CHAPTER 5

5-1. Frequency dependent noise sources: flicker and environmental noise.

Frequency independent sources: thermal and shot noise.

5-2. (a) Thermal noise.

(b) Certain types of environmental noise.

(c) Thermal andshot noise.

5-3. 10^3 to 10^5 Hz and 10^6 to 10^7 Hz, Enviromental noise is at a minimum in these regions (see Figure 5-3).

5-4. At the high impedance of a glass electrode, shielding is vital to minimize induced currents from power lines which can be amplified and can disturb the output.

5-5. (a) High-pass filters are used to remove low frequency flicker noise from higher frequency analytical signals.

(b) Low-pass filters are used to remove high frequency noise from dc analytical signals.

5-6. We estimate the maximum and theminimum in the recorded signal (0.9×10^{-15} A) to be 1.5×10^{-15} and 0.4×10^{-15} A. The standard deviation of the signal is estimated to be one-fifth of the difference or 0.22×10^{-15} A. Thus,

$$\frac{S}{N} = \frac{0.9 \times 10^{-15}\ \text{A}}{0.22 \times 10^{-15}\ \text{A}} = 4$$

5-7. (a)

	A	B	C
1			
2	**Problem 5-7**		
3		**Weighings**	
4		1.003	
5		1.004	
6		1.001	
7		1.000	
8		1.005	
9		0.999	
10		1.001	
11		1.006	
12		1.007	
13	**Mean**	1.003	
14	**Std. Dev.**	0.002804	
15	**RSD**	0.002796	
16	**S/N**	357.6933	
17			
18	**Spreadsheet Documentation**		
19	Cell B13=AVERAGE(B4:B12)		
20	Cell B14=STDEV(B4:B12)		
21	Cell B15=B14/B13		
22	Cell B16=1/B15		

Hence, S/N = 358 for these 9 measurements

(b) $\frac{S}{N} = \frac{S_n}{N_n}\sqrt{n}$ (Equation 5-11). For the nine measurements,

$$358 = \frac{S_n}{N_n}\sqrt{9}$$

For the S/N to be 500 requires n_x measurements. That is,

$$500 = \frac{S_n}{N_n}\sqrt{n_x}$$

Dividing the second equation by the first gives, after squaring and rearranging,

$$n_x = \left(\frac{500}{358}\times 3\right)^2 = 17.6$$ or 18 measurements

5-8. (a)

	A	B	C
1			
2	**Problem 5-8**		
3		**Voltages**	
4		1.37	
5		1.84	
6		1.35	
7		1.47	
8		1.10	
9		1.73	
10		1.54	
11		1.08	
12	**Mean**	1.435	
13	**Std. Dev.**	0.270713	
14	**RSD**	0.18865	
15	**S/N**	5.30081	
16			
17	**Spreadsheet Documentation**		
18	Cell B12=AVERAGE(B4:B11)		
19	Cell B13=STDEV(B4:B11)		
20	Cell B14=B13/B12		
21	Cell B15=1/B14		

Thus $S/N = 5.3$

(b) Proceeding as in Solution 5-7, we obtain

$$n_x = \left(\frac{10}{5.3} \times \sqrt{8}\right) = 28.5 \quad \text{or 29 measurements}$$

5-9. $\overline{v}_{\text{rms}} = \sqrt{4kTR\Delta f} = \sqrt{4 \times 1.38 \times 10^{-23} \times 298 \times 1 \times 10^6 \times 1 \times 10^6} = 1.28 \times 10^{-4}$ V

$\overline{v}_{\text{rms}} \propto \sqrt{\Delta f}$ So reducing Δf from 1 MHz to 100 Hz, means a reduction by a factor of

$10^6/10^2 = 10^4$ which leads to a reduction in $\overline{v}_{\text{rms}}$ of a factor of $\sqrt{10^4}$ = 100.

5-10. To increase the S/N by a factor of 10 requires 10^2 more measurements. So $n = 100$.

5-11. The middle spectrum S/N is improved by a factor of $\sqrt{50} = 7.1$ over the top spectrum.

The bottom spectrum *S*/*N* is improved by a factor of $\sqrt{200} = 14.1$ over the top spectrum.

The bottom spectrum is the result of 200/50 = 4 times as many scans so the *S*/*N* should be improved by a factor of $\sqrt{4} = 2$ over the middle spectrum

5-12. The magnitudes of the signals and the noise in the spectra in Figure 5-15 may be estimated directly from the plots. The results from our estimates are given in the table below. Baselines for spectra *A* and *D* are taken from the flat retions on the right side of the figure. Noise is calculated from one-fifth of the peak-to-peak excursions of the signal.

	A_{255}	A_{425}	A_b(peak)	A_b(valley)	A_b(mean)
Spectrum *A*	0.550	0.580	0.080	–0.082	0.001
Spectrum *D*	1.125	1.150	0.620	0.581	0.600

	S_{255}	S_{425}	$N = [A_b(\text{peak}) - A_b(\text{valley})]/5$	$(S/N)_{255}$	$(S/N)_{425}$
Spectrum *A*	0.549	0.579	0.0324	17	18
Spectrum *D*	0.525	0.550	0.0078	67	70

Note that the difference in *S*/*N* for the two peaks is due only to the difference in the peak heights.

So, at 255 nm, $(S/N)_D$ =67/17$(S/N)_A$ = 3.9$(S/N)_A$; at 425 nm, $(S/N)_D$ =79/18$(S/N)_A$ = 3.9$(S/N)_A$