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

Fall 2008

Instructions:

1. Please check to ensure that you have a complete exam booklet. There are 25 numbered problems. Note that **problem 20 has 2 pages.** Including the cover sheet, you should have **27 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:_________**

You are initially given the following Boolean expression.

$$F = \overline{(C(\overline{\overline{A} + B}))} + \overline{(\overline{B}D)}$$

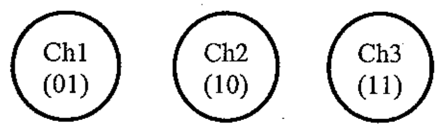
a) Provide a CMOS implementation of the expression using p-type and n-type transistors.

b) Provide an implementation using only 2 input NAND gates and inverters. Indicate the total number of transistors required and compare to part a).

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

Design a remote control logic circuit for a 3-channel TV using the finite state machine (FSM) method. The controller contains 2 buttons: Up (1) and Down (0) encoded as a single bit input in the circuit. The state itself indicates the current channel, e.g., state '10' (in binary) is Ch2. When holding the button, the channel will continue to change for each input clock edge. When in the terminal channels, Ch3 (or Ch1), pressing Up (or Down) will not change the channel. First, complete the state diagram shown below for all state transitions and derive the state table based on your state diagram. Then use a Karnaugh map to minimize your logic, you must take don't care states into account. Finally, implement your FSM with D flip-flop's and basic logic gates.

<u>State Diagram</u>



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

Virtual Memory.

The hardware design for this system uses a 2K page size (2048 bytes) and the same frame size. A sample direct–mapped page table is given below. The entries in the page table are *Frame Numbers*, not frame addresses. For each logical memory address specified below, give the corresponding physical memory address. Write *Page Fault* if the logical memory address is invalid. The logical addresses are *byte* addresses. **ALL NUMBERS GIVEN ARE IN HEXADECIMAL. GIVE ALL ANSWERS IN HEX.** Show work for partial credit.

Page Table

Page Number	Physical Page Frame Number
0	1234
1	9f9
2	98ba
3	ff
4	67abf
5	4321
6	1ff
7	abc
8	986a7
9	ab878
a	654a
b	100
c	8bbb
d	1
e	fffff
f	def

Logical Address : `12ff` Physical Address :

Logical Address : `0` Physical Address :

Logical Address : `f12` Physical Address :

Logical Address : `6800` Physical Address :

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

1. (2pts) (Circle the correct term in each set of square brackets.) In a pMOS transistor, we tie the n-well to [Vdd / Gnd] and apply a [negative / positive] gate-to-source voltage. This draws [electrons / holes] into the region below the gate, which in turn results in the channel changing to [p-type / n-type].

2. (2pts) (Circle the correct term in each set of square brackets.) The RC delay of an inverter (INV1) driving another inverter (INV2) increases if the width of transistors in INV1 [increases / decreases], the length of transistors in INV1 [increases / decreases], the width of transistors in INV2 [increases / decreases], and the length of transistors in INV2 [increases / decreases].

3. (3pts) Design a half adder using two 2x1 MUXs (and INVs if necessary). Use one of the two operands of the addition as the MUX selection input.

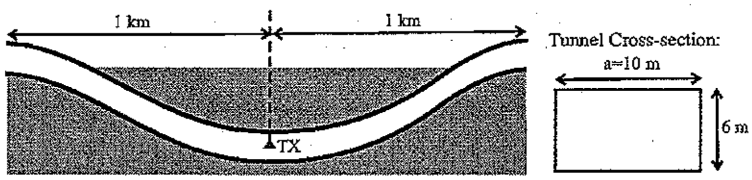
4. (3pts) Draw the CMOS stick diagram of your solution in problem 3 using the minimum number of transistors. Assume that complemented inputs are not available.

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

Two parallel infinite uniform line charge densities of charge per unit length ρ_ℓ are separated by distance *d*. What is the electrostatic force per unit length between the line charges?

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

Problem: A section of the Chesapeake bay-bridge tunnel is 2 kilometers long with a width of 10 meters and a height of 6 meters. In the middle of this tunnel is a small 850 MHz cellular base station that provides coverage for mobile users in the tunnel. This station is low-powered and uses the tunnel like a rectangular waveguide to communicate with motorists. Answer the following questions based on this scenario, which is illustrated below:



1. Find the highest value for x such that the TE_{x0} mode still propagates through this tunnel. **(3 points)**

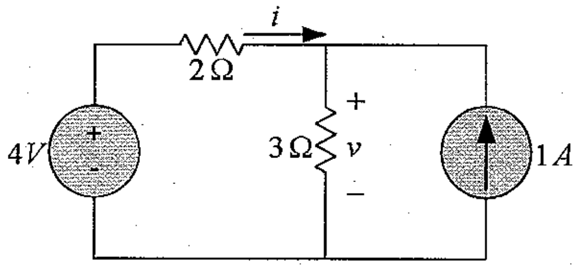
2. For a cell phone user operating at the end the tunnel, what is the dispersion (difference in delay) in nanoseconds between the power carried by the dominant TE_{10} mode and the TM_{77} mode? You may approximate the tunnel to be a straight (horizontal) two kilometers. **(5 points)**

3. What assumption are you making about the material properties of the tunnel in this problem? **(2 points)**

$$v_g = \frac{1}{\sqrt{\epsilon\mu}}\sqrt{1-\left(\frac{f_c}{f}\right)^2} \quad \lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} \quad (f_c)_{mn} = \frac{1}{2\sqrt{\mu\epsilon}}\sqrt{\left(\frac{m}{a}\right)^2+\left(\frac{n}{b}\right)^2} \quad \epsilon_0 = 8.85\times10^{-12}\text{ F/m} \quad \mu_0 = 4\pi\times10^{-7}\text{H/m}$$

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

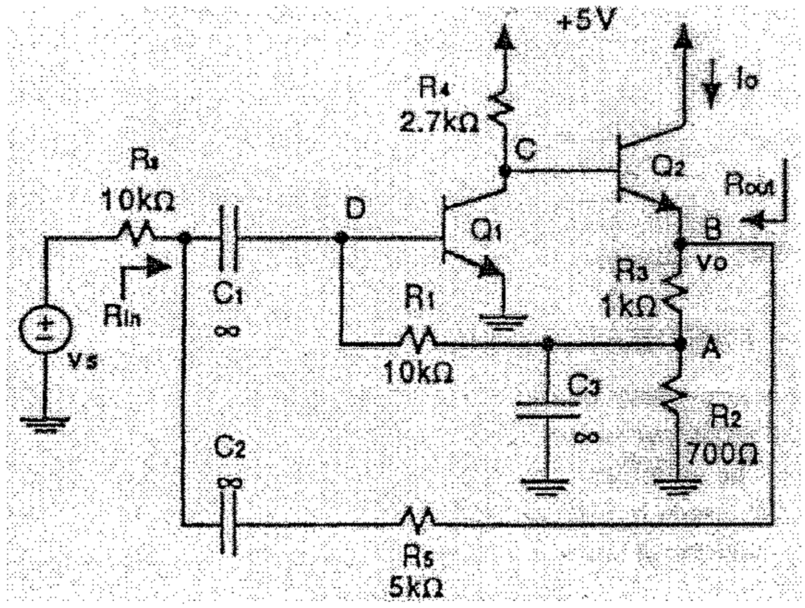
Problem: Determine the values of the current, i, and the voltage, v, in the following circuit.



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

The following circuit combines two feedbacks.

(Early voltage) $V_A = \infty$, $\beta_0 = 100$, $V_{BE} = 0.7$ V, $V_{th} = 26$ mV.



a) One feedback involving R_1, R_2, and R_3 only operates at DC but not at high frequency. Why? What type of feedback topology is this?

b) The other feedback, involving R_5, only operates at high frequency (HF), and not at DC. Why? What type of feedback topology is this?

c) The job of the DC feedback is to set the DC potential at node A to be ~V_{BE1}. With this information, find the DC bias points (I_C, V_{CE}) for Q_1 and Q_2.

d) Draw the midband small signal equivalent circuit of the entire circuit (no capacitive effect).

e) For the HF feedback, indicate the feedback network and its loading effect at the input and output of the feed forward path.

f) Draw the small signal equivalent circuit of the loaded (augmented) feed forward amplifier.

g) Find the open loop gain A. (considering the type of HF feedback in part b)

h) For the HF feedback, find the loop-gain $A\beta$.

i) For the HF feedback, find the closed-loop gain of this circuit.

j) For the HF feedback, find the voltage gain of this circuit.

k) Find R_{in} for the closed-loop circuit.

l) Find R_{out} for the closed-loop circuit.

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

A synchronous machine has the following ratings: 3-phase, Y-connected, 60 Hz, 8-pole, 4,000 V, synchronous reactance is 2.5 Ohms per phase. The machine is synchronized to a 4 kV network. Following synchronization, and without any other action, its excitation current was adjusted so that the machine produces 1 MVAr of reactive power. Calculate the needed percent increase of excitation current compared to the value at synchronization.

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

A 460 volt (L-L) three phase 25 hp, 60 Hz, four pole Y-connected stator induction motor has the following impedances in ohms per phase, ALL referred to the stator circuit.

$R_s = 0.641$	$R_r = 0.332$
$X_s = 1.106$	$X_r = 0.464$

The no-load current is negligibly small.

For a rotor slip of 2.2 % when the stator is supplied by the rated 460 volts (L-L) and 60 Hz, calculate the

(a) Rotor speed in rpm
(b) Stator current per phase
(c) Power factor at the stator terminals
(d) The total three phase power flowing into the stator winding.

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

PN Junction: Reverse-Bias Junction Capacity

The reverse-bias junction capacity of a silicon n^+p step junction has been measured for two applied voltages. The result is 43.4 nF/cm^2 at $V_A = -3$ V and 27.6 nF/cm^2 at $V_A = -10$ V

(a) Calculate the built-in potential V_{bi}.

(b) Calculate the substrate doping N_B.

Given are the elementary charge $q = 1.6 \cdot 10^{-19}$ C and the dielectric constant for silicon $\varepsilon = K_S\, \varepsilon_0 = 11.9 \cdot 8.85 \cdot 10^{-14}$ F/cm.

Also given is the depletion layer width of a step junction as a function of the applied bias:

$$W = \sqrt{\frac{2K_s\varepsilon_0}{q}\frac{N_A + N_D}{N_A N_D}\left(V_{bi} - V_A\right)}$$

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

A silicon wafer has been doped with a donor concentration $N_D = 10^{16}$ cm^{-3}. While maintaining room temperature, the wafer is first illuminated with light for a long time that generates $G_L = 10^{12}$ carriers cm^{-3} per sec uniformly throughout the wafer. At time t = 0 the light is switched off.

(a) If the minority carrier lifetime is $\tau_p = 1\mu sec$, derive an expression for the minority carrier concentration in the wafer as a function of time. Calculate values for all constants in the expression. State all your assumptions.

(b) Qualitatively describe what is happening to the minority and majority carriers during the process described in the problem statement.

The continuity equations for carriers are listed below.

$$\frac{\partial n}{\partial t} = \frac{1}{q} \bullet \frac{\partial J_N}{\partial x} + \left.\frac{\partial n}{\partial t}\right|_{thermal} + \left.\frac{\partial n}{\partial t}\right|_{\substack{other\\processes}}$$

$$\frac{\partial p}{\partial t} = \frac{1}{q} \bullet \frac{\partial J_P}{\partial x} + \left.\frac{\partial p}{\partial t}\right|_{thermal} + \left.\frac{\partial p}{\partial t}\right|_{\substack{other\\processes}}$$

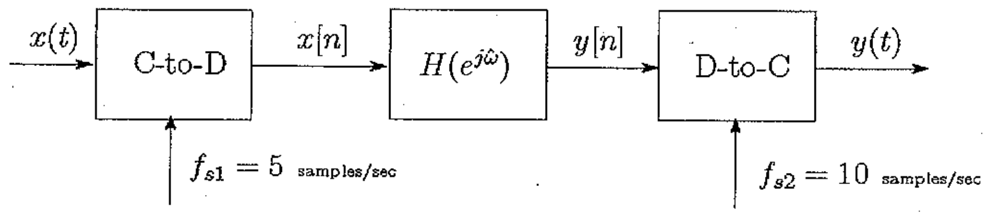
You may assume that:

$$\left.\frac{\partial n}{\partial t}\right|_{thermal} = -\frac{\Delta n}{\tau_n}$$

$$\left.\frac{\partial p}{\partial t}\right|_{thermal} = -\frac{\Delta p}{\tau_p}$$

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

(Note, this problem does not necessarily represent a real-time system.)



As shown in the figure above, a continuous-time signal $x(t) = 8\cos^3(2\pi t)$ is sampled through an ideal continuous-to-discrete converter (labelled as C-to-D in the figure) operating at a rate of 5 samples/second. The resulting discrete-time signal $x[n]$ goes through a linear time invariant (LTI) system. The frequency response of the LTI system is given as

$$H(e^{j\hat{\omega}}) = 1 - \frac{1}{\pi}|\hat{\omega}| \quad \text{for } [-\pi, \pi], \text{ and periodic with period of } 2\pi.$$

The output of the LTI system is denoted by $y[n]$. $y[n]$ then goes through an ideal discrete-to-continuous converter (labelled as D-to-C in the figure) that uses a sampling rate of 10 samples/second, resulting in $y(t)$.

a) [2 pts]- Plot the frequency spectrum of $x(t)$. Label all axis carefully.

b) [2 pts]- Plot the frequency spectrum of $x[n]$. Label all axis carefully.

c) [2 pts]- Plot the frequency spectrum of $y[n]$. Label all axis carefully.

d) [2 pts]- Plot the frequency spectrum of $y(t)$. Label all axis carefully.

e) [2 pts]- Write down $y(t)$ in terms of sum of cosines.

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

Suppose $X(t)$ is a continuous-time, zero mean, wide-sense stationary random process with autocorrelation function

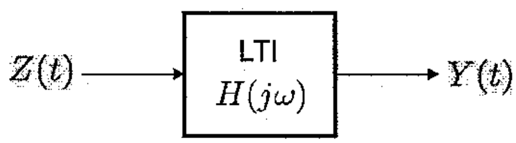
$$R_{XX}(\tau) = \delta(\tau).$$

Set

$$Z(t) = X(t) - X(t-4).$$

(a) Find the autocorrelation function $R_{ZZ}(\tau)$ for $Z(t)$.

(b) Now suppose we pass $Z(t)$ through an LTI system:



with frequency response

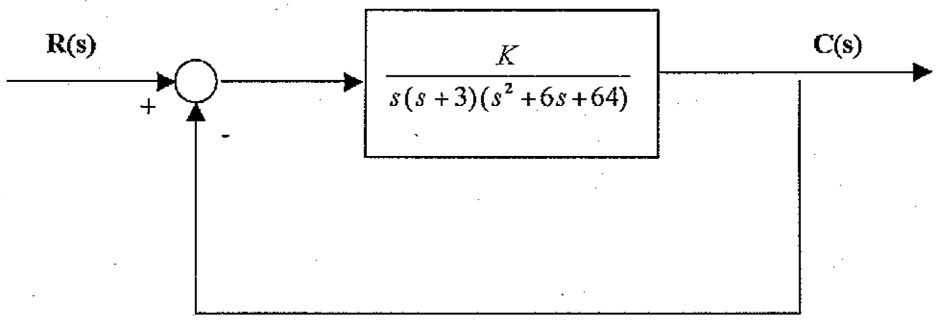
$$H(j\omega) = \begin{cases} 2 & 0 \leq |\omega| \leq \pi/8 \\ 0 & \text{otherwise} \end{cases}.$$

What is the power spectral density $\hat{P}_Y(\omega)$ of the output?

(c) What is the power $\mathrm{E}[|Y(t)|^2]$ of the output?

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

Given the system pictured below: (a) Sketch the root locus plot of the system including any relevant information pertaining to the plot (i.e., asymptotes, asymptote angles, and break-away/break-in points), (b) If there is a complex pole in the upper half of the S-plane, determine the departure angle of that pole, and (c) find the value of the gain K for which the system is stable.



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

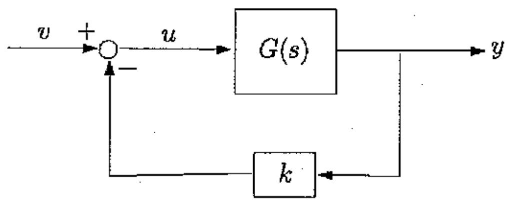
Consider the closed-loop system below, where the transfer function is either

$$G_1(s) = \frac{1}{s^2 + 2s + 5}$$

or

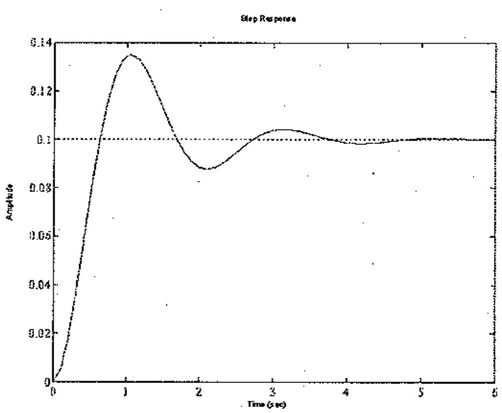
$$G_2(s) = \frac{1}{s^2 + 4s + 5},$$

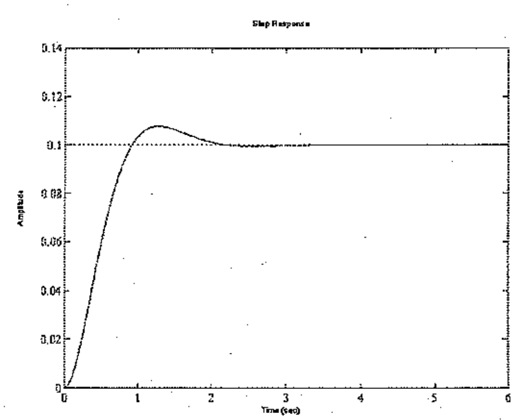
and where $u = -ky + v$ for some constant k.



Now, consider the two step responses below that were produced with a particular choice of k. **Find this k and determine which step response belongs to which closed-loop system** (as defined by G_1 or G_2).

Note, you must motivate your answer carefully - just giving an answer without justification will give no points, even if the answer happens to be correct.





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

Operating System Support for Synchronization
Synchronization is an important functionality provided by an operating system to support concurrent operations on shared data structures.

(a) (2) What is a **spin-lock** and how does it differ from a blocking lock, such as a **semaphore.** Under what circumstances might one choose one over the other?

(b) (2) What is a **read-write spin-lock**, and when might its use be desirable?

(c) (6) Using the hardware primitive **test-and-set(location)** (which atomically returns the value stored at Memory[location], and then sets Memory[location]=1), provide a pseudo-code implementation of a read-write spin-lock. Specifically, provide code for the functions **RW_spin_acquire(lock,mode) and RW_spin_release(lock)**, where mode is either read (R) or write (W),), as well as the declaration for the lock data structure. You do not need to ensure fairness, or acquisition priority in your implementation.

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

Part A: Perform the following standard compiler optimizations on the body of the C subroutine below by writing the optimized version (in C) to the right: strength reduction, loop invariant removal, common subexpression elimination. You may add additional local variables if needed.

```
int foo(int x, int y) {

  int i, d, z = 0;

  for (i=0; i < 5000; i++) {

    z = z + x * i;

    d = x/y + (z+y)*(z+y);

  }

  return z+d;}
```

⇨

```
int foo(int x, int y) {
```

Part B: Consider the following C fragment. Assume a 32-bit integer datapath with a 32-bit memory address space. Assume *int* datatypes are 1 word long and *double* datatypes are 2 words long. In C syntax, "&" is the address operator and "*" is the dereference or indirection operator.

```
int F (int A) {
   int      x = 5;
   double y = 20.0;
   int      *p = &x
   int      Vector[3] = {4, 9, 16};
   double G(int, *double, int V[]);
   y = G(*p, &y, Vector);
   return x+A;}
```

What is the total number of words of storage allocated in F's activation frame for F's input and output parameters and local variables?

____**words for F's I/O and local variables.**

What is the total number of words of storage allocated in G's activation frame for G's input and output parameters?

____**words for G's I/O and local variables.**

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

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

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

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

How do Internet routers build a Forwarding Table that is used 10 decide what outbound network link is best for forwarding a particular IP datagram?

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?

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

Once the IP address is known, how does your PC (on an Ethernet LAN) determine what destination Ethernet address to use?

What does Flow Control do?

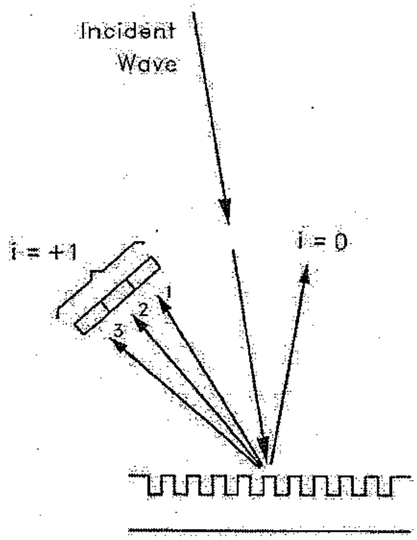
How does TCP implement Flow Control?

How does TCP implement Congestion Control?

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

Waveguide Grating Spectrometer - Wavelength Division Demultiplexing

A waveguide reflection grating spectrometer is used for wavelength division demultiplexing. Three telecommunication signal waves from the waveguide are incident in air upon the metallic grating at an angle of 15° counter-clockwise from the normal as shown in figure. The three waves have frequencies of 195.5 $TeraHz$, 196.0 $TeraHz$, and 196.5 $TeraHz$ which are frequencies on the ITU standard grid. The three wavelengths are dispersed by the grating into +1-order backward-diffracted waves as shown in the figure. The grating is designated as having 800 $lines\,per\,mm$. An array of photodetectors is oriented normal to the 196.0 $TeraHz$ (no. 2) beam as shown.



1) Calculate, showing all work, the wavelengths in nanometers of the waves numbered 1, 2, and 3 in the figure.

2) Calculate, showing all work, the backward-diffracted wave angles (measured counter-clockwise from the normal) in degrees for these waves.

3) The photodetector for the no. 2 beam is placed 10.0 mm away from the point of incidence upon grating. Calculate, showing all work, the ideal center-to-center distance that is needed between the photodetectors so that each beam is incident exactly at the center of its corresponding photodetector.

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

Express wavelengths accurately to six significant figures. Express the angles in degrees accurately to within $\pm 0.001°$. Express photodetector the center-to-center distances in microns accurately to five significant figures. Put your answers in the spaces provided.

Wave No.	Wavelength (nm)	Angle of Diffraction (°) (CCW from normal)
1	____________	____________
2	____________	____________
3	____________	____________

Center-to-center distance between photodetectors for beams 1 and 2

= ____________ μm

Center-to-center distance between photodetectors for beams 2 and 3

= ____________ μm

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

A point-to-point fiber communication link employs a laser transmitter having an average emitted power, $P_t = 10\,\text{mW}$, a PIN-based receiver having sensitivity $P_{rec} = -30$ dBm at the required BER. The single-mode fiber link will consist of two end-to-end joined fiber segments. The first fiber has loss coefficient, $\alpha_1 = 0.25$ dB/km, length L_1 (to be found), and dispersion $D = 5$ ps/nm-km. The second fiber has loss coefficient, $\alpha_2 = 0.40$ dB/km, length L_2 (to be found), and dispersion $D = -10$ ps/nm-km. The total length between source and receiver is $L = 150$ km. No other loss sources are present.

a. Write down the power budget equation that includes the transmitter power and receiver sensitivity (both in dBm), the fiber losses (including the unknown lengths, L_1 and L_2), and an assumed maximum dispersion penalty of 1 dB.

If the link were to be constructed using Fiber 1 alone, the dispersion-limited transmission distance would be $L_{max,D1} = 140.0$ km. If the link were to be constructed using Fiber 2 alone, the dispersion-limited transmission distance would be $L_{max,D2} = 70.0$ km. For this link, the dispersion-limited distance corresponds to an effective loss penalty of 1 dB, which is the maximum allowable.

b. Using the loss budget equation and assuming a 1 dB disperson penalty, evaluate L_1 and L_2.

c. With the lengths as found in part b, find the dispersion-limited transmission distance for the total link. With this result, is the link viable? Explain.

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

A boron diffusion into a 1 ohm-cm n-type wafer results in a Gaussian profile. The diffusion process was 20 minutes at 1000 C in a nitrogen environment.

(A) What is the background doping concentration in the wafer?
(B) What is the diffusion coefficient for boron at 1000 C?
(C) What is the junction depth?

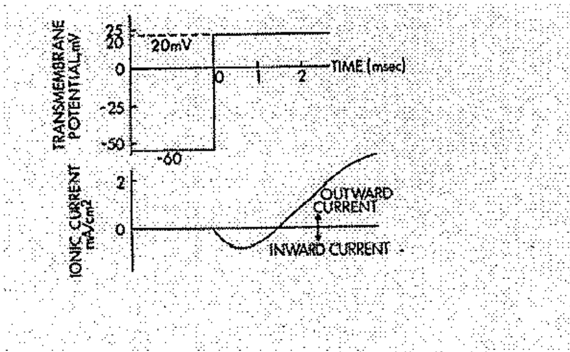
Constants: q=1.6E-19 Coulombs, D_o=0.76 cm^2/sec, E_a=3.46 eV, k=8.61E-5 eV/K, μ_n=1350 cm^2/V-sec, μ_p=480 cm^2/V-sec, C_s=1E18 cm^{-2}, g=9.8 m/sec^2

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

a) First sketch the full circuit model for the plasma membrane of an axon. Explain the physiological origin of each of the components.

b) Write the differential equation for the total membrane current associated with the model.

c) Based on this model and looking at the curves from a voltage clamp experiment presented below, what is not right about the curve for the ionic current.



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

Describe three different electrode problems that can occur when measuring the human EEG and ways to prevent each problem from producing an artifact.

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

Describe the pros and cons of using multiple pulse stimuli as advocated by Volterra to reveal time-dependant nonlinearities of a biological system.