

## Munkres - Topology - Chapter 3 Solutions

### Section 24

#### Problem 24.3.

**Solution:** Define  $g : X \rightarrow \mathbb{R}$  where  $g(x) = f(x) - i_{\mathbb{R}}(x) = f(x) - x$  where  $i_{\mathbb{R}}$  is the identity function. Since  $f$  and  $i_{\mathbb{R}}$  are continuous,  $g$  is continuous by Theorems 18.2(e) and 21.5. Since  $X$  is connected for all three possibilities given in this problem and  $\mathbb{R}$  is ordered, the intermediate-value theorem applies.

For  $X = [0, 1]$ , observe that  $g(0) \geq 0 - 0 = 0$  and  $g(1) \leq 1 - 1 = 0$ . Clearly if either  $g(0)$  or  $g(1)$  equals 0, then there is an  $x_0 \in X$  where  $f(x_0) - x_0 = 0$ , so  $f(x_0) = x_0$ . Otherwise,  $g(0) > 0$  and  $g(1) < 0$ , so by the intermediate-value theorem there is some  $x_1 \in X$  where  $g(x_1) = 0$ , so  $f(x_1) = x_1$ .

The proposition is not necessarily true if  $X = [0, 1)$  or  $X = (0, 1]$ . Let  $f(x) = (1+x)/2$ , which is obviously continuous. It follows that  $f(x) = x$  if and only if  $x = 1$ , which not in  $X$ .

#### Problem 24.4.

**Solution:** If  $X$  has only one element, it is trivially a linear continuum, so we will assume  $X$  has at least two elements. Let  $x, y \in Y$  where  $x < y$ . Since  $X$  is connected,  $(-\infty, y)$  and  $(x, \infty)$  cannot be a separation of the space. Since the two open sets are clearly non-empty, it must be that they are not disjoint. Therefore there is some  $z \in (-\infty, y) \cap (x, \infty)$ , from which it follows that  $z < y$  and  $x < z$ . We infer that  $x < z < y$ .

Next, let  $Y$  be a non-empty subset of  $X$  that is bounded above, and suppose  $Y$  has no supremum. Define  $M = \{m \in X : m \geq y \text{ for all } y \in Y\}$  (in other words, the set of upper bounds of  $Y$ ). Since  $Y$  is bounded above,  $M$  is non-empty. Then let  $A = \bigcup_{y \in Y} (-\infty, y)$  and  $B = \bigcup_{m \in M} (m, \infty)$ . It follows that  $A$  and  $B$  are a separation of  $X$ , contradicting that  $X$  is connected. Given  $x_0 \in X$ , if  $x_0 < y$  for some  $y \in Y$ , then  $x_0 \in (-\infty, y) \subset A$ . On the other hand, if  $x_0 \geq y$  for all  $Y$ , then there is some  $m \in M$  such that  $m < x_0$ , so  $x_0 \in (m, \infty) \subset B$ . Hence  $A$  and  $B$  partition  $X$ . Further, if  $x_1 \in A \cap B$ , then  $x_1 < y$  for some  $y \in Y$  and  $x_1 > y'$  for all  $y' \in Y$ , which is impossible. Therefore  $A$  and  $B$  are disjoint. Since  $A$  and  $B$  form an impossible separation of  $X$ , we conclude that  $Y$  must have a supremum. Accordingly,  $X$  is a linear continuum.

#### Problem 24.4.

**Solution:** Given  $x, y \in X \times [0, 1]$  where  $x < y$ , we have  $x = x_0 \times x_1$  and  $y = y_0 \times y_1$ . Since  $[0, 1]$  is a linear continuum, if  $x_0 < y_0$ , let  $z_1 \in (x_1, 1)$ ; if  $x_0 = y_0$ , let  $z_1 \in (x_1, y_1)$ . Hence if  $z = x_0 \times z_1$ , then  $x < z < y$ .

Now let  $U$  be a non-empty subset of  $X \times [0, 1]$  that is bounded above. Define  $M = \{m \in X \times [0, 1] : m \geq a \text{ for all } a \in U\}$ , which is the set of all upper bounds of  $U$ . Since  $U$  is bounded above, we're assured that  $M$  is non-empty. Designate  $V = \{\pi_1(m) : m \in M\}$ , which must be a non-empty subset of  $X$ . Since  $X$  is well-ordered, there is a least element  $x'$  of  $V$ . If  $x' \notin \pi_1(U)$ , then  $x' \times 0 > a$  for all  $a \in U$ . Further, if  $x'' < x'$ , then any element of  $x'' \times [0, 1]$  must be less than some element of  $U$  because no upper bound of  $U$  has a first coordinate less than  $x'$ . Hence  $x' \times 0$  is the supremum of  $U$ . On the other hand, if  $x' \in \pi_1(U)$ , the set  $V' = \{\pi_2(a) : a \in U\}$  is a non-empty subset of  $[0, 1]$  that is bounded above by 1, so it has a supremum  $y'$ . Accordingly, if  $c \in [0, y')$ , there is some  $d > c$  such that  $x' \times d \in U$ , which is greater than  $x' \times c$ . Therefore  $x' \times y'$  is the supremum of  $U$ , and  $X \times [0, 1]$  has the supremum property. We conclude that  $X \times [0, 1]$  is a linear continuum.

#### Problem 24.9.

**Solution:** Designate  $X = \mathbb{R}^2 \setminus A$ , and let  $x, y \in X$  be given. If there is no element of  $A$  on the straight-line path in  $\mathbb{R}^2$  from  $x$  to  $y$ , then there is obviously a path between the two points by exercise 24.8(a). In the non-trivial case where there is an element of  $A$  on the straight-line path between  $x$  and  $y$ , designate  $D_0 = \{\theta \in [0, 2\pi) : \tan^{-1}[(\pi_2(a) - \pi_2(x))/(\pi_1(a) - \pi_1(x))] \neq \theta \text{ for all } a \in A\}$ , which are all the angles around  $x$  for which there is no element of  $A$  on the straight line passing through  $x$  at that angle. We will show that  $D_0$  is not empty. Assume the contrary is true and  $D_0$  is empty. It would follow that for every element of the interval  $[0, 2\pi)$ , there is some element of  $A$  on the line at that angle. Consequently, there is an injection from  $[0, 2\pi) \rightarrow A$ . Because  $A$  is countable, there would be an injection from  $[0, 2\pi) \rightarrow \mathbb{N}$ , establishing that  $[0, 2\pi)$  is countable, a contradiction. Therefore  $D_0$  is not empty. Choose an arbitrary  $\theta_0$  from  $D_0$ .

# Munkres Topology Solutions Chapter 3

**Wolfgang Kollmann**



### **Munkres Topology Solutions Chapter 3:**

*Nonlinear Dynamics and Chaos with Student Solutions Manual* Steven H. Strogatz, 2018-09-21 This textbook is aimed at newcomers to nonlinear dynamics and chaos especially students taking a first course in the subject The presentation stresses analytical methods concrete examples and geometric intuition The theory is developed systematically starting with first order differential equations and their bifurcations followed by phase plane analysis limit cycles and their bifurcations and culminating with the Lorenz equations chaos iterated maps period doubling renormalization fractals and strange attractors

**Topologies and Uniformities** Ioan M. James, 2013-06-29 This book is based on lectures I have given to senior undergraduate and graduate audiences at Oxford and elsewhere over the years My aim has been to provide an outline of both the topological theory and the uniform theory with an emphasis on the relation between the two Although I hope that the prospective specialist may find it useful as an introduction it is the non specialist I have had more in mind in selecting the contents Thus I have tended to avoid the ingenious examples and counterexamples which often occupy much of the space in books on general topology and I have tried to keep the number of definitions down to the essential minimum There are no particular prerequisites but I have worked on the assumption that a potential reader will already have had some experience of working with sets and functions and will also be familiar with the basic concepts of algebra and analysis An earlier version of the present book appeared in 1987 under the title Topological and Uniform Spaces When the time came for a new edition I came to the conclusion that rather than just making the necessary corrections it would be better to make more substantial alterations Parts of the text have been rewritten and new material including new diagrams added [Climate Modeling for](#)

[Scientists and Engineers](#) John B. Drake, 2014-01-01 Climate modeling and simulation teach us about past present and future conditions of life on earth and help us understand observations about the changing atmosphere and ocean and terrestrial ecology Focusing on high end modeling and simulation of earth's climate Climate Modeling for Scientists and Engineers presents observations about the general circulations of the earth and the partial differential equations used to model the dynamics of weather and climate covers numerical methods for geophysical flows in more detail than many other texts discusses parallel algorithms and the role of high performance computing used in the simulation of weather and climate and provides supplemental lectures and MATLAB exercises on an associated Web page **Elements of Algebraic Topology**

James R. Munkres, Steven G. Krantz, Harold R. Parks, 2025-05-27 This classic text appears here in a new edition for the first time in four decades The new edition with the aid of two new authors brings it up to date for a new generation of mathematicians and mathematics students Elements of Algebraic Topology provides the most concrete approach to the subject With coverage of homology and cohomology theory universal coefficient theorems Künneth theorem duality in manifolds and applications to classical theorems of point set topology this book is perfect for communicating complex topics and the fun nature of algebraic topology for beginners This second edition retains the essential features of the original book

Most of the notation and terminology are the same There are some useful additions There is a new introduction to homotopy theory A new Index of Notation is included Many new exercises are added Algebraic topology is a cornerstone of modern mathematics Every working mathematician should have at least an acquaintance with the subject This book which is based largely on the theory of triangulations provides such an introduction It should be accessible to a broad cross section of the profession both students and senior mathematicians Students should have some familiarity with general topology [Books in Print](#), 1982

**Office Hours with a Geometric Group Theorist** Matt Clay, Dan Margalit, 2017-07-11 Geometric group theory is the study of the interplay between groups and the spaces they act on and has its roots in the works of Henri Poincaré Felix Klein J H C Whitehead and Max Dehn Office Hours with a Geometric Group Theorist brings together leading experts who provide one on one instruction on key topics in this exciting and relatively new field of mathematics It s like having office hours with your most trusted math professors An essential primer for undergraduates making the leap to graduate work the book begins with free groups actions of free groups on trees algorithmic questions about free groups the ping pong lemma and automorphisms of free groups It goes on to cover several large scale geometric invariants of groups including quasi isometry groups Dehn functions Gromov hyperbolicity and asymptotic dimension It also delves into important examples of groups such as Coxeter groups Thompson s groups right angled Artin groups lamplighter groups mapping class groups and braid groups The tone is conversational throughout and the instruction is driven by examples Accessible to students who have taken a first course in abstract algebra Office Hours with a Geometric Group Theorist also features numerous exercises and in depth projects designed to engage readers and provide jumping off points for research projects

*Foundations of Elementary Analysis* Roshan Trivedi, 2025-02-20 Foundations of Elementary Analysis offers a comprehensive exploration of fundamental mathematical concepts tailored for undergraduate students Designed as a bridge between introductory calculus and advanced mathematical analysis we provide a solid foundation in mathematical reasoning and analysis Through a systematic and accessible approach we cover essential topics such as sequences limits continuity differentiation integration and series Each chapter builds upon previous knowledge guiding students from basic definitions to deeper insights and applications What sets this book apart is its emphasis on clarity rigor and relevance Complex ideas are presented straightforwardly with intuitive explanations and ample examples to aid understanding Thought provoking exercises reinforce learning and encourage active engagement with the material preparing students for higher level mathematics Whether pursuing a degree in mathematics engineering physics or any other quantitative discipline Foundations of Elementary Analysis serves as an invaluable resource We equip students with the analytical tools and problem solving skills needed to excel in advanced coursework and beyond With its blend of theoretical rigor and practical relevance this book is not just a classroom companion it s a gateway to unlocking the beauty and power of mathematical analysis for students across diverse academic backgrounds

*Aspects of Combinatorics and Combinatorial Number Theory* Sukumar Das

Adhikari,2002      **Functional Analysis, Sobolev Spaces and Partial Differential Equations** Haim Brezis,2010-11-10

This textbook is a completely revised updated and expanded English edition of the important Analyse fonctionnelle 1983 In addition it contains a wealth of problems and exercises with solutions to guide the reader Uniquely this book presents in a coherent concise and unified way the main results from functional analysis together with the main results from the theory of partial differential equations PDEs Although there are many books on functional analysis and many on PDEs this is the first to cover both of these closely connected topics Since the French book was first published it has been translated into Spanish Italian Japanese Korean Romanian Greek and Chinese The English edition makes a welcome addition to this list      **One**

**Complex Variable from the Several Variable Point of View** Peter V. Dvobush,Steven G. Krantz,2025-06-30 Traditionally speaking those who study the function theory of one complex variable spend little or no time thinking about several complex variables Conversely experts in the function theory of several complex variables do not consider one complex variable One complex variable is the inspiration and testing ground for several complex variables and several complex variables are the natural generalization of one complex variable The authors thesis here is that these two subject areas have much in common These subject areas can gain a lot by learning to communicate with each other These two fields are logically connected and each can be used to explain and put the other into context This is the purpose of this book The point of view and the methodology of the two subject areas are quite different One complex variable is an aspect of traditional hard analysis Several complex variables are more like algebraic geometry and differential equations with some differential geometry thrown in The authors intend to create a marriage of the function theory of one complex variable and the function theory of several complex variables leading to a new and productive dialogue between the two disciplines The hope is for this book to foster and develop this miscegenation in a manner that leads to new collaborations and developments There is much fertile ground here and this book aims to breathe new life into it      Multivariate Data Analysis on Matrix Manifolds Nickolay

Trendafilov,Michele Gallo,2021-09-15 This graduate level textbook aims to give a unified presentation and solution of several commonly used techniques for multivariate data analysis MDA Unlike similar texts it treats the MDA problems as optimization problems on matrix manifolds defined by the MDA model parameters allowing them to be solved using free optimization software Manopt The book includes numerous in text examples as well as Manopt codes and software guides which can be applied directly or used as templates for solving similar and new problems The first two chapters provide an overview and essential background for studying MDA giving basic information and notations Next it considers several sets of matrices routinely used in MDA as parameter spaces along with their basic topological properties A brief introduction to matrix Riemannian manifolds and optimization methods on them with Manopt complete the MDA prerequisite The remaining chapters study individual MDA techniques in depth The number of exercises complement the main text with additional information and occasionally involve open and or challenging research questions Suitable fields include computational

statistics data analysis data mining and data science as well as theoretical computer science machine learning and optimization It is assumed that the readers have some familiarity with MDA and some experience with matrix analysis computing and optimization

**An Invitation to Real Analysis** Andrew D. Hwang, 2025-10-24 Adopting a student centered approach this book anticipates and addresses the common challenges that students face when learning abstract concepts like limits continuity and inequalities The text introduces these concepts gradually giving students a clear pathway to understanding the mathematical tools that underpin much of modern science and technology In addition to its focus on accessibility the book maintains a strong emphasis on mathematical rigor It provides precise careful definitions and explanations while avoiding common teaching pitfalls ensuring that students gain a deep understanding of core concepts Blending algebraic and geometric perspectives to help students see the full picture The theoretical results presented in the book are consistently applied to practical problems By providing a clear and supportive introduction to real analysis the book equips students with the tools they need to confidently engage with both theoretical mathematics and its wide array of practical applications Features Student Friendly Approach making abstract concepts relatable and engaging Balanced Focus combining algebraic and geometric perspectives Comprehensive Coverage Covers a full range of topics from real numbers and sequences to metric spaces and approximation theorems while carefully building upon foundational concepts in a logical progression Emphasis on Clarity Provides precise explanations of key mathematical definitions and theorems avoiding common pitfalls in traditional teaching Perfect for a One Semester Course Tailored for a first course in real analysis Problems exercises and solutions

*Abstract Algebra* William Paulsen, 2025-05-30 *Abstract Algebra An Interactive Approach* Third Edition is a new concept in learning modern algebra Although all the expected topics are covered thoroughly and in the most popular order the text offers much flexibility Perhaps more significantly the book gives professors and students the option of including technology in their courses Each chapter in the textbook has a corresponding interactive Mathematica notebook and an interactive SageMath workbook that can be used in either the classroom or outside the classroom Students will be able to visualize the important abstract concepts such as groups and rings by displaying multiplication tables homomorphisms by showing a line graph between two groups and permutations This in turn allows the students to learn these difficult concepts much more quickly and obtain a firmer grasp than with a traditional textbook Thus the colorful diagrams produced by Mathematica give added value to the students Teachers can run the Mathematica or SageMath notebooks in the classroom in order to have their students visualize the dynamics of groups and rings Students have the option of running the notebooks at home and experiment with different groups or rings Some of the exercises require technology but most are of the standard type with various difficulty levels The third edition is meant to be used in an undergraduate single semester course reducing the breadth of coverage size and cost of the previous editions Additional changes include Binary operators are now in an independent section The extended Euclidean algorithm is included Many

more homework problems are added to some sections Mathematical induction is moved to Section 1.2 Despite the emphasis on additional software the text is not short on rigor All of the classical proofs are included although some of the harder proofs can be shortened by using technology

*Uniform Trade List Annual*, 1977

*Number Theory and Geometry through History* J. S. Chahal, 2025-05-22 This is a unique book that teaches mathematics and its history simultaneously Developed from a course on the history of mathematics this book is aimed at mathematics teachers who need to learn more about mathematics than its history and in a way they can communicate it to middle and high school students The author hopes to overcome through the teachers using this book math phobia among these students

*Number Theory and Geometry through History* develops an appreciation of mathematics by not only looking at the work of individual including Euclid Euler Gauss and more but also how mathematics developed from ancient civilizations Brahmins Hindu priests devised our current decimal number system now adopted throughout the world The concept of limit which is what calculus is all about was not alien to ancient civilizations as Archimedes used a method similar to the Riemann sums to compute the surface area and volume of the sphere No theorem here is cited in a proof that has not been proved earlier in the book There are some exceptions when it comes to the frontier of current research Appreciating mathematics requires more than thoughtlessly reciting first the ten by ten then twenty by twenty multiplication tables Many find this approach fails to develop an appreciation for the subject The author was once one of those students Here he exposes how he found joy in studying mathematics and how he developed a lifelong interest in it he hopes to share The book is suitable for high school teachers as a textbook for undergraduate students and their instructors It is a fun text for advanced readership interested in mathematics

**Symplectic Twist Maps**

Christophe Golé, 2001

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**Math Anxiety—How to Beat It!** Brian Cafarella, 2025-06-23 How do we conquer uncertainty insecurity and anxiety over college mathematics You can do it and this book can help The author provides various techniques learning options and pathways Students can overcome the barriers that thwart success in mathematics when they prepare for a positive start in college and lay the foundation for success Based on interviews with over 50 students the book develops approaches to address the struggles and success these students shared Then the author took these ideas and experiences and built a process for overcoming and achieving when studying not only the mathematics many colleges and universities require as a minimum for graduation but more to encourage reluctant students to look forward to their mathematics courses and even learn to embrace additional ones Success breeds interest and interest breeds success Math anxiety is based on test anxiety The book provides proven strategies for conquering test anxiety It will help find ways to interest students in succeeding in mathematics and assist instructors on pathways to promote student interest while helping them to overcome the psychological barriers they face Finally the author shares how math is employed in the real world examining how both STEM and non STEM students can employ math in their lives and careers Ultimately both students and teachers of mathematics will better understand and appreciate the difficulties and how to attack these difficulties to achieve success in college mathematics Brian Cafarella Ph D is a mathematics professor at Sinclair Community College in Dayton Ohio He has taught a variety of courses ranging from developmental math through pre calculus Brian is a past recipient of the Roueche Award for teaching excellence He is also a past recipient of the Ohio Magazine Award for excellence in education Brian has published in several peer reviewed journals His articles have focused on implementing best practices in developmental math and various math pathways for community college students Additionally Brian was the recipient of the Article of the Year Award for his article Acceleration and Compression in Developmental Mathematics Faculty Viewpoints in the Journal of Developmental Education

**Scientific and Technical Books and Serials in Print**, 1984

**Navier-Stokes Turbulence** Wolfgang Kollmann, 2024-05-24 This updated augmented second edition retains its class tested content and pedagogy as a core text for graduate courses in advanced fluid mechanics and applied science The new edition adds revised sections clarification problems and chapter extensions including a rewritten section on Schauder bases for turbulent pipe flow coverage of Cantwell s mixing length closure for turbulent pipe flow and a section on the variational Hessian Consisting of two parts the first provides an introduction and general theory of



fully developed turbulence where treatment of turbulence is based on the linear functional equation derived by E Hopf governing the characteristic functional that determines the statistical properties of a turbulent flow In this section Professor Kollmann explains how the theory is built on divergence free Schauder bases for the phase space of the turbulent flow and the space of argument vector fields for the characteristic functional The second segment presented over subsequent chapters is devoted to mapping methods homogeneous turbulence based upon the hypotheses of Kolmogorov and Onsager intermittency structural features of turbulent shear flows and their recognition

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