LTA 2

NASA - AMATYC - NSF
Project Coalition

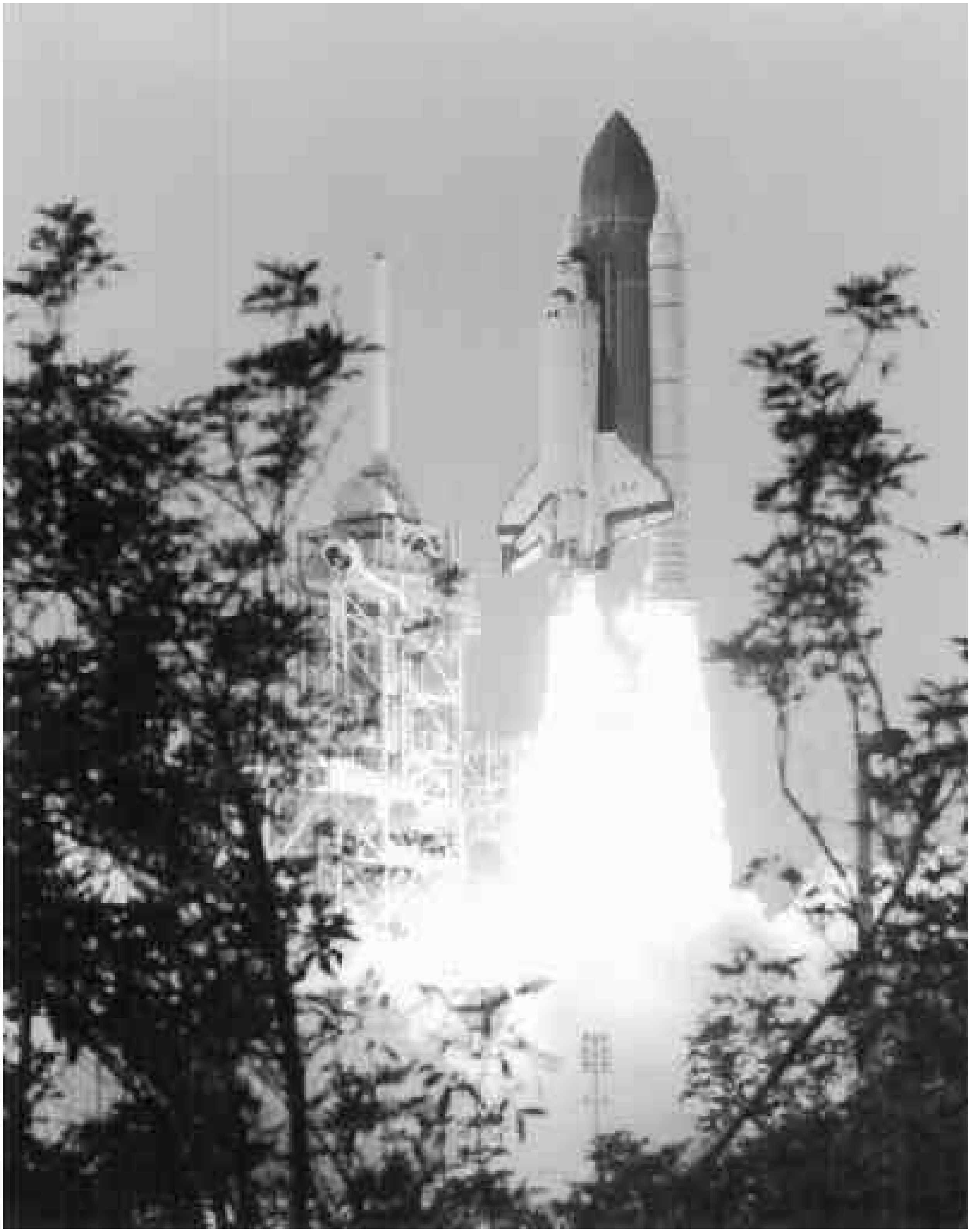
Kennedy Space Center

NASA Aquatics Lab

Mathematics for Engineering Technology

Industrial and Management
Civil

Capital Community-Technical College



The Space Shuttle Columbia hurtles skyward from Launch Pad 39B.

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NASA Aquatics Lab

Mathematics for
Industrial and Management Engineering Technology
Civil Engineering Technology

Ed Chandler - AMATYC Writing Team Member
Scottsdale Community College, Scottsdale, **Arizona**

Ed Chandler has taught at three colleges within the Maricopa County Community College Districts in Arizona since 1969 and is a past-president of ArizMATYC. He has twice been named Innovator of the Year at his college and has co-authored two computer laboratory books.

Jerry Keepers - AMATYC Writing Team Member
University of Wisconsin Center - Fox Valley, Menasha, **Wisconsin**

Jerry Keepers taught at the University of Wisconsin-Fox Valley from 1969 to 1998. He is currently teaching at Potomac State College, West Virginia. Jerry has received several degrees in both mathematics and physics. His Doctoral Thesis was titled “The Effect of a Computer Algebra System on the Development of Student Understanding of the Function Concept”.

Renee’ Ponik - NASA Scientist/Engineer
Kennedy Space Center, **Florida**

Renee’ Ponik served as Construction & Design Management Engineer in performance of functions relative to design, procurement, fabrication, construction, installation, and acceptance of complete multimillion dollar construction projects. She has worked for NASA since 1994 and has assisted in the administration of the chemical analysis lab. Renee’ planned and integrated overall repair depot certification and budget requirements, including financial, test and support equipment, training, documentation, and facility requirements.

Project Grant Team

John S. Pazdar
Project Director
Capital Comm-Tech College
Hartford, Connecticut

Peter A. Wursthorn
Principal Investigator
Capital Comm-Tech College
Hartford, Connecticut

Patricia L. Hirschy
Principal Investigator
Asnuntuck Comm-Tech College
Enfield, Connecticut

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NASA Aquatics Lab

Background Information

Governments and industries from around the world buy Shuttle space so that scientists can carry out experiments in a weightless environment. French and German scientists purchased space aboard the Shuttle Columbia for an August 1997 launch. Their experiment studied the effects of weightlessness on fish and snails. When in orbit aboard a Shuttle craft, the animals were contained in a flexible spherical aquarium. Due to weightlessness, air formed in a pocket at the center of the aquarium.

An aquatics lab was built at Kennedy Space Center to perform preliminary experiments in preparation for the launch. Unused office space on the second floor of an existing building was modified as shown on the floor plan that follows. The plan shows a number of racks of aquaria of different sizes which were distributed as shown in the plan. However, when NASA designers inspected the lab as equipment was being installed, there was an extra water tank, cylindrical in shape, 4 feet in diameter and 6 feet high, located along the outside wall at point **A** on the floor plan.

The purpose of the extra tank is to cool outside water before it is introduced into the tanks and to provide a source of “settled” water from which water could be drawn for the aquaria and related experiments. Unfortunately, the tank capacity was far too large given the strength of the reinforced concrete floor on which it was standing. A full tank might be too heavy and could cause the floor to collapse.

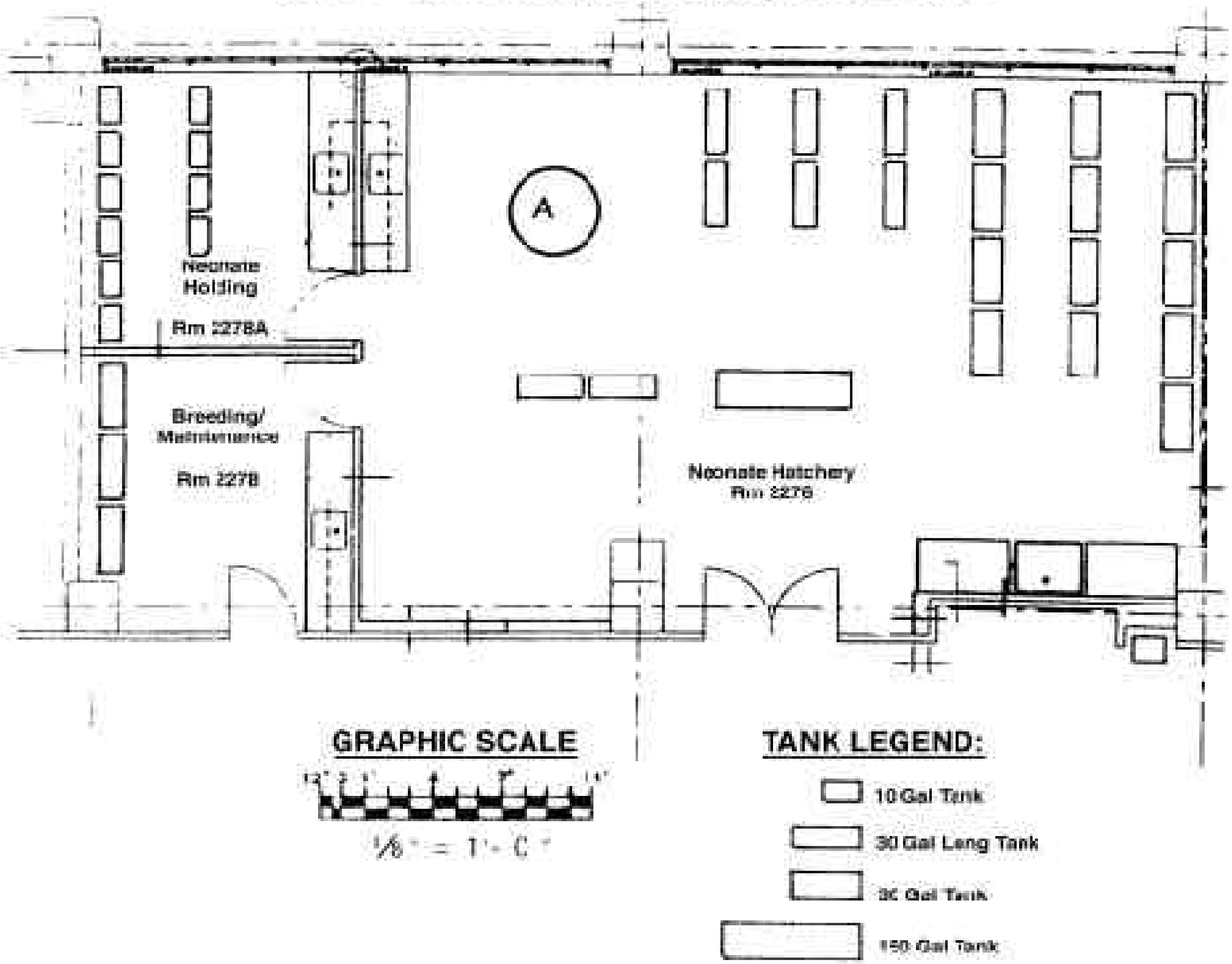
Student Task

The German and French scientists need help to determine safe limits for the amount of water allowed in the extra tank. You are to study and analyze the situation for them and then provide them with alternatives so that they can choose the best solution for their circumstances. Answer the questions which follow and provide a written summary of your results.

Technical Information

Water needed to be easily drained from the tank through a spout located at the bottom of the tank, so the tank was placed on a circular pallet as shown in Figure 1. The diameter of the pallet can vary as necessary. The pallet is about 4 inches thick, and it is sufficiently strong to support the concentrated load (weight) of the tank in a manner which justifies the assumption that the entire load of the tank of water is uniformly distributed on the floor under the pallet. The maximum allowable distributed load is 200 pounds per square foot. Water weighs 8.34 pounds per gallon or 62.4 pounds per cubic foot. The combined weight of the fiberglass tank and pallet are negligible compared to the weight of the water contained in the tank. Thus, the weight of the tank and pallet will be ignored.

Floor Plan for NASA Aquatics Lab



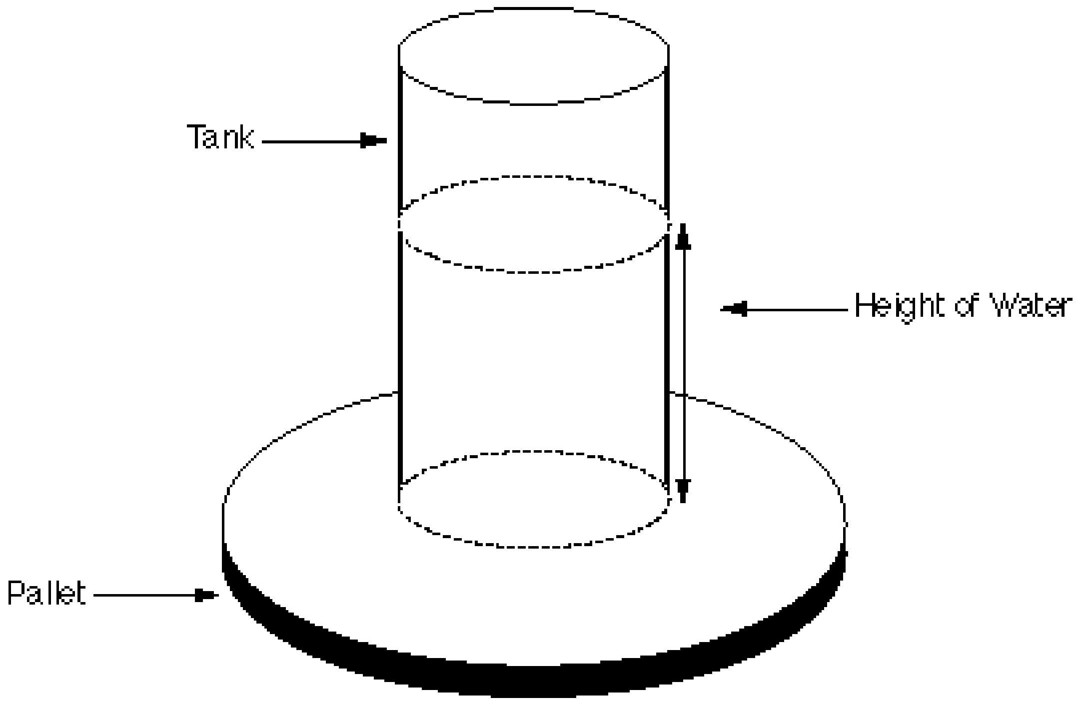


Figure 1

To help understand the difference between weight and weight per unit area, consider three people of identical weight walking through deep snow. One person is wearing high heels, another is wearing ordinary flat-soled shoes, and the third is wearing wide snowshoes. Discuss in your group: Which person would sink farthest in the snow? Which person would sink the least? Why?

Part I - Relevant Quantities

Quantities relevant to the problem are listed in Table 1. Specify whether the given quantity is a constant or variable in the situation. Represent each variable with a symbol of your choice. Give the numerical value of each constant quantity. Provide the units of measure for all quantities.

Table 1

Quantity	Constant or Variable	Constant Value or Variable Symbol	Appropriate Units
number of gallons per cubic foot			
volume of the entire tank in cubic feet			
volume of the entire tank in gallons			
radius of the tank			
radius of the pallet			
height of the tank			
water level in the tank			

Part II - Relationships

Four additional useful quantities related to those in Table 1 are listed below. The first three quantities are variables and the fourth is a constant. Fill in each blank with a correct answer. Remember to use correct units to identify all quantities.

1) Area of pallet:
   a) Represent the area of the pallet by a letter. _______
   b) Express the area of the pallet in contact with the floor as a function of (in terms of) the radius of the pallet. ___________________________

2) Volume of water in the tank:
   a) Represent the volume of water in the tank by a letter. ________
   b) Express the volume of water in the tank as a function of (in terms of) the height of the water. ___________________________

3) Weight of water in the tank:
   a) Represent the weight of water in the tank by a letter. ________
   b) Express the weight of water in the tank in terms of the height of the water.
   ____

4) Weight of the water in the tank when the tank is full:
   Determine the weight of the water in the tank when the tank is full. ________________

Part III - Modeling

The critical consideration in this situation is the load that the extra tank of water puts on the existing second story floor. Consider the example of calculating load as force per unit area when an object weighs 417 pounds and this weight rests on a platform with an area of 15 square feet. The distributed load can be calculated by dividing the weight by the area.

$$\frac{417\, lbs}{15\, ft^2} = 27.8 \frac{lbs}{ft^2}$$

The calculation assumes the weight is distributed evenly. Using original building plans and specifications, a NASA engineer calculated that the floor could safely support no more than 200 lbs/ft^2.

1) Calculate the distributed load of the **full** tank resting on the floor with **no** pallet, and write a concluding statement which indicates whether or not this is safe under the given conditions. This distributed load is equivalent to the load when the pallet exactly coincides with the tank's base.

2) Determine a function which gives the distributed load of the **full** tank in terms of the radius of the pallet. Be sure to specify appropriate units.

Independent variable (with units): ________________________

Dependent variable (with units): ________________________

Function: ________________________

3) Determine a function which gives the distributed load of the water in the tank in terms of the height of the water if there is **no** pallet is under the tank. Be sure to specify appropriate units.

Independent variable (with units): ________________________

Dependent variable (with units): ________________________

Function: ________________________

Note: Before proceeding to Part IV, verify your solutions to Part III with at least one other group or with your instructor.

Part IV - Analysis

There are two ways to overcome the problem of too much load on the floor:

a) increase the size of the pallet on which the tank rests, or
b) restrict the amount of water in the tank.

1) Use the floor plan to determine a reasonable maximum size for your pallet. Justify your reasoning. Include a sketch, drawn to scale, of the pertinent section of the floor plan

Maximum size: ____________

2) Graph the load of a full tank of water as a function of the radius of the pallet (from Part III Exercise 2) on your calculator, and sketch the graph on the coordinate axes in Figure 2. Use a reasonable domain in your sketch based on the information from Part IV Exercise 1, and determine an appropriate corresponding range. Label the axes appropriately.

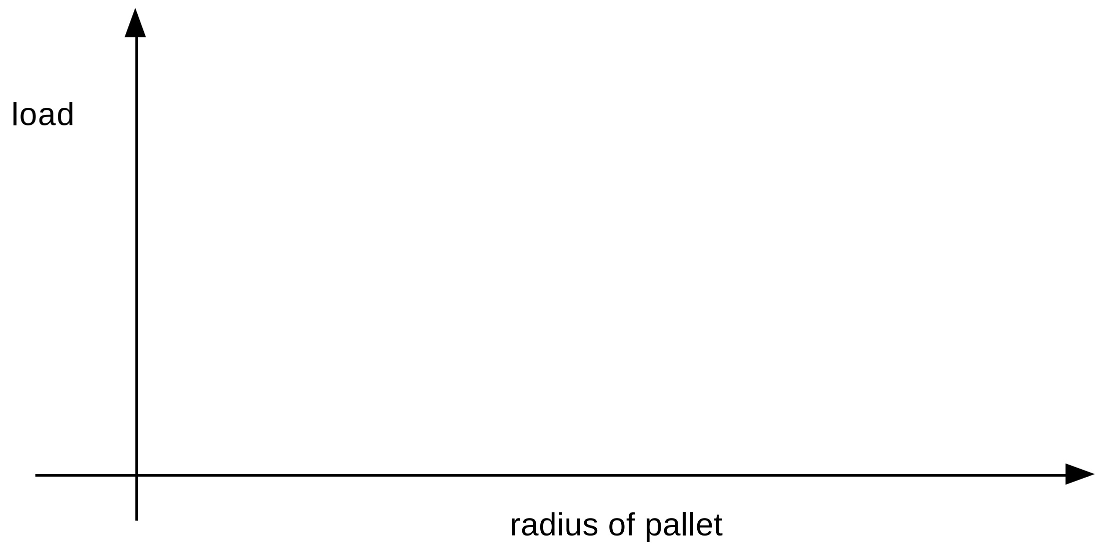


Figure 2

3) Recall that the maximum allowable distributed load on the floor is 200 pounds per square foot. Determine the smallest radius of the pallet that will safely support the full tank of water. Show at least two methods of solution (graphic, algebraic, or table of numbers).

4) If the pallet is not allowed to extend beyond the outside edge of the tank, what is the height of the largest amount of water that can be safely stored in the tank? Illustrate your result with a sketch of the tank showing the water level and the volume.

5) If the pallet is not allowed to extend beyond the outside edge of the tank, what is the largest number of gallons of water that can be safely stored in the tank? Show your method of solution.

Part V - Other Considerations

1) The actual tank is made of fiberglass which is opaque. Devise a warning device for determining (visually, audibly, etc.) when the water reaches its maximum allowable height under the conditions of Part IV Exercises 4 and 5. (The pallet size is restricted to the diameter of the base of the tank.) Use your imagination; use common sense; a non-mathematical solution is acceptable. Explain your method, and include a description of the installation and operation of the warning device.

2) Suppose the size of the pallet is allowed to increase without bound; i.e., the radius tends toward infinity. Explain mathematically what happens to the values of the load function. It is suggested that you sketch a graph of the load as a function of the radius when the radius is allowed to become quite large. Numerical reasoning can also be used to justify your conclusion. Explain in words what this means physically. (Include correct units in your discussion.)

Part VI - Conclusions

Write a final report to your clients, the German and French scientists. Include in this report:

a) A summary of your findings including a description of the loading problem.
b) A description of the two solutions to the problem considered in this Project.
c) A description of any additional solutions that you think are reasonable.
d) A recommendation for the best solution to the problem, including your reasons for choosing that solution.

Provide justifications for your conclusions. Please limit this report to two or three pages - double spaced; no equations, just words and possibly, graphs and drawings.