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 19A — Bubbles

LTA - SPINOFF 19B — Designing the Scott Carpenter Space Analog Station

LTA - SPINOFF 19C — Carbon Dioxide Buildup in the Scott Carpenter Space Analog Station

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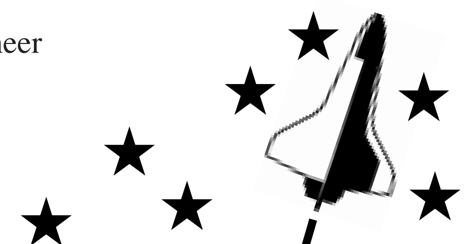

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SPINOFF 19C

Carbon Dioxide Buildup in the Scott Carpenter Space Analog Station

Part A

The cabin of the Scott Carpenter Space Analog Station has an approximate volume of 7000 liters. Air flows into the underwater cabin through a line from the surface at a rate of 15 cubic feet per minute, or 424.65 liters per minute. Air bubbles out though the open hatch at the bottom of the cabin at the same rate. The air flowing in has a carbon dioxide (CO_2) concentration of 0.04%. An aquanaut in the Station exhales air with a carbon dioxide concentration of 4%. This excess CO_2 must be removed before it reaches a level that is dangerous to the aquanauts, 20,000 parts per million, or 2%.

1) How many liters of CO_2 in the cabin would be dangerous to the aquanauts?

We would like to determine the amount of CO_2 normally present in the cabin, and then see what happens if the supply of fresh air is cut off. We will assume that all air mixes instantaneously in the cabin.

2) How many liters of CO_2 are in the air in the cabin when no aquanauts are present, assuming the airflow from the surface is constant?

3) How many liters of CO_2 are flowing into the cabin each minute?

4) If an aquanaut breathes 16 times per minute, and each breath has a volume of 0.5 liter, how many liters of CO_2 are exhaled by one aquanaut each minute?

5) What is the total amount of CO_2 coming into the cabin each minute, both from the air flowing in from the surface and from the breathing of the aquanaut?

Let A = the amount of CO_2 in the cabin t minutes after the aquanaut entered the Station. The notation, A(t), is also used to emphasize that the amount is a function of time.

6) Write an expression in terms of A for the amount of CO_2 bubbling out the hatch at the bottom of the cabin. Hint: The units for your answer will be liters per minute.

7) Use this information to write an expression for dA/dt, the rate of change in the amount of CO_2 in the cabin at time t, and solve this equation. (Remember what you know about the amount of CO_2 present initially.)

   dA/dt = rate in – rate out ____
   The solution of the differential equation, A(t) = ______________________________

8) Sketch the graph of your solution. What happens to the amount of CO_2 in the cabin? Is the level of CO_2 dangerous to the aquanaut?

9) Now consider what happens if more than one aquanaut is present. What is the total amount of CO_2 exhaled by two aquanauts in one minute?

10) Use the previous information to find dA/dt when two aquanauts are present, and sketch your graph. What happens to the CO_2 level this time?

11) Repeat the calculations to see what happens if three aquanauts are present, and sketch the graph. Compare your three graphs. What is the same? What is different?

12) Consider a situation where three aquanauts occupy the cabin. Assume that they leave the cabin when the level of CO_2 reaches 18 liters. Air continues to be pumped through the cabin at the same rate. Let t = the time in minutes after the aquanauts departed. Write and solve a differential equation involving A(t), the amount of CO_2 in the cabin at time t. Graph and explain your solution.

13) Consider a situation where three aquanauts occupy the cabin. Two of the aquanauts leave the cabin when the level of CO_2 reaches 18 liters, and one aquanaut remains in the cabin. Air continues to be pumped through the cabin at the same rate. Let t = the time in minutes after the two aquanauts departed. Write and solve a differential equation involving A(t), the amount of CO_2 in the cabin at time t. Graph and explain your solution.

Part B

Now let's look at what would happen if the supply of fresh air from the surface were stopped. Let A(t) = the amount of CO_2 in the cabin and t = the time in minutes after the air supply was cut off.

1) Suppose that one aquanaut has been working in the Station for several hours. What is the amount of carbon dioxide present?

If the supply of fresh air from the surface is cut off, the air in the cabin will stop bubbling out the bottom of the cabin and the CO_2 level will rise.

2) With the fresh air cut off, what is the amount of CO_2 entering the cabin each minute? Where does it come from?

3) How much CO_2 is removed from the cabin? Why?

4) Write an expression for dA/dt. Solve your equation and sketch the graph. Compare it to the graphs you did previously. What does it tell you?

5) Repeat the process if two aquanauts are present, and if three are present. (Is the amount of CO_2 present in the cabin when the air supply is cut off the same in all cases?) Describe the graphs. What happens if more people are present in the cabin?