ECE 115A
Fall ‘20
Midterm Exam
Thursday, November 5, 2020
Instructor: Prof. M.F. Chang

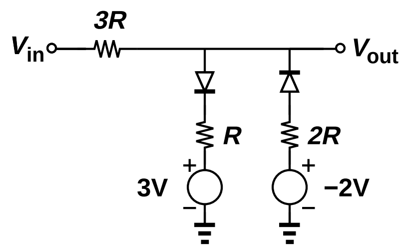
Name:
UID:

Problem 1: ....
Problem 2: ....
Problem 3: ....
Problem 4: ....
Problem 5: ....
Problem 6: ....(Bonus)
Problem 7: ....(Bonus)

Total : ....

Problem 1 (20 marks)

For the shown circuit, sketch V_{out} vs. V_{in} . Let V_{in} changes from -5 V to 5 V. Label the important break points. Assume ideal diodes.

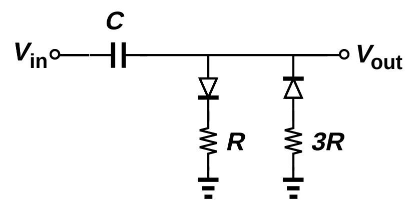


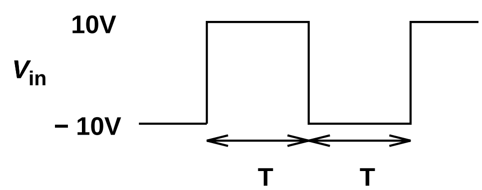
Problem 2 (20 marks)

For the circuit shown, utilizing ideal diodes, sketch the output waveform for the input shown. Label the most positive and most negative output levels.

(a) CR >> T

(b) CR = 0.5 T



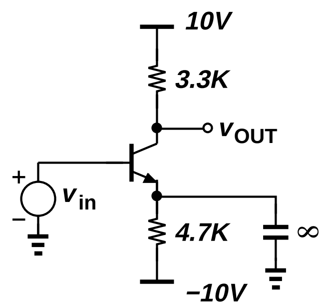


Problem 3 (20 marks)

For the common-emitter amplifier circuit shown below:

- Find the dc collector current of the transistor and the output dc voltage.
- Find g_m and r_π.
- Find the voltage gain (v_{out}/v_{in}) and the input resistance.

Assume β=100 and $V_{BE(on)}$=0.7 V.

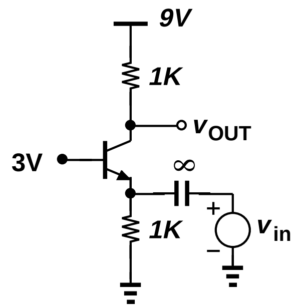


Problem 4 (20 marks)

For the common-base amplifier circuit shown below:

- Find the dc collector current of the transistor and the output dc voltage.
- Find g_m and r_e.
- Find the voltage gain (v_{out}/v_{in}) and the input resistance.

Assume β=100 and $V_{BE(on)}$=0.7 V.



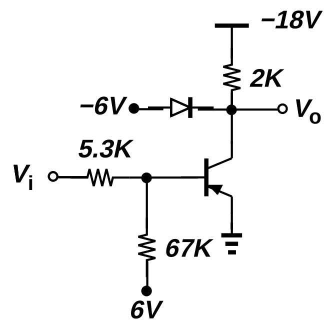
Problem 5 (20 marks)

For the circuit shown:

(a) find V_o when V_i=0

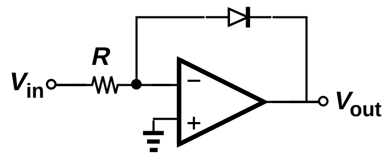
(b) What is the β to have Vo = 0 V and Vi = -6 V, assume device in forward active as long as V_{CE}<=0.

Assume ideal diode and $V_{EB(on)}$=0.7 V.



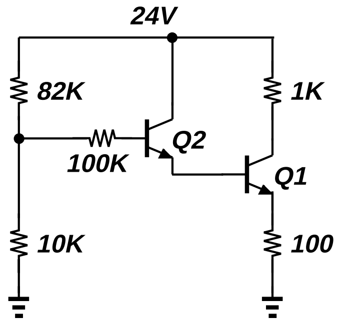
Problem 6 (Bonus - 10 marks)

For the circuit shown below, find the expression of the output V_{out} in terms of the input V_{in}. (For diode $I_D = I_S \exp(V_D / V_T)$)



<u>Problem 7 (Bonus - 10 marks)</u>

For the circuit shown, transistors Q_1 and Q_2 operate in the active mode region with $V_{BE1} = V_{BE2} = 0.7$ V, $\beta_1 = 100$ and $\beta_2 = 50$. Find I_{B1}, V_{C2} and V_{E2}.



20F-ECENGR115A-1 MIDTERM 1 UPLOAD

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TOTAL POINTS

106.5 / 120

QUESTION 1

1 1 **20** / **20**

✓ **- 0 pts** Correct

QUESTION 2

2 2 **20** / **20**

✓ **- 0 pts** Correct

QUESTION 3

3 3 **20** / **20**

✓ **- 0 pts** Correct

QUESTION 4

4 4 **20** / **20**

✓ **- 0 pts** Correct

QUESTION 5

5 5 **16** / **20**

✓ **- 4 pts** 4 points partial credit for a

QUESTION 6

6 6 **10** / **10**

✓ **- 0 pts** Correct

QUESTION 7

7 7 **0.5** / **10**

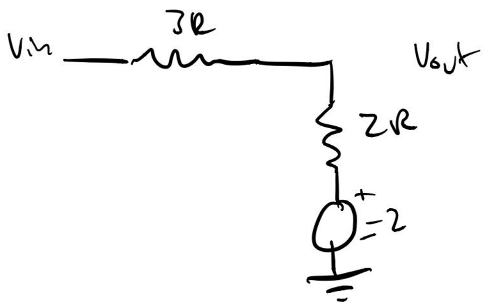
- 9.5 Point adjustment

Problem 1:

Start from -5V (low swing)

let us assume that $V_{out} < -2 < 3$

Then, D_1 will be open and D_2 will be short



$$\frac{V_{in}+2}{5R}(2R) - 2 = V_{out}$$

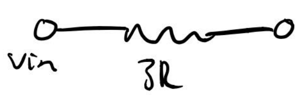
$$\frac{2}{5}(V_{in}+2) - 2 = V_{out}$$

$$\frac{2V_{in}+4-10}{5} = V_{out}$$

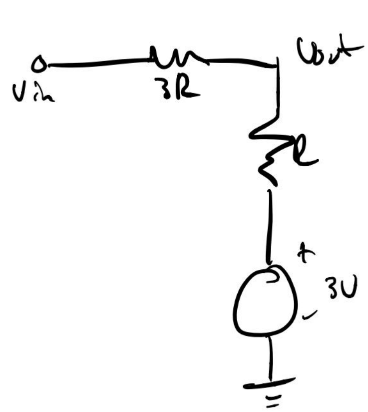
$$\frac{2V_{in}-6}{5} = V_{out}$$ → assumption is true until $V_{in}=-2$.

This remains true until $V_{out} = -2$ ⇒ $V_{in} = -2$

Then, D_2 is open and $V_{out} = V_{in}$



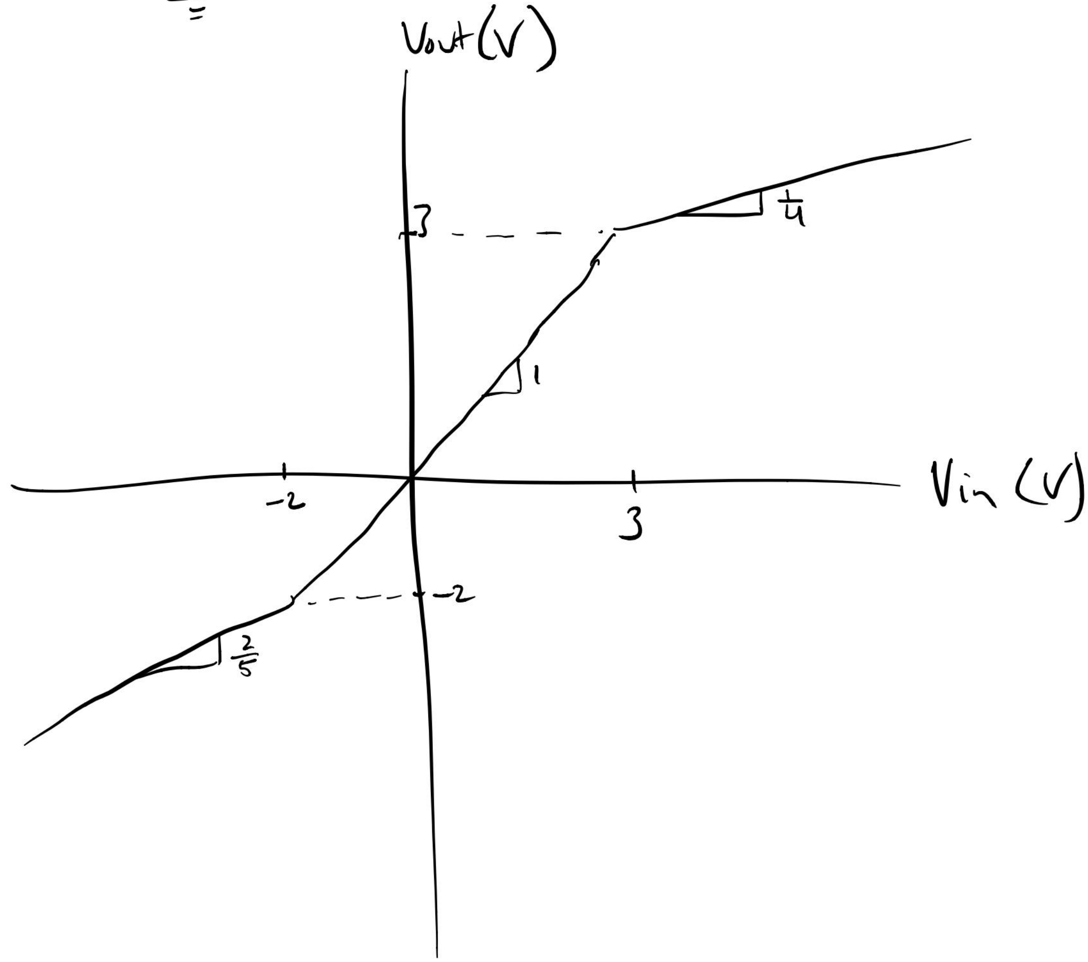
when $V_{out} = V_{in} = 3^{+}$, then D_1 is shorted



$$V_{out} = (V_{in} - 3)\left(\frac{1}{4}\right) + 3$$

$$= \frac{V_{in} - 3 + 12}{4}$$

$$V_{out} = \frac{V_{in} + 9}{4}$$



1 1 **20 / 20**

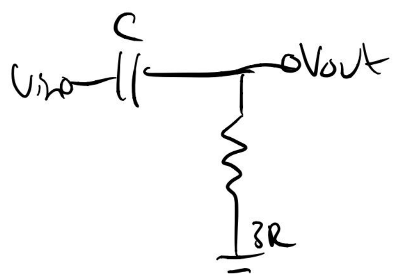
✓ **- 0 pts** Correct

Problem 2:

Note: I asked if we are to do this in steady state or draw the transients, and I was told to do steady state. I will still comment on the transients.

a) KCL:

For low swing, D_1 is open and D_2 is shorted. Then:



$$C\frac{d(V_{in}-V_{out})}{dt} = \frac{V_{out}}{3R}$$

Since V_{in} is constant,

Then $\frac{dV_{out}}{dt} = \frac{-1}{3RC}V_{out}$

$$V_{out} = Ce^{-\frac{t}{3RC}} = -10\, e^{-\frac{t}{3RC}}$$

For $RC \gg T$, $e^{-\frac{t}{3RC}} \simeq e^{-\frac{(t+T)}{3RC}}$

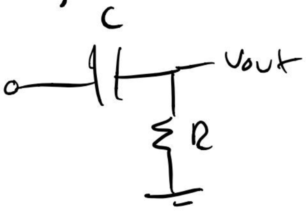
so the output is flat and $V_{out} = (0$

For the high swing at $t=T$,

$V_C(T-) = V_C(T+) = 0$ due to resistance and very little current because $T << RC$

so $V_{out} = V_{in} = 10$

Then, D_1 is short and D_2 is open



and $V_{out} = 10e^{-\frac{1}{RC}(t-T)}$

Since $RC >> T$, the same arguement is made and $V_{out}(2T) = 10$.

Then, $V_{out}(2T+) = V_{out}(2T-) - 20 = -10$ and the conditions repeat

Thus, for the first cycles, $V_{out} = V_{in}$

However, at steady state ($t \to \infty$), the transients will disappear and the output will look like:

Steady state:

$V_{out_H}(0+) - V_{out_L}(T-) = 20$

H → High
L → low

$V_{out_H}(T-) - V_{out_L}(0+) = 20$

→ $V_{out_H}(0+) - e^{-\frac{T}{3RC}} V_{out_L}(0+) = 20$

→ $V_{out_H}(0+) e^{-\frac{T}{RC}} - V_{out_L}(0+) = 20$

Approx $e^{-\frac{T}{RC}} = \left(1 - \frac{T}{RC}\right)$ because $T << RC$

$V_{out_H} - \left(1 - \frac{T}{3RC}\right) V_{out_L} = 20$

$\left(1 - \frac{T}{RC}\right) V_{out_H} - V_{out_L} = 20$

$\left(\frac{T}{RC}\right) V_{out_H} = -V_{out_L}\left(\frac{T}{3RC}\right)$

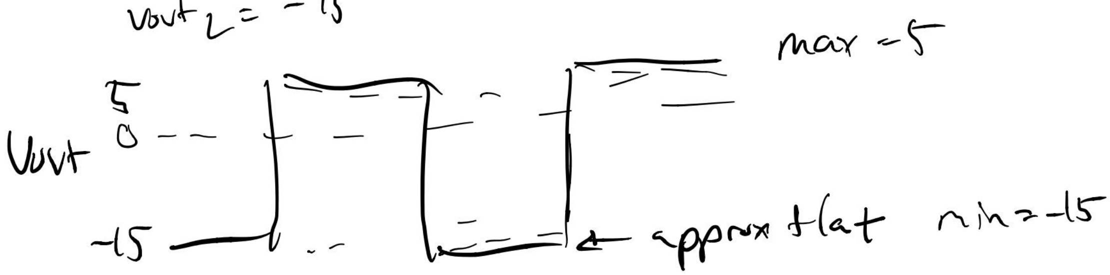
$V_{out_H} = -V_{out_L}\left(\frac{1}{3}\right)$

since V does not really decay

$V_{out_H} - V_{out_L} = 20$

$V_{out_H} = 5$

$V_{out_L} = -15$



b) For low swing:

$$V_{out}(T-) = -10 e^{-\frac{1}{3RC}T} \quad \text{as shown in a)}$$

since $T = 2RC$

$$V_{out}(T-) = -10 e^{-\frac{2}{3}} = \boxed{-5.134}$$

Note: $\boxed{V_{out_L}(T-) = V_{out_L}(0+)\, e^{-\frac{2}{3}}}$ For low

Then, when Vin jumps, Vc does not change so Vout jumps the same amount.

$$V_{out}(T+) = 20 - 5.134 = 14.86$$

$$V_{out}(2T-) = 14.86\, e^{-\frac{1}{RC}(t-T)} = 14.86 e^{-2}$$

$$= 2.011$$

$$\boxed{V_{out_H}(T-) = V_{out_H}(0+) e^{-2}}$$

For steady state:

$$V_{out_H}(0+)e^{-2} = V_{out_H}(T-)$$

$$V_{out_L}(0+)e^{-\frac{2}{3}} = V_{out_L}(T-)$$

$$V_{out_H}(0+) - V_{out_L}(T-) = 20$$

$$V_{out_H}(T-) - V_{out_L}(0+) = 20$$

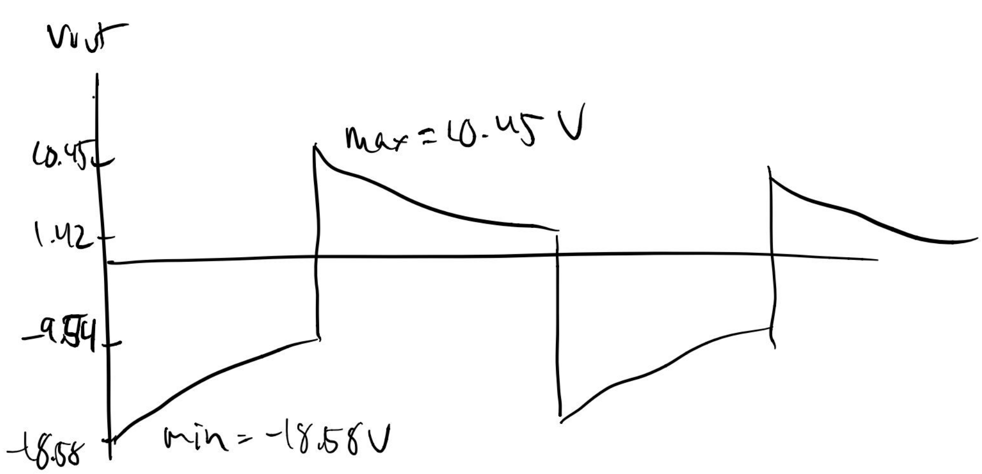
$$\rightarrow V_{out_H}(0+) - e^{-\frac{2}{3}} V_{out_L}(0+) = 20$$

$$\rightarrow V_{out_H}(0+)e^{-2} - V_{out_L}(0+) = 20$$

$$e^{\frac{2}{3}} V_{out_H} - e^{-2} V_{out_H} = 20e^{\frac{2}{3}} - 20$$

$$V_{out_H} = 10.45 \rightarrow V_{out_H}(T-) = 1.42$$

$$V_{out_L}(T-) = -9.54 \rightarrow V_{out_L}(0+) = -18.58$$



2 2 **20 / 20**

✓ **- 0 pts** Correct

Problem 3)

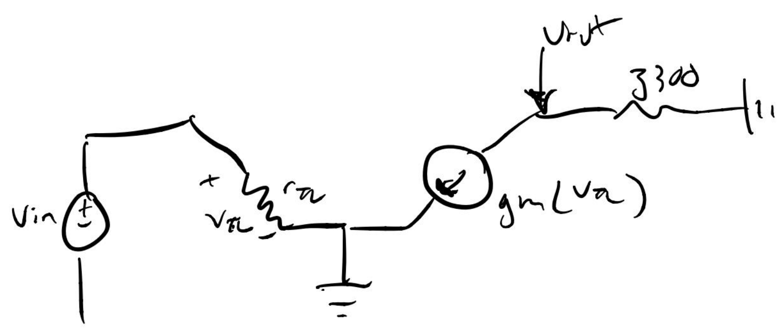
$$I_E = \left(\frac{V_{BE}+10}{4700}\right) = 0.00198\,A$$

$$I_C = I_E\left(\frac{100}{101}\right) = 0.00196\,A$$

(sat current is 0.0025 so not saturated)

$$g_m = \frac{I_C}{V_T} = 0.075\,S$$

$$r_\pi = \frac{\beta}{g_m} = 1327.12\,\Omega$$



$$V_{out} = -g_m(V_{in})(3300)$$

$$\frac{V_{out}}{V_{in}} = -g_m(3300) = 248.7$$

$$r_{in} = r_\pi = 1327.12\,\Omega$$

3 3 **20 / 20**

✓ **- 0 pts** Correct

Problem 4.

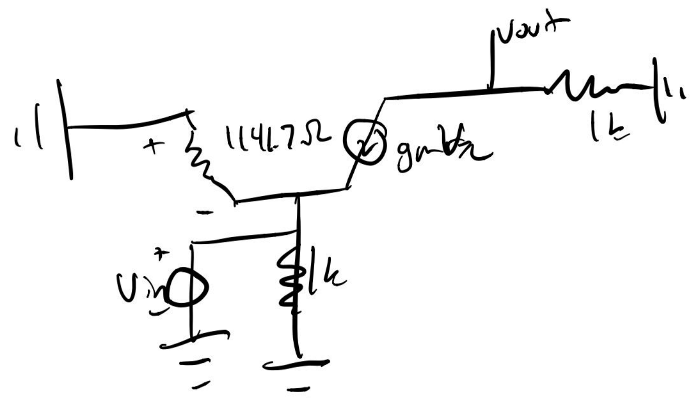
$$I_E = \frac{3-0.7}{1000} = 0.0023\,A$$

$$I_C = \frac{100}{101} I_E = 0.00228\,A$$

(~~start~~ I = 0.0045)

$$g_m = \frac{I_C}{V_T} = 0.0876\ S$$

$$r_e = \frac{r_\pi}{\beta+1} = \frac{\beta}{\beta+1}\frac{1}{g_m} = 11.3\,\Omega$$



$$V_{out} = -g_m(V_\pi)(1000)$$

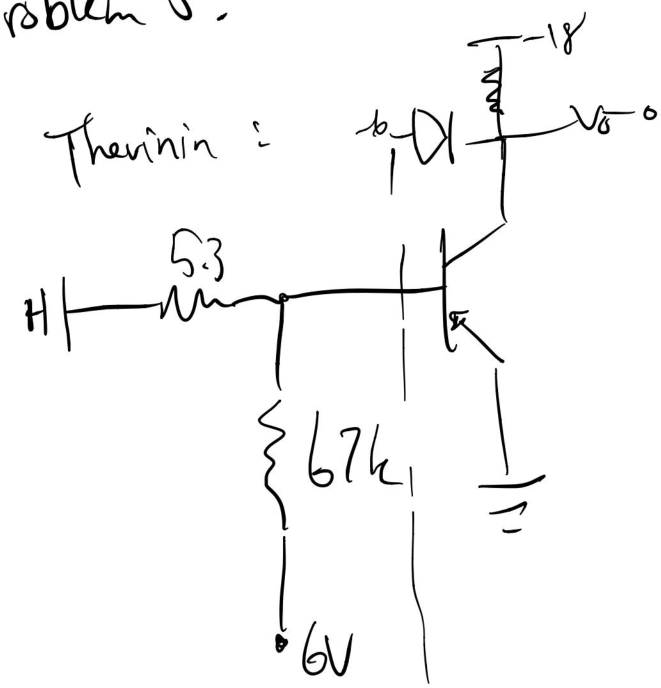
$$V_\pi = -V_{in}$$

$$\frac{V_{out}}{V_{in}} = g_m(1000)$$

input impedence = $(1k) \| (11.3) = \boxed{11.17\,\Omega}$

Problem 5.

a) Thevinin :



$$V_{TH} = \frac{6}{67000 + 5300}(5.3k) = 0.44V$$

$R_{TH} = 4911.5\ \Omega$

Assume Barely forward active

Vo is clamped above -6.7

We see current is extremely small

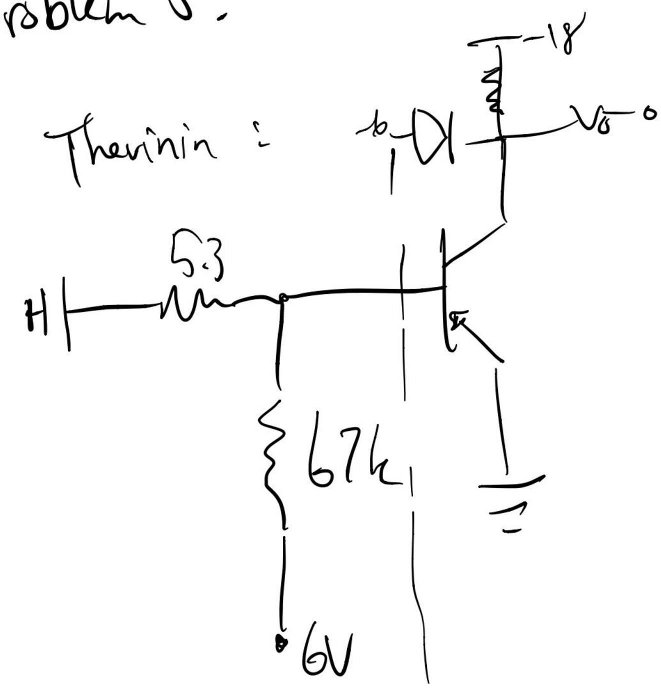
4 4 20 / 20

✓ - 0 pts Correct

input impedence = $(1k) \| (11.3) = \boxed{11.17\Omega}$

Problem 5.

a) Therinin :



$$V_{TH} = \frac{6}{67000 + 5300}(5.3k) = 0.44V$$

$R_{TH} = 4911.5\ \Omega$

Assume Barely forward active

Vo is clamped above -6.7

We see current is extremely small

as I_B has a really high input impedance.

Thus, $V_o = -6.7$.

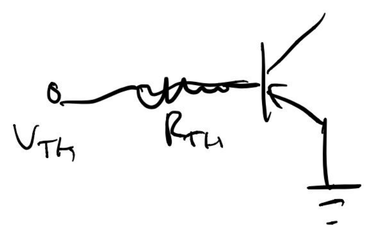
5)

Thevinin:

$$\frac{12}{67000+5300}(5.3k) - 6$$

$V_{TH} = -5.12\,V$

$R_{TH} = 4911.5\,\Omega$



$$I_B = \frac{5.12-0.7}{4911.5} = 9\times10^{-4}\,A$$

$$-18 + (2000)(\beta)(9\times10^{-4}) = 0$$

$\beta = 10$

5 5 16 / 20

✓ - 4 pts 4 points partial credit for a

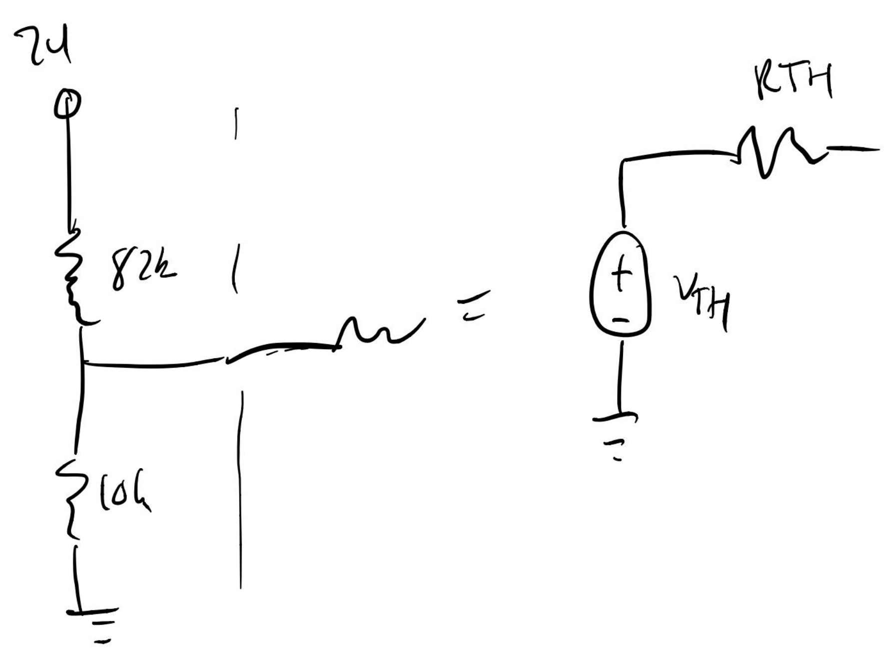
6)

$$\frac{V_{in}}{R} = I_s e^{-V_{out}/V_T}$$

$$V_{out} = -V_T \ln\left(\frac{V_{in}}{R I_s}\right)$$

7)

Th:



6 6 10 / 10

✓ - 0 pts Correct

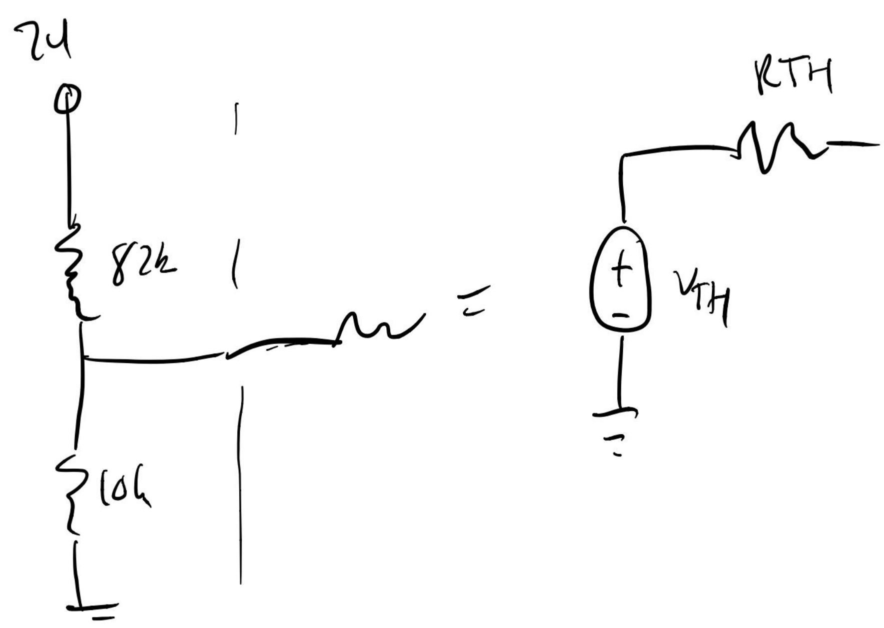
6)

$$\frac{V_{in}}{R} = I_s e^{-V_{out}/V_T}$$

$$V_{out} = -V_T \ln\left(\frac{V_{in}}{R I_s}\right)$$

7)

Th:



$$V_{TH} = \frac{24}{82+10}(10) = 2.6\,V$$

$$R_{TH} = 82k \parallel 10k = 8913\,\Omega$$

$$2.6 - .7 - .7 = I_{B_1}(8913 \overset{+100k}{)} + I_{E_2}(100)$$

$$I_{E_2} = 51(I_{B_2}) = (101)\,51\,(I_{B_1})$$

$$1.2 = I_{B_1}(8913 \overset{+100k}{+} 5151^{\times 100})$$

$$I_{B_1} = 2.28 \times 10^{-7}\,A$$

$$I_{E_2} = (0151)(I_{B_1}) = 0.0012\,A$$

$$V_{E_2} = 0.0012A \times 100\,\Omega = 0.12\,V$$

$$V_{C_2} = 24 - \frac{50}{51}\left(0.0012(1000)\right) = 22.8\,V$$

7 7 0.5 / 10

- **9.5** Point adjustment