THE NATIONAL UNIVERSITY OF IRELAND, GALWAY GX697

SUMMER EXAMINATION 1999

SECOND INDUSTRIAL ENGINEERING EXAMINATION

ELEMENTARY HYDRAULICS (EH201)

Examiners: Prof. P.E. O'Connell
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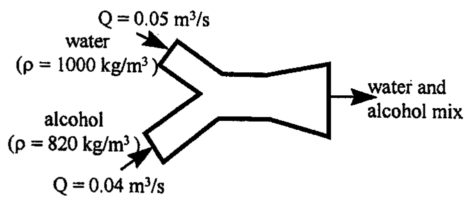
Mr. A.M. Cawley

Time allowed: **Three Hours.**

Attempt Question 1 and three other questions

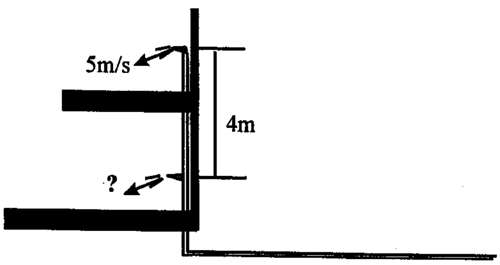
1. **Compulsory** ***(40 marks)***

(i) Applying the principle of conservation of mass determine the average density of the mixture of alcohol and water leaving the y-duct.



(ii) Water is flowing in a 300mm diameter pipe. If the shear stress at the pipe wall is 47.87 Pa and f = 0.04, what is the average velocity.

(iii) Water flows from the tap on the first floor of the building shown in the accompanying diagram with a maximum velocity of 5m/s. For steady frictionless flow, determine the maximum water velocity from the ground floor tap.

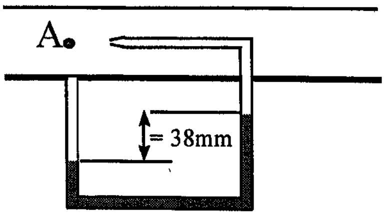


(iv) An empty balloon and its equipment weigh 445N; when inflated with gas weighing 5.4 N/m^3 the balloon is spiracle and 6100mm in diameter. What is the maximum weight of cargo that the balloon can lift, assuming air to weigh 12.02 N/m^3?

(v) Laminar flow occurs in a pipe of diameter 10mm. If the fluid viscosity is 0.096×10^{-3} m^2/s and the velocity of flow is 0.24m/s, determine the hydraulic gradient.

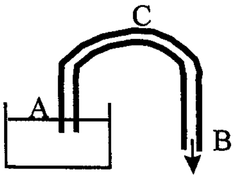
(vi) A pump installed on a pipeline delivers a flow rate of 0.025 m^3/s. If the energy head supplied by the pump is 12m and the overall pump/motor efficiency is 74% what is the cost of pumping 10,000 m^3 at a rate of 4.5p per kWhr?

(vii) Turpentine flows through a pipe in which a pitot tube is centred. The differential manometer containing mercury (ρ_m = 13600 kg/m^3) shows a deflection of 38mm. What is the centre velocity?



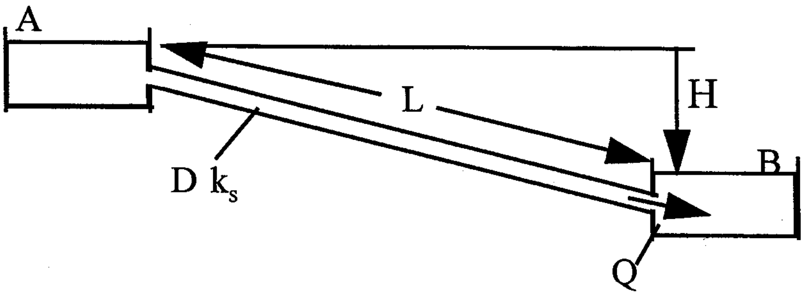
(viii) Water in a rectangular channel of width 1.6m flows into a gradual contraction section of width 1.2m. If the flow rate is 4m^3/s, the upstream depth is 0.6m and the velocity in the contracted section is 4.5m/s determine the downstream depth.

(ix) The pressure inside the pipe conveying water at C must not fall below 0.24 bar (Abs). Neglecting losses, how high above B may point C be located?



(x) Determine the drag force exerted by water flowing in a pipe at 0.1m^3/s on a sudden expansion where the inlet diameter is 200mm, the expanded diameter is 500mm and the inlet pressure is 200kPa (neglect energy losses). Hint: use the bulk flow equation.

2. Calculate the flow rate Q of water in a pipeline connecting two Reservoirs A and B having a uniform diameter D = 0.3m, absolute pipe roughness k_s = 0.06mm and total length 2km if the available head H = 18m. The kinematic viscosity of water can be taken as 1.14 x 10^{-6} m^2/s.



(20 marks)

3. (a) State Bernouilli's theorem for ideal fluids and the modified form used for real fluids.

(3 marks)

(b) Define potential head, kinetic energy head, piezometric head and hydraulic gradient.

(4 marks)

(c) Explain briefly, (with the help of suitable equations) what is meant by the following principles in the context of fluid flow. Derivation or proof of equations is not required.

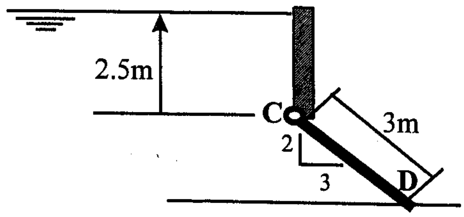
(i) Conservation of Mass
(ii) Conservation of Energy
(iii) Conservation of Momentum

(6 marks)

(d) List the types and relative magnitudes of energy losses, which occur in a flow system. Give Reynold's main findings relating them to the flow of liquids in pipes.

(7 marks)

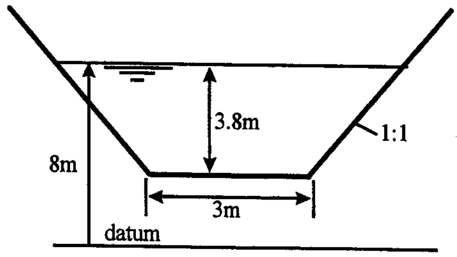
4. A rectangular gate CD is 2.2m wide and 3.0m long, determine the weight of the gate necessary to keep it shut until the water level rises to 2.5m above the hinge, see diagram for details.



(20 marks)

5. (a) A uniform trapezoidal open channel has a bed slope of 1:1250, bed width of 3m, side slopes of 1:1 and a Manning's Roughness n = 0.024, as shown in the accompanying diagram. If the steady state water depth in the channel is 3.8m, determine the following:

(i) the hydraulic radius
(ii) the flow rate
(iii) the stage height
(iv) the hydraulic mean depth
(v) the Froude number
(vi) Chezy's roughness coefficient



(12 marks)

(b) Sketch the location of the hydraulic grade line and the total energy line giving their respective values.

(4 marks)

(c) If a rectangular channel of width 6m and similar roughness was to convey the same discharge as the trapezoidal channel at the same water depth (3.8m) what value of bed slope would be required?

(4 marks)

6. (a) A Fluid of density 1026 kg/m^3 flow through a uniform pipe of diameter 2.4cm at a velocity of 6.3m/s. Determine (i) the volume flux, (ii) the mass flux (iii) the momentum flux and (iv) the kinetic energy flux.

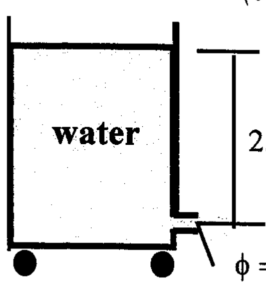
(4 marks)

(b) State the impulse momentum (bulk flow) equation of fluid mechanics and outline any restrictions on its use.

(6 marks)

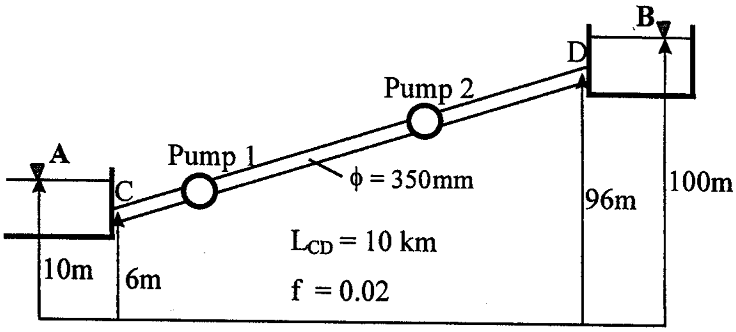
(c) If the 5mm diameter nozzle at the base of the water tank shown in the accompanying diagram is suddenly opened, determine the reaction force exerted on the tank and the direction that the tank would move. Use a coefficients of contraction $C_C = 0.91$ and a coefficient of velocity $C_v = 0.97$ for the nozzle in your calculations.

(10 marks)



$\phi = 5mm$
$C_v = 0.97, C_C = 0.91$

7. (a) Two identical pumps are placed in series on a trunk mains to deliver a flow rate of 0.2 m^3/s between two reservoirs as shown below. Ignoring shock losses determine the following:



(i) the total energy head to be provided by the pumps.

(ii) the electrical power required by the pumps using a combined pump/motor efficiency of 71%.

(iii) the maximum distance from C at which the first pump can be located so that the pump inlet pressure head do not fall below a permissible minimum value of -6.0m gauge.

(14 marks)

(b) In the context of pump-pipeline systems explain the following terms:

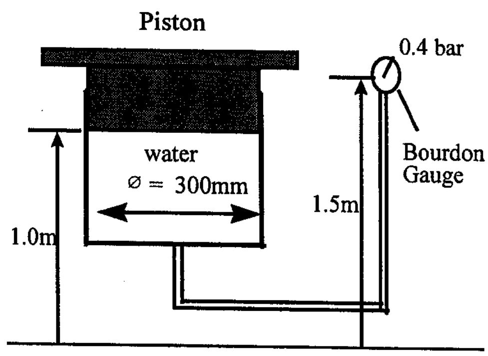
(i) system characteristic curve, (ii) operating point & (iii) pump efficiency coefficient

(6 marks)

8. (a) (i) If atmospheric pressure is 101kPa and a Bourdon gauge attached to a cylindrical tank reads 0.4 bar, determine the force that the piston exerts.

(ii) If the bourdon gauge was located at 1.0m height; what will the pressure reading be in kPa gauge and kPa absolute:

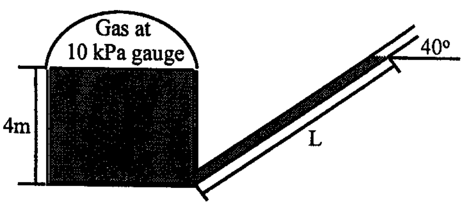
(iii) Explain the operation of a Bourdon gauge.



(10 marks)

(b) Determine the length to which the oil extends in the inclined pipe shown in the diagram on the right (density of oil 910 kg/m^3).

(6 marks)



(c) Show that the gauge pressure at a depth H below the surface of a liquid is $P = \rho g H$.

(4 marks)