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

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** and **Problem 3 occupies 2 pages**. **Problem 16 occupies 5 pages**. **Problem 18 occupies 2 pages**. Including the cover sheet, you should have **33 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**		

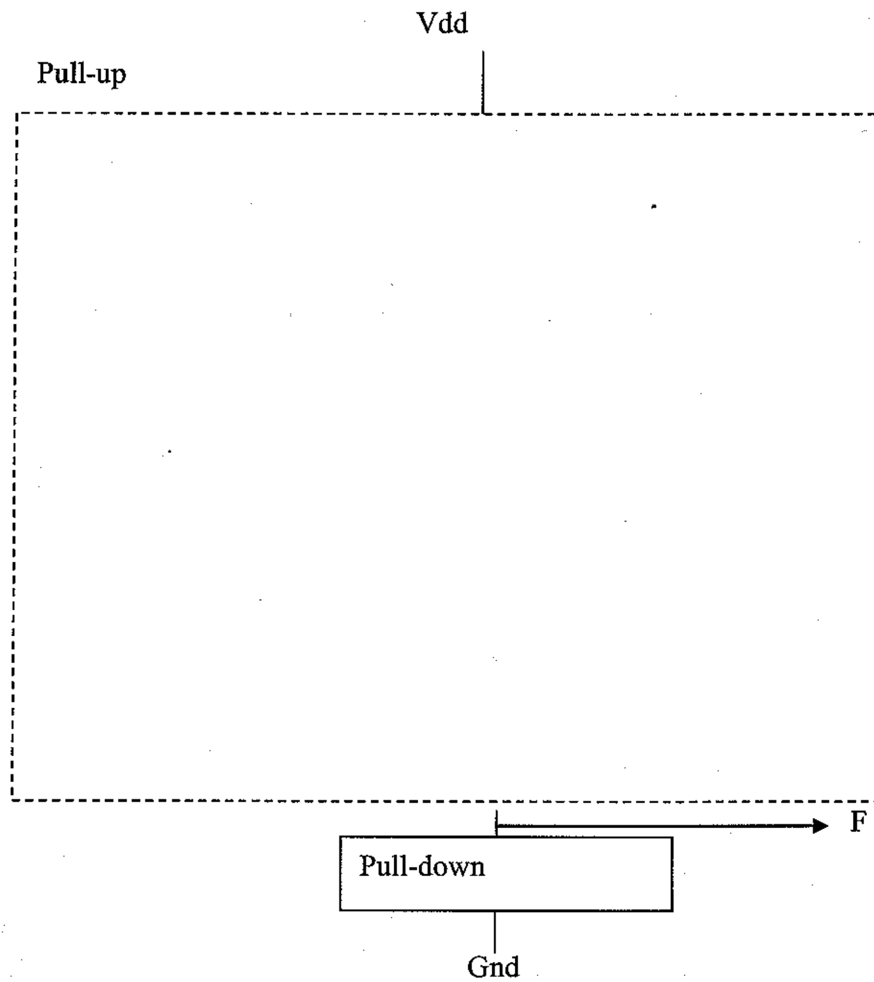
Problem 1 (Core: VSDD-ECE2030) Code Number:________

You are to implement the function $F = \overline{A + (\overline{B} \bullet \overline{(\overline{C} + D)})}$ using (a) inverters and NAND gates and (b) using a complex gate (pull-up/pull-dn chain combination):

(a) For the gate level implementation using inverters and NAND gates, draw the circuit below that realizes the function F using mixed-logic notation (i.e. use the slash "/" notation to represent inversion in the original function F above and cancel bubbles, etc.).

Problem 1 (Core: VSDD-ECE2030) **Code Number:________**

(b) For the complex gate implementation of the function F, draw the pull-up chain below using FETs. We assume that the pull-down chain has already been designed correctly.



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

Design a synchronous **finite state machine** that counts in the sequence 0,2,4,11,3,15,7,1,12 (and repeats). Assume that the 4-bit state register will be constructed using positive-edge-triggered D-type flip flops, with resets. Denote the four bits as "A,B,C,D" where "A" is the most-significant-bit (i.e. count 4 is encoded as ABCD=0100). Treat unused states as "don't care" conditions where appropriate (to minimize the logic).

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

(b) Draw the complete encoded **state transition table** that defines the operation of the counter. Be sure to show how unused states are handled in the table.

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

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

The memory system of a 32-bit processor is comprised of a 4Gbyte virtual address space with 4Kbyte pages, 4-entry fully associative data Translation Lookaside Buffer (TLB) with LRU replacement and a 2 Gbyte main memory. Memory is byte addressed. The L1 data cache is a 32Kbyte direct mapped cache with 64 byte lines that can be accessed in 1 cycle including TLB access. The L2 is a 1Mbyte 16-way set associative cache with 64 byte lines with a hit time of 8 cycles (this includes the line transfer to L1).

1. **(2 pts)** Show the breakdowns of the physical addresses used to access the L1 and the L2 caches, i.e., identify the fields used to access each cache. Clearly label each field.

2. **(2 pts)** Assuming a page table entry has i) a disk or page frame address (24 bits), ii) valid bit, iii) dirty bit, and iv) 6 bits for miscellaneous protection and page management, how large would a flat page table be in bytes?

3. **(3 pts)** The main memory has 16 interleaved banks accessed over a bus with a bank access time of 200 cycles for a 32-bit word. The memory bus can transmit a single address from the L2 to memory in 1 cycle. The data width of the bus is 8, 32-bit words, i.e., 8 words can be transmitted to the L2 in 1 cycle. Write an expression for the average memory access time in terms of the L1 and L2 miss rates (m_{L1} and m_{L2}) and the <u>actual</u> miss penalties at each level of the memory hierarchy. State any assumptions.

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

4. **(3 pts)** Consider a 32x32 matrix stored in memory in row major form starting at address 0x10010000, i.e., all elements in the first row followed by all elements in the second row, and so on. Each element is an integer number that takes 4 bytes. In what L2 set would you find element (10, 12) of the matrix (the first element of the first row is (0, 0)).

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

Consider implementing a logic function in static complementary CMOS style gates. Suppose we wish to minimize the delay for a given function, assuming the rise time and fall time for a given gate is equal in the worst case. Assume that the mobility of electrons is twice the mobility of holes, and thus a minimum size inverter is constructed from an nfet with width W_{min} and a pfet having width $2W_{min}$. For both devices, the gate length $L = L_{min}$. Using the method of Logical Effort, or other techniques, answer the following questions:

1. (6 pts) Given the boolean function $U = QRST + WXYZ$ explore three alternative implementations for this function, assuming that the load capacitance is 10 times the input capacitance for the first stage of the implementation. One implementation must use an AOI44 gate ($V = \overline{QRST + WXYZ}$) and some additional logic, one must use NAND4 and NAND2 gates, and one must use only NAND2 and INV gates. Implementations that do not follow these specifications will receive no credit. For each implementation, give the minimum achievable delay D_{min} including parasitic and effort delay, in units of $\tau = R_n C_{inv}$, where R_n is the resistance of a minimum size nfet, and C_{inv} is the gate capacitance of a minimum size inverter.

2. (4 pts) For the implementation above with the lowest delay, size each transistor in units of W_{min} and L_{min} assuming that $C = C_{inv}$.

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

Prelim Problem: ECE 3025

A coaxial transmission line has inner and outer conductor radii a and b. Between conductors ($a < \rho < b$) lies a "leaky" dielectric, having conductivity $\sigma(\rho) = \sigma_0/\rho$, where σ_0 is a constant. The inner conductor is charged to potential V_0, and the outer conductor is grounded.

a. Assuming dc radial current I per unit length in z, determine the radial current density field $\mathbf{J}$ in A/m^2.

b. Knowing that $\mathbf{J} = \sigma\mathbf{E}$, determine the electric field intensity $\mathbf{E}$ in terms of I and other parameters, given or known.

c. By taking an appropriate line integral of $\mathbf{E}$, find an expression that relates V_0 to I.

d. Find an expression for the conductance of the line per unit length, G.

e. If the capacitance of the line per unit length is known to be C, express the ratio of charge to current in terms of C and G.

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

A 50-MHz plane wave with electric field amplitude of 30 V/m is normally incident in air onto a semi-infinite, perfect (lossless and nonmagnetic) dielectric medium with ϵ_r=36.

[Use $\mu_o = 4 \times \pi \times 10^{-7}$ [H/m] and $\epsilon_o = 10^{-9}$ / (36 π) [F/m]]

(a) Determine the reflection coefficient Γ.

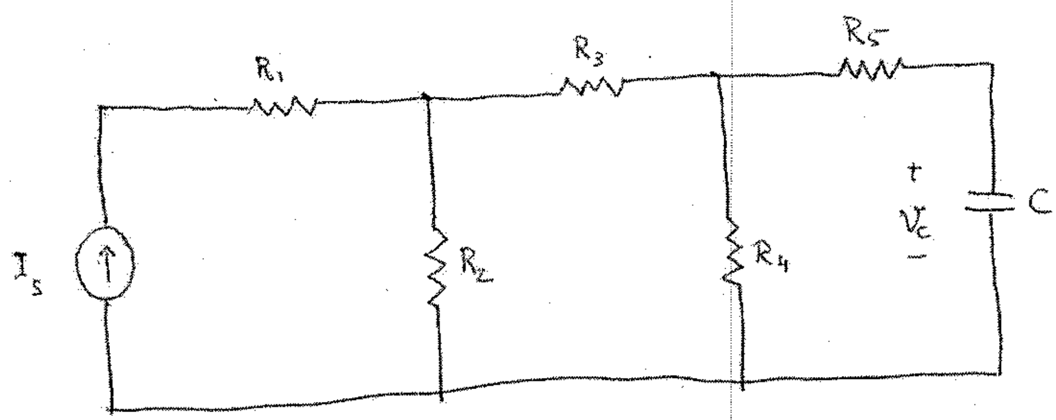
(b) Determine the average power densities of the incident and reflected waves.

(c) Can you design a material transformer (calculate dielectric constant ϵ_r, electrical length and physical length) to place in-between the two media in order to produce no reflection at the incidence point of the air medium?

(d) Repeat (a) after replacing the dielectric medium with a conductor with ϵ_r=1, μ_r=1 and σ=2.78 $\times$ 10^{-3} S/m.

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

Consider the circuit shown in the figure below, where $R_1 = R_2 = R_3 = R_4 = 1$ Ohm, $R_5 = \frac{1}{3}$ Ohm, and $C = 1$ F. Suppose that the current source supplies a constant current of $I_s = 1$ A for all $t \geq 0$. Derive a closed-form expression (formula) for the voltage across the capacitor, $v_c(t)$ (in the polarity shown in the figure), for all $t \geq 0$; assume that $v_c(0) = 0$.



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

In the following circuit assume all devices have:
$|V_t| = 1$ V, $\mu_n C_{ox} = 2\mu_p C_{ox} = 40\ \mu A/V^2$, $\lambda = 0.02\ V^{-1}$, L = 5 μm, $V_{DD} = -V_{SS} = 5$ V
Device widths are all multiples of W = 5 μm.

(a) Design R to provide a 10 μA reference current.

(b) Assuming $v_O = 0$ V, do a bias analysis and indicate the voltages of all the labeled nodes and current in all branches.

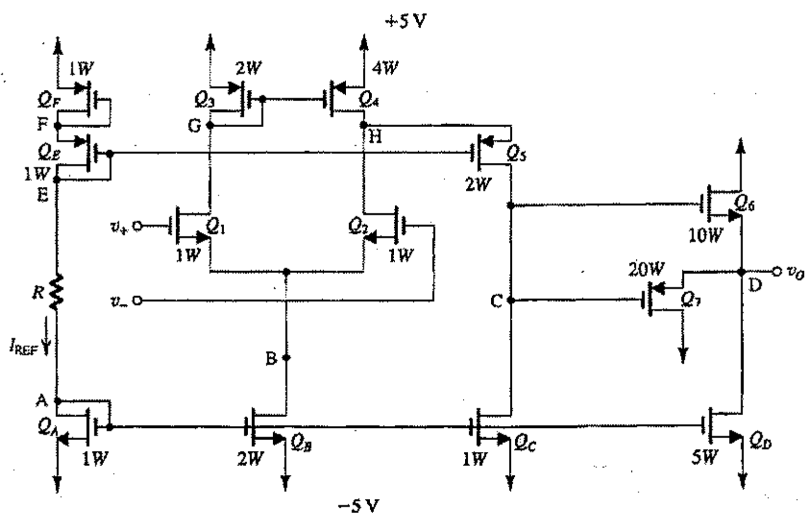
(c) Fill out the following table:

Transistor	I_D	V_{GS}	V_{DS}	g_m	r_o
Q_1					
Q_4					
Q_5					
Q_6					
Q_7					
Q_C					
Q_D					

(d) Find the differential voltage gain $v_O/(v_+ - v_-)$, R_{in} and R_{out}.

(e) What is the input common mode range (ICMR)?

(f) What is the output voltage swing with no load?



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

INDUCTION MACHINE PROBLEM

A 460-V, 25- hp 60 Hz four pole, Y-connected induction motor has the following impedances in ohms per phase referred to the stator circuit:

$R_1 = 0.641\ \Omega$, $R_2 = 0.332\ \Omega$, $X_1 = 1.106\Omega$, $X_2 = 0.464\ \Omega$, $X_M = 26.3\ \Omega$

Core and rotational losses are neglected. For a rotor slip of 2.2 % at the rated voltage and frequency,

a) Draw the per-phase equivalent circuit of this motor

b) Find the motor's speed, stator current, input and output power, and efficiency.

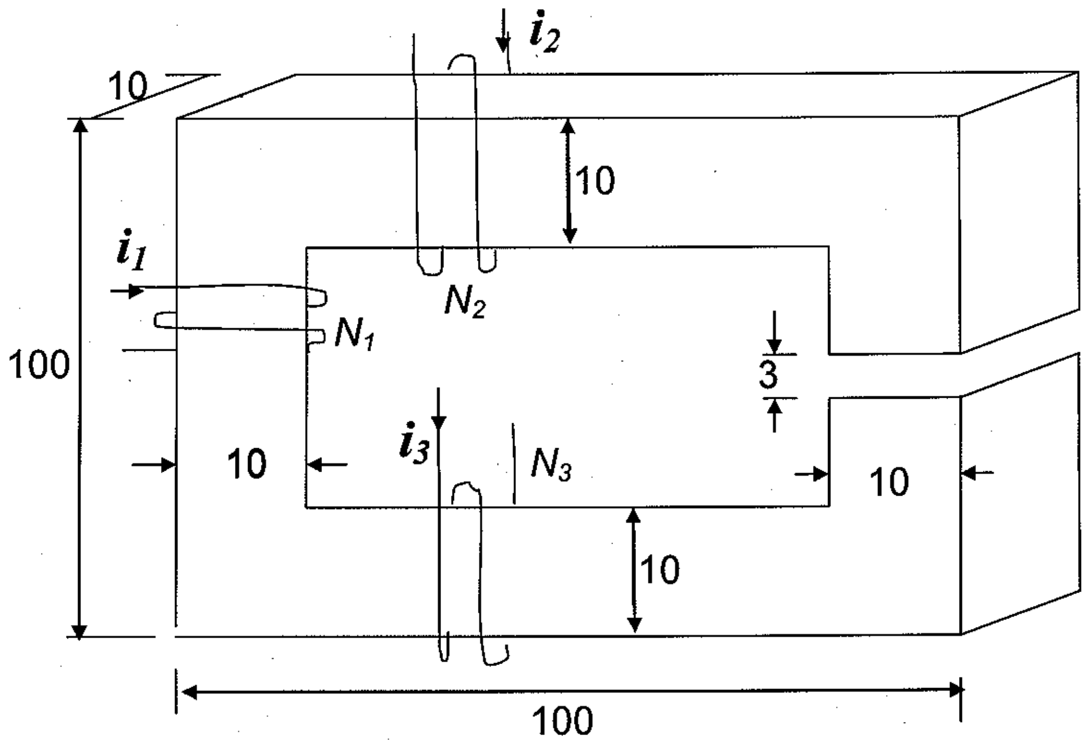
Problem 10 (Core: Power-ECE3070) **Code Number:__________**

MAGNETIC CIRCUIT PROBLEM

Consider the following magnetic circuit. All dimensions are in milli meters.
Relative permeability of the core is 250. Coil #1 has 100 turns, coil #2 has 200 turns and coil #3 has 300 turns. The currents are 3 amps in coil #1, and 8 amps in coil #2, both flowing in the direction as indicated in the diagram.

The flux in the air gap is 1 milli-Wb upwards. Coil #3 is also carrying current in the direction shown, but its magnitude is unknown. Permeability of air is $4\pi 10^{-7}$

Find the magnitude of current #3.



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

A. Show the atoms on the (110) plane of a body center cubic (bcc) lattice structure with a lattice constant of 5 Angstrom. Calculate the atoms per cm^2 in this plane.

B. Find the intrinsic resistivity of Ge at room temperature. The intrinsic concentration is 2.4×10^{13} cm^{-3}, and the electron and hole mobility is 3900 cm^2/Vs and 1900 cm^2/Vs, respectively.

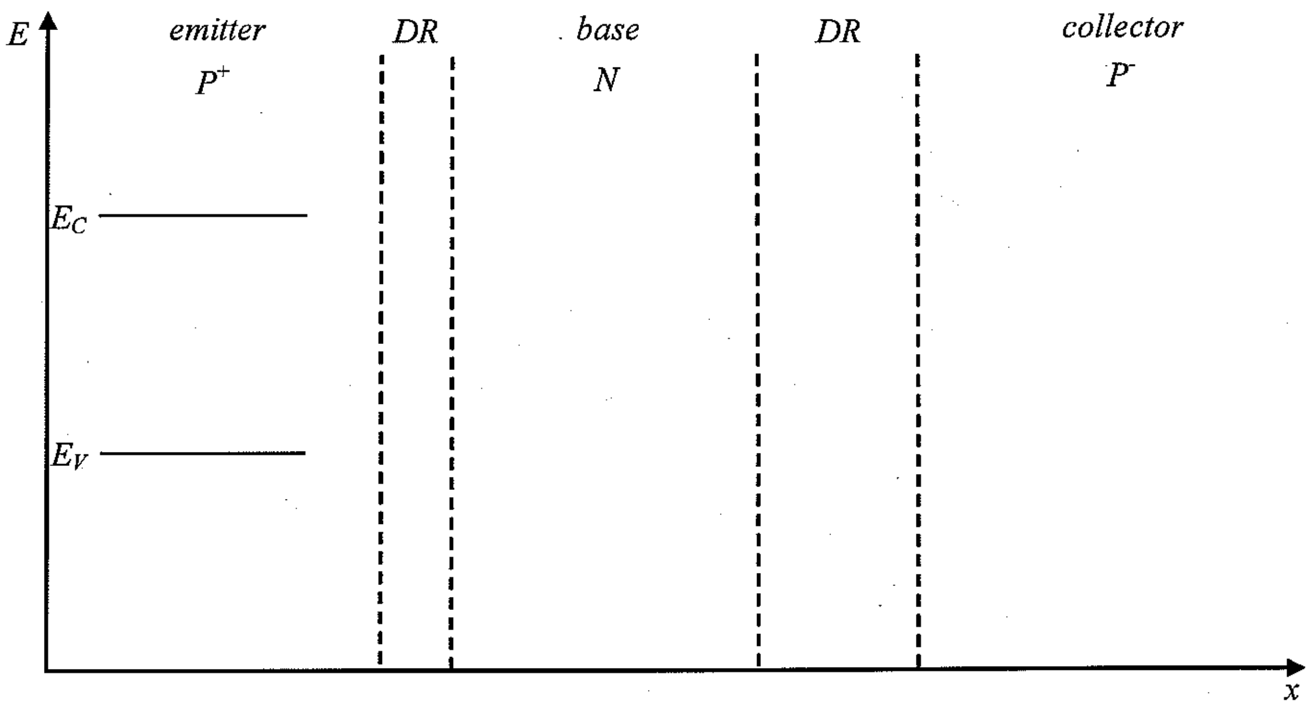
C. Assume that electron-hole pairs are created in an n-type silicon bar that is uniformly illuminated with light for a long period of time. Qualitatively show the quasi-Fermi levels for electrons and holes on an energy band diagram under this non-equilibrium condition. Assume *low-level injection* conditions prevail. For reference on your band diagram show where the equilibrium Fermi level, E_F, and the intrinsic Fermi level, E_i, might be to match the above conditions.

D. For part C, assume that the intrinsic carrier concentration of silicon at room temperature is 1.45e10 cm^{-3} and that the quasi-Fermi level for the minority carriers lie 0.1 eV below the intrinsic Fermi level. Calculate the minority carrier concentration.

E. If the silicon is doped with phosphorus atoms at a density of 5×10^{16} cm^{-3}, is the low-level injection assumption valid for the n-type semiconductor from part C and D. Why or why not?

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

Part 1: In the diagram below, **using solid lines**, show the E vs. x diagram for this **PNP** bipolar homojunction transistor in the ***NORMAL ACTIVE REGION*** of operation. Assume that the **BASE** is grounded and ***show and label the arrows*** corresponding to the energies related to the BASE-EMITTER and BASE-COLLECTOR bias voltages, V_{EB} and V_{CB} and indicate the polarities of these voltages. Draw and label E_C, E_V, E_i, and the "***majority-carrier Quasi-Fermi Energies***" in the each of the layers and label them appropriately. I have given you the starting point for the diagram in the Emitter layer.



Part 2: Why is the EMITTER region of a homojunction BJT generally more heavily doped than the BASE region?

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

PROBLEM :

(a) Determine the Nyquist Rate for sampling the signal $x(t) = \sin(400\pi(t+0.001))\cos(900\pi t - \pi/4)$.

(b) The MATLAB function `soundsc(xn, samplingRate)` will play a sound. If `xn=cos(1.7*pi*(0:99999))` and `samplingRate=10000`, determine the frequency (in hertz) of the sound you will hear.

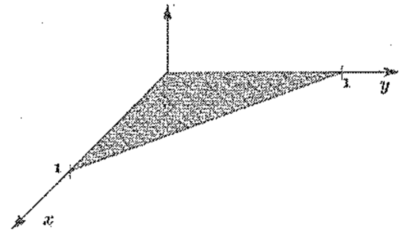
(c) Draw a stem plot of the signal $y[n] = u[n-2] * (\delta[n-3] - \delta[n-5])$, for $0 \le n \le 9$. (Note: $*$ denotes convolution.)

(d) Determine the Continuous-time Fourier transform of $x(t) = \left(\frac{4\pi}{t}\right)\sin(9t)$

(e) A signal $x[n]$ has a z-Transform $X(z) = \frac{7z^{-2}}{3+2z^{-1}}$. Determine the signal $x[n]$ from $X(z)$.

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

3075 PROBLEM



Suppose that the joint probability density function for a pair of continuous random variables X and Y is:

$$f(x, y) = \begin{cases} 24xy, & \text{for } x > 0, y > 0, x + y < 1 \\ 0, & \text{elsewhere} \end{cases}.$$

(The joint pdf is nonzero only for (x, y) pairs falling within the shaded triangle shown above.)

(a) YES ☐ NO ☐ Are X and Y are independent? Explain briefly.

(b) X and Y are [positively][negatively][un-]correlated. (Circle one.) Explain briefly.

(c) The expected value of $\frac{1}{XY}$ is $E\left(\frac{1}{XY}\right) =$ ☐.

(d) The pdf for X is $f(x) =$ ☐ for $0 < x < 1$, and $f(x) = 0$ elsewhere.

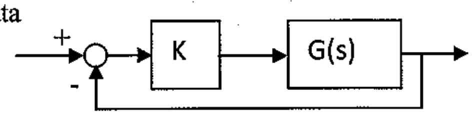
(e) The conditional pdf for Y given X is $f(y|x) =$ ☐, for $0 < y <$ ☐, and $f(y|x) = 0$ elsewhere.

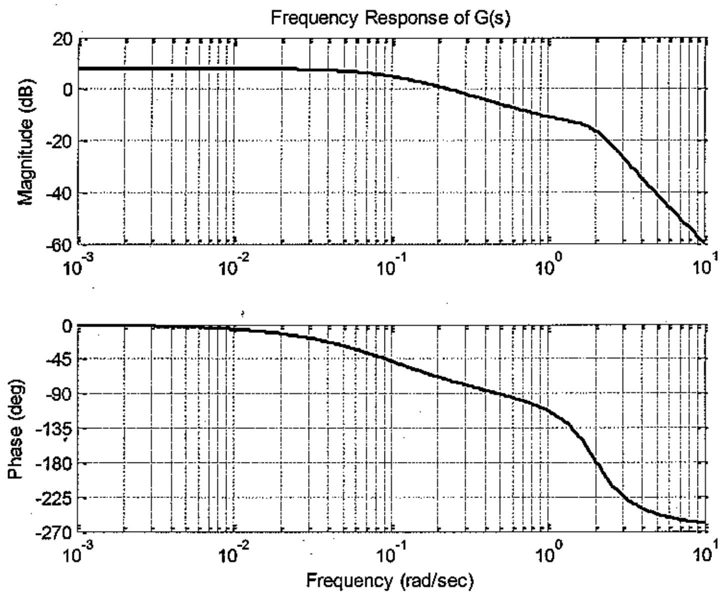
Problem 15 (Core: S&C-ECE3085) **Code Number:__________**

Part A) Suppose that frequency response data is recorded from a physical system and is shown on a Bode plot below.

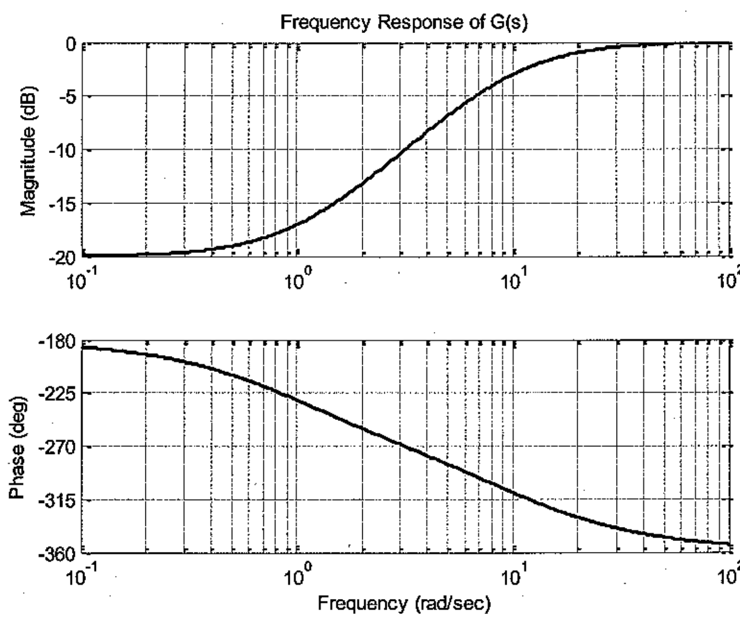
(i) identify the system transfer function, G(s), from the data

(ii) suppose that the system is put into a feedback loop, find the range of K>0 that results in a stable closed loop system





Part B) Repeat Part A) for the system shown in the following Bode Plot.



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

Consider four systems with the following transfer functions:

$$
\begin{aligned}
G_A(s) &= \frac{500s + 10000}{s^2 + 20s + 10000},\\
G_B(s) &= \frac{50s + 100}{s^2 + 2s + 100},\\
G_C(s) &= \frac{5000s - 10000}{s^2 + 40s + 10000},\\
G_D(s) &= \frac{-50s + 100}{s^2 + 4s + 100}.
\end{aligned}
$$

1. You are required to match these with their matching pole/zero plots, step responses, Bode plots, and Nyquist plots shown in the next four figures, Figures 1-4. (E.g., $G_A(s)$ corresponds to the first pole-zero plot. Then we should mark $zp1$ in the corresponding position as shown, etc.) **Each entry in the table should be filled with a distinct plot name** (you are not allowed to fill a column with the same plot name in order to guarantee one correct match). You'll notice that the Nyquist plots $nq2$ and $nq4$ are identical which means that you may choose from two different correct combinations for the last column.

Transfer fn	Pole-zero plot	Step response	Bode plot	Nyquist plot
A	$zp1$			
B				
C				
D				

2. Explain why the two Nyquist plots $nq2$ and $nq4$ are identical.

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

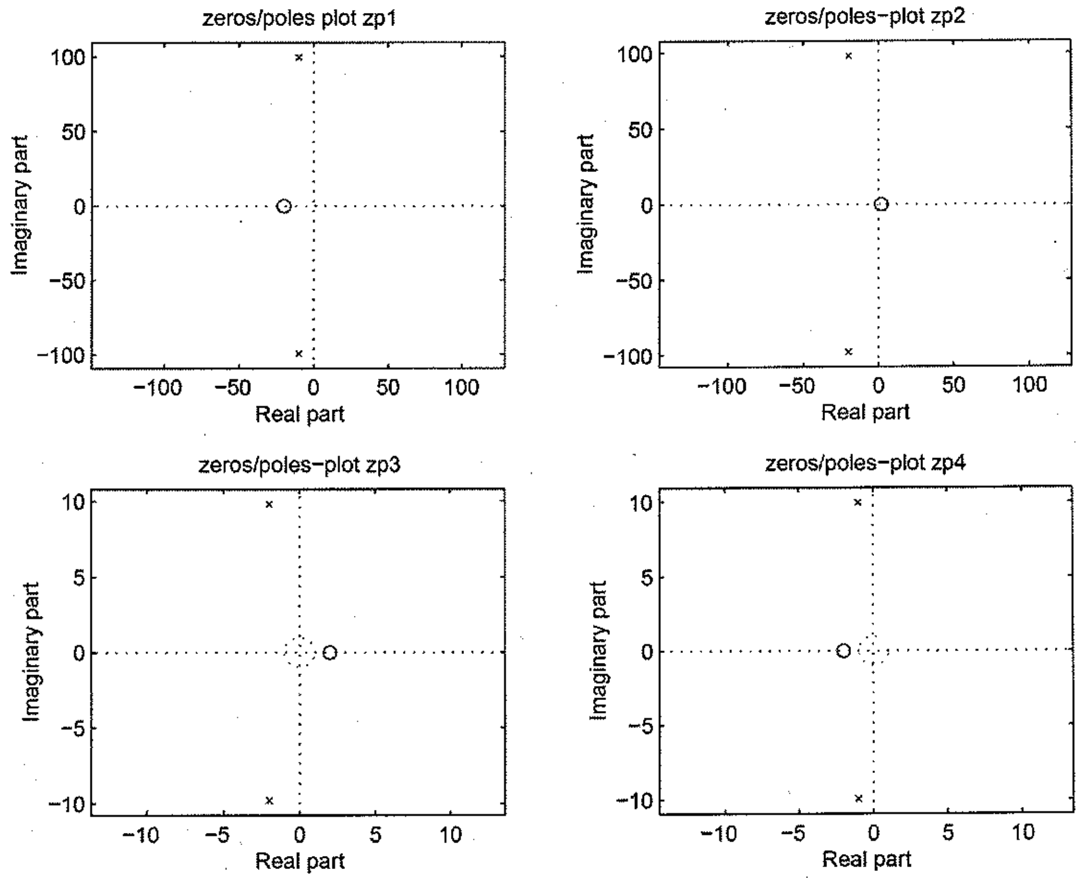


Figure 1: Pole-zero plots

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

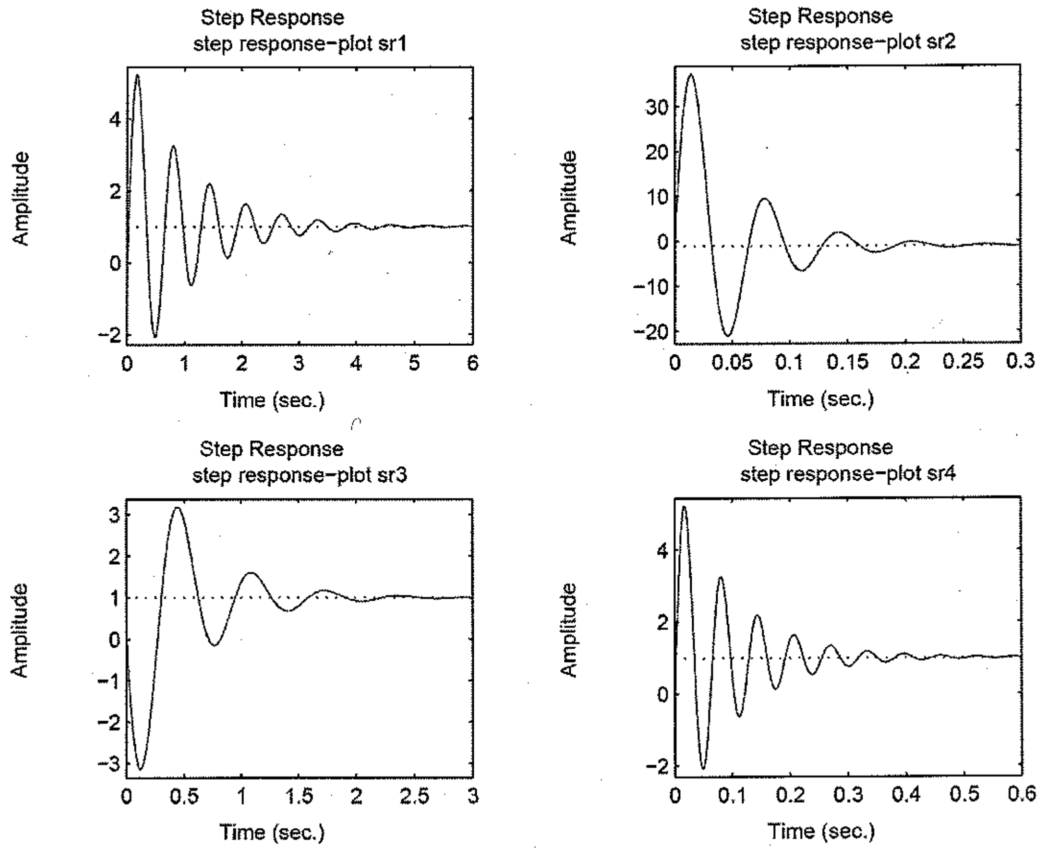


Figure 2: Step responses

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

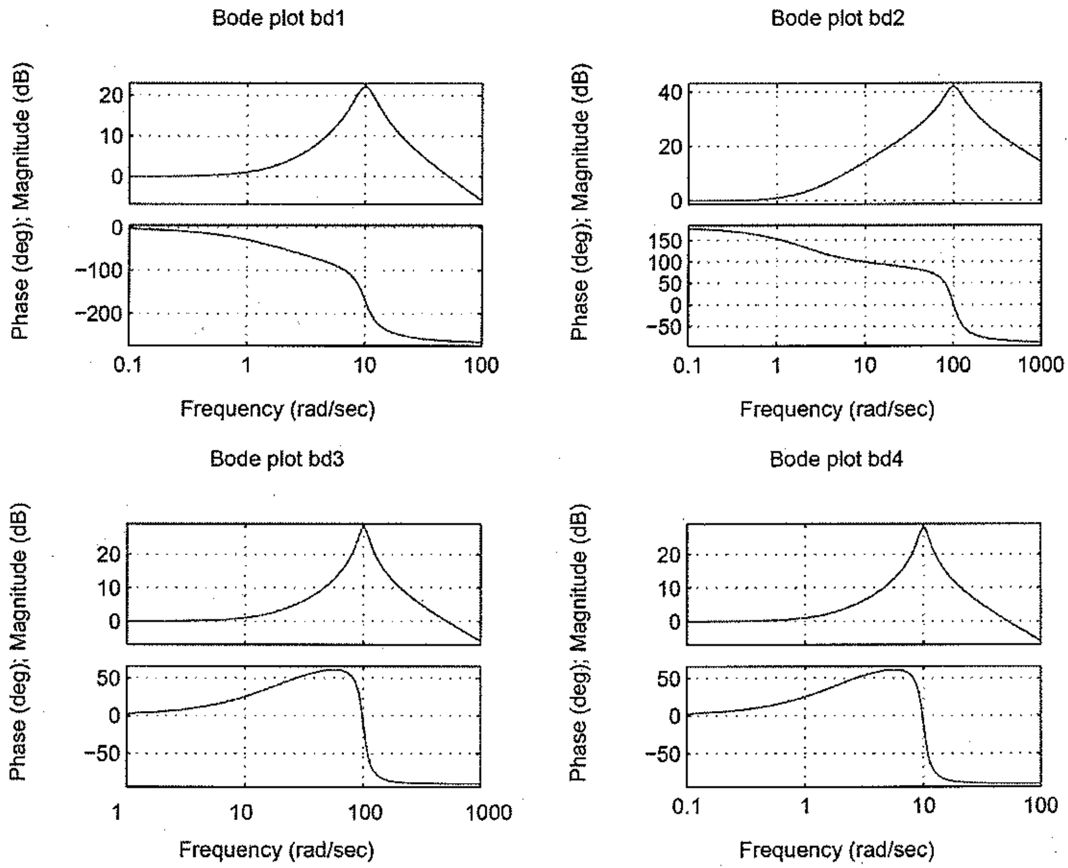


Figure 3: Bode plots

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

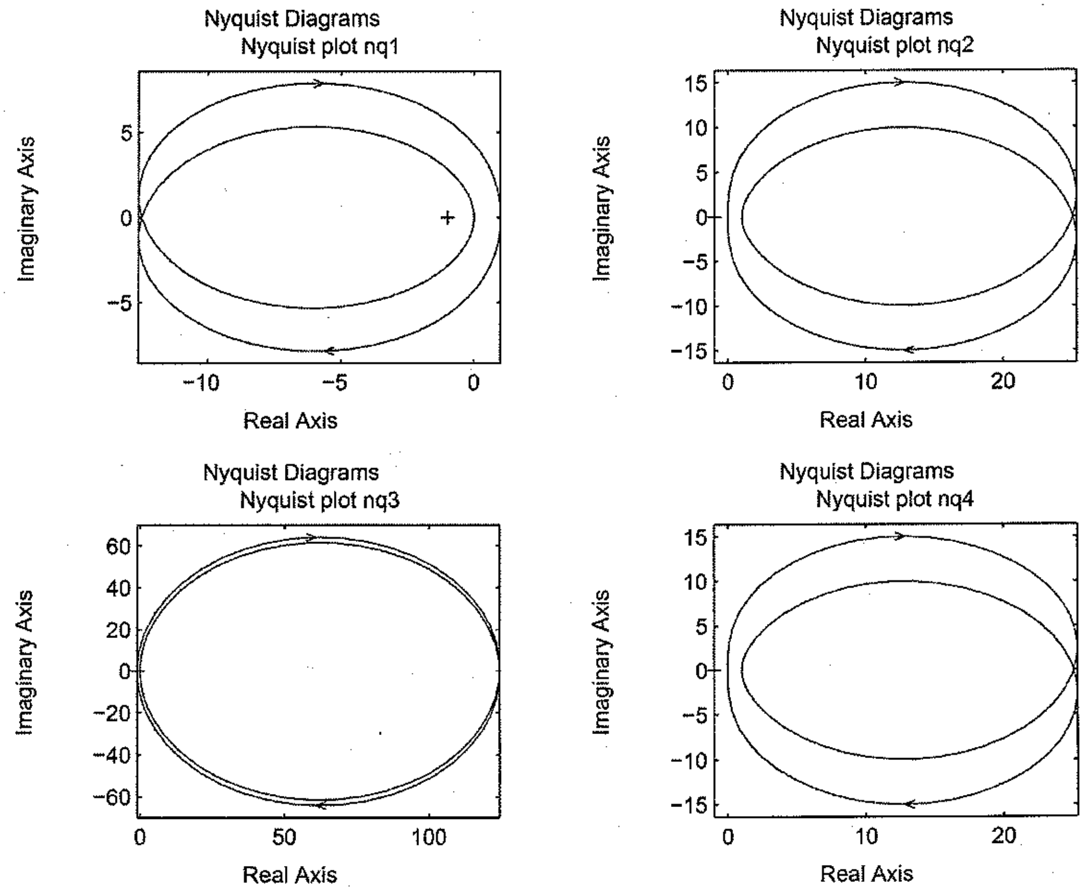


Figure 4: Nyquist plots

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

Consider the problem of finding the best order in which to multiply n matrices of different sizes together:

$$M_1 M_2 M_3 \cdots M_n$$

The overall cost of computing this multiplication sequence depends on the order chosen to do the individual matrix multiplications. Assume that M_i has r_i rows. (Note that the number of columns of M_i must be r_{i+1} in order for this to be a valid matrix multiplication sequence. For simplicity, let the number of columns of M_n be denoted by r_{n+1} also.) Assume cost is measured by the number of scalar multiplications performed, which for a single matrix multiplication $M_i M_{i+1}$ is equal to $r_i \cdot r_{i+1} \cdot r_{i+2}$.

Write a polynomial-time algorithm, using C++ or Java-like pseudo-code, to calculate the exact minimum number of scalar multiplications necessary to compute the entire multiplication sequence.

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

Assuming variable length arrays (VLA) store data on the stack (for example, GNU C compiler gcc allocates VLA on the stack). Depending on the size of the array, the exact amount of needed memory is allocated during runtime. Also, assume that when a function returns, the data in its activation frame is not erased – updating the stack/frame pointer (without erasing the activation frame byte by byte) is the efficient way of 'deallocating' an activation frame. Further assume that automatic variables are allocated on the stack in the order that they are defined.

Given the code segment below, trace the contents of the stack. (Note that this code should be avoided in practice – bar uses arrays 'a' and 'b' without proper initialization)

```
main() {
      ...
      foo(6);
      bar(2,4);
      bar(4,2);
      ...
}

void foo(int i) {
      int k;
      int a[i];

      for(k=0;k<i;k++) {
            a[k] = k;
      }
      return;
}

void bar(int i, int j) {
      int k;
      int a[i], b[j];

      for(k=0;k<i;k++) {
            a[k] = a[k] + 1;
      }
      for(k=0;k<j;k++) {
            b[k] = b[k] - 1;
      }
      return;
}
```

Part A: What is the content of the stack right before 'foo' returns? The input parameter and the return address has already been filled in.

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

address	content
...	...
1000	6 (input parameter for 'foo')
996	Return address
992 988 984 980 976 972 968 964 960 ...	

Part B: What are the contents of the stack right before the first and second 'bar' returns?

Stack right before the first 'bar' returns

address	content
...	...
1000	4 (second input parameter for the first 'bar')
996	2 (first input parameter for the first 'bar')
992	Return address
992 988 984 980 976 972 968 964 960 ...	

Stack right before the second 'bar' returns

address	content
...	...
1000	2 (second input parameter for the first 'bar')
996	4 (first input parameter for the first 'bar')
992	Return address
992 988 984 980 976 972 968 964 960 ...	

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

1. What devices forward IP datagrams across the Internet?

2. How do they build a Forwarding Table that is used to decide what outbound network link is best for forwarding a particular IP datagram?

3. How do Ethernet switches build a Forwarding Table that is used to decide what outbound network link is best for forwarding a particular Ethernet frame?

4. What is the primary advantage of a packet store-and-forward network?

5. What is the primary advantage of a circuit-switched network?

6. Which type of network (packet or circuit-switched) is the Internet?

7. How does your PC determine the 32-bit IP address for "www.amazon.com"?

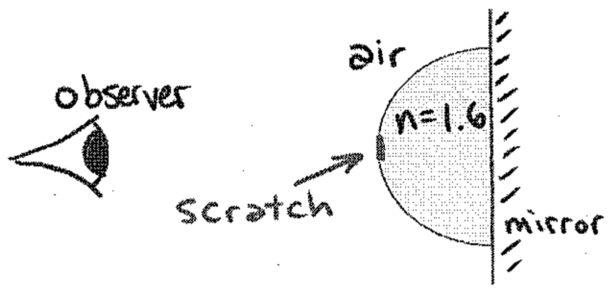
8. How does your browser authenticate a Web site that is using https?

9. What is the advantage of the TCP transport-layer protocol?

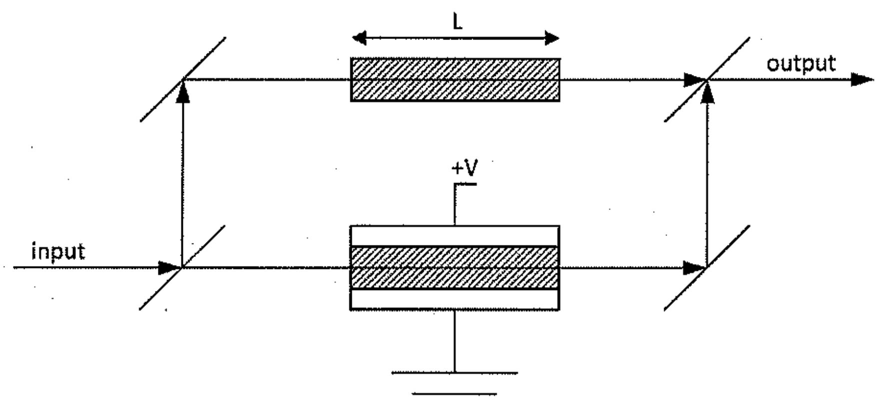
10. What is the advantage of the UDP transport-layer protocol?

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

(a) The flat face of a glass hemisphere with refractive index n = 1.6 and radius R = 5mm is cemented a perfect planar mirror. There is a small scratch on the surface of the hemisphere at the point farthest from the mirror. This is diagrammed below. What will be the apparent depth and magnification of the image of the scratch as seen by the observer? (Please give depth relative to the mirror surface.)



(b) A Kerr electro-optic modulator is diagrammed below.



The input light is split equally into two paths. Each path has identical length, and each path passes through a Kerr cell (represented by a crosshatched rectangle) of length L = 3 cm. A voltage V is applied to one of the Kerr cells, which changes the refractive index of that cell by an amount

$$\Delta n = KV^2\lambda$$

where λ is the free-space wavelength of the light passing through the cell, and K = 2.4e-8 V^{-2} m^{-1}. Neglect all reflections from the Kerr cell. Find the voltage V necessary to minimize the light intensity at the output.

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

Prelim Problem, ECE 4501

Consider a simple direct-detection optical receiver, based on a PIN photodiode that is known to have (for practical purposes) zero dark current. When using binary on-off keying, the bit error rate (BER) can be related to the respective current levels of the "one" and "zero" bits, I_1 and I_0, through the approximate formula:

$$\text{BER} \approx \frac{1}{Q\sqrt{2\pi}} \exp\left[-Q^2/2\right]$$

where $Q = (I_1 - I_0)/(\sigma_1 + \sigma_0)$, and where σ_1 and σ_0 are the rms noise currents associated with I_1 and I_0. The noise powers are known to be composed of shot (σ_s) and thermal (σ_T) contributions according to $\sigma_1^2 = \sigma_{s1}^2 + \sigma_T^2$ and $\sigma_0^2 = \sigma_{s0}^2 + \sigma_T^2$. In general, current is related to the optical power, P, through $I_i = RP_i$ ($i = 0, 1$), where R is the detector responsivity. P_1 and P_0 are the optical powers in the "one" and "zero" bits.

a. The signal-to-noise ratio (SNR) is defined as the average *electrical* power divided by the noise power. Determine an expression for the SNR in terms of I_1, I_0, σ_{s1}, σ_{s0}, and σ_T (as necessary) in which there is complete extinction (optical power in the zero bits is zero).

b. Construct the SNR expression for again, complete extinction, but in which shot noise is negligible compared to thermal noise.

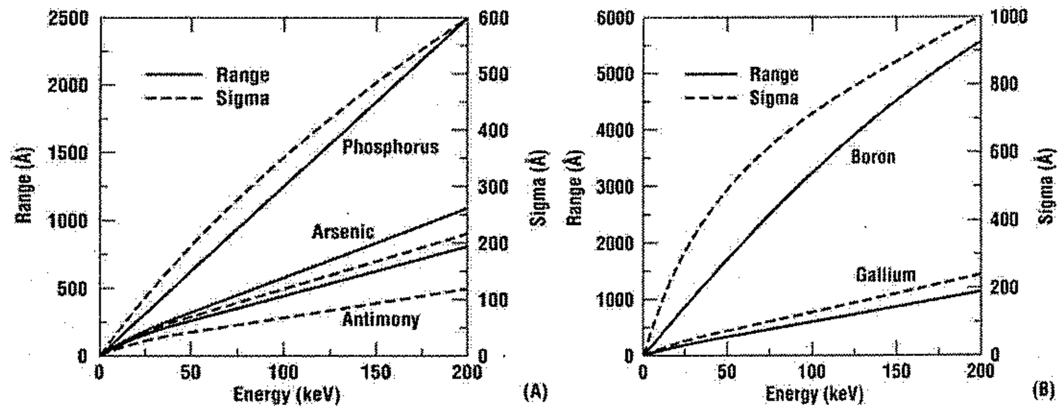
c. Determine an expression for Q in terms of the SNR under the conditions of part *b*.

d. Again, under conditions as specified in part *b*, suppose the BER for the given setup is known to be 10^{-9} ($Q = 6$). What BER would be obtained if the average *optical* power is reduced by 3dB? What is the effect on the SNR?

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

A particular silicon device needs to have a B implant with a peak at a depth of 0.3 μm and a peak concentration of 10^{17} cm^{-3}.

A. Determine the implant energy that should be used for this process.
B. Determine the dose that should be used for this process.
C. Find the as-implanted junction depth if the substrate is n-type with a concentration of 10^{15} cm^{-3}.



You might need: $$N(x) = \frac{\phi}{\sqrt{2\pi}\,\Delta R_p} e^{-\frac{(x-R_p)^2}{2\,\Delta R_p^2}}$$

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

Calculate the Nernst potential for the following ions and give the concentration of the ions in the same units as would be used for electrons or holes in a semiconductor device (i.e. in units of ions/cm^3) The organism in question is a (hypothetical) arctic squid with a body temperature of 6°C above freezing.

$R = 8.314\ J\ K^{-1}\ mol^{-1}$, $F = 96485\ C\ mol^{-1}$

a) through d) 1 point each

a) $[K^+]_i$ = 26mM, $[K^+]_e$ = 150mM

b) $[Na^+]_i$= 90mM, $[Na^+]_e$ =25 mM

c) $[Cl^-]_i$ = 170mM, $[Cl^-]_e$= 70mM

d) $[Ca^{++}]_i$ = 75mM, $[Ca^{++}]_e$ = 200mM

e) (3 pts)The membrane capacitance for the axons of this squid is found to be 2 μF/cm^2 . The thickness of the plasma membrane is 8nm. Find the relative permittivity of the membrane.

f) (3 pts) Through Hodgkin-Huxley type experiments it is determined that the membrane conductance for Na^+, Cl^- and Ca^{++} vary with time and voltage during the action potential. The conductance for K^+, however, does not change with time or voltage. Sketch the full circuit model for the membrane, including all components. Explain the physiological origin of each of the components.

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

You have been hired as a consultant to design a medical device which can be used to determine when a person is "Brain Dead." The device may use any number of surface EEG electrodes.

A. What are the main problems that make it difficult to achieve a high level of confidence via surface EEG electrodes (2 points)?

B. What if any stimuli would you use (2 points)?

C. Draw a sketch showing where you would position the EEG electrodes (2 points)?

D. How could you improve the accuracy of your proposed protocol (2 points)?

E. If you are fairly certain that a patient is Brain Dead, what types of other electrodes could you use to verify your conclusion (2 points)?

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

A. Write an equation that is linear and algebraic but does not obey the Law of Superposition (1 pts).

B. If a system is linear, time-invariant and causal, what is the best stimulus for characterizing the system and why (2 pts)?

C. What type of displacement sensor is described partly by a variable which is commonly referred to as Poisson's Ratio (1 pts)?

D. What is the biggest problem with semiconductor materials that are used to detect displacement (1 pts)?

E. What does R represent in the Nernst Equation (1 pts)?

F. What type of neuron has multiple axons (1 pts)?

G. What prevents an Action Potential from propagating backwards along a single neuron (1 pts)?

H. What is the lowest frequency band of the EEG called, which occurs during deep sleep (2 pts)?