Homework 3 Solutions:

1. Thermal noise, Shot noise, Flicker noise, Explained in details at noise ppts.

2. $V_{thermal} = \sqrt{4KTRB} = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 1000 \times 1000} = 1.287 \times 10^{-7}$ V

3. Thermal noise from Resistor

shot noise from photocurrent, Dark current noise

b) $V_{thermal} = \sqrt{4KTR\Delta F} = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 10000 \times 100000} = 4.07$ μV

$I_{shot} = \sqrt{2qI\Delta F} = \sqrt{2 \times 1.6 \times 10^{-19} \times 100000} = 5.56 \times 10^{-9}$

$V_{shot} = I_{shot} \times R = 56.57 \mu V$

$V_{total} = \sqrt{V_{thermal}^2 + V_{shot}^2} = 56.71 \mu V$

Shot noise dominates

4. since our signal is from 25 KHz to 35 KHz, but noise span from 0_100 KHz we can use a bandpass filter to pass only 25_35 KHz and reject noise elsewhere. In this case the central frequency is 30KHz and BW is 10KHz.

$V_{thermal} = \sqrt{4KTR\Delta F} = \sqrt{4 \times 1.38 \times 10^{-23} \times 10000 \times 10000} = 1.28 \mu V$

$I_{shot} = \sqrt{2qI\Delta F} = \sqrt{2 \times 1.6 \times 10^{-19} \times 10^{-3} \times 10000} = 1.78 \times 10^{-9}$

$v_{shot} = I_{shot} \times R = 17.89\ \mu v$

$v_{total} = \sqrt{v_{thermal}^2 + v_{shot}^2} = 17.93\ \mu v$

or we could simply say:

$v_{total_{new}} = v_{total,old} \times \sqrt{\frac{10^K}{100^K}} = 17.93\ \mu v$

5. Quantization noise, Thermal noise, clock noise, Power supply noise

6.

a) output voltage: $V = RI = 50 \times 10^3 \times 2 \times 10^{-6} = 0.1 v$

b) Thermal noise: $\sqrt{4KTRB} = \sqrt{4 \times 1.38 \times 10^{-23} \times 300 \times 50 \times 10^3 \times 10^6} = 2.87 \times 10^{-5}$ ✓

Shot noise: $I_{shot} = \sqrt{2qIB} = \sqrt{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{-6} \times 10^6} = 8 \times 10^{-10}$

$v_{shot} = 8 \times 10^{-10} \times 50 \times 10^3 = 4 \times 10^{-5}$ ✓

shot noise from dark current:

$I_{shot} = \sqrt{2qIB} = \sqrt{2 \times 1.6 \times 10^{-19} \times 1 \times 10^{-9} \times 10^6} = 1.78 \times 10^{-11}$

$v_{shot} = 1.78 \times 10^{-11} \times 50 \times 10^3 = 8.94 \times 10^{-7}$ ✓

total noise: $v_{total} = \sqrt{v_{thermal}^2 + v_{shot_{dark}}^2 + v_{shot}^2} = 4.93 \times 10^{-5}$

c) SNR: $\frac{v_{sig}^2}{v_{noise}^2} = \frac{(0.1)^2}{(4.93 \times 10^{-5})^2} = \frac{1 \times 10^{-2}}{24.30 \times 10^{-10}} = 4.11 \times 10^6$