Experimental determination of force on the wall of a cubic tank

(AS2100: Basic Aerospace Engineering Lab)

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In this experiment the force on the side wall of a cubic tank of dimensions $2m \times 2m \times 2m$ is estimated through the pressure measurements. The cubic shaped tank of water has 5 pressure gauges attached to it in 5 different locations height wise ($\{h1 = 0.4m, h2 = 0.8m, h3 = 1.2m, h4 = 1.6m, h5 = 2m\}$) as shown in fig 3. The pressure measurements are made from the pressure gauges, $\{P_1, P_2, ...P_5\}$. This is repeated 100 times and the observations are recorded in the data set `P3_Hydrostatics.mat`

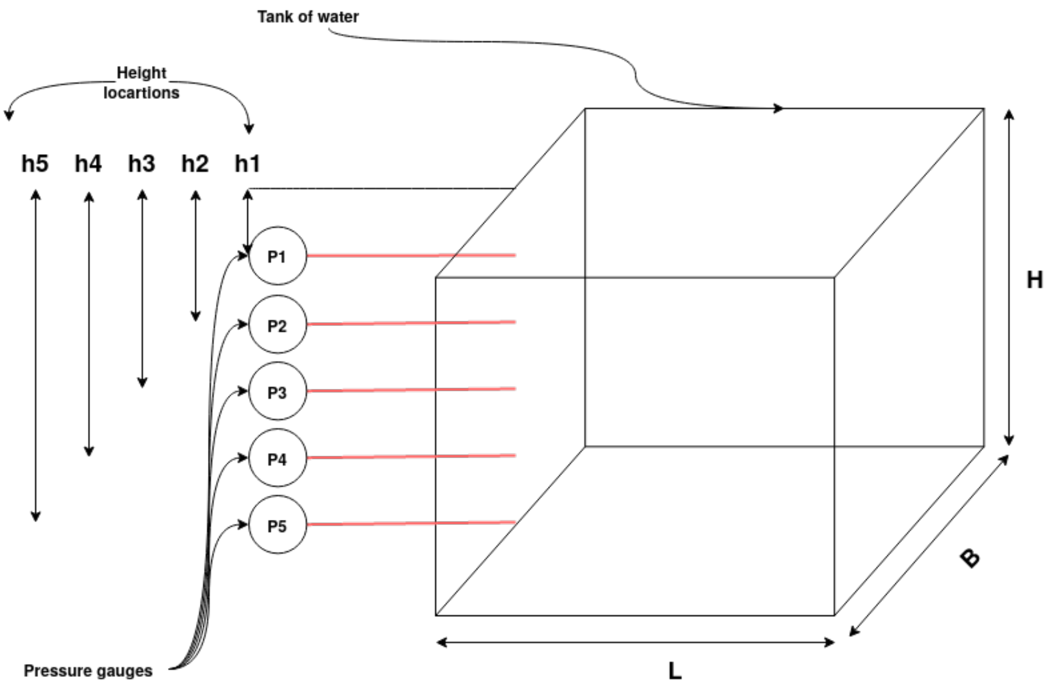

Figure 3: Schematics of the experimental setup.

Use the following properties for your calculations:

- Density of water (at $25°C$) $\rho_{water} = 997Kg/m^3$.
- Acceleration due to gravity, $g = 9.81m/s^2$

The data set provided in `P3_Hydrostatics.mat`) contains the following:

- Height locations (`H_Location`) where the pressure gauges are attached to the tank.

$$\boldsymbol{h} = \{h1 = 0.4m, h2 = 0.8m, h3 = 1.2m, h4 = 1.6m, h5 = 2m\}$$

- Pressure measurements(`P_Exp`) at different locations

$$\boldsymbol{P^{exp}} = \{P1^i, P2^i, P3^i, P4^i, P5^i\}_{i=1}^{N=100}$$

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Using the above information and the data set, do the following:

1. Explain the theory behind this experiment and detail the assumptions involved.
2. Use Pascal's law to obtain the true values of pressure at the different locations where the pressure gauges are placed. Represent these true values as

$$\boldsymbol{P^{true}} = \{\hat{P}1, \hat{P}2, \cdots \hat{P}5\}$$

3. What are the possible sources of error in this experiment? How can we minimise them?

4. Plot the normalised histograms of error in pressure observations at each height location by considering the theoretical pressures obtained in question 2) as true values. Also, plot the smoothened probability density trends over the corresponding histograms. Determine if the probability density functions resemble Gaussian, Log normal or Uniform density functions. (Hint: Read up on Log normal density function and its relationship with the normal density function).

5. Determine the accuracy of the pressure gauges and identify the least accurate pressure gauge.(Hint: Greater the $|Pj^{true} - \bar{Pj}^{exp}|$ for $j = 1 \cdots 5$, lesser the accuracy. Here, $\bar{Pj}^{exp}$ is the mean pressure measured experimentally.)

6. Derive the theoretical relationship for the force on the side wall F_{wall} and maximum pressure. Calculate the theoretical value of F_{wall} using the obtained relationship (**Note:** Choose the side wall with pressure gauges attached.). The theoretical F_{wall} can be considered the true value, F_{wall}^{true} for further calculations.

7. Estimate the force on the side wall of the tank using numerical integration for each set of pressure data at different height locations ($F_{wall}^{exp\,(i)}$ for $i = 1 \cdots 100$). Obtain the error in the force estimation($e^{(i)} = F_{wall}^{true} - F_{wall}^{exp\,(i)}$ for $i = 1 \cdots 100$). Plot the normalised histogram of the errors obtained and also plot the smoothened probability density trend over the histogram.

8. Determine the accuracy($|F_{wall}^{true} - mean(F_{wall}^{exp\,(i)})|$ for $i = 1 \cdots 100$) and precision (given in terms of $\pm 1\sigma_{F_{wall}}$).

9. Obtain the best linear fit for pressure as a function of height location and comment on how the linear relationship obtained compares with the theoretical relationship obtained in question 2). If there is a difference, please estimate the mean squared error between these trends.

10. On a conclusive note, what improvements can be made in the experimental setup to obtain a better force estimate.

In addition to answers to the above questions each report should also include introduction about the experiment , schematics of the experimental setup, a results and discussion section and a conclusion section.