University of South Australia

2011 SP5 End of Year Exam Period

School	NBE	Subject Area & Catalogue number	CIVE 2010	Paper	1
Course Name	Introduction to Water Engineering				

Length of Exam: 3:00

Official Reading Time: 10 Minutes
Additional Reading Time
(included in length of exam): NIL
Total Recommended Reading Time: 10 Minutes

Questions	**Time**	**Total Marks**
13 questions	180 mins	100 marks

Instructions to Candidates:
Answer all questions and show **all** working.

Student Notes:
AnyCalc 2H/WrittenDblSidedNotes

Question 1. **[3 marks]**

An unloaded pontoon weighs 200 kN and in plan, is 10m long and 7.5m wide. It is floating in oil (density 800 kg/m^3).

(a) What is the depth of immersion of the pontoon? [1.5 marks]

(b) What is the distance between the centre of buoyancy (B) and the metacentre (M)? [1.5 marks]

Question 2. **[6 marks]**

A horizontal pipeline terminates in a nozzle that discharges to the atmosphere. The pipeline has a diameter of 0.6m and operates with a velocity of flow of 1.5m/s.

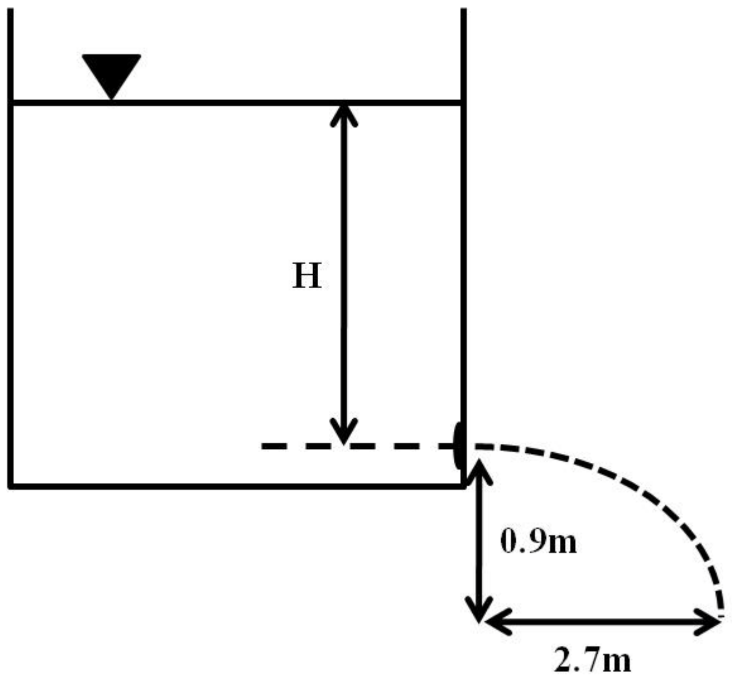
(a) What diameter nozzle is required to obtain a jet with a velocity of 7.5m/s? [2 marks]

(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. **[3 marks]**

A jet of water discharges from a small orifice. The trajectory of the jet is measured, and is found to travel 2.7m horizontally while dropping vertically through a distance of 0.9m.



(a) Calculate the speed of the jet. [1.5 marks]

(b) If the driving head H is 2.0m, calculate the coefficient of velocity (C_V) of the orifice. [1.5 marks]

Question 4. **[12 marks]**

A trapezoidal channel carries a discharge of 24.6 m^3/s, and has a bottom width of 12.5m and side slopes of 45°.

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

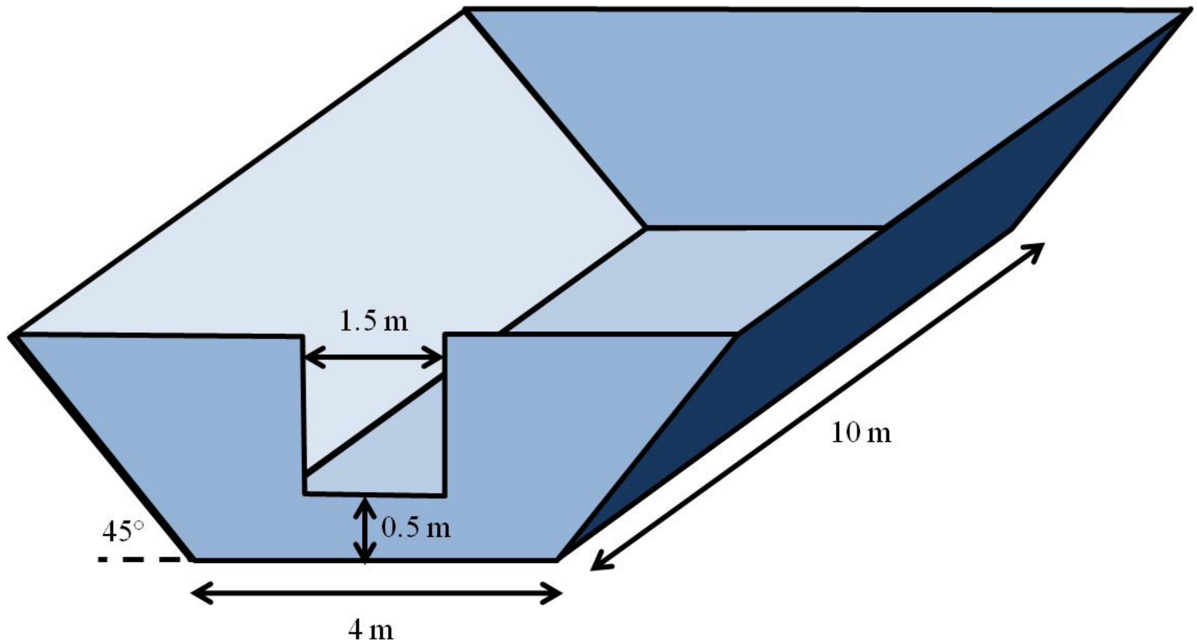
Calculate:

(a) the actual critical water depth on the channel centerline [10 marks]

(b) the hydraulic mean critical depth D_{MC} and the critical velocity V_C [2 marks]

Question 5. **[16 marks]**

A tank (shown below) is rectangular in plan with a base 10m by 4m. The cross-section of the tank trapezoidal, with the long sides sloping outwards at 45°. The short ends of the tank are vertical. A rectangular sharp-crested weir of width 1.5m is cut out of one of the vertical ends, with the crest of the weir 0.5m above the tank's base. The weir has a coefficient of discharge of 0.6.



(a) Calculate the inflow rate that would be required to maintain a constant water level in the tank of 2m (i.e. 1.5m above the weir crest). [2 marks]

(b) When the inflow is stopped, use **integration** to calculate the time taken for the water level in the tank to fall from 2m to 0.8m. [8 marks]

(c) Repeat part (b) using the **approximate technique**, with 3 slices 0.4m thick, and calculate the percentage error between this answer and the answer obtained by integration. [6 marks]

Question 6. **[8 marks]**

A reservoir must discharge to the atmosphere via a short horizontal pipeline. The entrance to the pipeline is sharp, and the diameter is 0.6m for the first 10m. The pipeline then contracts suddenly to 0.3m diameter for the last 10m. For both pipes, $\lambda = 0.05$. You may assume the head loss at the sudden contraction is given by $0.5\frac{V_1^2}{2g}$.

If 0.8 m^3/s of water must be discharged from the pipeline, determine the height that the water level in the reservoir must be above the centre of the outlet pipe:

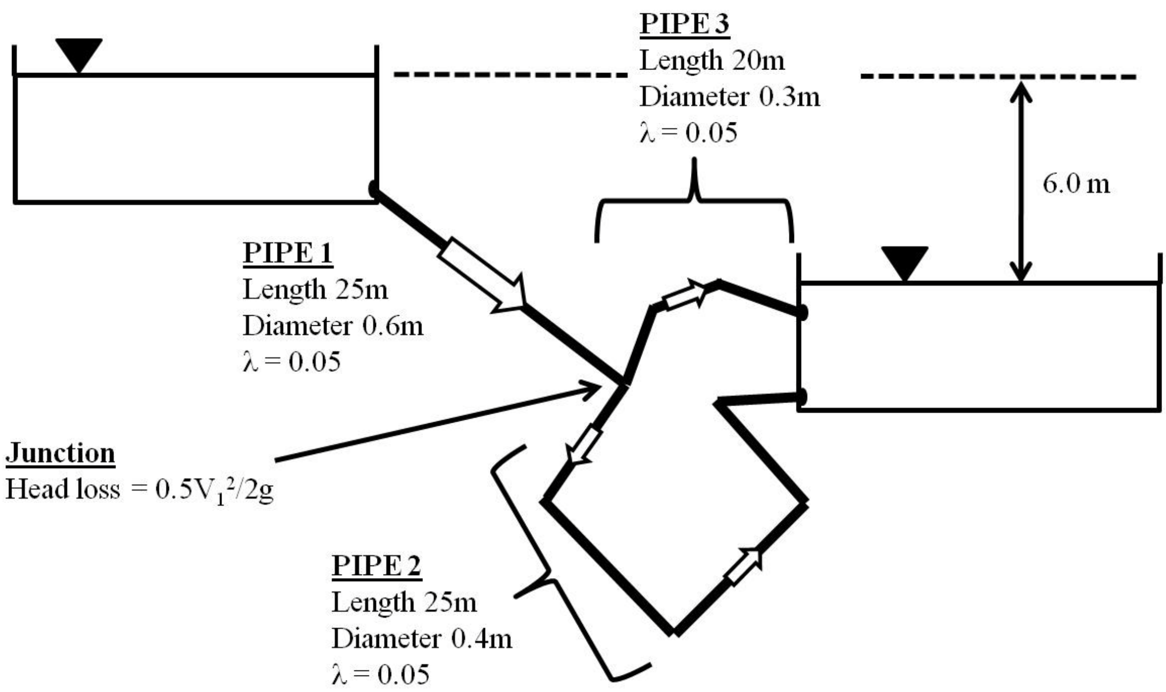
(a) ignoring minor losses [3 marks]

(b) considering both friction and minor losses [3 marks]

If the maximum water level possible in the reservoir is 5m, calculate the maximum discharge rate through the pipe. [2 marks]

Question 7. **[10 marks]**

Two reservoirs have a difference in surface level of 6.0m as shown schematically below. The pipeline connecting them is initially straight (pipe 1), but then branches into two smaller pipes (pipes 2 and 3). Pipe 2 is long, with 4 medium bends (all with K = 0.15). Pipe 3 is shorter, with 2 shallow bends (both with K = 0.1). There is a head loss at the junction, as indicated.



The discharge rates in all 3 pipelines are unknown. Your task is to complete the hydraulic analysis up to the point of obtaining 3 equations for the three pipe velocities. You must include friction and minor losses in your analysis. Simplify the equations as much as possible, but **you do not have to solve the three equations**.

Question 8. **[5 marks]**

(a) Explain – including a simple diagram – 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 **true** or **false**:

(a) A hydraulic jump occurs when flow transitions from supercritical to subcritical
(b) A hydraulic jump involves a small gain in energy
(c) Rough, turbulent conditions are typical in a hydraulic jump
(d) Generally, a small ramp is required to induce a hydraulic jump
(e) A hydraulic jump can only occur in wide, deep channels

[5 x 0.5 = 2.5 marks]

Question 9. **[6 marks]**

Drag force F_D is depends on the frontal area A, the velocity V, the fluid density ρ and the coefficient of drag C_{DR} according to the following relationship:

$$F_D \propto C_{DR} \rho A V^2$$

where C_{DR} is known to be dependent on the Reynolds number.

Use dimensional analysis to derive an equation for the drag force F_D (N) on a sphere of diameter D (m), when it is positioned in a fluid flowing with a mean velocity V (m/s), fluid density ρ (kg/m^3) and dynamic viscosity μ (kg/ms). Explain (in words) how the result of your dimensional analysis helps to confirm that C_{DR} must be dependent on the Reynolds number.

Question 10. **[4 marks]**

Water is to be pumped from a sump into a rising main, and there is a choice between two pipe diameters (D): either 150mm or 200mm. There is also a choice of two pumps (A and B). The head-discharge relationship for each pump is as follows:

Pump A

H (m)	9.8	8.68	8	7.48	6.88	6.1	4.87	3.45	1.4
Q (m^3/s)	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08

Pump B

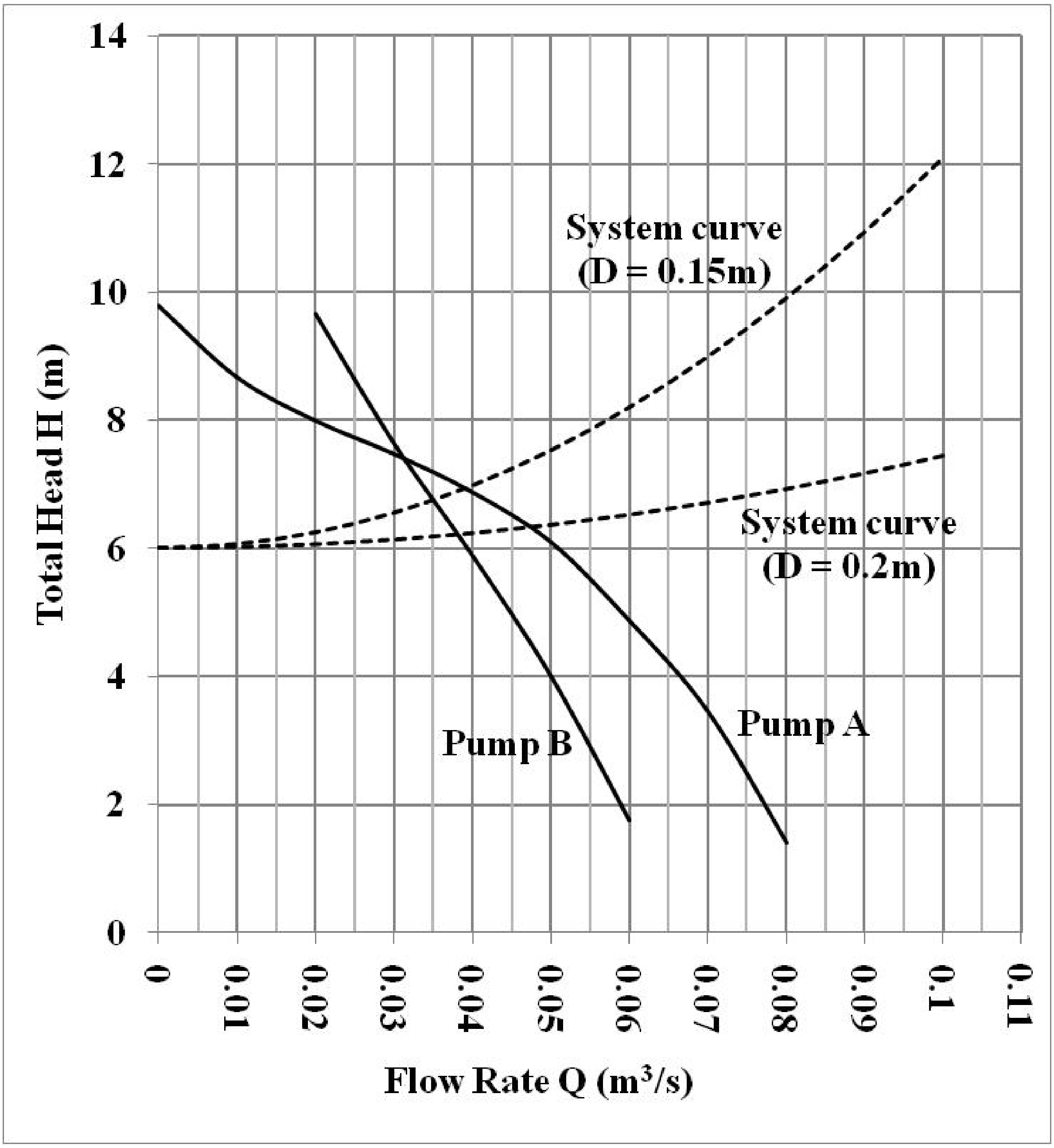
H (m)	9.65	7.63	5.88	4	1.75
Q (m^3/s)	0.02	0.03	0.04	0.05	0.06

The static lift is 6.0m, and the system curves (taking into account friction and minor losses) have been plotted with the individual pump curves over the page.

(a) Explain why there is a difference between the system curves for the two rising mains.

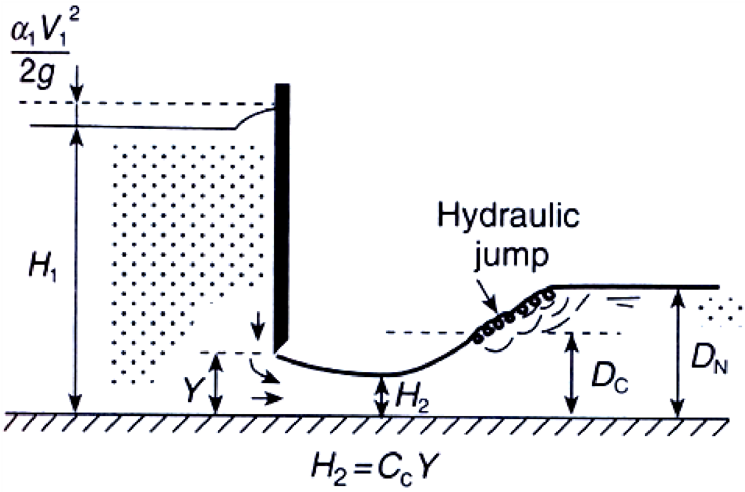
[1 mark]

(b) If Pump A is most efficient at low flows (Q < 0.01 m^3/s) and Pump B is most efficient at medium flow (Q approx 0.035 m^3/s), comment on the likely trade-offs or compromises that may have to be made when considering which combination of pipe and pump to use. [3 marks]



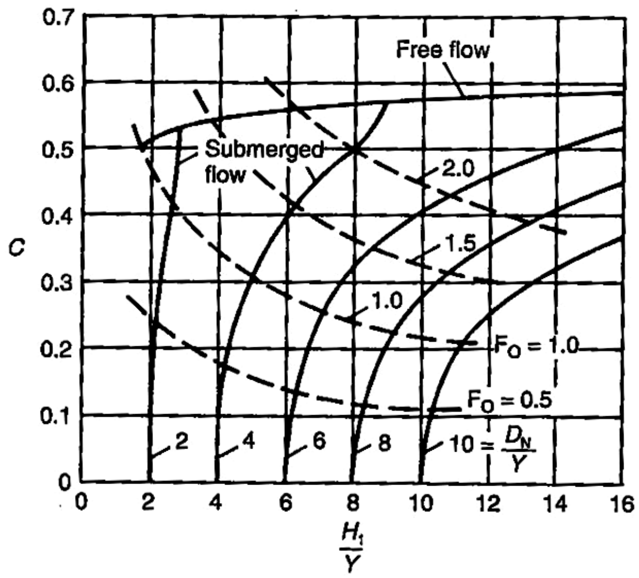
Question 11. **[10 marks]**

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 12.0 m^3/s to pass without inducing an upstream water depth greater than 3.25m.



(a) Using the chart below and iteration (if necessary), determine the height Y at which the gate should be set to give an upstream depth (H_1) of 3.25m.

[2 marks]



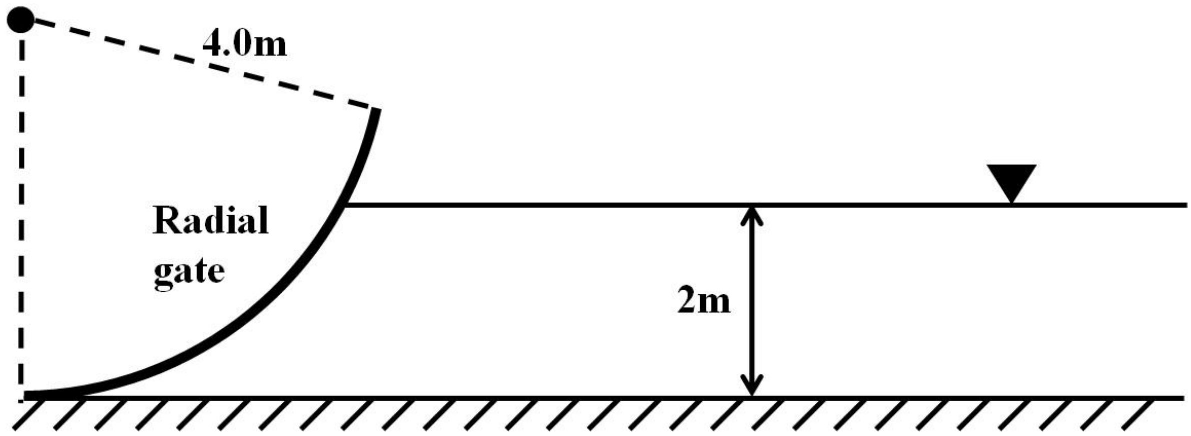
(b) Assuming a coefficient of contraction (C_C) of 0.6, what is the approximate depth of water at the *vena contracta*? [1 mark]

(c) Assuming an energy head loss through the gate of $0.05V_2^2/2g$ and $\alpha_1 = \alpha_2 = 1.05$, check the answer from (b) using the energy equation. If you find the upstream and downstream values of total energy are not equal, determine the actual depth (H_2) at the *vena contracta* by trial and error, and comment on likely sources of the observed discrepancy between (b) and (c). [4 marks]

(d) Determine whether the gate will discharge freely or not. [3 marks]

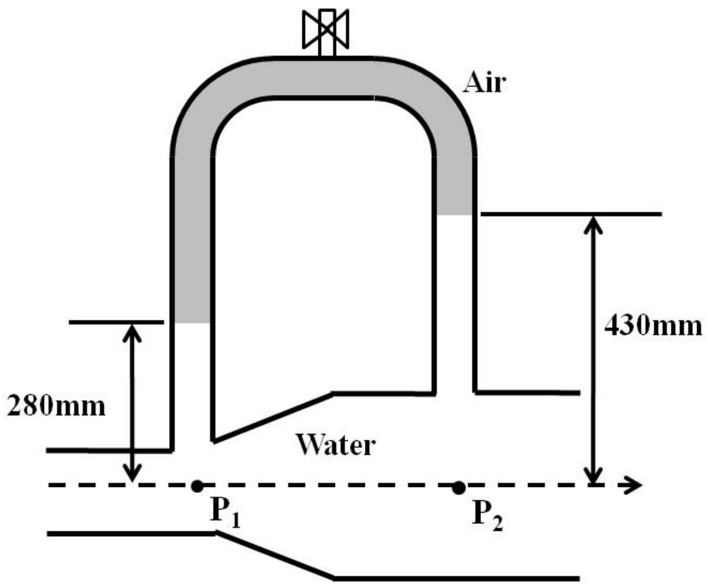
Question 12. [7 marks]

A gate which is a part-circle of radius 4.0m holds back 2.0m of fresh water as shown in the diagram below. Calculate the magnitude and direction of the resultant hydrostatic force on a unit length of the gate.



Question 13. [10 marks]

The figure below shows an inverted U-Tube manometer filled with air above the pipe liquid. The pipeline is horizontal and carries 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) Assuming the pipe diameters D_1 and D_2 are known, derive an expression for flow rate as a function of observed pressure difference. [6 marks]