Problem 1

In order to transmit encrypted messages, a free space optical system is used. The ambient light is about 10^4 photons/s. The system is based on a photon source emitting photon bursts at 500nm and a photodetector connected to an amplifier featuring an input impedance R_{IN} = 50Ω, a bandwidth limited by a single pole f_{PA} = 2GHz and a wideband input-referred noise generator with unilateral spectral density $\sqrt{S_V} = 4nV/\sqrt{Hz}$. The bit rate is 10Mbit/s (i.e., 100ns per bit) and an available auxiliary synchronous electrical signal identifies a frame, consisting of 10 bits.

1) In order to minimize the errors, a minimum $\boldsymbol{SNR_{MIN} = 5}$ is required. Using a **PMT** detector in **photon counting mode**, calculate the necessary **minimum optical power** of the emitter for each bit. Describe the acquisition chain and select reasonable sensor parameters for this application.
2) Consider now the possibility of replacing the PMT with an **APD**. Calculate the minimum value of the **gain** necessary to obtain the same SNR of point 1) with an emitted power of 1nW per bit and comment on the feasibility of the proposed solution.
3) Provide a quantitative **comparison of PMTs vs APDs**, explaining their operating principle and including their main features as detection efficiency, noise, time response and ease of use.

Problem 2

A sensor system emits **pairs of triangular pulses** having the shape reported in Figure with **Tp = 300ns** and variable amplitude $\mathbf{V_P}$. The signal is acquired by means of a preamplifier (bandwidth limited by a single pole f_{PA} = 100 MHz, input-referred noise having **unilateral** spectral density $\sqrt{S_V} = 4nV/\sqrt{Hz}$) followed by a synchronous acquisition system.

1) Describe how you can calculate the **optimum filter** and calculate the theoretical minimum detectable signal. Compare the result with what can be obtained with a **digital approach** and a maximum sampling frequency of 5MHz.
2) Design a possible **analog approximation of the optimum filter** and calculate the minimum measurable signal.
3) Considering now that the pulse pairs come with a fixed repetition rate of 1kHz and that the amplitude changes with a timescale of 1s. Describe if it is possible to exploit this new information and calculate the new **minimum measurable signal**.