Read the following instructions carefully:
1- The duration of the exam is strictly 100 minutes. No extra time will be given.
2- Answer each question on a separate sheet on your answers booklet.
3- Show all your work to receive credit.
4- Write your name, surname and student number on each page.
5- Return the question sheet along with your answers booklet.

1. (%25) An analog waveform $x(t)$ is converted into a PAM signal by using a sampling rate of 5 kHz and a pulse width of 100 $\mu$s. Assume that $X(f) = F\{x(t)\}$ is given below;

   \[ |X(f)| \]

   ![Magnitude Spectrum of PAM Signal](image)

   a) Find and sketch the magnitude spectrum of the naturally sampled PAM signal.

   b) Find and sketch the magnitude spectrum of the instantaneously sampled (flat-top) PAM signal.

   \[ W_s(f) = \sum_{n=-\infty}^{\infty} c_n W(f - nf_s), \quad c_n = d \frac{\sin \frac{n\pi d}{T_s}}{n\pi d}, \quad d = \frac{\tau}{T_s} \quad \text{for natural sampling} \]

   \[ W_s(f) = \frac{1}{T_s} H(f) \sum_{n=-\infty}^{\infty} W(f - nf_s), \quad H(f) = \tau \frac{\sin \frac{\pi f}{\pi f}}{\pi f} \quad \text{for instantaneous sampling} \]

2. (%25) A speech signal has a total duration of 10 seconds. It is sampled at the rate of 8 kHz and then encoded. The SNR is required to be 40 dB. Calculate the minimum storage capacity (in bytes) needed to accomodate this digitized speech signal.
3. (25%) 24 voice signals are sampled uniformly and then multiplexed using time division multiplexing (TDM). The sampling operation uses flat top samples with 1 \( \mu \) s (microsecond) duration. In the multiplexing operation, synchronization is done by adding an extra pulse of sufficient amplitude and also the same duration (1 \( \mu \) s). The bandwidth of each voice signal is 3.4 kHz.

   a) Assuming a sampling rate of 8 kHz, calculate the spacing between successive pulses of the multiplexed signal.
   b) Calculate the spacing between successive pulses, if Nyquist rate sampling is used.
   c) Sketch the TDM waveform.

4. (25%) A sinusoidal signal, with amplitude of 3.25 V \( (x(t) = 3.25 \sin t) \), is applied to a uniform quantizer shown below. Sketch the waveform of the resulting quantizer output \( (x_Q(t)) \) for one complete cycle of the input \( (-\pi \leq t \leq \pi) \).