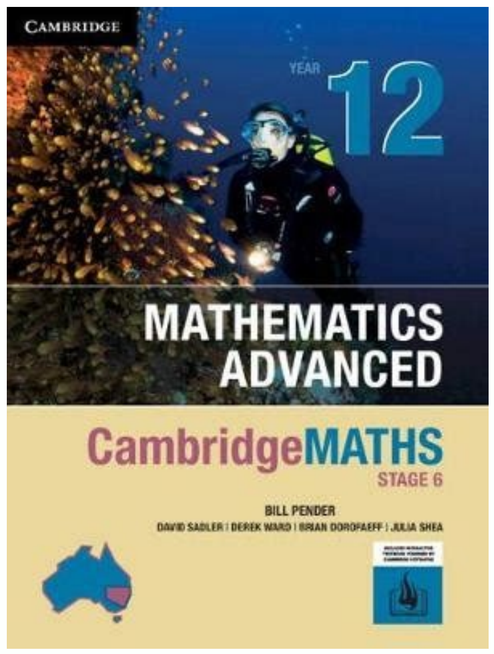
Mathematics 2 phillips exeter academy answers

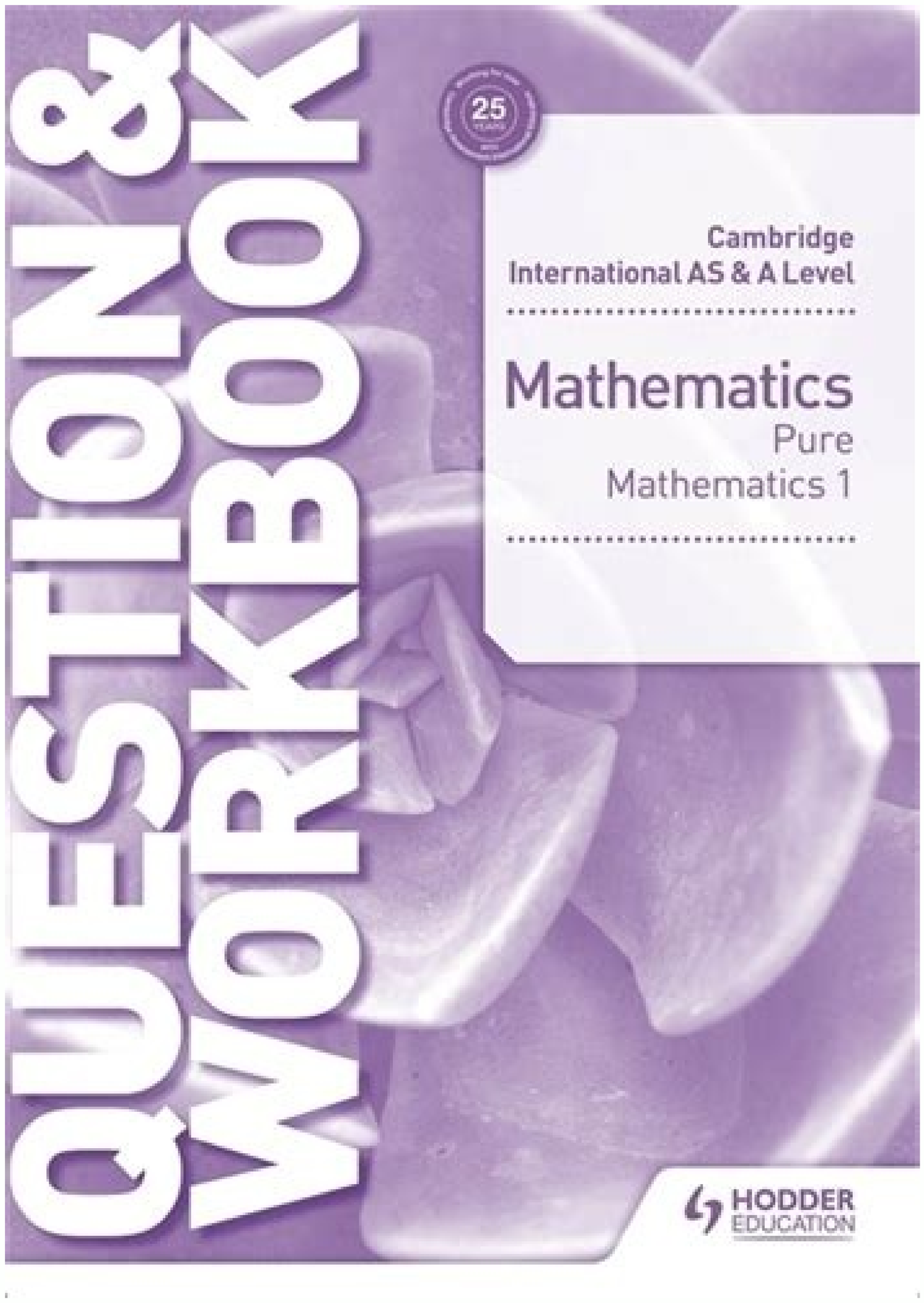


1. Write an inequality and an accompanying number line graph that represents each of the following:
   a) x is between -3 and 5 b) x is more than 3 units away from 4

2. Solve the following: a) $5(x-2)-2(x+1)=6$ b) $\frac{2}{3}(x-1)=\frac{3}{4}(x+1)$

3. Dan is 20% taller than Lucy, and Lucy's height is 30% less than Andy's. If Andy's height is A cm, write algebraic expressions for Lucy and Dan's height in terms of A. Put these expressions in simplest form.

4. Plot a number k on the number line that is between 1 and 2 as well as the related numbers in a, b and c below. Choose a number line scale that makes sense for this problem and will allow you to show reasonably accurately where each number below is located.
   $a) -k-1$ $b) 2k-3$ $c) \frac{k}{2}+2$



1 Mathematics Department Phillips Exeter Academy Exeter, NH July 2015 2 3 To the Student Contents: Members of the PEA Mathematics Department have written the material in this book As you work through it, you will discover that algebra, geometry, and trigonometry have been integrated into a mathematical whole There is no Chapter 5, nor is there a section on tangents to circles The curriculum is problem-centered, rather than topic-centered Techniques and theorems will become apparent as you work through the problems, and you will need to keep appropriate notes for your records there are no boxes containing important theorems There is no index as such, but the reference section that starts on page 201 should help you recall the meanings of key words that are defined in the problems (where they usually appear italicized) Comments on problem-solving: You should approach each problem as an exploration Reading each question carefully is essential, especially since definitions, highlighted in italics, are routinely inserted into the problem texts It is important to make accurate diagrams whenever appropriate Useful strategies to keep in mind are: create an easier problem, guess and check, work backwards, and recall a similar problem It is important that you work on each problem when assigned, since the questions you may have about a problem will likely motivate class discussion the next day Problem-solving requires persistence as much as it requires ingenuity When you get stuck, or solve a problem incorrectly, back up and start over Keep in mind that you re probably not the only one who is stuck, and that may even include your teacher If you have taken the time to think about a problem, you should bring to class a written record of your efforts, not just a blank space in your notebook The methods that you use to solve a problem, the corrections that you make in your approach, the means by which you test the validity of your solutions, and your ability to communicate ideas are just as important as getting the correct answer About technology: Many of the problems in this book require the use of technology (graphing calculators or computer software) in order to solve them Moreover, you are encouraged to use technology to explore, and to formulate and test conjectures Keep the following guidelines in mind: write before you calculate, so that you will have a clear record of what you have done; store intermediate answers in your calculator for later use in your solution; pay attention to the degree of accuracy requested; refer to your calculator s manual when needed; and be prepared to explain your method to your classmates Also, if you are asked to graph y = (2x 3)/(x + 1), for instance, the expectation is that, although you might use your calculator to generate a picture of the curve, you should sketch that picture in your notebook or on the board, with correctly scaled axes 4 5 Phillips Exeter Academy Introductory Math Guide for New Students (For students, by students!) 6 7 Introduction Annually, approximately 300 new students take up studies in the Mathematics Department

Coming from various styles of teaching, as a new student you will quickly come to realize the distinct methods and philosophies of teaching at Exeter One aspect of Exeter that often catches students unaware is the math curriculum I encourage all new students to come to the math table with a clear mind You may not grasp, understand, or even like math at first, but you will have to be prepared for anything that comes before you During the fall of 2000, the new students avidly voiced a concern about the math curriculum Our concern ranged from grading, to math policies, and even to the very different teaching styles utilized in the mathematics department The guide that you have begun reading was written solely by students, with the intent of preparing you for the task that you have embarked upon This guide includes tips for survival, testimonials of how we felt when entering the math classroom, and aspects of math that we would have liked to have known, before we felt overwhelmed Hopefully, this guide will ease your transition into math at Exeter Remember, Anything worth doing, is hard to do Mr Higgins 36 Anthony L Riley 04 I learned a lot more by teaching myself than by being taught by someone else One learns many ways to do different problems Since each problem is different, you are forced to use all aspects of math It takes longer for new concepts to sink in you understand, but because it didn t sink in, it s very hard to expand with that concept It makes me think more The way the math books are setup (ie simple problems progressing to harder ones on a concept) really helps me understand the mathematical concepts When you discover or formulate a concept yourself, you remember it better and understand the concept better than if we memorized it or the teacher just told us that the formula was xyz Homework Math homework = no explanations and eight problems a night For the most part, it has become standard among most math teachers to give about eight problems a night; but I have even had a teacher who gave ten though two problems may not seem like a big deal, it can be Since all the problems are scenarios, and often have topics that vary, they also range in complexity, from a simple, one-sentence question, to a full-fledged paragraph with an eight-part answer! Don t fret though, transition to homework will come with time, similar to how you gain wisdom, as you get older Homework can vary greatly from night to night, so be flexible with your time this leads to another part of doing your homework IN ALL CLASSES THAT MEET FIVE TIMES A WEEK, INCLUDING MATHEMATICS, YOU SHOULD SPEND 50 MINUTES AT THE MAXIMUM, DOING HOMEWORK! No teacher should ever expect you to spend more time, with the large workload Exonians carry Try your hardest to concentrate, and utilize those 50 minutes as much as possible i 8 Without any explanations showing you exactly how to do your homework, how are you supposed to do a problem that you have absolutely no clue about? (This WILL happen!) Ask somebody in your dorm Another person in your dorm might be in the same class, or the same level, and it is always helpful to seek the assistance of someone in a higher level of math Also remember, there is a difference between homework and studying; after you re through with the eight problems assigned to you, go back over your work from the last few days with homework, you wouldn t get marked down if you didn t do a problem Going to the Board It is very important to go to the board to put up homework problems Usually, every homework problem is put up on the board at the beginning of class, and then they are discussed in class If you regularly put problems up on the board, your teacher will have a good feel of where you stand in the class; a confident student will most likely be more active in participating in the class Plagiarism One thing to keep in mind is plagiarism You can get help from almost anywhere, but make sure that you cite your help, and that all work shown or turned in is your own, even if someone else showed you how to do it Teachers do occasionally give problems/quizzes/tests to be completed at home You may not receive help on these assessments, unless instructed to by your teacher; it is imperative that all the work is yours Math Extra-Help Getting help is an integral part of staying on top of the math program here at Exeter It can be rather frustrating to be lost and feel you have nowhere to turn There are a few tricks of the trade however, which ensure your safety, with this possibly overwhelming word problem extravaganza Teachers and Meetings The very first place to turn for help should be your teacher Since teachers at Exeter have many fewer students than teachers at other schools, they are never less than eager to help you succeed in any way they can There is actually one designated time slot a week for students to meet with teachers, which is meetings period on Saturday You can always call or ask a teacher for help If there is no time during the day, it is always possible to check out of the dorm after your check-in time, to meet with your teacher at their apartment, or house It is easiest to do this on the nights that your teacher is on duty in his/her dorm Getting help from your teacher is the first and most reliable source to turn to, for extra help You could meet with the teacher for extra help anytime Extra help sessions one-on-one with the teacher My old math text ii 9 7-9 Math Help Along with help from your teacher, there are several other places to get help From 7-9 PM every night, except Saturday, there is a Math and Science help group in the Science Center Each evening, the lab is filled with students in a broad range of math levels, which should be able to help you with problems you have Also, remember that your homework is not graded everyday, and your teacher will usually tell you when he/she will be grading a particular assignment This means that you can always find someone in your dorm that will help you catch up or simply help you with a tough problem If you are a day student, I would definitely recommend going to Science and Math Help harder to understand concepts if you don t understand a problem because each problem is trying to teach you something different that leads to a new concept Hard to separate different math concepts Not sure what kind of math it is I m learning More difficult to review Different Teachers Teach Differently The teachers at Exeter usually develop their own style of teaching, fitted to their philosophy of the subject they teach; it is no different in the math department Teachers vary at all levels: they grade differently, assess your knowledge differently, teach differently, and go over homework differently They offer help differently, too This simply means that it is essential that you be prepared each term to adapt to a particular teaching style For instance, my teacher tests me about every two weeks, gives hand-in problems every couple of days, and also gives a few quizzes However, my friend, who is in the same level math as I am, has a teacher who doesn t give any tests or quizzes; he only grades on class participation, and assigns a single hand-in problem, each assignment Don t be afraid to ask your teacher how they grade, because this can become very crucial; various teachers put more weight on class participation in grading while others do the opposite You must learn to be flexible to teaching styles and even your teacher s personality This is a necessity for all departments at Exeter, including math The tests are the hardest part between terms to adapt to, but if you prepare well, there shouldn t be a problem Tests are hard Can t go at your own pace My other teacher taught and pointed out which problems are related when they are six pages apart It took a few days adjusting to, but if you pay attention to what the teacher says and ask him/her questions about their expectations, transitions should be smooth Inconsistent Every teacher gave different amounts of homework and tests Class work varied too My fall term teacher made us put every problem on the board, whereas my winter term teacher only concentrated on a few Jonathan Barbee 04 Ryan Levihn-Coon 04 iii 10 New Student Testimonials There was not a foundation to build on There were no example problems After eight years of math textbooks and lecture-style math classes, math at Exeter was a lot to get used to My entire elementary math education was based on reading how to do problems from the textbook, then practicing monotonous problems that had no real-life relevance, one after the other This method is fine for some people, but it wasn t for me By the time I came to Exeter, I was ready for a change of pace, and I certainly got one Having somewhat of a background in algebra, I thought the Transition 1 course was just right for me It went over basic algebra and problem-solving techniques The math books at Exeter are very different from traditional books They are compiled by the teachers, and consist of pages upon pages of word problems that lead you to find your own methods of solving problems The problems are not very instructional, they lay the information down for you, most times introducing new vocabulary, (there is an index in the back of the book), and allow you to think about the problem, and solve it any way that you can When I first used this booklet, I was a little thrown back; it was so different from everything I had done before but by the time the term was over, I had the new method down The actual math classes at Exeter were hard to get used to as well Teachers usually assign about eight problems a night, leaving you time to explore the problems and give each one some thought Then, next class, students put all the homework problems on the board The class goes over each problem; everyone shares their method and even difficulties that they ran into while solving it I think the hardest thing to get used to, is being able to openly ask questions No one wants to be wrong, I guess it is human nature, but in the world of Exeter math, you can t be afraid to ask questions You have to seize the opportunity to speak up and say I don t understand, or How did you get that answer? If you don t ask questions, you will never get the answers you need to thrive Something that my current math teacher always says is to make all your mistakes on the board, because when a test comes around, you don t want to make mistakes on paper This is so true, class time is practice time, and it s hard to get used to not feeling embarrassed after you answer problems incorrectly You need to go out on a limb and try your best If you get a problem wrong on the board, it s one new thing learned in class, not to mention, one less thing to worry about messing up on, on the next test Math at Exeter is really based on cooperation, you, your classmates, and your teacher It takes a while to get used to, but in the end, it is worth the effort Hazel Cipolle 04 iv 11 At first, I was very shy and had a hard time asking questions Sometimes other students didn t explain problems clearly Solutions to certain problems by other students are sometimes not the fastest or easiest Some students might know tricks and special techniques that aren t covered I entered my second math class of Fall Term as a ninth grader, with a feeling of dread Though I had understood the homework the night before, I looked down at my paper with a blank mind, unsure how I had done any of the problems The class sat nervously around the table until we were prompted by the teacher to put the homework on the board One boy stood up and picked up some chalk Soon others followed suit I stayed glued to my seat with the same question running through my mind, what if I get it wrong? I was convinced that everyone would make fun of me, that they would tear my work apart, that each person around that table was smarter than I was I soon found that I was the only one still seated and hurried to the board The only available problem was one I was slightly unsure of I wrote my work quickly and reclaimed my seat We reviewed the different problems, and everyone was successful I explained my work and awaited the class response My classmates agreed with the bulk of my work, though there was a question on one part They suggested different ways to find the answer and we were able to work through the problem, together I returned to my seat feeling much more confident Not only were my questions cleared up, but my classmates questions were answered as well Everyone benefited I learned one of the more important lessons about math at Exeter that day; it doesn t matter if you are right or wrong Your classmates will be supportive of you, and tolerant of your questions Chances are, if you had trouble with a problem, someone else in the class did too Another thing to keep in mind is that the teacher expects nothing more than that you try to do a problem to the best of your ability If you explain a problem that turns out to be incorrect, the teacher will not judge you harshly They understand that no one is always correct, and will not be angry or upset with you Elisabeth Ramsey 04 v 12 My background in math was a little weaker than most people s, therefore I was unsure how to do many of the problems I never thoroughly understood how to do a problem before I saw it in the book I never thought math would be a problem That is, until I came to Exeter I entered into Math T1B, clueless as to what the curriculum would be The day I bought the Math One book from the Bookstore Annex, I stared at the problems in disbelief ALL WORD PROBLEMS Why word problems? I thought I had dreaded word problems ever since I was a second grader, and on my comments it always read, Charly is a good math student, but she needs to work on word problems I was in shock I would have to learn math in an entirely new language I began to dread my B format math class My first math test at Exeter was horrible I had never seen a D on a math test Never I was upset and I felt dumb, especially since others in my class got better grades, and because my roommate was extremely good in math I cried I said I wanted to go home where things were easier But finally I realized, I was being given a challenge I had to at least try I went to my math teacher for extra help I asked questions more often (though not as much as I should have), and slowly I began to understand the problems better My grades gradually got better, by going from a D to a C+ to a B and eventually I got an A It was hard, but that is Exeter You just have to get passed that first hump, though little ones will follow As long as you don t compare yourself to others, and you ask for help when you need it, you should get used to the math curriculum I still struggle, but as long as I don t get intimidated and don t give up, I am able to bring my grades up Charly Simpson 04 The above quotes in italics were taken from a survey of new students in the spring of 2001 vi 13 1 A 5 5 square and a 3 3 square can be cut into pieces that will fit together to form a third square (a) Find the length of a side of the third square (b) In the diagram at right, mark P on segment DC so that P D = 3, then draw segments P A and P F Calculate the lengths of these segments (c) Segments P A and P F divide the squares into pieces Arrange the pieces to form the third square A 5 D B G 5 C 3 F 3 E 2 (Continuation) Change the sizes of the squares to AD = 8 and EF = 4, and redraw the diagram Where should point P be marked this time? Form the third square again 3 (Continuation) Will the preceding method always produce pieces that form a new square? If your answer is yes, prepare a written explanation If your answer is no, provide a counterexample two specific squares that can not be converted to a single square 4 Instead of walking along two sides of a rectangular field, Fran took a shortcut along the diagonal, thus saving distance equal to half the length of the longer side Find the length of the longer side of the field, given that the the length of the short side is 156 meters 5 Let A = (0, 0), B = (7, 1), C = (12, 6), and D = (5, 5) Plot these points and connect the dots to form the quadrilateral ABCD Verify that all four sides have the same length Such a figure is called equilateral 6 The main use of the Pythagorean Theorem is to find distances Originally (6 th century BC), however, it was regarded as a statement about areas Explain this interpretation 7 Two iron rails, each 50 feet long, are laid end to end with no space between them During the summer, the heat causes each rail to increase in length by 004 percent Although this is a small increase, the lack of space at the joint makes the joint buckle upward What distance upward will the joint be forced to rise? [Assume that each rail remains straight, and that the other ends of the rails are anchored] D 8 In the diagram, AEB is straight and angles A and B are right Calculate the total distance DE + EC 9 (Continuation) If AE = 20 and EB = 10 instead, would DE + EC be the same? A 10 E 20 B 10 (Continuation) You have seen that the value chosen for AE determines the value of DE + EC One also says that DE + EC is a function of AE Letting x stand for AE (and 30 x for EB), write a formula for this function Then enter this formula into your calculator, graph it, and find the value of x that produces the shortest path from D to C through E Draw an accurate picture of this path, and make a conjecture about angles AED and BEC Use your protractor to test your conjecture 15 C 10 July Phillips Exeter Academy 14 1 Two different points on the line y = 2 are each exactly 13 units from the point (7, 14) Draw a picture of this situation, and then find the coordinates of these points 2 Give an example of a point that is the same distance from (3, 0) as it is from (7, 0) Find lots of examples Describe the configuration of all such points In particular, how does this configuration relate to the two given points? 3 Verify that the hexagon formed by A = (0, 0), B = (2, 1), C = (3, 3), D = (2, 5), E = (0, 4), and F = (1, 2) is equilateral Is it also equiangular? 4 Draw a 20-by-20 square ABCD Mark P on AB so that AP = 8, Q on BC so that BQ = 5, R on CD so that CR = 8, and S on DA so that DS = 5 Find the lengths of the sides of quadrilateral P QRS Is there anything special about this quadrilateral? Explain 5 Verify that P = (1, 1) is the same distance from A = (5, 1) as it is from B = (1, 3) It is customary to say that P is equidistant from A and B Find three more points that are equidistant from A and B By the way, to find a point means to find its coordinates Can points equidistant from A and B be found in every quadrant? 6 The two-part diagram below, which shows two different dissections of the same square, was designed to help prove the Pythagorean Theorem Provide the missing details 7 Inside a 5-by-5 square, it is possible to place four triangles so that they do not overlap Show how Then explain why you can be sure that it is impossible to squeeze in a fifth triangle of the same size 8 If you were writing a geometry book, and you had to define a mathematical figure called a kite, how would you word your definition? 9 Find both points on the line y = 3 that are 10 units from (2, 3) 10 On a number line, where is 1 2 (p + q) in relation to p and q? July Phillips Exeter Academy 15 1 Some terminology: Figures that have exactly the same shape and size are called congruent Dissect the region shown at right into two congruent parts How many different ways of doing this can you find? 2 Let A = (2, 4), B = (4, 5), C = (6, 1), T = (7, 3), U = (9, 4), and V = (11, 0) Triangles ABC and T UV are specially related to each other Make calculations to clarify this statement, and write a few words to describe what you discover 3 A triangle that has two sides of equal length is called isosceles Make up an example of an isosceles triangle, one of whose vertices is (3, 5) If you can, find a triangle that does not have any horizontal or vertical sides 4 Una recently purchased two boxes of ten-inch candles one box from a discount store, and the other from an expensive boutique It so happens that the inexpensive candles last only three hours each, while the expensive candles last five hours each One evening, Una hosted a dinner party and lighted two candles one from each box at 7:30 pm During dessert, a guest noticed that one candle was twice as long as the other At what time was this observation made? 5 Let A = (1, 5) and B = (3, 1) Verify that P = (8, 4) is equidistant from A and B Find at least two more points that are equidistant from A and B Describe all such points 6 Find two points on the y-axis that are 9 units from (7, 5) 7 A lattice point is a point whose coordinates are integers Find two lattice points that are exactly 13 units apart Is is possible to find lattice points that are 15 units apart? Is it possible to form a square whose area is 18 by connecting four lattice points? Explain Some terminology: When two angles fit together to form a straight angle (a 180-degree angle, in other words), they are called supplementary angles, and either angle is the supplement of the other When an angle is the same size as its supplement (a 90-degree angle), it is called a right angle When two angles fit together to form a right angle, they are called complementary angles, and either angle is the complement of the other Two lines that form a right angle are said to be perpendicular 8 The three angles of a triangle fit together to form a straight angle In one form or another, this statement is a fundamental postulate of Euclidean geometry accepted as true, without proof Taking this for granted, then, what can be said about the two non-right angles in a right triangle? 9 Let P = (a, b), Q = (0, 0), and R = (b, a), where a and b are positive numbers Prove that angle P QR is right, by introducing two congruent right triangles into your diagram Verify that the slope of segment QP is the negative reciprocal of the slope of segment QR July Phillips Exeter Academy 16 1 Find an example of an equilateral hexagon whose sides are all 13 units long Give coordinates for all six points 2 I have been observing the motion of a bug that is crawling on my graph paper When I started watching, it was at the point (1, 2) Ten seconds later it was at (3, 5) Another ten seconds later it was at (5, 8) After another ten seconds it was at (7, 11) (a) Draw a picture that illustrates what is happening What did you assume? (b) Where was the bug 25 seconds after I started watching it? What did you assume? (c) Where was the bug 26 seconds after I started watching it? What did you assume? 3 The point on segment AB that is equidistant from A and B is called the midpoint of AB For each of the following, find coordinates for the midpoint of AB: (a) A = (1, 5) and B = (3, 7) (b) A = (m, n) and B = (k, l) 4 Write a formula for the distance from A = (1, 5) to P = (x, y), and another formula for the distance from P = (x, y) to B = (5, 2) Then write an equation that says that P is equidistant from A and B Simplify your equation to linear form This line is called the perpendicular bisector of AB Verify this by calculating two slopes and one midpoint 5 Find the slope of the line through (a) (3, 1) and (3 + 4t, 1 + 3t) (b) (m 5, n) and (5 + m, n 2) 6 Is it possible for a line ax + by = c to lack a y- intercept? To lack an x-intercept? Explain y 7 The sides of the triangle at right are formed by the graphs of 3x + 2y = 1, y = x 2, and 4x + 9y = 22 Is the triangle isosceles? How do you know? 8 Pat races at 10 miles per hour, while Kim races at 9 miles per hour When they both ran in the same longdistance race last week, Pat finished 8 minutes ahead of Kim What was the length of the race, in miles? Briefly describe your reasoning x 9 (Continuation) Assume that Pat and Kim run at p and k miles per hour, respectively, and that Pat finishes m minutes before Kim Find the length of the race, in miles 10 A bug moves linearly with constant speed across my graph paper I first notice the bug when it is at (3, 4) It reaches (9, 8) after two seconds and (15, 12) after four seconds (a) Predict the position of the bug after six seconds; after nine seconds; after t seconds (b) Is there a time when the bug is equidistant from the x- and y-axes? If so, where is it? 11 What is the relation between the lines described by the equations 20x+12y = 36 and 35x + 21y = 63? Find a third equation in the form ax + by = 90 that fits this pattern July Phillips Exeter Academy 17 1 Rewrite the equation 3x 5y = 30 in the form ax + by = 1 Are there lines whose equations cannot be rewritten in this form? 2 Consider the linear equation y = 362(x 135) (a) What is the slope of this line? (b) What is the value of y when x = 135? (c) This equation is written in point-slope form Explain the terminology (d) Use your calculator to graph this line (e) Find an equation for the line through (423, 258) that is parallel to this line (f) Describe how to use your calculator to graph a line that has slope 125 and that goes through the point (375, 864) 3 The dimensions of rectangular piece of paper ABCD are AB = 10 and BC = 9 It is folded so that corner D is matched with a point F on edge BC Given that length DE = 6, find EF, EC, F C, and the area of EF C 4 (Continuation) The lengths EF, EC, and F C are all functions of the length DE The area of triangle EF C is also a function of DE Using x to stand for DE, write formulas for these four functions 5 (Continuation) Find the value of x that maximizes the area of triangle EF C B C D A F E G H 6 The x- and y-coordinates of a point are given by the equations shown below The position of the point depends on the value assigned to t Use your graph paper to plot points corresponding to the values t = 4, 3, 2, 1, 0, 1, 2, 3, and 4 Do you recognize any patterns? Describe them { x = 2 + 2t y = 5 t 7 Plot the following points on the coordinate plane: (1, 2), (2, 5), (3, 8) Write equations, similar to those in the preceding exercise, that produce these points when t-values are assigned There is more than one correct answer 8 Given that 2x 3y = 17 and 4x+3y = 7, and without using paper, pencil, or calculator, find the value of x 9 A slope can be considered to be a rate Explain this interpretation 10 Find a and b so that ax + by = 1 has x-intercept 5 and y-intercept 8 11 Given points A = (2, 7) and B = (3, 3), find two points P that are on the perpendicular bisector of AB In each case, what can you say about segments P A and P B? 12 Explain the difference between a line that has no slope and a line whose slope is zero July Phillips Exeter Academy 18 1 Three squares are placed next to each other as shown The vertices A, B, and C are collinear Find the dimension n 2 (Continuation) Replace the lengths 4 and 7 by m and k, respectively Express k in terms of m and n 4 7 n 3 A five-foot prep casts a shadow that is 40 feet long while standing 200 feet from a streetlight How high above the ground is the lamp? 4 (Continuation) How far from the streetlight should the prep stand, in order to cast a shadow that is exactly as long as the prep is tall? 5 An airplane feet above the ground begins descending at the rate of 1500 feet per minute Assuming the plane continues at the same rate of descent, how long will it be before it is on the ground? 6 (Continuation) Graph the line y = x, using an appropriate window on your calculator With the preceding problem in mind, explain the significance of the slope of this line and its two intercepts 7 An airplane is flying at feet directly above Lincoln, Nebraska A little later the plane is flying at feet directly above Des Moines, Iowa, which is 160 miles from Lincoln Assuming a constant rate of descent, predict how far from Des Moines the airplane will be when it lands 8 In a dream, Blair is confined to a coordinate plane, moving along a line with a constant speed Blair s position at 4 am is (2, 5) and at 6 am it is (6, 3) What is Blair s position at 8:15 am when the alarm goes off? 9 Find a way to show that points A = (4, 1), B = (4, 3), and C = (8, 5) are collinear 10 Find as many ways as you can to dissect each figure at right into two congruent parts 11 Let A = (4, 2), B = (11, 6), C = (7, 13), and D = (0, 9) Show that ABCD is a square 12 Lynn takes a step, measures its length and obtains 3 feet Lynn uses this measurement in attempting to pace off a 1-mile course, but the result is 98 feet too long What is the actual length of Lynn s stride, and how could Lynn have done a more accurate job? A B C July Phillips Exeter Academy 19 1 One of the legs of a right triangle is 12 units long The other leg is b units long and the hypotenuse c units long, where b and c are both integers Find b and c Hint: Both sides of the equation c 2 b 2 = 144 can be factored 2 Is there anything wrong with the figure shown at right? 3 Show that a 9-by-16 rectangle can be transformed into a square by dissection In other words, the rectangle can be cut into pieces that can be reassembled to form the square Do it with as few pieces as possible 4 At noon one day, Corey decided to follow a straight course in a motor boat After one hour of making no turns and traveling at a steady rate, the boat was 6 miles east and 8 miles north of its point of departure What was Corey s position at two o clock? How far had Corey traveled? What was Corey s speed? 5 (Continuation) Assume that the fuel tank initially held 12 gallons, and that the boat gets 4 miles to the gallon How far did Corey get before running out of fuel? When did this happen? When radioing the Coast Guard for help, how should Corey describe the boat s position? 6 Suppose that numbers a, b, and c fit the equation a 2 + b 2 = c 2, with a = b Express c in terms of a Draw a good picture of such a triangle What can be said about its angles? 7 The Krakow airport is 3 km west and 5 km north of the city center At 1 pm, Zuza took off in a Cessna 730 Every six minutes, the plane s position changed by 9 km east and 7 km north At 2:30 pm, Zuza was flying over the town of Jozefow In relation to the center of Krakow, (a) where is Jozefow? (b) where was Zuza after t hours of flying? 8 Golf balls cost $090 each at Jerzy s Club, which has an annual $25 membership fee At Rick & Tom s sporting-goods store, the price is $135 per ball for the same brand Where you buy your golf balls depends on how many you wish to buy Explain, and illustrate your reasoning by drawing a graph 9 Draw the following segments What do they have in common? from (3, 1) to (10, 3); from (13, 08) to (83, 48); from (π, 2) to (7 + π,) 10 (Continuation) The directed segments have the same length and the same direction Each represents the vector [7, 4] The components of the vector are the numbers 7 and 4 (a) Find another example of a directed segment that represents this vector The initial point of your segment is called the tail of the vector, and the final point is called the head (b) Which of the following directed segments represents [7, 4]? from (2, 3) to (5, 1); from (3, 2) to (11, 6); from (10, 5) to (3, 1); from (7, 4) to (0, 0) July Phillips Exeter Academy 20 1 Is it possible for a positive number to exceed its reciprocal by exactly 1? One number that comes close is 8 5, because is 40 Is there a fraction that comes closer? 2 Points (x, y) described by the equations x = 1 + 2t and y = 3 + t form a line Is the point (7, 6) on this line? How about (3, 1)? How about (6, 55)? How about (11, 7)? 3 The perimeter of an isosceles right triangle is 24 cm How long are its sides? 4 The x- and y-coordinates of a point are given by the equations shown below Use your graph paper to plot points corresponding to t = 1, 0, and 2 These points should appear to be collinear Convince yourself that this is the case, and calculate the { x = 4 + 3t slope of this line The displayed equations are called parametric, and y = 1 + 2t t is called a parameter How is the slope of a line determined from its parametric equations? 5 Find parametric equations to describe the line that goes through the points A = (5, 3) and B = (7, 1) There is more than one correct answer to this question 6 Show that the triangle formed by the lines y = 2x 7, x + 2y = 16, and 3x + y = 13 is isosceles Show also that the lengths of the sides of this triangle fit the Pythagorean equation Can you identify the right angle just by looking at the equations? 7 Leaving home on a recent business trip, Kyle drove 10 miles south to reach the airport, then boarded a plane that flew a straight course 6 miles east and 3 miles north each minute What was the airspeed of the plane? After two minutes of flight, Kyle was directly above the town of Greenup How far is Greenup from Kyle s home? A little later, the plane flew over Kyle s birthplace, which is 50 miles from home When did this occur? 8 A triangle has vertices A = (1, 2), B = (3, 5), and C = (6, 1) Image triangle A B C is obtained by sliding triangle ABC 5 units to the right (in the positive x-direction, in other words) and 3 units up (in the positive y-direction) It is also customary to say that vector [5, 3] has been used to translate triangle ABC What are the coordinates of image points A, B, and C? By the way, C prime is the usual way of reading C 9 (Continuation) When vector [h, k] is used to translate triangle ABC, it is found that the image of vertex A is (3, 7) What are the images of vertices B and C? 10 It is a simple matter to divide a square into four smaller squares, and as the figure at right shows it is also possible to divide a square into seventeen smaller squares In addition to four and seventeen, what numbers of smaller squares are possible? The smaller squares can be of any size whatsoever, as long as they fit neatly together to form one large square July Phillips Exeter Academy 21 1 Caught in another nightmare, Blair is moving along the line y = 3x + 2 At midnight, Blair s position is (1, 5), the x-coordinate increasing by 4 units every hour Write parametric equations that describe Blair s position t hours after midnight What was Blair s position at 10:15 pm when the nightmare started? Find Blair s speed, in units per hour 2 The parametric equations x = 2 3t and y = 6+4t describe the position of a particle, in meters and seconds How does the particle s position change each second? each minute? What is the speed of the particle, in meters per second? Write parametric equations that describe the particle s position, using meters and minutes as units 3 Let A = (1, 2), B = (5, 1), C = (6, 3), and D = (2, 5) Let P = (1, 1) Q = (3, 2), R = (4, 0), and S = (0, 2) Use a vector to describe how quadrilateral ABCD is related to quadrilateral P QRS 4 Let K = (3, 8), L = (7, 5), and M = (4, 1) Find coordinates for the vertices of the triangle that is obtained by using the vector [2, 5] to slide triangle KLM How far does each vertex slide? 5 Find parametric equations that describe the following lines: (a) through (3, 1) and (7, 3) (b) through (7, 1) and (7, 3) A B C D P Q R S 6 Find all points on the y-axis that are twice as far from (5, 0) as they are from (1, 0) Begin by making a drawing and estimating Find all such points on the x-axis In each case, how many points did you find? How do you know that you have found them all? 7 Let A = (5, 0), B = (5, 0), and C = (2, 6); let K = (5, 2), L = (13, 4), and M = (7, 7) Verify that the length of each side of triangle ABC matches the length of a side of triangle KLM Because of this data, it is natural to regard the triangles as being in some sense equivalent It is customary to call the triangles congruent The basis used for this judgment is called the side-side-side criterion What can you say about the sizes of angles ACB and KML? What is your reasoning? What about the other angles? 8 (Continuation) Are the triangles related by a vector translation? Why or why not? 9 Let A = (2, 4), B = (4, 5), and C = (6, 1) Triangle ABC is shown at right Draw three new triangles as follows: (a) P QR has P = (11, 1), Q = (10, 1), and R = (6, 1); (b) KLM has K = (8, 10), L = (7, 8), and M = (11, 6); (c) T UV has T = (2, 6), U = (0, 5), and V = (2, 9) These triangles are not obtained from ABC by applying vector translations Instead, each of the appropriate transformations is described by one of the suggestive names reflection, rotation, or glide-reflection Decide which is which, with justification A B C y x July Phillips Exeter Academy22 1 In baseball, the bases are placed at the corners of a square whose sides are 90 feet long Home plate and second base are at opposite corners To the nearest eighth of an inch, how far is it from home plate to second base? 2 A bug is moving along the line 3x + 4y = 12 with constant speed 5 units per second The bug crosses the x-axis when t = 0 seconds It crosses the y-axis later When? Where is the bug when t = 2? when t = 1? when t = 15? What does a negative t-value mean? 3 Give the components of the vector whose length is 10 and whose direction opposes the direction of [4, 3] 4 Find parametric equations to describe the line 3x+4y = 12 Use your equations to find coordinates for the point that is three-fifths of the way from (4, 0) to (0, 3) By calculating some distances, verify that you have the correct point 5 A 9-by-12 rectangular picture is framed by a border of uniform width Given that the combined area of picture plus frame is 180 square units, find the width of the border 6 Let A = (0, 0), B = (2, 1), C = (1, 3), P = (8, 2), Q = (10, 3), and R = (5, 3) Plot these points Angles BAC and QP R should look like they are the same size Find evidence to support this conclusion 7 An equilateral quadrilateral is called a rhombus A square is a simple example of a rhombus Find a non-square rhombus whose diagonals and sides are not parallel to the rulings on your graph paper Use coordinates to describe its vertices Write a brief description of the process you used to find your example 8 Using a ruler and protractor, draw a triangle that has an 8-cm side and a 6-cm side, which make a 30-degree angle This is a side-angle-side description Cut out the figure so that you can compare triangles with your classmates Will your triangles be congruent? 9 Compare the two figures shown below Is there anything wrong with what you see? Tracy and Kelly are running laps on the indoor track at steady speeds, but in opposite directions They meet every 20 seconds It takes Tracy 45 seconds to complete each lap How many seconds does it take for each of Kelly s laps? Check your answer July Phillips Exeter Academy23 1 Instead of saying that Remy moves 3 units left and 2 units up, you can say that Remy s position is displaced by the vector [3, 2] Identify the following displacement vectors: (a) Forrest starts at (2, 3) at 1 pm, and has moved to (5, 9) by 6 am; (b) at noon, Eugene is at (3, 4); two hours earlier Eugene was at (6, 2); (c) during a single hour, a small airplane flew 40 miles north and 100 miles west 2 Kirby moves with constant speed 5 units per hour along the line y = 3 4x + 6, crossing the y-axis at midnight and the x-axis later When is the x-axis crossing made? What does it mean to say that Kirby s position is a function of time? What is Kirby s position 15 hours after midnight? What is Kirby s position t hours after midnight? 3 A bug is initially at (3, 7) Where is the bug after being displaced by vector [7, 8]? 4 With the aid of a ruler and protractor, draw a triangle that has an 8-cm side, a 6-cm side, and a 45-degree angle that is not formed by the two given sides This is a sideside-angle description Cut out the figure so that you can compare triangles with your classmates Do you expect your triangles to be congruent? 5 Plot points K = (0, 0), L = (7, 1), M = (9, 3), P = (6, 7), Q = (10, 5), and R = (1, 2) Show that the triangles KLM and RP Q are congruent Show also that neither triangle is a vector translation of the other Describe how one triangle has been transformed into the other 6 (Continuation) If two figures are congruent, then their parts correspond In other words, each part of one figure has been matched with a definite part of the other figure In the triangle P QR, which angle corresponds to angle M? Which side corresponds to KL? In general, what can be said about corresponding parts of congruent figures? How might you confirm your hunch experimentally? 7 What is the slope of the line ax + by = c? Find an equation for the line through the origin that is perpendicular to the line ax + by = c 8 A debt of $450 is to be shared equally among the members of the Outing Club When five of the members refuse to pay, the other members shares each go up by $3 How many members does the Outing Club have? 9 Choose a point P on the line 2x + 3y = 7, and draw the vector [2, 3] with its tail at P and its head at Q Confirm that the vector is perpendicular to the line What is the distance from Q to the line? Repeat the preceding, with a different choice for point P 10 Let A = (3, 2) and B = (7, 10) What is the displacement vector that moves point A onto point B? What vector moves B onto A? 11 Let M = (a, b), N = (c, d), M = (a + h, b + k), and N = (c + h, d + k) Show that segments MN and M N have the same length Explain why this could be expected July Phillips Exeter Academy24 1 The position of a bug is described by the parametric equation (x, y) = (2 12t, 1+5t) Explain why the speed of the bug is 13 cm/sec Change the equation to obtain the description of a bug moving along the same line with speed 26 cm/second 2 Given the vector [5, 12], find the following vectors: (a) same direction, twice as long (b) same direction, length 1 (c) opposite direction, length 10 (d) opposite direction, length c 3 Some terminology: When the components of the vector [5, 7] are multiplied by a given number t, the result may be written either as [5t, 7t] or as t[5, 7] This is called the scalar multiple of vector [5, 7] by the scalar t Find components for the following scalar multiples: (a) [12, 3] by scalar 5 (b) [5, 10] by scalar 5 (c) [3 4, 2 3] by scalar (d) [p, q] by scalar p q 4 Find the lengths of the following vectors: (a) [3, 4] (b) 1998 [3, 4] (c) [3, 4] (d) 2 [3, 4] (e) t[3, 4] (f) t[a, b] 5 With the aid of a ruler and protractor, cut out three non-congruent triangles, each of which has a 40-degree angle, a 60-degree angle, and an 8-cm side One of your triangles has an angle-side-angle description, while the other two have angle-angle-side descriptions What happens when you compare your triangles with those of your classmates? 6 A triangle has six principal parts three sides and three angles The SSS criterion states that three of these items (the sides) determine the other three (the angles) Are there other combinations of three parts that determine the remaining three? In other words, if the class is given three measurements with which to draw and cut out a triangle, which three measurements will guarantee that everyone s triangles will be congruent? 7 The initial position of an object is P 0 = (7, 2) Its position after being displaced by the vector t[8, 7] is P t = (7, 2) + t[8, 7] Notice that the meaning of + is to apply a vector translation to P 0 Notice also that the position is a function of t Calculate P 3, P 2, and P 2 Describe the configuration of all possible positions P t By the way, P t and P 2 are usually read P sub t and P sub two 8 Alex the geologist is in the desert, A 10 km from a long, straight road On the road, Alex s jeep can do 50 kph, but 10 desert in the desert sands, it can manage only 30 kph Alex is very thirsty, and knows P that there is a gas station 25 km down N 25 the road (from the nearest point N on the road) that has ice-cold Pepsi (a) How many minutes will it take for Alex to drive to P through the desert? (b) Would it be faster if Alex first drove to N and then used the road to P? (c) Find an even faster route for Alex to follow Is your route the fastest possible? July Phillips Exeter Academy25 1 Let A = (1, 4), B = (0, 9), C = (7, 2), and D = (6, 9) Prove that angles DAB and DCB are the same size Can anything be said about the angles ABC and ADC? 2 A puzzle: Cut out four copies of the quadrilateral ABCD formed by points A = (0, 0), B = (5, 0), C = (6, 2), and D = (0, 5) Show that it is possible to arrange these four pieces to form a square Explain why you are sure that the pieces fit exactly 3 Two of the sides of a right triangle have lengths and Find the possible lengths for the third side 4 The diagram at right shows the graph of 3x + 4y = 12 The shaded figure is a square, three of whose vertices are on the coordinate axes The fourth vertex is on the line Find (a) the x- and y-intercepts of the line; (b) the length of a side of the square 5 (Continuation) Draw a rectangle that is twice as wide as it is tall, and that fits snugly into the triangular region formed by the line 3x + 4y = 12 and the positive coordinate axes, with one corner at the origin and the opposite corner on the line Find the dimensions of this rectangle y x 6 Plot the three points P = (1, 3), Q = (5, 6), and R = (114, 108) Verify that P Q = 5, QR = 8, and P R = 13 What is special about these points? 7 Sidney calculated three distances and reported them as T U = 29, UV = 23, and T V = 54 What do you think of Sidney s data, and why? 8 Find the number that is two thirds of the way (a) from 7 to 17; (b) from m to n 9 The diagonal of a rectangle is 15 cm, and the perimeter is 38 cm What is the area? It is possible to find the answer without finding the dimensions of the rectangle try it 10 After drawing the line y = 2x 1 and marking the point A = (2, 7), Kendall is trying to decide which point on the line is closest to A The point P = (3, 5) looks promising To check that P really is the point on y = 2x 1 that is closest to A, what should Kendall do? Is P closest to A? 11 Dissect a 1-by-3 rectangle into three pieces that can be reassembled into a square 12 Let K = (2, 1) and M = (3, 4) Find coordinates for the two points that divide segment KM into three congruent segments July Phillips Exeter Academy26 1 The components of vector [24, 7] are 24 and 7 Find the components of a vector that is three fifths as long as [24, 7] 2 Let A = (5, 2) and B = (19, 9) Find coordinates for the point P between A and B that is three fifths of the way from A to B Find coordinates for the point Q between A and B that is three fifths of the way from B to A 3 Given the points K = (2, 1) and M = (3, 4), find coordinates for a point J that makes angle JKM a right angle 4 When two lines intersect, four angles are formed It is not hard to believe that the nonadjacent angles in this arrangement are congruent If you had to prove this to a skeptic, what reasons would you offer? 5 One of the legs of a right triangle is twice as long as the other, and the perimeter of the triangle is 28 Find the lengths of all three sides, to three decimal places 6 A car traveling east at 45 miles per hour passes a certain intersection at 3 pm Another car traveling north at 60 miles per hour passes the same intersection 25 minutes later To the nearest minute, figure out when the cars are exactly 40 miles apart 7 Find a point on the line y = 2x 3 that is 5 units from the x-axis 8 Find a point on the line 2x + y = 8 that is equidistant from the coordinate axes How many such points are there? 9 A line goes through the points (2, 5) and (6, 1) Let P be the point on this line that is closest to the origin Calculate the coordinates of P 10 If I were to increase the length of my stride by one inch, it would take me 60 fewer strides to cover a mile What was the length of my original stride? 11 The lines defined by P t = (4+5t, 1+2t) and Q u = (4 2u, 1+5u) intersect perpendicularly Justify this statement What are the coordinates of the point of intersection? 12 What number is exactly midway between and ? What number is exactly midway between b b 2 4ac and b + b 2 4ac? 2a 2a 13 Given that P = (1, 1), Q = (4, 3), A = (1, 2), and B = (7, k), find the value of k that makes the line AB (a) parallel to line P Q; (b) perpendicular to line P Q 14 Let A = (6, 4), B = (1, 1), C = (0, 4), and D = (7, 7) Show that the opposite sides of quadrilateral ABCD are parallel A quadrilateral that has this property is called a parallelogram July Phillips Exeter Academy

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