DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
OLD DOMINION UNIVERSITY
MS COMPREHENSIVE EXAM
Fall 2023

ODU HONOR PLEDGE

I pledge to support the Honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism. I am aware that as a member of the academic community, it is my responsibility to turn in all suspected violators of the Honor Code. I will report to a hearing if summoned.

Student Signature: ____

Student Name (BLOCK CAPITALS): _____________________________________

UIN Number: ____

Please turn in this examination document with the pledge above signed and with one answer book for each solved problem.

1. This examination contains 30 problems in the following seven areas:

A.	MATH (At most 2 problems can be answered from the Math area)	A1	A2	A3	A4		
B.	CIRCUITS & ELECTRONICS	B1	B2	B3			
C.	SYSTEMS, SIGNAL AND IMAGE PROCESSING	C1	C2	C3	C4	C5	C6
D.	PHYSICAL ELECTRONICS I	D1	D2	D3			
E.	PHYSICAL ELECTRONICS II	E1	E2	E3			
F.	COMPUTER SYSTEMS	F1	F2	F3	F4	F5	F6
G.	CYBERSECURITY	G1	G2	G3	G4	G5	

2. You must answer five problems (no more than two from the MATH group).
3. Answer in the blue books provided. **Use a separate book for each problem. Put the title and problem number on the front of each book (eg., MATH A-1)**
4. Return all the 30 problems.
5. You will be graded on your answers to five problems only.
6. The examination is "closed-book;" only blue books, exam problems and a scientific calculator are allowed. **No formula sheet is allowed**. Some problems include reference formulas. No material shall be shared without prior permission of the proctor(s).
7. You have four hours to complete this examination.

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
OLD DOMINION UNIVERSITY
PH.D. DIAGNOSTIC EXAM
Fall 2023

ODU HONOR PLEDGE

I pledge to support the Honor system of Old Dominion University. I will refrain from any form of academic dishonesty or deception, such as cheating or plagiarism. I am aware that as a member of the academic community, it is my responsibility to turn in all suspected violators of the Honor Code. I will report to a hearing if summoned.

Student Signature: ____

Student Name (BLOCK CAPITALS): ________________________________

UIN Number: ____

Please turn in this examination document with the pledge above signed and with one answer book for each solved problem.

1. This examination contains 30 problems in the following seven areas:

A.	MATH (At most 3 problems can be answered from the Math area)	A1	A2	A3	A4		
B.	CIRCUITS & ELECTRONICS	B1	B2	B3			
C.	SYSTEMS, SIGNAL AND IMAGE PROCESSING	C1	C2	C3	C4	C5	C6
D.	PHYSICAL ELECTRONICS I	D1	D2	D3			
E.	PHYSICAL ELECTRONICS II	E1	E2	E3			
F.	COMPUTER SYSTEMS	F1	F2	F3	F4	F5	F6
G.	CYBERSECURITY	G1	G2	G3	G4	G5	

2. You must answer eight problems (no more than three from the MATH group).
3. Answer in the blue books provided. **Use a separate book for each problem. Put the title and problem number on the front of each book (eg., MATH A-1)**
4. Return all the 30 problems.
5. You will be graded on your answers to eight problems only**.**
6. The examination is "closed-book;" only blue books, exam problems and a scientific calculator are allowed. **No formula sheet is allowed**. Some problems include reference formulas. No material shall be shared without prior permission of the proctor(s).
7. You have four hours to complete this examination.

PROBLEM A1 – MATH

Solve the 2nd order inhomogeneous differential equation for y as a function of x. We know that $y'(0)=1$ and $y(0)=2$.

$$y''+2y'+y=3x^2$$

PROBLEM A2 – MATH

Consider a surface of revolution generated by rotating a curve $y = f(x)$ about the x-axis, for $a \leq x \leq b$. Show that the surface area is given by

$$A = 2\pi \int_a^b dx\, f(x)\sqrt{1 + f'^2(x)}$$

Now consider the curve $y = \frac{1}{x}$, for $1 \leq x \leq 2$. Prove that the area

$$A > 2\pi\, ln2$$

PROBLEM A3 – MATH

PROBLEM A4 – MATH

<u>Probability</u>

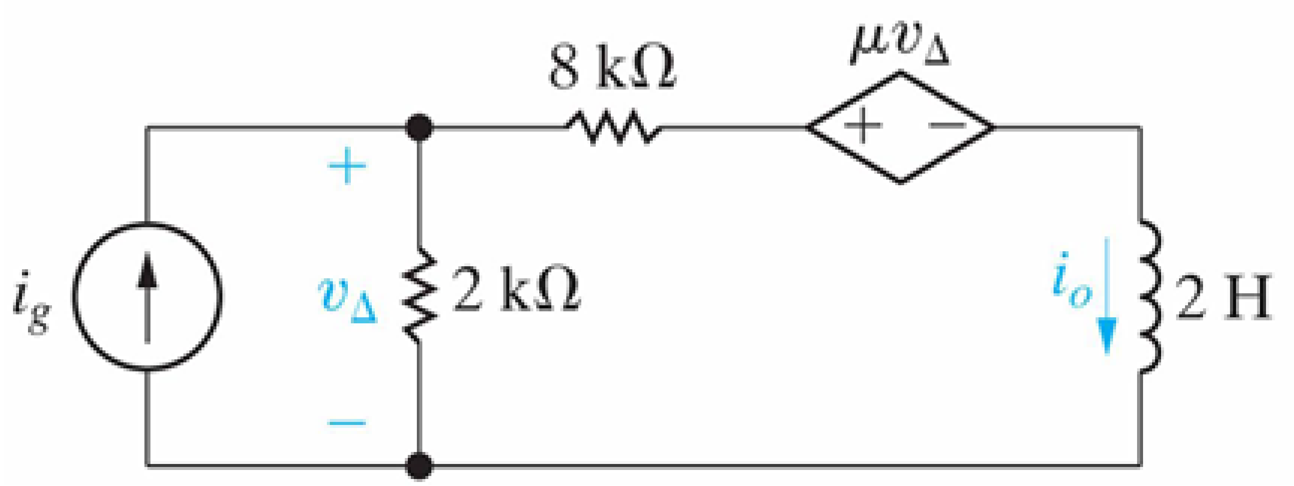
A stick of length 1 is broken at an arbitrary point, and the left piece, say l_1, is selected. The piece l_1 is then broken at an arbitrary point, and now the left piece l_2 is selected.

(a) What is the density function for the length of l_2?

(b) Compute the expected value of the length of l_2.

PROBLEM B1 – CIRCUITS AND ELECTRONICS

Consider the following circuit with a sinusoidal current source.



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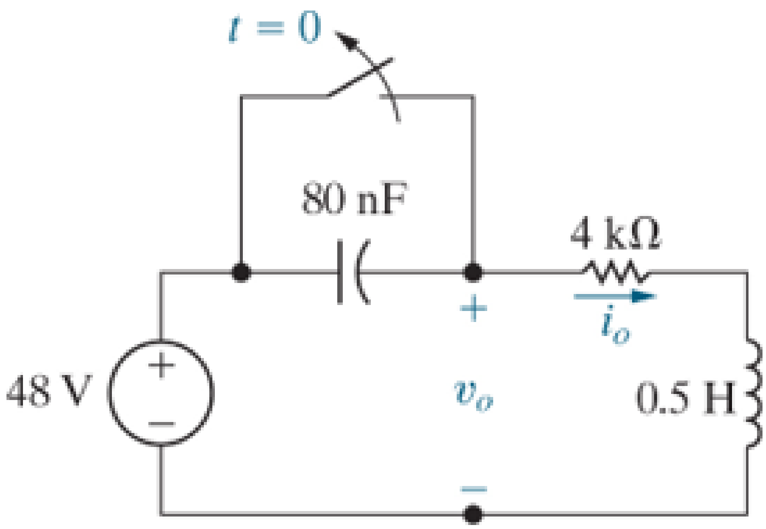
a) (5 points) Use phasor analysis to find the Thevenin equivalent seen by the current source terminals.

b) (5 points) If $i_g(t) = \cos(10t)$ A determine the steady state expression for the voltage $v_\Delta(t)$. Is the voltage waveform leading or lagging the input current waveform?

PROBLEM B2 – CIRCUITS AND ELECTRONICS

The switch in the circuit has been closed for a long time. At time $t = 0$, the switch is opened.

a) Find $V_0(s)$.
b) Find $v_0(t)$ for $t \geq 0$.
c) Find $I(s)$.
d) Find $i_0(t)$ for $t \geq 0$.

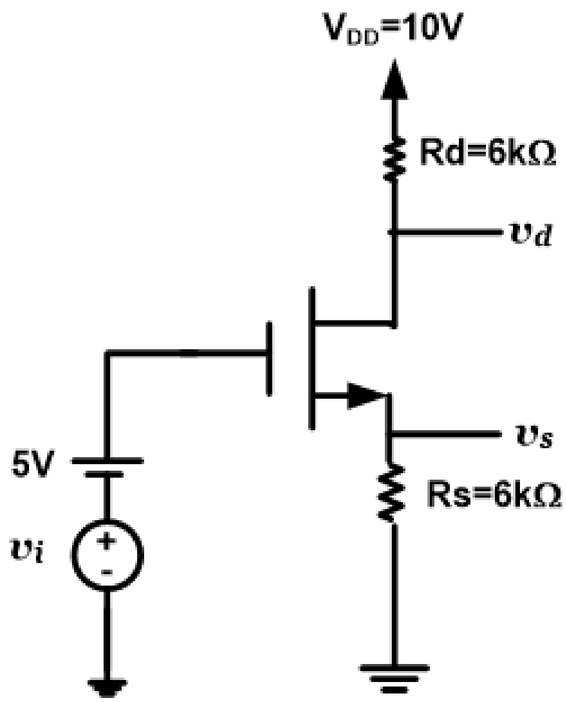


PROBLEM B3 – CIRCUITS AND ELECTRONICS

Electronics

The MOSFET in the below circuit has V_t=1V, $k'(W/L)$=1mA/V^2.

(a) Find $\mathbf{I_D}$
(b) Find the values of $\mathbf{g_m}$
(c) Draw a complete **small signal model** for the amplifier (neglect early voltage)
(d) Calculate the voltage gains (v_s/v_i) and (v_d/v_i)



PROBLEM C1 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Digital Imaging

a. Explain Histogram Equalization.

b. Given the following 3x3 image I (grey image), you need to conduct Histogram Equalization on it and show each step to get the result.

Hint: $\mathbf{J}(r,c,b) = 255 \cdot P_{\mathbf{I}}\left[\mathbf{I}(r,c,b)+1\right].$, where P_I is the cumulative distribution function (CDF) of image, *I*.

100	11	11
100	255	11
50	50	11

Intensity Values for 3x3 Image, *I*

PROBLEM C2 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Consider a LTI system described by the following difference equation:

$$y[n] - 5y[n-1] + 6\,y[n-2] = x[n]$$

a) Determine the system function H[z] for the system. (2 points)

b) Find the impulse response $h[n]$ for the system. (2 points)

c) Is the system stable? Justify it. (2 points)

d) Is the system causal? Justify it (2 points)

e) Determine the zero-state response for input $x[n] = (1/5)^n u[n]$. (2 points)

PROBLEM C3 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

a) We are using N-point DFT to compute linear convolution for two sequences $x[n]$ and $h[n]$, where the length of $x[n]$ is 8 and the length of $h[n]$ is 9. What is the minimum value for N that can avoid time aliasing? (3 points)

b) Two finite length signals, $x_1[n]$ and $x_2[n]$ are given as:

$x_1[n] = u[n] - u[n-6]$

$x_2[n] = u[n] - u[n-3]$

Let $x_3[n]$ be the 7-point circular convolution of $x_1[n]$ and $x_2[n]$, determine $x_3[n]$. (7 points)

PROBLEM C4 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

<u>**Control Systems**</u>

The heading control of bi-wing Stearman aircraft is represented by the block diagram in Figure C2.1.

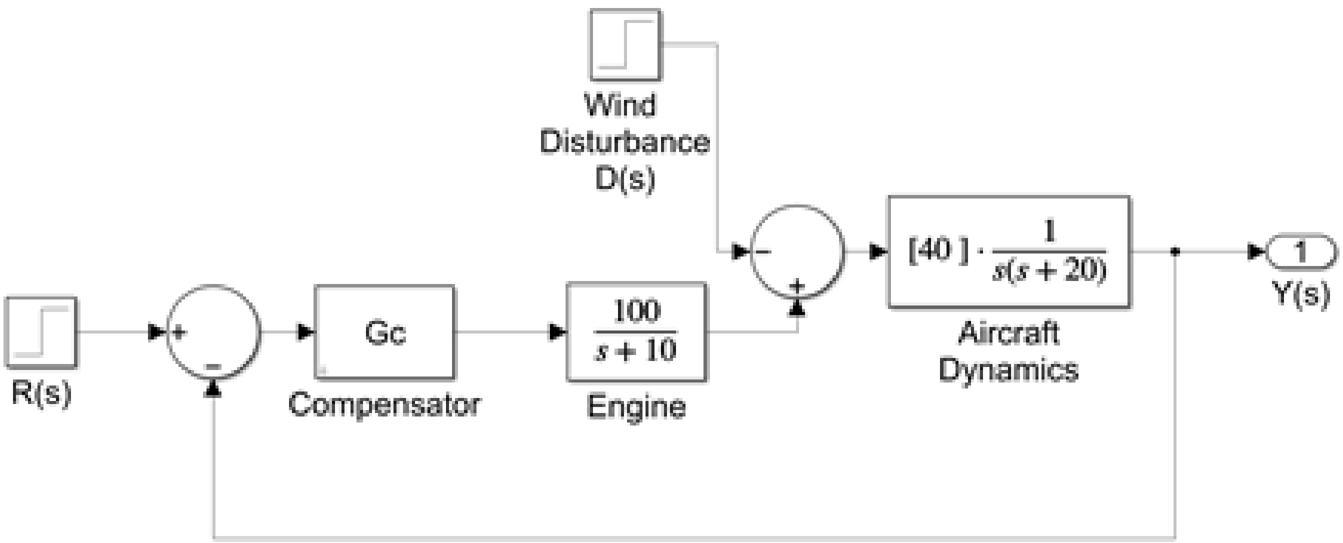


Figure C2.1. Block diagram of heading control in Stearman bi-wing aircraft.

Consider the following control specifications:

Percent Overshoot □ 12%

Settling Time □ 0.8 sec.

The specifications need to be met when R(s) is a unit step input and there is no wind disturbance. Design a lead controller with a pole at s = -60 and a zero at s = -10, that is, the lead compensator is of the form Gc(s) = Kc (s+10)/(s+60). The root locus for Kc > 0 is given in Figure C2.2.

a) Derive the range of values of Kc so that all the design specifications are met. Explain.

b) Select a value of Kc from the range determined in part (a) that gives the smallest steady state error to unit steps in r(t) and wind disturbance, d(t). What is this error?

c) For this value of Kc, approximately what are the gain and phase margins? Are the margins better than when Kc=1 (see Figure C2.3)? Explain why or why not. INCLUDE ALL YOUR WORK IN YOUR SOLUTIONS BOOKLET.

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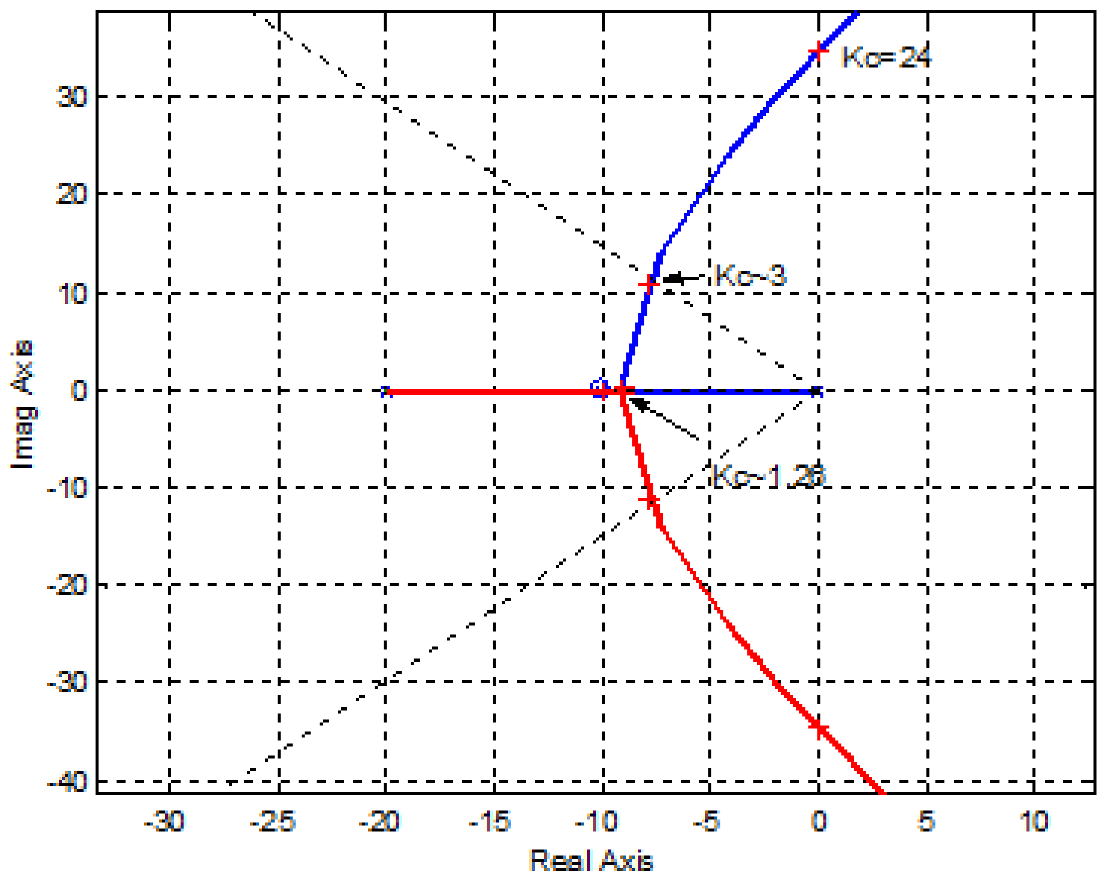

Figure C2.2. Root locus for closed-loop poles with a lead compensator.

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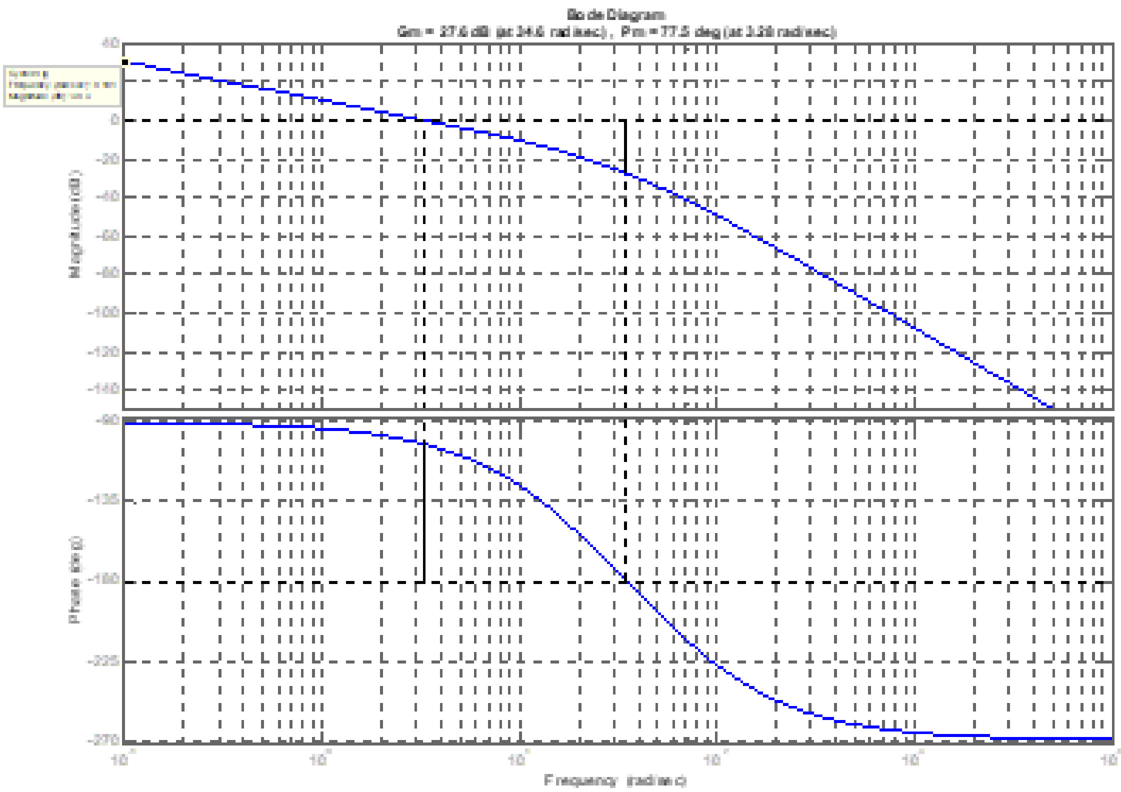


Figure C2.3. Bode plots of loop gain when Kc=1. The magnitude plot crosses the w=0.1 rad/sec line with a magnitude of 30.3 dB.

<u>REVIEW</u>

For a prototype second order open-loop transfer function $G(s) = \omega_n^2/(s^2 + 2\varsigma\omega_n s + \omega_n^2)$ the following unit step response relations are useful:

- percent overshoot = $100 \exp(-\varsigma\pi / \mathrm{sqrt}(1 - \varsigma^2))$
- 2% settling time $\approx 4 / (\varsigma\omega_n)$

Suppose that the loop gain of the closed-loop system can be written as $KG(s)$ with

$G(s) = K_G \dfrac{\prod_{i=1}^{m}(s - z_i)}{\prod_{j=1}^{n}(s - p_j)}$, where K is the gain of the controller that needs to be determined,

$G(s)$ represents the loop gain when K=1, and the loop gain has m zeros at z_i and n poles at p_j. The magnitude condition of root locus states that

$$|K| = \frac{\prod_{j=1}^{n}|s-p_j|}{K_G\left(\prod_{i=1}^{m}|s-z_i|\right)}, \quad \text{whenever } s \text{ a closed-loop pole}.$$

PROBLEM C5 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

PROBLEM C6 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Communications Networks

1. (5 pts) Consider a signal transmitted over a 50KHz channel. If the SNR is 30 dB, what is the maximum achievable rate?

2. (5 pts) Please derive the optimal throughput of pure ALOHA.

PROBLEM D1 – PHYSICAL ELECTRONICS I

Electromagnetics

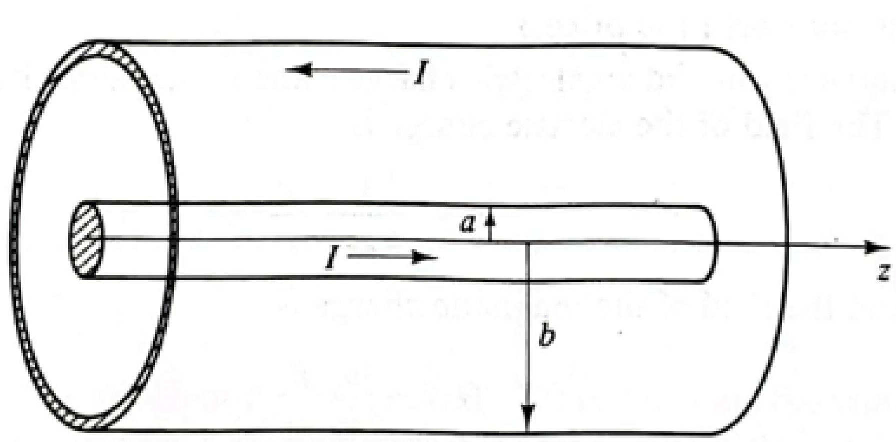
The magnetic field outside a long straight wire carrying a steady current I is

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}\hat{\phi}$$

The electric field inside the wire is uniform:

$$E = \frac{I}{\pi a^2 \sigma}\hat{x}$$

where σ is the conductivity and a is the radius.

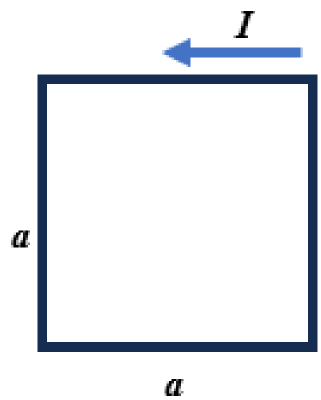


Calculate the electric field outside the wire?

PROBLEM D2 – PHYSICAL ELECTRONICS I

Electrostatics

A square loop of side length a in free space carriers ***a*** steady current of intensity ***I***. Calculate the expression for the magnetic flux density vector at the loop center.



PROBLEM D3 – PHYSICAL ELECTRONICS I

Optical Fiber Communications

A small bug is embedded at the middle of a rectangular block of amber ($\epsilon_r = 1.55$). The top surface of the amber block is a square 5 cm by 5 cm and the height is 2.5 cm. Is it possible to cover the top surface of the block so that the bug will not be seen at any viewing angle from the top? If yes, find the shape and the minimum area to cover. Neglect multiple internal reflections.

PROBLEM E1 - PHYSICAL ELECTRONICS II

Consider a long n-channel **MOSFET** characterized by the following technical parameters:

N^+ polySi gate (with work function $\mathbf{\Phi_M = \chi_S = 4.04\ eV}$);
gate oxide thickness $\mathbf{d_{ox} = 15\ nm}$,
uniform doping $\mathbf{N_A = 10^{17}\ cm^{-3}}$; length $\mathbf{L = 1.0\ \mu m}$, width $\mathbf{Z = 10.0\ \mu m}$,
at a bias given by $\mathbf{V_G = 2.5\ V}$, and $\mathbf{V_{DS} = 1.0V}$, plus back-bias $\mathbf{V_{BS} = 0\ V}$.
Use $\mathbf{\mu_e = 500\ cm^2/\ V\text{-}s}$.

a) Calculate the oxide capacitance $\mathbf{C_{ox}}$ and the factor $\mathbf{K} = (\varepsilon_s\, q\, N_A)^{1/2}/C_{ox}$

b) Calculate the surface potential $\mathbf{\Psi_s}$

c) Calculate the flatband voltage $\mathbf{V_{FB}}$

d) Calculate the threshold voltage $\mathbf{V_T}$

e) Calculate the sheet charge density $\mathbf{Q_i\,(x=0)}$ at the source end of the channel at the indicated bias.

f) Calculate the sheet charge density $\mathbf{Q_i\,(x=L)}$ at the drain end of the channel at the indicated bias. Determine if this MOSFET is actually biased in the linear regime or the saturation regime.

g) Calculate the drain current $\mathbf{I_D}$

If the same MOSFET is now biased with $V_G = 2.5$ V and $V_{DS} = 4$ V, the transistor is now biased in the saturation regime.

a) Calculate the saturation drain current $\mathbf{I_{Dsat}}$

PROBLEM E2 – PHYSICAL ELECTRONICS II

Physical electronics

1. Using an energy-momentum diagram, explain the difference between a direct band gap semiconductor and indirect band gap semiconductor

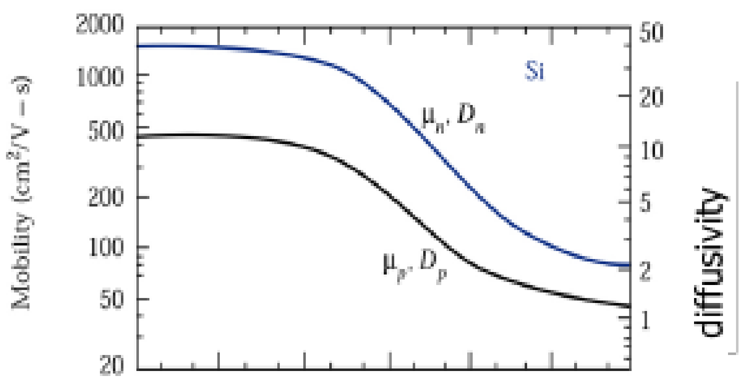
2. A Silicon sample at 300K contains an acceptor impurity concentration of $N_A = 10^{15}$ cm^{-3}. Determine the concentration of donor impurity atoms that must be added so that the silicon is n-type and the Fermi energy is 0.20 eV below the conduction band edge.

3. Find the electron and hole concentration, mobilities and resistivity of Silicon samples at 300K, for each of the following impurity concentrations.

   a) 1.5×10^{15} Boron atoms/cm^3

   b) 5×10^{17} Boron atoms/cm^3 and 2×10^{17} Arsenic atoms/cm^3

Equations and data



$$n = N_c \exp\left(\frac{-(E_c - E_F)}{kT}\right) \qquad p = N_v \exp\left(-\frac{(E_F - E_v)}{kT}\right)$$

$$np = n_i^2 = N_c N_v \exp\left(\frac{-Eg}{kT}\right) \qquad E_{Fi} = \frac{(E_c + E_v)}{2} + \frac{kT}{2}\ln\left(\frac{N_v}{N_c}\right)$$

Silicon (300 K): N_C= 2.86 10^{19} cm^{-3} ; N_V = 2.66 10^{19} cm^{-3} ; n_i = 9.65 10^9 cm^{-3}

m_p =1 m_0; m_n = 0.19 m_0; m_0 = 0.91 10^{-30} kg; k = 1.38 10^{-23} J/K ; q = 1.6 10^{-19} C

$$J = J_n + J_p = (qn\mu_n + qp\mu_p)\mathscr{E}. \qquad \sigma = q(n\mu_n + p\mu_p)$$

PROBLEM E3 – PHYSICAL ELECTRONICS II

(a) (5 points) Consider a homogeneous plasma where the electrons are generated only by electron collisional ionization and lost only by electron-ion recombination. Write an equation for the steady-state electron density n_{e0}.

(b) (5 points) If the ionization is suddenly turned off, how long does it take until the plasma decays to 0.1 n_{e0}?

Assume that the ionization rate coefficient is $k_i = 10^{-15}$ cm^3 s^{-1}, the recombination rate coefficient is $k_r = 10^{-9}$ cm^3 s^{-1}, and the gas density is $n_{gas} = 10^{17}$ cm^{-3}.

PROBLEM F1 – COMPUTER SYSTEMS

<u>Microprocessors</u>

You may used the assembly code listed on the next page or any assembly code for an alternate processor you are familiar with to solve this problem. If you use an alternate processor, please indicate which you are using.

1. (3 points) A real time system guarantees that required tasks complete within a designated time interval. If, due to unforseen circumstances, the task is not completed, some sort of recovery action is required. Describe with original simple code example, how this can be managed if the designated time interval is 1μs. You may assume you have programmable timers available.

2. (5 points) You are implementing an embedded system that can read several 16-bit inputs using memory mapped I/O. Each time you read from the input's designated memory location, you receive a new value. Upon reading the value, you need to confirm it is consistent with previous inputs. If the difference between successive values exceeds 25%, discard that value and continue on to the next. Give the assembly code that will accomplish this.

3. (2 points) Assuming you have 1μs available to process inputs, given your answer to Part 2, assuming the worst case, how many inputs can you process during this interval. Assume your clock frequency is 1GHz and all instructions complete in exactly 5 clock cycles.

Continued on next page

Category	Instruction				Low power	Meaning
Arithmetic	addi	rB,	rA	imm[1]		$rB \leftarrow rA + imm_s$
	add	rC,	rA,	rB		$rC \leftarrow rA + rB$
	sub	rC,	rA,	rB		$rC \leftarrow rA - rB$
	muli	rC,	rA,	rB		$rC \leftarrow (rA \times imm_s)_{31..0}$
	mul	rC,	rA,	rB		$rC \leftarrow (rA \times rB)_{31..0}$
	mulxuu	rC,	rA,	rB		$rC \leftarrow ((unsigned)rA \times (unsigned)rB)_{63..32}$
Logical	and	rC,	rA,	rB		$rC \leftarrow rA$ *and* rB
	andi	rB,	rA,	imm	y	$rB \leftarrow rA$ *and* imm_u
	or	rC,	rA,	rB		$rC \leftarrow rA$ *or* rB
	ori	rB,	rA,	imm	y	$rB \leftarrow rA$ *or* imm_u
	xor	rC,	rA,	rB		$rC \leftarrow rA$ *xor* rB
	xori	rB,	rA,	imm	y	$rB \leftarrow rA$ *xor* imm_u
	nor	rC,	rA,	rB		$rC \leftarrow rA$ *nor* rB
Comparator	cmpgei	rB,	rA,	imm		$rB \leftarrow (rA \geq imm_s)?\ 1 : 0$
	cmplti	rB,	rA,	imm		$rB \leftarrow (rA < imm_s)?\ 1 : 0$
	cmpnei	rB,	rA,	imm		$rB \leftarrow (rA \neq imm_s)?\ 1 : 0$
	cmpeqi	rB,	rA,	imm		$rB \leftarrow (rA = imm_s)?\ 1 : 0$
	cmpgeui	rB,	rA,	imm		$rB \leftarrow (rA \geq imm_u)?\ 1 : 0$
	cmpltui	rB,	rA,	imm		$rB \leftarrow (rA_u < imm_u)?\ 1 : 0$
	cmpge	rC,	rA,	rB		$rC \leftarrow (rA \geq rB)?\ 1 : 0$
	cmplt	rC,	rA,	rB		$rC \leftarrow (rA < rB)?\ 1 : 0$
	cmpne	rC,	rA,	rB		$rC \leftarrow (rA \neq rB)?\ 1 : 0$
	cmpeq	rC,	rA,	rB		$rC \leftarrow (rA = rB)?\ 1 : 0$
	cmpgeu	rC,	rA,	rB		$rC \leftarrow (rA_u \geq rB_u)?\ 1 : 0$
	cmpltu	rC,	rA,	rB		$rC \leftarrow (rA_u < rB_u)?\ 1 : 0$
Shifts	sll	rC,	rA,	rB		$rC \leftarrow rA \ll rB_{4..0}$
	slli	rC,	rA,	imm		$rC \leftarrow rA \ll imm_{4..0}$
	srl	rC,	rA,	rB		$rC \leftarrow rA_u \gg rB_{4..0}$
	srli	rC,	rA,	imm		$rC \leftarrow rA_u \gg imm_{4..0}$
	sra	rC,	rA,	rB		$rC \leftarrow rA_s \gg rB_{4..0}$
	srai	rC,	rA,	imm		$rC \leftarrow rA_s \gg imm_{4..0}$
	rol	rC,	rA,	rB		$rC \leftarrow rA$ *rol* $rB_{4..0}$
	ror	rC,	rA,	rB		$rC \leftarrow rA$ *ror* $rB_{4..0}$
	roli	rC,	rA,	imm		$rC \leftarrow rA$ *rol* $imm_{4..0}$
Memory	ldw	rB,	imm	(rA)	y	$rB \leftarrow MEM[imm_s+rA]$
	stw	rB,	imm	(rA)	y	$MEM[imm_s+rA] \leftarrow rB$
Branch	br	imm			y	$PC \leftarrow PC+4+imm_s$
	bge	rA,	rB,	imm		$if(rA \geq rB)\ PC \leftarrow PC+4+imm_s$
	blt	rA,	rB,	imm		$if(rA < rB)\ PC \leftarrow PC+4+imm_s$
	bne	rA,	rB,	imm	y	$if(rA \neq rB)\ PC \leftarrow PC+4+imm_s$
	beq	rA,	rB,	imm	y	$if(rA = rB)\ PC \leftarrow PC+4+imm_s$
	bgeu	rA,	rB,	imm		$if(rA_u \geq rB_u)\ PC \leftarrow PC+4+imm_s$
	bltu	rA,	rB,	imm		$if(rA_u < rB_u)\ PC \leftarrow PC+4+imm_s$
Jump[2]	call	imm				$PC \leftarrow imm \ll 2$; $retAdd \leftarrow PC+4$
	callr	rA				$PC \leftarrow rA$; $retAdd \leftarrow PC+4$
	ret					$PC \leftarrow retAdd$
	jmp	rA				$PC \leftarrow rA$
	jmpi	imm			y	$PC \leftarrow imm \ll 2$
System	IntEn					Enable interrupt
	IntDs					Disable interrupt

[1] $imm = IR_{15..0}$ unless otherwise noted, imm_s is signed, imm_u is unsigned
[2] for Jump instructions $imm = IR_{27..0}$

PROBLEM F2 – COMPUTER SYSTEMS

Digital Systems

Devise a clocked sequential state machine with one input and two outputs. The input is a 4 bit BCD value, input serially least significant bit to most significant bit on `X`. The two outputs are `Y` and `Z`. Output `Y` outputs the excess-3 encoded version of the input, again least significant bit first. The output `Z` is the overflow. If the excess-3 encoder attempts to encode a value greater than 9, it must report the error by turning on `Z`.

Here are a couple of input/output examples. Note that all values on `X` and `Y` are orientated least significant bit first.

Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
X=1111 Y=0100 Z=0001	X=0000 Y=1100 Z=0000	X=1000 Y=0010 Z=0000	X=0001 Y=1101 Z=0000	X=1001 Y=0011 Z=0000	X=0101 Y=1011 Z=0001

1. (4 points) Give the State Machine (SM) Chart that satisfies the problem description. Please include an encoded state assignment in your solution.

2. (4 points) Provide the State Machine (SM) Table for the SM Chart, and give the logic equations for the next state and outputs.

3. (2 points) Provide all hardware resources necessary to implement the excess-3 encoder using a ROM based controller.

PROBLEM F3 – COMPUTER SYSTEMS

Computer Architecture

Draw a pipeline diagram based on basic 5-stage pipeline to trace the execution of the following instructions. Show any forwarding paths or stalls.

```
ADD   $t0, $t1, $t2
SUBI  $to, $to, 8
LW    St3, 0($to)
ADD   St4, $t3, $t3
```

PROBLEM F4 – COMPUTER SYSTEMS

<u>Computer Algorithms</u>

1. (2 points) Solve the recurrence $T(n) = 4T(n/3) + O(n)$.
2. (5 points) Given an undirected graph, you want to determine whether the graph is a tree. Using depth-first search, give the pseudocode for an algorithm to determine whether the undirected graph is a tree.
3. (3 points) For the previous problem, What is the worst case time and space complexity for your algorithm?

PROBLEM F5 – COMPUTER SYSTEMS

Data Structure

Consider the following pseudocode algorithm for evaluating a postfix expression:

```
for (each character ch in a string){
  if (ch is an operand){
    push value of ch onto stack
  }
  else{ // ch is an operator named op
    operand2 = pop top of stack;
    operand1 = pop top of stack;
    result = operand1 op operand2;
    push result onto stack;
  } // end else
} // end for
 The value is the top of the stack
```

Evaluate the following postfix expression using the algorithm above, assuming the variable values $a = 7, b = 3, c = 12, d = -5, e = 1$. Show the status of the stack at each step of the algorithm.

ab+c-de*+

In here, * is the multiplication sign

PROBLEM F6 – COMPUTER SYSTEMS

Logic Design

A circuit accepts a 4-bit (A, B, C and D) decimal (0-9) numbers such that:

F =1 iff the number is in decimal range ($0 \leq x \leq 9$ and is divisible by 3.

F = 0 elsewhere for the decimal numbers. Remember 0 is not an odd number.

F = d for numbers outside the decimal numbers range. (d = don't care)

(a) (4 pts) Using K-map give the minimal **Sum-of-Product (SOP)** form.

AB \ CD	00	01	11	10
00				
01				
11				
10				

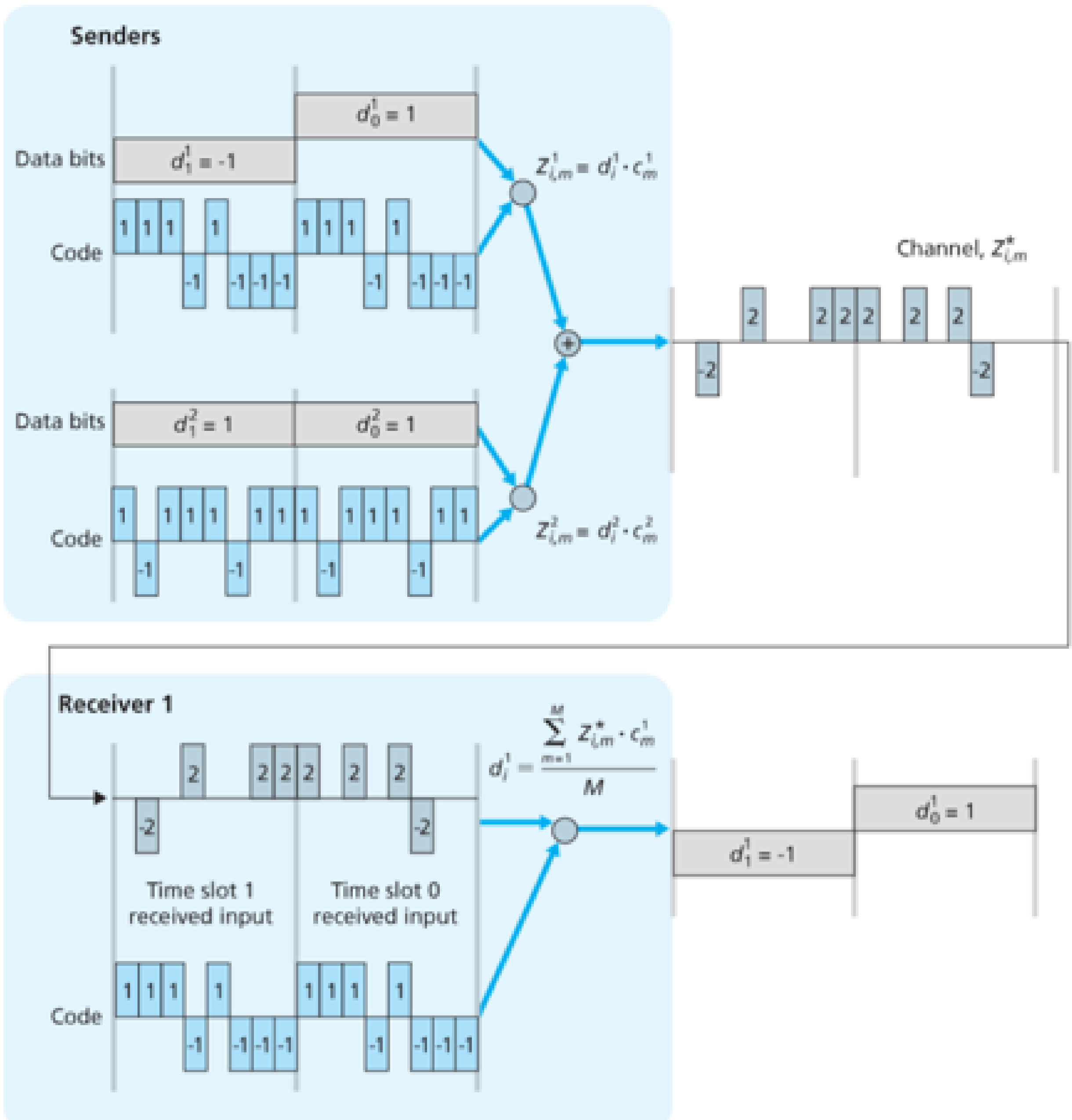
(b) (3 pts) Draw the **minimized SOP of F** in part (a) using "NAND" and "NOT" (INV) gates.

(c) (3 pts) Give the longest path delay and the shortest path delay of the circuit in part b using the gates information in the table

Gate	Max delay t_{pd} (ps)	Min delay t_{cd} (ps)
NOT	15	10
2-input NAND	20	15
3-input NAND	30	25
2-input NOR	30	25
3-input NOR	45	35
2-input AND	30	25
3-input AND	40	30
2-input OR	40	30
3-input OR	55	45
2-input XOR	60	40

PROBLEM G1 – CYBERSECURITY

1. Consider sender 2 in Figure below,
   a) What is the sender's output to the channel if the sender's 2 CDMA code were $(1, -1, 1, -1, 1, -1, 1, -1)$ (before it is added to the signal from sender 1), $Z^2_{i,m}$?
   b) Suppose that the receiver in the Figure wanted to receive the data being sent by sender 2. Show (by calculation) that the receiver is indeed able to recover sender 2's data from the aggregate channel signal by using sender 2's code given in part a.



PROBLEM G2 – CYBERSECURITY

Cyber Defense Fundamentals

1. (5 pts) Assume one year has 365 days. What is the probability that among four people, at least two have the same birthday?

2. (5 pts) What are the important properties that a hash function should have?

PROBLEM G3 – CYBERSECURITY

Cyber Physical System Security

1. (5 pts) Give two approaches for authentication and discuss at least one problem for each approach.

2. (5 pts) Why is the WEP protocol for wireless network security easy to be cracked? Give at least two reasons.

PROBLEM G4 – CYBERSECURITY

Problem 1 - (Format String Vulnerability)

```
int main(int argc, char *argv[])

{

char user_input[100];

scanf("%s", user_input); /* Getting a string from user */

printf(user_input); /* Potential Vulnerability */

return 0;

}
```

For the above code, let us assume that the user_input was "\x11\x01\x84\x08 %x %x %x %x %s".

1) Provide the stack layout after the user_input was provided.
2) Explain how printf function will process the user_input.

Problem 2 – (Race Condition)

```
#include <stdio.h>
#include <unistd.h>
int main()
{
char * fn = "/tmp/XYZ";
char buffer[60];
FILE *fp;
/* get user input */
scanf("%50s", buffer );
if(!access(fn, W_OK))
{
       fp = fopen(fn, "a+");
       fwrite("\n", sizeof(char), 1, fp);
       fwrite(buffer, sizeof(char), strlen(buffer), fp);
       fclose(fp);
}
else printf("No permission \n");
}
```

1. Explain the race condition vulnerability in the above program. Provide an example how the vulnerability can be exploited.
2. Explain how you would fix the vulnerability.

PROBLEM G5 – CYBERSECURITY

A. Define Security and Privacy in cyber-physical systems. Why they are now front and center for system designers? (4 points)

B. Medical devices are increasingly software-controlled, personalized, and networked. An example of such a device is a blood glucose meter, used by doctors and patients to monitor a patient's blood glucose level. Consider a hypothetical glucose meter that can take a reading of a patient's glucose level, show it on the device's display, and transmit it over the network to the patient's hospital. The code is a highly-abstracted version of the software that might perform these tasks.

```
int patient_id; // initialized to the patient's unique identifier.

void take_reading () {

  float reading = read_from_sensor () ;

  display(reading) ;

  send (network_socket, hospital_server, reading, patient_id) ;

  return;

}
```

The function ***take reading*** records a single blood glucose reading and stores it in a floating- point variable ***reading***. It then writes this value, suitably formatted, to the device's display. Finally, it transmits the value along with the patient's ID without any encryption over the network to the hospital server for analysis by the patient's doctor.

a. Does this program preserve privacy of the patient's information? (3 pts)

b. The flow of information from ***reading*** to ***network_socket***, which one is visible to the attacker? (3 pts)