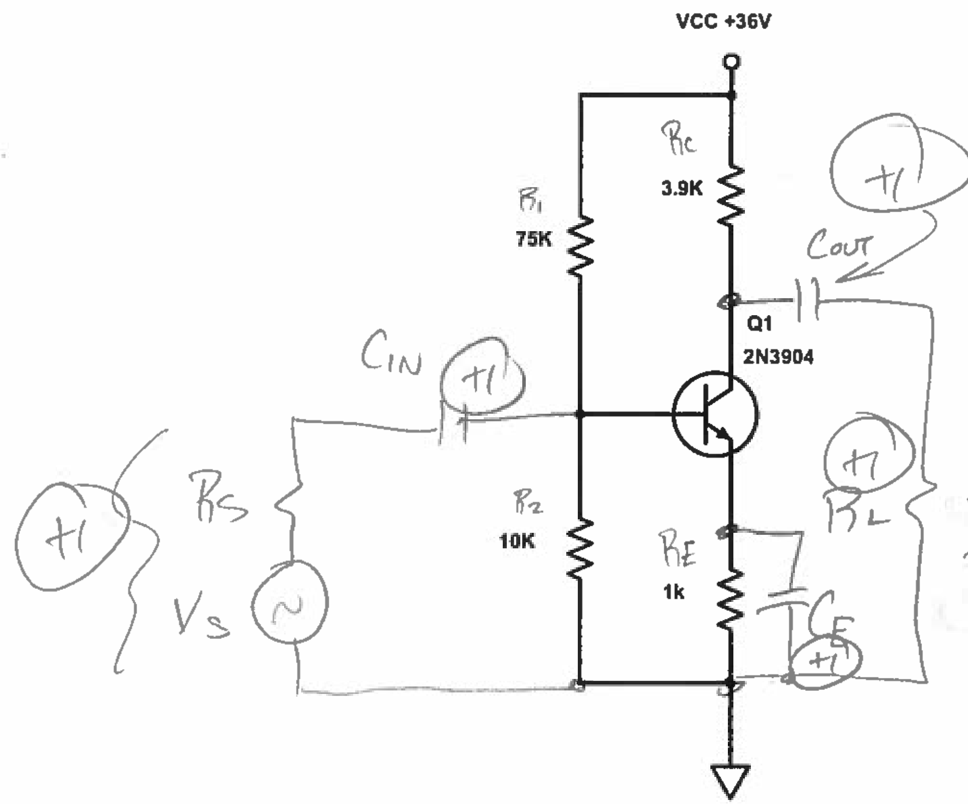
BME-ISE 3512 • Exam V • 12 April 2019 NAME SOLUTION

Determine the D.C. operating point of the following circuit (I_C and V_{CE}) if base current may be assumed negligible. Check P_{diss} and verify that the transistor is operating in the active region. Draw additional components on the circuit to create a common-emitter voltage amplifier with a source resistance of 600 Ω and a load resistance of 25 kΩ. Don't worry about the actual values of added capacitors yet; just draw them correctly.



$V_{BE} \doteq 0.7V$
$V_{CE} > 0.2V$
positive I
✓ yes, active region
+1

$$V_B = V_{cc}\left[\frac{R_2}{R_1+R_2}\right] = 36\left[\frac{10k}{10k+75k}\right] = 4.235\ V \quad (+1)$$

$$V_{BE} = 0.7V \ (\text{Si NPN}) \quad (+1)$$

$$\therefore V_E = 4.235 - 0.7 = 3.535\ V \quad (+1)$$

$$I_E = \frac{3.535}{1k} = 3.535\ mA \quad (+1)$$

$$\text{high-}\beta \rightarrow I_C = 3.535\ mA \quad (+1)$$

$$V_C = V_{CC} - I_C R_C = 36 - 3.535 \cdot 3.9 = 22.21\ V \quad (+1)$$

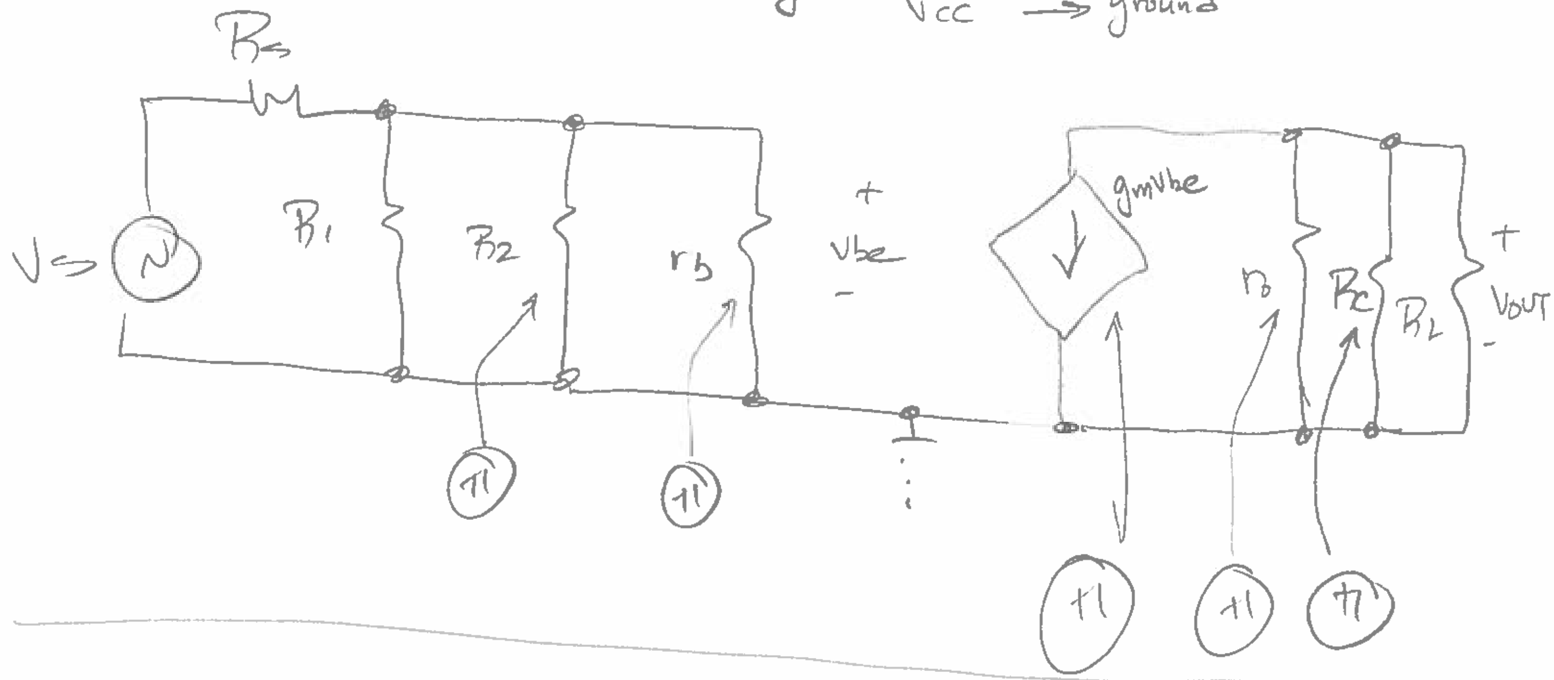
$$V_{CE} = V_C - V_E = 22.21 - 3.535$$

$$V_{CE} = 18.68\ V$$

$$P_{diss} = I_C \cdot V_{CE} = 3.535 \cdot 18.68 = 66.02\ mW \quad (+1)$$

Draw the mid-frequency AC small-signal model of the amplifier. Calculate the parameters g_m, r_b, and r_o if $\beta = 250$. and $|V_A| = 50V$
Include a unit with each answer.

mid-frequency : capacitors → shorts
Vcc → ground



$$g_m = 35\, I_C \quad \text{(Ebers/Moll)}$$ (+1) eqn

$$= 35 \cdot 3.535$$

$$g_m = 123.7 \ \text{mA/V}$$

(+1) unit

(+1) eqn

$$r_b = \frac{\beta}{g_m} = \frac{250}{123.7} = 2.021\ \text{k}\Omega$$

(+1) unit

$$r_o = \frac{|V_A|}{I_C}$$ (+1) eqn

$$= \frac{50}{3.535} = 14.14\ \text{k}\Omega$$

(+1) unit

Determine the mid-frequency gain A_V and A_V(dB). ~~Also calculate the approximate A_V(dB) with C_E removed.~~

input network :

$$R_b' = R_1 \| R_2 \| r_b = 10k \| 75k \| 2.021k = 1.644k \quad (+1)$$

$$V_{be} = V_S \left[\frac{R_b'}{R_b' + R_{IN}} \right] = V_S \left[\frac{1.644}{0.6 + 1.644} \right] = 0.7327\, V_S \quad (+1) \quad (+1)$$

output network :

$$R_c' = r_o \| R_c \| R_L = 14.14k \| 3.9k \| 25k = 2.724k \quad (+1)$$

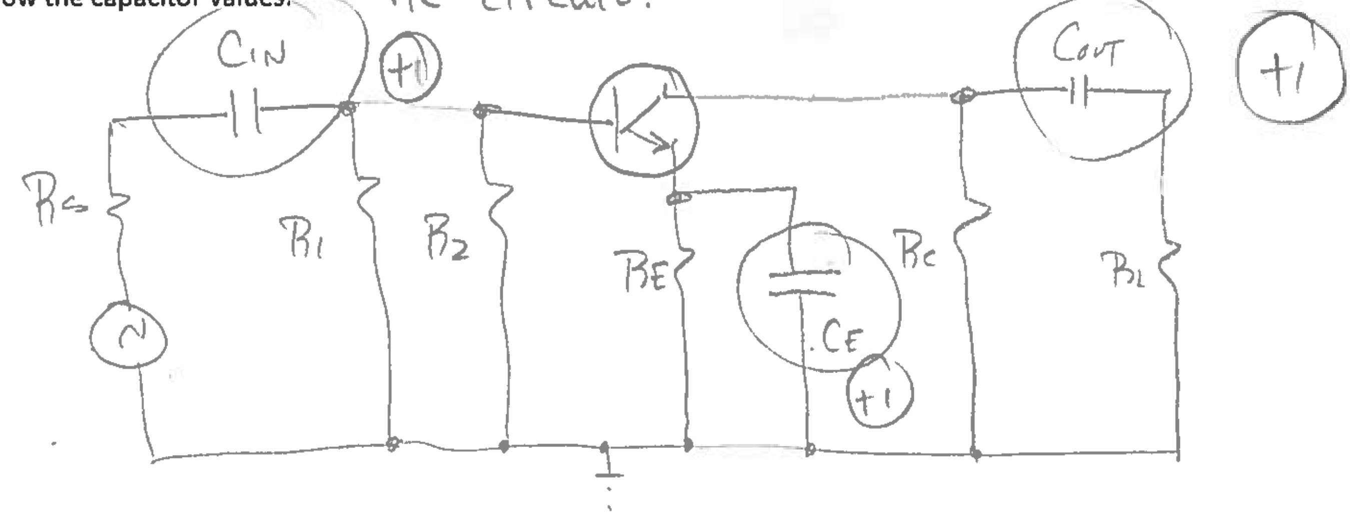
$$V_{OUT} = -g_m V_{be} \cdot R_c' \quad (+1)$$

$$= -123.7 \cdot 0.7327 V_S \cdot 2.724$$

$$V_{OUT} = -246.9\ V_S$$

$$A_V = -246.9 \quad (+1) \quad \text{or} \quad +47.85 \text{ dB} \ (+1), \text{ inverting} \ (+1)$$

Draw the low-frequency ~~small-signal model including C_E~~ AC circuit. You do not have to compute ~~anything because you don't~~ know the capacitor values.



Determine the high-frequency input and output capacitances using Miller's Theorem if C_{BC} = 6 pF and C_{BE} = 22 pF. Compute the input and output HF cutoff frequencies and the approximate overall high-frequency cutoff, f_H. [redacted]

$$C_{BC\,(IN)} = C_{BC}\,(1 - A_V) \quad +1 \text{ eqn}$$

$$= 6 \cdot (1 - -246.9)$$

$$= \underbrace{1487 \text{ pF}} \quad +1$$

$$C_{BC\,(OUT)} = C_{BC}\left(1 - \frac{1}{A_V}\right) \approx C_{BC}$$

$$= 6 \text{ pF} \quad +0$$

$$\therefore \quad C_{IN\,(HF)} = C_{BC\,(IN)} + C_{BE}$$

$$= 1487 + 22$$

$$= \underbrace{1509 \text{ pF}} \quad +1$$

$$\rightarrow f_{H\,(IN)} = \frac{1}{2\pi \cdot C_{IN} \cdot (R_b' \| R_S)} = \frac{1}{2\pi \cdot 1509 \times 10^{-12}\,\underbrace{(1.644k \| 600)}_{=440\Omega}} = 240 \text{ kHz} \quad +1$$

$$C_{OUT\,(HF)} = \underbrace{6 \text{ pF}} \quad +0$$

$$f_{H\,(OUT)} = \frac{1}{2\pi\, C_{OUT} \cdot r_o \| R_C \| R_L} = \frac{1}{2\pi \cdot 6 \times 10^{-12} \cdot 2{,}724k} = 9.7 \text{ MHz} \quad +1$$

$$f_H \approx 240 \text{ kHz} \quad +1$$

(dominant pole; > 5x separation)