

Contents

1 Overview 1

- 1.1 Instrument Design and Selection 1
 - 1.1.1 Performance Characteristics 2
 - 1.1.2 Functional Model 2
 - 1.1.3 Sources of Error 4
- 1.2 Standards 6
 - 1.2.1 Calibration 6
 - 1.2.2 Performance 6
 - 1.2.3 Exposure 6
 - 1.2.4 Procedural 7
- 1.3 System Integration 8
 - 1.3.1 Instrument Platforms 8
 - 1.3.2 Communication Systems 8
 - 1.3.3 Power Source 10
- 1.4 Human Aspects of Measurement 11
 - 1.4.1 Human Perception versus Sensor Measurements 11
 - 1.4.2 Reasons for Automation 11
 - 1.4.3 Design, Implementation, and Maintenance of Measurement Systems 12
 - 1.4.4 Interpretation of Sensor Specifications 12
 - 1.4.5 Interpretation of Results 13
 - 1.4.6 Human Judgment 14
- 1.5 Quality Assurance 15
 - 1.5.1 Laboratory Calibrations 16
 - 1.5.2 Field Intercomparisons 17
 - 1.5.3 Data Monitoring 17

1.5.4	Documentation	18
1.5.5	Independent Review	18
1.5.6	Publication of Data Quality Assessment	19
1.6	Scope of this Text	19
	Questions	19
	Bibliography	20
	General Instrumentation References	21
2	Barometry	22
2.1	Atmospheric Pressure	22
2.2	Direct Measurement of Pressure	23
2.2.1	Mercury Barometers	24
2.2.2	Aneroid Barometers	29
2.3	Indirect Measurement of Pressure	33
2.3.1	Boiling Point of a Liquid	34
2.4	Comparison of Barometer Types	37
2.4.1	Mercury Barometers	38
2.4.2	Aneroid Barometers	38
2.4.3	Hypsometer	38
2.5	Exposure Error	39
2.6	Laboratory Experiment	40
2.7	Calibration of Barometers	42
	Questions	43
	Bibliography	45
3	Static Performance Characteristics	47
3.1	Some Definitions	47
3.2	Static Calibration	49
3.2.1	Definition of Terms Related to the Transfer Plot	50
3.2.2	Calibration Procedure	52
3.3	Example of a Static Calibration	56
3.4	Multiple Sources of Error	57
3.5	Significant Figures	58
	Questions and Problems	60
	Bibliography	61
4	Thermometry	62
4.1	Thermal Expansion	63
4.1.1	Bimetallic Strip	63
4.1.2	Liquid-in-Glass Thermometer	65
4.2	Thermoelectric Sensors	67
4.3	Electrical Resistance Sensors	70
4.3.1	Resistance Temperature Detectors	70
4.3.2	Thermistors	74
4.4	Comparison of Temperature Sensors	76
4.5	Exposure of Temperature Sensors	77
	Questions	82
	Bibliography	84
	Notes	85
5	Hygrometry	86
5.1	Water Vapor Pressure	86
5.2	Definitions	89
5.3	Methods for Measuring Humidity	93

5.3.1	Removal of Water Vapor from Moist Air	93
5.3.2	Addition of Water Vapor to Air	93
5.3.3	Equilibrium Sorption of Water Vapor	96
5.3.4	Measurement of Physical Properties of Moist Air	100
5.3.5	Attainment of Vapor–Liquid or Vapor–Solid Equilibrium	104
5.3.6	Chemical Reactions	107
5.4	Choice of Humidity Sensor	107
5.5	Calibration of Humidity Sensors	108
5.6	Exposure of Humidity Sensors	110
	Questions	111
	Laboratory Exercises	114
	Bibliography	114
	Notes	116
6	Dynamic Performance Characteristics, Part 1	117
6.1	First-Order Systems	118
6.1.1	Step-Function Input	119
6.1.2	Ramp Input	122
6.1.3	Sinusoidal Input	123
6.2	Experimental Determination of Dynamic Performance Parameters	125
6.3	Application to Temperature Sensors	126
	Questions	127
	Bibliography	128
7	Anemometry	129
7.1	Methods of Measurement	129
7.1.1	Wind Force	130
7.1.2	Heat Dissipation	140
7.1.3	Speed of Sound	141
7.2	Calibration	144
7.3	Exposure	144
7.4	Wind Data Processing	144
	Questions	145
	Bibliography	147
8	Dynamic Performance Characteristics, Part 2	151
8.1	Generalized Dynamic Performance Models	151
8.2	Energy Storage Reservoirs	152
8.3	Second-Order Systems	154
8.3.1	Step Function Input	154
8.3.2	Ramp Input	157
8.3.3	Sinusoidal Input	158
8.4	Application to Sensors	159
8.5	Experimental Determination of Dynamic Performance Parameters	162
	Questions	164
	Bibliography	165
9	Precipitation Rate	166
9.1	Definitions	166
9.2	Methods of Measurement	167
9.2.1	Point Precipitation Measurement	167
9.2.2	Radar Rain Measurement	182
	Questions	185
	Bibliography	187

10 Solar and Earth Radiation 189

- 10.1 Definitions 189
- 10.2 Methods of Measurement 192
 - 10.2.1 Pyrheliometers 193
 - 10.2.2 Pyranometers 194
 - 10.2.3 Pyrgeometers 197
 - 10.2.4 Pyrradiometers 197
- 10.3 Measurement Errors 198
- 10.4 Exposure 199
- Questions 200
- Bibliography 201

11 Visibility and Cloud Height 202

- 11.1 Definitions 202
- 11.2 Measurement of Visibility 204
 - 11.2.1 Transmissometer 205
 - 11.2.2 Forward Scatter Meters 206
- 11.3 Measurement of Cloud Height 207
 - 11.3.1 Rotating Beam Ceilometer 207
 - 11.3.2 Laser Ceilometer 208
- Questions 210
- Bibliography 211

12 Upper Air Measurements 213

- 12.1 Methods for Making Upper Air Measurements 213
 - 12.1.1 Remote Sensing 214
 - 12.1.2 In-Situ Platforms 214
- 12.2 Balloons 215
- 12.3 Wind Measurement 219
 - 12.3.1 Theodolites 220
 - 12.3.2 Radar 223
 - 12.3.3 Navigation Aids 223
- 12.4 Radiosondes 225
- 12.5 Exposure Error 228
- Questions 228
- Bibliography 229

13 Sampling and Analog-to-Digital Conversion 231

- 13.1 Signal Path 232
- 13.2 Drift 233
- 13.3 Sampling 233
- 13.4 Analog-to-Digital Conversion 235
- 13.5 Information Content of a Signal 239
- Questions 241
- Bibliography 243

A Units and Constants 245

- International System of Units (SI) 245
- Numerical Values 246
- Bibliography 247

B Thermistor Circuit Analysis 248

- B.1 A Thermistor 248
- B.2 A Circuit 250
- B.3 An Alternative Calibration Equation 252

C	A Data Logger	253
	C.1 The Data Logger	253
	C.2 Application in a Measurement System	255
D	Circuits	258
	D.1 Fundamentals	258
	D.2 Simple Circuits	261
	Questions	263
E	Geophysical Coordinate System	266
	E.1 Geophysical versus Mathematical Coordinate System	266
	E.2 Mathematical Coordinates	266
	E.3 Geophysical Coordinates	267
F	Instrumentation Glossary	269
	Index	285