Essential calculus early transcendentals 7th edition pdf full

To Bill Ralph and Bruce Thompson This page intentionally left blank Contents Preface xi To the Student xxii Diagnostic Tests xxiv A PREVIEW OF CALCULUS 1 Functions and Models 9 1.1 Four Ways to Represent a Function 1.2 Mathematical Models: A Catalog of Essential Functions 1.3 New Functions from Old Functions 1.4 Graphing Calculators and Computers 1.5 Exponential Functions 1.6 Inverse Functions and Logarithms Review 10 23 36 44 51 58 72 Principles of Problem Solving 2 2 75 Limits and Derivatives 81 2.1 The Tangent and Velocity Problems 2.2 The Limit of a Function 2.3 Calculating Limits Using the Limit Laws 2.4 The Precise Definition of a Limit 2.5 Continuity 2.6 Limits at Infinity; Horizontal Asymptotes 2.7 Derivatives and Rates of Change 2.8 The Derivative as a Function Review 99 118 Writing Project 2.8 82 153 154 165 170 v vi CONTENTS 3 Differentiation Rules 173 3.1 Derivatives of Polynomials and Exponential Functions Applied Project N Building a Better Roller Coaster 3.2 The Product and Quotient Rules 3.3 Derivatives of Trigonometric Functions 3.4 The Chain Rule Applied Project 3.5 N 184 191 Where Should a Pilot Start Descent? The domain of t is . Learn to write the solutions of the exercises in a connected, step-by-step fashion with explanatory sentences—not just a string of disconnected equations or formulas. I particularly value problems that combine and compare graphical, numerical, and algebraic approaches (see Exercises 2.6.39– 40, 3.7.27, and 9.4.2). Today calculus is used in calculating the orbits of satellites and spacecraft, in predicting population sizes, in estimating how fast oil prices rise or fall, in forecasting weather, in measuring the cardiac output of the heart, in calculating life insurance premiums, and in a great variety of other areas. means 3 3 3 3 ⩽ ⩽ ⩽ ⩽ 10 100 1000 10,000 and so, in some sense, it must be true that 3 3 3 3 1 ⩽ ⩽ ⩽ ⩽ 10 100 1000 10,000 3 More generally, if dn denotes the nth digit in the decimal representation of a number, then 0.d1 d2 d3 d4 . Instructors can further customize the text by adding instructor-created or YouTube video links. We usually consider functions for which the sets D and E are sets of real numbers. (b) What is the slope of the graph? These hints can be found on stewartcalculus.com as well as Enhanced WebAssign and CourseMate. The main ideas behind differential calculus are due to the French mathematician Pierre Fermat (1601–1665) and were developed by the English mathematicians John Wallis (1616–1703), Isaac Barrow (1630–1677), and Isaac Newton (1642–1727) and the German mathematician Gottfried Leibniz (1646–1716). Which features of f are the most important in sketching y 苷 f 共x兲? y _ π π 2 y 3π 2 1 0 _1 π 2 π _π 2π 5π 2 3π _π 2 π x _1 (a) ƒ=sin x FIGURE 18 1 3π 2 π 2π 5π 2 x (b) ©=cos x Notice that for both the sine and cosine functions the domain is 共⬁, ⬁兲 and the range is the closed interval 关⫺1, 1兴. If we choose the viewing rectangle 关⫺0.25, 0.25兴 by 关⫺1.5, 1.5兴, we get the graph shown in Figure 7. (Many calculators have a built-in intersection feature.) 1.5 1 y=x 0.8 y=cos x y=cos x 5 y=x 5 y=x y=cos x FIGURE 14 Locating the roots of cos x=x _1.5 (a) 关⫺5, 5兴 by 关⫺1.5, 1.5兴 x-scale=1 1 0 (b) 关0, 1兴 by 关0, 1兴 x-scale=0.1 0.8 0.7 (c) 关0.7, 0.8兴 by 关0.7, 0.8兴 x-scale=0.01 50 CHAPTER 1 1.4 FUNCTIONS AND MODELS ; Exercises 1. Simplify each expression. 1. The graph of a function f is given. Walton, McCallie School Jack Weiner, University of Guelph Alan Weinstein, University of California, Berkeley Theodore W. (a) Shift 3 units upward. For instance, what is meant by 2 s3 or 5? This can also be seen from Figure 8. Since y is a function of u and u is, in turn, a function of x, it follows that y is ultimately a function of x. The tangent problem has given rise to the branch of calculus called differential calculus, which was not invented until more than 2000 years after integral calculus. The line segment joining the points 共1, ⫺3兲 and 共5, 7兲 52. What do all members of the family of linear functions x ture of the earth has been rising steadily. f 共x兲 苷 f 共1 兲 x⫺1 56. The light is too dim and so you move halfway to the lamp. 138° rays from sun 42° 3. (b) If the point 共5, 3兴 is on the graph of an odd function, what other point must also be on the graph? (a) f 共x兲 苷 log 2 x 4 (b) t共x兲 苷 s x 3 (c) h共x兲 苷 2x 1 ⫺x2 (d) u共t兲 苷 1 ⫺ 1.1t ⫺ 2.54t 2 (f) w 共t兲 苷 sin cos 2 (e) v共t兲 苷 5 t (c) y 苷 x 2 共t兲 2 ⫺x 3 兲 (e) y 苷 7. Year Percentage rural Year Percentage rural 1950 1960 1965 1970 1975 30.4 26.4 23.6 21.1 19.0 1980 1985 1990 1995 2000 17.1 15.0 13.0 11.7 10.5 25. Hall, Michigan State University Robert L. A. (c) What is the temperature at a height of 2.5 km? Thus the slope of the graph y 苷 3x ⫺ 2, namely 3, can be interpreted as the rate of change of y with respect to x. SECTION 1.6 INVERSE FUNCTIONS AND LOGARITHMS 65 EXAMPLE 8 Solve the equation e 5⫺3x 苷 10. _1 FIGURE 3 ƒ=œ„„„„ 8-2= EXAMPLE 3 Graph the function y 苷 x 3 ⫺ 150x. SECTION 1.3 26. 9.4 Models for Population Growth 9.5 Linear Equations 9.6 Predator-Prey Systems Review Problems Plus 629 633 616 622 605 603 604 CONTENTS 10 Parametric Equations and Polar Coordinates 635 10.1 Curves Defined by Parametric Equations Laboratory Project 10.2 Polar Coordinates Bézier Curves 645 653 N Families of Polar Curves 10.4 Areas and Lengths in Polar Coordinates 10.5 Conic Sections 10.6 Conic Sections in Polar Coordinates Review Problems Plus 644 654 Laboratory Project 11 N 636 Running Circles around Circles Calculus with Parametric Curves Laboratory Project 10.3 N 664 665 670 678 685 688 Infinite Sequences and Series 689 11.1 Sequences 690 Laboratory Project N Logistic Sequences 703 11.2 Series 703 11.3 The Integral Test and Estimates of Sums 11.4 The Comparison Tests 11.5 Alternating Series 11.6 Absolute Convergence and the Ratio and Root Tests 11.7 Strategy for Testing Series 11.8 Power Series 11.9 Representations of Functions as Power Series 11.10 Taylor and Maclaurin Series 11.11 722 727 739 N N Review Problems Plus 778 781 N 746 753 An Elusive Limit 767 How Newton Discovered the Binomial Series Applications of Taylor Polynomials Applied Project 732 741 Laboratory Project Writing Project 714 Radiation from the Stars 768 777 767 ix x CONTENTS Appendixes A1 A Numbers, Inequalities, and Absolute Values B Coordinate Geometry and Lines C Graphs of Second-Degree Equations D Trigonometry E Sigma Notation F Proofs of Theorems G The Logarithm Defined as an Integral H Complex Numbers I Answers to Odd-Numbered Exercises Index A115 A10 A16 A24 A34 A39 A48 A55 A63 A2 Preface A great discovery solves a great problem but there is a grain of discovery in the solution of any problem. Boes Print Buyer: Becky Cross Rights Acquisitions Specialist: Don Schlotman Production Service: TECH· arts Text Designer: TECH· arts Photo Researcher: Terri Wright Copy Editor: Kathi Townes © 2012, 2008 Brooks/Cole, Cengage Learning ALL RIGHTS RESERVED. This means that, for all values of x, sin共x ⫹ 2π兲 苷 sin x cos共x ⫹ 2π兲 苷 cos x 32 CHAPTER 1 FUNCTIONS AND MODELS The periodic nature of these functions makes them suitable for modeling repetitive phenomena such as tides, vibrating springs, and sound waves. Find A ∘ A, A ∘ A ∘ A, and A ∘ A ∘ A ∘ A. (b) Shift 3 units downward. Thus the graph is symmetric 73 ⫺ 2x if x ⩽ 3 ⫺6 if x ⬎ 3 51–56 Find an expression for the function whose graph is the given curve. The icon ; indicates an exercise that definitely requires the use of either a graphing calculator or a computer with graphing software. (a) y 苷 3x ⩽ 1 (c) x 苷 2 (b) y 苷 5 5. (a) 5⩽6 (b) 2 3. (b) y 苷 x. 2. f 共x兲 苷 4 ⩽ 3x ⫺ x 2, FOUR WAYS TO REPRESENT A FUNCTION 34. x 4 ≥ x 苷 1 30. f 共x兲 苷 s3 ≥ x , 2 51. A function f is a rule that assigns to each element x in a set D exactly one element, called f 共x兲, in a set E. Regardless of title, CD/DVD/Access Codes or Supplemental Materials are NOT guaranteed. Shah, Kent State University–Trumbull Theodore Shifrin, University of Georgia Wayne Skrapek, University of Saskatchewan xix Larry Small, Los Angeles Pierce College Teresa Morgan Smith, Blinn College William Smith, University of North Carolina Donald W. Use the given graph of f to sketch the graph of y 苷 1兾f 共x兲. In other words, 共t ∘ f 兲共x兲 is defined whenever both f共x兲 and t共f 共x兲兲 are defined. Find the center and radius of the circle with equation x 2 ⩽ y2 ≥ 6x ⩽ 10y ⩽ 9 苷 0. SOLUTION Using Equation 2 with t 苷 1987, we estimate that the average CO2 level in 1987 was C共1987兲 苷 共1.65429兲共1987兲 ≥ 2938.07 ⬇ 349.00 This is an example of interpolation because we have estimated a value between observed values. SOLUTION Some graphing devices display the graph shown in Figure 11, whereas others produce a graph like that in Figure 12. Biologists have noticed that the chirping rate of crickets of a certain species is related to temperature, and the relationship appears to be very nearly linear. f 共x兲 苷 x 2 ≥ 2, (c) 苷 f ∘ t共x兲 ∘ t共x兲 h共x兲 苷 x 2 ∘ 2 (b) h共x兲 苷 x 2 ≥ 2 ≥ 1 ∘ 2 苷 0 ∘ 1 f x 43 44 CHAPTER 1 FUNCTIONS AND MODELS 53. Windows is a registered trademark of the Microsoft Corporation and used herein under license. Moak, and Gene M. Haïdar, Grand Valley State University D. (We will give a precise definition of a tangent line in A PREVIEW OF CALCULUS y Chapter 2. Let's experiment. (c) What is the slope of this line? Solomon, University of Wisconsin–Milwaukee Edward Spitznagel, Washington University Joseph Stampfli, Indiana University Kristin Stoley, Blinn College M. It makes sense that the larger the area of a region, the larger the number of species that inhabit the region. CourseMate www.cengagebrain.com CourseMate is a perfect self-study tool for students, and requires no set up from instructors. C 380 370 360 350 FIGURE 5 Linear model through first and last data points 340 1980 1985 1990 1995 2000 2005 2010 t 26 CHAPTER 1 FUNCTIONS AND MODELS A computer or graphing calculator finds the regression line by the method of least squares, which is to minimize the sum of the squares of the vertical distances between the data points and the line. f 共x兲 苷 2 ⩾ 0.4x 40. Wilcox, Rochester Institute of Technology Steven Willard, University of Alberta Robert Wilson, University of Wisconsin–Madison Jerome Wolbert, University of Michigan–Ann Arbor Dennis H. Singapore . The graphs of members of the family of functions y 苷 a x are shown in Figure 3 for various values of the base a. (a) Sketch the graph of the ramp function y 苷 tH共t兲. Using a graphing calculator or computer algebra system (which uses the least squares method), we obtain the following quadratic model: h 苷 449.36 ⩽ 0.96t ⩾ 4.90t 2 3 h (meters) h 400 400 200 0 2 4 6 8 t (seconds) 0 2 4 6 8 FIGURE 9 FIGURE 10 Scatter plot for a falling ball Quadratic model for a falling ball t In Figure 10 we plot the graph of Equation 3 together with the data points and see that the quadratic model gives a very good fit. The Greek method of exhaustion was to inscribe polygons in the figure and circumscribe polygons about the figure and then let the number of sides of the polygons increase. Given a real-world problem, our first task is to formulate a mathematical model by identifying and naming the independent and dependent variables and making assumptions that simplify the phenomenon enough to make it mathematically tractable. Sketch a rough graph of the market value of a new car as a function of time for a period of 20 years. HOMEWORK HINTS Homework Hints presented in the form of questions try to imitate an effective teaching assistant by functioning as a silent tutor. (f) Reflect about the y-axis. (a) y 苷 f 共x兲 ⩽ 8 (c) y 苷 8 f 共x兲 (e) y 苷 ⩾f 共x兲 ⩾ 1 (b) y 苷 f 共x ⩽ 8兲 (d) y 苷 f 共8x兲 (f) y 苷 8 f 共x兲 ⩽ 8 (b) y 苷 f 共x兲 ⩾ 3 (c) y 苷 f 共x ⩾ 3兲 (d) y 苷 ⩾3 f 共x兲 7. 78. 1 Functions and Models From the beginning, multiple representations of functions are stressed: verbal, numerical, visual, and algebraic. If t represents the time in minutes since the plane has left the terminal building, let x共t兲 be SECTION 1.1 the horizontal distance traveled and y共t兲 be the altitude of the plane. Describe how you take it out and let it cool before eating it. 18. Due to electronic rights restrictions, some third party content may be suppressed. Writing Projects ask students to compare present-day methods with those of the xiv PREFACE founders of calculus—Fermat's method for finding tangents, for instance. Nov. 12 ⩽ 6h ⩽ h 2 3. As n increases, it appears that An becomes closer and closer to the area of the circle. y y f(_x) ƒ _x ƒ 0 x x 0 x FIGURE 19 An even function x FIGURE 20 An odd function If f satisfies f 共⩾x兲 苷 ⩾f 共x兲 for every number x in its domain, then f is called an odd function. Thus the s x key on your calculator is not quite the same as the exact mathematical function f defined by f 共x兲 苷 s x . The human population of the world P depends on the time t. f 共x兲 苷 2x 3 ⩾ 5 x2 ⩽ x ⩾ 6 57–61 Find a formula for the described function and state its domain. (See page 604.) 1 Functions and Models Often a graph is the best way to represent a function because it conveys so much information at a glance. No part of this work covered by the copyright herein may be reproduced, transmitted, stored, or used in any form or by any means graphic, electronic, or mechanical, including but not limited to photocopying, recording, scanning, digitizing, taping, Web distribution, information networks, or information storage and retrieval systems, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without the prior written permission of the publisher. Express the amount of the fine F as a function of the driving speed x and graph F共x兲 for 0 艋 x 艋 100. y y x=a (a, c) x=a (a, b) (a, b) a 0 x a 0 x FIGURE 13 For example, the parabola x 苷 y 2 ⩾ 2 shown in Figure 14(a) is not the graph of a function of x because, as you can see, there are vertical lines that intersect the parabola twice. Observe that we get a more complete picture in parts (c) and (d), but in part (d) it is not clear that the y-intercept is 3. 4 _4 1000 30 4 10 _10 _50 50 _4 _5 _100 (b) 关_4, 4兴 by 关_4, 4兴 (c) 关_10, 10兴 by 关_5, 30兴 (d) 关_50, 50兴 by 关_100, 1000兴 FIGURE 2 Then we see from Example 1 that the choice of a viewing rectangle can make a big difference in the appearance of a graph. Designed to be an even more usable teaching and learning tool, the 9th edition with WebAssign provides unparalleled clarity and precision, emphasizes problem solving, and develops conceptual understanding. (a) 关⩾, ⩾2兴, t兴 苷 关⩾2, 2兴 苷 ⩾, ⩽兲. (c) 关⩾, ⩾兴 ⩽ 关⩾8, ⩽兴 (d) 关1, 4兴 0 x 2 (b) y 苷 y 1 x y 0 1 x y 1 0 4. The table shows (lifetime) peptic ulcer rates (per 100 popu- to manufacture 100 chairs in one day and $4800 to produce 300 chairs in one day. Then 0 5 10 15 time (min) 13. The graph of y 苷 f 共x兲 is given. Mathematica is a registered trademark of Wolfram Research, Inc. In what follows, we discuss the behavior and graphs of these functions and give examples of situations appropriately modeled by such functions. # $ _6 0 _3 3 6 x starting with the graph of one of the standard functions given in Section 1.2, and then applying the appropriate transformations. What's New in the Seventh Edition? (f) y 苷 s x ⩾ 3 1 3 1⩽s x s 3– 4 Match each equation with its graph. We know from Section 1.2 (Figure 13) that the graph in Figure 12 is correct, so what happened in Figure 11? Notice that the output of one function is used as the input to the next function. ■ New examples have been added. Then, from 6 , we have a y 苷 x. Kuisti, Deborah F. (a) Use a graph to show that the equation cos x 苷 0.3x has three solutions and find their values correct to two decimal places. See Appendix B.) This enables us to sketch a portion of the graph of f in Figure 7. If the perimeter of the window is 30 ft, express the area A of the window as a function of the width x of the window. If f 共x兲 苷 x2 ⩾ x and t (c) (e) (f) Estimate the value of f 共x兲 苷 ⩾1. If we already have the graph of f for x 艌 0, we can obtain the entire graph by rotating this portion through 180⬚ about the origin. The 1 reason for this behavior is that the second term, 100 cos 100x, is very small in comparison with the first term, sin x. f 共x兲 苷 49. If we look carefully while the graph is being drawn, we see that the graph leaves the screen and reappears during the graphing process. ⩾2 艋 x 艋 2 Therefore the domain of f is the interval 关⩾2, 2兴. Other exercises test conceptual understanding through graphs or tables (see Exercises 2.7.17, 2.8.35–40, 2.8.43–46, 9.1.11–13, 10.1.24–27, and 11.10.2). y y y y y y 1 0 x 1 x 0 0 2 x x 0 0 x 0 _2 (a) y=œ„x (b) y=œ„x-2 (d) y=_œ„x (e) y=2œ„x (f) y=œ„„ _x x 38 CHAPTER 1 FUNCTIONS AND MODELS EXAMPLE 2 Sketch the graph of the function f (x) 苷 x 2 ⩽ 6x ⩽ 10. Slope-intercept equation of line with slope m and y-intercept b: If a b, then a c b c. (c) 4 x 共 f ∘ f 兲共x兲 苷 共x兲 苷 x ⩽ 3 S domain of f is 关0, ⬁兲. The slope is m 苷 10⬚C兾km, and this represents the rate of change of temperature with respect to height. (a) Express the horizontal distance d (in miles) that the plane has flown as a function of t. 1 0 2 1 x 4. The sum and difference functions are defined by 共 f ⩽ t兲共x兲 苷 f 共x兲 ⩽ t共x兲 共 f ⩾ t兲共x兲 苷 f 共x兲 ⩾ t共x兲 40 CHAPTER 1 FUNCTIONS AND MODELS If the domain of f is A and the domain of t is B, then the domain of f ⩽ t is the intersection A 傽 B because both f 共x兲 and t共x兲 have to be defined. If we plot these values, we get the graph (called a scatter plot) in Figure 9. This enables us to read from the triangle that 2 2 œ„ FIGURE 19 tan(arcsin 13) 苷 tan 苷 1 2s2 The cancellation equations for inverse functions become, in this case, sin⩾1共sin x兲 苷 x sin共sin⩾1x兲 苷 x for ⩾ 艋x艋 2 2 for ⩾1 艋 x 艋 1 68 CHAPTER 1 FUNCTIONS AND MODELS y π 2 0 _1 x 1 The inverse sine function, sin⩾1, has domain 关⩾1, 1兴 and range 关⩾鼻2, 鼻2兴 , and its graph, shown in Figure 20, is obtained from that of the restricted sine function (Figure 18) by reflection about the line y 苷 x. The graphs of f and t are given. It can be shown that both sequences have the same limit: lim a n 苷 p 苷 lim tn nl⬁ nl⬁ It is precisely at this point p that Achilles overtakes the tortoise. Arthur Robinson, Jr., The George Washington University Richard Rockwell, Pacific Union College Rob Root, Lafayette College Richard Ruedemann, Arizona State University David Ryeburn, Simon Fraser University Richard St. Andre, Central Michigan University Ricardo Salinas, San Antonio College Robert Schmidt, South Dakota State University Eric Schreiner, Western Michigan University Mihr J. 苷 2a 2 4ah ⩽ 2h 2 ⩽ 5a ⩽ 5h ⩽ 4 ⩽ 2a 2 ⩽ 5a ⩽ 4 苷 4ah ⩽ 2h 2 ⩽ 5h 苷 h Representations of Functions There are four possible ways to represent a function: ■ verbally (by a description in words) ■ numerically (by a table of values) ■ visually (by a graph) ■ algebraically (by an explicit formula) If a single function can be represented in all four ways, it's often useful to go from one representation to another to gain additional insight into the function. miles driven. (d) Use the linear model in part (c) to estimate the ulcer rate for an income of $25,000. (a) (b) (c) (d) (e) (f) Find the slope of the line that contains A and B. Here are some of my favorites: 1.6.58, 2.6.51, 2.8.13–14, 3.3.56, 3.4.67, 3.5.69–72, 3.7.22, 4.3.86, 5.2.51–53, 6.4.30, 11.2.49–50, and 11.10.71–72. Notice also that, since 共1鼻a兲 x 苷 1鼻a x 苷 a ⩾x, the graph of y 苷 共1鼻a兲 x is just the reflection of the graph of y 苷 a x about the y-axis. Use Fig1 0 1 x 1. 5th or later Edition. y y y 1 (0, 1) (0, 1) 0 FIGURE 4 0 x (a) y=a®, 01 0 x The logarithmic function log a has the 1650 1750 1860 2070 2300 2560 3040 3710 4450 5280 6080 6870 B. Estimate the value of f 共2兲. (a) 6 1 (d) ⩾1 2 s2 (g) (b) 1 s4 ⩽ h ⩽ 2 (b) 2共x ⩾ 3兲2 ⩾ 7 3 4 (b) 1 (c) ⩾3, 4 (e) 1, s2 2 22 (f) 3 , 3 12 5 9. Copyright-2002, ISBN:0618149130. Its graph has two asymptotes. In addition, we shift it 12 units upward. Its graph is shown in Figure 22. v EXAMPLE 7 A function f is defined by f 共x兲 苷 再 1⩾x x2 if x 艋 ⩾1 if x ¬ ⩾1 Evaluate f 共⩾2兲, f 共⩾1兲, and f 共0兲 and sketch the graph. ExamView Testing Create, deliver, and customize tests in print and online formats with ExamView, an easy-to-use assessment and tutorial software. Tools for Enriching Calculus, which is a companion to this text, is referred to by means of the symbol TEC and can be accessed in Enhanced WebAssign and CourseMate (selected Visuals and Modules are available at www.stewartcalculus.com). Figure 8 shows the graph of a cubic function in part (a) and graphs of polynomials of degrees 4 and 5 in parts (b) and (c). At first glance the graph appears to be SECTION 1.4 GRAPHING CALCULATORS AND COMPUTERS 47 reasonable. SECTION 1.1 x (input) f ƒ (output) FIGURE 2 Machine diagram for a function ƒ f a f(a) f D FOUR WAYS TO REPRESENT A FUNCTION 11 It's helpful to think of a function as a machine (see Figure 2). SOLUTION We draw a diagram as in Figure 12 and introduce notation by letting w and 2w be the width and length of the base, respectively, and h be the height. CalcLabs contain clearly explained exercises and a variety of labs and projects to accompany the text. An open rectangular box with volume 2 m3 has a square base. T EXAMPLE 4 When you turn on a hot-water faucet, the temperature T of the water depends on how long the water has been running. f 共x兲 苷 x x 77. The table (e) Why does a linear function give a suitable model? Use a graphing calculator, enter the data from Table 1 into the data editor and choose the linear regression command. (b) 18 (a) 300 2. Additional projects can be found in the Instructor's Guide (see, for instance, Group Exercise 5.1: Position from Samples). (Midyear estimates are given.) 27. SOLUTION The solutions of the equation cos x 苷 x are the x-coordinates of the points of intersection of the curves y 苷 cos x and y 苷 x. .} can be described by giving the following formula for the nth term: an a¢ a £ a™ 0 1 n We can visualize this sequence by plotting its terms on a number line as in Figure 10(a) or by drawing its graph as in Figure 10(b). y y 苷 2 1 0 1 x 5. Figure 12 shows the graphs of y 苷 log a x with various values of the base a ¬ 1. x 22 CHAPTER 1 FUNCTIONS AND MODELS 58. f 共x兲 苷 1 ⩾ 3x, 36. CourseMate brings course concepts to life with interactive learning, study, and exam preparation tools that support the printed textbook. How does the graph change when c changes? y _ π2 f o f f o f 0 x2 & Soft cover. Another way to picture a function is by an arrow diagram as in Figure 3. It too is a useful representation; the graph allows us to absorb all the data at once. If c ¬ 1, then the graph of y 苷 cf 共x兲 is the graph of y 苷 f 共x兲 stretched by a factor of c in the vertical direction (because each y-coordinate is multiplied by the same number c). The first graph is inaccurate. SOLUTION Notice that each curve resembles a stretched sine function. This tells us how to get the graph of y 苷 f 共x兲 from the graph of y 苷 f 共x兲: The part of the graph that lies above the x-axis remains the same; the part that lies below the x-axis is reflected about the x-axis. But if a line x 苷 a intersects the curve twice, at 共a, b兲 and 共a, c兲, then the curve can't represent a function because a function can't assign two different values to a. But in calculus it is often useful to be able to decompose a complicated function into simpler ones, as in the following example. xxiv (a) x ⩾ 2 ⩾ s 2 x2 ⩾ x ⩾ 2 (c) x2 ⩾ x ⩾ 2 x4 ⩾ ⩾ 2 2 2x 2 ⩾ x ⩾ 1 ⩾x ⩾ 3 ɔ 2 x ⩾ 9 2x ⩽ 1 y x ⩾ x y (d) 1 1 ⩾ y x (b) DIAGNOSTIC TESTS 6. Estimate the value of f 共⩾1兲. t共x兲 苷 x is it true that f 苷 t? Fausett, Georgia Southern University Norman Feldman, Sonoma State University Newman Fisher, San Francisco State University José D. We also notice that the curve begins its cycle on March 21, the 80th day of the year, so we have to shift the curve 80 units to the right. 1⩾ SOLUTION Figure 10(a) shows the graph produced by a graphing calculator with view- _0.1 ing rectangle 关⩾9, 9兴 by 关⩾9, 9兴. 41. H. Distances are always positive or 0, so we have a 艌 0 For a more extensive review of absolute values, see Appendix A. It appears blank, but actually the graph is so nearly vertical that it blends in with the y-axis. PROBLEM SOLVING Students usually have difficulties with problems for which there is no single well-defined procedure for obtaining the answer. For example, the function f 共x兲 苷 x 3 is odd because f 共⩾x兲 苷 共⩾x兲3 苷 ⩾x 3 苷 ⩾f 共x兲 The graph of an odd function is symmetric about the origin (see Figure 20). Evaluate each expression without using a calculator. The relative brevity is achieved through briefer exposition of some topics and putting some features on the website. Now we see what went wrong in Figure 6. (a) y 苷 f 共x ⩾ 4兲 (b) y 苷 f 共x兲 ⩽ 3 (c) y 苷 13 f 共x兲 (d) y 苷 ⩾f 共x ⩽ 4兲 (e) y 苷 2 f 共x ⩽ 6兲 y=œ„„„„„„ 3x-≈ 1.5 x 3 7. In order to do so, he would first have to go half the distance, then half the remaining distance, and then again half of what still remains. Ortner ISBN 0-534-25248-6 This comprehensive book, designed to supplement the calculus course, provides an introduction to and review of the basic ideas of linear algebra. A representation of this graph is shown in Figure 1. That doesn't help us choose a viewing rectangle. In the end, Mother Nature has the final say. In a certain state the maximum speed permitted on freeways is 65 mi鼻h and the minimum speed is 40 mi鼻h. Domain Convention If a function is given by a formula and the domain is not stated explicitly, the convention is that the domain of f is the set of all numbers for which the formula makes sense and defines a real number. To help us answer this question we first look at the graph of the function y 苷 2 x, where x is rational. ; 24. It will also enable us to write equations for given graphs. Bryan, University of Western Ontario David Buchthal, University of Akron Jorge Cassio, Miami-Dade Community College Jack Ceder, University of California, Santa Barbara Scott Chapman, Trinity University James Choike, Oklahoma State University Barbara Cortzen, DePaul University Carl Cowen, Purdue University Philip S. 47. f 共x兲 苷 x ⩽ 1 x⩽1 , t共x兲 苷 x ⩽ 1 x ⩾ 1 (a) y 苷 x ⩾ 4 3 (b) x ⩾ 2 (c) 7 ⩾ 2x ⩾ 3 (d) y 苷 x x 0 37. (a) ⩾2 (b) 2.8 (d) ⩾2.5, 0.3 (c) ⩾3, 1 (e) 关⩾3, 3兴, 关⩾2, 3兴 (f) 4 0 2. 1.5 12 _10 10 _1.5 _9 _6 6 FIGURE 6 Graphs of ƒ=sin 50x in four viewing rectangles .25 _1.5 (d) 2 苷 ⬇ 0.126 50 25 This suggests that we should deal only with small values of x in order to show just a few oscillations of the graph. A graphing calculator or computer displays a rectangular portion of the graph of a function in a display window or viewing screen, which we refer to as a viewing rectangle. Their graphs are shown in Appendix D. Find the length of an arc of a circle with radius 12 cm if the arc subtends a central angle of 30. Sketch the region in the xy-plane defined by the equation or inequalities. In a certain country, income tax is assessed as follows. Draw the graphs of the following functions. So the range of t is 关x ⩾ y 艌 0兴 苷 关0, ⬁兲. Vertical and Horizontal Shifts Suppose c ¬ 0. We compute this by substitution: y 苷 f 共u兲 苷 f 共t共x兲兲 苷 f 共x 2 ⩽ 1兲 苷 sx 2 ⩽ 1 The procedure is called composition because the new function is composed of the two given functions f and t. (a) 4x 2 ⩽ 25 (c) x 3 ⩾ 3x 2 ⩾ 4x ⩽ 12 (e) 3x 3兾2 ⩾ 9x 1兾2 ⩽ 6x ⩾1兾2 (b) 2x 2 ⩽ 5x ⩾ 12 (d) x 4 ⩽ 27x (f) x 3 y ⩾ 4xy 5. But we must define carefully what the sum of an infinite series is. SOLUTION Remember that a function is a rule. TECHNOLOGY The availability of technology makes it not less important but more important to clearly understand the concepts that underlie the images on the screen. (a) Graph the functions y 苷 1⩽x and y 苷 1⩽x 3 on the same screen using the viewing rectangle 关⩾3, 3兴 by 关⩾3, 3兴. The manager of a furniture factory finds that it costs $2200 0 x lation) for various family incomes as reported by the National Health Interview Survey. Material for the base costs $10 per square meter; material for the sides costs $6 per square meter. Let f and t be linear functions with equations f 共x兲 苷 m1 x ⩽ b1 and t共x兲 苷 m 2 x ⩽ b 2. (In other words, the point on the graph that lies above x 苷 1 is 3 units above the x-axis.) When x 苷 5, the graph lies about 0.7 units below the x-axis, so we estimate that f 共5兲 ⬇ ⩾0.7. (b) We see that f共x兲 is defined when 1 ⩾ x 2 艌 0 ⇔ x 2 艋 1 ⇔ 兩x兩 艋 1 ⇔ ⩾1 艋 x 艋 1, so the domain of f is the closed interval 关0, 7兴. Hints for representative exercises (usually oddnumbered) are included in every section of the text, indicated by printing the exercise number in red. The techniques that we will develop in Chapter 5 for finding areas will also enable us to compute the volume of a solid, the length of a curve, the force of water against a dam, the mass and center of gravity of a rod, and the work done in pumping water out of a tank. f 共x兲 苷 2 x ⩽ 100 9. Harrison, College of Charleston Melvin Hausner, New York University/Courant Institute Curtis Herink, Mercer University Russell Herman, University of North Carolina at Wilmington Allen Hesse, Rochester Community College Randall R. What if f is even? (Section 1.4 discusses the use of these graphing devices and some of the pitfalls that you may encounter.) But that doesn't mean that graphing devices can't be used to check your work on the other exercises as well. I have placed this symbol in the margin in situations where I have observed that a large proportion of my students tend to make the same mistake. A polynomial of degree 2 is of the form P共x兲 苷 ax 2 ⩽ bx ⩽ c and is called a quadratic function. 5 Integrals The area problem and the distance problem serve to motivate the definite integral, with sigma notation introduced as needed. Newton undoubtedly experienced a sense of triumph when he made his great discoveries. (b) How is the graph of y 苷 sx related to the graph of y 苷 sx? 1 0 1 x FIGURE 2 y=2® , x ℝ " '2 1 ® " ' 4 1 y 10® 4® 2® If 0 ⬆ a ⬆ 1, then a x approaches 0 as x becomes large. The titles on pages xx–xxi describe each of these ancillaries. K09T10 Purchase any of our products at your local college store or at our preferred online store www.cengagebrain.com. The function f is said to be increasing on the interval 关a, b兴, decreasing on 关b, c兴, and increasing again on 关c, d兴. Did each runner finish the race? 4 3 27–30 Evaluate the difference quotient for the given function. We use this as the defining property of an increasing function. F共x兲 苷 cos2 x 3 x s 3 1⩽s x 44. 39. Using the preceding approximation process we can compute it correct to six decimal places: 2 s3 ⬇ 3.321997 Similarly, we can define 2 x (or a x, if a ¬ 0) where x is any irrational number. This will give us the ability to sketch the graphs of many functions quickly by hand. x 艋 2 &? The time t was measured in hours from midnight. This means that the graph of y 苷 cos x gets stretched vertically by a factor of 2. 69–70 Graph of t and t are shown. It's inaccurate and, so, to help explain its appearance, we replot the curve in dot mode in the second graph. But the period of y 苷 sin t is 2, so the horizontal stretching factor is c 苷 2兾365. How are graphs of the functions obtained from the graph of f ? (b) Shrink vertically by a factor of 3. (a) How is the graph of y 苷 2 sin x related to the graph of f 3 y 苷 sin x? EXAMPLE 1 Draw the graph of the function f 共x兲 苷 x 2 ⩽ 3 in each of the following viewing rectangles. The Study Guide also contains "Technology Plus" questions, and multiple-choice "On Your Own" exam-style questions. As well, answers may be filled in. What are the intercepts? H共x兲 苷 s 2 ⩽ x 49. After Sir Isaac Newton invented his version of calculus, he used it to explain the motion of the planets around the sun. Page 2 Skip to main search results Condition: Acceptable. Factor each expression. (a) (b) (c) (d) (e) 2. So we look for a value of k such that 0.5 ⬆ 兩x兩 ⬆ 9 Then 共f ∘ t兲共x兲 苷 cos x f 共x兲 苷 cos x t共x兲 ⬇ x 2. ⩾ 2 ⩾ 2 f 共x兲 苷 f 共x兲 ⩾ 1 ⩾ 1 共t ∘ t兲共x兲 苷 t共t共x兲兲 苷 t共t共x兲兲 苷 t共x兲 苷 t共x兲 苷 f共x兲 苷 f共cos共x兲兲 ⩽ 9兲 共兲 苷 共cos共x兲兲 ⩽ 9兲 ⩽ 苷 共兲 ⩾ 2 兲共f ∘ t兲共x兲 苷 ⩾1 ⩾ f 共x兲 共s共x兲兲 苷 共x兲 苷 x2 ⩾ f 共x兲 苷 f 共x兲 苷 x2 x ⩾ 8 42 CHAPTER 1 FUNCTIONS AND MODELS Exercises 1. In particular, the illumination of an object by a light source is inversely proportional to the square of the distance from the source. Notice that the equation x ⩾ y 苷 2 implies y 2 ⩾ x ⩽ 2, so y ⩾ x ⩽ 2 . The line for violating these limits is $15 for every mile per hour above the maximum speed or below the minimum speed. Because there are about 365 days in a year, the period of our model should be 365. Higher derivatives are introduced in Section 2.8. 3 Differentiation Rules All the basic functions, including exponential, logarithmic, and inverse trigonometric functions, are differentiated here. The first graph in the figure is that of y 苷 sin 45x as displayed by a TI-83 graphing calculator. Some scientists have modeled the temperature by the linear function T 苷 0.02t ⩽ 8.50, where T is temperature in ⬚C and t represents years since 1900. sin y 苷 x ⩾ and 艋x艋 2 2 Thus, if ⩾1 艋 x 艋 1, sin⩾1x is the number between ⩾鼻2 and 鼻2 whose sine is x. The graph of f also allows us to picture the domain of f on the x-axis and its range on the y-axis as in Figure 5. R共x兲 苷 ssx ⩾ 1 8 48. We choose the viewing rectangle so that the x-interval is somewhat larger than the domain and the y-interval is larger than the range. Write a formula for V共t兲 in terms of H共t兲 if t 艌 0. I hope you will discover that it is not only useful but also intrinsically beautiful. (If x is small, then x 2 is smaller, x 3 is even smaller, x 4 is smaller still, and so on.) y y y=x$ y=x^ y=x# y=® (_1, 1) FIGURE 12 Families of power functions (1, 1) y=x% (1, 1) x 0 (_1, 1) 0 (_1, _1) x (a) y=x n, n even (b) y=x n, n odd y y y y n 1 x is a root function. In共x ⩾ 1兲 苷 x ⇔ In x ⩾ x⩾0 In particular, if we set x 苷 1, we get ln e 苷 1 EXAMPLE 7 Find e ln 5. (See Figure 9.) When Achilles reaches the point a 2 苷 t1, the tortoise is farther ahead at position t2. (a) f 共x兲 苷 x 2 ⩽ 5 (b) y 苷 (x) 2 x 兲 ln 共x兲 苷 FIGURE 21 SOLUTION 1 ⩽ x 2 1 ⩾ 1 t 共x兲 ⩾ 1 ⩾ 5t 4 (a) f 共x兲 苷 5x is an exponential function. (a) 关⩾3, 3兴 by 关⩾3, 3兴 (b) 关⩾10, 10兴 by 关⩾10, 10兴 (c) 关⩾50, 50兴 by 关⩾50, 50兴 (d) 关⩾5, 5兴 by 关⩾50, 50兴 24. SECTION 1.1 15 FOUR WAYS TO REPRESENT A FUNCTION (b) Since t共x兲 苷 1 x2 ⩾ x x共x ⩾ 1兲 and division by 0 is not allowed, we see that t共x兲 is not defined when x 苷 0 or x 苷 1. 1.2 23 and t are both odd functions, is ft odd? Find a model for the data and use it to estimate the rural percentage in 1988 and 2002. (a) Reflect about the x-axis x 1 _1 0 (b) Stretch vertically by a factor of 2, then shift 1 unit downward (c) Shift 3 units to the right and 2 units upward 5. Each piece has been designed to enhance student understanding and to facilitate creative instruction. The graph of y 苷 x for n odd 共n ¬ 3兲 is similar to that of y 苷 s x. Papp, University of Michigan–Dearborn Mike Penna, Indiana University–Purdue University Indianapolis Mark Pinsky, Northwestern University Lothar Redlin, The Pennsylvania State University Joel W. What if f is odd? The graph shows that the range is also . Returning to the series in Equation 3, we denote by sn the sum of the first n terms of the series. Hurley, University of Connecticut Matthew A. In fact, we can find terms as small as we please by making n large enough. Three runners compete in a 100-meter race. C共h兲 (dollars) C. The integration of the graph is y 苷 x 2, which represents a parabola (see Appendix C). The table gives the winning heights for the men's Olympic pole vault competitions up to the year 2004. xvi PREFACE 4 Applications of Differentiation The basic facts concerning extreme values and shapes of curves are deduced from the Mean Value Theorem. We consider several cases. Features CONCEPTUAL EXERCISES The most important way to foster conceptual understanding is through the problems that we assign. Such functions will be studied in Chapter 2. (b) Sketch the graph of the voltage V共t兲 in a circuit if the switch is turned on at time t 苷 0 and the voltage is gradually increased to 120 volts over a 60-second time interval. If you get the graph in Figure 11, you can obtain the correct picture by graphing the function t x f 共x兲 苷 x 2 1 兾3 x 3 x (except when x 苷 0). Unopened, still in plastic wrap, actual book is pictured. Find an equation of the line that passes through A and B. The graphs for the viewing rectangles in parts (b), (c), and (d) are also shown in Figure 2. Complete Solutions Manual Single Variable Early Transcendentals By Daniel Anderson, Jeffery A. SOLUTION The expression for f 共x兲 is defined when 8 ⩾ 2x ⩾ 2 艌 0 ⇔ 2x 艋 8 Thus we need to choose a larger vertical rectangle. The natural logarithm In as an increasing function defined on 共0, ⬁兲 and the y-axis is a vertical asymptote. y y=sin x 1 0 π 2 π FIGURE 6 y=sin 2x 1 x 0 π 4 π x 2 π FIGURE 7 To obtain the graph of y 苷 1 ⩾ sin x, we again start with y 苷 sin x. Lynn found that in May it cost her $380 to drive 480 mi and in June it cost her $460 to drive 800 mi. The Vertical Line Test A curve in the xy-plane is the graph of a function of x if and only if no vertical line intersects the curve more than once. (This means that the values of ln x become very large negative as x approaches 0.) EXAMPLE 11 Sketch the graph of the function y 苷 ln共x ⩾ 2兲 ⩾ 1. With this in mind, let's reexamine the four situations that we considered at the beginning of this section. The changes have resulted from talking with my colleagues and students at the University of Toronto and from reading journals, as well as suggestions from users and reviewers. Brady, Wichita State University Michael Breen, Tennessee Technological University Robert N. (a) ⩾ 3 4 (b) (c) (d) (e) (f) 4x ⩾ 3y ⩽ 16 苷 0; x-intercept ⩾4, y-intercept ⩾ 163 共⩽1⩽, ⩾4兲 20 3x ⩾ 4y 苷 13 共x ⩽ 1兲2 ⩽ 共y ⩽ 4兲2 苷 100 (d) (e) (f) y 2 ⩽ ⩾4 y 3 0 _1 1 x y=⩾1 x ⩾ 4y 1 1. If you have had difficulty with these problems, you may wish to consult the review of analytic geometry in Appendixes B and C. (c) What is the y-intercept of the graph and what does it represent? I have included four kinds of projects: Applied Projects involve applications that are designed to appeal to the imagination of students. Discovery Projects anticipate results to be discussed later or encourage discovery through pattern recognition (see the one following Section 7.6). When was it the highest? 6 A PREVIEW OF CALCULUS The concept of the limit of a sequence occurs whenever we use the decimal representation of a real number. (b) Find an equation for the family of linear functions such that f 共2兲 苷 1 and sketch several members of the family. cos y 苷 x and 0 艋 y 艋 FIGURE 20 y=sin-¹ x=arcsin x y π 1 π 2 0 π 2 x π 0 _1 1 FIGURE 21 FIGURE 22 y=cos x, 0¯x¯π y=cos-¹ x=arccos x x The cancellation equations are cos ⩾1共cos x兲 苷 x cos共cos⩾1x兲 苷 x for 0 艋 x 艋 for ⩾1 艋 x 艋 1 The inverse cosine function, cos⩾1, has domain 关⩾1, 1兴 and range 关0, 兴. Explain your reasoning. 25. SOLUTION (a) Because we are assuming that T is a linear function of h, we can write T 苷 mh ⩽ b We are given that T 苷 20 when h 苷 0, so 20 苷 m ⩽ 0 ⩽ b 苷 b In other words, the y-intercept is b 苷 20. (See page 456.) Does a ball thrown upward take longer to reach its maximum height or to fall back to its original height? The tangent problem and the area problem are inverse problems in a sense that will be described in Chapter 5. Many physical quantities are connected by inverse square laws, that is, by power functions of the form f 共x兲 苷 kx ⩾2. When c is negative, the curve has a maximum point and a minimum point. log a x 苷 log a 再 log a y 再. 2. y 苷 1 ⩾ s x 3 19. If possible, sketch a rough graph of each function. Polynomials A function P is called a polynomial if P共x兲 苷 a n x n ⩽ a n⩾1 x n⩾1 ⩽ ⩽ a 2 x 2 ⩽ a 1 x ⩽ a 0 where n is a nonnegative integer and the numbers a 0 , a 1, a 2 , . SOLUTION Figure 6(a) shows the graph of f produced by a graphing calculator using the viewing rectangle 关⩾12, 12兴 by 关⩾1.5, 1.5兴. A good model simplifies reality enough to permit mathematical calculations but is accurate enough to provide valuable conclusions. Real-world problem Formulate Mathematical model Solve Mathematical conclusions Interpret Real-world predictions Test FIGURE 1 The modeling process The second stage is to apply the mathematics that we know (such as the calculus that will be developed throughout this book) to the mathematical model that we have formulated in order to derive mathematical conclusions. 20. 57. Condition: New. f 共x兲 苷 tan x, x 52. y 苷 x 3 x 1 x 3 3 x 11. We want to enlarge the domain of y 苷 2 x to include both rational and irrational numbers. h SOLUTION We first evaluate f 共a ⩽ h兲 by replacing x by a ⩽ h in the expression for f 共x兲: f 共a ⩽ h兲 苷 2共a ⩽ h兲2 ⩾ 5共a ⩽ h兲 ⩽ 1 苷 2共a 2 ⩽ 2ah ⩽ h 2兲 ⩾ 5共a ⩽ h兲 ⩽ 1 苷 2a 2 ⩽ 4ah ⩽ 2h 2 ⩾ 5a ⩾ 5h ⩽ 1 Then we substitute into the given expression and simplify: f 共a ⩽ h兲 ⩾ f 共a兲 共2a 2 ⩽ 4ah ⩽ 2h 2 ⩾ 5a ⩾ 5h ⩽ 1兲 ⩾ 共2a 2 ⩾ 5a ⩽ 1兲 苷 h h The expression f 共a ⩽ h兲 ⩾ f 共a兲 h in Example 3 is called a difference quotient and occurs frequently in calculus. f 共x兲 苷 x , t f 共x兲 苷 f 共a兲 x ⩾ a 30. Graphing Calculators and Computers In this section we assume that you have access to a graphing calculator or a computer with graphing software. All shipments contain tracking numbers. Below the surface, the water pressure increases by 4.34 lb鼻in2 for every 10 ft of descent. (c) Sketch the graph of the voltage V共t兲 in a circuit if the switch is turned on at time t 苷 7 seconds and the voltage is gradually increased to 100 volts over a period of 25 seconds. The book printed in black and white, generally send in twenty-four hours after the order confirmed. Isom, Arizona State University Gerald Janusz, University of Illinois at Urbana-Champaign John H. Write a formula for V共t兲 in terms of H共t兲 for t 艋 32. By looking at the blue curve we see that, at the latitude of Philadelphia, daylight lasts about 14.8 hours on June 21 and 9.2 hours on December 21, so the amplitude of the curve (the factor by which we have to stretch the sine curve vertically) is 12 共14.8 ⩾ 9.2兲 苷 2.8. By what factor do we need to stretch the sine curve in time 18 days? v EXAMPLE 2 Table 1 lists the average carbon dioxide level in the atmosphere, measured in parts per million at Mauna Loa Observatory from 1980 to 2008. Visuals are animations of figures in text; Modules are more elaborate activities and include exercises. 29. It is this basic idea of a limit that sets calculus apart from other areas of mathematics. (b) Draw the graph of the function in part (a). If a particular hint doesn't enable you to solve the problem, you can click to reveal the next hint. FIGURE 9 Another way to avoid the extraneous line is to change the graphing mode on the calculator so that the dots are not connected. We will approximate the desired area A by areas of rectangles (as in Figure 4), let the width of the rectangles decrease, and then calculate A as the limit of these sums of areas of rectangles. It still doesn't quite reveal all the main features of f, so we try 关⩾20, 20兴 by 关⩾1000, 1000兴 in Figure 5(c). f 共x兲 苷 sec2 0 x兲 35. 11. If n 苷 1, a positive integer, then a n 苷 a ⩾ a ⩾ ⩾ a n factors If n 苷 0, then a 0 苷 1, and if n 苷 ⩾n, where n is a positive integer, then a ⩾n 苷 1 a n If x is a rational number, x 苷 p兾q, where p and q are integers and q ¬ 0, then a p q a x 苷 a p兾q 苷 s q (a) p 苷 (sa) p 1 0 1 x FIGURE 1 Representation of y=2®, x rational But what is the meaning of a x if x is an irrational number? Find the length of the segment AB. y 苷 2 共x 1 兾 x 2 ⩾ 3 16 y 苷 x 2 ⩾ 3x 18. Implicit Differentiation 3.6 Derivatives of Logarithmic Functions 3.7 Rates of Change in the Natural and Social Sciences 3.8 Exponential Growth and Decay 3.9 Related Rates 3.10 Linear Approximations and Differentials Hyperbolic Functions Review 208 209 3.6 Laboratory Project 4 184 198 Laboratory Project 3.11 250 256 257 264 268 Applications of Differentiation 273 4.1 Maximum and Minimum Values Applied Project N 274 The Calculus of Rainbows 282 4.2 The Mean Value Theorem 4.3 How Derivatives Affect the Shape of a Graph 4.4 Indeterminate Forms and l'Hospital's Rule Writing Project N 284 Summary of Curve Sketching 4.6 Graphing with Calculus and Calculators 4.7 Optimization Problems N 4.8 Newton's Method 4.9 Antiderivatives Review Problems Plus 351 355 344 310 310 325 The Shape of a Can 338 290 301 The Origins of l'Hospital's Rule 4.5 Applied Project 174 337 318 324 CONTENTS 5 Integrals 359 5.1 Areas and Distances 360 5.2 The Definite Integral 371 Discovery Project 385 The Fundamental Theorem of Calculus 5.4 Indefinite Integrals and the Net Change Theorem 5.5 N Problems Plus 386 397 Newton, Leibniz, and the Invention of Calculus The Substitution Rule Review 406 407 415 419 Applications of Integration 421 6.1 Areas Between Curves Applied Project N 422 The Gini Index 6.2 Volumes 6.3 Volumes by Cylindrical Shells 6.4 Work 6.5 Average Value of a Function 429 430 441 446 451 Applied Project N Calculus and Baseball Applied Project N Where to Sit at the Movies Review Problems Plus 7 Area Functions 5.3 Writing Project 6 N 455 456 457 459 Techniques of Integration 463 7.1 Integration by Parts 7.2 Trigonometric Integrals 7.3 Trigonometric Substitution 7.4 Integration of Rational Functions by Partial Fractions 7.5 Strategy for Integration 7.6 Integration Using Tables and Computer Algebra Systems Discovery Project N 464 471 478 484 494 Patterns in Integrals 505 500 vii viii CONTENTS 7.7 Approximate Integration 7.8 Improper Integrals Review Problems Plus 519 529 533 Further Applications of Integration 537 8.1 Arc Length 538 Discovery Project 8.2 8.3 N Arc Length Contest Area of a Surface of Revolution Discovery Project N 545 545 Rotating on a Slant 551 Applications to Physics and Engineering Discovery Project N Applications to Economics and Biology 8.5 Probability Review Problems Plus 552 Complementary Coffee Cups 8.4 Review 9 506 562 563 568 575 577 Differential Equations 579 9.1 Modeling with Differential Equations 9.2 Direction Fields and Euler's Method 9.3 Separable Equations 580 585 594 Applied Project N How Fast Does a Tank Drain? Spain . (It is now accessible from the Internet at www.stewartcalculus.com and in Enhanced WebAssign and CourseMate.) Developed by Harvey Keynes, Dan Clegg, Hubert Hohn, and myself, TEC uses a discovery and exploratory approach. 61. This exercise explores the effect of the inner function t on a composite function y 苷 f 共t共x兲兲. The table shows the percentage of the population of Argentina that has lived in rural areas from 1955 to 2000. SECTION 1.2 31 MATHEMATICAL MODELS: A CATALOG OF ESSENTIAL FUNCTIONS y y y 1 1 2 1 _3 x 0 FIGURE 17 (a) ƒ=xœ„„„„ x+3 x 5 0 (b) ©=œ„„„„„„ ≈-25 x 1 (c) h(x)=#(x-2)@ An example of an algebraic function occurs in the theory of relativity. Notice that whenever x increases by 0.1, the value of f 共x兲 increases by 0.3. So f 共x兲 increases three times as fast as x. Palmer, Utica College Vincent Panico, University of the Pacific F. If so, what is the slope of its graph? The graph might even suggest a suitable algebraic formula in some cases. The domain of any polynomial is 苷 共⩾⬁, ⬁兲. ⩾x ⬇ 4 and y ⬇ 2 (a) ⩾1 艋 y 艋 3 (b) (c) y ⬇ 1 ⩾ x (d) y 苷 20 ⩾ x 1 (e) x 2 ⩽ y 2 ⬇ 4 (f) 9x 2 ⩽ 16y 2 苷 144 1 2 Answers to Diagnostic Test B: Analytic Geometry 1. CengageBrain.com To access additional course materials and companion resources, please visit www.cengagebrain.com. (b) Find and graph the regression line. 0⬆w 1⬆w 2⬆w 3⬆w 4⬆w 80 1 2 3 4 5 The function P is typical of the functions that arise whenever we attempt to apply calculus to the real world. CourseMate for Stewart's Calculus includes: an interactive eBook, Tools for Enriching Calculus, videos, quizzes, flashcards, and more! For instructors, CourseMate includes Engagement Tracker, a first-of-its-kind tool that monitors student engagement. Using the transfor- mations of Section 1.3, we shift it 2 units to the right to get the graph of y 苷 ln共x ⩾ 2兲 and then we shift it 1 unit downward to get the graph of y 苷 ln共x ⩾ 2兲 ⩾ 1. .兲 form what is known as a sequence. At 6 PM? If we zoom in toward the origin, we see the graph of f for the viewing rectangle 关⩾0.1, 0.1兴 by 48 CHAPTER 1 FUNCTIONS AND MODELS 0.1 _0.1 0.1 关⩾0.1, 0.1兴, we can see much more clearly the shape of these bumps in Figure 9. t共t兲 苷 s3 ⩽ t ⩾ s2 ⩽ t angle as a function of one of its sides. The parabola, however, does contain the graphs of two functions of x. ■ Three new projects have been added: The Gini Index (page 429) explores how to measure income distribution among inhabitants of a given country and is a nice application of areas between curves. Explain why the two graphs appear identical. 31. (c) Find f ∘ t ∘ h. This enables us to see how the graph of f would look if x were in the field of complex numbers. Figure 21 shows the graphs of four logarithmic functions with various bases. For instance, the sequence (1, 12 , 13 , 14 , 15 , . . Why? We reflect about the x-axis to get the graph of y 苷 ⩾sin x, and we shift 1 unit upward to get y 苷 1 ⩾ sin x. (b) At what depth is the pressure 100 lb鼻in2 ? SOLUTION We start with the graph of y 苷 ln x as given in Figure 13. (b) Since t共2兲 苷 2 2 苷 4 and t共4兲 苷 共1兲 苷 1兾2 苷 2, we could plot the points 共2, 4兴 and 共⩾1, 1兴, together with a few other points on the graph, and join them to produce the graph (Figure 8). For example, if the answer given in the back of the book is s2 ⩾ 1 and you obtain 1兾(1 ⩽ s2), then you're right and rationalizing the denominator will show that the answers are equivalent. f 共x兲 苷 48. They are applied, both explicitly and implicitly, throughout the book. The parabola opens upward if a ¬ 0 and downward if a ⬆ 0. Four reliable suppliers in the market. ISBN 0-534-39339-X Single Variable Calculus Early Transcendentals, 7e Available online on pricing, review costs as of this page and is very seldom done, not relevant to the page's content. (a) What is the distance? 3. 0 3 ln 3 Find the domain of each function. Graphing calculators and computers are great aids for sketching the graphs of many types of functions. (b) Find the formula for the function whose graph is (a). It can be seen from Figure 4 that we need a factor of 8. For more information about our products, contact us at: Cengage Learning Customer & Sales Support, 1-800-354-9706. For permission to use material from this text or product, submit all requests online at www.cengage.com/permissions Further permissions questions can be emailed to Library of Congress Control Number: 2010936598 Student Edition: ISBN-13: 978-0-538-49790-9 ISBN-10: 0-538-49790-4 Loose-leaf Edition: ISBN-13: 978-0-8400-5829-4 ISBN-10: 0-8400-5829-X Brooks/Cole 20 Davis Drive Belmont, CA 94002-3098 USA Cengage Learning is a leading provider of customized learning solutions with office locations around the globe, including Singapore, the United Kingdom, Australia, Mexico, Brazil, and Japan. Locate your local office at www.cengage.com/global. Cengage Learning products are represented in Canada by Nelson Education, Ltd. To learn more about Brooks/Cole, visit www.cengage.com/brookscole. Purchase any of our products at your local college store or at our preferred online store www.cengagebrain.com. Trademarks ExamView® and ExamViewPro® are registered trademarks of FSCreations, Inc. Then we shift the graph of y 苷 ln x by ⩽1 unit, the graph of the function y 苷 2 x, shown in Figure 1, 2 x 2 ⩾ 1. Before you look at the Solutions, it's very important that you make your best try at each problem. Unlike sin 2x, the graph changes are smaller when x is near zero; cos x is almost constant. Review of Calculus From the Instructor's Guide and other publications of the same author. The period of the function is 2, the figure with few sides and the resolution of the picture, and to learn the basics and facts of calculus fast. ISBN-10: 0538497904. In 1963 the diagram was 62.1 years. The solution is an exponential expression in the form of 3 x = 8, and the equation can be written in logarithmic form. Any idea of how I can get the edition? Find the equation of the line through the given points. Then find the slope and the y-intercept of the graph, and to interpret them. Then the value of t is quite well defined. If we look at the sine graph at the interval from 0 to 2π, we see that it repeats itself. Express the cost as a function of the width of the base. In particular, you should look at the definitions to see the exact meanings of the terms. f 共x兲 苷 s 2t ⩾ 1 21 function h共x兲 苷 s4 ⩾ x 2 . Then we may be able to construct a table of values of the function, perhaps from instrument readings in a scientific experiment. Holmes, Auburn University James F. 46 CHAPTER 1 FUNCTIONS AND MODELS EXAMPLE 2 Determine an appropriate viewing rectangle for the function f 共x兲 苷 s8 ⩾ 2x 2 and use it to graph f. Its graph is shown in Figure 16. 21. Harrison, Daylight, Twilight, Darkness and Time (New York, 1935) page 40. 7 (a) How is the graph of y 苷 f 共x 28. **INTERNATIONAL EDITION** Read carefully before purchase: This book is the international edition in mint condition with the different ISBN and book cover design (Full Bundle), the major content is printed in full English as same as the original North American edition. Although there is no simple formula that connects t and C, the post office has a rule for determining C when w is known. I have tried to write a book that assists students in discovering calculus—both for its practical power and its surprising beauty. and decreases. The rule that connects r and A is given by the equation A 苷 r 2. 1 y y y 1 f g h 1 11 _1 x x 1 _1 FIGURE 21 ( ) (b) (c) x SECTION 1.1 y D The graph shown in Figure 22 rises from A to B, falls from B to C, and rises again from C to D. y 苷 f 共x兲 苷 x a, b兴 关c, d兴 FUNCTIONS 39 20 18 16 14 12 20° N 30° N 40° N 50° N Hours 10 8 6 FIGURE 9 Graph of the length of daylight from March 21 through December 21 at various latitudes 4 Lucia C. 35. This is not a rental. 59. May June July Aug. I think that nearly everybody agrees that this should be the primary goal of calculus instruction. Figure 11 shows how to picture f ∘ t in terms of machines. Convert from degrees to radians. y=log a x, a¬1 y FIGURE 11 1 0 y=log² x y=log¡¸ x 1 0 1 x y=log£ x y=log∞ x y=ln x, FIGURE 12 The following properties of logarithmic functions follow from the corresponding properties of exponential functions given in Section 1.5. Laws of Logarithms If x and y are positive numbers, then 1. The f ∘ g machine is composed of the g machine (first) and then the f machine. Also, 3 ⩽ s8 苷 ⩽ 2 in the interval 关0, 2s2 兴 2.83 so the range of t is the interval 关0, 2s2 兴. The solid dot indicates that the point 共⩾1, 2兲 is excluded from the graph. In particular, since the irrational number s3 satisfies 1.7 ⬇ s3 ⬇ 1.8 we must have 2 1.7 ⬇ 2 s3 ⬇ 2 1.8 and we know what 21.7 and 21.8 mean because 1.7 and 1.8 are rational numbers. (a) y 苷 15. If the ground temperature is 20⬚C and the temperature at a height of 1 km is 10⬚C, express the temperature T (in °C) as a function of the height h (in kilometers), assuming that a linear model is appropriate. 0 2 x 5. Figure 2 illustrates this process for the special case of a circle with inscribed regular polygons. To obtain the graph of y 苷 cf 共x兲, stretch the graph of y 苷 f 共x兲 vertically by a factor of c y 苷 f 共x兲 ⩾ c, shift the graph of y 苷 f 共x兲 a distance c units downward horizontally by a factor of c y 苷 f 共x兲, stretch the graph of y 苷 f 共x兲 horizontally by a factor of c y 苷 ⩾f 共x兲, reflect the graph of y 苷 f 共x兲 about the x-axis y 苷 f 共⩾x兲, reflect the graph of y 苷 f 共x兲 about the y-axis Figure 3 illustrates these stretching transformations when applied to the cosine function with c 苷 2. ** ACCESS CODES ARE NEVER GUARANTEED ** Could have writing & highlighting from previous use. 5 Dept. For an online version, see catechbook.library.caltech.edu/197/ 1.73 ⬇ s3 ⬇ 1.74 What does the slope represent? ENHANCED W E B A S S I G N Technology is having an impact on the way homework is assigned to students, particularly in large classes. You can see that the secant line rotates and approaches the tangent line as its limiting position. Expand and simplify. We will then use Newton's idea of combining infinite series with the differential and integral calculus. For now you can think of it as a line that touches the curve at P as in Figure 5.) Since we know that the point P lies on the tangent line, we can find the equation of t if we know its slope m. xxviii D DIAGNOSTIC TESTS Diagnostic Test: Trigonometry 1. An electronic version of the Instructor's Guide is available on the PowerLecture DVD. The goal is for students to be able to divide a quantity into small pieces, estimate with Riemann sums, and recognize the limit as an integral. I recommend that you keep this book for reference purposes after you finish the course. The book contains elements of reform, but within the context of a traditional curriculum. To check the accuracy of your model, use the fact that on March 31 the sun rises at 5:51 AM and sets at 6:18 PM in New Orleans. Hamilton, California State University, Sacramento Darel Hardy, Colorado State University Gary W. Then sketch a rough graph of the temperature of the water as a function of the time that has elapsed since the tap was turned on. The icon ; indicates an exercise that definitely requires the use of such technology, but that is not to say that it can't be used on the other exercises as well. Another type of exercise uses verbal description to test conceptual understanding (see Exercises 2.5.10, 2.8.58, 4.3.63–64, and 7.8.67). The table of values of world population provides a convenient representation of this function. Condition: GOOD. (a) Express the water pressure as a function of the depth below the ocean surface. The top half of the circle x 2 ⩽ 共y ⩾ y 2 苷 4 55. However, by indirect reasoning, Eudoxus (fifth century BC) used exhaustion to prove the familiar formula for the area of a circle: A r 2. EXAMPLE 10 Evaluate log 8 5 correct to six decimal places. Homework Hints available at stewartcalculus.com ure 9 to find a function that models the number of hours of daylight at New Orleans as a function of the time of year. (a) Find

the values of f 共1兲 and f 共5兲. (See, for instance, the first few exercises in Sections 2.2, 2.5, and 11.2.) Similarly, all the review sections begin with a Concept Check and a True-False Quiz. When Achilles reaches a 3 t2 , the tortoise is at t3 . Suppose t is an even function and let h 苷 f o t. SECTION 1.2 29 MATHEMATICAL MODELS: A CATALOG OF ESSENTIAL FUNCTIONS (i) a 苷 n, where n is a positive integer The graphs of f 共x兲 苷 x n for n 苷 1, 2, 3, 4, and 5 are shown in Figure 11. Paperback. The graphs of y 苷 2 x and y 苷 0.5 x are shown in Figure 20. Ferguson, University of California–Riverside Shari Harris, John Wood Community College Amer Iqbal, University of Washington—Seattle Akhtar Khan, Rochester Institute of Technology Marianne Korten, Kansas State University Joyce Longman, Villanova University Richard Millspaugh, University of North Dakota Lon H. Write equations for the graphs that are obtained from the graph of f as follows. In fact, we see from Figure 6 that the trend has been for CO2 levels to increase rather more rapidly in recent years, so the level might exceed 420 ppm well before 2030. Find the midpoint of the segment AB. 3–14 Determine an appropriate viewing rectangle for the given 26. Some students start by trying their homework problems and read the text only if they get stuck on an exercise. After taking each test you can check your answers against the given answers and, if necessary, refresh your skills by referring to the review materials that are provided. It therefore seems reasonable to say that the sum of the infinite series is 1 and to write 1 1 1 1 ⩽ ⩽ ⩽ n ⩽ 苷 1 2 4 8 2 8 A PREVIEW OF CALCULUS In other words, the reason the sum of the series is 1 is that lim sn 苷 1 n l∞ In Chapter 11 we will discuss these ideas further. With this edition, we PREFACE xvii media and technologies have been developed that help students to visualize so that instructors can customize content to better align with the way they teach their course. Because you will likely forget some of the specific details of calculus, the book will serve as a useful reminder when you need to use calculus in subsequent courses. y y 1 (_3, 1) x 0 FIGURE 5 _3 (a) y=œ _1 0 x (b) y=(x+3)@+1 EXAMPLE 3 Sketch the graphs of the following functions. This enables us to sketch the graph in Figure 15. But everything a geologist needs to know—amplitudes and patterns—can be easily seen from the graph. The details are explained in Section 14.7. Notice that our model gives values higher than most of the actual CO2 levels. Notice that the domain of the function is 共x 兩 x 苷 1兲. Consider the following four situations. Thus we can think of the domain as the set of all possible inputs and the range as the set of all possible outputs. The slope of this line is 385.6 苷 338.7 46.9 苷 1.675 2008 ⩾ 1980 28 and its equation is C 苷 338.7 苷 1.675共t ⩾ 1980兲 or C 苷 1.675t ⩾ 2977.8 1 Equation 1 gives one possible linear model for the carbon dioxide level; it is graphed in Figure 5. The Sum of a Series Another of Zeno's paradoxes, as passed on to us by Aristotle, is the following: "A man standing in a room cannot walk to the wall. The inverse function of this restricted sine function exists and is denoted by sin 1 or arcsin. PREFACE ■ More than 25% of the exercises in each chapter are new. A Preview of Calculus This is an overview of the subject and includes a list of questions to motivate the study of calculus. The graph shows how the number of 1 is the most natural representation of the vertical acceler- lope with weight w. If we change the viewing rectangle to 关⩾20, 20兴 by 关⩾20, 20兴, we get the picture shown in Figure 5(a). (See Figure 2 and the following chart, where the results of other stretching, shrinking, and reflecting transformations are also given.) Vertical and Horizontal Stretching and Reflecting Suppose c ¬ 1. (c) Sketch the graph of the total assessed tax T as a function of the income I. 1.5 Exponential Functions In Appendix G we present an alternative approach to the exponential and logarithmic functions using integral calculus. We will see that the use of such a device enables us to graph more complicated functions and to solve more complex problems than would otherwise be possible. Printed Test Bank By William Steven Harmon ISBN 0-8400-5419-X Contains text-specific multiple-choice and free response test items. 28. Symmetry If a function f satisfies f 共⩾x兲 苷 f 共x兲 for every number x in its domain, then f is called an even function. BOOK ONLY (no code). All of them have contributed greatly to the success of this book. Figure 1 shows a graph generated by seismic activity during the Northridge earthquake that shook Los Angeles in 1994. Observe from either picture that the terms of the sequence a n 苷 1兾n are becoming closer and closer to 0 as n increases. f 2 33. In order to convey a sense of the power of the subject, we end this preview with a list of some of the questions that you will be able to answer using calculus: 1. f 共x兲 苷 s15x ⩾ x 2 7. SOLUTION Figure 8 shows the graph of f produced by a graphing calculator with viewing rectangle ⩾关6.5, 6.5兴 by 关⩾1.5, 1.5兴. I have also included a section on probability. Recent studies indicate that the average surface tempera- g h 0 y (_2, 2) f (d) y 苷 tan t ⩾ cos t s 1⩽3. f 共x兲 苷 x 2 ⩾ 4 , 40. ■ Essential Calculus: Early Transcendentals resembles Essential Calculus, but the exponential, logarithmic, and inverse trigonometric functions are covered in Chapter 3. It is the called the composition (or composite) of f and t and is denoted by f o t (" f circle t"). The graph shows the height of the water in a bathtub as a function of time. f 共x兲 苷 2t ⩽ t 2 42. 19–20 Do the graphs intersect in the given viewing rectangle? (a) y 苷 3 (d) y 苷 x 2 (g) y 苷 2 x 6. (c) Sketch the graph of y 苷 e x . ■ The data in examples and exercises have been updated to be more timely. It is undefined whenever cos x 苷 0, that is, when x 苷 兾2, 3兾2, . t ¬ t t ¬ t t . How does the graph change as t increases? 7. The symbol CAS is reserved for problems in which the full resources of a computer algebra system (like Derive, Maple, Mathematica, or the TI-89/92) are required. Locate your local office at www.cengage.com/global. We also point out some of the pitfalls that can occur with these machines. Heuvers, William P. In Example A, for instance, r is the independent variable and A is the dependent variable. EXAMPLE 6 Draw the graph of the function y 苷 1 . f 共x兲 苷 sin x 12. We start with a verbal description of a function. 9 10 CHAPTER 1 1.1 FUNCTIONS AND MODELS Four Ways to Represent a Function Year Population (millions) 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 1650 1750 1860 2070 2300 2560 3040 3710 4450 5280 6080 6870 Functions arise whenever one quantity depends on another. Give two other examples of step functions that arise in everyday life. Figure 17 illustrates some of the possibilities. Explain your choices. (a) f 共x兲 苷 5 ⩽ x (b) f 共x兲 苷 1 ⩽ x 4 (c) h共x兲 苷 2x ⩽ x 2 SOLUTION f 共x兲 苷 f 共x兲 苷 1 共⩾x兲5 5 ⩽ 共⩾x兲 苷 x⩽5 共⩾x兲 苷 x 5 ⩾x 5 (a) 苷 ⩽x 5 ⩽ x 苷 ⩽ 共x5 ⩽ x兲 苷 ⩽f 共x兲 Therefore f is an odd function. x x y x 64. Shown is a graph of the ground acceleration created by the 2008 earthquake in Sichuan province in China. (a) Try to find an appropriate viewing rectangle for f 共x兲 苷 共x 兲 10共3 2兲 x ⩽ 1 2 22. (a) y 苷 2x, 3 y 共0, 7兲. Acknowledgments The preparation of this and previous editions has involved much time spent reading the reasoned (but sometimes contradictory) advice from a large number of astute reviewers. Solve each inequality. Assume the car is well maintained. If f and t are 80. Sketch a rough graph of the number of hours of daylight as a function of the time of year. The purpose of the model is to understand the phenomenon and perhaps to make predictions about future behavior. Don't be discouraged if you have to read a passage more than once in order to understand it. (a) Find the slope of the graph of c. In each case we say that the second number is a function of the first number. 45. Since the y-coordinate of any point 共x, y兲 on the graph is y 苷 f 共x兲, we can read the value of f 共x兲 from the graph as being the height of the graph above the point x (see Figure 4). If f 共x兲 苷 x 3 , evaluate the difference quotient f 共2 ⩽ h兲 ⩾ f 共2兲 and simplify your answer. ExamView testing is available on the PowerLecture DVD. When we say that y is a linear function of x, we mean that the graph of the function is a line, so we can use the slope-intercept form of the equation of a line to write a formula for 24 CHAPTER 1 FUNCTIONS AND MODELS the function as y 苷 f 共x兲 苷 mx ⩽ b where m is the slope of the line and b is the y-intercept. The successive positions of Achilles and the tortoise form sequences 兵an兲 and 兵tn兲, where a n ⩾ tn for all n. Decide whether each function is even, odd, or neither. A rectangle has area 16 m2. 30 Day From Purchase Return Policy. In general, an exponential function is a function of the form f 共x兲 苷 a x where a is a positive constant. When the tank is drained, T decreases to the temperature of the water supply. 20 CHAPTER 1 FUNCTIONS AND MODELS 7–10 Determine whether the curve is the graph of a function of x. This chapter prepares the way for calculus by discussing the basic ideas concerning functions, their graphs, and ways of transforming and combining them. The figure shows the graphs of y 苷 sin 96x and y 苷 sin 2x as 2π 0 2π 0 2π displayed by a TI-83 graphing calculator. y y y=sin x _π2 _π 0 π 2 0 x π π 2 x π π FIGURE 18 y=sin x, _ 2 ˇxˇ 2 FIGURE 17 Since the definition of an inverse function says that f ⩾1共x兲 苷 y f 共y兲 苷 x &? y y=3x-2 0 x _2 f 共x兲 苷 3x ⩾ 2 1.0 1.1 1.2 1.3 1.4 1.5 1.0 1.3 1.6 1.9 2.2 2.5 FIGURE 2 y EXAMPLE 1 (a) As dry air moves upward, it expands and cools. Use your answer and Figure 6 to sketch the graph of y 苷 2 sin x. 65. Of all possible bases a for logarithms, we will see in Chapter 3 that the most convenient choice of a base is the number e, which was defined in Section 1.5. The logarithm with base e is called the natural logarithm and has a special notation: log e x 苷 ln x If we put a 苷 e and replace log e with "ln" in 6 and 7 , then the defining properties of the natural logarithm function become ln x 苷 y &? e y 苷 x &? Let's recall what this means. Linear Models The coordinate geometry of lines is reviewed in Appendix B. ; 28. In Example 4 we had to make the viewing rectangle smaller. (Note that starting at t 苷 5 corresponds to a translation.) 58. f 共x兲 苷 1 ⩽ 3x 3 0 x 5 SECTION 1.2 MATHEMATICAL MODELS: A CATALOG OF ESSENTIAL FUNCTIONS 79. Martin, University of Virginia Gerald Y. 17. 6–7 The graph of y 苷 s3x ⩾ x 2 is given. a semicircle. In connecting successive points on the graph, the calculator produced a steep line segment from the top to the bottom of the screen. In the next example we graph members of a family of cubic polynomials. Solution Builder allows you to create customized, secure solutions printouts (in PDF format) matched exactly to the problems you assign in class. If each vertical line x 苷 a intersects a curve only once, at 共a, b兲, then exactly one functional value is defined by f 共a兲 苷 b. 23. State the domain and range of f. ■ Calculus: Concepts and Contexts, Fourth Edition, emphasizes conceptual understanding even more strongly than this book. Ancillaries Single Variable Calculus, Early Transcendentals, Seventh Edition, is supported by a complete set of ancillaries developed under my direction. Similarly, if we use better approximations for s3 , we obtain better approximations for 2 s3 . A proof of this fact is given in J. Even though we don't have complete knowledge of the values of the function, we will see throughout the book that it is still possible to perform the operations of calculus on such a function. The city of New Orleans is located at latitude 30□N. 34. Rationalize the expression and simplify. The graph depicts the distance run as a function of time for each runner. © Brett Mulcahy / Shutterstock © iofoto / Shutterstock Calculus is fundamentally different from the mathematics that you have studied previously: calculus is less static and more dynamic. Because the curve y 苷 e x crosses the y-axis with a slope of 1, it follows that the reflected curve y 苷 ln x crosses the x-axis with a slope of 1. Similarly, Formula 10 allows us to graph any logarithmic function on a graphing calculator or computer (see Exercises 43 and 44). FIGURE 3 Arrow diagram for f y y f (x) f (_x) 0 _x x x 0 FIGURE 5 FIGURE 4 y EXAMPLE 1 The graph of a function f is shown in Figure 6. In this edition, as in the first six editions, I aim to convey to the student a sense of the utility of calculus and develop technical competence, but I also strive to give some appreciation for the intrinsic beauty of the subject. A Norman window has the shape of a rectangle surmounted by 68 11. How many species of bats would you expect to find in that cave? SOLUTION Here 苷 1 0 1 苷 x x2 ⩽ x tan苷1x. The range of t consists of all values of t共x兲, that is, all numbers of the form x 2. It directs you to modules in which you can explore aspects of calculus for which the computer is particularly useful. NB: this is book 2 of "CALCULUS COMBINED" and begins with Chapter 12. (a) f 共x兲 苷 sx ⩽ 2 (b) t共x兲 苷 1 x ⩾ x2 SOLUTION (a) Because the square root of a negative number is not defined (as a real number), the domain of f consists of all values of x such that x ⩽ 2 ⩾ 0. In writing the seventh edition my premise has been that it is possible to achieve conceptual understanding and still retain the best traditions of traditional calculus. Suggested references are supplied. 5 _5 FIGURE 4 20 _20 500 20 _20 1000 20 20 _20 _20 _500 _1000 (a) (b) (c) FIGURE 5 Graphs of y=_-150x v EXAMPLE 4 Graph the function f 共x兲 苷 sin 50x in an appropriate viewing rectangle. J. If ⩽ ⬆ 0, then x is not in the domain of this function; that is, x is not an acceptable input, and the calculator will indicate an error. If we start with the viewing rectangle 关⩾5, 5兴 by 关⩾5, 5兴, we get the graph in Figure 4. 1 4 5 7. 11 Infinite Sequences and Series The convergence tests have intuitive justifications (see page 714) as well as formal proofs. ■ Calculus, Seventh Edition, is similar to the present textbook except that the exponential, logarithmic, and inverse trigonometric functions are covered in the second semester. Condition: Fair. (c) Sketch a possible graph of the ground speed. For product information and technology assistance, contact us at Cengage Learning Customer & Sales Support, 1-800-354-9706. 5 _5 SOLUTION Here the domain is , the set of all real numbers. Of course, it's impossible to devise an explicit formula that gives the exact human population P共t兲 at any time t. But there are many possible lines that approximate these data points, so which one should we use? For a given value of t, the graph provides a corresponding value of a. (See Figure 14.) FIGURE 13 The graph of y=ln x is the reflection of the graph of y=´ about the line y=x y y y x=2 y=ln(x-2)-1 y=ln(x-2) 0 x 2 x (3, 0) 2 0 x (3, _1) FIGURE 14 Although ln x is an increasing function, it grows very slowly when x ¬ 1. The Limit of a Sequence In the fifth century BC the Greek philosopher Zeno of Elea posed four problems, now known as Zeno's paradoxes, that were intended to challenge some of the ideas concerning space and time that were held in his day. Zooming in to the viewing rectangle 关0, 1兴 by 关0, 1兴, we see from Figure 14(b) that the root lies between 0.7 and 0.8. So we zoom in further to the viewing rectangle 关0.7, 0.8兴 by 关0.7, 0.8兴 in Figure 14(c). If a ¬ 1, then a x approaches 0 as x decreases through negative values. How does this graph differ from the graph of the sine function? 15. 12 The appearance of the graphs in Figure 6 depends on the machine used. Additional media assets include: animated figures, video clips, highlighting, notes, and more! YouBook is available in Enhanced WebAssign. y 苷 3x 2 ⩽ 6x ⩽ 1 y 苷 0.23x ⩾ 2.25; 关⩾3, 3兴 by 关⩾2.5, 1.5兴 20. Justify your answers. These books are an ACCEPTABLE condition with the interior pages and binding blocks fully intact, and VISIBLE wear and tear to the exterior covers! We ship daily, Mon-Sat. y y y y (1, 1) (1, 1) (1, 1) (1, 1) y=x y=1 0 x y=x 0 x 0 x 0 x 0 y=x 0 y=2x 0 x y x 1 0 x 1 0 x 0 x y FIGURE 4 The area problem is the central problem in the branch of calculus called integral calculus. f 4. 43. If x 苷 0, then an approximation to s x will appear in the display. To get around the problem we first find an approximation to mPQ by taking a nearby point Q on the curve and computing the slope mPQ of the secant line PQ. 6 Applications of Integration Here I present the applications of integration—area, volume, work, average value—that can reasonably be done without specialized techniques of integration. Hardcover. If this number satisfies 1 ⩽ x ⩽ 3共x兲 is in the domain of f , then we can calculate t the value of f 共t共x兲兲. The plan includes 400 free minutes and charges 10 cents for each additional minute of usage. y 1 (b) y=| x|+1 FIGURE 10 2 (a) y=⩾1 0 x ⩾1 The plan Another transformation of some interest is taking the absolute value of a function. The machine connects each point to the preceding plotted point to form a representation of the graph of f. Give a verbal description of what you think happened. (a) 苷 f o t 共x兲 共x兲 苷 共x兲 2x 4 ⩾ 8x ⩽ 2 (b) 共x兲 t o f 共x兲 苷 2 共x兲 2x 4 ⩾ 8x ⩽ 5 (c) f 共x兲 t o t o f 共x兲 苷 8x ⩾ 21 y (2, 3) 1 1 0 (c) y 苷 1 0 x 1 0 x If you have had difficulty with these problems, you should look at Sections 1.1–1.3 of this book. Mitchell, Virginia Commonwealth University Ho Kuen Ng, San Jose State University Norma Ortiz-Robinson, Virginia Commonwealth University Qin Sheng, Baylor University Magdalena Toda, Texas Tech University Ruth Trygstad, Salt Lake Community College Klaus Volpert, Villanova University Peiyong Wang, Wayne State University TECHNOLOGY REVIEWERS Maria Andersen, Muskegon Community College Eric Aurand, Eastfield College Joy Becker, University of Wisconsin–Stout Przemyslaw Bogacki, Old Dominion University Amy Elizabeth Bowman, University of Alabama in Huntsville Monica Brown, University of Missouri–St. Louis Roxanne Byrne, University of Colorado at Denver and Health Sciences Center Teri Christiansen, University of Missouri–Columbia Bobby Dale Daniel, Lamar University Jennifer Daniel, Lamar University Andras Domokos, California State University, Sacramento Timothy Flaherty, Carnegie Mellon University Lee Gibson, University of Louisville Jane Golden, Hillsborough Community College Semion Gutman, University of Oklahoma Diane Hoffoss, University of San Diego Lorraine Hughes, Mississippi State University Jay Jahangiri, Kent State University John Jernigan, Community College of Philadelphia Brian Karasek, South Mountain Community College Jason Kozinski, University of Florida Carole Krueger, The University of Texas at Arlington Ken Kubota, University of Kentucky John Mitchell, Clark College Donald Paul, Tulsa Community College Chad Pierson, University of Minnesota, Duluth Lanita Presson, University of Alabama in Huntsville Karin Reinhold, State University of New York at Albany Thomas Riedel, University of Louisville Christopher Schroeder, Morehead State University Angela Sharp, University of Minnesota, Duluth Patricia Shaw, Mississippi State University Carl Spitznagel, John Carroll University Mohammad Tabanjeh, Virginia State University Capt. Nur, California State University, Fresno Wayne N. This indicates that we need to see more in the vertical direction, so we change the viewing rectangle to 关⩾20, 20兴 by 关⩾500, 500兴. State the domain and range of f. The first inequality means x ⩾2, and the second is equivalent to s2 ⩽ x ⩾ 2, or 2 ⩾ x ⩾ 4, or x ⩽ 2. At the CengageBrain.com home page, search for the ISBN of your title (from the back cover of your book) using the search box at the top of the page. A 1 1 C x y 10. 3 % ⩾24 Graph the function by hand, not by plotting points, but by 4. The first four of the five sections of this chapter serve as a good introduction to first-year calculus. (b) Find and graph a linear model using the first and last data points. For instance, if a 1 苷 3.1 a 2 苷 3.14 a 3 苷 3.141 a 4 苷 3.1415 a 5 苷 3.14159 a 6 苷 3.141592 a 7 苷 3.1415926 then lim a n 苷 then n l∞ The terms in this sequence are rational approximations to . 1.4 (c) Sketch the graph of the voltage V共t兲 in a circuit if the switch is turned on at time t 苷 5 seconds and 240 volts are applied instantaneously to the circuit. The graph of a function f gives us a useful picture of the behavior or "life history" of a function. The emphasis is on understanding concepts. Simplify the rational expression. This means that the numbers a n can be made as close as we like to the number L by taking n sufficiently large. This will take you to the product page where these companion resources can be found. Enhanced WebAssign www.webassign.net WebAssign's homework delivery system lets instructors deliver, collect, grade, and record assignments via the web. You will also encounter the symbol ⌊, which warns you against committing an error. f 共x兲 苷 s5 ⩾ 2 x 6. We are given a description of the function in words: P共t兲 is the human population of the world at time t. (b) y 苷 2 f 共x兲 ⩾ 1 (c) y 苷 f 共x ⩾ 3兲 ⩽ 2 5. 1⩽x (c) h共x兲 苷 x 3 ⩾ x is an algebraic function. A spherical balloon with radius r inches has volume V共r兲 苷 3 r 3. Graphing with technology emphasizes the interaction between calculus and calculators and the analysis of families of curves. f 共x兲 苷 x⩽2 ⩽ 1 74. Families of Polar Curves (page 664) exhibits the fascinating shapes of polar curves and how they evolve within a family. What happens as c increases? In Examples 1 and 3 we solved the problem by changing to a larger viewing rectangle. Then the equation becomes log e e 苷 5; so, by the definition of logarithm, e 5 苷 x.) SOLUTION 2 Start with the equation ln x 苷 5 and apply the exponential function to both sides of the equation: e ln x 苷 e 5 But the second cancellation equation in 9 says that e ln x 苷 x. (a) If the point 共5, 3兲 is on the graph of an even function, what x x 12 x shown. The use of computer algebra systems is discussed in Section 7.6. 8 Further Applications of Integration Here are the applications of integration—arc length and surface area—for which it is useful to have available all the techniques of integration, as well as applications to biology, economics, and physics (hydrostatic force and centers of mass). x (a) We could find the maximum value on the graph of f, so we should have the value of f at 1 is f 共1兲 苷 2. (b) Express the perimeter of the rect- 67. (These are polynomials with only one term.) We already know the shape of the graphs of y 苷 x (a line through the origin with slope 1) and y 苷 x 2 [a parabola, see Example 2(b) in Section 1.1]. Enhanced WebAssign for Stewart's Calculus now includes opportunities for students to review prerequisite skills and content both at the start of the course and at the beginning of each section. The relationship between the Fahrenheit 共F兲 and Celsius 共C兲 G 5. FIGURE FOR PROBLEM 1 2x ⩽ 1 x ⩽x⩾2 (a) y 苷 f 共2x兲 (b) t共x兲 苷 3 x s x ⩽1 (c) h共x兲 苷 x 5 s4 ⩾ x ⩽ sx 2 ⩾ 1 2 4. For instance, P共1950兲 ⬇ 2,560,000,000 But for each value of the time t there is a corresponding value of P, and we say that P is a function of t. A box with an open top is to be constructed from a rectangular piece of cardboard with dimensions 12 in. May have used book stickers on cover/binding. Use it to graph the following functions. Power Functions A function of the form f 共x兲 苷 x a, where a is a constant, is called a power function. The graph of V has a function of P (see Figure 15) has the same general shape as the right half of Figure 14. If you invest x dollars at 4% interest compounded annually, then the amount A共x兲 of the investment after one year is A共x兲 苷 1.04x. In situations where there is no physical law to guide us, we may need to collect data (either from a library or the Internet or by conducting our own experiments) and examine the data in the form of a table in order to discern patterns. A¢ A=A¡+A™+A£+A¢+A∞ FIGURE 2 A¡ A£ A∞ A8 A¶ A™ FIGURE 2 Let An be the area of the inscribed polygon with n sides. Find an equation for the line that passes through the point 共2, ⩾5兲 and (a) (b) (c) (d) has slope 3. is parallel to the x-axis is parallel to the y-axis is parallel to the line 2x ⩾ 4y 苷 3 2. A case in point: I added details to the solution of Example 2.3.11 because when I taught Section 2.3 from the sixth edition I realized that students need more guidance when setting up inequalities for the Squeeze Theorem. Suppose that after dark you are in a room with just one lamp and you are trying to read a book. Therefore y苷 ln x ln a Scientific calculators have a key for natural logarithms, so Formula 10 enables us to use a calculator to compute a logarithm with any base (as shown in the following example). These three cases are illustrated in Figure 4. Accordingly, in Section 7.5, I present a strategy for integration. It is suitable for students taking Engineering and Physics courses concurrently with calculus. This function arises in physics and chemistry in connection with Boyle's Law, which says that, when the temperature is constant, the volume V of a gas is inversely proportional to the pressure P : y=A 1 0 x 1 V苷 C P FIGURE 14 where C is a constant. But technology doesn't make pencil and paper obsolete. 苷 d1 d2 d3 dn ⩽ 2 ⩽ 3 ⩽ ⩽ n ⩽ 10 10 10 10 n Therefore some infinite sums, or infinite series as they are called, have a meaning. In the more advanced mathematical and scientific literature and in computer languages, however, the notation log x usually denotes the natural logarithm. Then we can draw a right triangle with angle as in Figure 19 and deduce from the Pythagorean Theorem that the third side has length s9 ⩾ 1 苷 2s2 . Instructors can choose to become involved at several different levels, ranging from simply encouraging students to use the Visuals and Modules for independent exploration, to assigning specific exercises from those included with each Module, or to creating additional exercises, labs, and projects that make use of the Visuals and Modules. Homework Hints available at stewartcalculus.com 34 CHAPTER 1 FUNCTIONS AND MODELS (b) Draw the graph of the equation in part (a). The table shows the number N of species of reptiles and amphibians inhabiting Caribbean islands and the area A of the island in square miles. t 28. Dec. (See Figures 6 and 7.) Thus, whereas the period of y 苷 sin x is 2, the period of y 苷 sin 2x is 2兾2 苷 . EXAMPLE 9 Express ln a ⩽ 2 ln b as a single logarithm. *This book is in A Good Condition. He passes Ann Arbor, 40 mi from Detroit, at 2:50 PM. If c is a positive number, then the graph of y 苷 f 共x兲 ⩽ c is just the graph of y 苷 f 共x兲 shifted upward a distance of c units (because each y-coordinate is increased by the same number c). Student resources are available online through a customizable eBook, a Show Your Work feature, Just in Time review of precalculus prerequisites, an improved Assignment Editor, and an Answer Evaluator that accepts more mathematically equivalent answers and allows for homework grading in much the same way that an instructor grades. For s2 ⩾ sx to be defined we must have 2 ⩾ sx ⩾ 0. that is, sx ⩽ 2, or x ⩽ 4. Printed in the United States of America 1 2 3 4 5 6 7 1 4 1 3 1 2 1 1 1 0 Trademarks ExamView ® and ExamViewPro ® are registered trademarks of FSCreations, Inc. If we write d 苷 f 共t兲, then d is the number of feet traveled after t seconds. Consequently, we are far less certain about the accuracy of our prediction. The monthly cost of driving a car depends on the number of 0 ; 21. For instance, in Example 4 in Section 1.3 we will see that a reasonable model for the number of hours of daylight in Philadelphia t days after January 1 is given by the function L共t兲 苷 12 ⩽ 2.8 sin 2 共t ⩾ 80兲 365 苷 The tangent function is related to the sine and cosine functions by the equation tan x 苷 1 _0 3π _π 2 π 2 _π 2 0 π 3π x and its graph is shown in Figure 19. 4. Limits are treated from descriptive, graphical, numerical, and algebraic points of view. We are educational resource professionals with an A+ Better Business Bureau rating!!. Loose-Leaf / Binder Version. 52 CHAPTER 1 FUNCTIONS AND MODELS There are holes in the graph of y = cos x. Figure 5 shows how the holes in Figure 1 have been filled to complete the graph of the function f 共x兲 苷 2 x ⩾ ⩾ ■ If the predictions don't compare well with reality, we need to refine our model or to formulate a new model and start the cycle again. (b) The Caribbean island of Dominica has area 291 m2. ■ Calculus: Early Transcendentals, Seventh Edition, Hybrid Version, is similar to the present textbook in content and coverage except that all end-of-section exercises are available only in Enhanced WebAssign. (c) Which function belongs to both families? In the following example we start with a verbal description of a function in a physical situation and obtain an explicit algebraic formula. How does the graph change when c is changed? C 380 370 360 350 340 FIGURE 6 1980 The regression line 1985 1990 1995 2000 2005 2010 t v EXAMPLE 3 Use the linear model given by Equation 2 to estimate the average CO2 level for 1987 and to predict the level for the year 2015. Lockhart, Daniel S. f 共x兲 苷 cos共0.001x兲 2 3 2 11. Sketch several members of the family. The display window is blank! A moment's thought provides the explanation: Notice that x 2 ⩾ 0 for all x, so x 2 ⩽ 3 ⩾ 3 for all x. Use it to estimate the range of the vertical ground acceleration function at USC during the Northridge earthquake. (a) (b) y苷 s3x 共1 ⩾ x兲 y苷 3x ⩾ 8 x ⩾ 1 y共x兲 苷 s3x ⩾ 3共x兲 苷 2共x兲 (a) y 苷 3 (d) y 苷 x 2 Graph the curve. Then sketch a rough graph of the temperature of the water as a function of time. The graphs you get with your own graphing device might not look like these figures, but they will also be quite inaccurate. The function f 共x兲 苷 x 2 is called an exponential function because the variable, x, is the exponent. (a) 关⩾2, 2兴 by 关⩾2, 2兴 (b) 关⩾4, 4兴 by 关⩾4, 4兴 (c) 关⩾10, 10兴 by 关⩾5, 30兴 (d) 关⩾50, 50兴 by 关⩾100, 1000兴 _2 2 _2 (a) 关⩾2, 2兴 by 关⩾2, 2兴 SOLUTION For part (a) we select the range by setting X min 苷 2, X max 苷 2, Y min 苷 2, and Y max 苷 2. You'll get a lot more from looking at the solution if you do so. Possible ex library copy, will have the markings and stickers associated from the library. Single Variable Calculus: Early Transcendentals, Seventh Edition James Stewart Executive Editor: Liz Covello Assistant Editor: Liza Neustaetter Editorial Assistant: Jennifer Staller Media Editor : Maureen Ross Marketing Manager: Jennifer Jones Marketing Coordinator: Michael Ledesma Marketing Communications Manager: Mary Anne Payumo Content Project Manager: Cheryll Linthicum Art Director: Vernon T. y y 苷 f x y f x x g x y 63. A ship is moving at a speed of 30 km兾h parallel to a straight shoreline. (b) If we use a computer, we get the equation f x 苷 x x ⩽ 1. Notice that as n increases, the graph of y 苷 x n becomes flatter near 0 and steeper when x ⩾ 1. 2 1.732 1.7 4 2 s3 1 7 2 1.7320 ⬇ s3 ⬇ 1.7321 Express the area of an equilateral triangle as a function of the length of a side. Thus we really need two graphs to see the true nature of this function. A homeowner mows the lawn every Wednesday afternoon. But where did this function come from? This is not implicitly use infinite sums. the air pressure above the water, 15 lb兾in2. Express the surface area of the box as a function of the length of a side of the base. This means that the slope mPQ of the secant line becomes closer and closer to the slope of the tangent line. 8. In Chapter 4 we will be able to see that the graph shown in Figure 5(c) does indeed reveal all the main features of the function. TOOLS FOR ENRICHING™ CALCULUS TEC is a companion to the text and is intended to enrich and complement its contents. If x is in the domain of the function f, then when x enters the machine, it's accepted as an input and the machine produces an output f 共x兲 according to the rule of the function. Describe how the temperature of the pie changes as time passes. Describe how the temperature of the water changes as time passes. See, for instance, the introduction to maximum and minimum values on page 270. Marsden and A. We also indicate the solutions to some of the existing examples here and quantified. G. Write a formula for V共t兲 in terms of H共t兲 for t ⩽ 60. We observe that if x ⩽ 1, then f 共x兲 苷 1 ⩾ x, so the part of the graph of f that lies to the left of the vertical line x 苷 1 must coincide with the line y 苷 1 ⩾ x, which has slope ⩾1 and y-intercept 1. (a) Sketch a possible graph of x共t兲. (a) (x ⩽ 1 2 2) ⩽ 8. Use the given graph of f and t to evaluate each expression, or explain why it is undefined. 22. Accessories such as CD, codes, toys, may not be included. of Mines and Geology Each of these examples describes a rule whereby, given a number (r, t, w, or t), another number (A, P, C, or a) is assigned. If f is a function with domain D, then its graph is the set of ordered pairs 共x, f 共x兲兲 兩 x ∈ D其 E (Notice that these are input-output pairs.) In other words, the graph of f consists of all points 共x, y兲 in the coordinate plane such that y 苷 f 共x兲 and x is in the domain of f. And before you read each example, I suggest that you cover up the solution and try solving the problem yourself. SECTION 1.2 ; 23. Ancillaries for Students Student Solutions Manual Single Variable Early Transcendentals By Daniel Anderson, Jeffery A. 3 5 (b) Graph the functions y 苷 x, y 苷 s x , and y 苷 s x on the same screen using the viewing rectangle 关⩾3, 3兴 by 关⩾2, 2兴. (With Maple we use the fit[leastsquare] command in the stats package; with Mathematica we use the Fit command.) The machine gives the slope and y-intercept of the regression line as m 苷 1.65429 b 苷 2938.07 So our least squares model for the CO2 level is C 苷 1.65429t ⩾ 2938.07 2 In Figure 6 we graph the regression line as well as the data points. Then, in the third stage, we take these mathematical conclusions and interpret them as information about the original real-world phenomenon by way of offering explanations or making predictions. h苷 ⩾x兲 苷 f 共t共⩾x兲兲 苷 f 共t共x兲兲 苷 h共x兲 ⩽ x 2 (c) Since h共x兲 苷 h共⩾x兲 and h共⩾x兲 苷 ⩾h共x兲, we conclude that h is neither even nor odd. (d) Is it reasonable to use the model to predict the winning height at the 2100 Olympics? The restricted cosine function f 共x兲 苷 cos x, 0 ⩽ x ⩽ , is one-to-one (see Figure 21) and so it has an inverse function denoted by cos ⩾1 or arccos. Hilary Davies, University of Alaska Anchorage Gregory J. What do these compositions represent? We write The tangent line at P y t m lim mPQ Q P Q (x, f) f(a) P (a, f(a)) and we say that m is the limit of mPQ as Q approaches P along the curve. But it is possible to find an expression for a function that approximates P共t兲. Find a function that models the area of the window in terms of x. (b) Stretch vertically by a factor of 3. SOLUTION If f o t 苷 f共t共x兲兲 苷 f共x ⩽ 3兲 苷 x ⩽ 3共10 兲 ⩾ x ⩽ 3共10 兲 x 3 So far we have used composition to build complicated functions from simpler ones. If 0 ⬇ a ⬇ 1, the exponential function decreases; if a 苷 1, it is a constant; and if a ¬ 1, it increases. Give a reason for your choice. The most common method for visualizing a function is its graph. (See Figure 7.) y y 2 2 x 1 0 FIGURE 7 The graphs of quadratic functions are parabolas. Notice that the graph of h is symmetric neither about the y-axis nor about the origin. SOLUTION 1 From 8 we see that ln x 苷 5 means e5 苷 x Therefore x 苷 e 5. Davis, University of Wisconsin–Green Bay Elias Deeba, University of Houston–Downtown Daniel DiMaria, Suffolk Community College Seymour Ditor, University of Western Ontario Greg Dresden, Washington and Lee University Daniel Drucker, Wayne State University Kenn Dunn, Dalhousie University Dennis Dunninger, Michigan State University Bruce Edwards, University of Florida David Ellis, San Francisco State University John Ellison, Grove City College Martin Erickson, Truman State University Garret Etgen, University of Houston Theodore G. This has the graphs of the sine and cosine functions are as shown in Figure 18. x 1 2 5 10 50 100 500 1000 10,000 100,000 ln x 0 0.69 1.61 2.30 3.91 4.6 6.2 6.9 9.2 11.5 x 1 1.41 2.24 3.16 7.07 10.0 22.4 31.6 100 316 ln x sx 0 0.49 0.72 0.73 0.55 0.46 0.28 0.22 0.09 0.04 y y x y=x y=x 0 y=x, _20 x y=x, _ 1 0 y=ln x y=ln x 1 0 x 1 0 x FIGURE 15 x FIGURE 16 10000 x SECTION 1.6 INVERSE FUNCTIONS AND LOGARITHMS 67 Inverse Trigonometric Functions When we try to find the inverse trigonometric functions, we have a slight difficulty: Because the trigonometric functions are not one-to-one, they don't have inverse functions. Page 3 Enter at least one of author, title, ISBN, keyword, or publisher to search. For instance, in order to get the graph of y 苷 2 cos x we multiply the y-coordinate of each point on the graph of y 苷 cos x by 2. EXAMPLE 6 If f 共x兲 苷 x 2 and t共x兲 苷 x ⩾ 3, find the composite functions f o t and t o f. (b) What is the dosage for a newborn? The final step is to test our predictions by checking against new data. Figure 11 shows the case where n ¬ 1. 2 Limits and Derivatives The material on limits is motivated by a prior discussion of the tangent and velocity problems. Since x approaches a as Q approaches P, we could also use Equation 1 to write x-a 0 3 x x m lim 2 x a f 共x兲 ⩾ f 共a兲 x⩾a FIGURE 6 The secant line PQ y Q P 0 P FIGURE 7 Secant lines approaching the tangent line x Specific examples of this procedure will be given in Chapter 2. 共x ⩽ 兲 2 共t ⩽ y 苷 4共x兲 苷 52 1 y=1⩾ 2 x 0 3. Visit www.cengage.com/brookscole. From Figure 6 we see that t=P P 0 x 0 FIGURE 3 t P P 0 FIGURE 6 Now imagine that Q moves along the curve toward P as shown in Figure 7. 9 4.7 9 4.7 (a) (b) 3 EXAMPLE 7 Graph the function y 苷 sin x. In general, a sequence 兵an兲 is a list of numbers written in a definite order. It is a much more difficult problem to find the area of a curved figure. In other words, the expression ⩽ [illegible] one-to-one function. Greg Dresden, the graphs of ... I greatly appreciate the time they spent to understand my motivation for the approach taken. Bevelacqua, University of North Dakota Zhen-Qing Chen, University of Washington—Seattle Jenna Carpenter, Louisiana Tech University Le Baron O. y 苷 1 ⩾ 2x ⩾ x 20. Use these estimates to sketch a rough graph of f o t. The difficulty is overcome by restricting the domains of these functions so that they become one-to-one. Some exercises ask for a verbal explanation or interpretation or description. (a) Complete the graph of f if it is known that f is even. If f and t are both even functions, is f ⩽ t even? (b) 共x ⩽ 1兲 (e) 共x ⩽ 3兲 1 ⩽ x ⩽ 2兾 (c) 共x ⩽ 3兲 3 ⩽ 2 (f) 共x ⩽ 2兲 共x兲 (a) 共x ⩽ 2兲 ⩾ 0, (b) ⩾ x ⩽ 3共x兲 ⩽ 2 (c) ⩾ 2 ⩽ 2 ⩾ 2兴 (e) ⩾ 2 ⩽ 2兲 (c) ⩾ x⩽2 ⩾ 2 ⩽ x⩽2 ⩾ 2. SOLUTION Using Law 2, we have log 2 80 ⩾ log 2 5 苷 log 2 80 5 苷 log 2 16 苷 4 because 2 4 苷 16. In the following example we use a quadratic function to model the fall of a ball. From an observer up to the highest point in a rainbow is 42°? Do those times seem reasonable? (d) What conclusions can you make from these graphs? Graph some of these curves to see why. If y 苷 f 共x兲 , then according to the definition of absolute value, y 苷 f 共x兲 when f 共x兲 ⩾ 0 and y 苷 ⩾f 共x兲 when f 共x兲 ⬇ 0. SEVENTH EDITION REVIEWERS Amy Austin, Texas A&M University Anthony J. (See Example 7.) 3 4 (c) Graph the functions y 苷 sx , y 苷 s x, y 苷 s x , and y 苷 s x on the same screen using the viewing rectangle 关⩾1, 3兴 by 关⩾1, 2兴. 37. At the surface of the ocean, the water pressure is the same as 18. In such cases there is no single correct way of expressing the answer, so don't worry that you haven't found the definitive answer. The hardest hit town was Beichuan, as pictured. (The TI-83's graphing window is 95 pixels wide.) 36. In addition, I thank those who have contributed to past editions: Ed Barbeau, Fred Brauer, Andy Bulman-Fleming, Bob Burton, David Cusick, Tom DiCiccio, Garret Etgen, Chris Fisher, Stuart Goldenberg, Arnold Good, Gene Hecht, Harvey Keynes, E.L. Koh, Zdislav Kovarik, Kevin Kreider, Emile LeBlanc, David Leep, Gerald Leibowitz, Larry Peterson, Lothar Redlin, Carl Riehm, John Ringland, Peter Rosenthal, Doug Shaw, Dan Silver, Norton Starr, Saleem Watson, Alan Weinstein, and Gail Wolkowicz. Sept. Graph the function f 共x兲 苷 x 3 ⩽ cx for various values of c. Here I reward a student significantly for ideas toward a solution and for recognizing which problem-solving principles are relevant. To that end I have devised various types of problems. Rewrite by completing the square. f 共x兲 苷 2 ⩽ 145. Some substantial optimization problems are included, providing an explanation of why you need to raise your head 42° to see the top of a rainbow. 70. An optional final section uses predator-prey models to illustrate systems of differential equations. They are constructed so as not to reveal any more of the actual solution than is minimally necessary to make further progress, and are available to students at stewartcalculus.com in CourseMate and Enhanced WebAssign. The successive positions of Achilles 共a1 , a 2 , a 3 , . 19–20 For each scatter plot, decide what type of function you might choose as a model for the data. The curves with equations y 苷 x 0 x ⩽ c are called bullet-nose curves. The cost of mailing an envelope depends on its weight w. Under what circumstances are the kinds of graphs? For instance, if a cricket produces 113 chirps per minute at 80 ˚F. (The answer might surprise you.); the following section 10.2 shows how to use Bézier curves to design shapes that represent letters for a laser printer. Graham, Buckingham Browne & Nichols School Richard Grassl, University of New Mexico Michael Gregory, University of North Dakota Charles Groetsch, University of Cincinnati Paul Triantafilos Hadavas, Armstrong Atlantic State University Salim M. What do you think happened when this person was 30 years old? Aggarwala, University of Calgary John Alberghini, Manchester Community College Michael Albert, Carnegie-Mellon University Daniel Anderson, University of Iowa Donna J. Write your answer without negative exponents. I have been very fortunate to have worked with some of the best mathematics editors in the business over the past three decades: Ron Munro, Harry Campbell, Craig Barth, Jeremy Hayhurst, Gary Ostedt, Bob Pirtle, Richard Stratton, and now Liz Covello. Selected Visuals and Modules are available at www.stewartcalculus.com. SECTION 1.3 v NEW FUNCTIONS FROM OLD FUNCTIONS 41 EXAMPLE 7 If f 共x兲 苷 sx and t共x兲 苷 s2 ⩾ x , find each function and its domain. The printed text includes an end-of-chapter review material. Hand calculation and sketches are often preferable to technology for illustrating and reinforcing some concepts. See, for instance, Figure 1 in Section 11.1 (seismogram from the Northridge earthquake), Exercise 2.8.36 (percentage of the population under age 18), Exercise 5.1.16 (velocity of the space shuttle Endeavour), and Figure 4 in Section 5.4 (San Francisco power consumption). Then sketch the graph. y=log™ x y=log£ x y=log¡¸ x y=log¸ x y=log¸ x EXAMPLE 5 Classify the following functions as one of the types of functions that we have discussed. GEORGE POLYA The art of teaching, Mark Van Doren said, is the art of assisting discovery. Crooke, Vanderbilt University Charles N. Yasskin and Robert Lopez ISBN 0-8400-5811-X CalcLabs with Maple Single Variable By Phillip B. Yasskin and Art Belmonte ISBN 0-8400-5814-4 Each of these comprehensive lab manuals will help student learn to use the technology tools available to them. The two branches of calculus and their chief problems, the area problem and the tangent problem, appear to be very different, but it turns out that there is a very close connection between them. Buying this item means that you agree to this message. y _1 2 共x兲 苷 80兲 365 ⩾ Combinations of Functions Two functions f and t can be combined to form new functions f ⩽ t, f ⩾ t, ft, and f兾t in a manner similar to the way we add, subtract, multiply, and divide real numbers. To obtain the graph of y 苷 f 共x兲 ⩾ c, shift the graph of y 苷 f 共x兲 down c units downward y 苷 f 共x ⩾ c兲, shift the graph of y 苷 f 共x兲 a distance c units to the right y 苷 f 共x ⩽ c兲, shift the graph of y 苷 f 共x兲 a distance c units to the left y y y=f(x+c) y=f(x)+c y=ƒ y=cƒ (c>1) y=f(_x) y=f(x-c) y=f(x) 0 y=f(x) y=f(x)-c x c x c 0 x y=1 c ƒ x 0 y=_ƒ FIGURE 1 Translating the graph of ƒ FIGURE 2 Stretching and reflecting the graph of ƒ Now let's consider the stretching and reflecting transformations. We want to find cos y but, since tan y is known, it is easier to find sec y first: π π y=tan x, _2 0 (p, 0) (p, 0) 0 (b) =4py, p0 (d) y苷4px, p1 1 1 _1 (d) y苷 tan cos y 苷 1兾2. If f 共x兲 苷 2x 3 ⩾ 1 兲 苷 共s2 ⩾ x 兲 This expression is defined when both 2 ⩾ x ⩾ 0 and s2 ⩾ x Therefore f 共x兲 苷 共s2兲 苷 ⩽ 2 ⩾ x This Homework Hints are available at stewartcalculus.com SECTION 1.5 33. www.iris.edu © Mark Ralston / AFP / Getty Images The fundamental objects that we deal with in calculus are functions. But x ⩾ 0 for all numbers x and any positive number y is a square. Center 共3, ⩽5兲, radius 5 x _1 4 0 4x 0 2 x _2 4 (Remember that the rental charge per space and the number of spaces rented can't be negative quantities.) (d) What do the slope, the y-intercept, and the x-intercept of the graph represent? f 共x兲 ⩾ 1 , t共x兲 苷 2x ⩽ 1 EXAMPLE 9 Given F共x兲 苷 cos2共x ⩽ 9兲, find functions f, t, and h such that F 苷 f o t o h. You place a frozen pie in an oven and bake it for an hour. Find the domain and range of this function. 1 29. (b) Sketch the graph of the voltage V共t兲 in a circuit if the switch is turned on at time t 苷 0 and 120 volts are applied instantaneously to the circuit. Spine creases, wear to binding and pages from reading. Your graphing calculator automatically makes the conversion from radians to degrees. In fact, it can be shown that by taking n large enough (by adding sufficiently many terms of the series), we can make the partial sum sn as close as we please to the number 1. Johansson, University of Vermont Jerry Johnson, Oklahoma State University Zsuzsanna M. Soft cover. y y (1, 1) 0 (1, 1) x 0 FIGURE 13 Graphs of root functions x (a) ƒ=œ„ x (b) ƒ=œ„ x 30 CHAPTER 1 FUNCTIONS AND MODELS (ii) a 苷 1 y The graph of the reciprocal function f 共x兲 苷 x ⩾1 苷 1兾x is shown in Figure 14. sin EXAMPLE 12 Evaluate (a) sin⩾1(1 2) and (b) tan(arcsin 13). Use transformations to create a function whose graph is as shown. A discussion of mathematical models leads to a review of the standard functions, including exponential and logarithmic functions, from these four points of view. Apr. Find an equation of the circle that has AB as a diameter. [See Figure 13(a).] For other even values of n, the graph of y 苷 x n is similar to that of y 苷 x 2. I think nobody has improved very much on George Polya's four-stage problem-solving strategy and, accordingly, I have included a version of his problem-solving principles following Chapter 1. 1 0 1 x EXAMPLE 3 If f 共x兲 苷 2x 2 ⩾ 5x ⩽ 1 and h 苷 0, evaluate f 共a ⩽ h兲 ⩾ f 共a兲 h (a) Express the radius r of the balloon as a function of the time t (in seconds). SECTION 1.1 FOUR WAYS TO REPRESENT A FUNCTION 13 A. Because a circle has to have a positive radius, the domain is 兵r 兩 r ⬎ 0其, the range is also 兵0, ∞兲. For instance, the function f 共x兲 苷 x 2 is even because f 共⩾x兲 苷 共⩾x兲2 苷 x 2 苷 f 共x兲 The geometric significance of an even function is that its graph is symmetric with respect 18 CHAPTER 1 FUNCTIONS AND MODELS to the y-axis (see Figure 19). Why does part of the graph appear to be missing? The area A of a circle depends on the radius r of the circle. United Kingdom . Search Preferences 最近30天 最近90天 最近180天 *限购物车所用使用 最近1年 – 落價– 降價– Page 2 最近30天 最近90天 最近180天 *限购物车所使用 最近1年 – 落價– 降價– Page 3 最近30天 最近90天 最近180天 *限购物车所使用 最近1年 – File loading please wait... Let's first consider translations. For n 苷 3 we have the cube root function f 共x兲 苷 sx whose domain is (recall that every real number has a cube root) and whose graph is shown in 3 in Figure 13(b). I also thank Kathi Townes, Stephanie Kuhns, and Rebekah Million of TECHarts for their production services and the following Brooks/Cole staff: Cheryll Linthicum, content project manager; Liza Neustaetter, assistant editor; Maureen Ross, media editor; Sam Subity, managing media editor; Jennifer Jones, marketing manager; and Vernon Boes, art director. ; 22. Write the monthly cost C as a function of x. The total cost of renting x units is and graph C as a function of the number of minutes used and graph C as a function of t 苷 0 ⩽ x ⩽ 600. A spherical balloon is being inflated and the radius of the bal- loon is increasing at a rate of 2 cm兾s. Instead, we evaluate the functions on domain D, and for which the domain is D. The sum and difference functions are defined by 共x兲 苷 f 共x兲 ⩽ t共x兲 共f ⩾ t兲共x兲 苷 f 共x兲 ⩾ t共x兲 苷 共x兲 苷 f 共x兲 ⩾ t共x兲 共f t兲共x兲 苷 Notice that the graph of f is A 僅 B, but we can't divide by 0 and so the domain of f兾t is 兵x 僅 A 僅 B 兩 t共x兲 ⬆ 0其. For each of these functions, give the domain and range. For example, suppose that y 苷 f 共u兲 苷 su and u 苷 t共x兲 苷 x 2 ⩽ 1. Robbin, University of Wisconsin–Madison Lila Roberts, Georgia College and State University E. Find the exact values. The alternate version Stewart/Clegg/Watson Calculus, 9e, will publish later this spring.Selected and mentored by James Stewart, Daniel Clegg and Saleem Watson continue Stewart's legacy of providing students with the strongest foundation for a STEM future. Taking the viewing rectangle to be 关⩾3, 3兴 by 关⩾1, 4兴, we get the graph shown in Figure 3. You can see from Figure 23 that the function f 共x兲 苷 e x is increasing on the interval 共⩾∞, 0兲 and increasing on the interval 共0, ∞兲. Sections 2.7 and 2.8 deal with derivatives (especially with functions defined graphically and numerically) before the differentiation rules are covered in Chapter 3. x2 x4 x ⩽ ⩽ x 73. Two of the sides have area x, and the other two have area 2xh, so the cost of the material for the sides is 6关2共x兲h ⩽ 2共xh兲兴. Such functions are called piecewise defined functions. Zeno argued, as follows, that Achilles could never pass the tortoise: Suppose that Achilles starts at position a 1 and the tortoise starts at position t 1. The function in Example 10 and Exercise 67 are called step functions because their graphs look like stairs. Graph the function f 共x兲 苷 x 2s30 ⩾ x in an appropriate viewing rectangle. Lawlor, University of Vermont Christopher C. Therefore we model the length of daylight in Philadelphia on the tth day of the year by the function 同 L共t兲 苷 12 ⩽ 2.8 sin 0 1 EXAMPLE 5 Sketch the graph and find the domain and range of each function. This is not to be confused with the power function f 共x兲 苷 x 2, in which the variable is the base. In both cases the x-axis is a horizontal asymptote. Notice that t takes on all values from ⩾2 to 4, so the range of t is 共y 兩 ⩾2 ⩽ y ⩽ 4其苷关⩾2, 4兴 12 CHAPTER 1 FUNCTIONS AND MODELS y 1 (b) Find the domain and range of f. Find a formula for the function f whose graph is the given curve. 1.2 Mathematical Models: A Catalog of Essential Functions A mathematical model is a mathematical description (often by means of a function or an equation) of a real-world phenomenon such as the size of a population, the demand for a product, the speed of a falling object, the concentration of a product in a chemical reaction, the life expectancy of a person at birth, or the cost of emission reductions. (b) Find the domain and range of f 共x兲 苷 sin 2x. (c) Use the function to estimate the number of chirps per minute at 100 ˚F. EXAMPLE 4 Find a formula for the function f graphed in Figure 17. This ... SOLUTION (a) Because f 共x兲 苷 2x ⩽ 3 ... Ideally, a teacher ... of a new function t ... 3 .) 2 ⩽ ⩾ ... (see Example 10.) ...

for Kepler's Laws in Chapter 13. This is equivalent to x 艌 ≥2, so the domain is the interval 关≥2, ⬁兲. I suggest that a far better plan is to read and understand a section of the text before attempting the exercises. As c decreases, the maximum point becomes higher and the minimum point lower. v共t兲 苷 sec共t 2 兲 tan共t 2 兲 27. The project after Section 9.3 asks whether a ball thrown upward takes longer to reach its maximum height or to fall back to its original height. When derivatives are computed in applied situations, students are asked to explain their meanings. t共≥x兲 苷 1 ≥ 共≥x兲4 苷 1 ≥ x 4 苷 t共x兲 (b) So t is even. The line segment joining the points 共≥5, 10兲 and 共7, ≥10兲 f 共3 ⩽ h兲 ≥ f 共3兲 h f 共a ⩽ h兲 ≥ f 共a兲 h 36. h 3. y 苷 mx b If a b and c 0, then ca cb. Some exercise sets begin with requests to explain the meanings of the basic concepts of the section. by cutting out equal squares of side x at each corner and then folding up the sides as in the figure. Oct. If the recommended adult dosage for a drug is D (in mg), then to determine the appropriate dosage c for a child of age a, pharmacists use the equation c 苷 0.0417D共a ⩽ 1兲. General methods are emphasized. After the other chapters I have placed sections called Problems Plus, which feature examples of how to tackle challenging calculus problems. F 共x兲 苷 x 2 ≥ 2x ⩽ 1 41. Explain how each graph is obtained from the graph of y 苷 f 共x兲. Express the surface area of a cube as a function of its volume. (b) If A is the area of this circle as a function of the radius, find A ◦ r and interpret it. (a, d) y=d (b, d) x=b x=a FIGURE 1 The viewing rectangle 关a, b兴 by 关c, d兴 (a, c) y=c (b, c) The machine draws the graph of a function f much as you would. (a) (b) y 1 x _1 6. (a) Express the monthly cost C as a function of the distance driven d, assuming that a linear relationship gives a suitable model. ■ The art program has been revamped: New figures have been incorporated and a substantial percentage of the existing figures have been redrawn. 26. In this exercise we consider the family of root functions 15. The graph shows the power consumption for a day in Septem- ber in San Francisco. If a 0, then x 苷 a x a x a means x 苷 a or means a x a means x a or h h Factoring Special Polynomials 共x y兲2 苷 x 2 2xy y 2 s x 苷 a x a Circles Equation of the circle with center 共h, k兲 and radius r: 共x h兲2 共y k兲2 苷 r 2 R E F E R E N C E PA G E 2 TRIGONOMETRY Angle Measurement Fundamental Identities radians 苷 180⬚ csc 苷 1 sin sec 苷 1 cos tan 苷 sin cos cot 苷 cos sin 共 in radians兲 cot 苷 1 tan sin 2 ⩽ cos 2 苷 1 Right Angle Trigonometry 1 ⩽ tan 2 苷 sec 2 1 ⩽ cot 2 苷 csc 2 sin共≥兲 苷 ≥sin cos共≥兲 苷 cos tan共≥兲 苷 ≥tan sin ≥ 苷 cos 2 tan ≥ 苷 cot 2 1⬚ 苷 rad 180 1 rad 苷 180⬚ ¨ r s 苷 r sin 苷 cos 苷 tan 苷 opp hyp csc 苷 adj hyp sec 苷 opp adj cot 苷 s r hyp opp hyp hyp adj 冊 冊 冊 冊 opp ¨ adj adj opp cos 冊 冊 ≥ 苷 sin 2 Trigonometric Functions sin 苷 y r csc 苷 r y cos 苷 x r sec 苷 r x tan 苷 y x cot 苷 x y The Law of Sines y sin A sin B sin C 苷 苷 a b c (x, y) C c ¨ The Law of Cosines x b 2 苷 a 2 ⩽ c 2 ≥ 2ac cos B y A c 2 苷 a 2 ⩽ b 2 ≥ 2ab cos C y=tan x y=cos x 1 1 π b a 2 苷 b 2 ⩽ c 2 ≥ 2bc cos A y y=sin x a r Graphs of Trigonometric Functions y B 2π Addition and Subtraction Formulas 2π x _1 π 2π x π x sin共x ⩽ y兲 苷 sin x cos y ⩽ cos x sin y sin共x ≥ y兲 苷 sin x cos y ≥ cos x sin y _1 cos共x ⩽ y兲 苷 cos x cos y ≥ sin x sin y y y y y=csc x y y=sec x cos共x ≥ y兲 苷 cos x cos y ⩽ sin x sin y y=cot x 1 1 π 2π x π 2π x π 2π x tan共x ⩽ y兲 苷 tan x ⩽ tan y 1 ≥ tan x tan y tan共x ≥ y兲 苷 tan x ≥ tan y 1 ⩽ tan x tan y _1 _1 Double-Angle Formulas sin 2x 苷 2 sin x cos x Trigonometric Functions of Important Angles cos 2x 苷 cos 2x ≥ sin 2x 苷 2 cos 2x ≥ 1 苷 1 ≥ 2 sin 2x radians sin cos tan 0⬚ 30⬚ 45⬚ 60⬚ 90⬚ 0 兾6 兾4 兾3 兾2 0 1兾2 s2兾2 s3兾2 1 1 s3兾2 s2兾2 1兾2 0 0 s3兾3 1 s3 — tan 2x 苷 2 tan x 1 ≥ tan2x Half-Angle Formulas sin 2x 苷 1 ≥ cos 2x 2 cos 2x 苷 1 ⩽ cos 2x 2 SINGLE VARIABLE CA L C U L U S EARLY TRANSCENDENTALS SEVENTH EDITION JAMES STEWART McMASTER UNIVERSITY AND UNIVERSITY OF TORONTO Australia . y y 3 _1 0 _4 x _1 _2.5 0 5 2 x y @ ! 6 8. The coverage of topics is not encyclopedic and the material on transcendental functions and on parametric equations is woven throughout the book instead of being treated in separate chapters. You can see from Figure 17 that the sine function y 苷 sin x is not one-to-one (use the Horizontal Line Test). When c 苷 0, the curve is flat at the origin. ation function a共t兲. Japan . (See Figure 23.) It is denoted by tan≥1 or arctan. Buyer ships back. (b) Sketch the graph of y 苷 sin x . For instance, in Section 3.7 we will explain why economists often use a polynomial P共x兲 to represent the cost of producing x units of a commodity. It is concerned with change and motion; it deals with quantities that approach other quantities. f 共x兲 苷 sx ≥ 3 , t共x兲 苷 x 2 , h共x兲 苷 x 3 ⩽ 2 t共x兲 苷 g h共x兲 苷 x 2 38. y (m) 0 0 x 1 y 9. (b) What are the domain and range of f ? Taking natural logarithms of both sides of this equation, we get y ln a 苷 ln x. (f) Do you think it would be reasonable to apply the model to someone with an income of $200,000? The resulting graph is shown in Figure 5(b). Hardcover. With each positive number r there is associated one value of A, and we say that A is a function of r. If it is, state the domain and range of the function. Here are two more examples: f 共x兲 苷 sx 2 ⩽ 1 t共x兲 苷 x 4 ≥ 16x 2 3 ⩽ 共x ≥ 2兲s x⩽1 x ⩽ sx When we sketch algebraic functions in Chapter 4, we will see that their graphs can assume a variety of shapes. v EXAMPLE 8 Graph the function y 苷 x 3 ⩽ cx for various values of the number c. (a) 5s2 ⩽ 2s10 7. Find a function that models the brightness of Delta Cephei as a function of time. Condition: Good. we have sin≥1x 苷 y | sin≥1x 苷 1 &? (c) Graph all of the functions in parts (a) and (b) on the same screen using the viewing rectangle 关≥1, 3兴 by 关≥1, 3兴. The ball hits the ground when h 苷 0, so we solve the quadratic equation ≥4.90t 2 ⩽ 0.96t ⩽ 449.36 苷 0 The quadratic formula gives t苷 ≥0.96 s共0.96兲2 ≥ 4共≥4.90兲共449.36兲 2共≥4.90兲 The positive root is t ⬇ 9.67, so we predict that the ball will hit the ground after about 9.7 seconds. Mexico . For what values of x is it true that tan x ≥ x ⬇ 0.01 and ≥兾2 ⬍ x ⬍ 兾2? Use your answer and Figure 4(a) to sketch the graph of y 苷 1 ⩽ sx . The number f 共x兲 is the value of f at x and is read " f of x." The range of f is the set of all possible values of f 共x兲 as x varies throughout the domain. y y=x y=≈ y 1 1 0 1 x 0 y=x# y y x 0 1 x 0 y=x% y 1 1 1 y=x$ 1 1 x 0 x 1 FIGURE 11 Graphs of f=x n for n=1, 2, 3, 4, 5 The general shape of the graph of f 共x兲 苷 x n depends on whether n is even or odd. One possibility is the line that passes through the first and last data points. A characteristic feature of linear functions is that they grow at a constant rate. Jason leaves Detroit at 2:00 PM and drives at a constant speed west along I-96. (a) 5兾3 (b) 兾10 6. Find the domain of the function. a {cm/} 100 50 5 FIGURE 1 Vertical ground acceleration during the Northridge earthquake 10 15 20 25 30 t (seconds) _50 Calif. Faticoni, Fordham University Laurene V. Write your answer using interval notation. .兲 or the successive positions of the tortoise 共t1, t2 , t3 , . SOLUTION We use the data in Table 1 to make the scatter plot in Figure 4, where t repre- sents time (in years) and C represents the CO2 level (in parts per million, ppm). (b) Let 苷 arcsin 13 , so sin 苷 13. (If you have trouble working with the "ln" notation, just replace it by log e . Walker, Carnegie Mellon University William L. Its range is 共≥⬁, ⬁兲. (a) What do the slope and T -intercept represent? In Example 6, f ◦ t is the function that first subtracts 3 and then squares; t ◦ f is the function that first squares and then subtracts 3. Without using a calculator, make a rough sketch of the graph. The resulting graph is shown in Figure 2(a). f 共x兲 苷 x ≥ 36x ⩽ 32 4. Bowers, Florida State University Amy Elizabeth Bowman, University of Alabama in Huntsville Jay Bourland, Colorado State University Stephen W. We also discuss the use of graphing calculators and graphing software for computers. (b) If you discover that four species of bats live in a cave, estimate the area of the cave. (a) 共≥3兲4 (d) (b) ≥34 5 23 5 21 (e) 冉冊 2 3 (c) 3≥4 ≥2 (f) 16 ≥3兾4 2. Technology Enhancements ■ The media and technology to support the text have been enhanced to give professors greater control over their course, to provide extra help to deal with the varying levels of student preparedness for the calculus course, and to improve support for conceptual understanding. TABLE 2 Time (seconds) Height (meters) 0 1 2 3 4 5 6 7 8 9 450 445 431 408 375 332 279 216 143 61 EXAMPLE 4 A ball is dropped from the upper observation deck of the CN Tower, 450 m above the ground, and its height h above the ground is recorded at 1-second intervals in Table 2. There are more applications here than can realistically be covered in a given course. It is designed for calculus courses that integrate the review of precalculus concepts or for individual use. SOLUTION The initial temperature of the running water is close to room temperature t 0 FIGURE 11 because the water has been sitting in the pipes. A stone is dropped into a lake, creating a circular ripple that travels outward at a speed of 60 cm兾s. The Rule of Three has been expanded to become the Rule of Four by emphasizing the verbal, or descriptive, point of view as well. y 1 0 x 1 State the value of f 共≥1兲. 1 ≥ sx (d) u共t兲 苷 1 ≥ t ⩽ 5t 4 is a polynomial of degree 4. 1 SOLUTION Using Laws 3 and 1 of logarithms, we have ln a ⩽ 12 ln b 苷 ln a ⩽ ln b 1兾2 苷 ln a ⩽ ln sb 苷 ln(asb) The following formula shows that logarithms with any base can be expressed in terms of the natural logarithm. You put some ice cubes in a glass, fill the glass with cold water, and then let the glass sit on a table. (c) Use the linear model to predict the height of the winning pole vault at the 2008 Olympics and compare with the actual winning height of 5.96 meters. t 0 2 4 6 8 10 12 14 T 82 75 74 75 84 90 93 94 (a) Use the readings to sketch a rough graph of T as a function of t. In fact, the impetus for the current calculus reform movement came from the Tulane Conference in 1986, which formulated as their first recommendation: Focus on conceptual understanding. (Recall the slope-intercept form of the equation of a line: y 苷 mx ⩽ b. Your problem may be modest; but if it challenges your curiosity and brings into play your inventive faculties, and if you solve it by your own means, you may experience the tension and enjoy the triumph of discovery. The ship is 6 km from shore and it passes a lighthouse at noon. Match each equation with its graph and give reasons for your choices. SOLUTION Completing the square, we write the equation of the graph as y 苷 x 2 ⩽ 6x ⩽ 10 苷 共x ⩽ 3兲2 ⩽ 1 This means we obtain the desired graph by starting with the parabola y 苷 x 2 and shifting 3 units to the left and then 1 unit upward (see Figure 5). by 20 in. ■ Calculus: Early Vectors introduces vectors and vector functions in the first semester and integrates them throughout the book. JAMES STEWART xxiii Diagnostic Tests Success in calculus depends to a large extent on knowledge of the mathematics that precedes calculus: algebra, analytic geometry, functions, and trigonometry. Here we give a glimpse of some of the main ideas of calculus by showing how the concept of a limit arises when we attempt to solve a variety of problems. The oscillations of y 苷 sin 50x are so rapid that when the calculator plots points and joins them, it misses most of the maximum and minimum points and therefore gives a very misleading impression of the graph. (c) Draw the graph of the linear function. 54. 24. Again the function is described in words: Let C共w兲 be the cost of mailing a large enve- 0.88 1.05 1.22 1.39 1.56 D. Given that Philadelphia is located at approximately 40⬚N latitude, find a function that models the length of daylight at Philadelphia. EXAMPLE 6 Find the domain of each function. Bailey, Northeast Missouri State University Wayne Barber, Chemeketa Community College Marilyn Belkin, Villanova University Neil Berger, University of Illinois, Chicago David Berman, University of New Orleans Richard Biggs, University of Western Ontario Robert Blumenthal, Oglethorpe University Martina Bode, Northwestern University Barbara Bohannon, Hofstra University Philip L. State the domain and range of t. y 苷 x 2 ⩽ 0.02 sin 50x f 共x兲 苷 x 4 ≥ 100x 3 and t共x兲 苷 x 3 is eventually larger. FFEP stained, surface scratching, nick to laminate at front fore-edge; corners rubbed, spine tail creased & laminate peeling there; previous owner's name on both head & tail. Graphing calculators and computers can give very accurate graphs of functions. We will use a similar idea in Chapter 5 to find areas of regions of the type shown in Figure 3. If n is even, then f 共x兲 苷 x n is an even function and its graph is similar to the parabola y 苷 x 2. (a) ≥4 ⬍ 5 ≥ 3x 艋 17 (c) x共x ≥ 1兲共x ⩽ 2兲 ¬ 0 2x ≥ 3 (e) 艋1 x⩽1 (b) x 2 ⬍ 2x ⩽ 8 (d) x ≥ 4 ⬍ 3 10. Table of Contents: 12 Three-Dimensional Space Vectors 13 Vector-Valued Functions 14 Partial Derivatives 15 Multiple Integrals 16 Topics in Vector Calculus AppendiceS Parametric Equations (Section 1.8) Mathematical Modeling and Differential Equations (Ch. 9) Analytic Geometry in Calculus (Ch. 11) Size: 4to - over 9¾" - 12" tall. SOLUTION Since F共x兲 苷 关cos共x ⩽ 9兲兴 2, the formula for F says: First add 9, then take the cosine of the result, and finally square. If sin x 苷 3 and sec y 苷 4 , where x and y lie between 0 and 2, evaluate sin共x y兲. Matsumoto, American River College Tom Metzger, University of Pittsburgh Michael Montaño, Riverside Community College Teri Jo Murphy, University of Oklahoma PREFACE Martin Nakashima, California State Polytechnic University, Pomona Richard Nowakowski, Dalhousie University Hussain S. 1 2 A PREVIEW OF CALCULUS A¡ The Area Problem A∞ A™ A£ The origins of calculus go back at least 2500 years to the ancient Greeks, who found areas using the "method of exhaustion." They knew how to find the area A of any polygon by dividing it into triangles as in Figure 1 and adding the areas of these triangles. D. 64. Flores, The University of South Dakota William Francis, Michigan Technological University James T. 0 2 x 0 4 x xxvii DIAGNOSTIC TESTS C Diagnostic Test: Functions 1. f 共x兲 苷 sx , 3 t共x兲 苷 s 1≥x 35. ■ Electronic items xx ■ Printed items Ancillaries for Instructors and Students Stewart Website www.stewartcalculus.com Contents: Homework Hints ■ Algebra Review ■ Additional Topics ■ Drill exercises ■ Challenge Problems ■ Web Links ■ History of Mathematics ■ Tools for Enriching Calculus (TEC) TEC Tools for Enriching™ Calculus By James Stewart, Harvey Keynes, Dan Clegg, and developer Hu Hohn Tools for Enriching Calculus (TEC) functions as both a powerful tool for instructors, as well as a tutorial environment in which students can explore and review selected topics. (a) f 共 t共2兲兲 (b) t共 f 共0兲兲 (d) 共 t ◦ f 兲共6兲 (e) 共t ◦ t兲共≥2兲 31–36 Find the functions (a) f ◦ t, (b) t ◦ f , (c) f ◦ f , and (d) t ◦ t and their domains. But, when properly used, graphing calculators and computers are powerful tools for discovering and understanding those concepts. Express the lengths a and b in the figure in terms of . Estimate the value of x such that f 共x兲 苷 0. Therefore the graph of y 苷 f 共x ≥ c兲 is just the graph of y 苷 f 共x兲 shifted c units to the right (see Figure 1). The graphs of the functions in Example 11 are shown in Figure 21. ■ Tools for Enriching Calculus (TEC) has been completely redesigned and is accessible in Enhanced WebAssign, CourseMate, and PowerLecture. (c) Shift 3 units to the right. Observe that if a 苷 1, then the exponential function y 苷 a x has domain and range 共0, ⬁兲. [See Figures 14(b) and (c).] We observe that if we reverse the roles of x and y, then the equation x 苷 h共y兲 苷 y 2 ≥ 2 does define x as a function of y (with y as the independent variable and x as the dependent variable) and the parabola now appears as the graph of the function h. y y y _2 (_2, 0) FIGURE 14 0 (a) x=¥-2 x _2 0 (b) y=œ„„„„ x+2 x 0 (c) y=_œ„„„„ x+2 x 16 CHAPTER 1 FUNCTIONS AND MODELS Piecewise Defined Functions The functions in the following four examples are defined by different formulas in different parts of their domains. (Full coverage of sigma notation is provided in Appendix E.) Emphasis is placed on explaining the meanings of integrals in various contexts and on estimating their values from graphs and tables. (b) Use your graph to estimate the number of cell-phone subscribers at midyear in 2001 and 2005. Find an equation for the circle that has center 共≥1, 4兲 and passes through the point 共3, ≥2兲. For the most visible variable star, Delta Cephei, the time between periods of maximum brightness is 5.4 days, the average brightness (or magnitude) of the star is 4.0, and its brightness varies by 0.35 magnitude. (See Figure 8.) y y=1-sin x 2 1 0 FIGURE 8 π 2 π 3π 2 2π x EXAMPLE 4 Figure 9 shows graphs of the number of hours of daylight as functions of the time of the year at several latitudes. (I thank Klaus Volpert for suggesting this project.) Families of Implicit Curves (page 217) investigates the changing shapes of implicitly defined curves as parameters in a family are varied. (See page 208.) How can we fit curves together to design shapes to represent letters on a laser printer? The graph of y 苷 ≥f 共x兲 is the graph of y 苷 f 共x兲 reflected about the x-axis because the point 共x, y兲 is SECTION 1.3 NEW FUNCTIONS FROM OLD FUNCTIONS 37 replaced by the point 共x, ≥y兲. Hardcover. Graph the hyperbola y 2 ≥ 9x 2 苷 1 by graphing the functions whose graphs are the upper and lower branches of the hyperbola. Find an expression for a cubic function f if f 共1兲 苷 6 and f 共≥1兲 苷 f 共0兲 苷 f 共2兲 苷 0. (a) Find an equation for the family of linear functions with slope 2 and sketch several members of the family. You can see why functions similar to this one are called step functions—they jump from one value to the next. Macintosh and Power Macintosh are registered trademarks of Apple Computer, Inc. Maple is a registered trademark of Waterloo Maple, Inc. We want to fill in the holes by defining f 共x兲 苷 2 x, where x 僆 , so that f is an increasing function. We say that the area of the circle is the limit of the areas of the inscribed polygons, and we write TEC In the Preview Visual, you can see how areas of inscribed and circumscribed polygons approximate the area of a circle. Dust Jacket Condition: New. But if we change the viewing rectangle to the ones shown in the following parts of Figure 6, the graphs look very different. (See page 451.) Where should an infielder position himself to catch a baseball thrown by an outfielder and relay it to home plate? There is another way of combining two functions to obtain a new function. On what interval is f increasing? What two sine curves does the calculator appear to be plotting? The graph of f is given. (The same is true for the patterns seen in electrocardiograms of heart patients and polygraphs for lie-detection.) 14 CHAPTER 1 FUNCTIONS AND MODELS In the next example we sketch the graph of a function that is defined verbally. 2 1.73 ⬍ 2 s3 ⬍ 2 1.74 1.732 ⬍ s3 ⬍ 1.733 ? Skip to main search results Condition: Acceptable. We TEC In Visual 1.4 you can see an animation of Figure 13. (a) Express the distance s between the lighthouse and the ship as a function of d, the distance the ship has traveled since noon; that is, find f so that s 苷 f 共d兲. Parametric curves are well suited to laboratory projects; the three presented here involve families of curves and Bézier curves. Using Equation 2, we see that the CO2 level exceeds 420 ppm when 1.65429t ≥ 2938.07 ¬ 420 Solving this inequality, we get t¬ 3358.07 ⬇ 2029.92 1.65429 SECTION 1.2 MATHEMATICAL MODELS: A CATALOG OF ESSENTIAL FUNCTIONS 27 We therefore predict that the CO2 level will exceed 420 ppm by the year 2030. y 苷 1 17. Biologists have observed that the chirping rate of crickets of a (d) What does the C-intercept represent? We say that the limit of the sequence is 0, and we indicate this by writing a¡ 1 (a) 1 lim nl⬁ 1 2 3 4 5 6 7 8 1 0 n n In general, the notation (b) FIGURE 10 lim a n L nl⬁ is used if the terms a n approach the number L as n becomes large. In the other parts of the figure we sketch y 苷 sx ≥ 2 by shifting 2 units downward, y 苷 sx ≥ 2 by shifting 2 units to the right, y 苷 ≥sx by reflecting about the x-axis, y 苷 2sx by stretching vertically by a factor of 2, and y 苷 s≥x by reflecting about the y-axis. An electricity company charges its customers a base rate of $10 a month, plus 6 cents per kilowatt-hour (kWh) for the first 1200 kWh and 7 cents per kWh for all usage over 1200 kWh. Express the monthly cost E as a function of the amount x of electricity used. _ π2 cos≥1x 苷 y &? C. (a) Graph the function y 苷 sin(sx) using the viewing rectangle 关0, 400兴 by 关≥1.5, 1.5兴. Graph the ellipse 4x 2 ⩽ 2y 2 苷 1 by graphing the functions whose graphs are the upper and lower halves of the ellipse. y Since 0 ¬ ≥1, we have f 共0兲 苷 0 2 苷 0. The homework hints ask you questions that allow you to make progress toward a solution without actually giving you the answer. Notice that all of these graphs pass through the same point 共0, 1兲 because a 0 苷 1 for a 苷 0. _5 0 5 x 73–78 Determine whether f is even, odd, or neither. f 共x兲 苷 y t共x兲 苷 2x ⩽ 1 32. Thus the upper and lower halves of the parabola are the graphs of the functions f 共x兲 苷 s x ⩽ 2 [from Example 6(a)] and t共x兲 苷 ≥s x ⩽ 2 . The result is a new function h共x兲 苷 f 共t共x兲兲 obtained by substituting t into f . A Companion to Calculus By Dennis Ebersole, Doris Schattschneider, Alicia Sevilla, and Kay Somers ISBN 0-495-01124-X Written to improve algebra and problem-solving skills of students taking a Calculus course, every chapter in this companion is keyed to a calculus topic, providing conceptual background and specific algebra techniques needed to understand and solve calculus problems related to that topic. In sections of the book where technology is particularly appropriate, marginal icons direct students to TEC modules that provide a laboratory environment in which they can explore the topic in different ways and at different levels. A simple example of a rational function is the function f 共x兲 苷 1兾x, whose domain is 兵x x 苷 0其; this is the reciprocal function graphed in Figure 14. 10 Change of Base Formula For any positive number a 共a 苷 1兲, we have log a x 苷 ln x ln a PROOF Let y 苷 log a x. The average velocity in the time interval 关2, t兴 is d Q { t, f(t)} average velocity 苷 which is the same as the slope of the secant line PQ in Figure 8. On what interval is f decreasing? Condition: Good. Graph the function y 苷 x n 2 ≥x, x 艌 0, for n 苷 1, 2, 3, 4, 5, 51 EXPONENTIAL FUNCTIONS [Hint: The TI-83's graphing window is 95 pixels wide. Hardcover. On the other hand, if x ¬ ≥1, then the value of f 共x兲 is x 2. Sketch the graph of the amount of a particular brand of coffee 10 sold by a store as a function of the price of the coffee. What is the F-intercept and what does it represent? If we choose the x-values to range from a minimum value of Xmin 苷 a to a maximum value of Xmax 苷 b and the y-values to range from a minimum of Ymin 苷 c to a maximum of Ymax 苷 d , then the visible portion of the graph lies in the rectangle 关a, b兴 关c, d兴 苷 兵共x, y兲 a 艋 x 艋 b, c 艋 y 艋 d其 shown in Figure 1. Use the given graphs of f and t to estimate the value of t共x兲 苷 sin 2x 37– 40 Find f ◦ t ◦ h. P P 5x10' 5x10' 0 20 40 60 FIGURE 9 w (ounces) 艋 艋 艋 艋 艋 100 120 t 0 20 40 60 80 100 120 t FIGURE 10 A function defined by a table of values is called a tabular function. PROJECTS One way of involving students and making them active learners is to have them work (perhaps in groups) on extended projects that give a feeling of substantial accomplishment when completed. 66. When we change to the smaller viewing rectangle 关≥4.7, 4.7兴 by 关≥4.7, 4.7兴 on this particular calculator, we obtain the much better graph in Figure 10(b). W. What does this function represent? Let's measure t so that t 苷 0 corresponds to the year 1900. (a) 共 p ⩽ q兲2 苷 p 2 ⩽ q 2 (b) sab 苷 sa sb (c) sa 2 ⩽ b 2 苷 a ⩽ b (d) 1 ⩽ TC 苷1⩽T C (f) 1兾x 1 苷 a兾x ≥ b兾x a≥b (e) 1 1 1 苷 ≥ x≥y x y Answers to Diagnostic Test A: Algebra 1. 10. These matters are discussed in Section 2.6. FIGURE 3 1.5® 1® 0 1 x SECTION 1.5 53 EXPONENTIAL FUNCTIONS You can see from Figure 3 that there are basically three kinds of exponential functions y 苷 a x. (a) Sketch a graph of this function. x2 艋 4 &? y 2. (Think about what operations you would have to perform on the formula for t to end up with the formula for h.) (b) If f 共x兲 苷 3x ⩽ 5 and h共x兲 苷 3x 2 ⩽ 3x ⩽ 2, find a function t such that f ◦ t 苷 h. 62. As a result, many of the examples and exercises deal with functions defined by such numerical data or graphs. Solution Builder www.cengage.com /solutionbuilder This online instructor database offers complete worked out solutions to all exercises in the text. If an x-value is not in the domain of f , or if f 共x兲 lies outside the viewing rectangle, it moves on to the next x-value. Since ≥1 艋 ≥1, we have f 共≥1兲 苷 1 ≥ 共≥1兲 苷 2. In addition, there are often several different forms in which to express a numerical or algebraic answer, so if your answer differs from mine, don't immediately assume you're wrong. f 共x兲 苷 x ⩽ 15x ⩽ 65x 5. But the question arises: Which curves in the xy-plane are graphs of functions? Find a model to fit the data and use the model to predict the time at which the ball hits the ground. A PREVIEW OF CALCULUS 5 Thus, when we solve the tangent problem in differential calculus, we are also solving problems concerning velocities. Study Guide Single Variable Early Transcendentals By Richard St. Andre ISBN 0-8400-5420-3 For each section of the text, the Study Guide provides students with a brief introduction, a short list of concepts to master, as well as summary and focus questions with explained answers. (a) Find a linear equation that models the temperature T as a function of the number of chirps per minute N. 37. Further permissions questions can be e-mailed to Library of Congress Control Number: 2010936598 Student Edition: ISBN-13: 978-0-538-49867-8 ISBN-10: 0-538-49867-6 Cover Designer: Irene Morris Cover Illustration: Irene Morris Compositor: Stephanie Kuhns, TECH· arts Brooks/Cole 20 Davis Drive Belmont, CA 94002-3098 USA Cengage Learning is a leading provider of customized learning solutions with office locations around the globe, including Singapore, the United Kingdom, Australia, Mexico, Brazil, and Japan. Island A N Saba Monserrat Puerto Rico Jamaica Hispaniola Cuba 4 40 3,459 4,411 29,418 44,218 5 9 40 39 84 76 (a) Use a power function to model N as a function of A. y y=2 cos x y 2 y=cos x 2 1 2 1 1 0 y= cos x 2 x 0 x 1 y=cos 1 x y=cos x y=cos 2x FIGURE 3 v EXAMPLE 1 Given the graph of y 苷 sx , use transformations to graph y 苷 sx ≥ 2, y 苷 sx ≥ 2 , y 苷 ≥sx , y 苷 2sx , and y 苷 s≥x . a¡ a™ a£ a¢ a∞ ... (a) False (d) False (b) True (e) False If you have had difficulty with these problems, you may wish to consult the Review of Algebra on the website www.stewartcalculus.com (b) 共≥2, 4兲 (d) 共1, 7兲 (c) False (f) True xxv xxvi B DIAGNOSTIC TESTS Diagnostic Test: Analytic Geometry 1. Let A共≥7, 4兲 and B共5, ≥12兲 be points in the plane. For example, the domain of f 共x兲 苷 sx is A 苷 关0, ⬁兲 and the domain of t共x兲 苷 s2 ≥ x is B 苷 共≥⬁, 2兴, so the domain of 共 f ⩽ t兲共x兲 苷 sx ⩽ s2 ≥ x is A 僆 B 苷 关0, 2兴. The table shows the mean (average) distances d of the planets from the sun (taking the unit of measurement to be the distance from the earth to the sun) and their periods T (time of revolution in years). (b) Express d as a function of t, the time elapsed since noon; that is, find t so that d 苷 t共t兲. Notice that this function is equal to s SECTION 1.4 GRAPHING CALCULATORS AND COMPUTERS 49 To understand how the expression for a function relates to its graph, it's helpful to graph a family of functions, that is, a collection of functions whose equations are related. 9 Differential Equations Modeling is the theme that unifies this introductory treatment of differential equations. In this exercise we consider the family of functions f 共x兲 苷 1兾x n, where n is a positive integer. 15. (b) Complete the graph of f if it is known that f is odd. In both cases the domain is 共≥⬁, ⬁兲 and the range is 共0, ⬁兲. 2 (a) f ◦ t (b) t ◦ f (c) t ◦ t ◦ t Answers to Diagnostic Test C: Functions 1. G共x兲 苷 胄 3 x 1⩽x tan t 1 ⩽ tan t 46. (a) s3 (b) 12 5. Since ≥2 艋 ≥1, we have f 共≥2兲 苷 1 ≥ 共≥2兲 苷 3. Explain how they are used. A variable star is one whose brightness alternately increases NEW FUNCTIONS FROM OLD FUNCTIONS 41– 46 Express the function in the form f ◦ t. The length of its base is twice its width. 60. Homework Hints available at stewartcalculus.com 6. 72. Is h always an odd function? Estimate the values of x such that f 共x兲 苷 0. B. SOLUTION (a) We have sin≥1(12) 苷 3 1 ¨ 6 because sin共兾6兲 苷 12 and 兾6 lies between ≥兾2 and 兾2. For what values of x is f 共x兲 苷 1? (b) If 0 艋 a 艋 b, then a 2 艋 b 2. SOLUTION We draw a scatter plot of the data in Figure 9 and observe that a linear model is inappropriate. (b) If V is the volume of the balloon as a function of the radius, find V ◦ r and interpret it. Part of the aim of this course is to train you to think logically. y in words what the graph tells you about this race. height (inches) 16. (c) Use the linear model in part (b) to estimate the chirping rate at 100⬚F. Natural Logarithms Notation for Logarithms Most textbooks in calculus and the sciences, as well as calculators, use the notation ln x for the natural logarithm and log x for the "common logarithm," log10 x. For example, the square root key on your calculator computes such a function. The rule that the US Postal Service used as of 2010 is as follows: The cost is 88 cents for up to 1 oz, plus 17 cents for each additional ounce (or less) up to 13 oz. Soft cover. Find expressions for the quadratic functions whose graphs are shown. The Flash simulation modules in TEC include instructions, written and audio explanations of the concepts, and exercises. , 5. (See page 653.) How can we estimate the number of workers that were needed to build the Great Pyramid of Khufu in ancient Egypt? Both instructors and students need to develop the ability to decide where the hand or the machine is appropriate. , a n are constants called the coefficients of the polynomial. For instance, in decimal notation, the symbol 0.3 苷 0.3333 . We are also given that T 苷 10 when h 苷 1, so 10 苷 m ⊃ 1 ⩽ 20 T The slope of the line is therefore m 苷 10 ≥ 20 苷 ≥10 and the required linear function is 20 T=_10h+20 T 苷 ≥10h ⩽ 20 10 0 1 FIGURE 3 3 h (b) The graph is sketched in Figure 3. f 共x兲 苷 x 3 ⩽ 2x 2, t共x兲 苷 3x 2 ≥ 1 t共x兲 苷 sx ≥ 1 30. 5 20. SECTION 1.1 FOUR WAYS TO REPRESENT A FUNCTION 17 EXAMPLE 9 Find a formula for the function f graphed in Figure 17. The answers to the odd-numbered exercises appear at the back of the book, in Appendix I. There are many different types of functions that can be used to model relationships observed in the real world. (a) 关≥4, 3兲 (c) 共≥2, 0兲 僆 共1, ⬁兲 (e) 共≥1, 4兴 10. (b) Sketch the graph of f . It can be shown that there is exactly one number that is greater than all of the numbers 2 1.7, 2 1.73, 2 1.7320, 2 1.73205, ... Algebraic Functions A function f is called an algebraic function if it can be constructed using algebraic operations (such as addition, subtraction, multiplication, division, and taking roots) starting with polynomials. If n is odd, then f 共x兲 苷 x n is an odd function and its graph is similar to that of y 苷 x 3. (See page 337.) Where is the best place to sit in a movie theater? f 共t兲 苷 53. The inverse cosine function is handled similarly. ■ Brief Applied Calculus is intended for students in business, the social sciences, and the life sciences. Brazil . Wortman, University of Massachusetts, Boston Mary Wright, Southern Illinois University–Carbondale Paul M. y t共x兲 苷 sin x, t共x兲 苷 2 x, 39. We also show how to combine pairs of functions by the standard arithmetic operations and by composition. y 苷 6 ≥ 4x ≥ x 2 , y 苷 3x ⩽ 18; 关≥6, 2兴 by 关≥5, 20兴 21–23 Find all solutions of the equation correct to two decimal places. y 苷 1 x⩽2 10. R E F E R E N C E PA G E 1 Cut here and keep for reference ALGEBRA GEOMETRY Arithmetic Operations Geometric Formulas a c ad bc 苷 b d bd a d ad b a 苷 苷 c b c bc d a共b c兲 苷 ab ac a c ac 苷 b b b Formulas for area A, circumference C, and volume V: Triangle Circle Sector of Circle A 苷 12 bh A 苷 r 2 A 苷 12 r 2 C 苷 2 r s 苷 r 共 in radians兲 1 2 苷 ab sin a Exponents and Radicals x 苷 x mn xn 1 xn 苷 n x x m x n 苷 x mn 共x 兲 苷 x m n mn 冉冊 x y 共xy兲n 苷 x n y n n 苷 xn yn n n x m兾n 苷 s x m 苷 (s x)m n x 1兾n 苷 s x 冑 n n n xy 苷 s xs y s n r h ¨ m r ¨ b r Sphere Cylinder Cone V 苷 43 r 3 V 苷 r 2h V 苷 13 r 2h A 苷 rsr 2 h 2 A 苷 4 r 2 n x x s 苷 n y sy r r r x 2 y 2 苷 共x y兲共x 2 xy y 2兲 x 3 y 3 苷 共x y兲共x 2 xy y 2兲 Distance and Midpoint Formulas Binomial Theorem 共x y兲2 苷 x 2 2xy y 2 Distance between P1共x1, y1兲 and P2共x 2, y2兲: d 苷 s共x 2 x1兲2 共 y2 y1兲2 共x y兲3 苷 x 3 3x 2 y 3xy 2 y 3 共x y兲3 苷 x 3 3x 2 y 3xy 2 y 3 共x y兲n 苷 x n nx n1y 冉冊 n共n 1兲 n2 2 x y 2 冉冊 n nk k x y nxy n1 y n k n共n 1兲 共n k 1兲 n 苷 where k 1 ⊃ 2 ⊃ 3 ⊃ ⊃ k Midpoint of P1 P2 : 冉 x1 x 2 y1 y2 , 2 2 冊 Lines Slope of line through P1共x1, y1兲 and P2共x 2, y2兲: m苷 Quadratic Formula If ax 2 bx c 苷 0, then x 苷 b sb 2 4ac . It is important to realize the limitations of the model. The Heaviside function H is defined by H共t兲 苷 再 0 1 if t ⬍ 0 if t 艌 0 It is used in the study of electric circuits to represent the sudden surge of electric current, or voltage, when a switch is instantaneously turned on. So we have f 共x兲 苷 2 ≥ x or y苷2≥x if 1 ⬍ x 艋 2 We also see that the graph of f coincides with the x-axis for x ¬ 2. Numerical estimates of sums of series are based on which test was used to prove convergence. Rational Functions A rational function f is a ratio of two polynomials: f 共x兲 苷 y 20 0 2 x where P and Q are polynomials. Putting this information together, we have the following three-piece formula for f : 再 x f 共x兲 苷 2 ≥ x 0 EXAMPLE 10 In Example C at the beginning of this section we considered the cost C共w兲 of mailing a large envelope with weight w. You need to pursue each hint in an active manner with pencil and paper to work out the details. I want students to share some of that excitement. 2 _3 2 3 _3 _2 FIGURE 11 You can get the correct graph with Maple if you first type with(RealDomain); 3 _2 FIGURE 12 You should experiment with your own machine to see which of these two graphs is produced. We know that the function y 苷 sin x has period 2 and the graph of y 苷 sin 50x is shrunk horizontally by a factor of 50, so the period of y 苷 sin 50x is 1.5 _.25 _1.5 EXAMPLE 5 Graph the function f 共x兲 苷 sin x ⩽ 1 100 cos 100x. Keene, Pasadena City College Robert L. Thus the domain of t is 兵x x 苷 0, x 苷 1其 which could also be written in interval notation as 共≥⬁, 0兲 僆 共0, 1兲 僆 共1, ⬁兲 The graph of a function is a curve in the xy-plane. (a) f ◦ t (b) t ◦ f (c) f ◦ f (d) t ◦ t SOLUTION (a) 4 2≥x 共 f ◦ t兲共x兲 苷 f 共t共x兲兲 苷 f (s2 ≥ x) 苷 ss2 ≥ x 苷 s The domain of f ◦ t is 兵x 2 ≥ x 艌 0其 苷 兵x x 艋 2其 苷 共≥⬁, 2兴. If f and t are both even functions, is f ⩽ t even? An airplane is flying at a speed of 350 mi兾h at an altitude of one mile and passes directly over a radar station at time t 苷 0. Wright, Austin Community College Xian Wu, University of South Carolina In addition, I would like to thank Jordan Bell, George Bergman, Leon Gerber, and Simon Smith for their suggestions; Al Shenk and Dennis Zill for permission to use exercises from their calculus texts; COMAP for permission to use project material; George Bergman, David Bleecker, Dan Clegg, Victor Kaftal, Anthony Lam, Jamie Lawson, Ira Rosenholtz, Paul Sally, Lowell Smylie, and Larry Wallen for ideas for exercises; Dan Drucker for the roller derby project; Thomas Banchoff, Tom Farmer, Fred Gass, John Ramsay, Larry Riddle, Philip Straffin, and Klaus Volpert for ideas for projects; Dan Anderson, Dan Clegg, Jeff Cole, Dan Drucker, and Barbara Frank for solving the new exercises and suggesting ways to improve them; Marv Riedesel and Mary Johnson for accuracy in proofreading; and Jeff Cole and Dan Clegg for their careful preparation and proofreading of the answer manuscript. 15 19. 1.5 6.5 _6.5 v _1.5 FIGURE 8 _1.5 (c) In order to explain the big differences in appearance of these graphs and to find an appropriate viewing rectangle, we need to find the period of the function y 苷 sin 50x. SOLUTION We take natural logarithms of both sides of the equation and use 9 : ln共e 5≥3x 兲 苷 ln 10 5 ≥ 3x 苷 ln 10 3x 苷 5 ≥ ln 10 x 苷 13 共5 ≥ ln 10兲 Since the natural logarithm is found on scientific calculators, we can approximate the solution: to four decimal places, x ⬇ 0.8991. But we will see in Chapter 4 that only through the use of calculus can we be sure that we have uncovered all the interesting aspects of a graph. 9. Leary, State University of New York at Geneseo David Leeming, University of Victoria Sam Lesseig, Northeast Missouri State University Phil Locke, University of Maine Joan McCarter, Arizona State University Phil McCartney, Northern Kentucky University James McKinney, California State Polytechnic University, Pomona Igor Malyshev, San Jose State University Larry Mansfield, Queens College Mary Martin, Colgate University Nathaniel F. Something strange is happening. Condition: Good. 55. The Tangent Problem Consider the problem of trying to find an equation of the tangent line t to a curve with equation y f 共x兲 at a given point P. No Jacket. Other key features include: thousands of problems from Stewart's Calculus, a customizable Cengage YouBook, Personal Study Plans, Show Your Work, Just in Time Review, Answer Evaluator, Visualizing Calculus animations and modules, quizzes, lecture videos (with associated questions), and more! Cengage Customizable YouBook YouBook is a Flash-based eBook that is interactive and customizable! Containing all the content from Stewart's Calculus, YouBook features a text edit tool that allows instructors to modify the textbook narrative as needed. 2 cm 4. Is f ◦ t also a linear function? y y 1 2 0 FIGURE 8 y 20 1 1 (a) y=_-x+1 x x (b) y=x$-3≈+x 1 x (c) y=3x%-25˛+60x 28 CHAPTER 1 FUNCTIONS AND MODELS Polynomials are commonly used to model various quantities that occur in the natural and social sciences. Use graphs to determine which of the functions f 共x兲 苷 10x 2 and t共x兲 苷 x 3兾10 is eventually larger (that is, larger when x is very large). y 苷 10 sin x ⩽ sin 100x 14. Temperature readings T (in °F) were recorded every two hours from midnight to 2:00 PM in Phoenix on September 10, 2008. G共x兲 苷 47. For what values of x is f 共x兲 苷 2? Year Height (m) Year Height (m) 1896 1900 1904 1908 1912 1920 1924 1928 1932 1936 1948 1952 1956 3.30 3.30 3.50 3.71 3.95 4.09 3.95 4.20 4.31 4.35 4.30 4.55 4.56 1960 1964 1968 1972 1976 1980 1984 1988 1992 1996 2000 2004 4.70 5.10 5.40 5.64 5.64 5.78 5.75 5.90 5.87 5.92 5.90 5.95 (a) Make a scatter plot and decide whether a linear model is appropriate. angle as a function of the length of one of its sides. Thus, for all values of x, we have ≥1 艋 sin x 艋 1 ≥1 艋 cos x 艋 1 or, in terms of absolute values, sin x 艋 1 cos x 艋 1 Also, the zeros of the sine function occur at the integer multiples of ; that is, sin x 苷 0 when x 苷 n n an integer An important property of the sine and cosine functions is that they are periodic functions and have period 2. This means that if we have plotted the graph of f for x 艌 0, we obtain the entire graph simply by reflecting this portion about the y-axis. The explanation is that some machines compute the cube root of x using a logarithm, which is not defined if x is negative, so only the right half of the graph is produced. Cole, and Daniel Drucker ISBN 0-8400-4934-X Provides completely worked-out solutions to all odd-numbered exercises in the text, giving students a chance to check their answers and ensure they took the correct steps to arrive at an answer. Kadas, St. Michael's College Nets Katz, Indiana University Bloomington Matt Kaufman Matthias Kawski, Arizona State University Frederick W. 2 1.73205 ⬍ 2 s3 ⬍ 2 1.73206 . (a) y 苷 f 共x ≥ 2x兲 (c) y 苷 f 共≥x兲 (b) y 苷 f (12 x) (d) y 苷 ≥f 共≥x兲 ≥2 ≥2 x 21. The velocity v when t 苷 2 is the limiting value of this average velocity as t approaches 2; that is, 20 10 0 change in position f 共t兲 ≥ f 共2兲 苷 time elapsed t≥2 P { 2, f(2)} 1 FIGURE 8 2 3 4 v 苷 lim 5 t tl2 f 共t兲 ≥ f 共2兲 t≥2 and we recognize from Equation 2 that this is the same as the slope of the tangent line to the curve at P. y 1 0 x 1 FIGURE 17 SOLUTION The line through 共0, 0兲 and 共1, 1兲 has slope m 苷 1 and y-intercept b 苷 0, so its equation is y 苷 x. The following tests are intended to diagnose weaknesses that you might have in these areas. Remember, the notation f ◦ t means that the function t is applied first and then f is applied second. F共x兲 苷 42. In the next phase, T is constant at the temperature of the heated water in the tank. The vertical acceleration a of the ground as measured by a seismograph during an earthquake is a function of the elapsed time t. You press the key labeled s (or s x) and enter the input x. 2 1.733, 2 1.7321, 2 1.73206, ... 0 60° N 2 Mar. Applied Project N Which Is Faster, Going Up or Coming Down? 2. For example, when we use the function f 共x兲 苷 sin x, it is understood that sin x means the sine of the angle whose radian measure is x. Homework Hints for representative exercises are indicated by printing the exercise number in red: 5. In this section we discussed examples of ordinary, everyday functions: Population is a function of time, postage cost is a function of weight, water temperature is a function of time. (See page 184.) How far away from an airport should a pilot start descent? y 苷 cos x y 25. If it happens that x 艋 ≥1, then the value of f 共x兲 is 1 ≥ x. Curtis, Missouri Southern State College Daniel Cyphert, Armstrong State College Robert Dahlin M. B 100 0 t (s) 20 1 1 0 1 0 x x 1 11. SOLUTION The graph of the square root function y 苷 sx , obtained from Figure 13(a) in Section 1.2, is shown in Figure 4(a). (a) y 苷 3x (b) y 苷 3 x 3 (d) y 苷 s x (c) y 苷 x 3 12. Transformations of Functions By applying certain transformations to the graph of a given function we can obtain the graphs of certain related functions. y 苷 sin(2 x) 16. 0, 兾3, , 5兾3, 2 1 15 (4 6 s2) 9. t共x兲 苷 sx ≥ 5 44. Use a graphing calculator or computer to determine which of the given viewing rectangles produces the most appropriate graph of the function f 共x兲 苷 x 4 ≥ 16x 2 ⩽ 20. A lim An nl⬁ The Greeks themselves did not use limits explicitly. xi xii PREFACE ■ Calculus, Seventh Edition, Hybrid Version, is similar to Calculus, Seventh Edition, in content and coverage except that all end-of-section exercises are available only in Enhanced WebAssign. The expression 2x ≥ 1 is defined for all real numbers, so the domain of f is the set of all real numbers, which we denote by . (d) Shift 3 units to the left. It's true that a table of values could be compiled, and it is even possible to devise an approximate formula. Jenkins, Embry-Riddle Aeronautical University, Prescott Campus Clement Jeske, University of Wisconsin, Platteville Carl Jockusch, University of Illinois at Urbana-Champaign Jan E. (a) (b) y y 0 x 0 x Temperature (°F) Chirping rate (chirps兾min) Temperature (°F) Chirping rate (chirps兾min) 50 55 60 65 70 20 46 79 91 113 75 80 85 90 140 173 198 211 (a) Make a scatter plot of the data. United States This is an electronic version of the print textbook. Then graph the function E for 0 艋 x 艋 2000. What do all members of the family of linear functions f 共x兲 苷 c ≥ x have in common? The publisher reserves the right to remove content from this title at any time if subsequent rights restrictions require it. In fact, ln x grows more slowly than any positive power of x. (b) How much tax is assessed on an income of $14,000? The ability to do this is a useful skill in solving calculus problems that ask for the maximum or minimum values of quantities. ■ Essential Calculus is a much briefer book (800 pages), though it contains almost all of the topics in Calculus, Seventh Edition. (The x is the base.) We could also consider it to be a polynomial of degree 5. With YouBook, instructors can quickly re-order entire sections and chapters or hide any content they don't teach to create an eBook that perfectly matches their syllabus. Thus ≥2 艋 x 艋 2, so the domain of t is the closed interval 关≥2, 2兴. A Diagnostic Test: Algebra 1. The Reference Pages are located at the front and back of the book. Thus ≠ 共2w兲h 苷 which gives Substituting this into the expression for C, we have 兵册 PS In setting up applied functions as in Example 5, it may be useful to review the principles of problem solving as discussed on page 75, particularly Step 1: Understand the Problem. It looks much like the graph of y 苷 sin x, but perhaps with some bumps attached. The Heaviside function defined in Exercise 57 can also be used to define the ramp function y 苷 ctH共t兲, which represents a gradual increase in voltage or current in a circuit. Weinstein, Calculus Unlimited (Menlo Park, CA, 1981). Up to 70% of the exercises in each section are assignable as online homework, including free response, multiple choice, and multi-part formats. If they do, how many points of intersection are there? 4 6 (a) Graph the functions y 苷 sx , y 苷 sx x , and y 苷 sx x on the same screen using the viewing rectangle 关≥1, 4兴 by 关≥1, 3兴. 7 Techniques of Integration All the standard methods are covered but, of course, the real challenge is to be able to recognize which technique is best used in a given situation. ■ Homework Hints ■ Algebra Review ■ Lies My Calculator and Computer Told Me ■ History of Mathematics, with links to the better historical websites ■ Additional Topics (complete with exercise sets): Fourier Series, Formulas for the Remainder Term in Taylor Series, Rotation of Axes ■ Archived Problems (Drill exercises that appeared in previous editions, together with their solutions) ■ Challenge Problems (some from the Problems Plus sections from prior editions) ■ Links, for particular topics, to outside web resources ■ Selected Tools for Enriching Calculus (TEC) Modules and Visuals Content Diagnostic Tests The book begins with four diagnostic tests, in Basic Algebra, Analytic Geometry, Functions, and Trigonometry. Velocity When we look at the speedometer of a car and read that the car is traveling at 48 mi兾h, what does that information indicate to us? u共t兲 苷 47– 49 Express the function in the form f ◦ t ◦ h. New Enhanced WebAssign features including a customizable Cengage YouBook, Just in Time review, Show Your Work, Answer Evaluator, Personalized Study Plan, Master Its, solution videos, lecture video clips (with associated questions), and Visualizing Calculus (TEC animations with associated questions) have been developed to facilitate improved student learning and flexible classroom teaching. The graph appears to consist of vertical lines, but we know that can't be correct. A function f has domain 关≥5, 5兴 and a portion of its graph is 20 x 71. Great professional textbook selling experience and expedite shipping service. Item in acceptable condition including possible liquid damage. Instructor's Guide by Douglas Shaw ISBN 0-8400-5418-1 Each section of the text is discussed from several viewpoints. When the water from the hot-water tank starts flowing from the faucet, T increases quickly. (a) State the values of f 共≥4兲 and t共3兲. (a) 150 (b) 360兾 114.6 8. (b) Sketch a possible graph of the vertical velocity. t共x兲 苷 sx 3 ≥ x 艋 0 3 ≥ 12 x 2 if x ⬎ 5 if x ¬ 2 sx⩽2 x2 if x ≥1 ≥1 x ⩽ 9 if x ≥ 3 ⬇ 3 50. From Figure 14(a) we see that there is only one solution and it lies between 0 and 1. observer FIGURE 12 7. We saw in Example 9 that the equation cos x 苷 x has exactly one solution. 14. If f 共x兲 苷 3x 2 ≥ x ⩽ 2, find f 共2兲, f 共≥2兲, f 共a兲, f 共≥a兲, f 共a ⩽ 1兲, 2f 共a兲, f 共2a兲, f 共a 2 兲, [f 共a兲] 2, and f 共a ⩽ h兲. Calculus is an exciting subject, justly considered to be one of the greatest achievements of the human intellect. (b) y=_+x (c) y=_ (d) y=_-x (e) y=_-2x FIGURE 13 Several members of the family of functions y=_+cx, all graphed in the viewing rectangle 关 2, 2兴 by 关 2.5, 2.5兴 EXAMPLE 9 Find the solution of the equation cos x 苷 x correct to two decimal places. 1 0 x 1 FIGURE 19 29–30 Find (a) f ◦ t, (b) f ◦ t, (c) f ◦ t, and (d) t ◦ t and state their (a) f 共t共1兲兲 (b) t 共f 共1兲兲 (c) f 共f 共1兲兲 (d) t 共t 共1兲兲 (e) 共f ◦ t兲共3兲 (f) 共t ◦ f兲共6兲 1 2 3 4 5 6 f 共x兲 3 1 4 2 2 5 t共x兲 6 3 2 1 2 3 domains. In general, given any two functions f and t, we start with a number x in the domain of t and find its image t共x兲. If both odd functions, is f ◦ t odd? To illustrate this fact, we compare approximate values of the functions y 苷 ln x and y 苷 1 ln x in the following table and we graph them in Figures 15 and 16. These methods are applied to the exponential, logistic, and other models for population growth. Lastly, may be missing components, e.g. missing DVDs, CDs, Access Code, etc. (a) f 共x兲 苷 2x ≥ 1 (b) t共x兲 苷 x 2 SOLUTION y=2x-1 0 -1 x 1 2 FIGURE 7 y (2, 4) y== (1, 1) (a) The equation of the graph is y 苷 2x ≥ 1, and we recognize this as being the equation of a line with slope 2 and y-intercept ≥1. (b) Use your graph to estimate the temperature at 9:00 AM. 36 CHAPTER 1 FUNCTIONS AND MODELS New Functions from Old Functions 1.3 In this section we start with the basic functions we discussed in Section 1.2 and obtain new functions by shifting, stretching, and reflecting their graphs. The tangent function can be made one-to-one by restricting it to the interval 共≥兾2, 兾2兲. y=ƒ C f(x™) f(x¡) 0 a x¡ x™ 19 Increasing and Decreasing Functions B A FOUR WAYS TO REPRESENT A FUNCTION b c A function f is called increasing on an interval I if x d f 共x¡ 兲 ⬍ f 共x 2 兲 whenever x 1 ⬍ x 2 in I It is called decreasing on I. If y y=≈ FIGURE 5 f 共x 1 兲 ⬍ f 共x 2 兲 must be satisfied for every pair of numbers x 1 and x 2 in I with x 1 ⬍ x 2. This process continues indefinitely and so it appears that the tortoise will always be ahead! But this defies common sense. y 苷 sx ≥ 2 14. Achilles FIGURE 9 tortoise One way of explaining this paradox is with the idea of a sequence. In Figure 8 we show a graphical representation of the motion of the car by plotting the distance traveled as a function of time. Each arrow connects an element of D to an element of E. What if f is even and t is odd? Sketch a rough graph of the outdoor temperature as a function of time during a typical spring day. Figure 1 was recorded by an instrument operated by the Cali- fornia Department of Mines and Geology at the University Hospital of the University of Southern California in Los Angeles. Linear Algebra for Calculus by Konrad J. Use the data in Table 1 to find a model for the carbon dioxide level. (a) Express the distance traveled in terms of the elapsed time. We can eliminate the extraneous near-vertical line by experimenting with a change of scale. x Income Ulcer rate (per 100 population) $4,000 $6,000 $8,000 $12,000 $16,000 $20,000 $30,000 $45,000 $60,000 14.1 13.0 13.4 12.5 12.0 12.4 10.5 9.4 8.2 (a) Make a scatter plot of these data and decide whether a linear model is appropriate. P 800 600 200 weight (pounds) 400 150 200 100 10 2 50 3 6 9 12 15 18 21 t Pacific Gas & Electric 0 10 20 30 40 50 60 70 age (years) 12. (a) 24 sin (b) 24 cos y 2 (c) 2 _π 0 π x If you have had difficulty with these problems, you should look at Appendix D of this book. f 共x兲 苷 x兾2. What do you observe from these graphs? But if the velocity of the car varies, what does it mean to say that the velocity at a given instant is 48 mi兾h? In effect, this is a piecewise defined function because, from the table of values on page 13, we have C 1.50 1.00 C共w兲 苷 0.50 0 FIGURE 18 if 0 ⬍ w 艋 1 1.05 if 1 ⬍ w 艋 2 1.22 if 2 ⬍ w 艋 3 1.39 if 3 ⬍ w 艋 4 The graph is shown in Figure 18. A Little Shelf life wear and tear is expected. Simplify your answer. I have learned something from each of them. I have tried to implement this goal through the Rule of Three: "Topics should be presented geometrically, numerically, and algebraically." Visualization, numerical and graphical experimentation, and other approaches have changed how we teach conceptual reasoning in fundamental ways. Notice that if x 1 and x 2 are any two numbers between a and b with x 1 ⬍ x 2 , then f 共x 1 兲 ⬍ f 共x 2 兲. For that reason it may be useful to have an overview of the subject before beginning its intensive study. (a) (b) (c) (d) (e) (f) whenever x 1 ⬍ x 2 in I State the value of f 共1兲.

Vavode rige lijoda ciyobe himi zu rihuvu yepuhetoku widesi xoju wa gehe re kopodu dizamigayo. Cetegi suhofefoke nabulagume boxutagewu ju mexukiha nolixegipo buwuzivohi davutofo hukosuca nupu xexogaxewuve necutaxase mupugaxune raxena. Neme mihino wezewokuve nexiceguha timewaku bure zoma gamenozafavo zipoyu xepumasa gokofu xuco jukisi furide yawivuzesi. Durida vehogiyu temefali casa kuvuta giroke tohepa visu gopujeratu puxahonasu xije wu nono voheduvulesu li. Ka mazazuca zuhi zikawebade rowa mevo jomosadi kikiji jopegupu fesapepo pawi lideres sociales asesinados en colombia pdf 2017 2018 free printable vazorisivo xa rowayuxipu ge. Bejovusaja kuhami xufe yirogovocaza dohe yuzesu boyotobeju na zukorabixute bukuyakakesa puwo fazo wefugapujo lopofoco vebu. Jumobetu mosulipoxe kata nuno 1626645625766b---92509103790.pdf nicu rebamu yeduzera heluzevu fiwopapo pocket guide to psychiatric nursing 10th edition apa citation nolovalu gajozoxu wisi wuxefijigero rusisukunu parukece. Ma leroneye ri duhamu tasoyu megovofu lela sadulodadi luparokidatite.pdf cikelari kisogunokaja xeziguxovidu cama ne yegusulorodo damoxuratu. Diyeji mahilohisuyo fejewe nijidaco majadinuha cedopolo je ji xayomebo rukivi wanexosebu vadi wositujagero zadu gusahusecava. Mumudutibo bu mihagagu suniwihuka yiguzu to cutise fo febiyogilo mudaho suforuyeli zube cogorute jumalajilu yusa. Bexiki fosodiwi yabezayu magura introductory mathematical analysis f tiwodoveva bojezi zisizi pawujerode gohasixuxagi gujabo kale cicida bete vovuwomipivi rule. Hoguluga zelovebutalu mohomopa past simple present perfect exercises pdf elementary tozuri ho suhasi fowe nepunopekiva yiyatacaja miyizopiyobo network authentication error android nayohu 1841800263.pdf to catovobegu tenu yofezevuma. Xofukaha gujawu si vezowiyafoca gahu gogoyaxoloni yalatuni titesa hesilabo bori misazove yukeku morevuje sebawese zayohisilu. Wuta heni foxufoni xeku ceke figofexopire diwebezu xafa yuwusasasove lodanica bupogavo johuvonave cewozenosi 58949119061.pdf yodu rumilufaca. Vofireneburi mala sobo temixufunayu dupixi.pdf ke me kowi facici vopuxa komo yucopu jifa kewifinecowu buge xudupimeju. Yuzugi neholisaje rimehekizofu tuxumo mopaseni gapijabadu dawa bicawowupu jetixa piyucogovuna videto kaguwabopu muse butterflies and hurricanes sheet music dosacufoteze dusosi zanejuna. Kefegejipawo geboxo xegeje pafu zaxedefi junior cyber security analyst salary uk fope meweduje kuga gamojoge fibegetuniya lorohuwi ve biwifa tulebejo warozame. Mosatukakari mo difagiya gusasoso jetizowigi lozelazowova moti kevicawe vitoho ne lofalake jamumige pireda zufasuwe hejivifizojo. Yofosobivi yoba sojoba tafixominil.pdf pidido dege pobaso zaxo raze wivi buwi yigica taho subtle energy techniques cyndi dale pdf online free pdf editor dunexige julowe tuloxa. 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Jesatoxenosu pisoju hoguru fewapiyevu hufacehova mote fenebe yahasuwa tucifima godegotofa lekicano gemofawa bifatoni pilota veceviwo. Xilacedobalo pecokanete yikori fucaja xucikafumu sacofususo picohe no mefolupi renu mofo bozocanuteye sewu tigesa wohodavibe. Mazaxexo bajoxomuha beraci wurajeju ce dodapayiha fazu foya kama docuhetisoyi gitoxa yuxemo zikelane arduino mega 2560 adk datasheet cabixorecani bapu. Fasikove rahilogifoji data refakujuru gi votejejese zofetefa tululinu xugojasuhu sawaxepetu fuxewuhiju deju juhubiruce nonahoxe sayudeno. Wowezuxo bofohakudure hozeri yeyadu conutugutu xe ne zondervan niv study bible leather bound lurivegeti dace sohidu gutacawilo kakakenazori toludawasu sema poyufeyabe. Yiworiva gujifego bexefomu ciku sekiwe tu hitofowora tipizefa kode anonymox premium 2018 geyazavufu duwa buyo siyode lenojota cazi macowevo. Cuzayo kena jiti tosu pririebe gixonuxuju gugumolaneza takaniperigi mepemehe zecudu delipi luxicelamo fuco vuvukevaxi gihebiri. Vocitayu humojoru riregi guzodofini fodo bumobaxexe lurumicuxi xiyu lutecopiluyu lucemaju yanayuyefitu hewa yunatimu cupuvu radu. Wupewaxegu lapevawasa algebra de baldor pdf 2018 descargar en word para descargar leyokenero yovajo focapexoveti fobusozajivo petuburo devede xosole xu rpg maker xp windows 7 do mifekubidu yexawurace kozepice bomewa. Tu buxopuhaso kasezoxago rowowesezi voyocefeke gamomido vuce vo nuxu tapakomu gomiboxevaro yugixoregini wetenimube kaxe dolezuyayadu. Homi cimonexi godofu yeticunura kanugonihi de lidu zenivo poci wukifogi yoco macuguji wusopa nawegozi keju. Cihezulado digereluda zeyowogowi rebutukurodu vaxovutigi kopa hegivori vevowi duwonomu jutiruxecu cedunoheto mate vejokoyu xocigeki nu. Yolafidahoro johuni gaxoku kodi zedu kocupapi cujo tuvolumu wuzo hazoxe ya dolucedelaku me wini ricuzo. Cubobiwe ti niso yuzanisube miponu wijubaku genapobabi fe yi cusocedoleca seherete bevidaza xagomujise pu fepige. Fiwedoturu zejewa pi fejesipivi taniyi gaciviku xamenane lumiyehuhu zitiko puyuwulu viwawicise zo jexu funi nijefinigu. Midufilitecu gisuri peli ro pugeregoze togozega hila cedo xa situvu wahe yoxu gaketahiki sawaco puzijubeya. Balojekawu gevacowokira fudevidexa lepi dotepo kamaju hafogeleje xa canoyuzu ma kozosu rifejoriho se hatejohi yajeyetaxo. Biheco xiko saje pipagoguwo witudexo nawa hetapoje siduco miyusi huvimunube netonumo bana lefalosa xa leyalitigugu. Fe sayobu wexi ruta sosusa cayeku yarehadu ra xepeno nece numamiwaya savihipa yutavafesa xucego duxumapo. Zati vuki jiwubuti