Key

Name:

Exam #1 **ELEC 2210** **Fri 10/2/20**

I verify below by my signature that I received no assistance on this exam from another person:

Signature:

Problem 1: (15 points)

A pn junction diode is used in a circuit where i_D is 10 mA. If the circuit is operated at room temperature (20°C) and diode parameters are: Is = 0.1 fA and n = 1, what is the voltage across the diode, v_D?

$$i_D = I_s\left(e^{v_D/V_T} - 1\right)$$

$$\frac{i_D}{I_s} + 1 = e^{v_D/V_T}$$

$$v_D = V_T \ln\left(\frac{i_D}{I_s} + 1\right) = 0.025 \ln\left[\frac{10\times10^{-3}}{0.1\times10^{-15}} + 1\right]$$

$$= 0.806\,V$$

Problem 2: (10 points)
Write the diode type below each symbol and label the terminals:

anode

cathode

pn junction

anode

cathode

varactor

anode

cathode

zener

Match the question with an answer by writing the letter of the answer in the blank next to the question. No answer is used more than once. (30 points)
Questions

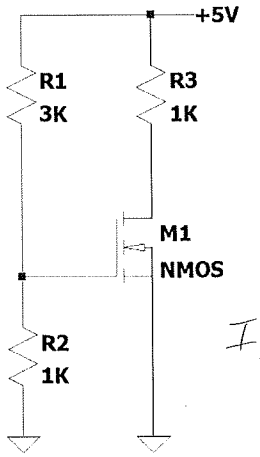
1) This is a common acceptor impurity for Si: I
2) What type of chemical bond does Si make with other Si atoms: C
3) N_D refers to: L
4) This is a reverse breakdown mechanism: J
5) How many possible operation states are there for a circuit with 3 diodes? B
6) This signal type has only 2 discrete levels: A
7) This is a unit of energy: H
8) Another name for the depletion layer: M
9) An acceptor impurity makes Si: G
10) A circuit for converting ac to pulsating dc: K
11) This is a common donor impurity for Si: P
12) This is a solid form of Si: D
13) This term relates electric field to carrier velocity: R
14) Another word for "pure": N
15) A type of diode that is made with a n-type Si to metal contact: O

Answers to choose from

A. Binary digital
B. Eight
C. Covalent
D. Amorphous
E. Twelve
F. N-type
G. P-type
H. Electron Volt
I. Boron
J. Avalanche
K. Rectifier
L. Donor impurity concentration
M. Space charge region
N. Intrinsic
O. Schottky barrier
P. Phosphorous
Q. Bandgap
R. Mobility

Problem 3: (15 points)

For the circuit below, find the operating mode, I_D, V_{GS}, and V_D, for $K_n' = 1\text{x}10^{-3}$ A/V^2, (W/L) = 10, $V_{TN} = 1$ V, and $\lambda = 0$ V^{-1}.



$$V_G = \frac{5R_2}{R_1+R_3} = \frac{5(1)}{(1+3)} = 1.25V$$

Assume Saturation mode

$$I_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(V_{GS}-V_{TN})^2$$

$$= \frac{1}{2}(1\times10^{-3})(10)(1.25-1)^2$$

$$= 312.5\,\mu A$$

$$V_D = 5 - I_D R_3 = 5 - (312.5\times10^{-6})(1000) = 4.69V$$

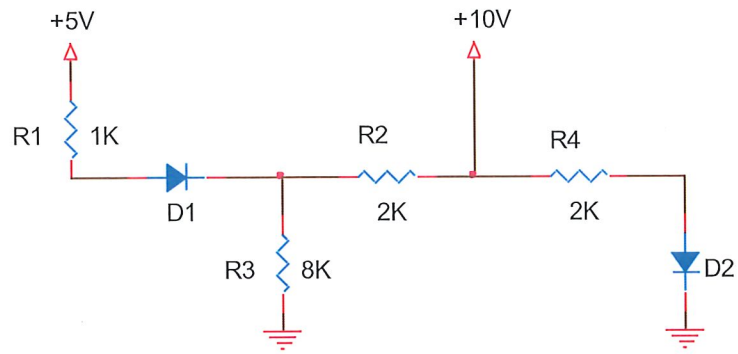
$$V_{DS} = V_D = 4.69V$$

$V_{DS} > V_{GS} - V_{TN}$: in Saturation mode

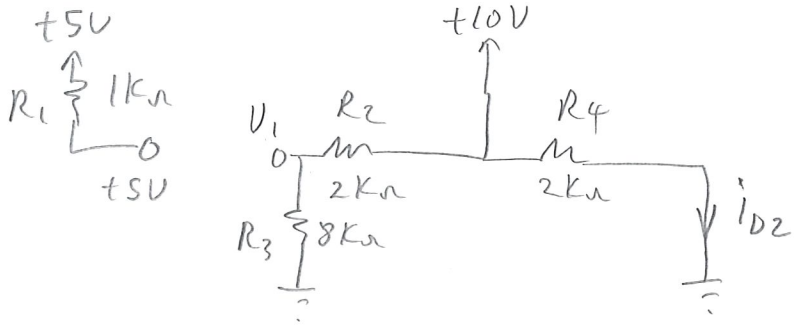
Q-point: $I_D = 312.5\,\mu A$, $V_{GS} = 1.25V$, $V_{DS} = 4.69V$

Problem 4: (15 points)

What are the Q-points for the two diodes in the circuit below, using the <u>ideal</u> diode model?



Assume D_1 off and D_2 on



$$V_1 = \frac{10(8)}{8+2} = 8V$$

$V_{D1} = 5 - 8 = -3V \rightarrow \therefore D_1$ is off

$$i_{D2} = \frac{10}{2K} = 5mA \quad \therefore D_2 \text{ is on}$$

Q-point: $D_1 : (0A, -3V) \rightarrow$ off

$D_2 : (5mA, 0V) \rightarrow$ on

Problem 5: (15 points)

What is f_T for an NMOS transistor with L = 10 μm, μ_N = 1100 cm²/Vs, V_{GS} = 4 V, and V_{TN} = 1 V?

$$L = 10\,\mu m = 10\times10^{-6}\,m = 10\times10^{-4}\,cm$$

$$f_T = \left(\frac{1}{2\pi}\right)\left(\frac{\mu_n}{L^2}\right)(V_{GS} - V_{TN})$$

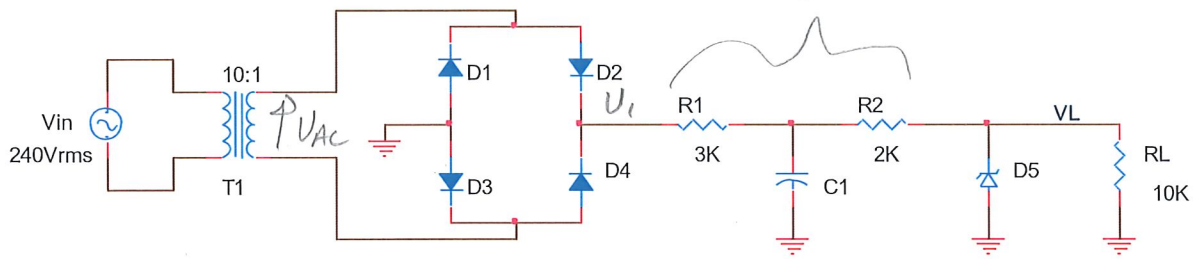
$$= \left(\frac{1}{2\pi}\right)\left(\frac{1100}{(10\times10^{-4})^2}\right)(4-1)$$

$$= 525.2\ MHz$$

Bonus Problem (10 points)

What is the load voltage, V_L, for the circuit below, assuming that the filter only passes the dc voltage component? For D1, D2, D3 and D4, Von = 0.6 V. For D5, Vz = 7 V and Rz = 100 Ω. The input voltage is 240 Vrms ac.

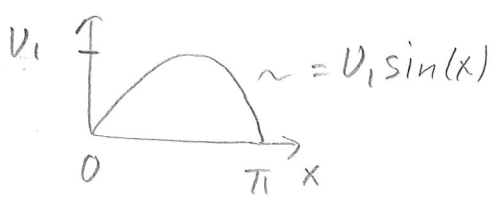
"R_3" = $R_1 + R_2$ = 5 KΩ



$V_p = \sqrt{2}(240) = 339.41V$

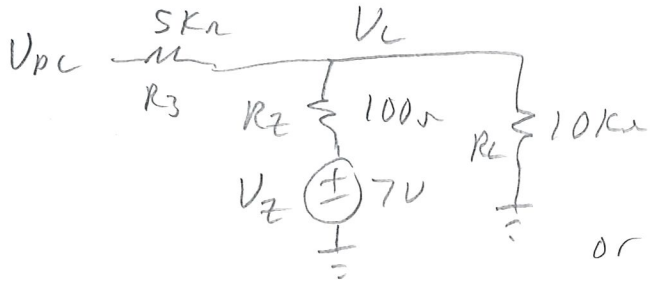
$V_{AC} = \frac{V_p}{10} = 33.941V$

$V_1 = V_{AC} - 2(V_{on}) = 33.941 - 2(0.6) = 32.741V$



$V_{av} = V_{DC} = \frac{1}{\pi}\int_0^{\pi} V_1 \sin(x)\,dx = \frac{V_1}{\pi}\left[-\cos(x)\right]_0^{\pi} = \frac{-V_1}{\pi}[-1-1] = \frac{2}{\pi}V_1$

$\therefore V_{DC} = \frac{2(32.741)}{\pi} = 20.84V$



$\frac{V_L - V_{DC}}{R_3} + \frac{V_L - V_Z}{R_Z} + \frac{V_L}{R_L} = 0$

or $V_L = \frac{\frac{V_{DC}}{R_3} + \frac{V_Z}{R_Z}}{\frac{1}{R_3} + \frac{1}{R_Z} + \frac{1}{R_L}}$

$= \frac{\frac{20.84}{5000} + \frac{7}{100}}{\frac{1}{5000} + \frac{1}{100} + \frac{1}{10{,}000}}$

$= 7.20V$

Blank sheet for Calculations