LU 8.11. An experiment on measuring volumes

Learning from "The crow and the pitcher" story

Do you remember the childhood fable of the crow and the pitcher? (See figure 1.) In this unit, we will imitate the crow in the story and use the concept that 'a body submerged in water displaces an amount of water equivalent to its volume', to carry out some measurements. The last task in this unit is closely related to the tale — and you may reach a surprising conclusion at the end of it!

Figure 1: *The Crow and the Pitcher*
From The Aesop for Children, by Aesop, illustrated by Milo Winter, Project Gutenberg etext 1994

Materials

- A narrow transparent cylinder (or a transparent 500 mL water bottle with the top cut off; the cylinder need not have uniform diameter across its length)
- Glass marbles (~40) of similar size
- Small irregular stone which can fit into the cylinder comfortably (see note in task 4)
- Ruler
- Marker pen (fine tipped)
- Straight edge (like another ruler or edge of a notebook)
- Beaker (with graduated volume markings)
- A tray or tough may be kept to collect water spills

Are you familiar with these ideas?

- Volume
- Displacement of fluids by solid objects
- Average/ Mean

Task 1: Creating your own volume measuring instrument (a graduated cylinder)

i. Use a beaker to carefully measure 50 mL water and transfer it to the transparent cylinder. Mark the height of the water column on the cylinder using a marker pen.
ii. Repeat this till the cylinder is almost full, marking successive heights at the steps of 50 mL.
iii. Label the markings with appropriate multiples of 50 mL. (50, 100, 150,...)

Now, you have a graduated cylinder which measures volume. You will notice that we can use this cylinder to measure volume only in multiples of 50 mL. Hence 50 mL is the least count of this graduated cylinder. If the water level is between two markings, we take the reading as the mark that is closest to the water level.

The maximum volume your graduated cylinder can measure is ________________________(Highest marking on the cylinder)

Task 2: Measuring the average volume of marbles

i. Take the empty graduated cylinder and fill it up to the 200 mL mark.

ii. Drop the marbles in the cylinder, one by one while counting them, until the water level rises up to the next mark. Ensure that **all** the marbles are **fully** submerged in water. That is, the level of the water should be above all the marbles. The water level rises because each marble displaces an amount of water equal to its own volume.

Volume of water before adding marbles __________________________________

Volume of water after adding marbles __________________________________

Number of marbles required to raise the water level to the next mark __________________
Thus, _______ marbles displace ___________ volume of water.

iii. Use this result to estimate the average volume of one marble, obtained experimentally (V_{exp}).

Average volume of one marble ___________________________

Task 3: Comparing the volume of a marble estimated by two different methods

i. Keep ten marbles in a straight line touching each other. (You can create a long narrow channel by placing a straight edge and a ruler parallel to one another with a gap in between, with the marbles lined up in the gap.)

ii. Measure the end-to-end length of the line of marbles.
End-to-end length of ten marbles ________________________________

iii. Use this measurement to estimate the average radius of the marbles.
Average radius of one marble ________________________________

iv. Calculate the volume of a marble (sphere) $\left(V_{calc}=\frac{4}{3}\pi r^3\right)$ using the radius you have obtained.

Volume of one marble (obtained using the formula) _______________________________

v. You may notice that the volumes obtained by these two methods differ slightly from each other. One can estimate percentage difference as the ratio (expressed in percentage) of the difference in volume to the volume of a marble (by either method).
Percentage difference = __________________________________

Task 4: Measuring the volume of an irregular stone

i. Fill the cylinder with water to the 200 mL mark.

ii. Put an irregular stone in the water. (The stone should be completely immersed inside the water with the water level at least 2-3 cm above the upper surface of the stone.)

iii. Estimate the volume of the stone by observing the amount of water displaced. Unless the water level matches with one of the markings, this will only be approximate measurement.

iv. Now, immerse enough marbles to bring the water level up to the next marking.

Volume of water before adding the stone ____________________________

Number of marbles required to raise the water level to the next mark _____________________

The irregular stone + ________ marbles displaced _________ volume of water.

v. Use the mean volume of marbles, V_{exp} obtained in task 2 to determine the volume of the stone more precisely.
Volume of the irregular stone _____________________________

Task 5: A challenge

1) Fill up the cylinder with water to the 50 mL mark.
2) By adding enough marbles, try to raise the **water level** to the top of the cylinder.
3) If you do not succeed in raising the water level to the top, can you estimate the maximum marking to which the water level rises?

   Maximum marking to which the water level rises ________________

   Number of marbles required to increase the volume by this amount ________________
4) Can you think of an explanation for this?

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5) Do you think the thirsty crow would have succeeded in quenching its thirst? Explain your answer.

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