THE STATE UNIVERSITY OF NEW JERSEY

RUTGERS

College of Engineering

Department of Electrical and Computer Engineering

332:322   **Principles of Communications Systems**   **Spring**

Problem Set 7

Haykin section 3.6
Web notes on convexity
Web notes on quantization

1. **Quantization:** Show that a nonuniform quantizer with sufficiently small bin sizes Δ_i, has mean-square quantization error of approximately $\frac{1}{12} \sum_i \Delta_i^2 p_i$, where p_i is the probability that the input signal amplitude lies within the ith interval.

   HINT: You may assume that for Δ_i sufficiently small, you have an approximately uniform distribution given that x lies in the i$^{\text{th}}$ bin.

2. **Quantization Example:**

   (a) A random waveform $x(t)$ has amplitude uniformly distributed over $[-1, 1]$. Please provide an optimal 4 bit quantizer for this signal. Show your choice satisfies the Lloyd-Max optimality conditions.

   (b) Let $\hat{x}(0)$ be a quantized sample of the signal level $x(t_0)$. What is $E[\hat{x}(0) - x(t_0)]$? What is $E[(\hat{x}(0) - x(t_0))^2]$? What is the probability distribution on the random variable $e(0) = \hat{x}(0) - x(t_0)$? You must justify your results.