Problem 1

We want to measure the distance of a reflecting wall by measuring the intensity received back on the sensor when illuminating the wall with a laser beam as sketched in the lower left figure. The laser emits a square pulse with duration of 10ns at $\lambda = 510nm$, and it emits a $\pm 30°$ aperture cone. For the measurement of the signal, a PMT with G=10^6, diameter of 2cm, dark noise of 10^3 e/s, and an amplifier with 200MHz bandwidth and $S_V = 10nV/\sqrt{Hz}$ have to be used.

a) Design a suitable filter and calculate the minimum laser optical power that is necessary to obtain a S/N=1 at a wall distance of 100m.
b) Considering now that also a background illumination of 1.6pW at 510nm is present, calculate and compare how the answer to point a) changes if one laser pulse or 100 laser pulses can be used for the measurement.
c) The 1/f noise is removed with a zero setting at the beginning of the measurement. Describe in detail from the theoretical point of view how the CDF works, its weighting function and the effect on the noise of its different parameters

Problem 2

Consider the signal in the lower right figure. The signal can be measured exploiting a digital sampling at 40MHz at the output of a preamplifier featuring 100MHz bandwidth and $S_V = 10nV/\sqrt{Hz}$. The duration Tp is 100ns while the signal then exponentially decays with τ_P=500ns. The sync signal is available.

a) Design and describe the best digital filter that can be applied in this case and calculate the minimum measurable V_P.
b) Supposing instead of being able to have only two digital samples spaced by 20ns and that the pole of the preamplifier is now 10MHz. What would be the minimum measurable V_P in this case?
c) Explain from a theoretical point of view, in the frequency domain, how the S/N of a discrete time integrator changes as the frequency increases.