Note: These answers are only reference answers. Other answers may also correct as long as you can provide reasonable explanations!

1. Television channels are 6 MHz wide. How many bits/sec can be sent if eight-level digital signals are used? Assume a noiseless channel is used.

   Answer: Using the Nyquist theorem, we can sample 12 million times/sec. Four-level signals provide 3 bits per sample, for a total data rate of 36 Mbps.

2. If a binary signal is sent over a 3-kHz channel whose signal-to-noise ratio is 20 dB, what is the maximum achievable data rate?

   Answer: A signal-to-noise ratio of 20 dB means S/N = 100. Since $\log_2 101$ is about 6.658, the Shannon limit is about 19.975 kbps. The Nyquist limit is 6 kbps. The bottleneck is therefore the Nyquist limit, giving a maximum channel capacity of 6 kbps.

3. Assume that the following chip sequences are used in a CDMA system for communication.

   A = (–1 –1 –1 +1 +1 –1 +1 +1)
   B = (–1 –1 +1 –1 +1 +1 +1 –1)
   C = (–1 +1 –1 +1 +1 +1 –1 –1)
   D = (–1 +1 –1 –1 –1 –1 +1 –1)

   (a) Suppose station A, B and C are simultaneously transmitting "0" bits, while station D remains silent. What is the resulting chip sequence in the channel?
   (b) Suppose a receiver gets the following chips: (−1 +1 −3 +1 −1 −3 +1 +1). Which stations transmitted, and which bits did each one send?

   Answer:
   (a) The result is obtained by negating each of *A*, *B*, and *C* and then adding the three chip sequences. Alternatively, the three can be added and then negated. The result is (+3 +1 +1 −1 −3 −1 −1 +1).
   (b) Just compute the normalized inner products with chip sequences of each station. The result is that *A* and *D* sent bit "1", *B* sent a bit "0", and *C* was silent.

4. What is the minimum bandwidth needed to achieve a data rate of B bits/sec if the signal is transmitted using NRZ and Manchester encoding, respectively? Explain your answer.

   Answer:
   (1) In NRZ, the signal completes a cycle at most every 2 bits (alternating 1s and 0s). So, the minimum bandwidth needed to achieve B bits/sec data rate is B/2

Hz.

(2) In Manchester encoding, the signal completes a cycle in every bit, thus requiring at least B Hz to achieve B bits/sec data rate.

5. Explain that in 4B/5B encoding (using NRZI), a signal transition will occur at least every four bit times.

Answer: Since 4B/5B encoding uses NRZI, there is a signal transition every time a 1 is sent. Furthermore, the 4B/5B mapping (see Figure 2-21) ensures that a sequence of consecutive 0s cannot be longer than 3. Thus, in the worst case, the transmitted bits will have a sequence 10001, resulting in a signal transition in 4 bits.