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 $m \geqslant 3$.

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 $d|g$.

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.

International Math Olympiad Problems And Solutions

Titu Andreescu,Razvan Gelca

International Math Olympiad Problems And Solutions:

   USA and International Mathematical Olympiads, 2005 Zuming Feng,Cecil Rousseau,Melanie Matchett Wood,2006 The Mathematical Olypiad books covering the USA Mathematical Olypiad USAMO and the International Mathematical Olypiad IMO have been published annually by the MAA American Mathematics Competitions since 1976 This is the sixth volume in that series published by the MAA in its Problem Book series The IMO is the work mathematics championship for high school students It takes place annually in a different country each year The aims of the IMO are 1 to discover encourage and challenge mathematically gifted young people in all countries 2 to foster friendships between mathematicians around the world 3 to create an opportunity for the exchange of information on school syllabi and practice throughout the world The USAMO and the Team Selection Test TST are the last two stages of the selection process for the United states of America IMO team The preceding examinations are the AMC 10 or AMC12 and the American Invitational Mathematics Examination AIME Participation in the AIME USAMO and the TST is by invitation only based on performance in the preceding exams of the sequence Through the AMC contests and the IMO young gifted mathematicians are identified and recognized while they are still in secondary school Participation in the competitions provides them with the chance to measure themselves against other exceptional students from all over the world This work was prepared by Zuming Feng Melanie Matchett Wood the Leader and Deputy Leader of the 2004 USA IMO team and by Cecil Rousseau the chair of the USAMO Committee In addition to presenting their own carefully written solutions to the problems Zuming and Melanie provide remarkable solutions developed by the examination committees contestants and experts during or after the contests They also provide a detailed report of the 2000 2004 USAMO IMO results and a comprehensive guide to other material that emphasize advances problem solving This collection of excellent problems and beautiful solutions is a valuable companion for students who wish to develop their interest in mathematics outside the school curriculum and to deepen their knowledge of mathematics

   Mathematical Olympiad Challenges Titu Andreescu,Razvan Gelca,2008-12-04 Hundreds of beautiful challenging and instructive problems from algebra geometry trigonometry combinatorics and number theory Historical insights and asides are presented to stimulate further inquiry Emphasis is on creative solutions to open ended problems Many examples problems and solutions with a user friendly and accessible style Enhanced motivatio References   *Index to Mathematical Problems, 1975-1979* Stanley Rabinowitz,Mark Bowron,1999   Index to Mathematical Problems, 1980-1984 Stanley Rabinowitz,1992 A compendium of over 5 000 problems with subject keyword author and citation indexes   **The IMO Compendium** Dušan Djukić,Vladimir Janković,Ivan Matić,Nikola Petrović,2006-06-07 This is the ultimate collection of challenging high school level mathematics problems It is the result of a two year long collaboration to rescue these problems from old and scattered manuscripts and produce the definitive source of IMO practice problems in book form for the first time This book attempts to gather all the problems and solutions appearing on the IMO and contains a grand total of 1900

problems It is an invaluable resource for high school students preparing for mathematics competitions and for anyone who loves math   Problems And Solutions In Mathematical Olympiad (High School 3) Hong-bing Yu,2022-03-16 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   You Failed Your Math Test, Comrade Einstein Mikhail A. Shifman,2005 This groundbreaking work features two essays written by the renowned mathematician Ilan Vardi The first essay presents a thorough analysis of contrived problems suggested to undesirable applicants to the Department of Mathematics of Moscow University His second essay gives an in depth discussion of solutions to the Year 2000 International Mathematical Olympiad with emphasis on the comparison of the olympiad problems to those given at the Moscow University entrance examinations The second part of the book provides a historical background of a unique phenomenon in mathematics which flourished in the 1970s 80s in the USSR Specially designed math problems were used not to test students ingenuity and creativity but rather as killer problems to deny access to higher education to undesirable applicants The focus of this part is the 1980 essay Intellectual Genocide written by B Kanevsky and V Senderov It is being published for the first time Also featured is a little known page of the Soviet history a rare example of the oppressed organizing to defend their dignity This is the story of the so called Jewish People s University the inception of which is associated with Kanevsky Senderov and Bella Subbotovskaya   **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   *Problems And Solutions In Mathematical Olympiad (High School 1)* Bin Xiong,Zhi-gang Feng,2022-04-07 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   *Number Theory* Titu Andreescu,Dorin Andrica,2009-06-12 This introductory textbook takes a problem solving approach to number theory situating each concept within the framework of an example or a problem for solving Starting with the essentials the text covers divisibility unique factorization modular arithmetic and the Chinese Remainder Theorem Diophantine equations binomial coefficients Fermat and Mersenne primes and other special numbers and special sequences Included are sections on mathematical induction and the pigeonhole principle as well as a discussion of other number systems By emphasizing examples and applications the authors motivate and engage readers   **The IMO Compendium** Dušan Djukić,Vladimir Janković,Ivan Matić,Nikola Petrović,2011-05-05 The IMO Compendium is the ultimate collection of challenging high school level mathematics problems and is an invaluable resource not only for high school students preparing for mathematics competitions but for anyone who loves and appreciates mathematics The International Mathematical Olympiad IMO nearing its 50th anniversary has become the most popular and prestigious competition for high school students interested in mathematics Only six students from each participating country are given the honor of

participating in this competition every year The IMO represents not only a great opportunity to tackle interesting and challenging mathematics problems it also offers a way for high school students to measure up with students from the rest of the world Until the first edition of this book appearing in 2006 it has been almost impossible to obtain a complete collection of the problems proposed at the IMO in book form The IMO Compendium is the result of a collaboration between four former IMO participants from Yugoslavia now Serbia and Montenegro to rescue these problems from old and scattered manuscripts and produce the ultimate source of IMO practice problems This book attempts to gather all the problems and solutions appearing on the IMO through 2009 This second edition contains 143 new problems picking up where the 1959 2004 edition has left off **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 **The IMO Compendium** Dušan Djukić,Vladimir Janković,Ivan Matić,Nikola Petrović,2010-11-25 This is the ultimate collection of challenging high school level mathematics problems It is the result of a two year long collaboration to rescue these problems from old and scattered manuscripts and produce the definitive source of IMO practice problems in book form for the first time This book attempts to gather all the problems and solutions appearing on the IMO and contains a grand total of 1900 problems It is an invaluable resource for high school students preparing for mathematics competitions and for anyone who loves math **Imo Problems, Theorems, And Methods: Number Theory** Bin Xiong,Gengyu Zhang,2025-08-08 The problems in the International Mathematical Olympiad IMO are not only novel and interesting but also deeply rooted in profound mathematical context The team at the International Mathematical Olympiad Research Center at East China Normal University has compiled and studied problems from past IMOs dividing them into four volumes based on the mathematical fields involved algebra geometry number theory and combinatorics In the number theory volume the IMO number theory problems are organized into three chapters Divisibility of Integers Modular Arithmetic and Indeterminate Equations Each chapter begins with an introduction to the relevant foundational knowledge and methods followed by a reclassification and reorganization of past IMO problems Multiple elegant solutions are provided for some of the problems along with a statistical

analysis of their difficulty The book concludes with a record of past IMO participation and award information as well as an index of number theory problems facilitating further study and convenient reference This series is suitable for researchers in mathematical competitions mathematics educators and contestants **Mathematical Olympiad In China (2017-2018): Problems And Solutions** Bin Xiong,2022-08-29 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 Wang Shanping and Chen Haoran The materials of this book come from a series of two books in Chinese on Forward to IMO A Collection of Mathematical Olympiad Problems 2017 2018 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 USA and International Mathematical Olympiads, 2001 Titu Andreescu,Zuming Feng,2002 The Mathematical Olympiad examinations covering the USA Mathematical Olympiad USAMO and the International Mathematical Olympiad IMO have been published annually by the MAA American Mathematics Competitions since 1976 The IMO is the world mathematics championship for high school students It takes place annually in a different country The IMO competitions help to discover encourage and challenge mathematically gifted young people all over the world The USAMO and the Team Selection Test TST are the last two stages of the selection process leading to representing the United States of America in the IMO The preceding examinations are the AMC 10 or AMC 12 and the American Invitational Mathematics Examination AIME Participation in the AIME USAMO and the TST is by invitation only based on performance in the preceding exams of the sequence Through the AMC contests and the IMO young gifted mathematicians are identified and recognized while they are still in secondary school Participation in these competitions provides them with the chance to measure themselves against other exceptional students from all over the world Editors Andreescu and Feng provide remarkable solutions developed by the examination committees contestants and experts during or after the contests They also provide a detailed report of the 1995 2000 USAMO IMO results and a comprehensive guide to other materials emphasizing advanced problem solving This collection of excellent problems and beautiful solutions is a valuable companion for students who wish to develop their interest in mathematics outside the school curriculum and to deepen their knowledge of mathematics Imo Problems, Theorems, and Methods: Algebra JINHUA. XIONG CHEN (BIN.),XIONG,2025-07-27 The problems in the International Mathematical Olympiad IMO are not only novel and interesting but also deeply rooted in profound mathematical context The team at the International Mathematical Olympiad Research Center at East China Normal University has compiled and studied problems from past IMOs dividing them into four volumes based on the mathematical fields involved algebra geometry number theory and combinatorics In the algebra volume the

IMO algebra problems are organized into five chapters Equation Problems Function Problems Sequence Problems Inequality Problems and Other Algebra Problems Each chapter begins with an introduction to the relevant foundational knowledge and methods followed by a reclassification and reorganization of past IMO problems Multiple elegant solutions are provided for some of the problems along with a statistical analysis of their difficulty The book concludes with a record of past IMO participation and award information as well as an index of algebra problems facilitating further study and easy reference for readers This series is suitable for researchers in mathematical competitions mathematical educators and contestants

Mathematical Olympiad Problems Jagat Narain Kapur,1993   International Mathematical Olympiad, 1959-1999 István Reiman,2001 A fantastic selection of mathematical puzzles for all age groups This book represents a compilation of questions set for the famed International Maths Olympiads A book of logic puzzles and questions that will tease the minds of all those with a mathematical mind Features all questions from the annual Olympiad from 1959 to date Includes solutions to every question with multiple answers where applicable Of interest to serious mathematicians and enthusiasts alike

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