# Solutions

## Twentieth International Olympiad, 1978

**1978/1.** Since $1978^n$ and $1978^m$ agree in their last three digits, the difference

$$1978^n - 1978^m = 1978^m(1978^{n-m} - 1)$$

is divisible by $10^3 = 2^3 \cdot 5^3$; and since the second factor above is odd, $2^3$ divides the first. Also

$$1978^m = 2^m \cdot 989^m,$$

so $m \geq 3$.

We can write $m + n = (n - m) + 2m$; to minimize this sum, we take $m = 3$ and seek the smallest value of $d = n - m$, such that $1978^d - 1$ is divisible by $5^3 = 125$, i.e.

$$1978^d \equiv 1 \pmod{125}.$$

We shall twice make use of the following

**LEMMA.** *Let $d$ be the smallest exponent such that $a^d \equiv 1 \pmod{N}$. Then any other exponent $g$ for which $a^g \equiv 1 \pmod{N}$ is a multiple of $d$.*

**PROOF:** If $d$ does not divide $g$, then $g = qd + r$ with $0 < r < d$, and $a^g = a^{qd}a^r \equiv 1 \pmod{N}$ implies $a^r \equiv 1 \pmod{N}$ with $0 < r < d$, contradicting the minimality of $d$. So $d \mid g$.

Fermat's theorem states:[†] For any prime $p$ and any integer $a$ not divisible by $p$,

(1) $$a^{p-1} \equiv 1 \pmod{p}.$$

For example,

$$1978^4 \equiv 1 \pmod{5}.$$

[†]For a proof, see e.g. p. 126 of S. L. Greitzer, *The International Mathematical Olympiads*, vol. 27 in this NML series.

# [Math Olympiad Problems And Solutions](#)

**Steve Dinh**

**Math Olympiad Problems And Solutions:**

Problems And Solutions In Mathematical Olympiad (Secondary 2) Xiong-hui Zhao,2024-07-02 The series is edited by the head coaches of China s IMO National Team Each volume catering to different grades is contributed by the senior coaches of the IMO National Team The Chinese edition has won the award of Top 50 Most Influential Educational Brands in China The series is created in line with the mathematics cognition and intellectual development levels of the students in the corresponding grades All hot mathematics topics of the competition are included in the volumes and are organized into chapters where concepts and methods are gradually introduced to equip the students with necessary knowledge until they can finally reach the competition level In each chapter well designed problems including those collected from real competitions are provided so that the students can apply the skills and strategies they have learned to solve these problems Detailed solutions are provided selectively As a feature of the series we also include some solutions generously offered by the members of Chinese national team and national training team **The Hard Mathematical Olympiad Problems and Their Solutions** Steve Dinh,2011 This book shows the approaches to solving many difficult Mathematical Olympiad and other international problems posted at the www mathlinks ro the largest mathematical webpage that has most of the problems used to select the talented students of the world At the time of this book s publication the solutions to many of these problems are not yet available This book is not only as much about methods of solving mathematical problems as it is about various approaches to solving the difficult problems in general It is a first step in examining the creativity that goes into problem solving The real points of the book are the enumeration of problem solving strategies and the tricks applied to solve the problems The approaches in the book build understanding and not just methods in solving problems This book is a must read for many math students and is useful for many teachers around the world Mathematical Olympiad Challenges Titu Andreescu,Razvan Gelca,2013-12-01 Mathematical Olympiad Challenges is a rich collection of problems put together by two experienced and well known professors and coaches of the U S International Mathematical Olympiad Team Hundreds of beautiful challenging and instructive problems from algebra geometry trigonometry combinatorics and number theory were selected from numerous mathematical competitions and journals An important feature of the work is the comprehensive background material provided with each grouping of problems The problems are clustered by topic into self contained sections with solutions provided separately All sections start with an essay discussing basic facts and one or two representative examples A list of carefully chosen problems follows and the reader is invited to take them on Additionally historical insights and asides are presented to stimulate further inquiry The emphasis throughout is on encouraging readers to move away from routine exercises and memorized algorithms toward creative solutions to open ended problems Aimed at motivated high school and beginning college students and instructors this work can be used as a text for advanced problem solving courses for self study or as a resource for teachers and students training for mathematical competitions and for

teacher professional development seminars and workshops **Mathematical Olympiads 1999-2000** Titu Andreescu,Zuming Feng,2002-05-16 Challenging problems in maths plus solutions to those featured in the earlier Olympiad book Mathematical Olympiads 1998-1999 Titu Andreescu,Zuming Feng,2000-11-02 A large range of problems drawn from mathematics olympiads from around the world **Problems and Solutions in Mathematical Olympiad** Hong-Bing Yu,2022 The series is edited by the head coaches of China s IMO National Team Each volume catering to different grades is contributed by the senior coaches of the IMO National Team The Chinese edition has won the award of Top 50 Most Influential Educational Brands in China The series is created in line with the mathematics cognition and intellectual development levels of the students in the corresponding grades All hot mathematics topics of the competition are included in the volumes and are organized into chapters where concepts and methods are gradually introduced to equip the students with necessary knowledge until they can finally reach the competition level In each chapter well designed problems including those collected from real competitions are provided so that the students can apply the skills and strategies they have learned to solve these problems Detailed solutions are provided selectively As a feature of the series we also include some solutions generously offered by the members of Chinese national team and national training team *Index to Mathematical Problems, 1980-1984* Stanley Rabinowitz,1992 A compendium of over 5 000 problems with subject keyword author and citation indexes Mathematical Olympiad In China (2019-2020): Problems And Solutions Bin Xiong,2022-09-29 In China lots of excellent maths students take an active part in various maths contests and the best six senior high school students will be selected to form the IMO National Team to compete in the International Mathematical Olympiad In the past ten years China s IMO Team has achieved outstanding results they won the first place almost every year The authors of this book are coaches of the China national team They are Xiong Bin Yao Yijun Qu Zhenhua et al Those who took part in the translation work are Zhao Wei and Zhou Tianyou The materials of this book come from a series of two books in Chinese on Forward to IMO A Collection of Mathematical Olympiad Problems 2019 2020 It is a collection of problems and solutions of the major mathematical competitions in China It provides a glimpse of how the China national team is selected and formed Mathematical Olympiads 2000-2001 Titu Andreescu,Zuming Feng,George Lee,2003-10-16 Problems and solutions from Mathematical Olympiad Ideal for anyone interested in mathematical problem solving Mathematical Olympiad In China (2007-2008): Problems And Solutions Bin Xiong,Peng Yee Lee,2009-05-21 The International Mathematical Olympiad IMO is a competition for high school students China has taken part in the IMO 21 times since 1985 and has won the top ranking for countries 14 times with a multitude of golds for individual students The six students China has sent every year were selected from 20 to 30 students among approximately 130 students who took part in the annual China Mathematical Competition during the winter months This volume comprises a collection of original problems with solutions that China used to train their Olympiad team in the years from 2006 to 2008 Mathematical Olympiad problems with solutions for the years 2002 2006 appear in an

earlier volume Mathematical Olympiad in China     Mathematical Olympiad In China (2011-2014): Problems And Solutions Bin Xiong,Peng Yee Lee,2018-03-22 The International Mathematical Olympiad IMO is a very important competition for high school students China has taken part in the IMO 31 times since 1985 and has won the top ranking for countries 19 times with a multitude of gold medals for individual students The six students China has sent every year were selected from 60 students among approximately 300 students who took part in the annual China Mathematical Competition during the winter months This book includes the problems and solutions of the most important mathematical competitions from 2010 to 2014 in China such as China Mathematical Competition China Mathematical Olympiad China Girls Mathematical Olympiad These problems are almost exclusively created by the experts who are engaged in mathematical competition teaching and researching Some of the solutions are from national training team and national team members their wonderful solutions being the feature of this book This book is useful to mathematics fans middle school students engaged in mathematical competition coaches in mathematics teaching and teachers setting up math elective courses     A Second Step To Mathematical Olympiad Problems Derek Allan Holton,2011-06-30 See also A FIRST STEP TO MATHEMATICAL OLYMPIAD PROBLEMS The International Mathematical Olympiad IMO is an annual international mathematics competition held for pre collegiate students It is also the oldest of the international science olympiads and competition for places is particularly fierce This book is an amalgamation of the booklets originally produced to guide students intending to contend for placement on their country s IMO team See also A First Step to Mathematical Olympiad Problems which was published in 2009 The material contained in this book provides an introduction to the main mathematical topics covered in the IMO which are Combinatorics Geometry and Number Theory In addition there is a special emphasis on how to approach unseen questions in Mathematics and model the writing of proofs Full answers are given to all questions Though A Second Step to Mathematical Olympiad Problems is written from the perspective of a mathematician it is written in a way that makes it easily comprehensible to adolescents This book is also a must read for coaches and instructors of mathematical competitions     **A First Step To Mathematical Olympiad Problems** Derek Allan Holton,2009-07-30 See also A SECOND STEP TO MATHEMATICAL OLYMPIAD PROBLEMS The International Mathematical Olympiad IMO is an annual international mathematics competition held for pre collegiate students It is also the oldest of the international science olympiads and competition for places is particularly fierce This book is an amalgamation of the first 8 of 15 booklets originally produced to guide students intending to contend for placement on their country s IMO team The material contained in this book provides an introduction to the main mathematical topics covered in the IMO which are Combinatorics Geometry and Number Theory In addition there is a special emphasis on how to approach unseen questions in Mathematics and model the writing of proofs Full answers are given to all questions Though A First Step to Mathematical Olympiad Problems is written from the perspective of a mathematician it is written in a way that makes it easily comprehensible to adolescents This book is also a must read for coaches and instructors of mathematical

competitions **The William Lowell Putnam Mathematical Competition 1985–2000: Problems, Solutions, and Commentary** Kiran S. Kedlaya,Bjorn Poonen,Ravi Vakil,2020-01-16 This third volume of problems from the William Lowell Putnam Competition is unlike the previous two in that it places the problems in the context of important mathematical themes The authors highlight connections to other problems to the curriculum and to more advanced topics The best problems contain kernels of sophisticated ideas related to important current research and yet the problems are accessible to undergraduates The solutions have been compiled from the American Mathematical Monthly Mathematics Magazine and past competitors Multiple solutions enhance the understanding of the audience explaining techniques that have relevance to more than the problem at hand In addition the book contains suggestions for further reading a hint to each problem separate from the full solution and background information about the competition The book will appeal to students teachers professors and indeed anyone interested in problem solving as a gateway to a deep understanding of mathematics **Problems And Solutions In Mathematical Olympiad (Secondary 1)** Zun Shan,2024-05-28 The series is edited by the head coaches of China s IMO National Team Each volume catering to different grades is contributed by the senior coaches of the IMO National Team The Chinese edition has won the award of Top 50 Most Influential Educational Brands in China The series is created in line with the mathematics cognition and intellectual development levels of the students in the corresponding grades All hot mathematics topics of the competition are included in the volumes and are organized into chapters where concepts and methods are gradually introduced to equip the students with necessary knowledge until they can finally reach the competition level In each chapter well designed problems including those collected from real competitions are provided so that the students can apply the skills and strategies they have learned to solve these problems Detailed solutions are provided selectively As a feature of the series we also include some solutions generously offered by the members of Chinese national team and national training team Puzzle and Proof Samuel Dittmer,Hiram Golze,Grant Molnar,Caleb Stanford,2024-08-13 Puzzle and Proof A Decade of Problems from the Utah Math Olympiad is a compilation of the problems and solutions for the first 10 years of the Utah Math Olympiad The problems are challenging but should be understandable at a high school level Besides putting all problems in one place 70 in total which have not previously appeared in print the book provides additional inspiration for many of the problems and will contain the first published solutions for 10 problems that were originally published on the contest flyer The book will be a fantastic resource for anyone who enjoys mathematical and or logic puzzles or is interested in studying for mathematics competitions Features 70 carefully designed high quality high school level math proof problems with full solutions Detailed pictures and diagrams throughout to aid understanding Suitable for anyone with high school level mathematics skills with an interest in furthering their understanding or just enjoying the puzzles Solutions in the back of the book sorting the problems by difficulty and topic **Mathematical Olympiad In China (2009-2010): Problems And Solutions** Bin Xiong,Peng Yee Lee,2013-02-20 The International Mathematical Olympiad IMO

is a competition for high school students China has taken part in the IMO 21 times since 1985 and has won the top ranking for countries 14 times with a multitude of golds for individual students The six students China has sent every year were selected from 20 to 30 students among approximately 130 students who took part in the annual China Mathematical Competition during the winter months This volume of comprises a collection of original problems with solutions that China used to train their Olympiad team in the years from 2009 to 2010 Mathematical Olympiad problems with solutions for the years 2002 2008 appear in an earlier volume Mathematical Olympiad in China    **Mathematical Circle Diaries, Year 1** Anna Burago,2013 Early middle school is a great time for children to start their mathematical circle education This time is a period of curiosity and openness to learning The thinking habits and study skills acquired by children at this age stay with them for a lifetime Mathematical circles with their question driven approach and emphasis on creative problem solving have been rapidly gaining popularity in the United States The circles expose children to the type of mathematics that stimulates development of logical thinking creativity analytical abilities and mathematical reasoning These skills while scarcely touched upon at school are in high demand in the modern world This book contains everything that is needed to run a successful mathematical circle for a full year The materials distributed among 29 weekly lessons include detailed lectures and discussions sets of problems with solutions and contests and games In addition the book shares some of the know how of running a mathematical circle The curriculum which is based on the rich and long standing Russian math circle tradition has been modified and adapted for teaching in the United States For the past decade the author has been actively involved in teaching a number of mathematical circles in the Seattle area This book is based on her experience and on the compilation of materials from these circles The material is intended for students in grades 5 to 7 It can be used by teachers and parents with various levels of expertise who are interested in teaching mathematics with the emphasis on critical thinking Also this book will be of interest to mathematically motivated children In the interest of fostering a greater awareness and appreciation of mathematics and its connections to other disciplines and everyday life MSRI and the AMS are publishing books in the Mathematical Circles Library series as a service to young people their parents and teachers and the mathematics profession    **The Colorado Mathematical Olympiad and Further Explorations** Alexander Soifer,2011-04-11 Over the past two decades the once small local Colorado Springs Mathematics Olympiad founded by the author himself has now become an annual state wide competition hosting over one thousand high school contenders each year This updated printing of the first edition of Colorado Mathematical Olympiad the First Twenty Years and Further Explorations offers an interesting history of the competition as well as an outline of all the problems and solutions that have been a part of the contest over the years Many of the essay problems were inspired by Russian mathematical folklore and written to suit the young audience for example the 1989 Sugar problem was written as a pleasant Lewis Carroll like story Some other entertaining problems involve old Victorian map colorings King Arthur and the knights of the round table rooks

in space Santa Claus and his elves painting planes football for 23 and even the Colorado Springs subway system The book is more than just problems their solutions and event statistics it tells a compelling story involving the lives of those who have been part of the Olympiad from every perspective    *Methods of Solving Number Theory Problems* Ellina Grigorieva,2018-07-06 Through its engaging and unusual problems this book demonstrates methods of reasoning necessary for learning number theory Every technique is followed by problems as well as detailed hints and solutions that apply theorems immediately so readers can solve a variety of abstract problems in a systematic creative manner New solutions often require the ingenious use of earlier mathematical concepts not the memorization of formulas and facts Questions also often permit experimental numeric validation or visual interpretation to encourage the combined use of deductive and intuitive thinking The first chapter starts with simple topics like even and odd numbers divisibility and prime numbers and helps the reader to solve quite complex Olympiad type problems right away It also covers properties of the perfect amicable and figurate numbers and introduces congruence The next chapter begins with the Euclidean algorithm explores therepresentations of integer numbers in different bases and examines continued fractions quadratic irrationalities and the Lagrange Theorem The last section of Chapter Two is an exploration of different methods of proofs The third chapter is dedicated to solving Diophantine linear and nonlinear equations and includes different methods of solving Fermat s Pell s equations It also covers Fermat s factorization techniques and methods of solving challenging problems involving exponent and factorials Chapter Four reviews the Pythagorean triple and quadruple and emphasizes their connection with geometry trigonometry algebraic geometry and stereographic projection A special case of Waring s problem as a representation of a number by the sum of the squares or cubes of other numbers is covered as well as quadratic residuals Legendre and Jacobi symbols and interesting word problems related to the properties of numbers Appendices provide a historic overview of number theory and its main developments from the ancient cultures in Greece Babylon and Egypt to the modern day Drawing from cases collected by an accomplished female mathematician Methods in Solving Number Theory Problems is designed as a self study guide or supplementary textbook for a one semester course in introductory number theory It can also be used to prepare for mathematical Olympiads Elementary algebra arithmetic and some calculus knowledge are the only prerequisites Number theory gives precise proofs and theorems of an irreproachable rigor and sharpens analytical thinking which makes this book perfect for anyone looking to build their mathematical confidence

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