

**Association of Professional Engineers of Ontario**

Annual Examinations  
07-Elec-A3, December 2015

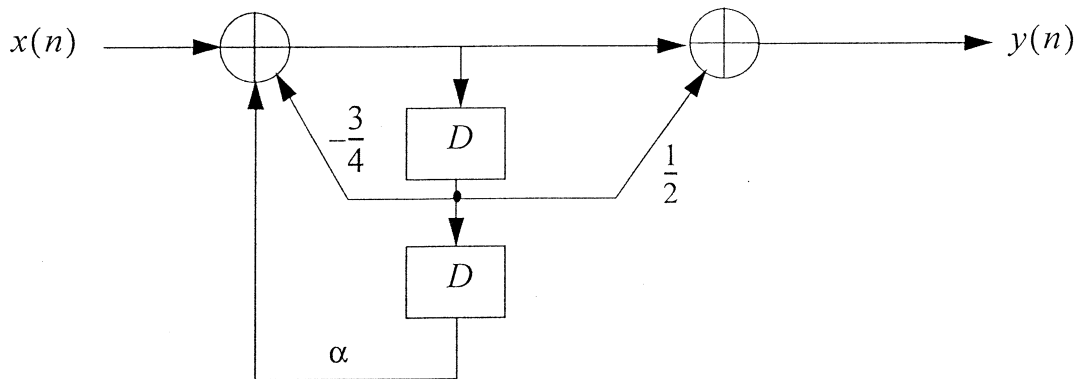
Signals and Communications

3 hours duration

**Notes:**

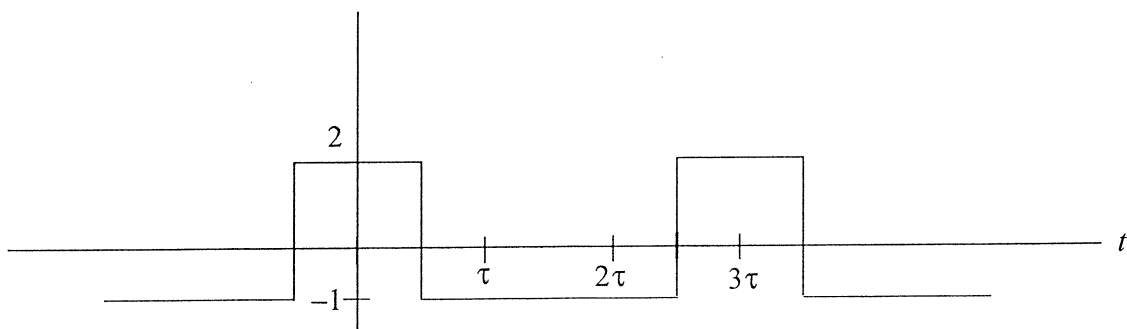
- 1) If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumption made.
- 2) "Closed-Book" - no aids other than a standard non-programmable (no text storage) calculator are permitted.
- 3) Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
- 4) All 6 questions are of equal value.

1) A discrete time linear system is described by the following block diagram:



- Give the transfer function of the system.
- For which values of the parameter  $\alpha$  is the system stable?
- Find the impulse response of the system if  $\alpha = \frac{1}{2}$ .

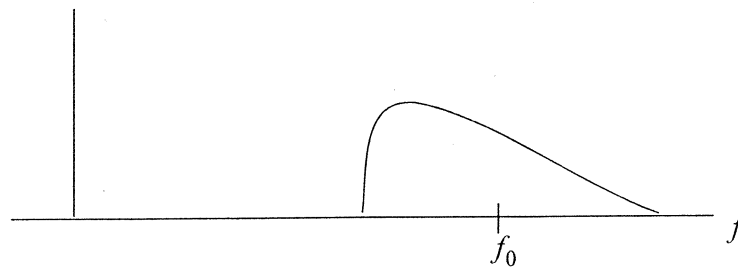
2) Consider the following periodic time signal where  $\tau = 100 \mu\text{s}$ :



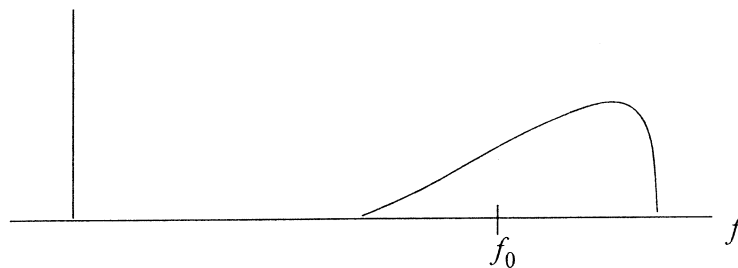
- Determine the Fourier series of  $x(t)$  in terms of real basis functions.
- Determine the power spectral density of the signal  $x(t)$ .
- If the signal  $x(t)$  is input to an ideal band pass filter with center frequency 10 KHz and bandwidth  $B = 5$  KHz, determine the output signal in the time domain.

- 3) An AM signal has a modulation index  $a = 0.8$  and an average power equal to 2W. The message is a triangular wave with frequency equal to 10 KHz. The carrier frequency is 10 MHz.
- Give an expression for the AM signal in the time domain including all parameter values, and plot it.
  - What is the power efficiency of this modulation scheme.
  - Plot the spectrum of the AM signal assuming that all harmonics of the message beyond the 4th can be neglected.
  - Plot the envelope of the AM signal. Give all the parameters.
  - Give the block diagram for an envelope detector that will demodulate the AM signal.
- 4) An audio signal is to be transmitted using PCM in a baseband channel. The bandwidth of the signal is equal to 8 KHz and the signal has a dynamic range of 2V peak to peak. The signal is to be reconstructed using a low pass filter that has a transition region (from the passband to the stopband) equal to 10% of the bandwidth of the passband of the filter. The reconstructed signal must have a quantization noise that is less than 1 mv rms. Assume that the frequency response of the filter is constant within the passband.
- What is the required sampling rate so that we can reconstruct the signal with zero distortion except for quantization noise?
  - Find the smallest number of bits required to represent each sample of the signal.
  - What is the bit rate of the resulting PCM signal?
  - Suppose 10 of the above PCM signals (as in c)) are to be multiplexed and transmitted through a baseband channel using a binary scheme. What is the minimum bandwidth required for the channel assuming optimum filtering of the transmitted pulses?

- 5) An FM signal has the form  $s(t) = A_c \cos(2\pi f_c t + \phi(t))$ , where  $A_c = 5$   
 $\phi(t) = a \cos(2\pi f_1 t) + b \cos(2\pi f_2 t)$ ,  $a = 1$ ,  $b = 2$ ,  $f_1 = 2000$  Hz, and  $f_2 = 2f_1$
- Determine the message signal  $m(t)$ , assuming that the frequency deviation constant is 5 KHz/volt.
  - What is the average power of the FM signal  $s(t)$ ?
  - Determine the peak frequency deviation of the FM signal.
  - Determine the bandwidth of the FM signal.
  - Give the block diagram of a suitable demodulator.
- 6) A real bandpass signal has center frequency  $f_0$  as shown in the following Figure (shown only for positive frequencies).



- Give the block diagram of a system that transforms the above signal to a bandpass signal with the same carrier frequency but with a spectrum that is the mirror image about the carrier frequency (for positive frequencies), i.e. the spectrum is as follows (for positive frequencies).



- A modulated signal has a carrier frequency equal to 10 MHz. We wish to convert the carrier frequency to 12 MHz. We have a local oscillator that produces a square wave and it has a variable frequency setting up to a maximum of 1 MHz. Give the block diagram of a system to perform the frequency conversion. No other oscillators are to be used.