# ECE 476
# Exam #1
# Spring 2021

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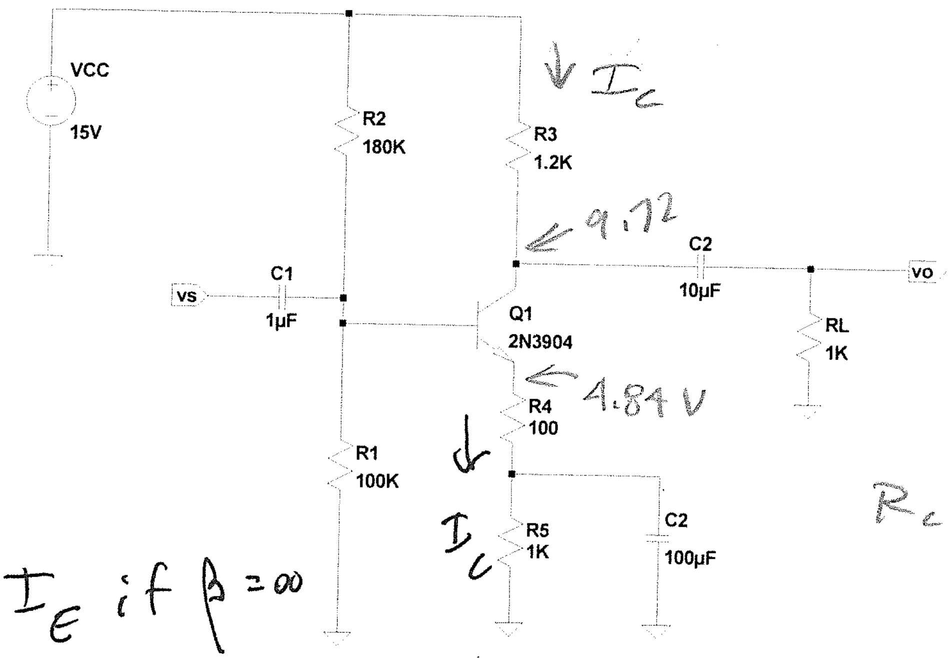
## Problem 1. (20 points)

For the circuit shown below the Early voltage and beta are assumed infinite. The DC voltage measured on the collector of $Q_1$ is 9.72 Volts.




$I_C = I_E$ if $\beta = \infty$

$R_C \parallel R_L = 0.545$

(a) Classify the amplifier. Circle one of the following: common-emitter, common-base, common-collector, common-emitter with emitter degeneration.

(b) Determine the DC collector current, $I_C$.

$$I_C = \frac{15 - 9.72}{1.2K} = \boxed{4.4mA}$$

(c) What is the DC voltage on the emitter terminal, $V_E$?

$$I_C = I_E \quad \text{so} \quad V_E = (4.4mA)(1.1K) = \boxed{4.84V}$$

(d) What is the small-signal mid-band gain, $A = \frac{v_o}{v_s}$?

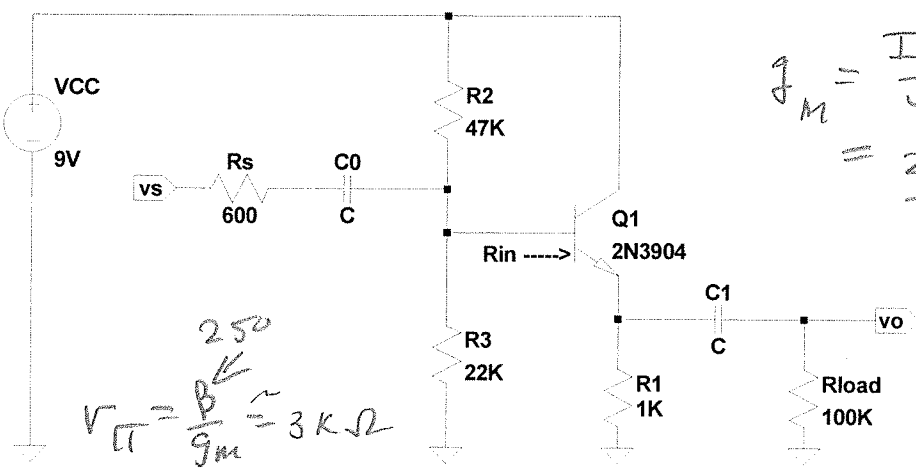
$$g_m = I_C/V_T = \frac{4.4mA}{25.9mV} \cong 170m℧$$

$$A_v = \frac{-g_m(R_C \parallel R_L)}{1 + g_m R_{E1}} = \frac{-170m℧(0.545)}{1 + (170m℧)(0.1K)}$$

$$A_v = \frac{-92.65}{18} = \boxed{-5.15} \; A_v$$

## Problem 2. (20 points)

Answer the following questions for the circuit shown below. Assume the value of C for both capacitors is **infinite**. The transistor has $\beta = 250$ and an Early voltage of 100 Volts. Assume $V_{BE}$ is 700 mV.




$g_M = \frac{I_C}{V_T} = \frac{2.17mA}{25.9mV} \cong 84m℧$

$r_\pi = \frac{\beta}{g_m} \overset{\sim}{=} 3K\Omega$ (250)

(a) Classify the amplifier as either common-emitter, common-emitter with emitter degeneration, or common-collector (a.k.a. emitter follower). Circle one!

(b) Determine the DC collector current, $I_C$, You may assume infinite $\beta$ for this calculation. $I_B = 0,\ I_C = I_E$

$V_B = \left(\frac{R_3}{R_3 + R_2}\right) V_{CC} = \left(\frac{22K}{69K}\right)(9V) = 2.87V$

$V_E = V_B - V_{BE} = 2.87 - 0.7 \Rightarrow I_C = I_E = \frac{2.17}{1K} = \boxed{2.17mA}$

(c) Determine the $r_0$ of the transistor.

$r_o = \frac{V_A}{I_c} = \frac{100V}{2.17mA} = \boxed{46K\Omega}$

(d) Determine the small signal input resistance, $R_{in}$ for the circuit.

$R_{IN} = r_\pi + (\beta + 1) R_E'$

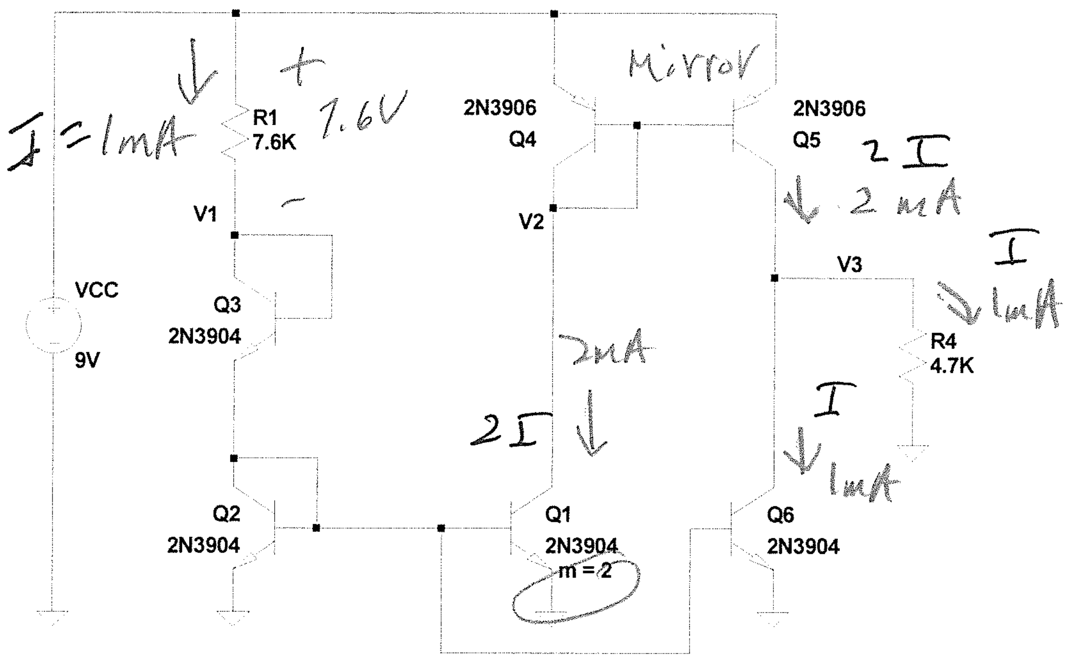
$R_E' = R_1 \| r_o \| R_L = 1K \| 46K \| 100K$

$R_E' \overset{\sim}{=} 0.97K \Rightarrow R_{IN} = 3K + (251)(0.97K)$

$\boxed{R_{IN} \overset{\sim}{=} 247K\Omega}$

## Problem 3. (20 points)

Answer the following questions for the circuit shown below. Assume **infinite** $\beta$ and Early Voltage, $V_A$, for all transistors. Also, assume that all transistors are in the active region and assume that the base-emitter voltage (for NPNs), $V_{BE}$, and emitter-base voltage (for PNPs), $V_{EB}$, is 700 mV.




(a) Determine the DC voltage, $V_1$.

1.4 V

(b) Determine the DC voltage, $V_2$.

8.3 V

(c) Determine the DC current collector current for $Q_5$.

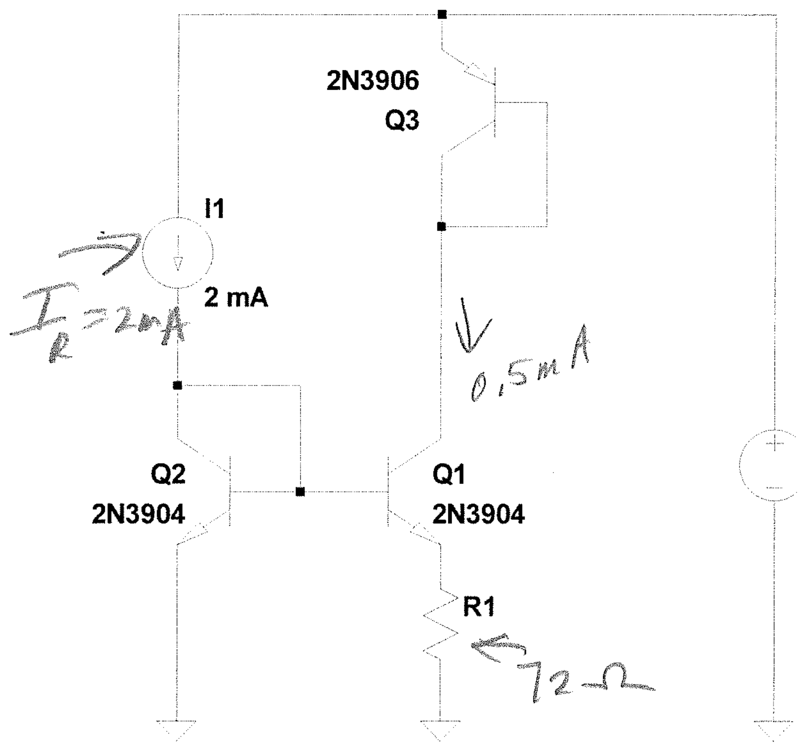
$I = 1mA = \frac{7.6V}{7.6K}$ so $I_{C5} = 2mA$

(d) Determine the DC voltage, $V_3$.

4.7 V

## Problem 4. (15 points)

For the circuit shown below assume the transistors are matched. Moreover, assume the $\beta$ of the transistors is infinite and the Early voltage is 125 V.




$r_o = \frac{V_A}{I_C} = \frac{125V}{0.5mA} = 250K$

since $\beta = \infty$

$r_\pi = \frac{\beta}{g_m} = \infty$

(a) Transistors $Q_1$, $Q_2$, and resistor R1 implement what type of current mirror? Please CIRCLE one of the followng: simple, Widlar, cascoded, or Wilson.

(b) Find the value of $R_1$ so that the output current of the mirror is 0.5 mA. $I_O$

$$R_1 = \frac{U_T \ln\left(\frac{I_R}{I_O}\right)}{I_O} = \frac{25.9mV' \ln(4)}{0.5mA}$$

$$\boxed{R_1 \approx 72\,\Omega}$$

(c) Determine the small-signal output resistance $R_O$ of the resulting current mirror.

$$g_m = \frac{I_C}{U_T} = \frac{0.5mA}{25.9mV} = 19.3\,m\mho$$

We've proved $R_O = r_o\left[1 + g_m(R_W \parallel r_\pi)\right]$ $\infty$

$$R_O = 250K\left[1 + (19.3\,m\mho)(72\,\Omega)\right]$$

$$R_O = 2.4(250K) = \boxed{600\,K\Omega}$$

## Problem 5. (15 points)

A diode-connected BJT has an emitter current of 400 $\mu A$. The transistor $I_{ES}$ is 4 fA. The base-emitter voltage temperature coefficient for the device is -2 $\frac{mV}{C}$.

(a) Compute the base-emitter voltage at room temperature?

$$V_{BE} = U_T \ln\left(\frac{I_E}{I_{ES}}\right)$$

$$V_{BE} = (25.9mV) \cdot \ln\left(\frac{400\mu A}{4fA}\right) = \boxed{656\ mV}$$

(b) If the current is reduced to 50 $\mu A$, then what is the new base-emitter voltage?

$$\Delta V_{BE} = U_T \ln\left(\frac{400\mu A}{50\mu A}\right) \cong 54\ mV$$

$$\text{So } V_{BE}' = 656 - 54 = \boxed{602\ mV}$$

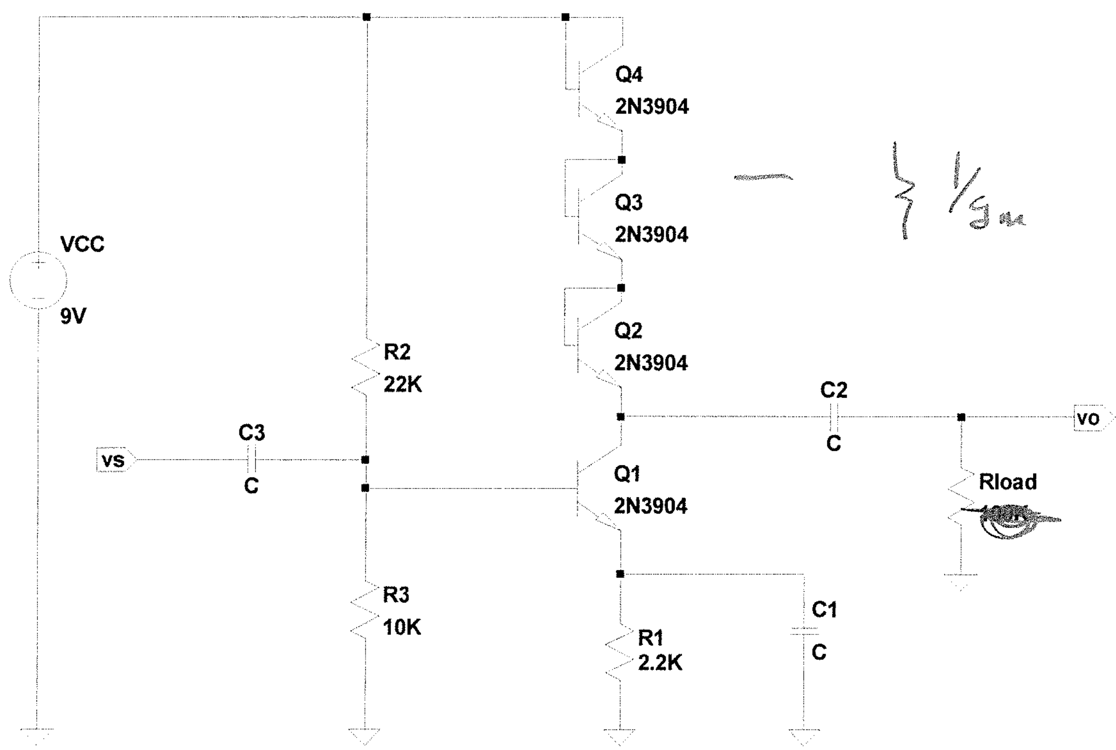
(c) If the the emitter current is returned to 400 $\mu A$, then what is the base-emitter voltage if the temperature of the device is raised by 50 degrees Celsius?

$$V_{BE}'' = 656\ mV + (-2\ mV/°C)(50°C)$$

$$\boxed{V_{BE}'' = 556\ mV}$$

## Problem 6. (10 points) GRADUATE STUDENTS ONLY

For the circuit shown below, you may make the following simplifying assumptions: $V_{BE}$ is 700 mV, $\beta$ is infinite, $V_A$ is infinite, and the capacitors can be treated as shorts for the small-signal analysis. Please determine the voltage gain, $\frac{v_o}{v_s}$. Assume $R_L$ is infinite




Common Emitter

$$\frac{v_o}{v_s} = -g_m (R_c \parallel \overset{\infty}{R_L})$$

Here $R_c = 3\left(\frac{1}{g_m}\right)$

$$\boxed{v_o/v_s = -3}$$