

Contents

Preface, *iii*

List of figures, *xv*

List of tables, *xviii*

Part I	The Engineering Profession	1
Chapter 1	An Introduction to Engineering	3
	1.1 What is an engineer? 3	
	1.2 The role of the engineer, 5	
	1.3 Engineering disciplines, 6	
	1.4 Engineers across Canada, 10	
	1.5 Canadian engineering achievements, 11	
	1.5.1 Sources related to Canadian engineering history, 13	
	1.6 Becoming a competent engineer, 13	
	1.7 Challenges for engineering, 15	
	1.8 Further study, 15	
	1.9 References, 18	
Chapter 2	The Licensed Professional Engineer	19
	2.1 Engineering is a profession, 20	
	2.2 Regulation of the engineering profession, 20	
	2.2.1 Case study of a critical event: The Québec Bridge tragedy, 21	
	2.2.2 The laws regulating engineering, 24	
	2.2.3 The legal definition of engineering, 26	
	2.3 Admission to the engineering profession, 27	
	2.3.1 Academic requirements, 27	
	2.3.2 Experience requirements, 29	
	2.3.3 The professional practice examination, 30	
	2.3.4 Offering engineering services to the public, 31	
	2.4 The purpose of provincial Associations, 31	
	2.5 Further study, 32	
	2.6 References, 34	

Chapter 3	Professional Engineering Ethics	35
3.1	Introduction to professional ethics, 35	
3.1.1	Ontario code of ethics, 36	
3.2	Ethics in the workplace, 38	
3.3	Professional misconduct and discipline, 40	
3.3.1	Definition of professional misconduct, 40	
3.4	Common professional complaints, 42	
3.4.1	Case studies in ethics, 42	
3.5	The professional use of computer programs, 45	
3.6	Proper use of the engineer's seal, 47	
3.7	The iron ring and the engineering oath, 48	
3.8	Further study, 48	
3.9	References, 52	
Chapter 4	Engineering Societies	53
4.1	The purpose of engineering societies, 53	
4.2	The history of engineering societies, 54	
4.3	The importance of engineering societies, 55	
4.4	The relationship of the engineer to laws and organizations, 56	
4.5	Choosing your engineering society, 57	
4.5.1	Canadian engineering societies, 58	
4.5.2	American and international engineering societies, 59	
4.6	Further study, 60	
4.7	References, 62	
Chapter 5	Advice on Studying, Exams, and Learning	63
5.1	The good and bad news about university studies, 63	
5.2	How much study time is required? 64	
5.3	Managing your time, 64	
5.4	Preparing for the start of lectures, 66	
5.5	Developing a note-taking strategy, 66	
5.6	A checklist of good study skills, 67	
5.7	Hints for assigned work, 68	
5.8	Preparing for examinations, 69	
5.9	Writing examinations, 70	
5.10	When things go wrong, 70	
5.11	Your professional career and lifelong learning, 71	
5.12	Further study, 72	
5.13	References, 74	

Part II	Engineering Communications	75
Chapter 6	Technical Documents	77
	6.1 Types of technical documents, 77	
	6.1.1 Letters, 77	
	6.1.2 Memos, 79	
	6.1.3 Email, 79	
	6.1.4 Specification documents, 81	
	6.1.5 Bids and proposals, 81	
	6.1.6 Reports, 82	
	6.2 Finding information, 85	
	6.3 Technical presentations, 87	
	6.3.1 Visual aids, 88	
	6.4 Further study, 90	
	6.5 References, 92	
Chapter 7	Technical Writing Basics	93
	7.1 The importance of clarity, 93	
	7.2 Hints for improving your writing style, 94	
	7.3 Punctuation: A basic summary, 97	
	7.4 The parts of speech: A basic summary, 98	
	7.5 Avoid these writing errors, 99	
	7.6 The Greek alphabet in technical writing, 100	
	7.7 Further study, 100	
	7.8 References, 104	
Chapter 8	Formal Technical Reports	105
	8.1 Components of a formal report, 106	
	8.1.1 The front matter, 106	
	8.1.2 The report body, 111	
	8.1.3 The back matter, 115	
	8.2 Steps in writing a technical report, 117	
	8.3 A checklist for engineering reports, 119	
	8.4 Further study, 121	
	8.5 References, 124	
Chapter 9	Report Graphics	125
	9.1 Graphics in engineering documents, 126	
	9.2 Standard formats for graphs, 126	
	9.2.1 Bar charts and others, 128	
	9.2.2 Straight-line graphs, 129	
	9.2.3 Logarithmic scales, 130	

- 9.3 Engineering calculations, 133
- 9.4 Sketches, 135
- 9.5 Further study, 137
- 9.6 References, 140

Part III	Engineering Measurements	141
Chapter 10	Measurements and Units	143
	10.1 Measurements, 143	
	10.2 Unit systems for engineering, 144	
	10.3 Writing quantities with units, 147	
	10.4 Basic and common units, 149	
	10.5 Unit algebra, 151	
	10.6 Further study, 152	
	10.7 References, 154	
Chapter 11	Measurement Error	155
	11.1 Measurements, uncertainty, and calibration, 155	
	11.2 Systematic and random errors, 156	
	11.2.1 Systematic errors, 156	
	11.2.2 Random errors, 157	
	11.3 Precision, accuracy, and bias, 157	
	11.4 Estimating measurement error, 158	
	11.5 How to write inexact quantities, 159	
	11.5.1 Explicit uncertainty notation, 159	
	11.5.2 Implicit uncertainty notation, 160	
	11.6 Significant digits, 160	
	11.6.1 Rounding numbers, 161	
	11.6.2 The effect of algebraic operations, 161	
	11.7 Further study, 164	
	11.8 References, 166	
Chapter 12	Error in Computed Quantities	167
	12.1 Method 1: Exact range of a calculated result, 167	
	12.2 Method 2: Linear estimate of the error range, 169	
	12.2.1 Sensitivities, 170	
	12.2.2 Relative sensitivities, 172	
	12.2.3 Approximate error range, 173	
	12.2.4 Application of Method 2 to algebraic functions, 174	
	12.3 Method 3: Estimated uncertainty, 176	
	12.3.1 Derivation of the estimated value, 178	
	12.4 Further study, 179	

12.5 References, 182

Chapter 13	Basic Statistics	183
	13.1 Definitions and examples, 183	
	13.2 Presentation of measured data: The histogram, 186	
	13.3 Measures of central value, 187	
	13.4 Measures of spread, 191	
	13.5 Measures of relative standing, 193	
	13.6 Further study, 195	
	13.7 References, 196	
Chapter 14	Gaussian Law of Errors	197
	14.1 Conditions for applying the Gaussian model, 198	
	14.2 Properties of the Gaussian distribution function, 201	
	14.2.1 Probability intervals, 201	
	14.3 Fitting a Gaussian curve to sample data, 203	
	14.4 Least squares, 205	
	14.4.1 Optimality of the sample mean, 205	
	14.4.2 The best straight line, 206	
	14.4.3 Correlation coefficient, 208	
	14.5 Rejection of an outlying point, 210	
	14.5.1 Standard deviation test, 210	
	14.6 Further study, 211	
	14.7 References, 212	
Part IV	Engineering Practice	213
Chapter 15	Fundamentals of Engineering Design	215
	15.1 Defining engineering design, 216	
	15.1.1 Types of engineering design, 216	
	15.2 Characteristics of good design practice, 217	
	15.2.1 Design heuristics, guidelines, standards, and specifications, 219	
	15.3 The engineering design process, 220	
	15.4 Design skills, 222	
	15.4.1 Clearly defining the problem, 223	
	15.4.2 Generating solutions, 223	
	15.4.3 Building models, simulations, and prototypes, 224	
	15.5 Systematic decision-making, 225	
	15.5.1 Computational decision-making, 225	
	15.6 A tale of two design solutions, 227	
	15.6.1 The requirement, 228	
	15.6.2 Feasibility cycle, 228	

- 15.6.3 Preliminary and detailed design cycles, 229
- 15.6.4 Final design solutions, 230
- 15.7 Design documentation, 230
- 15.8 System life cycle, 233
- 15.9 Organizing effective design teams, 234
 - 15.9.1 Becoming a design engineer, 235
- 15.10 Further study, 235
- 15.11 References, 238

Chapter 16**The Engineer in Business****239**

- 16.1 Business organizations, 239
 - 16.1.1 Legal business structures, 240
- 16.2 The individual in corporate culture, 242
- 16.3 Starting or joining a small company, 243
 - 16.3.1 The business plan, 243
 - 16.3.2 Getting advice, 245
- 16.4 Further study, 245
- 16.5 References, 246

Chapter 17**Intellectual Property****247**

- 17.1 Introduction, 247
 - 17.1.1 Proprietary intellectual property, 248
 - 17.1.2 The public domain, 248
- 17.2 The importance of intellectual property, 250
 - 17.2.1 Rights of employers and employees, 251
- 17.3 Copyright, 251
 - 17.3.1 Copyright registration, 252
 - 17.3.2 Fair dealing, 252
 - 17.3.3 Copyright and computer programs, 253
- 17.4 Patents, 253
 - 17.4.1 The patent application process, 255
- 17.5 Industrial designs, 256
- 17.6 Trademarks, 257
- 17.7 Integrated circuit topographies, 259
- 17.8 Trade secrets, 259
- 17.9 Further study, 259
- 17.10 References, 262

Chapter 18**Project Planning and Scheduling****263**

- 18.1 Gantt charts and the critical-path method, 263
- 18.2 Planning with CPM, 264
- 18.3 Scheduling with CPM, 267
- 18.4 Refinement of CPM, 269

- 18.5 Summary of steps in CPM, 270
- 18.6 Further study, 271
- 18.7 References, 272

Chapter 19**Safety in Engineering Design****273**

- 19.1 Responsibility of the design engineer, 273
- 19.2 Principles of hazard recognition and control, 274
- 19.3 Eliminating workplace hazards, 277
- 19.4 Cost-benefit justification of safety issues, 279
- 19.5 Codes and standards, 280
 - 19.5.1 Finding and using safety codes and standards, 281
- 19.6 Further study, 282
- 19.7 References, 286

Chapter 20**Safety, Risk, and the Engineer****287**

- 20.1 Evaluating risk in design, 287
- 20.2 Risk management, 287
- 20.3 Analytical methods, 288
 - 20.3.1 Checklists, 289
 - 20.3.2 Hazard and operability studies, 289
 - 20.3.3 Failure modes and effects analysis, 290
 - 20.3.4 Fault-tree analysis, 291
- 20.4 Safety in large systems, 293
- 20.5 System risk, 294
- 20.6 Expressing the costs of a hazard, 295
- 20.7 Further study, 296
- 20.8 References, 298

Appendix**Answers to Quick Quiz and selected Further Study questions****299**

- Chapter 1, 299
- Chapter 2, 299
- Chapter 3, 299
- Chapter 4, 299
- Chapter 5, 299
- Chapter 6, 299
- Chapter 7, 299
- Chapter 8, 300
- Chapter 9, 300
- Chapter 10, 301
- Chapter 11, 302
- Chapter 12, 302
- Chapter 13, 304
- Chapter 14, 304

Chapter 15, 304

Chapter 16, 304

Chapter 17, 304

Chapter 18, 305

Chapter 19, 305

Chapter 20, 305

Index, 307

List of figures

- I.1 The Canadarm, 1
- 1.1 The iron ring, 3
- 1.2 Names of accredited Canadian engineering programs, 7
- 1.3 Our dependence on electric power, 15
- 2.1 The collapse of the Québec Bridge, 19
- 2.2 A typical engineering licence, 25
- 2.3 The steps to take to become an engineer through an accredited program, 28
- 3.1 A typical professional engineer's seal, 47
- 4.1 A Formula SAE race, 53
- 4.2 The relationship of the licensed engineer to engineering organizations, 56
- 5.1 A large university lecture hall, 63
- II.1 A flowchart of a manufacturing process, 75
- 6.1 An antique typewriter, 77
- 6.2 The format of a typical business letter, 78
- 6.3 A typical memo, 80
- 6.4 Draft illustrations for a talk on the status of a small design project, 89
- 7.1 Part of an entry from a thesaurus, 93
- 7.2 A general-purpose latch, 94
- 8.1 A well-produced technical report makes a subtle statement, 105
- 8.2 A typical company report cover, 108
- 9.1 Napoleon's campaign in Russia, 125
- 9.2 The standard format for graphs, 127
- 9.3 A bar chart and a pie chart comparing six quantities, 128
- 9.4 A straight-line function, 129
- 9.5 Moore's law, 130

- 9.6 A graph with linear scales and a log-linear plot of a decaying exponential, 131
- 9.7 A power function produces a straight line on a log-log plot, 132
- 9.8 A standard format for engineering calculations, 134
- 9.9 A sketch conveys essential details informally, 135
- 9.10 Standard letters for sketches and draft diagrams, 136
- 9.11 Typical views used in sketches, 137
- 9.12 Lines used for sketching, 137

- III.1 A railroad transit from the Bausch & Lomb 1908 Catalog of Engineering Instruments, 141

- 10.1 Ancient measurement standards, 143
- 10.2 A written quantity, 148

- 11.1 A modern vernier caliper, 155
- 11.2 True value, measured estimate, and interval of uncertainty, 156
- 11.3 Precision, bias, and accuracy, 158

- 12.1 Computing the extremes of a function over an interval, 169
- 12.2 The change in $f(x)$ is approximately the slope of f at x_0 multiplied by the deviation Δx , 170
- 12.3 The surface $f(x, y)$, with a tangent plane at (x_0, y_0, f_0) , 171
- 12.4 Graphs of Δx_k , Δy_k , the squared quantities, and the products $\Delta x_k \Delta y_k$, 179

- 13.1 Language test mark distribution for all tests, 185
- 13.2 Sample and parent distribution functions of ball bearing diameters, 186
- 13.3 The effect of bin size on a histogram, 187
- 13.4 The distribution of salaries in a small company, 190
- 13.5 Example distribution functions, 191
- 13.6 Salaries of survey respondents in the year 2003, 194

- 14.1 The Gaussian (or normal) distribution function with mean μ and standard deviation σ , 197
- 14.2 Probability mass and density functions, 198
- 14.3 The occurrences of heads in n coin flips, 200
- 14.4 Interval probabilities for the Gaussian distribution, 202
- 14.5 Observations from 662 paper clips fatigue-tested to failure, 204
- 14.6 Fuel consumption of a group of new vehicles, 207
- 14.7 A nonlinear transformation changes the relative size of error ranges, 208
- 14.8 Three cases where a straight-line fit is suspect, 209

- IV.1 A construction site, 213

- 15.1 Design of a solar car involves collaboration, 215
- 15.2 Criteria, requirements, and constraints, 217
- 15.3 A trial design for a power-on indicator light, 220
- 15.4 The spiral approach to design, 221
- 15.5 A typical waterfall design, 222
- 15.6 Two different proposed solutions to a design problem, 229
- 15.7 Formats for a design logbook, 233
- 15.8 A typical system design life cycle, 234

- 16.1 The engineer in business, 239

- 17.1 Microchip humour, 247
- 17.2 A self-congratulatory apparatus, 254
- 17.3 Certification marks from the CIPO database, 257

- 18.1 A basic Gantt chart for a design project, 263
- 18.2 Activities and events in an arrow diagram, 265
- 18.3 A one-operator tire purchase, 266
- 18.4 A large-store tire purchase, 266
- 18.5 The improved procedure, 266
- 18.6 The format for an event circle, 267
- 18.7 The schedule for one operator, from Figure 18.3, 268
- 18.8 The schedule for the large store, from Figure 18.4, 268
- 18.9 The improved procedure, from Figure 18.5, 269
- 18.10 Gantt chart for the improved procedure of Figure 18.9, 270

- 19.1 Examples of standard hazard signs, 277

- 20.1 Partial fault tree for the hair dryer in Example 20.2, 292
- 20.2 Illustrating lines of constant risk, 295
- 20.3 Compressed-air supply unit, 298

List of tables

- 1.1 Distribution of engineers in Canada by province and territory, *10*
- 2.1 The provincial and territorial Associations that regulate the engineering profession, *24*
- 4.1 Major Canadian engineering societies, *58*
- 4.2 Major American and international engineering societies, *60*
- 6.1 Components of a typical laboratory report, *84*
- 6.2 Technology subcategories in the Library of Congress classification, *86*
- 7.1 Tenses for the verb *to* see in both active and passive voice, *96*
- 7.2 The Greek alphabet, showing English equivalents, *100*
- 8.1 Physical components of a formal report, *107*
- 10.1 Base and derived SI units, *146*
- 10.2 Comparison of unit systems, *147*
- 10.3 Magnitude prefixes in the SI unit system by symbol, name, and numerical value, *149*
- 11.1 Significant digits appended to the mean of n measurements, *164*
- 13.1 Examples of description and inference, *184*
- 13.2 Mark occurrences and relative frequencies for past language tests, *185*
- 15.1 Cost computation for the student-travel problem, *227*
- 17.1 Type, criteria for protection, and term intellectual property is protected, *249*
- 18.1 Activities for the sale and installation of winter tires, *265*
- 19.1 Examples of hazard-control methods, *275*
- 19.2 Hazard checklist for machine design, *278*
- 19.3 Hazard checklist for workplace layout, *279*