Electronics
EECE2412 — Fall 2018
Exam #2

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Name: Solutions

General Rules:

- You may make use of two sheets of notes, 8.5–by–11 inches, using both sides of the page.
- You may use a calculator.
- Present your work as clearly as possible. I give partial credit if I can figure out that you know what you are doing. I do not give credit for putting down everything you know and hoping I will find something correct in it.
- Each question has a vertical black bar providing space for your work and a line for numerical answers or box for plots or drawings. Please write your answer to each question clearly. If it happens to be correct, I give you points quickly and move on to the next problem. Please show your work in the space provided, or on extra pages, clearly labeled with the problem number. If the answer is wrong, this will make it easy for me to find ways to give you partial credit.
- Avoid any appearance of academic dishonesty. Do not talk to other students during the exam. Keep phones, computers, and other electronic devices other than calculators secured and out of reach.

1 Short–Answer Questions

The arrow on a PNP transistor symbol

- [x] is on the emitter and points toward the base
- [ ] is on the emitter and points away from the base
- [ ] is on the collector and points toward the base
- [ ] is on the collector and points away from the base

The base–emitter voltage of a NPN transistor in cutoff is . . .

- [ ] 0.7 V
- [ ] 0 V
- [x] determined by the rest of the circuit.

The voltage gain, $A_V \approx 1$ for a

- [ ] Common Emitter amplifier
- [ ] Common Base amplifier
- [x] Common Collector amplifier

To bias the base of an NPN transistor at zero volts in active mode requires a bipolar power supply.

- [x] True
- [ ] False

The emitter current is equal to the sum of the base and collector current in saturation.

- [x] True
- [ ] False

It is possible to design a single–stage common–emitter amplifier with the DC input and output voltages both equal to zero.

- [ ] True
- [x] False

A resistor–transistor logic (RTL) inverter consumes power . . .

- [x] when the input is high.
- [ ] when the input is low.
- [ ] only during transitions.
- [ ] always.

The majority carriers in an NPN transistor are ...

- [ ] holes
- [x] electrons

In cutoff, the base–emitter and base–collector junctions are both reverse biased.

- [x] True
- [ ] False

A BJT NOR logic gate requires

- [x] A pull–up resistor
- [ ] A pull-down resistor

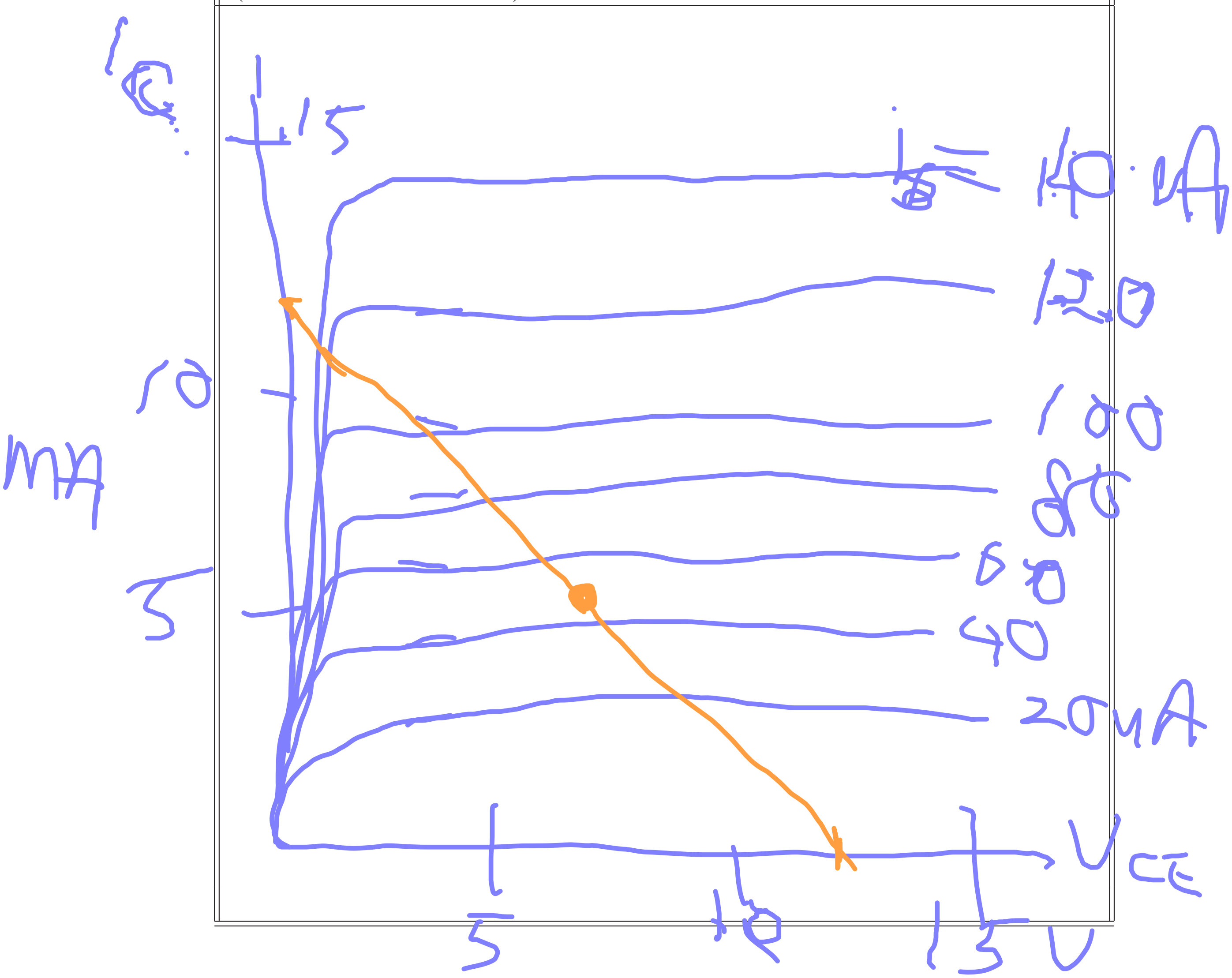
2 BJT Characteristics

A NPN transistor has $\beta = 100$, and $I_s = 10^{-12}$ A. The maximum voltage to be used is 15 V.

2.1 Characteristic Curves

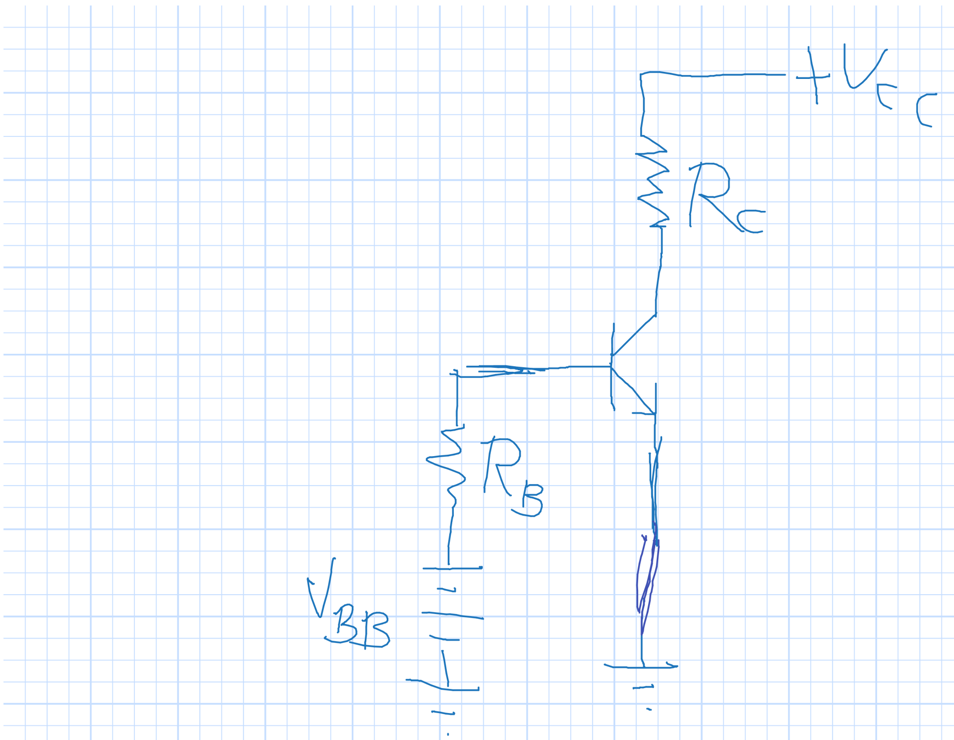
Draw the characteristic curves i_C *vs.* v_{ce}, carefully for $i_B = 0$ to $i_B = 140\ \mu$A in 20 μA increments. Make sure axes are labelled and units are shown.

(Characteristic Curves:)



2.2 Active Mode Circuit Analysis

The transistor is placed in the following circuit, with $R_C = 1\,\text{k}\Omega$, $R_B = 50\,\text{k}\Omega$, $V_{CC} = 12$ V and $V_{BB} = 3$ V.



What is the collector current?

$$i_B = \frac{3 - 0.7\text{ V}}{50\text{k}} = 46\ \text{uA}$$

$$i_C = \beta\, i_B$$

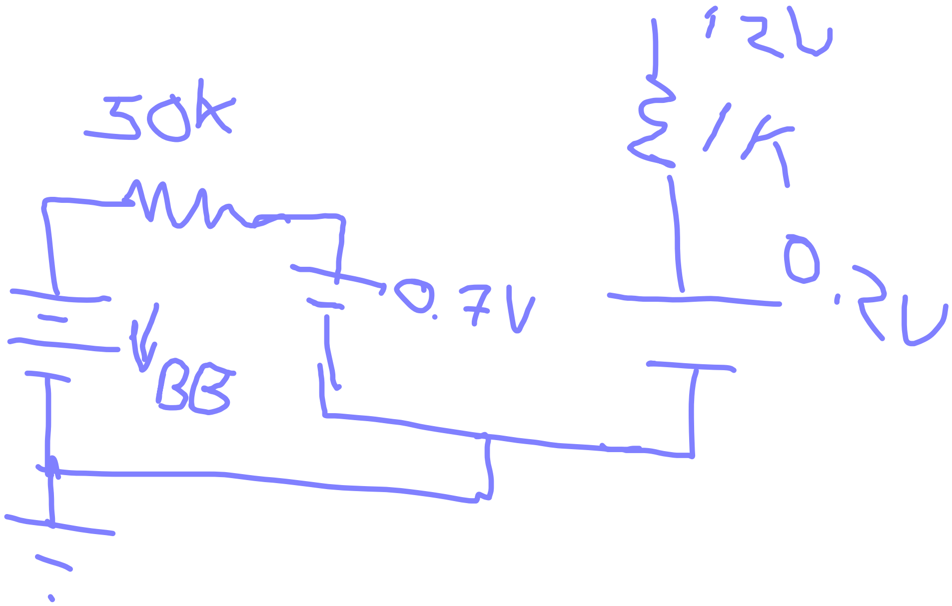
$i_C =$ 4.6 mA

Plot the load line and label the operating point on your graph in Section 2.1.

2.3 Saturation

Re–draw the circuit using the DC model of a transistor in saturation. Determine a new supply voltage for the base, V_{BB} so that the transistor will be "just barely" in saturation. Hint: Calculate the collector current, i_C, in saturation. Then you want βi_B to be approximately that current.

(Circuit with Saturation Model:)



$$i_C = \frac{11.8\,V}{1k} = 11.8\,mA$$

$$i_B = 118\,\mu A$$

$$V_{BB} = i_B R_B = 118\,\mu A \times 50k + 0.7$$

$V_{BB} =$ 6.6 V

2.4 Cutoff

Now change V_{BB} again, this time so that the transistor is just barely in cutoff.

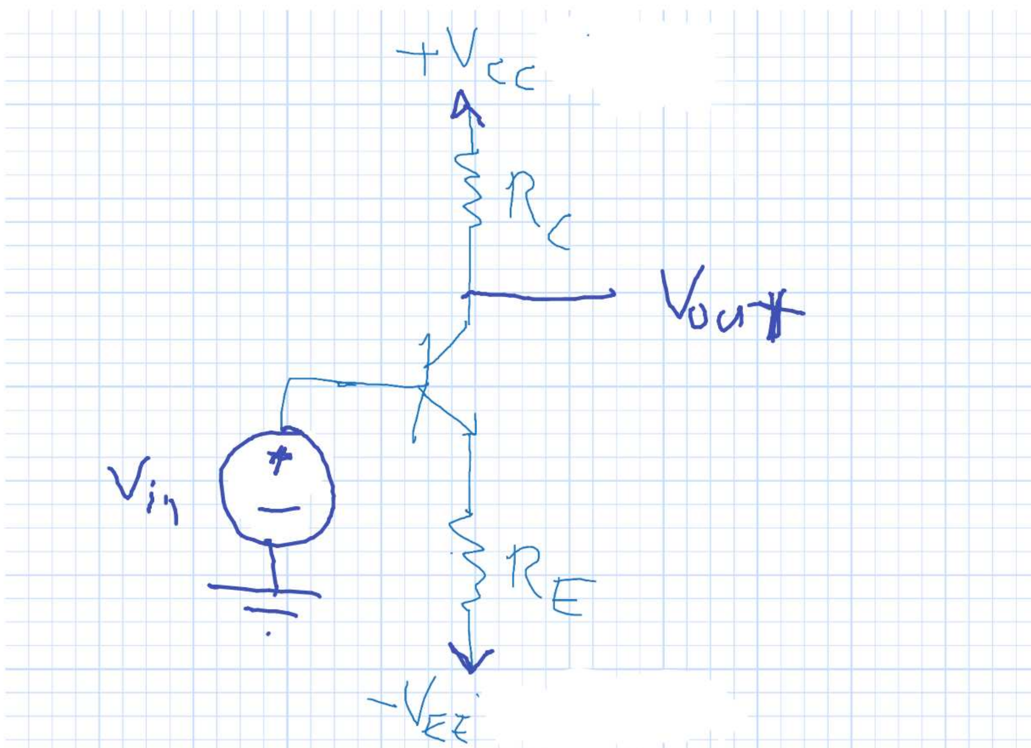
$i_C = 0 \rightarrow i_B = 0$

0.7

$V_{BB} =$ 0.7 V

3 BJT Amplifier

In the following circuit, $V_{CC} = V_{EE} = 20$ V, $R_C = 3.3$ kΩ, $R_E = 6.4$ kΩ, and the transistor has $\beta = 100$.



3.1 DC Analysis

Analyze the curcuit for DC and compute i_C, i_B, V_C, and V_E.

$$V_E = 0 - 0.7\ V$$

$$i_E = \frac{-0.7 - (-20)\ V}{6.4\ K} = 3.01\ mA$$

$$i_C = (\beta/(\beta+1))\ i_E = 2.98\ mA$$

$$i_B = i_E/(\beta+1) = 30\ uA$$

$V_c = 20V - 3mA \times 3.3k$

-0.7

$V_E =$ ______ Volts

$i_C =$ 3.0 mA

$i_B =$ 30×10^{-3} mA

$V_C =$ 10 Volts

3.2 Small–Signal Parameters

What is the value of r_π?

$r_\pi =$ 833 Ω

What is the value of g_m?

$g_m =$ 120 mA/V

$$r_\pi = \frac{100 \times 25\,mV}{3\,mA}$$

3.3 AC Analysis

Draw the AC circuit.

(AC Circuit:)

$i_b = \frac{V_{in}}{r_\pi + (\beta+1)R_E}$

What is the voltage gain in decibels?

$A_v =$ −6 dB dB

$V_{out} = -\beta i_b R_c$

What is the input resistance?

$R_{in} =$ 646 K Ω

What is the output resistance?

$\frac{V_{out}}{V_{in}} = -\frac{\beta R_c}{r_\pi + (\beta+1)R_E} = -0.5$

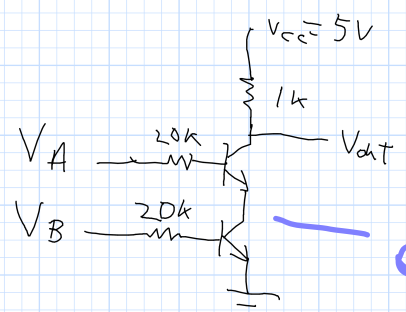
$R_{out} =$ $R_C = 3.3$ K Ω

$R_{in} = r_\pi + (\beta+1)R_E$

4 BJT Logic

4.1 Boolean Logic Gate

Consider the RTL circuit shown here. What is it's function?



— 0.2V

$i_B = \frac{V_A - 0.9V}{20k}$

$i_C = i_B \times \beta$

$V_c = 5V - i_c \times 1k$

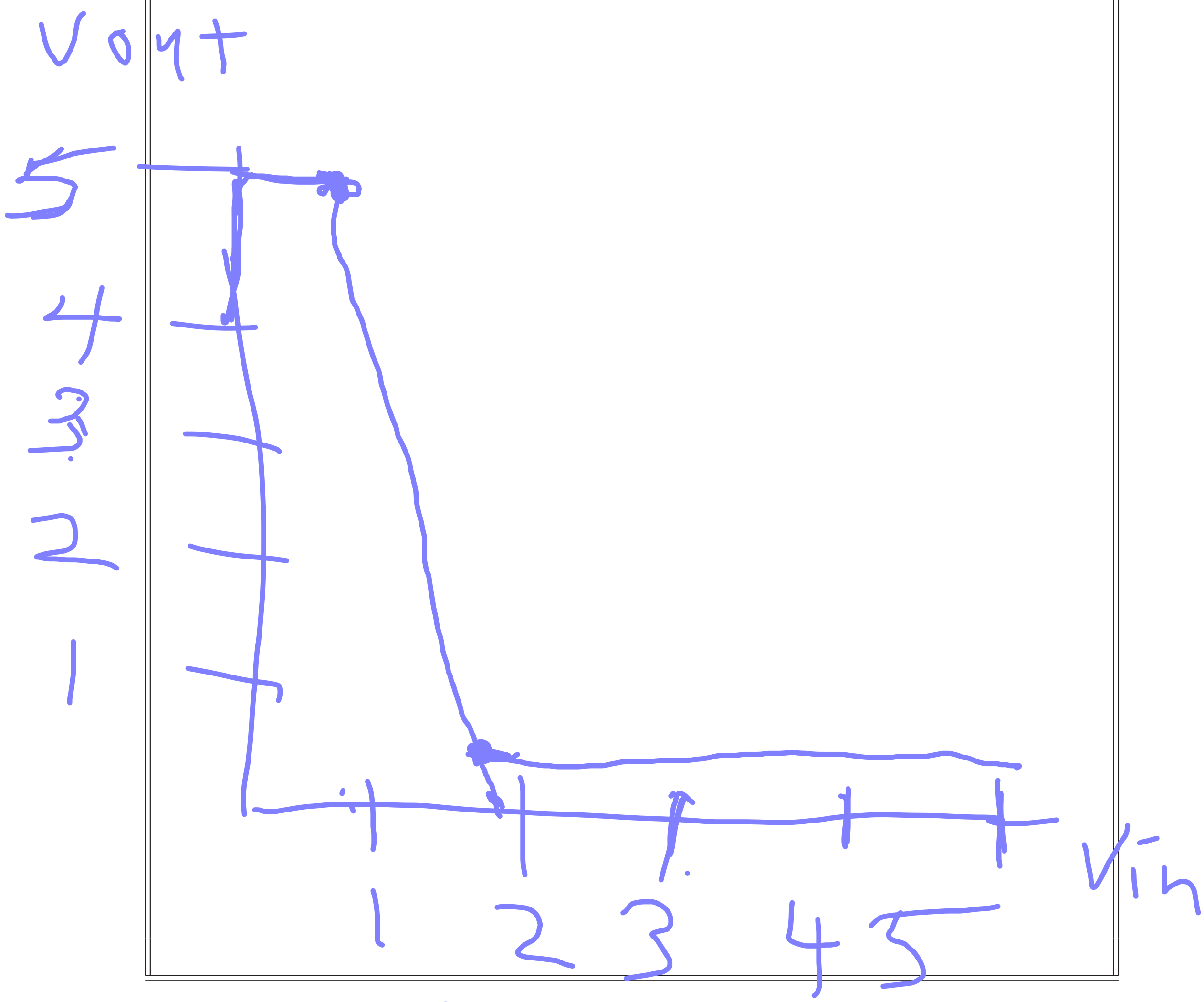
$V_c = 5V - 5V_A + 4.5V$

4.2 Transfer Function

Assume that the input, $V_B = 5$. Plot the transfer function for the V_A input. In other words, plot V_{out} as a function of V_A. Include axis labels and values. Show the low and high input and output limits on the curve and list their values.

$V_c = 0$ at $V_A = \frac{9.5}{5} V = 1.9V$

(Transfer Function:)



V_{LI} = 0.9 V

V_{HI} = 1.9 V

V_{LO} = 0.4 V

V_{HO} = 5.0 V