PROBLEM OF THE WEEK SOLUTIONS - MONDAY, OCTOBER 25

	Eastville	Westview
Number of Virus A copies per liter of wastewater	4×10^9	2×10^7
Number of standard virus copies per liter of wastewater	3×10^8	9×10^5

1. For Eastville, there are $(4 \times 10^9)/(3 \times 10^8) = 13.3$ copies of Virus A per standard virus copy. For Westview, there are $(2 \times 10^7)/(9 \times 10^5) = 22.2$ copies of Virus A per standard virus copy. **Westview** has more of Virus A in its wastewater shed by its population.

2. In Eastville, there are 4×10^9 copies of Virus A per 1 liter (or 1×10^3 milliliters). So, we can set up and solve the following proportion to find the number of copies of Virus A in the original sample: $(4 \times 10^9)/(1 \times 10^3) = x/(1 \times 10^2) \rightarrow (4 \times 10^9)(1 \times 10^2) = (1 \times 10^3)x \rightarrow 4 \times 10^{11} = (1 \times 10^3)x \rightarrow x = (4 \times 10^{11})/(1 \times 10^3) =$ **4×10^8** copies. Alternatively, you could simply divide 4×10^9 by 10 (or 1×10^1).

3. First, we need to find how many people are currently shedding Virus A. So, we'll take 40% of 878,500, which is $0.4 \times 878{,}500 = 351{,}400 = 3.514 \times 10^5$ people. So, on average, each person is shedding $(2 \times 10^7)/(3.514 \times 10^5) = 0.5691519636 \times 10^2 \approx$ **57** copies.

4. The entire process takes 3 hours, which is $3 \times 60 = 180$ minutes, on average, for 35 PCR cycles. So, on average, 1 cycle takes $180/35 \approx$ **5.1** minutes.

5. In order to get all given times into the same units, we must first convert 51 seconds to minutes: $51/60 = 0.85$ minutes. So, the total time of a PCR cycle is $0.85 + 2 + 2.25 = 5.1$ minutes. Thus, $2/5.1 \approx 0.39$, which is **39**% of a cycle.

Huge thanks to DoD STEM for helping us with this Problem of the Week! To learn more about DoD STEM, visit dodstem.us.

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***Biotechnology** is a field of engineering that uses living systems to produce a wide range of technologies and products used in medicine, energy, fuels and sensors.* *You can see biotechnology in action when, for example, you use yeast (a living organism) to create bread! Biotechnology involves collaboration with many other types of engineers, including microbiologists, chemical engineers, electrical engineers, data scientists and more.*

Biotechnology can be used to monitor wastewater to determine what microorganisms are present in a human population. This is especially important when people with a virus may not show symptoms immediately; the presence of the virus can be detected in their wastewater before a person even knows they are sick.

Scientists can predict a spike of a virus in a population using a technique called **PCR**, which makes copies of DNA. Scientists take a small amount of DNA (in this case, found in wastewater) and amplify it in order to more easily detect a dangerous virus. If there is a very small amount of the virus in the wastewater sample, more PCR cycles must be conducted to get the dangerous virus to a detectable level. If there is a large amount of the virus, fewer cycles are needed to detect it. Scientists then use the results of the PCR cycle(s) to determine the number of copies of the dangerous virus per liter of wastewater. They can also compare the amount of the dangerous virus (Virus A in our example) to the amount of standard virus that is always detected in wastewater.

	Eastville	Westview
Number of Virus A copies per liter of wastewater	4×10^9	2×10^7
Number of standard virus copies per liter of wastewater	3×10^8	9×10^5

1. Using the information in the table, which location, Eastville or Westview, has a greater ratio of Virus A to standard virus in its wastewater?

2. When testing wastewater, scientists use a sample of 100 mL, rather than 1 liter. How many copies of Virus A would have been in Eastville's wastewater sample? Express your answer in scientific notation.

3. The current population of Westview is 878,500 people. If 40% of the population is currently shedding Virus A into the wastewater, on average, how many copies of Virus A per liter of wastewater is shed by each person? Express your answer to the nearest whole number.

4. The average number of PCR cycles needed in testing a wastewater sample is 35. If the entire process takes an average of 3 hours, what is the average number of minutes a single PCR cycle takes? Express your answer as a decimal to the nearest tenth.

5. The first step of a PCR cycle lasts approximately 2 minutes, during which the DNA is at 96°C. The second step of a PCR cycle lasts approximately 2.25 minutes, during which the temperature is 60°C. Assuming an average total of 51 seconds of a PCR cycle is spent raising or lowering the temperature, and there are only these two steps in a PCR cycle, what percent of the time during a PCR cycle is spent with the temperature at 96°C? Express your answer to the nearest whole percent.

How is this relevant in the real world? Currently, scientists are monitoring wastewater to determine the level of SARS-CoV-2, the virus that causes COVID-19, in populations. A person with COVID-19 often does not show symptoms until 4-7 days after infection, but the virus can show up in their waste (a process called shedding) before they begin to show symptoms (which is called the asymptomatic stage). Spikes in SARS-CoV-2 in wastewater can be used to predict spikes in COVID-19 cases up to one week in advance.

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