DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING
OLD DOMINION UNIVERSITY
Ph.D. DIAGNOSTIC EXAMINATION
Fall 2013

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 26 problems from the following six 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	D4		
E.	PHYSICAL ELECTRONICS II	E1	E2	E3			
F.	COMPUTER SYSTEMS	F1	F2	F3	F4	F5	F6

2. You must answer Eight problems, but 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 26 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

Complex Variables and Differential Equations

Does the trigonometric identity $\sin(2z) = 2 \sin z \cos z$, which holds when z is a real number, also hold when z is a complex number? Either prove this is true in general *or* provide a specific counterexample to show it is false.

PROBLEM A2 – MATH

Vector Calculus

Consider the vector field

$$A(x,y) = \begin{pmatrix} -x \\ y \end{pmatrix}$$

(a) Make a sketch of $A(x,y)$. You do not need to be numerically accurate, but you need to capture the qualitative features of A.
(b) Compute curl(A) and interpret your result.
(c) Is there a function $f(x,y)$ so that $A(x,y) = \text{grad}(f)$? If yes, provide such an f. If no, explain why not.

Good luck!

PROBLEM A3 – MATH

Linear Algebra

Consider a complex-valued matrix with dimensions $n \times n$: $A = [a_{ij}]_{1 \le i,j \le n}$.

1. Define the transpose matrix A^T, the complex conjugate matrix A^*, the Hermitian transpose matrix A^H, and show that if $A = A^H$ all of its eigenvalues are real.
2. Knowing the power series for the exponential function $e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!}$ state the definition of the matrix exponential e^A.
3. State what is the condition for matrix A to be diagonalizable, and assuming that this condition is satisfied, write the expression of the matrix exponential e^A which involves its diagonal form.

PROBLEM A4 – MATH

Probability

Consider a race with N runners, where N is unknown. Each runner is assigned at random a unique number between 1 and N. Suppose a group of n runners is observed crossing the finish line. Let z denote the largest number assigned within this group.

(a) Compute the expected value of z.
(b) Estimate N using your answer from part (a).
(c) Suppose 5 runners cross the finish line, and the largest number observed in this group is 100. About how many runners are in the race total?

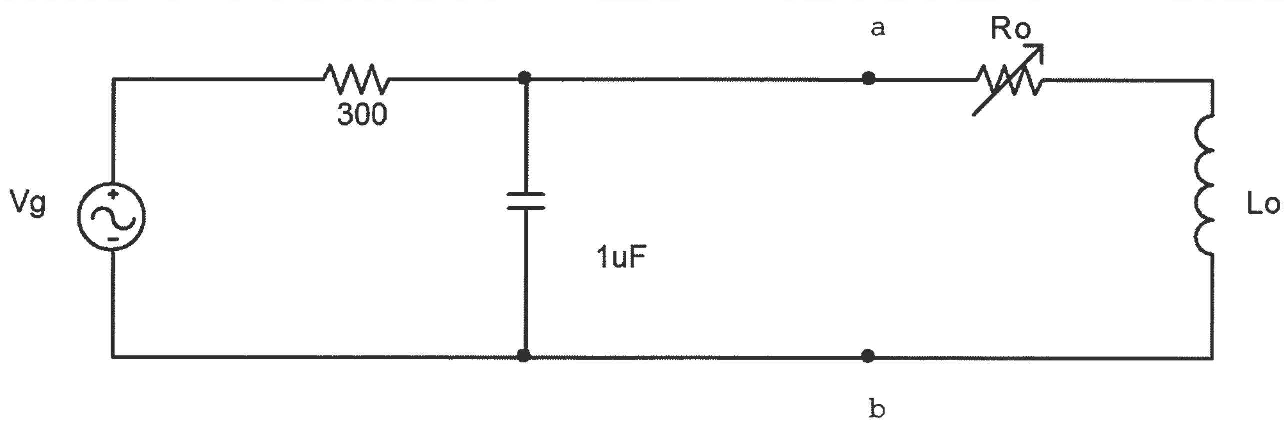
PROBLEM B1 – CIRCUITS AND ELECTRONICS

<u>**Circuits**</u>

Sinusoidal Steady State Analysis

The peak amplitude of the sinusoidal voltage source in the circuit shown is $150\sqrt{2}$ V, and its period is 200π µs. The load resistor can be varied from 0 to 20Ω, and the load inductor can be varied from 1 to 8 mH.

a) Calculate the average power delivered to the load when $R_o = 10\Omega$ *and* $L_o = 6mH$.
b) Determine the settings of R_o *and* L_o that will result in the most power being transferred to R_o.
c) What is the most average power in (b)? Is it greater than the power in (a).
d) If there are no constraints on R_o *and* L_o, what is the maximum average power that can be delivered to a load?
e) What are the values of R_o *and* L_o for the condition of (d)?
f) Is the average power calculated in (d) larger than that calculated in (c)?



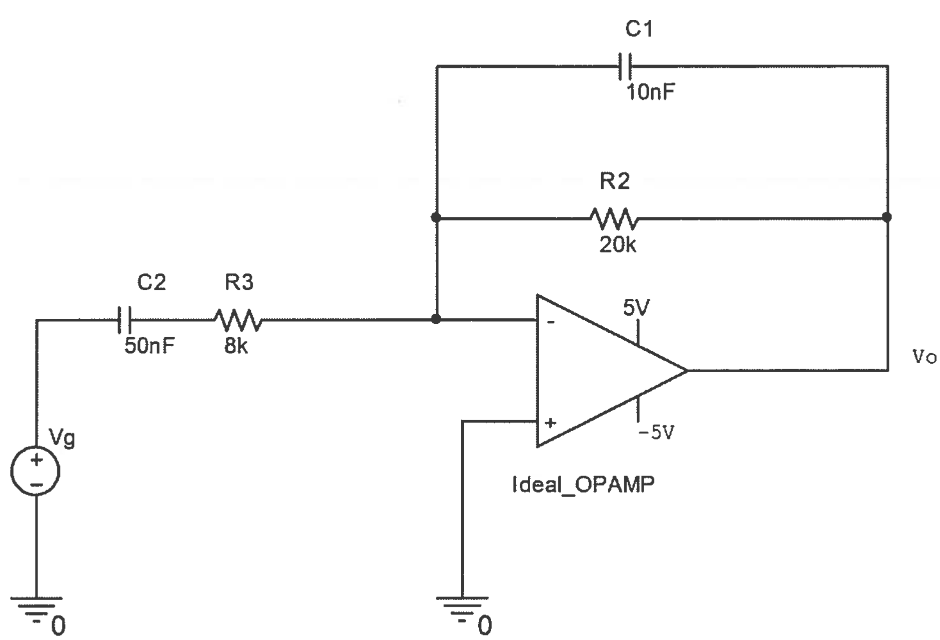
PROBLEM B2 – CIRCUITS AND ELECTRONICS

Circuits

Laplace Application to Circuit Analysis

The op amp shown in the circuit is ideal. There is no energy stored in the circuit at the time it is energized. Let $v_g = 20{,}000\, u(t)\, V$, where $u(t)$ is a unit step function.

a. Find $V_o(s)$.
b. Find $v_o(t)$.
c. How long does it take to saturate the operational amplifier?
d. How small the rate of increase in v_g must be to prevent saturation?

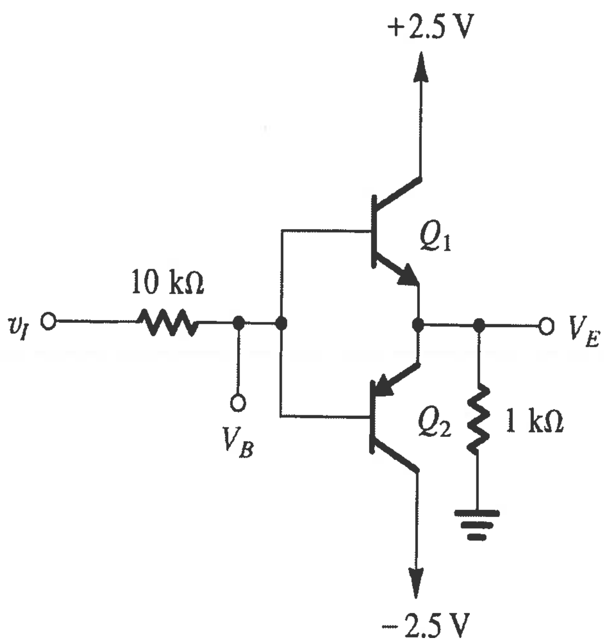


PROBLEM B3 – CIRCUITS AND ELECTRONICS

Electronics

For a BJT circuit and v_i=2.5V. Calculate V_B, V_E, I_B, I_C, I_E when the BJTs Q1 and Q2 have β=100. Assume a constant voltage drop of 0.7V when BJTs Q1 and Q2 are on.

V_B=	V_E=	I_B=
I_C=	I_E=	



PROBLEM C1 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Image Processing

1) Analytically prove that Laplacian operator is rotation invariant. (5 points)
2) Show that Fourier transform is linear. (5 points)

PROBLEM C2 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Digital Signal Processing

Consider the discrete-time sequence given below:

$$x[n] = 4\delta[n-1] + 3\delta[n-2] + 2\delta[n-3] + \delta[n-4]$$

a. Determine the z-transform of x[n]. (1 pt)

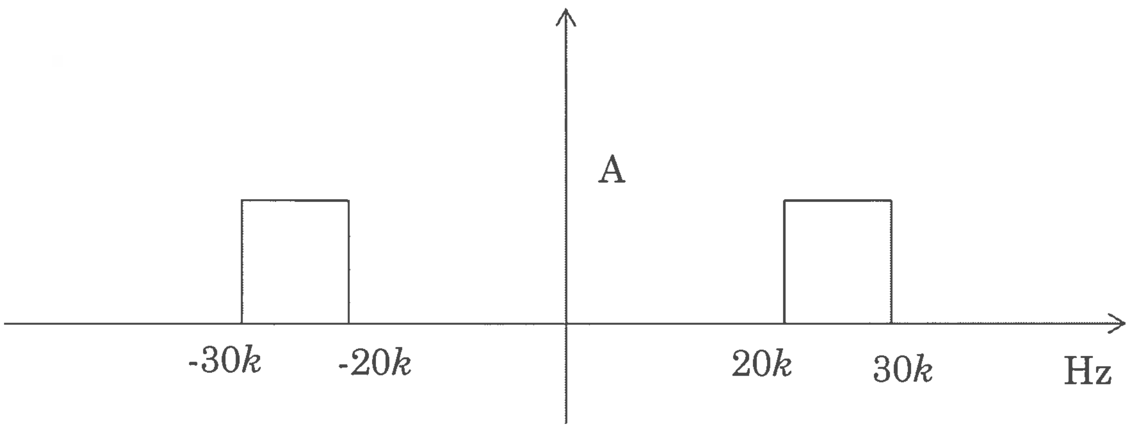
b. Determine the z-transform of the convolution $-2x[n] * x[3-n]$. (3 pts)

c. A new discrete-time sequence, y[n], is created by repeating x[n] with a period of $N = 5$ for $n \geq 0$ and $y[n] = 0$ for $n < 0$. Determine the z-transform of y[n]. (6 pts)

PROBLEM C3 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Digital Signal Processing

An analog signal, $x(t)$, has a spectrum as shown below.



a) What is the bandwidth of the signal? What is the Nyquist rate for $x(t)$? (2 points)
b) Assume that you sampled the analog signal, $x(t)$, using a sampling frequency of 80k Hz and obtained a discrete-time signal $x[n]$, draw the spectrum of $x[n]$. (4 points)
c) If we generate another analog signal by the following equation,

$$y(t) = x(t)^2$$

draw the spectrum of $y(t)$. (2 points)

d) What is the bandwidth of $y(t)$? (2 points)

PROBLEM C4 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Control Systems

CONTROL SYSTEMS

A practical and daily application of control is the control of the arm position of a hard drive as shown in Figure 1. Careful placement of the arm is important, since at its tip is the head used to read the information on the drive's platters.

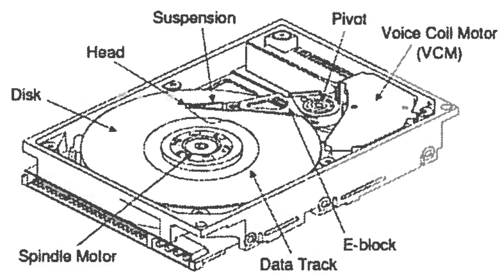


Figure 1. Components of a typical hard disk drive.

For the purpose of this problem, consider a simplified transfer function of the arm system. The output is the translational displacement $c(t)$ and the input is a force $u(t)$. Suppose that the transfer function of this arm system is

$$G_p(s) = \frac{10^4}{s^2}.$$

If the arm's position is measured and a controller can deliver the force to the arm system, the closed-loop system of interest is shown in Figure 2.

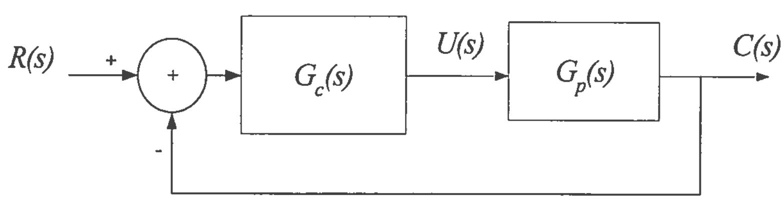


Figure 2. Block diagram of a closed-loop system.

a) Determine if a proportional controller, that is, if $G_c(s) = K$, can result in a stable closed-loop system.

b) Let $G_c(s) = \dfrac{K(s+1000)}{s+15000}$.

   a. Find the range of K that results in a stable closed loop system.

   b. When $K = 1$ the Bode diagram of $G_c(s)G_p(s)$ is given in Figure 3. Determine the Gain and Phase Margins. Explain the significance of these margins for this closed-loop system.

c. Select a value for the gain K so that the Phase Margin is as large as possible. What is this Phase Margin?

d. For your designed closed-loop system in (c), find the steady-state error to a unit step input.

e. For your designed closed-loop system in (c), when a unit step input is applied to the closed-loop system, what is the initial value of the force applied by the controller?

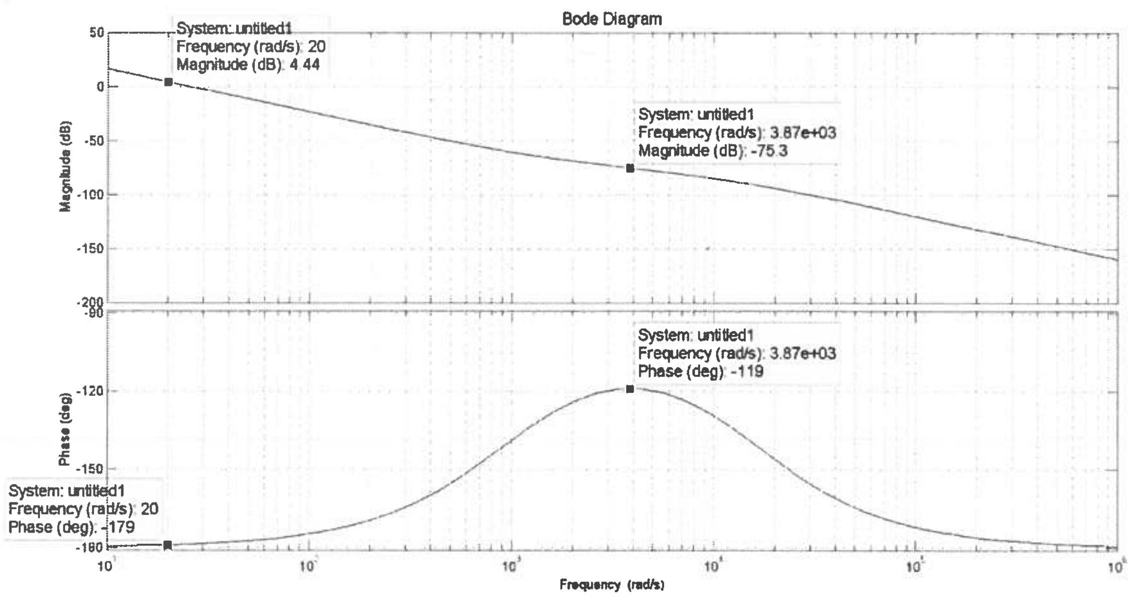


Figure 3. Bode diagram when K=1.

Laplace's Theorems

Let F(s) be the Laplace transform of f(t) .

- Initial Value Theorem
  - Now, if *F(s)* be a strictly proper rational transfer function (degree denominator > degree numerator), then

$$f\left(0^+\right) = \lim_{s\to\infty} sF\left(s\right).$$

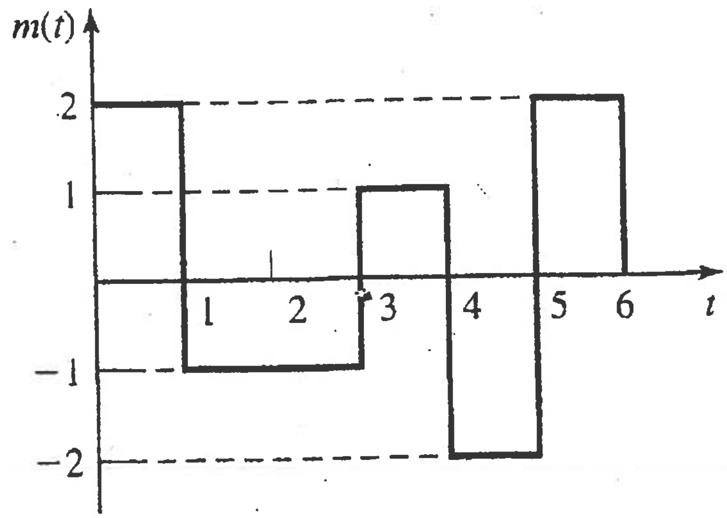
- Final Value Theorem
  - If all the poles of *sF(s)* have negative real parts, then

$$\lim_{t\to\infty} f\left(t\right) = \lim_{s\to 0} sF\left(s\right).$$

PROBLEM C5 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Communication systems

Consider the information-bearing signal $m(t)$ given in the figure below:



which modulates in frequency the sinusoidal carrier $c(t) = 10\cos(6000\pi t)$ V. The frequency deviation constant of the modulator is $k_f = 25$ Hz/V.

1. Describe how frequency modulation (FM) of the carrier $c(t)$ with $m(t)$ is accomplished and write the mathematical expression of the instantaneous frequency of the resulting FM signal $u(t)$.
2. Write the expression of the frequency deviation $f_d(t)$ of the FM signal from the instantaneous frequency of the unmodulated carrier and sketch its plot.
3. Write the expression of the phase deviation $\phi_d(t)$ from the instantaneous phase of the unmodulated carrier and sketch its plot.

PROBLEM C6 – SYSTEMS, SIGNALS AND IMAGE PROCESSING

Communication Networks

1. (6 points) In the slotted ALOHA system, the time is slotted and all stations are synchronized. All frames have the same length and the slot duration is the frame time. Whenever a station has a frame ready, it transmits the frame at the start of the following slot. The sender has the ability to find if the frame is destroyed. If the frame is destroyed, the sender waits a random number of slots and retransmits the frame. Note that the frame transmission always begins at the start of a slot. Assume the number of new and retransmitting frames follows a Poisson distribution, with mean of G frames per frame time (slot).

(a) (4 points) Derive the throughput of the slotted ALOHA system.

(b) (2 points) What is the maximum throughput of the slotted ALOHA system? You need to write down the procedure to derive the maximum throughput.

2. (4 points) Please describe what are the 1-persistent and non-persistent CSMA protocols, and the difference between them. It is recommended to draw a flow chart to illustrate the protocols.

PROBLEM D1 – PHYSICAL ELECTRONICS I

Electromagnetics

The complex wavenumber, k, is given as: $\omega\,[\mu\varepsilon\{1\text{-}j\sigma/(\omega\varepsilon)\}]^{1/2} = k_r - j\,k_{im}$.

(a) If ice has $\sigma \sim 10^{-6}$ /Ωm, $\varepsilon = 3.2\ \varepsilon_0$, and $\mu = \mu_0$ calculate a possible frequency range for which ice would behave as a good conductor.

(b) Compute the penetration depth of EM waves in ice at 10^6 Hz.

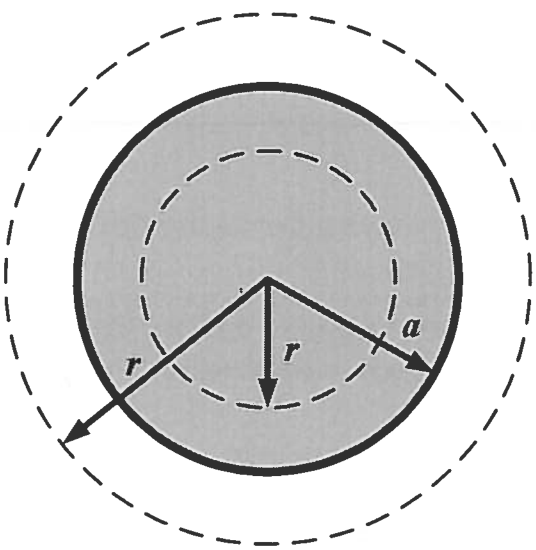
Use $\varepsilon_0 = 8.85\text{x}10\ \text{-}12$ F/m and $\mu_0 = 4\ \pi\ \ 10^{-7}$ Henry/m if needed.

PROBLEM D2 – PHYSICAL ELECTRONICS I

Electromagnetics

A total of q coulombs of charge is uniformly distributed in a spherical region defined by r ≤ a as shown in below figure. Calculate the electric fields when i) r ≤ a and r ≥ a. Assume that the permittivity of the material is ε.

$$E_r = \begin{cases} & \text{For } r \leq a \\ & \text{For } r \geq a \end{cases}$$



PROBLEM D3 – PHYSICAL ELECTRONICS I

Lasers

A helium-neon laser cavity consists of two mirrors separated by 30 cm. The gain bandwidth over which lasing can occur is 1.6 GHz. The laser is operating with an average power of 8 mW. If the laser is modelocked, find:

(2 points) (a) The time between two pulses.

(2 points) (b) The approximate pulse duration.

(2 points) (c) The approximate peak power of each pulse.

(2 points) (d) Write a paragraph that discusses active and passive modelocking.

(2 points) (e) Discuss why we can get femtosecond laser pulses in modelocked Ti:sapphire lasers but only picosecond pulses in modelocked Nd:YAG lasers.

Mass of electron = 9.10938×10^{-31} kg
Mass of hydrogen atom = 1.67372×10^{-27} kg
Charge of electron = $-1.6021766 \times 10^{-19}$ Coulombs
Avagadro's number = 6.022141×10^{23}
Boltzamann's constant = 1.38065×10^{-23} J/K

Gas constant = 8.3145 J/(mol K)
Planck's constant = 6.62607×10^{-34} Js
Permittivity of free space = 8.854×10^{-12} F/m
Permeability of free space = 1.257×10^{-6} H/m
Velocity of light in free space = 3×10^{8} m/s

1 atm = 760 torr = 1.013×10^{5} $\mathrm{N/m^2}$; 1 Å = 10^{-10} cm

eV	electron volt	1.6×10^{-19} J
1 eV of temperature KT		11,600°K

$$\int_0^\infty e^{-x^2}\,dx = \frac{\pi^{1/2}}{2}$$

$$\int_0^\infty x^{1/2} e^{-ax}\,dx = \frac{(\pi/a)^{1/2}}{2a}$$

$$\int_0^\infty x^n e^{-ax^2}\,dx = \begin{cases} \dfrac{(1)(3)(5)\cdots(n-1)}{2(2a)^{n/2}}\left(\dfrac{\pi}{a}\right)^{1/2} & \text{for even } n \geq 2 \\ \dfrac{[(n-1)/2]!}{2a^{(n+1)/2}} & \text{for odd } n \geq 1 \end{cases}$$

$$\int_{-\infty}^\infty x^n e^{-ax^2}\,dx = \begin{cases} 2\int_0^\infty x^n e^{-ax^2}\,dx & \text{for even } n \\ 0 & \text{for odd } n \end{cases}$$

$$\frac{2}{\pi^{1/2}}\int_0^z e^{-x^2}\,dx = \mathrm{erf}\,(z)$$

PROBLEM D4 – PHYSICAL ELECTRONICS I

Optical Fiber Communications

When a current pulse is applied to a laser diode, the injected carrier pair density n within the recombination region of width d changes with time according to the relationship

$$\frac{\partial n}{\partial t} = \frac{J}{qd} - \frac{n}{\tau}$$

a) Assume τ is the average carrier lifetime in the recombination region when the injected carrier pair density is n_{th} near the threshold current J_{th}. That is, in the steady state we have

$$\frac{\partial n}{\partial t} = 0 \qquad \text{so that} \qquad n_{th} = \frac{\tau J_{th}}{qd}$$

If a current pulse of amplitude I_p is applied to an unbiased laser diode, show that the time needed for the onset of stimulated emission is,

$$t_d = \tau \, ln \frac{I_p}{I_p - I_{th}}$$

PROBLEM E1 - PHYSICAL ELECTRONICS II

Solid State Electronics
An abrupt Si P-N Junction with a cross-section of $A = 10^{-4}$ cm^2 has the following properties:

P side	N side
$N_a = 10^{17}$ cm^{-3}	$N_d = 10^{15}$ cm^{-3}
$\tau_n = 0.1$ µs	$\tau_p = 10$ µs
$\mu_p = 200$ cm^2/ V-s	$\mu_n = 1300$ cm^2/ V-s
$\mu_n = 700$ cm^2/ V-s	$\mu_p = 450$ cm^2/ V-s

The junction is forward biased by 0.5 V.

a) What is the total forward current for an ideal p-n junction at + 0.5V bias?
(Need to calculate D_p, D_n, L_p, L_n, p_n, n_p)
b) What is the total current at a reverse bias of – 0.5V?
c) Calculate the junction potential Φ_0
d) What is the total Transition Capacitance C_T (also known as depletion capacitance) at -4 V reverse bias ?
e) Calculate the depletion widths l_{po} and l_{no} for the following reverse biases -4 V and -10 V

Equations: Hole Current:

$$I_p = -qAD_p\frac{dp}{dx} = qA\frac{D_p}{L_p}(\Delta p)e^{-\frac{x}{L_p}}$$

Depletion Capacitance:

$$C_j = \sqrt{\epsilon}A\left[\frac{q}{2(V_0 - V)}\frac{N_dN_a}{N_d + N_a}\right]^{1/2}$$

Physical Constants :

Intrinsic carrier concentration in Si : $n_i = 1.45 \times 10^{10}$ cm^{-3}

Permittivity in Vacuum $\varepsilon = 8.8854 \times 10^{-14}$ F/ cm ;

Elementary Charge : $q = 1.602 \times 10^{-19}$ C

Boltzman Constant: $k = 1.38066 \times 10^{-23}$ J/ K

Thermal voltage at 300K: $kT/q = 0.0259$ V

PROBLEM E2 – PHYSICAL ELECTRONICS II

Physical Electronics

1. Draw a (111) plane and a (110) plane for crystalline silicon

2. Assume that you have an intrinsic silicon wafer
    a. Calculate the location of the intrinsic Fermi level, *Ei*, in silicon at liquid nitrogen temperature (77K), at 330K, and at 200°C. Assume that $m_p = 1.0\ m_0$ and that $m_n = 0.21\ m_0$.
    b. Is it reasonable to assume that *Ei* is in the center of the forbidden gap?

Equations:

$$E_i = (E_C + E_V)/2 + (kT/2)\ln(N_V/N_C)$$

$$N_V = 2(2\pi m_p kT / h^2)^{3/2}$$

$$N_C = 2(2\pi m_n kT / h^2)^{3/2}$$

$Eg(T) = Eg(0) - \alpha T^2/(T+\beta)$ with $Eg(0) = 1.17$ eV; $\alpha = 4.73\ 10^{-4}$ eV/K ; $\beta = 636$ K

$k = 1.38\ 10^{-23}$ J/K $\quad h = 6.62\ 10^{-34}$ J.s

PROBLEM E3 – PHYSICAL ELECTRONICS II

Plasma Science and Discharges

A vacuum chamber with a volume of 1 m^3 develops a leak. The pressure inside the chamber rises from 1μTorr to 0.1 mTorr in 1 minute. Consider the air as purely nitrogen gas at room temperature.

a./ Calculate the flux of nitrogen molecules impinging on the outer surface of the chamber.
b./ How many nitrogen molecules leaked into the chamber?
c./ What is the area of the leak?

Note: Nitrogen atomic mass is 14. Nitrogen gas is diatomic (N_2).
Consider room temperature as 300 K
Mass of the proton, m_p, is $1.67\text{x}10^{-27}$ kg.
Boltzmann's constant is: $k = 1.38\text{x}10^{-23}$ J/°K
Assume that the particle density, n, as a function of pressure, P, is given by:
$n = 3.25\text{x}10^{16}.\ P$
where n is in cm^{-3}, and where the pressure is in Torr.

PROBLEM F1 - Computer Systems

Microprocessors

Write a subroutine that calculates the nth number in the Fibonacci series in a **Motorola 6811 microprocessor based system**. The Fibonacci series is defined as follows. Given that $F_1 = 1, F_2 = 1$, then the nth Fibonacci number $F_n = F_{n-1} + F_{n-2},\ \ n > 2$. The value of n is an 8-bit value found in memory location **$0000**. Upon completion the nth Fibonacci number should be stored in memory location **$1000.**

You may safely use memory locations **$0001** to **$00FF** for storage of any temporary variables.

Details:	Style - Write your code in a three column format, i.e.:			
	LABEL:*	**MNEMONIC**	**OPERAND***	(* use only when required / needed)
Example:	***LOOP:***	***BRA***	***LOOP***	

Symbols: The use of a # sign before an operand designates immediate addressing mode, $ - hexadecimal, % - binary.

Example: LDAA #$F0 – The value F0 hexadecimal is loaded into AccA.

Addressing modes:
- Immediate example: LDAA #$F0 (A← $F0)
- Direct example: LDAA $F0 (A← M[$00F0])
- Extended example: LDAA $00F0 (A← M[$00F0])
- Indexed example: LDAA 0, X (A ← M[X+0])

Available instructions:

LDAA / STAA : Load / Store Accumulator A (one byte)
LDAB / STAB : Load / Store Accumulator B (one byte)
LDD/STD : Load / Store Accumulator D (A + B, double byte)
LDX / STX : Load / Store index register X (double byte)
LDY / STY : Load / Store index register Y (double byte)
LDS/STS : Load/Store Stack Pointer (double byte)
TSX / TXS : Transfer SP in X / Transfer X in SP

ABA : Add Accumulators A + B → A
ABX/ABY : Add B to X/Y, IX/IY + 00:B → IX/IY
ADCA/ADCB : Add with Carry to A/B, A/B + M + C → A/B
ADDA/ADDB : Add Memory to A/B, A/B + M → A/B

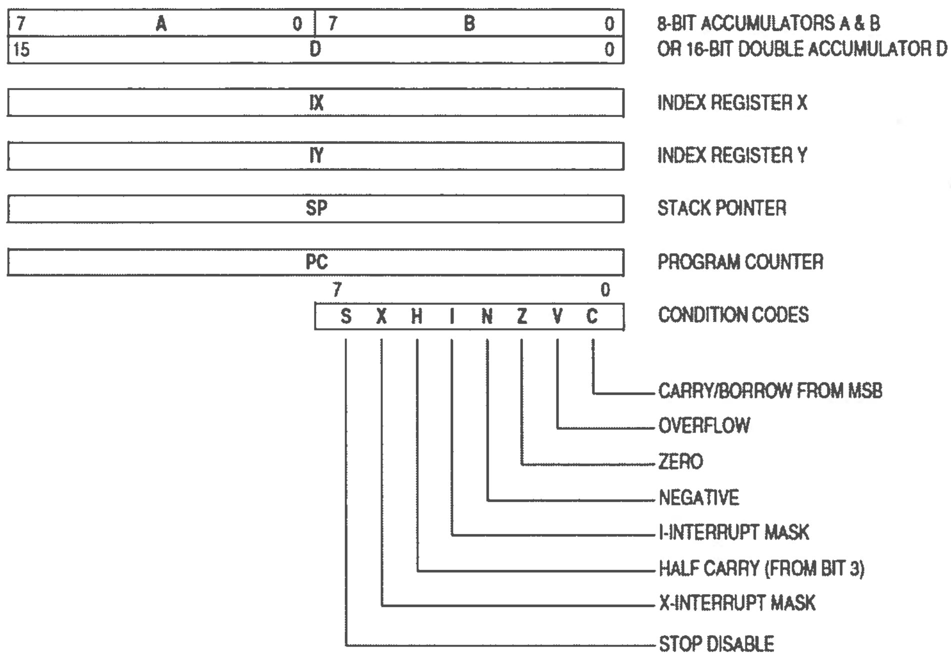
PSHA / PULA : Push / Pull Acc. A on / from the stack
PSHB / PULB : Push / Pull Acc. B on / from the stack
PSHX / PULX : Push / Pull index register X on / from the stack
PSHY / PULY : Push / Pull index register Y on / from the stack

INCA / DECA : Increment / Decrement AccA – Inherent addressing
INCB / DECB : Increment / Decrement AccB
INC / DEC : Increment / Decrement memory location contents
INX / DEX : Increment / Decrement index register X
INY / DEY : Increment / Decrement index register Y
INS / DES : Increment / Decrement stack pointer

BRA : Branch always - Relative addressing
BEQ : Branch if equal to zero
BNE : Branch if not equal to zero
BGT : Branch if greater than zero
BLT : Branch if less than zero
BGE : Branch if greater than or equal to zero
BLE : Branch if less than or equal to zero
BMI : Branch if minus
BPL : Branch is plus
JMP : Jump to the given address – Absolute addressing
RTS : Return from subroutine

CLRA : Clear contents of AccA (A ← $00)
CLRB : Clear contents of AccB (B ← $00)
CLR : Clear memory location contents (M ←$00)

CMPA : Compare AccA to memory (A – M)
CMPB : Compare AccB to memory (B – M)
CBA : Compare AccB to AccA (A-B)
CPX : Compare index register X to memory (X – MM)
CPY : Compare index register Y to memory (Y – MM)


7
A
0
7
B
0
15
D
0
IX
IY
SP
PC
7
0
S X H I N Z V C
8-BIT ACCUMULATORS A & B
OR 16-BIT DOUBLE ACCUMULATOR D
INDEX REGISTER X
INDEX REGISTER Y
STACK POINTER
PROGRAM COUNTER
CONDITION CODES
CARRY/BORROW FROM MSB
OVERFLOW
ZERO
NEGATIVE
I-INTERRUPT MASK
HALF CARRY (FROM BIT 3)
X-INTERRUPT MASK
STOP DISABLE

PROBLEM F2 – COMPUTER SYSTEMS

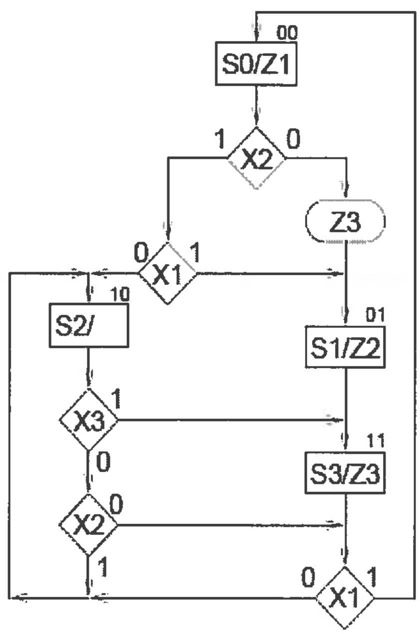
Digital System Design

Digital Systems

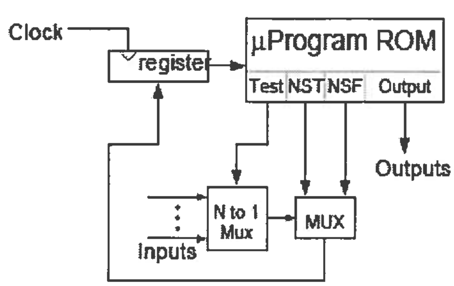
Fall 2013

Problem Description:

1. (4 points) Modification the SM chart given below so that it is compatible with a two-address microcoded controller.



2. (6 points) Give the configuration of the two-address microcoded controller as well as the contents of the control store for the compatible state machine from Part 1. Use the following two-address controller schematic as a reference.



PROBLEM F3 – COMPUTER SYSTEMS

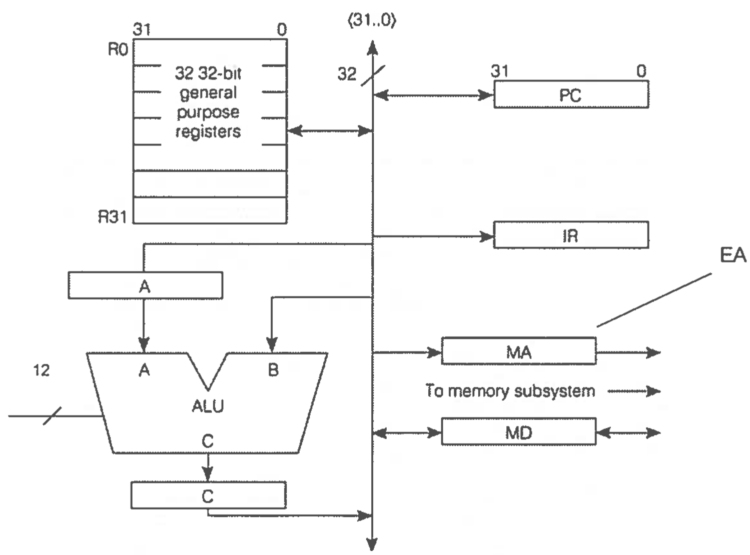
Computer Architecture

1. (6 points) Suppose the following code segment is going to be executed in the 5-stage pipeline of the SRC processor.

```
ld   r9, addr1
sub r5, r3, r9
add r7, r5, r10
st   r7, addr2
```

(a) (2 points) Find out all RAW hazards in the code segment.
(b) (2 points) How many cycles are needed to complete the execution if data forwarding is used? Explain how all the RAW hazards are resolved.
(c) (2 points) How many cycles are needed to complete the execution if data forwarding is **not** used? If an instruction needs to be stalled, list the number of cycles that this instruction has to be stalled.

2. (4 points) Referring to the following 1-bus SRC microarchitecture, write the concrete RTN steps for the instruction "sub ra, rb, rc".



PROBLEM F4 – COMPUTER SYSTEMS

Algorithms

You are given a graph G=(V,E) with distances associated with each edge.

(4 points) Give an algorithm that determines if at least one path exists that includes all nodes exactly once.

(4 points) Extend your algorithm to determine if multiple such paths exist and if so to report the length of the shortest path.

(2 points) Comment on the time complexity of your algorithm.

In solving this problem, be sure to clearly state any assumptions you have had to make.

PROBLEM F5 – COMPUTER SYSTEMS

Data Structures

1.

Recall the array-based implementation of class template `Stack` has the following data members:

```
template <class T>
class Stack{
  // public function declarations here ...
 private:
  static const int MAX_STACK = 10;
  T items[MAX_STACK];
  int top;  /* array index of top element of the stack;
               is -1 when stack is empty
            */
};
```

(a)

Write a member function

```
template <class T>
bool Stack<T>::operator== (const Stack<T>& rhsStack) const
```

which checks to see if two stacks are equal (in other words, they have the same number of items, and all these items, from the top to the bottom, are equal).

(b)

A stack of integers `aStack` has the following private data:

```
top: 4
items: 8 0 0 4 7 10 -34323 0 67823 -78999
```

What is the output of the following code?

```
int x;
while (!aStack.isEmpty()){
  aStack.pop(x);
  cout << x << " ";
}
```

Hint: Recall that `top` is the *array index* of the top of the stack.

PROBLEM F6 – COMPUTER SYSTEMS

Data Structures

2. Please provide pseudo code or diagram (explanations) for following questions

Given the input A (2, 0, 1, 3, 6, 2, 1, 10),

2.1 Construct a binary search tree according to the input A sequence.

2.2 Add a node, 5, into this binary search tree?

2.3 Delete a node, 0, from this binary search tree?

2.4 Given another binary search tree with the input B sequence (4, 5, 7), how to join two trees (Input A and B) into one tree?