

Prove Transitivity Through Mathematical Induction

Example Proof by Induction

Prove that $1 + 3 + 6 + 10 + \dots + \frac{n(n+1)}{2} = \frac{n(n+1)(n+2)}{6}$.

Step 1: $P_1 = \frac{1(1+1)(1+2)}{6} = 1$ **TRUE**

Step 2: If P_i is true, then

$$P_i = 1 \bullet 2 + 2 \bullet 3 + 3 \bullet 4 + 4 \bullet 5 + \dots + k(k+1) = \frac{k(k+1)(k+2)}{3}$$

$$P_{i+1} = \frac{k(k+1)(k+2)}{3} + (k+1)(k+2)$$

Factoring out the common factor of $(k+1)(k+2)$

$$= (k+1)(k+2) \left(\frac{1}{3}k + 1 \right)$$

$$= (k+1)(k+2) \left(\frac{k+3}{3} \right) = \frac{(k+1)(k+1+1)(k+1+2)}{3}$$

Prove Transitivity Through Mathematical Induction: A Step-by-Step Guide

Transitivity, a fundamental property in mathematics, states that if A is related to B, and B is related to C, then A is related to C. But how do we rigorously prove this seemingly intuitive concept? This post will guide you through a comprehensive explanation of how to prove transitivity using the powerful tool of mathematical induction. We'll demystify the process, providing a clear step-by-step approach with examples, ensuring you understand not just the what, but the crucial why behind each step. Prepare to conquer transitivity proofs!

Understanding Transitivity and Mathematical Induction

Before diving into the proof, let's solidify our understanding of the key concepts.

Transitivity: In a set with a relation R (often denoted by $\leq$, $<$, $=$, or a custom symbol), transitivity means: If aRb and bRc , then aRc . This holds true for various relations, from simple numerical comparisons to more complex relationships in abstract algebra or set theory.

Mathematical Induction: This powerful proof technique is used to establish the truth of a statement for all natural numbers (or a subset thereof). It relies on two key steps:

Base Case: Proving the statement holds true for the first natural number (usually $n=1$).

Inductive Step: Assuming the statement is true for an arbitrary natural number k (the inductive hypothesis), then proving it's also true for $k+1$.

Combining these steps, we show the statement's validity for all natural numbers.

Proving Transitivity by Mathematical Induction: A Detailed Approach

Proving transitivity using mathematical induction is not directly about proving transitivity for all numbers in general. Instead, you typically use induction to prove that a specific relation defined on a set possesses the transitive property. Let's outline the process:

1. **Define the Relation:** Clearly define the relation R on your set. This might involve a specific formula, an algorithm, or a descriptive statement that determines whether aRb is true or false for any elements a and b in your set.

2. **Formulate the Inductive Hypothesis:** This step is crucial. We won't directly use the " aRb and bRc implies aRc " form in our induction. Instead, we'll frame our statement based on the structure of the relation. Let's consider an example:

Example: Let's prove that the "less than or equal to" relation ($\leq$) on the set of natural numbers ($\mathbb{N}$) is transitive. Our inductive statement will be: "If $a \leq b$ and $b \leq c$, then $a \leq c$, for all $a, b, c \in \mathbb{N}$ ".

We can't directly apply induction to this statement in this form. Instead we will focus on a related property which implies transitivity. It will focus on the structure of the relationship, often involving building the relationship through finite steps.

3. **Base Case:** Prove the statement is true for a small, finite number of elements. For example, you might prove transitivity for a sequence of length 2 or 3. If your relationship can be broken down into smaller building block steps you can show this.

4. **Inductive Step:** Assuming the statement is true for a sequence of k elements (the inductive hypothesis), you need to prove it remains true for $k+1$ elements. This is where careful construction is crucial. You'll often need to cleverly leverage the inductive hypothesis to demonstrate the desired transitivity property for the extended sequence.

Illustrative Example: Proving Transitivity of "Divisibility"

Let's illustrate the process with an example. We'll prove the transitivity of the divisibility relation " $\mid$ " on the set of positive integers. The relation " $a \mid b$ " means "a divides b" (b is a multiple of a).

1. Definition: $a \mid b$ if there exists an integer k such that $b = ka$.
2. Statement to Prove (modified for induction): If $a \mid b$ and $b \mid c$, then $a \mid c$. We will use a slightly modified approach, focusing on the number of steps needed to create the relationship.
3. Base Case ($n=2$): If $a \mid b$ and $b \mid c$, then $a \mid c$. This is a fundamental property of divisibility and forms our base case.
4. Inductive Step: Assume the statement holds for $n=k$, meaning if $a \mid b_1$ and $b_1 \mid b_2$ and ... and $b_{k-1} \mid b_k$, then $a \mid b_k$. Now, let's consider a sequence of $k+1$ elements: $a \mid b_1$ and $b_1 \mid b_2$ and ... and $b_{k-1} \mid b_k$ and $b_k \mid b_{k+1}$. Since $a \mid b_1$ and $b_1 \mid b_2$... and $b_{k-1} \mid b_k$, from the inductive hypothesis, we know $a \mid b_k$. Since we also have $b_k \mid b_{k+1}$, by the fundamental property of divisibility (the base case extended), we have $a \mid b_{k+1}$. This completes the inductive step.

Therefore, by mathematical induction, the divisibility relation is transitive.

Conclusion

Proving transitivity using mathematical induction requires a strategic approach. It's not a direct application of the induction principle to the transitivity definition but rather relies on creating an appropriate inductive statement that reflects the structure of the relation and proving it through careful stepwise construction. By understanding the core concepts and following the outlined steps, you can effectively demonstrate the transitive property of various mathematical relations.

FAQs

1. Can I always prove transitivity using mathematical induction? No, not all transitive relations lend themselves readily to proof by mathematical induction. The structure of the relation is crucial. Some might require different proof techniques.
2. What if my base case is more complex than $n=1$ or $n=2$? The base case should cover the smallest nontrivial instance of the statement. The complexity of the base case depends entirely on the relation being investigated.

3. Why do we use a modified statement for induction in the divisibility example? The original statement "If $a|b$ and $b|c$ then $a|c$ " is already intrinsically true for all integers and doesn't lend itself well to an inductive argument about how the relationship is built up sequentially. The inductive approach focuses on showing that the relationship holds for longer chains based on the assumption it holds for shorter chains.

4. Can I use strong induction for this type of proof? Yes, strong induction (where you assume the statement holds for all values up to k , not just k) can be a more powerful tool in some transitivity proofs, particularly when the relation's structure involves dependence on multiple previous elements.

5. Are there alternative methods to prove transitivity besides mathematical induction? Yes, direct proof or proof by contradiction are other approaches that may be more suitable depending on the specific relation involved. The choice of the best method depends entirely on the structure and properties of the relationship at hand.

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prove transitivity through mathematical induction: The Oxford Handbook of Value Theory Iwao Hirose, Jonas Olson, 2015-05-01 Value theory, or axiology, looks at what things are good or bad, how good or bad they are, and, most fundamentally, what it is for a thing to be good or bad. Questions about value and about what is valuable are important to moral philosophers, since most moral theories hold that we ought to promote the good (even if this is not the only thing we ought to do). This Handbook focuses on value theory as it pertains to ethics, broadly construed, and provides a comprehensive overview of contemporary debates pertaining not only to philosophy but also to other disciplines-most notably, political theory and economics. The Handbook's twenty-two newly commissioned chapters are divided into three parts. Part I: Foundations concerns fundamental and interrelated issues about the nature of value and distinctions between kinds of value. Part II: Structure concerns formal properties of value that bear on the possibilities of

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David Kreps, 2018-05-04 In this book, Professor Kreps presents a first course on the basic models of choice theory that underlie much of economic theory. This course, taught for several years at the Graduate School of Business, Stanford University, gives the student an introduction to the axiomatic method of economic analysis, without placing too heavy a demand on mathematical sophistication. The course begins with the basics of choice and revealed preference theory and then discusses numerical representations of ordinal preference. Models with uncertainty come next: First is von Neumann-Morgenstern utility, and then choice under uncertainty with subjective uncertainty, using the formulation of Anscombe and Aumann, and then sketching the development of Savage's classic theory. Finally, the course delves into a number of special topics, including de Finetti's theorem, modeling choice on a part of a larger problem, dynamic choice, and the empirical evidence against the classic models.

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Computability James Hein, 2010-10-25 Thoroughly updated, the new Third Edition of Discrete Structures, Logic, and Computability introduces beginning computer science and computer engineering students to the fundamental techniques and ideas used by computer scientists today, focusing on topics from the fields of mathematics, logic, and computer science itself. Dr. Hein provides elementary introductions to those ideas and techniques that are necessary to understand and practice the art and science of computing. The text contains all the topics for discrete structures in the reports of the IEEE/ACM Joint Task Force on Computing Curricula for computer science programs and for computer engineering programs.

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and Computer Science David Liben-Nowell, 2022-08-04 Computer science majors taking a non-programming-based course like discrete mathematics might ask 'Why do I need to learn this?' Written with these students in mind, this text introduces the mathematical foundations of computer science by providing a comprehensive treatment of standard technical topics while simultaneously illustrating some of the broad-ranging applications of that material throughout the field. Chapters on core topics from discrete structures – like logic, proofs, number theory, counting, probability, graphs – are augmented with around 60 'computer science connections' pages introducing their applications: for example, game trees (logic), triangulation of scenes in computer graphics (induction), the Enigma machine (counting), algorithmic bias (relations), differential privacy (probability), and paired kidney transplants (graphs). Pedagogical features include 'Why You Might Care' sections, quick-reference chapter guides and key terms and results summaries, problem-solving and writing tips, 'Taking it Further' asides with more technical details, and around 1700 exercises, 435 worked examples, and 480 figures.

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Kathryn Porter, 2017-04-24 CSET Mathematics Test Prep with Online Practice Fifth Edition - Completely Aligned with Today's Exam REA's CSET Mathematics test prep is designed to help teacher candidates pass the CSET and get certified to teach secondary school mathematics in California. This Book + Online prep pack is perfect for teacher education students and career-changing professionals who are seeking certification as California math teachers. In fact, it's a great resource for reviewing mathematics for anyone interested in teaching! Written by a California-based math educator with years of experience teaching and advising future elementary and secondary school math teachers, this new edition is fully aligned with the latest test framework and California's Common Core State Standards. Our in-depth review covers all the content domains and topics tested on the CSET Mathematics exam's three subtests---Subtest I: Number and Quantity & Algebra, Subtest II: Geometry and Probability & Statistics, Subtest III Calculus. Examples and exercises reinforce the concepts taught in each chapter. An online diagnostic test based on actual CSET Math exam questions pinpoints strengths and weaknesses and helps you identify areas in need of further study. Two full-length practice tests (one in the book, another online) are balanced to include every type of question on the exam. Our timed online tests feature automatic scoring and diagnostic feedback to help you zero in on the topics and types of questions that give you trouble now, so you can succeed on test day. This test prep is a must-have for anyone who wants to become a California math teacher!

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Construction Tarmo Uustalu, 2006-06-27 This volume contains the proceedings of the 8th International Conference on Mathematics of Program Construction, MPC 2006, held at Kuressaare, Estonia, July 3-5, 2006, colocated with the 11th International Conference on Algebraic Methodology and Software Technology, AMAST 2006, July 5-8, 2006.

The MPC conference aims to promote the development of mathematical principles and techniques that are demonstrably useful and usable in the process of constructing computer programs. Topics of interest range from algorithmics to support for program construction in programming languages and systems. The previous MPCs were held at Twente, The Netherlands (1989, LNCS 375), Oxford, UK (1992, LNCS 669), Kloster Irsee, Germany (1995, LNCS 947), Marstrand, Sweden (1998, LNCS 1422), Ponte de Lima, Portugal (2000, LNCS 1837), Dagstuhl, Germany (2002, LNCS 2386) and Stirling, UK (2004, LNCS 3125, colocated with AMAST 2004). MPC 2006 received 45 submissions. Each submission was reviewed by four Programme Committee members or additional referees. The committee decided to accept 22 papers. In addition, the programme included three invited talks by Robin Cockett (University of Calgary, Canada), Olivier Danvy (Aarhus University, Denmark) and Oege de Moor (University of Oxford, UK). The review process and compilation of the proceedings were greatly helped by Andrei Voronkov's EasyChair system that I can only recommend to every programme chair. MPC 2006 had one satellite workshop, the Workshop on Mathematically Structured Functional Programming, MSFP 2006, organized as a small workshop of the FP6 IST

coordination action TYPES. This took place July 2, 2006.

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Philosophy, Volume 1 Scott Soames, 2014-03-23 This is the first of five volumes of a definitive history of analytic philosophy from the invention of modern logic in 1879 to the end of the twentieth century. Scott Soames, a leading philosopher of language and historian of analytic philosophy, provides the fullest and most detailed account of the analytic tradition yet published, one that is unmatched in its chronological range, topics covered, and depth of treatment. Focusing on the major milestones and distinguishing them from the dead ends, Soames gives a seminal account of where the analytic tradition has been and where it appears to be heading. Volume 1 examines the initial phase of the analytic tradition through the major contributions of three of its four founding giants—Gottlob Frege, Bertrand Russell, and G. E. Moore. Soames describes and analyzes their work in logic, the philosophy of mathematics, epistemology, metaphysics, ethics, and the philosophy of language. He explains how by about 1920 their efforts had made logic, language, and mathematics central to philosophy in an unprecedented way. But although logic, language, and mathematics were now seen as powerful tools to attain traditional ends, they did not yet define philosophy. As volume 1 comes to a close, that was all about to change with the advent of the fourth founding giant, Ludwig Wittgenstein, and the 1922 English publication of his *Tractatus*, which ushered in a linguistic turn in philosophy that was to last for decades.

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