City& Guilds

9210-118
Level 6 Graduate Diploma in Engineering
Communication systems

Sample Paper

You should have the following for this examination
- one answer book
- non-programmable calculator
- pen, pencil, ruler, drawing instruments

No additional data is attached

General instructions
- This examination paper is of **three hours** duration.
- This examination paper contains **nine** questions.
- Answer **any five** questions.
- All questions carry equal marks. The maximum marks for each section within a question are given against that section.
- An electronic, non-programmable calculator may be used, but the candidate **must** show clearly the steps prior to obtaining final numerical values.
- Drawings should be clear, in good proportion and in pencil. Do **not** use red ink.

1 a) Open Systems Interconnection (OSI) model is a set of standards for communication.
- i) List the seven layers of the OSI model. (4 marks)
- ii) List four functions of the data link layer. (2 marks)

b) John calls Adam on a PSTN. The PSTN uses SS7 signalling. John and Adam are not served by the same local exchange. Explain the call setup process. (5 marks)

c) Draw a diagram, which interconnects the main components of a GSM network, and briefly explain the functions of each component. (5 marks)

d) Briefly explain what frequency re-use is. (2 marks)

e) Briefly explain why frequency re-use is useful for a mobile service provider. (2 marks)

2 a) Represent the main components of an optical fibre communication system using a block diagram. (3 marks)

b) List four advantages of optical fibre communication. (2 marks)

c) Using simple ray theory and appropriate diagrams, briefly describe the mechanism of the transmission of light within an optical fibre. (3 marks)

d) A silica optical fibre with a core diameter large enough to be considered by ray theory analysis has a core refractive index of 1.50 and a cladding refractive index of 1.47. Determine,
- i) the critical angle at the core-cladding interface (2 marks)
- ii) the Numerical Aperture (NA) for the fibre (2 marks)
- iii) the Acceptance Angle in air for the fibre. (2 marks)

e) Give two advantages and two disadvantages of single mode step-index fibre. (4 marks)

f) List three main characteristics that a good source (emitter) in an optical fibre system should satisfy. (2 marks)

3 A discrete information source *Y* transmits six symbols with probabilities {0.12, 0.05, 0.2, 0.3, ***a***, 0.25},
Where '***a***' is a positive constant and represents a probability.

a) Calculate ***a***. (2 marks)

b) Find the entropy of the source. (2 marks)

c) Construct a binary Huffman code for *Y*. (5 marks)

d) Calculate the code efficiency of the Huffman code. (2 marks)

e) Construct a binary Shannon Fano code for *Y*. (4 marks)

f) Calculate the code efficiency of the Shannon Fano code. (2 marks)

g) If the entropy of the source needs to be maximized, at what probabilities should *Y* transmit the six symbols and what will be the maximum entropy? (3 marks)

4 a) Briefly explain what line coding is. (2 marks)

b) List three favourable properties of a good line code. (3 marks)

c) Draw line codes for the bit pattern 11100101 for each of the coding schemes given below. (5 marks)
- i) Unipolar return to zero (RZ).
- ii) Unipolar non-return to zero (NRZ).
- iii) Polar RZ.
- iv) Polar NRZ.
- v) Bipolar RZ.

d) State Nyquist's sampling theorem. (2 marks)

e) A signal has a bandwidth of 5 MHz. The signal is sampled, quantized and binary coded before transmission.
- i) Determine the sampling rate if the signal has to be sampled 20% above the Nyquist rate. (2 marks)
- ii) If the samples are quantized into 1024 levels, determine the number of binary samples required to encode each sample. (2 marks)
- iii) Find the binary pulse rate of the binary coded signal. (2 marks)
- iv) Find the minimum bandwidth required to transmit the signal. (2 marks)

5 a) For an error control code, express the relationship between the minimum Hamming distance and the maximum number of errors the coding scheme can detect. (2 marks)

b) Briefly explain the relationship expressed in part a) above. (3 marks)

c) For an error control code, express the relationship between the minimum Hamming distance and the maximum number of errors the coding scheme can correct. (2 marks)

d) The generator matrix for a (7,4) Hamming code is given by,

$$\begin{pmatrix} 1\,0\,0\,0\,0\,1\,1 \\ 0\,1\,0\,0\,1\,0\,1 \\ 0\,0\,1\,0\,1\,1\,0 \\ 0\,0\,0\,1\,1\,1\,1 \end{pmatrix}.$$

i) Using the generator matrix, calculate the code words for source blocks 1101 and 1010. (4 marks)

ii) Obtain the Hamming distance between the code words obtained for source blocks 1101 and 1010. (2 marks)

iii) Write the parity check matrix for the above generator matrix. (3 marks)

iv) For a received code word, which may contain errors, explain how the associated syndrome can be determined. (2 marks)

v) Find the corresponding syndrome for error vector 0000010. (2 marks)

6 a) List four advantages of digital communication over analogue communication. (2 marks)

b) Briefly explain the advantage of using non-uniform quantization in Pulse Code modulation (PCM). (2 marks)

c) Consider a PCM system where its quantizer consists of an A-*law* compander (with A = 87.6) followed by a uniform quantizer. The input/output characteristics of the uniform quantizer are given in the following tables, where *i* represents the end points, and represents the output levels.

i_0	i_1	i_2	i_3	i_4	i_5	i_6	i_7	i_8
–5 V	–3.75 V	–2.5 V	–1.25 V	0 V	1.25 V	2.5 V	3.75 V	5 V

j_1	j_2	j_3	j_4	j_5	j_6	j_7	j_8
–4.375 V	–3.125 V	–1.875 V	–0.625 V	0.625 V	1.875 V	3.125 V	4.375 V

The maximum value of the input signal, which is sampled at 20 ksamples/sec, is 5 V.
The signal at the output of the sampler is equal to 3.7 V.
A-*law* for positive amplitudes is given by:

$$y = \frac{AX}{1+\ln A} \text{ for } 0 \le X \le \frac{1}{A} \text{ and } y = \frac{1+\ln(AX)}{1+\ln A} \text{ for } \frac{1}{A} \le X \le 1,$$

Where = $\frac{\text{Input Value}}{\text{Maximum input}}$.

i) Calculate the output voltage of the A-*law* encoder. (5 marks)

ii) Calculate the output voltage of the quantizer. (2 marks)

iii) Calculate the output voltage of the A-*law* decoder. (4 marks)

iv) Calculate the quantization noise. (2 marks)

v) Calculate the length of the audio signal (in hours) corresponding to 7.5 GB of PCM data. (3 marks)

7 a) Modulation is an essential element in communications.

- i) Briefly explain what modulation is. (2 marks)
- ii) List two advantages of modulation. (2 marks)

b) Two modulation schemes BPSK (Binary Phase Shift Keying) and QPSK (Quadrature Phase Shift Keying) have been used to modulate a channel of bandwidth 50 kHz.

- i) Sketch the signal constellation diagrams for each of the modulation schemes. (2 marks)
- ii) Calculate the theoretical maximum data rate that can be achieved with each of the modulation schemes over the given channel. (2 marks)
- iii) Briefly discuss the relative advantages and disadvantages of the two modulation techniques. (2 marks)

c) Consider a binary FSK (Frequency Shift Keying) signal with a mark frequency of 50 kHz and a space frequency of 52 kHz. Input bit rate is 4 kbps.

- i) Calculate the peak frequency deviation. (2 marks)
- ii) Calculate the minimum bandwidth of the signal. (2 marks)
- iii) Calculate the baud rate. (2 marks)
- iv) Calculate the minimum bandwidth and baud rate if ASK (Amplitude Shift Keying) was used for the same input bit stream. (4 marks)

8 a) Determine the received optical power in dBm and watts for the 20 km optical link with the following parameters,

Consider the following optical link.
Length of the link: 20 km
Length of each optical cable: 5 km
LED output power: 40 mW
Cable loss: 0.4 dB/km
Cable connector loss: 2.1 dB each
Light source to fibre interface loss: 1.8 dB
Fibre to light detector loss: 2 dB

- i) Calculate the output LED power in dBm. (2 marks)
- ii) Calculate the total loss. (4 marks)
- iii) Calculate the received power in dBm and Watts. (2 marks)
- iv) Name two possible losses that have been neglected in this calculation. (2 marks)
- v) If the receiver sensitivity is 0.5 mW, what is the allowable degradation in dB for the losses in iv)? (2 marks)

b) Three amplifiers A,B and C are connected in series. The system implementer is considering two configurations. The two configurations differ from each other with respect to the order these amplifiers are connected with each other. The first configuration is A→B→C, and the second is A→C→B. Amplifier gains and noise factors are as follows:

	A	B	C
Gain (dB)	6	12	20
Noise figure	1.7	2	4

The noise factor at A is 1.7. Calculate the system Noise figure for each of the two configurations. (8 marks)

9 a) A periodic signal has the following components.

Component	Frequency (kHz)	Amplitude (V)	Phase (Degrees)
1	4	4	45
2	8	2.8	150
3	12	1.7	30
4	16	0.5	190

i) Using the Fourier series, write an equation that represents this signal. (2 marks)
ii) Calculate the fundamental frequency of the signal. (2 marks)
iii) Calculate the average power of the signal. (2 marks)
iv) Calculate the bandwidth of the signal. (2 marks)
v) Calculate the power contained in the frequency band 0 – 10 kHz. (2 marks)
vi) Calculate the percentage of signal power loss if the signal is transmitted over a low-pass channel of bandwidth 9 kHz. (2 marks)
vii) Express the power loss in dB. (2 marks)

b) Inter-symbol interference (ISI) is a well-known bottleneck for reliable communication. Explain ISI considering the transmission of a square pulse through a band-limited channel. (6 marks)