2023A4 VOLUME, RATES

Level 1: We want to fill a turbine foundation with concrete using concrete trucks. The foundation is 6 feet deep and 40 feet in diameter; the rebar takes up about 5% of the volume of the foundation. If each concrete truck holds 10 cubic yards of concrete, how many trucks will be needed to fill the turbine foundation? Assume the foundation is cylindrical in shape.

First, we can find the total volume of the foundation using the volume equation for a cylinder.

$$V_{total} = \pi r^2 h$$

$$V_{total} = \pi * \left(\frac{40}{2} ft\right)^2 * 6\ ft$$

$$V_{total} = 7{,}539.8\ ft^3$$

Then we can find the fillable volume taking away the 5% of the total volume taken up by the rebar.

$$V_{fill} = (1 - 0.05) * 7{,}539.8\ ft^3$$

$$V_{fill} = 7{,}162.8\ ft^3$$

Next, we can convert our concrete truck volume to ft^3, so we have consistent units.

$$10\ yd^3 * \left(\frac{(3\ ft)^3}{1\ yd^3}\right) = 270\ ft^3$$

Now we can divide our fillable volume by the concrete truck volume to get the number of concrete trucks needed to fill the foundation.

$$Number\ of\ trucks = \frac{7{,}162.8\ ft^3}{270\ ft^3}$$

$$Number\ of\ trucks = 27$$

Level 2: If each concrete truck pours concrete into the foundation at a rate of 4 gallons per second and it takes 10 minutes to switch between empty and full trucks, how much time (in hours) will it take to fill the foundation with concrete? Assume the same foundation and concrete truck volume from the previous question.

We can start this problem by converting our flow rate into ft^3 so that we have consistent units.

$$4\ {}^{gal}/_{s} * \left(\frac{0.133681 ft^3}{1\ gal}\right) * \left(\frac{60\ s}{1\ min}\right) = 32.1\ {}^{ft^3}/_{min}$$

Now we can make an equation to calculate the total time it takes for one truck to empty its contents and the next truck to begin filling. We know that each truck carries 270 ft^3 of concrete and the truck empties the concrete at 32.1 ft^3/min. Then there is a constant 10-minute period between when one truck finishes and the next one begins. Our equation would look like this:

$$t_{total} = \left(\frac{truck\ volume}{flow\ rate} + transition\ time\right) * number\ of\ trucks$$

Then we can substitute in our given values.

$$t_{total} = \left(\frac{270\ ft^3}{32.1\ {ft^3}/{min}} + 10\ min\right) * 27\ trucks$$

$$t_{total} = 497.1\ min$$

Finally, we need to convert this answer into hours.

$$t_{total} = 497.1\ min * \left(\frac{1\ hr}{60\ min}\right)$$

$$t_{total} = 8.3\ hr$$