Introduction to Digital Communication

Exercise 1: Give an example of a communication network. What are the information source and sink? What channels does it operate over? What transmitters and receivers do you think are used on each channel?

network	source	sink	channel	tx	rx
AM radio	audio mic.	audio spk.	free space	radio tx	"radio" rx

Exercise 2: Speech is intelligible even if only frequencies below about 4 kHz are transmitted. What is the minimum sampling rate that should be used to sample speech if we first remove frequencies above 4 kHz?

$4\,kHz \times 2 = 8\,kHz$

$\frac{1}{8\,kHz} = 125\,\mu s.$

Exercise 3: A signal-to-noise power ratio of about 48 dB is considered "toll quality" (the SNR conventional telephone networks provide). How many bits per sample are required to obtain a quantization SNR equivalent to "toll quality" speech?

$6B = 48$

$B = \frac{48}{6} = 8$ bits

Exercise 4: What if the signal was a video signal with a 5 MHz bandwidth and required a quantization SNR of 40 dB?

$f_s = 2 \cdot 5\,MHz = 10\,MHz$

$B = \frac{40}{6} = 6\frac{2}{3}$ bits ≈ 7 bits

Exercise 5: How many bits per second need to be transmitted in these two examples?

telephone : 8,000 × 8 bits/sample = 64 kb/s.

video : 10 MHz × 7 bits/sample = 70 Mb/s

Exercise 6: Write the sequence of bits that would be transmitted if the 16-bit value 525 was transmitted with the bytes in little-endian order and the bits lsb-first. Write the sequence of bits that would be transmitted in "network order" and the bits msb-first.

$525_{10} = 020D_{16}$

first → 0D, 02 → last

0000 1101 0000 0010

first bit → 1011 0000 0100 0000 → last bit

0000 0010 0000 1101

first → last

Exercise 7: How many bits would be required to uniquely identify 100,000 different characters? (Hint: $2^{16} = 65536$).

$2^{17} \simeq 130{,}000$

need 17 bits

Exercise 8: The Chinese character for "Rice" (the grain) is 米 with Unicode value (code point) U+7C73. What is the UTF-8 encoding for this character?

7 C 7 3 — 0111 1100 0111 0011

Use third row: z = 0111, y = 1100, x = 0111 0011

1110 0111 — 10 111001 — 10 110011

E 7 — B 1 — B 3

Exercise 9: Convert the decimal number 525 to a 16-bit (two-byte) binary number. How would you write this in hexadecimal notation?

Find the ASCII codes for the *characters* '525'. Write out the bits of the sequence that would be transmitted assuming each character is encoded in UTF-8. *Hint: the UTF-8 character code for a digit is 0x30 plus the value of the digit.*

Which of these two sequences of bits is the text format and which is the binary format? How many more bits would need to be stored or transmitted for the text format?

020D ← binary

0000 0010 0000 1101

0x35, 0x32, 0x35

0011 0101 — 0011 0010 — 0011 0101 ← text

3 5 — 3 2 — 3 5

Exercise 10: We observe a source that outputs letters. Out of 10,000 letters 1200 were 'E'. What would be a reasonable estimate of the probability of the letter 'E'?

$$\log_a b = \frac{\log b}{\log a}$$

$$\frac{1200}{10,000}$$

$$0.12 = 12\%$$