Preface

University Calculus: Early Transcendentals, Fourth Edition, provides a streamlined treatment of the material in a standard three-semester or four-quarter STEM-oriented course. As the title suggests, the book aims to go beyond what many students may have seen at the high school level. The book emphasizes mathematical precision and conceptual understanding, supporting these goals with clear explanations and examples and carefully crafted exercise sets.

Generalization drives the development of calculus and of mathematical maturity and is pervasive in this text. Slopes of lines generalize to slopes of curves, lengths of line segments to lengths of curves, areas and volumes of regular geometric figures to areas and volumes of shapes with curved boundaries, and finite sums to series. Plane analytic geometry generalizes to the geometry of space, and single variable calculus to the calculus of many variables. Generalization weaves together the many threads of calculus into an elegant tapestry that is rich in ideas and their applications.

Mastering this beautiful subject is its own reward, but the real gift of studying calculus is acquiring the ability to think logically and precisely; understanding what is defined, what is assumed, and what is deduced; and learning how to generalize conceptually. We intend this text to encourage and support those goals.

New to This Edition

We welcome to this edition two new co-authors: Christopher Heil from Georgia Institute of Technology and Przemyslaw Bogacki from Old Dominion University. Heil’s focus was primarily on the development of the text itself, while Bogacki focused on the MyLab™ Math course.

Christopher Heil has been involved in teaching calculus, linear algebra, analysis, and abstract algebra at Georgia Tech since 1993. He is an experienced author and served as a consultant on the previous edition of this text. His research is in harmonic analysis, including time-frequency analysis, wavelets, and operator theory.

Przemyslaw Bogacki joined the faculty at Old Dominion University in 1990. He has taught calculus, linear algebra, and numerical methods. He is actively involved in applications of technology in collegiate mathematics. His areas of research include computer-aided geometric design and numerical solution of initial value problems for ordinary differential equations.

This is a substantial revision. Every word, symbol, and figure was revisited to ensure clarity, consistency, and conciseness. Additionally, we made the following text-wide changes:

• Updated graphics to bring out clear visualization and mathematical correctness.
• Added new types of homework exercises throughout, including many that are geometric in nature. The new exercises are not just more of the same, but rather give different perspectives and approaches to each topic. In preparing this edition, we analyzed aggregated student usage and performance data from MyLab Math for the previous edition of the text. The results of this analysis increased both the quality and the quantity of the exercises.
• Added short URLs to historical links, thus enabling students to navigate directly to online information.
• Added new annotations in blue type throughout the text to guide the reader through the process of problem solution and emphasize that each step in a mathematical argument is rigorously justified.

New To MyLab Math

Many improvements have been made to the overall functionality of MyLab Math since the previous edition. We have also enhanced and improved the content specific to this text.
• Every online exercise in the course was reviewed for accuracy and alignment with the text by author Przemyslaw Bogacki.
• Instructors now have more exercises than ever to choose from in assigning homework. There are approximately 8550 assignable exercises in MyLab Math, 490 of which are new to this edition.
• The MyLab Math exercise-scoring engine has been updated to allow for more robust coverage of certain topics, including differential equations.

   • A full suite of Interactive Figures have been added to support teaching and learning. The figures are designed to be used in lecture as well as by students independently. The figures are editable via the freely available GeoGebra software.
   • Enhanced Sample Assignments include just-in-time prerequisite review, help keep skills fresh with spaced practice of key concepts, and provide opportunities to work exercises without learning aids (to help students develop confidence in their ability to solve problems independently).
   • Additional Conceptual Questions augment the text exercises to focus on deeper, theoretical understanding of the key concepts in calculus. These questions were written by faculty at Cornell University under an NSF grant. They are also assignable through Learning Catalytics.
• This MyLab Math course contains pre-made quizzes to assess the prerequisite skills needed for each chapter, plus personalized remediation for any gaps in skills that are identified.
• Additional Setup & Solve exercises now appear in many sections. These exercises require students to show how they set up a problem, as well as the solution itself, better mirroring what is required of students on tests.
• PowerPoint lecture slides have been expanded to include examples as well as key theorems, definitions, and figures.
• Over 200 new instructional videos augment the already robust collection within the course. These videos support the overall approach of the text—specifically, they go beyond routine procedures to show students how to generalize and connect key concepts.
Content Enhancements

Chapter 1

• Shortened 1.4 to focus on issues arising in use of mathematical software, and potential pitfalls. Removed peripheral material on regression, along with associated exercises.

• Clarified explanation of definition of exponential function in 1.5.

• Replaced $\sin^{-1}$ notation for the inverse sine function with $\arcsin$ as default notation in 1.6, and similarly for other trig functions.

Chapter 2

• Added definition of average speed in 2.1.

• Updated definition of limits to allow for arbitrary domains. The definition of limits is now consistent with the definition in multivariable domains later in the text and with more general mathematical usage.

• Reworded limit and continuity definitions to remove implication symbols and improve comprehension.

• Replaced Example 1 in 2.4, reordered, and added new Example 2 to clarify one-sided limits.

• Added new Example 7 in 2.4 to illustrate limits of ratios of trig functions.

• Rewrote Example 11 in 2.5 to solve the equation by finding a zero, consistent with the previous discussion.

Chapter 3

• Clarified relation of slope and rate of change.

• Added new Figure 3.9 using the square root function to illustrate vertical tangent lines.

• Added figure of $x \sin \left(\frac{1}{x}\right)$ in 3.2 to illustrate how oscillation can lead to non-existence of a derivative of a continuous function.

• Revised product rule to make order of factors consistent throughout text, including later dot product and cross product formulas.

• Expanded Example 7 in 3.8 to clarify the computation of the derivative of $x^r$.

• Updated and improved related rates problem strategies in 3.10, and correspondingly revised Examples 2–6.

Chapter 4 & 5

• Added summary to 4.1.

• Added new Example 3 with new Figure 4.27, and Example 12 with new Figure 4.35, to give basic and advanced examples of concavity.

• Updated and improved strategies for solving applied optimization problems in 4.6.

• Improved discussion in 5.4 and added new Figure 5.18 to illustrate the Mean Value Theorem.

Chapter 6 & 7

• Clarified cylindrical shell method.

• Converted Example 4 in 6.5 to metric units.

• Added introductory discussion of mass distribution along a line, with figure, in 6.6.

• Clarified discussion of separable differential equations in 7.2.

Chapter 8

• Updated Integration by Parts discussion in 8.2 to emphasize $u(x)v'(x) \, dx$ form rather than $u \, dv$. Rewrote Examples 1–3 accordingly.

• Removed discussion of tabular integration, along with associated exercises.

• Updated discussion in 8.4 on how to find constants in the method of partial fractions, and clarified the corresponding calculations in Example 1.

Chapter 9

• Clarified the different meanings of sequence and series.

• Added new Figure 9.9 to illustrate sum of a series as area of a histogram.

• Added to 9.3 a discussion on the importance of bounding errors in approximations.

• Added new Figure 9.13 illustrating how to use integrals to bound remainder terms of partial sums.

• Rewrote Theorem 10 in 9.4 to bring out similarity to the integral comparison test.
• Added new Figure 9.16 to illustrate the differing behaviors of the harmonic and alternating harmonic series.
• Renamed the $n$th-Term Test the “$n$th-Term Test for Divergence” to emphasize that it says nothing about convergence.
• Added new Figure 9.19 to illustrate polynomials converging to $\ln(1 + x)$, which illustrates convergence on the half-open interval $(-1, 1]$.
• Used red dots and intervals to indicate intervals and points where divergence occurs and blue to indicate convergence throughout Chapter 9.
• Added new Figure 9.21 to show the six different possibilities for an interval of convergence.
• Changed the name of 9.10 to “Applications of Taylor Series.”

Chapter 10
• Added new Example 1 and Figure 10.2 in 10.1 to give a straightforward first Example of a parametrized curve.
• Updated area formulas for polar coordinates to include conditions for positive $r$ and non-overlapping $\theta$.
• Added new Example 3 and Figure 10.37 in 10.4 to illustrate intersections of polar curves.
• Moved Section 10.6 (“Conics in Polar Coordinates”), which our data showed is seldom used, to online Appendix B (bit.ly/2IDD18w).

Chapters 11 & 12
• Added new Figure 11.13b to show the effect of scaling a vector.
• Added new Example 7 and Figure 11.26 in 11.3 to illustrate projection of a vector.
• Added discussion on general quadric surfaces in 11.6, with new Example 4 and new Figure 11.48 illustrating the description of an ellipsoid not centered at the origin via completing the square.
• Added sidebars on how to pronounce Greek letters such as kappa and tau.

Chapter 13
• Elaborated on discussion of open and closed regions in 13.1.
• Added a Composition Rule to Theorem 1 and expanded Example 1 in 13.2.
• Expanded Example 8 in 13.3.
• Clarified Example 6 in 13.7.
• Standardized notation for evaluating partial derivatives, gradients, and directional derivatives at a point, throughout the chapter.
• Renamed “branch diagrams” as “dependency diagrams” to clarify that they capture dependence of variables.

Chapter 14
• Added new Figure 14.21b to illustrate setting up limits of a double integral.
• In 14.5, added new Example 1, modified Examples 2 and 3, and added new Figures 14.31, 14.32, and 14.33 to give basic examples of setting up limits of integration for a triple integral.

Chapter 15
• Added new Figure 15.4 to illustrate a line integral of a function, new Figure 15.17 to illustrate a gradient field, and new Figure 15.18 to illustrate a line integral of a vector field.
• Clarified notation for line integrals in 15.2.
• Added discussion of the sign of potential energy in 15.3.
• Rewrote solution of Example 3 in 15.4 to clarify its connection to Green’s Theorem.
• Updated discussion of surface orientation in 15.6, along with Figure 15.52.

Appendices
• Rewrote Appendix A.8 on complex numbers.
• Added online Appendix B (bit.ly/2IDD18w) containing additional topics. These topics are supported fully in MyLab Math.

Continuing Features

**Rigor** The level of rigor is consistent with that of earlier editions. We continue to distinguish between formal and informal discussions and to point out their differences. We think starting with a more intuitive, less formal approach helps students understand a new or difficult concept so they can then appreciate its full mathematical precision and outcomes. We pay attention to defining ideas carefully and to proving theorems appropriate...
for calculus students, while mentioning deeper or subtler issues they would study in a more advanced course. Our organization and distinctions between informal and formal discussions give the instructor a degree of flexibility in the amount and depth of coverage of the various topics. For example, although we do not prove the Intermediate Value Theorem or the Extreme Value Theorem for continuous functions on a closed finite interval, we do state these theorems precisely, illustrate their meanings in numerous examples, and use them to prove other important results. Furthermore, for those instructors who desire greater depth of coverage, in Appendix A.7 we discuss the reliance of these theorems on the completeness of the real numbers.

**Writing Exercises** Writing exercises placed throughout the text ask students to explore and explain a variety of calculus concepts and applications. In addition, the end of each chapter includes a list of questions that invite students to review and summarize what they have learned. Many of these exercises make good writing assignments.

**End-Of-Chapter Reviews** In addition to problems appearing after each section, each chapter culminates with review questions, practice exercises covering the entire chapter, and a series of Additional and Advanced Exercises with more challenging or synthesizing problems.

**Writing And Applications** This text continues to be easy to read, conversational, and mathematically rich. Each new topic is motivated by clear, easy-to-understand examples and is then reinforced by its application to real-world problems of immediate interest to students. A hallmark of this text is the application of calculus to science and engineering. These applied problems have been updated, improved, and extended continually over the last several editions.

**Technology** In a course using this text, technology can be incorporated according to the taste of the instructor. Each section contains exercises requiring the use of technology; these are marked with a [T] if suitable for calculator or computer use, or they are labeled **Computer Explorations** if a computer algebra system (CAS, such as Maple or Mathematica) is required.

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**Dedication**

We regret that prior to the writing of this edition, our co-author Maurice Weir passed away. Maury was dedicated to achieving the highest possible standards in the presentation of mathematics. He insisted on clarity, rigor, and readability. Maury was a role model to his students, his colleagues, and his co-authors. He was very proud of his daughters, Maia Coyle and Renee Waina, and of his grandsons, Matthew Ryan and Andrew Dean Waina. He will be greatly missed.