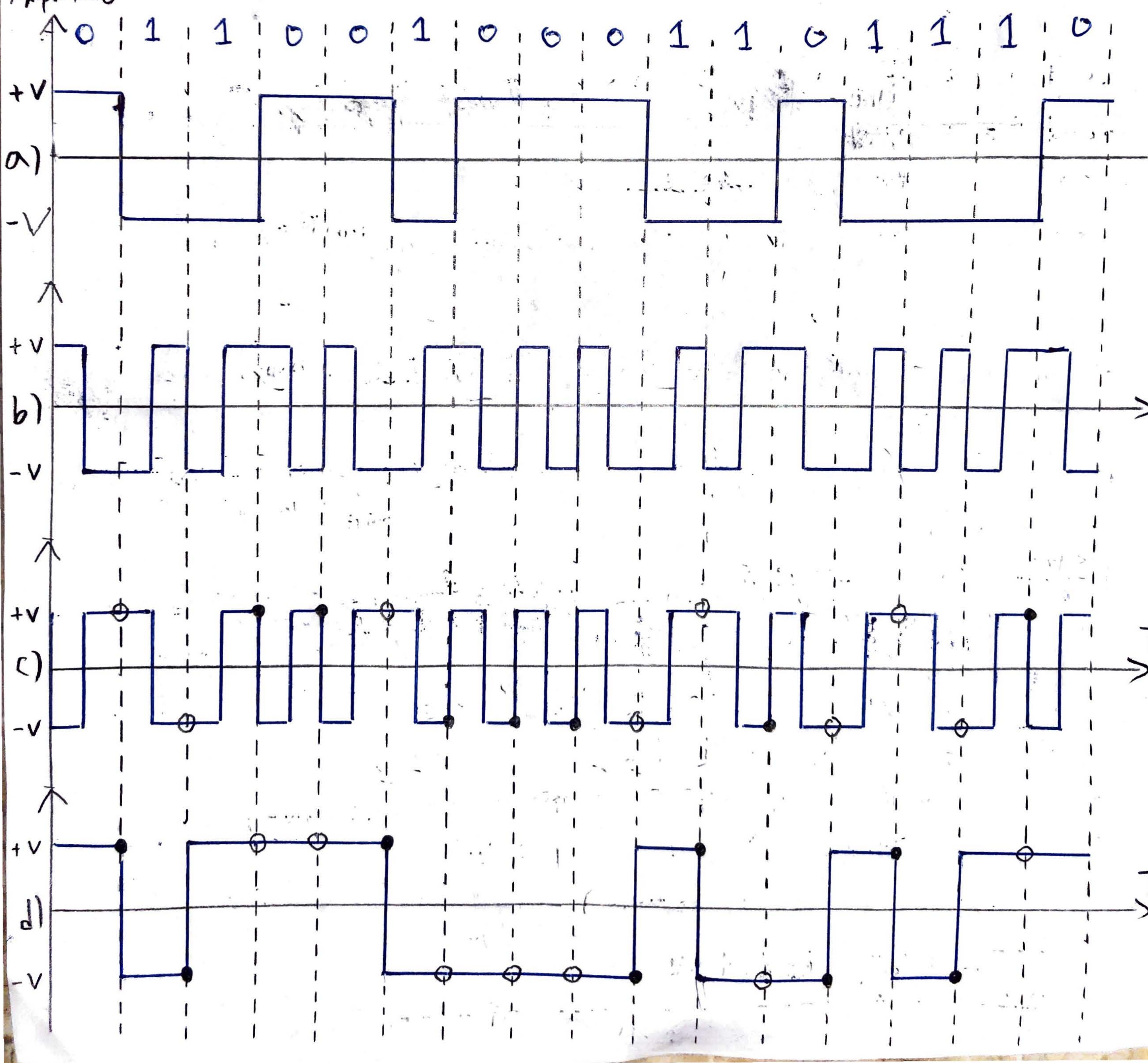
(1) **[8 marks]** Draw the following line coding schemes, as defined in Forouzan, B.A., Data Communications and Networking, 5th Ed. New York, NY: McGraw-Hill, 2013, for the 16-bit data stream **0110010001101110.** Use **+V** for the positive voltage, **-V** for the negative voltage. If applicable, assume that the previous data bit transmitted prior to this 16-bit data stream was **0** at **+V.**

a) [2 marks] Polar NRZ-L
b) [2 marks] Polar biphase Manchester
c) [2 marks] Polar biphase Differential Manchester
d) [2 marks] Polar NRZ-I

Amplitude



(2) **[8 marks]** Consider a composite analog signal composed of simple waves with frequencies of 35 kHz, 42 kHz, 70 kHz and 140 kHz is sampled for digital transmission using Pulse Code Modulation (PCM).

a) [1 mark] Determine the bandwidth of the composite signal.
b) [1 mark] Determine the minimum sampling rate required such that the original analog signal can be accurately reproduced.
c) [3 marks] Determine the minimum number of uniform quantization levels required to achieve a quantizing SNR of no less than 28 dB.
d) [3 marks] Determine the SNR required, in dB, if the PCM signal, with sampling rate obtained in part (b) and number of uniform quantization levels obtained in part (c), is to be transmitted over a noisy channel with a channel bandwidth of 0.15 MHz.

a) Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth.
$B = f_h - f_l = 140 - 35 = 105$ (kHz)

b) Based on the Nyquist theorem, to reproduce the original analog signal, the sampling rate must be at least 2times the highest frequency contained in the signal. Therefore,
the minimum sampling rate $= 2 \times f_{max} = 2 \times 140k = 280{,}000$ samples per second.

c) The signal strength in relation to the quantization error, SNR_Q, is estimated by $SNR_Q = 6n_b - 1.25$, where n_b is the number of bits per sample.
Therefore, we can calculate the number of bits as
$SNR_Q = 6n_b - 1.25 \geq 28db$, $n_b \geq 4.46$, $\log_2 L \geq 4.46$
So, the minimum number of uniform quantization levels is 2^5.

d) After quantizing, the bit rate can be found as
Bit rate $= f_s \times n_b = 280k \times 5 = 1400$ kbps.
The noisy channel capacity is $C = 0.15MHz \times \log_2(1+SNR)$
Channel capacity $\geq$ signal capacity $= 1400$ kbps
C_{min} = bandwidth $\times \log_2(1+SNR_{min}) \Rightarrow \log_2(1+SNR_{min}) = \frac{1400(kbps)}{150(kHz)} = \frac{28}{3}$
$\therefore SNR_{min} = 2^{\frac{28}{3}} - 1 \simeq 644.08$.
$SNR_{db} = 10\log_{10} SNR = 10\log_{10}(644.08) \simeq 28.09(db)$

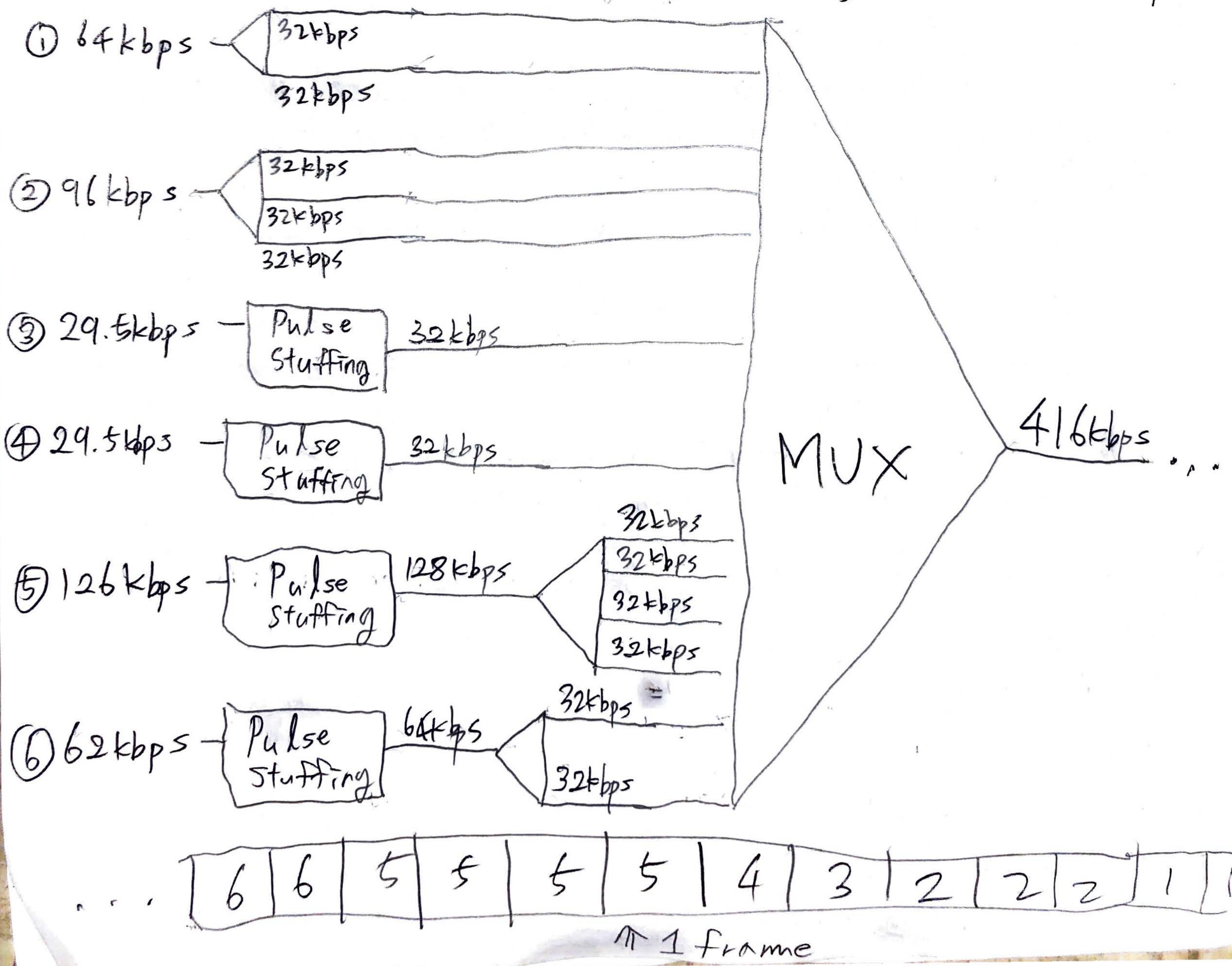
(3) **[8 marks]** Consider a system with 6 signals to be time-division multiplexed onto a single link. Analog signals are baseband and quantized using 16 bits per sample. The signals are as follows:

①	Signal 1:	Analog, 2 kHz bandwidth
②	Signal 2:	Analog, 3 kHz bandwidth
③,④	Signals 3-4:	Digital, 29.5 kbps each
⑤	Signal 5:	Digital, 126 kbps
⑥	Signal 6:	Digital, 62 kbps

Draw a block diagram depicting the TDM system and specify the bit rates at each point in the system. Depict the output timeslots in the final TDM output frame.

① $f_s = 2\times 2kHz = 4kHz \to \text{Bit rate} = \frac{4\times10^3}{s} \times 16\,\text{bits} = 64\,kbps$

② $f_s = 2\times 3kHz = 6kHz \to \text{Bit rate} = \frac{6\times10^3}{s} \times 16\,\text{bits} = 96\,kbps$

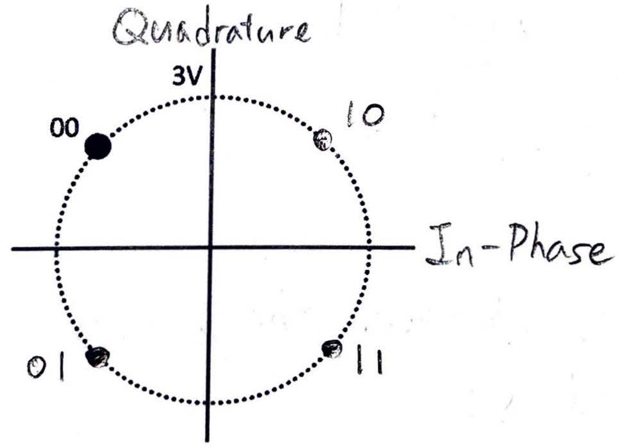


(4) **[11 marks]** Phase shift keying (PSK) is a modulation technique that transmits data by changing the phase of the carrier signal. Consider the following QPSK modulation scheme defined by

$$s(t) = \begin{cases} 3\cos(2\pi f_c t + \frac{3\pi}{4}), & \text{for data bits} = 00 \\ 3\cos(2\pi f_c t + \frac{5\pi}{4}), & \text{for data bits} = 01 \\ 3\cos(2\pi f_c t + \frac{\pi}{4}), & \text{for data bits} = 10 \\ 3\cos(2\pi f_c t + \frac{7\pi}{4}), & \text{for data bits} = 11 \end{cases},$$

where f_c is the carrier frequency. Assume f_c = 2.4 kHz and the baud rate = 800 symbol/s.

a) [3 marks] Complete the following signal constellation diagram for this modulation scheme. Label the axes and for each symbol, indicate the associated data bits.

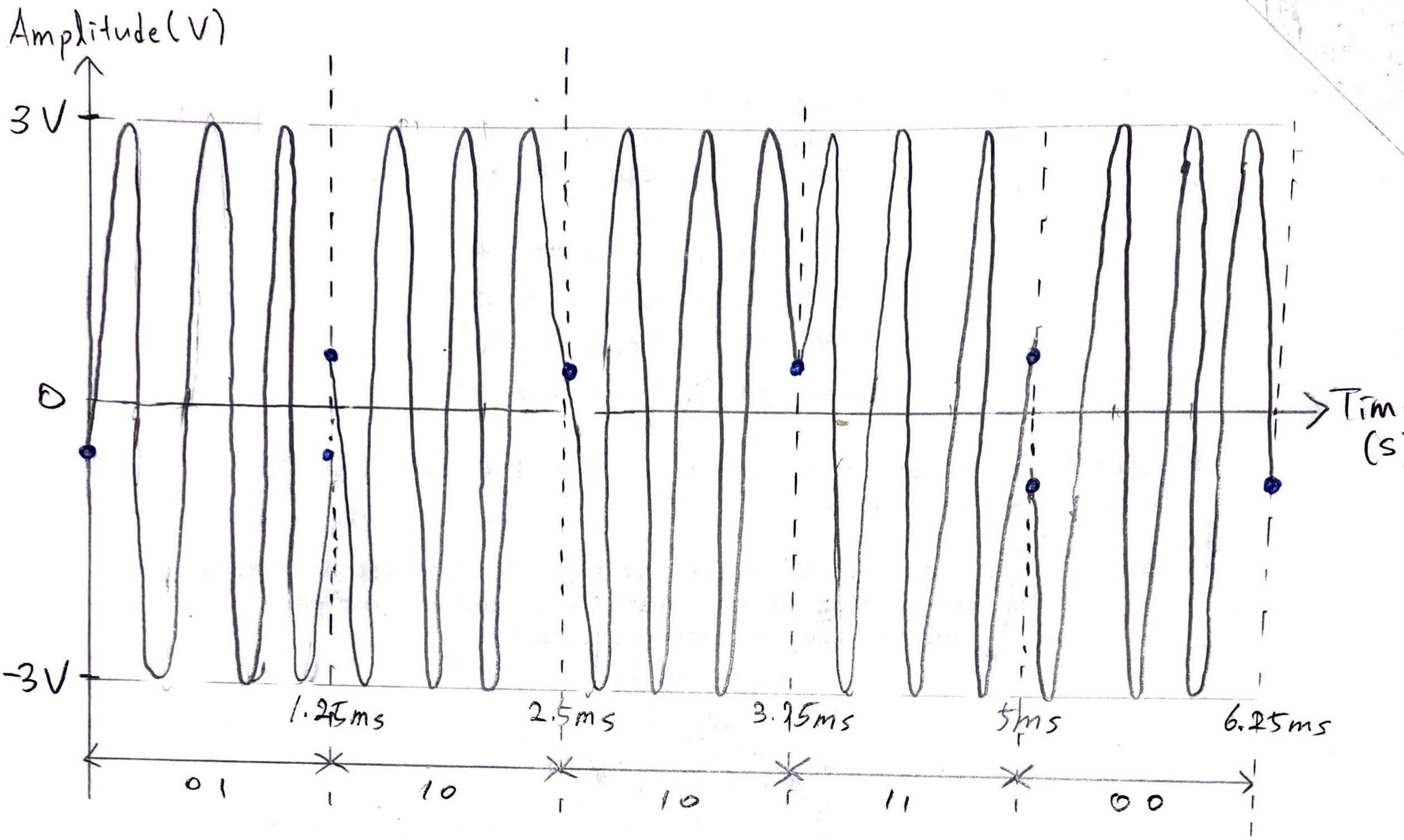


b) [1 mark] Determine the period of the carrier signal.
c) [1 mark] Determine the symbol duration.
d) [5 marks] Plot the modulated signal for the data stream **0110101100**. Clearly indicate the beginning and the end of each symbol and the associated data bits in the plot.
e) [1 mark] Determine the bit rate of the modulated signal.

b) period $= \frac{1}{\text{frequency}} = \frac{1}{2.4k} \simeq 0.00417 = 0.417$ (ms)

c) The baud rate = 800 symbol/sec

The symbol duration $= \frac{1}{\text{baud rate}} = \frac{1}{800} = 0.00125 = 1.25$ (ms) d)



e) The relationship between the datarate, N, and the signal rate, S, is defined as

$$S = N \times \frac{1}{r}$$

where $r = \log_2 L$, is the number of data elements carried in one signal element and L is the number of different signal elements.

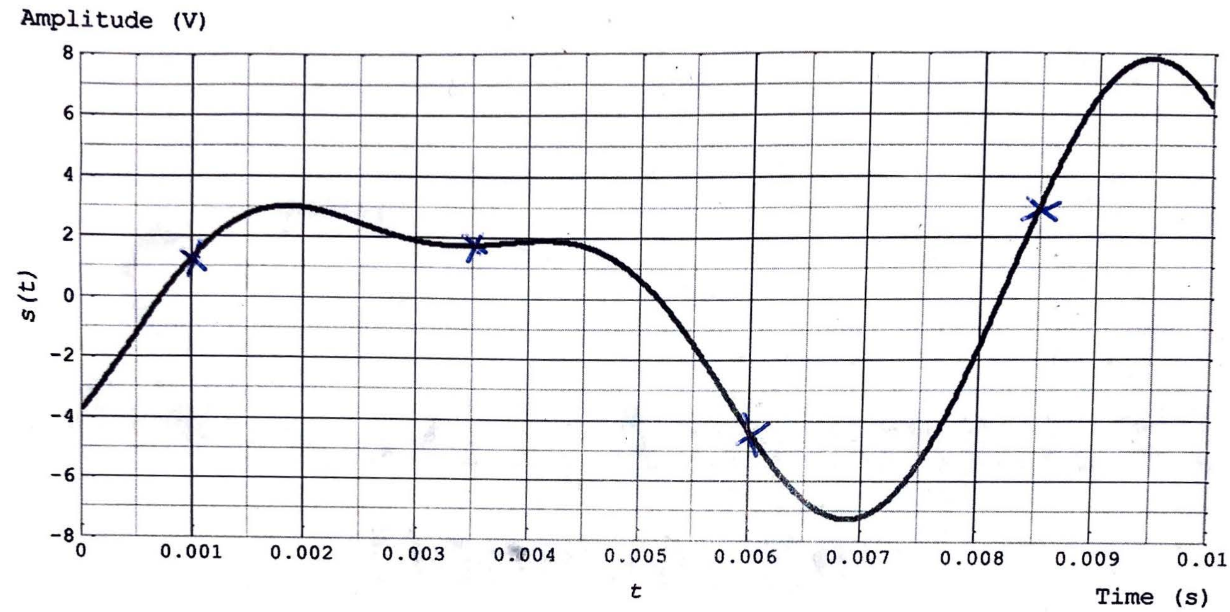
Therefore, the bit rate $N = S \times r$

$$= 800 \times \log_2 4$$

$$= 1600$$

$$= 1.6 \text{ (kbps)}$$

(5) **[5 marks]** Consider the following analog signal, *s*(*t*), with minimum and maximum amplitudes of -8 V and +8 V, respectively. The signal, *s*(*t*), is sampled for digital transmission using Pulse Code Modulation (PCM) with a sampling rate of 400 samples/s and 8 uniform quantization levels.



Assuming that the first sample is taken at 0.001 s, determine both the quantization codes and the resulting encoded words of the PCM signal for *t* = [0, 0.01] s.

The sampling period is 0.0025 s since a sampling rate is 400 samples per second

Therefore, there are 4 samples for $t = [0, 0.01]$ s.

$$\Delta = \frac{8-(-8)}{8} = 2V$$