



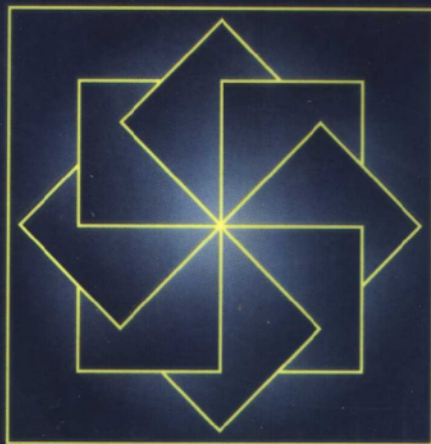
经 典 原 版 书 库

拓扑学

(英文版·第2版)

TOPOLOGY

SECOND EDITION



JAMES R. MUNKRES

(美) James R. Munkres 著
麻省理工学院



机械工业出版社
China Machine Press

拓扑学

(英文版·第2版)

Topology

(Second Edition)

本书作者在拓扑学领域享有盛誉。

本书分为两个独立的部分。第一部分普通拓扑学，讲述点集拓扑学的内容：前4章作为拓扑学的引论，介绍作为核心题材的集合论、拓扑空间、连通性、紧性以及可数性和分离性公理；后4章是补充题材。第二部分代数拓扑学，讲述与拓扑学核心题材相关的主题，其中包括基本群和覆盖空间及其应用。

本书最大的特点在于对理论的清晰阐述和严谨证明，力求让读者能够充分理解。对于疑难的推理证明，将其分解为简化的步骤，不给读者留下疑惑。此外，书中还提供了大量练习，可以巩固加深学习的效果。严格的论证、清晰的条理、丰富的实例，让深奥的拓扑学变得轻松易学。

This edition is authorized for sale in the People's Republic of China only, excluding Hong Kong, Macao SARs and Taiwan.

此英文影印版仅限在中华人民共和国境内（不包括香港、澳门特别行政区及台湾）销售。

PEARSON
Prentice
Hall

www.PearsonEd.com

ISBN 7-111-13688-8



9 787111 136880



华章图书



网上购书：www.china-pub.com

北京市西城区百万庄南街1号 100037

读者服务热线：(010)68995259, 68995264

读者服务信箱：hzedu@hzbook.com

<http://www.hzbook.com>

ISBN 7-111-13688-8/O · 358

定价：59.00 元

经典原版书库

0189
Y19

拓扑学

(英文版·第2版)

Topology

(Second Edition)

(美) James R. Munkres 著
麻省理工学院

北方工业大学图书馆

00731026



机械工业出版社
China Machine Press

English reprint edition copyright © 2004 by Pearson Education Asia Limited and China Machine Press.

Original English Language title: *Topology, Second Edition* (ISBN: 0-13-181629-2) by James R. Munkres, Copyright © 2000, 1975.

All rights reserved.

Published by arrangement with the original publisher, Pearson Education, Inc., publishing as Prentice Hall, Inc.

For sale and distribution in the People's Republic of China exclusively (except Taiwan, Hong Kong SAR and Macau SAR).

本书英文影印版由 Pearson Education Asia Ltd. 授权机械工业出版社独家出版。未经出版者书面许可, 不得以任何方式复制或抄袭本书内容。

仅限于中华人民共和国境内(不包括中国香港、澳门特别行政区和中国台湾地区) 销售发行。

本书封面贴有 Pearson Education 培生教育出版集团激光防伪标签, 无标签者不得销售。

版权所有, 侵权必究。

本书版权登记号: 图字: 01-2004-0181

图书在版编目 (CIP) 数据

拓扑学 (英文版 · 第2版) / (美) 默可雷斯 (Munkres, J. R.) 著. -北京: 机械工业出版社, 2004.2

(经典原版书库)

书名原文: *Topology, Second Edition*

ISBN 7-111-13688-8

I. 拓… II. 默… III. 拓扑 - 英文 IV. O189

中国版本图书馆CIP数据核字 (2003) 第121061号

机械工业出版社 (北京市西城区百万庄大街22号 邮政编码 100037)

责任编辑: 迟振春

北京瑞德印刷有限公司印刷 · 新华书店北京发行所发行

2004年2月第1版第1次印刷

787mm × 1092mm 1/16 · 34.5印张

印数: 0 001-3 000册

定价: 59.00元

凡购本书, 如有倒页、脱页、缺页, 由本社发行部调换
本社购书热线: (010) 68326294

Preface

This book is intended as a text for a one- or two-semester introduction to topology, at the senior or first-year graduate level.

The subject of topology is of interest in its own right, and it also serves to lay the foundations for future study in analysis, in geometry, and in algebraic topology. There is no universal agreement among mathematicians as to what a first course in topology should include; there are many topics that are appropriate to such a course, and not all are equally relevant to these differing purposes. In the choice of material to be treated, I have tried to strike a balance among the various points of view.

Prerequisites. There are no formal subject matter prerequisites for studying most of this book. I do not even assume the reader knows much set theory. Having said that, I must hasten to add that unless the reader has studied a bit of analysis or “rigorous calculus,” much of the motivation for the concepts introduced in the first part of the book will be missing. Things will go more smoothly if he or she already has had some experience with continuous functions, open and closed sets, metric spaces, and the like, although none of these is actually assumed. In Part II, we do assume familiarity with the elements of group theory.

Most students in a topology course have, in my experience, some knowledge of the foundations of mathematics. But the amount varies a great deal from one student to another. Therefore, I begin with a fairly thorough chapter on set theory and logic. It starts at an elementary level and works up to a level that might be described as “semi-sophisticated.” It treats those topics (and only those) that will be needed later in the book. Most students will already be familiar with the material of the first few sections, but many of them will find their *expertise* disappearing somewhere about the middle

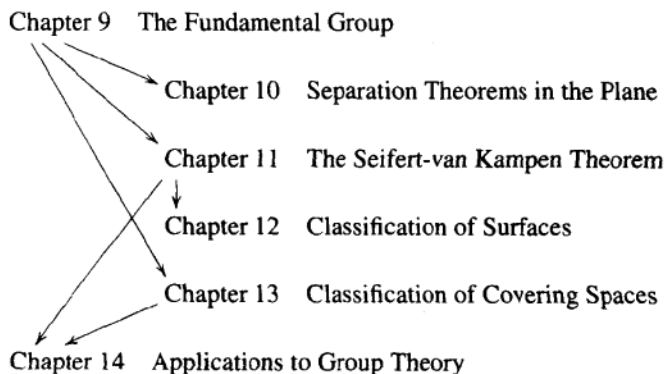
of the chapter. How much time and effort the instructor will need to spend on this chapter will thus depend largely on the mathematical sophistication and experience of the students. Ability to do the exercises fairly readily (and correctly!) should serve as a reasonable criterion for determining whether the student's mastery of set theory is sufficient for the student to begin the study of topology.

Many students (and instructors!) would prefer to skip the foundational material of Chapter 1 and jump right in to the study of topology. One ignores the foundations, however, only at the risk of later confusion and error. What one *can* do is to treat initially only those sections that are needed at once, postponing the remainder until they are needed. The first seven sections (through countability) are needed throughout the book; I usually assign some of them as reading and lecture on the rest. Sections 9 and 10, on the axiom of choice and well-ordering, are not needed until the discussion of compactness in Chapter 3. Section 11, on the maximum principle, can be postponed even longer; it is needed only for the Tychonoff theorem (Chapter 5) and the theorem on the fundamental group of a linear graph (Chapter 14).

How the book is organized. This book can be used for a number of different courses. I have attempted to organize it as flexibly as possible, so as to enable the instructor to follow his or her own preferences in the matter.

Part I, consisting of the first eight chapters, is devoted to the subject commonly called general topology. The first four chapters deal with the body of material that, in my opinion, should be included in any introductory topology course worthy of the name. This may be considered the "irreducible core" of the subject, treating as it does set theory, topological spaces, connectedness, compactness (through compactness of finite products), and the countability and separation axioms (through the Urysohn metrization theorem). The remaining four chapters of Part I explore additional topics; they are essentially independent of one another, depending on only the core material of Chapters 1–4. The instructor may take them up in any order he or she chooses.

Part II constitutes an introduction to the subject of Algebraic Topology. It depends on only the core material of Chapters 1–4. This part of the book treats with some thoroughness the notions of fundamental group and covering space, along with their many and varied applications. Some of the chapters of Part II are independent of one another; the dependence among them is expressed in the following diagram:



Certain sections of the book are marked with an asterisk; these sections may be omitted or postponed with no loss of continuity. Certain theorems are marked similarly. Any dependence of later material on these asterisked sections or theorems is indicated at the time, and again when the results are needed. Some of the exercises also depend on earlier asterisked material, but in such cases the dependence is obvious.

Sets of supplementary exercises appear at the ends of several of the chapters. They provide an opportunity for exploration of topics that diverge somewhat from the main thrust of the book; an ambitious student might use one as a basis for an independent paper or research project. Most are fairly self-contained, but the one on topological groups has as a sequel a number of additional exercises on the topic that appear in later sections of the book.

Possible course outlines. Most instructors who use this text for a course in general topology will wish to cover Chapters 1–4, along with the Tychonoff theorem in Chapter 5. Many will cover additional topics as well. Possibilities include the following: the Stone-Čech compactification (§38), metrization theorems (Chapter 6), the Peano curve (§44), Ascoli's theorem (§45 and/or §47), and dimension theory (§50). I have, in different semesters, followed each of these options.

For a one-semester course in algebraic topology, one can expect to cover most of Part II.

It is also possible to treat both aspects of topology in a single semester, although with some corresponding loss of depth. One feasible outline for such a course would consist of Chapters 1–3, followed by Chapter 9; the latter does not depend on the material of Chapter 4. (The non-asterisked sections of Chapters 10 and 13 also are independent of Chapter 4.)

Comments on this edition. The reader who is familiar with the first edition of this book will find no substantial changes in the part of the book dealing with general topology. I have confined myself largely to “fine-tuning” the text material and the exercises. However, the final chapter of the first edition, which dealt with algebraic topology, has been substantially expanded and rewritten. It has become Part II of this book. In the years since the first edition appeared, it has become increasingly common to offer topology as a two-term course, the first devoted to general topology and the second to algebraic topology. By expanding the treatment of the latter subject, I have intended to make this revision serve the needs of such a course.

Acknowledgments. Most of the topologists with whom I have studied, or whose books I have read, have contributed in one way or another to this book; I mention only Edwin Moise, Raymond Wilder, Gail Young, and Raoul Bott, but there are many others. For their helpful comments concerning this book, my thanks to Ken Brown, Russ McMillan, Robert Mosher, and John Hemperly, and to my colleagues George Whitehead and Kenneth Hoffman.

The treatment of algebraic topology has been substantially influenced by the excellent book by William Massey [M], to whom I express appreciation. Finally, thanks are

due Adam Lewenberg of MacroTeX for his extraordinary skill and patience in setting text and juggling figures.

But most of all, to my students go my most heartfelt thanks. From them I learned at least as much as they did from me; without them this book would be very different.

J.R.M.

A Note to the Reader

Two matters require comment—the exercises and the examples.

Working problems is a crucial part of learning mathematics. No one can learn topology merely by poring over the definitions, theorems, and examples that are worked out in the text. One must work part of it out for oneself. To provide that opportunity is the purpose of the exercises.

They vary in difficulty, with the easier ones usually given first. Some are routine verifications designed to test whether you have understood the definitions or examples of the preceding section. Others are less routine. You may, for instance, be asked to generalize a theorem of the text. Although the result obtained may be interesting in its own right, the main purpose of such an exercise is to encourage you to work carefully through the proof in question, mastering its ideas thoroughly—more thoroughly (I hope!) than mere memorization would demand.

Some exercises are phrased in an “open-ended” fashion. Students often find this practice frustrating. When faced with an exercise that asks, “Is every regular Lindelöf space normal?” they respond in exasperation, “I don’t know what I’m supposed to do! Am I suppose to prove it or find a counterexample or what?” But mathematics (outside textbooks) is usually like this. More often than not, all a mathematician has to work with is a conjecture or question, and he or she doesn’t know what the correct answer is. You should have some experience with this situation.

A few exercises that are more difficult than the rest are marked with asterisks. But none are so difficult but that the best student in my class can usually solve them.

Another important part of mastering any mathematical subject is acquiring a repertoire of useful examples. One should, of course, come to know those major examples from whose study the theory itself derives, and to which the important applications are made. But one should also have a few counterexamples at hand with which to test plausible conjectures.

Now it is all too easy in studying topology to spend too much time dealing with “weird counterexamples.” Constructing them requires ingenuity and is often great fun. But they are not really what topology is about. Fortunately, one does not need too many such counterexamples for a first course; there is a fairly short list that will suffice for most purposes. Let me give it here:

\mathbb{R}^J the product of the real line with itself, in the product, uniform, and box topologies.

\mathbb{R}_ℓ the real line in the topology having the intervals (a, b) as a basis.

S_Ω the minimal uncountable well-ordered set.

I_o^2 the closed unit square in the dictionary order topology.

These are the examples you should master and remember; they will be exploited again and again.



华章教育 永诚奉献

经典原版书库

(相关部分)

具体数学：计算机科学基础（第2版）	Graham/49.00
组合数学（第3版）	Brualdi/35.00
离散数学及其应用（第5版）	Rosen/79.00
离散数学及其应用（第4版）	Rosen/59.00
高等微积分	Fitzpatrick/69.00
金融数学	Stampfli/35.00
数值分析（第3版）	Kincaid/75.00
概率论及其在投资、保险、工程中的应用	Bean/55.00
代数	Isaacs/65.00
傅里叶分析与小波分析导论	Pinsky/49.00
数学建模（第3版）	Giordano/59.00（附光盘）
微分方程与边界值问题（第5版）	Zill/69.00
应用回归分析和其他多元方法	Kleinbaum/88.00
概率统计	Stone/89.00
多元数据分析	Lattin/69.00（附光盘）
数理统计和数据分析	Rice/78.00
随机过程导论	Kao/49.00
预测与时间序列（第3版）	Bowerman/89.00
线性代数	Jain/49.00（附光盘）
复变函数及应用（第7版）	Brown/42.00
实分析与复分析（第3版）	Rudin/39.00
数学分析原理（第3版）	Rudin/35.00
逼近论教程	Cheney/39.00

计算机科学丛书

(相关部分)

离散数学及其应用（原书第4版）	Rosen/袁崇义/75.00
组合数学（原书第3版）	Brualdi/冯舜玺/38.00

重点大学计算机教材

(相关部分)

数值方法	金一庆/25.00
------	-----------

Contents

Preface	vii
A Note to the Reader	xi

Part I GENERAL TOPOLOGY

Chapter 1 Set Theory and Logic	3
1 Fundamental Concepts	4
2 Functions	15
3 Relations	21
4 The Integers and the Real Numbers	30
5 Cartesian Products	36
6 Finite Sets	39
7 Countable and Uncountable Sets	44
*8 The Principle of Recursive Definition	52
9 Infinite Sets and the Axiom of Choice	57
10 Well-Ordered Sets	62
*11 The Maximum Principle	68
*Supplementary Exercises: Well-Ordering	72

Chapter 2 Topological Spaces and Continuous Functions	75
12 Topological Spaces	75
13 Basis for a Topology	78
14 The Order Topology	84
15 The Product Topology on $X \times Y$	86
16 The Subspace Topology	88
17 Closed Sets and Limit Points	92
18 Continuous Functions	102
19 The Product Topology	112
20 The Metric Topology	119
21 The Metric Topology (continued)	129
*22 The Quotient Topology	136
*Supplementary Exercises: Topological Groups	145
Chapter 3 Connectedness and Compactness	147
23 Connected Spaces	148
24 Connected Subspaces of the Real Line	153
*25 Components and Local Connectedness	159
26 Compact Spaces	163
27 Compact Subspaces of the Real Line	172
28 Limit Point Compactness	178
29 Local Compactness	182
*Supplementary Exercises: Nets	187
Chapter 4 Countability and Separation Axioms	189
30 The Countability Axioms	190
31 The Separation Axioms	195
32 Normal Spaces	200
33 The Urysohn Lemma	207
34 The Urysohn Metrization Theorem	214
*35 The Tietze Extension Theorem	219
*36 Imbeddings of Manifolds	224
*Supplementary Exercises: Review of the Basics	228
Chapter 5 The Tychonoff Theorem	230
37 The Tychonoff Theorem	230
38 The Stone-Čech Compactification	237
Chapter 6 Metrization Theorems and Paracompactness	243
39 Local Finiteness	244
40 The Nagata-Smirnov Metrization Theorem	248
41 Paracompactness	252
42 The Smirnov Metrization Theorem	261

Chapter 7 Complete Metric Spaces and Function Spaces	263
43 Complete Metric Spaces	264
*44 A Space-Filling Curve	271
45 Compactness in Metric Spaces	275
46 Pointwise and Compact Convergence	281
47 Ascoli's Theorem	290
Chapter 8 Baire Spaces and Dimension Theory	294
48 Baire Spaces	295
*49 A Nowhere-Differentiable Function	300
50 Introduction to Dimension Theory	304
*Supplementary Exercises: Locally Euclidean Spaces	316

Part II ALGEBRAIC TOPOLOGY

Chapter 9 The Fundamental Group	321
51 Homotopy of Paths	322
52 The Fundamental Group	330
53 Covering Spaces	335
54 The Fundamental Group of the Circle	341
55 Retractions and Fixed Points	348
*56 The Fundamental Theorem of Algebra	353
*57 The Borsuk-Ulam Theorem	356
58 Deformation Retracts and Homotopy Type	359
59 The Fundamental Group of S^n	368
60 Fundamental Groups of Some Surfaces	370
Chapter 10 Separation Theorems in the Plane	376
61 The Jordan Separation Theorem	376
*62 Invariance of Domain	381
63 The Jordan Curve Theorem	385
64 Imbedding Graphs in the Plane	394
65 The Winding Number of a Simple Closed Curve	398
66 The Cauchy Integral Formula	403
Chapter 11 The Seifert-van Kampen Theorem	407
67 Direct Sums of Abelian Groups	407
68 Free Products of Groups	412
69 Free Groups	421
70 The Seifert-van Kampen Theorem	426
71 The Fundamental Group of a Wedge of Circles	434
72 Adjoining a Two-cell	438
73 The Fundamental Groups of the Torus and the Dunce Cap	442

Chapter 12 Classification of Surfaces	446
74 Fundamental Groups of Surfaces	446
75 Homology of Surfaces	454
76 Cutting and Pasting	457
77 The Classification Theorem	462
78 Constructing Compact Surfaces	471
Chapter 13 Classification of Covering Spaces	477
79 Equivalence of Covering Spaces	478
80 The Universal Covering Space	484
*81 Covering Transformations	487
82 Existence of Covering Spaces	494
*Supplementary Exercises: Topological Properties and π_1	499
Chapter 14 Applications to Group Theory	501
83 Covering Spaces of a Graph	501
84 The Fundamental Group of a Graph	506
85 Subgroups of Free Groups	513
Bibliography	517
Index	519

Part I

GENERAL TOPOLOGY

