ECE 3040 Microelectronic Circuits

Exam 2

Nov ~~September~~ *9, 2015*

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Print your name clearly and largely: Solutions

Instructions:
Read all the problems carefully and thoroughly before you begin working. You are allowed to use 1 new sheet of notes (1 page front and back), your note sheet from the previous exam as well as a calculator. There are 100 total points in this exam. Observe the point value of each problem and allocate your time accordingly. SHOW ALL WORK AND CIRCLE YOUR FINAL ANSWER WITH THE PROPER UNITS INDICATED. Write legibly. If I can not read it, it will be considered to be a wrong answer. Do all work on the paper provided. Turn in all scratch paper, even if it did not lead to an answer. Report any and all ethics violations to the instructor. Good luck!

Sign your name on **ONE** of the two following cases:

I DID NOT observe any ethical violations during this exam:

I observed an ethical violation during this exam:

First 20% **True /False and Multiple Choice - Select the most correct answer(s)**

1.) (2-points) True / False: For a p-n junction in equilibrium, the drift of minority carriers is balanced with the diffusion of majority carriers.

2.) (2-points) True / False: A saturated transistor typically has a very small collector emitter voltage.

3.) (2-points) True / False: Base width modulation is the process of adjusting the base during the manufacture of a BJT.

4.) (2-points) True / False: Base width modulation manifests as a DC current gain, β, which changes with varying collector-emitter voltage.

5.) (2-points) True / False: Common Base amplifiers have the input entering the base and the output leaving the collector.

6.) (2-points) True / False: Junction capacitance is a result of minority carriers injected across the junction.

7.) (2-points) True / False: In the hybrid pi model, the output resistance of a BJT results from the finite, non-zero slope in the collector current vs collector emitter voltage.

8.) (2-points) True / False: A diode used as a peak detector can demodulate an amplitude modulated (AM) signal.

9.) (2-points) Which of the following is not an application of a p-n diode, ...

a. ...Full Wave Rectifier
b. ...Solar Cell
c. ...Light Emitting Diode
d. ...Amplifier
e. ...A DC switch.

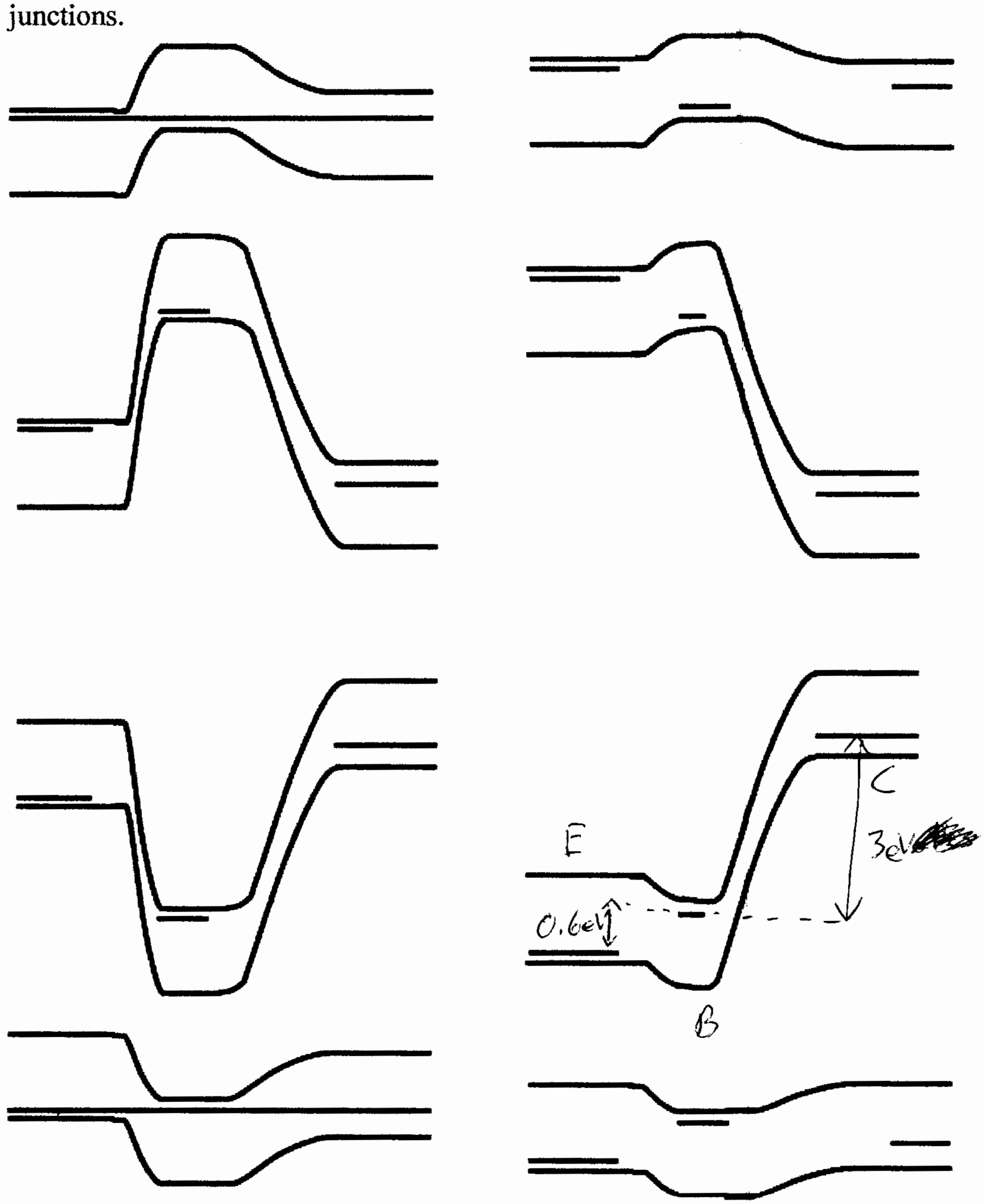
10.) (2-points) When a Zener diode is reverse biased to breakdown...

a. ... the junction is biased at 0.7 volts.
b. ... the dominant current is diffusion current.
c. ... the device could be operating in avalanche or in Zener tunneling mode.
d. ... the voltage across the diode is fairly constant.
e. ... the energy bands are strongly sloped
f. ... the energy bands are almost flat.
g. None of the above.

11.) (20 points)

The following BJT is to be operated in forward active mode. It has a base-emitter voltage of 0.6 volts and a base-collector voltage of 3 volts.

Select the correct energy band diagram below and label the emitter, base and collector as well as well as the (numeric) energy difference in eV for the base-emitter and base-collector junctions.



12) (20 – points) A silicon p-n junction with an intrinsic concentration of 1e10 cm^{-3} has an acceptor doping of 1e16 cm^{-3} and a donor concentration of 1e18 cm^{-3}. It is forward biased to 0.6 volts. Determine the minority carrier concentrations on both sides of the depletion region (at the depletion width edges).

$$\Delta n = \frac{n_i^2}{N_A}\left(e^{qV_A/kT} - 1\right) \qquad \Delta p = \frac{n_i^2}{N_D}\left(e^{qV_A/kT} - 1\right)$$

$\frac{n_i^2}{N_A} = 10^4\ cm^{-3}$, $V_A = 0.6\ v$ $\qquad$ $\frac{n_i^2}{N_D} = 100\ cm^{-3}$

$\Delta n = 1.15 \times 10^{14}\ cm^{-3}$ $\qquad$ $\Delta p = 1.15 \times 10^{12}\ cm^{-3}$

Law of the Junction!

13.)

~~14~~. **Pulling all the concepts together for a useful purpose:**

(40-points total: DC solution = 12 points, conversion to small signal model = 12 points, AC solution = 12 points and 4 points for accuracy of the graph)

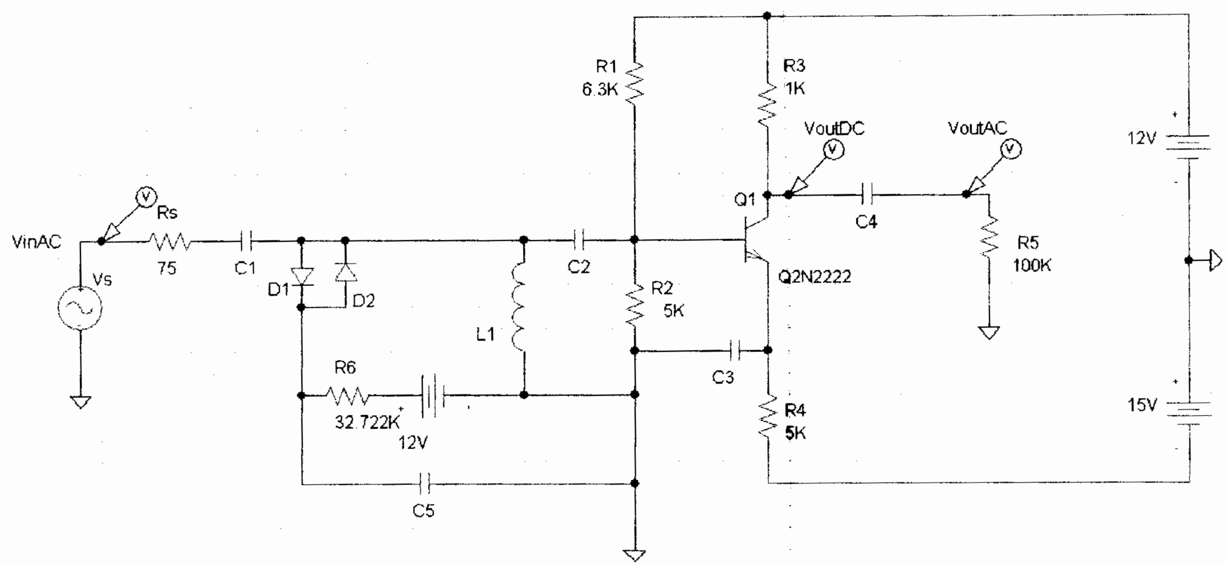
For the circuit below:

Q1: $V_{turn\ on}$=0.7 V, β_{DC}=255.9, V_A=100V

D1 and D2: I_s=I_o=0.6317566 fA (i.e. 6.317566e-16A)

NOTE: There are 3 different DC power supply values, 12V, 12V, and 15V.

VinAC = 1mV amplitude (i.e. 2mV peak to peak) at 1 KiloHertz

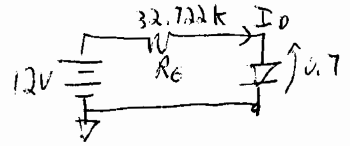


Given the above input voltage, VinAC, sketch and accurately label a plot of the output waveforms VoutAC and VoutDC <u>on the graph paper provided on the next page</u>. Assume the turn on voltages for all forward biased junctions are 0.7 V. You may assume all capacitors and inductors are very large values. Additionally consider the circuit to be operated at low frequencies where you can neglect all small signal capacitances of transistors and diodes. Also, neglect all resistances that result from quasi-neutral regions. Do not ignore the diodes in your solution as they make a big difference in the gain. **For full Credit, <u>CLEARLY SHOW ALL WORK</u> and be sure to check your assumptions on the mode of operation of the transistor and to clearly label the axes of your plot.**

Extra work can be done here, but clearly indicate with problem you are solving.

DC Solution:

Diodes: D2 on D1 off

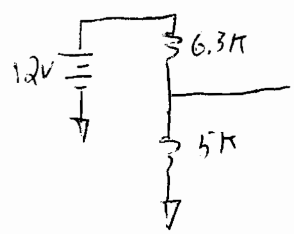


$$I_D = \frac{12 - 0.7}{32.722k} = 3.4533e\text{-}4 \text{ Amps}$$

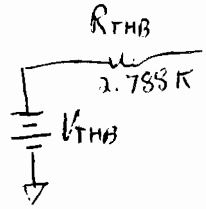
$$g_d = \frac{I_D - I_0}{V_T} = 0.01\overline{3}$$

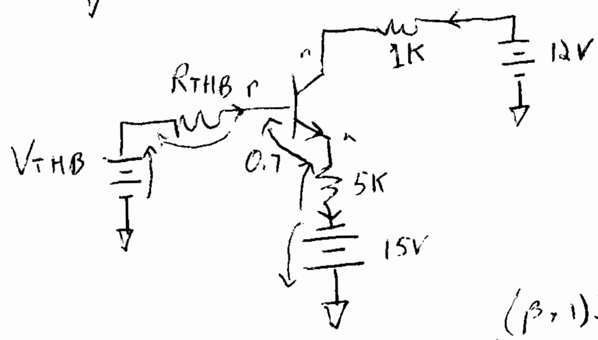
$$r_d = \frac{1}{g_d} = 75\Omega$$

Transistor: Base Thev



=> 5.309V





$(\beta+1)I_B$

$$V_{THB} - I_B R_{THB} - 0.7 - I_E(5K) + 15V = 0$$

$$I_B = \frac{(5.309 + 15 - 0.7)}{2.788K + (1 + 255.9)(5K)}$$

$$I_B = 15.232 \ \mu A$$

$$I_C = \beta I_B = 3.898 \text{ mA}$$

$$I_E = (\beta+1)I_B = 3.913 \text{ mA}$$

Check Assumptions:

$V_C = 12 - I_C(1K) = 8.102V$ $\quad V_C > V_B$ ✓

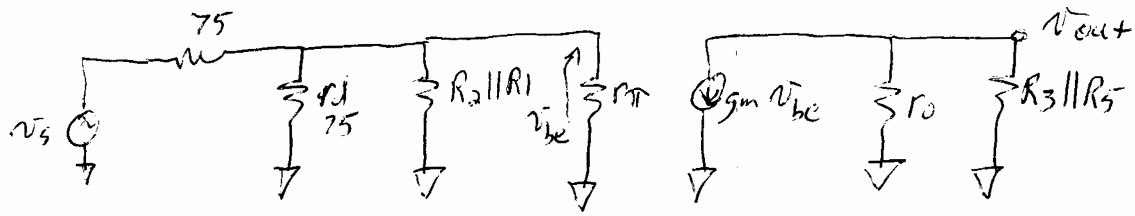
$V_B = V_{THB} - I_B(2.788K) = 5.266V$ ✓ } 0.7 $\quad V_B > V_E$ ✓

$V_E = -15 + I_E(5K) = 4.565V$ ✓

$\beta = g_m r_\pi$

Extra work can be done here, but clearly indicate with problem you are solving.

AC Solution



$r_\pi = 1700\,\Omega$ $\quad g_m = \frac{I_c}{V_T} = 0.15\ \mho$ $\quad r_o = \frac{|V_A| + |V_{CE}|}{I_c} = \frac{103{,}537}{3.898\,mA} = 26.56\,k\Omega$

(2) $$\frac{v_{be}}{v_s} = \frac{rd \| R_2 \| R_1 \| r_\pi}{75 + rd \| R_2 \| R_1 \| r_\pi} = 0.483$$

(1) $$\frac{v_{out}}{v_{be}} = -g_m (r_o \| R_3 \| R_5) = -143.65$$

$$\boxed{\frac{v_{out}}{v_s} = (1) \times (2) = -69.36\ V/V}$$

Answer Page

Plot VoutDC