1. (a) State the sampling theorem. Explain what is meant by the *Nyquist rate* and *spectral folding*. Outline any practical considerations that arise when employing the sampling theorem.

[8 marks]

(b) An analogue speech signal is bandlimited to 3.4 kHz and sampled at 1.25 times the Nyquist rate and quantised to 256 levels. What is the bit rate of the digital signal required to represent this analogue signal?

[8 marks]

(c) Explain what is meant by *companding*. Comment on where the A-law and the μ–law for *companding* may be used.

[8 marks]

(d) Derive an expression for the signal-to-noise ratio (SNR) of a decoded pulse code modulation (PCM) signal in the presence of noise. State all assumptions used in its derivation. You may assume the following expressions for the average signal and average quantisation noise powers respectively:

$$\overline{S} = \frac{M^2 - 1}{12} q^2$$

$$\overline{N_q} = \frac{q^2}{12}$$

where q is the quantisation interval and M is the number of quantisation levels.

[9 1/3 marks]

2. (a) Explain what is meant by *multiplexing*. Describe each of the following techniques: *frequency division multiplexing (FDM), time division multiplexing (TDM),* and *code division multiplexing (CDM)*. In each case indicate where the technique might be used.

[8 marks]

(b) Compare the performance of frequency division multiple access (FDMA) and time division multiple access (TDMA) in terms of throughput and average delay. State all assumptions made in carrying out the comparison.

[9 1/3 marks]

(c) Using appropriate diagrams describe the structure of a frame and multiframe in the 30 channel PCM TDM signal. Include in your answer how synchronisation and signalling information is carried in the signal.

[8 marks]

(d) Explain what is meant by *plesiochronous operation* and *plesiochronous digital hierarchy*.

[8 marks]

3. (a) Describe with the aid of a block diagram the two basic steps in the detection of digital signals

[8 marks]

(b) Explain what is meant by a *matched filter* in the context of the detection of digital signals. Show how under certain conditions, this filter may be implemented as a correlation process.

[10 marks]

(c) Assuming the use of a matched filter digital receiver, compare the error performance of unipolar, polar and orthogonal baseband signalling schemes. You may assume binary signalling in the presence of AWGN where the average probability of error P_e is given by

$$P_e = Q\left(\frac{d_{\min}}{\sqrt{2N_0}}\right)$$

where $Q(.)$ is the complementary function, d_{min} is the minimum distance between the signal vectors and $N_0/2$ is the average noise power spectral density.

[15 1/3 marks]

4. (a) Explain what is meant by *attenuation* and *dispersion* in the context of digital baseband signal transmission.

[8 marks]

(b) Explain what is meant by an *amplifying repeater* and a *regenerative repeater*.

[8 marks]

(c) Compare the performance of an amplifying repeater and a regenerative repeater by deriving an expression for the average probability of error after m hops for each case. You may assume binary polar signaling in the presence of AWGN where the average probability of error P_e is given by

$$P_e = Q\left(\sqrt{\frac{2E_s}{N_0}}\right)$$

where $Q(.)$ is the complementary error function, E_s is the average symbol energy and $N_0/2$ is the average noise power spectral density.

[8 marks]

(d) Explain how intersymbol interference (ISI) can arise in the transmission of digital baseband signals over bandlimited channels.

[9 1/3 marks]