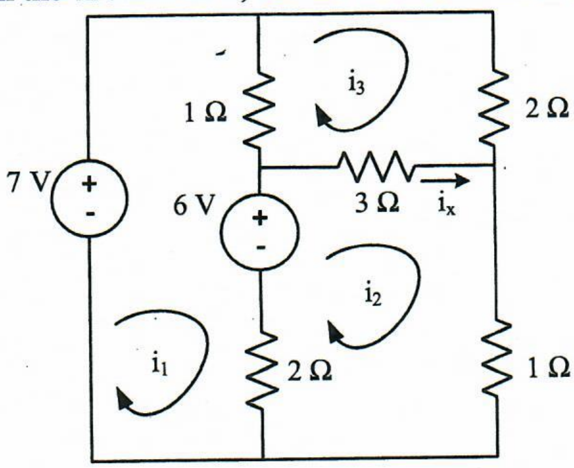
P1 Area: CIRCUITS/ELECTRONICS. **Code** ____________

In the circuit below, use the method of mesh currents to:



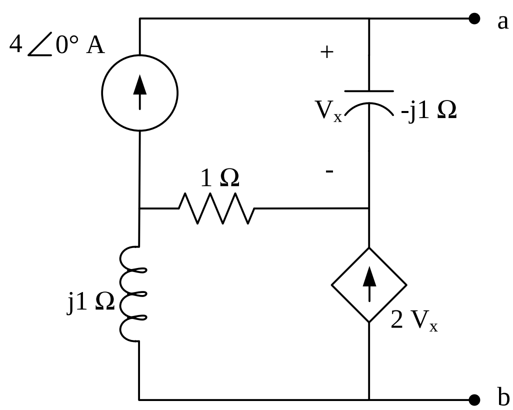
a. Set up the mesh current equations in the matrix provided below.
b. Solve for the current i_x.

$$\begin{bmatrix} & & \\ & & \\ & & \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} \\ \\ \\ \end{bmatrix}$$

i_x = ____________

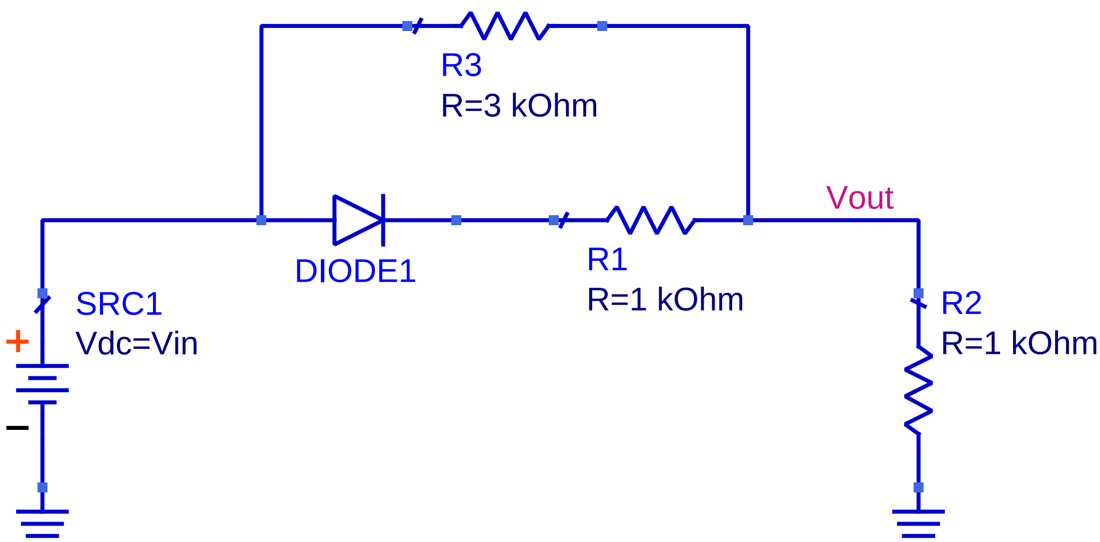
Problem :___<u>P2</u>__ Area:___<u>Circuits/Electronics</u>______________________________ Student Code:____

Calculate the value of the load impedance which should be attached between terminals *a* and *b* so that maximum average power is delivered to that load impedance.



Problem :__P3___ Area:_____ Circuits/Electronics ____________________________ Student Code:____

In the circuit below the input voltage V_{in} changes from -10 V to 10 V. Plot the output DC voltage V_{out} as a function of the input DC voltage V_{in}. Determine the coordinates of all breaking points of the curve. For the V-I curve of the diode use the piecewise-linear approximation with the following parameters: turn-on voltage V_{γ}=0.7 V, break-down voltage V_b=-3 V, differential resistance r_f=0 Ohm.



Refer to Fig. 1 for the system with ideal Continuous-to-Discrete (C-to-D) and Discrete-to-Continuous (D-to-C) converters.

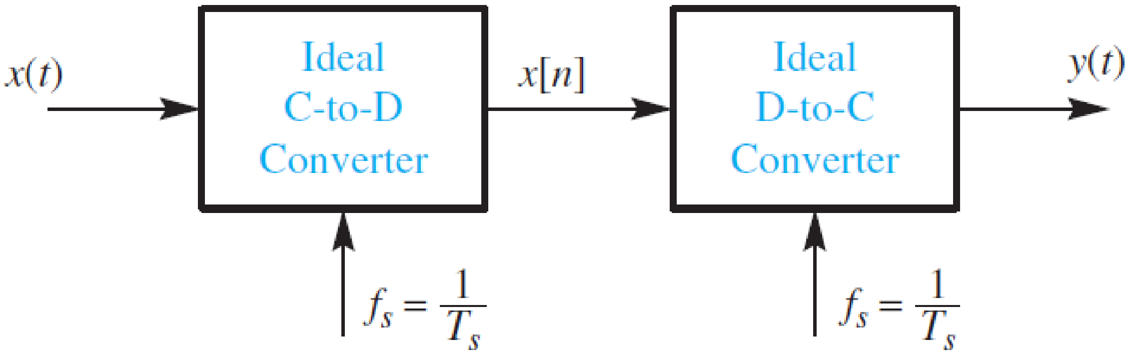


Figure 1: Ideal C-to-D and D-to-C system.

(a) Suppose that the output from the C-to-D converter is $x[n] = \cos(0.2\pi n)$, and the sampling rate of the C-to-D converter is $f_s = 8000$ samples/s. Determine a formula for the continuous-time sinusoidal input x(t) using the smallest frequency greater than 10000 Hz.

(b) Suppose the output from the C-to-D converter is $x[n] = \cos(0.25\pi n)$, the input signal is $x(t) = \cos(510\pi t)$, and the sampling rate (fs) of the C-to-D converter is less than 130 samples/s. Determine the largest possible sampling rate satisfying these three conditions.

(i) Suppose the random variable x has density function $f(x)$. Compute the cumulative density function of x^2 and then find its density function.

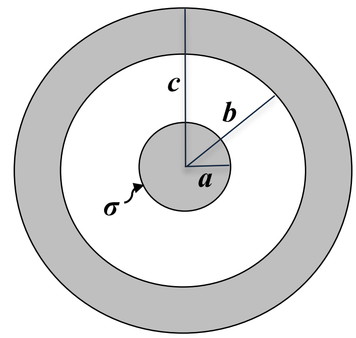
(ii) Work out the answer when the random variable x has a standard normal distribution ($f(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2}$) to find the density of the chi-square distribution.

Problem : 17 **Area: Waves & Devices** **Student Code:____**

Concentric spherical metal shell. The figure below shows a cross-section of a concentric spherical metal shell. The radii of the inner solid spherical conductor, the inner wall of the outer spherical conductor, and the outer wall of the outer spherical conductor are $\boldsymbol{a}$, $\boldsymbol{b}$, and $\boldsymbol{c}$, respectively, as marked in the figure. Consider a positive surface charge density $\boldsymbol{\sigma}$ at the surface of the inner spherical conductor.

A) Find the electric field everywhere as a function of radial distance $\boldsymbol{r}$ (i.e., $\boldsymbol{r} < \boldsymbol{a}$, $\boldsymbol{a} < \boldsymbol{r} < \boldsymbol{b}$, $\boldsymbol{b} < \boldsymbol{r} < \boldsymbol{c}$ and $\boldsymbol{r} > \boldsymbol{c}$).

B) Please plot the electric field strength as a function of radial distance $\boldsymbol{r}$.



Problem : 19 **Area: Waves & Devices** **Student Code:____**

Consider the following two antennas that are directly pointed at each other. Antenna #1 is linearly polarized with an electric field vector given by $(2\hat{a}_x + \hat{a}_y)$. Antenna #2 is elliptically polarized with its *x*- and *y*-directed electric field components being 90° out of (time) phase and with the relative magnitude of one component being three times the other.

1. Write one possible expression for the polarization unit vector of antenna #2.
2. Write all possible (mathematical) expressions for the polarization unit vector of antenna #2 for obtaining maximum polarization loss factor (PLF), given by: $PLF = |\hat{\rho}_w \cdot \hat{\rho}_a|^2$, where $\hat{\rho}_w$ and $\hat{\rho}_a$ are the polarization unit vectors of antenna #1 and #2, respectively.

Problem : 20 **Area: Waves & Devices** **Student Code:____**

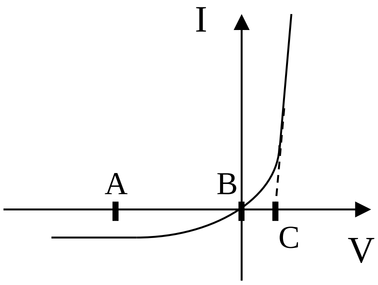
I. An abrupt silicon p-n junction diode has a net acceptor concentration 10^{19} cm^{-3} in the p-side and a net donor concentration 10^{17} cm^{-3} in the n-side, respectively. Answer the following questions assuming all dopants are ionized at room temperature (i.e. 300 K).

a. [30%] Calculate the carrier concentrations and fill out the following table.

	Majority carrier type (circle one)	Majority carrier concentration [cm^{-3}]	Minority carrier type (circle one)	Minority carrier concentration [cm^{-3}]
p-type	electron / hole	( )	electron / hole	( )
n-type	electron / hole	( )	electron / hole	( )

b. [20%] Calculate the potential difference across the depletion region (or space charge region) at thermal equilibrium (i.e. contact potential or built-in potential).

c. [20%] Fill out the following table based on the diode I-V characteristics shown below (I: diode current, V: external bias).



External bias V [V]	Potential difference across the depletion region [V]
A. - 2.0	( )
B. 0.0	( )
C. 0.7	( )

II. Consider a silicon sample doped with donors (10^{14} cm^{-3}) at room temperature. Excess carriers by photon absorption (steady-state concentrations of 2.0 x 10^{13} cm^{-3} electrons and 2.0 x 10^{13} cm^{-3} holes) are generated during a light illumination. Answer the following questions assuming electron mobility = 1,500 $cm^2/V\cdot sec$ and hole mobility = 500 $cm^2/V\cdot sec$, respectively.

a. [20%] Calculate the <u>increased</u> conductivity of the sample during illumination (i.e. additional conductivity excluding the base conductivity without illumination).

b. [10%] Discuss a possible application of this sample (must be no more than one sentence or ~20 words).

Constants*	Equations*
▪ Elementary charge = 1.6 x 10^{-19} [C] ▪ kT = 0.0259 [eV] (at 300 K) ▪ Intrinsic concentration = 9.65 x 10^9 [cm^{-3}] (for silicon at 300 K)	▪ $n_o p_o = n_i^2$ ▪ $n_o = n_i \exp[(E_F - E_i) / kT]$ or $(E_F - E_i) = kT \ln(n_o/n_i)$ ▪ $p_o = n_i \exp[(E_i - E_F) / kT]$ or $(E_i - E_F) = kT \ln(p_o/n_i)$ ▪ $\sigma = q(n\mu_n + p\mu_p)$

* Definitions of parameters are not given for the provided information. It is expected that the examinees interpret the meaning.

Problem : P21 **Area: Computational Intelligence** **Student Code:____**

Describe the formulation of reinforcement learning in terms of the Bellman equation. Why is this well-suited for the problem of learning from reward and punishment. Describe at least two ways of dealing with the infinite horizon problem.

Problem : P22 **Area: Computational Intelligence** **Student Code:____**

Discuss the primary issues involving embedded systems in computational intelligence. Be specific about technical details.

Problem : P23 **Area: Computational Intelligence** **Student Code:____**

Discuss the primary issues involving high-performance computing in computational intelligence. Be specific about technical details.

Problem : P24 **Area: Computational Intelligence** **Student Code:____**

Describe the fuzzification – defuzzification process in using Fuzzy Logic.

Problem : P29 **Area: Integrated Circuits and Logic Design** **Student Code:____**

Answer the questions for parts a and b below.

a. Simplify the logic expression $F(x,y,z) = (x'+y')(y'+z')(x'+z)y$ using algebraic manipulation to obtain a logic expression that uses as few gates as possible (exclude inverters from the total gate count). Note that x' denotes NOT x. Show your work for full credit. DO NOT USE K-MAPS.

b. Construct the truth table for $F(x,y,z) = (x'+y')(y'+z')(x'+z)y$.

Problem : P30 **Area: Integrated Circuits and Logic Design** **Student Code:____**

Answer the questions for parts a and b below.

a. Draw a circuit to implement the function $f(w,x,y,z) = \Pi M(0,2,3,4,5,6,7,10,11,12,15)$ using an 8:1 MUX and other logic gate(s) as needed. You may use the truth table to help if needed.

w	x	y	z	f
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

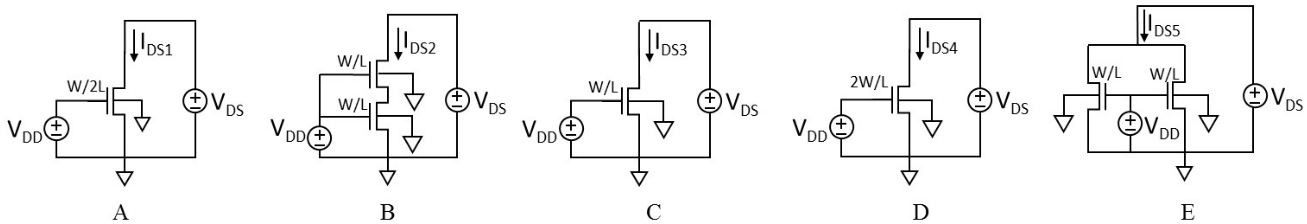
b. Draw a circuit to implement the function $f(w,x,y,z) = \Pi M(0,2,3,4,5,6,7,10,11,12,15)$ using a 3-to-8 decoder with active high outputs and other logic gate(s) as needed. You may use the truth table to help if needed.

w	x	y	z	f
0	0	0	0	
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

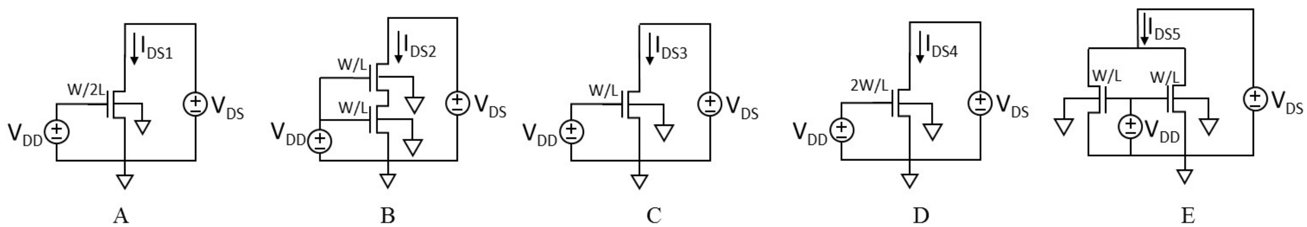
Problem : P31 **Area: Integrated Circuits and Logic Design** **Student Code:____**

Multiple choice problem. Each problem may have more than one answer.

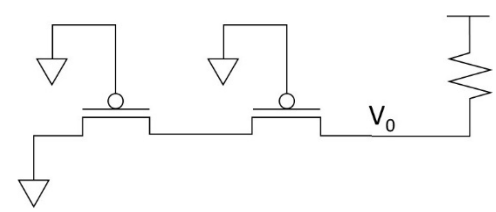
a) Ignore the body effect. Which of the following circuits provide the smallest I_{DS} (drain-source current)?



b) If the body effect is considered, which of the following circuits provide the smallest I_{DS} (drain-source current)?



c) Suppose V_{DD}=1.2V and V_{tn}=| V_{tp} |=0.4V. Determine the output voltage, V_0 for the pass transistor network shown below. Neglect the body effect.

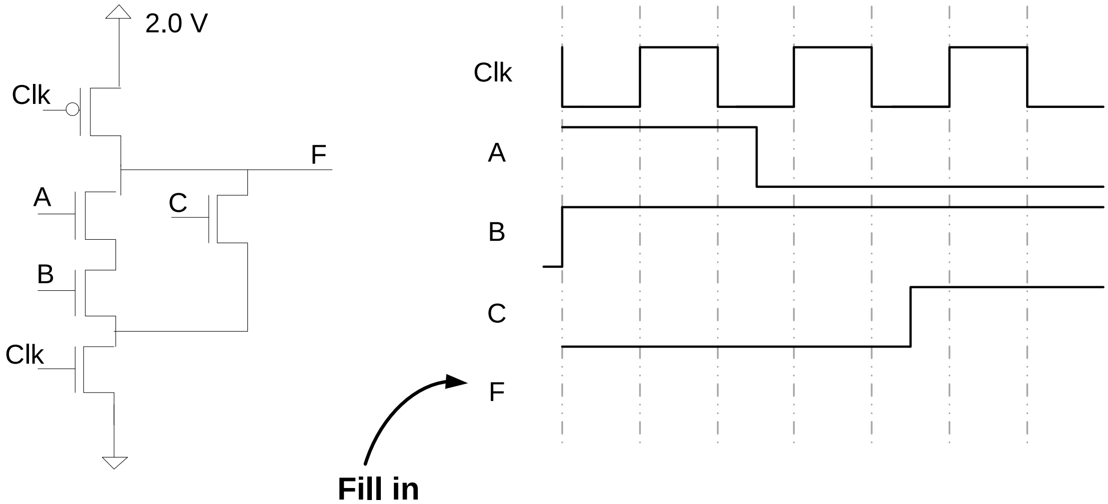


A. 0.4V B. 0.8V C. 0V D. -0.4V

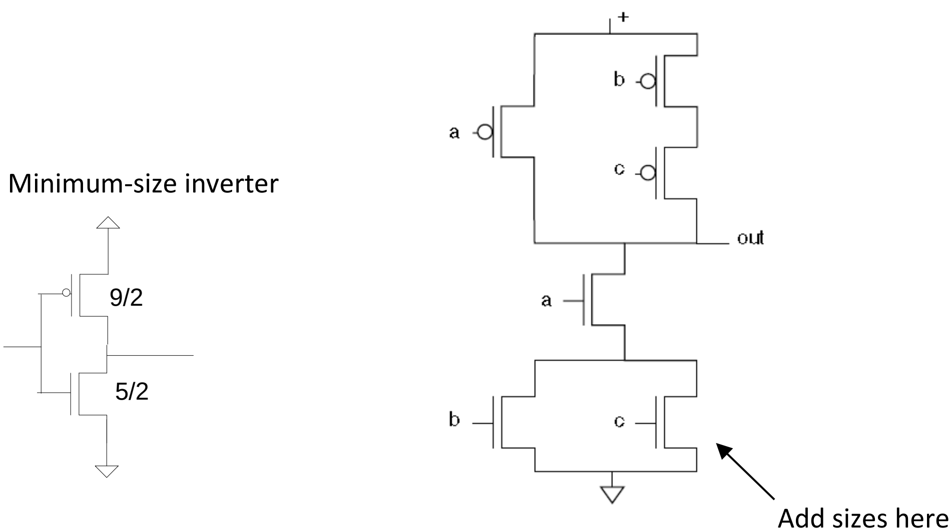
Problem : P32 **Area: Integrated Circuits and Logic Design** **Student Code:____**

CMOS logic circuits

a) Following is a dynamic logic gate. Sketch the output waveform for the given inputs (i.e. sketch output F)



b) A minimum sized inverter with equal rise and fall times is shown on the left. Give the sizes of the transistors in the circuit on the right so it has roughly the same rise and fall times as the inverter.



Problem : P33 **Area: Networking, Security and Dependability** **Student Code:____**

Answer all three questions below, in the context of wireless transmission and modulation.

a. Explain which of the basic modulation techniques (ASK, FSK, PSK) is better suited to wireless RF communication.

b. Is OFDM less vulnerable to Inter Symbol Interference (ISI) than conventional techniques? Justify your answer.

c. Why is OFDM more efficient in frequency use than conventional FDM techniques?

Problem : P34 **Area: Networking, Security and Dependability** **Student Code:____**

This problem has two parts. For full credit, you must answer both parts correctly.

a. For any block cipher, the fact that it is a nonlinear function is crucial to its security. To see this, suppose that we have a linear block cipher EL that encrypts 128-bit blocks of plaintext into 128-bit blocks of ciphertext. Let EL(k, m) denote the encryption of a 128-bit message m under a key k (the actual bit length of k is irrelevant). Thus, EL(k, [m1 XOR m2]) = EL(k, m1) XOR EL(k, m2) for all 128-bit patterns m1, m2.

Describe (mathematically) how, with 128 chosen ciphertexts, an adversary can decrypt any ciphertext without knowledge of the secret key k. Prove that your method works for any 128-bit ciphertext.

Note that a "chosen ciphertext" means that an adversary has the ability to choose a ciphertext and then obtain its decryption. Here, you have 128 plaintext/ciphertext pairs to work with and you have the ability to choose the value of the ciphertexts.

b. What is the difference between an unconditionally secure cipher and a computationally secure cipher?

Problem : P35 **Area: Networking, Security and Dependability** **Student Code:____**

Suppose a router has built up the routing table shown below. The router can deliver packets directly over interfaces 0 and 1, or it can forward packets to routers R2, R3, or R4.

Describe what the router does with a packet addressed to each of the following destinations. <u>Show your work. Answers without work will receive no credit.</u>

a. 128.96.39.10

b. 128.96.40.12

c. 128.96.40.151

d. 192.4.153.17

e. 192.4.153.90

SubnetNumber	SubnetMask	NextHop
128.96.39.0	255.255.255.128	Interface 0
128.96.39.128	255.255.255.128	Interface 1
128.96.40.0	255.255.255.128	R2
192.4.153.0	255.255.255.192	R3
default		R4

You may find some of the following information useful: 10D = 0AH, 17D = 11H, 39D = 27H, 90D = 5AH, 96D = 60H, 128D = 80H, 153D = 99H, 192D = C0H, 255D = FFH.

Problem : P36 **Area: Networking, Security and Dependability** **Student Code:____**

Suppose that a 200 MB message on a flash drive attached to a server is to be uploaded to a destination server through a virtual-circuit packet-switched network with three serially connected intermediate nodes. This network forces packets to be of size 10 KB, including a packet header of 40 bytes. Nodes are 400 miles apart from each other and each server is 50 miles away from its corresponding node. All transmission links are of type 1000 Mbps. The processing time at each node is 0.2 seconds. For this purpose, the signaling packet is 500 bits long.

Answer all three parts below.

a. Find the total connection setup (request/accept) time.

b. Find the total connection teardown (release) time.

c. Find the total time required to send the message.