
TABLE OF CONTENTS

Preface	xiii
1 Introduction	1
1.1 Engineering and Statics	1
1.2 A Brief History of Statics	3
Galileo Galilei (1564–1642) 4	
Isaac Newton (1643–1727) 4	
1.3 Fundamental Principles	5
Newton’s laws of motion 7	
1.4 Force	8
1.5 Units and Unit Conversions	9
Dimensional homogeneity and unit conversions 9	
Prefixes 10	
Angular measure 11	
Accuracy of calculations 12	
1.6 Newton’s Law of Gravitation	15
Relationship between specific weight and density 16	
1.7 Failure	20
1.8 Chapter Review	22
2 Vectors: Force and Position	27
2.1 Basic Concepts	27
Introduction—force, position, vectors, and tides 27	
Denoting vectors in figures 29	
Basic vector operations 30	
Performing vector operations 32	
Resolution of a vector into vector components 33	
2.2 Cartesian Representation of Vectors in Two Dimensions	44
Introduction—Cartesian representation and a walk to work 44	
Unit vectors 44	
Cartesian coordinate system 45	
Cartesian vector representation 45	
Addition of vectors using Cartesian components 47	
Position vectors 48	
2.3 Cartesian Representation of Vectors in Three Dimensions ...	60
Right-hand Cartesian coordinate system 60	
Cartesian vector representation 60	

	Direction angles and direction cosines	60
	Position vectors	61
	Use of position vectors to write expressions for force vectors	62
	Some simple structural members	62
2.4	Vector Dot Product	76
	Dot product using Cartesian components	77
	Determination of the angle between two vectors	78
	Determination of the component of a vector in a particular direction	78
	Determination of the component of a vector perpendicular to a direction	79
2.5	Vector Cross Product	91
	Cross product using Cartesian components	92
	Evaluation of cross product using determinants	93
	Determination of the normal direction to a plane	95
	Determination of the area of a parallelogram	95
	Scalar triple product	95
2.6	Chapter Review	104
3	Equilibrium of Particles	111
3.1	Equilibrium of Particles in Two Dimensions	111
	Free body diagram (FBD)	112
	Modeling and problem solving	116
	Cables and bars	117
	Pulleys	119
	Reactions	120
3.2	Behavior of Cables, Bars, and Springs	135
	Equilibrium geometry of a structure	135
	Cables	135
	Bars	136
	Modeling idealizations and solution of $\sum \vec{F} = \vec{0}$	136
	Springs	136
3.3	Equilibrium of Particles in Three Dimensions	148
	Reactions	148
	Solution of algebraic equations	148
	Summing forces in directions other than x , y , or z	150
3.4	Engineering Design	161
	Objectives of design	161
	Particle equilibrium design problems	162
3.5	Chapter Review	175
4	Moment of a Force and Equivalent Force Systems	181
4.1	Moment of a Force	181
	Scalar approach	182
	Vector approach	183
	Varignon's theorem	185
	Which approach should I use: scalar or vector?	186

4.2	Moment of a Force About a Line	198
	Vector approach	198
	Scalar approach	199
4.3	Moment of a Couple	208
	Vector approach	209
	Scalar approach	209
	Comments on the moment of a couple	209
	Equivalent couples	210
	Equivalent force systems	211
	Resultant couple moment	211
	Moments as free vectors	211
4.4	Equivalent Force Systems	221
	Transmissibility of a force	221
	Equivalent force systems	222
	Some special force systems	224
	Wrench equivalent force systems	225
	Why are equivalent force systems called <i>equivalent</i> ?	226
4.5	Chapter Review	238
5	Equilibrium of Bodies	245
5.1	Equations of Equilibrium	245
5.2	Equilibrium of Rigid Bodies in Two Dimensions	246
	Reactions	246
	Free body diagram (FBD)	248
	Alternative equilibrium equations	250
	Gears	251
	Examples of correct FBDs	252
	Examples of incorrect and/or incomplete FBDs	252
5.3	Equilibrium of Bodies in Two Dimensions—Additional Topics	270
	Why are bodies assumed to be rigid?	270
	Treatment of cables and pulleys	270
	Springs	271
	Superposition	272
	Supports and fixity	273
	Static determinacy and indeterminacy	274
	Two-force and three-force members	276
5.4	Equilibrium of Bodies in Three Dimensions	292
	Reactions	292
	More on bearings	292
	Scalar approach or vector approach?	294
	Solution of algebraic equations	295
	Examples of correct FBDs	295
	Examples of incorrect and/or incomplete FBDs	297
5.5	Engineering Design	312
	Codes and standards	314
	Design problems	315
5.6	Chapter Review	321

6	Structural Analysis and Machines	329
6.1	Truss Structures and the Method of Joints	329
	When may a structure be idealized as a truss? 331	
	Method of joints 331	
	Zero-force members 333	
	Typical truss members 335	
6.2	Truss Structures and the Method of Sections	346
	Treatment of forces that are not at joints 348	
	Static determinacy and indeterminacy 349	
	Design considerations 351	
6.3	Trusses in Three Dimensions	363
	Stability of space trusses and design considerations 364	
6.4	Frames and Machines	372
	Analysis procedure and free body diagrams (FBDs) 372	
	Examples of correct FBDs 373	
	Examples of incorrect and/or incomplete FBDs 375	
6.5	Chapter Review	388
7	Centroids and Distributed Force Systems	395
7.1	Centroid	395
	Introduction – center of gravity 395	
	Centroid of an area 397	
	Centroid of a line 397	
	Centroid of a volume 398	
	Unification of concepts 399	
	Which approach should I use: composite shapes or integration? 399	
	Finer points: surfaces and lines in three dimensions 400	
7.2	Center of Mass and Center of Gravity	413
	Center of mass 413	
	Center of gravity 414	
7.3	Theorems of Pappus and Guldinus	425
	Area of a surface of revolution 425	
	Volume of a solid of revolution 426	
	Proof of the Pappus–Guldinus theorems 426	
7.4	Distributed Forces, Fluid and Gas Pressure Loading	432
	Distributed forces 432	
	Distributed forces applied to beams 432	
	Fluid and gas pressure 433	
	Forces produced by fluids 435	
	Forces produced by gases 437	
7.5	Chapter Review	450

8	Internal Forces	457
8.1	Internal Forces in Structural Members	457
	Why are internal forces important? 457	
	Internal forces for slender members in two dimensions 458	
	Internal forces for slender members in three dimensions 459	
	Determination of internal forces 459	
8.2	Internal Forces in Straight Beams	467
	Determination of V and M using equilibrium 467	
	Shear and moment diagrams 467	
8.3	Relations Among Shear, Moment, and Distributed Force ...	478
	Relations among V , M , and w 478	
	Determination of V and M using integration 479	
	Which approach should I use? 480	
	Tips and shortcuts for drawing shear and moment diagrams 481	
	Design considerations 482	
8.4	Chapter Review	491
9	Friction	497
9.1	Basic Concepts	497
	A brief history of tribology 497	
	A simple experiment 498	
	Coulomb's law of friction 499	
	Coefficients of friction 499	
	Dry contact versus liquid lubrication 501	
	Angle of friction 501	
	Problems with multiple contact surfaces 501	
	Wedges 502	
	Coulomb's law of friction in three dimensions 502	
	Design considerations 502	
9.2	Problems with Multiple Contact Surfaces	513
	Determination of sliding directions 513	
9.3	Belts and Cables Contacting Cylindrical Surfaces	521
	Equilibrium analysis 521	
9.4	Chapter Review	529
10	Moments of Inertia	533
10.1	Area Moments of Inertia	533
	An example—test scores 533	
	An example—beam loading 534	
	Definition of area moments of inertia 534	
	What are moments of inertia used for? 535	
	Radius of gyration 536	
	Evaluation of moments of inertia using integration 537	

10.2	Parallel Axis Theorem	545
	Use of parallel axis theorem in integration	546
	Use of parallel axis theorem for composite shapes	546
10.3	Mass Moments of Inertia	553
	An example—figure skating	553
	Definition of mass moments of inertia	553
	What are mass moments of inertia used for?	554
	Radius of gyration	555
	Parallel axis theorem	555
	Evaluation of moments of inertia using integration	556
	Evaluation of moments of inertia using composite shapes	557
10.4	Chapter Review	572
A	Technical Writing	579
B	Answers to Selected Problems	583
	Credits	585
	Index	587