Ph.D. Preliminary Examination **Code Number** ____________
Fall 2007

Instructions:

1. Please check to ensure that you have a complete exam booklet. There are 25 numbered problems. Note that **Problem 3 occupies 3 pages**, **Problem 4 occupies 2 pages,** and **Problem 20 occupies 2 pages**. Including the cover sheet, you should have **30 pages**. There should be no blank pages in the booklet.
2. The examination is closed book and closed notes. No reference material is allowed at your desk. A calculator is permitted.
3. All wireless devices must be turned off for the entire duration of the exam.
4. You may work a problem directly on the problem statement (if there is room) or on blank sheets of paper available from the exam proctor. Do not write on the back side of any sheet.
5. Your examination code number **MUST APPEAR ON EVERY SHEET**. This includes this cover sheet, the problem statement sheets, and any additional work sheets you turn in. **DO NOT** write your name on any of these sheets. Use the preprinted numbers whenever possible, or **WRITE LEGIBLY!!!**
6. Under the rules of the examination, you must choose 8 problems to be handed in for grading. Each problem to be graded should be separated from the rest of the materials, stapled to the associated worksheets, and placed on the top of the appropriate envelope in the front of the exam room. **DO NOT TURN IN ANY SHEETS FOR THE OTHER 17 PROBLEMS!!**
7. The examination lasts 4 hours, from 9:30 AM to 1:30 PM.
8. When you hand in the exam:
   (a) Separate the 8 problems to be graded as explained above.
   (b) Check to see that your Code Number is in **EVERY** sheet you are turning in.
   (c) On the section at the bottom of this page, **CIRCLE** the problem numbers that you are turning in for grading.
   (d) Turn in this cover sheet (containing your code number) and the 8 problems to be graded.
   (e) All other material is to be placed in the discard box at the front of the room. You are not allowed to take any of the exam booklet pages from the room!

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
19	**20**	**21**	**22**	**23**	**24**	**25**		

Problem 1 (Core: CompE-ECE2030) Code Number:__________

Design a synchronous **3-bit binary counter** with one input (z) that counts in the sequence 0,2,4,7,3 (for z=0) and repeats, or the sequence 0,3,2,7,4 (for z=1) and repeats. Denote the three bits as "A,B,C" where "A" is the most-significant-bit (i.e. count 4 is encoded as ABC=100). Treat unused states as "don't care" conditions where appropriate.

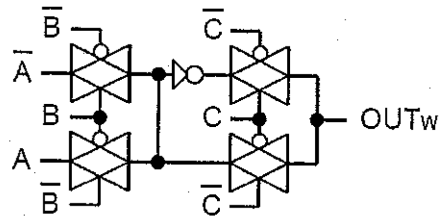
(a) Draw a **state diagram** for the counter.

(b) Draw the complete **state transition table** that defines the operation of the counter. Hint: be sure to show unused states.

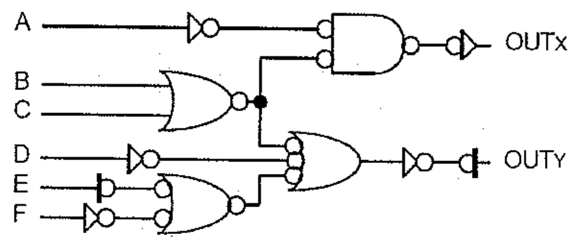
(c) Minimize the flip flop **input logic functions** and specify these as sum-of-products (SOP) Boolean expressions.

Problem 2 (Core: CompE-ECE2030) **Code Number:**__________

For each part below, determine the behavior and write as a Boolean expression.

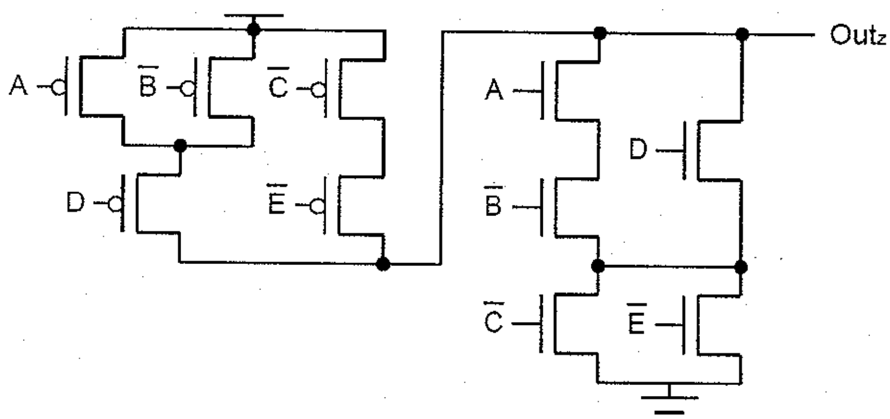


OUT_W = ____



OUT_X = ____

OUT_Y = ____



OUT_Z = ____

Problem 3 (Core: CompE-ECE3055) Code Number:_________

Given a 32-bit MIPS architecture with the following program being executed in a 5-stage pipeline shown in next page. The address of the beginning instruction is 0x4F010AC0. The corresponding ALUop control signals are provided in Table 1. At the end of the 5th cycle when the beginning instruction finishes the WB stage, please fill the blanks with the resulting values. Assume each data memory byte is loaded with the least significant byte of its own address. For example, a byte at 0xFFFFFF01 contains 0x01, a byte at 0x0000003F contains 0x3F, etc. Assume that each register contains a value equal to the register ID number prior to the execution. Also assume that a reg-write takes place (the first half cycle) prior to a reg-read (the second half) when accessing the same register in the ID stage. MIPS instruction encoding is given in next page as well.

```
L1:           sub   $14, $8, $2
              add   $15, $14, $14
              lw    $23, ($15)
              j     L2
0x4F010AC0:   lw    $5,  28($14)
              bne   $6,  $0, L1
              addi  $8,  $5, -10
              add   $10, $8, $5
              sw    $23, 4($10)
L2:           sub   $22, $23, $10
```

Problem 3 (Core: CompE-ECE3055) Code Number: ______

Please fill hex for data signals and binary for control signals and 'x' for don't care.

Input to the "PC" in the IF stage

____

"Read Data 1" in the ID stage

____

Output of the MUX3 in the EX stage

____

"Read Data 2" in the ID stage

____

"PCSrc" in the IF stage

____

EX[3:1] (3 bits) in the EX stage

____

OpMux1[1:0] in the EX stage

____

OpMux2[1:0] in the EX stage

____

M[2:0] in the MEM stage

____

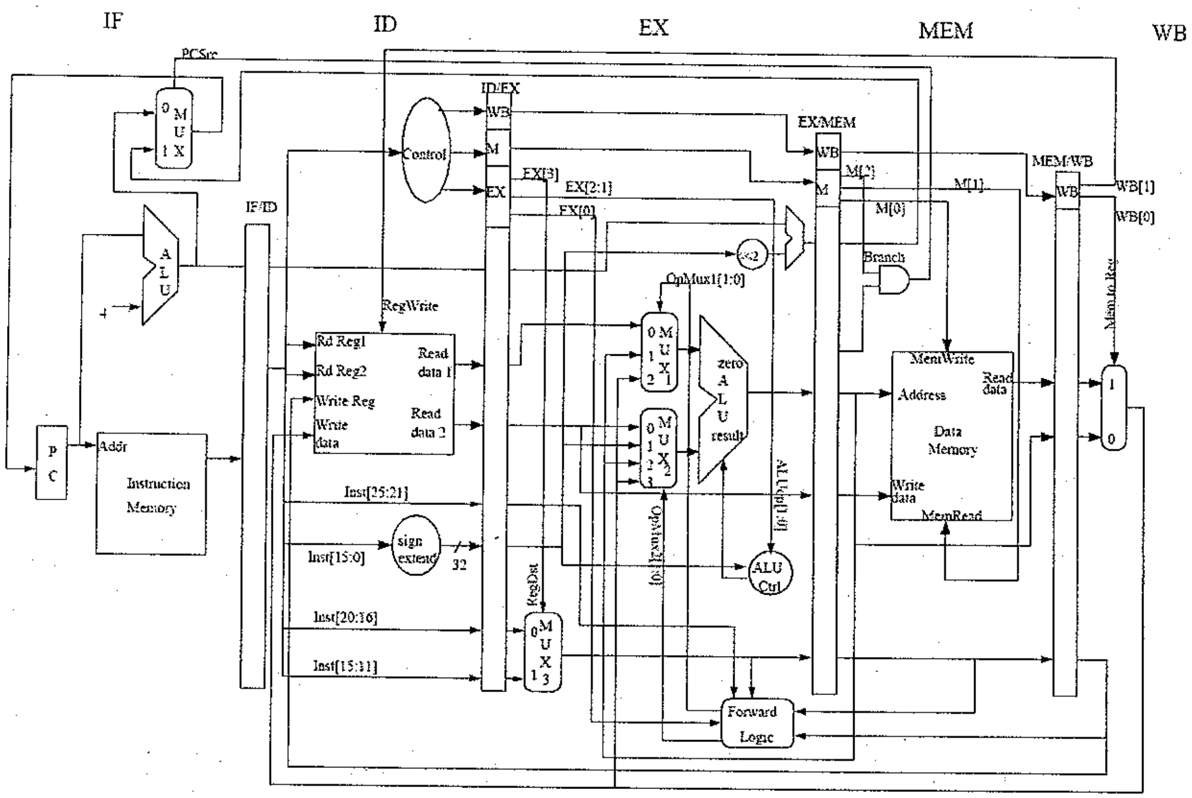
WB[1:0] in the WB stage

____

Instruction	ALUop[1]	ALUop[0]
Arithmetic	1	0
"lw"	0	0
"sw"	0	0
"bne"	1	1

Table 1. ALU Signal Definition

Problem 3 (Core: CompE-ECE3055) Code Number:______



	31	25	20	15	10	5	
R Format	op	rs	rt	rd	shamt	func	rd = rs op rt

	31	25	20	15	
I Format	op	rs	rt	offset	rt = offset(rs) or rt = rs op offset

	31	25	
J Format	op	26-bit address	op address

Problem 4 (Core: CompE-ECE3060) Code Number:__________

Consider the boolean function $f = \overline{ab + cd}$ implemented using static CMOS technology and driving a load capacitance C_L given in units of C_{inv}, the input capacitance of a minimum sized inverter.

(a) Implement f using only one CMOS complex gate and some number of inverters. Give a transistor schematic and a gate schematic for this implementation. Your solution should minimize the total number of inverters used.

(b) Consider an alternate implementation using only two-input NAND gates and inverters. Draw a gate level schematic for this circuit.

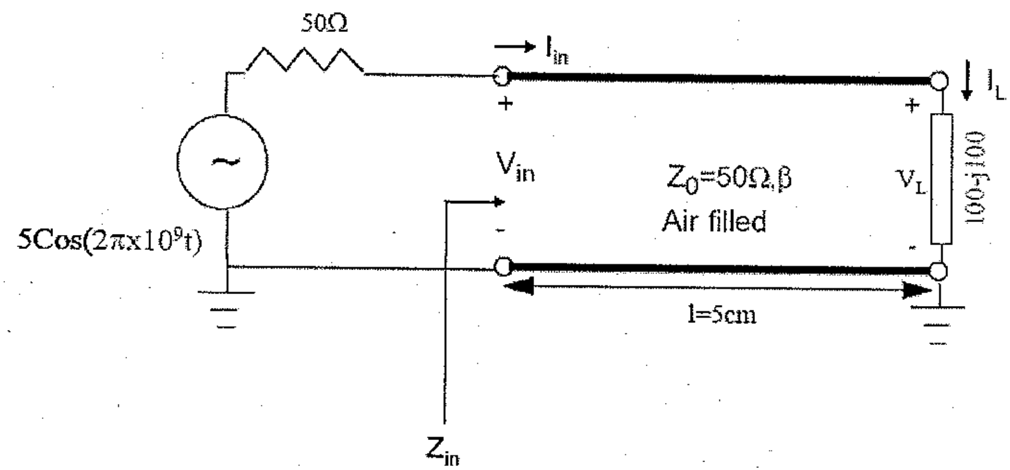
Problem 4 (Core: CompE-ECE3060) **Code Number:**__________

(c) Derive delay expressions for both implementations above, assuming that i) they are sized to minimize delay, ii) all gates are designed to equalize rise and fall time in the worst case, and iii) the input load (on every input) is C_{inv}. Delay should be expressed in units of $\tau = RC$ where τ is the delay of a minimum size inverter driving a minimum size inverter. Also, the effect of parasitic delay should be accounted for.

(d) Qualitatively describe the conditions at which you would prefer one implementation over the other

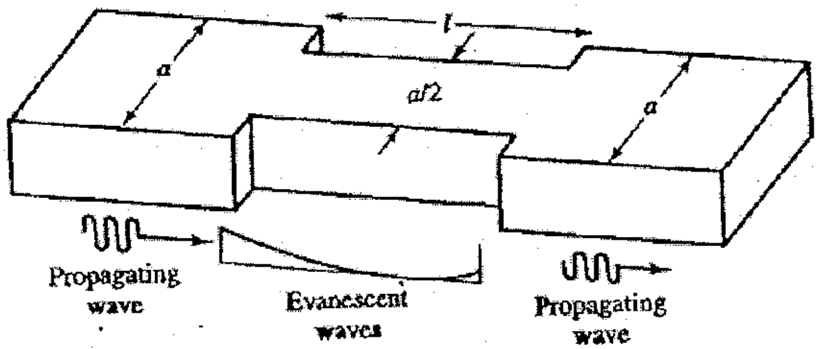
Problem 5 (Core: E&M-ECE3025) **Code Number:__________**

1. Consider the transmission line circuit shown below which consists of a generator connected to a transmission line through a 50Ω resistor. The transmission line is air-filled, is of length 5cms and has a characteristic impedance of 50Ω. The far end of the transmission line is connected to a load with complex impedance 100 – j100 Ω. Using the circuit, calculate the following:
   a) The reflection coefficient at the load.
   b) The input impedance of the transmission line.
   c) The input voltage V_{in} and current I_{in} on the transmission line.
   d) The load voltage V_L and current I_L.
   e) The power delivered to the load.



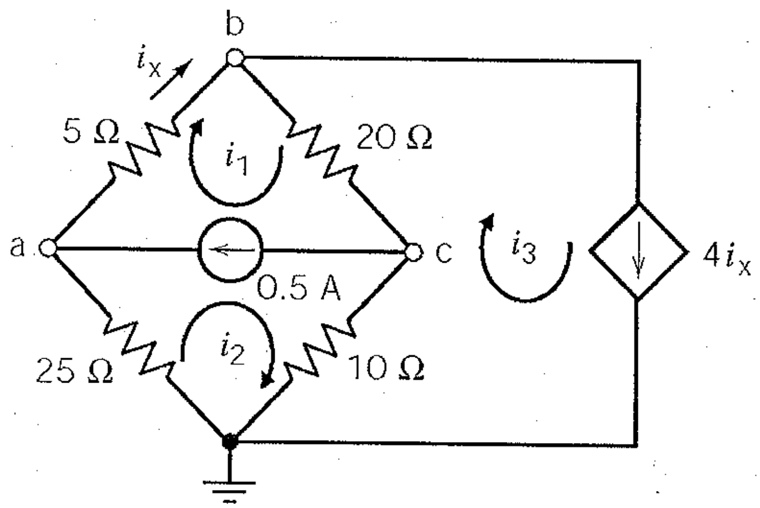
Problem 6 (Core: E&M-ECE3065) **Code Number:__________**

An attenuator can be made using a section of a rectangular waveguide operating below cut-off, as shown below. If a=2.286 cm and the operating frequency is 12 GHz, determine the required length of the below cut-off section of the rectangular waveguide to achieve an attenuation of 80 dB between the input and output guides. Ignore the effect of reflections at the step discontinuities.



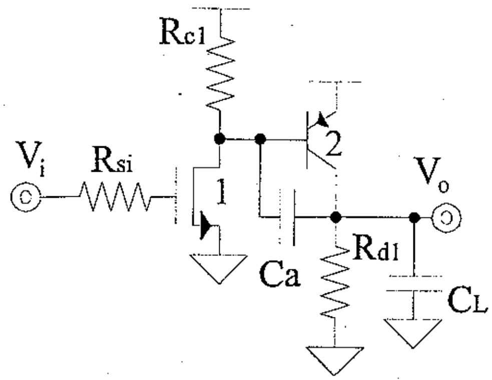
Problem 7 (Core: EDA-ECE2040) **Code Number:__________**

Determine the values of the mesh currents i_1, i_2, and i_3. of the circuit below.



Problem 8 (Core: EDA-ECE3050) **Code Number:_________**

Referring to the circuit shown below, please answer the following questions:



a) Draw the ac-equivalent circuit and ***USE*** the ac-equivalent models of the BJT and MOSFET, but neglect parasitic capacitors C_π, C_μ, C_{gs}, and C_{dg}. Carefully ***LABEL*** all components and ***DO NOT*** apply the Miller theorem. **(2 pts)**

b) Draw the ac-equivalent circuit of part (a) but now apply the Miller theorem (carefully ***LABEL*** all components). **(3 pts)**

c) Give an expression for the dominant pole frequency of the circuit (i.e., the lowest high-frequency pole) using r_π, r_{o1}, g_{m1}, g_{m2}, r_{ds2}, R_{c1}, R_{d1}, C_c, and/or C_L. **(2.5 pts)**

d) Give an expression for the 2nd dominant pole (i.e., the next higher frequency pole) using r_π, r_{o1}, g_{m1}, g_{m2}, r_{ds2}, R_{c1}, R_{d1}, C_c, and/or C_L. **(2.5 pts)**

Problem 9 (Core: Power-ECE3070) **Code Number:__________**

1. A balanced three phase line-line voltage of 13.8 kV rms at 60 hertz is used to feed an industrial plant, where the load varies between 10 MW and 30 MW. The load has a lagging power factor that varies between 0.8 at 10 MW to 0.92 at 30 MW

a) Calculate the current rating of the utility service that is required to meet the plant requirements?

b) A delta connected three phase capacitor is to be used to improve the plant's power factor. Calculate the smallest capacitance value that will provide the minimum VAR loading for the plant over the load operating range. What is the range of improved power factor for the plant?

Problem 10 (Core: Power-ECE3070) **Code Number:_________**

Synchronous Machines

The per phase synchronous reactance of a three-phase, Y-connected, 60 Hz, 4-pole, synchronous generator is 10 ohms. When a certain load is connected to the generator terminals, it supplies 2.5 MVA (total three phase) at 60 Hz, at a leading power factor of 0.8 and a terminal voltage of 6.6 kV (L-L), to the load. Neglect armature resistance, magnetic saturation, and all mechanical losses. For the above load condition:

a) Find the speed of the generator.

b) Calculate the mechanical torque supplied by the turbine which drives this generator.

c) Draw the phasor diagram showing $\tilde{V}_t$, $\tilde{E}_{af}$, $\tilde{I}_a$ and $jX_s\tilde{I}_a$. Recall that $\tilde{V}_t = \tilde{E}_{af} - jX_s\tilde{I}_a$. Use V_t as the reference phasor. Calculate the magnitude (expressed as a L-N value) of the excitation voltage (or induced voltage) $\mathbf{E}_{af}$.

d) The load is now removed from the generator terminals and the field current and speed of the generator remain unchanged. Find the new value of the terminal voltage expressed as a Line-to-Neutral (L-N) value.

Problem 11 (Core: Microsystems-ECE3040) Code Number:__________

Consider a Silicon npn transistor at room temperature with the following parameters and dimensions. Recombination in the base can be neglected.

Emitter: $N_E = 9 \times 10^{18}$ cm^{-3}, W_E = 500nm, D_E = 2cm^2/s

Base: $N_B = 1.5 \times 10^{17}$ cm^{-3}, W_B = 400nm, D_B = 16cm^2/s

Collector: $N_C = 2 \times 10^{16}$ cm^{-3}, W_C = 2μm, D_C = 11cm^2/s

Emitter area = A_E = 50μm^2 Collector area = A_C = 50μm^2

Intrinsic carrier concentration = $n_i = 1.0 \times 10^{10}$ cm^{-3}

Calculate and sketch the minority carrier concentrations in the emitter, base and collector under forward active bias, given that I_C = 25μA and V_{BC} = 0V.

Problem 12 (Core: Microsystems-ECE3080) Code Number:__________

A silicon semiconductor resistor at room temperature is doped with donor atoms at a concentration of $N_D = 5\times10^{16}$ cm^{-3}. The cross-sectional area of the resistor is 85 μm^2.

(a) Determine the minority and majority carrier concentrations.

(b) Determine the Fermi energy location with respect to E_C, i.e. calculate $E_C - E_F$.

(c) Determine the resistivity ρ of the semiconductor assuming an electron and hole mobility of $\mu_n = 986$ cm^2/Vs and $\mu_p = 378$ cm^2/Vs.

(d) The current in the resistor is to be I = 20 mA with 10 V applied along the resistor length. Determine the required length of the device.

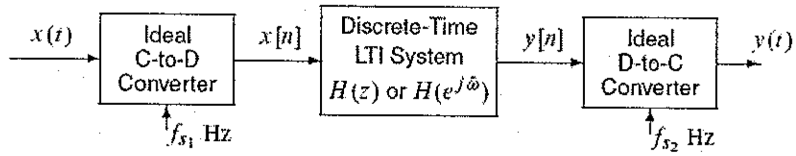
(e) By illumination, you generate excess electron-hole pairs in the semiconductor. In steady state, the excess carrier concentration is $\Delta n = \Delta p = 10^{17}$ cm^{-3}. Determine the resistivity of the illuminated sample. Assume that the carrier mobilities do not change.

(f) Sketch the energy band diagram (E_C, E_V, E_F, E_i) along the length of the resistor in the case of 10 V applied along the resistor length.

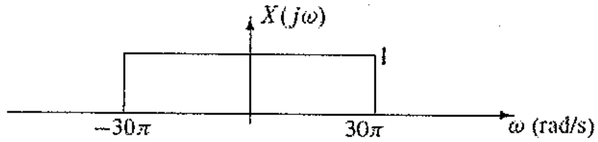
You might need: $E_g = 1.12$ eV, kT = 0.026 eV, $n_i = 10^{10}$ cm^{-3}, $N_C = 2.8 \times 10^{19}$ cm^{-3}, $N_V = 1.04 \times 10^{19}$ cm^{-3}, $q = 1.6 \times 10^{-19}$ C

Problem 13 (Core: DSP-ECE2025) Code Number:__________

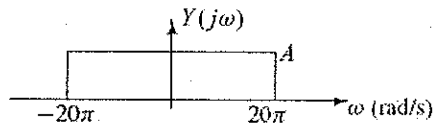
Consider the following system for continuous-time and discrete-time processing of a signal:



In all parts, the Fourier transform of the input $X(j\omega)$ is



(a) If $H(e^{j\hat{\omega}}) = 1$, and the Fourier transform of the output is $Y(j\omega)$:



If $f_{s_1} = 48$ Hz, then determine the rate of the D-to-C converter, f_{s_2}, as well as A. Note: $f_{s_2} \neq f_{s_1}$.

(b) In this part, assume that $H(z) = z^{-3}$ and $f_{s_1} = f_{s_2} = 33$ Hz; then determine a closed-form mathematical expression for the output time signal, $y(t)$.

(c) In this part, assume that the discrete-time LTI system, $H(e^{j\hat{\omega}})$, is a highpass filter (given below), and that the output Fourier transform $Y(j\omega)$ is given by the formula below.

$$H(e^{j\hat{\omega}}) = \begin{cases} 0 & |\hat{\omega}| \leq \hat{\omega}_c \\ 1 & \hat{\omega}_c < |\hat{\omega}| \leq \pi \end{cases} \qquad Y(j\omega) = \begin{cases} 0 & |\omega| \leq 20\pi \\ 1 & 20\pi < |\omega| \leq 30\pi \\ 0 & |\omega| > 30\pi \end{cases}$$

If $f_{s_1} = f_{s_2} = 50$ Hz, then determine the cutoff frequency of the highpass filter, $\hat{\omega}_c$.

Problem 14 (Core: DSP-ECE3075)   Code Number:__________

A random variable X has a probability density function of the form $f_X(x) = \exp\{-\lambda |x|\}$ $\quad -\infty < x < \infty$
A second random variable Y is related to X by $Y = |X|$.

a) Find the numeric value of λ;

b) Find the probability density function of Y;

c) Find the probability density function of W, where $W = \frac{1}{3}(X + 2Y)$;

d) Random variable Z is a function of X and Y. $Z = \frac{X}{2Y}$; find the first and second moment of Z.

Problem 15 (Core: S&C-ECE3085) Code Number:__________

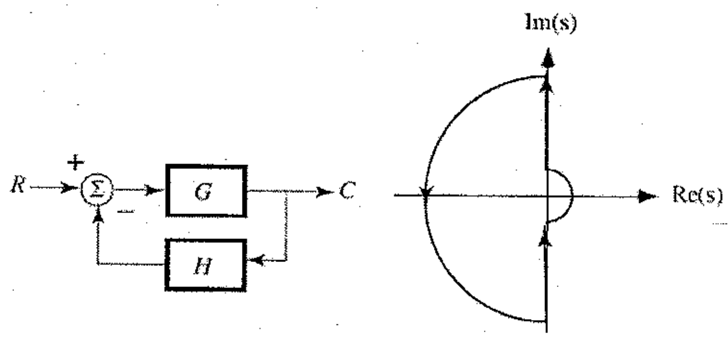


Figure 1: (a) System with feedback, (b) Nyquist path in s-plane.

For the system of Figure 1(a), let

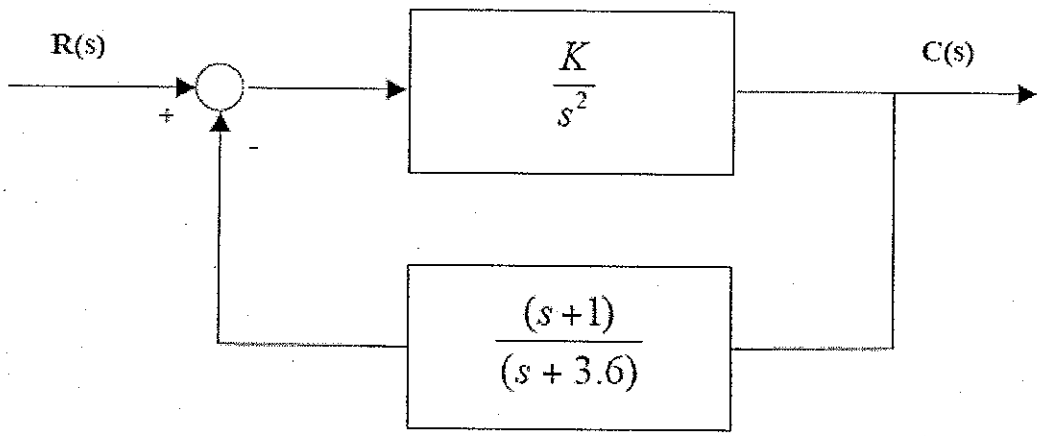
$$GH(s) = \frac{K(s+1)}{s^2(s+10)(s+20)}.$$

a. (5) Draw the Nyquist plot in the GH-plane for the contour shown in Figure 1(b).

b. (5) From the Nyquist plot, determine the number of stable and unstable poles as K ranges from $-\infty$ to $+\infty$, and indicate the range of K for which all poles are in the left half of the s-plane.

Problem 16 (Core: S&C-ECE3085) **Code Number:__________**

For the following system pictured below sketch the root locus plot of the system including any relevant information pertaining to the plot. Given the point $s_1 = -0.75 + j1.7$ is a point on the root locus, find the corresponding value of the gain K.



Problem 17 (Specialized: Comp Science-CS3210) Code Number:______

Mutual Exclusion. Assume that we have an multi–threaded application using the Unix/Linux *pthreads* library, and that we have created 10 threads using `pthread_create`. Further assume that the system we are running on has *only one CPU*. Part of our application requires exclusive access to a particular section of code called the *Critical Section*. Exclusive access means that only one thread can execute in the critical section at any point in time. We decide to implement this exclusive access using a global *Locked* flag, as follows:

```
1  // Define the global locked flag.  0 means unlocked, 1 means locked
2  int Locked = 0;
3
4  // The code for the critical section.
5  void CriticalSection()
6  {
7    // Wait until any other thread having the lock releases it
8    while(Locked == 1)
9      {
10       // Do nothing here, or perhaps sleep for a small amount of time
11     }
12
13   // No other thread in the critical section, set the locked flag
14   Locked = 1;
15
16   // Now the code for the actual critical section
17   // Ommited here
18
19   // We are now done with the critical section, unlock the flag
20   Locked = 0;
21 }
```

Program q1-code.cc

At first glance, the locking mechanism above seems reasonable and correct, but when we test our program it fails mysteriously and at apparently random times.

1. Explain clearly what the problem is in the code snippet above. Refer to the lines of code by line number as needed.

2. Explain what could be done to fix the problem, without a complete re-write of the code. If you need to make assumptions about the CPU instruction set, state what assumption you made.

Problem 18 (Specialized: Software Sys- ECE3035) Code Number: _____

Below is a snapshot of heap storage in byte addressed memory. Values that are pointers are denoted with a "$". The heap pointer is $6128. The heap has been allocated contiguously beginning at $6000, with no gaps between objects. Objects are word-aligned. Each allocated object has a header word containing the size of the object in bytes. The address of the object points to the word just after the header (i.e., the first word allocated for the object's data). For example, the object pointed to by $6004 has size 16 bytes, so the next allocated object in the heap is of size 8 bytes and is pointed to by $6024.

addr	value	addr	value	addr	value	addr	value	addr	value
6000	16	6032	12	6064	8	6096	12	6128	0
6004	33	6036	28	6068	4	6100	$6092	6132	0
6008	$6100	6040	24	6072	$6092	6104	16	6136	0
6012	16	6044	$6092	6076	8	6108	0	6140	0
6016	$6080	6048	12	6080	$6004	6112	12	6144	0
6020	8	6052	$6080	6084	0	6116	0	6148	0
6024	25	6056	16	6088	4	6120	0	6152	0
6028	52	6060	$6004	6092	$6004	6124	0	6156	0

Part A Suppose the stack holds a local variable whose value is the memory address $6036. No registers or static variables currently hold heap memory addresses. List the addresses of all objects in the heap that are *not* garbage.

Addresses of Non-Garbage Objects: ______________________________

Part B Create a free list by scanning the memory for garbage, starting at address $6000 and pushing each garbage object on the front of the free list. List the addresses of the objects (in order) on the free list at the end of the scan.

Free List: ______________________________

Part C Based on the free list created in part B, If an object of size 7 bytes is allocated, what address will be returned as a pointer to the newly allocated object using a first-fit allocation strategy?

Address: ______________________________

Part D Based on the free list created in part B, if an object of size 13 bytes is allocated, what address will be returned using a *best-fit* allocation strategy?

Address: ______________________________

Part E If the local variable whose value is the address $6036 is popped from the stack, which addresses listed in Part A will be reclaimed by each of the following strategies? If none, write "none."

Reference Counting:	
Mark and Sweep:	

Problem 19 (Specialized: Telecom-ECE3076) Code Number:_________

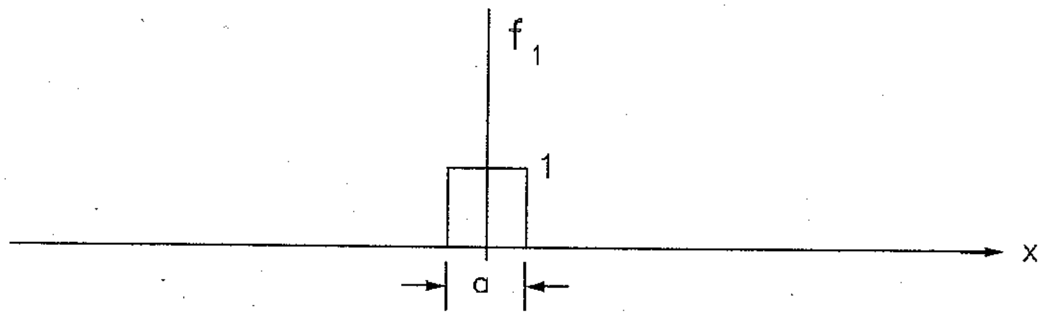
Explain the conditions under which the CSMA/CD (carrier-sense multiple access with collision detection) medium-access control protocol is always guaranteed to provide better performance than CSMA (carrier-sense multiple access). Assume that the stations sharing the medium are backlogged (have data to send). Derive (and explain) the condition in terms of the following parameters:

P (the frame size in bits)
B (the bandwidth in bits/second)
D (the largest distance between any two stations sharing the medium)
c (speed of light).

Problem 20 (Specialized: Optics-ECE4500) Code Number:__________

Fraunhofer Diffraction by Two Slits

A metal plate in air contains a single slit of width a. The metal slit plate is illuminated at normal incidence by a plane wave of freespace wavelength λ. The amplitude transmittance of the slit plate is shown in the diagram below. There is 100% transmittance within a slit and 0% transmittance elsewhere.



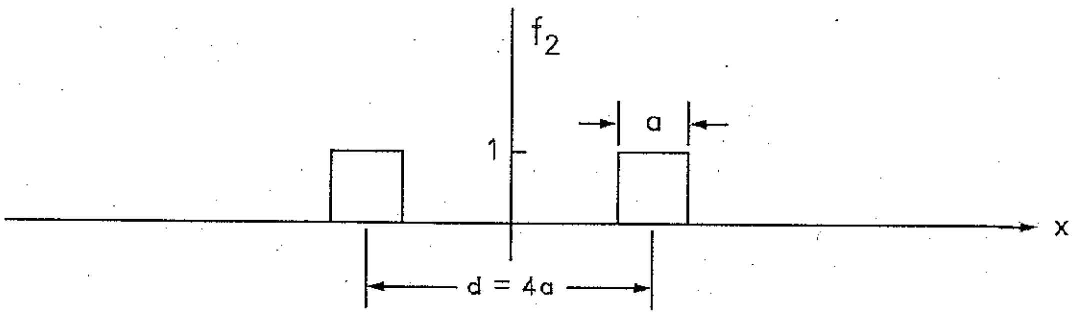
The far-field (Fraunhofer) amplitude diffraction pattern, F_1, resulting from the diffraction of the plane wave by this slit is determined to be

$$F_1 = a \frac{sin\left(\frac{k_x a}{2}\right)}{\left(\frac{k_x a}{2}\right)}$$

where $k_x = \frac{2\pi}{\lambda} sin\,\theta$ and where θ is the angle of propagation in the far-field (as measured from the normal to the surface of the slit plate).

Problem 20 (Specialized: Optics-ECE4500) Code Number:__________

A second metal plate in air contains two parallel slits, each of width a. The distance between the slits is d with $d = 4a$. The metal slit plate is illuminated at normal incidence by a plane wave of freespace wavelength λ. The amplitude transmittance of the slit plate is shown in the diagram below. The transmittance is 100% within the slits and 0% transmittance elsewhere.



Calculate, showing all work, the far-field (Fraunhofer) amplitude diffraction pattern, F_2, resulting from the diffraction of the plane wave by these two slits. Express your answer as a function of $\frac{sin\left(\frac{k_x a}{2}\right)}{\left(\frac{k_x a}{2}\right)}$, the functional form of the amplitude diffraction pattern of a single slit. Your answer for F_2 should contain k_x and a *only*.

F_2 = ______________________________

Problem 21 (Specialized: Optics-ECE4501) Code Number:__________

A fiber communication link consists of three sections of single-mode fiber that are joined end-to-end to form a net transmission span of 14 km. The three segments are:

1. a 2.0-km length having dispersion $D_1 = +16.0$ ps/nm-km, and loss coefficient, $\alpha_1 = 0.20$ dB/km;
2. a 6.0-km length having dispersion $D_2 = -5.0$ ps/nm-km, and loss coefficient, $\alpha_2 = 0.15$ dB/km;
3. a 6.0-km length having dispersion $D_3 = +4.1$ ps/nm-km, and loss coefficient, $\alpha_3 = 0.15$ dB/km.

a. Assuming that all splice losses are negligible, what is the net power loss of the link in decibels?

b. Suppose the fibers are all to be replaced by a single fiber, having the same overall length. What value of D should the new fiber have, such that the link dispersion penalty is unchanged?

c. In the original three-fiber link, an optical source provides an input average power of 10 dBm. What is the link output power in mW?

d. The input power in mW is now doubled, so that the span distance can be increased. Assuming that additional lengths of the original three fibers are available, make a choice as to the best fiber to use *to add to the existing link*, and find the new span length (such that the output power is the same as in part c). The new link should be as long as possible. What other factor(s) (if any) influenced your decision?

Problem 22 (Specialized: Microsystems-ECE4752) Code Number:_____

Boron diffusion is used to form the base region of an npn transistor in a n-type silicon wafer with a background doping concentration of 3.0×10^{16} cm^{-3}. A solid solubility limited boron predeposition is performed at 900 C for 15 minutes followed by a five hour drive-in at 1100 C. Find the total dose delivered from the pre-deposition and the junction depth following the drive-in step.

The solid solubility limit for boron in silicon is of 1.1×10^{20} cm^{-3}. Activation Energy for Boron in Silicon, E_a=3.6 eV. Diffusion Coefficient, D_o=10.5 cm^2/sec.

Problem 23 (Specialized: Bio Eng-ECE4784) Code Number:__________

a) (3 pts) Describe the proper sequence of firing events for the heart.

b) (4pts) Sketch the anticipated ECG/EKG in the case where there is an AV block, i.e. the atrial muscle and the AV node lose their electrical connection.

c) (4pts) Explain, using mathematical arguments why the p wave in the case where the SA node fails to fire will be inverted. Be sure to use the curve for the membrane voltage of the atrial muscle as a function of distance in your answer.

Problem 24 (Specialized: Bio Eng-ECE4781) Code Number:__________

a) (3 pts) What type of electrode is used to measure the resting membrane potential of a neuron? Draw a sketch and label the parts of the electrode.

b) (2 pts) What are the most important specs of the Differential Amplifier used to measure the membrane potential of a neuron?

c) (3 pts) The Nernst Equation estimates the membrane potential across a neuron as a function of ion concentrations. What happens to the membrane potential if the absolute temperature increases by 10%?

d) (2 pts) What physiological mechanism could cause this change?

Problem 25 (Specialized: Bio Eng-ECE4782) Code Number:__________

Pretend that you have accepted a senior research position at a company called Mortem Ltd, and they have asked you to design a noninvasive, portable diagnostic device that will prove that a comatose patient on a ventilator is legally dead. The selling price of this medical device needs to be less than $10,000.

a) (3 pts) What biological signal(s) should you measure and explain your reasoning?

b) (4 pts) What types of stimuli should you use? Remember that the RMS Signal-to-Noise levels could be really small.

c) (3 pts) If one of the above stimuli is Gaussian and White-noise modulated, write an equation that shows how to calculate the first-order Wiener Kernel.