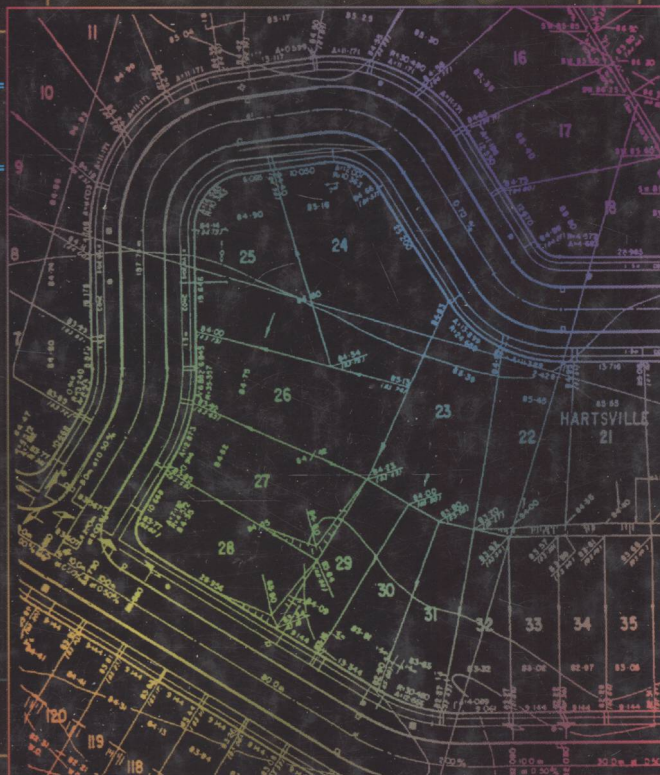


# Surveying with Construction Applications

Fifth Edition



Barry F. Kavanagh

P21  
K21  
E.S.

教育部高校国外  
赠书转运站赠书

# **SURVEYING**

## **With Construction Applications**

*Fifth Edition*



**Barry F. Kavanagh**



Upper Saddle River, New Jersey  
Columbus, Ohio

## Library of Congress Cataloging in Publication Data

Kavanagh, Barry F.

Surveying: with construction applications/Barry F. Kavanagh.-5th ed.

p. cm.

Includes indexes.

ISBN 0-13-048215-3

1. Surveying. 2. Building sites. I. Title.

TA625.K38 2004

526.9—dc21

2002044574

**Editor in Chief:** Stephen Helba

**Executive Editor:** Ed Francis

**Development Editor:** Linda Cupp

**Production Editor:** Holly Shufeldt

**Design Coordinator:** Diane Ernsberger

**Cover and Insert Designer:** Bryan Huber

**Production Manager:** Matt Ottenweller

**Marketing Manager:** Mark Marsden

This book was set in Times by Carlisle Communications, Ltd. It was printed and bound by R.R. Donnelley & Sons Company. The cover was printed by The Lehigh Press, Inc.

---

**Copyright © 2004, 2001, 1997, 1992, 1989 by Pearson Education, Inc., Upper Saddle River, New Jersey 07458.**

Pearson Prentice Hall. All rights reserved. Printed in the United States of America. This publication is protected by Copyright and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or likewise. For information regarding permission(s), write to: Rights and Permissions Department.

**Pearson Prentice Hall™** is a trademark of Pearson Education, Inc.

**Pearson®** is a registered trademark of Pearson plc

**Prentice Hall®** is a registered trademark of Pearson Education, Inc.

Pearson Education Ltd.

Pearson Education Singapore Pte. Ltd.

Pearson Education Canada, Ltd.

Pearson Education—Japan

Pearson Education Australia Pty. Limited

Pearson Education North Asia Ltd.

Pearson Educación de México, S.A. de C.V.

Pearson Education Malaysia Pte. Ltd.



10 9 8 7 6 5 4 3 2  
ISBN 0-13-048215-3

## ABBREVIATIONS

### GENERAL

AASHTO	American Association of State Highway and Transportation Officials
ACSM	American Congress on Surveying and Mapping
Az	azimuth
Bg	bearing
BM	benchmark
	(TBM) temporary benchmark
BS	backsight (rod reading in leveling; line sighting in transit work)
C <sub>L</sub>	correction due to erroneous length of tape
C <sub>P</sub>	correction due to nonstandard tension
C <sub>S</sub>	correction due to effects of sag
C <sub>T</sub>	corrections due to nonstandard temperature
CAD	computer assisted drafting (or design)
CADD	computer assisted drafting and design
cc	cut cross
CIG	Canadian Institute of Geomatics
conc.mon.	concrete monument
c + r	error in line of sight due to combined effects of curvature and refraction
Deg	degree
Dep	departure
DoD	Department of Defense
EDM	electronic distance measurement
Elev	elevation
FS	foresight (rod reading in leveling; line sighting in transit work)
GIS	geographic information system
GPS	global positioning system
HARN	high accuracy reference network
HI	height of instrument above a datum
hi	height of instrument above the instrument station
HOT	hub on tangent
IB	iron bar
Inst	instrument
IP	iron pipe
IS	intermediate sight, used in leveling and Total Station activities (also IFS, intermediate foresight)
Lat	latitude
Long	longitude
Lt	left
Mon	monument
NSPS	National Society of Professional Surveyors
Occ	occupied station reference
OG	original ground
o/s	offset
ppm	parts per million
RAP	reference azimuth point
ROW	right of way
RP	reference point
RR	rod reading
Rt	right
TBM	temporary benchmark
TP	turning point
Twp	township
UTM	universal transverse Mercator projection
X-sect	cross section

## IMPERIAL UNITS

ac	acre
bbl	barrel
cu ft	cubic foot
cu in.	cubic inch
cu yd	cubic yard
cwt	hundred weight
fbm	foot board measure
ft	foot or feet
gal	gallon(s)
in.	inch(es)
lb	pound
lf	linear foot (feet)
mi	mile(s)
mph	miles per hour
psi	pounds per square inch
sq ft	square foot (feet)
sq in.	square inch(es)
sq yd	square yard(s)
mf bm	thousand foot board measure
m gal	thousand gallons
yd	yard(s)

## METRIC UNITS

C	Celsius
cm	centimeter
ha	hectare
kg	kilogram(s)
km	kilometer(s)
kN	kilonewton(s)
kPa	kilopascal(s)
L	liter(s)
m	meter(s)
m <sup>2</sup>	square meter
m <sup>3</sup>	cubic meter
mm	millimeter(s)
t	tonne

# Preface

---

There have been many technological advances in surveying since *Surveying with Construction Applications* was first published. This fifth edition is up to date, with the latest information about advances in instrumentation technology, field data capture, and data-processing techniques. Although surveying is becoming much more efficient and automated, the need for a clear understanding of the principles underlying all forms of survey measurement remains unchanged. Every effort has been made to keep this text on the leading edge of new developments in techniques and instrumentation, while maintaining complete coverage of traditional techniques and instrumentation.

General surveying principles and techniques, used in all branches of surveying, are presented in Chapters 1 to 9. Contemporary applications for the construction of most civil projects are covered in Chapters 10 to 16. Not only is the current edition useful for the student, but it can also be used as a reference for the graduate who may choose a career in civil design or construction.

Many new topics have been added to this edition; as a result, some topics have been shifted from the text proper to the appendixes. Moving the evolution of surveying to Appendix G has shortened Chapter 1. Chapter 2 has been expanded to include electronic distance measurement (EDM). The topic of taping corrections has been moved from Chapter 2 to Appendix F. Chapters 3 and 4 have also been streamlined by moving the discussion of four-screw instruments (the dumpy level and vernier transit) to Appendix G. Chapter 5, now called Total Stations, has been revised to more clearly present total station basic operations. Chapter 7 has been completely revised to introduce the concept of geomatics. The techniques of traditional data collection have been expanded because the student is introduced now to the data-collection techniques involved in airborne and satellite imaging. The topic of mapping has been expanded by the inclusion of introductory GIS topics. Chapters 8 and 9 (Global Positioning Systems – GPS, and Construction Control Surveying) have been revised and switched in order of inclusion in the text.



The Instructor's Manual includes solutions for end-of-chapter problems; a typical evaluation scheme; subject outlines (two terms or two semester programs); term assignments; sample instruction class handouts for instrument use, etc.; and mid-term and final tests. Also included for the first time is a PowerPoint CD presentation that can be used both as an aid in presenting text material and as a source for overhead projector transparencies.

The surveyor now has to struggle to keep up with the amazing explosion of technology advances. These advances have both deepened and broadened the traditional field of surveying. It is my hope that students using this text will be completely up to date in this subject area whether they continue their education in surveying or they seek employment in this rewarding field.

Comments and suggestions about the text and the Instructor's Manual are welcome: *barry\_kavanagh@sympatico.ca*

Barry F. Kavanagh

## Acknowledgments

The author is grateful for the comments and suggestions offered by professors who have adopted the text for class use. Particular thanks are due to James Scolaro, California State University, Chico; Linford L. Harley, Penn State, Harrisburg; Dianne Kay, Southern Illinois University, Edwardsville; Subhi M. Bazlamit, Ohio Northern University, Ada; Gregory Mills, Western Kentucky University, Bowling Green; and Amitabha Bandyopadhyay, State University of New York, Farmingdale, for their assistance with the fifth edition text review. Additionally, thanks are due the faculty and staff of the Center For The Built Environment, Seneca College, for their generous assistance and support.

The following surveying, engineering, and equipment manufacturing companies provided generous assistance:

Amberg Measuring Technique, Switzerland  
American Association of State Highway and Transportation Officials (AASHTO),  
Washington, D.C.  
American Augers, Loudon, Tennessee  
American Concrete Pipe Association  
American Congress on Surveying and Mapping, Bethesda, Maryland  
American Society for Photogrammetry and Remote Sensing  
American Society of Civil Engineers, New York, New York  
Applanix, Richmond Hill, Ontario  
Ausran, Alexandra Hills, Australia  
Canadian Hydrographic Service, Ottawa, Ontario  
Caterpillar, Inc., Peoria, Illinois  
Cooper Tool Group (Lufkin Tapes), Barrie, Ontario  
Corrugated Steel Pipe Institute, Cambridge, Ontario  
CST/Berger-David White, Watseka, Illinois  
Department of Energy, Mines, and Resources, Canada  
Department of Roads and Traffic, City of Toronto  
Euclid-Hitachi Heavy Equipment, Ltd., Cleveland, Ohio  
Geomatics Canada, Ottawa, Ontario

J. D. Barnes, Ltd., Surveyors, Markham, Ontario  
J. I. Case Co., Chicago, Illinois  
John Deere, Moline, Illinois  
Laser Atlanta, Norcross, Georgia  
Laser Technology Inc., Englewood, Colorado  
Leica Geosystems Inc., Norcross, Georgia  
LH Systems, San Diego, California  
Marathon Letourneau Co., Longview, Texas  
Marshall, Macklin, Monaghan, Surveyors and Engineers, Markham, Ontario  
MicroSurvey Software Inc., Westbank, BC, Canada  
Ministry of Transportation, Toronto, Ontario  
National Geodetic Survey (NGS), Silver Spring, Maryland  
National Swedish Institute for Building Research, Gävle, Sweden  
Nikon Instruments, Inc., Melville, New York  
Optech, Toronto, Ontario  
Pacific Crest Corporation, Santa Clara, California  
Pentax Corporation, Englewood, Colorado  
Position Inc., Calgary, Alberta  
Roads and Transportation Association, Ottawa, Canada  
Sokkia Corporation, Olathe, Kansas  
The Robbins Company, Solon, Ohio  
Topcon Positioning Systems, Inc., Pleasanton, California  
Toronto Department of Roads and Traffic, Toronto, Ontario  
Trimble, Sunnyvale, California  
Tripod Data Systems (TDS), Corvallis, Oregon  
U.S. Census Bureau  
U.S. Department of Interior, Geological Survey  
U.S. Department of the ARMY, TM5-241-4/1  
U.S. Geological Survey, Sioux Falls, South Dakota  
U.S. Coast Guard  
Wild Heerbruug, Heerbruug, Switzerland  
XYZ Works, Masonville, Colorado



## FIELD NOTE INDEX

Page	Figure	Description
36	2-21	Taping field notes for a closed traverse.
37	2-22	Taping field notes for building dimensions.
72	3-15	Leveling field notes and arithmetic check (data from Figure 3-14).
76	3-19	Profile field notes.
78	3-21	Cross-section notes (municipal format).
79	3-22	Cross-section notes (highway format).
83	3-28	Survey notes for three-wire leveling.
103	4-8	Field notes for repeated angles.
110	4-13	Field notes for directions.
145	5-17	Field notes for total station graphics descriptors—MicroSurvey Software Inc. codes.
146	5-18	Field notes for total station graphics descriptors—Sokkia codes.
160	6-3	Field notes for open traverse.
161	6-4	Field notes for a closed traverse.
197	7-3	Topographic field notes. (a) Single baseline. (b) Split baseline.
198	7-4	Original topographic field notes, 1907 (distances shown are in chains).
286	8-19	Station visibility diagram.
288	8-20	GPS field log.
347	9-24	Field notes for control point directions and distances.
348	9-25	Prepared polar coordinate layout notes.
456	12-5	Property markers used to establish centerline.
542	16-1	Example of the method of recording sodding measurements.
543	16-2	Field notes for fencing measurements.
544	16-3	Example of field-book entries regarding removal of sewer pipe, etc.
545	16-4	Example of field notes for pile driving.
595	D-2	Sample taping field notes for building dimensions—Project 1.
597	D-3	Sample field notes for Project 3 (traverse distances).
599	D-4	Sample field notes for Project 4 (differential leveling).
601	D-5	Sample field notes for Project 5 (traverse angles).
602	D-6	Sample field notes for Project 6 (topography tie-ins).
603	D-7	Sample field notes for Project 6 (topography cross sections).
605	D-9	Sample field notes for Project 6 (topography by theodolite/EDM).
606	D-10	Sample field notes for Project 6 (topography by total station).
609	D-11	Sample field notes for Project 7 (building layout).
649	G-19	Stadia field notes.

## SYMBOLS

$B$	baseline
$CL$	centerline
$SL$	street line
$\Delta N$	change in northing
$\Delta E$	change in easting
$\Delta \lambda''$	change in longitude (seconds)
$\Delta hi$	difference in height between transit and EDM
$\Delta R$	difference in height between reflector and target
$\phi, \lambda$	latitude, longitude
$\bar{\pi}$	instrument
$P$	occupied station (instrument)
$P$	reference sighting station
$\times$	point of intersection
$=$	is equal to
$\neq$	is not equal to
$>$	is greater than
$<$	is less than
$\approx$	is approximately equal to
$\Sigma$	the sum of

## THE GREEK ALPHABET

Name	Uppercase	Lowercase
alpha	A	$\alpha$
beta	B	$\beta$
gamma	$\Gamma$	$\gamma$
delta	$\Delta$	$\delta$
epsilon	E	$\epsilon$
zeta	Z	$\zeta$
eta	H	$\eta$
theta	$\Theta$	$\theta$
iota	I	$\iota$
kappa	K	$\kappa$
lambda	$\Lambda$	$\lambda$
mu	M	$\mu$
nu	N	$\nu$
xi	$\Xi$	$\xi$
omicron	O	$\omicron$
pi	$\Pi$	$\pi$
rho	P	$\rho$
sigma	$\Sigma$	$\sigma$
tau	T	$\tau$
upsilon	$\Upsilon$	$\upsilon$
phi	$\Phi$	$\phi$
chi	X	$\chi$
psi	$\Psi$	$\psi$
omega	$\Omega$	$\omega$

## CONVERSIONS

### LENGTH

1 ft = 0.3048 m exactly  
1 in. = 2.54 cm = 25.4 mm  
1 m = 10 decimeters = 100 cm = 1,000 mm  
1 m = 39.37 in. = 3.2808 ft  
1 mi = 5,280 ft = 1,609 m = 1.609 km  
1 km = 1,000 m = 0.62137 mi.  
1 nautical mi = 6,076.1 ft = 1852 m = 1.852 km  
1 vara = about 33 in. in Mexico and California and  $33\frac{1}{3}$  in. in Texas  
1 rod = 16.5 ft  
1 chain = 66 ft = 4 rods  
1 U.S. survey foot = 0.30480061 m (original ratio of 1,200/3,937)

### AREA

1 acre = 43,560 sq. ft = 4,047 sq. m = 10 chains squared (i.e.,  $10(66 \text{ ft} \times 66 \text{ ft})$ )  
1 ha (hectare) = 10,000 sq. m = 2.47 acres  
1 sq. km = 247.1 acres  
1 sq. ft = 0.09290 sq. m  
1 sq. in. = 6.452 sq. cm

### VOLUME

1 cu. m = 35.31 cu. ft  
1 cu. yd = 27 cu. ft = 0.7646 cu. m  
1 gal (U.S.) = 3.785 litres  
1 gal (Imperial) = 4.546 litres  
1 cu. ft = 7.481 gal. (U.S.) = 28.32 litres  
1 liter = 0.001 cu. m

### FORCE

1 lb weight = 16 oz. = 4.418 N (newtons) = 0.4536 kg weight  
1 N = 100,000 dynes = 0.2248 lbs. weight = 0.1020 kg weight  
1 kg weight = 9.807 N

### PRESSURE

1 atmosphere = 760 mm Hg. = 14.7 lb/sq. in.  
1 atmosphere = 101,300 N/sq. m (pascals) = 101 kilopascals  
1 atmosphere = 1.013 bars = 760 torrs

### ANGLES

1 revolution = 360 degrees  
1 degree = 60 minutes  
1 minute = 60 seconds  
1 revolution = 400 grad, also known as grade and as gon  
1 right angle = 90 degrees = 100.0000 grad (gon)  
1 revolution = 2 pi radians  
1 radian = 57.29578 degrees  
1 degree = 0.017453 radians

# Contents

---

## **PART I SURVEYING PRINCIPLES 1**

### **1 *Surveying Fundamentals* 2**

- 1-1 Surveying Defined 2
- 1-2 Surveying: General Background 4
- 1-3 Control Surveys 4
- 1-4 Preliminary Surveys 4
- 1-5 Construction Surveys 5
- 1-6 Distance Measurement 5
- 1-7 Angle Measurement 8
- 1-8 Position Measurement 8
- 1-9 Units of Measurement 9
- 1-10 Stationing 11
- 1-11 Types of Construction Projects 11
- 1-12 Random and Systematic Errors 12
- 1-13 Accuracy and Precision 12
- 1-14 Mistakes 14
- 1-15 Field Notes 14

### **2 *Distance Measurement* 16**

- 2-1 Methods of Linear Measurement 16
- 2-2 Gunter's Chain 17
- 2-3 Tapes 18
- 2-4 Steel Tapes 18
- 2-5 Taping Accessories and Their Use 21

2-6	Taping Techniques	25
2-7	Standard Conditions for the Use of Steel Tapes	29
2-8	Systematic Taping Errors and Corrections	29
2-9	Random Taping Errors	33
2-10	Techniques for “Ordinary” Taping Precision	34
2-11	Mistakes in Taping	35
2-12	Field Notes for Taping	35
2-13	Electronic Distance Measurement (EDM)	37
2-14	Electronic Angle Measurement	38
2-15	Principles of Electronic Distance Measurement (EDM)	39
2-16	EDM Characteristics	42
2-17	Prisms	42
2-18	EDM Instrument Accuracies	43
2-19	EDM Operation	45
2-20	Geometry of Electronic Distance Measurements	48
2-21	EDM Without Reflecting Prisms	50
	<i>Problems</i>	52

### **3    *Leveling*    54**

3-1	General Background	54
3-2	Theory of Differential Leveling	54
3-3	Curvature and Refraction	57
3-4	Types of Surveying Levels	59
3-5	Leveling Rods	65
3-6	Definitions for Differential Leveling	65
3-7	Techniques of Leveling	68
3-8	Benchmark Leveling (Vertical Control Surveys)	72
3-9	Profile and Cross-Section Leveling	73
3-10	Reciprocal Leveling	78
3-11	Peg Test	79
3-12	Three-Wire Leveling	82
3-13	Trigonometric Leveling	84
3-14	Level Loop Adjustments	85
3-15	Suggestions for Rod Work	87
3-16	Suggestions for Instrument Work	87
3-17	Mistakes in Leveling	88
	<i>Problems</i>	88

### **4    *Angles and Theodolites*    95**

4-1	General Background	95
4-2	Reference Directions for Vertical Angles	95
4-3	Meridians	95
4-4	Horizontal Angles	96
4-5	Theodolites	98
4-6	Electronic Theodolites	100

4-7	Theodolite Setup	104
4-8	Repeating Optical Theodolites	105
4-9	Angle Measurement with an Optical Theodolite	107
4-10	Direction Optical Theodolites	107
4-11	Angles Measured with a Direction Theodolite	108
4-12	Geometry of the Theodolite	109
4-13	Adjustment of the Theodolite	110
4-14	Laying Off Angles	116
4-15	Prolonging a Straight Line	117
4-16	Bucking-In (Interlining)	117
4-17	Intersection of Two Straight Lines	118
4-18	Prolonging a Measured Line by Triangulation over an Obstacle	119
4-19	Prolonging a Line Past an Obstacle	121
	<i>Review Questions</i>	122

## **5 Total Stations 123**

5-1	General Background	123
5-2	Total Station Characteristics	127
5-3	Total Station Basic Operations	131
5-4	Field Procedures for Total Stations in Topographic Surveys	137
5-5	Field-Generated Graphics	144
5-6	Construction Layout Using Total Stations	147
5-7	Motorized Total Stations	152
	<i>Review Questions</i>	157

## **6 Traverse Surveys and Computations 158**

6-1	General Background	158
6-2	Balancing Field Angles	160
6-3	Meridians	162
6-4	Bearings	162
6-5	Azimuths	166
6-6	Latitudes and Departures	170
6-7	Traverse Precision and Accuracy	176
6-8	Compass Rule Adjustment	178
6-9	Effects of Traverse Adjustments on Measured Angles and Distances	180
6-10	Omitted Measurement Computations	180
6-11	Rectangular Coordinates of Traverse Stations	182
6-12	Area of a Closed Traverse by the Coordinate Method	185
	<i>Problems</i>	188

## **7 An Introduction to Geomatics 191**

7-1	Geomatics Defined	191
7-2	Branches of Geomatics	191
7-3	Data Collection Branch	193
7-4	Survey Drafting and Plotting	200



7-5	Contours	205
7-6	Aerial Photography	213
7-7	Airborne and Satellite Imagery	225
7-8	Remote Sensing Satellites	237
7-9	Geographic Information System (GIS)	238
7-10	Database Management	244
7-11	Metadata	244
7-12	Spatial Entities or Features	245
7-13	Typical Data Representation	247
7-14	Spatial Data Models	248
7-15	GIS Data Structures	249
7-16	Topology	252
7-17	Remote Sensing Internet Web Sites and Further Reading	254
	<i>Review Questions</i>	256
	<i>Problems</i>	256

## **8 Global Positioning Systems 261**

8-1	General Background	261
8-2	Global Positioning	263
8-3	Receivers	264
8-4	Satellites	265
8-5	Satellite Signals	268
8-6	Position Measurements	271
8-7	Errors	277
8-8	Continuously Operating Reference Station (CORS)	279
8-9	Canadian Active Control System	281
8-10	Survey Planning	281
8-11	GPS Field Procedures	287
8-12	GPS Applications	291
8-13	Vertical Positioning	297
8-14	Conclusion	301
8-15	GPS Glossary	303
8-16	Recommended Readings and Web Sites	304
	<i>Review Questions</i>	305

## **9 Control Surveys 306**

9-1	General Background	306
9-2	Plane Coordinate Grids	313
9-3	Lambert Projection	318
9-4	Transverse Mercator Grid System	320
9-5	Universal Transverse Mercator (UTM) Grid System	321
9-6	Use of Grid Coordinates	325
9-7	Illustrative Examples	334
9-8	Horizontal Control Techniques	341
9-9	Project Control	343

<i>Review Questions</i>	351
<i>Problems</i>	351

## **PART II CONSTRUCTION APPLICATIONS 355**

II-1	General Background	355
II-2	Grade	356
II-3	Machine Guidance and Control: General Background	356
II-4	Total Station Guidance and Control	358
II-5	GPS RTK Guidance and Control	359
II-6	The Surveyor's Role in Machine Guidance and Control	361

### **10 Highway Curves 362**

10-1	Route Surveys	362
10-2	Circular Curves: General Background	363
10-3	Circular Curve Geometry	364
10-4	Circular Curve Deflections	370
10-5	Chord Calculations	372
10-6	Metric Considerations	373
10-7	Field Procedure	374
10-8	Moving up on the Curve	375
10-9	Offset Curves	376
10-10	Compound Circular Curves	384
10-11	Reverse Curves	385
10-12	Vertical Curves: General Background	387
10-13	Geometric Properties of the Parabola	388
10-14	Computation of the High or the Low Point on a Vertical Curve	389
10-15	Computing a Vertical Curve	390
10-16	Design Considerations	393
10-17	Spiral Curves: General Background	395
10-18	Spiral Curve Computations	396
10-19	Spiral Layout Procedure Summary	405
10-20	Approximate Solution for Spiral Problems	412
10-21	Superelevation: General Background	413
10-22	Superelevation Design	414
	<i>Review Questions</i>	420
	<i>Problems</i>	421

### **11 Highway Construction Surveys 426**

11-1	Preliminary (Preengineering) Surveys	426
11-2	Highway Design	430
11-3	Highway Construction Layout	436
11-4	Clearing, Grubbing, and Stripping Topsoil	436
11-5	Placement of Slope Stakes	437

11-6	Layout for Line and Grade	441
11-7	Grade Transfer	444
11-8	Ditch Construction	447
	<i>Review Questions</i>	448
<b>12</b>	<b><i>Municipal Street Construction Surveys</i></b>	<b>449</b>
12-1	General Background	449
12-2	Classification of Roads and Streets	450
12-3	Road Allowances	450
12-4	Road Cross Sections	450
12-5	Plan and Profile	451
12-6	Establishing Centerline (C)	454
12-7	Establishing Offset Lines and Construction Control	457
12-8	Construction Grades for a Curbed Street	459
12-9	Street Intersections	463
12-10	Sidewalk Construction	466
12-11	Site Grading	467
	<i>Problems</i>	467
<b>13</b>	<b><i>Pipeline and Tunnel Construction Surveys</i></b>	<b>474</b>
13-1	Pipeline Construction	474
13-2	Sewer Construction	476
13-3	Layout for Line and Grade	478
13-4	Catch-Basin Construction Layout	488
13-5	Tunnel Construction	489
	<i>Problems</i>	494
<b>14</b>	<b><i>Culvert and Bridge Construction Surveys</i></b>	<b>500</b>
14-1	Culvert Construction	500
14-2	Culvert Reconstruction	500
14-3	Bridge Construction: General Background	503
14-4	Contract Drawings	507
14-5	Layout Computations	512
14-6	Offset Distance Computations	512
14-7	Dimension Verification	513
14-8	Vertical Control	515
14-9	Cross Sections for Footing Excavations	516
	<i>Review Questions</i>	517
<b>15</b>	<b><i>Building Construction Surveys</i></b>	<b>518</b>
15-1	Building Construction: General Background	518
15-2	Single-Story Construction	518
15-3	Multistory Construction	530
	<i>Review Questions</i>	537