Electronics
EECE2412 — Spring 2017
Exam #2

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Name: ______________________________ :

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. Sharing of calculators is not allowed.
- 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. 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 (33%)

The majority carriers in a PNP bipolar junction transistor are ...
☐ electrons ☒ holes

What does the emitter of a bipolar junction transistor emit?
☐ electrons ☐ holes ☒ majority carriers

What is the usual goal in designing a common–collector amplifier?
☒ $A_V = 1$ ☐ $A_V = -1$ ☐ $A_i = 1$ ☐ $A_i = -1$
☐ High Power Gain

In the DC circuit analysis of a BJT amplifier, we ...
☐ short the capacitors and the AC voltage sources
☒ open the capacitors and the AC current sources
☐ open the capacitors and the AC voltage sources

A common–emitter amplifier normally has a very high input impedance:
☐ True ☒ False

In active mode, the base–emitter junction is forward biased and the base–collector junction is reverse biased:
☒ True ☐ False

In saturation mode, the base–collector junction is forward biased:
☒ True ☐ False

It is possible to design a common–emitter amplifier with the DC input and output voltages both equal to zero.
☐ True ☒ False

In an amplifier with a PNP transistor, the DC voltage on the collector is more positive than that on the emitter:
☐ True ☒ False

A resistor–transistor logic (RTL) circuit produces a high output when the transistor is in ...
☐ saturation ☐ active mode ☒ cutoff

A resistor–transistor logic (RTL) circuit consumes power ...
☒ when the output is low
☐ when the output is high
☐ only when in transition between states

2 BJT Characteristics and Bias (33%)

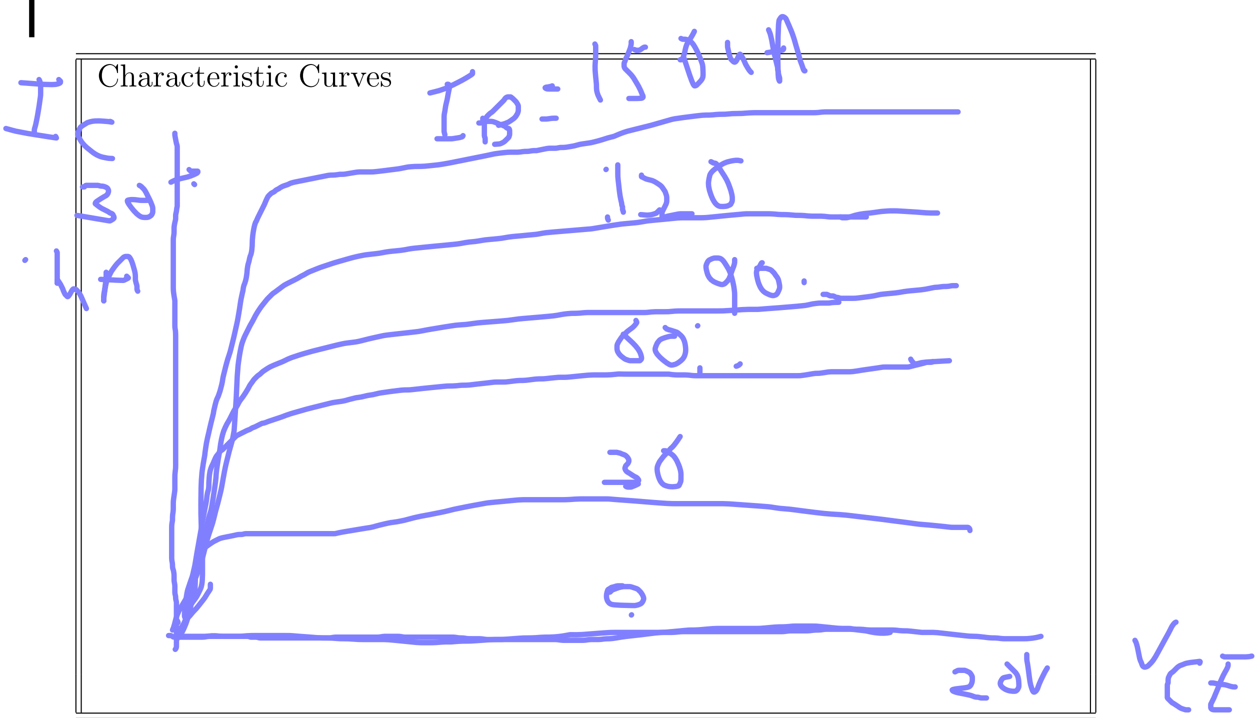
Consider an NPN BJT with $\beta = 200$ and $V_A = 100$ V. The transistor can operate with V_{CE} up to 20 V, and a maximum current of 30 mA.

2.1 Characteristic Curves

Draw the characteristic curves with six different, equally spaced base currents from zero to the value at which the maximum collector current is reached. Label the axes and the different curves.

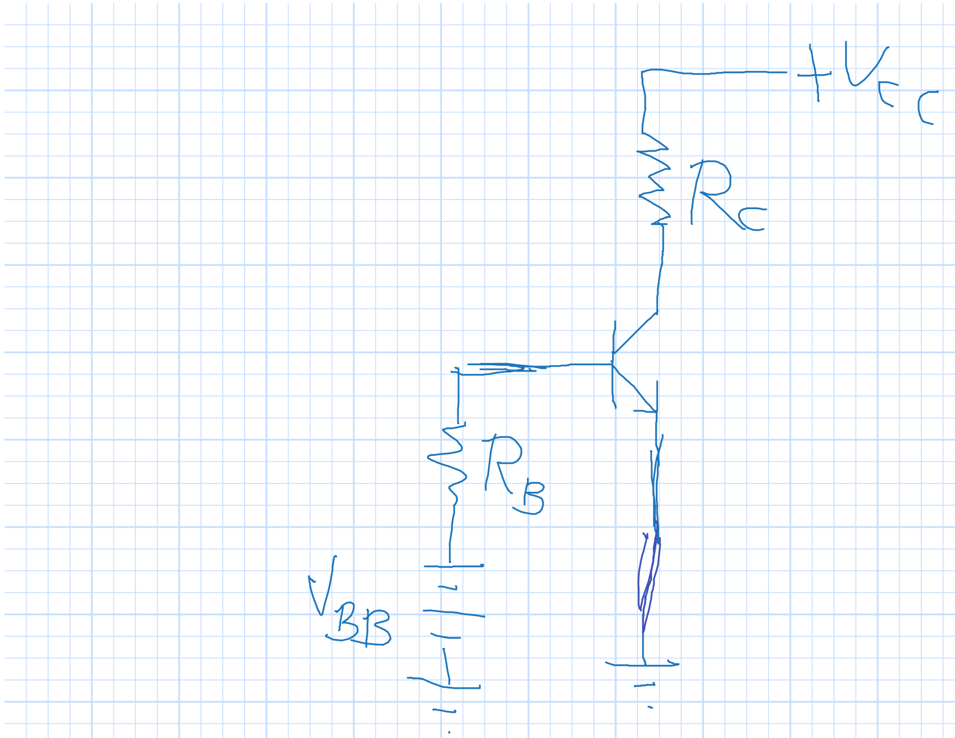
$I_{B\,max} = I_{C\,max} / \beta = \frac{30\text{ mA}}{200} = 150\ \mu A$

Characteristic Curves



2.2 DC Circuit

Now suppose we have a circuit such as the one shown below. The supply voltages are $V_{CC} = 12$ V and $V_{BB} = 3$ V. Design the circuit to bias the transistor so that the operating point is $V_{CE} = V_{CC}/2$ and $I_C = 10$ mA. Specifically, choose R_C and R_B.



$$R_C = \frac{6\text{V}}{10\text{mA}} = 600\ \Omega$$

$$R_B = \frac{3 - 0.7\ \text{V}}{10\text{mA}/200} = 0.23\ \text{k}\Omega \times 200$$

$$= 46\text{k}$$

$R_C =$ 600 Ohms.

$R_B =$ 46k Ohms.

2.3 Small–Signal Parameters

Determine g_m, r_π and r_0 at the above DC operating point.

$$g_m = \frac{I_C}{V_T} = \frac{10\,mA}{25\,mV} = 0.4\,\frac{A}{V}$$

$$r_\pi = \frac{\beta V_T}{I_C} = \frac{200 \times 25\,mV}{10\,mA} = 500\,\Omega$$

$$r_o = \frac{100\,V}{10\,mA} = 10k$$

$g_m =$ 0.4 A/V.

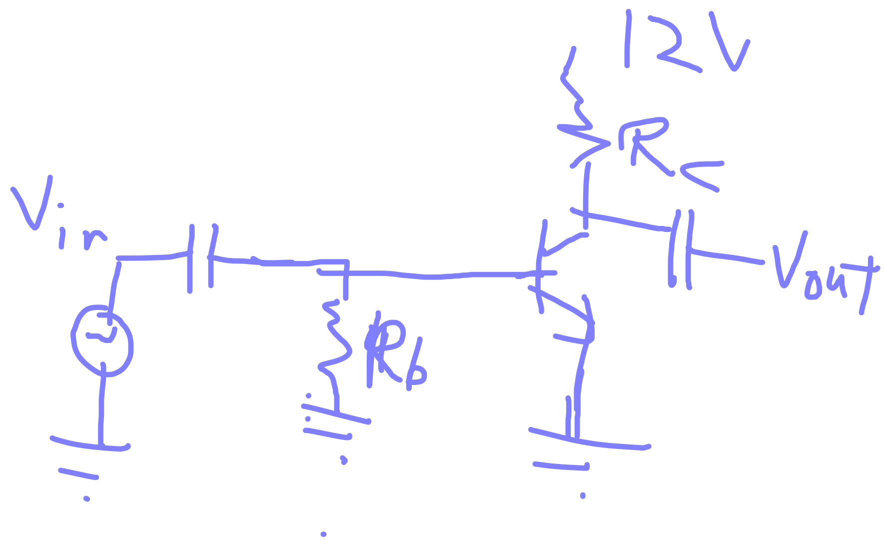
$r_\pi =$ 500 Ohms.

$r_0 =$ 10k Ohms.

2.4 BJT Amplifier Circuit

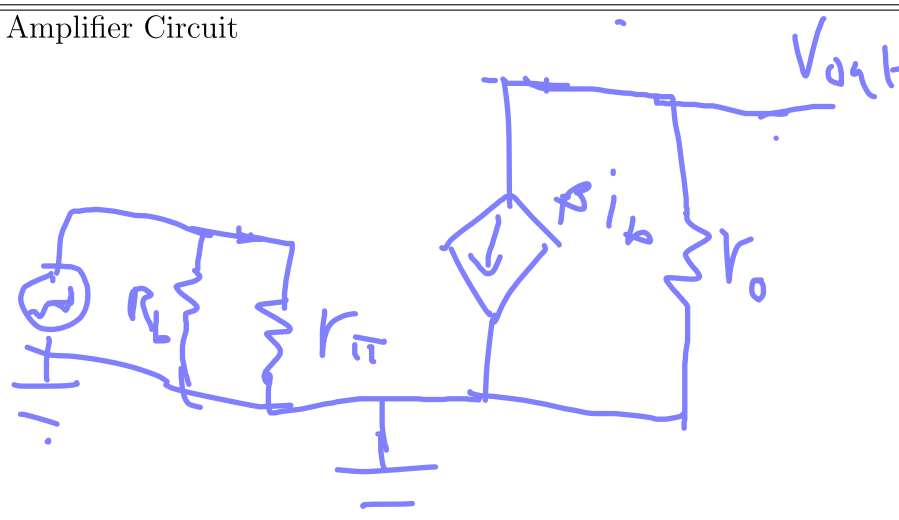
Add a source and load resistor with coupling capacitors to make an amplifier circuit. Draw the actual circuit with the transistor symbol and all components shown.

Actual Amplifier Circuit



Draw the AC circuit with the small–signal model of the transistor.

AC Amplifier Circuit



Compute the open–circuit voltage gain for your circuit.

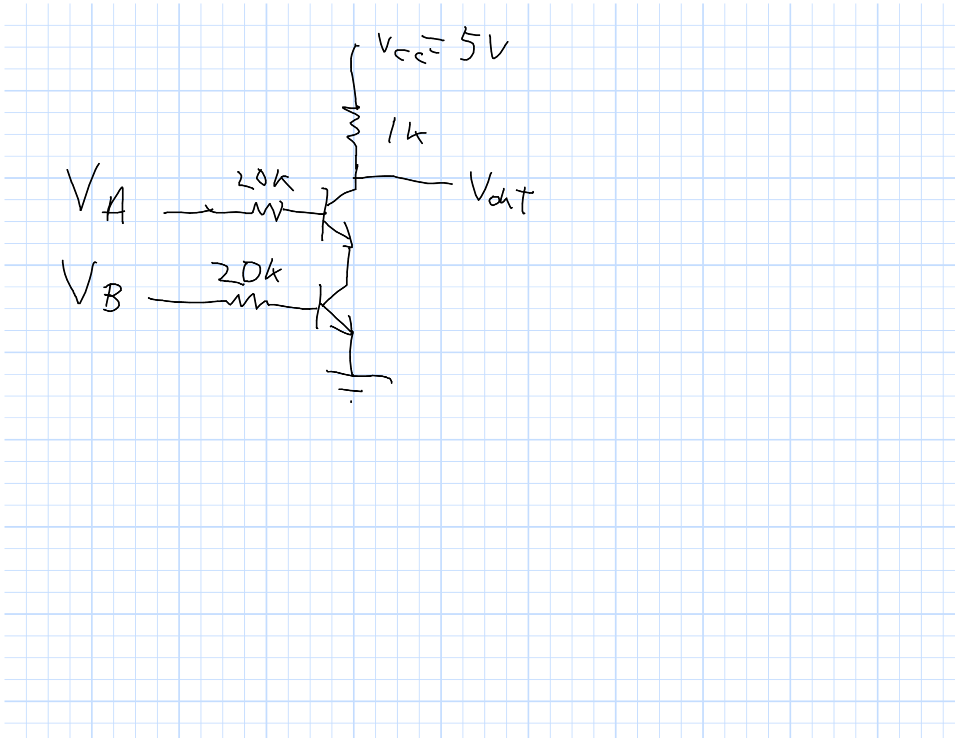
$$A_V = \frac{-200\, R_C}{R_L \| r_\pi} = \frac{-200 \times 600}{500}$$

$$= -240$$

$A_V =$ -240 .

3 BJT Logic (33%)

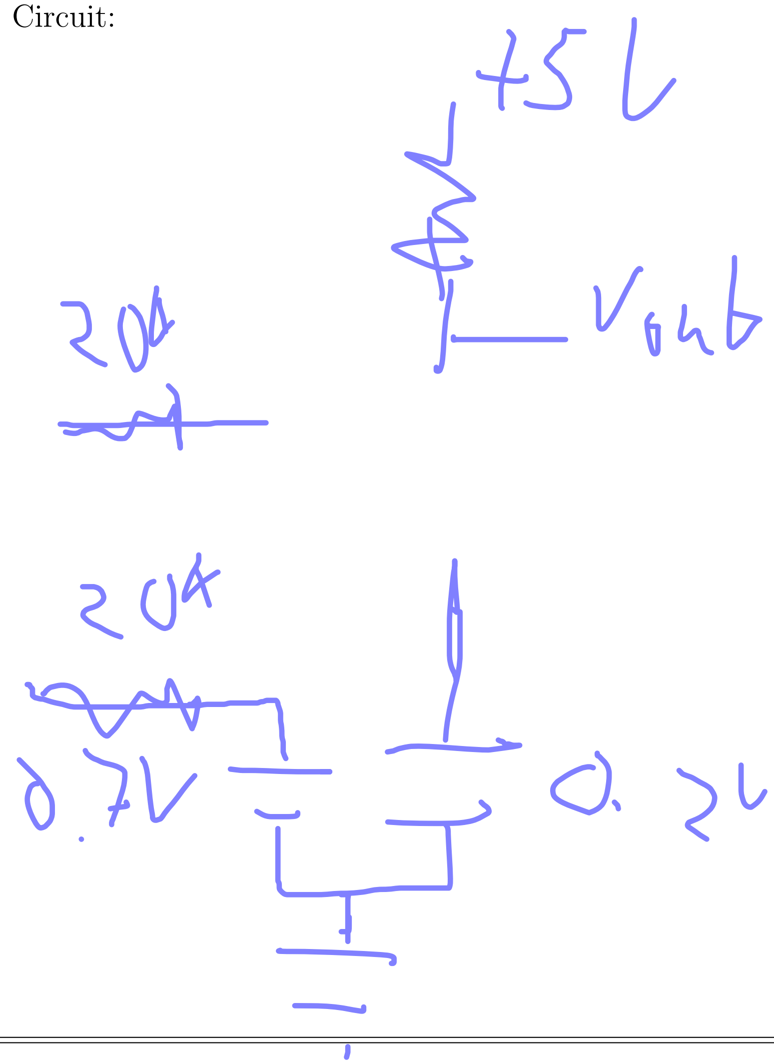
Consider the NAND gate shown in the figure below.



3.1 A False and B True

Assume that input $V_A = 0$ V is “low enough” that the upper transistor is in cutoff and $V_B = 5$ V is “high enough” that the lower transistor is in saturation. Draw the DC circuit using the appropriate DC models for the transistors. Label the voltages and currents.

DC Circuit:



What is the output voltage? What is the ideal output voltage with both inputs true?

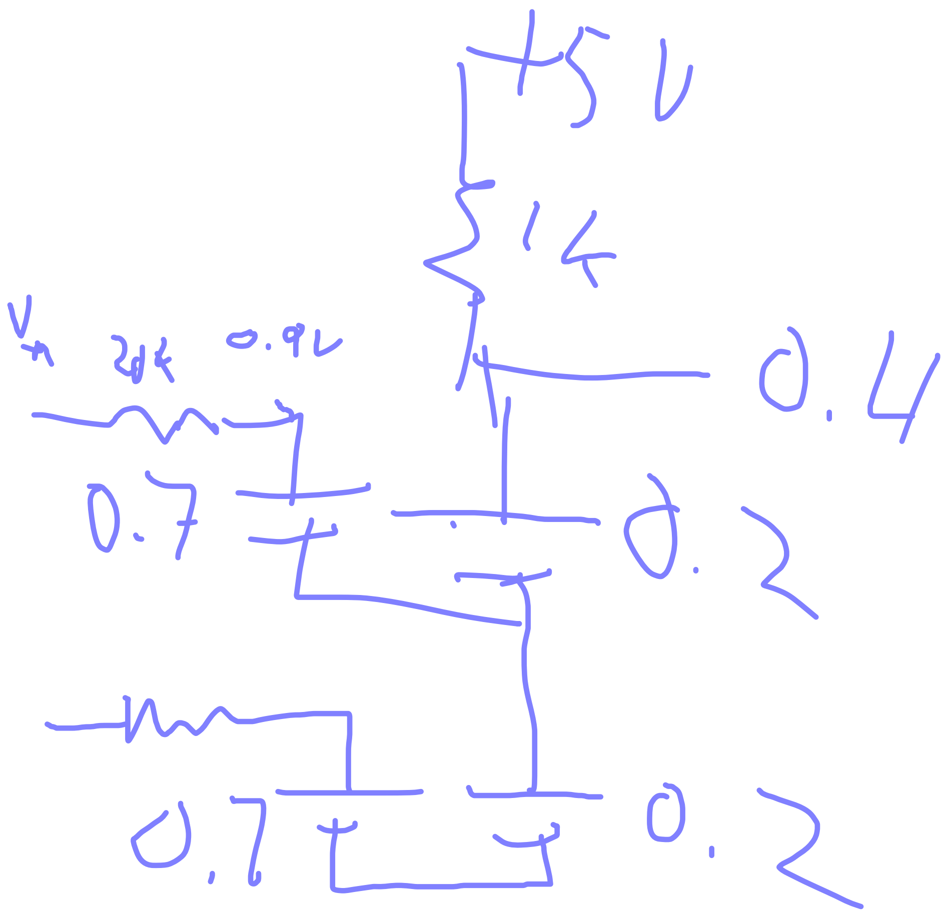
V_{out} = 5V Volts.

Ideal Output 5V Volts.

3.2 A and B True

Repeat for the case that the inputs $V_A = 5$ V and $V_B = 5$ V are both "high enough" that the transistors are in saturation. Draw the DC circuit using the appropriate DC models for the transistors. Label the voltages and currents.

DC Circuit:



What is the output voltage? What is the ideal output voltage with both inputs true?

$V_{out} =$ 0.4 Volts.

Ideal Output 0 Volts.

3.3 High Input Limit

We want both inputs to be true as in Problem 3.2. What is the smallest value of V_A that will produce a base current of 100 μA? We'll assume that this is more than enough to ensure that the transistor is in saturation, and we'll call this limit V_{IH}.

$V_A - 0.9V = 10^{-4}A \times 20000\,\Omega$

$V_A = 2V + 0.9V$

$V_{IH} =$ 2.9V .