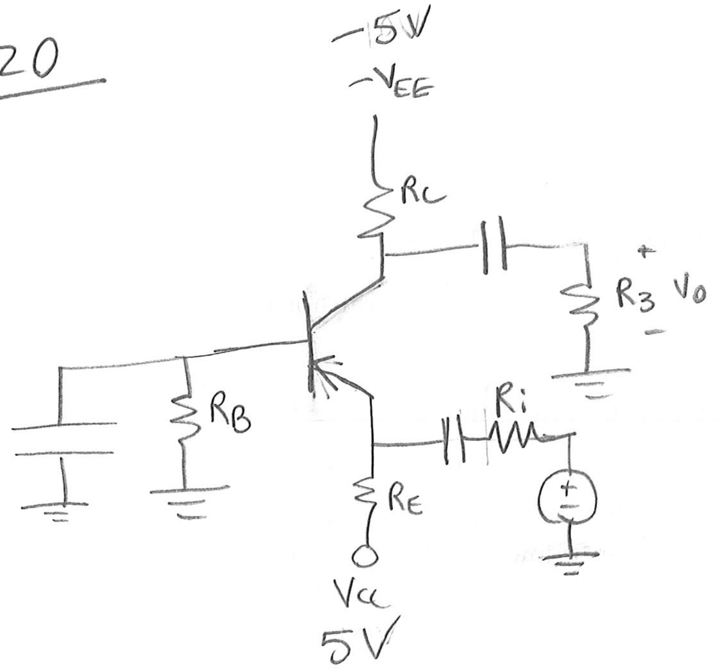
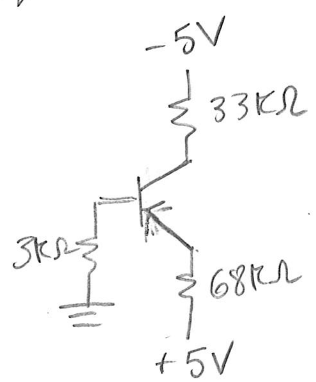
13.20



$\beta_F = 65$
$R_I = 470\Omega$
$R_B = 3k\Omega$
$R_E = 68k\Omega$
$R_C = 33k\Omega$
$R_3 = 120k\Omega$
$V_{eb} = 0.7\text{ V}$ (Assum

DC Equiviltent ⇒ capacitors open circuit



$5V = I_e(68k\Omega) + V_{eb} + I_B(3k\Omega)$
$5V = (\beta+1) I_B(68k\Omega) + 0.7V + I_B(3k\Omega)$
$5V = ((66)(68k\Omega) + 3k\Omega) I_B + 0.7V$
$I_B = \dfrac{4.3V}{(66(68k\Omega) + 3k\Omega)} = \boxed{957nA = I_B}$

$I_c = \beta I_B = \boxed{62\mu A = I_c}$
$I_e = (\beta+1)I_B = \boxed{63\mu A = I_e}$

$V_{ec} = 10V - 33k\Omega(I_c) - 68k\Omega(I_e)$
$\boxed{V_{ec} = 3.65V}$

13.65

$R_S = 750\Omega$

$R_B = 100k\Omega$

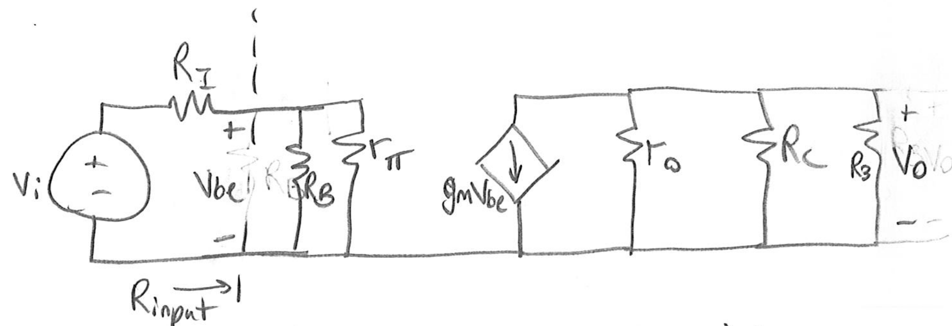
$R_C = 100k\Omega$

$R_3 = 100k\Omega$

$V_{CE} = 10V$, $I_C \approx I_E \approx 40\mu A$

$\beta_o = 100$

$V_A = 75V$



Since R_I is not given, I will call this the input resistance. This may not be the convention for every problem.

$R_{input} = R_B // r_\pi$, $\quad r_\pi = \frac{\beta_o}{g_m} = \frac{100}{I_C/V_T} = \frac{100}{40\mu A / 0.025V}$

$= 100k\Omega // 62.5k\Omega$ $\quad = \frac{100}{(40\mu A)(40)10^{-6}}\Omega$

$\boxed{= 38.5k\Omega}$ $\quad = \frac{1}{16}10^6 = 62.5k\Omega$

(Note that V_i sees an input resistance of $R_I + R_B // r_\pi$)

$$\text{Gain} = \frac{V_o}{V_i} = \frac{V_o}{V_{be}} \cdot \frac{V_{be}}{V_i} = \frac{V_o}{V_{be}} \cdot \frac{R_{input}}{R_I + R_{input}}$$

$$V_o = -g_m V_{BE} (r_o // R_C // R_3)$$

$$r_o \approx \frac{75V}{I_C} = \frac{75V}{40\mu A} = 1.875M\Omega$$

$$r_o // R_C // R_3 = 1.875M\Omega // 100k\Omega // 100k\Omega = 1.875M\Omega // 50k\Omega = 48.7k\Omega$$

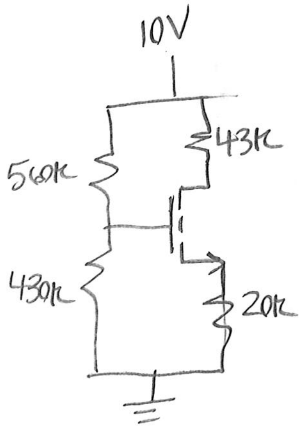
$$g_m = \frac{I_C}{V_T} = (40\mu A)(40 \tfrac{1}{V}) = 16 \cdot 100 \cdot 10^{-6} = 1.6\text{ mS}$$

$$\frac{V_o}{V_{BE}} = -g_m (r_o // R_C // R_3) = -(1.6mS)(48.7k\Omega) = -77.9\frac{V}{V}$$

$$\boxed{\frac{V_o}{V_i} = \left(-77.9\frac{V}{V}\right)\left(\frac{R_{input}}{R_I + R_{input}}\right)}$$

13.106

First, find the DC Q-point using DC equivilent circuit.



$$V_g = 10V \cdot \frac{430k}{430k + 560k} = 4.34V$$

① $V_{gs} = 4.34V - (20k\Omega) I_D$

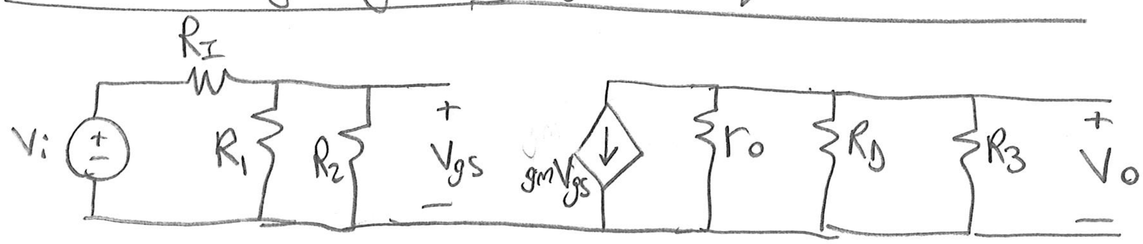
② $I_D = \frac{1}{2}(500\mu A/V^2)(V_{gs} - 1V)^2$ $(1+\lambda$

* For the purpose of finding I_D, we can ignore the λV_{DS} term because $\lambda V_{DS} \ll 1$.

Solve ① and ② for I_D, V_{gs}

$V_{gs} = 1.72V$ $I_D = 131\mu A$

Find small signal gain using AC equivilent circuit



$$\frac{V_o}{V_i} = \frac{1}{V_i} \cdot g_m V_{gs} \cdot (r_o // R_D // R_3)$$

$$= \frac{-R_1//R_2}{R_I + R_1//R_2} g_m (r_o // R_D // R_3)$$

$$g_m = \sqrt{2 K I_D} = \sqrt{2(500\mu A/V^2)(131\mu A)} = 362\mu S$$

$$\frac{R_1//R_2}{R_I + R_1//R_2} = 0.996, \quad r_o = \frac{1}{\lambda I_D} = \frac{1}{(131\mu A)(0.0133 V^{-1})} = 574k\Omega$$

$r_o // R_D // R_3 = 28.6k\Omega$

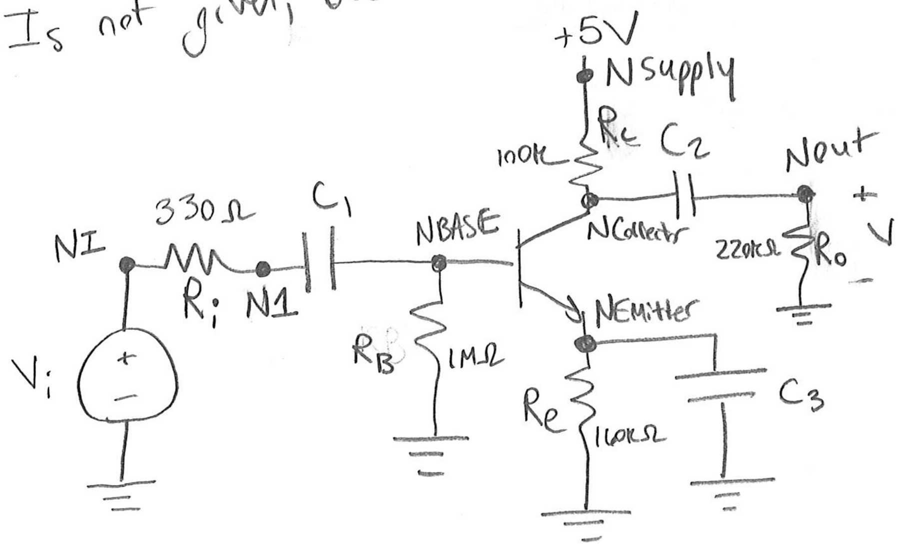
$$\frac{V_o}{V_i} = -(0.996)(362 \times 10^{-6} S)(28.6 \times 10^3 \Omega) = \boxed{-10.3 \frac{V}{V}}$$

13.132

Diagram of Node labels for spice

use $\beta_F = 65$ and $V_A = 50V$ from 1.129 in forward Active

I_S not given, but not important, so use spice default is fine



From Spice output

$V_i = 1mV$

$V_o = -62.7mV$

$$\boxed{\frac{V_o}{V_i} = -62.7}$$

Gain @ 1000Hz

Q-point

$V_{BE} = 0.677V$

$V_{BC} = -2.91V$

$V_{CE} = 2.91V + 0.677V$

$= 3.59V$

$I_C = 24.5\mu A$