Ph.D. Preliminary Examination **Code Number _____**
Spring 2010

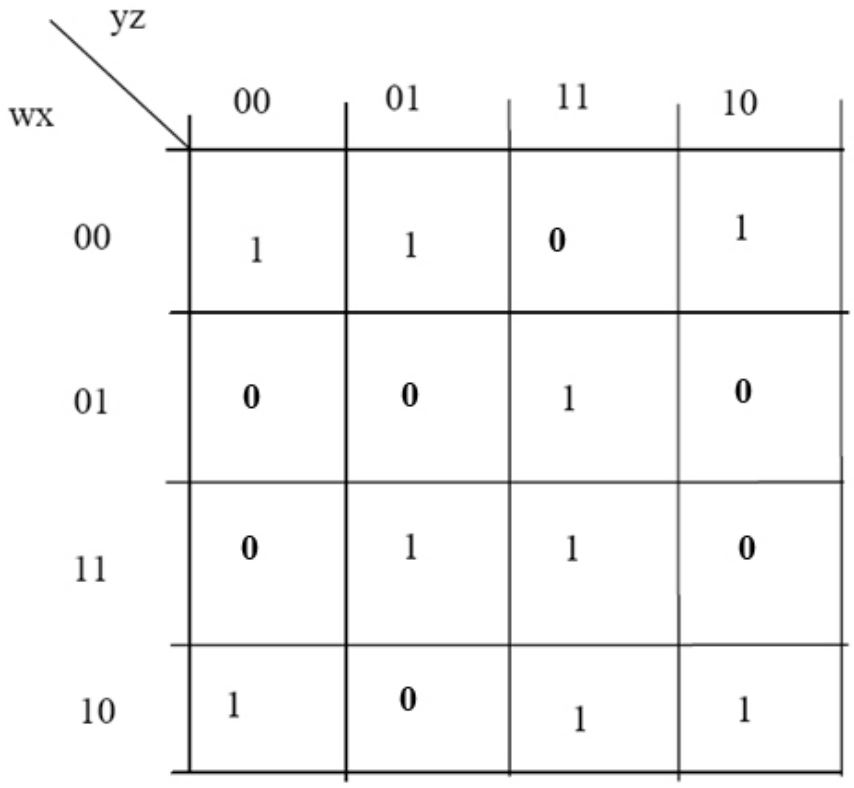
Instructions:

1. Please check to ensure that you have a complete exam booklet. There are 25 numbered problems. Note that **Problem 1 occupies 2 pages**, **Problem 2 occupies 2 pages** and **Problem 18 occupies 2 pages**. Including the cover sheet, you should have **29 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:_____**

Consider the following K-map for the boolean function f( ):



(a) Give a minimal *sum of products* form expression for the function f( ) below:
f(wxyz) =

(b) Give a minimal *product of sums* expression for the same function f( ) below:
f(wxyz) =

(c) Show an implementation of the function obtained in part (a) using a *minimum* number of inverters and NOR gates only. You must use only two or three input NOR gates in your design and may give your final circuit in mixed-logic notation if you prefer.

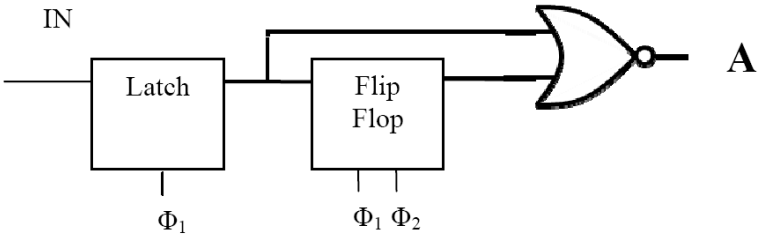
(d) Show an implementation of the function obtained in part (b) using a *minimum* number of inverters and NAND gates only. You must use only two or three input NAND gates in your design and may give your final circuit in mixed-logic notation if you prefer.

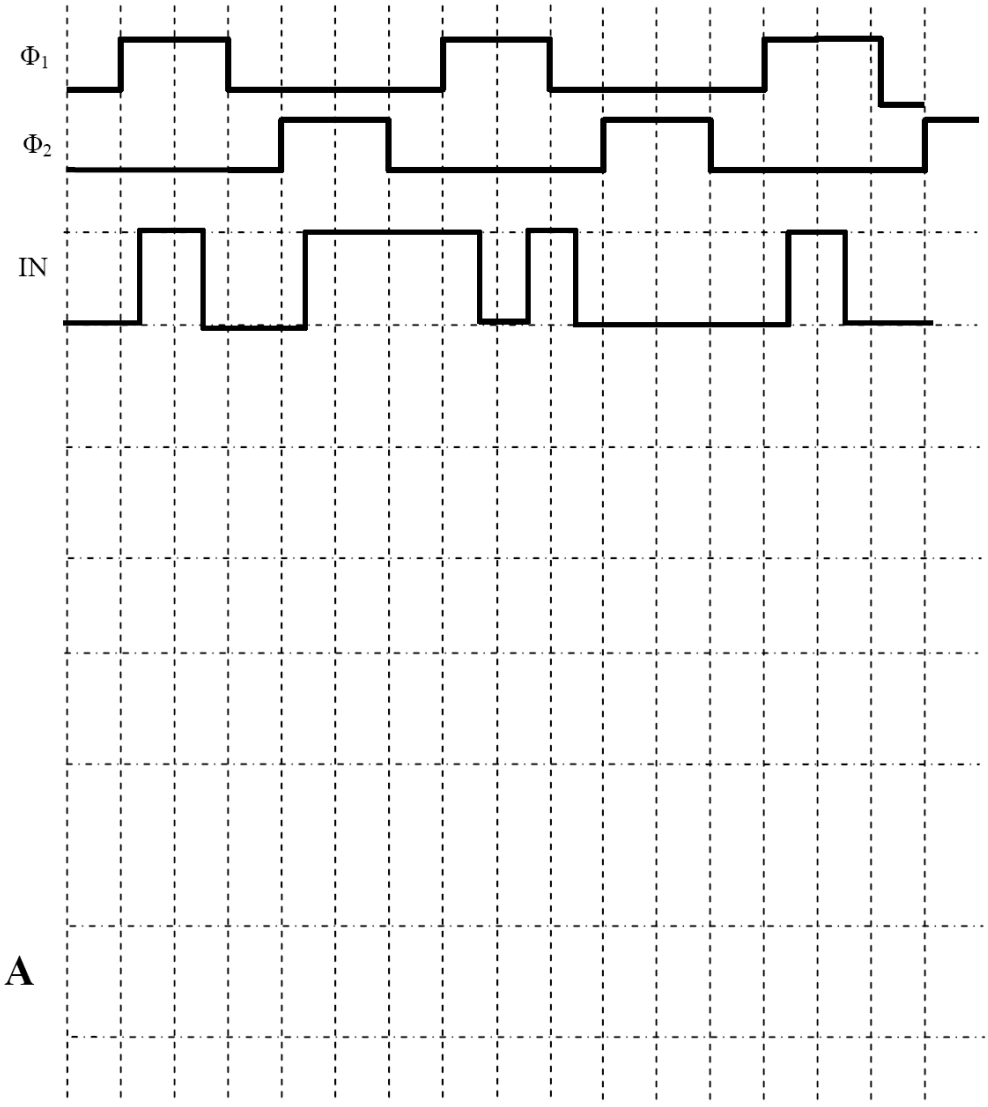
Problem 2 (Core: CompE-ECE2030) Code Number:_____

a. (4 pts) Consider an encryption device where a 3-bit input number is encrypted by performing a bit by bit exclusive-OR operation with a secret key 110 followed by a circular left shift of the result by one bit. Design and show a minimized circuit implementation of this device using only 2 input NAND gates.

Problem 2 (Core: CompE-ECE2030) Code Number:_____

b. (6 pts) Draw the waveform of A. Flip flops use two phase non-overlapping clocks. Assume all registers and latches are initialized to 0 and ignore gate delays. State any other assumptions you wish to make.





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

The following RISC assembly language program is executed on a 32-bit MIPS processor. Fill in the register values that will be present, after execution of this program. A summary of MIPS instructions is included at the bottom of the page – for anyone unfamiliar with the MIPS instruction set. Prior to execution of the program, memory location 0x04000 contains 0x30552031. ***Note**:* 0x indicates hexadecimal and all answers must be in hexadecimal, default is decimal in the MIPS assembly language source file. A MIPS memory word or register contains 32-bits. Use XXXXXXXX for an undefined value.

```
            lw      $3, 0x04000
            srl     $4, $3, 9
            sub     $2, $4, $3
            xor     $3, $4, $2
            lui     $5, 10
            ori     $5, $5, 12562
            add     $6, $4, $3
            bne     $5, $6, LABEL1
            addi    $6, $0, -20
LABEL1:     sw      $6, 0x04000
```

After execution of the MIPS code sequence above,

R2 = 0x_____(*in hexadecimal*)

R3 = 0x_____(*in hexadecimal*)

R4 = 0x_____(*in hexadecimal*)

R5 = 0x_____(*in hexadecimal*)

Memory Location 0x04000 contains: 0x_____(*in hexadecimal*)

The MIPS processor contains thirty-two 32-bit registers, $0 through $31. $0 always contains a zero. By default, all arithmetic operations use two's complement arithmetic. Assume no branch delay slot is present.

MIPS Instruction			***Meaning***
ADDI	Rd, Rs, *Immed*	-	Rd = Rs + *Immediate* value
ADD	Rd, Rs, Rt	-	Rd = Rs + Rt (R – register ($))
ORI	Rd, Rs, *Immed*	-	Rd = Rs low 16-bits bitwise logical OR *Immediate* value
LUI	Rd, *Immed*	-	Rd = 16-bit *Immediate* value high 16-bits, 0's low 16-bits
BNE	Rs, Rt, *address*	-	Branch to *address*, only if Rs not equal to Rt
LW	Rd, *address*	-	LOAD - Rd gets contents of memory at *address*
SRL	Rd, Rs, *count*	-	Shift right logical (*use 0 fill*) by *count* bits
SUB	Rd, Rs, Rt	-	Rd = Rs - Rt
SW	Rd, *address*	-	STORE - memory at *address* gets contents of Rd
XOR	Rd, Rs, Rt	-	Rd = Rs bitwise logical XOR Rt

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

You are part of a design team working on a new 3D integrated massively multi-core processor with 2^{18} cores. The implementation technology is CMOS. You are investigating the design of a hardware barrier synchronization mechanism in which the global AND ($B = \prod_{i=0}^{2^{18}-1} b_i$) of a signal b_i from each processor is computed and then distributed back to each processor. Assume a design style in which the ratio of pfet to nfet width in an inverter is $\gamma = 1$ and all gates are designed so that worst case risetime/falltime ratios correspond to that ratio for the inverter. Calculate delay in units of τ (the delay of an inverter driving an identically sized inverter), and include gate parasitic delays but neglect interconnect parasitic capacitance. Assume that the input capacitance of a minimum size inverter is C_{inv} and the parasitic delay of an inverter is τ. You may wish to solve the problem using the method of logical effort.

(a) Estimate the minimum delay required to compute B. Assume alternating *k*-input NAND and NOR gates (a radix *k* tree), and compare implementations with $k = 2$ and $k = 4$. Also assume that B drives a load of C_{inv}.

(b) Estimate the minimum delay to distribute B back to each processor.

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

A coaxial transmission line is constructed from two conducting cylindrical shells, one of radius 2 mm and the other of radius 5 mm, centered along the *z*-axis and separated by a material with $\mu_r = 4.0$ and $\varepsilon_r = 1.0$. When energized so that a current flows down one cylinder and returns on the other, the magnetic field between the cylinders is

$$\bar{H} = \frac{7.958 \times 10^{-2}}{\rho}\hat{\phi} \quad \text{(A/m)}$$

where ρ (the radial distance from the center) is in units of meters. You may use $\mu_0 = 4\pi \times 10^{-7}$ H/m. Provide numerical answers whenever possible.

(a) What is the total current in Amperes on the inner conductor?

(b) What is the surface current density $\bar{J}_S$ in A/m on the inner cylinder?

(c) What is the magnetic flux density $\bar{B}$ as a function of ρ between the cylinders?

(d) What is the total energy per unit length stored in these fields?

(e) What is the total inductance *L* per unit length of the transmission line?

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

2. The electric field of a plane wave propagating in a nonmagnetic material is given by:

$\mathbf{E}=[\hat{\mathbf{y}}\ 3\ \sin(2\ \pi \times 10^7\ t - 0.4\ \pi\ x) + \hat{\mathbf{z}}\ 4\ \cos(2\ \pi \times 10^7\ t - 0.4\ \pi\ x)]$ (V/m)

(a) What is the direction of propagation? Is the medium lossy or lossless and why?

(b) Calculate the wavelength and the dielectric constant ϵ_r.

(c) Calculate the intrinsic impedance of the medium η.

(d) Calculate the instantaneous expression of magnetic field $\mathbf{H}$.

(e) Does this wave feature linear, circular or eliptical polarization and why?

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

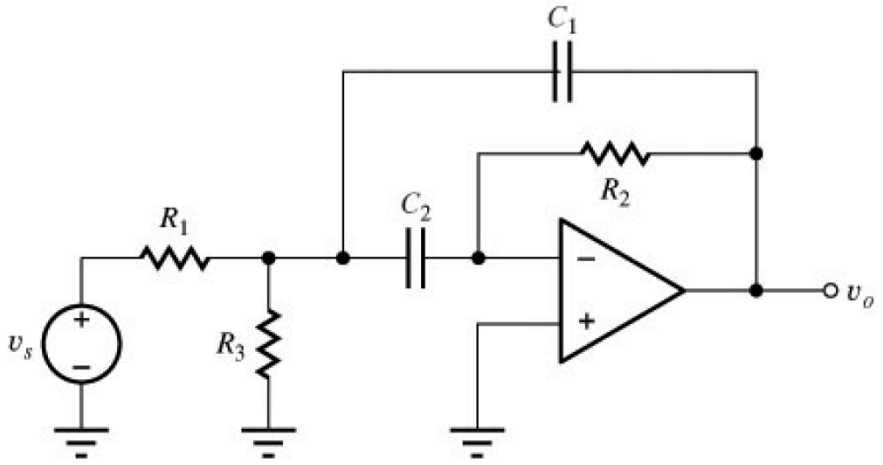
Revision requested

Problem 8 (Core: EDA-ECE3050) Code Number:_____

1. In the following circuit assume that the OpAmp is ideal.
a) Find the transfer function $A_v(s) = v_o(s)/v_s(s)$
b) Draw the Bode plot (amplitude and phase).
c) What is the function of this circuit? Describe an application where it can be used.
d) Find the frequency at which the voltage gain is maximized if:

$C_1 = C_2 = C$, $R_3 \to \infty$, $\omega_0 = \dfrac{1}{C\sqrt{R_1 R_2}}$, and $Q = \dfrac{1}{2}\sqrt{\dfrac{R_2}{R_1}}$

e) Find the bandwidth of this circuit (Hint: Q is the quality factor).



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

A 7.5 kVA, 440/220 V transformer has the following readings from Open Circuit (OC) and Short Circuit (SC) tests:

OC test: Voc = 220 V, Ioc = 1 A, Poc = 50 W
SC test: Vsc = 15V, Isc = 17A, Psc = 60 W

Find the equivalent circuit and all parameters referred to the high voltage side.

Problem 10 (Core: Power-ECE3070) Code Number:_____

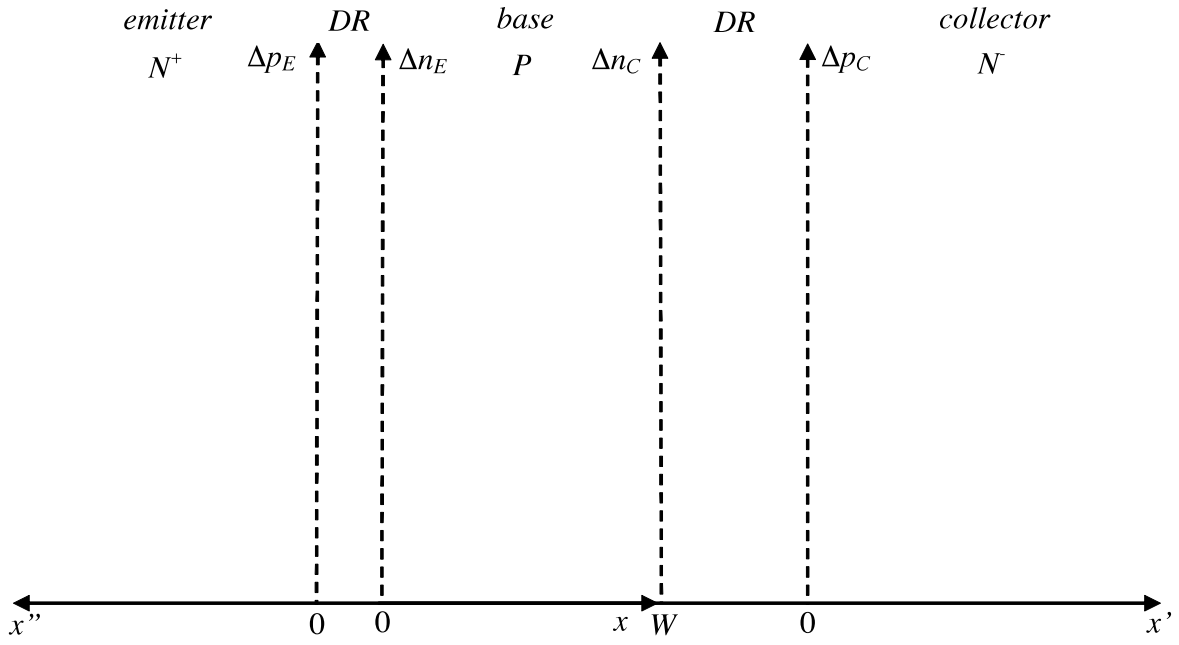
A 6-pole, 230-V (L-L), 60 Hz, Y-connected stator, three phase induction motor has the following parameters on a per phase basis, all referred to the stator side:

Stator resistance = 0.5 ohm
Stator leakage reactance = 0.75 ohm
Rotor resistance referred to stator side = 0.25 ohm
Rotor leakage reactance referred to stator side = 0.05 ohm
Core loss equivalent resistance = 500 ohm
Magnetizing current is small enough to be neglected.
Neglect mechanical losses.

Use the approximate equivalent circuit for the motor, which has the core loss resistance across the input terminals to the circuit. Draw the circuit, insert your symbols, and then determine the efficiency of the motor at its rated slip of 2.5%.

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

In the diagram below, USING SOLID LINES, draw the ***total*** minority carrier distribution on a LINEAR SCALE for an **N^+-P-N^- BJT** under "low-level" ***Normal Active Region*** bias conditions. Clearly indicate the polarity of the voltages V_{BE} and V_{BC}, the minority carrier types, and the boundary values of *excess minority carrier concentrations* in each region (in list below the figure). To construct carrier distribution profiles, use the "narrow base" approximation to simplify your drawing. The sketch of each curve should also reflect relative magnitudes of the equilibrium and excess carrier concentrations for a **N^+-P-N^-** BJT. Random drawings will receive zero credit—even if they look like a Picasso–use your best "engineering artistic skills".



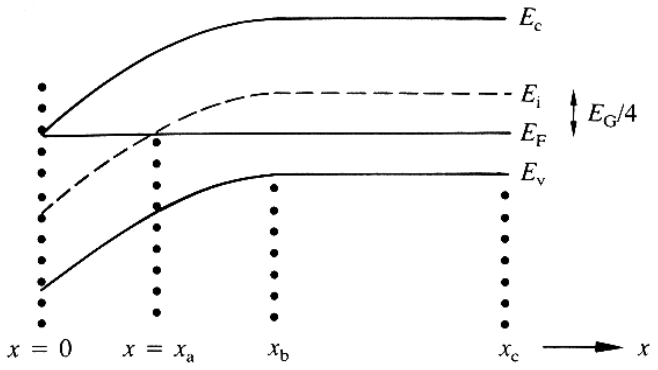
Normal Active Region

$D p_E (x"=0)$ = _____ $D p_C (x'=0)$ = _____

$D n_B (x=0)$ = _____ $D n_B (x=W)$ = _____

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

A semiconductor is characterized by the energy band diagram below. It is also known that $E_G = 1.12$ eV, kT = 0.0259 eV, $n_i = 10^{10}$ cm^{-3}, $\mu_n = 1350$ cm^2/Vs, $\mu_p = 460$ cm^2/Vs and $t_n = 10^{-4}$ s.



(a) Sketch the electrostatic potential and the electric field inside the semiconductor as a function of x, labeling the positions x = 0, x_a, x_b, and x_c.

(b) Sketch the **electron** concentration n as a function of the position x (indicate n_i) and calculate n at $x = x_a$ and $x = x_c$.

(c) Calculate the resistivity of the semiconductor at $x = x_a$ and $x = x_c$.

(d) Is there an electron drift current at $x = x_a$? Is there an electron diffusion current at $x = x_a$? What is the total electron current density J_n at $x = x_a$? Explain your answers but don't calculate particular values for the diffusion and drift current.

(e) An electron at $x = x_b$ with total energy $E = E_C$ moves from $x = x_b$ to x = 0 without changing its total energy. What is the kinetic energy of the electron upon arriving at x = 0?

(f) By illumination, an excess of electron-hole pairs is generated at $x = x_c$ at a rate $G_L = 10^{19}$ cm^{-3} s^{-1}. Calculate the resistivity of the semiconductor at $x = x_c$ after illumination.

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

(a) (5 pts) Suppose we have a **linear, time-invariant** continuous-time system, and that the system outputs the signal

$$y_1(t) = 8(t-5)^3 \cdot 3e^{-2(t-5)}u(t-5)$$

when it is given the input signal

$$x_1(t) = 4(t-4)^2 \cdot 2e^{-2(t-4)}u(t-4).$$

Find the output of the system, $y(t)$, if the input is

$$x_2(t) = 12(t-6)^2 \cdot 2e^{-2(t-6)}u(t-6) - 4(t-8)^2 \cdot 2e^{-2(t-8)}u(t-8)$$

Note: the signal $u(t)$ is the *unit-step* signal.

(b) (5 pts) Suppose that we have a discrete-time system whose output $y[n]$, given an input $x[n]$, is specified by

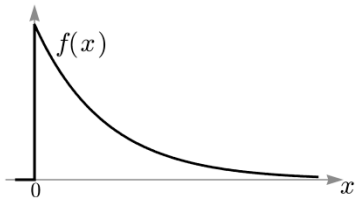
$$y[n] = 4\sum_{k=5}^{15} x[n-k]$$

Consider the input $x[n] = 8\sin(\hat{\omega}n + \pi/7)$. For what value(s) of $\hat{\omega}$ does $y[n] = 0$ for all n? If there are many such frequencies, $\hat{\omega}$, then clearly and concisely specify all of them in the interval $0 \leq \hat{\omega} < 2\pi$.

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

3075 PROBLEM

Let X and Y be independent and identically distributed random variables with pdf $f(x) = e^{-x}u(x)$, as sketched to the right. (The unit step is $u(x) = 1$ for $x > 0$ and $u(x) = 0$ elsewhere.)



Put all answers in *simplest form*.

(a) The mean and variance of $Z = 2X - 3Y$ are: $E(Z) =$ [ ], and $\text{var}(Z) =$ [ ].

(b) Find $E(e^{0.9(X+Y)}) =$ [ ].

(c) The pdf for the ratio $R = \dfrac{X}{Y}$ is $f(r) =$ [ ].

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

Let N be an integer greater than 59. Have a look at the system with impulse response

$$h_N(t) = \frac{1 - t^{2N} \sin^{2N} t}{1 - t^2 \sin^2 t}$$

i) Is $h_N(t)$ bounded for bounded t?

ii) Is this a BIBO stable system?

iii) Determine the time-invariant ODE of *least degree* to which it is the solution (express your answer as $a(\mathbf{D})h_N = 0$, where $a(\mathbf{D})$ is a function of the derivative operator $\mathbf{D} = \mathrm{d}/\mathrm{d}t$, you may leave it in factored form).
What is the *minimal* order of this system?

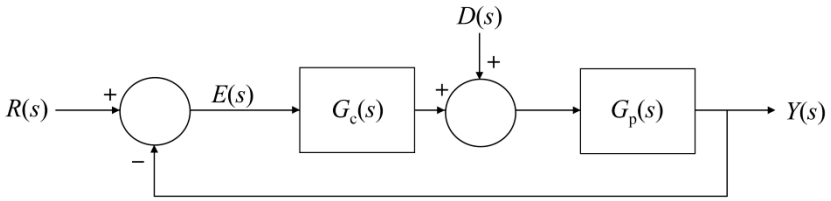
iv) Characterize all solutions to the ODE obtained in (iii).

v) Does this ODE possess periodic solutions? If yes, what are the *minimum* (nonzero) and *maximum* frequencies (in Hz)?

Remark: No guessing! Justify your answers. 4 points for each part solved correctly.

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

Consider the following closed loop control system with both a reference input and a disturbance:



(a) What is the general expression for $E(s)$ in terms of $R(s)$ and $D(s)$?

(b) What is $E(s)$ for the following controller and plant transfer functions?

$$G_c(s) = K_p + \frac{K_i}{s}, \qquad G_p(s) = \frac{3}{s-7}$$

(c) Consider $r(t) = Au(t)$ and $d(t)=Bu(t)$. What are the restrictions (if any) on K_p and K_i so that the steady state error is zero (i.e, $e(t)\to 0$ as $t\to\infty$)?

(d) Determine the expression for the transfer function of the closed loop system, $G_{cl}(s)$, with $r(t)$ as the input, $d(t) = 0$, and $y(t)$ as the output. Determine K_p and K_i so that there is a pair of complex poles at $-4+j$ and $-4-j$. What is the steady state error for a step input?

(e) Now consider the system with $d(t)$ as the input, $r(t) = 0$ and $y(t)$ as the output. Derive a general expression for the transfer function of this system, $H_d(s)$, in terms of $G_c(s)$ and $G_p(s)$. Determine $H_d(s)$ for the specific plant and controller of part (d). What is the steady state response for a step disturbance?

(f) Discuss how these results demonstrate the ability of the feedback system to track the input $r(t)$ and reject the disturbance $d(t)$.

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

Barriers

The *BuggyBarrier* algorithm given below is an attempt to implement a function that is used in multi-threaded applications to insure that all threads have completed some sub-task before proceeding to the next sub-task. Here, we assume that the barrier function is entered repeatedly by all threads, after each thread has performed some specific computation and must wait for all others to complete their computation as well.

Explain why the *BuggyBarrier* algorithm below is incorrect. Assume the variable `CountBarrier` is a global variable visible to all threads in the application. Assume that the **FetchAndIncrement** operation increments the `CountBarrier` variable atomically, and returns the value of the `CountBarrier` variable *before* it's incremented. Also assume that variable `numprocs` indicates the total number of processes participating in the barrier. Finally assume that *spin* call means *do nothing*.

Algorithm BuggyBarrier

This Can't Possibly Work!

```
1 int CountBarrier = 0; /* Global Variable */
2 void BuggyBarrier() {
3    mycount = FetchAndIncrement(&CountBarrier); /* Atomic */
4    if(mycount == (numprocs - 1)) {
5      CountBarrier = 0; // All there, let others know and reset
6    else
7      while(CountBarrier != 0) spin() // Wait for others
8 }
```

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

Suppose we have the following C code segment:

```
main() {
        int x;
        int n=6;
        …
        foo(n);
        x = x + 1;
        …
}

void foo (int n) {
        int a[5];
        int i;

        for(i=0;i<5;i++) a[i] = i;
        for(i=0;i<=5;i++) a[i] = a[i] – 4;

        return;
}
```

Assume that

(1) the above code is compiled and executed on a 32-bit MIPS computer where each instruction is 4 bytes long.
(2) statement 'x=x+1' in 'main' is complied into an add instruction at address 1000.
(3) all the input parameters are passed through the stack.
(4) it is the caller's responsibility to push the input parameters onto the stack.
(5) it is the callee's responsibility to store the return address onto the stack.
(6) local variables in a function are allocated in the order that they are declared.
(7) local variables follow the return address immediately on the stack.
(8) the stack grows downwards (i.e. the top of the stack is at a lower address than the bottom).

There is a problem with the above code, it will cause the program to behave drastically.

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

Part 1: The following figure shows the content of the stack when 'main' is ready to call 'foo' (suppose the stack is at 6000 when 'foo' is called.) Fill the content of the stack when 'foo' finishes the first 'for' loop.

address	content
…	…
6000	6 (the input parameter)
5996	

Use more rows as necessary

Part 2: Fill the content of the stack when 'foo' finishes the second 'for' loop and is about the return.

address	content
…	…
6000	6
5996	

Use more rows as necessary

Part 3: What will happen with the code?

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

What are the characteristics of an Internet Autonomous System (AS).

1. It has a block of Internet Protocol (fill in the word) ____________________________ ,

2. assigned by what organization? ______________________________

3. If it also a "domain", it must maintain two servers, of what type? ______________________________

4. An Autonomous System has a boundary router or routers that connect to the worldwide Internet using what routing protocol? ______________________________

5. What routing protocol is most likely to be used internally by a contiguous AS like Georgia Tech?

____

- -

6. What causes the transit time for Internet datagrams to vary? ____________________________________

7. What causes Internet datagrams to arrive out of order? ____

8. Why are there no MAC address conflicts when a local area network is a mixture of wired Ethernet (IEEE 802.3) hosts and wireless WiFi (IEEE 802.11) hosts.

____

9. If signals travel at 2E8 m/s through 100 Mb/s fiber and wire connections, what is the minimum round trip time, **RTT**, between hosts over a 4000 km path length (neglecting any delay at nodes)?

____

____

10. What is the maximum data transfer rate for a single TCP connection between a host in Atlanta and a host in Chattanooga if the round trip delay is 20 milliseconds, the connection bit rate is 100 Mbps, and the TCP window size is 24,000 bytes?

____

____

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

Focused Laser Beam Spot Size

It is desired to focus an argon-ion laser beam (in air) to the smallest possible spot size using a commercially available optical lens. The argon-ion laser is operating at a freespace wavelength of 488.0 *nm*. The laser can be adjusted to produce a collimated Gaussian beam of either 2 *mm* diameter or 5 *mm* diameter. Commercial lenses are available with focal lengths of 25 *mm* and 50 *mm*. Both lenses can accommodate either beam diameter and produce diffraction-limited performance.

Specify a lens and a beam diameter combination to produce the smallest possible focused laser beam spot size. Calculate, showing all work, the diameter of the resulting focused laser beam spot. Express your answer in *microns* accurately to four significant figures. Put all of your final answers in the spaces provided.

Lens focal length = _____ *mm.*

Laser beam diameter = _____ *mm.*

Minimum spot size diameter = _____ μm.

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

Geometric Optics

A double convex lens has a diameter of 5 cm and zero thickness at its edges. A point object on an axis through the center o the lens produces a real image on the opposite side. Both object and image distances are 30cm, measured from a plane bisecting the lens which has a refractive index of 1.520.

a) Sketch the lens together with two paths one path being a marginal ray and the other being an axial ray, identify each.
b) What can be said of the two paths between object and image?
c) Determine the thickness of the lens
d) What is the focal length of the lens?
e) If the point object is moved 1cm above the optic axis where is the new image located?

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

A two-step boron diffusion is performed in an n-type wafer with substrate doping of 3×10^{16} cm^{-3}. Predeposition is done at 900°C for 15 min followed by a 5-hr drive in at 1100°C. Assume $D = 1.45 \times 10^{-15}$ cm^2/s at 900°C and $D = 2.96 \times 10^{-13}$ cm^2/s at 1100°C

(a) Find the surface concentration and dose after the predeposition if the solubility of boron at 900°C is $1.2 \times 10^{20}/cm^3$

(b) Find the junction depth after the drive in if the surface concentration is $1.1 \times 10^{18}/cm^3$ after the drive in

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

Draw a general action potential for a nerve. Include the temporal characteristics for the sodium and potassium conductances. Include relative numbers for the potential and time axes. Label the schematic with critical features, regions, values, etc.

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

The intracellular and extracellular concentrations and conductances for the axon of a newly discovered squid species at rest are given below.

A) Find the Nernst potential for Na^+, K^+, and Cl^-.

B) Find the membrane resting potential.

$k = 1.38 \times 10^{-23}$ J/K

$q = 1.6 \times 10^{-19}$ ^oC

$T = 37$ ^oC

Species	Intracellular (mM)	Extracellular (mM)	Conductances (mS/cm^2)
K	500	10	0.415
Na	70	350	0.010
Cl	24	350	0.582

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

Draw a standard electrocardiogram for a healthy human being. Label the intervals and describe the relevant heart function for each interval.

The resting (or filling) phase of the heart cycle is called the _____ .

The contractile (or pumping) phase of the heart cycle is called the _____.