DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
ROY G. PERRY COLLEGE OF ENGINEERING
PRAIRIE VIEW A&M UNIVERSITY
MICROELECTRONICS – SPRING 2021
PRELIMINARY EXAMINATION
THURSDAY, JANUARY 14, 2021

READ THIS CAREFULLY AND SIGN BELOW

I declare truthfully that the work I am presenting here is my own, and that I have not conducted myself in any manner unethical. I have not copied from anyone nor have I let anyone copy from me. I am aware of the ethical requirements of my profession and I firmly believe in practicing and implementing them.

Name:

____

Signature:

____

Note: This examination will be conducted in two parts:

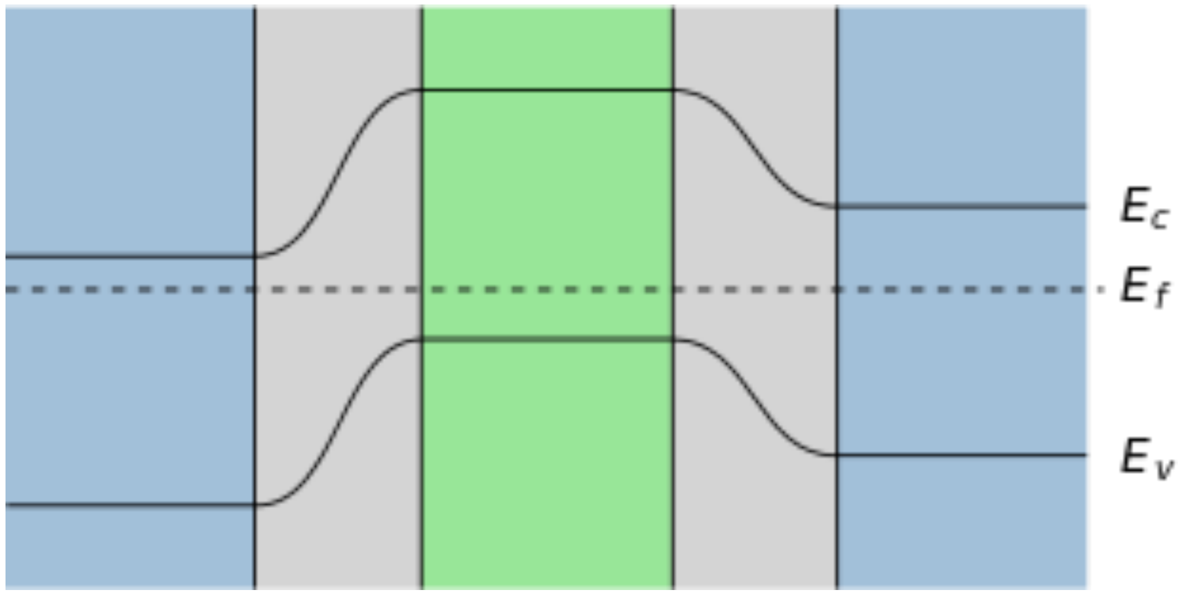
1. Online synchronous – you can work out the questions at your own location and send your workout by e-mail to Dr. Rick Wilkins: rtwilkins@pvamu.edu.
2. Video Chat: On Wednesday, January 20, 2021, you will be asked to participate in a Zoom session with a professor. You will be asked to explain how you solved the problems on the examination. This session may last upto thirty minutes.

Your grade on the examination will be determined based on these two parts.

All the best.

PROBLEM 1 (5 POINTS)

Examine carefully the schematic of the energy band picture of a bipolar junction transistor (p-n-p or n-p-n), which can be seen as two p-n junctions put together back-to-back. Label each part approrpriately (p or n). Show the depletion region, the depletion width and the built in potential. Is each part equally doped? If not, show which part is more doped than the other.



PROBLEM 2 (15 POINTS)

Find the equilibrium electron and hole concentrations, and the location of the Fermi level for germanium at 300K if the germanium contains the following concentrations of shallow dopant atoms:

(a) 5×10^{16} cm^{-3} phosphorus atoms.

(b) 10^{18} cm^{-3} boron atoms and 5×10^{17} cm^{-3} phosphorus atoms.

(c) Calculate the resistivity for these two samples.

PROBLEM 3 (5 POINTS)

Consider a circuit with a Si p-n diode in series with a resistance of 1 KΩ. A forward potential of 10V is applied. I argue that the current through the diode should be, by Ohm's Law,

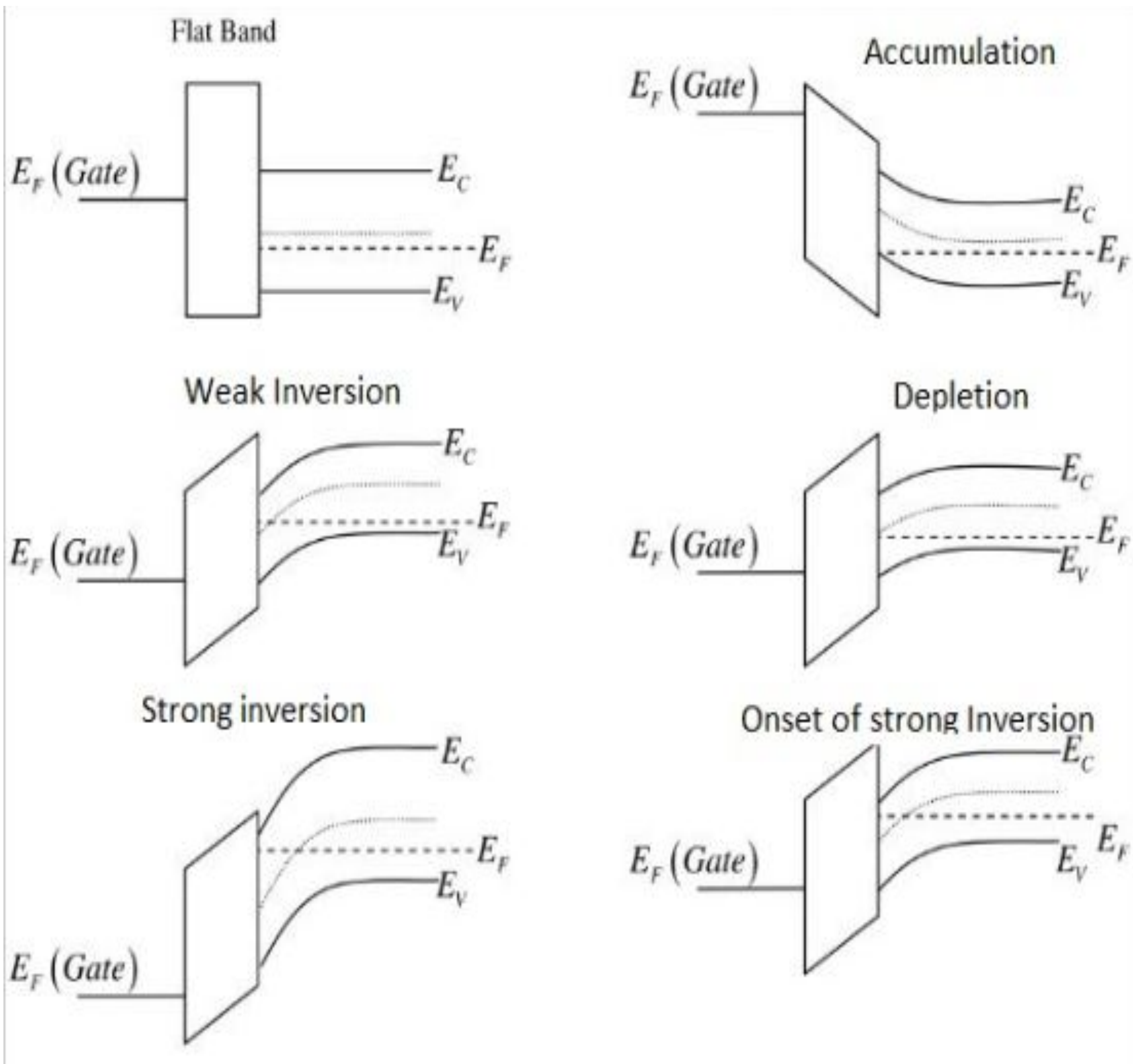
$$I_D = \frac{10\ V}{1\ K\Omega} = 10\ mA.$$

My colleague claims that the correct answer should be 9.3 mA. Who do you agree with? Justify your response.

PROBLEM 4 (10 POINTS)

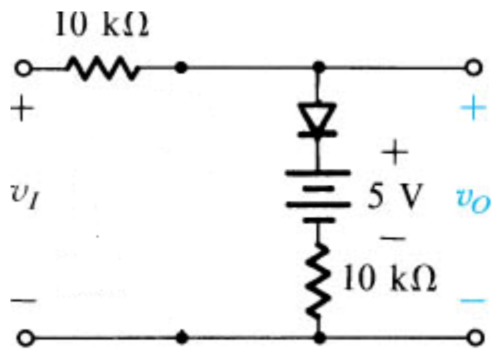
Silicon atoms, at a concentration of 10^{10} cm^{-3}, are added to gallium arsenide. Assume that the silicon atoms act as fully ionized dopant atoms and that 5 percent of the concentration added replace gallium atoms and 95 percent replace arsenic atoms. Let T = 300 K. Determine the donor and acceptor concentrations.

PROBLEM 5 (15 points)
Examine the MOS-Capacitor band diagram below, under various biasing conditions. Label the M, O, S parts on the diagrams. Is the semiconductor p-type or n-type? Explain. Show the types of charge carrier – electrons and holes – in each biasing mode in the bulk and at the interface.



Problem 6. (10 points) Assuming that the voltage across a forward-biased conducting diode is 0.7 volts, and

(a) If $V_I = 10.0$ V, find v_0

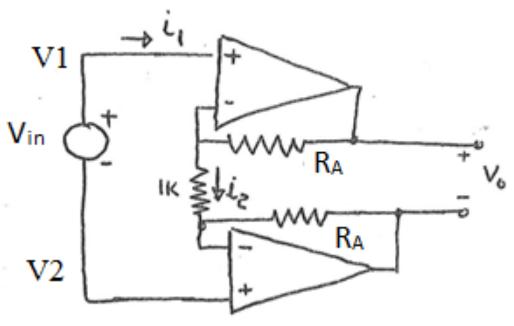


$v_0 =$ ____________

(b) If $V_I =$ -8.0 V, find v_0

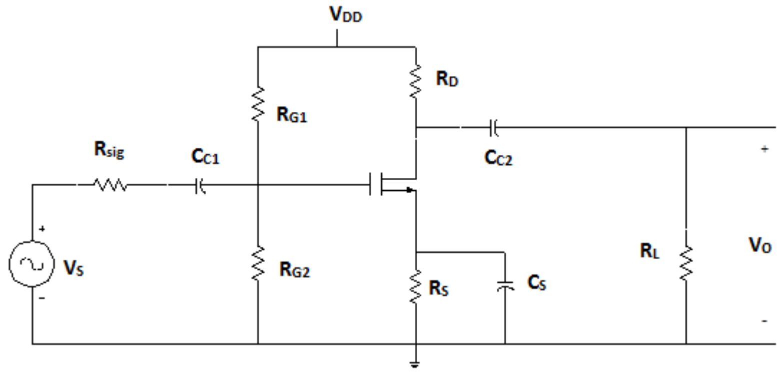
$v_0 =$ ____________

Problem 7. (15 points) Assuming that the op amp is ideal, V_{in} = 1.0 mV, and R_A = 10 KΩ, find i_1, i_2, and V_o. (Hint: Vin = V1 – V2)



i_1 = _______________ i_2 = _______________ V_0 = ________________

Problem 8. (25 points) For the common-source amplifier shown below, g_m = 50 mA/V, r_{ds} = 50 KΩ, R_{sig} = 0.1 MΩ, R_{G1} = 10 MΩ, R_{G2} = 10 MΩ , R_S = 500 Ω , R_D = 8 KΩ, and output resistor R_L = 8 KΩ. Assume that the coupling and bypass capacitors are very, very large.



(a) Draw the small signal equivalent circuit

(b) Determine the voltage gain, $\frac{V_0}{V_S}$ at midband frequencies.

$\frac{V_0}{V_S}$ = ____________________

APPENDIX A
BANDGAP MOBILITY TABLE

Semiconductor	Bandgap (eV) 300 K	Bandgap (eV) 0 K	Mobility at 300 K (cm^2/V-s) Elec.	Mobility at 300 K (cm^2/V-s) Holes
C	5.47	5.48	1800	1200
GaN	3.4	3.5	1400	350
Ge	0.66	0.74	3900	1900
Si	1.12	1.17	1500	450
α-SiC	3.00	3.30	400	50
GaSb	0.72	0.81	5000	850
GaAs	1.42	1.52	8500	400
GaP	2.26	2.34	110	75
InSb	0.17	0.23	80000	1250
InAs	0.36	0.42	33000	460
InP	1.35	1.42	4600	150
CdTe	1.48	1.61	1050	100
PbTe	0.31	0.19	6000	4000
$In_{0.53}Ga_{0.47}As$	0.8	0.88	11000	400

Intrinsic Carrier Concentrations

	Germanium	Silicon	Gallium Arsenide
300 K	2.02×10^{13}	8.72×10^{9}	2.03×10^{6}
400 K	1.38×10^{15}	4.52×10^{12}	5.98×10^{9}
500 K	1.91×10^{16}	2.16×10^{14}	7.98×10^{11}
600 K	1.18×10^{17}	3.07×10^{15}	2.22×10^{13}

APPENDIX B – USEFUL INFORMATION

$h = 6.63 \times 10^{-34}$ J.s.	$q = 1.602 \times 10^{-19}$ C
$c = 3 \times 10^{8}$ m/s	$k_B = 1.38 \times 10^{-23}$ J/K
$m_n = m_p = 9.1 \times 10^{-31}$ kg	$np = n_i^2$
$n = n_i e^{(E_f - E_i)/kT}$ $p = n_i e^{(E_i - E_f)/kT}$	$n_i = \sqrt{N_c N_v} e^{-\frac{E_g}{2k_B T}}$
$N_V = 2\left(\frac{m_p k_B T}{2\pi \hbar^2}\right)^{3/2}$	$n = \frac{N_D - N_A}{2} + \left[\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2\right]^{1/2}$ $p = \frac{N_A - N_D}{2} + \left[\left(\frac{N_A - N_D}{2}\right)^2 + n_i^2\right]^{1/2}$ $= \frac{n_i^2}{n}$
$n = N_C e^{(\varepsilon_F - \varepsilon_c)/k_B T}$	$E = hf = \frac{hc}{\lambda}$
$D = \frac{k_B T}{q} \mu$	

Property	Si	GaAs	Ge
Bandgap Energy	1.12	1.42	0.66
Dielectric Constant	11.7	13.1	16.0
Effective density of states in conduction band N_c (cm^{-3})	2.8×10^{19}	4.7×10^{17}	1.04×10^{19}
Effective density of states in valence band N_v (cm^{-3})	1.04×10^{19}	7.0×10^{18}	6.0×10^{18}
Intrinsic carrier concertration n_i (cm^{-3})	1.5×10^{10}	1.8×10^{6}	2.4×10^{13}
Mobility Electron Hole	 1350 480	 8500 400	 3900 1900