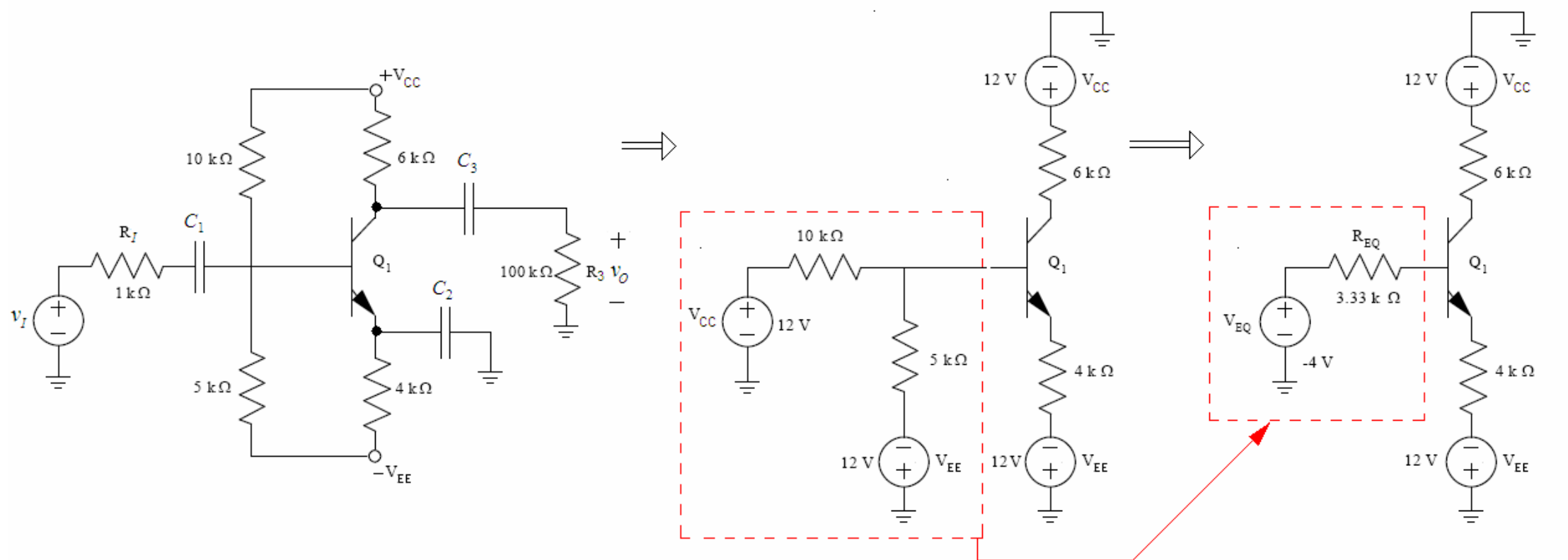


13.14



$$V_{EQ} = 5\text{ k}\Omega \frac{(V_{CC} + V_{EE})}{5\text{ k}\Omega + 10\text{ k}\Omega} - V_{EE}$$

$$V_{EQ} = 5\text{ k}\Omega \frac{24\text{ V}}{5\text{ k}\Omega + 10\text{ k}\Omega} - 12\text{ V} = -4\text{ V}$$

$$R_{EQ} = R_1 \parallel R_2 = 5\text{ k}\Omega \parallel 10\text{ k}\Omega = 3.33\text{ k}\Omega$$

Assume Transistor Operates in Forward Active Region ;

$$-4 = 3300I_B + 0.7 + 76(4000)I_B - 12$$

$$I_B = 23.8\text{ }\mu\text{A} \quad | \quad I_C = 75I_B = 1.78\text{ mA}$$

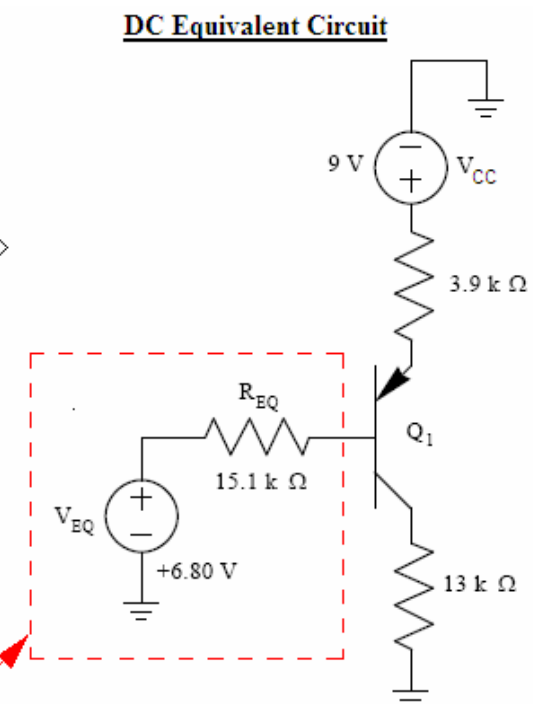
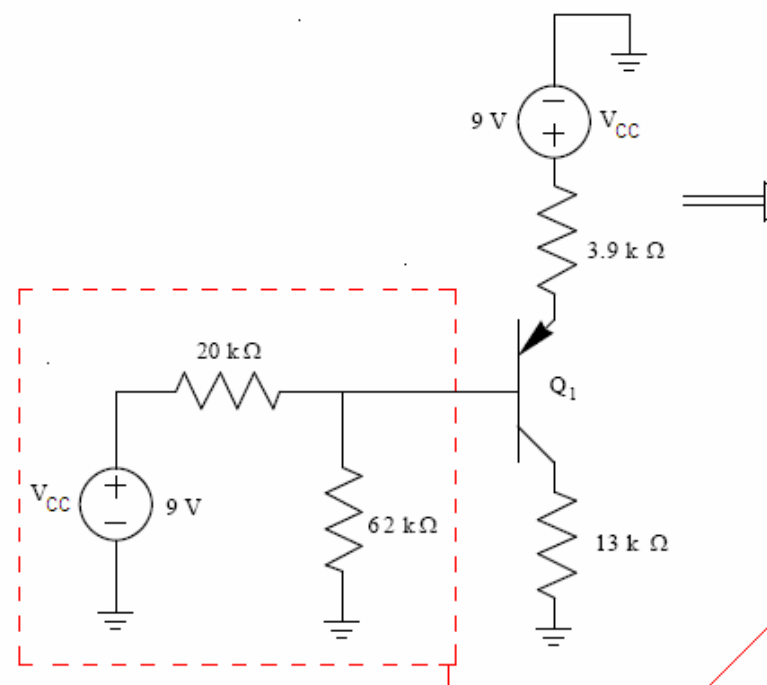
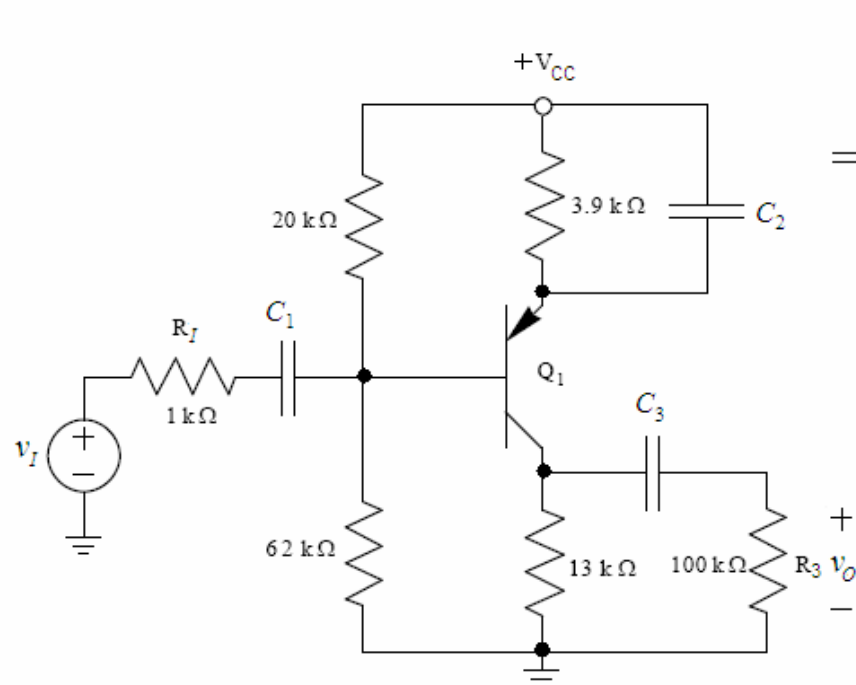
$$V_{CE} = 12 - 6000I_C - 4000I_E - (-12) = 6.11\text{ V}$$

$$V_{BE} = 0.7 \quad V_{BC} = 0.7 - 6.11 = -5.41\text{ V}$$

Assumption is Correct

Q - point : (1.78 mA, 6.11 V)

13.18



$$V_{EQ} = 9V \frac{62k\Omega}{62k\Omega + 20k\Omega} = 6.80V$$

$$R_{EQ} = 62k\Omega \parallel 20k\Omega = 15.1k\Omega$$

Assume Transistor Operates in Forward Active Region ;

$$9 = 3900(136)I_B + 0.7 + 15100I_B + 6.80$$

$$I_B = 2.75 \mu A \mid I_C = 135I_B = 371 \mu A \mid$$

$$I_E = 136I_B = 374 \mu A$$

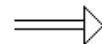
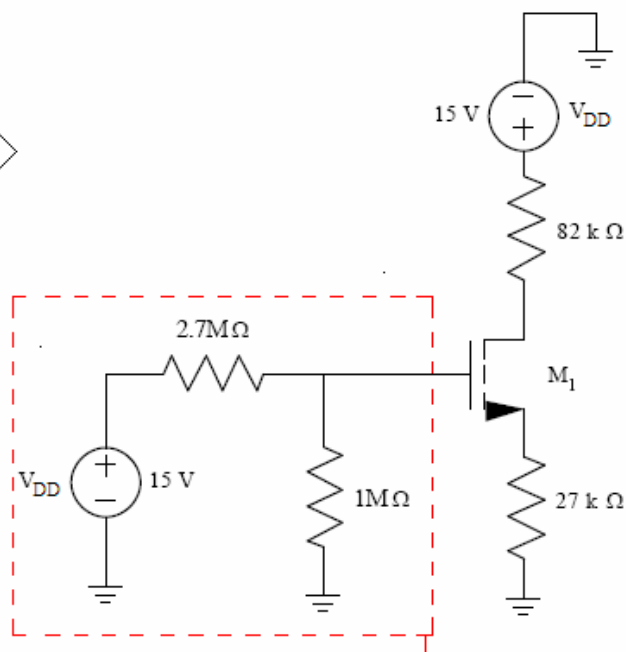
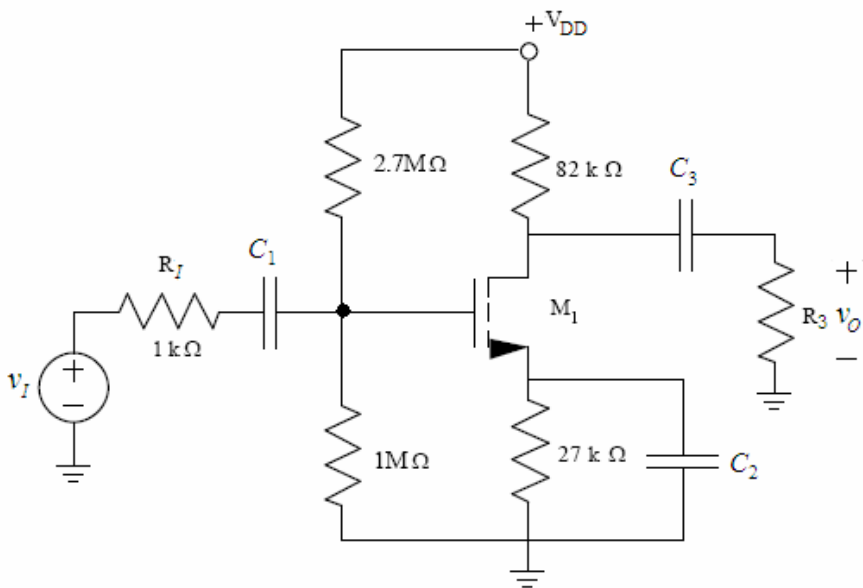
$$V_{EC} = 9 - 3900I_E - 13000I_C = 2.72 V$$

$$V_{EB} = 0.7 \quad V_{CB} = 0.7 - 2.72 = -2.02 V$$

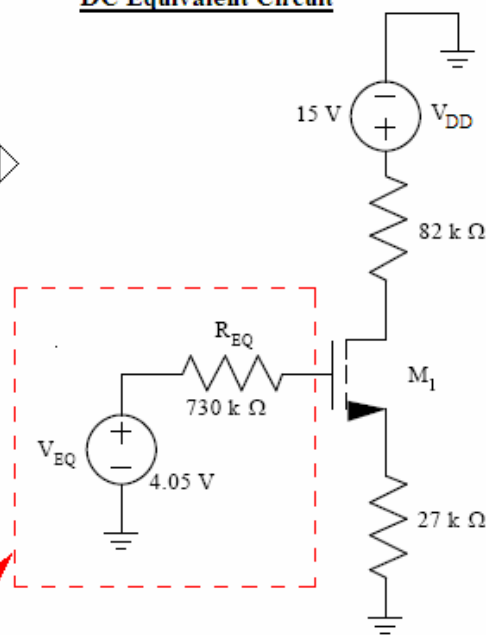
Assumption is Correct

Q - point : (371 μA , 2.72 V)

13.20



DC Equivalent Circuit



$$V_{EQ} = 15V \frac{1M\Omega}{1M\Omega + 2.7M\Omega} = 4.05V$$

$$R_{EQ} = 1M\Omega \parallel 2.7M\Omega = 730k\Omega$$

Assume Transistor Operates in Saturation Region ;

$$I_D = \frac{0.25mA}{2} (V_{GS} - 1)^2 \quad V_{GS} = 4.05 - 27000I_D$$

$$I_D = 0.125mA (3.05 - 27000I_{DS})^2 \rightarrow I_D = 82.2 \mu A$$

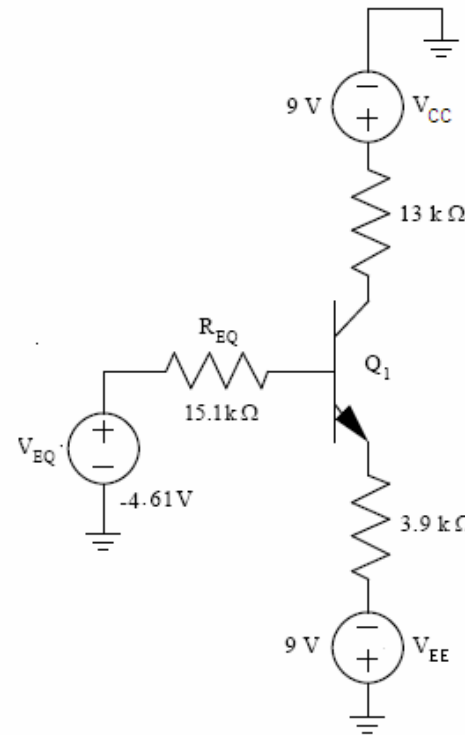
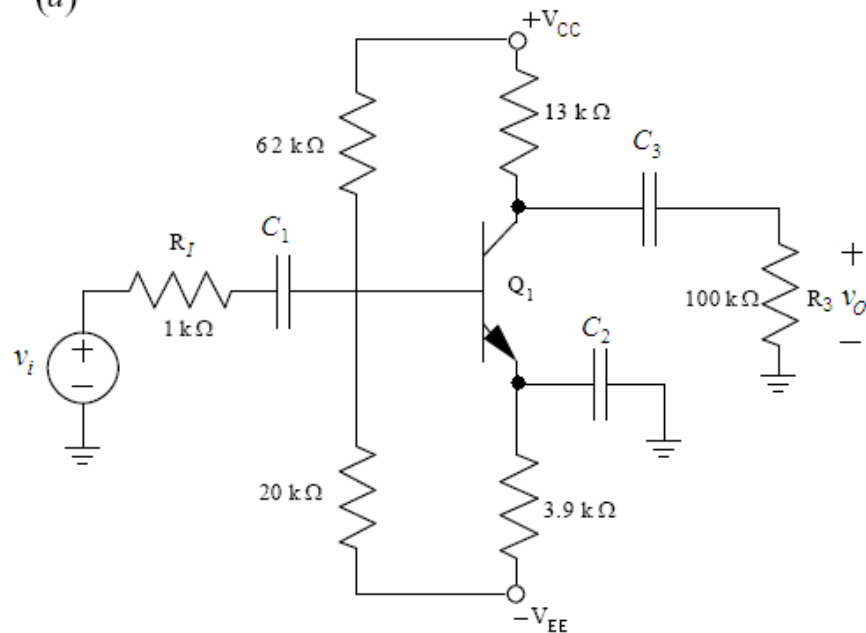
$$V_{DS} = 15 - 82000I_D - 27000I_D = 6.04V$$

$$V_{GS} - V_{TN} = 0.84V \quad V_{DS} > (V_{GS} - V_{TN})$$

Assumption is Correct

Q - point : (82.2 μA , 6.04 V)

(a)



$$V_{EQ} = -9 + \frac{20k\Omega}{62k\Omega + 20k\Omega} 18 = -4.61V$$

$$R_{EQ} = 20k\Omega \parallel 62k\Omega = 15.1k\Omega$$

Assume Transistor Operates in Forward Active Region ;

$$I_B = \frac{-4.61 - 0.7 - (-9)}{15.1k\Omega + 136(3.9k\Omega)} = 6.76\mu A$$

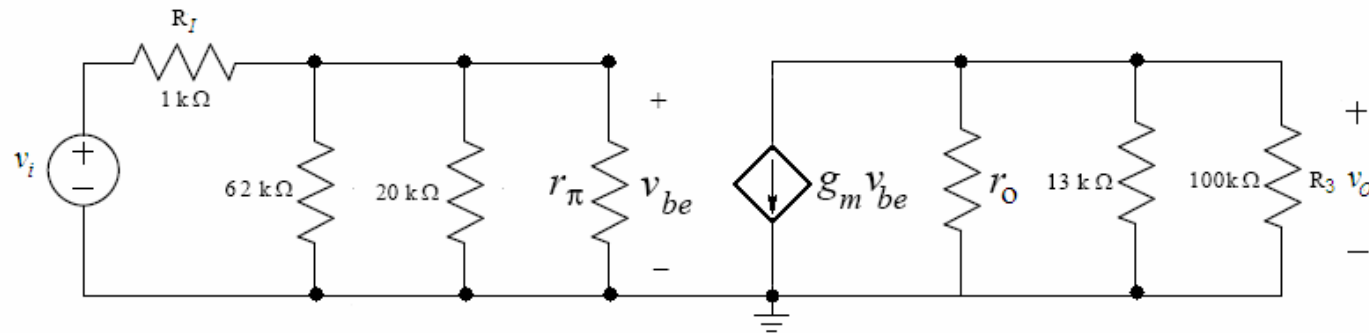
$$I_C = 135I_B = 913\mu A$$

$$V_{CE} = 9 - 13000I_C - 3900I_E - (-9) = 2.54V$$

$$V_{BE} = 0.7 \quad V_{BC} = 0.7 - 2.54 = -1.84V$$

Assumption is Correct

AC Equivalent Circuit with BJT replaced by Small Signal Model



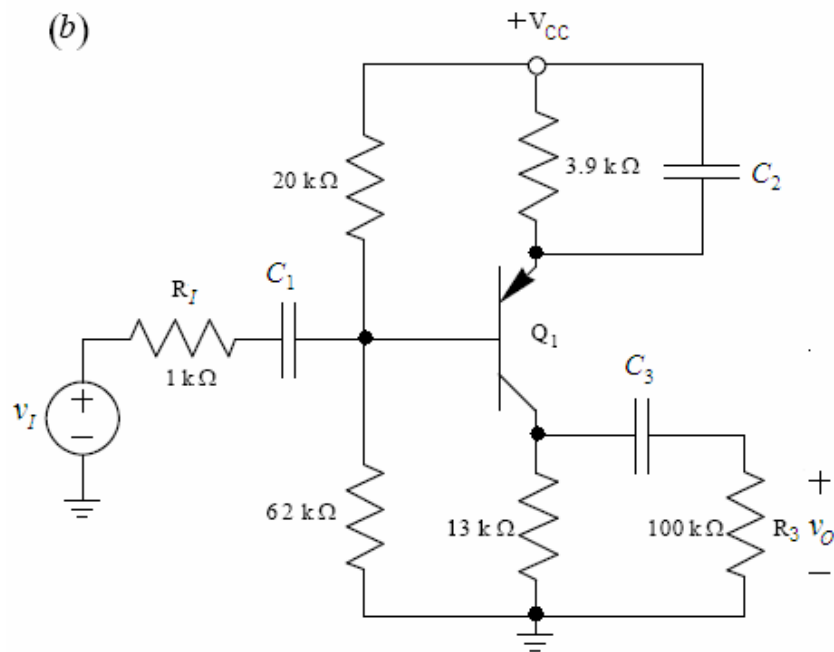
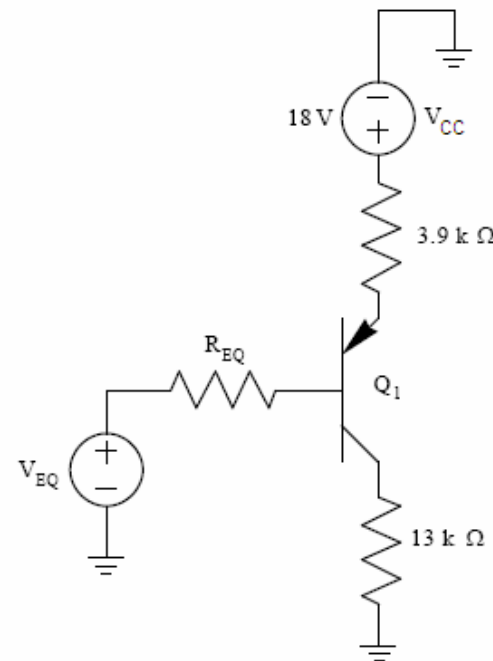
$$g_m = 40I_C = 0.0365S \quad \left| \quad r_\pi = \frac{135}{g_m} = 3.70k\Omega \quad \left| \quad r_o = \infty \right. \right.$$

$$\frac{v_{be}}{v_i} = \frac{(r_\pi \parallel 62k\Omega \parallel 20k\Omega)}{1k\Omega + (r_\pi \parallel 62k\Omega \parallel 20k\Omega)} \quad \left| \quad \frac{v_O}{v_{be}} = -g_m(13k\Omega \parallel 100k\Omega) \right.$$

$$A_v = \frac{v_{be}}{v_i} \times \frac{v_O}{v_{be}} = -\left(\frac{2.97k\Omega}{1k\Omega + 2.97k\Omega}\right)(0.0365)(11.5k\Omega) = -314$$

13.64

(b)

DC Equivalent Circuit

$$V_{EQ} = 18V \frac{62k\Omega}{62k\Omega + 20k\Omega} = 13.6V$$

$$R_{EQ} = 62k\Omega \parallel 20k\Omega = 15.1k\Omega$$

Assume Transistor Operates in Forward Active Region ;

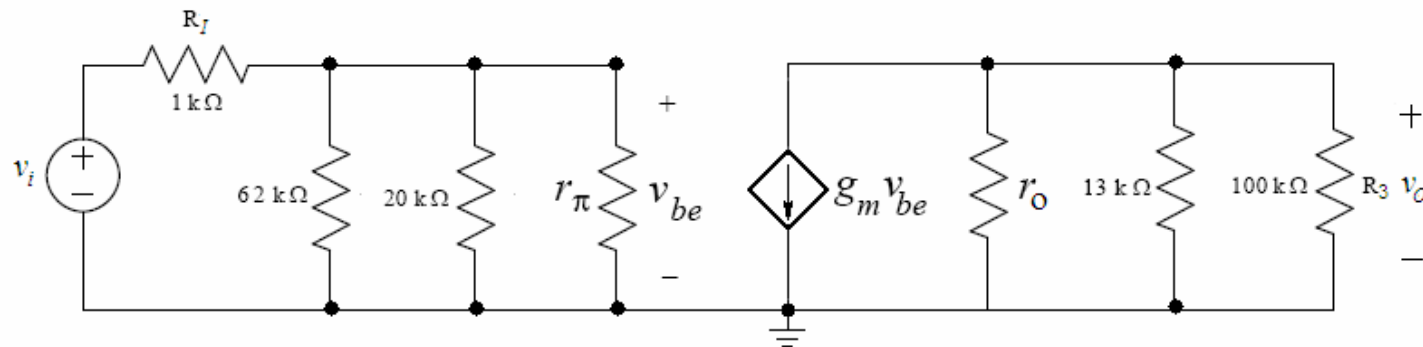
$$18 = 3900(136)I_B + 0.7 + 15100I_B + 13.6V$$

$$I_B = 6.76\mu A \mid I_C = 135I_B = 913\mu A$$

$$V_{EC} = 18 - 3900I_E - 13000I_C = 2.54V$$

$$V_{EB} = 0.7 \quad V_{CB} = 0.7 - 2.54 = -1.84V$$

Assumption is Correct

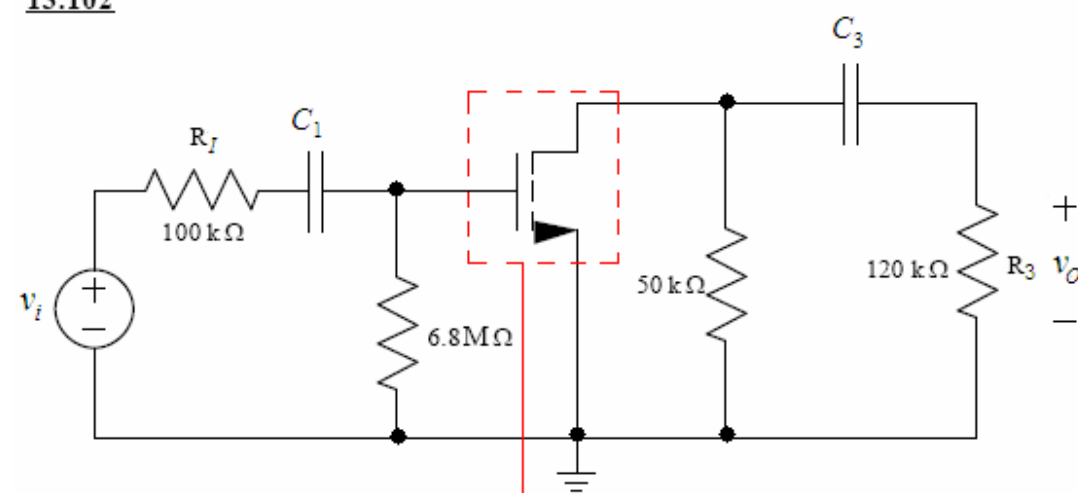
AC Equivalent Circuit with BJT replaced by Small Signal Model

$$g_m = 40I_C = 0.0365S \mid r_\pi = \frac{135}{g_m} = 3.70k\Omega \mid r_o = \infty$$

$$\frac{v_{be}}{v_i} = \frac{(r_\pi \parallel 62k\Omega \parallel 20k\Omega)}{1k\Omega + (r_\pi \parallel 62k\Omega \parallel 20k\Omega)} \mid \frac{v_O}{v_{be}} = -g_m (13k\Omega \parallel 100k\Omega)$$

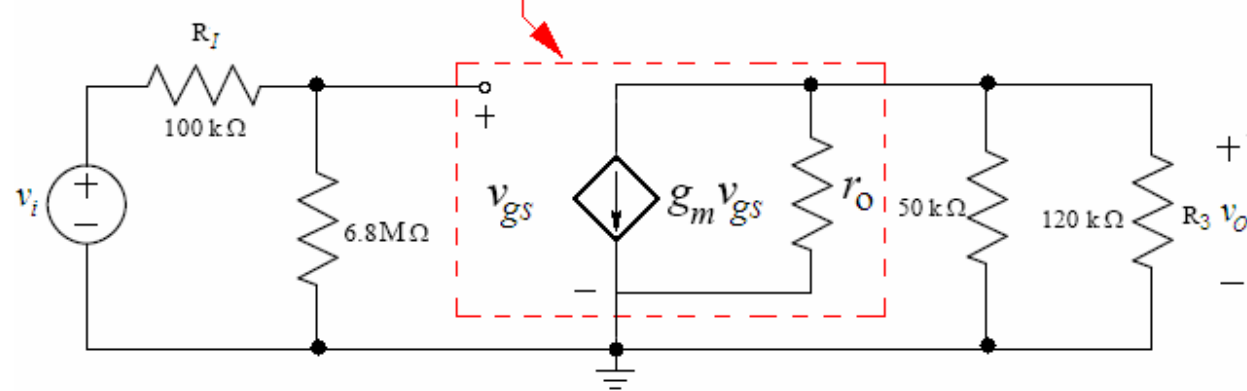
$$A_v = \frac{v_{be}}{v_i} \times \frac{v_O}{v_{be}} = -\left(\frac{2.97k\Omega}{1k\Omega + 2.97k\Omega}\right)(0.0365)(11.5k\Omega) = -314$$

13.102



$$g_m = \sqrt{2K_n I_D (1 + \lambda V_{DS})} = \sqrt{2 \left(500 \frac{\mu A}{V^2} \right) (100 \mu A) (1 + 0.02(5))} = 332 \mu S$$

$$r_o = \frac{\left(\frac{1}{\lambda} + V_{DS} \right)}{I_D} = \frac{50 + 5V}{100 \mu A} = 550 k\Omega$$



$$\frac{v_{gs}}{v_i} = \left(\frac{6.8 M\Omega}{6.8 M\Omega + 0.1 M\Omega} \right) \quad \left| \quad \frac{v_o}{v_{gs}} = -g_m (r_o \parallel 50 k\Omega \parallel 120 k\Omega) \right.$$

$$A_v = \frac{v_{gs}}{v_i} \times \frac{v_o}{v_{gs}}$$

$$A_v = - \left(\frac{6.8 M\Omega}{6.8 M\Omega + 0.1 M\Omega} \right) (332 \mu S) (550 k\Omega \parallel 50 k\Omega \parallel 120 k\Omega) = -10.9$$