CHAPTER 2
Experimental Data and Errors

2.1) Accuracy of a measurement specifies the difference between the measured and the true value of the quantity. Precision specifies the repeatability of a set of readings, each made independently with the same instrument. P. 33-34

2.2) The three classes of measurement errors are Human, System, and Random. Fig. 2.4, P. 38

2.3) Several examples are given in Fig. 2.4, P. 38

2.4) Error for voltmeter:

$$\pm 2\% \times 50\text{V} = \pm 1\text{V}$$

$$\text{Percent error} = \frac{\text{Measured Value - True Value}}{\text{True Value}} \times 100\%$$

$$\text{Percent error for 15 V measurement} = \frac{(15 \pm 1) - 15}{15} \times 100\% = \pm 6.67\%$$

$$\text{Percent error for 42 V measurement} = \frac{(42 \pm 1) - 42}{42} \times 100\% = \pm 2.4\%$$

2.5) Error for ammeter

$0.5\% \times 50\text{ mA} = 0.25\text{ mA}$ (The error on most analog meters is usually based on full scale.

Possible error $13\text{ mA} \pm 0.25\text{ mA}$

Limits $12.75\text{ mA} \rightarrow 13.25\text{ mA}$

2.6) a) $0.35\text{ A}\left(\frac{1000\text{ mA}}{1\text{ A}}\right) = 350\text{ mA}$

$0.35\text{ A}\left(\frac{1\times 10^6\ \mu\text{A}}{1\text{ A}}\right) = 3.5 \times 10^5\ \mu\text{A}$

b) $0.041\text{ mV}\left(\frac{10^3\ \mu\text{V}}{1\text{ mV}}\right) = 41\ \mu\text{V}$

c) $400{,}000\ \Omega\left(\frac{1\text{ M}\Omega}{10^6\ \Omega}\right) = 0.4\text{ M}\Omega$

d) $67\ \mu V \left(\dfrac{1\ mV}{10^3\ \mu V} \right) = 0.067\ mV$

2.7) a) 2 b) 6 c) 3 d) 3 e) 2
f) 6 Note: non-technical writers commonly consider zeros to the left of the decimal point as non-significant.

2.8) For series resistance

$$R_{EQ} = R_1 + R_2 + ... + R_n$$

$$\begin{array}{r} 14.5 \pm 0.1 \\ 5.36 \pm 0.01 \\ 64.2 \pm 0.1 \\ 4.37 \pm 0.01 \\ \hline R_{EQ} = 88.43 \pm 0.22\ \Omega \end{array}$$

2.9)

$$\begin{array}{r} 635 \pm 4 \\ -296 \pm 4 \\ \hline 339 \pm 8 \end{array}$$

$$\%Error = \frac{8}{339} \times 100\%$$

$$\%Error = 2.36\%$$

2.10) a)

$$AVG = \frac{50.2 + 50.6 + 49.7 + 51.1 + 50.3 + 49.9 + 50.4 + 49.6 + 50.3 + 51.0}{10} = 50.31$$

b) Standard Deviation $\sigma = \sqrt{\dfrac{d_1^2 + d_2^2 + d_3^2 + ... + d_n^2}{n-1}}$

d = Deviation from the average value

$\sigma = 0.474$

c) Probable error $= 0.675\ \sigma = \pm 0.31995$ mA

2.11) a) 21.107 V b) $\sigma = 0.927$ Probable Error $= 0.675\ \sigma = \pm 0.6257$

c) The deviation from the average value $d_4 = 2.04$ is $< 3\sigma$, so the value 19.07 should be retained.

2.12) Decibel Power Gain

$$A_P = 10 \log_{10} \left(\frac{P_{out}}{P_{in}} \right) dB$$

a) $A_P = 10 \log_{10} \left(\dfrac{45 \times 10^{-3}\ W}{7.4 \times 10^{-3}\ W} \right) = 2.23\ dB$

b) $A_P = 10 \log_{10}\left(\frac{52 \times 10^{-6}\ W}{14 \times 10^{-6}\ W}\right) = 1.23\ dB$

c) $A_P = 10 \log_{10}\left(\frac{32 \times 10^{-3}\ W}{16 \times 10^{-3}\ W}\right) = 3.01\ dB$

d) $A_P = 20 \log_{10}\left(\frac{1.414\ V}{2\ V}\right) = -3.01\ dB$

2.13) Magnitude Power Gain

$$\frac{P_{out}}{P_{in}} = \log_{10}^{-1}\left(\frac{A_P}{10}\right) = 10^{A_P/10}$$

$$\frac{P_{out}}{P_{in}} = \log_{10}^{-1}\left(\frac{82}{10}\right) = 10^{82/10} = 158 \times 10^{6}$$

2.14) $\frac{P_{out}}{P_{in}} = \log_{10}^{-1}\left(\frac{-40}{10}\right) = 10^{-40/10} = 1 \times 10^{-4}$

2.15) a) Power gain in dB

$$A_P = 10 \log_{10}\left(\frac{P_{out}}{P_{in}}\right) = 10 \log_{10}\left(\frac{150\ W}{300\ W}\right) = -3.01\ dB$$

b) Power gain in dB

$$A_P = 10 \log_{10}\left(\frac{P_{out}}{P_{in}}\right) = 10 \log_{10}\left(\frac{V_o^2/R_o}{V_{in}^2/R_{in}}\right) = 20 \log_{10}\left(\frac{V_o}{V_{in}}\sqrt{\frac{R_{in}}{R_o}}\right)$$

$$A_V = 20 \log_{10}\left(\frac{V_o}{V_{in}}\right) \text{ if } R_o = R_{in}$$

Voltage Out = $V_o = \sqrt{P_o \times R_o} = \sqrt{150\ W \times 8\ \Omega} = 34.6\ V$

Voltage In = $V_{in} = 12\ V$

$$A_{V\,dB} = 20 \log_{10}\left(\frac{34.6\ V}{12\ V}\right) = 9.20\ dB$$

c) $R_o = 8\ \Omega$ $\qquad$ $R_{in} = \left(\frac{V_{in}^2}{P_{in}}\right) = \left(\frac{12^2}{300}\right) = 0.48\ \Omega$

$A_P = A_V$ only if $R_o = R_{in}$, but in this case $R_o \neq R_{in}$

2.16) a) $A_P = 10 \log_{10}\left(\frac{P_o}{P_{in}}\right)$

$$\therefore\ P_{in} = \frac{P_o}{\log^{-1}\left(\frac{A_P}{10}\right)} = \frac{30\ \text{W}}{\log^{-1}\left(\frac{42\ \text{dB}}{10}\right)} = 1.89\ \text{mW}$$

b) $V_o = \sqrt{P_o \times R_o} = \sqrt{30\ \text{W} \times 10\ \Omega} = 17.32\ \text{V}$

$$A_V = 60\ \text{dB} = 20 \log_{10}\left(\frac{17.32}{V_{in}}\right)$$

$$\therefore\ V_{in} = \frac{17.32}{10^{60/20}} = 17.32\ \text{mV}$$