Problem: CM1 **Area: Computers and Architecture** **Code #________**

The viability of cache systems depends on the concept of locality.

1. Explain how a loop structure in a program exhibits both temporal and spatial locality.

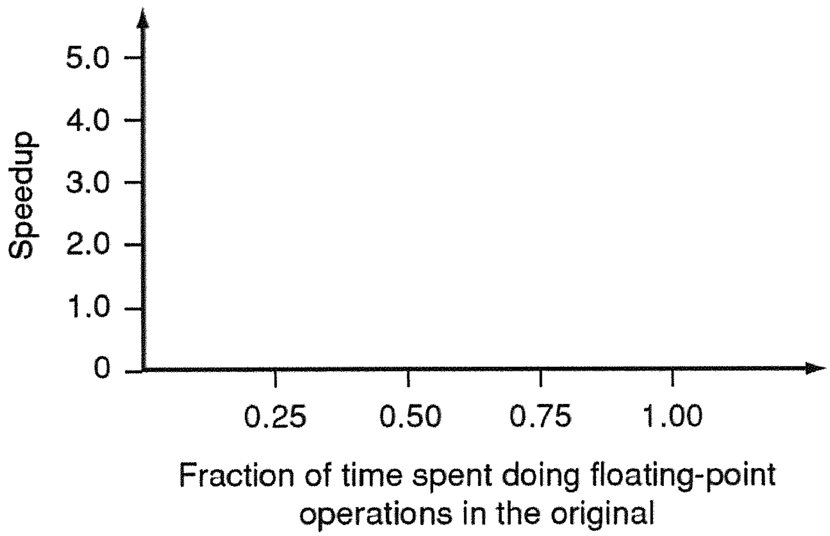
2. Suppose we have three arrays x, y, and z stored contiguously in memory (that is, the y array starts at the memory location where the x array ends, etc.)

Describe how to access the three arrays in a way that maximizes the benefits of a cache.

Describe how to access the three arrays in a way that minimizes the benefits of a cache.

Problem: CM2 **Area: Computers and Architecture** **Code #_________**

Suppose we enhance a computer to make all floating-point instructions run five times faster. Plot the speedup obtained, versus the fraction of time in the original computer spent during floating-point operations, on a graph given below. Make sure to show your calculations.



Problem: CM3 **Area: Computers and Architecture** **Code #_________**

When adding two n-bit signed (2's complement) binary numbers A and B, the following Boolean expression can be used to detect overflow where a_i and b_i are bits at bit position i in A and B, and s_i is the sum bit at bit position i:

$$OV = a_{n-1} \cdot b_{n-1} \cdot \overline{s_{n-1}} + \overline{a_{n-1}} \cdot \overline{b_{n-1}} \cdot s_{n-1}$$

A simpler formula for overflow detection is given as:

$$OV = c_n \oplus c_{n-1}$$

where c_{n-1} and c_n are the carry-in and carry-out of the leftmost full adder.

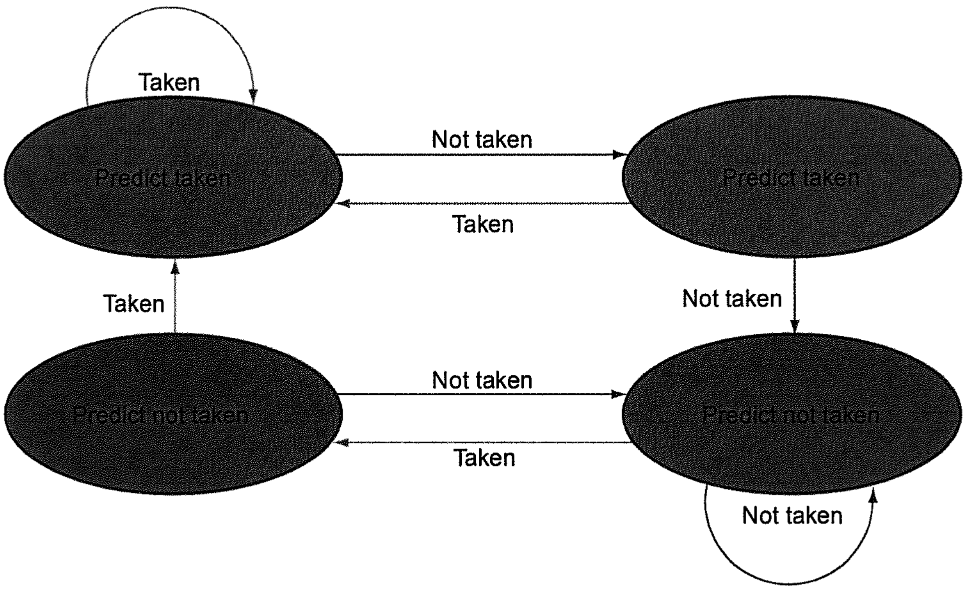
Prove that this simpler formula is equivalent to the previously given formula by showing the following two cases are equivalent to two product terms in the previously given formula:

Case 1: 0 carried in, and 1 carried out.

Case 2: 1 carried in, and 0 carried out.

Problem: CM4 **Area: Computers and Architecture** **Code #__________**

Consider the dynamic branch predictor given below. Calculate the branch prediction accuracy ratio (= total number of correct branch predictions / total number of branch trials) for the following branching pattern: T-T-T-N-N-N-T-N-T-N-N-N-T-T-T, where T means a branch actually taken and N means a branch actually not taken. Assume that the starting state is one at the **top-left corner**.

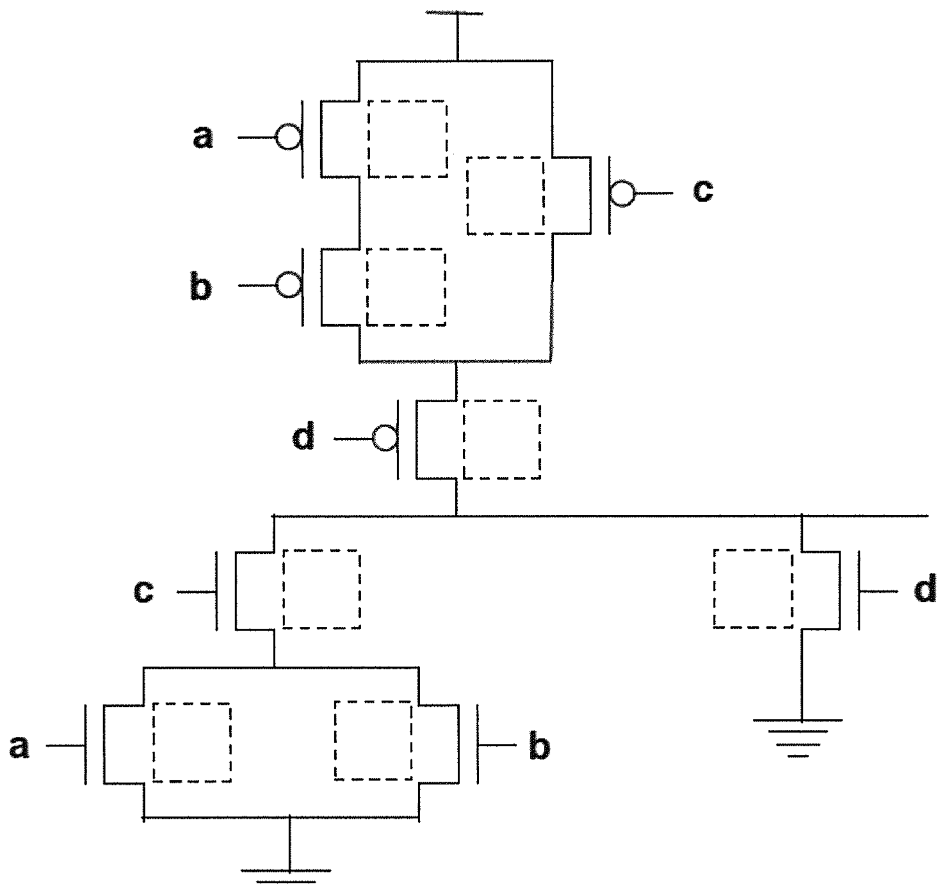


Problem: CM5 **Area: Integrated Circuits and Logic Design** **Code #_________**

Find the minimal sum and the minimal products expressions for the function
$f(v,w,x,y,z)=\prod M(0,13,15,16,17,18,19,20,21,23,27,31)$.

Problem: CM6 **Area: Integrated Circuits and Logic Design** **Code #_________**

Size the following complex gate so that it has the worst-case drive strength of an equivalent inverter with PW = 3 and NW = 2.



Problem: CM7 **Area: Integrated Circuits and Logic Design** **Code #________**

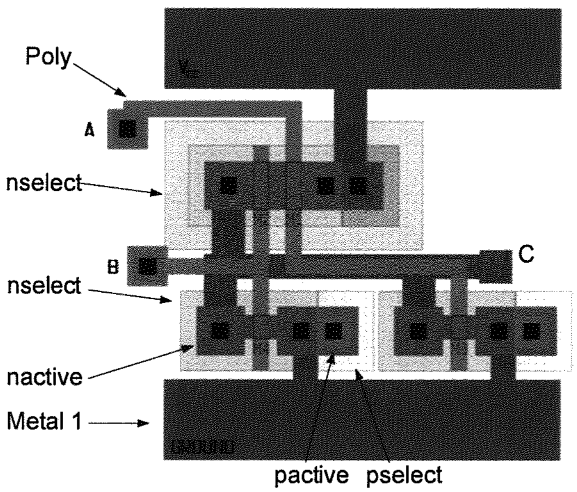
Answer the questions for parts **a** and **b** below.

a) Define latch and flip-flop as memory devices, including different types of implementations and physical operation based on the clock or input signal. Provide two examples of real-world devices that use latches and two examples of real-world devices that use flip-flops.

b) Describe the difference between a rising edge and a falling edge flip-flop. Illustrate the difference using a schematic/drawing.

Problem: CM8 **Area: Integrated Circuits and Logic Design** **Code #________**

Draw the transistor-level circuit for the layout shown below.



Problem: CM17 **Area: Networking and Software Engineering** **Code #________**

Answer all three questions below.

a. In the context of computer networks, describe the difference between error-detecting and error-correcting codes.
b. Describe why networks might use an error-correcting code instead of error detection and retransmission.
c. Give two applications where error-correcting codes are used and two applications where error detection and retransmission are used.

Problem: CM18 **Area: Networking and Software Engineering** **Code #_________**

Answer both questions below.

a. Describe the operation/purpose of each layer (physical, data link, network, transport, session, presentation, application) of the ISO OSI (Open Systems Interconnection) model.
b. Why do the different layers exist in this model?

Problem: CM19 **Area: Networking and Software Engineering** **Code #________**

Answer <u>all four</u> questions below.

a. Consider a half-duplex point-to-point link using a stop-and-wait scheme, in which a series of messages is sent, with each message segmented into a number of frames. Ignore errors and frame overhead. What is the effect on line utilization of increasing the number of frames for a constant message size? Justify your answer.

b. Why is pulse code modulation preferable to delta modulation for encoding analog signals that represent digital data? Note that such signals have high-frequency components and hence change rapidly.

c. What key factors affect channel capacity? Justify your answer using the Shannon theorem.

d. What geometric shape is used in cellular system design? Why?

Problem: CM20 **Area: Networking and Software Engineering** **Code #_________**

Answer both questions below.

a. What percentage of the total IP address space does each of network classes A through C represent? Justify each answer.

b. Given a company with five individual departments, each department of which has eleven computers or networked devices, what mask (expressed in binary) could be applied to the company network to provide the subnetting necessary to divide up the network equally?

Problem M.1 **Power/Machinery** **Code #__________**

A round-rotor, three-phase synchronous generator is rated for 60 Hz, 7.2 kV, 25 MVA. Because of field heating limits, excitation voltage E_a is limited to 6.0 kV. Because of stator copper loss, output apparent power is limited to 25 MVA. Synchronous reactance is 1.3 Ω. The generator is connected to a three-phase, 60 Hz, 7.2 kV bus. Useful equations:

$$P_a = \frac{V_a E_a}{X_s} \sin \delta$$

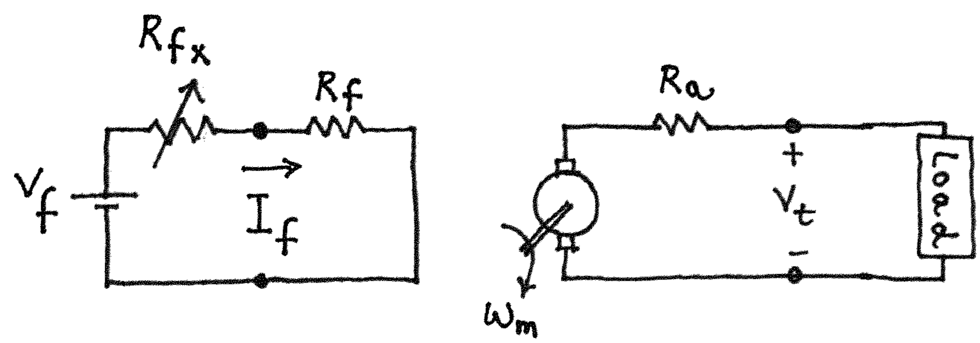
$$Q_a = \frac{V_a E_a}{X_s} \cos \delta - \frac{V_a^2}{X_s}$$

a. Determine the maximum VAR output for this machine if operated as a synchronous condenser. Also find the torque angle and line current magnitude.
b. Determine the minimum excitation voltage and corresponding torque angle to generate 15 MW. Compute the VAR consumption at this operating point and the line current magnitude. Is this a valid operating point within ratings?

Problem M.2 **Power/Machinery** **Code #__________**

The separately excited dc generator depicted in the figure below has the following parameters:

$\omega_m = 200$ rad/s $V_f = 12$ V $R_f = 1\ \Omega$ $R_a = 0.5\ \Omega$



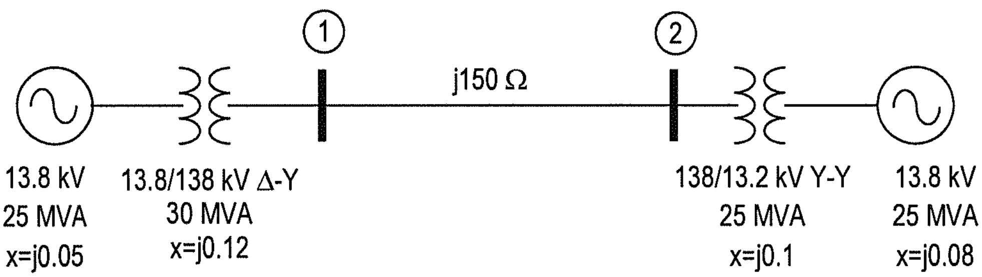
When R_{fx} is set to be 11 Ω, the no-load terminal voltage of the generator appears to be 100 V.

When a load resistance of 3 Ω is connected to the generator and R_{fx} is adjusted to a new value, the terminal voltage of the generator appears to be 102 V. Find the new value for R_{fx}.

Problem M.3 **Power/Machinery** **Code #__________**

EE207

1. Draw the per unit diagram of the system below using a 25MVA, 138kV base in the zone of the transmission line.



You may find the following equation useful:

$$z_{pu}^{new} = z_{pu}^{old}\left(\frac{V_{base}^{old}}{V_{base}^{new}}\right)^2\left(\frac{S_{base}^{new}}{S_{base}^{old}}\right)$$

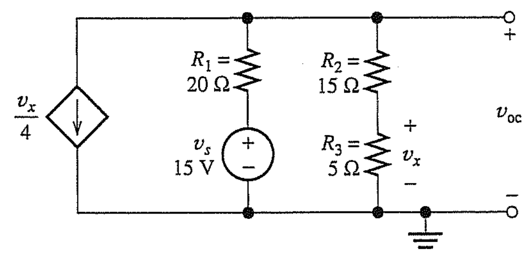
Problem M.4 **Power/Machinery** **Code #__________**

EE207

A three-phase load draws 200 kW at a power factor of 0.85 lagging from a 440 V line. Find the rating (in kVAr) of a capacitor bank installed in parallel with the load needed to raise the power factor to 0.95 lagging.

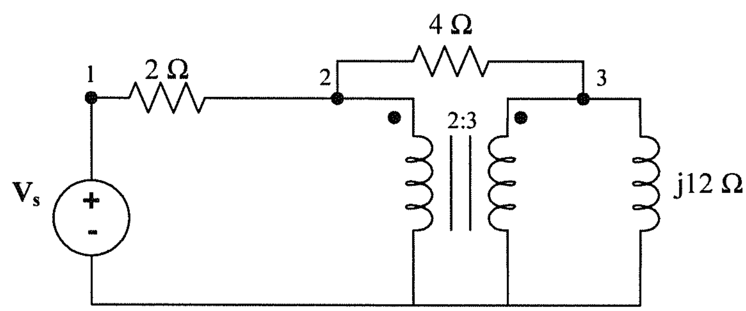
Prob. M5 **Area: Circuits/Electronics** **Code # ________**

Determine the Thevenin Voltage and resistance for the circuit below and calculate the maximum power it can deliver.

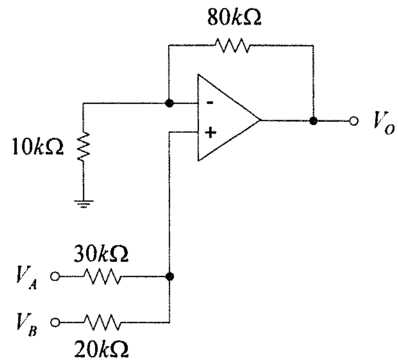


For the following ideal transformer circuit, find:

a. The phasor node voltages $\mathbf{V_1}$, $\mathbf{V_2}$ and $\mathbf{V_3}$ if $\mathbf{V_s} = 10\angle 0°$V.
b. The impedance seen by the source $\mathbf{V_s}$.



Consider the op-amp circuit shown.



a) Assuming the op-amp is ideal, find V_O in terms of V_A and V_B.
(50%)

Answer: V_O =____

b) Now suppose the op-amp is non-ideal with an input offset voltage of zero, an input bias current of 300nA (flowing into the input terminals), and an input offset current of zero. Find V_O under these conditions if $V_A = V_B = O$.
(50%)

Answer: V_O =____

Problem: M10 Area: Waves, Devices, & Optics Code #:

Consider the junction between two transmission lines TL1 and TL2. TL1 has a characteristic impedance Z_{01}, and length ℓ_1, and is fed by a unit step source matched to the characteristic impedance of the line. TL2 has characteristic impedance Z_{02}, and length ℓ_2, and has a matched load. These two transmission line sections are cascaded together. Define a reflection coefficient ρ_{21} at the junction as the ratio of the reflected wave v_1^- to the incident wave v_1^+ on TL1, and a transmission coefficient τ_{21} as the ratio of the outgoing wave v_2^+ on TL2 to the incoming wave v_1^+ from TL1. Then solve for the reflection and transmission coefficients in terms of the line parameters Z_{01} and Z_{02}. What is the relationship between the reflection coefficient and the transmission coefficient? For what case can the transmitted voltage be greater than the reflection coefficient? Does this violate any conservation law? What conservation law must be satisfied.

Problem #M11 — Area: Waves & Devices Code

A slab of crystalline gallium arsenic (GaAs) is doped such that the Fermi level with respect to the middle of the bandgap is -0.1293 eV. The slab is 5 cm in length and 10 mm^2 in cross-sectional area. T = 300 K. Important physical constants are:

Boltzmann's constant:	$k = 1.38 \times 10^{-23}$ J/K = 8.62×10^{-5} eV/K	
Planck's constant:	$h = 4.14 \times 10^{-15}$ eV-s	
Electronic charge:	$q = 1.60 \times 10^{-19}$ C	
Carrier Mobilities	$\mu_n = 9200$ cm^2/V-s	$\mu_p = 400$ cm^2/V-s
Bandgap Energy of Si	$E_g = 1.42$ eV	
Intrinsic Carrier Concentration	$n_i = 2.10 \times 10^6$ cm^{-3} at 300 K	

(a) Is the material n-type, p-type, or intrinsic? Circle the correct choice and justify your answer with a statement (reason).

n-type **p-type** **intrinsic**

(b) Assume that the doping is done with silicon (Si) and no other dopant. Noting that Si is a column IV material, Ga is a column III material, and P is a column V material, what conditions, if any, are needed regarding the Si dopants? Circle the correct choice.

Si on Ga site **Si on As site** **Si on either Ga and As sites**
Si as an interstitial **Insufficient Information**

(c) Calculate the equilibrium minority and majority carrier concentrations.

(d) Calculate the sample resistivity, i.e. ρ.

(e) Answer the following multiple-choice questions. Circle the one best answer.

The crystal structure of semiconductor GaAs is ???
simple cubic **diamond** **zincblende**

The correct units for the diffusion coefficient are ???
(1/Ω) **$(\Omega\text{-cm})^{-1}$** **$(\Omega/\text{cm})^{-1}$** **(cm^2/s)** **(cm^2/V-s)**

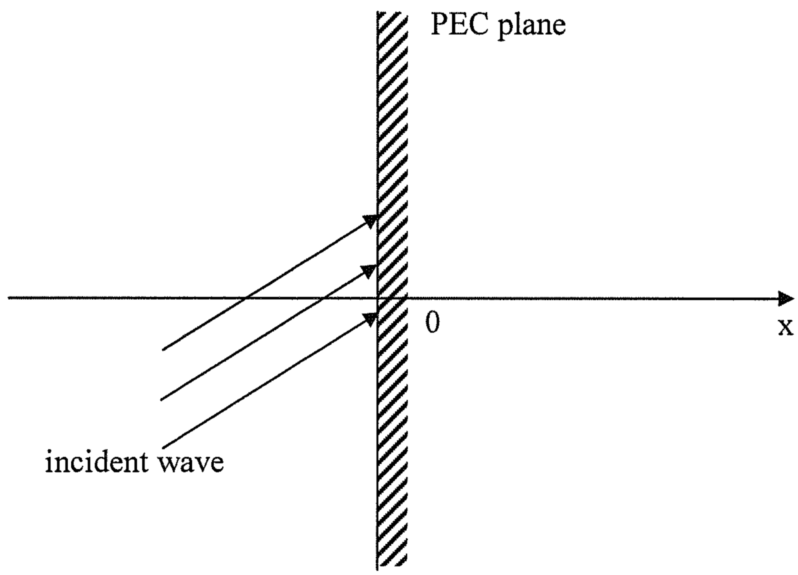
As T increases, the intrinsic carrier concentration of a semiconductor ???
increases **decreases** **stays the same**

Problem: M12 Area: Waves, Devices, & Optics Code #: ____________

A uniform plane wave propagating in air given by

$$\vec{E}_i(x) = 600\pi e^{-j40\pi x - j30\pi z}\,\hat{y}\ \text{(V/m)}$$

is incident on a perfectly conducting plane located at x = 0. Find the electric and magnetic field vectors of the reflected wave $\vec{E}_r(x)$ and $\vec{H}_r(x)$.



Problem M13 **Area: Control** Code#____________

A discrete-time control system is described by

$$\begin{bmatrix} Y_1(z) \\ Y_2(z) \end{bmatrix} = \begin{bmatrix} \dfrac{z-0.3}{z^2-0.6z+0.05} & \dfrac{z+0.3}{z-0.1} \\ 0 & \dfrac{z+0.3}{z-0.2} \end{bmatrix} \begin{bmatrix} U_1(z) \\ U_2(z) \end{bmatrix},$$

where $U_1 = Z[u_1], U_2 = Z[u_2], Y_1 = Z[y_1]$, and $Y_2 = Z[y_2]$ are the two input and the two output variables, respectively. Obtain a state-space representation of the system with minimal number of state variables.

Problem M16 **Area: Control** Code#________

Use the Routh-Hurwitz test to find the range of K for which the following characteristic equation is stable.

$$s^4 + 5s^3 + 2s^2 + 4s + K = 0$$

Problem M-21 Communications / Signal Processing Code# ___

Find the complex exponential Fourier Series coefficients for

$$x(t) = sgn\{sgn[10\cos(2\pi 10t) + 5\sqrt{2}]\} + 10$$

Where sgn() is the signum function, defined as

$$sgn(y) = \begin{cases} -1 & for\ y < 0 \\ 0 & for\ y = 0 \\ +1 & for\ y > 0 \end{cases}$$

Show your work for full credit. If you think it is impossible to find the Fourier Series coefficients for x(t), explain why it is impossible.

Problem M22 **Communications** **Code:______**

Let

$$x[n] = \begin{cases} 1 & n = 0,1,2,3,4 \\ 0 & elsewhere \end{cases} \quad \text{and} \quad h[n] = \begin{cases} 1 & n = 0,1,2,3 \\ 0 & elsewhere \end{cases}$$

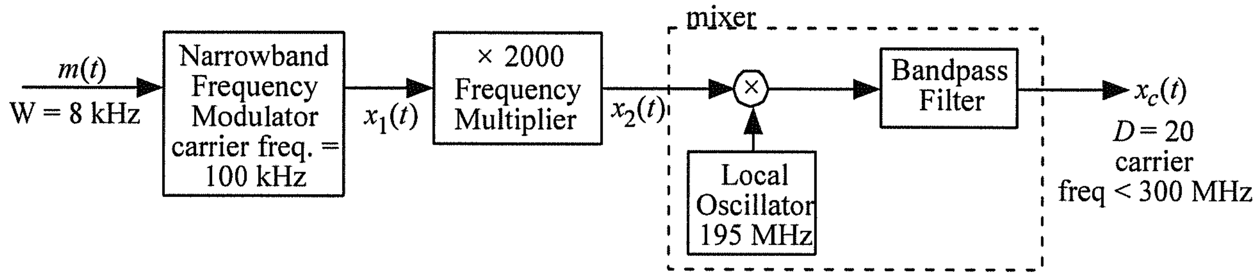
We wish to compute the linear convolution of $x[n]$ and $h[n]$ using circular convolution from finite sequences $\underline{x}[n]$ and $\underline{h}[n]$ derived from $x[n]$ and $h[n]$.

a) From the non-zero lengths of $x[n]$ and $h[n]$ find the minimum finite length, N of $\underline{x}[n]$ and $\underline{h}[n]$ to accomplish our goal.

b) Write the finite sequences $\underline{x}[n]$ and $\underline{h}[n]$ with the minimum N from part (a)

c) Perform the linear convolution of $x[n]$ and $h[n]$ and the N-point circular convolution of $\underline{x}[n]$ and $\underline{h}[n]$ from part (b) and show that the output is the same.

A message signal $m(t)$ with a bandwidth W of 8 kHz is the input to a narrowband frequency modulator that uses a carrier frequency of 100 kHz. The narrowband FM output of this modulator $x_1(t)$ is to be converted to wideband FM. $x_1(t)$ is the input to a $\times 2000$ frequency multiplier. The output of the frequency multiplier, $x_2(t)$, is the input to a mixer which contains a local oscillator operating at 195 MHz. The output of the mixer $x_c(t)$ is wideband FM with a deviation ratio D = 20 and with a carrier frequency less than 300 MHz.



a) What is the carrier frequency for the signal $x_2(t)$?
(10%)

Answer: $f_2 =$ ____________________

b) What is the carrier frequency for the output $x_c(t)$?
(15%)

Answer: $f_c =$ ____________________

c) What is the deviation ratio D_2 for the signal $x_2(t)$?
(10%)

Answer: $D_2 =$ ____________________

d) What is the approximate bandwidth of the signal $x_2(t)$?
(15%)

Answer: $B_2 =$ ____________________

e) What is the deviation ratio D_1 for the signal $x_1(t)$?
(15%)

Answer: $D_1 =$ ____________________

f) What is the approximate bandwidth of the signal $x_1(t)$?
(15%)

Answer: $B_1 =$ ____________________

g) What must be the center frequency and bandwidth of the bandpass filter?
(20%)

Answer: Center frequency = ____________________
Bandwidth = ____________________

Figure 1 shows three baseband signal pulses.

1. Prove or disprove that the pulses are pair-wise orthogonal.
2. If there are orthogonal pairs, what value of T ensures that they are orthonormal?
3. sketch the signals $x(t) = P_1(t) - P_2(t) + P_3(t)$ and $y(t) = P_1(t) + P_2(t)$. Clearly mark all relevant values on the horizontal axis and vertical axis.

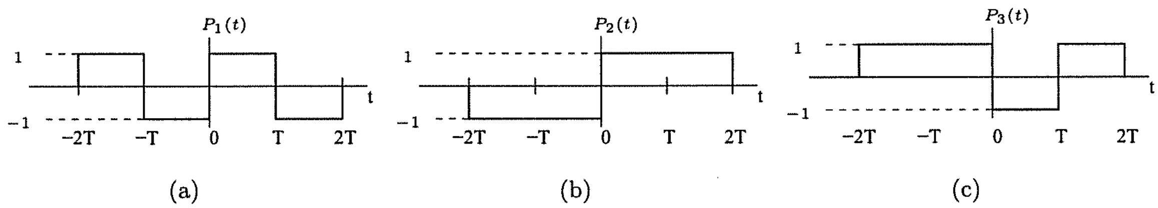


Figure 1: Baseband signal pulses.