National Examinations December 2009

04-BS-7, Mechanics of Fluids

3 hours duration

NOTES:

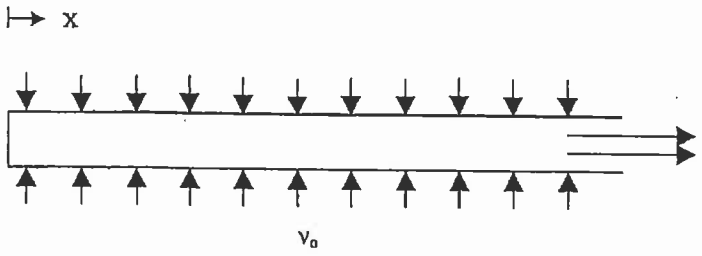
1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK exam. No aids other than a Casio or Sharp approved models calculator is permitted.
3. Any data required are given with the questions or are listed in point 7 below.
4. All questions have equal value.
5. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book(s) will be marked. Indicate clearly any questions you do not wish to have marked.
6. Neat sketches, wherever possible, should accompany your solutions. All calculations must be clearly shown.
7. Unless otherwise stated, assume that the density of water ρ is 1000 kg/m^3 and the acceleration due to gravity is 9.81 m/s^2.
8. One 8 ½ inches by 11 inches aid sheet (both sides) is permitted.

1. The pressure developed by a centrifugal pump (ΔP) is a function of the diameter of the impeller (D), the speed of rotation (n), the discharge (Q), and the fluid density (ρ). Using Buckingham-Pi, develop a dimensionless relationship for this flow.

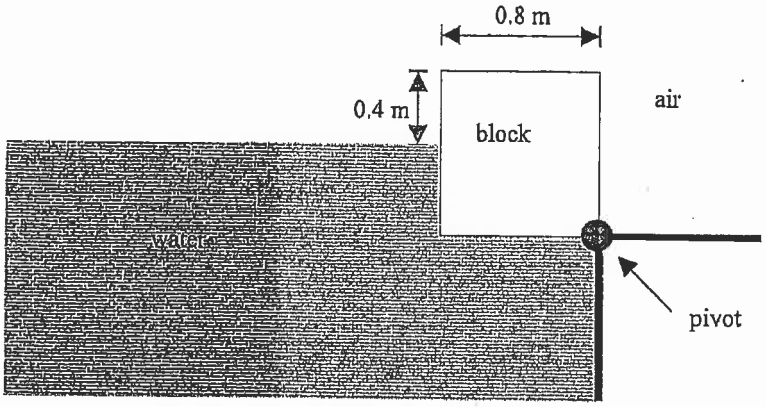
2. Water flows out of a kitchen faucet (diameter of 1.5 cm) at a volumetric flow rate of 0.15 litres/s. Develop an expression for the cross-sectional area of the stream as a function of the distance from the faucet outlet. You may assume that the velocity profile across the stream is uniform so that the flow is one-dimensional. Does the area change with distance? Explain physically why it increases, decreases, or remains constant as the distance from the faucet is increased.

3. An incompressible inviscid fluid flows through a horizontal round tube made of a porous material. The left end of the tube is closed and the right end is open to the atmosphere. Fluid enters the tube through the porous wall with velocity v_o of 0.8 m/s and travels horizontally to the right end of the tube where it discharges to the atmosphere. You may assume that the flow is steady and uniform across any cross-section. The fluid has a density of 1000 kg/m^3, the tube length is 0.5 m, and the tube diameter is 0.02 m. Find an expression for:

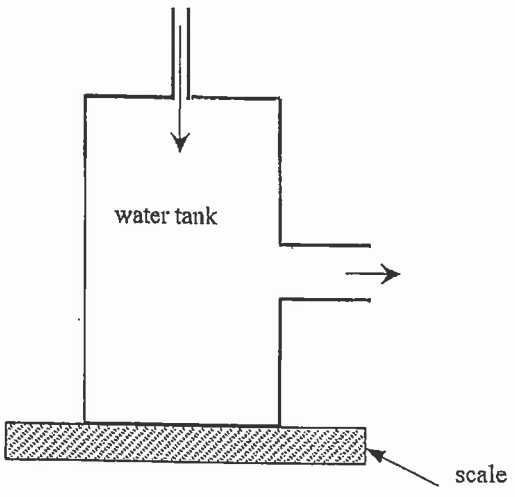
   a) The pressure of the fluid along the centreline.
   b) The acceleration of a particle at the centreline and at x=0.25 m (where x=0 at the left end of the round tube).



4. A long plastic block (of square cross-section) rests in water as shown in the diagram below. There is a pivot at the bottom right corner of the block which would allow the block to rotate. The block is in equilibrium when located in water at a depth shown in the diagram. Calculate the density of the block material.



5. Consider the water tank (as shown below) which is filled completely with water. The tank is resting on a scale and water flows in vertically at a velocity of 2.5 m/s through an inlet pipe of diameter (2.0 cm) and flows out through a horizontal pipe of diameter 4.0 cm. The tank is 0.75 m high and has a diameter of 0.5 m. If the tank material and the water in it have a mass of 175 kg, what reading will the scale have?



6. Consider a hollow cube that has sides of 200 mm which is immersed in a container of oil and water. The cube is floating at the interface between the layer of oil (ρ=900 kg/m^3) and water such that 15% of the cube is exposed to the oil and the remaining 85% is exposed to the water. Calculate the average density of the cube.

7. A rough pipe (diameter=30mm) has water flowing through it at a flow rate of 0.3 m^3/min. The pipe is straight and is 7 m long and the pressure at the inlet is 800 kPa (gage) and the outlet (located 3 m below the inlet) has a pressure of 500 kPa (gage). What is the relative roughness of the pipe? You may use the attached Moody diagram to assist with this question. The viscosity of the water is μ = 9.0E-04 Ns/m^2. If the old rough pipe were replaced with a new smooth pipe, what would be the percentage savings in pumping power to obtain the same flow rate?

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