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

Define stored-program concept. Give at least 3 advantages of this architecture, and corresponding applications/systems.

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

Suppose we have two implementations (Machine A and machine B, namely) of the same instruction set architecture. For some program which has 1 million instructions,

Machine A has a clock cycle time of 100ps and an average CPI of 4.0.

Machine B has a clock cycle time of 130ps and an average CPI of 3.0.

a. What machine is faster for this program, and by how much?

b. If overclocking (i.e., driving the given machine with faster clock speed) of the slower machine is possible, what clock rate should be used to execute the given program to achieve the same execution time of the faster machine?

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

Answer the following questions.

1. Name three different hazard types of pipelined processors.

2. For the five stage MIPS pipeline processor, Indicate which of the following instructions will generate hazard, and what type of hazard?

   ADD R1, R3, R4
   ADD R5, R6, R7
   SUB R8, R1, R7
   OR R9, R7, R6

3. If there is a hazard in 2, could it be handled using forward path? If so, please indicate the forward path. If not, please explain why.

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

Below is a list of 32-bit memory address references, given as word addresses.

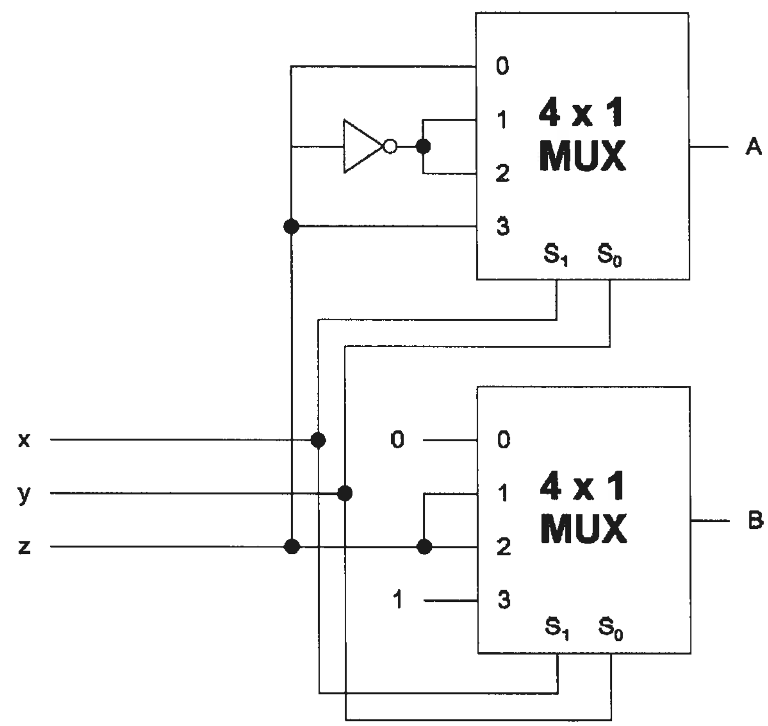
3, 180, 43, 2, 191, 88, 190, 14, 181, 44, 186, 253

For each of these references, identify the binary address, the tag, and the index given a direct-mapped cache with two-word blocks and a total size of 8 blocks. Also list if each reference is a hit or a miss, assuming the cache is initially empty.

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

Answer the following questions regarding combinational logic.

a) Determine the outputs functions A and B as sums of minterms. You may use any process to determine the result, but show your work.



b) The circuit shown in a) has the functionality of a commonly used arithmetic component. What does the circuit do and what are other names for A and B?

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

Design a circuit (combinational, not sequential) that takes an unsigned 2-bit number, $X=X_1X_0$, and computes the square of that number, $Y=X^2$.

Answer the following questions.

a) How many outputs do you need?

b) Show the truth table for this combinational circuit. Name the outputs Y_n, ..., Y_1, Y_0 (with n depending on what you have determined in a).

c) Determine the minimized output functions.

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

Design a 2-bit up/down counter with rollover (i.e. counting up 0-1-2-3-0... and down 3-2-1-0-3...). The counter is controlled by signal C, where C = 0 means counting down and C = 1 means counting up. Use JK flip-flops in your design and show all steps for full credit.

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

Draw the 2-input NAND and 2-input NOR implementation of the following function: $F\ (A, B, C) = A\bar{B} + BC + A\bar{C}$.

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

Assume you are given an 8-bit timer. If 12MHz crystal clock frequency is used to drive the given timer and one timer tick is equivalent to 12 crystal clock periods, what would be an appropriate timer initialization value (i.e., 8-bit binary word) to achieve 1ms delay? Show your work clearly.

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

Assume that you have an 8051 microcontroller with a 12 MHz operation. Write an assembly language program to create a 83.3 kHz square wave on P1.0. Timers or interrupts are not required for this assembly language program. Show your work for the timing involved for: 1) executing each instruction and 2) generating the time delay associated with the 83.3 kHz square wave.

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

Low -level programming is still an important way to optimize performance in embedded devices. For this problem, fully explain how low-level instruction sets handle various required programming features found in high-level languages. When possible, use specific examples from instruction sets you may know. Include relevant architectural details when appropriate.

(a) arrays

(b) function calls

(c) conditionals

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

Answer the following:

a) What does the baud rate measure in serial communication?

b) Explain (a) what interrupts are and (b) what advantage they give us when designing a digital system.

c) A common function used in embedded systems programming is the DELAY subroutine. Calculate the number of machine cycles the following function consumes. Include overhead. (Note: MOV and NOP consume 1 cycle while the other instructions all consume 2. The DJNZ instruction will decrement the register and, if the register is not zero, jump to the indicated label.)

```
DELAY:MOV R3, #50
OUT:        MOV R2, #100
IN:         NOP
                DJNZ R2, IN
                DJNZ R3, OUT
RET
```

Answer = ________________

Problem: CM14 **Area: Computational Intelligence** **Code #_________**

Explain Particle Swarm Optimization. Cover the motivation, pseudocode or flowchart, and where and how it may be used.

Problem: CM15 **Area: Computational Intelligence** **Code #_________**

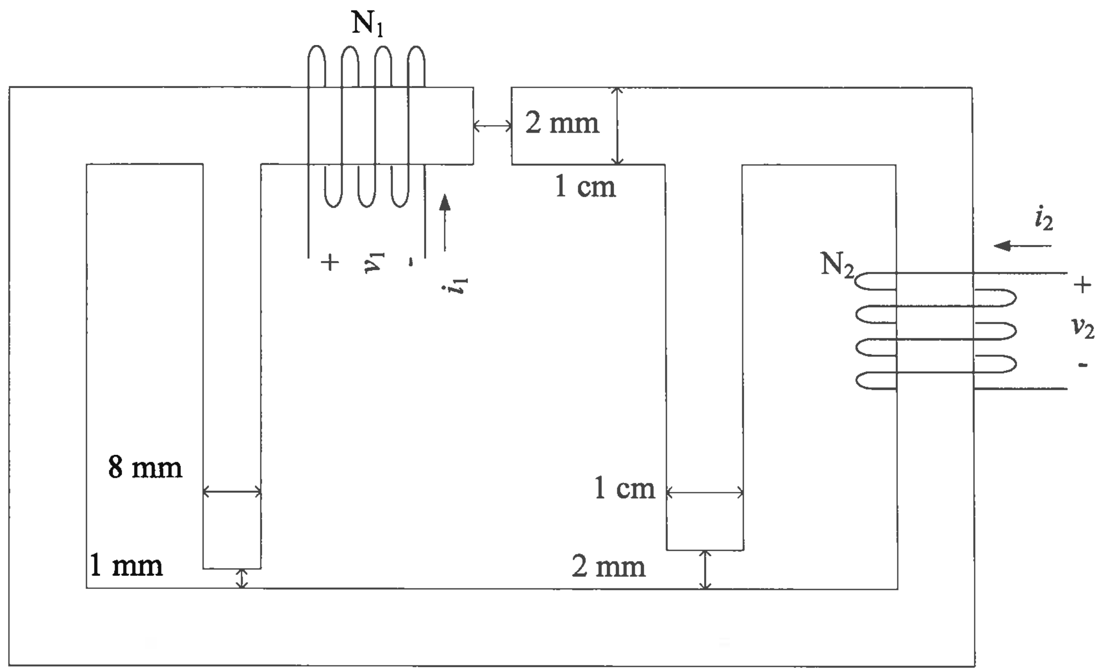
Describe the use of alpha-cuts and defuzzification in Fuzzy Logic, and what this is good for.

Problem: CM16 **Area: Computational Intelligence** **Code #________**

Describe overfitting. Is it desirable or undesirable? Why? What does one do to achieve or prevent it? Give plenty of detail. A right answer without sufficient supporting details won't get many points.

Problem M.1 **Power/Machinery** **Code #________**

Consider the magnetic structure drawn below. The steel has infinite permeability. Depth into the page is 1.5 cm. Other dimensions are shown (NOT TO SCALE). N1 = 300, N2 = 100.



a. Draw the magnetic equivalent circuit. Mark all polarities, and find all reluctances numerically. Recall that $\mu_0 = 4\pi \times 10^{-7}$ H/m.
b. Determine the inductance matrix for the device that relates λ_1 and λ_2 to i_1 and i_2.

Problem M.2 **Power/Machinery** **Code #__________**

A certain magnetic structure has the following λ-i relationship:

$$\begin{bmatrix} \lambda_1 \\ \lambda_2 \end{bmatrix} = \frac{1}{g} \begin{bmatrix} 17.7\times10^{-6} & 11.8\times10^{-6} \\ 11.8\times10^{-6} & 53.1\times10^{-6} \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \end{bmatrix}$$

Notice that there are two coils and one air gap.

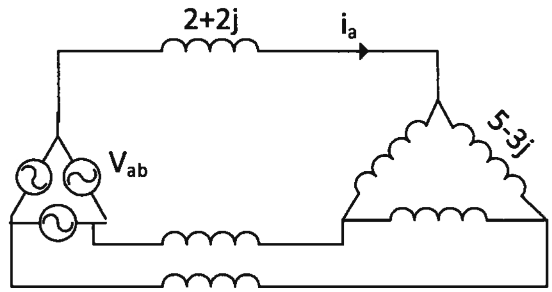
a. Determine the co-energy $W'_{fld}(i_1, i_2, g)$.

b. Taking g as the position variable, determine the force acting to close the air gap $f_{fld}(i_1, i_2, g)$.

c. Suppose that the two coils are wired in series (that is, $i_1 = i_2$) and that we would like to use this device as a clamp. We are clamping a non-magnetic object with thickness 1 mm in the air gap. Determine the current needed to achieve 20 N of clamping force.

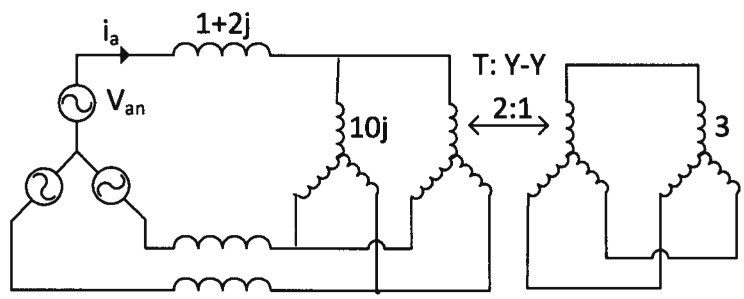
Problem M.3 **Power/Machinery** **Code #_________**

Calculate the power delivered by the 3-phase source for the following system (sources, lines, and loads are balanced): $V_{ab} = 200 \angle (0.5 \text{ radian})$ V. Calculate P_{load}, I_a, $V_{load\ ab}$, P_{source}

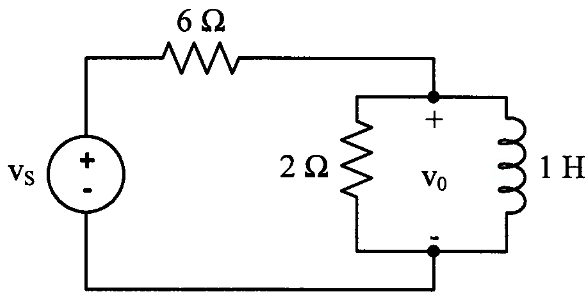


Problem M.4 **Power/Machinery** **Code #__________**

Q2. Calculate the current of the source (i_a) in the following circuit. The ratio of the 3-phase Y-Y transformer is 2:1. Loads, lines, and sources are balanced. The Y load is 3 ohms per-phase. The Y reactance is 10j ohms per-phase. $V_{an} = 110 \angle (0.2 \text{ radian})$ V



For the following circuit:



- Find the transfer function $\mathbf{H}(j\omega) = \dfrac{\mathbf{V_0}}{\mathbf{V_S}}$.
- Plot $|\mathbf{H}(j\omega)|$ vs. ω . Clearly label your axes and indicate the maximum value.
- Find the steady-state output, $v_0(t)$, if $v_S(t) = 3\sin(2t) + 5\cos\left(10t + \dfrac{\pi}{6}\right)\text{V}$.

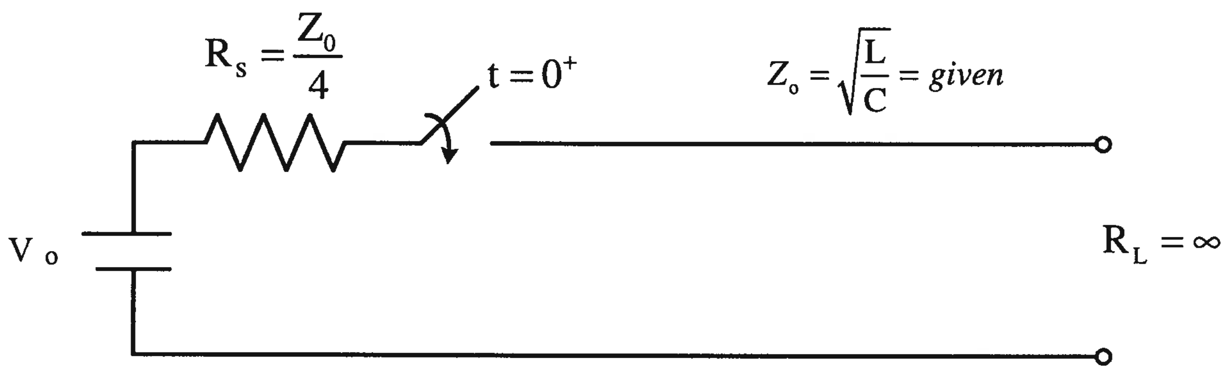
Problem: M9 Area: Waves, Devices, & Optics Code #:_____

Find the Electric Field, $\overline{E}$, at a point a radial distance of R away from the following charge distributions. All charge distributions are located in freespace. In addition (for parts b and c), find ρ_s and ρ_v. For full credit, show all of your work.

a. A point charge, Q (C), located at the origin.
b. A constant surface charge density, ρ_s (C/m^2), of radius, 'a' (where $R > a$), located at the origin, containing total charge, Q.
c. A constant volume charge density, ρ_v (C/m^3), of radius 'b' (where $R > b$), located at the origin, containing total charge, Q.

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

Referring to the transmission line of intrinsic impedance Z_0 in the right figure, the DC source voltage is V_0 with an internal resistance of $R_s = Z_0 / 4$. The switch is turned on at $t = 0^+$. The load resistance is $R_L = \infty$ (that is "open-circuited"). Through the use of a proper bounce diagram, plot the value of voltage at the source point as function of time up to 6 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 in which only donors are on the n-side and only acceptors are on the p-side. The doping concentrations for the n and p sides are $N_{d(n)}^{+} = (1.00 \times 10^{15})\ cm^{-3}$ and $N_{a(p)}^{-} = (1.00 \times 10^{16})\ cm^{-3}$. T = 300 K. The diode has uniform cross-sectional area. Important physical constants are:

Boltzmann's constant:	$k = 1.38 \times 10^{-23}$ J/K = 8.62×10^{-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	$\mu_n = 1350\ cm^2/V\text{-}s$	$\mu_p = 480\ cm^2/V\text{-}s$	
Bandgap Energy of Si	$E_g = 1.11$ eV		

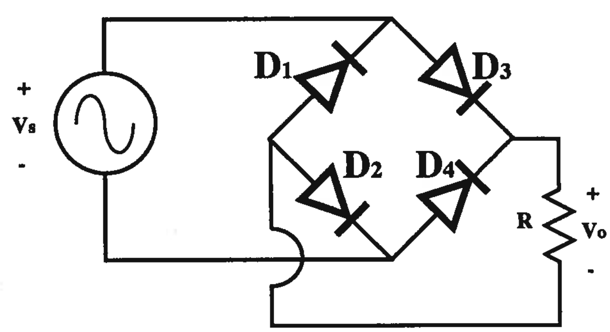
Intrinsic Carrier Concentration $n_i = 1.50 \times 10^{10}\ cm^{-3}$ at 300 K

(a) Calculate the Fermi levels on each side of the junction in eV relative the intrinsic levels.
For the p side

For the n side

(b) Calculate the contact potential V_O and the ratio x_{n0}/x_{p0}, i.e. the ratio of how far the depletion region extends into each side of the junction.

(c) For each diode, let the turn-on voltage be $V_{to} = 0.70$ V and the reverse saturation current be 0.50 mA. In the circuit, the parameters are R = 2,000 Ω and $V_S = +10 \sin(10t)$ V. For the maximum source voltage, calculate the resistor current I_R and the current supplied by the source I_S (passive sign convention).



Problem M13 **Area: Control** Code#____________

A discrete-time control system is described by

$$\begin{bmatrix} Y_1(z) \\ Y_2(z) \end{bmatrix} = \begin{bmatrix} \dfrac{z-0.3}{z^2-0.6z+0.05} \\ \dfrac{z+0.3}{z-0.1} \end{bmatrix} U(z),$$

where $U_1 = Z[u]$, $Y_1 = Z[y_1]$, and $Y_2 = Z[y_2]$ are the one input and the two output variables, respectively. Obtain a state-space representation of the system with minimal number of state variables.

Problem M14 **Area: Control** Code #__________

Consider the following discrete-time system

$$x(k+1)=\begin{bmatrix} 0.6 & 0.3 \\ -1.2 & -0.6 \end{bmatrix} x(k)+\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} u(k),$$

$$y(k)=\begin{bmatrix} c_1 & c_2 \end{bmatrix} x(k)$$

Where u, x, and y are the input, state and output variables respectively.

1. Determine the conditions for b_1 and b_2 such that the system is reachable (30%)
2. Determine the conditions for b_1 and b_2 such that the system is controllable but not reachable.(40%)
3. Determine the conditions b_1 and b_2 such that the system is not controllable.(30%)

Problem M15 **Area: Control** Code#________

Consider the third-order system with the differential equation

$$\frac{d^3y}{dt^3}+5\frac{d^2y}{dt^2}+3\frac{dy}{dt}+2y=u.$$

(a) Determine the state variable representation (30%)

(b) Design a state feedback gain matrix K if we seek a rapid response to a low overshoot, and a settling time of 1 second with $\omega_n=6$. (70%)

Problem M16 **Area: Control** Code#________

Use the Routh-Hurwitz test to find the range of K for which the following characteristic equation is stable.

$$s^4 + 5s^3 + 2s^2 + 4s + K = 0$$

Problem M-21 Communications/Signal Processing Code # ________

I find a black box on a laboratory bench. The box has one connection marked "input" and one connection marked "output". It is impossible to see what is contained inside the box.

I test it by putting in an ideal Dirac delta, $\delta(t)$, voltage source on the input. I connect the output to an oscilloscope, and notice that it looks $5\ e^{-10t}\ u(t)$, where $u(t)$ is the unit step function. Based on this measurement, and making no other assumptions about the box, tell me what output you will observe when each of the two signals listed below is put in the input. If you think there is insufficient information provided to answer this question, explain what else you would need to know before you can answer these questions.

A) Input is $-10\ \delta(t+9)$

B) Input is $-10\ \cos(2\pi 700t-6)$

Problem M22 **Area: Communications** **Code_______**

A system has input $x(n)$ and output $y(n)$ where

$$y(n) = \begin{cases} \dfrac{x(n-20)}{n-20}, & n \geq 0 \\ 0, & elsewhere \end{cases}$$

Show whether or not the system is

a) Linear
b) Bounded Input/Bounded Output (BIBO) Stable
c) Time Invariant
d) Causal

Figure 1 shows three baseband signal pulses.

1. Prove or disprove that the pulses are pair-wise orthogonal.
2. If there are orthogonal pairs, what value of T ensures that they are orthonormal?
3. sketch the signals $x(t) = P_1(t) - P_2(t) + P_3(t)$ and $y(t) = P_1(t) + P_2(t)$. Clearly mark all relevant values on the horizontal axis and vertical axis.

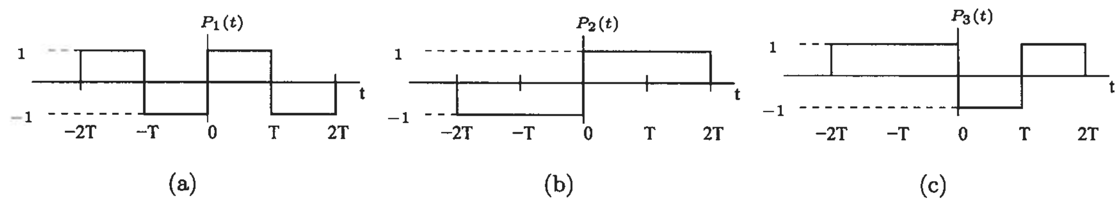


Figure 1: Baseband signal pulses.