Problem 1

1) With the available electronics, the minimum gain to detect a single photon (considering a 3σ threshold) is $2*10^5$, which is a reasonable value for a PMT. Parameters of the PMT: G= 10^6 (conservative choice), S_D=50mA/W @500nm (S20 or S11 photocathode), dark count rate n_D=1000cps. To achieve a SNR=5 within each time bin, Ns_{MIN}=25, corresponding to $P_{emitter}$=0.8nW.
2) The APD must be exploited in analog mode. Parameters for the APD: R=0.2, t_N=0.1µm, t_D=5µm. As a result, S_D=0.3A/W @500nm. A gated integrator on each bit can be used. To achieve SNR=5, G= 3400 would be needed. This value is too high for an APD.
3) Refer to textbook, slides and video lessons.

Problem 2

1) The weighting function of the optimum filter has the same shape of the signal. SNR_{OPT}= V_P/sqrt(S_V/2)) * sqrt(16/3 * T_P). Vp_{MIN}=2.2µV. Noise samples at 5MHz are uncorrelated. 3 samples for each pulse can be collected, starting from the peak and proportionally decreasing the weight. SNR=(4V_P*14/9)/sqrt(2S_Vπ/2f_{PA}*14/9). Vp_{MIN}=14.2µV.
2) A gated integrator can be used, with a double acquisition (one per pulse) without resetting the capacitor between the two. The optimized width of the single integration window is 4/3 T_P. Vp_{MIN}= 2.73µV.
3) A Boxcar or a ratemeter can be used to improve the SNR. Sizing the parameters to have a duration of the weighting function of 1s, Vp_{MIN} calculated in point 2) is reduced by a factor 28,3. Vp_{MIN} =83.7nV