

The Rockdale Mathematics Competition
Problem Book

Chuck Garner

The Rockdale Mathematics Competition Problem Book

Second Edition, 2007-2023



Chuck Garner, Editor

Lulu Publishing

THE ROCKDALE MATHEMATICS COMPETITION PROBLEM BOOK

SECOND EDITION, 2007-2023

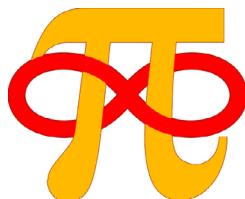
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Special Thanks to anyone who has ever been a member of
the Rockdale Magnet Math Team.



Parts of this book first appeared in "The Rockdale Mathematics Competition, 2004-2009"

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Preface to the Second Edition

The big change to this new edition is that the competitions from the years 2004 and 2006 have been removed, and the competitions from 2015 to 2023 are now included (with the exception of 2020, which did not occur).

The 2004 and 2006 competitions were removed because the format of those two first-ever Rockdale Mathematics Competitions were a different format than the current RMC. (An explanation of that format is below, in the preface for the first edition.) Consequently, students using the book to prepare for an upcoming RMC do not find those tests useful. Also, the multiple-choice tests don't seem to fit in well with so many competitions in an ARML-style format. The results and the summary discussion for each of those years are still included. The tests themselves are now posted on the RMC website, www.rockdalemathcompetition.com.

With the addition of the 2015 to 2023 competitions, this brings the book up-to-date... well, at least until the November 2024 RMC!

I have also updated the following table. The table gives an indication of the difficulty of the RMC over the years. Compare this with the table from the first edition, which is reproduced below in the preface from the first edition.

	Individual	Team	Relay	Power	Total Team Score
Lowest Middle School Averages	2022	2010	2009	2012	2010
Highest Middle School Averages	2008	2018	2015	2008	2008
Lowest JV Averages	2016	2008	2007	2008	2007
Highest JV Average	2012	2021	2019	2023	2021
Lowest Varsity Averages	2017	2021	2016	2015	2016
Highest Varsity Averages	2012	2009	2023	2011	2009

Speaking of the format of the Competition, the Relay Round was re-formatted in 2015. Previously, the Relay consisted of two different rounds in which the team split into two groups of three. Each person in the three-person Relay received a unique problem unseen by the other two. Person 1 passed back their answer to person 2 who used it to help solve their problem. Person 2 passed back their answer to person 3, who used that to help solve their problem. Then person 3 turned in their answer. In 2015, the Relay Round was completely restructured from two rounds of three

problems each to one round of six problems. The answer to Problem N is used in Problem $N + 1$, for $N = 1, 2, 3, 4, 5$. The entire four-student team works together on all six problems in a ten-minute time limit. The team must turn-in answers to all six problems for credit, since the scoring is determined by the number of *consecutive* correct answers beginning with the first. The problems are also “numbered” A through F. Points are awarded for the following consecutive correct answers: a correct answer for problem A gets 2 points; A and B correct gets 5 points; A, B, and C correct gets 8 points; A, B, C, and D correct gets 15 points; A, B, C, D, and E correct gets 25 points; and all six correct earns the team 40 points. Offering the Relay in this format not made it easier for the proctors to administer the Relay, and, as feedback from participants and sponsors indicated, it made the Relay more enjoyable.

When you read the new Relay problems, each one says “Let N be the number in Box N ” (where N is A, B, C, D, E , or F). Students are to write their answers in boxes on the Relay Round answer sheet. Below is what that answer sheet looks like, so you can understand what the “boxes” are.

Sample Relay Round Answer Sheet

A	B	C	D	E	F
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There was another big change in the 2015 RMC: the number of students per team. Previously, we required a team be made up of six students. But it was increasingly more difficult for sponsors to field full teams of six, and it was increasingly more difficult to find enough room in the building for teams of six! Beginning with 2015, a team consists of four students. However, this implied that the points per Round needed to be changed, since a 10-problem Individual Round with six team members is a possible 60 points, but a 10-problem Individual Round with four team members is only 40 possible points! So this was an opportunity to re-think the points each Round is worth. Prior to 2015, the points were 60 for Individual, 50 for Team, 40 for Relay, and 50 for Power. As this is a team competition, the collaborative Team and Power Rounds should be worth a little more. Beginning with 2015, the points became 40 for Individual, 60 for Team, 40 for Relay, and 60 for Power. (This makes each Team Round problem worth 6 points instead of the previous 5 points.) The total points possible for a team remained the same at 200.

The authors of the recent problem sets in this book are the students listed below. They were all students at Rockdale Magnet School when writing these problems. From the 2015 competition, I took on the task of writing all the Relay Rounds, and many of the Power Rounds. If students wrote those two rounds, they are indicated below.¹

2015 Jaire Duncan

2017 Zarek Syed and Matthew York (Matthew wrote all the Power Rounds)

2018 Angel Brooks, Sarah Goldgar, Brandon Hong, Steven Hua, Payton Lovett, Kwatcho Mahinanda, Courtney Melvin, Kep Nana, Chiemeka Nzerue, Abby Oser, Brianna Pinckney, Nawal Reza, Zarek Syed, Shivam Vohra, and Ian Westcott (Matthew York wrote the JV and Varsity Power rounds)

¹2016 and 2021 are not listed because I wrote the entirety of both competitions. 2020 is not listed because there was no Competition in 2020.

-
- 2019** Zora Duncan, Laura Goldgar, Huong Ho, Brandon Hong, Steven Hua, Patricia Ilic, Colin Kennelly, Anthony Mays, Kep Nana, Chiemeka Nzerue, Abby Oser, Nawal Reza, Mariana Rios, Shivam Vohra, Ian Westcott (Angel Brooks, Brandon Hong, Patricia Ilic, Kwatcho Mahinanda, and Mariana Rios wrote the Relays)
- 2022** Xander Atkison, Camila Moreno, and faculty member David Hornbeck contributed to the JV competition
- 2023** Elissa Anderson, Xander Atkinson, Camila Moreno, Ian Morgan, Stewart Oser, Delano Page, Lucas Rodgers, Matilda Rodgers, Muna Yassin, Maxwell Zhang, and faculty member David Hornbeck

The emcee role has continued to be expertly handled by former students: Jonathan Johnson, Anika Reza, Lamisa Syed, and Stewart Oser. Jonathan still holds the record for being present at the most RMCs.

Another change in the new edition is the typesetting. I have used Utopia and Avant-Garde to typeset the actual competition papers since 2007. I used Utopia and Avant-Garde to typeset the original *RMC Problem Book 2004-2009*. However, when putting together the *RMC Problem Book 2004-2014*, I chose not to use Utopia (for some reason that escapes me now)! That decision has been reversed, and the this new edition is in Utopia and Avant-Garde. This more resembles the actual look of the papers the students would receive on competition day.

Finally, I'd like to give special thanks to some fellow Math Team sponsors. Storie Atkins from Columbus High School and Brian Stone from Northview High School have brought their school's teams to the RMC every year since 2007 – more than anyone else! – for a total of 16 times. I also must mention Chris Michael from Brookwood High School, Ann Dorminy from Soli Deo Gloria Home Education, and Carolyn Smothers from Tattnall Square Academy who have brought their teams to the RMC 15 times. Their support is appreciated, generous, and humbling.

Chuck Garner
CONYERS, GA
JUNE 2024

Preface to the First Edition

This book includes all competition papers from the first ten Rockdale Mathematics Competitions—those over the years 2004 to 2014. Some of these competition papers have appeared in an earlier edition of this book, but the new edition brought with it the opportunity to make corrections of some typos in those competition papers, as well as make some changes and additions.

This new edition is printed on standard $8\frac{1}{2} \times 11$ page size to make it easier on teachers to copy materials for practice with their teams. The former 6×9 size was a nice compact little volume, but it was difficult to make copies from those pages. This new edition features five Ciphering problems to a page and the Individual questions separated with horizontal lines. This is so teachers can make copies and then cut the copies so students can practice one set of problems at a time, simulating actual competition conditions. The Relay problems are similarly formatted. The Power and Team Round problems are each on a single page, again to help teachers make copies for their students.

There are other new additions to this volume. Included at the beginning of each year's problems is a list of the top 5 team and individual winners of that year's tournament, and the average number of correct responses and scores. There is a new index of topics, terms, and names used in the problems. Finally, there is a special Appendix which lists only the answers, so teachers may use it to quickly check students' answers, or so students can check their own work before reading the solutions.

The format of the tournament has remained ARML-style, with some tweaks. Beginning in 2011, we increased the number of individual and team questions from 8 to 10. This meant the point values and the timing of the rounds changed. The Power Round — to be completed by teams of six students in 40 minutes — and the Team Round — to be completed by a team in 20 minutes — are now each worth 50 points. Each of the two Relay Rounds remained 20 points but the timing changed to 4 minutes per Relay. The Individual Round is now worth 60 points with each pair of problems to be completed within 6 minutes. The maximum point total for a team is therefore 200.

The Individual Round is the sole determining factor in the individual awards. Of course, it is possible for students to get the same number of problems correct; indeed, this always happens. To distinguish among the top 12 award winners, it would seem that we would need to hold a large tie-breaker round. However, the possibility of such a large round eliminated by weighting the individual problems. Beginning in 2007, the problems were designed to be in order of difficulty, so the easiest problems was #1 and the most difficult was #10. This resulted in many automatic tie-breakers. For instance, say Pat and Chris each got 8 problems correct. If Pat correctly answered 1, 2, 3, 4, 5, 6, 7, and 8, but Chris correctly answered 1, 2, 3, 4, 5, 6, 8, and 9, then Chris would “win” the tie since Chris answered more of the difficult problems correctly.

However, we realized over the years that we didn't always get the order of difficulty quite right! So beginning in 2013, we calculated the difficulty based on how many participants answered each problem incorrectly. This means that if 80% answer #10 incorrectly, but 95% answer problem #9 incorrectly, then we consider #9 more difficult than #10, and break any ties accordingly. (The only tie-breakers left for us to break in a special tie-breaker round are those participants who answer the exact same problems correctly, and we only do this for those under consideration for an award.)

The difficulty of the tournament has varied over the years. At the beginning of each chapter is a short introduction, describing the tournament and the results. Included in this is a summary of the average score on each round. If we use this average score as a measure of difficulty, then some interesting statistics emerge. Below is a table listing the rounds and years of the lowest and highest average scores for the 8 years of the Team, Relay, and Power Rounds, as well as the Total Team Score. (To make the comparisons easier and because the rounds have changed point-values over the years, the average score was converted to a percentage of the points possible on that round.) The Individual Round difficulty was determined by the average percentage of correct responses from all participants. The actual average scores can be found in the introductions to each competition.

Competition Years with the Highest and Lowest Average Scores

	Individual	Team	Relay	Power	Total Team Score
Lowest Middle School Averages	2011	2010	2009	2012	2010
Highest Middle School Averages	2008	2013	2014	2008	2008
Lowest JV Averages	2014	2008	2007	2008	2007
Highest JV Average	2012	2012	2014	2011	2011
Lowest Varsity Averages	2013	2013	2013	2014	2013
Highest Varsity Averages	2014	2009	2008	2011	2009

The authors of the more recent problem sets in this book are the students listed below. They were all students at Rockdale Magnet School when writing these problems. Even though some of the problems they submitted were heavily edited and rewritten by me, their ideas and problem-solving strategies remained. They were wonderful young people who were enthused about running mathematics competitions.

2010 Samantha Allen, Julian Hinds, Jonathan Johnson, Vaidehi Joshi, Faustine Li, Kevin Lin, Valeska Lobo, Aaron Roberts, Ken Sinmura, Edwin White, Ksenia Zakirova

2011 Ksenia Zakirova

2012 Gedeion Addisu, Carmen Candal, Johnathan Davis, Cameron Easley, Ray Garner, Shoman Kasbekar, Gabe Kustick, Jason Mitchell, Jeremy Rachels, Anika Reza, Brian Silva, Anna Grace Slifko, Zachary York, Michelle Zhang

2013 Heeyoon Kim

2014 Jeff Bang, Sidney Billingsley, Jaire Duncan, Ray Garner, Ashley Hong, Carlan Ivey, Bethany Mays, Ashley Robbins, Naomi Siddiquee

Thanks to Michelle Zhang who supplied many of the solutions (in \LaTeX) to the 2004 competition. The photographs reproduced in this book were taken by Emily Pace, except for the photo on page 437 which was taken by Jeff Bang.

I am pleased that the Rockdale Mathematics Competition has remained a popular math tournament for students in Georgia. It is a large undertaking. Although I handle the registration and communicate with sponsors, the students do all the rest. In addition to the problems writers listed above, there have been hundreds of students who help run the tournament, functioning as scorers, runners, graders, and food prep workers. Thanks also to the alumni who come back to be proctors. In fact, special recognition should go to Jonathan Johnson. Jonathan attended the 2004 and 2006 tournaments as a middle school student. He then went on to help run the 2007, 2008, and 2009 tournaments during high school. He has also returned to be the emcee at the 2010, 2011, 2013, and 2014 tournaments while attending Georgia Tech. (Yes, he missed the 2012 tournament, but the emcee role was superbly and graciously filled by former team captain Amy Lanchester.) Jonathan holds the student/alumni record for being present at the most RMCs.

Thanks also to everyone who has been a member of the Rockdale Magnet Math Team or a member of the Rockdale County High School chapter of Mu Alpha Theta.

Chuck Garner
CONYERS, GA
JANUARY 2015

Preface to the RMC Problem Book 2004-2009

Contained in this book are all the problems given at the first five Rockdale Mathematics Competitions. The problems contained within were all written and solved by the students of the Rockdale Magnet School's award-winning Math Team. The Competition itself is run and hosted by the Math Team as well. The Competition has evolved over its short life, and so a little history is warranted.

As soon as we had the idea to host our own event, we also realized that we wanted to make this more than a high school competition. We wanted a format that would encourage middle schools to take part. So we decided on a format made popular in Alabama, that of subject area tests: pre-algebra, first-year algebra, geometry, second-year algebra, and a comprehensive division.

The competitive rounds in each division involved a written test and ciphering. The test format was simply a 30-question multiple-choice test with a 70-minute time limit. Students received four points per correct answer, zero points per problem left blank, and -1 points per incorrect answer. The ciphering round format was as follows. One student from each school was selected to answer a total of five problems, each with a two-minute time limit. After the first student, a second student was selected to represent his team, and he got five more problems under the same constraints. A total of four students per school were involved in the ciphering. The individual awards were based solely on the written test, while the team awards were based on the sum of the team's best four written test scores plus any ciphering points. This format served us well, and we decided to continue it for next year's Competition. Unfortunately, we had to wait two years for the next one!

The first Competition was held in January 2004, and we diligently worked towards the next one scheduled for January 2005. However, the day before the Competition was to take place, an ice storm came through the Atlanta area which forced the cancellation of all activities for the following day. No other date was available for us in the Spring of 2005, so we held all the materials until January 2006. (Which is why there is no 2005 Competition in this book!)

After two years of the same format, we were unhappy with the lack of team-oriented competition and we wanted to change it to encourage more team activity. We settled on an ARML-style competition. We introduced three divisions: middle school, junior varsity, and varsity (the middle school division is self explanatory, I think; the JV division is for competitors who have *not* started the study of precalculus, and the Varsity division is for anyone). We also introduced four rounds, three of which are team-oriented, designed for teams of six students from a school.

The Power Round In which a team must justify or prove their solutions to a series of related problems in a thirty-five minute time limit (40 points).

The Team Round In which a team must simply write answers to eight unrelated problems in a twenty minute time limit (5 points per correct answer).

The Relay Rounds In which the team splits into two groups of three where the first person must answer a problem, send that answer back to the second person where the second person must use the first person's answer to solve the second problem, then the second person passes that answer back to the third person who solves the final problem using the second person's answer. This is to be done within five minutes (5 points per correct final answer within three minutes and 2 points per correct final answer by five minutes – a total of 20 points).

The Individual Round In which each competitor is given two problems to answer in a seven-minute time limit, and then does this four times for a total of eight problems (one point per correct answer for a total of 48 points). The 8 problems increase in difficulty, with number 8 being the most difficult.

The individual awards were based solely on the individual round. With only eight problems in the individual round, we avoided numerous tie-breakers by ranking students not only on how many of these problems they answered correctly, but also on *which* problems they answered correctly. For example, if Pat got the first 6 out of the 8 correct, and Chris got the last 6 of the 8 correct, then Chris is ranked higher than Pat since Chris was able to answer the more difficult problems. Even though many tie-breakers were avoided with this system, some still had to be broken; this necessitated a tie-breaker round before the awards ceremony could begin. (The tiebreaker questions are not included in this book.) The team awards were based on the sum of all points from all rounds.

The new format in January 2007 was a success, and we endeavored to continue in January 2008 with the next Competition. Unfortunately, Mother Nature again dealt us a cold blow in the form of another ice storm! Once more, we were forced to cancel. The 2008 Competition was finally held in November 2008. Having learned our lesson, we scheduled the next Competition for December 2009.

This takes us to the present, and this book.

The problems represent the hard work of many students over the years. I edited the problems and wrote the 54 Relay Round problems; however, the authors of the other 700 problems in this book are the students listed below.

2004 Kenny Baskett, Max Bernardy, Mitch Costley, Amin Makhani, Ben Wu

2006 Max Bernardy, Mitch Costley, Kevin Todd, Ben Wu, Jodie Wu, Drew Yaun

2007 Sam Brotherton, Nayoon Kim, Amy Lanchester

2008 Sam Brotherton, Nayoon Kim, Jacob Kovac, Steven Rouk

2009 Kevin Brawley, Kathryn Daniel, Ashley Jackson, Jonathan Johnson, Kathryn Johnson, Patti Murphy, James Rives

Finally, I am so happy that I got to work with these mathematically gifted young people. They are truly amazing individuals. This book is dedicated to them.

Chuck Garner
CONYERS, GA
APRIL 2010

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2008

The 2008 Rockdale Mathematics Competition

Last year's change in format did not decrease the participants, but changing from January to November did. The fourth RMC on November 1, 2008 was attended by 382 students from 32 different schools. Schools attending the RMC for the first time were Dodgen Middle School, Druid Hills High School, Fort Payne High School, Lakeside High School (from Atlanta), Pizitz Middle School, South Forsyth High School, and Vestavia Hills High School.

The top five individual winners of the tournament are listed in the table below.

	Middle School	Junior Varsity	Varsity
First place	Gil Goldshlager <i>Dickerson MS</i>	Suyoung Jang <i>Vestavia Hills HS</i>	Eric Morphis <i>Woodward Academy</i>
Second place	Tony Zeng <i>Pizitz MS</i>	Owen Scott <i>Vestavia Hills HS</i>	Allen Park <i>Walton HS</i>
Third place	Sean Eikhoff <i>Dickerson MS</i>	Kyle Julian <i>Vestavia Hills HS</i>	Benjamin Hu <i>Northview HS</i>
Fourth place	Botong Ma <i>Pizitz MS</i>	Luke Bishop <i>Vestavia Hills HS</i>	Henry Mei <i>Walton HS</i>
Fifth place	Jimmy Liu <i>Pizitz MS</i>	Grant Carlson <i>Westminster</i>	Billy Dorminy <i>Soli Deo Gloria</i>

The top two Middle School winners were the only middle school students to answer all eight Individual Round problems correctly. The top four JV winners answered 8, 7, 6, and 6 of the JV Individual Round problems correctly (and were the only JV students to correctly answer more than 5). The item difficulty for this year's Individual Round is in the table below.

	Percentage of correct responses								Average
	#1	#2	#3	#4	#5	#6	#7	#8	
Middle School	62	36	38	83	23	41	11	4	38
Junior Varsity	33	47	8	19	25	47	12	11	25
Varsity	75	47	39	12	17	11	26	16	30

Awards were given to the top schools in each classification in each division. The overall top five middle school, junior varsity, and varsity teams are listed below. Schools were allowed to register more than one 6-student team.

	Middle School	Junior Varsity	Varsity
First place	Dickerson MS	Vestavia Hills HS A-team	Walton HS
Second place	Pizitz MS	Vestavia Hills HS C-team	Northview HS
Third place	Chamblee MS	Vestavia Hills HS B-team	Vestavia Hills HS
Fourth place	Hull MS	Walton HS	Chamblee HS
Fifth place	Dodgen MS	Chamblee HS	Lassiter HS

The Middle School tournament was a run-away for Dickerson, but the next four places were separated by only 9 points! All of the top five Middle School teams listed above obtained perfect scores on both the Power and Team Rounds (as well as Kendrick Middle School's team who got a perfect Power Round score). So the deciding factors were the Individual Round and the Relays. Another two problems correct, and the results would have been very different!

The JV tournament was the opposite of the Middle School: there were no perfect scores on the Power or Team Rounds.

Notable scores for the Varsity teams were the perfect Power Round scores obtained by Brookwood, Chamblee, Columbus, Lassiter, Vestavia Hills, Walton, and Woodward Academy, and the perfect Team Round scores obtained by Lassiter, Northview, and Woodward Academy. You may be wondering, if a team got perfect Power and Team scores, why that team may not be in the top five. Usually, when a school has perfect Power and Team and is not one of the top five, that team probably has one or two individuals who are veteran champions of mathematics competitions, while the rest of the team may not be. This tournament is structured to reward good teams, not individuals. It is possible for an individual to answer the Team and Power alone, but the other teammates must be able to contribute to the Individual Round and the Relays. Without everyone working together, it is not possible for one or two students to "carry" a team to victory.

Average Team Scores

	Individual	Team	Relay	Power	Total
Maximum Possible	48	40	20	40	148
All Middle School Teams	16.3	25.0	4.1	33.4	78.9
Top 5 Middle School Teams	30.4	40.0	11.4	40.0	121.8
All JV Teams	9.9	12.9	4.2	7.4	34.4
Top 5 JV Teams	19.6	22.0	9.8	9.6	61.0
All Varsity Teams	13.0	19.4	2.0	20.3	54.3
Top 5 Varsity Teams	29.0	36.0	8.2	39.8	112.6