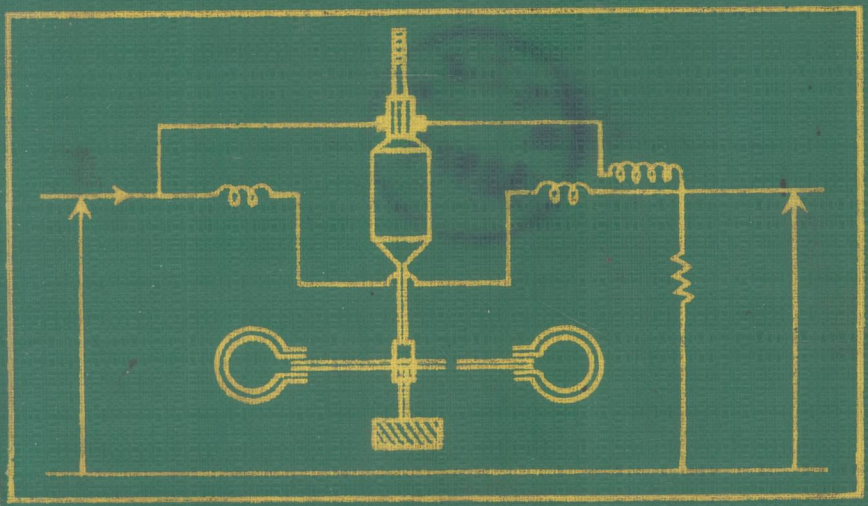
# ELECTRICAL MEASUREMENTS AND MEASURING INSTRUMENTS

RAJENDRA PRASAD



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# ELECTRICAL MEASUREMENTS
**AND**
# MEASURING INSTRUMENTS

[A Textbook for Engineering Students]



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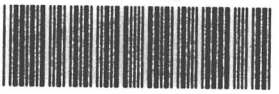



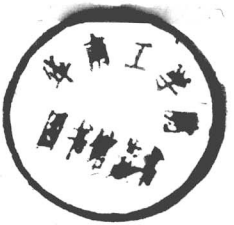

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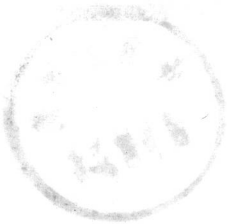

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## PREFACE

This book is a humble presentation by the author to the students studying principles of electrical measurements and measuring instruments in various Indian universities and polytechnics. The purpose of this book is to present a comprehensive coverage of the subject. The current books on the subject address themselves either to the advanced undergraduate students or to the diploma students. It has been tried to write this text so as to bridge the gap between the two groups of students. This book will also be helpful to students preparing for the A.M I.E. examinations.

The first chapter of the book deals with the preliminaries of measurement theory which includes the choice of a measurement method, accuracy and errors in measurements and general precautions to be observed while measuring an electrical quantity. The second chapter deals with various units and standards. SI units have, now, been internationally accepted and hence special emphasis is given on this topic. Chapter 3 describes about the electrical circuit components (resistors, inductors, and capacitors). Chapter 4 to 11 consider various types of electrical measuring instruments, while chapters 12 to 17 describe different methods of measurement of electrical quantities. The usefulness of electronic measuring devices makes it necessary to include chapter 18 which deals with some important devices of this type. In chapter 19 different types of transducers used for measuring non-electrical quantities are described. At the end of each chapter, a large number of important solved examples are given. In addition, some unsolved problems are given with each of the chapters for the exercise of the students. The answers to unsolved problems are, intentionally, given at the end of the book and not with the problems.

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*—Rajendra Prasad*

*TO*
**SUSHMA, SHAILENDRA**
*AND*
**ANAMIKA**

## CONTENTS

# 1

# Preliminaries of Measurement

## 1·1. Choice of Measurement Method

It is an important work to select a suitable method of measurement before starting it. At the time of selection, the following points should be kept in mind :

(1) Apparatus available
(2) Accuracy desired
(3) Time required
(4) Difficulties in measurement
(5) Necessary conditions of measurement

A method must be selected that makes use of available apparatus to obtain the desired result without sacrifying the desired accuracy. During the time of selection it should be kept in mind that the difficulties faced during measurement can be easily overcome. At the same time necessary conditions must be fulfilled. It is not wise to choose a method giving higher accuracy than desired one at the cost of time and money. The method should be as simple as possible and consistent with requirements of the task. It is always beneficial to study carefully different apparatus before starting the actual measurement. Before starting measurement with a particular method, it is advisable to look whether there is a better and simpler method. Wide experiences in the field of measurement are very helpful in selecting a method.

After selection of the method and the apparatus, it is important that they be intelligently used. For this each piece of apparatus and its method of operation should be thoroughly understood. The line diagram of electrical circuits should be drawn in the beginning. It saves time and minimizes the possibilities of wrong corrections of apparatus. Before energising it is necessary to check measuring instruments, other apparatus and electrical circuits. Taking necessary precautions gives better result.

## 1·2. Record Preparation

Record preparation of any experiment is not less important. Therefore, the data necessary for preparation of record must be

written carefully. These data are recorded mostly in bound note-book. Sometimes data may be written on loose sheets and after arranging them properly they can be permanently bound together. The habit of memorizing the data or writing them in short is not good because there is every possibility of forgetting some of the data which may cause great inconvenience. Without the line diagram of electrical circuits and specifications of all apparatus, a report can never be said to be complete. Report should be such that the experiment can be repeated with the same method and apparatus at any time. Thus error in the result due to unusual functioning of the instrument or due to any other reason can be removed. Any unusual behaviour of apparatus should be noted on the data sheet, and, if recorded data are rejected or discarded, the reasons for the action should be recorded at the time. In short, the report must be such that any other persons can get every information about the experiment just by going through the record or even can repeat the experiment at any time.

### 1·3. Experimental Accuracy

Accuracy plays an important role in the measurement of any quantity. So, it is necessary to discuss about it. The measurement of a quantity is based on some international fundamental standards. These fundamental standards are perfectly accurate, while others are derived from these. These derived standards are not perfectly accurate in spite of all precautions. In general measurement of any quantity is done by comparing with derived standards which themselves are not perfectly accurate. So, the error in measurement is not only due to error in methods but also due to standards (derived) not being perfectly accurate. Thus measurement with 100% accuracy is not possible with any method. So, a measurement without error is impossible. Now, it is the duty of the person performing the experiment to keep the error within limit.

The final value of any quantity obtained by any method of measurement is being influenced by so many factors. For example, the value of resistance measured is influenced by temperature, current density along the wire, tension in the wire and other factors. Sometimes it is possible that due to some factors the error may be positive while due to some other factor it may be negative This may result in accurate measurements as positive and negative errors would cancel each other. Sometimes it is also possible that due to some reasons the error at one time is positive while at other time it is negative. This may give an average value, with infinite number of readings, free from error. But these are not always possible. In general, in a method or in an instrument error remains constant at any time and so the average value may not be accurate.

The word 'precision' is often used in place of accuracy as if they are interchangeable. So, they should be distinguished. Accuracy of measurement is defined as the deviation of the measured

value from the accurate value. On the other hand, precision of measurement is defined as the deviation of different readings from an average value. Thus it is a measurement of consistency in measurement. An example will clarify the point. A thermometer does not give accurate value of temperature, but, whenever the same temperature is measured, it gives the same reading. The thermometer is said to be a precision thermometer though it is not perfectly accurate.

## 1·4. Errors in Measurement

In last section, it became clear that a quantity can never be measured with perfect accuracy in practice. So, it is necessary to know the limit of maximum possible error in any measurement. Measurements without this have no meaning. It has no meaning in saying that the resistance of a resistor is 100 ohms. But, if it is said that the resistance of a resistor is $100 \pm 2{\cdot}5$ ohms, then it means that the resistor can be used wherever a resistance of value varying from 97·5 ohms to 102·5 ohms can be tolerated. Some definitions are being given below :

**Absolute-error.** 'Absolute-error' is also called as 'maximum possible error'. Error in measurement,

$$\delta R = A_m - A \qquad \ldots(1{\cdot}4\text{-}1)$$

where $A_m$ = measured value

$A$ = accurate value

Absolute-error ($\in_0$) is the limit of error in measurement. In other words $\delta R$ must never be higher than $\in_0$. So,

$$| \in_0 | = \text{max.} | A_m - A | \qquad \ldots(1{\cdot}4\text{-}2)$$

**Relative-error.** Absolute-error does not give any information about accuracy. For example, $-1$ volt error in measurement of 1100 volt is negligible, but $-1$ volt error in measurement of 10 volt is never acceptable. Relative-error is the ratio of absolute-error with the accurate value. So, relative-error,

$$\in_r = \frac{\in_0}{A} \qquad \ldots(1{\cdot}4\text{-}3)$$

If $\in_0$ is negligibly small as compared to $A_m$, then equation (1·4-3) can be written as

$$\in_r = \frac{\in_0}{A_m} \qquad \ldots(1{\cdot}4\text{-}4)$$

Generally, relative-error is given in per cent of measured value,

*i.e.* per cent error $= 100 \in_r$ $\qquad \ldots(1{\cdot}4\text{-}5)$

**Correction.** Correction is negative of error. So, correction—

$$\delta c = \delta R \qquad \ldots(1{\cdot}4\text{-}6)$$

Also $$A = A_m + \delta c \qquad \ldots(1{\cdot}4\text{-}7)$$