SPINOFFS

Spinoffs are relatively short learning modules inspired by the LTAs. They can be easily implemented to support student learning in courses ranging from prealgebra through calculus. The Spinoffs typically give students an opportunity to use mathematics in a real world context.

LTA - SPINOFF 8A	Exploring Shuttle Preparations: Crawler and VAB
LTA - SPINOFF 8B	Unit Analysis
LTA - SPINOFF 8C	Pressure and Volume
LTA - SPINOFF 8D	At What Cost? High Versus Low Pressure K - Bottles for the Space Shuttle

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SPINOFF 8D

At What Cost?
High Versus Low Pressure K-Bottles for the Space Shuttle

Part 1 - A Different Kind Of K-Bottle

There are actually two different choices for K-bottles containing compressed air. The one discussed so far is under a pressure of 2200 lbs/in^2. We will refer to this as the low pressure K-bottle. You can also use a high pressure K-bottle in which the air is under a pressure of 3600 lbs/in^2. The volume of each bottle is still 1.5 ft^3, but because of the greater pressure, there is a greater volume of air available at 14.8 lbs/in^2 in the high pressure K-bottle.

1) Refer back to the LTA, Part 1, Question 1. You will need to repeat some of these calculations for this new type of bottle. First you need to determine the volume of air available at 14.8 lbs/in^2 in this new bottle using the equation $P_1V_1 = P_2V_2$. Once you have this volume in ft^3, you will need to convert to cm^3. Round your answers to two decimal places.

   Volume of air available at 14.8 lb/in^2 in one high pressure K-bottle = __________ cm^3

2) Your goal now is to produce a **formula** for the number of high pressure K bottles needed for 7 days of purging at different flow rates. You should take the time to refer back to the process you used in Part 1 of the LTA for the low pressure K-bottles. Although you could repeat these steps using the three specific flow rates of 60, 100, and 120 cm^3/sec, and then create your formula from the table, try a more general strategy using a variable flow rate, *x*. Create a general guideline outlining the steps you followed to determine the number of bottles (*y*) needed at a flow rate of *x* cm^3/sec. Use this strategy to develop your formula directly.

   Formula for the number of bottles **without** the 10 % "safety factor" (round to 2 decimal places): ____________

   Formula for the number of bottles **with** the 10 % "safety factor" (use 3 decimal places): _______________

3) Use your formula with the "safety factor" to complete Table 1:

Table 1

Flow rate	Whole number of bottles
60	
100	
120	

If you compare the table for the low-pressure K-bottle (refer back to the original LTA, Part 1) and this table for the high-pressure K-bottle, you will see that you need fewer of the high pressure K-bottles for a given flow rate. You might therefore assume that it would be better to always use the high pressure K-bottles. However, it's time to talk about money.

Part 2 - Cost

The space center stocks these bottles, so we will just consider the cost to fill the bottles. A low pressure bottle costs $25 to fill, while a high pressure bottle costs $40. We can develop formulas for determining the cost of using each type of K-bottle to purge for 7 days depending on the flow rate. Your calculator will be helpful here, but first we need to pay some attention to the rounding method you used to complete the above Table 1.

1) Notice that in each row of the table, you rounded **up** to get your answer. Explain why.

2) To try to represent this method of rounding mathematically, notice that you simply dropped the decimal part of the number and added 1 to the integer (whole number) part. Your TI-82™ or TI-83™ has a built-in function called *iPart*, which will take the integer part of a number. You will find it under MATH, NUM. You will use *iPart* to evaluate the following:

iPart (calculation from your formula for # of bottles) + 1

Try this out for the flow rates in the table and verify that the answers come out the same.

3) You can now use the lists in your calculator to develop more complete tables for both the low and the high pressure K-bottles. List L_1 will contain the flow rate. Lists L_2 and L_3 will be the number of bottles and the cost for filling the low pressure bottles. Lists L_4 and L_5 will be the number of bottles and the cost for filling the high pressure bottles.

   a) In list L_1, enter flow rates of 20 to 200 cm^3/sec in steps of 10.
   b) Define list L_2 to be iPart (coefficient of x in your formula for the low pressure bottles * L_1)+1.
   c) Define list L_3 to be 25 * L_2.
   d) Define list L_4 to be iPart (coefficient of x in your formula for the high pressure bottles * L_1) + 1.
   e) Define list L_5 to be 40 * L_4.
   f) Once you have all the lists completed, copy the information into Table 2. You will be using this table to help make decisions, and to complete later sections of this exploration. [NOTE: Using iPart + 1 only works if the original answer is not an integer. When the original answer is an integer you will need to calculate the number of bottles by hand. For our values, this will happen when low pressure bottles are used with flow rates of 100 cm^3/sec and 200 cm^3/sec.]

Table 2

Flow rate	Number of low-pressure bottles	Cost for low-pressure bottles	Number of high-pressure bottles	Cost for high-pressure bottles	Which bottle is cheaper? (L or H)
20					
30					
40					
50					
60					
70					
80					
90					
100					
110					
120					
130					
140					
150					
160					
170					
180					
190					
200					

4) Consider the data produced. Using the data, decide whether there is a linear relationship between the cost of filling the K-bottles and the flow rate. Explain why or why not.

5) Create a new column on your table to indicate which type of bottle is cheaper to use for a given flow rate. Use L if the low pressure bottle is cheaper and H if the high pressure bottle is cheaper.

6) Review the work you have done so far. Then suppose you are the engineer in charge of this comparison. Brainstorm in your groups on how you would respond if someone asked whether you should always use the high pressure K-bottles. Think about how you might decide what kind of bottle to use and what rationale you would give to support your decision. Think about what factors in addition to cost might affect your decision as to what type of bottles to use.

7) After your group discussion, write a brief memo to your supervisor outlining the results of your investigation, and the decisions you would make as well as the rationale for these decisions. One way to know if you have written a clear memo is to read it to someone who has not worked through this entire problem. There must be enough information presented in the memo so that the person can understand the objective of your project as well as the results of your analysis. Although the process you went through is important, you should not include all of the details. Rather, present the major points, equations, and how you use the information in the table to make decisions.

Part 3 - More Compartments

Some orbiting spacecraft could carry several different instruments that need to be purged. Depending upon the nature and function of the instrument, each instrument may need to be isolated in its own compartment. (The radiation given off by one instrument may be enough to affect the operation of another instrument.) Suppose that there are two instruments, each housed in separate compartments, with each requiring the same flow rate of 50 cm^3/sec for purging.

Let's first talk about the physical scenario. The simplest way to set this up is to have a single hose coming from the K-bottles, and a T-connector at the end of the hose with one end going to each compartment. As long as all hoses are the same diameter, we can assume that each compartment will receive half of the flow rate coming through the main tube. Create a sketch depicting this scenario.

1) What flow rate is required through the main tube in order for each compartment to receive a flow rate of 50 cm^3/sec?

   Total flow rate = ____________

2) Since you now know the total required flow rate through the main tube, assuming that we purge for 7 days, determine from the table you created in Part 2 the number of each type of K-bottle needed.

   Number of K-bottles needed to purge two compartments at a rate of 50 cm^3/sec each
   # of Low Pressure bottles ________ # of High Pressure bottles _________

Let's now assume that the two instruments need **different** flow rates for purging. One instrument requires 70 cm^3/sec, while the other needs 100 cm^3/sec. We need a way to change the flow into each separate compartment. We can accomplish this by inserting a flow regulator into the hosing that leads from the main tube to the instrument requiring the **smaller** flow rate. This flow regulator will ensure that only 70 cm^3/sec flows to that compartment. The remaining air must therefore flow into the other compartment.

3) What flow rate is required through the main tube in order for each compartment to receive the appropriate flow rate?

   Total flow rate required = ____________

4) Use this flow rate and your table to determine the number of each type of K-bottle needed to purge for 7 days.

Number of K-bottles needed for two compartments at different rates
# of Low Pressure bottles ________ # of High Pressure bottles _______

Due to space constraints on the crawler, you are allowed a maximum of 12 K-bottles for the portable purge system. Your information above should help you determine a reason why you may sometimes opt to use the high pressure bottles as opposed to the low pressure bottles.

5) Suppose you were told that you needed to provide purging for 7 days for 2 instruments, with the first compartment requiring a flow rate of 50 to 100 cm^3/sec, and the second compartment requiring a flow rate of 30 to 80 cm^3/sec.

What is the minimum flow rate you must be able to provide? ________________

What is the maximum flow rate that would be required? ____________________

For each of these two situations, determine how many of each type of K-bottle you would need. Can you satisfy the demand using either type of bottle considering the space constraints for the K-bottles?

6) Suppose you were the engineer in charge of this project and you had to make recommendations based on the number of bottles required and the cost for each possible situation. You would want to consider all the different combinations of flow rates for the two compartments. One way to do this would be to create a table with the possible flow rates (in increments of 10) for one compartment along the top, and the flow rates for the other compartment along the side. The boxes within this table can then represent the combined flow rate required to purge both compartments. Fill in Table 3, making sure you clearly label what the numbers inside the table represent.

Table 3

		Flow Rate for Compartment 1					
		50	60	70	80	90	100
Flow Rate for Compartment 2	30						
	40						
	50						
	60						
	70						
	80						

The numbers within Table 3 represent: ____

7) Use your Table 2 from Part 2 of this investigation and the information in Table 3 to help set up Table 4. The interior numbers represent the number of low pressure bottles needed, followed by the cost of filling these bottles.

Table 4

		Flow Rate for Compartment 1					
		50	60	70	80	90	100
Flow Rate for Compartment 2	30	\	\	\	\	\	\
	40	\	\	\	\	\	\
	50	\	\	\	\	\	\
	60	\	\	\	\	\	\
	70	\	\	\	\	\	\
	80	\	\	\	\	\	\

The numbers within Table 4 represent: ____

Remember, you cannot attach more than 12 bottles to the manifold on the crawler. What implications does this have for your table? Are all cells in the table valid? Why or why not?

8) Fill in Table 5 using the information on the high pressure bottles.

Table 5

		Flow Rate for Compartment 1					
		50	60	70	80	90	100
Flow Rate for Compartment 2	30	\	\	\	\	\	\
	40	\	\	\	\	\	\
	50	\	\	\	\	\	\
	60	\	\	\	\	\	\
	70	\	\	\	\	\	\
	80	\	\	\	\	\	\

The numbers within Table 5 represent ____

9) After reviewing the work you have done so far, brainstorm with your group members on what ideas and highlights you would want to emphasize if you were to present a report to a team of scientists and administrators. Make sure you consider options other than the lowest and highest cost. What information in the tables would you want to highlight? How would you summarize the results in the tables? What suggestions would you make in terms of the type of K-bottle to be used? How would you explain and defend these suggestions?

10) Finally, use the ideas generated in your brainstorming session to write a report to the team of scientists and administrators. Your report should contain a clear description of how you approached the problem, what information is evident from your tables, and your suggestions for how they can use the tables to make their final decision on what type of K-bottles to use.