

NATIONAL EXAMINATIONS, May 2009, 04-BS-7, Mechanics of Fluids

National Examinations May 2009

04-BS-7, Mechanics of Fluids

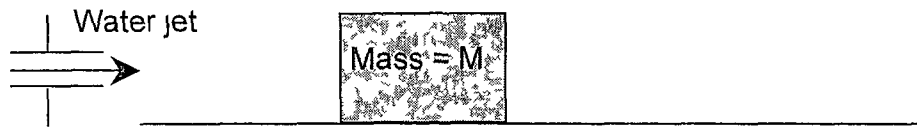
3 hours duration

NOTES

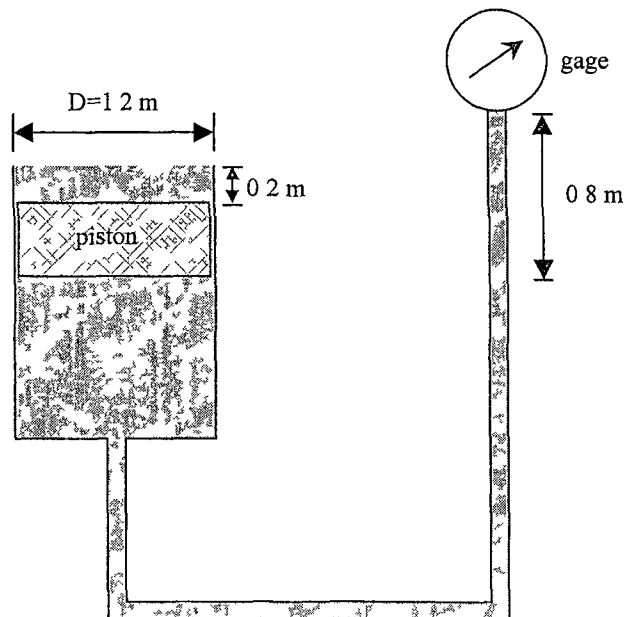
- 1 If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made
- 2 This is a CLOSED BOOK exam No aids other than a CASIO or a SHARP electronic calculator is permitted
- 3 Any data required are given with 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

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- 1 As shown in the figure below, a block (mass = M) is initially at rest on a frictionless surface. At time $t=0$, the block is subjected to a horizontal water jet (density ρ , velocity V_{jet} and cross-sectional area A_{jet})
- Develop an algebraic expression for the velocity and displacement of the block as a function of time
 - If $\rho=1000 \text{ kg/m}^3$, $V_{jet} = 1.2 \text{ m/s}$, $A_{jet}=0.01 \text{ m}^2$ and $M=5 \text{ kg}$, calculate how far the mass has moved after being subjected to the water jet for 3 seconds



- 2 In the diagram below, the cylinder (diameter = 1.2 m) which is open to the atmosphere contains oil of density 860 kg/m^3 . The piston is submerged in the oil as shown. The gage is located at 0.8 m above the bottom of the piston. What is the mass of the piston if the gage pressure reading is 75 kPa ?

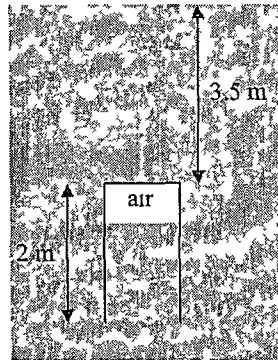
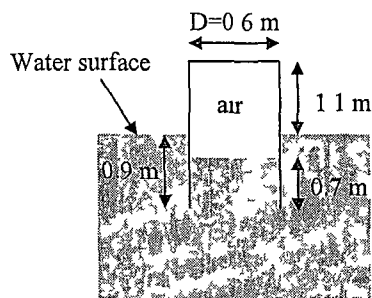


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- 3 Water flows from an elevated reservoir to a lower reservoir through a single smooth pipe that has a length of 1500 m and diameter of 120 mm. You may use the attached Moody Diagram to assist with this question.
- a) If the flow rate is $0.020 \text{ m}^3/\text{s}$, calculate the difference between water surface elevations of the two reservoirs. You may neglect minor losses and assume that the viscosity of water is $\mu = 9.0 \times 10^{-4} \text{ N}\cdot\text{s}/\text{m}^2$ and atmospheric pressure is 101 kPa.
- b) Now suppose that rather than having a single pipe connecting the two reservoirs, the 1500 m long pipe is replaced with two 750 m long smooth pipes connected together in series. The first pipe has a diameter of 120 mm, while the second pipe has a diameter of 200 mm. Using the elevation difference calculated from part a), determine the flow rate for this new system. Explain physically why the flow rate changes.
- 4 Experiments show that the pressure drop in a horizontal pipe is a function of the diameter of the pipe (D), the viscosity (μ) and density (ρ) of the fluid, fluid velocity (V), the length of pipe (L) and the pipe relative roughness (k/D). Use the Buckingham- Π theorem to determine the relevant dimensionless groups for this problem.
- 5 Consider the flow of air (density = $1.2 \text{ kg}/\text{m}^3$) over an airfoil.
- a) How does the drag force on an airfoil change as the Reynolds number increases (i.e. discuss which force dominates at low Reynolds number and which dominates at high Reynolds number)?
- b) Sketch the streamlines around an airfoil at a low angle of attack. Does the flow separate from the airfoil?
- c) Now consider the same airfoil but at a higher angle of attack. Sketch the streamlines and explain how the flow has changed.
- d) What is meant by airfoil stall? What does the flow look like under stall conditions and how does this affect lift?
- e) What speed should an airplane having a wing planform area of 45 m^2 and weighing 25 kN be flown at in order to maintain its altitude? You may assume a lift coefficient of 0.95 and air density of $1.2 \text{ kg}/\text{m}^3$.

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- 6 A cylindrical tank contains air as shown in the two figures below. Assume that atmospheric pressure is 101 kPa and the density of water is 1000 kg/m^3 .
- If the tank floats at the surface, find the mass of air in the tank and the mass of the tank walls. Assume that the air temperature is 300 K and the ideal gas constant for air is $R=287 \text{ J/kgK}$.
 - If the tank is held so that the top is 3.5 m below the surface of the water, what is the force on the inside top of the tank? You may assume the temperature of the air is the same as in part a).



- 7 A rectangular gate of width 3.0 m (i.e., depth into the page) is hinged as shown in the diagram below. Calculate the depth H at which the gate will remain closed. If the water level is greater than H , will the gate rotate clockwise or counterclockwise? Does the width of the gate (i.e., into the page) influence your answer? Explain.

