CONTENTS

CONTENTS **3**

1 OVERVIEW **8**

1.1 Preface 8
1.2 Acknowledgements 8
1.3 Role of Mechanics of Materials, Solid Mechanics and Strength of Materials in Design 8

2 LOADING **20**

2.1 Force 20
Example 2.1 22
2.2 Gravitation 23
2.3 Loading 25
Example 2.2 27
Example 2.3 28

3 TENSION AND COMPRESSION **29**

3.1 Introduction 29
3.2 Direct or Normal Stress (σ) 30
3.3 Direct or Normal Strain (ε) 30
3.4 Sign Convention for Direct Stress and Strain 31
3.5 Saint-Vénant's Principle 31
3.6 Elastic materials - Hooke's Law for Direct Stress and Strain 33
3.7 Modulus of Elasticity - Young's Modulus (E) for Direct Stress and Strain 35
3.8 Tensile Test 37
3.9 Ductile Materials 40
3.10 Brittle Materials 41
3.11 Hyper-Elastic Materials (Elastomers) and Cellular Materials 41
3.12 Normal Forces (N.F.) (N) 42
3.13 Reactions 43
Example 3.1 43
3.14 Stress, Strain and Elongation in Pure Tension or Compression 44
3.15 Temperature Stresses, Strains and Elongations 46
3.16 Gravity Load in Axial Direction 48
Example 3.2 48
3.17 Poisson's Ratio (μ) 50
3.18 Application of Poisson's Ratio to a Two-Dimensional Stress System 52
3.19 Volume Change 53
3.20 Strain Energy 53

3.21 Allowable Working Stress ($\sigma_{ALLOWABLE}$) - Factor of Safety 55
3.22 Stress Concentrations 57
3.23 Stress-Concentration Factors (α_σ) in Pure Tension or Compression 58
Example 3.3 59
Example 3.4 60
Example 3.5 62
3.24 Trusses 63
3.25 Ideal Plane Trusses 65
Example 3.6 66
3.26 Castigliano's Theorem in Pure Tension or Compression 68
Example 3.7 69
3.27 Theory of 1st and 2nd Order for Small Deformations 70
3.28 Examples 72
Example 3.8 72
Example 3.9 75
Example 3.10 78
Example 3.11 80
Example 3.12 82
Example 3.13 85
Example 3.14 87
Example 3.15 90
Example 3.16 91
Example 3.17 94
Example 3.18 96
Example 3.19 98

4 SHEAR **100**

4.1 Introduction 100
4.2 Shear Stress (τ) 100
4.3 Shear Strain (γ) 101
4.4 Modulus of Rigidity - Shear Modulus (G) - Hooke's Law 101
4.5 Allowable Working Stress ($\tau_{ALLOWABLE}$) - Factor of Safety 102
4.6 Examples 103
Example 4.1 103

5 SHEARING FORCE, BENDING MOMENT DIAGRAMS **105**

5.1 Introduction and Summary 105
5.2 Beams 106
5.3 Supports 109
5.4 Reactions 111
Example 5.1 111

	Example 5.2	112
	Example 5.3	112
	Example 5.4	113
5.5	Shearing Force (S.F., T) and Bending Moment (B.M., M_o)	113
5.6	(S.F.) Sign Convention	115
5.7	(B.M.) Sign Convention	115
5.8	(S.F.) and (B.M.) Diagrams	116
5.9	(S.F.) and (B.M.) Diagrams for Cantilever Beams	116
	Example 5.5	116
	Example 5.6	117
5.10	(S.F.) and (B.M.) Diagrams for Simple Supported Beams	119
	Example 5.7	119
	Example 5.8	121
	Example 5.9	122
5.11	Relationship between (S.F.), (B.M.) and Intensities q and m	123
5.12	Gerber-Girder (Continuous Beam Divided by Pin-Joints)	126
5.13	Examples	127
	Example 5.10	127
	Example 5.11	132
	Example 5.12	132
	Example 5.13	133
	Example 5.14	134
	Example 5.15	135
	Example 5.16	135
	Example 5.17	137
	Example 5.18	139
	Example 5.19	139
	Example 5.20	140
6	**SIMPLE BENDING OF STRAIGHT BEAMS**	**141**
6.1	Introduction and Summary	141
6.2	Bending	151
6.3	Centroid and First Moment of Plane Area	151
	Example 6.1	153
6.4	Simple Bending (Euler-Bernoulli) Theory	154
6.5	Neutral Axis (N.A.)	157
6.6	Maximal Stress, Section Modulus (W_o)and Allowable Working Stress	159
6.7	Second Moments (J_Z) and Product Moments (J_{YZ}) of Areas	160
	Example 6.2	161
	Example 6.3	162
	Example 6.4	163

	Example 6.5	163
6.8	Parallel Axis Theorem	164
	Example 6.6	165
6.9	Principal Second Moments of Areas	167
	Example 6.7	170
6.10	Strain Energy in Simple Bending	173
6.11	Stress-Concentrations in Bending	174
6.12	Stress-Concentration Factors (α_σ) in Bending	174
	Example 6.8	176
6.13	Examples	178
	Example 6.9	172
	Example 6.10	179
7	**SLOPE AND DEFLECTION OF STRAIGHT BEAMS**	**181**
7.1	Introduction and Summary	181
7.2	Deflection (v), Slope (φ) and Allowable Working Deflection ($v_{ALLOWABLE}$)	183
7.3	Relationship between Slope, Deflection and Curvature of Beams	183
7.4	Differential Equations for Deflection of Beams	185
7.5	Direct integration Method	187
	Example 7.1	189
	Example 7.2	191
	Example 7.3	194
	Example 7.4	195
7.6	Direct Integration Method Applied for Statically Indeterminate Beams	199
	Example 7.5	200
7.7	Principle of Superposition	203
	Example 7.6	204
7.8	Maxwell's Theorems of Reciprocal Displacements	205
	Example 7.7	208
7.9	Energy methods	209
7.10	Castigliano's Theorems	210
7.11	Castigliano's First Theorem for Deflection of Beams	210
	Example 7.8	214
7.12	Castigliano's Second Theorem for Slope of Beams	215
	Example 7.9	215
7.13	Use of Fictitious Force and Fictitious Moment in the Castigliano's Theorems	216
	Example 7.10	217
7.14	Castiglano's Theorems Applied for Statically Indeterminate Beams	219
	Example 7.11	219
	Example 7.12	221
7.15	Examples	223
	Example 7.13	223

	Example 7.14	224
	Example 7.15	225
	Example 7.16	226
8	**TORSION OF CIRCULAR SHAFTS**	**229**
8.1	Introduction and Summary	229
8.2	Torsion Test	231
8.3	Simple Torsion Theory	235
8.4	Twisting angle (ϕ)	235
8.5	Shear stresses (τ)	237
8.6	Polar Second Moment of Area (J_k)	238
8.7	Shear Stress and Shear Strain in Circular Shafts	239
8.8	Polar Section Modulus (W_k)	240
8.9	Relative Angle of Twist and Torsional Rigidity	241
8.10	Strain Energy in Torsion	241
8.11	Allowable Working Stress ($\tau_{ALLOWABLE}$), Allowable Working Angle of Twist ($\varphi_{ALLOWABLE}$) and Factor of Safety	242
8.12	Torsion of Hollow Shafts	242
	Example 8.1	243
8.13	Composite Shafts - Series Connection	244
	Example 8.2	244
8.14	Composite Shafts - Parallel Connection	245
	Example 8.3	245
8.15	Castigliano's Theorem for Angle of Twist in Torsion	246
	Example 8.4	246
9	**APPENDIX**	**249**
9.1	Solution of the Supported Beam via FEM Software ANSYS	249
9.2	Printout of the Programme (for ANSYS Software)	250
9.3	Calculation of Maximal Bending Stress (Probabilistic Assessment) via AntHill Software	251
9.4	Printout of the Programme (for AntHill Software)	254
9.5	English Czech Dictionary (Basic Words Used in this Book)	256
	REFERENCES	**260**