



United Kingdom  
Mathematics Trust

## SENIOR MATHEMATICAL CHALLENGE

Organised by the United Kingdom Mathematics Trust

### SOLUTIONS AND INVESTIGATIONS

6 November 2018

These solutions augment the printed solutions that we send to schools. For convenience, the solutions sent to schools are confined to two sides of A4 paper and therefore in many cases are rather short. The solutions given here have been extended. In some cases we give alternative solutions, and we have included some problems for further investigation. We welcome comments on these solutions. Please send them to [enquiry@ukmt.org.uk](mailto:enquiry@ukmt.org.uk).

The Senior Mathematical Challenge (SMC) is a multiple-choice paper. For each question, you are presented with five options, of which just one is correct. It follows that often you can find the correct answers by working backwards from the given alternatives, or by showing that four of them are not correct. This can be a sensible thing to do in the context of the SMC.

However, this does not provide a full mathematical explanation that would be acceptable if you were just given the questions without any alternative answers. So we aim at including for each question a complete solution with each step explained (or, occasionally, left as an exercise), and not based on the assumption that one of the given alternatives is correct. We hope that these solutions provide a model for the type of written solution that is expected when presenting a complete solution to a mathematical problem (for example, in the British Mathematical Olympiad, the Mathematical Olympiad for Girls and similar competitions).

These solutions may be used freely within your school or college. You may, without further permission, post these solutions on a website that is accessible only to staff and students of the school or college, print out and distribute copies within the school or college, and use them in the classroom. If you wish to use them in any other way, please consult us. © UKMT November 2018

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# Mathematical Challenge

**Andrew Jobbings**



## Mathematical Challenge:

The Ultimate Mathematical Challenge: Over 365 puzzles to test your wits and excite your mind The UK Mathematics Trust, 2018-11-01 Be warned cracking puzzles releases a very addictive drug Marcus du Sautoy Have you ever wanted to be a puzzle pro or logical luminary Well look no further Maths Challenge Anthony Gardiner, Tony Gardiner, 2000 Maths Challenge has been written to provide an enrichment programme for able students at lower secondary level DT Challenges provide stimulating questions to help students think more deeply about basic mathematical ideas DT Comments and solutions explain the mathematical ideas and provide tips on how to approach later questions DT A Glossary defines all the mathematical terms used in the books in a precise way making the books self contained DT Suitable for individual group or class work in school or at home DT Fully trialled over the last ten years by a group of teachers and advisers led by Tony Gardiner

**Mathematical Challenges For All** Roza Leikin, 2023-03-17 This book argues that mathematical challenge can be found at any level and at every age and constitutes an essential characteristic of any mathematics classroom aimed at developing the students mathematical knowledge and skills Since each mathematics classroom is heterogeneous with respect to students mathematical potential quality mathematical instruction results from matching the level of mathematical challenge to different students potential Thus effective integration of mathematical challenge in the instructional process is strongly connected to the equity principle of mathematics education In the three sections in this volume readers can find diverse views on mathematical challenges in curriculum and instructional design kinds and variation of mathematically challenging tasks and collections of mathematical problems Evidence based analysis is interwoven with theoretical positions expressed by the authors of the chapters Cognitive social and affective characteristics of challenging mathematical activities are observed and analyzed The volume opens new avenues of research in mathematics education and pose multiple questions about mathematical instruction rich in mathematical challenge for all The authors invite readers to explore and enjoy mathematical challenges at different levels *Singapore Math Challenge, Grades 5 - 8* Frank Schaffer Publications, 2013-02-01 Get ready to take the Math Challenge Singapore Math Challenge will provide fifth grade students with skill building practice based on the leading math program in the world Singapore Math Common Core Standards accelerate math expectations for all students creating a need for challenging supplementary math practice Singapore Math Challenge is the ideal solution with problems puzzles and brainteasers that strengthen mathematical thinking Step by step strategies are clearly explained for solving problems at varied levels of difficulty A complete worked solution is also provided for each problem Singapore Math Challenge includes the tools and practice needed to provide a strong mathematical foundation and ongoing success for your students The Common Core State Standards cite Singapore math standards as worldwide benchmarks for excellence in mathematics

**Singapore Math Challenge, Grades 4 - 6**, 2013-02-01 Get ready to take the Math Challenge Singapore Math Challenge will provide fourth grade students with skill building practice based

on the leading math program in the world Singapore Math **Mathematical Challenge!** Leroy S. R. Mbili, 1978

**Singapore Math Challenge, Grades 5 - 8**, 2013-02-01 Get ready to take the Math Challenge Singapore Math Challenge will provide fifth grade students with skill building practice based on the leading math program in the world Singapore Math Common Core Standards accelerate math expectations for all students creating a need for challenging supplementary math practice Singapore Math Challenge is the ideal solution with problems puzzles and brainteasers that strengthen mathematical thinking Step by step strategies are clearly explained for solving problems at varied levels of difficulty A complete worked solution is also provided for each problem Singapore Math Challenge includes the tools and practice needed to provide a strong mathematical foundation and ongoing success for your students The Common Core State Standards cite Singapore math standards as worldwide benchmarks for excellence in mathematics Math Challenge II-A Geometry Kevin Wang, 2018-08-24 The math challenge curriculum textbook series is designed to help students learn the fundamental mathematical concepts and practice their in depth problem solving skills with selected exercise problems Ideally these textbooks are used together with Areteem Institute s corresponding courses either taken as live classes or as self paced classes According to the experience levels of the students in mathematics the following courses are offered Fun Math Problem Solving for Elementary School grades 3 5 Algebra Readiness grade 5 preparing for middle school Math Challenge I A Series grades 6 8 intro to problem solving Math Challenge I B Series grades 6 8 intro to math contests e g AMC 8 ZIML Div M Math Challenge I C Series grades 6 8 topics bridging middle and high schools Math Challenge II A Series grades 9 or younger students preparing for AMC 10 Math Challenge II B Series grades 9 or younger students preparing for AMC 12 Math Challenge III Series preparing for AIME ZIML Varsity or equivalent contests Math Challenge IV Series Math Olympiad level problem solving These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education These programs are ideal for students who wish to win in Math Competitions AMC AIME USAMO IMO ARML MathCounts Math League Math Olympiad ZIML etc Science Fairs County Science Fairs State Science Fairs national programs like Intel Science and Engineering Fair etc and Science Olympiad or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical logical thinking and creative problem solving skills Math Challenge II A is for students who are preparing for the American Mathematics Competition 10 AMC 10 contest Students are required to have fundamental knowledge in Algebra I Geometry Basic Number Theory and Counting and Probability up to the 10th grade level Topics include polynomials inequalities special algebraic techniques triangles and polygons collinearity and concurrency vectors and coordinates numbers and divisibility modular arithmetic advanced counting strategies binomial coefficients sequence and series and various other topics and problem solving techniques involved in math contests such as the AMC 10 advanced MathCounts American Regions Math League ARML and Zoom International Math League ZIML Division H and Junior Varsity Division The course is divided into four

terms Summer covering Algebra Fall covering Geometry Winter covering Combinatorics Spring covering Number Theory The book contains course materials for Math Challenge II A Geometry We recommend that students take all four terms Each of the individual terms is self contained and does not depend on other terms so they do not need to be taken in order and students can take single terms if they want to focus on specific topics Students can sign up for the course at <https://classes.aretteam.org> for the live online version or at <https://www.edurila.com> for the self paced version

**Math Challenge I-B Pre-Algebra and Word Problems** David Reynoso, John Lensmire, Kelly Ren, 2018-08-29 The math challenge curriculum textbook series is designed to help students learn the fundamental mathematical concepts and practice their in depth problem solving skills with selected exercise problems Ideally these textbooks are used together with Areteem Institute's corresponding courses either taken as live classes or as self paced classes According to the experience levels of the students in mathematics the following courses are offered Fun Math Problem Solving for Elementary School grades 3 5 Algebra Readiness grade 5 preparing for middle school Math Challenge I A Series grades 6 8 intro to problem solving Math Challenge I B Series grades 6 8 intro to math contests e g AMC 8 ZIML Div M Math Challenge I C Series grades 6 8 topics bridging middle and high schools Math Challenge II A Series grades 9 or younger students preparing for AMC 10 Math Challenge II B Series grades 9 or younger students preparing for AMC 12 Math Challenge III Series preparing for AIME ZIML Varsity or equivalent contests Math Challenge IV Series Math Olympiad level problem solving These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education These programs are ideal for students who wish to win in Math Competitions AMC AIME USAMO IMO ARML MathCounts Math League Math Olympiad ZIML etc Science Fairs County Science Fairs State Science Fairs national programs like Intel Science and Engineering Fair etc and Science Olympiad or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical logical thinking and creative problem solving skills In Math Challenge I B students expand middle school math skills to a deeper level with topics in beginning algebra fundamental geometry counting strategies and basic number theory The students not only learn practical skills of challenging problem solving that are supplemental to their school curricula but also develop skills in creative thinking logical reasoning oral and written presentation and team work This course helps 6th to 8th graders to participate in the American Mathematics Competition AMC 8 MathCounts Math Olympiads for Elementary and Middle School MOEMS and Zoom International Math League ZIML Division M The course is divided into four terms Summer covering Pre Algebra and Word Problems Fall covering Geometry Winter covering Combinatorics Spring covering Number Theory The book contains course materials for Math Challenge I B Pre Algebra and Word Problems We recommend that students take all four terms Each of the individual terms is self contained and does not depend on other terms so they do not need to be taken in order and students can take single terms if they want to focus on specific topics Students can sign up for the course at <https://classes.aretteam.org> for the live online version or at <https://www.edurila.com>

edurila.com for the self-paced version      **Problem-mathics** Carole E. Greenes, Rika Spungin, Justine M. Dombrowski, 1977

**The Ultimate Mathematical Challenge: Test Your Wits Against Our Finest Mathematicians** The UK Mathematics Trust, 2018-10-22 Be warned cracking puzzles releases a very addictive drug Marcus du Sautoy Do you consider yourself a puzzle pundit or leading logician Well look no further The perfect way to liven up your day The Ultimate Mathematical Challenge has over 365 puzzles to test your wits and excite your mind From easy problems to intermediate brainteasers stretching puzzles to pressure builders this book is the ideal forum to get your brain into gear and feed it with the challenges it craves Specially curated from the UK Mathematics Trust's puzzle programme most of these problems can be cracked using no more than a little numerical knowledge logical thinking and native wit Including interludes of cross number conundrums and shuttle challenges space for your working out and a handy glossary for those obscure mathematical terms this book has everything you need to solve captivating problems all year round Gather your friends and family put your thinking cap on and see if you have what it takes to conquer the ultimate mathematical challenge      [Math Challenge II-A Algebra](#) John Lensmire, David Reynoso, Kevin Wang Ph D, 2018-10-10 The math challenge curriculum textbook series is designed to help students learn the fundamental mathematical concepts and practice their in-depth problem solving skills with selected exercise problems Ideally these textbooks are used together with Areteem Institute's corresponding courses either taken as live classes or as self-paced classes According to the experience levels of the students in mathematics the following courses are offered Fun Math Problem Solving for Elementary School grades 3-5 Algebra Readiness grade 5 preparing for middle school Math Challenge I A Series grades 6-8 intro to problem solving Math Challenge I B Series grades 6-8 intro to math contests e.g. AMC 8 ZIML Div M Math Challenge I C Series grades 6-8 topics bridging middle and high schools Math Challenge II A Series grades 9 or younger students preparing for AMC 10 Math Challenge II B Series grades 9 or younger students preparing for AMC 12 Math Challenge III Series preparing for AIME ZIML Varsity or equivalent contests Math Challenge IV Series Math Olympiad level problem solving These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education These programs are ideal for students who wish to win in Math Competitions AMC AIME USAMO IMO ARML MathCounts Math League Math Olympiad ZIML etc Science Fairs County Science Fairs State Science Fairs national programs like Intel Science and Engineering Fair etc and Science Olympiad or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical logical thinking and creative problem solving skills Math Challenge II A is for students who are preparing for the American Mathematics Competition 10 AMC 10 contest Students are required to have fundamental knowledge in Algebra I Geometry Basic Number Theory and Counting and Probability up to the 10th grade level Topics include polynomials inequalities special algebraic techniques triangles and polygons collinearity and concurrency vectors and coordinates numbers and divisibility modular arithmetic advanced counting strategies binomial coefficients sequence and series and

various other topics and problem solving techniques involved in math contests such as the AMC 10 advanced MathCounts American Regions Math League ARML and Zoom International Math League ZIML Division H and Junior Varsity Division The course is divided into four terms Summer covering Algebra Fall covering Geometry Winter covering Combinatorics Spring covering Number Theory The book contains course materials for Math Challenge II A Algebra We recommend that students take all four terms Each of the individual terms is self contained and does not depend on other terms so they do not need to be taken in order and students can take single terms if they want to focus on specific topics Students can sign up for the course at <https://classes.aretteam.org> for the live online version or the self paced version A Special Announcement and Mathematical Challenge to the Members of the 1950 International Congress of Mathematicians American Institute of Mathematics, 1950

**Math Challenge** James Riley, Marge Eberts, Peggy Gisler, 2004-05 Educational resource for teachers parents and kids

**Math Challenge I-B Geometry** Kevin Wang Ph D, 2018-08-24 The math challenge curriculum textbook series is designed to help students learn the fundamental mathematical concepts and practice their in depth problem solving skills with selected exercise problems Ideally these textbooks are used together with Areteem Institute's corresponding courses either taken as live classes or as self paced classes According to the experience levels of the students in mathematics the following courses are offered Fun Math Problem Solving for Elementary School grades 3-5 Algebra Readiness grade 5 preparing for middle school Math Challenge I A Series grades 6-8 intro to problem solving Math Challenge I B Series grades 6-8 intro to math contests e.g. AMC 8 ZIML Div M Math Challenge I C Series grades 6-8 topics bridging middle and high schools Math Challenge II A Series grades 9 or younger students preparing for AMC 10 Math Challenge II B Series grades 9 or younger students preparing for AMC 12 Math Challenge III Series preparing for AIME ZIML Varsity or equivalent contests Math Challenge IV Series Math Olympiad level problem solving These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education These programs are ideal for students who wish to win in Math Competitions AMC AIME USAMO IMO ARML MathCounts Math League Math Olympiad ZIML etc Science Fairs County Science Fairs State Science Fairs national programs like Intel Science and Engineering Fair etc and Science Olympiad or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical logical thinking and creative problem solving skills In Math Challenge I B students expand middle school math skills to a deeper level with topics in beginning algebra fundamental geometry counting strategies and basic number theory The students not only learn practical skills of challenging problem solving that are supplemental to their school curricula but also develop skills in creative thinking logical reasoning oral and written presentation and team work This course helps 6th to 8th graders to participate in the American Mathematics Competition AMC 8 MathCounts Math Olympiads for Elementary and Middle School MOEMS and Zoom International Math League ZIML Division M The course is divided into four terms Summer covering Pre Algebra and Word Problems Fall covering Geometry Winter covering

Combinatorics Spring covering Number Theory The book contains course materials for Math Challenge I B Geometry We recommend that students take all four terms Each of the individual terms is self contained and does not depend on other terms so they do not need to be taken in order and students can take single terms if they want to focus on specific topics Students can sign up for the course at <https://classes.areteem.org> for the live online version or at <https://www.edurila.com> for the self paced version

Math Challenge II-A Combinatorics David Reynoso, John Lensmire, Kevin Wang Ph D, 2018-10-23

The math challenge curriculum textbook series is designed to help students learn the fundamental mathematical concepts and practice their in depth problem solving skills with selected exercise problems Ideally these textbooks are used together with Areteem Institute's corresponding courses either taken as live classes or as self paced classes According to the experience levels of the students in mathematics the following courses are offered Fun Math Problem Solving for Elementary School grades 3-5 Algebra Readiness grade 5 preparing for middle school Math Challenge I A Series grades 6-8 intro to problem solving Math Challenge I B Series grades 6-8 intro to math contests e.g. AMC 8 ZIML Div M Math Challenge I C Series grades 6-8 topics bridging middle and high schools Math Challenge II A Series grades 9 or younger students preparing for AMC 10 Math Challenge II B Series grades 9 or younger students preparing for AMC 12 Math Challenge III Series preparing for AIME ZIML Varsity or equivalent contests Math Challenge IV Series Math Olympiad level problem solving These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education These programs are ideal for students who wish to win in Math Competitions AMC AIME USAMO IMO ARML MathCounts Math League Math Olympiad ZIML etc Science Fairs County Science Fairs State Science Fairs national programs like Intel Science and Engineering Fair etc and Science Olympiad or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical logical thinking and creative problem solving skills Math Challenge II A is for students who are preparing for the American Mathematics Competition 10 AMC 10 contest Students are required to have fundamental knowledge in Algebra I Geometry Basic Number Theory and Counting and Probability up to the 10th grade level Topics include polynomials inequalities special algebraic techniques triangles and polygons collinearity and concurrency vectors and coordinates numbers and divisibility modular arithmetic advanced counting strategies binomial coefficients sequence and series and various other topics and problem solving techniques involved in math contests such as the AMC 10 advanced MathCounts American Regions Math League ARML and Zoom International Math League ZIML Division H and Junior Varsity Division The course is divided into four terms Summer covering Algebra Fall covering Geometry Winter covering Combinatorics Spring covering Number Theory The book contains course materials for Math Challenge II A Combinatorics We recommend that students take all four terms Each of the individual terms is self contained and does not depend on other terms so they do not need to be taken in order and students can take single terms if they want to focus on specific topics Students can sign up for the course at <https://classes.areteem.org>



for both the live online version and the self paced version      **Mathematical Challenge** Tony Gardiner,1996-08-28 This book contains almost 600 unusual and challenging multiple choice problems designed for students aged 11 15 The first part consists of past papers 1988SH93 for the annual UK Schools Mathematical Challenge The second part contains forty two short papers of ten questions each in the same style and are designed to fill a thirty minute class or homework slot This collection of unusual high quality problems will provide an invaluable resource for all mathematics teachers      **Math Challenge II-B Combinatorics** John Lensmire,David Reynoso,Kelly Ren,2018-11-26 The math challenge curriculum textbook series is designed to help students learn the fundamental mathematical concepts and practice their in depth problem solving skills with selected exercise problems Ideally these textbooks are used together with Areteem Institute s corresponding courses either taken as live classes or as self paced classes According to the experience levels of the students in mathematics the following courses are offered Fun Math Problem Solving for Elementary School grades 3 5 Algebra Readiness grade 5 preparing for middle school Math Challenge I A Series grades 6 8 intro to problem solving Math Challenge I B Series grades 6 8 intro to math contests e g AMC 8 ZIML Div M Math Challenge I C Series grades 6 8 topics bridging middle and high schools Math Challenge II A Series grades 9 or younger students preparing for AMC 10 Math Challenge II B Series grades 9 or younger students preparing for AMC 12 Math Challenge III Series preparing for AIME ZIML Varsity or equivalent contests Math Challenge IV Series Math Olympiad level problem solving These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education These programs are ideal for students who wish to win in Math Competitions AMC AIME USAMO IMO ARML MathCounts Math League Math Olympiad ZIML etc Science Fairs County Science Fairs State Science Fairs national programs like Intel Science and Engineering Fair etc and Science Olympiad or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical logical thinking and creative problem solving skills In Math Challenge II B students learn and practice in areas such as algebra and geometry at the high school level as well as advanced number theory and combinatorics Topics include polynomials inequalities special algebraic techniques trigonometry triangles and polygons collinearity and concurrency vectors and coordinates numbers and divisibility modular arithmetic residue classes advanced counting strategies binomial coefficients and various other topics and problem solving techniques involved in math contests such as the American Mathematics Competition AMC 10 12 ARML beginning AIME and Zoom International Math League ZIML Junior Varsity and Varsity Divisions The course is divided into four terms Summer covering Algebra Fall covering Geometry Winter covering Combinatorics Spring covering Number Theory The book contains course materials for Math Challenge II B Combinatorics We recommend that students take all four terms Each of the individual terms is self contained and does not depend on other terms so they do not need to be taken in order and students can take single terms if they want to focus on specific topics Students can sign up for the course at <https://classes.areteem.org> for the live or self paced course

*Senior Problems* Andrew Jobbings, 2018      Math Challenge II-B Algebra John Lensmire, David Reynoso, Kevin Wang, 2019-03-07

The math challenge curriculum textbook series is designed to help students learn the fundamental mathematical concepts and practice their in depth problem solving skills with selected exercise problems. Ideally these textbooks are used together with Areteem Institute's corresponding courses either taken as live classes or as self paced classes. According to the experience levels of the students in mathematics the following courses are offered:

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- intro to problem solving Math Challenge I B Series grades 6-8
- intro to math contests e.g. AMC 8 ZIML Div M Math Challenge I C Series grades 6-8
- topics bridging middle and high schools Math Challenge II A Series grades 9 or younger students preparing for AMC 10
- Math Challenge II B Series grades 9 or younger students preparing for AMC 12
- Math Challenge III Series preparing for AIME ZIML Varsity or equivalent contests
- Math Challenge IV Series Math Olympiad level problem solving

These courses are designed and developed by educational experts and industry professionals to bring real world applications into the STEM education. These programs are ideal for students who wish to win in Math Competitions: AMC, AIME, USAMO, IMO, ARML, MathCounts, Math League, Math Olympiad, ZIML, etc. Science Fairs, County Science Fairs, State Science Fairs, national programs like Intel Science and Engineering Fair, etc. and Science Olympiad or purely want to enrich their academic lives by taking more challenges and developing outstanding analytical, logical thinking and creative problem solving skills.

In Math Challenge II B students learn and practice in areas such as algebra and geometry at the high school level as well as advanced number theory and combinatorics. Topics include polynomials, inequalities, special algebraic techniques, trigonometry, triangles and polygons, collinearity and concurrency, vectors and coordinates, numbers and divisibility, modular arithmetic, residue classes, advanced counting strategies, binomial coefficients and various other topics and problem solving techniques involved in math contests such as the American Mathematics Competition, AMC 10/12, ARML, beginning AIME and Zoom International Math League, ZIML Junior Varsity and Varsity Divisions.

The course is divided into four terms: Summer covering Algebra, Fall covering Geometry, Winter covering Combinatorics, Spring covering Number Theory. The book contains course materials for Math Challenge II B Algebra. We recommend that students take all four terms. Each of the individual terms is self contained and does not depend on other terms so they do not need to be taken in order and students can take single terms if they want to focus on specific topics. Students can sign up for the online live or self paced course at <https://classes.areteem.org>

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