Learning Objectives to Accompany
MEASUREMENT AND DATA ANALYSIS FOR
ENGINEERING AND SCIENCE
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This document presents the learning objectives developed for each chapter of MEASUREMENT AND DATA ANALYSIS FOR ENGINEERING AND SCIENCE. The Table of Contents is listed on the next page, followed by each chapter’s learning objectives.

The following lists the action verbs and their specific meanings related to the learning objectives.

- **know**: memorize and give an example
- **convert**: calculate the equivalent quantity in another system of units
- **identify**: choose from and specify
- **round off**: self-explanatory according to its defined method
- **express**: write out in numerical form
- **describe**: explain in words, being as specific as possible
- **perform**: go through the procedure as specified in the notes
- **plot**: self-explanatory, but according to the format specified in the notes
- **determine**: calculate using equations and information given or provided in tables to determine a specified result
- **calculate**: use equations to determine a specified result
- **differentiate**: compare and contrast in words, being as specific as possible
- **apply**: use standard approach in a new situation
- **estimate**: approximate through the use of simple calculations
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Chapter 1

Experiments

- Know the meanings of the scientific method, an experiment, a variable and the types of variables
- Identify the types of variables for a given experiment
- Know the various purposes of experiments
Chapter 2

Electronics

- Determine the equivalent resistance, capacitance and inductance of series and parallel combinations of resistors, capacitors and inductors
- Know Kirchhoff’s laws
- Apply Kirchhoff’s laws to elementary DC and AC circuit analysis
- Know the relationship between input and output voltages and the resistances of a Wheatstone bridge
- Know the relationship between resistances for a balanced Wheatstone bridge
- Determine the Thévenin equivalent voltage and equivalent impedance for an elementary circuit
- Know the rules for proper impedance matching and minimizing loading error
Chapter 3

Measurement Systems

- Know each element and its primary function in a measurement system
- Differentiate between a sensor and a transducer
- Describe how resistive and capacitive sensors each work
- Give an example of a common sensor/transducer system and describe how it works
- Give examples of several sensor/transducers, their characteristics and the physical principles upon which they are based
- Determine the gain of an amplifier
- Describe the major attributes of an operational amplifier
- Calculate the output voltages for the six common operational amplifier configurations
- Describe the various types of filters
- Know the electrical components and configuration for simple $RC$ low-pass and high-pass filters
- Know the definitions of a simple RC filter’s time constant, cut-off frequency, magnitude ratio and phase lag
- Determine the magnitude ratio and phase lag of a simple $RC$ filter given its input signal frequency
- Know the definitions of a decibel, decade, and octave, and determine the magnitude ratio attenuation in dB per decade or octave for a given system
- Describe how a digital filter works
- Describe how the two most common types of analog-to-digital converters work
- Determine the number of possible digital values, resolution and absolute quantization error for a M-bit A/D converter
- Identify each of the elements of a typical measurement system
- Determine the specific characteristics of a measurement system’s elements given its design constraints
Chapter 4

Probability

- Know the definitions for and differences between an event, an independent event, a dependent event and an outcome
- Know the definitions for null and mutually exclusive sets
- Determine the intersection and union of multiple sets
- Apply Bayes’ Rule to determine the probability of an event using a test that has a specified accuracy
- Determine the number of permutations and combinations of an event
- Know the meaning of and differences between a population and a sample
- Know the meaning of and differences between the true mean and variance and the sample mean and variance
- Know the meaning of and differences between analog, discrete and digital signal representations
- Know the definitions for a histogram, frequency distribution and frequency density distribution and be able to plot each from discrete data
- Know the definitions for the first through fourth central moments of a specified probability density function and be able to calculate them
Chapter 5

Statistics

- Describe the main attributes of the binomial, Poisson and Normal distributions
- Know the definition of the normalized z-variable and the % P coverage for the values of $z = 1, 2, 3$ and $4$
- Determine probability that a value will fall within a certain range of values using the z-variable table
- Determine probability that a value will fall within a certain range of values using the Student’s t-variable table
- Know the definition of the standard deviation of the means, and be able to calculate it
- Know the definition of the degrees of freedom and the specific formulas for sample mean and variance calculations, and least-squares linear regression and $\chi^2$-analysis
- Know the definitions of the $\chi^2$-variable and the level of significance
- Calculate the range that contains the true mean by using the Student’s t-variable table
- Calculate the range that contains the true variance by using the $\chi^2$-variable table
- Determine using $\chi^2$-analysis the percent chance that a difference between expected and observed values is due to random effects
- Determine using $\chi^2$-analysis the percent chance of agreement between a histogram of discrete data and an assumed probability density function
- Describe the methods of DOE and factorial analysis and how each can be used to plan experiments
Chapter 6

Uncertainty Analysis

- Know the sources of modeling uncertainty
- Know the definitions of modeling uncertainty and error, measurement uncertainty and error
- Differentiate between systematic and random errors, accuracy and precision
- Differentiate between repetition and replication
- Estimate the relative systematic uncertainty for an instrument
- Know the definition of design-stage uncertainty and its common instrument errors
- Estimate the design-stage uncertainty of an entire measurement system
- Differentiate between general and detailed uncertainty analysis
- Estimate the uncertainty in a (1) single-measurement measurand, (2) single-measurement result, (3) multiple-measurement measurand and (4) multiple-measurement result
- Estimate the discretization error of a derivative and of an integral
Chapter 7

Regression and Correlation

- Describe the concept and mathematical approach of least-squares regression analysis
- Perform a linear least-squares regression analysis on discrete data
- Differentiate the various regression parameters
- Determine the standard error of the fit of a linear fit of discrete data
- Know the common cases that occur when fitting data having uncertainty
- Determine the confidence intervals for the sample mean value, a new $y$ value, the precision interval and an $x$ value for a given $y$ value
- Describe the concept of the correlation coefficient and the coefficient of determination
- Determine the percent chance of no correlation given the linear correlation coefficient and the number of discrete data
- Calculate the auto and cross-correlation functions and coefficients for a specified periodic signal
Chapter 8

Signal Characteristics

- Know the meaning of signal, amplitude, frequency, time history record, ensemble and waveform
- Know the classifications of signals
- Know the definition of an ensemble-averaged quantity
- Know the definitions of and be able to calculate the mean, mean square, root-mean-square, variance and standard deviation of a deterministic signal from discrete data
- Know the definition of the trigonometric Fourier series and the Fourier coefficients
- Determine the Fourier series of a deterministic function
- Plot the amplitude spectrum and the power spectrum of a Fourier series
- Know the abscissa and ordinate units of the amplitude, power and power density spectra plots
Chapter 9

Signal Analysis

- Know the difference between analog, discrete, and digital signals
- Describe how a signal’s amplitude, time and frequency are related to one another
- Determine the frequency resolution, Nyquist frequency, and minimum and maximum frequencies for a given sample rate and number of discrete data
- Know the sampling theorem
- Describe aliasing
- Determine the sampling frequency given a deterministic signal to avoid aliasing
- Use the folding diagram to determine any aliased frequencies
- Describe amplitude ambiguity
- Determine whether or not aliasing and/or amplitude ambiguity will occur for a given a periodic signal
- Describe the effects of windowing and ensemble averaging on the frequency spectrum
- Know the concept of the Fourier transform
- Use provided MATLAB software to plot the spectra of discrete data
- Determine the appropriate sample period and rate, filtering and instrument signal ranges for a typical experiment using a PC-based data acquisition system
Chapter 10

Units and Significant Figures

- Know the meaning of the following terms: dimension, unit, measure, consistent, base unit, supplementary unit, derived unit
- Know the seven fundamental dimensions in the SI and Technical English systems
- Know the units for the following quantities in both the SI and Technical English systems: mass, length, time, velocity, acceleration, force, pressure, work, energy, torque, and power
- Convert between SI and Technical English systems
- Identify the least and most significant digits in a number
- Express calculated results with the correct number of significant figures
Chapter 11

Technical Communication

- Know the standard formats of technical memos and reports
- Make clear, easy-to-understand figures with appropriate labeling
- Know the proper formats for presenting numbers and units
- Produce a high-quality technical memo or report following the appropriate formats
- Give an excellent oral technical presentation