Question 1. **[3 marks]**

An unloaded rectangular pontoon is 9m long and 7.5m wide. It is floating in fresh water with a depth of immersion of 2.0m.

(a) What is the density of the pontoon in kg/m^3? [2 marks]
(b) What is the distance between the centre of buoyancy B and the metacentre M? [1 mark]

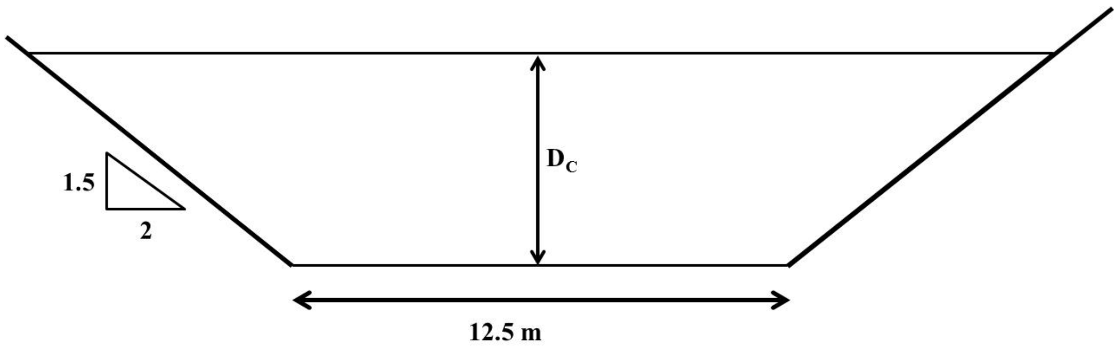
Question 2. **[6 marks]**

A horizontal pipeline terminates in a nozzle of diameter 100mm that discharges to the atmosphere with a jet velocity of 8.0m/s. The pipeline has a diameter of 0.3m.

(a) What is the velocity of the water upstream of the nozzle? [2 marks]
(b) What is the pressure of the water in the pipeline? [2 marks]
(c) What is the force exerted by the water on the nozzle? [2 marks]

Question 3. **[7 marks]**

A trapezoidal channel carries a discharge of 25 m^3/s, and has a bottom width of 12.5m and side slopes of 1.5:2.

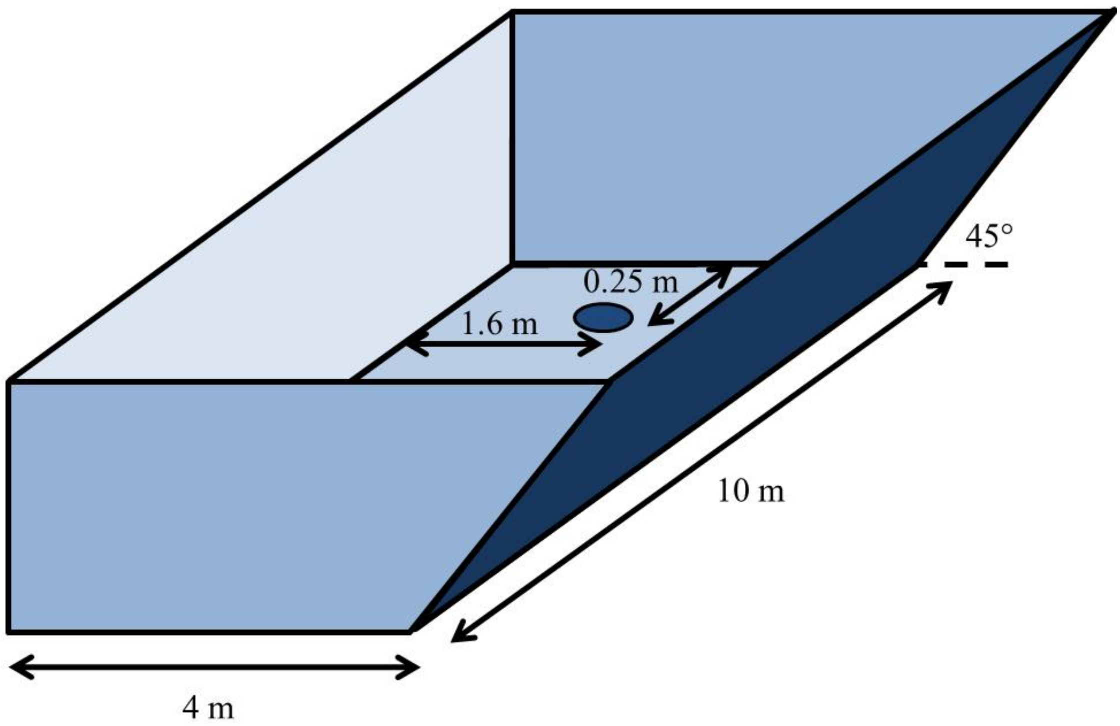


The critical water depth D_C on the channel centreline is known to be between 0.65 and 0.75 m.

Calculate the actual critical water depth on the channel centreline [7 marks]

Question 4. [16 marks]

A tank (shown below) is rectangular in plan with a base 10m by 4m. The cross-section of the tank is a "half trapezium", with one of the long sides vertical and the other sloping outwards at 45°. The short ends of the tank are both vertical. A circular orifice of diameter 0.20m is cut into the horizontal base of the tank, with the centre of the orifice located 1.6m from the long vertical side, and 0.25m from one of the short vertical sides. The orifice has a coefficient of discharge of 0.65.



(a) Calculate the inflow rate that would be required to maintain a constant water level in the tank of 2.0m [2 marks]

(b) Assuming the inflow is zero, use **integration** to calculate the time taken for the water level in the tank to fall from 2.0m to 0.2m. [7 marks]

(c) Repeat part (b) using the **approximate technique**, with 3 slices 0.6m thick, and calculate the percentage error between this answer and the answer obtained by integration. [7 marks]

Question 5. **[12 marks]**

A reservoir must discharge to the atmosphere via a short horizontal pipeline. The entrance to the pipeline is sharp, and the diameter is 0.8m for the first 10m. The pipeline then contracts suddenly to 0.4m diameter for the last 10m. For both pipes, $\lambda = 0.05$. You may assume the head loss at the sudden contraction is given by $0.5\frac{V_1^2}{2g}$.

(a) If the maximum height of water in the tank is 5.0m above the centre of the pipeline, determine the corresponding discharge in m^3/s:

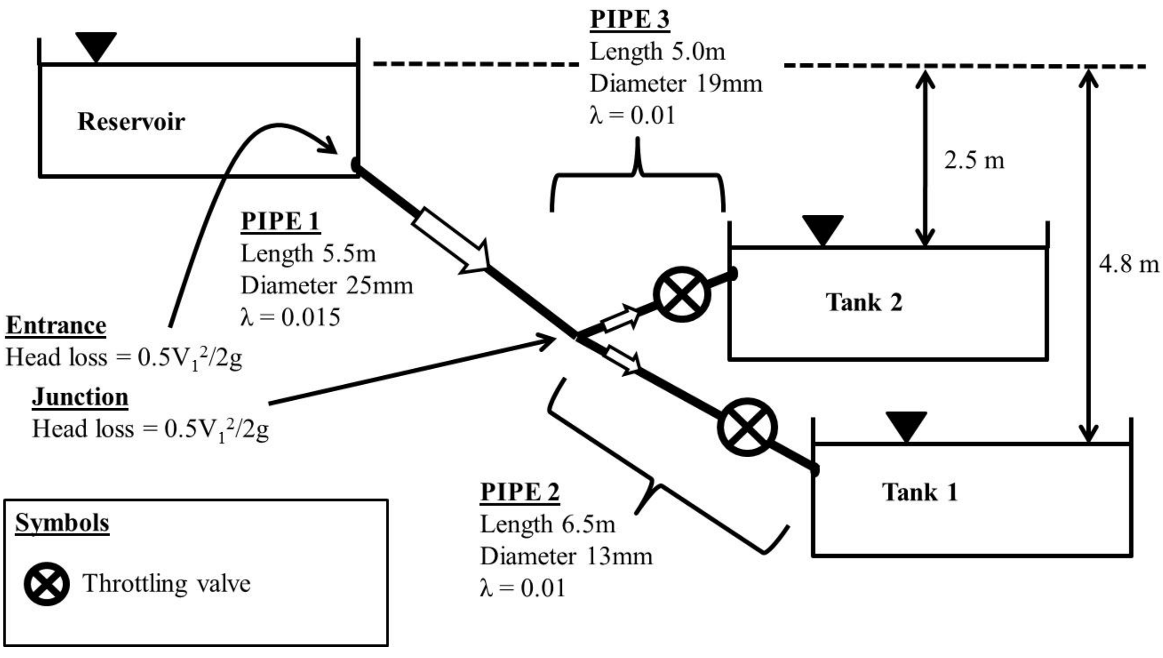
i. ignoring minor losses [5 marks]

ii. considering both friction and minor losses [3 marks]

(b) Calculate the water level that would be required to deliver 1.0 m^3/s. [4 marks]

Question 6. **[17 marks]**

Jason's indoor hydroponics setup involves a main reservoir located in the roof, draining to two lower tanks via a branched pipeline. The two lower tanks have a difference in water surface level of 2.5m and 4.8m (measured from the water level in the top reservoir), as shown below. The 25mm poly pipe (pipe 1) connected to the top reservoir branches into two smaller pipes (pipe 2, diameter 13mm, and pipe 3, diameter 19mm). All pipes are assumed to be straight but there is a head loss at the entrance to pipe 1 and at the junction, as indicated. Pipes 2 and 3 are fitted with a "throttling valve" that can be adjusted to regulate the flow to the tanks.



(QUESTION CONTINUES ON THE NEXT PAGE)

Table 6.1 - Throttling valve positions and corresponding head loss

Throttling valve position	**Minor loss coefficient (K)**
Fully open	5.5
20% closed	12
40% closed	33
60% closed	55
80% closed	160

Table 6.2 - Design Flow Rates

	Min. flow (litres / sec)	Max. flow (litres / sec)
Tank 1	0.2	0.3
Tank 2	0.15	0.25

IMPORTANT: Don't forget to convert L/s into m^3/s!!!

<u>Your task</u>

1. Use the minimum design flow rates from table 6.2, to determine the minimum pipe velocities V_2 and V_3, and use the continuity equation to determine the corresponding minimum pipe velocity V_1. [2 marks]
2. Repeat step 1 using the maximum flow values. [2 marks]
3. Write out the two energy equation for pipes 1-2 and pipes 1-3, including head losses due to the entrance loss, junction loss, exit loss, pipe friction, and the minor loss from the throttling valve (where *K* is unknown). [3 marks]
4. Rearrange the two energy equations and solve for *K* (for the throttling valve) in pipe 2 and pipe 3 using velocities for the <u>minimum flow</u> case. [4 marks]
5. Repeat step 4 for the <u>maximum flow</u> case. [3 marks]
6. Finally, provide Jason with an upper and lower valve position for each of the two throttling valves, in order to maintain the flow within the design range (e.g. "pipe 2 valve must be between 20% closed and 40% closed…"). These valve positions can be approximate – i.e. use positions listed in table 6.1 and justify your choice on the basis that they are close to the required *K* values you obtained from your analysis. [3 marks]

Question 7. **[5 marks]**

(a) Explain – including a simple diagram and explicit reference to <u>specific energy</u> – how it is possible for the flow at a particular cross-section in a channel to occur at two significantly different (alternate) depths of flow for the same discharge.

[2.5 marks]

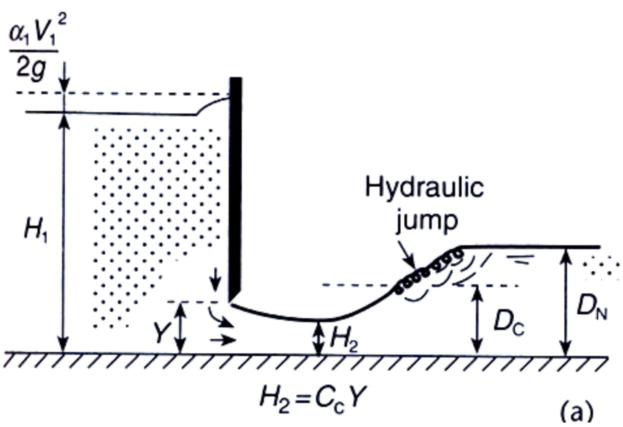
For each of the following statements, say whether the statement is **<u>true</u>** or **<u>false</u>**:

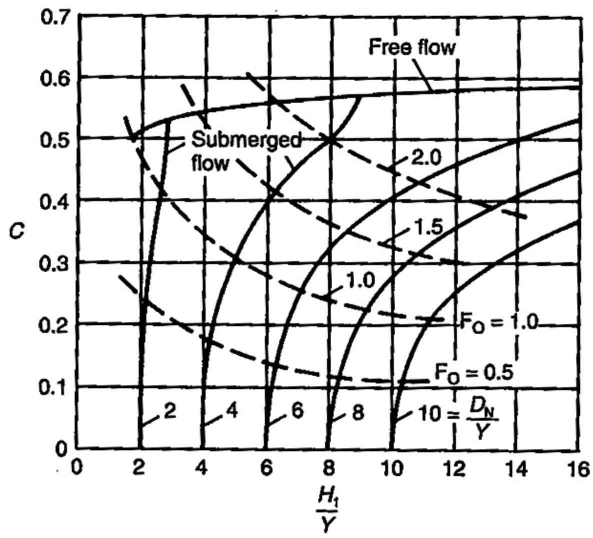
(a) A hydraulic jump occurs when flow transitions from subcritical to supercritical
(b) A hydraulic jump involves a significant gain in energy
(c) A hydraulic jump is characterized by smooth, non-turbulent conditions
(d) A hydraulic jump is mostly theoretical and is rarely encountered in reality
(e) A hydraulic jump cannot occur unless the upstream Froude number is greater than 1

[5 x 0.5 = 2.5 marks]

Question 8. **[12 marks]**

A 4.0m wide vertical sluice gate is positioned in a horizontal, rectangular channel of the same width. The gate must operate freely and allow a discharge of 10.0 m^3/s to pass without inducing an upstream water depth greater than 3.5m.





(QUESTION CONTINUES ON THE NEXT PAGE)

(a) Using the chart above, determine by trial and error the height Y at which the gate should be set to give an upstream depth (H_1) of 3.5m. [3 marks]

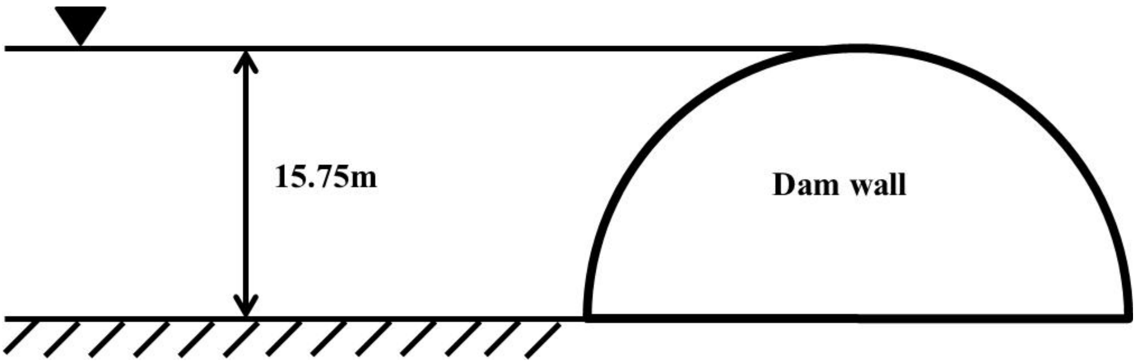
(b) Assuming a coefficient of contraction (C_C) of 0.6, what is the approximate depth of water at the *vena contracta*? [1 mark]

(c) Assuming an energy head loss through the gate of $0.05V_2^2/2g$ and $\alpha_1 = \alpha_2 = 1.05$, use the energy equation to determine the actual depth (H_2) at the *vena contracta* by trial and error. [5 marks]

(d) Determine whether the gate will discharge under subcritical or supercritical flow conditions. [3 marks]

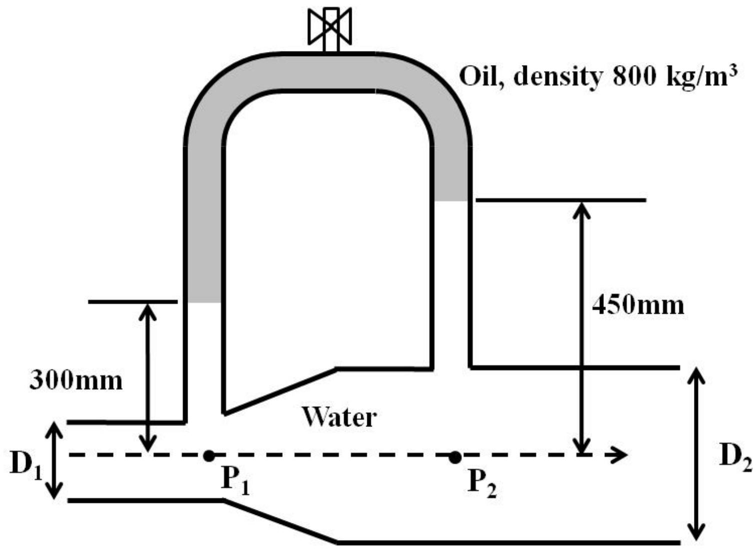
Question 9. [10 marks]

A dam of height 15.75m has been constructed to hold fresh water. The dam wall has a semi-circular cross section as shown. Calculate the magnitude and direction of the hydrostatic force on a unit length of the dam wall, assuming the dam is operating at maximum capacity.



Question 10. **[12 marks]**

The figure below shows an inverted U-Tube manometer filled with oil above the pipe liquid. The pipeline is horizontal and carries fresh water, and undergoes a change in diameter between P_1 and P_2.



(a) What is the differential pressure ($P_1 - P_2$)? [4 marks]

(b) If the pipe diameters D_1 and D_2 are 0.04m and 0.08m respectively, use the energy equation to determine the flow rate (assuming no head loss). [8 marks]

END OF EXAMINATION