1. (a) State the Nyquist 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 5 kHz and sampled at 1.5 times the Nyquist rate and quantised to 1024 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* in the context of digitally encoding human speech. 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.

You may also assume the following series:

$$\sum_{n=1}^{M} n = \frac{M(M+1)}{2}$$

[9 1/3 marks]

2. (a) Explain with the aid of a block diagram the operation of a delta modulation (DM) system. Outline the advantages of the DM system.

[8 marks]

(b) Describe the two types of quantisation error that can occur in a DM system.

[8 marks]

(c) A 1 V_{pp}, 10 kHz sinusoid is to be converted to a digital signal by DM with a step size of 50 mV. Determine the minimum sampling rate that will allow the DM system to follow the fastest changes in the input analogue signal.

[9 marks]

(d) Explain what is meant by *waveform coding* and *source coding* in the context of digitizing human speech. In each case give an example that is representative of the technique.

[8 1/3 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.

[10 marks]

(d) Explain what is meant by intersymbol interference (ISI) and describe how can arise in the transmission of digital baseband signals over bandlimited channels.

[7 1/3 marks]