Problem 1

a) Without any filtering, white noise is limited only by the preamp.
$\sigma_N=\sqrt{(S_{V,Signal}+S_{V,preamp})*\frac{\pi}{2}*f_{PA}}=25.8\mu V$, corresponding to a SNR=0.38.

b) Because of the preamp, noise is correlated with $\tau=1/(2*\pi*1MHz)$ = 0.159µs. Samples are uncorrelated if $T_{SAMPLING}$= 5 τ=0.795µs. We can collect 62 samples. Noise is reduced by $\sqrt{N}$=7.87. Therefore, SNR=3.

c) We can use a Boxcar or a ratemeter with overall duration of the weighting function = 10s.
For example, with a Boxcar, T_F=(10s/5)*(50µs/1s) we can obtain an improvement factor of 2 leading to a SNR= 6.
The same result can be obtained with a ratemeter.

d) See theory. Lesson HPF_02 from page 21.

Problem 2

a) See theory.

b) At λ=800nm, considering a neutral region of 100nm, the PIN photodiode can provide a photon detection efficiency as high as 75% (S_D=0.48A/W). We can consider a read-out resistor= 1kΩ. Its noise spectral density is S_{IR}= 4pA/(Hz)$^{1/2}$, leading to an overall current white noise $S_{I,TOT}$= 4.2pA/(Hz)$^{1/2}$.
Because of 1/f noise a continuous measurement cannot be performed.
Two possible solutions are:
   - Initial zero setting.
     If we consider a measurement duration of at least 30min, the high-pass equivalent pole is at a frequency fi=88.4μHz.
     With a LPF at 10Hz, P_{MIN}=78.75pW corresponding to a minimum transparency coefficient= Pmin/(PLaser/2)=157.5 * 10^{-9}
   - We could use the laser in continuous mode followed by a mechanical chopper to feed a modulated signal to the preamplifier, i.e. the signal is modulated before it mixes with noise. A reasonable value for the frequency of the chopper could be 10Hz. P_{MIN}=50.4pW corresponding to a minimum transparency coefficient= Pmin/(PLaser/2)=101 * 10^{-9}

c) With a sinusoidal laser signal we can use a Lock-in with a sinusoidal reference. P_{MIN}=48.96pW corresponding to a minimum transparency coefficient= Pmin/(PLaser,mod)=490 * 10^{-9}

d) See theory.