Problem: CM1 **Area: Computers and Architecture** **Code #_____**

a) Name three different types of hazards that can be encountered in pipelined architectures.

b) Given a generic 5-stage pipeline, indicate which one(s) of the instructions in the following sequence will generate a hazard and what type of hazard? Justify your answer. Assume the processor does not have a branch predictor and branch conditions are computed in the ALU.

```
ADD   R1, R2, R3     ; R1 ← R2 + R3
SUB   R5, R1, R3     ; R5 ← R1 - R3
BEQ   R5, R4, 100    ; Branch to PC+100 if R4 = R5
ADD   R1, R3, R5     ; R1 ← R3 + R5
ADD   R1, R2, R4     ; R1 ← R2 + R4
```

c) If the sequence of instructions above produces a hazard, is it possible to avoid it by operand forwarding? Justify your answer using specific instructions from part b).

Problem: CM2 **Area: Computers and Architecture** **Code #_____**

The instruction type breakdown of a program is given in the table below.

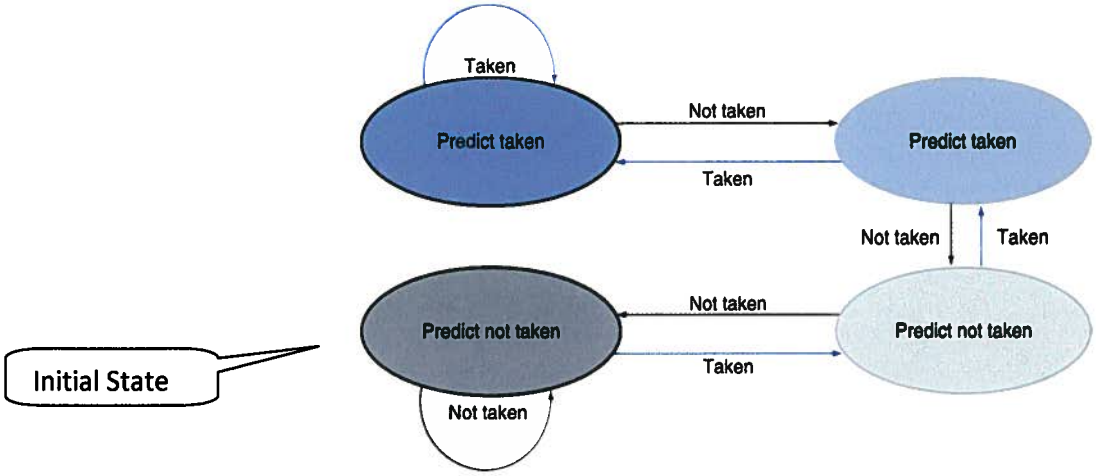
	ALU	Load	Store	Branch	Total
Number of instructions	900	500	300	100	1800

Compute the execution time of this program on two separate processors with given CPI's for each type of instruction as shown in the table below. Assume Processor 1 runs at 1GHz whereas Processor 2 runs at 1.6GHz.

	CPI's for each type of instruction			
	ALU	**Load**	**Store**	**Branch**
Processor 1	1	5	8	3.5
Processor 2	2	8	10	3

Problem: CM3 **Area: Computers and Architecture** **Code #_____**

Calculate the branch prediction accuracy (= # of correct predictions / # of total predictions) of the following branch outcome sequence using the 2-bit predictor shown below. Assume that the **initial state is one on bottom-left**.



Branch outcome sequence (**T** means "branch-taken and **N** means "branch-not-taken"):

T, T, N, N, N, T, N, T, N, T

Problem: CM4 **Area: Computers and Architecture** **Code #_____**

Given the bit pattern 1011 0011, what does it represent in decimal, assuming that it is:

a. a **signed** (two's complement) integer.

b. an **unsigned** integer.

Problem: CM5 **Area: Integrated Circuits and Logic Design** **Code #_____**

Consider a Boolean function f (A, B, C, D)

a) What is the maximum number of product terms f can have in its minimal SOP expression? Give an example of such function f.

b) Is it possible for f to have three product terms in its minimal SOP expression and three sum terms in its minimal POS expression? If yes, give an example. If no, explain why.

Problem: CM6 **Area: Integrated Circuits and Logic Design** **Code #_____**

Simplify the following Boolean expression: f(A, B, C, D) = A'C'D + A'BD + BCD + ABC + ACD'

Problem: CM7 **Area: Integrated Circuits and Logic Design** **Code #_____**

Given the function below, answer the following questions.

$$F = \sum m(0,2,5,7,8,10,13,15) + dc(1,3)$$

a) Write the canonical SOP for F.

b) Write the minimal SOP for F.

c) Draw the circuit for F using any combination of gates.

Problem: CM8 **Area: Integrated Circuits and Logic Design** **Code #_____**

Simplify the following equations using theorems and axioms of Boolean algebra. DO NOT USE K-MAPS!

a) $F(A,B,C,D) = (\bar{a}b + a)\bar{a} + (c + d)(c + \bar{d})$

b) $G(A,B,C) = \bar{b}\bar{c} + b\bar{c} + a\bar{b}c + abc$

c) $H(A,B,C) = \bar{a}\bar{b} + \bar{a}b\bar{c} + \overline{(a + \bar{c})}$

Problem: CM9 **Area: Embedded Computer Systems** **Code #_____**

a) (30 %) List at least 5 important factors/criteria when choosing a microcontroller and explain your choices.

b) (30 %) What is the purpose for having many types of addressing modes? Enumerate at least 4 different addressing modes generally used in microcontrollers.

c) (30 %) Give a definition for interrupts and explain what purpose and advantage they serve in a digital system.

d) (10 %) List 2 differences between general-purpose microprocessors and microcontrollers and explain your choices.

Problem: CM10 **Area: Embedded Computer Systems** **Code #_____**

Assume you are given an 8051 microcontroller with a clock running at 12MHz. This microcontroller has a timer that can run in two modes. In the first mode, the microcontroller uses a 16-bit number as input and the initial value needs manual reload on an overflow. In the second mode, it uses an 8-bit value which auto-reloads on overflow. One timer tick is equivalent to 12 oscillator/clock ticks. Assume the 16-bit number can be written as TH0 and TL0 for the high and low byte, respectively, and the 8-bit number only needs to be loaded with the TH0 value for operation. A delay can be generated by starting your time with a particular value and have it count up to its "overflow" value. Your task is to find the timer initialization value to create a 2μs delay and explain which timer mode you would use and why. Show your work clearly for full credit.

Problem: CM11 **Area: Embedded Computer Systems** **Code #_____**

a) (50%) Write a C-language code that executes the same operation as the following 8051 assemble code. Assume assembly syntax to be: "<instruction> <destination>, <source>. Make sure to declare any needed variables.

```
funny_name segment data
        w: DS2; byte variable declaration
        z: DS 1; another variable declaration
CSEG AT 0000H
        MOV w, #3333h
        MOV A, #32d
        CLR C
        RLC A
        MOV R0, #0Ah
LOOP:   ADD A, R0
        DJNZ R0, LOOP
        MOV z, A
        END
```

b) (50%) You can write a code in C-language (high level) or in assembly. Give at least two advantages (pros) of using each.

Problem: CM12 **Area: Embedded Computer Systems** **Code #_____**

Write an assembly program to find the bit position of the first '1' (starting from the most significant bit) in an 8-bit number stored in register R7. You can consider either 8015 or other embedded processor. Assume you have Rotate Right (RR) and Rotate Left (RL) instructions, but no Shift Left or Shift Right instructions. Also, the microcontroller uses Carry bit to save overflow bit (while pushing the previous Carry bit back into the register). Your program should output the bit position of the first '1' on Port 2 (P2). Assume it is possible the given 8-bit number can have no '1's.

Problem: CM13 **Area: Computational Intelligence** **Code #_____**

Describe the pros and cons of the LMS algorithm in detail. Give some math for the learning step at one weight and explain where each term comes from.

Problem: CM17 **Area: Networking** **Code #_____**

Answer both questions below.

1. Complete the table below, which represents the seven-layer hybrid OSI network model. For each layer, state the name, a one-sentence description of the functionality, and one protocol that is used in implementing the services of the layer.

Layer	Name	Functionality	Sample Protocol
7			
6			
5			
4			
3			
2			
1			

2. In the table above, which can represents a layered network model, exactly one protocol data unit (PDU) in layer *N* is encapsulated in a PDU at layer (*N*-1). It is also possible to break one *N*-level PDU into multiple (*N*-1)-level PDUs (segmentation) or to group multiple *N*-level PDUs into one (*N*-1)-level PDU (blocking).

   a. In the case of segmentation, is it necessary that each (*N*-1)-level segment contain a copy of the *N*-level header? Why or why not?

   b. In the case of blocking, is it necessary that each *N*-level PDU retain its own header, or can the data be consolidated into a single *N*-level PDU with a single *N*-level header? Why or why not?

Problem: CM18 **Area: Networking** **Code #_____**

Answer all four questions below. Show your work for every answer.

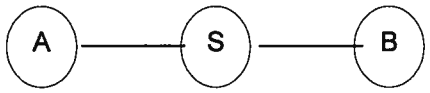
1. Compare the two basic flow control mechanisms: stop-and-wait and sliding window. Describe the advantages and disadvantages of each scheme.
2. Consider a satellite link with data rate of 1Mbps and total link delay of 0.5s. User data is sent as fast as possible, using 2500 byte (octet) packets. What is the effective throughput achievable by the (i) stop-and-wait scheme and (ii) the sliding window scheme with a window size of 20?

For the scenario from (2), calculate the optimal window size, i.e., the window size that will maximize throughput. What will be the effective throughput in such a case?

Problem: CM19 **Area: Networking** **Code #_____**

Answer both questions below. Show every step of your work.

1. Hosts A and B are each connected to a switch S via 100-Mbps links as in the figure below. The propagation delay on each link is 20 μs. S is a store-and-forward device; it begins retransmitting a received packet 35 μs after it has finished receiving it. Calculate the total time required to transmit 10,000 bits from A to B
    a. As a single packet
    b. As two 5000-bit packets sent one right after the other



What is the Hamming distance of two-dimensional parity? Justify your answer.

Problem: CM20 **Area: Networking** **Code #_____**

Answer both questions below.

1. Provide each of the following parameters for each of the network classes A, B, and C, respectively. Be sure to consider any special or reserved addresses in your calculations.
   a. Number of bits in network portion of address
   b. Number of bits in host portion of address
   c. Number of distinct networks allowed
   d. Number of distinct hosts allowed per network
   e. Integer range of first (most significant) byte of IP address

2. An organization has been assigned the prefix 212.1.1//24 (class C) and wants to form subnets for four departments, with hosts as follows:

A	75 hosts
B	35 hosts
C	20 hosts
D	18 hosts

   There are a total of 148 hosts in all. Give a possible arrangement of subnet masks to make this possible.

Problem: CM21 **Area: Security and Reliability** **Code #_____**

Answer all five of the questions below.

1. What is the difference between a one-way hash function and a message authentication code?
2. Why is it preferable to generate a signature before applying compression?
3. What is the difference between symmetric and asymmetric encryption? Which technique is preferable, and why?
4. Describe two types of attacks that can be addressed by message authentication and explain how message authentication addresses them.
5. You are comparing two different encryption techniques. How can you tell which one achieves better diffusion? Justify your answer.

Problem: CM22 **Area: Security and Reliability** **Code #_____**

Suppose you have a true random bit generator where each bit in the generated stream has the same probability of being a 0 or 1 as any other bit in the stream and that the bits are not correlated; that is, the bits are generated from identical independent distributions. However, the bit stream is biased. The probability of a 1 is $0.5 + \delta$, where $0 \leq \delta \leq 0.5$. A simple deskewing algorithm is as follows: Examine the bit stream as a sequence of nonoverlapping pairs. Discard all 00 and 11 pairs. Replace each 01 pair with 0 and each 10 pair with 1. Answer all three questions below. Justify your answers.

a. What is the probability of occurrence of each pair in the original sequence?
b. What is the probability of occurrence of 0 and 1 in the modified sequence?
c. Suppose that the algorithm uses overlapping successive bit pairs instead of non-overlapping successive bit pairs. That is, the first output bit is based on input bits 1 and 2, the second output bit is based on input bits 2 and 3, and so on. What can you say about the output bit stream?

Problem: CM23 **Area: Security and Reliability** **Code #_____**

Use the function table and assumed fault set F shown below to determine the following. Note that only one fault from the fault set can occur at a time.

Cubes	Input		Output		Validity
	A	B	X	Y	
C0	0	0	0	1	Invalid
C1	0	1	1	1	**Valid**
C2	1	0	0	0	**Valid**
C3	1	1	1	0	Invalid

$F = \{A_{s\text{-}a\text{-}0}, A_{s\text{-}a\text{-}1}, B_{s\text{-}a\text{-}0}, B_{s\text{-}a\text{-}1}\}$

a. (10pts) Does this combinational circuit have "self-testing" property? Explain why or why not using examples.

b. (10pts) Does this combinational circuit have "fault-secure" property? Explain why or why not using examples.

Problem: CM24 **Area: Security and Reliability** **Code #_____**

An **NMR** system consists of **five** identical computing modules and a voter. Assume the reliability of the voter is much more reliable than the modules and can be neglected. Determine the following.

a. (5pts) Find the reliability of the module R_M and the reliability of the NMR system R_{NMR} using the exponential failure law.

b. (10pts) Assume that an individual module fails every 10,000 hours. Find the Reliability Improvement Factor (RIF) at t = 5,000 hours.

c. (10pts) Consider a Hybrid Redundancy system consists of a TMR system with two dynamic spares (e.g, (3,2) system). Compare R_{NMR} and R_{HYBRID}, assuming that an individual module fails every 10,000 hours and t=5,000. Which one is better in terms of the reliability?

Problem: CM25 **Area: Computer Science** **Code #_____**

A recursive procedure solves a problem of size n by calling itself n − 1 times on n−1 sub-problems, where the i^{th} sub-problem has size i. Then the answers are combined in unit time. That is, let T(n) be the running time of the procedure when it solves a problem of size n, then we have the following recurrence:

$$T(n) = \begin{cases} 1 & n = 1 \\ 1 + \sum_{i=1}^{n-1} T(i) & n > 1 \end{cases}$$

Solve the above recurrence exactly, and prove the correctness of your answer by induction.

Problem: CM26 **Area: Computer Science** **Code #_____**

Given two sorted arrays of integers denoted by A and B, give an efficient solution to find the median of $A \cup B$.

Problem: CM27 **Area: Computer Science** **Code #_____**

Prove by mathematical induction that $\forall n \in Z, n \geq 4, n! > n^2$

Problem: CM28 **Area: Computer Science** **Code #_____**

Prove, formally, whether the following are True or False; show your work.

a. $\log_2 n$ is $O(\log_3 n)$

b. $\sum_{1}^{n} 5ni$ is $\Theta(n^3)$

Problem: M1 ***Area: Power/Machinery*** **Student Code____**

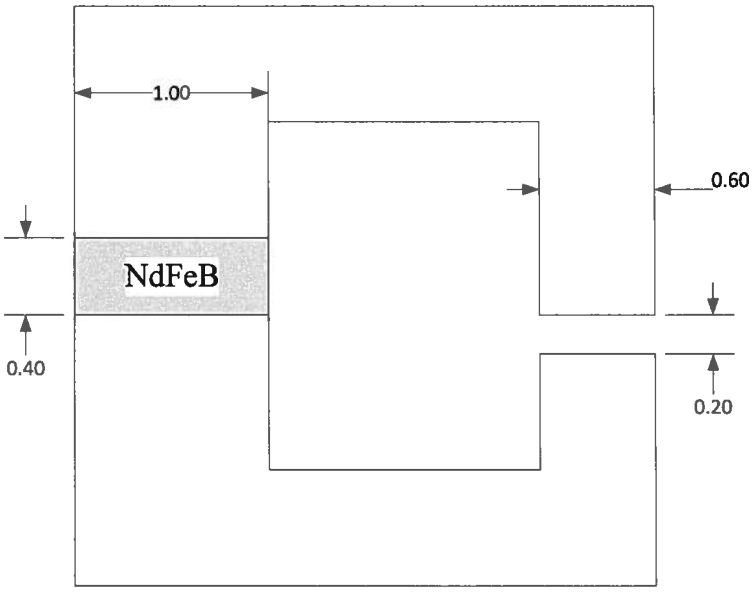
The following structure is composed of infinitely permeable steel, a block of NdFeB, and an air gap. Your task is ultimately to find the force acting to close the air gap. The NdFeB may be modeled as having an equivalent coercivity of $H_c' = -940\ \mathrm{kA/m}$ and a recoil permeability of $\mu_R = 1.05\mu_0$, where $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H/m}$. Depth into the page is 2.5 cm. Other dimensions are as shown, all in centimeters. Equations you may need:

$$\mathcal{R} = \frac{\ell}{\mu A}$$

$$(Ni)_{eq} = -H_c' d$$

$$W_{fld}' = \int \lambda di$$

$$f_{fld} = -\frac{\partial W_{fld}'}{\partial x}$$



a. Draw the magnetic equivalent circuit. Indicate all elements numerically, EXCEPT leave the length of the air gap as "g."
b. Find the co-energy.
c. Find the force acting to close the gap, $f_{fld}(g)$.
d. Find the force numerically for g = 2 mm = 0.2 cm.

Problem: M2 ***Area: Power/Machinery*** **Student Code____**

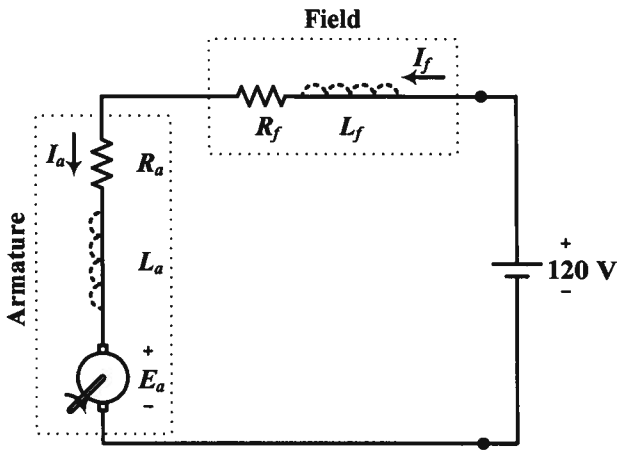
In the series-connected dc motor depicted in the figure,

1) Back emf can be described as $E_a = K \cdot I_f \omega_m$.
2) $R_a = 0.6\ \Omega$, $R_f = 0.4\ \Omega$, and the supply voltage is 120 V.

a) Find the developed torque by the motor at the speed of 65 rad/s if the armature current is 12 Amps.

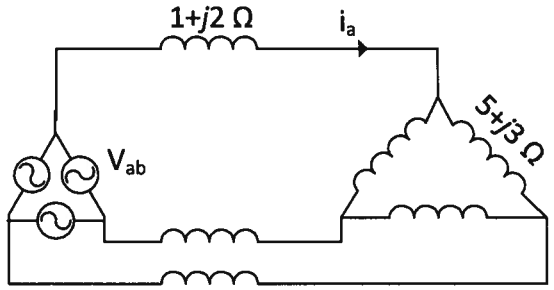
b) Find constant ***K***.

c) Find the new value for the armature current if the mechanical speed changes to 250 rad/s.



Problem: M3 ***Area: Power/Machinery*** **Student Code____**

A 3-phase voltage source feeds a 3-phase load connected through lines as shown in the system below. The sources, lines, and loads are balanced, and $V_{ab} = 140\angle 0^{\circ}$ volts.

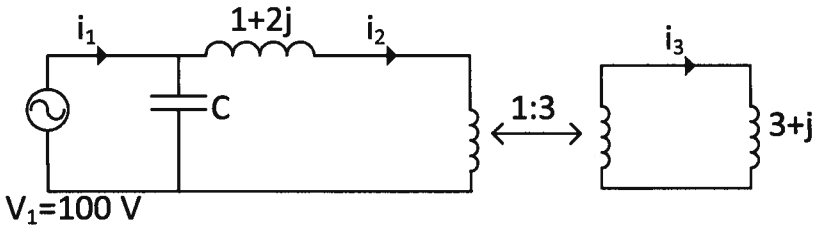


1) Calculate the active and reactive power delivered by the source.
2) What is the power factor of the system?

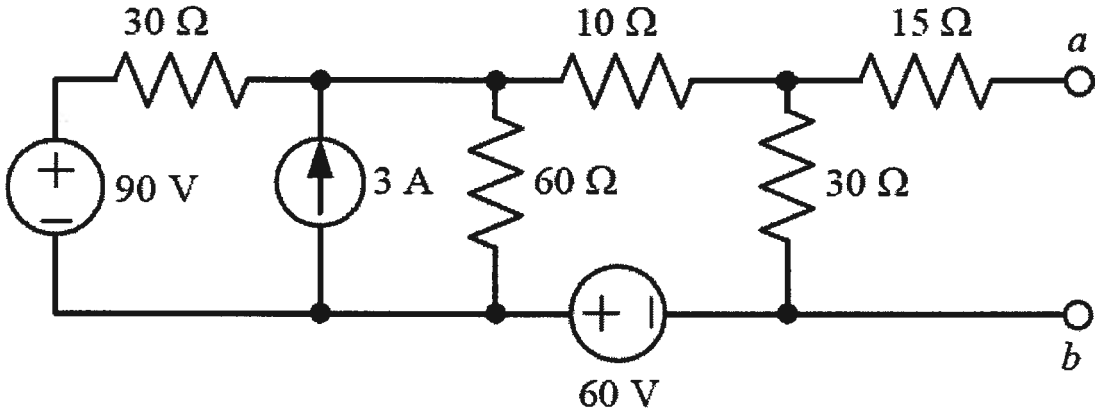
Problem: M4 ***Area: Power/Machinery*** **Student Code____**

In the following single phase system, the input voltage is 100V. A load of 3+j is connected to a transformer with a ratio of 1:3. A transmission line with an impedance of 1+2j is connecting the transformer to a power source V_1. Please calculate: 1. load current i_3, 2. transmission line current i_2, and 3. source active and reactive power (without considering C).

Assume that a capacitor C is connected to the source to compensate for reactive power. If a source power factor of 1 (unity) is of interest, what is the proper value for capacitor C?

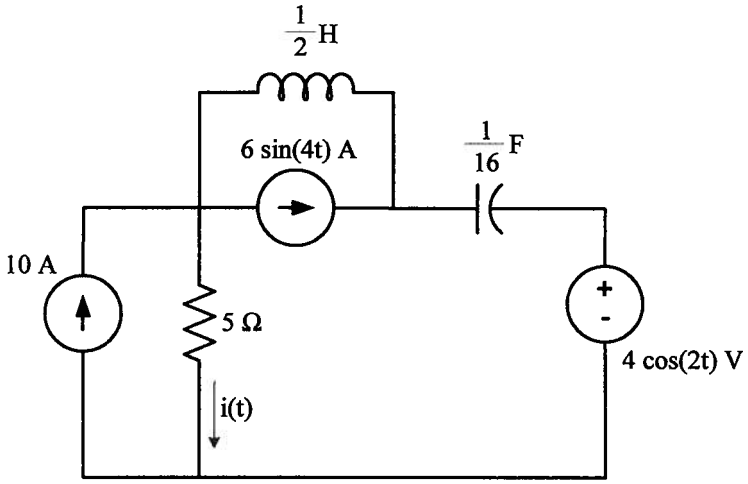


For the following circuit, use repeated source transformation to find the Norton equivalent with respect to terminals *a* and *b*.



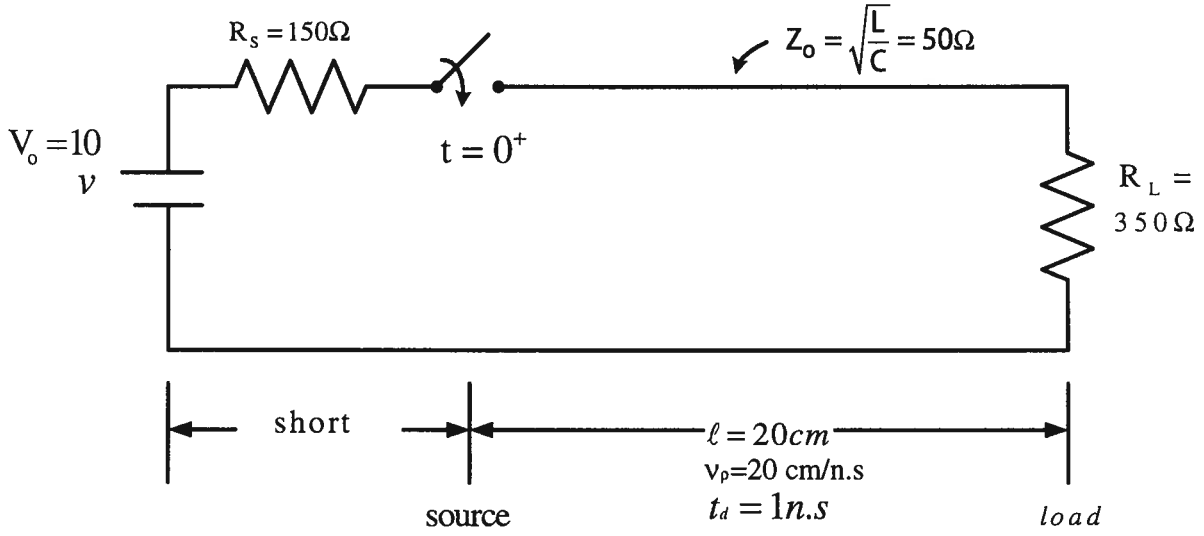
PROBLEM M6 CIRCUITS AND ELECTRONICS AREA Code #_____

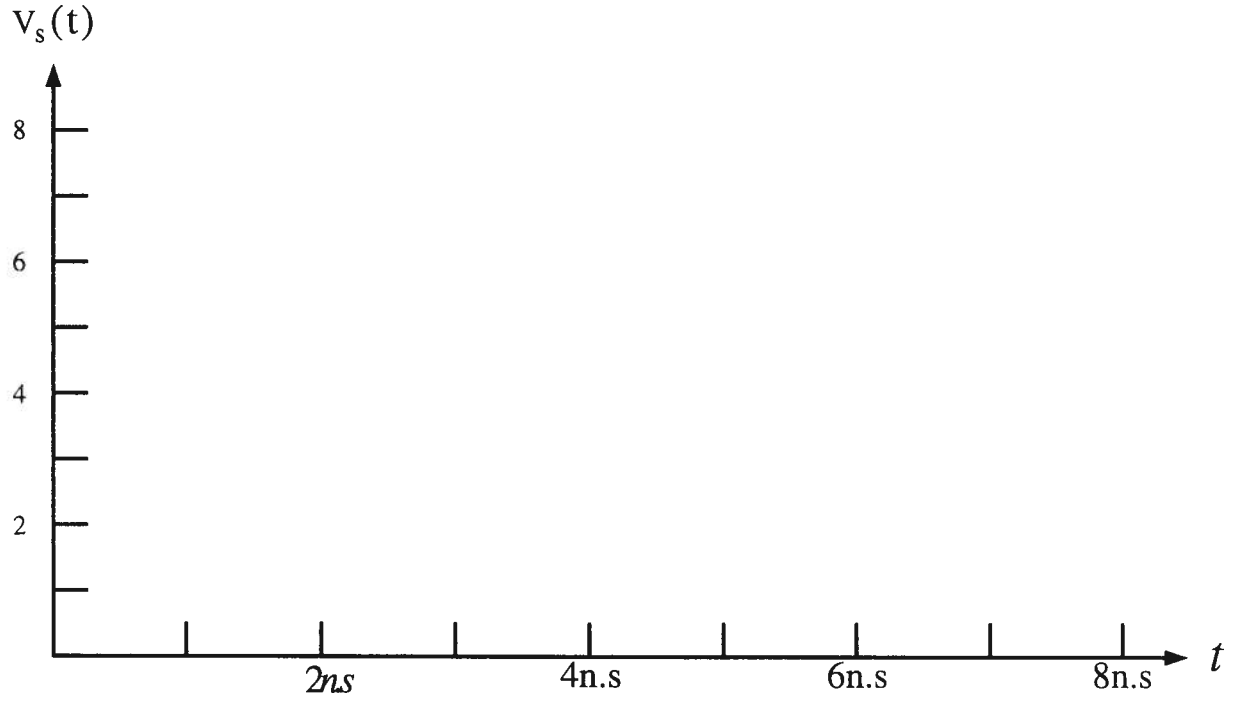
Find the steady-state current i(t) in the following circuit:



Problem M10 Area: Waves, Devices, & Optics Code # _____

Referring to the transmission line of intrinsic impedance $Z_0 = 50\Omega$ below, the DC source voltage is V_0 with an internal resistance of $R_s = 150\Omega$. The switch is turned on at $t = 0^+$. The load resistance is $R_L = 350\Omega$.. The length $\ell = 20cm$ and the propagation speed is 20cm/nano-second (that is the transit time= 1 nano-second). Through the use of a proper bounce diagram, plot the value of voltage at the source point as function of time up to 8 times the transit time from the source to the load. What is the steady-state value of the voltage?





Problem #M11 **Area: Waves & Devices Code #**

Consider a silicon (Si: a Col. IV material)) abrupt-junction pn diode with only $N_{ap}^{-} = 10^{18}$ cm^{-3} on the p side and only $N_{dn}^{+} = 10^{13}$ cm^{-3} on the n side. One side is doped with aluminum (Al: a Col. III materials) and the other side is doped with phosphorous (P: a Col. V material). T = 300 K. Important physical constants are:

Boltzmann's constant: $k = 1.38 \times 10^{-23}$ J/K $= 8.62 \times 10^{-5}$ eV/K

Planck's constant: $h = 4.14 \times 10^{-15}$ eV-s Electronic charge: $q = 1.60 \times 10^{-19}$ C

Carrier Mobilities $\mu_n = 1350$ cm^2/V-s $\mu_p = 480$ cm^2/V-s

Bandgap Energy of Si $E_g = 1.11$ eV

Intrinsic Carrier Concentration $n_i = 1.50 \times 10^{10}$ cm^{-3} at 300 K

(a) Silicon (Si) is a column IV material on the periodic table and it is in the third row. Neon (Ne) is a column VIII material on the periodic table and it is at the end of the second row. If the electronic configuration for Neon is $1s^2 2s^2 p^6$, state the electronic configuration for Silicon.

(b) Specify which material is the dopant for the respective sides of the diode. Justify.

p-side of diode: _____ n-side of diode: _____

Justification:

(c) Calculate the contact potential V_o.

(d) Calculate the equilibrium carrier concentrations on the p-side.

(e) Answer the following multiple-choice questions. Circle the one best answer.

For forward bias, the depletion width is ??? the equilibrium depletion region width.

Equal to **Greater than** **Less than**

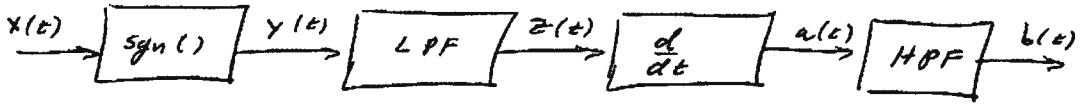
The diode current is primarily ???

Holes **Electrons** **Neither (holes=electrons)** **Insufficient Information**

Prob. M21 Communications / Signal Processing Code#_____

Show all work for full credit, using this page, and the following two blank pages on the exam. Express all answers to an accuracy of at least three decimal places. State all assumptions you make when working the problem.

A system contains 4 blocks connected in series as shown in the figure below



The first block is a signum operator, sgn(). The output of this block is +1 when x(t) is positive, -1 when x(t) is negative, and zero when x(t) is zero.

The lowpass filter (LPF) passes signals from 0 Hz to 8.5 kHz, and perfectly removes all signals above that frequency.

The differentiator (d/dt) is ideal.

The highpass filter (HPF) passes all signals above 7.5 kHz, and perfectly removes all signals below that frequency.

What is the rms value of the HPF output, b(t), when the input to the system is

$$x(t) = 34.23 \sin(2000 \pi t + 7.8 \pi)$$

A set of symbols $S = \{a, b, c, d, e\}$ is found in a discrete source with the probability of occurrence being $P = \{0.1, 0.15, 0.30, 0.16, 0.29\}$.

1. What is the self-information of each symbol?
2. What is the entropy of the discrete source?
3. Use Huffman Coding to encode the symbols.
4. Compute the average coding length of the resulting Huffman code and compare it with the entropy.