

ALGEBRAIC AND GEOMETRIC TOPOLOGY

HOMEWORK 4 SOLUTIONS

Feedback Exercises:

4.1. Write down the definition of a homotopy (with fixed endpoints) of paths in a space X , and of concatenation of paths. Write out proofs of two of the following (your choice):

- homotopy is a reflexive relation;
- homotopy is a symmetric relation;
- homotopy is a transitive relation;
- concatenation respects homotopy classes.

Solution:

A homotopy between two paths f_0 and f_1 in X with $f_i(0) = x_0$ and $f_i(1) = x_1$ is a continuous map

$$F : I \times I \rightarrow X$$

satisfying $F(s, 0) = f_0(s)$, $F(s, 1) = f_1(s)$, $F(0, t) = x_0$, and $F(1, t) = x_1$ for all $s, t \in [0, 1]$.

Given paths f and g in X with $f(1) = g(0)$, their concatenation $f \cdot g$ is given by

$$f \cdot g(s) = \begin{cases} f(2s) & \text{if } s \in [0, 1/2] \\ g(2s - 1) & \text{if } s \in [1/2, 1]. \end{cases}$$

Reflexive: a homotopy from f to itself is given by $F(s, t) = f(s)$.

Symmetric: if F is a homotopy from f to g then $G(s, t) = F(s, 1 - t)$ is a homotopy from g to F .

Transitive: if F is a homotopy from f to g and G is a homotopy from g to h , then a homotopy H from f to h is given by

$$H(s, t) = \begin{cases} F(s, 2t) & \text{if } t \in [0, 1/2] \\ G(s, 2t - 1) & \text{if } t \in [1/2, 1]. \end{cases}$$

This is continuous by the gluing lemma, since $F(s, 1) = f_1(s) = G(s, 0)$.

Concatenation respects homotopy classes: if F is a homotopy from f_0 to f_1 , both paths from x_0 to x_1 , and G is a homotopy from g_0 to g_1 , both paths from x_1 to x_2 , then a homotopy H from $f_0 \cdot g_0$ to $f_1 \cdot g_1$ is given by

$$H(s, t) = \begin{cases} F(2s, t) & \text{if } s \in [0, 1/2] \\ G(2s - 1, t) & \text{if } s \in [1/2, 1]. \end{cases}$$

This is continuous by the gluing lemma, since $F(1, t) = x_1 = G(0, t)$.

Algebraic Topology Homework 4 Solutions Boun

VM Jensen



Algebraic Topology Homework 4 Solutions Boun:

Science Citation Index, 1992 Vols for 1964 have guides and journal lists [Lectures on Algebraic Topology](#) Sergei Vladimirovich Matveev, 2006 Algebraic topology is the study of the global properties of spaces by means of algebra It is an important branch of modern mathematics with a wide degree of applicability to other fields including geometric topology differential geometry functional analysis differential equations algebraic geometry number theory and theoretical physics This book provides an introduction to the basic concepts and methods of algebraic topology for the beginner It presents elements of both homology theory and homotopy theory and includes various applications The author's intention is to rely on the geometric approach by appealing to the reader's own intuition to help understanding The numerous illustrations in the text also serve this purpose Two features make the text different from the standard literature first special attention is given to providing explicit algorithms for calculating the homology groups and for manipulating the fundamental groups Second the book contains many exercises all of which are supplied with hints or solutions This makes the book suitable for both classroom use and for independent study **Algebraic Topology** Marvin J. Greenberg, 2018-03-05 Great first book on algebraic topology Introduces co homology through singular theory *Algebraic Topology* George A. Duckett, 2016-05-18 If you have a question about Algebraic Topology this is the book with the answers Algebraic Topology Questions and Answers takes some of the best questions and answers asked on the mathoverflow stackexchange com website You can use this book to look up commonly asked questions browse questions on a particular topic compare answers to common topics check out the original source and much more This book has been designed to be very easy to use with many internal references set up that makes browsing in many different ways possible Topics covered include Homotopy Theory Geometric Topology Algebraic Geometry Reference Request Differential Geometry Stable Homotopy Category Theory General Topology Cohomology K Theory Homology Homology Differential Topology Vector Bundles Group Theory Homological Algebra Characteristic Classes Simplicial Stuff and many more *Algebraic Topology: A Structural Introduction* Marco Grandis, 2021-12-24 Algebraic Topology is a system and strategy of partial translations aiming to reduce difficult topological problems to algebraic facts that can be more easily solved The main subject of this book is singular homology the simplest of these translations Studying this theory and its applications we also investigate its underlying structural layout the topics of Homological Algebra Homotopy Theory and Category Theory which occur in its foundation This book is an introduction to a complex domain with references to its advanced parts and ramifications It is written with a moderate amount of prerequisites basic general topology and little else and a moderate progression starting from a very elementary beginning A consistent part of the exposition is organised in the form of exercises with suitable hints and solutions It can be used as a textbook for a semester course or self study and a guidebook for further study **Elements Of Algebraic Topology** James R. Munkres, 2018-03-05 Elements of Algebraic Topology provides the most concrete approach to the subject With coverage of

homology and cohomology theory universal coefficient theorems Kunneth 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 *Algebraic Topology* Clark Bray, Adrian Butscher, Simon Rubinstein-Salzedo, 2021-06-18 Algebraic Topology is an introductory textbook based on a class for advanced high school students at the Stanford University Mathematics Camp SUMaC that the authors have taught for many years Each chapter or lecture corresponds to one day of class at SUMaC The book begins with the preliminaries needed for the formal definition of a surface Other topics covered in the book include the classification of surfaces group theory the fundamental group and homology This book assumes no background in abstract algebra or real analysis and the material from those subjects is presented as needed in the text This makes the book readable to undergraduates or high school students who do not have the background typically assumed in an algebraic topology book or class The book contains many examples and exercises allowing it to be used for both self study and for an introductory undergraduate topology course *Lectures On Algebraic Topology* Haynes R Miller, 2021-09-20 Algebraic Topology and basic homotopy theory form a fundamental building block for much of modern mathematics These lecture notes represent a culmination of many years of leading a two semester course in this subject at MIT The style is engaging and student friendly but precise Every lecture is accompanied by exercises It begins slowly in order to gather up students with a variety of backgrounds but gains pace as the course progresses and by the end the student has a command of all the basic techniques of classical homotopy theory *Algebraic Topology: An Intuitive Approach* Hajime Satō, 1999 Develops an introduction to algebraic topology mainly through simple examples built on cell complexes Topics covers include homeomorphisms topological spaces and cell complexes homotopy homology cohomology the universal coefficient theorem fiber bundles and vector bundles and spectral sequences Includes chapter summaries exercises and answers Includes an appendix of definitions in sets topology and groups Originally published in Japanese by Iwanami Shoten Publishers Tokyo 1996 Annotation copyrighted by Book News Inc Portland OR ***Algebraic Topology*** ,1973 *Algebraic Topology* C. R. F. Maunder, 1970 ***Algebraic Topology*** Wolfgang Franz, 1968 No detailed description available for Algebraic Topology ***Algebraic topology*** J. F. Adams, 1973 *Algebraic Topology and Related Topics* Mahender Singh, Yongjin Song, Jie Wu, 2019-02-02 This book highlights the latest advances in algebraic topology from homotopy theory braid groups configuration spaces and toric topology to transformation groups and the adjoining area of knot theory It consists of well written original research papers and survey articles by subject experts most of which were presented at the 7th East Asian Conference on Algebraic Topology held at the Indian Institute of Science Education and Research IISER Mohali Punjab India from December 1 to 6 2017 Algebraic topology is a broad area of mathematics that has seen enormous developments over the past decade and as such this book is a valuable resource for graduate students and researchers working in the field *Topology of 4-Manifolds* Michael H. Freedman, Frank Quinn, 2014-07-14 One of the great achievements of contemporary

mathematics is the new understanding of four dimensions Michael Freedman and Frank Quinn have been the principals in the geometric and topological development of this subject proving the Poincaré and Annulus conjectures respectively Recognition for this work includes the award of the Fields Medal of the International Congress of Mathematicians to Freedman in 1986 In *Topology of 4 Manifolds* these authors have collaborated to give a complete and accessible account of the current state of knowledge in this field The basic material has been considerably simplified from the original publications and should be accessible to most graduate students The advanced material goes well beyond the literature nearly one third of the book is new This work is indispensable for any topologist whose work includes four dimensions It is a valuable reference for geometers and physicists who need an awareness of the topological side of the field Originally published in 1990 The Princeton Legacy Library uses the latest print on demand technology to again make available previously out of print books from the distinguished backlist of Princeton University Press These editions preserve the original texts of these important books while presenting them in durable paperback and hardcover editions The goal of the Princeton Legacy Library is to vastly increase access to the rich scholarly heritage found in the thousands of books published by Princeton University Press since its founding in 1905

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

Lectures on Algebraic Topology Marvin J. Greenberg, 1971 *Algebraic Topology Colloquium on Algebraic Topology*, 1962 **Lectures on Algebraic Topology** Albrecht Dold, 1972-06-13 This is essentially a book on singular homology and cohomology with special emphasis on products and manifolds It does not treat homotopy theory except for some basic notions some examples and some applications of cohomology to homotopy Nor does it deal with generalised homology but many formulations and arguments on singular homology are so chosen that they also apply to general homology Because of these absences I have also omitted spectral sequences their main applications in topology being to homotopy and general cohomology theory Čech cohomology is

treated in a simple ad hoc fashion for locally compact subsets of manifolds a short systematic treatment for arbitrary spaces emphasizing the universal property of the Čech procedure is contained in an appendix The book grew out of a one year course on algebraic topology and it can serve as a text for such a course For a shorter basic course say of half a year one might use chapters II III IV 1 4 V 1 5 7 8 VI 3 7 9 11 12 As prerequisites the student should know the elementary parts of general topology abelian group theory and the language of categories although our chapter I provides a little help with the latter two For pedagogical reasons I have treated integral homology only up to chapter VI if a reader or teacher prefers to have general coefficients from the beginning he needs to make only minor adaptations

Algebraic Topology William

Fulton, 1997-09-05 To the Teacher This book is designed to introduce a student to some of the important ideas of algebraic topology by emphasizing the relations of these ideas with other areas of mathematics Rather than choosing one point of view of modern topology homotopy theory simplicial complexes singular theory axiomatic homology differential topology etc we concentrate our attention on concrete problems in low dimensions introducing only as much algebraic machinery as necessary for the problems we meet This makes it possible to see a wider variety of important features of the subject than is usual in a beginning text The book is designed for students of mathematics or science who are not aiming to become practicing algebraic topologists without we hope discouraging budding topologists We also feel that this approach is in better harmony with the historical development of the subject What would we like a student to know after a first course in topology assuming we reject the answer half of what one would like the student to know after a second course in topology Our answers to this have guided the choice of material which includes understanding the relation between homology and integration first on plane domains later on Riemann surfaces and in higher dimensions winding numbers and degrees of mappings fixed point theorems applications such as the Jordan curve theorem invariance of domain in spaces of vector fields and Euler characteristics fundamental groups

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