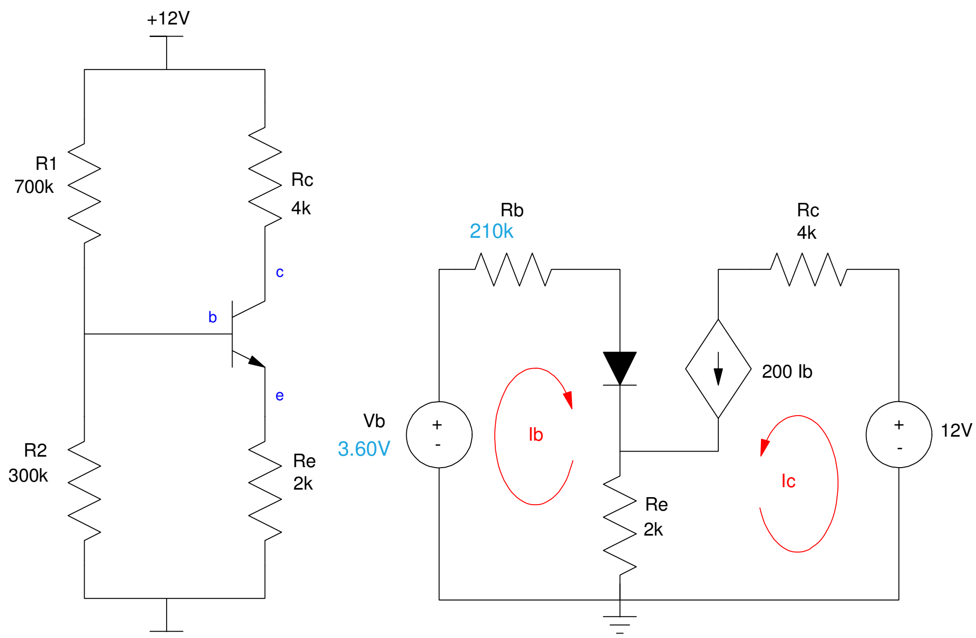
ECE 321 - Homework #5

DC Analsis of Transtor Amplfiers, 2-Ports, CE Amplifiers. Due Monday, May 1st
Please email to jacob.glower@ndsu.edu, or submit as a hard copy, or submit on BlackBoard

1) Determine the Q-point for the following transistor circuit. Assume C's are large and assume 3904 transistors:

- Vbe = 0.7V
- β=200



$$V_b = V_{th} = \left(\frac{300k}{300k+700k}\right) 12V = 3.60V$$

$$R_b = 300k || 700k = 210k$$

$$I_b = \left(\frac{V_b - 0.7}{R_b + (1+\beta)R_e}\right) = 4.739\mu A$$

$$I_c = 200 I_b = 947.7\mu A$$

$$V_{ce} = 12V - I_c R_c - (I_b + I_c) R_e = 6.304V$$

The Q-point is

- Vce = 6.304V
- Ic = 947.7uA

2) Modify this circuit so that

- The Q-point is stabilized for variations in β, and
- The Q-point is Vce = 5.0V

Stabilize the Q-Point

$$(1+\beta)R_e >> R_b$$

$$402k >> R_b$$

Let Rb = 40k

Vce = 5.00V

$$V_{ce} = 12 - I_c R_c - (I_b + I_c) R_e$$

$$5V = 12V - 4000 I_c - 2000\left(\frac{I_c}{200} + I_c\right)$$

$$I_c = 1.165 mA$$

$$I_b = \frac{I_c}{200} = 5.824 \mu A$$

$$V_b = I_b R_b + 0.7 + (I_b + I_c) R_e$$

$$V_b = 3.274V$$

Finding R1 and R2

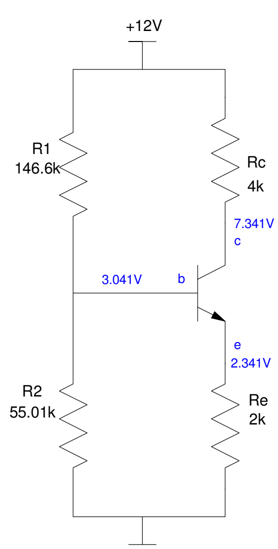
$$R_1 || R_2 = \left(\frac{R_1 R_2}{R_1 + R_2}\right) = 40k$$

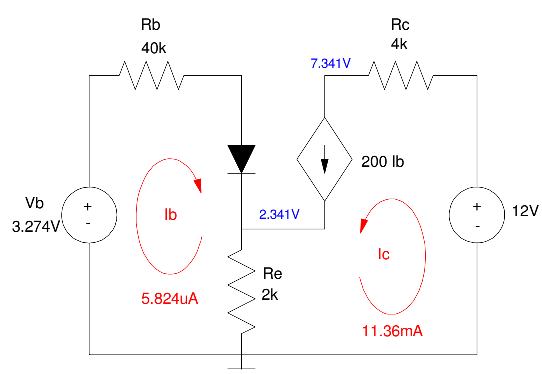
$$\left(\frac{R_2}{R_1 + R_2}\right) 12V = 3.274V$$

Solving

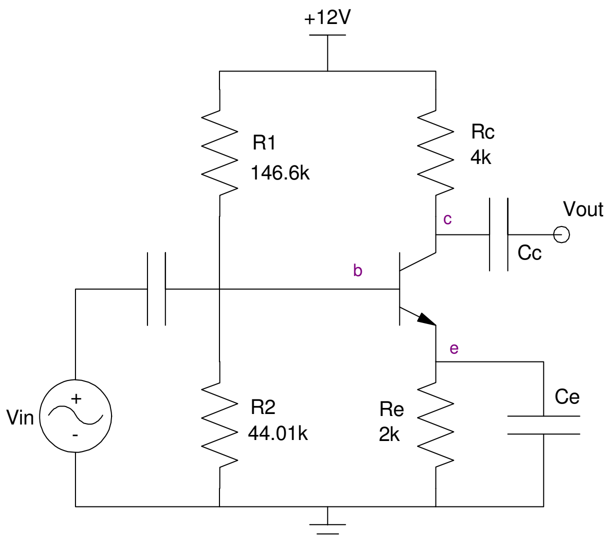
$$R_1 = \left(\frac{12V}{3.274V}\right) 40k = 146.6 k\Omega$$

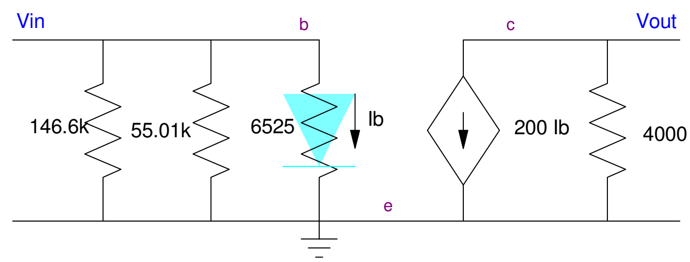
$$R_2 = 55.01 k\Omega$$





3) Draw the small-signal model for the circuit of problem #2 connected as a common emitter amplifier (below). From this, determine the 2-port model





Using n = 1.45 (from CircuitLab)

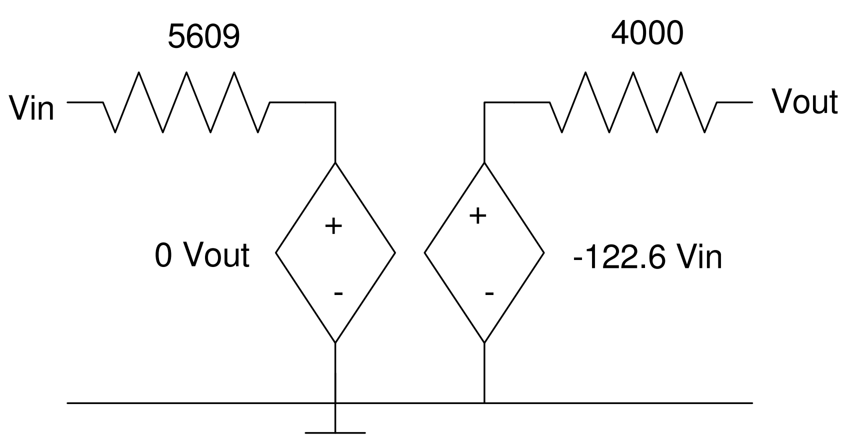
$$r_f = \left(\frac{nV_T}{I_b}\right) = \left(\frac{1.45 \cdot 26mV}{5.824\mu A}\right) = \left(\frac{0.038V}{5.824\mu A}\right) = 6525\Omega$$

$$R_{in} = 146.6k || 55.01k || 6525 = 5609.9\Omega$$

$$A_{in} = 0$$

$$R_{out} = 4k$$

$$A_{out} = -\frac{\beta R_c}{r_f} = -122.60$$



4) Simulate this circuit in CircuitLab. Verify each of the 2-port parameters at 1kHz

- Rin
- Rout
- Ao

Simulation	R8	R5	gain	
Ao	0	10M	144.4	Ao = 144.4 vs. 122.60
Rin	5k	10M	72.15	Rin = 5020 vs. 5609
Rout	0	4k	73.89	Rout = 3817 vs 4000

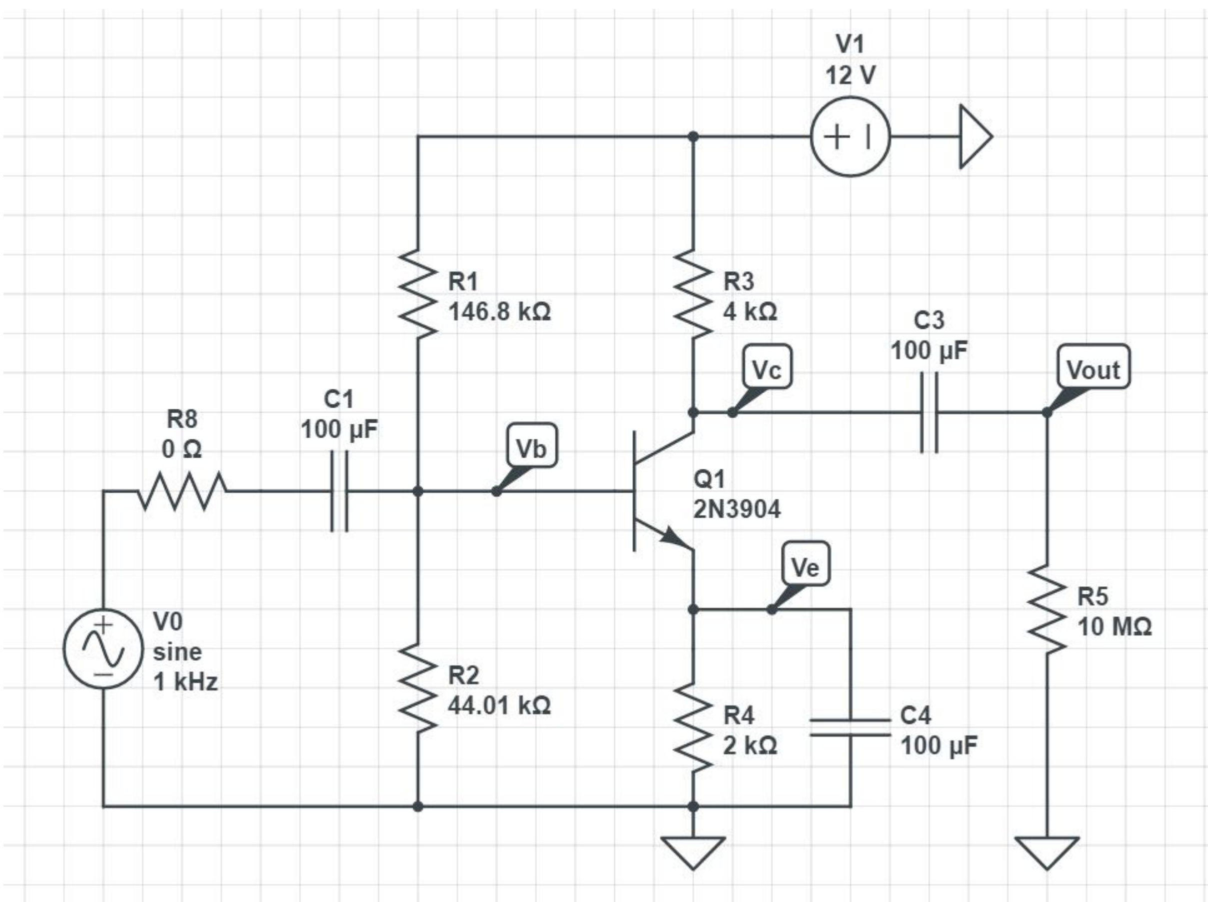
Sample Calculations

$$72.15 = \left(\frac{R_{in}}{R_{in}+5000}\right)144.4$$

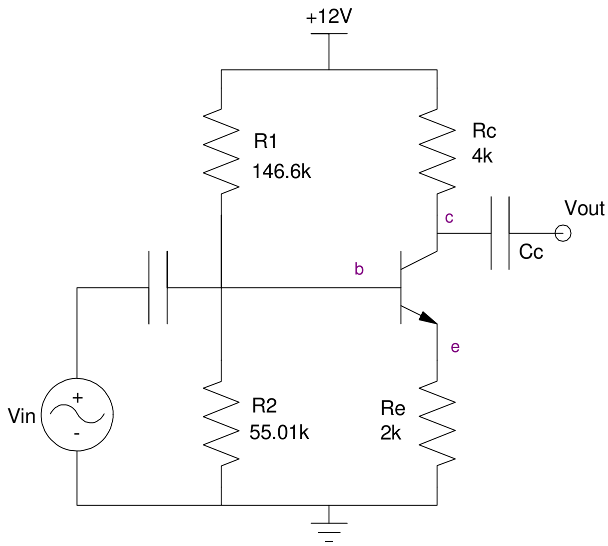
$$R_{in} = \left(\frac{72.15}{144.4-72.15}\right)\cdot 5000\Omega$$

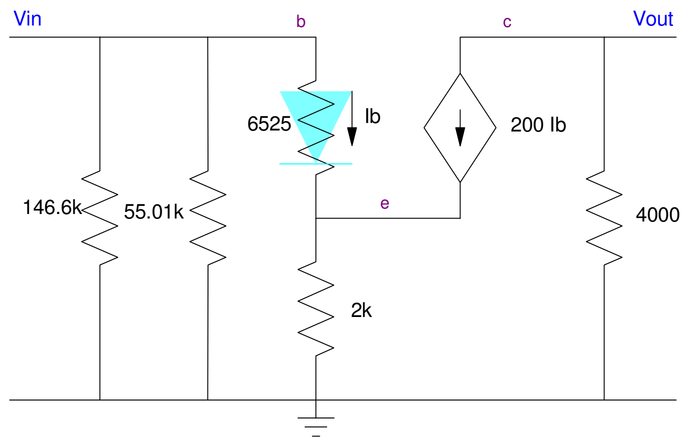
$$73.89 = \left(\frac{4k}{4k+R_{out}}\right)144.4$$

$$R_{out} = \left(\frac{144.4-73.89}{73.89}\right)\cdot 4k\Omega$$



5) Remove Ce. Now draw the small-signal model for the circuit of problem #2. From this, determine the 2-port model for the Common Emitter amplifier





Rin:

$$R_{in} = 146.6k||55.01k||)6525 + 2000 \cdot (1+\beta)$$

$$R_{in} = 21.55k$$

Ai = 0

Rout = 4k

$$A_o = -(200)(4000)\left(\frac{1}{6525+2000\cdot\beta+1}\right)$$

$$A_o = -1.9583$$

6) Simulate this circuit in CircuitLab. Verify each of the 2-port parameters at 1kHz

- Rin
- Rout
- Ao

Simulation	R8	R5	gain	Simulation Result
Ao	0	10M	1.962	Ao = 1.962 1.9583 calculated
Rin	22k	10M	1.152	Rin = 31.22k 21.55k calculated
Rout	0	4k	0.9821	Rout = 3991 4000 calculated