

# MATH2068 MATHEMATICAL ANALYSIS II (2023-24)

CHI-WAI LEUNG

## 1. DIFFERENTIATION

Throughout this section, let  $I$  be an open interval (not necessarily bounded) and let  $f$  be a real-valued function defined on  $I$ .

**Definition 1.1.** Let  $c \in I$ . We say that  $f$  is differentiable at  $c$  if the following limit exists:

$$\lim_{x \rightarrow c} \frac{f(x) - f(c)}{x - c}.$$

In this case, we write  $f'(c)$  for the above limit and we call it the derivative of  $f$  at  $c$ . We say that  $f$  is differentiable on  $I$  if  $f'(x)$  exists for every point  $x$  in  $I$ .

**Proposition 1.2.** Let  $c \in I$ . Then  $f'(c)$  exists if and only if there is a function  $\varphi$  defined on  $I$  such that the function  $\varphi$  is continuous at  $c$  and

$$f(x) - f(c) = \varphi(x)(x - c)$$

for all  $x \in I$ .

In this case,  $\varphi(c) = f'(c)$ .

*Proof.* Assume that  $f'(c)$  exists. Define a function  $\varphi : I \rightarrow \mathbb{R}$  by

$$\varphi(x) = \begin{cases} \frac{f(x) - f(c)}{x - c} & \text{if } x \neq c; \\ f'(c) & \text{if } x = c. \end{cases}$$

Clearly, we have  $f(x) - f(c) = \varphi(x)(x - c)$  for all  $x \in I$ . We want to show that the function  $\varphi$  is continuous at  $c$ . In fact, let  $\varepsilon > 0$ , by the definition of the limit of a function, there is  $\delta > 0$  such that

$$|f'(c) - \frac{f(x) - f(c)}{x - c}| < \varepsilon$$

whenever  $x \in I$  with  $0 < |x - c| < \delta$ . Therefore, we have  $|f'(c) - \varphi(x)| < \varepsilon$  as  $x \in I$  with  $0 < |x - c| < \delta$ . Since  $\varphi(c) = f'(c)$ , we have  $|f'(c) - \varphi(x)| < \varepsilon$  as  $x \in I$  with  $|x - c| < \delta$ , hence the function  $\varphi$  is continuous at  $c$  as desired.

The converse is clear since  $\varphi(x) = \frac{f(x) - f(c)}{x - c}$  if  $x \neq c$ . The proof is complete.  $\square$

**Proposition 1.3.** Using the notation as above, if  $f$  is differentiable at  $c$ , then  $f$  is continuous at  $c$ .

*Proof.* By using Proposition 1.2, if  $f'(c)$  exists, then there is a function  $\varphi$  defined on  $I$  such that the function  $\varphi$  is continuous at  $c$  and we have  $f(x) - f(c) = \varphi(x)(x - c)$  for all  $x \in I$ . This implies that  $\lim_{x \rightarrow c} f(x) = f(c)$ , so  $f$  is continuous at  $c$  as desired.  $\square$

**Remark 1.4.** In general, the converse of Proposition 1.3 does not hold, for example, the function  $f(x) := |x|$  is a continuous function on  $\mathbb{R}$  but  $f'(0)$  does not exist.

# Mathematical Analysis II

**Wiesława J. Kaczor, Maria T. Nowak**

## **Mathematical Analysis II:**

*Mathematical Analysis II* Vladimir A. Zorich, 2004-01-22 This work by Zorich on Mathematical Analysis constitutes a thorough first course in real analysis leading from the most elementary facts about real numbers to such advanced topics as differential forms on manifolds asymptotic methods Fourier Laplace and Legendre transforms and elliptic functions

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V. A. Zorich, 2016-02-22 This second English edition of a very popular two volume work presents a thorough first course in analysis leading from real numbers to such advanced topics as differential forms on manifolds asymptotic methods Fourier Laplace and Legendre transforms elliptic functions and distributions Especially notable in this course are the clearly expressed orientation toward the natural sciences and the informal exploration of the essence and the roots of the basic concepts and theorems of calculus Clarity of exposition is matched by a wealth of instructive exercises problems and fresh applications to areas seldom touched on in textbooks on real analysis The main difference between the second and first English editions is the addition of a series of appendices to each volume There are six of them in the first volume and five in the second The subjects of these appendices are diverse They are meant to be useful to both students in mathematics and physics and teachers who may be motivated by different goals Some of the appendices are surveys both prospective and retrospective The final survey establishes important conceptual connections between analysis and other parts of mathematics This second volume presents classical analysis in its current form as part of a unified mathematics It shows how analysis interacts with other modern fields of mathematics such as algebra differential geometry differential equations complex analysis and functional analysis This book provides a firm foundation for advanced work in any of these directions

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[Analysis II](#) Terence Tao,2016-08-22 This is part two of a two volume book on real analysis and is intended for senior undergraduate students of mathematics who have already been exposed to calculus The emphasis is on rigour and foundations of analysis Beginning with the construction of the number systems and set theory the book discusses the basics of analysis limits series continuity differentiation Riemann integration through to power series several variable calculus and Fourier analysis and then finally the Lebesgue integral These are almost entirely set in the concrete setting of the real line and Euclidean spaces although there is some material on abstract metric and topological spaces The book also has appendices on mathematical logic and the decimal system The entire text omitting some less central topics can be taught in two quarters of 25 30 lectures each The course material is deeply intertwined with the exercises as it is intended that the student actively learn the material and practice thinking and writing rigorously by proving several of the key results in the theory

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**Basic Analysis II** James K. Peterson,2020-07-19 Basic Analysis II A Modern Calculus in Many Variables focuses on differentiation in  $R^n$  and important concepts about mappings from  $R^n$  to  $R^m$  such as the inverse and implicit function theorem and change of variable formulae for multidimensional integration These topics converge nicely with many other important applied and theoretical areas which are no longer covered in mathematical science curricula Although it follows on from the preceding volume this is a self contained book accessible to undergraduates with a minimal grounding in analysis Features Can be used as a traditional textbook as well as for self study Suitable for undergraduates in mathematics and

associated disciplines Emphasises learning how to understand the consequences of assumptions using a variety of tools to provide the proofs of propositions *Advanced Courses Of Mathematical Analysis Ii - Proceedings Of The Second International School* M Victoria Velasco,Angel Rodriguez-palacios,2007-03-22 This volume comprises a collection of articles by leading researchers in mathematical analysis It provides the reader with an extensive overview of new directions and advances in topics for current and future research in the field *Advanced Courses of Mathematical Analysis II A*.

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of convex analysis and approximation theory The author discusses the sources of these two trends in mathematical analysis develops the main concepts and results and mentions some beautiful theorems The relationship of convex analysis to optimization problems to the calculus of variations to optimal control and to geometry is considered and the evolution of the ideas underlying approximation theory from its origins to the present day is discussed The book is addressed both to students who want to acquaint themselves with these trends and to lecturers in mathematical analysis optimization and numerical methods as well as to researchers in these fields who would like to tackle the topic as a whole and seek inspiration for its further development Problems and Theorems in Analysis II George Polya, Gabor Szegö, 1976-01-01 Few mathematical books are worth translating 50 years after original publication Poly Szeg is one It was published in German in 1924 and its English edition was widely acclaimed when it appeared in 1972 In the past more of the leading mathematicians proposed and solved problems than today Their collection of the best in analysis is a heritage of lasting value Mathematical Analysis and Applications II Hari M. Srivastava, 2020-03-19 This issue is a continuation of the previous successful Special Issue Mathematical Analysis and Applications Investigations involving the theory and applications of mathematical analytical tools and techniques are remarkably widespread in many diverse areas of the mathematical physical chemical engineering and statistical sciences In this Special Issue we invite and welcome review expository and original research articles dealing with the recent advances in mathematical analysis and its multidisciplinary applications

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