INSTRUCTIONS:

Answer __ALL__ questions. Each question carries equal marks. [100 MARKS]

1. A carrier signal, $A_c cos(\omega_c t + \theta)$ is amplitude modulated by a message signal, $A_m cos\omega_m t$, where $A_m < A_c$.

    (a) Derive the expression for the spectrum of the modulated signal.   [4 marks]

    (b) Derive the expression for the total power in the modulated signal.   [4 marks]

    (c) Derive the expression for the efficiency of transmission in terms of only the modulation index.   [3 marks]

    (d) An AM signal is given by $x_{AM}(t) = [29 + 9cos2000\pi t + 12cos3000\pi t]cos2\pi \times 10^5 t$

    (i)   Sketch the spectrum of the modulated signal.   [3 marks]

    (ii) Determine the effective modulation index.   [3 marks]

    (iii) Determine the carrier power and total sideband power.   [3 marks]

2. (a) Explain the term *frequency deviation constant* and *phase deviation constant* as used in angle modulation.   [4 marks]

    (b) Describe how an FM signal can be obtained by using a phase modulator.   [3 marks]

    (c) An angle modulated signal is of the form:

    $$x_\theta(t) = 50cos[2\pi \times 10^7 t + 5sin2\pi \times 1.5 \times 10^3 t]$$

    (i)   If $x_\theta(t)$ is a frequency modulated signal, determine the modulation index and the transmission bandwidth required.   [4 marks]

(ii) If $x_\theta(t)$ is a phase modulated signal, determine the modulation index and the transmission bandwidth required. [4 marks]

(iii) In part (i), if the frequency of the modulating signal is doubled, what will be the modulation index and the transmission bandwidth? [5 marks]

3. **(a)** Describe the operation of an *Automatic Gain Controller*, AGC and an *Automatic Frequency Controller, AFC* as used in heterodyne receivers. [2 marks]

(b) Explain why AFCs are hardly used in radio receivers these days. [3 marks]

(c) Draw a block diagram of a superheterodyne receiver and state the function of each block. [8 marks]

(d) A superheterodyne receiver has an IF of 460 kHz. Its RF amplifier is tuned to an incoming signal of carrier frequency 700 kHz. If at this frequency the tuned circuit of the RF amplifier has a Q of 60, determine the image frequency rejection in dB. [4 marks]

(e) Assuming you have decided to buy a radio receiver for your home. State and explain three performance characteristics you would be looking out for. [3 marks]

4. **(a)** Explain the concept of *entropy* of a communication source. [3 marks]

(b) For a discrete memoryless source, there are three symbols with probabilities $p_1 = \alpha$ and $p_2 = p_3$. Determine the entropy of the source. [4 marks]

(c) A telegraph source having two symbols *dot* and a *dash*. The dot duration is 0.2 sec and the dash duration is 3 times that of the dot duration. The probability of dots occurring is twice that of the dash and the time between symbols is 0.2 seconds. Calculate the information rate of the telegraph. [4 marks]

(d) Explain the concept of the capacity of a communication channel and state its relationship with Shannon's capacity theorem. [3 marks]

(e) A black and white TV picture consists of 525 lines of picture information. Assuming each line consists of 525 picture elements, each element having 256 brightness levels and the pictures are repeated at the rate of 30 picture elements per sec. Calculate the average information conveyed by a TV set to a viewer. [6 marks]

5. (a) Explain the concept of PAM/TDM system for N number of channels. [2 marks]

(b) The information in an analog signal voltage waveform is to be transmitted over a PCM system with an accuracy of $\pm 0.1\%$ (full scale). The analog voltage waveform has a bandwidth of 100 Hz and an amplitude range of -10 to +10 volts. Determine the following:

(i) The maximum sampling rate required. [2 marks]

(ii) The number of bits in each PCM word. [2 marks]

(iii) The minimum bit rate required in the PCM signal. [2 marks]

(c) Briefly describe the process involved in the generation of a PCM data. [3 marks]

(d) A compact disc (CD) records audio signals digitally by using PCM. Assuming the audio signal bandwidth to be 15 kHz:

(i) If the Nyquist samples are quantized into $L= 65,536$ levels and then binary coded, determine the number of binary digits required to encode a sample. [3 marks]

(ii) Determine the number of binary digits per seconds (bits/sec) required to encode the audio signal [3 marks]

(iii) For practical reasons, the signals are sampled at a rate well above Nyquist rate at 44100 samples per second. If $L= 65536$, determine the number of bits per second required to encode the signal and transmission bandwidth of the encoded signal. [3 marks]