

Calculator Use on the ASVAB

Presented to: Defense Advisory Committee on Military Personnel Testing

Presenter: Peter Ramsberger, HumRRO

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Background

- There is pressure from the Services and other stakeholders to allow calculator use on AR and MK
 - Recruiters think this will result in greater numbers of qualified applicants
 - Applicants question why calculators are not allowed when they have used them in high school math classes
- Current policy remains that calculators are not allowed
- Primary reasons from a March 2018 Policy Paper
 - Allowing calculator use would not increase the number of eligible recruits due to the test scaling and equating requirements
 - Although allowing calculator use would give the appearance of keeping up with the latest trends and better align with college entrance exams, the ASVAB and college entrance exams serve different purposes
 - The change lacks the technical and psychometric merit necessary to enact it, and the reliability and validity of ASVAB scores would be at risk
 - The cost of allowing calculators outweighs any possible benefits given the complexity of necessary re-standardization processes

Background

- HumRRO was asked to examine this issue
 - Review test anxiety literature for relevant information
 - Obtain insight into how math is taught in high school and students' preparedness to perform hand calculations required on ASVAB
 - Evaluate calculator use on other standardized tests (e.g., ACT, SAT, NAEP)
 - Obtain insight from recruiters and applicants via focus groups
 - Assess importance of math skills and hand calculations for success in military training and on the job
 - Consolidate findings into a presentation for multiple audiences

Arithmetic Reasoning (AR) Test Blueprint

Category	Subcategory	Other Specs	Proportion of Items
Operations with Whole Numbers	One- and Two-Step Problems	Whole numbers, one two-digit number, includes single or more than one instance of a single operation	23
Operations with Rational Numbers	One-Step Problem with Fractions One-Step Problem with Decimals/Money Two-Step Problem with Fractions Two-Step problem with Decimals/Money	Calculation must involve a single/more than one instance of an operation involving fraction/decimal/money value	26
Ratio and Proportion	Whole Numbers Rational Numbers	Stem values are whole numbers, including at least one two-digit number Stem must include a fraction or decimal Calculation involves correctly interpreting a rate that is not a unit rate	17
Interest and Percentage	One- and Two-Step Problems	Stem involves percent increase/decrease of simple interest/compound interest	17
Measurement	Perimeter, Circumference Area Volume Time, Temperature	Calculate perimeter/area/volume/ time/temperature	17

Mathematics Knowledge (MK) Test Blueprint

Category	Subcategory	Other Specs	Proportion of Items
Number Theory	Common Factors Common Multiples Reciprocal Properties Primes Integers Factorial	Which of the following are common factors of Which of the following pairs of numbers has a common multiple of What is the reciprocal of The expression ___ is equal to Which of the following is a prime number Which of the following numbers is an integer Solve...	12
Numeration	Fractional Parts, Ratio, Percent, Probability Equivalent Forms (conversion) Order of Operations Exponents Logarithms Rounding Reduce/Simplify Fractions Roots/Radicals Signed Numbers Place, Value, Decimals	Which of the following fractions is closest in value to Which of the following is the same as [fraction or percent] What should be calculated [first/last/second] to solve [expression with at least five terms] What is ___ rounded to the nearest [words for place value] What factor should be used to reduce the fraction ___ to its simplest form Simplify [expression that includes roots or radicals] [expression that includes positive or negative values] What value is represented by ___ in the number ___	24

Mathematics Knowledge (MK) Test Blueprint

Category	Subcategory	Other Specs	Proportion of Items
Algebraic Operations and Equations	Substitute Given Values and Solve Solve Equation/Expression for Unknown Determine Equation and/or Solve Factoring Simplify Algebraic Expression Convert Sentence to Equation Inequities	If $x = _$, what is the value of [expression with variable x] What is the value of x if [equation with variable x] The sum of an integer cubed and $_$ is $_$. What is the integer Factor $_$ [polynomial expression] Which of the following is equivalent to $_$ Which expression represents the statement [expression in words] Solve for x [inequality with one variable]	36
Geometry and Measurement	Coordinates/Slope Pythagorean Theorem Angle Measurement Measuring Instruments Properties of Polygons Properties of Circles Perimeter Area Volume Unit Conversion	What is the slope of the line that contains the points $_$ and $_$ If a right triangle has one side that measures $_$ and one side that measures $_$, what is the measure of the hypotenuse The measure of angle B in the triangle is $_$ degrees. What is the measure of angle A Protractor illustration in stem, answer choices are angle measures Stem asks about sides or about interior/exterior angles of polygons If the sum of the diameters of circles A and B is $_$ inches, what is the diameter of circle B What is the perimeter of the figure shown What is the volume of the figure shown How many yards are there in $_$ inches	28

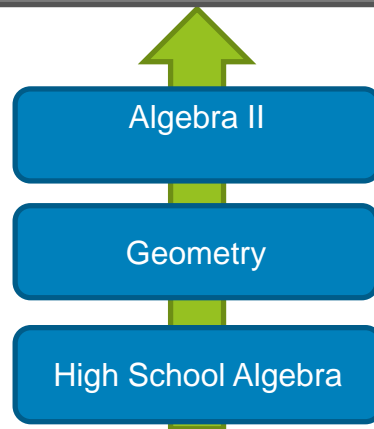
Test Anxiety Literature—Main Findings

- Calculators are widely used in education
- Racial and ethnic minorities tend to use calculators less frequently
- There is an **inverted** U-shaped function between calculator use and performance
 - Examinees at the upper and lower ends of the performance curve use them less
- Research on the impact of calculator use on performance has yielded mixed results
 - Impact may depend on a variety of factors (e.g., experience in using, types of questions, overall math ability, demographic characteristics)
- Examinees tend to have more favorable attitudes toward math/math tests when calculators are allowed
- Test anxiety can have a negative impact on performance
 - 85% of students reported experiencing at least some math anxiety
 - Not much evidence to suggest that calculators mitigate the impact of test anxiety on math test performance
 - With adaptive tests, anxiety can be mitigated by explaining how the test works

How Math is Taught—Main Findings

- Typical math sequence is Algebra I, Geometry, Algebra II.

Courses in higher-level mathematics: Pre-calculus, Calculus, Advanced Statistics, Discrete Mathematics, Advanced Quantitative Reasoning, or courses designed for career technical programs of study



- Percentage of students enrolled in each course (2009) and percentage of students whose most advanced high school mathematics credit was earned in each course (2013)

Year	No mathematics	Basic mathematics	Pre-algebra	Algebra I	Geometry	Algebra II	Pre-calculus	Calculus	Other mathematics
2009 ¹	10.3	0.7	5.4	51.3	22.1	6.3	-	-	8.5
2013 ⁴	1.4	-	2.2	5.0	10.6	22.6	19.2	14.9	24.0

How Math is Taught—Main Findings

- According to a 2015 survey of 767 2- and 4-year college instructors, less than 50% of students are adequately prepared for college math
- Approximately 39% of undergraduates reported taking a remedial math class after high school
- Over 99% of schools require or allow calculators
- 90% of schools allow calculator use on tests
- Teachers surveyed agreed that calculators should not be used until basic math skills are mastered
- Standardized test consortia policies dictate that if a student is expected to demonstrate proficiency without the use of a tool, it should not be allowed
- Our analysis suggests that non-calculator Smarter Balanced items align with ASVAB, although they involve more diverse and language-intense contexts

Question 3. If $x - y \neq 0$, then $\frac{x^2 - y^2}{x - y} =$

- A.** $x + y$
- B.** $x - y$
- C.** $x + 2y$
- D.** $2x - y$

Sample Smarter Balanced Algebraic Operations and Equations Item

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A student solved $\frac{3}{x-4} = \frac{x}{7}$ in six steps, as shown.

Step 1: $3 = \frac{x(x-4)}{7}$

Step 2: $21 = x(x-4)$

Step 3: $21 = x^2 - 4x$

Step 4: $0 = x^2 - 4x - 21$

Step 5: $0 = (x-7)(x+3)$

Step 6: $x = -3, x = 7$

Which statement is an accurate interpretation of the student's work?

- (A) The student solved the equation correctly.
- (B) The student made an error in step 2.
- (C) The student made an error in step 5.
- (D) Only $x = 7$ is a solution to the original equation.

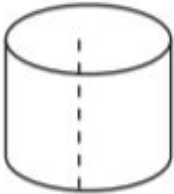
Calculator Use on Major Standardized Tests—Main Findings

- Examined four tests
 - National Assessment of Educational Progress (NAEP), ACT, SAT, GED
- ACT allows calculator use on all math items
 - ACT states that all items can be solved without a calculator and many are best done without a calculator
 - ACT’s rationale for allowing calculators for all items:
 - In recent years, there appears to be more and more reliance on calculators as a tool in schools, particularly in mathematics classrooms. ACT continued to monitor curriculum information and conducted several small research studies and surveys to determine the prevalence of calculator usage in the schools, and to examine what the likely effect of allowing calculator use would be on the types of items included on the ACT Assessment and PLAN Mathematics Tests. Based on this research, it was determined that it would be advisable to allow calculator use on the ACT Assessment and PLAN Mathematics Tests, and that this introduction should occur as soon as possible.

Calculator Use on Major Standardized Tests—Main Findings

- NAEP classifies items as calculator inactive (not required), calculator neutral (not necessary, but allowed), and calculator active (difficult to solve without)
- NAEP, SAT, and GED include calculator-allowed and non-calculator items
 - Two-thirds of NAEP items are non-calculator
 - Two-thirds of SAT items are calculator allowed
 - GED includes 46 math items, with the first 5–6 non-calculator

- Calculator Inactive

<p>Example: Calculator-Inactive Item Grade 8 Geometry: Transformation of shapes and preservation of properties</p>	<p>Source: 2005 NAEP 8M3 #4 Percent correct: 86% Calculator available</p>
<p style="text-align: center;"></p> <p>The paper tube in the figure above is to be cut along the dotted line and opened up. What will be the shape of the flattened piece of paper?</p> <p>Answer: _____</p> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-left: auto; margin-right: auto;"><p>Correct answer: Rectangle or square</p></div>	

NAEP Items

- Calculator Neutral

Example: Calculator-Neutral Item Grade 8 Algebra: Patterns, relations, and functions	Source: 2005 NAEP 8M3 #12 Percent correct: 60% Calculator available
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$1 + 3 = 4$
 $1 + 3 + 5 = 9$
 $1 + 3 + 5 + 7 = 16$
 $1 + 3 + 5 + 7 + 9 = 25$

According to the pattern suggested by the four examples above, how many consecutive odd integers are required to give a sum of 144?

A. 9
B. 12
C. 15
D. 36
E. 72

Correct answer: B

NAEP Items

- Calculator Active

Example: Calculator-Active Item Grade 12 Measurement: Measuring physical attributes	Source: 2005 NAEP 3M12 #15 Percent correct: 41% Calculator available
<p>A cat lies crouched on level ground 50 feet away from the base of a tree. The cat can see a bird's nest directly above the base of the tree. The angle of elevation from the cat to the bird's nest is 40°. To the nearest foot, how far above the base of the tree is the bird's nest?</p> <p>A. 32 B. 38 C. 42 D. 60 E. 65</p>	
<div style="border: 1px solid black; padding: 5px; display: inline-block;">Correct answer: C</div>	

SAT Items

- Calculator Inactive

If $\frac{1}{2}x + \frac{1}{3}y = 4$, what is the value of $3x + 2y$?

	1	1	
.	.	.	.
	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

Content: Heart of Algebra

SAT Items

- Calculator Active

If $-\frac{9}{5} < -3t + 1 < -\frac{7}{4}$, what is one possible value of $9t - 3$?

	1	1	
•	•	•	•
	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

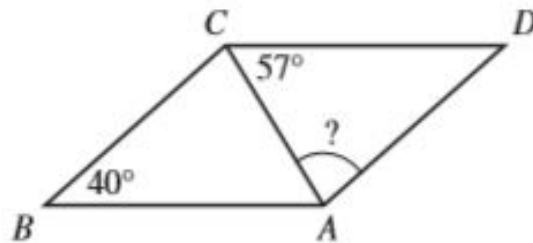
Content: Heart of Algebra

ACT Items

- Math content editor judged this to be similar to a medium difficulty MK item

In parallelogram $ABCD$ below, \overline{AC} is a diagonal, the measure of $\angle ABC$ is 40° , and the measure of $\angle ACD$ is 57° . What is the measure of $\angle CAD$?

- A. 40°
- B. 57°
- C. 77°
- D. 83°
- E. 97°



ACT Items

- Math content editor judged this to be similar to a difficult AR item

22. The length of a rectangle is 5 inches longer than the width. The perimeter of the rectangle is 40 inches. What is the width of the rectangle, in inches?
- F. 7.5
G. 8
H. 15
J. 16
K. 17.5

GED Items

- Similar to a medium difficulty MK Item

Mathematical Reasoning - Candidate Name Question 3 of 10

Answer Explanation Calculator Flag for Review

Formula Sheet Calculator Reference

Annie is planning a business meeting for her company. She has a budget of \$1,325 for renting a meeting room at a local hotel and providing lunch. She expects 26 people to attend the meeting. The cost of renting the meeting room is \$270. Which inequality shows how to find the amount, x , Annie can spend on lunch for each person?

- A. $26x + 270 \geq 1,325$
- B. $26x + 270 \leq 1,325$
- C. $270x + 26 \geq 1,325$
- D. $270x + 26 \leq 1,325$

GED Items

- Similar to a medium difficulty AR Item

Mathematical Reasoning - Candidate Name Question 1 of 10

Answer Explanation Calculator Flag for Review

[Formula Sheet](#) [Calculator Reference](#)

A painter rented a wallpaper steamer at 9 a.m. and returned it at 4 p.m. He paid a total of \$28.84. What was the rental cost per hour?

- A. \$2.43
- B. \$3.61
- C. \$4.12
- D. \$5.77

Calculator Use on Major Standardized Tests—Main Findings

- ASVAB math content editor reviewed 134 released items
 - SAT 34, ACT 33, GED 33, and NAEP 34
 - Asked her to (a) map items to AR/MK, (b) compare difficulty level, and (c) judge whether a calculator would be needed to answer
- Most items were judged to be comparable to ASVAB, with far more mapping to MK
 - 28 AR
 - 86 MK
 - 2 either/both
- 18 items judged to not map to AR/MK
 - 6 calculator inactive
 - 12 calculator allowed

Calculator Use on Major Standardized Tests—Main Findings

- In terms of difficulty, the math content editor rated most of the items as being of medium difficulty by ASVAB standards

Test Platform	Difficulty	
SAT	Easy	2
	Medium	29
	Difficult	1
ACT	Easy	1
	Medium	24
	Difficult	5
NAEP	Easy	10
	Medium	14
	Difficult	6
GED	Easy	14
	Medium	17
	Difficult	2

- In the math content editor's judgment, only 2 items (1 NAEP, 1 GED) fell in the calculator-needed category.
 - 60 were judged to be calculator neutral (won't hurt, won't help)
 - In 59 cases, a calculator was judged to be not necessary but potentially helpful

Recruiters and Applicants

- Developed interview/focus group protocols
- Examining ways to conduct virtually
- Surveyed recruiters attending Career Exploration Program Post-Test Interpretation training in Knoxville (n = 30)
 - Also conducted focus group with those willing to participate (n = 12)
- Survey results
 - Applicants occasionally (n = 10) or frequently (n = 16) ask if they can use a calculator when taking the ASVAB
 - The most common applicant reactions to not being able to use a calculator are to question why (n = 10), express concern about impact on performance (n = 9), or to just accept it (n = 7)
 - When asked their opinion about whether calculators should be allowed, 14 recruiters had no strong opinion either way, 11 felt they should be allowed, 4 agreed with current policy, and 2 expressed mixed feelings

Recruiters and Applicants

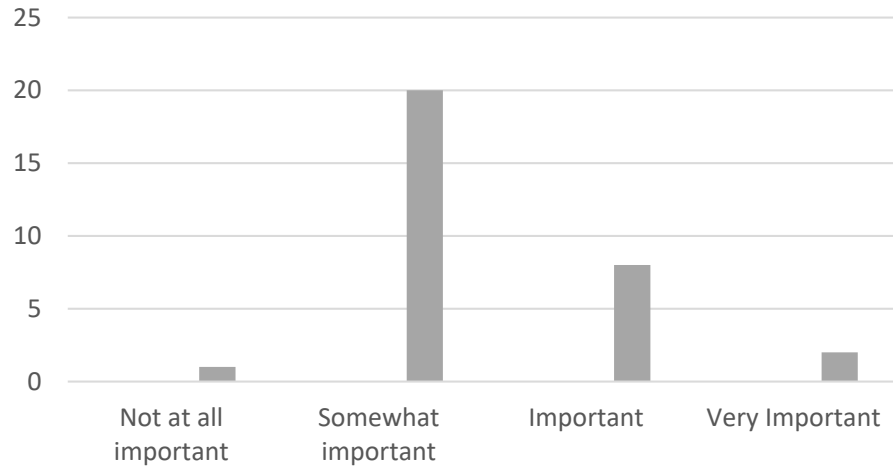
- Some focus group comments
 - Many applicants are most concerned about the math portions of ASVAB
 - Not allowing calculators has an impact on their self-confidence going into the test
 - Some jobs require use of a calculator, so this skill may be worth assessing
 - As a recruiter, they would like to see calculators allowed, but also recognize that math skills are required for many jobs and tools are not always available
 - Calculators are allowed in schools, so why not on the ASVAB?

Importance of Math Skills for Military Jobs—Main Findings

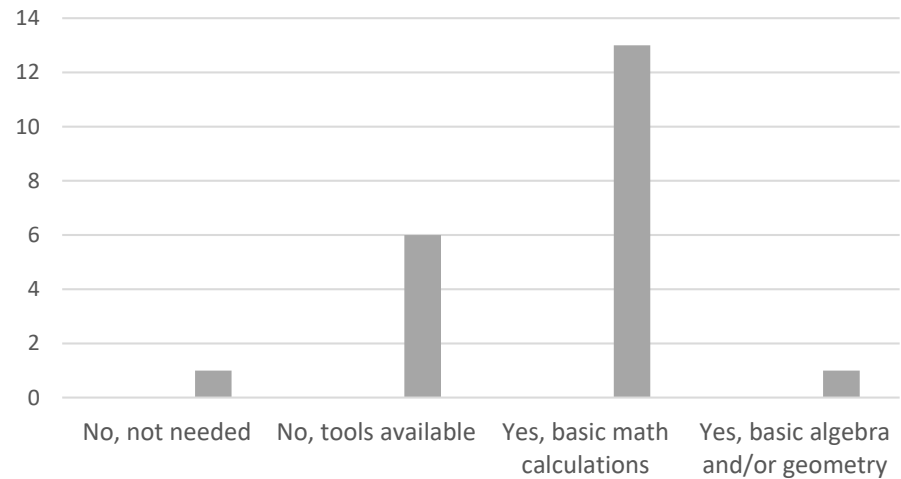
- Goal is to survey SMEs in selected career fields across Services to obtain judgments about the importance of math skills and the likely need to employ those skills in training or on the job without the aid of a calculator
 - Selected jobs based on
 - number of incumbents
 - importance of math skills based on existing data
 - mix of jobs with AR/MK in their selection composites
- Developed online survey that asked both general and occupation-specific questions about calculator use
- At this point there are 25 respondents
 - 13 Army, 4 Navy, 2 Marine Corps, 3 unknown
 - 9 Communications Equipment Operators
 - 4 Information Systems Technicians
 - 2 Artillery
 - 1 each EMT, Construction, Security, Electronics Tech Nuclear

Importance of Math Skills for Military Jobs—Main Findings

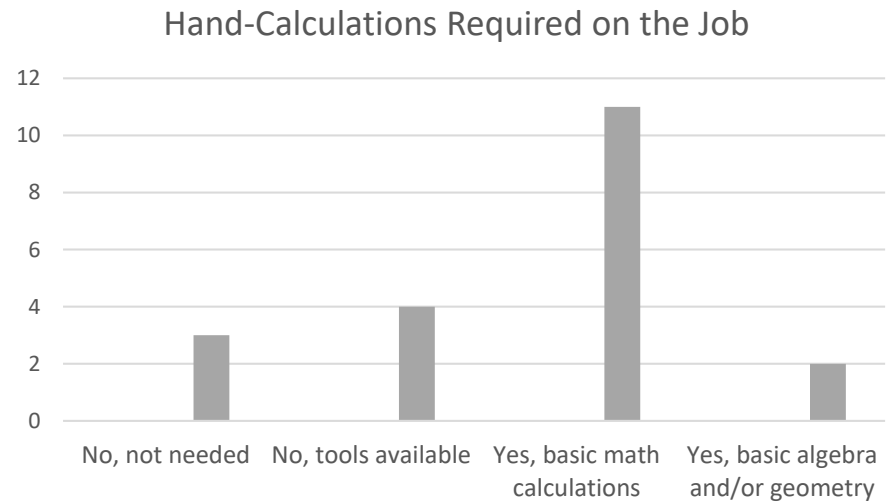
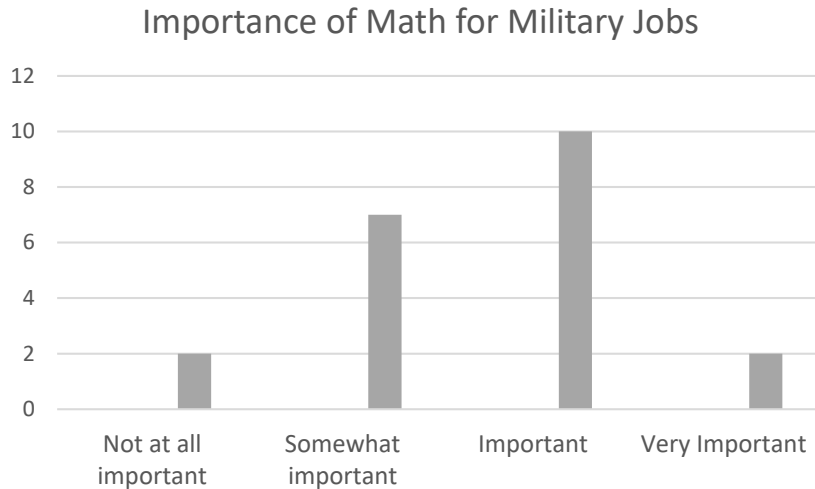
Importance of Math in Military Training



Hand-Calculations Required in Training



Importance of Math Skills for Military Jobs—Main Findings



What would a change in the policy entail?

- Develop specifications for new item development
 - Review existing items
 - Field test new items
 - Conduct test scaling and equating
 - Develop norms
 - Evaluate test fairness
 - Evaluate and establish new testing times
 - Develop and implement applicable software updates
 - Evaluate test reliability and validity
-
- Estimated time and cost—Up to 10 years and 30 million dollars

Other Considerations

- Other standardized tests provide specific guidelines for the types of calculators allowed
 - SAT lists 82 allowed calculators
 - ACT lists calculators that are not allowed and/or functions that must be disabled
 - NAEP provides calculators to 4th- and 8th-grade students and has restrictions on the types 12th-grade students can use
 - GED allows one type of calculator and provides one embedded in the test software
- Issue would need to be addressed by
 - Supplying all MEPS and MET sites with calculators, or
 - Require test administrators to screen those brought by applicants, or
 - Embed calculator in CAT software
- How would policy be adapted to APT and PiCAT?
- Would be a challenge to standardize in the CEP

Conclusions

- Calculators are widely used in high school math instruction and testing
- Most other large-scale standardized tests allow calculators on some portion of their math assessments
 - Based on whether students should have the knowledge and ability to perform the required calculations without the use of a tool
- Although there is evidence that a significant portion of students experience math test anxiety, there is no strong evidence that calculators serve to alleviate it
- Allowing calculators on ASVAB for some or all questions would require a substantial investment in item development, field testing, scaling and equating, and possibly norming
- A policy change would also introduce significant logistical challenges, particularly for the CEP
- Some evidence that performing hand-calculations is important for at least some military jobs
 - Seeking more input from SMEs

Backup Slide—Comparison of Test Blueprints

ASVAB Content		GED content	SAT Content	ACT Content	NAEP Content
Arithmetic Reasoning	Math Knowledge				
A. Operations with whole numbers. A1 One-step problems. A2 Two (or more) step problems.	A. Number theory. A1 Common Factors. A2 Common multiples. A3 Reciprocal. A4 Properties. A5 Primes. A6 Integers. A7 Factorial.	Quantitative problems in rational numbers 1. Demonstrating fluency with operations using rational numbers 2. Using rational numbers to formulate solutions to problems set within real-world contexts 3. Solving problems with rational numbers that involve proportionality	Heart of Algebra: 1. Analyzing and fluently solving linear equations and systems of linear equations. 2. Creating linear equations and inequalities to represent relationships between quantities and to solve problems 3. Understanding and using the relationship between linear equations and inequalities and their graphs to solve problems.	Preparing for Higher Mathematics: Numbers and Quantity: Demonstrate knowledge of real and complex number systems. Reason with numerical quantities in many forms, including expressions with integer and rational exponents, and vectors and matrices. Algebra: Solve, graph, and model multiple types of expressions. Interpret and use many kinds of equations, such as linear, polynomial, radical, and exponential relationships. Find solutions to systems of equations, even when represented by a simple matrix equation, and apply results to real-world contexts. Functions: Demonstrate knowledge of function: definition, notation, representation, and application. Use functions including linear, radical, piecewise, polynomial, and logarithmic. Manipulate and translate functions, as well as interpret and use important features of graphs. Geometry: Apply your knowledge of shapes and solids, using concepts such as congruence and similarity relationships or surface area and volume measurements. Apply your understanding to composite objects, and solve for missing values in triangles, circles, and other figures. Use trigonometric ratios and equations of conic sections.	Number and properties and operations. 1. Number sense. 2. Estimation. 3. Number operations. 4. Ratios and proportional reasoning. 5. Properties of number and operations. 6. Mathematical reasoning using numbers.
B. Operations with rational numbers. B1 One-step problems with rational numbers. B2 One-step problems with decimals or money. B3 Two-step problems with fractions. B4 Two-step problems with decimals/money	B. Numeration. B1 Fractional parts, ratio, percent, probability. B2 Equivalent forms (conversion). B3 Order of operations. B4 exponents, logarithms. B5 Rounding. B6 Reduce or simplify fractions. B7 Roots and radicals. B8 Signed numbers. B9 Place value, decimals.	Quantitative problems in measurement 1. Engaging with geometric figures in a variety of graphic presentations. 2. Engaging with descriptive statistics in a variety of graphic presentations 3. Using formulas or decomposition to calculate perimeter, area, surface area, and volume of figures. 4 Using descriptive statistics to summarize and compare data sets and understand. 5. concepts relating to basic theoretical probability.	Problem solving and data analysis. 1. Creating and analyzing relationships using ratios, proportional relationships, percentages, and units. 2. Representing and analyzing quantitative data. 3. Finding and applying probabilities in context		Measurement. 1. Measuring physical attributes. 2. Systems of measurement. 3. Measurement in triangles.
C. Ratio & Proportion. C1 Whole numbers. C2 Rational numbers.	C. Algebraic operations & equations. C1 Substitute given values and solve. C2 Solve equation/expression for unknown. C3 Determine equation &/or solve. C4 Factoring. C5 Simplify algebraic expressions. C6 Convert sentence to equation. C7 Inequalities.				Geometry. 1. Dimension and shape. 2. Transformation of shapes and preservation of properties 3. Relationships between geometric figures. 4. Position, direction, and coordinate geometry. 5. Mathematical reasoning in geometry
D. Interest & Percentage. D1 One-step problems. D2 Two-step problems		Linear equations and expressions. 1. Writing linear mathematical expressions and equations that correspond to given situations. 2. Evaluating the expressions for specific values of the variable. 3. Solving linear equations, inequalities, and systems of linear equations and finding the equation of a line with varying criteria.	Passport to Advanced Math: 1. Identifying and creating equivalent algebraic expressions. 2. Creating, analyzing, and fluently solving quadratic and other nonlinear equations. 3. Creating, using, and graphing exponential, quadratic, and other nonlinear functions.	Integrating Essential Skills: This category focuses on measuring how well you can synthesize and apply your understandings and skills to solve more complex problems. The questions ask you to address concepts such as rates and percentages; proportional relationships; area, surface area, and volume; average and median; and expressing numbers in different ways. Solve non-routine problems that involve combining skills in chains of steps; applying skills in varied contexts; understanding connections; and demonstrating fluency	Data analysis, Statistics, and Probability. 1. Data representation. 2. Characteristics of data sets. 3. Experiments and samples. 4. Probability. 5. Mathematical reasoning with data.
E. Measurement. E1 Perimeter, circumference. E2 Area. E3 Volume. E4 Time, temperature.	D. Geometry & Measurement. D1 Coordinates/slope. D2 Pythagorean Theorem. D3 Angle measurement. D4 Measuring instruments. D5 Properties of polygons. D6 Properties of a circle. D7 Perimeter. D8 Area. D9 volume. D10 Unit conversion	Function concepts and nonlinear expressions and equations. 1. Understanding and applying the concept of a function. 2. Using function notation. 3. Translating a variety of representations of a function, including tables and equations. 4. Solving quadratic equations. 5. Interpreting key features of both linear and nonlinear functions	Additional Topics in Math 1. Solving problems related to area and volume. 2. "Applying definitions and theorems related to lines, angles, triangles, and circles. 3. "Working with right triangles, the unit circle, and trigonometric functions.	Modeling: This category represents all questions that involve producing, interpreting, understanding, evaluating, and improving models. Each question is also counted in other appropriate reporting categories above. This category is an overall measure of how well you use modeling skills across mathematical topics.	Algebra. 1. Patterns, relations, and functions. 2. Algebraic representations. 3. Variables, expressions, and operations. 4. Equations and inequalities. 5. Mathematical reasoning in algebra.