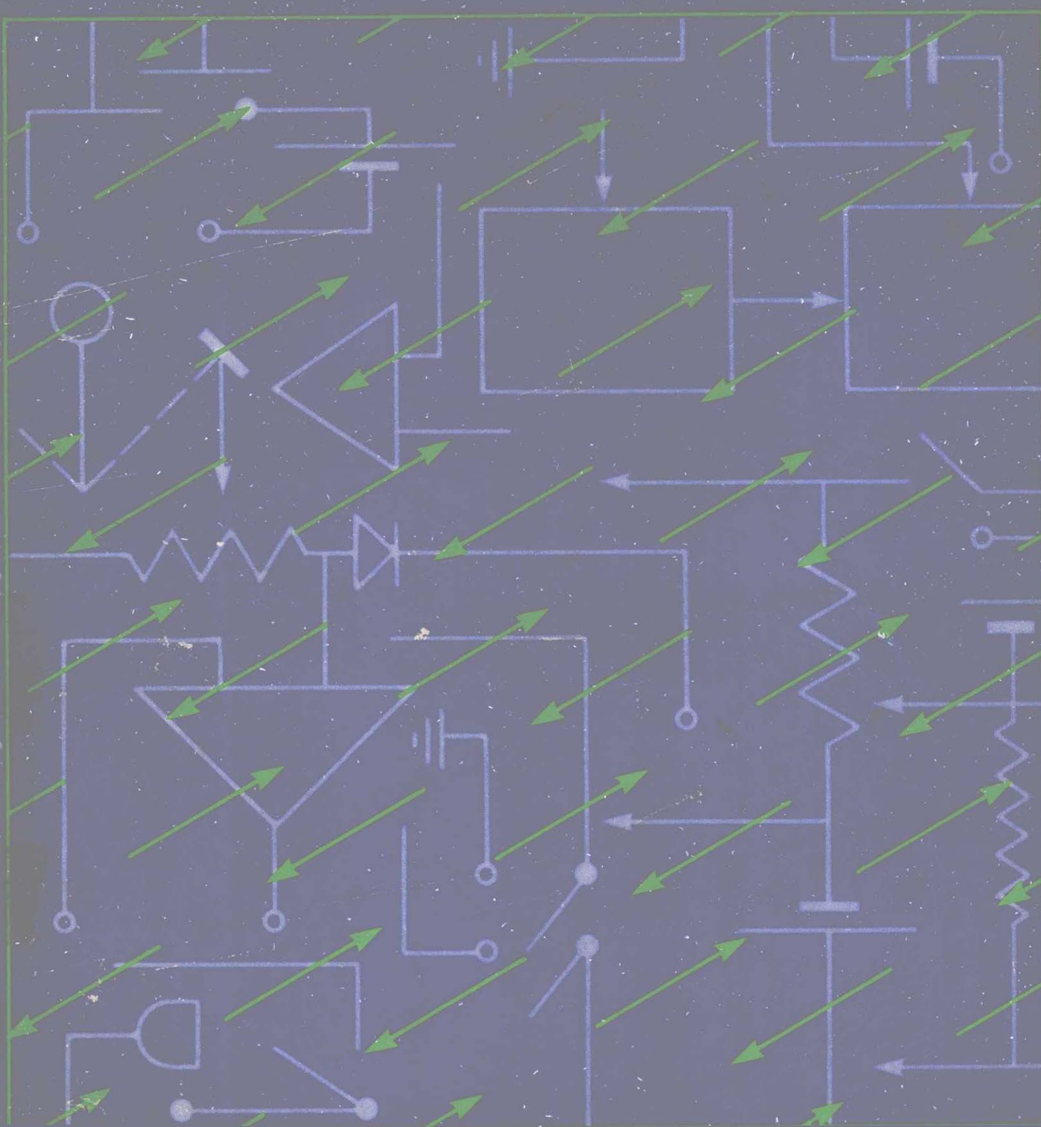
GUIDE TO MEDICAL LABORATORY INSTRUMENTS

Clifford D. Ferris, D.Sc., P.E.



Guide to Medical Laboratory Instruments

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Preface

This book has evolved from a course taught during the past 6 years to second-semester, junior-year students in the Medical Technology Program at the University of Wyoming. The purpose of the course and this text is to familiarize students with the operating principles of various classes of electronic instruments used in the clinical laboratory before they enter their year of clinical training. Electronic equipment is now used extensively in clinical chemistry laboratories. In most programs, unfortunately, much, if not all, of the training during the internship year is devoted to chemistry, hematology, and microbiology. The little training given in the operation of electronic equipment is frequently provided only as an afterthought. Many of the instruments and applications described in this book are equally useful in research laboratories. Thus, the book should prove valuable to workers outside of hospital clinical laboratories.

The book is divided into four subject areas. The first two chapters provide the basic electrical "vocabulary" necessary for intelligent reading of equipment instruction and operation manuals, as well as the elementary principles of electricity and electronics. Chapter 3 describes some of the many optical devices used in clinical laboratory instruments. Chapters 4 to 12 cover the design and operation of various classes of equipment. With only a few exceptions, there is no mention of specific models or suppliers of commercial equipment. This policy was adopted for two reasons: First, model changes occur annually—more often in some cases. Basic design philosophy, however, remains relatively stable. Second, differences among different instrument models usually relate to user convenience features, measurement range, sensitivity, and degree of automation, while the physical principles of operation are very similar, if not identical. Thus, our approach is to emphasize certain design techniques common to a specific class of instruments. With this type of background, the reader should then be able to operate any model of that class of instrument with only a brief reading of the operation manual.

It should be pointed out that the occasional reference to a commercial product of a particular manufacturer does not constitute an endorsement of the product or lack of endorsement of other such products.

The subject of Chapter 13 is general laboratory safety, especially the hazard of electric shock and its prevention. Various regulations and regulatory bodies that affect laboratory operation are described briefly. While possible device malfunctions and operator errors are stressed throughout the instrument description chapters, Chapter 14 focuses specifically on troubleshooting procedures. The emphasis is placed on those procedures that the technologist can carry out in the laboratory environment.

The final chapter examines several matters related to the use of equipment and general laboratory operation. Included are instrument accuracy and precision, calibration, quality control, data reporting, record keeping, liability, and licensing.

The Appendix provides a review of basic exponential and logarithmic functions. Techniques for graphic presentation of data are included, with emphasis on instrument calibration curves.

A set of 10 exercise problems is included at the end of each chapter (including the Appendix), some of which require outside work on the student's part. These include checking instrument specifications and other matters that would normally occur in practice.

For the most part, the International System of Units (SI units) has been used in the text. Where medical convention differs from general scientific convention, the medical units are used. An example is the use of millimeters of mercury for pressure measurements, rather than kilopascals.

The book has been designed for readers with varying degrees of mathematical background. A knowledge of basic algebra, logarithms, and scientific notation is assumed. When the book is used as a class text, certain sections may be omitted at the discretion of the instructor. These sections are designated by an asterisk preceding the section heading.

Preparation of the first draft of the book was conducted while the author was on sabbatical leave from the University of Wyoming and serving as a Visiting Professor at the University of Colorado Medical School, in the Department of Biophysics, Biochemistry and Genetics. Mr. Kingsley C. Rock, Director of Bioengineering, kindly provided office space in his facility and made initial arrangements for the author to visit various laboratory facilities. Dr. J. Richard Pearson, Director of the Clinical Chemistry Laboratory, and Dr. Yasuhiko Takeda, Director of the Immunoassay Laboratory, willingly provided access to their respective laboratories and discussed operation of their facilities at Colorado General Hospital.

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C.D.F.

Symbols, Units, and Definitions

1. *Physical Quantity*	*Name of Unit*	*Unit Symbol*
mass	kilogram (gram)	kg (g)
length	meter	m
time	second	s, sec
electric charge	coulomb	C
amount of substance	mole	mol
energy	joule	J
force	newton	N
power	watt	W
pressure	millimeters of mercury or pounds per square inch	mm Hg, psi
temperature	degrees Kelvin or Celsius	K, °C
volume	liter	l
frequency	hertz	Hz
radian frequency	radians/second	rad/sec, rad s^{-1}
osmolality	osmol	Osm
atomic mass unit	dalton	D
electric current	ampere	A
electric potential (voltage)	volt	V
electrical conductivity	siemen/meter	S/m, S m^{-1}
electrical capacitance	farad	F (C^2 J^{-1})
electrical inductance	henry	H (J C^{-2} s^2)
electrical resistance	ohm	Ω (J s C^{-2})
gamma*	microgram	μg

*This is an old term; we have restricted its use to fluorescent materials.

2. *Symbol*	*Definition*	*Symbol for Physical Unit*
A	area	m^2
A	optical absorbance	—
C	electrical capacitance	F
E	electric field intensity	V m^{-1}, V/m
F	Faraday constant	96,495 C mol^{-1}
F	force	N
H	amount of heat	J (calorie)
H	heat flux	W m^{-2}
I, ***I***	electric current	A
I	light intensity	W m^{-2}
L	electrical inductance	H
P	power	W
PCO_2	partial pressure of carbon dioxide	mm Hg
PO_2	partial pressure of oxygen	mm Hg
Q	electric charge	C
Q	figure of merit	—
R	electrical resistance	Ω

Symbol	*Definition*	*Symbol for Physical Unit*
R	universal gas constant	8.315 kJ kg^{-1} mol deg K
T	temperature	K, °C
$\%T$	optical percent transmittance	—
U	particle mobility	$m^2\ V^{-1}\ s^{-1}$, $m^2\ C\ J^{-1}\ s^{-1}$
V, $\mathbf{V}$	electrical potential, voltage	V
W	energy	J
X	electrical reactance (AC resistance)	Ω
$\mathbf{Z}$	electrical impedance	Ω
Z	valence	—
c	speed of light	$\sim 3\times10^{8}\ m\ s^{-1}$
d	length	m
dB	decibel	—
e	electronic charge	1.6×10^{-19} C
f	frequency	Hz
g%	concentration	g/100 ml
g/d1	concentration	g/100 ml
h	Planck's constant	6.625×10^{-34} J s
i	electric current	A
j	unit imaginary $\sqrt{-1}$	—
mEq/l	number of milliequivalents per liter	—
P	pressure	mm Hg
q	electric charge	C
t	time	s, sec
u	particle velocity	$m\ s^{-1}$, m/s
v	electric potential, voltage	V
x	distance	m, cm
ε	dielectric permittivity	$F\ m^{-1}$
ε_r	dielectric constant	—
η	dynamic viscosity	$N\ s\ m^{-2}$
θ	geometric angle	degrees, radians
λ	optical wavelength	nm, m
μ	charge mobility	$m^2\ V^{-1}\ s^{-1}$, $m^2\ C\ J^{-1}\ s^{-1}$
μ	magnetic permeability	$H\ m^{-1}$
π	physical constant	3.1416
σ	electrical conductivity	$S\ m^{-1}$
ω	radian frequency	rad/sec, rad s^{-1}
O	osmolality	Osm
κ	osmotic coefficient	—

3. Mathematical Symbols

$=$	equality
$\sim$	proportional to
$>$	greater than ($\geqslant$ greater than or equal to)
$<$	less than ($\leqslant$ less than or equal to)
∞	infinity
$\lvert\ \rvert$	absolute value, magnitude
$\sqrt{\ }$	square root
!	factorial
log	logarithm to the base 10
ln	logarithm to the base e
e	physical constant = 2.718

4. Multiples and Scientific Notation (S.N.)

Factor	*S.N.*	*Prefix*	*Symbol*
million millionth	10^{-12}	pico	p
thousand millionth	10^{-9}	nano	n
millionth	10^{-6}	micro	μ
thousandth	10^{-3}	milli	m
hundredth	10^{-2}	centi	c
tenth	10^{-1}	deci	d
ten	10^{1}	deca	da
hundred	10^{2}	hecto	h
thousand	10^{3}	kilo	k
million	10^{6}	mega	M

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