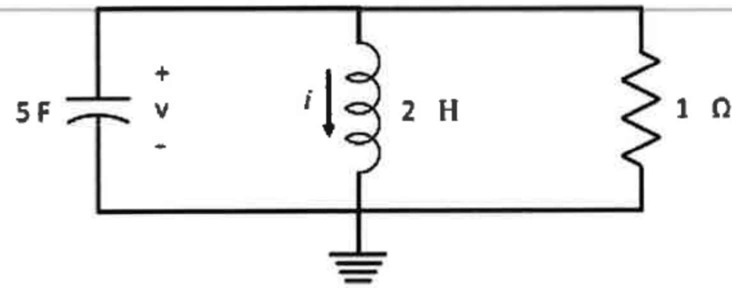
Problem : Q1 **Area: Circuits/Electronics** **Student Code:** ____

For the following circuit,

a) Determine the Source-Free **time** response, $v(t)$, for $t > 0$. Let $i(0) = 1$ A, $v(0) = 50$ V.

Quadratic eq:

$$s = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

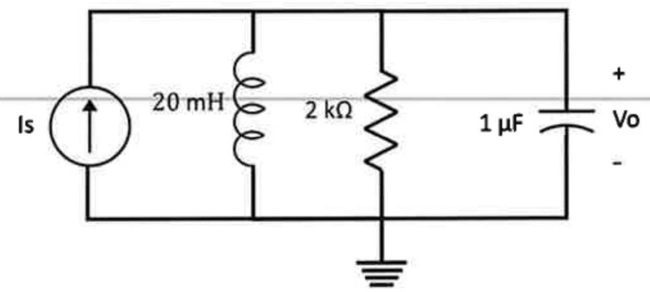


b) Is the circuit (Overdamped \ Critically Damped \ Underdamped -- Circle One)?

$v(t) =$ ________________________

Problem : Q2 **Area: Circuits/Electronics** **Student Code:** ____

For the following circuit:



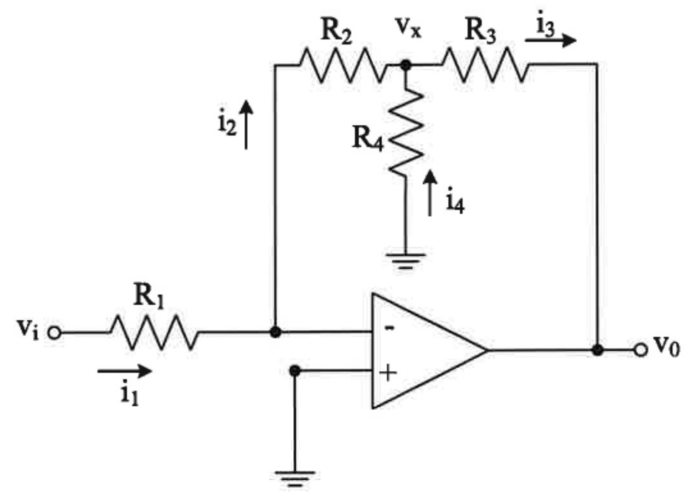
- Find the admittance function

$$Y(j\omega) = \frac{\boldsymbol{V_o}}{\boldsymbol{I_s}}$$

- Find the resonant frequency $f_0 = \omega_0/2\pi$.
- Find the damping coefficient α.
- Find the natural resonant frequency $f_d = \omega_d/2\pi$.
- Plot $|Y(j\omega)|$ vs. ω. Clearly label your axes and indicate the maximum value.

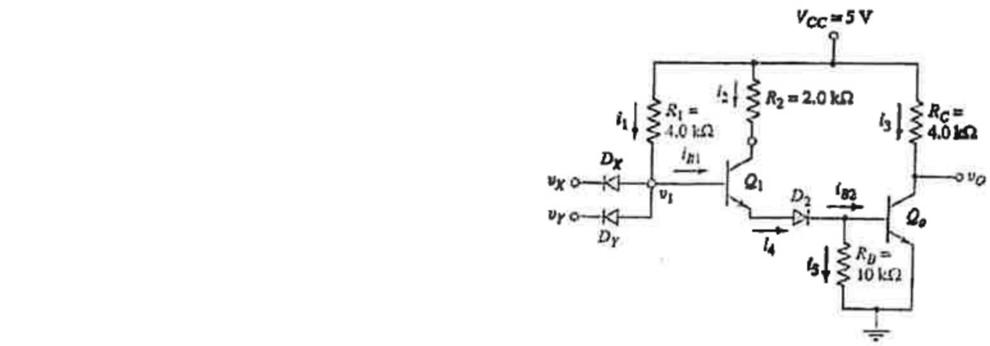
Problem : Q3 **Area Circuits/Electronics** **Student Code____**

In the circuit below, $R_1 = R_2 = 10k\Omega$ and $R_3 = 1k\Omega$. Assuming the op-amp is ideal, calculate the value of R_4 so that the current gain $\frac{i_3}{i_1} = 11$.



Problem: P4 **Area: Circuits/Electronics** **Student Code____**

Consider the Diode Transistor Logic (DTL) gate shown below. Assume V_γ = 0.7 V, V_{BE} (ON) = 0.7 V, V_{BE} (Sat) = 0.8 V, V_{CE} (Sat) = 0.1 V, and β = 20 for both transistors. Assume that Logic 0 and Logic 1 corresponds to 0.1 and 5 V respectively.



For logic 1 on the input side, $v_x = v_y$ = 5 V.

Calculate v_1, i_1, i_2, i_3, i_4, and i_5.

Problem : P5 **Area: Communications / Signal Processing** **Student Code: _____**

The analog signal x(t) has the Fourier Transform X(f), given by the equation

$$X(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}\,dt$$

Where

t is time measured in seconds
f is frequency measured in Hz
x(t) is voltage measured in volts
j is the square root of -1

Is it possible for two different signals to have the same Fourier Transform? Carefully justify your answer for full credit.

Just to be clear, two analog signals are considered "different" if there exists at least one point of time where their voltages are not the same. This can be written mathematically

$$\exists t_o : x_1(t_o) \neq x_2(t_o)$$

Two Fourier Transforms are considered "the same" if for every value of frequency, they have exactly the same value. This can be written mathematically

$$X_1(f) = X_2(f)\forall f$$

You may work with mathematically ideal signals in this problem. You do not have to restrict yourself to only those signals that we can produce in a laboratory.

Problem : P6 **Area: Communications / Signal Processing** **Student Code: _____**

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

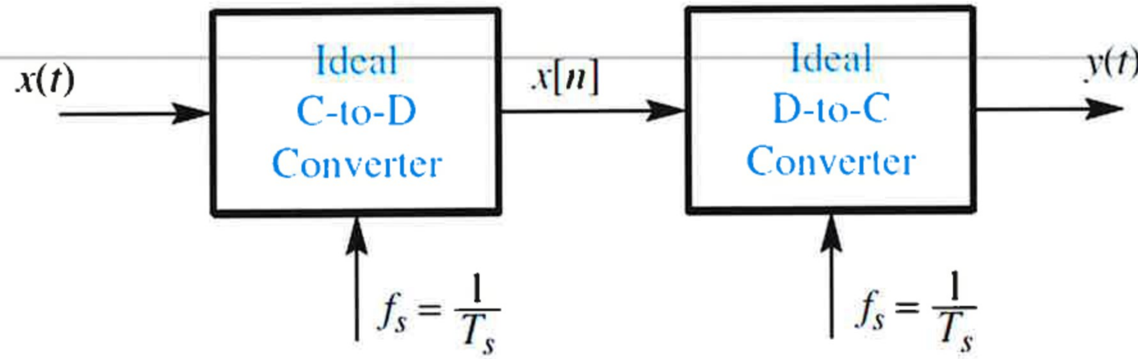


Figure 1: Ideal C-to-D and D-to-C system.

(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.

Problem : P7 **Area: Communications / Signal Processing** **Student Code: _____**

Let a be a random variable which is uniformly distributed on the interval $[0,2]$. Define two random variables X and Y as

$$X \triangleq \begin{cases} a, & if\ a < 1, \\ 2 - a, & otherwise, \end{cases}$$
$$Y \triangleq \begin{cases} a, & if\ a > 1, \\ 2 - a, & otherwise, \end{cases}$$

and let $Z \triangleq \frac{Y}{X}$.

(1) Please derive the probability density function of X.
(2) Please derive the probability density function of Z.
(3) Please calculate the expectation of $\frac{X}{Y}$.

Problem : 9 **Area: Controls** **Student Code____**

Use the Routh-Hurwitz test to find the number of roots, if any, of the following characteristic equation that are in the right half-plane. Also determine the number of left half-plane and imaginary axis roots. If imaginary roots exist, find their location from the Routh array.

$$s^5 + 3s^4 + 7s^3 + 9s^2 + 44s + 40 = 0$$

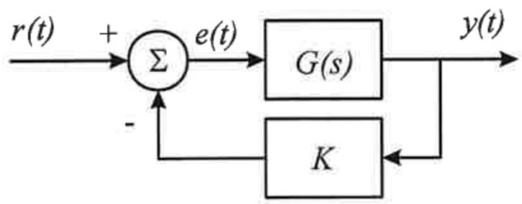
Problem : 10 **Area: Controls** **Student Code____**

Consider the system defined by $G(z) = \frac{z+1}{z^2 + z + 0.16}$, obtain the

(a) Controllable canonical form (33%)
(b) Observable canonical form (33%)
(c) Diagonal canonical form (34%)

The characteristic polynomial of the *closed-loop* transfer function of the following control system is

$$s^3 + 6s^2 + (12 + K)s + (8 - K) = 0$$



(a) Find the range of K such that the system is stable.
(b) Determine $G(s)$.
(c) For the positive value of K for which the system is *marginally stable*, determine the location of *all* closed-loop poles.

Problem : 12 **Area: Controls** **Student Code____**

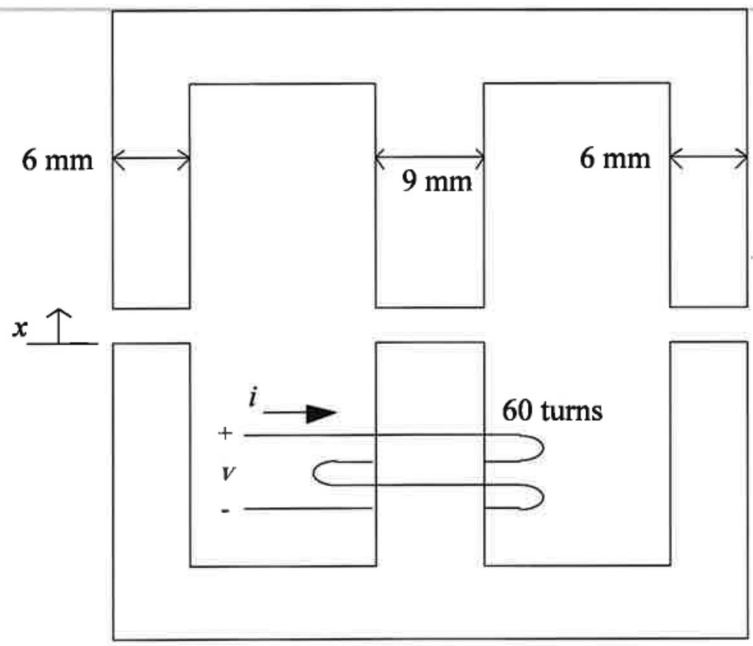
a. Evaluate the stability of the following system

$$\dot{x}_1 = (x_1 - x_2)(x_1^2 + x_2^2 - 1)$$
$$\dot{x}_2 = (x_1 + x_2)(x_1^2 + x_2^2 - 1)$$

b. Evaluate the stability of the following system

$$\dot{x}_1 = -x_1 + x_2^2$$
$$\dot{x}_2 = -x_2$$

In the magnetic structure drawn below (not to scale), the lower half is fixed and the upper half is constrained to move in the *x* direction only. The permeability of the structure is infinite, and the depth into the page is 15 mm. Neglect fringing.



a. Sketch the magnetic equivalent circuit. Substitute numbers where available. Indicate polarities clearly. (40 points)

b. Solve for flux linkage in the coil, $\lambda(i,x)$. (20 points)

c. Find the co-energy, $W'_{fld}(i,x)$. (20 points)

d. Find the force acting to close the air gaps, $f_{fld}(i,x)$. (20 points)

Useful equations:

$$\mu_0 = 4\pi \times 10^{-7}\ H/m$$

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

$$\mathfrak{F} = \phi \mathfrak{R}$$

$$W'_{fld} = \int_0^i \lambda(\hat{i},x)\,d\hat{i}$$

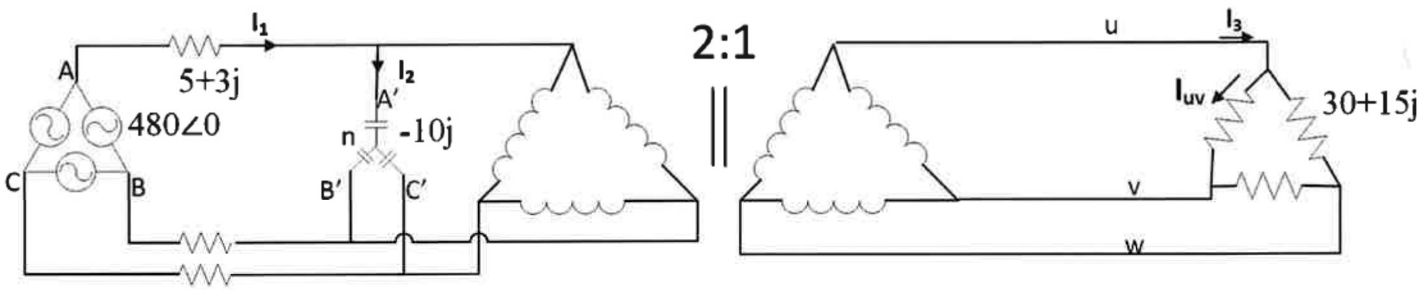
$$f_{fld} = \frac{\partial W'_{fld}}{\partial x}$$

Problem: 14 **Area: Power** **Student Code: ______**

In the following circuit, $V_{AB} = 480\angle 0$. Please find the following (both amplitude and the angle):

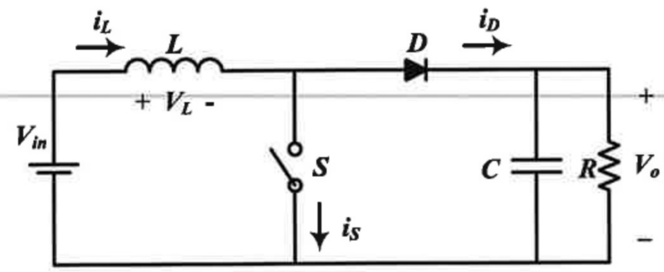
a) I_1, I_2, and I_3. (45 points)
b) I_{uv} (load current). (15 points)
c) Phase voltage of each capacitor (-10j) equal to $V_{A'n}$. (15 points)
d) 3-phase complex power of the source. (15 points)
e) 3-phase complex power of the load (30+15j). (10 points)

Note: The circuit is fully symmetrical.



Problem 15 **Power** **Student Code #_______**

A Boost dc-dc converter has the following parameters: $V_{in} = 400$ V, $d = 0.25$, $V_{out} = 650$ V, $L = 100$ μH, and $f_{sw} = 100$ kHz.



a) Find the peak value of the inductor current. (20 points)

b) Accurately plot the waveform of the inductor current. (20 points)

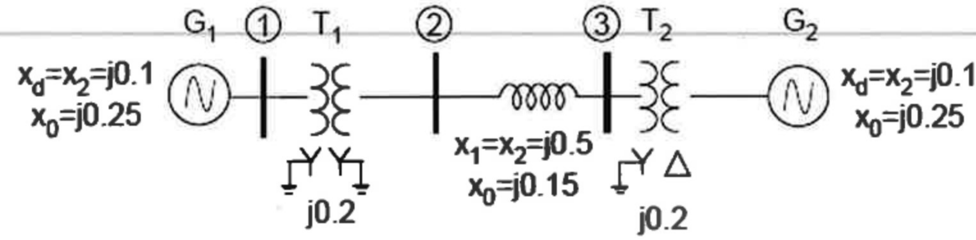
c) Find the average value of the inductor current. (20 points)

d) Find the input power. (20 points)

e) Find the value of the load resistor. (20 points)

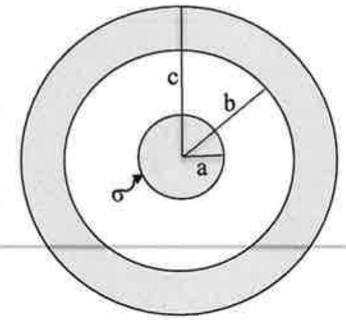
Problem: 16 **Area: Power** **Student Code:______**

In the system shown below, a solid single line-ground fault occurs on bus 3. Both generators are solidly grounded.



What are the positive, negative and zero sequence fault currents in line 2-3? The prefault voltages are 1.0 per unit.

Metallic concentric shell. The figure on the right shows a cross-section of a coaxial cable (a metallic concentric shell). The radii of the inner conductor, the inner wall of the outer conductor, and the outer wall of the outer conductor are **a**, **b**, and **c**, respectively. Consider a positive surface charge density $\boldsymbol{\sigma}$ at the surface of the inner conductor. A) Find the electric field everywhere as a function of radial distance r (**r < a**, **a < r < b**, **b < r < c**, and **r > c**). B) Please plot the electric field strength as a function of radial distance r. C) If the outer wall of the outer conductor is grounded, find the electric field at **r > c**.



Problem :__P19__ **Area:___Waves/Devices___** **Student Code:____**

Answer the following questions about a MOS capacitor which has p-type Si substrate. P-type Si doping concentration is 1.0×10^{15} cm^{-3}. The silicon dioxide thickness is 10 nm. Assume room temperature of 300 K.

a. Calculate the surface potential, Ψ_s, at the onset of strong inversion.

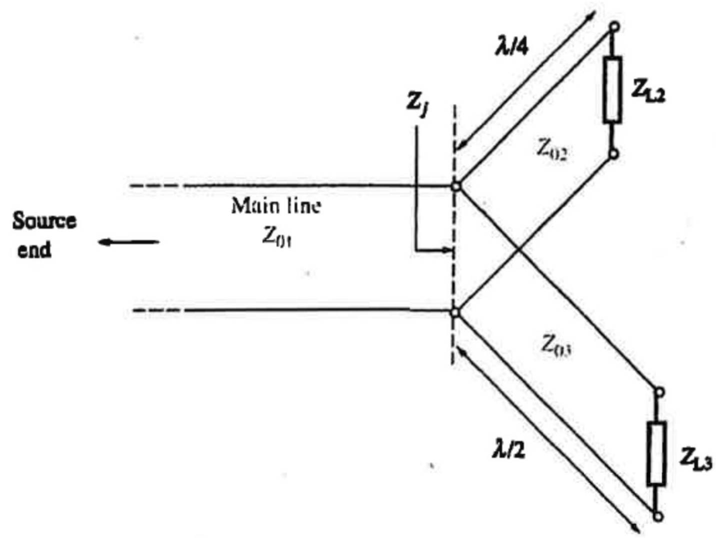
b. Calculate the maximum depletion width, W_m.

c. Calculate the threshold voltage, V_T.

Constants*		Equations (p-type substrate MOSFET)*	
kT = 0.0259 [eV]	(at 300 K)	$\Psi_{s(inv)} = 2\Psi_B = (2kT / q) \ln(p_{po} / n_i)$	
Si Bandgap = 1.12 [eV] (at 300 K)		$W_m = \sqrt{(2\varepsilon_s \Psi_{s(inv)} / qN_A)}$	
Intrinsic carrier concentration of Silicon = 1×10^{10} [cm^{-3}]	(at 300 K)	$V_T = V_o + \Psi_{s(inv)}$	
$N_c = 2.86\times10^{19}$ [cm^{-3}]	(at 300 K)	$V_T = qN_A W_m / C_o + \Psi_{s(inv)} = \sqrt{(2\varepsilon_s qN_A \Psi_{s(inv)})} / C_o + \Psi_{s(inv)}$	
$N_v = 2.66\times10^{19}$ [cm^{-3}]	(at 300 K)	$V_{FB} = \varphi_{ms} - (Q_f + Q_m + Q_{ot}) / C_o$	
Elementary charge = 1.6×10^{-19} [C] ε_o = 8.85E−14 [F/cm]		$I_D = (Z / L)\mu_n C_o (V_G - V_T) V_D$ $I_D = (Z / 2L)\mu_n C_o (V_G - V_T)^2$	(when $V_D < V_G - V_T$) (when $V_D \geq V_G - V_T$)
$\varepsilon_s = 11.9\ \varepsilon_o$ [F/cm]	(Si)		
$\varepsilon_{ox} = 3.9\ \varepsilon_o$ [F/cm]	(SiO_2)		

* Definition of parameters are not provided. It is expected that the examinee interprets the meaning.

Three lossless transmission lines are connected in parallel as shown in the figure below. Assuming sinusoidal steady-state excitation with a source to the left of the main line and the lengths of Z_{02} and Z_{03} lines are shown in the figure, find the reflection coefficient Γ_j on the main line if $Z_{01} = Z_{02} = Z_{03} = Z_{L2} = Z_{L3} = 100\Omega$ and find the main line impedance Z_j .



Problem: 21 **Area: Computational Intelligence** **Code #_________**

Answer the following questions.

(a) What is Computational Intelligence (CI)?

(b) What is the different between the traditional Artificial Intelligence and the modern CI?

Problem: 23 **Area: Computational Intelligence** **Code #_________**

Answer the following questions.

(a) Describe the different types of hardware evolution. Provide diagrams where possible.

(b) Define the following terms:

(i) Clustering

(ii) Augmentation

Problem: 24 **Area: Computational Intelligence** **Code #________**

Answer the questions for parts **a** and **b** below:

(a) Describe with a diagram the steps involved in the design of a fuzzy rule-based reasoning system.

(b) Describe an application and the characteristics of a representative data set for that application that would be appropriate for a:

i) Fuzzy rule-based system

ii) Neural network

a) A program's run time is decided by the product of instructions per program (IC), average clock cycles per instruction (CPI), and clock frequency (f). Assume the following instruction mix for a MIPS-like RISC instruction set: 15% stores, 25% loads, 15% branches, and 35% integer arithmetic, 5% integer shift, and 5% integer multiply. Given that load/store instructions require two cycles, branches requires four cycles, integer ALU instructions require one cycle, and integer multiplies require ten cycles, compute the CPI.

---

b) Given the same parameters in Question A, consider an optimization that converts multiplies by a compile-time constant into a sequence of shifts and adds. For this instruction mix, 50% of the multipliers can be converted to shift-add sequences with an average length of three instructions. Compute the change in instructions per program (IC), average clock cycles per instruction (CPI), and overall program speed-up.

Problem : P26 **Area: Computer Architecture & Embedded Systems** **Student Code:____**

Suppose you are given a simple memory hierarchy with a **direct-mapped** cache memory which can store **8 one-word data blocks** and a **word-addressable** main memory which can store **16 data words**. For a word address sequence of 0000, 1000, 0000, 1000, 1100, 0100 and 1100 in binary, **complete the following table** by showing: tag, index, hit/miss and cache contest after each access. Then, **calculate its hit ratio.**

Addr	Tag	Index	Hit/	Cache content after access							
			Miss	000	001	010	011	100	101	110	111
0000											
1000											
0000											
1000											
1100											
0100											
1100											

Hit ratio =___________

Problem : P27 **Area: Computer Architecture & Embedded Systems** **Student Code:____**

a) Construct a block diagram of 2-way set-associative cache memory. Assume word size is 32 bits, block size is 2 words and this cache memory has 8 blocks. Be sure to show details.

b) If this cache memory is access with 32-bit address, calculate size of tag and index.

Problem : P28 **Area: Computer Architecture & Embedded Systems** **Student Code:____**

Consider the following data for the execution of given instruction sequence of 10 million instructions in different processors.

Processor	Clock Rate	CPI
P1	2GHz	1.25
P2	1.5GHz	0.75

a. Calculate **CPU execution time** for P1 and P2. Which one is better in terms of CPU execution time?

b. Calculate **MIPS** (Millions of instructions per second) for P1 and P2. Which one is better in terms of MIPS?

Problem: 29 **Area: Integrated Circuits and Logic Design** **Code #_________**

Answer the questions for parts **a** and **b** below.

a. Simplify the logic expression $F(a,b,c) = (\bar{a}+\bar{b})(\bar{c}+\bar{b})+(\bar{a}+b)c$ using algebraic manipulation to obtain a logic expression that uses as few gates as possible (exclude inverters from the total gate count). *Show your work for full credit.* DO NOT USE K-MAPS.

b. Construct the truth table for $F(a,b,c) = (\bar{a}+\bar{b})(\bar{c}+\bar{b})+(\bar{a}+b)c$.

Problem: 30 **Area: Integrated Circuits and Logic Design** **Code #_________**

Implement the function $f(a,b,c,d) = b'c' + ac + d'$ based on the approaches in parts **a** and **b** below.

a) Using a 4:1 multiplexer

b) Using a 3-to-8 decoder with active low outputs

Problem: 31 **Area: Integrated Circuits and Logic Design** **Code #_________**

Use full adders (FAs) and logic gates to build a device to compute 5y-3z, where y and z are 4-bit unsigned inputs ($y = y_3y_2y_1y_0$, $z = z_3z_2z_1z_0$). Use an 8-bit representation for all the numbers. Hint: determine how to compute 5y and 3z, then determine how to compute the difference 5y-3z.

Problem: 32 **Area: Integrated Circuits and Logic Design** **Code #_________**

Given the function $f(w, x, y, z) = \sum m\,(0,1,2,3,5,6,8,9,10,12,15)$. Answer the questions for parts a and b below.

---

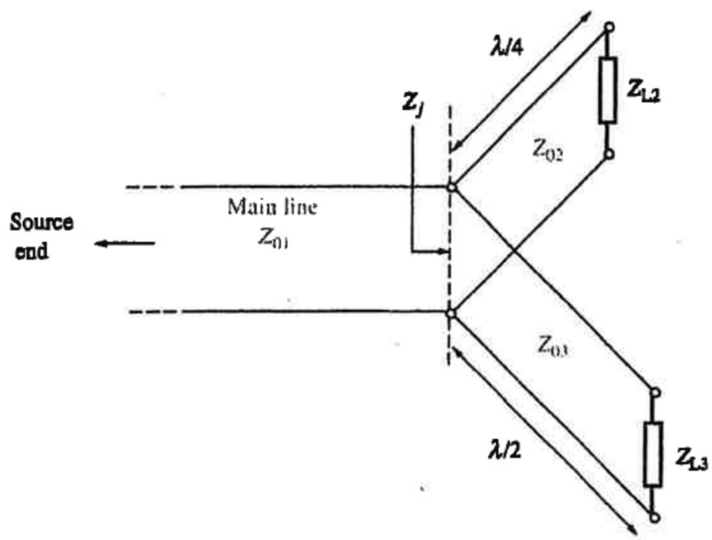
a) Find the minimal POS expression for f.

b) Draw/implement the minimal SOP expression for f only using NAND gates (NAND gates may have any number of inputs).

Solutions

Area: Waves, Devices, & Optics Code #________

Three lossless transmission lines are connected in parallel as shown in the figure below. Assuming sinusoidal steady-state excitation with a source to the left of the main line and the lengths of Z_{02} and Z_{03} lines are shown in the figure, find the reflection coefficient Γ_j on the main line if $Z_{01} = Z_{02} = Z_{03} = Z_{L2} = Z_{L3} = 100\Omega$ and find the main line impedance Z_j.



① $Z_{02} = Z_{L2}$
Matched

② $Z_{03} = Z_{L3}$
Matched

③ parallel $Z_j = \dfrac{1}{\frac{1}{100} + \frac{1}{100}} = 50\Omega$

④ $\Gamma_j = \dfrac{Z_j - Z_{01}}{Z_j + Z_{01}} = \dfrac{50 - 100}{50 + 100} = -\dfrac{1}{3}$