CHAPTER 1

1-1. A transducer is a device that converts chemical or physical information into an electrical signal or the reverse. The most common input transducers convert chemical or physical information into a current, voltage, or charge, and the most common output transducers convert electrical signals into some numerical form.

1-2. The information processor in a visual color measuring system is the human brain.

1-3. The detector in a spectrograph is a photographic film or plate.

1-4. Smoke detectors are of two types: photodetectors and ionization detectors. The photodetectors consist of a light source, such as a light-emitting diode (LED) and a photodiode to produce a current proportional to the intensity of light from the LED. When smoke enters the space between the LED and the photodiode, the photocurrent decreases, which sets off an alarm. In this case the photodiode is the transducer.

In ionization detectors, which are the typical battery-powered detectors found in homes, a small radioactive source (usually Americium) ionizes the air between a pair of electrodes. When smoke enters the space between the electrodes, the conductivity of the ionized air changes, which causes the alarm to sound. The transducer in this type of smoke detector is the pair of electrodes and the air between them.

1-5. A *data domain* is one of the modes in which data may be encoded. Examples of data domain classes are the analog, digital and time domains. Examples of data domains are voltage, current, charge, frequency, period, number.

1-6. Analog signals include voltage, current, charge, and power. The information is encoded in the amplitude of the signal.

1-7.

Output Transducer	**Use**
LCD display	Alphanumeric information
Computer monitor	Alphanumeric information, text, graphics
Laser printer	Alphanumeric and graphical information
Motor	Rotates to change position of attached elements

1-8. A figure of merit is a number that provides quantitative information about some performance criterion for an instrument or method.

1-9. Let c_s= molar concentration of Cu^{2+} in standard = 0.0287 M

c_x = unknown Cu^{2+} concentration

V_s = volume of standard = 0.500 mL

V_x = volume of unknown = 25.0 mL

S_1 = signal for unknown = 23.6

S_2 = signal for unknown plus standard = 37.9

Assuming the signal is proportional to c_x and c_s , we can write

$$S_1 = Kc_x \quad \text{or} \quad K = S_1/c_x$$

After adding the standard

$$S_2 = K\left(\frac{V_x c_x + V_s c_s}{V_x + V_s}\right)$$

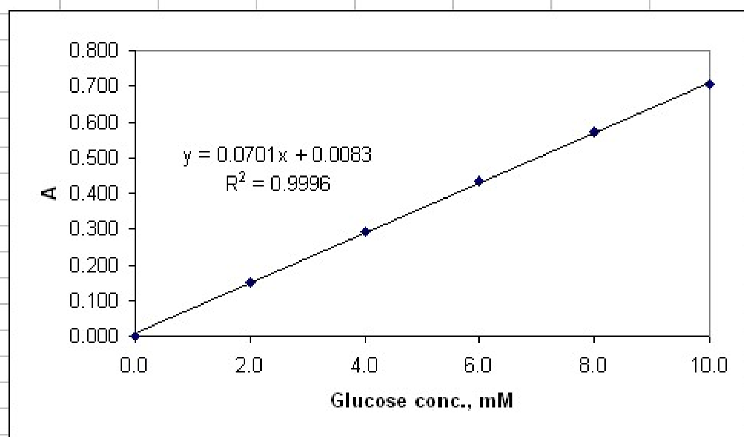
Substituting for K and rearranging gives,

$$c_x = \frac{S_1 V_s c_s}{S_2(V_x + V_s) - S_1 V_x}$$

$$c_x = \frac{23.6 \times 0.500\ \text{mL} \times 0.0287\ \text{M}}{37.9(0.500\ \text{mL} + 25.0\ \text{mL}) - (23.6 \times 25.0\ \text{mL})} = 9.00 \times 10^{-4}\ \text{M}$$

1-10. The results are shown in the spreadsheet below.

	A	B	C	D	E	F	G	H	I	J
1	**Determination of Glucose**									
2										
3		**Glucose conc**	**Absorbance**		**Linest Results**					
4		0.0	0.002		0.0701	0.0083				
5		2.0	0.150		0.0007	0.0040				
6		4.0	0.294		0.9996	0.0056				
7		6.0	0.434		11058.76	4				
8		8.0	0.570		0.3444	0.0001				
9		10.0	0.704							
10		**unknown**	0.350							
11	**Slope**	0.0701								
12	**Intercept**	0.0083								
13	**Unknown conc.**	4.87								
14	**Standard error in *Y***	0.0056								
15	***N***	6								
16	**S_{xx}**	70								
17	***y* bar**	0.359								
18	***M***	1								
19	**Standard deviation in c**	0.086								
20										
21	**Documentation**									
22	Cell E4=LINEST(C4:C9,B4:B9,TRUE,TRUE)									
23	Cell B11=SLOPE(C4:C9,B4:B9)									
24	Cell B12=INTERCEPT(C4:C9,B4:B9)									
25	Cell B13=(C10-B12)/B11									
26	Cell B14=STEYX(C4:C9,B4:B9)									
27	Cell B15=COUNT(C4:C9)									
28	Cell B16=DEVSQ(B4:B9)									
29	Cell B17=AVERAGE(C4:C9)									
30	Cell B18=COUNT(C7)									
31	Cell B19=(B14/B11)*SQRT(1/B18+1/B15+((C10-B17)^2)/((B11^2)*B16))									



(a) Slope, $m = 0.0701$, intercept, $b = 0.0083$

(b) From LINEST results, SD slope, $s_m = 0.0007$, SD intercept, $s_b = 0.0040$

(c) 95% CI for slope m is $m \pm ts_m$ where t is the Student t value for 95% probability and $N - 2 = 4$ degrees of freedom = 2.78

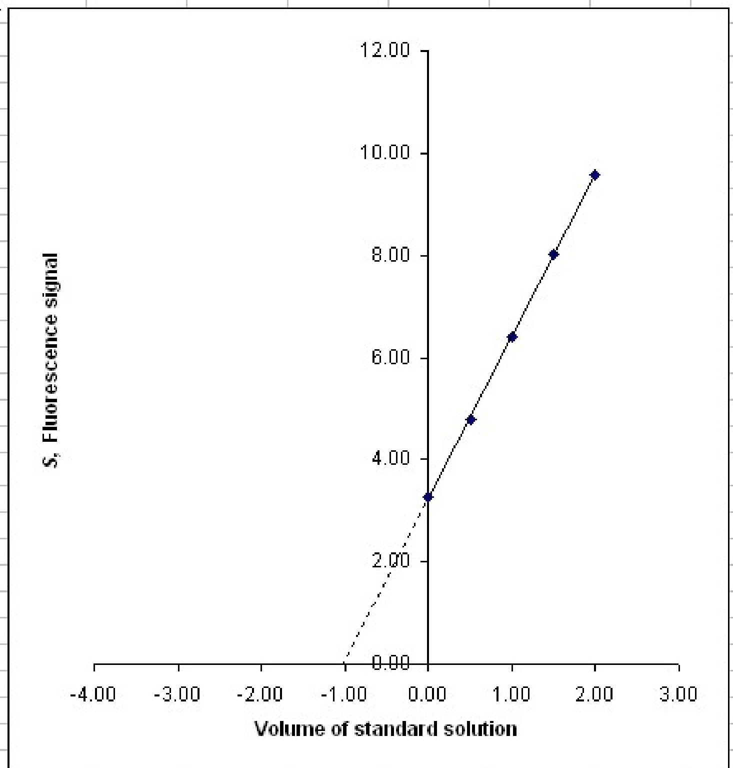
$$95\%\ \text{CI for}\ m = 0.0701 \pm 2.78 \times 0.0007 = 0.0701 \pm 0.0019\ \text{or}\ 0.070 \pm 0.002$$

For intercept, 95% CI = $b \pm ts_b = 0.0083 \pm 2.78 \times 0.004 = 0.0083 \pm 0.011$ or 0.08 ± 0.01

(d) $c_u = 4.87 \pm 0.086$ mM or 4.87 ± 0.09 mM

1-11. The spreadsheet below gives the results

	A	B	C
1	**Determination of Phenobarbital by Fluorescence with Multiple Additions**		
2	Concentration of standard, c_s	2.000	μg/mL
3	Volume of unknown used, V_x	5.00	mL
4	**Volume of standrd added**	**Signal, *S***	
5	0.00	3.26	
6	0.50	4.80	
7	1.00	6.41	
8	1.50	8.02	
9	2.00	9.56	
10			
11	**Regression Equation**		
12	Slope	3.164	
13	Intercept	3.246	
14	Volume intercept	-1.02592	
15	Concentration of unknown	0.410367	
16	**Error Analysis**		
17	Standard error in *y*	0.02556	
18	*N*	5	
19	S_{xx}	2.5	
20	*y* bar	6.4	
21	Standard deviation in volume	0.006239	
22	Standard deviation in *c*	0.002496	
23	**Spreadsheet Documentation**		
24	Cell B12=SLOPE(B5:B9,A5:A9)		
25	Cell B13=INTERCEPT(B5:B9,A5:A9)		
26	Cell B14=-B13/B12		
27	Cell B15=-B14*B2/B3		
28	Cell B17=STEYX(B5:B9,A5:A9)		
29	Cell B18=COUNT(B5:B9)		
30	Cell B19=DEVSQ(A5:A9)		
31	Cell B20=AVERAGE(B5:B9)		
32	Cell B21=(B17/B12)*SQRT(1/B18+((B5-B20)^2)/((B12^2)*B19))		
33	Cell B22=B21*B2/B3		



(a) See plot in spreadsheet.

(b) $c_u = 0.410\ \mu\text{g/mL}$

(c) $S = 3.16V_s + 3.25$

(d) $$c_u = \frac{bc_s}{mV_u} = \frac{3.246 \times 2.000\ \mu\text{g/mL}}{3.164\ \text{mL}^{-1} \times 5.00\ \text{mL}} = 0.410\ \mu\text{g/mL}$$

(e) From the spreadsheet $s_c = 0.002496$ or $0.002\ \mu\text{g/mL}$

2-3. $V_{2.4} = 12.0 \times [(2.5 + 4.0) \times 10^3]/[(1.0 + 2.5 + 4.0) \times 10^3] = 10.4$ V

With meter in parallel across contacts 2 and 4,

$$\frac{1}{R_{2,4}} = \frac{1}{(2.5 + 4.0)\ \text{k}\Omega} + \frac{1}{R_M} = \frac{R_M + 6.5\ \text{k}\Omega}{R_M \times 6.5\ \text{k}\Omega}$$

$R_{2,4} = (R_M \times 6.5\ \text{k}\Omega)/(R_M + 6.5\ \text{k}\Omega)$

(a) $R_{2,4} = (5.0\ \text{k}\Omega \times 6.5\ \text{k}\Omega)/(5.0\ \text{k}\Omega + 6.5\ \text{k}\Omega) = 2.83\ \text{k}\Omega$

$V_M = (12.0\ \text{V} \times 2.83\ \text{k}\Omega)/(1.00\ \text{k}\Omega + 2.83\ \text{k}\Omega) = 8.87$ V

$$\text{rel error} = \frac{8.87\ \text{V} - 10.4\ \text{V}}{10.4\ \text{V}} \times 100\% = -15\%$$

Proceeding in the same way, we obtain (b) –1.7% and (c) –0.17%

2-4. Applying Equation 2-19, we can write

(a) $$-1.0\% = \frac{750\ \Omega}{(R_M - 750\ \Omega)} \times 100\%$$

$R_M = (750 \times 100 - 750)\ \Omega = 74250\ \Omega$ or $74\ \text{k}\Omega$

(b) $$-0.1\% = \frac{750\ \Omega}{(R_M - 750\ \Omega)} \times 100\%$$

$R_M = 740\ \text{k}\Omega$

2-5. Resistors R_2 and R_3 are in parallel, the parallel combination R_p is given by Equation 2-17

$R_p = (500 \times 200)/(500 + 200) = 143\ \Omega$

(a) This 143 Ω R_p is in series with R_1 and R_4. Thus, the voltage across R_1 is

$V_1 = (15.0 \times 100)/(100 + 143 + 1000) = 1.21$ V

$V_2 = V_3 = 15.0\ \text{V} \times 143/1243 = 1.73$ V

$V_4 = 15.0\ \text{V} \times 1000/1243 = 12.1$ V

(b) $I_1 = I_5 = 15.0/(100 + 143 + 1000) = 1.21 \times 10^{-2}$ A

$I_2 = 1.73$ V/500 Ω= 3.5×10^{-3} A

$I_3 = I_4 = 1.73$ V /200 Ω = 8.6×10^{-3} A

(c) $P = IV = 1.73$ V× 8.6×10^{-3} A = 1.5×10^{-2} W

(d) Since point 3 is at the same potential as point 2, the voltage between points 3 and 4 V' is the sum of the drops across the 143 W and the 1000 W resistors. Or, $V' = 1.73$ V + 12.1 V = 13.8 V. It is also the source voltage minus the V_1

$V' = 15.0 - 1.21 = 13.8$ V

2-6. The resistance between points 1 and 2 is the parallel combination or R_B and R_C

$R_{1,2} = 2.0$ kΩ × 4.0 kΩ/(2.0 kΩ + 4.0 kΩ) = 1.33 kΩ

Similarly the resistance between points 2 and 3 is

$R_{2,3} = 2.0$ kΩ × 1.0 kΩ/(2.0 kΩ + 1.0 kΩ) = 0.667 kΩ

These two resistors are in series with R_A for a total series resistance R_T of

$R_T = 1.33$ kΩ + 0.667 kΩ + 1.0 kΩ = 3.0 kΩ

$I = 24/(3000\ \Omega) = 8.0 \times 10^{-3}$ A

(a) $P_{1,2} = I^2R_{1,2} = (8.0 \times 10^{-3})^2 \times 1.33 \times 10^3 = 0.085$ W

(b) As above $I = 8.0 \times 10^{-3}$ A

(c) $V_A = IR_A = 8.0\times 10^{-3}$ A $\times 1.0 \times 10^3\ \Omega = 8.0$ V

(d) $V_D = 14 \times R_{2,3}/R_T = 24 \times 0.667/3.0 = 5.3$ V

(e) $V_{5,2} = 24 - V_A = 24 - 8.0 = 16$ V

2-7. With the standard cell in the circuit,

$V_{std} = V_b \times AC/AB$ where V_b is the battery voltage

$1.018 = V_b \times 84.3/AB$

With the unknown voltage V_x in the circuit,

$V_x = V_b \times 44.2/AB$

Dividing the third equation by the second gives,

$$\frac{1.018\text{ V}}{V_x} = \frac{84.3\text{ cm}}{44.3\text{ cm}}$$

$$V_x = 1.018 \times 44.3\text{ cm}/84.3\text{ cm} = 0.535\text{ V}$$

2-8. $E_r = -\dfrac{R_S}{R_M + R_S} \times 100\%$

For $R_S = 20\ \Omega$ and $R_M = 10\ \Omega$, $E_r = -\dfrac{20}{10+20} \times 100\% = -67\%$

Similarly, for $R_M = 50\ \Omega$, $E_r = -\dfrac{20}{50+20} \times 100\% = -29\%$

The other values are shown in a similar manner.

2-9. Equation 2-20 is $E_r = -\dfrac{R_{\text{std}}}{R_L + R_{\text{std}}} \times 100\%$

For $R_{\text{std}} = 1\ \Omega$ and $R_L = 1\ \Omega$, $E_r = -\dfrac{1\ \Omega}{1\ \Omega + 1\ \Omega} \times 100\% = -50\%$

Similarly for $R_L = 10\ \Omega$, $E_r = -\dfrac{1\ \Omega}{10\ \Omega + 1\ \Omega} \times 100\% = -9.1\%$

The other values are shown in a similar manner.

2-10. (a) $R_s = V/I = 1.00\text{ V}/50 \times 10^{-6}\text{ A} = 20000\ \Omega$ or $20\text{ k}\Omega$

(b) Using Equation 2-19

$$-1\% = -\frac{20\text{ k}\Omega}{R_M + 20\text{ k}\Omega} \times 100\%$$