
CALCULUS

EARLY TRANSCENDENTALS

EIGHTH EDITION

JAMES STEWART

McMASTER UNIVERSITY

AND

UNIVERSITY OF TORONTO



Australia • Brazil • Mexico • Singapore • United Kingdom • United States

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 Models 9

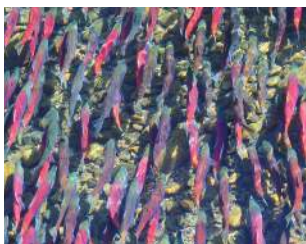


- 1.1 Four Ways to Represent a Function 10
- 1.2 Mathematical Models: A Catalog of Essential Functions 23
- 1.3 New Functions from Old Functions 36
- 1.4 Exponential Functions 45
- 1.5 Inverse Functions and Logarithms 55
- Review 68

Principles of Problem Solving 71

2

Limits and Derivatives 77



- 2.1 The Tangent and Velocity Problems 78
- 2.2 The Limit of a Function 83
- 2.3 Calculating Limits Using the Limit Laws 95
- 2.4 The Precise Definition of a Limit 104
- 2.5 Continuity 114
- 2.6 Limits at Infinity; Horizontal Asymptotes 126
- 2.7 Derivatives and Rates of Change 140
 - Writing Project • Early Methods for Finding Tangents 152
- 2.8 The Derivative as a Function 152
- Review 165

Problems Plus 169

3

Differentiation Rules

171



- 3.1 Derivatives of Polynomials and Exponential Functions 172
 Applied Project • Building a Better Roller Coaster 182
- 3.2 The Product and Quotient Rules 183
- 3.3 Derivatives of Trigonometric Functions 190
- 3.4 The Chain Rule 197
 Applied Project • Where Should a Pilot Start Descent? 208
- 3.5 Implicit Differentiation 208
 Laboratory Project • Families of Implicit Curves 217
- 3.6 Derivatives of Logarithmic Functions 218
- 3.7 Rates of Change in the Natural and Social Sciences 224
- 3.8 Exponential Growth and Decay 237
 Applied Project • Controlling Red Blood Cell Loss During Surgery 244
- 3.9 Related Rates 245
- 3.10 Linear Approximations and Differentials 251
 Laboratory Project • Taylor Polynomials 258
- 3.11 Hyperbolic Functions 259
 Review 266

Problems Plus 270

4

Applications of Differentiation

275



- 4.1 Maximum and Minimum Values 276
 Applied Project • The Calculus of Rainbows 285
- 4.2 The Mean Value Theorem 287
- 4.3 How Derivatives Affect the Shape of a Graph 293
- 4.4 Indeterminate Forms and l'Hospital's Rule 304
 Writing Project • The Origins of l'Hospital's Rule 314
- 4.5 Summary of Curve Sketching 315
- 4.6 Graphing with Calculus *and* Calculators 323
- 4.7 Optimization Problems 330
 Applied Project • The Shape of a Can 343
 Applied Project • Planes and Birds: Minimizing Energy 344
- 4.8 Newton's Method 345
- 4.9 Antiderivatives 350
 Review 358

Problems Plus 363

5

Integrals

365



- 5.1 Areas and Distances 366
 - 5.2 The Definite Integral 378
 - Discovery Project • Area Functions 391
 - 5.3 The Fundamental Theorem of Calculus 392
 - 5.4 Indefinite Integrals and the Net Change Theorem 402
 - Writing Project • Newton, Leibniz, and the Invention of Calculus 411
 - 5.5 The Substitution Rule 412
 - Review 421
- Problems Plus 425**

6

Applications of Integration

427



- 6.1 Areas Between Curves 428
 - Applied Project • The Gini Index 436
 - 6.2 Volumes 438
 - 6.3 Volumes by Cylindrical Shells 449
 - 6.4 Work 455
 - 6.5 Average Value of a Function 461
 - Applied Project • Calculus and Baseball 464
 - Applied Project • Where to Sit at the Movies 465
- Review 466
- Problems Plus 468**

7

Techniques of Integration

471



- 7.1 Integration by Parts 472
 - 7.2 Trigonometric Integrals 479
 - 7.3 Trigonometric Substitution 486
 - 7.4 Integration of Rational Functions by Partial Fractions 493
 - 7.5 Strategy for Integration 503
 - 7.6 Integration Using Tables and Computer Algebra Systems 508
 - Discovery Project • Patterns in Integrals 513
 - 7.7 Approximate Integration 514
 - 7.8 Improper Integrals 527
 - Review 537
- Problems Plus 540**

8

Further Applications of Integration

543



- 8.1 Arc Length 544
 Discovery Project • Arc Length Contest 550
- 8.2 Area of a Surface of Revolution 551
 Discovery Project • Rotating on a Slant 557
- 8.3 Applications to Physics and Engineering 558
 Discovery Project • Complementary Coffee Cups 568
- 8.4 Applications to Economics and Biology 569
- 8.5 Probability 573
- Review 581
- Problems Plus 583

9

Differential Equations

585



- 9.1 Modeling with Differential Equations 586
- 9.2 Direction Fields and Euler's Method 591
- 9.3 Separable Equations 599
 Applied Project • How Fast Does a Tank Drain? 608
 Applied Project • Which Is Faster, Going Up or Coming Down? 609
- 9.4 Models for Population Growth 610
- 9.5 Linear Equations 620
- 9.6 Predator-Prey Systems 627
 Review 634
- Problems Plus 637

10

Parametric Equations and Polar Coordinates

639



- 10.1 Curves Defined by Parametric Equations 640
 Laboratory Project • Running Circles Around Circles 648
- 10.2 Calculus with Parametric Curves 649
 Laboratory Project • Bézier Curves 657
- 10.3 Polar Coordinates 658
 Laboratory Project • Families of Polar Curves 668
- 10.4 Areas and Lengths in Polar Coordinates 669

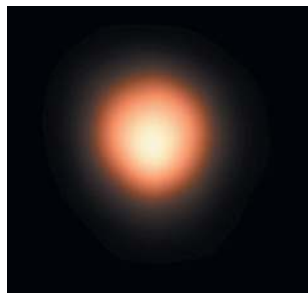
- 10.5 Conic Sections 674
- 10.6 Conic Sections in Polar Coordinates 682
- Review 689

Problems Plus 692

11

Infinite Sequences and Series

693



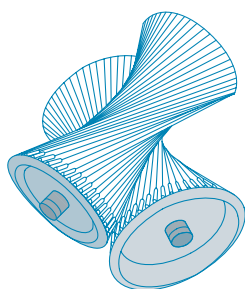
- 11.1 Sequences 694
 - Laboratory Project • Logistic Sequences 707
- 11.2 Series 707
- 11.3 The Integral Test and Estimates of Sums 719
- 11.4 The Comparison Tests 727
- 11.5 Alternating Series 732
- 11.6 Absolute Convergence and the Ratio and Root Tests 737
- 11.7 Strategy for Testing Series 744
- 11.8 Power Series 746
- 11.9 Representations of Functions as Power Series 752
- 11.10 Taylor and Maclaurin Series 759
 - Laboratory Project • An Elusive Limit 773
 - Writing Project • How Newton Discovered the Binomial Series 773
- 11.11 Applications of Taylor Polynomials 774
 - Applied Project • Radiation from the Stars 783
- Review 784

Problems Plus 787

12

Vectors and the Geometry of Space

791



- 12.1 Three-Dimensional Coordinate Systems 792
- 12.2 Vectors 798
- 12.3 The Dot Product 807
- 12.4 The Cross Product 814
 - Discovery Project • The Geometry of a Tetrahedron 823
- 12.5 Equations of Lines and Planes 823
 - Laboratory Project • Putting 3D in Perspective 833
- 12.6 Cylinders and Quadric Surfaces 834
- Review 841

Problems Plus 844

13

Vector Functions

847



- 13.1 Vector Functions and Space Curves 848
 - 13.2 Derivatives and Integrals of Vector Functions 855
 - 13.3 Arc Length and Curvature 861
 - 13.4 Motion in Space: Velocity and Acceleration 870
 - Applied Project • Kepler's Laws 880
- Review 881

Problems Plus 884

14

Partial Derivatives

887



- 14.1 Functions of Several Variables 888
 - 14.2 Limits and Continuity 903
 - 14.3 Partial Derivatives 911
 - 14.4 Tangent Planes and Linear Approximations 927
 - Applied Project • The Speedo LZR Racer 936
 - 14.5 The Chain Rule 937
 - 14.6 Directional Derivatives and the Gradient Vector 946
 - 14.7 Maximum and Minimum Values 959
 - Applied Project • Designing a Dumpster 970
 - Discovery Project • Quadratic Approximations and Critical Points 970
 - 14.8 Lagrange Multipliers 971
 - Applied Project • Rocket Science 979
 - Applied Project • Hydro-Turbine Optimization 980
- Review 981

Problems Plus 985

15

Multiple Integrals

987



- 15.1 Double Integrals over Rectangles 988
- 15.2 Double Integrals over General Regions 1001
- 15.3 Double Integrals in Polar Coordinates 1010
- 15.4 Applications of Double Integrals 1016
- 15.5 Surface Area 1026

- 15.6** Triple Integrals 1029
 - Discovery Project • Volumes of Hyperspheres 1040
- 15.7** Triple Integrals in Cylindrical Coordinates 1040
 - Discovery Project • The Intersection of Three Cylinders 1044
- 15.8** Triple Integrals in Spherical Coordinates 1045
 - Applied Project • Roller Derby 1052
- 15.9** Change of Variables in Multiple Integrals 1052
 - Review 1061
- Problems Plus 1065**

16**Vector Calculus**

1067



- 16.1** Vector Fields 1068
- 16.2** Line Integrals 1075
- 16.3** The Fundamental Theorem for Line Integrals 1087
- 16.4** Green's Theorem 1096
- 16.5** Curl and Divergence 1103
- 16.6** Parametric Surfaces and Their Areas 1111
- 16.7** Surface Integrals 1122
- 16.8** Stokes' Theorem 1134
 - Writing Project • Three Men and Two Theorems 1140
- 16.9** The Divergence Theorem 1141
- 16.10** Summary 1147
 - Review 1148
- Problems Plus 1151**

17**Second-Order Differential Equations**

1153



- 17.1** Second-Order Linear Equations 1154
- 17.2** Nonhomogeneous Linear Equations 1160
- 17.3** Applications of Second-Order Differential Equations 1168
- 17.4** Series Solutions 1176
 - Review 1181

 **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** The Logarithm Defined as an Integral A50
- H** Complex Numbers A57
- I** Answers to Odd-Numbered Exercises A65

 **Index** A139