Developing Algebra Concepts through Applications Related to NASA's Space Exploration Program

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Abstract

The United States' National Aeronautics and Space Administration [NASA] has a new focus for manned space travel to go beyond Earth's orbit for purposes of human exploration and scientific discovery. This emphasis on the Earth, Moon, Mars and beyond opens new opportunities for mathematical applications. It is essential that students in schools are exposed to these ideas so that they may develop an appreciation for how mathematics is connected to space travel. The algebra-related problems that are the focus of this workshop provide authentic situations developed to provide conceptual and intuitive meaning for applications of algebraic concepts and skills. These tasks emphasize real-world and contextualized problems, focus on using algebraic principles to create mathematical models, and require the use of algebraic and mathematical procedures and processes to solve the problems. Problems are specifically designed to emphasize the effective and appropriate use of technology as a problem solving tool. The connection between and among mathematical ideas and to real-world situations creates a rich context for the development of algebraic thinking.

Background

Algebra is considered a gateway course in that it provides a foundation essential for success in future secondary and college level mathematics courses. One of the challenges in the teaching of algebra is to reconceptualize the subject so that it has relevance to students and in a way that assists students in perceiving that relevance (Stacey, Chick & Kendall, 2004). Problems that provide a connection to real world situations and build an understanding of the symbolic and algorithmic processes required to solve these problems offers one component to address this challenge. NCTM (2000) stresses that algebra encompasses the study of relationships among quantities, the use of symbols, the modeling of phenomena, and contexts of change. Technology and its potential to work with applications where visualizing and problem solving are highlighted also offers promise in making algebra more relevant. The tasks developed within the context of NASA's space exploration problems were designed with these ideas in mind.

Algebraic thinking has become a popularized phrase that communicates the need for algebra to move beyond an emphasis on memorizing procedures to deductive and inductive thinking about applying algebra. Kriegler (2004) asserts that algebraic thinking involves mathematical thinking tools and informal algebraic ideas. Mathematical thinking tools include problem solving, representation skills, and reasoning skills. Informal algebraic ideas involve computational strategies as well as work with ratio and proportion, working with variables, symbolic representations and manipulation of symbols using conventions and procedures, and algebra as a tool for modeling real-world contexts and making generalizations. Likewise, Driscoll (1999) proposes that the types of questions teachers engage students in are critical to the development of these algebraic habits of mind. Teachers should engage students with questions that build on arithmetic skills, support development of number sense, operation sense in working with number systems, generalization of functional relationships, how and when to engage in symbolic representation and manipulation, and helping students understand and use multiple representations. Tasks that are open-ended and engage students in representing real-world phenomena in algebraic terms in order to arrive a plausible solutions encompasses the foundation of these ideas. Such tasks as the NASA related algebra problems further connect two primary difficulties students experience in solving word problems: comprehension problems related to creating representations of situation-based problems and solution phase problems related to transforming quantitative relationships to arrive at a solution (Koedinger & Nathan, 2004).

Problem Development

Each problem was designed to emphasize a mathematical connection to NASA's space exploration program focusing on algebra concepts as articulated by NCTM (2000). Problem development began with research into the activities of NASA where potential algebra applications were likely. The conceptualization of the problem situation was followed by contextualizing the problem within the skills and concepts relevant for students study algebra, algebra II or pre-algebra in secondary and middle school settings. All problems encourage the effective use of technology. The problem was developed and reviewed by multiple experts to assure accuracy, relevancy, and pedagogical appropriateness. Reviewers included scientists and engineers at NASA particularly those at Langley Research Center in Hampton, VA. Problems were further reviewed by university faculty and field-tested with high school students. Algebra problems related to NASA's work will initially be available through the Texas Instrument Activities Exchange website (search by topic – algebra- or NASA as keywords) [http://education.ti.com/educationportal/sites/US/sectionHome/classroomactivities.html]. All problems include an educator's section and student worksheets.

Example Activity: Reviewing Area: Next Generation Spacecraft

Background Information for Problem

NASA's new spacecraft, the Crew Exploration Vehicle (CEV), is the key to making the Vision for Space Exploration a reality. The CEV will use an improved, larger, blunt-body capsule, much like the shape of the Apollo spacecraft. With an outside diameter of approximately five meters, the spacecraft will have more than three times the volume of the Apollo capsules. This design will shorten development time, reduce reentry loads, increase landing stability and permit safe travel for up to six crewmembers.

The CEV will be able to support landings anywhere on the moon's surface and sustain itself for six months in lunar orbit. Reusability is another important feature since the number of flights per vehicle is a key cost driver.

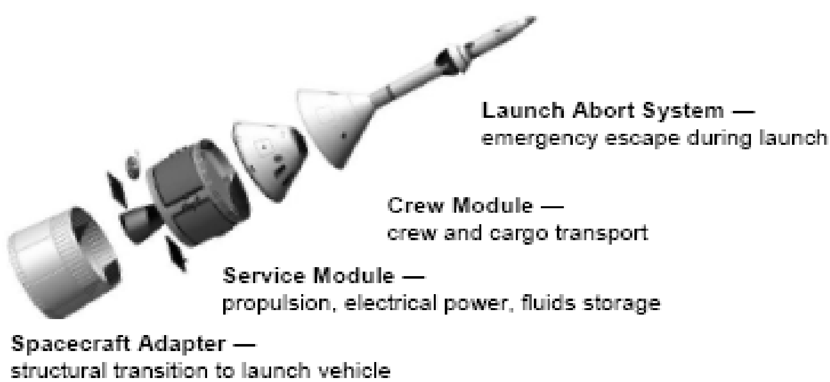


Figure 1: Components of the Orion Spacecraft (NASA Concept)

During the CEV planning, NASA studied several different kinds of entry vehicles and rockets. NASA didn't set out to make this vehicle identical to Apollo, though several Apollo era researchers were consulted. Ultimately, this design was found to meet the requirements while being the most effective within the safety goals. NASA will launch as early as possible, but no later than 2014. This date is budget driven. Figure 1 shows the components of the CEV. For more information about Orion and the Vision for Space Exploration, visit www.nasa.gov. Figure 1 shows components of the Orion spacecraft and Figure 2 shows the crew module

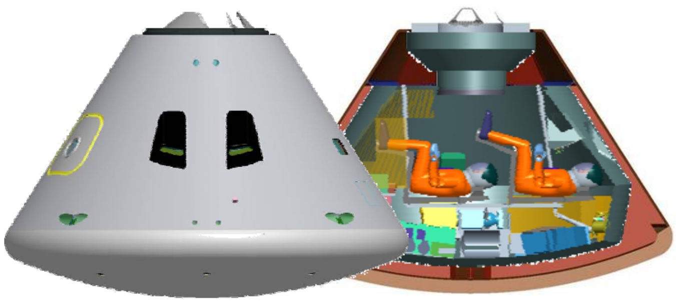


Figure 2. Cross-section of crew module (NASA concept).

Instructional Objectives

Students will:

decompose a larger geometric shape into smaller parts.

use area formulas for various geometric figures.

estimate the area of a complex geometric figure using decomposition methods.

NCTM Standards

Number and Operations

Develop and use strategies to estimate the results of rational-number computations and judge the reasonableness of the results.

Algebra standards

Model problem situations with objects and use representations such as graphs, tables, and equations to draw conclusions.

Model and solve contextualized problems using various representations, such as graphs, tables, and equations.

Geometry standards

Recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life.

Measurement standards

Understand both metric and customary systems of measurement.

Understand relationships among units and convert from one unit to another within the same system.

Understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, and volume.

Select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision.

Problem solving standards

Solve problems that arise in mathematics and in other contexts.

Apply and adapt a variety of appropriate strategies to solve problems.

Monitor and reflect on the process of mathematical problem solving.

Communication standards

Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.

Use the language of mathematics to express mathematical ideas precisely.

Connections

Recognize and apply mathematics in contexts outside of mathematics

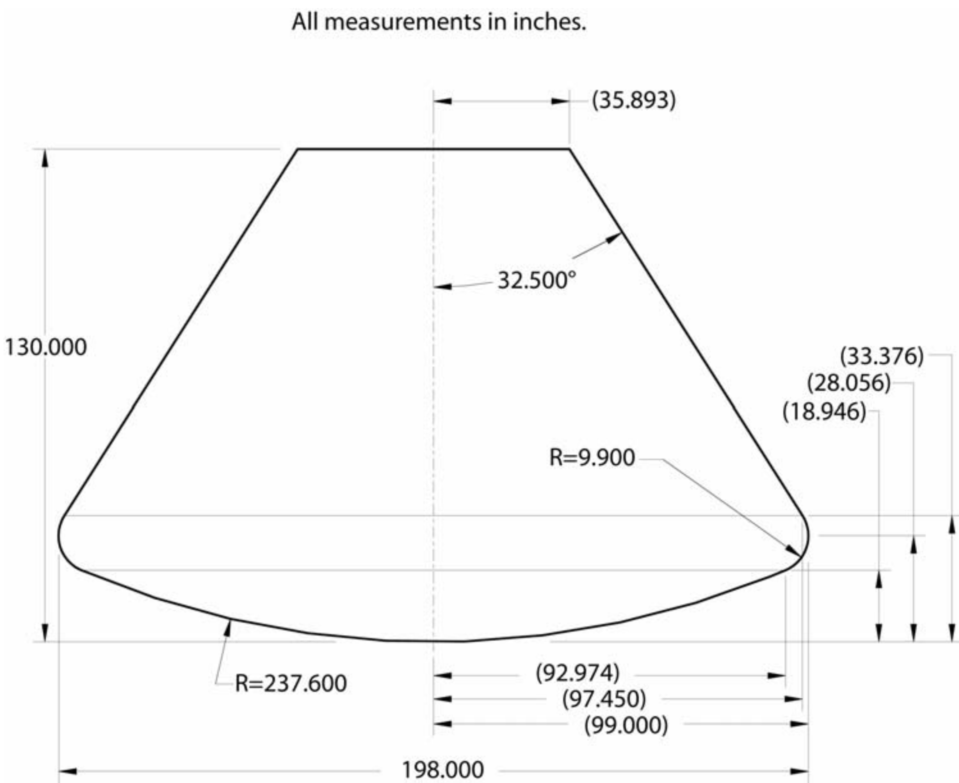
Representation

Use representations to model and interpret physical, social, and mathematical phenomena.

Problem

Use the sample Computer Aided Design (CAD) drawing provided on the next page to answer the following questions.

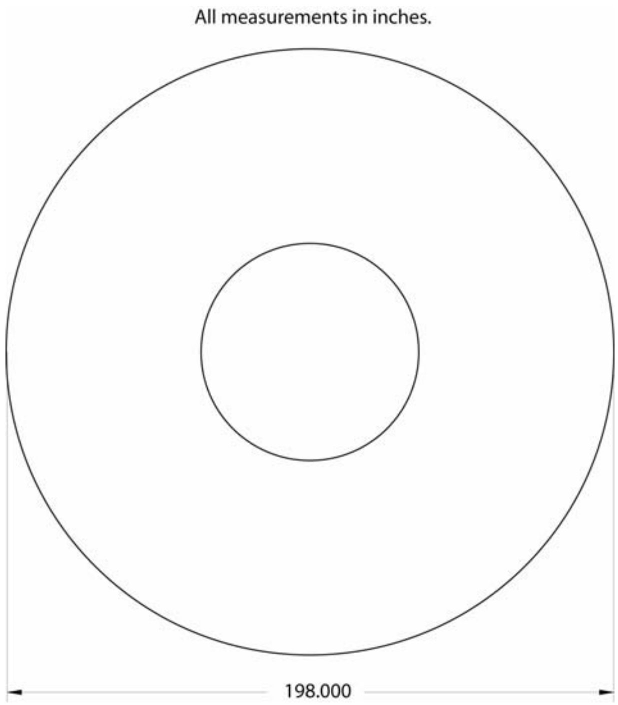
1. To get a sense of the space inside the Crew Module, find the area, in square feet (ft^2), for the largest vertical cross-section. If necessary, show how you would decompose or break the figure into smaller parts to estimate the total vertical area. Use a calculator to evaluate the formulas. Record your information in the table provided. Round your answer to three significant figures.



2. If the actual largest vertical cross-sectional area of the Crew Module is 125.507 ft^2, how far off was your estimate? Express your answer in terms of a percent (percent error). Round your answer to the nearest percent.

3. Find the area, in square feet (ft^2), for the largest horizontal cross-section. If necessary, show how you would decompose or break the figure into smaller parts to estimate the total horizontal

area. Use a calculator to evaluate the formulas. Record your information in the table provided. Round your answer to three significant figures.



4. How many crew modules do you think would fit in your classroom? Explain your answer.

Solutions

The Educator's guide presents a detailed solution, including alternate approaches to solving the problem. All materials are available via the Texas Instruments website.

References

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