Problem of the Day
2014.Oct.29

Discussion

The equation relating time (t), volume (V) and flow rate (Q) has been given several times and it is repeated here:

$$t = \frac{V}{Q}$$

This is the equation that will be used for every question asking about fill time, empty time, detention time or, as in yesterday's Problem of the Day, how long it takes to transfer a given volume from one tank to another. This equation can also be used to measure the flow rate of a pump, for example, in a "fill time test." This is done by timing how long it takes for a pump to fill a known volume. To use the equation, however, it has to be algebraically rearranged to solve for Q:

$$Q = \frac{V}{t}$$

This makes sense, of course, because flow rate is always in units of volume per time (for example, cubic feet per second, gallons per minute, million gallons per day), which is exactly what this equation says, flow equals volume divided by time.

Problem

Today's problem describes a very useful technique.

Problem of the Day: The operator of a small plant in the California Sierra wants to know what her RAS pumping rate is. One of the aeration basins is partially full, and she temporarily shuts off the flow to the plant by allowing it to back up into the collection system. An off-line secondary clarifier is full of water. She turns on the RAS pump withdrawing from this clarifier and starts the stopwatch on her iPhone. In 103 minutes the level in the partially full aeration basin comes up 3 feet. The aeration basin is 75 feet long and 15 feet wide. What is the pumping rate of the RAS pump in gallons/minute?

Solution

The following summarizes the information given:

- t = 103 min
- Length = 75 ft
- Width = 15 ft
- Depth (change) = 3 ft

Volume, of course, is calculated by multiplying length times width times depth, so volume can be calculated from the information given.

The question asks for the answer to be in gal/min so these units are entered into the railroad track between heavy vertical lines followed by an equals sign and the empty track as has been done before.

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$$\left| \frac{\text{gal}}{\text{min}} \right| = \text{\_\_\_\_\_}$$

We could use the second equation given on the previous page to populate the railroad track, but let's see what the units can do for us. First of all, there is no unit of gal in the list above so we can't start the railroad track out like we have done before with the units needed in the numerator of the answer in the numerator of the first entry on the right-hand side of the equals sign. There is, however, a piece of information given in the list above that has the unit, min, in it: the time it takes to fill 3 feet of volume, 103 minutes. We will start the railroad track out with these units but remember they must go in the denominator as shown below. The unit, min, needed in the answer is now in the railroad track.

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$$\left| \frac{\text{gal}}{\textbf{min}} \right| = \left| \frac{}{103\ \textbf{min}} \right| \text{\_\_\_\_\_}$$

Next, in the information listed above, we see that we can calculate volume in ft^3 (length x width x depth). But we also know we need the unit, gal, in our answer. What's the conversion factor for converting ft^3 to gal? That is what is entered into the railroad track next to get gal, needed in the answer in the numerator of the railroad track.

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$$\frac{\textbf{gal}}{\textbf{min}} = \frac{}{103\ \textbf{min}} \quad \frac{7.48\ \textbf{gal}}{\text{ft}^3}$$

In order for the units, ft^3, to cancel in the denominator (they are not in the answer so they need to be canceled), we see we have to enter volume in the numerator as shown below.

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$$\frac{\textbf{gal}}{\textbf{min}} = \frac{}{103\ \textbf{min}} \quad \frac{7.48\ \textbf{gal} \quad 75\ \cancel{\text{ft}} \quad 15\ \cancel{\text{ft}} \quad 3\ \cancel{\text{ft}}}{\cancel{\text{ft}^3}}$$

That was easy! Since only the units needed in the answer remain, gal/min, the math is done and the arithmetic completes the question:

7.48 x 75 x 15 x 3 ÷ 103 = **<u>245 gal/min</u>**.

Although we didn't use the equation, we see the units told us to do exactly what the equation tells us: to calculate flow rate, divide volume by time. There really is little need to memorize equations if you embrace this unit approach.

Good calculating!