Contents

PREFACE xi

TO THE STUDENT xxiii

CALCULATORS, COMPUTERS, AND OTHER GRAPHING DEVICES xxiv

DIAGNOSTIC TESTS xxvi

A Preview of Calculus 1

1 Functions and Limits

9



- 1.1 Four Ways to Represent a Function 10
- 1.2 Mathematical Models: A Catalog of Essential Functions 23
- 1.3 New Functions from Old Functions 36
- 1.4 The Tangent and Velocity Problems 45
- 1.5 The Limit of a Function 50
- 1.6 Calculating Limits Using the Limit Laws 62
- 1.7 The Precise Definition of a Limit 72
- **1.8** Continuity 82

Review 94

Principles of Problem Solving 98

2 Derivatives

105



- 2.1 Derivatives and Rates of Change 106
 Writing Project Early Methods for Finding Tangents 117
- 2.2 The Derivative as a Function 117
- 2.3 Differentiation Formulas 130Applied Project Building a Better Roller Coaster 144
- 2.4 Derivatives of Trigonometric Functions 144
- 2.5 The Chain Rule 152Applied Project Where Should a Pilot Start Descent? 161
- 2.6 Implicit Differentiation 161
 Laboratory Project Families of Implicit Curves 168

2.7

2.9

Related Rates 181

Review 195

Problems Plus 200

Julia Mil	Applications	s of Differentiation
41	3.1 Maximum a	and Minimum Values 204
West	Applied P	Project • The Calculus of Rainbows 213
	3.2 The Mean V	alue Theorem 215
	3.3 How Deriva	tives Affect the Shape of a Graph 221
	3.4 Limits at Inf	finity; Horizontal Asymptotes 231
5	3.5 Summary o	f Curve Sketching 244
ADDRESS OF THE OWNER, THE PARTY OF THE PARTY	3.6 Graphing w	rith Calculus and Calculators 251
	3.7 Optimization	on Problems 258
	Applied F	Project • The Shape of a Can 270
	Applied F	Project • Planes and Birds: Minimizing Energy 271
	3.8 Newton's M	lethod 272
	3.9 Antiderivat	ives 278
	J. Milliactivat	1103 270
	Review 28	5
		5
4	Review 28	5
4	Review 28. Problems Plus 28 Integrals	5 80 wawall 80 wawall 80 80 wakan Ara-algamini
4	Review 28. Problems Plus 28 Integrals 4.1 Areas and 0	5 89 Distances 294
4	Review 28. Problems Plus 28. Integrals 4.1 Areas and I. 4.2 The Definit	Distances 294 e Integral 306
4	Review 28. Problems Plus 28. Integrals 4.1 Areas and I 4.2 The Definit Discovery	Distances 294 re Integral 306 ry Project • Area Functions 319
4	Review 28. Problems Plus 28. Integrals 4.1 Areas and 6 4.2 The Definit Discovery 4.3 The Fundar	Distances 294 re Integral 306 y Project • Area Functions 319 mental Theorem of Calculus 320
4	Review 28. Problems Plus 28. Integrals 4.1 Areas and I. 4.2 The Definit Discovery 4.3 The Fundar 4.4 Indefinite I.	Distances 294 The Integral 306 The Project • Area Functions 319 The Integral Theorem of Calculus 320 The Integrals and the Net Change Theorem 330
4	Review 28. Problems Plus 28. Integrals 4.1 Areas and I. 4.2 The Definit Discovery 4.3 The Fundar 4.4 Indefinite I. Writing F	Distances 294 The Integral 306 The Project • Area Functions 319 The Integral 306 The Project • Newton, Leibniz, and the Invention of Calculus 320
4	Review 28. Problems Plus 28. Integrals 4.1 Areas and I. 4.2 The Definit Discovery 4.3 The Fundar 4.4 Indefinite I. Writing F	Distances 294 The Integral 306 The Project • Area Functions 319 The Integral Theorem of Calculus 320 The Integrals and the Net Change Theorem 330
4	Review 28. Problems Plus 28. Integrals 4.1 Areas and I. 4.2 The Definit Discovery 4.3 The Fundar 4.4 Indefinite I. Writing F	Distances 294 The Integral 306 The Project • Area Functions 319 The Integral Theorem of Calculus 320 The Integrals and the Net Change Theorem 330 Theorem • Newton, Leibniz, and the Invention of Calculus 339 Theorem 1340

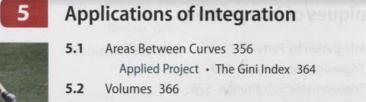
Rates of Change in the Natural and Social Sciences 169

203

293

Linear Approximations and Differentials 188

Laboratory Project • Taylor Polynomials 194



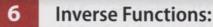
5.3 Volumes by Cylindrical Shells 377

5.4 Work 383

Applied Project • Calculus and Baseball 392

Review 393

Problems Plus 395



Exponential, Logarithmic, and Inverse Trigonometric Functions

6.1 Inverse Functions 400

Problems Pros 73.0

Instructors may cover either Sections 6.2–6.4 or Sections 6.2*–6.4*. See the Preface.



6.2	Their Derivatives 408	6.2*	Function 438
6.3	Logarithmic Functions 421	6.3*	The Natural Exponential Function 447
6.4	Derivatives of Logarithmic Functions 428	6.4*	General Logarithmic and Exponential Functions 455

6.5 Exponential Growth and Decay 466
Applied Project • Controlling Red Blood Cell Loss During Surgery 473

6.6 Inverse Trigonometric Functions 474

Applied Project • Where to Sit at the Movies 483

6.7 Hyperbolic Functions 484

6.8 Indeterminate Forms and l'Hospital's Rule 491
Writing Project • The Origins of l'Hospital's Rule 503

Review 503

Problems Plus 508

355

399

288 / 7	Techniques of Integration	511
	 7.1 Integration by Parts 512 7.2 Trigonometric Integrals 519 7.3 Trigonometric Substitution 526 7.4 Integration of Rational Functions by Partial Fractions 533 7.5 Strategy for Integration 543 7.6 Integration Using Tables and Computer Algebra Systems 548 Discovery Project • Patterns in Integrals 553 7.7 Approximate Integration 554 7.8 Improper Integrals 567 	
	Review 577 Problems Plus 580	
8	Further Applications of Integration	583
	8.1 Arc Length 584 Discovery Project • Arc Length Contest 590	
	 8.2 Area of a Surface of Revolution 591 Discovery Project • Rotating on a Slant 597 8.3 Applications to Physics and Engineering 598 	
	Discovery Project • Complementary Coffee Cups 608 8.4 Applications to Economics and Biology 609	
Jr. 102 2	8.5 Probability 613	
	Review 621 Problems Plus 623	
	Applied Project - Controlling Red II and Cell Loss During St.	
9	Differential Equations	625
The second secon	9.1 Modeling with Differential Equations 6269.2 Direction Fields and Euler's Method 631	
	9.3 Separable Equations 639 Applied Project • How Fast Does a Tank Drain? 648 Applied Project • Which Is Faster, Going Up or Coming Down?	649
1	9.4 Models for Population Growth 650	
4	9.5 Linear Equations 660	

		Review 674	1
	Proble	ms Plus 677	
10	Para	metric Equations and Polar Coordinates	679
	10.1	Curves Defined by Parametric Equations 680 Laboratory Project • Running Circles Around Circles 688	
	10.2	Calculus with Parametric Curves 689 Laboratory Project • Bézier Curves 697	
	10.3	Polar Coordinates 698 Laboratory Project • Families of Polar Curves 708	
	10.4	Areas and Lengths in Polar Coordinates 709	
	10.5	Conic Sections 714	
	10.6	Conic Sections in Polar Coordinates 722	
		Review 729	
	Droblo	ems Plus 732	
	Flobie	HIS Flus 732	
11	Infin	ite Sequences and Series	733
	11.1	Sequences 734 Laboratory Project • Logistic Sequences 747	
	11.2	Series 747	
	11.3	The Integral Test and Estimates of Sums 759	
	11.4	The Comparison Tests 767	
	11.5	Alternating Series 772	
	11.6	Absolute Convergence and the Ratio and Root Tests 777	
	11.7	Strategy for Testing Series 784	
	11.8	Power Series 786	
	11.9	Representations of Functions as Power Series 792	
	11.10	Taylor and Maclaurin Series 799	
		Laboratory Project • An Elusive Limit 813	
		Writing Project • How Newton Discovered the Binomial Series 813	
	11.11	Applications of Taylor Polynomials 814	
		Applied Project • Radiation from the Stars 823	
		Review 824	
	Proble	ems Plus 827	

Predator-Prey Systems 667

9.6

12	Vectors and the Geometry of Space	831
	12.1 Three-Dimensional Coordinate Systems 832	
	12.2 Vectors 838	
	12.3 The Dot Product 847	
	12.4 The Cross Product 854	
	Discovery Project • The Geometry of a Tetrahedron 863	
W Made and a second	12.5 Equations of Lines and Planes 863	
	Laboratory Project • Putting 3D in Perspective 873	
	12.6 Cylinders and Quadric Surfaces 874	
	Review 881	
	Problems Plus 884	
_	10.4 Areas and Lengths in Polar Coordinates 708	
13	Vector Functions	887
	13.1 Vector Functions and Space Curves 888	
	13.2 Derivatives and Integrals of Vector Functions 895	
A A	13.3 Arc Length and Curvature 901	
	13.4 Motion in Space: Velocity and Acceleration 910	
and the same	Applied Project • Kepler's Laws 920	
	Review 921	
	Problems Plus 924	
	The Company of the Co	
14	Partial Derivatives	927
	Tay steril 822 1 No. aleni nigeraquina Art 2444	
A	14.1 Functions of Several Variables 928	
Fig.	14.2 Limits and Continuity 943	
Di	14.3 Partial Derivatives 951	
65	14.4 Tangent Planes and Linear Approximations 967	
48	Applied Project • The Speedo LZR Racer 976	
	14.5 The Chain Rule 977	
	14.6 Directional Derivatives and the Gradient Vector 986	
	14.7 Maximum and Minimum Values 999	
	Applied Project • Designing a Dumpster 1010	10.1.1.1010
1	Discovery Project • Quadratic Approximations and Critical	al Points 1010

15	Mult	riple Integrals	1027
	15.1	Double Integrals over Rectangles 1028	
- XA	15.2	Double Integrals over General Regions 1041	
A A	15.3	Double Integrals in Polar Coordinates 1050	
Jan	15.4	Applications of Double Integrals 1056	
AGA TO	15.5	Surface Area 1066	
	15.6	Triple Integrals 1069	
		Discovery Project • Volumes of Hyperspheres 1080	
	15.7	Triple Integrals in Cylindrical Coordinates 1080	
		Discovery Project • The Intersection of Three Cylinders 1084	
	15.8	Triple Integrals in Spherical Coordinates 1085	
		Applied Project • Roller Derby 1092	
	15.9	Change of Variables in Multiple Integrals 1092	
		Review 1101	
	Proble	ems Plus 1105	
	riobic	n verte best for a use ALA molfisol/semples (all of use both he	
16	Vect	or Calculus	1107
	16.1	Vector Fields 1108	
V 3 6	16.2	Line Integrals 1115	
	16.3	The Fundamental Theorem for Line Integrals 1127	
	16.4	Green's Theorem 1136	
No.	16.5	Curl and Divergence 1143	
	16.6	Parametric Surfaces and Their Areas 1151	

Writing Project • Three Men and Two Theorems 1180

Lagrange Multipliers 1011

Applied Project • Rocket Science 1019 Applied Project • Hydro-Turbine Optimization 1020

14.8

16.7

16.8

Surface Integrals 1162

Stokes' Theorem 1174

Review 1021

Problems Plus 1025

16.9	The Divergence Theorem	1181
16.10	Summary 1187	
	Review 1188	
Proble	ms Plus 1191	

17 Second-Order Differential Equations

1193



17.1 Second-Order Linear Equations 119	17.1	Second-Order	Linear	Equations	1194
--	------	--------------	--------	-----------	------

- 17.2 Nonhomogeneous Linear Equations 1200
- 17.3 Applications of Second-Order Differential Equations 1208
- 17.4 Series Solutions 1216 Review 1221

Appendixes

A1

- A Numbers, Inequalities, and Absolute Values A2
- B Coordinate Geometry and Lines A10
- C Graphs of Second-Degree Equations A16
- D Trigonometry A24
- E Sigma Notation A34
- F Proofs of Theorems A39
- G Complex Numbers A48
- H Answers to Odd-Numbered Exercises A57

Index

A131