Problem of the Day

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An 18-inch (1.5-feet) sewer is flowing half full. A temporary, in-line flow meter indicates a flow rate of 910 gpm. Calculate the velocity in the sewer in ft/s.

Introduction

Yesterday's Problem of the Day was requested in a comment left by a reader. Today's problem is similar.

Mathematically, the relationship between flow rate (Q), area through which the flow is passing (A) and the velocity of flow (v) is:

$$v = \frac{Q}{A}$$

This is a very simple equation, v = Q/A. If you can't remember it, which I hope is not the case, I know it is given on the California State Water Resources Control Board Operator Certification Examination Equivalents and Formulae Sheet (http://www.swrcb.ca.gov/water_issues/programs/operator_certification/docs/opcert_formulasheet.pdf) and in the ABC Formula/Conversion Table for Wastewater Treatment, Industrial, Collection and Laboratory Exams (http://www.abccert.org/pdf_docs/abcwwtfctable.pdf). I am sure it is given on most, if not all, certification exam "cheat sheets" throughout the USA. The reason for this is because it is used a lot in wastewater math problems. It turns out that Q/A is how you also calculate hydraulic loading to wastewater treatment ponds, hydraulic loading to primary, secondary and tertiary clarifiers (in clarifiers hydraulic loading is also known as the surface overflow rate), and $(Q + Q_R)/A$ (where Q_R is the recirculation flow) is how the hydraulic loading to trickling filters is calculated. This equation is very simple to remember. Where we get bogged down is all the different units that Q and A and v can be in. Let the solution bridge do the unit conversions for you because you already know all of them. You just need to remember this equation. Remember, too, that not all problems will ask you to solve for v. Some may ask to calculate A, in which case you'd have to be given Q and v, and some may ask to calculate Q, in which case you'd have to be given A and v. The equations for these calculations, algebraically derived from the equation above, are:

$$A = \frac{Q}{v}$$

and

$$Q = A \times v$$

Remember these, too.

Solution

The question asks to calculate velocity in ft/s. These units, as always, are put between heavy vertical lines followed by the equals sign and the blank solution bridge.

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$$\left| \frac{ft}{s} \right| = \_\_\_\_\_$$

We use the first equation given above, because we are finding v, to start the solution bridge. In order to calculate velocity (v), we have to divide the flow rate (Q) by the area through which the flow is passing (A). Keep in mind we are calculating the area of a circle, A = 0.785 x diameter^2, but we have to divide by 2 because the "sewer is flowing half full." Dividing the denominator by 2 brings it to the numerator as shown.

ft	=	910 gal	2			
s		min	0.785	1.5 ft	1.5 ft	

Entered onto the solution bridge, Q/A, is the math you have to know to do this problem. Once you have Q/A on the solution bridge, all that is needed is to convert the units of Q and A on the solution bridge to the units called for in the answer.

We are all familiar with the conversion factor 7.48 gal/ft^3. But how do we know where to put it on the solution bridge? The units tell you: the 7.48 gal goes in the denominator to cancel the gal in 910 gal in the numerator. By entering the 7.48 gal in the denominator, the ft^3 automatically goes up to the numerator. That's good for us because two of the three feet in ft^3 cancel with the two ft from $diameter^2$ (1.5 ft x 1.5 ft) in the denominator leaving one ft in the numerator, which we need for the answer so it is shown in bold.

ft	=	910 ~~gal~~	2			**ft^3**	
s		min	0.785	1.5 ~~ft~~	1.5 ~~ft~~	7.48 ~~gal~~	

We now have minutes in the denominator, but we need seconds. We all know there are 60 s/min, so this is entered on the solution bridge so min cancel, denominator and numerator, and s is in the denominator where it is needed in the answer (shown in bold).

ft	=	910 ~~gal~~	2			**ft^3**	~~min~~
s		~~min~~	0.785	1.5 ~~ft~~	1.5 ~~ft~~	7.48 ~~gal~~	60 **s**

Since all the units have now canceled except those needed in the answer, we know the solution bridge is complete. The arithmetic gives the answer.

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ft	=	910 ~~gal~~	2			**ft^3**	~~min~~
s		~~min~~	0.785	1.5 ~~ft~~	1.5 ~~ft~~	7.48 ~~gal~~	60 **s**

910 x 2 ÷ 0.785 ÷ 1.5 ÷ 1.5 ÷ 7.48 ÷ 60 = **2.30 ft/s**.

Discussion

The question told us that 18 inches is equivalent to 1.5 feet. If this information had not been given, we could just as easily converted inches to feet on the solution bridge (twice since diameter is squared, $diameter^2$). We all know how many inches are in a foot.

By the way, the velocity we like to maintain in a gravity sewer is 2 ft/s to keep solids in suspension, so our answer definitely works.

Happy calculating! Let us know, by leaving a comment, if you want us to do a specific problem, if you see a mistake, or if you have a question on any of the Problems of the Day you are looking at.