INSTRUMENTS AND MEASUREMENTS FOR ELECTRONICS

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PREFACE

Electronics is a new and expanding field of scientific endeavor with many diverging areas, each changing rapidly, so that the devices we study and use today may soon be replaced by more sophisticated devices tomorrow. The electronic instrumentation used to make today's measurements will be replaced eventually with newer and more sophisticated instruments. However, there is a common core of knowledge threading through these areas, devices, and instruments.

It is the purpose of "Instruments and Measurements for Electronics" to provide the electronics technology student with a sound background in the basic theory and common-core concepts of measurements and electronic measuring instruments. To accomplish this purpose, the student is led through graduated measuring concepts and techniques using the measuring instrument as the supporting vehicle.

The student is also presented with a basic core of measuring concepts and techniques through the study of electronic instruments. These instruments can be applied as the basis in every facet of measurement in electronics. Textual treatment includes both intuitive and descriptive approaches, as well as conceptual and analytic approaches.

The text provides the student with an understanding of the logic behind the selection of a specific type of instrument for a measurement and the accuracy to be expected from this instrument. The student will also learn the importance of proper care and application of each type of measuring instrument and the purpose of calibration and maintenance of this instrument. Careful distinction is made between accuracy and precision. The student will also obtain an understanding of the probability of error analysis for electronic instruments and measurements, and the limitation of each type of measuring instrument.

The foregoing objectives are realized in "Instruments and Measurements for Electronics" through the presentation of materials under six topics: Basic Measuring Instruments (Meters); Bridge-Type Instruments; Electronic Display Instruments; Generating Instruments; Tube and Semiconductor Device Testers; and Electronic Counters and Frequency Meters.

CLYDE N. HERRICK

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I

BASIC MEASURING INSTRUMENTS

1

PROBABILITY AND ERROR ANALYSIS

1.1 PRECISION OF MEASUREMENTS

Although beginning students tend to confuse the *precision* of a measurement with the *accuracy* of a measured value, there is a basic distinction between these terms. For example, a battery or cell such as illustrated in Fig. 1.1 has a terminal voltage (strictly an electromotive force) that we call its true or actual voltage. Furthermore, this actual voltage value is not measurable, although we can approximate this value by careful measurement. The accuracy of a measurement denotes the extent to which we approach this actual value. Even the most careful measurements can establish an actual voltage value only within certain limits of accuracy. Of course, new and improved measuring techniques can narrow these accuracy limits.

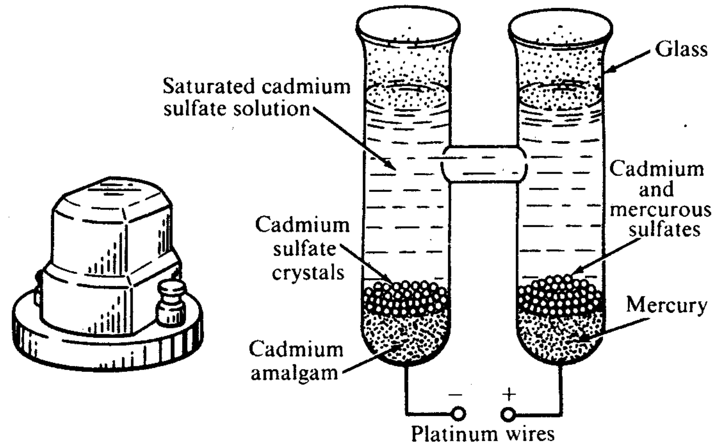

FIG. 1.1 *Appearance (a) and construction (b) of a Weston standard cell.*

On the other hand, the precision of a measurement denotes its departure from the average of a number of measured values. For example, suppose that we carefully measure the terminal voltage of a dry cell six times. Since an observational error is inevitably present in any voltmeter reading (except nonanalog types), we may take the precaution of asking five other observers to repeat this measurement and thus we have six separate measured values:

1.49	1.49
1.51	1.52
1.50	1.50

In this example, we are using the most accurate voltmeter available and accordingly are concerned only with the precision of the foregoing measurements. We proceed as follows: The *sum* of the measured values is 9.01 V. We divide this sum by 6 to find its *average value* of 1.50+ V. Since the remainder in the quotient is less than 5, we round off 1.50+ to 1.50 and thereby determine its *most probable value.* In turn, we conclude that the third and sixth measurements were the most precise within the group of six measurements.

Note that the first measurement has a precision of approximately 99.3 percent; this precision can also be stated as approximately +0.7 percent deviation from the mean. The third measurement has a precision of 100 percent, and so on. Next, if we obtain a voltmeter with a higher accuracy