Stock answers to the forces on submerged surfaces experiment.

1. How well does the measured position of the centre of pressure agree with theory? Can the experiment be improved to get better accuracy?

The comparison between the theoretical and experimental results will depend on the care with which the experiment was conducted. Because of the simple nature of the experiment, it is likely the results will match to within 5-10%. If the results are significantly (orders of magnitude) different from the theoretical prediction, it may be that there is an arithmetic error in processing the data. If this is proving difficult, a “check my answers” excel spreadsheet is provided that can be used to convert the raw data to the processed data using the correct formulas. If the order of magnitude is correct but the results are further out than you consider acceptable, then it may be something to do with the dimensions of the equipment. While these are supplied on the lab sheet, there are some quite large manufacturing differences between particular rigs.

When conducting the experiment, it is ideal for all members of the group to independently record the results. This can be used to ensure that transcription errors are not present and that variation of different users reading the same equipment can be accounted for. Uncertainty in the scale should be recorded in the experimental record. The weight of each mass could be checked by placing these on precise and accurate scales.

2. Is the moment measured due to the hydrostatic force on the rectangular face alone?

The quarter toroid used in the experiment has two side faces, two curved faces and the rectangular face on which the analysis is performed. These faces (or parts of them) are submerged below the water surfaces so why are the hydrostatic forces present on the other faces not included during the data processing?

In the case of the side faces, these are of an equal size and facing one another. The hydrostatic forces on these faces will cancel each other out. More interestingly are the curved surfaces on the inside and outside of the toroidal shape. These will each have different hydrostatic forces acting on them, as they are different in area and depth. Both are circular and the point of the centre of the circle around which they are formed is the location of the fulcrum. Although the forces from the upper and lower surface will be different, regardless of the amount they are submerged the line of force will always pass through the fulcrum. As the data processing is based on a moment balance, the moment that these curved surfaces contribute to the system around the fulcrum will always be zero.

This is why this equipment is shaped in this particular way - to isolate the contribution of the moment balance from the rectangular surface.

3. If a valve controlling the flow from a reservoir into a conduit was built as a rectangular plate pivoted about a horizontal axis through its centroid, how would the moment required to open it change as the depth of water in the reservoir increased?

The valve in the sidewall of the reservoir opens and closes to release and contain the water. The valve rotates around the central, horizontal axis, as per the picture in the lab sheet. There will be hydrostatic force pressing on the top part of the valve, creating an anticlockwise moment on the valve (in the direction depicted on the lab sheet). There will be hydrostatic force pressing on the bottom part of the valve, creating a clockwise moment on the valve (in the direction depicted on the lab sheet). The upper force will be greater than the lower force because the lower part is deeper than the top part. There will therefore be a moment around the pivot trying to turn it in the clockwise direction. An equal and opposite moment would need to be supplied to keep the valve closed.

The question asks about what would happen if the depth of water would change. If the depth increases, the forces on both the top and the bottom would increase. But, because they would increase by the same amount, the *difference* between the top and bottom force would remain the same, so the moment needed to keep the valve closed or to open it would remain the same, regardless of the depth.

With careful design of the location pivot of the valve, it would be possible to retain the water without needing to apply much additional moment. If the area above the pivot, where the pressure is less, was larger than the area on the bottom, the clockwise and anticlockwise movement could be made to cancel out.