B38CN: Introduction Communications and Networks
Tutorial 2 (Chapter 2)

1. For a pulse code modulation (PCM) telephone-quality voice, the signal has a bandwidth of 4 KHz.
   1) What is the minimum sampling rate of this signal?
   2) If each PCM voice sample is represented by 8 bits, calculate the bit rate of the digitized PCM voice signal.
   3) A digital transmission system has a bit rate of 45 megabits/second. How many PCM voice calls can be carried by the system?
   4) Suppose that at a given time of the day, in a city with a population of 1 million, 1% of the people are on the phone. If each call is encoded using PCM, what is the total bit rate generated by all these people?
2. Consider an analog repeater system in which the signal has power σ_x^2 and each stage adds noise with power σ_n^2. For simplicity assume that each repeater recovers the original signal without distortion but that the noise accumulates. Find the SNR after *n* repeater links. Write the expression in decibels: SNR dB = $10\log_{10}$SNR.
3. Suppose that a signal has twice the power as a noise signal that is added to it. Find the SNR in decibels. Repeat if the signal has 10 times the noise power? 2^n times the noise power? 10^k times the noise power? (*Hint:* $10 \log_{10} 2 = 3$ dB.)
4. A way of visualizing the Nyquist theorem is in terms of periodic sampling of the second hand of a clock which makes one revolution around the clock every 60 seconds. The Nyquist sampling rate here should correspond to 2 samples per cycle, that is, sampling should be done at least every 30 seconds.
   1) Suppose we begin sampling when the second hand is at 12 o'clock and that we sample the clock every 15 seconds. Draw the sequence of observations that result. Does the second hand appear to move forward?
   2) Now suppose we sample every 30 seconds. Does the second hand appear to move forward or backward? What if we sample every 29 seconds?
   3) Explain why a sinusoid should be sampled at a little more than twice its frequency.
   4) Now suppose that we sample every 45 seconds. What is the sequence of observations of the second clock hand?
5. An audio digitizing utility in a PC samples an input signal at a rate of 44 kHz and 16 bits/sample. How big a file is required to record 20 seconds?
6. A 10 kHz baseband channel is used by a digital transmission system. Ideal pulses are sent at the Nyquist rate and the pulses can take 16 levels. What is the bit rate of the system?
7. Suppose a baseband transmission system is constrained to a maximum signal level of ±1 volt and that the additive noise that appears in the receiver is uniformly distributed between [–1/16, 1/16]. How many levels of pulses can this transmission system use before the noise starts introducing errors?
8. Suppose we wish to transmit at a rate of 64 kbps over a 3 kHz telephone channel. What is the minimum SNR required to accomplish this?
9. Suppose that a low-pass communications system has a 1 MHz bandwidth. What bit rate is attainable using 8-level pulses? What is the Shannon capacity of this channel if the SNR is 20 dB? 40 dB?