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

1. For a pulse code modulation (PCM) telephone-quality voice, the signal has a bandwidth of 4 KHz.
   1) The minimum sampling rate of this signal is 8000 samples/second.
   2) If each PCM voice sample is represented by 8 bits, the bit rate of the digitized PCM voice signal is 8000 samples/second x 8bits/sample=64 kbps.
   3) A digital transmission system has a bit rate of 45 megabits/second. Then, PCM channels = ($45\text{x}10^6$ bits/sec) / ($64\text{x}10^3$ bits/sec channel) = 703 channels.
   4) The number of people on the phone at a given time is $10^6 \times 10^{-2} = 10^4$, so the total bit rate is $10^4 \times 64 \times 10^3$ bits/second = 640 megabits/second.
2. After n stages, the signal power is σ_x^2 and the noise power is $n\sigma_n^2$, so the SNR is:
   SNR dB= $10\log_{10}\sigma_x^2/(n\sigma_n^2) = 10\log_{10}\sigma_x^2/\sigma_n^2 + 10\log_{10} 1/n = 10\log_{10}\sigma_x^2/\sigma_n^2 - 10\log_{10} n$
3. SNR dB = $10\log_{10}\sigma_x^2/\sigma_n^2 = 10\log_{10} 2 = 3$ dB
   SNR dB = $10\log_{10} 10 = 10$ dB
   SNR dB = $10\log_{10} 2^n = 10n\log_{10} 2 = 3n$ dB
   SNR dB = $10\log_{10} 10^k = 10k\log_{10} 10 = 10k$ dB
4. 1) 0 15 30 45 0 15 30 45 0 ... Yes, the second hand appears to move forward.
   2) 0 30 0 30 0 30 0 30 0 30 ... No. It's hard to tell if it moves forward or backward because either direction will give the same sequence.
   0 29 58 27 56 25 54 23 ... Yes, the second hand appears to move forward.
   3) When a sinusoid is being sampled at exactly twice its frequency, it is possible that all samples have value of zero. Therefore, the sampling rate should be a little more than twice its frequency.
   4) One sampling every 45 seconds $\rightarrow$ 0 45 30 15 0 45 30 15 0 … The second hand appears to be moving backward.
5. The bit rate: $R = 44 \times 10^3 \times 16 = 704 \times 10^3$ bps
   Number of bits generated in 20 seconds = $20 \times 704 \times 10^3$ bits = 14080×10^3 bits.
   The file size = $14080 \times 10^3/(8 \times 1024)$ ≈ 1719 k bytes ≈ 1.7 M bytes.
6. Nyquist pulses can be sent over this channel at a rate of 20000 pulses per second. Each pulse carries $\log_2 16$ = 4 bits of information, so the bit rate is 80000 bps.
7. If two adjacent signal levels are separated by more than 2/16 then the noise cannot translate one adjacent signal into the next. The maximum range that the signal can span is +1 – (–1) = 2, so the maximum number of levels is 2/(1/8) = 16.
8. We know that R = 64 kbps and W = 3 kHz. What we need to find is SNRmin. The channel capacity is:
   $$\mathrm{C} = \mathrm{W}\log_2(1+\mathrm{SNR}), \mathrm{C} \geq \mathrm{C_{min}} = 64\text{ kbps}$$
   $$\mathrm{C_{min}} = \mathrm{W}\log_2(1+\mathrm{SNR_{min}}) \Rightarrow \log_2(1+\mathrm{SNR_{min}}) = \frac{64}{3} \Rightarrow 1+\mathrm{SNR_{min}} = 2^{64/3}$$
   $$\Rightarrow \mathrm{SNR_{min}} = 2.64 \times 10^6$$
   $\mathrm{SNR_{min}}$ (dB) $= 10\log_{10}(2.64 \times 10^6) = 64.2$ dB. This implies a very clean channel.
9. Nyquist pulses can be sent over this system at a rate of 2 million pulses per second. Eight-level signaling carries 3 bits per pulse, so the bit rate is 6 Mbps.

The Shannon capacities are:

$C = 1000000 \log_2 (1 + 100) = 6.6$ Mbps.

$C = 1000000 \log_2 (1 + 10000) = 13.3$ Mbps.