**Ollscoil na hÉireann, Gaillimh**
**NATIONAL UNIVERSITY OF IRELAND, GALWAY**

**SEMESTER I EXAMINATION, 2002**

**SECOND CIVIL AND SECOND ENVIRONMENTAL ENGINEERING**

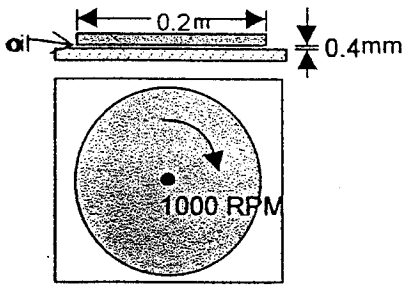
**ELEMENTARY HYDRAULICS (EH 201)**

Examiners: Prof. K.J. Beven
Prof. C. Cunnane

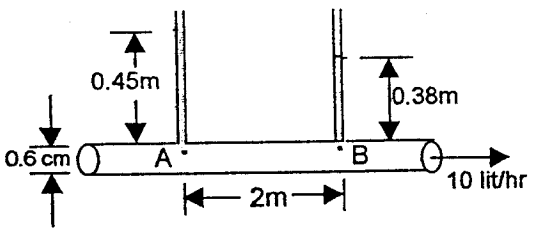
Time Allowed: **Three hours**

Attempt **any five** questions

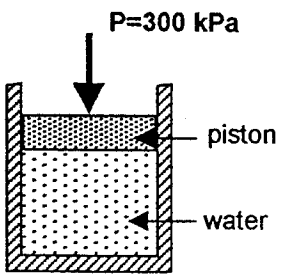
1 (a) A flat disk, of diameter 0.2 m supported on a 0.4mm thick film of oil of dynamic viscosity 0.02 Pa s, rotates at a speed of 1000 revolutions per minute. Determine the power required to maintain this movement. *[10 marks]*



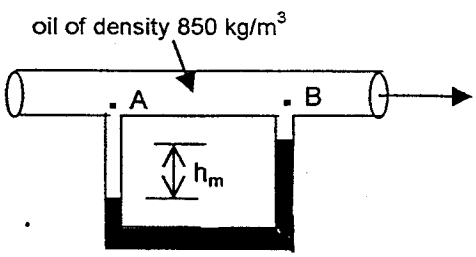

(b) A light lubricating oil of density 855 kg/m$^3$ flows in a 0.6 cm delivery pipe. Pressure tappings at locations A and B, which are 2 m apart, show pressure heads of 0.45 m and 0.37 m oil respectively. Given that the flow rate is 10 litre/hour determine the viscosity of the oil. *[6 marks]*




(c) A pressure of P = 200 kPa is exerted on a sample of water in a cylinder as shown. Given that the Bulk Modulus of water is K = 2.2 x 10$^9$ Pa calculate the percentage change in the volume of the sample. *[4 marks]*




2(a) Points A and B in a pipeline are joined by a U-tube differential manometer as shown. Derive an expression for the pressure difference $P_A - P_B$ and hence calculate the pressure head difference between A and B, in m oil, if $h_m$ = 5 cm. *[6 marks]*




*Question 2 continued overleaf.../*

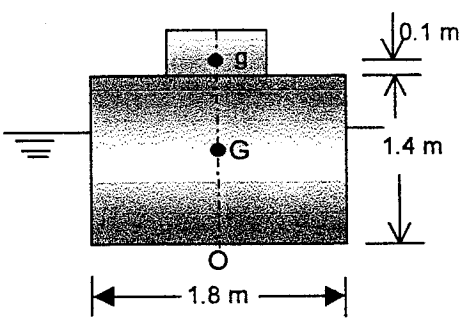
(b) Explain briefly the principles of operation of
(i) a modern pressure transducer
(ii) an electromagnetic flow meter. *[4 marks each]*

(c) An 0.8 m wide sharp crested weir is installed centrally in a 1 m wide outflow channel of a wastewater treatment works. If the crest is 0.3 m above the channel base determine the depth of water upstream of the weir when the discharge is 0.14 $m^3/s$. Take $C_d = 0.65$. *[6 marks]*

3 (a) State Archimedes Principle. What information does it convey about the volume of immersion of a floating body? *[4 marks]*

(b) In the context of a floating object explain the terms
(i) centre of buoyancy
(ii) meta centre
(iii) stable equilibrium *[2 marks each]*

(c) A cylindrical buoy of mass 980kg and diameter 1.8 m is 1.4 m high. Its centre of gravity is 0.6 m above the base. An instrument box is attached to the top of the buoy. Its mass is 150 kg and its centre of gravity is 0.1 m above its base.




Determine whether the assembly can float in fresh water in a stable manner in the position shown. *[10 marks]*

4 (a) Show that in steady uniform flow in an open channel the boundary shear stress can be expressed as $\tau_o = \rho g m i$, in the usual notation. *[6 marks]*

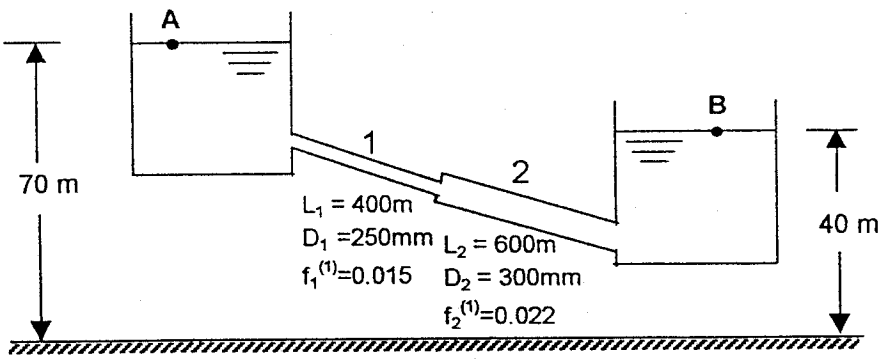
(b) Demonstrate that in open channel flow the hydraulic grade line coincides with the liquid surface. *[4 marks]*

(c) A trapezoidal channel of base width 5 m, side slopes 1:1, longitudinal slope 1/400 and Chezy coefficient C = 46 conveys a flow of 8.8 $m^3/s$. Determine the depth of flow. *[10 marks]*

5 (a) Describe, with the help of a sketch, the main features of the Moody or Universal Resistance Diagram. *[6 marks]*

(b) Explain why head loss in a pipe in which laminar flow occurs can be calculated with an f value of 64/Re *[4 marks]*

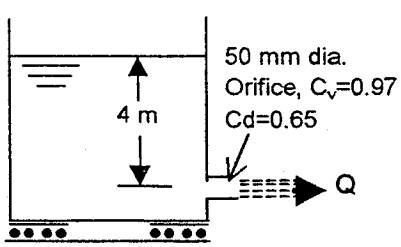
(c) Water flows between two open-topped reservoirs as shown below. Commencing with friction factor values of $f_1 = 0.015$ and $f_2 = 0.022$ determine the flow rate in $m^3/s$. In doing so determine one new set of f values only. Both pipes are made of cast iron with $k = \varepsilon = 0.25$ mm. *[10 marks]*




6 (a) Show that a horizontal jet of volume flux $Q_J$ and velocity $V_J$ exerts a force of $F_x = \rho \frac{Q_J}{V_J} (V_J - u)^2$ on a flat vertical surface which is moving away from the nozzle at velocity u. *[4 marks]*

(b) A jet of water delivers 15 litre/s through a 25 mm diameter nozzle. It strikes a curved object, which deflects the jet through an angle of 120° and which is travelling away from the nozzle at a velocity of 7 m/s. Determine the total force exerted on the curved object and the direction of the force. *[8 marks]*

(c) A container of water is resting on smooth frictionless rollers. Its total mass is 180 kg. A jet of water emerges from a 50 mm diameter orifice on the side of the tank. The coefficients of velocity and of discharge of the orifice are 0.97 and 0.65 respectively and the orifice is 4 m below the water surface.




Calculate the magnitude and direction of the force acting on the container and the distance it travels from a stationary position in 2 seconds. You may assume that the mass of the container does not change appreciably during these 2 seconds. *[8 marks]*

7 (a) Distinguish between the terms

(i) total acceleration
(ii) local or temporal acceleration and
(iii) convective acceleration as applied to fluid flow. *[2 marks each]*

(b) A horizontal pipeline tapers from a diameter of 200 mm at point A to 180mm at point B over a distance of 0.5 m. At time t = 0 the flow rate is Q = 0.045 $m^3/s$ and 3 seconds later the flowrate has increased to Q = 0.055 $m^3/s$. Determine the convective acceleration at time t = 0 and the local acceleration at point B. *[3 marks each]*

(c) The general dynamic equation for flow, per unit mass of fluid, along a streamline is

$$-\frac{\delta}{\delta s}\left(\frac{P}{\rho}+gz+\frac{1}{2}v_s^{\,2}\right)-\frac{\tau}{\rho}\frac{2}{r}=\frac{\delta v_s}{\delta t}$$

(i) List the forces which are taken into account by this expression (a derivation of this expression is not required). *[5 marks]*

(ii) What assumptions are necessary in order for the equation to become the Bernoulli equation? *[3 marks]*

8. **Attempt any 5 of the following** *[4 marks each]*

(a) Indicate which of the following are True or False:

(i) Gauge Pressure = Absolute Pressure + Atmospheric Pressure
(ii) One atmospheric pressure is 101 kPa.
(iii) One atmospheric pressure is 76 mm mercury.
(iv) Water rises 40 mm in a clean glass tube of 0.1 mm diameter.
($\gamma_{water}$ =0.073 N/m)

(b) A flat plate 0.8 m long and 0.4 m wide is pulled through a narrow tank of oil, with both sides of the plate touching the oil, with a velocity of 0.2 m/s. The clearances between the plate and the sides of the tank are 0.5 mm and 0.75 mm respectively. Calculate the force required to do this, given the viscosity of oil to be $\mu$ = 0.018 Pa s.

(c) A Pitot tube is inserted into a flowing fluid at a point where velocity is 1.5 m/s. What is the magnitude of the reading provided by the Pitot tube?

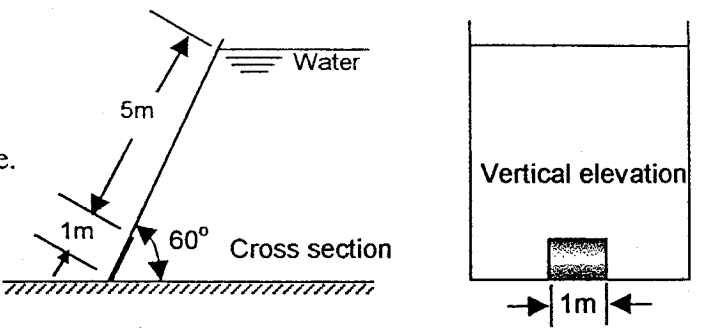
*Question 8 continued overleaf..../*

(d) Oil of density 855 kg/m$^3$ flows in a pipe of 20 mm diameter. If the oil viscosity is 0.018 Pa s what is the maximum flow rate, in m$^3$/s, possible which guarantees laminar flow.

(e) Water flows in a smooth pipe of 50 mm diameter with a velocity of 1.8 m/s. Calculate the corresponding hydraulic gradient.

(f) A pump is connected to a tank in which the liquid surface is 4 m below the level of the pump. They are connected by a 50 m long, 25 mm diameter pipe, with friction factor f = 0.018. Calculate the pressure at the pump inlet if the flow velocity is 1.5 m/s.

(g) A 1 m square gate is located as shown. Calculate the hydrostatic thrust on the gate.




(h) Water is pumped at a rate of 0.09 m$^3$/s against a total head of 30 m. If the pump/motor efficiency is 70% determine how much energy is required to deliver 2000 m$^3$.