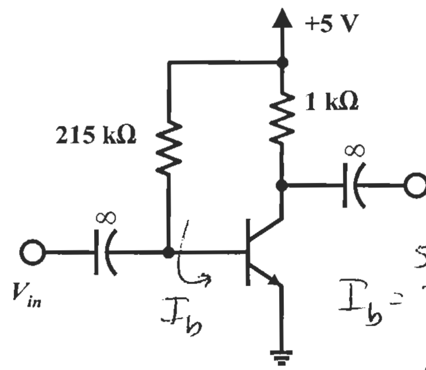
Problem 5

(20 points)
In this common-emitter amplifier the BJT has $\beta = 100$, $|V_A| = \infty$, $C_\pi = 1\text{pF}$, $C_\mu = 0.1\text{pF}$, and $V_{be} = 0.7\text{V}$ when biased in the forward conduction region. Assume room temperature such that $kT/q \approx 25\,\text{mV}$.



$I_b = \frac{5-0.7}{215k}$

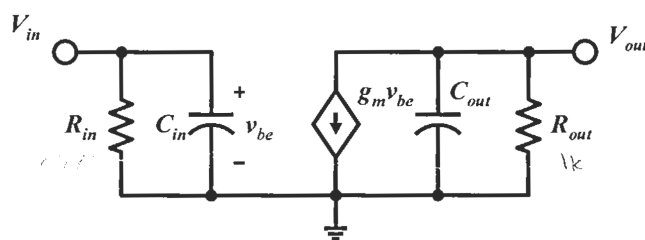
$= 20\mu A$

a) Find the DC collector current I_c, DC collector voltage V_c, and transconductance g_m

$I_c =$ 2 mA $\quad V_c =$ 3 V $\quad g_m =$ 80 mS

$5 - I_c R_c \qquad I_c / 25mV$

b) Using the ***Miller approximation***, the equivalent circuit for the high-frequency response of this amplifier can be reduced to the circuit shown at right. Find the parameters below.



Mid-band gain $A_v =$ -80

$R_{in} =$ 1250 Ω $\quad R_{out} =$ 1k Ω

$C_{in} =$ 9.1 pF $\quad C_{out} =$ 0.1 pF

$r_\pi = \beta / g_m = 1250$

$R_{in} = 215k \,||\, r_\pi \cong r_\pi$

$A_v = -g_m R_{out} = -80$

$C_{in} = C_\pi + C_\mu(1 - A_v)$

$= 1 + 0.1(81) = 9.1$

$C_{out} \approx C_\mu$

c) Find the dominant pole in the high-frequency response (express your answer in Hz or some engineering multiple such as MHz, GHz, etc., ***not*** rad/s)

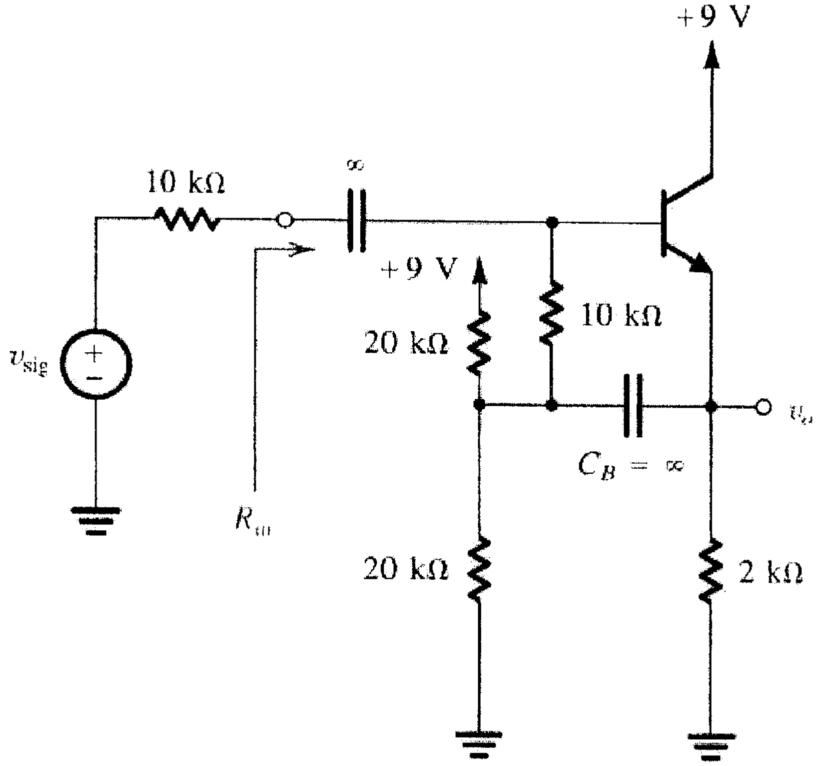
$\omega_{p1} = \frac{1}{R_{in} C_{in}} \qquad \omega_{p2} = \frac{1}{R_{out} C_{out}} \gg \omega_{p1}$

$= 88 \times 10^6$ rad/s $\qquad \Rightarrow \omega_{p1}$ is dominant (lowest frequency)

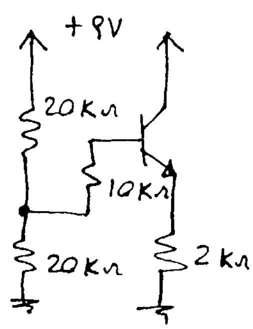
$= \boxed{14 \text{ MHz}}$

Problem 3 [Total 40 pt.]

(3-a) [10 pt.] Find the dc emitter current and the NPN's small-signal equivalent circuit parameters: g_m, r_e, and r_π for $\beta = 100$.



(a) DC Analysis

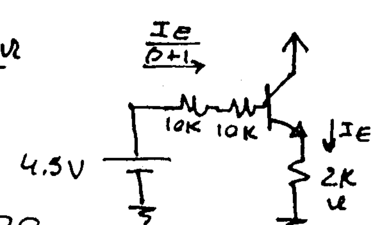


$$I_E = \frac{4.5 - 0.7}{2 + \frac{10+10}{101}} = \underline{\underline{1.73\,mA}}$$

$$I_c = 0.99 \times 1.73 = \underline{\underline{1.71\,mA}}$$

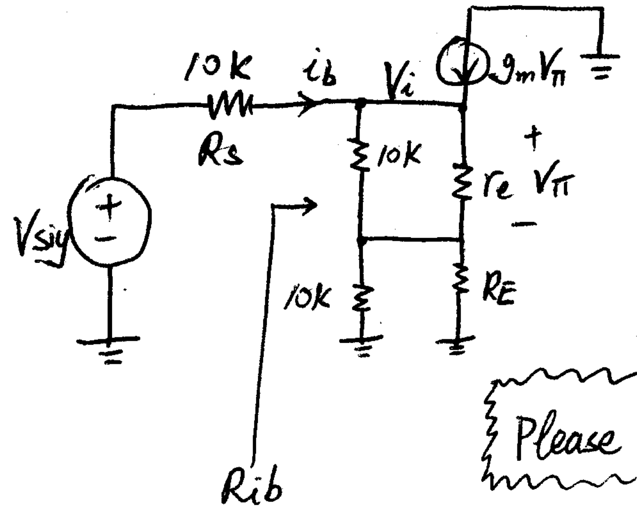
$$g_m = \frac{I_c}{V_T} = 68.5\,mA/V$$

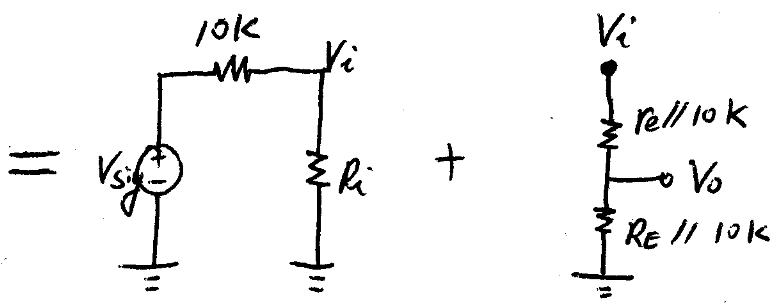
$$r_e = \frac{V_T}{I_e} = \underline{\underline{14.5\,\Omega}}$$



$$r_\pi = \frac{\beta}{g_m} = \frac{100}{68.5} = \underline{\underline{1.46\,K\Omega}}$$

(3-b) [15 pt.] Using BJT small signal model (neglect r_o), analyze the circuit to determine the input resistance R_{in} and the voltage gain v_o/v_{sig}.





Please refer to Figure 3.61 in textbook!

For Rib, we know that $R_{ib} = (\beta+1)(r_e // 10k + R_E // 10k)$

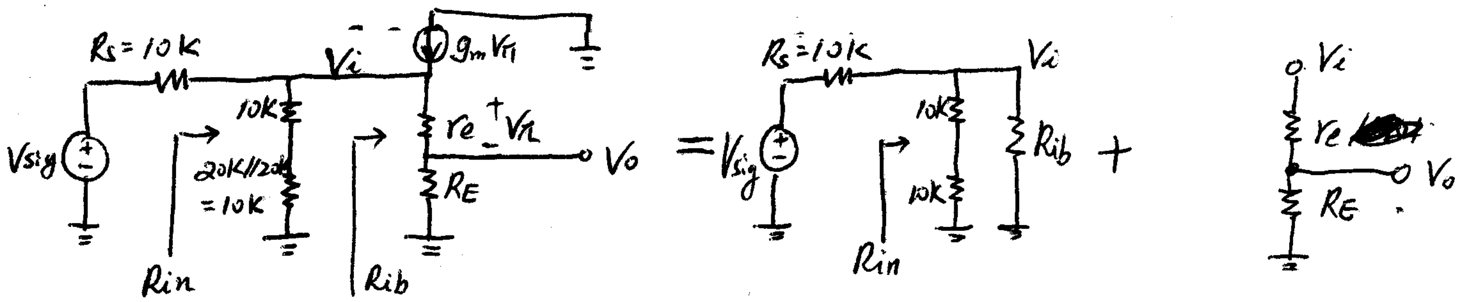
$\approx 101 \times (14.5\Omega + 1666.67\Omega) = 169.798\ k\Omega$

Here $R_{in} = R_{ib}$. Also $\dfrac{V_o}{V_{sig}} = \dfrac{V_o}{V_i} \times \dfrac{V_i}{V_{sig}}$

where $\dfrac{V_o}{V_i} = \dfrac{R_E // 10k}{R_E // 10k + r_e // 10k} = \dfrac{1666.67\Omega}{1681.17\Omega}$, $\dfrac{V_i}{V_{sig}} = \dfrac{R_i}{R_i + 10k} = \dfrac{169.798\ k\Omega}{179.798\ k\Omega}$

$\therefore \dfrac{V_o}{V_{sig}} = \dfrac{1666.67}{1681.17} \times \dfrac{169.798}{179.798} = 0.936\ V/V$

(3-c) [15 pt.] Repeat (3-b) for the case when capacitor C_B is open-circuited?



Obviously, $R_{ib} = (\beta+1)(r_e + R_E) = 101 \times (2014.5\Omega) = 203.46\ k\Omega$

Here $R_{in} = R_{ib} // (10K + 10k) = 18.21\ k\Omega$

Also, $\dfrac{V_o}{V_{sig}} = \dfrac{V_o}{V_i} \times \dfrac{V_i}{V_{sig}} = \dfrac{R_E}{R_E + r_e} \times \dfrac{R_{in}}{R_s + R_{in}} = \dfrac{2000}{2014.5} \times \dfrac{18.21}{28.21} = 0.641\ V/V$