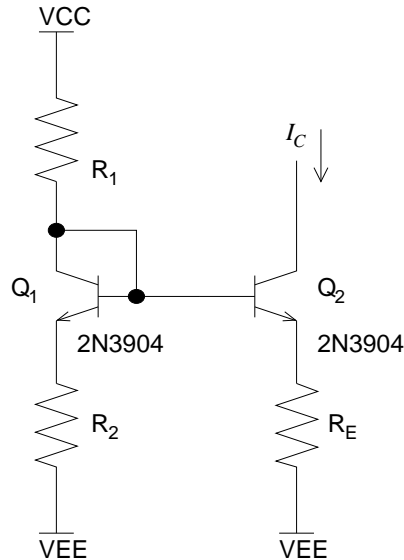
(b) Using the model for the 2N3904 transistor from assignment #6, use SPICE to calculate the DC operating point of this circuit. Find the optimal value of R_2 that will yield a current of $I_C = 10.0$ mA.

(c) Use the command

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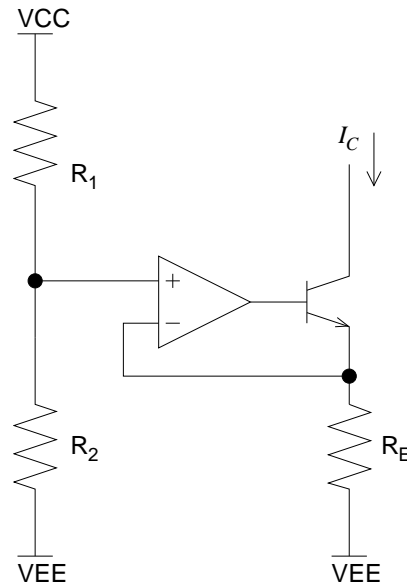
to calculate I_C at a junction temperature of 100° C. Prepare a table showing I_C at 0, 20, 40, 60, 80 and 100° C.

2. Consider the following current mirror circuit, designed to sink a current of 10 mA into the collector of the transistor Q_2 .



- (a) If transistor Q_1 is to sink a current of 5 mA into its collector, what values of R_1 and R_2 are needed so that $V_b \approx -2$ V? Assume $V_{CC} = 5$ V, $V_{EE} = -5$ V, etc.
- (b) What value of R_E is required so to give $I_C = 10$ mA?
- (c) Use SPICE to calculate the DC operating point of this circuit. Find the optimal value of R_2 that will yield a current of $I_C = 10.0$ mA.
- (d) Prepare a table showing I_C at 0, 20, 40, 60, 80 and 100° C.

3. Consider the following current source that uses an operational amplifier to control the voltage at the base of the transistor:



- (a) Calculate the values of R_1 and R_2 that will produce a bias voltage of $v_+ = -3$ V, and use only 1 mA. Recall that the inputs to the operational amplifier are *very* high impedance and essentially draw no current. Assume $V_{CC} = 5$ V, $V_{EE} = -5$ V.
- (b) Using the fundamental equation for operational amplifiers,

$$v_{\text{out}} = A_0(v_+ - v_-), \tag{1}$$

with $A_0 \sim 10^6$, calculate the voltage applied to the base of the operational amplifier.

- (c) Calculate the value of R_E that will yield $I_C = 10$ mA.
- (d) Explain why the current, I_C , will not change with temperature even though V_{be} might change.