PROPULSION TEST
Teaching Guidelines

Summary: Students analyze the vertical and horizontal components of the forces required to restrain a rocket during a propulsion test.

Subject: Physics

Topics: Forces, Resolution of Vectors

Grades: 11-12

Concepts

- Vector

Procedure

Prepare for presentation the Futures Channel movie, *Ares: Testing Rockets*. Tell students that they will be watching a movie about rockets, and that, as they watch, you want them to think about this question:

What are some things that would be measured in the tests described in this movie?

Play the movie, *Ares: Testing Rockets*, all the way through. Accept some answers to the prompt and guide the discussion to focus on the need to measure not just the amount of force being applied by the propulsion system, but also the exact direction of the force. Review the concept of vectors as needed.

Distribute the handout and have students work on it individually or in teams. Circulate as they do so and facilitate as needed.

Answers:

1) If the cables were not spaced evenly, it would be quite difficult to ensure that, during the test, the forces being applied through the cables to hold the rocket down were balanced so as to keep the rocket from tipping. Spacing the cables exactly symmetrically makes it easier to ensure that the horizontal components of those restraining forces are exactly balanced.

2) The thrust is the sum of the vertical components of the forces being applied by the cables, thus the vertical component of force applied by each cable is ¼ of the total thrust, or 900,000 pounds.

3) Without knowing the angles at which the cables are attached, it is impossible to resolve the forces being applied into horizontal and vertical components, and thus the rocket thrust cannot be calculated.

4) The horizontal component of force is tan(10º) x (vertical component) = 158,694 pounds of force.

5) Total force is (vertical component)÷cos(10º) = 913,883 pounds.

6) Not practical—no cables are strong enough to withstand a force of nearly 1,000,000 pounds. Even if there were, the building itself could not withstand the concentrated horizontal forces pulling the walls inward.

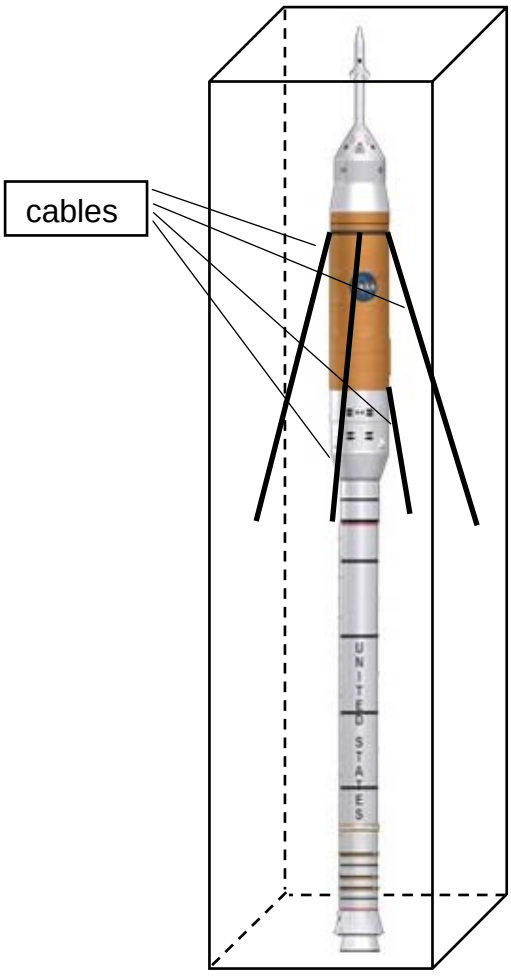
7) Attaching the cable higher would increase the angle and therefore the horizontal component of the force being applied by the cables. This means there is even greater force pulling the walls of the structure inward.

   Calculation: If the angle between the cable and wall were 45 degrees, which has a tangent of 0.5, each cable would be pulling the wall of the structure inward with a force of ¼ x 0.5 x 3,600,000 = 450,000 pounds of force.

Propulsion Test

When engineers are looking for solutions to problems, they will often develop highly simplified models to help them better understand aspects of the problem they are trying to solve. The diagram below presents an example of this: a simplified model of how a propulsion test might be carried out in a vertical structure. Although no one would propose that rockets be tested in this way, a model such as this can be analyzed to improve one's understanding of the forces involved.

In this diagram, the rocket to be tested is attached to the walls of the structure by four cables, spaced equally around its circumference. Use the diagram as the basis for your analysis of this situation as you answer the questions on the next page.



1) Do you think it would be important that the cables be spaced evenly around the rocket—that is, with each cable exactly ¼ of the way around the circumference of the rocket body, and that each cable be exactly the same length and be attached to the rocket at exactly the same angle? Explain your answer.

2) The rocket will produce a total amount of thrust of around 3.6 million pounds. What is the vertical restraining force that would be exerted by each of the four cables to hold the rocket in place? Explain your answer.

3) Can you also determine the horizontal force that would be being applied by each cable to the wall of the structure? Explain your answer.

4) Suppose that in the test described above, the angle between the cables and the vertical walls of the test structure is known to be exactly 10º. Now can you determine the horizontal component of the force? What is it?

5) If the angle is 10º, what is the total force that would be exerted by the cable?

6) Do you think this is a feasible method of propulsion testing? Explain your answer.

7) Would it help to have the cables attached higher on the structure, so that the angle is greater? Explain your answer, with calculations to support your explanation.