
Single Variable Calculus

Early Transcendentals



This work is licensed under the Creative Commons Attribution-NonCommercial-ShareAlike License. To view a copy of this license, visit <http://creativecommons.org/licenses/by-nc-sa/3.0/> or send a letter to Creative Commons, 543 Howard Street, 5th Floor, San Francisco, California, 94105, USA. If you distribute this work or a derivative, include the history of the document.

This text was initially written by David Guichard. The single variable material in chapters 1–9 is a modification and expansion of notes written by Neal Koblitz at the University of Washington, who generously gave permission to use, modify, and distribute his work. New material has been added, and old material has been modified, so some portions now bear little resemblance to the original.

The book includes some exercises and examples from *Elementary Calculus: An Approach Using Infinitesimals*, by H. Jerome Keisler, available at <http://www.math.wisc.edu/~keisler/calc.html> under a Creative Commons license. In addition, the chapter on differential equations (in the multivariable version) and the section on numerical integration are largely derived from the corresponding portions of Keisler's book. Albert Schueller, Barry Balof, and Mike Wills have contributed additional material.

This copy of the text was compiled from source at 16:53 on 5/30/2018.

I will be glad to receive corrections and suggestions for improvement at guichard@whitman.edu.

*For Kathleen,
without whose encouragement
this book would not have
been written.*

Contents

1

Analytic Geometry 13

1.1	Lines	14
1.2	Distance Between Two Points; Circles	19
1.3	Functions	20
1.4	Shifts and Dilations	25

2

Instantaneous Rate of Change: The Derivative 29

2.1	The slope of a function	29
2.2	An example	34
2.3	Limits	36
2.4	The Derivative Function	46
2.5	Adjectives For Functions	51

6 Contents

3

Rules for Finding Derivatives 55

3.1	The Power Rule	55
3.2	Linearity of the Derivative	58
3.3	The Product Rule	60
3.4	The Quotient Rule	62
3.5	The Chain Rule	65

4

Transcendental Functions 71

4.1	Trigonometric Functions	71
4.2	The Derivative of $\sin x$	74
4.3	A hard limit	75
4.4	The Derivative of $\sin x$, continued	78
4.5	Derivatives of the Trigonometric Functions	79
4.6	Exponential and Logarithmic functions	80
4.7	Derivatives of the exponential and logarithmic functions	82
4.8	Implicit Differentiation	87
4.9	Inverse Trigonometric Functions	92
4.10	Limits revisited	95
4.11	Hyperbolic Functions	100

5

Curve Sketching 105

5.1	Maxima and Minima	105
5.2	The first derivative test	109
5.3	The second derivative test	110
5.4	Concavity and inflection points	111
5.5	Asymptotes and Other Things to Look For	113

6

Applications of the Derivative 117

6.1	Optimization	117
6.2	Related Rates	129
6.3	Newton's Method	137
6.4	Linear Approximations	141
6.5	The Mean Value Theorem	143

7

Integration 147

7.1	Two examples	147
7.2	The Fundamental Theorem of Calculus	151
7.3	Some Properties of Integrals	158

8

Techniques of Integration 163

8.1	Substitution	164
8.2	Powers of sine and cosine	169
8.3	Trigonometric Substitutions	171
8.4	Integration by Parts	174
8.5	Rational Functions	178
8.6	Numerical Integration	182
8.7	Additional exercises	187

9

Applications of Integration 189

9.1	Area between curves	189
9.2	Distance, Velocity, Acceleration	194
9.3	Volume	197
9.4	Average value of a function	204
9.5	Work	207
9.6	Center of Mass	211
9.7	Kinetic energy; improper integrals	217
9.8	Probability	221
9.9	Arc Length	230
9.10	Surface Area	232

10

Polar Coordinates, Parametric Equations 239

10.1	Polar Coordinates	239
10.2	Slopes in polar coordinates	243
10.3	Areas in polar coordinates	245
10.4	Parametric Equations	248
10.5	Calculus with Parametric Equations	251

11

Sequences and Series	255
11.1 Sequences	256
11.2 Series	262
11.3 The Integral Test	266
11.4 Alternating Series	271
11.5 Comparison Tests	273
11.6 Absolute Convergence	276
11.7 The Ratio and Root Tests	277
11.8 Power Series	280
11.9 Calculus with Power Series	283
11.10 Taylor Series	285
11.11 Taylor's Theorem	288
11.12 Additional exercises	294

A

Selected Answers	297
-------------------------	------------

B

Useful Formulas	313
------------------------	------------

Index	317
--------------	------------

Introduction

The emphasis in this course is on problems—doing calculations and story problems. To master problem solving one needs a tremendous amount of practice doing problems. The more problems you do the better you will be at doing them, as patterns will start to emerge in both the problems and in successful approaches to them. You will learn fastest and best if you devote some time to doing problems every day.

Typically the most difficult problems are story problems, since they require some effort before you can begin calculating. Here are some pointers for doing story problems:

1. Carefully read each problem twice before writing anything.
2. Assign letters to quantities that are described only in words; draw a diagram if appropriate.
3. Decide which letters are constants and which are variables. A letter stands for a constant if its value remains the same throughout the problem.
4. Using mathematical notation, write down what you know and then write down what you want to find.
5. Decide what category of problem it is (this might be obvious if the problem comes at the end of a particular chapter, but will not necessarily be so obvious if it comes on an exam covering several chapters).
6. Double check each step as you go along; don't wait until the end to check your work.
7. Use common sense; if an answer is out of the range of practical possibilities, then check your work to see where you went wrong.

12 Introduction

Suggestions for Using This Text

1. Read the example problems carefully, filling in any steps that are left out (ask someone for help if you can't follow the solution to a worked example).
2. Later use the worked examples to study by covering the solutions, and seeing if you can solve the problems on your own.
3. Most exercises have answers in Appendix A; the availability of an answer is marked by “ \Rightarrow ” at the end of the exercise. In the pdf version of the full text, clicking on the arrow will take you to the answer. The answers should be used only as a final check on your work, not as a crutch. Keep in mind that sometimes an answer could be expressed in various ways that are algebraically equivalent, so don't assume that your answer is wrong just because it doesn't have exactly the same form as the answer in the back.
4. A few figures in the pdf and print versions of the book are marked with “(AP)” at the end of the caption. Clicking on this should open a related interactive applet or Sage worksheet in your web browser. Occasionally another link will do the same thing, like this example. (Note to users of a printed text: the words “this example” in the pdf file are blue, and are a link to a Sage worksheet.)