Ph.D. Preliminary Examination **Code Number ___________**
Fall 2011

Instructions:

1. Please check to ensure that you have a complete exam booklet. There are 25 numbered problems. Note that **Problem 2 occupies 2 pages, Problem 6 occupies 2 pages, Problem 11 occupies 3 pages, Problem 12 occupies 2 pages, Problem 14 occupies 2 pages, Problem 16 occupies 2 pages, Problem 17 occupies 2 pages**, and **Problem 20 occupies 2 pages.** Including the cover sheet, you should have **35 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: VSDD-ECE2030) Code Number:________

ECE 2030 Prelim Problem:
Complete each design below. Be sure to label all signals.

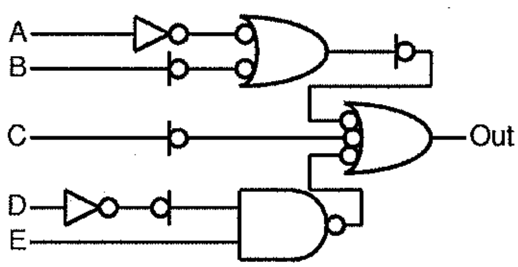
Part A: Implement the following expression using N and P type switches (NFETs and PFETs).

$$Out_X = A \cdot \overline{B} \cdot C + \overline{D}$$

Part B: Implement a transparent latch using only pass gates and inverters.

IN	Y	OUT	$\overline{OUT}$
A	0	Q_o	$\overline{Q_o}$
A	1	A	$\overline{A}$

Part C: Determine the appropriate expression for this mixed logic design. How many transistors are required?



Out =

transistors =

Part D: Reimplement the design in Part C using *only* NOR gates. Use proper mixed logic notation. How many transistors are required?

transistors =

Problem 2 (Core: VSDD-ECE2030) Code Number:__________

(a) Consider the signed twos complement numbers X = 10110101 (8 bit signed twos complement) and Y = 1101 (4 bit signed twos complement). Compute the arithmetic sum Z = X+Y (write Z in 8 bit signed twos complement format)

Is there any overflow while computing Z ? Yes or No

If not, write the correct value of Z below, else leave blank.

Z =

What is the value of Z in decimal (if you gave a value for Z above) ?
Z =

(b) Consider X = 1011010 and Y = 1000101, where X and Y are 7 bit signed twos complement numbers. Compute the arithmetic Z = X+Y, where Z is 7 bit signed twos complement as well (write Z in binary).

Is there overflow while computing Z ? Yes or No

If not, write the correct value of Z below, else leave blank.

Z =

What is the value of Z in decimal (if you gave a value for Z above) ?
Z =

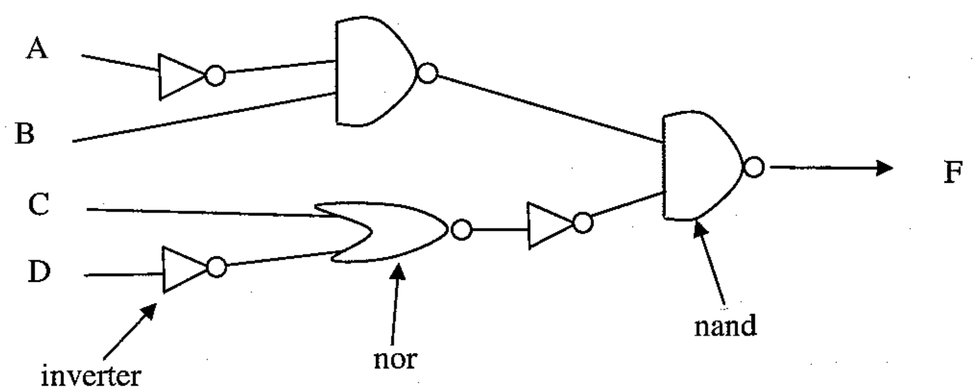
Problem 2 (Core: VSDD-ECE2030) Code Number:__________

(c) Give a minimal *product of sums* expression for the function f( ) below:

wx \ yz	00	01	11	10
00	1			1
01	1	1	1	
11	1		1	
10	1		1	1

f(wxyz) =

(d) Using DeMorgan's Law, express F for the circuit below in terms of A, B, C and D in minimal sum of products form. Simplify the expression for F to the maximum extent possible



F =

Problem 3 (Core: CSS-ECE3055) Code Number:__________

Consider a virtual memory system with the below characteristics. For ease of analysis, assume that all memory operations are independent.

- inverted page table with a perfect hash function, i.e. each virtual page has a unique hash value
- TLB hit and cache hit together take 1 cycle
- cache access or TLB access by itself takes 1 cycle
- main memory access takes 50 cycles
- page fault takes 10^6 cycles
- page table entries are not cached, i.e. TLB misses go directly to main memory
- cache is indexed by physical addresses
- miss rates are as follows: TLB 0.02, cache 0.01, main memory 0.001

Calculate the average number of cycles taken on a memory access. Show your work.

Problem 4 (Core: VSDD-ECE3060) Code Number:_________

Compare transistor sizes in NAND and NOR gates as multiples of minimum-size transistors. Assume the effective resistance of a minimum-size n-type transistor is 6.47 k Ohms and that of a minimum-size p-type transistor is 29.6 k Ohms.

a) Size the transistors in a three-input, static complementary NAND gate so that the gate's rise and fall times are approximately equal.

b) Size the transistors in a three-input, static complementary NOR gate so that the gate's rise and fall times are approximately equal.

c) Find the ratio of total transistor area in the NAND gate vs. the NOR gate.

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

A parallel-plate capacitor is constructed from two metal plates of dimension 1 cm by 1 cm, held a distance of 5 mm apart by a material with $\varepsilon = 4\varepsilon_0$. The electric field between the plates is 400 V/m. Neglect fringing effects at the plate edges.

(a) What is the voltage between the plates?

(b) What is the surface charge density magnitude on either plate?

(c) How much energy is stored in the capacitor?

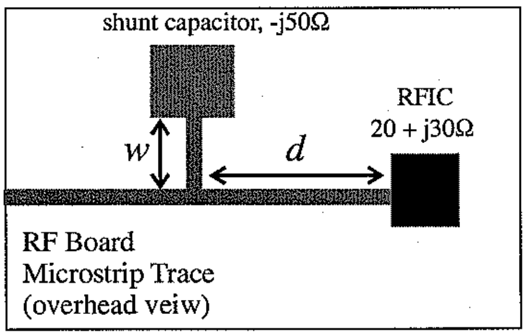
(d) What is the magnitude of the force, in Newtons, on each plate?

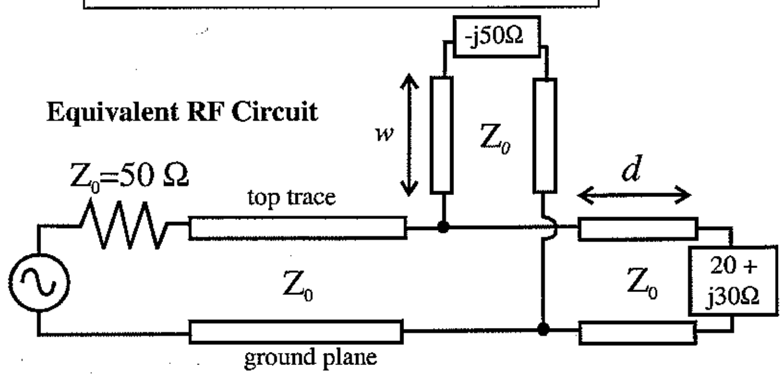
(e) What is the capacitance?

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

You must match an RF integrated circuit (RFIC) with impedance 20 + j30Ω to a standard 50Ω trace on a thin microstrip printed circuit board. This particular match is difficult because the board must be as small as possible. Thus, a patch capacitor with impedance -j50Ω is placed at the end of the stub line in the hopes of minimizing the stub's length on the printed circuit board. Find the geometrical lengths *w* and *d* in terms of wavelength λ. Neglecting the dimensions of the capacitor itself, how much less stub length *w* (in terms of wavelength λ) does this design require compared to a conventional open-circuit parallel stub match design?

w =_____ λ d =_____ λ   space savings over an open-circuit stub: Δw = _____ λ



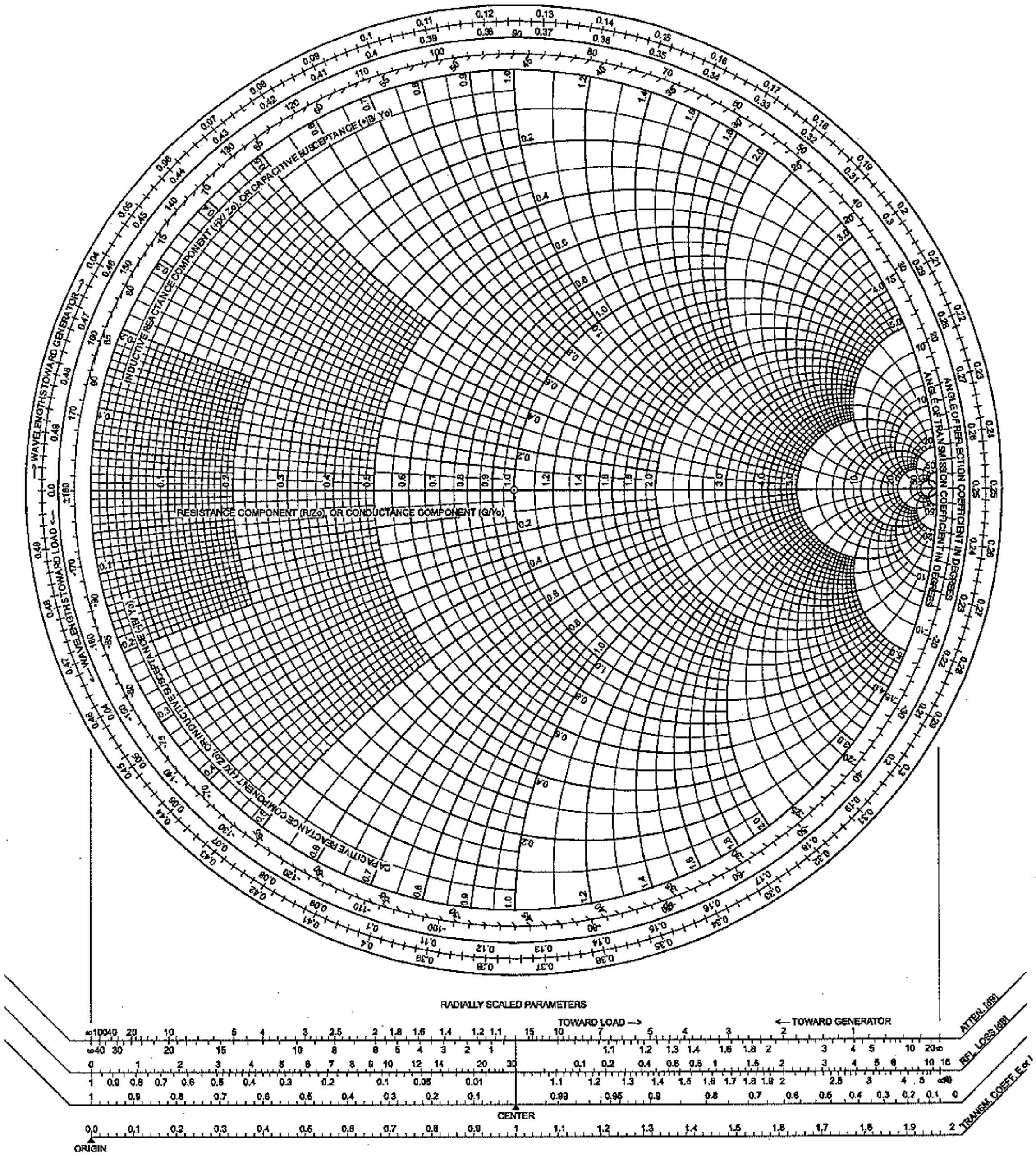


Useful Formulas:

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta D}{Z_0 + jZ_L \tan \beta D} \qquad \beta = \frac{2\pi}{\lambda} \qquad \text{Reflection: } \Gamma_{L,G} = \frac{Z_{L,G} - Z_0}{Z_{L,G} + Z_0}$$

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

The Complete Smith Chart



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

(Möbius and his resistive ladder)

You are given the Möbius band shown below on which a ladder network containing $6n-1$ equal resistors ($R=\sqrt{2\pi e}$ Ohm) are connected as shown. The "runs" of the ladder are labeled by the numbers 0 to $2n-1$. (The figure is drawn for $n=4$). A voltage source of V Volt is connected to the terminals A and B.

In order to determine the Thévenin equivalent network with respect to the terminals at C and D, you want to derive the open circuit voltage V_{oc} and the shortcircuit current I_{sc} for the terminals C and D.

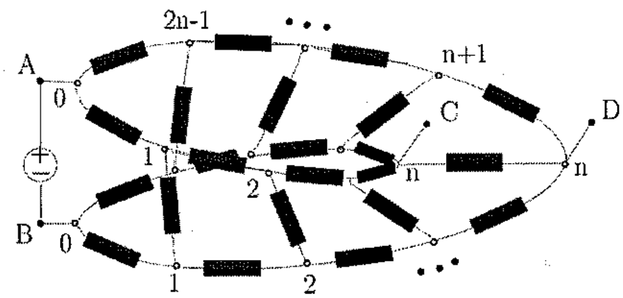
i) Determine these V_{oc} and I_{sc}.

ii) Let ρ_n denote the ratio of the Thévenin equivalent resistance and R for the circuit with $6n-1$ resistors. Determine ρ_1 and ρ_2.

iii) Set up an iteration by determining ρ_{n+1} in terms of ρ_n.

iv) Let $n\rightarrow\infty$. Show that ratio of the Norton equivalent resistance to R approaches $1/\sqrt{3}$.

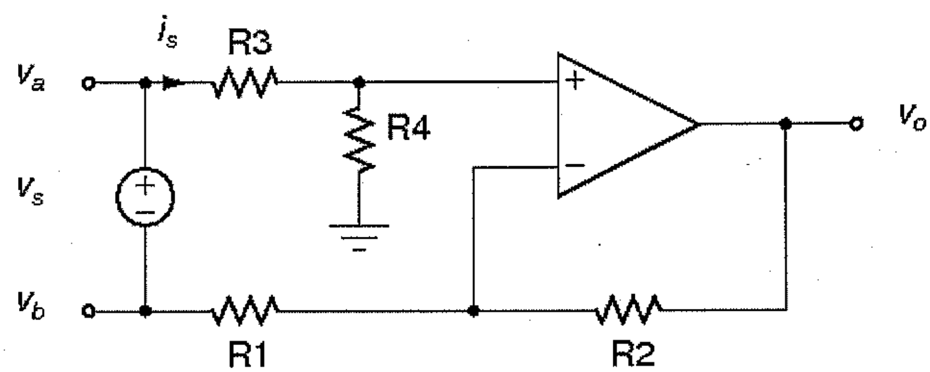
Explain all answers in detail.



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

For the given circuit, calculate the values for R1, R2, R3, and R4 given the following specifications:

(1) $v_o \ / \ v_s = 10$
(2) $R_{in} = v_s \ / \ i_s = 10\text{k}\Omega$
(3) CMRR = ∞ , i.e., $(v_o \ / \ v_a = - \ v_o \ / \ v_b)$
(4) Zero induced common mode input voltage, i.e, $v_a = - \ v_b$



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

A 13.8 kV, 10 MVA, 0.8 power factor lagging, 60 Hz, two-pole, Y-connected steam-turbine synchronous generator has a synchronous reactance of 12 Ohms and a rotor resistance of 1.5 Ohms per phase. The generator is operating connected to a large power system (infinite bus). **(a)** What is the magnitude of the voltage behind synchronous impedance E_A at rated conditions? **(b)** What is the power angle of the generator at rated conditions? **(c)** If the rotor (field) current is kept constant, what is the maximum power possible out of this generator? How much reserve power does this generator have at full rated load? **(d)** At the maximum power condition described in part (c), how much reactive power will the generator be supplying or consuming?

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

An induction motor draws 50A from a 480 V line-line, 3 phase source at a lagging power factor of 0.85. Its stator and rotor losses are 1000 W and 500 W, respectively. Its core losses are 500 W, and the friction and windage (mechanical losses) are 250 W.

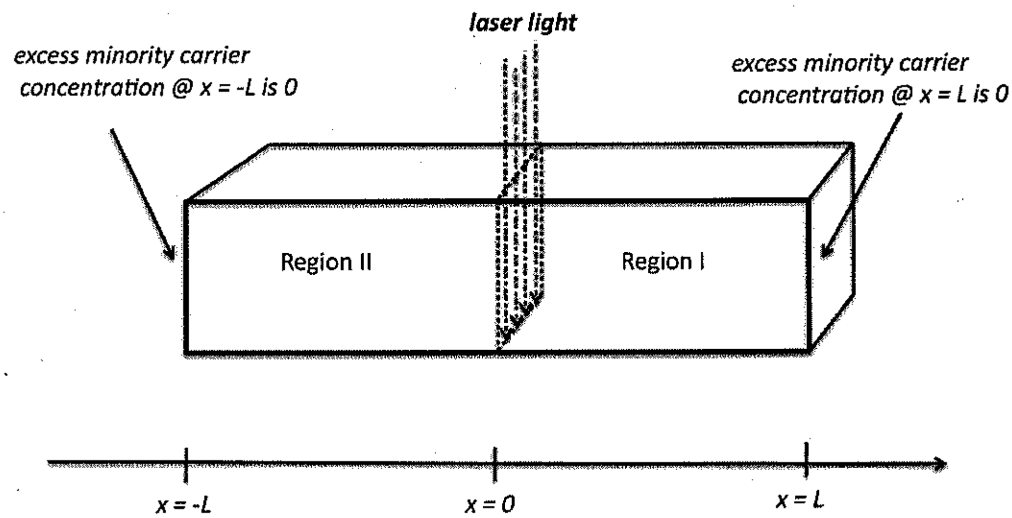
a) Determine the air gap power

b) Determine the mechanical power developed by the motor.

c) Determine the shaft output power in horsepower.

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

Assume that a laser is used to illuminate a thin cross-section of a uniformly doped bar of silicon maintained at room temperature (i.e. T = 300°K). Assume that the laser-induced photogeneration occurs only at x =0 and is uniform across the cross-section as seen in the following diagram. At x=0, assume that the steady-state number of electron hole pairs (EHPs) is 10^{11} EHP/cm^3 and that there is no electric field inside the silicon bar. The dopant in this case is boron and the doping density is 10^{16} /cm^3. Also assume that the excess minority carrier concentration at the edges of this bar is zero at $x=L$ and $x=-L$. The minority carrier lifetime for this bar can be assumed to be one microsecond. Also assume that the mobility for the minority carriers is approximately 800 cm^2/V-s, and that the intrinsic carrier concentration for silicon at room temperature is approximately 10^{10} /cm^3.



Please note that the equations in the following table may be useful for this problem.

Minority carrier diffusion equation for electrons	$\frac{\partial \Delta n}{\partial t} = D_N \frac{\partial^2 \Delta n}{\partial x^2} - \frac{\Delta n}{\tau_n} + G_L$
Minority carrier diffusion equation for holes	$\frac{\partial \Delta p}{\partial t} = D_P \frac{\partial^2 \Delta p}{\partial x^2} - \frac{\Delta p}{\tau_n} + G_L$
Diffusion constants	D_N, D_P
Minority carrier lifetimes	τ_p, τ_n
Photogeneration rate	G_L

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

a.) What is the value of the diffusion constant for the minority carriers in this silicon bar?

b.) Assuming no significant variations of the carrier concentrations in the y and z directions, what is the differential equation that describes the excess minority carrier concentration in steady-state as a function of x in Region I and Region II of the semiconducting bar.

c) For the case where L is much greater than the average diffusion length, please give the approximate expression for the excess minority carrier concentration in Region I and Region II.

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

d) For the same assumptions as in part c, please provide an expression for the quasi-Fermi level for the minority carriers (relative to the intrinsic Fermi level) in Region I.

e) For the same assumptions as in part c, please show the band diagram for this bar and approximately show the quasi-Fermi levels for majority and minority carriers, the intrinsic Fermi level, the conduction band, and the valence band. For reference, show the equilibrium Fermi level on your diagram as well.

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

For an NMOS capacitor, assume that the metal has a work function, Φ_m, that is ***greater*** than the semiconductor work function, Φ_S. Also assume that there are no extra insulator or interface charges. Assume that approximately 50% of the applied gate voltage, V_G, is across the oxide layer and 50% is across the semiconductor and that the Fermi Energy in the semiconductor is grounded.

a. On the energy (E) vs. x scales (shown on the next page) labeled "***equilibrium***", draw the schematic energy-band diagram at **equilibrium** (V_G = 0) for a ***"real NMOS ENHANCEMENT-MODE"*** capacitor made of a metal, SiO_2 and Si.
You have been "given" the equilibrium Fermi Energy in the metal as a "reference point". Label your drawing clearly, showing each of the important energies and potentials: Draw the "complete" diagram including the relevant work functions, the oxide conduction band energy, E_{COX}, the semiconductor and valence conduction bandedge energies, Fermi energies, quasi-Fermi energies, intrinsic Fermi energy, vacuum energy level, E_O, the surface potential, Fermi potential, and the relevant electron affinities:

$$V_G,\ \Phi_m,\ \Phi_S,\ E_{COX},\ E_C,\ E_V,\ E_{F_S},\ E_{F_m},\ E_i,\ E_O\ (or\ E_{vac}),\ \phi_S,\ \phi_F,\ \chi_i \text{ and } \chi_S.$$

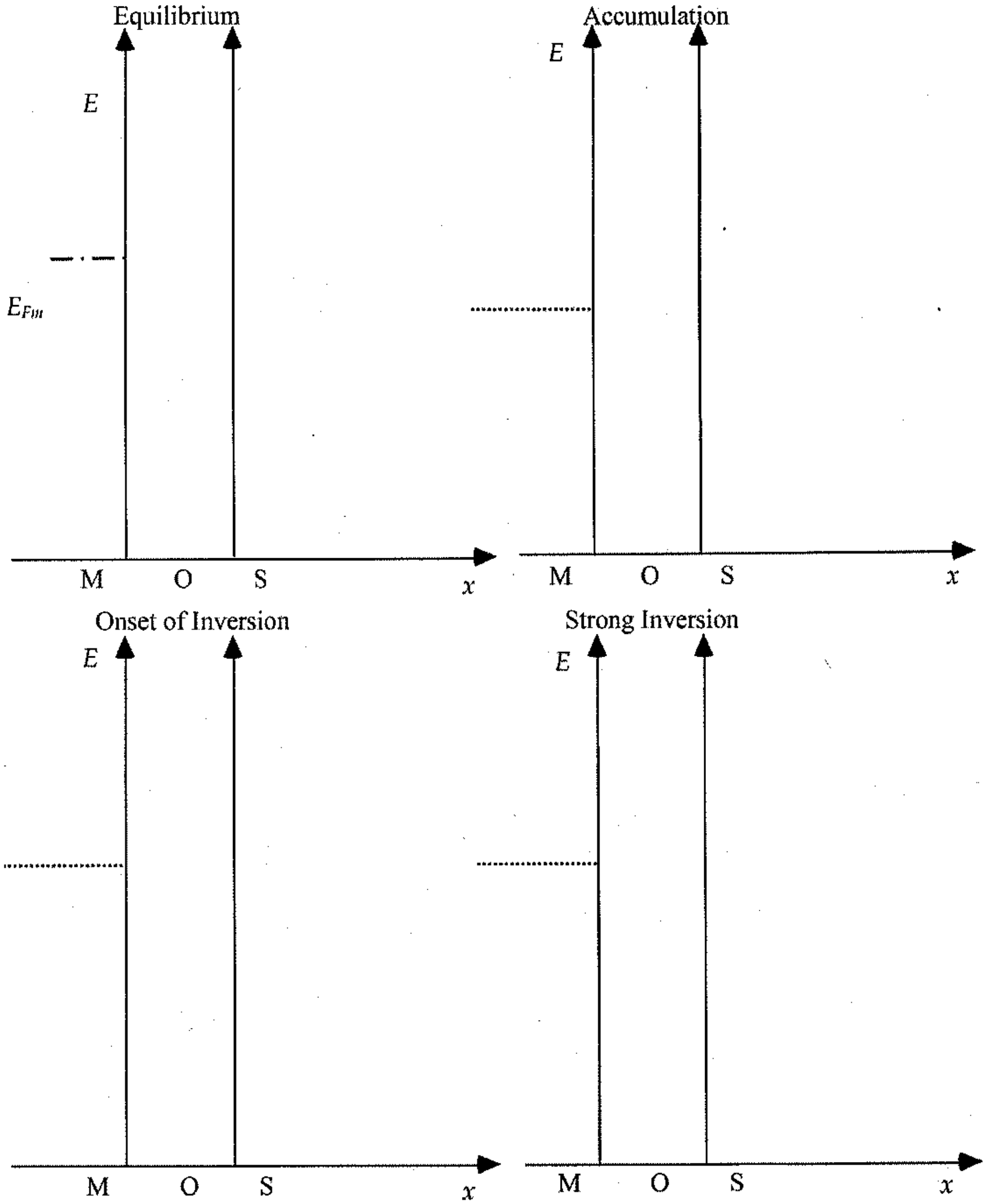
b. On the E vs. x scales (shown on the next page) labeled "***accumulation***", draw the schematic energy-band diagram for the above capacitor under the **accumulation** condition. Label **all** of the above energies and potentials, and the appropriate applied gate voltage, V_G. For full credit, you MUST label the drawing completely. Use the given "energy reference point" as above for your sketch!

c. On the E vs. x scales labeled "***on-set of inversion***", draw the schematic energy-band diagram for the above capacitor under the **on-set of inversion** conditions. Label **all** of the energies and potentials listed in Part 1a, and the appropriate applied gate voltage, V_G. For full credit, you MUST label the drawing completely. NOTE: Use the given "energy reference point" as above for your sketch!

d. On the E vs. x scales labeled "***strong inversion***", draw the schematic energy-band diagram for the above capacitor under **strong inversion** conditions. Label **all** of the energies and potentials listed in Part 1a, and the appropriate applied GATE voltage, V_G. For full credit, you MUST label the drawing completely. NOTE: Use the given "energy reference point" as above for your sketch!

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

a – d: ***NMOS Capacitor with $\Phi_m > \Phi_S$:*** Show Φ_m, Φ_S, E_{COX}, E_C, E_V, E_{F_S}, E_{F_m}, E_i, E_O, ϕ_S, ϕ_F, and χ_s and draw and label an arrow showing the ***magnitude of the applied gate voltage, V_G,*** for each relevant case.



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

Problem 13 (Core: DSP-ECE2025)

Consider a continuous time signal $s(t) = 1 + 2\cos(0.2\pi t) + 3\cos(1.5\pi t + 0.4\pi)$.

(a) Find the fundamental frequency f_0 and the Fourier series coefficients a_k's of $s(t)$, i.e., $s(t) = \sum_{k=-\infty}^{\infty} a_k e^{j2\pi k f_0 t}$. Note that you need to list all the non-zero coefficients a_k's and their corresponding indices k.

(b) The signal $s(t)$ is filtered by a linear time-invariant system whose impulse response is $h(t)$, and whose frequency response is $H(j\omega) = \int_{-\infty}^{\infty} h(t)e^{-j\omega t}dt = (1 - e^{-|\frac{\omega}{2\pi}|})e^{-j0.1\omega}$. Find the resulting output $y(t) = s(t) \star h(t)$ with $\star$ denoting the linear convolution. Express your answer for $y(t)$ as a real-valued function of t.

(c) The signal $s(t)$ is sampled by an ideal continuous-to-discrete (C-to-D) converter operating at a rate of $f_s = 1$ Hz. The resulting discrete-time signal $x[n]$ goes through an ideal discrete-to-continuous (D-to-C) converter operating at a higher rate of $f_s = 2$ Hz. Find the D-to-C output $z(t)$ as a real-valued function of t.

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

For this problem, you may find the following formula useful:

$$\int_0^\infty x^n \exp[-ax]dx = \frac{n!}{a^{n+1}}$$

Max and Addie are engaged in a timed Sudoku tournament.

For Max, the probability density function for the time (in minutes) required to finish is:

$f_X(x) = \lambda^2 x e^{-\lambda x} u(x)$.

For Addie, the probability density function for the time required to finish is:

$f_Y(y) = \lambda e^{-\lambda y} u(y)$.

The notation $u(x)$ signifies the unit step function.

The times are statistically independent of each other.

(a) Find the joint density function for X and Y. A drawing will be helpful.

(b) Let Z be the difference between the two times: $Z = X - Y$. Find the means and variances for X, Y, and Z.

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

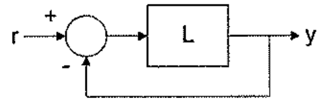
(c) Let W represent the event {Max beats Addie} (i.e., $X < Y$). Find Prob(W).

(d) Find $f_{X|W}(x|W)$, the conditional probability density function for Max's time, given that he beat Addie.

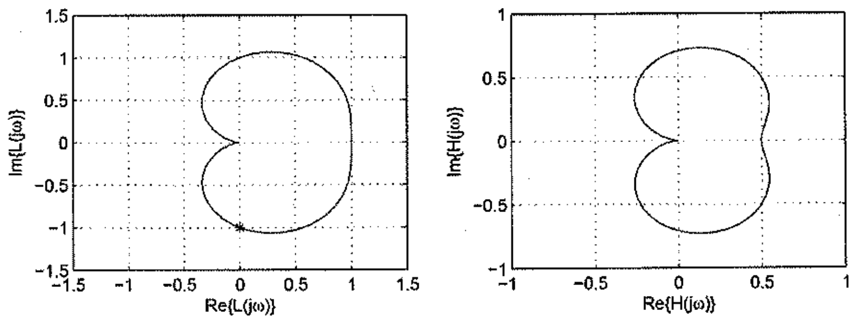
(e) Independent of whether she wins or not, Addie will receive N dollars in prize money, where $N = e^{-Y}$. Find $f_N(n)$, the pdf for her winnings.

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

A control system has the following structure, where $L(s)$ is a ratio of two polynomials; $L(s)$ has more poles than zeros, and all its poles are located in the open left half plane. Let $H(s)$ denote the overall transfer function satisfying $Y(s) = H(s)R(s)$.



(a) The loop transfer function $L(s)$ is characterized in the diagram to the left and the overall transfer function $H(s)$ is characterized in the diagram to the right; the labeling of these diagrams establishes a unique correspondence between them. Precisely mark the diagram to the right with an asterisk corresponding to the asterisk found on the diagram to the left.



(b) Prove that this system is internally stable.

(c) Determine the phase margin and the gain margin of this system.

(d) Assume $r(t) = 1(t)$, where $1(t)$ denotes the unit step function.
Find α such that $\lim_{t\to\infty} y(t) = \alpha$.

(e) Assume $r(t) = \cos(\omega_0 t) \cdot 1(t)$, where $1(t)$ denotes the unit step function.
Find α and θ such that $\lim_{t\to\infty} y(t) = \alpha\cos(\omega_0 t + \theta)$, where ω_0 corresponds to the asterisk in part (a).

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

Consider the control system shown in Figure 1, where $G(s)$ is the plant's transfer function, $G_c(s)$ is the controller's transfer function, $r(t)$ is the reference input, and $y(t)$ is the output. Given constants $A > 0$ and $\tau > 0$, let

$$G(s) = \frac{A}{s(1+\tau s)}.$$

1. Design a controller $G_c(s)$ such that the closed-loop system yields a zero steady-state tracking error in response to a ramp input. That is, for $r(t) = \alpha \times ramp(t)$ for any $\alpha \in R$, $\lim_{t\to\infty}(y(t) - r(t)) = 0$. Express your answer in terms of A and τ.

   Note: If your design yields an unstable closed-loop system you will not get any partial credit.

2. Suppose now that the sensor at the output has a bias, modeled as a step input $v(t) := \beta \times step(t)$ for some $\beta > 0$. The resulting system is shown in Figure 2. Can there be a controller $G_c(s)$ that gives a zero-steady-state tracking error in response to a a ramp input as in part (1), and a disturbance rejection to v? In other words, is it possible to have a controller $G_c(s)$ such that, for every $\alpha \in R$ and $\beta > 0$, with $r(t) = \alpha \times ramp(t)$ and $v(t) = \beta \times step(t)$, $\lim_{t\to\infty}(y(t) - r(t)) = 0$? Explain your answer.

   Please note: The grading of this part of the problem will be based on the explanation, so an answer without an explanation will carry no points.

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

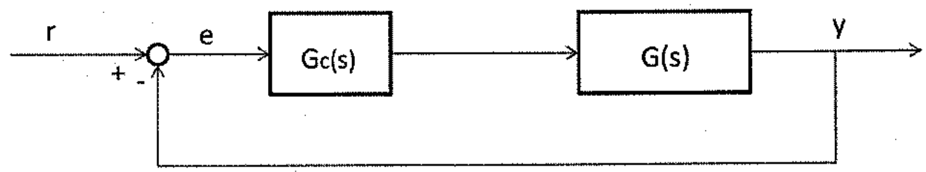


Figure 1: The system configuration for the first part of the problem

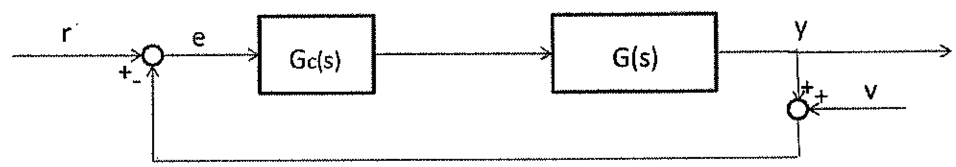


Figure 2: The system configuration for the second part of the problem

Problem 17 (Specialized: CSS-CS3210) Code Number:______

```
// PTHread example

#include <pthread.h>
#include <iostream>

int activeThreads ;

pthread_mutex_t activeMutex;
pthread_cond_t  allDoneCondition;

void* Thread(void* v)
{ // This is the thread starting point
  unsigned long myId = (unsigned long)v;
  std::cout << "Hello from thread " << myId
            << " active threads " << activeThreads << std::endl;
  pthread_mutex_lock(&activeMutex);
  activeThreads--;
  if (activeThreads == 0)
    {
      pthread_cond_signal(&allDoneCondition);
    }
  pthread_mutex_unlock(&activeMutex);
}

int main(int argc, char** argv)
{
  pthread_mutex_init(&activeMutex, 0);
  pthread_cond_init(&allDoneCondition, 0);

  pthread_mutex_lock(&activeMutex);
  activeThreads = 8;
  for (int i = 0; i < 8; ++i)
    {
      pthread_t t;
      pthread_create(&t, 0, Thread,  (void*)i);
    }
  // All threads created, now main waits for all to complete
  std::cout << "Main before wait" << std::endl;
  pthread_cond_wait(&allDoneCondition, &activeMutex);
  std::cout << "Main after wait" << std::endl;
}
```

Program simpleThread.cc

Problem 17 (Specialized: CSS-CS3210) Code Number:______

The sample code above is a simple example demonstrating the use of pthreads. The main program simply creates 8 child threads at lines 32-36, and then waits for all child threads to complete. Each child thread simply prints a hello message, decrements the activeCount variable, and signals the main if all have exited.

1. Notice the main locks the activeMutex at line 30, and never unlocks it. Also notice the child threads lock the same mutex at line 16. This seems like it should deadlock since the main has the mutex and does not unlock it. Explain why does the code not deadlock? Why does every thread decrement the variable once?

2. Below is the output from running this program. Notice that threads 0, 1 and 3 all claim 8 active threads at that time, and no threads claim the active count is 4. Explain how this is possible.

```
Hello from thread 0 active threads 8
Hello from thread 1 active threads 8
Main before wait
Hello from thread 3 active threads 8
Hello from thread 4 active threads 7
Hello from thread 2 active threads 5
Hello from thread 5 active threads 3
Hello from thread 6 active threads 2
Hello from thread 7 active threads 1
Main after wait
```

3. Which thread number do you think will execute the pthread_cond_signal at line 20. Explain your answer.

Problem 18 (Specialized: CSS - ECE3035) Code Number: _____

Consider a 32-bit system where the memory image of each process starts with the code at the bottom of the address space, followed immediately by the global data, and then the heap. The stack is on the top of the address space and grows downward. Any process can use up the entire 4GB of address space.

The program below consists of a series of recursive function calls. Suppose you can change the value of N defined in line 3. Estimate the maximum value you can define for N before the program will crash. You don't need to come up with an exact number but you need to show your steps.

Notes: 1. double data type is 8 bytes.

2. the code uses Variable Length Array, which is supported in the C99 dialect of C. For example, the GNU C Compiler gcc allocates memory for VLAs on the stack.

```
#include <stdio.h>
#include <stdlib.h>
#define N 7000

int dowork(int n)
{
   register int i,j;
   double A[n][n];

   if( n > 7000 ) {
      dowork(n-1);
   } else {
      for (i=0; i<n; i++)
        for (j=0; j<n; j++)
          A[i][j] = ((i*j)/3.452) + (N-i);
   }

   return 0;
}

int main(int argc, char *argv[])
{
   dowork(N);
   return 0;
}
```

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

Given that the end-end delay between Host A and Host B is 10 milli-seconds, and a bottleneck link has bandwidth 12.8Mbps. Assume that the bottleneck link dominates the end-end delay which is half of the round trip time (RTT). Assume maximum segment size (MSS) is 1000 bytes, and all segments are MSS.

(a) Assume TCP now uses a window size *n* to sent segments. What should *n* be to fill the "bit pipe" at the bottleneck link in one RTT? (In other words, what is the bandwidth-delay product when the delay is considered as RTT?)

(b) Consider that TCP starts from slow-start. Assume that there is no loss. How many RTTs are needed for the TCP congestion window size to grow to be at least *n*? How many bytes are sent in all the RTTs from the beginning of the slow start to the window size n?

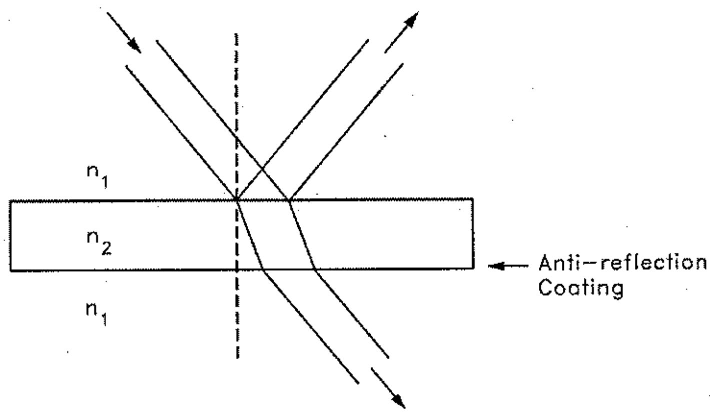
(c) Now consider that two TCP flows are sharing the bottleneck link. Assume that each flow is "on" with probability p ($0 < p < 1$) when an end-user is active and each flow is "off" when an end-user is inactive with probability $1-p$. Users are either active or inactive independently. Assume other conditions remain the same, i.e., TCP still starts from slow start and there is no loss.

Assume TCP is fair. On the average, would one user send more bytes, or fewer bytes, or the same bytes, compared with your answer in Part (b), when the TCP congestion window grows sufficiently large to fill the bit pipe? Why?

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

Linear Polarization by Brewster Angle Incidence

A wide beam (like a plane wave) of light of freespace wavelength 480.0 nm is incident in air (of refractive index, $n_1 = 1.000$) upon a slab of glass (of refractive index, $n_2 = 1.500$) as shown in the diagram. The angle of incidence is the Brewster angle. The back side of the slab has an anti-reflection coating as shown in the figure.



Half of the power in the incident beam of light is TE polarized and half of the power is TM polarized. This configuration is used to produce linearly polarized light (the reflected beam).

Specify the polarization of the reflected light. Calculate, showing all work, the Brewster angle and the fraction of the total optical power that becomes linearly polarized. Express the angle in degrees and the fraction of the power as a percent both accurately to within four significant figures. Put your final answers in the spaces provided.

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

The polarization of the reflected light is (cirle one)

(right-elliptically polarized)

(left-elliptically polarized)

(right-circularly polarized)

(left-circularly polarized)

(linearly polarized normal to plane of incidence)

(linearly polarized in the plane of incidence)

(none of the above)

Brewster angle = ____________ °

Percent of the total incident power that becomes linearly polarized = __________ %

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

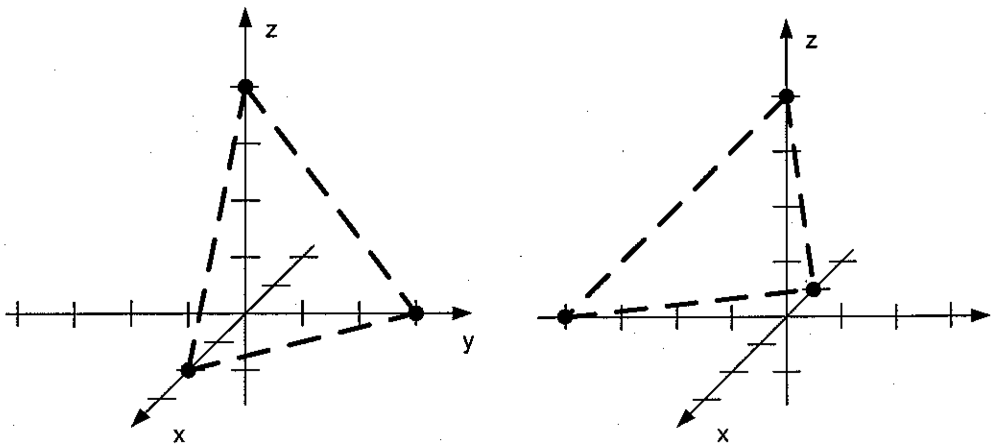
Optical Fiber

For a wave with free space wavelength 1550nm and propagating in a fiber with effective index of refraction n_{eff}=1.470

a) Determine the frequency and wavelength in the fiber at 1550nm.
b) Calculate the phase velocity and wavenumber at 1550nm.
c) If $dn/d\lambda$ = -2x10^(-5) [1/nm] at 1550nm, determine the group velocity.
d) Sketch the ray picture of two different modes in a step index multimode fiber, identify which mode has the highest group velocity and identify which has the largest cutoff frequency.

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

A) Find the Miller indices for the planes illustrated in the figures below.



B) Calculate the angle between the (100) plane and the (111) plane in single crystal silicon material.

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

For a voltage clamped membrane, find the minimum seal resistance to achieve a signal to noise ratio of 75 for a potassium channel with the following characteristics.
g_k=20 pS , V_m = -40 mV, E_k = -90 mV, T = 25 C, frequency range = 10 KHz.

Problem 24 (Specialized: Bio Eng-ECE4782) Code Number:________

There could be diagnostic value in estimating a transfer function for the blink reflex in a patient with closed head injury. A "white-noise protocol" could be used.

A. (2 points) How would you create a Gaussian, band-limited, white-noise stimulus?
B. (4 points) How would you calculate a first-order linear transfer function?
C. (4 points) What are the possible pitfalls in your diagnostic protocol that could lead to inaccurate results?

Problem 25 (Specialized: Bio Eng-ECE4781) Code Number:________

Spinal cord injured patients can often recover some level of motor control by practicing movements with EMG feedback.

A. (2 points) Describe how you would design and construct a surface electrode that mounts onto a finger.
B. (4 points) Show a block diagram that indicates all of the components you would need for a data acquisition system for a human EMG training protocol, i.e. to help the patient relearn how to control his/her finger. Also describe any software algorithms that would be needed.
C. (2 points) Specify and justify the corners you would use for each analog filter and describe any phase shift considerations.
D. (2 points) What sort of feedback would you provide to the patient to help the patient quantify the level of motor control of his/her finger.