

Combinatorics 2 - More on Enumerative Combinatorics

Henry Liu, 29 November 2010

This set of notes acts as a sort of addendum to the previous set titled 'Combinatorics'. In the previous notes, many techniques on counting are covered. However, one method that is absent is the idea of *recurrence relations*. The idea is simple. If we have some parameter n , and a_n is the number of certain objects in relation to n , then we may be able to derive a recurrence relation for a_n . This will enable us to calculate a_n for small values of n .

Let us look at an example.

Example. *How many anagrams of the word 'orange' are there such that no letter is in its original position?*

Solution. This problem can be interpreted as follows. We would like to find the number of permutations of $\{1, 2, 3, 4, 5, 6\}$ with no fixed points. Recall that if S is a set and $f : S \rightarrow S$ is a permutation of S , then $i \in S$ is a *fixed point* of f if $f(i) = i$.

We consider the more general problem with n in place of 6. Let a_n be the number of permutations of $\{1, 2, \dots, n\}$ with no fixed points. We shall derive a recurrence relation for a_n . The number of permutations fixing at least one element is $n! - a_n$. Also, for $1 \leq k \leq n-1$, the number of permutations fixing exactly k elements is $\binom{n}{k} a_{n-k}$, since there are $\binom{n}{k}$ choices for the positions of the k fixed elements, and there are a_{n-k} ways to position the other $n-k$ elements so that there is no fixed point among them. There is also one permutation fixing every element (the identity permutation). It follows that $n! - a_n = 1 + \sum_{k=1}^{n-1} \binom{n}{k} a_{n-k}$, and hence the required recurrence relation is

$$a_n = n! - 1 - \sum_{k=1}^{n-1} \binom{n}{k} a_{n-k}.$$

In particular, we have

$$a_1 = 0,$$

$$a_2 = 2! - 1 - \binom{2}{1} a_1 = 2 - 1 - 0 = 1,$$

$$a_3 = 3! - 1 - \binom{3}{1} a_2 - \binom{3}{2} a_1 = 6 - 1 - 3 \cdot 1 - 0 = 2,$$

$$a_4 = 4! - 1 - \binom{4}{1} a_3 - \binom{4}{2} a_2 - \binom{4}{3} a_1 = 24 - 1 - 4 \cdot 2 - 6 \cdot 1 - 0 = 9,$$

$$\begin{aligned} a_5 &= 5! - 1 - \binom{5}{1} a_4 - \binom{5}{2} a_3 - \binom{5}{3} a_2 - \binom{5}{4} a_1 \\ &= 120 - 1 - 5 \cdot 9 - 10 \cdot 2 - 10 \cdot 1 - 0 = 44, \end{aligned}$$

Enumerative Combinatorics

Peter J. Cameron



Enumerative Combinatorics:

Enumerative Combinatorics: Volume 1 Richard P. Stanley, 2002 This book is the first of a two volume basic introduction to enumerative combinatorics at a level suitable for graduate students and research mathematicians It concentrates on the theory and application of generating functions a fundamental tool in enumerative combinatorics The book covers those parts of enumerative combinatorics of greatest applicability to other areas of mathematics The four chapters are devoted to an introduction to enumeration suitable for advanced undergraduates sieve methods including the Principle of Inclusion Exclusion partially ordered sets and rational generating functions There are a large number of exercises almost all with solutions which greatly augment the text and provide entry into many areas not covered directly Graduate students and research mathematicians who wish to apply combinatorics to their work will find this an authoritative reference

Enumerative Combinatorics: Volume 1 Richard P. Stanley, 2012 Richard Stanley's two volume basic introduction to enumerative combinatorics has become the standard guide to the topic for students and experts alike This thoroughly revised second edition of Volume 1 includes ten new sections and more than 300 new exercises most with solutions reflecting numerous new developments since the publication of the first edition in 1986 The author brings the coverage up to date and includes a wide variety of additional applications and examples as well as updated and expanded chapter bibliographies Many of the less difficult new exercises have no solutions so that they can more easily be assigned to students The material on P partitions has been rearranged and generalized the treatment of permutation statistics has been greatly enlarged and there are also new sections on q analogues of permutations hyperplane arrangements the cd index promotion and evacuation and differential posets

Handbook of Enumerative Combinatorics Miklos Bona, 2015-03-24 Presenting the state of the art the Handbook of Enumerative Combinatorics brings together the work of today's most prominent researchers The contributors survey the methods of combinatorial enumeration along with the most frequent applications of these methods This important new work is edited by Miklos Bona of the University of Florida where he

Enumerative Combinatorics Richard Stanley, 2023-08-17 Revised second volume of the standard guide to enumerative combinatorics including the theory of symmetric functions and 159 new exercises

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tools of the subject generating functions and recurrence relations which are then used to study the most important combinatorial objects namely subsets partitions and permutations of a set Later chapters deal with more specialised topics including permanents SDRs group actions and the Redfield Plya theory of cycle indices Mbius inversion the Tutte polynomial and species

Enumerative Combinatorics: 10. Two q-Analogues of Permutations Richard P. Stanley, 2012

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Enumerative Combinatorics Ch. A. Charalambides, 2002 *Lessons in Enumerative Combinatorics* Ömer Eğecioğlu, Adriano M. Garsia, 2021-05-13 This textbook introduces enumerative combinatorics through the framework of formal languages and bijections By starting with elementary operations on words and languages the authors paint an insightful unified picture for readers entering the field Numerous concrete examples and illustrative metaphors motivate the theory throughout while the overall approach illuminates the important connections between discrete mathematics and theoretical computer science Beginning with the basics of formal languages the first chapter quickly establishes a common setting for modeling and counting classical combinatorial objects and constructing bijective proofs From here topics are modular and offer substantial flexibility when designing a course Chapters on generating functions and partitions build further fundamental tools for enumeration and include applications such as a combinatorial proof of the Lagrange inversion formula Connections to linear algebra emerge in chapters studying Cayley trees determinantal formulas and the combinatorics that lie behind the classical Cayley Hamilton theorem The remaining chapters range across the Inclusion Exclusion Principle graph theory and coloring exponential structures matching and distinct representatives with each topic opening many doors to further study Generous exercise sets complement all chapters and miscellaneous sections explore additional applications *Lessons in Enumerative Combinatorics* captures the authors distinctive style and flair for introducing newcomers to combinatorics The conversational yet rigorous presentation suits students in mathematics and computer science at the graduate or advanced undergraduate level Knowledge of single variable calculus and the basics of discrete mathematics is assumed familiarity with linear algebra will enhance the study of certain chapters

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Counting: The Art of Enumerative Combinatorics George E. Martin,2001-06-21 This book provides an introduction to discrete mathematics At the end of the book the reader should be able to answer counting questions such as How many ways are there to stack n poker chips each of which can be red white blue or green such that each red chip is adjacent to at least 1 green chip The book can be used as a textbook for a semester course at the sophomore level The first five chapters can also serve as a basis for a graduate course for in service teachers

Inquiry-Based Enumerative Combinatorics T. Kyle Petersen,2019-06-28 This textbook offers the opportunity to create a uniquely engaging combinatorics classroom by embracing Inquiry Based Learning IBL techniques Readers are provided with a carefully chosen progression of theorems to prove and problems to actively solve Students will feel a sense of accomplishment as their collective inquiry traces a path from the basics to important generating function techniques Beginning with an exploration of permutations and combinations that culminates in the Binomial Theorem the text goes on to guide the study of ordinary and exponential generating functions These tools underpin the in depth study of Eulerian Catalan and Narayana numbers that follows and a selection of advanced topics that includes applications to probability and number theory Throughout the theory unfolds via over 150 carefully selected problems for students to solve many of which connect to state of the art research Inquiry Based Enumerative Combinatorics is ideal for lower division undergraduate students majoring in math or computer science as there are no formal mathematics prerequisites Because it includes many connections to recent research students of any level who are interested in combinatorics will also find this a valuable resource

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