American University of Beirut

Department of Electrical and Computer Engineering

EECE 310 – Electronics
Midterm – November 16, 2012
Closed Book – No Programmable Calculators

120 minutes

There are 24 problems and 7 pages. All problems are equally graded.

Penalty is 5 to 1
(1 to 4 wrong answers do not result in a penalty; 5 to 9 wrong answers cancel one correct answer; 10 to 14 wrong answers cancel two correct answers; and so on)

Name: ________________________________ **ID number:** ________________

Unless otherwise specified, assume that:

$V_T = 25$ mV $n = 1$ $n_i = 1.5\times10^{10}$ cm^{-3} $q = 1.6\times10^{-19}$ C

$$J_p = -qD_p \frac{dp}{dx} \qquad J_n = qD_n \frac{dn}{dx}$$

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = V_T \qquad V_O = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$J_d = \left(qp\mu_p + qn\mu_n\right)E$$

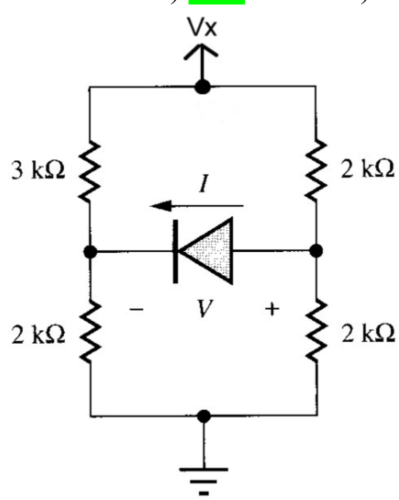
$$I = J \times A$$

1. A diode has a reverse saturation current $I_s = 10^{-12}$ A and $n = 1.2$. What is the diode forward voltage drop (in mV) at a current of 4 mA?

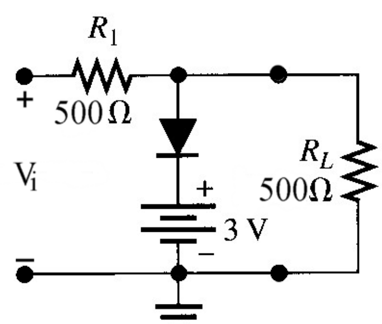
a) 717.0 b) 704.9 c) 663.3 d) 684.1 e) 696.2

2. The diode in the circuit shown below is ideal. Find the forward current in the diode (in mA) if Vx = 5.5 V.

a) 0.3 b) 0.35 c) 0.2 d) 0.25 e) 0.15



In the circuit shown below, the pure sine-wave input V_i has a peak value of 14 V. The diode is modeled by a fixed 0.8 V drop when conducting, and by an open circuit when OFF. Refer to this circuit for questions 3 and 4.



3. Find the peak inverse voltage (PIV) of the diode (in V).

a) 12 b) 8 c) 9 d) 10 e) 11

4. Find the peak value of the diode current (in mA).

a) 4.8 b) 8.8 c) 12.8 d) 16.8 e) 20.8

5. The average (DC) value of the output voltage of a *half-wave* rectifier is 6 V. If the diode is ideal and the load is purely resistive, find the RMS value of the sinusoidal AC supply voltage (in V rms) at the transformer secondary.

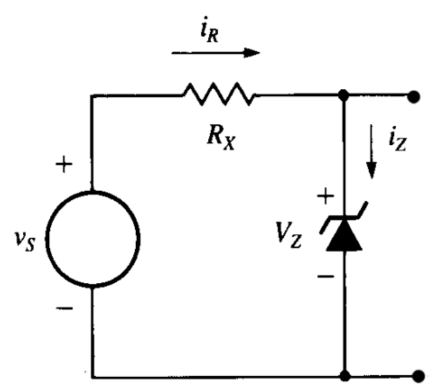
a) 31.1 b) 13.3 c) 17.8 d) 26.6 e) 22.2

6. A *full-wave* bridge rectifier with a filter capacitor is fed with a sinusoidal voltage source $v_I = V_p \times \sin(2\pi f t)$ V. The diode is ideal, the frequency $f = 50$ Hz, the capacitance $C = 100\ \mu$F, and the load resistance $R = 50$ kΩ. Find $(V_r / V_p) \times 100$, where V_r is the output ripple voltage.

a) 0.4 b) 0.5 c) 1 d) 0.2 e) 0.25

7. The Zener diode shown below has $V_Z = 15.1$ V at $I_Z = 5$ mA, with $r_Z = 20\ \Omega$ and $I_{ZK} = 0.5$ mA. Assume that $R_X = 980\ \Omega$ and the supply voltage $v_S = 20$ V. What is the power dissipation in the Zener diode (in mW)?

a) 83.9 b) 94.5 c) 108.2 d) 75.5 e) 126.4



8. The total voltage across a diode is $v_D = 800 + 4 \times \sin(\omega t)$ mV when the total current is $i_D = I_D + i_{dm} \times \sin(\omega t)$ mA. The diode has $n = 1.4$ and negligible reverse saturation current. If the diode incremental small-signal resistance $r_d = 50\ \Omega$, find maximum value of the total current i_D (in mA).

a) 1.08 b) 0.88 c) 0.98 d) 0.68 e) 0.78

The drain current of an enhancement N-channel MOSFET is measured at several values of V_{GS} and V_{DS}, as shown in the table below. Refer to this table to answer questions 9 to 12.

V_{GS} (V)	V_{DS} (V)	I_D (mA)
2	3	0.393
2	5	0.454
3	3	1.433
3	0.1	I_X

9. Find the Early Voltage $V_A = 1/\lambda$ (in V).

a) 8 b) 10 c) 12 d) 14 e) 16

10. Find the value of V_t (in V).

a) 0.6 b) 0.7 c) 1.0 d) 0.9 e) 0.8

11. Find the value of $k'\left(\frac{W}{L}\right)$ (in mA/V^2).

a) 0.4 b) 0.5 c) 0.6 d) 0.8 e) 0.9

12. Find the value of I_X (in mA), assuming in this question that $V_t = 0.75$ V, $k'\left(\frac{W}{L}\right) = 0.65$ mA/V^2, and $\lambda = 0$.

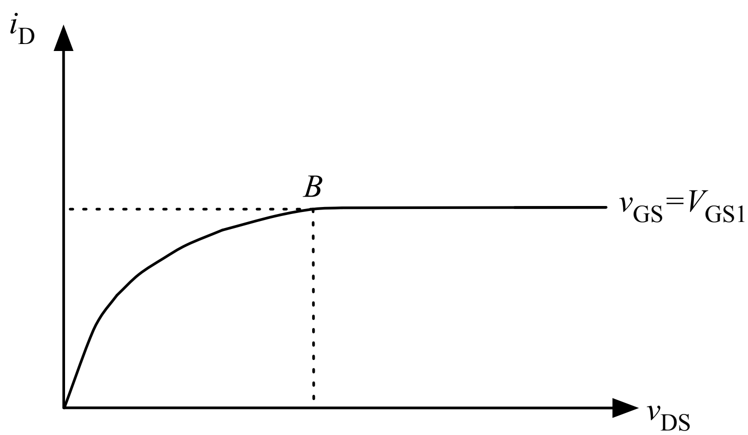
a) 0.187 b) 0.165 c) 0.099 d) 0.121 e) 0.143

13. An enhancement N-channel MOSFET is operated at a value of $v_{GS} = V_{GS1} > V_t$, and has the $i_D - v_{DS}$ characteristics illustrated below. At point B (which is the edge between triode and saturation), $v_{DS,B} = 5$ V and $i_{D,B} = 9$ mA. Find the value of $k'\left(\frac{W}{L}\right)$ (in mA/V^2) for this MOSFET.

a) 0.48 b) 0.56 c) 0.72 d) 0.64 e) 0.80

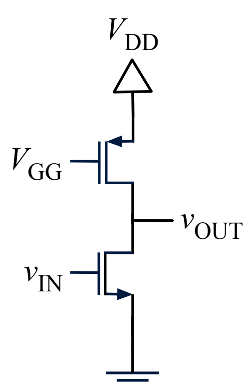
14. In the previous problem, find the slope of the $i_D - v_{DS}$ curve (in mA/V) near $v_{DS} = 0$.

a) 3.2 b) 2.8 c) 2.4 d) 4.0 e) 3.6

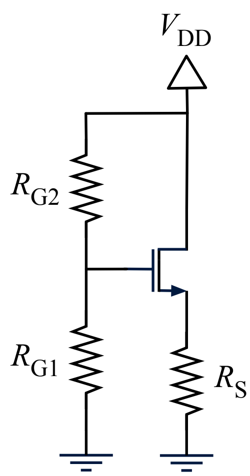


15. In the circuit shown below, the MOSFETs are designed such that $k'_n\left(\frac{W}{L}\right)_n = k'_p\left(\frac{W}{L}\right)_p$ and $V_{tn} = |V_{tp}| = 1$ V, and have negligible λ. The P-channel MOSFET should operate in SATURATION. Find the value of V_{GG} (in V) that results in the condition $V_{IN} = V_{DD}/2 \Rightarrow V_{OUT} = V_{DD}/2$. Assume $V_{DD} = 10$ V.

a) 6.0 b) 4.0 c) 4.5 d) 5.0 e) 5.5



16. In the circuit shown below $R_{G1} = 2R_{G2}$, and the N-channel enhancement MOSFET has negligible λ, $k_n' \left(\frac{W}{L}\right) = 0.8$ mA/V^2, and $V_{tn} = 1$ V. The supply voltage is $V_{DD} = 7.0$ V. The voltage at the source terminal of the MOSFET is 3 V. Find R_S (in kΩ).



a) 4.22 b) 5.51 c) 7.50 d) 10.8 e) 16.9

17. The transfer characteristics of a voltage amplifier are described by the equation: $v_O = 15 - 15\,(v_I - 2)^4$, where v_O and v_I are in V, and v_I is limited to the range between 2 and 3 V. Find the value of the DC input voltage at the bias point (V_{IQ} in V) in order to obtain a voltage gain of 33 dB.

a) 2.67 b) 2.81 c) 2.91 d) 2.42 e) 2.55

18. The efficiency of an amplifier powered from a single 9 V DC supply is 12% when the RMS voltage across a 100 Ω resistive load, connected from the amplifier output to ground, is 3 V. Find the DC current drawn from the supply (in mA).

a) 83.3 b) 66.7 c) 22.2 d) 28.6 e) 40.0

19. In the previous problem, find the power lost in the amplifier (in mW).

a) 510 b) 660 c) 167 d) 270 e) 110

20. The transfer characteristics of a voltage amplifier are described by the following equation: $v_O = 3 + 12v_I$ with saturation levels at $v_O = -3$ V and at $v_O = +4.2$ V.
The input voltage $v_I = A + B\sin(t)$ produces the largest undistorted output (i.e. largest D in $v_O = C + D\sin(t)$). Find this maximum value of D (in V).

a) 3.60 b) 3.45 c) 3.30 d) 3.90 e) 3.75

21. In the previous problem, find the value of A (in V).

a) –0.175 b) –0.225 c) –0.213 d) –0.200 e) –0.188

22. A semiconductor volume with length $L = 1$ cm and cross-sectional area $A = 1$ cm^2 carries a current of 1 mA when a voltage $V = 6.1$ μV is applied across its length. Find the doping density (in cm^{-3}) in the semiconductor when the majority carriers are electrons with a mobility of 1330 cm^2/V.s. Note that the electric field is $E = V/L$.

a) 1.5×10^{18} b) 1.1×10^{18} c) 7.7×10^{17} d) 5.2×10^{17} e) 4.7×10^{18}

23. A doped semiconductor with a free electron density $n(x) = a_0 + a_1 x$, is also subjected to an electric field E with intensity $E(x) = 3V_T\, a_1/(a_0 + a_1 x)$, where V_T is the thermal voltage. Find the ratio of electron drift current density to electron diffusion current density ($J_{drift} / J_{diffusion}$).

a) 4 b) 5 c) 6 d) 2 e) 3

24. The potential barrier across a PN junction doped such that $N_A = 2A\, n_i$, and $N_D = 3A\, n_i$, is $20V_T$. Find the value of A.

a) 14800 b) 24400 c) 40300 d) 66400 e) 9000