National Examinations May 2010

04-BS-7, Mechanics of Fluids

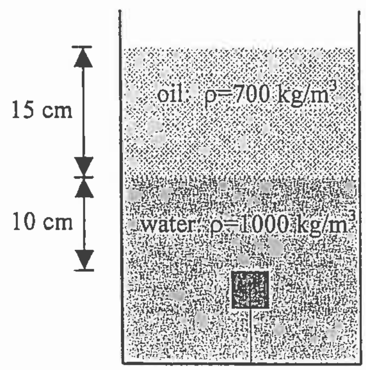
3 hours duration

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 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.

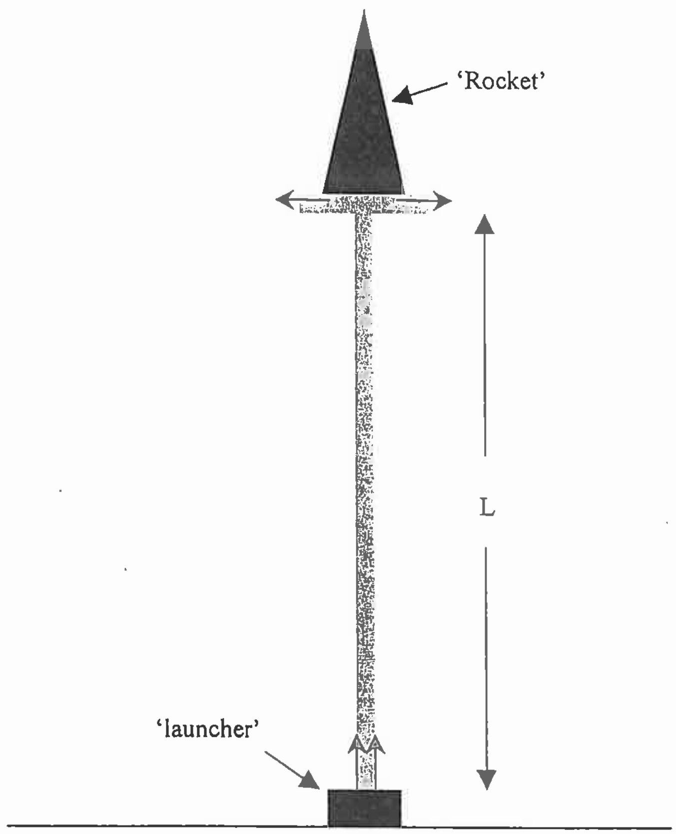
1. A figure skater is gliding on one skate at a speed of 6 m/s. The skater has a mass of 50 kg and the skate blade is 30 cm long and 3 mm wide. A liquid water film (thickness = 1.5×10^{-6} m) is formed under the blade. Assuming that end effects can be neglected, calculate the deceleration of the skater resulting from viscous shear. Use water properties of ρ=1000 kg/m^3 and μ= 9.0×10^{-4} Ns/m^2.

2. A solid cube of wood (length of each side=3cm) is submerged in a tank containing oil and water. The cube is held in place with a tether as shown in the figure below. The tank is open to the atmosphere.
   a) Calculate the force on the tether if the density of the wood is 600 kg/m^3.
   b) Suppose that the tether breaks and the cube is now released from rest and moves towards the surface of the fluid. You may assume that the drag coefficient for the cube is given by C_D=1.05 and that the important forces acting on the cube are hydrostatic pressure, gravity, and fluid drag.
      i) Develop a mathematical expression for the force balance on the cube;
      ii) Determine what the terminal velocity of the cube would be if it attains that velocity in the oil region of the tank.



3. Air (ρ = 1.2 kg/m^3) at atmospheric pressure enters a wind tunnel. A static pressure tap is drilled into the test section of the wind tunnel where the fluid flow is approximately uniform and parallel to the wall. A manometer connected to the tap indicates a pressure of 50 mm of water below atmospheric. Calculate the air speed in the test section of the wind tunnel.

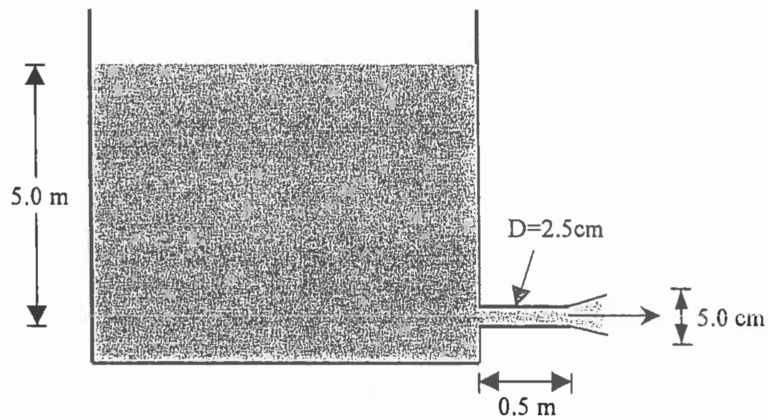
4. A child's outdoor water toy consists of a 'rocket' and 'launcher'. The launcher attaches to a garden hose and produces a high velocity jet which supports the weight of the rocket as shown in the figure below. If the rocket has a mass of 0.1 kg, the flow rate of water is 0.065 kg/s and the jet diameter is 2 mm, calculate the maximum height (L) that the rocket attains. To simplify this problem, you may assume that the jet diameter is constant.



5. Consider a continuous belt that moves vertically through a bath of viscous fluid. The belt carries a liquid layer of thickness h along with it. The volume flow rate of liquid (Q) is found to depend on ρ, μ, h, g and V where V is the speed of the belt. Use Buckingham-Pi to determine the relevant dimensionless groups for this problem.

6. Consider flow in the reservoir/pipe as shown below. The reservoir is large and the height of the water surface in the reservoir is 5 m above the smooth horizontal pipe. The horizontal pipe has a diameter of 2.5 cm and a length of 0.5 m. The k-factor associated with the square edged entrance to the pipe is 0.4. A diffuser with a K-factor of 0.25 is attached to the outlet of the pipe as shown below. The diameter at the diffuser outlet is 5 cm and the fluid exits to atmospheric conditions.

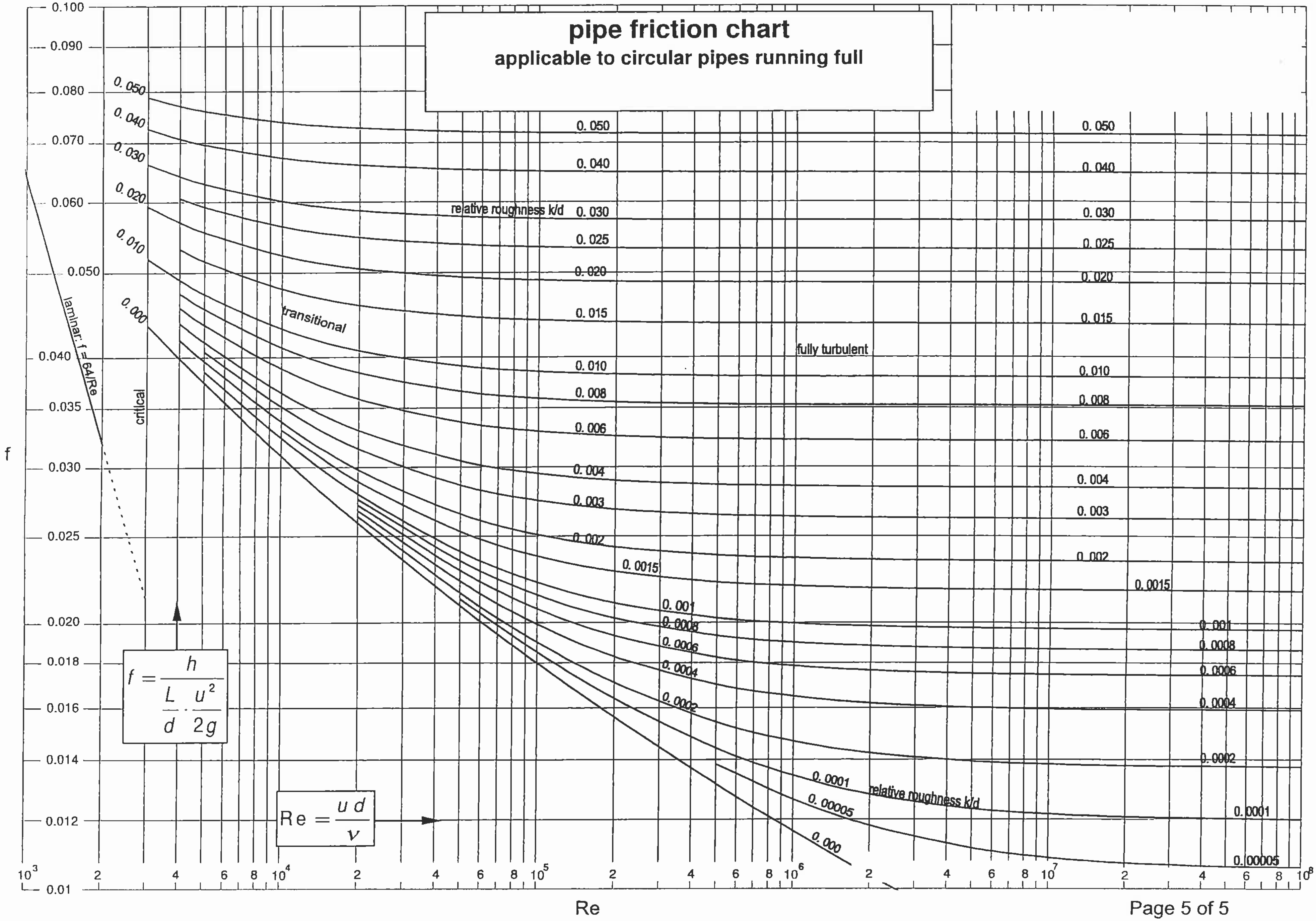
   a) Calculate the flow rate exiting the diffuser. Use water properties of $\mu=1.14 \times 10^{-3}$ Ns/m^2 and $\rho=1000\ kg/m^3$. You may use the attached Moody Diagram to assist with this problem.
   b) Sketch the pressure along the centreline of the pipe and diffuser as a function of the axial distance from the reservoir. Can the pressure in the diffuser be less than atmospheric pressure? Explain your answer.



7. Consider a two-dimensional velocity field given by:

$$u(x,y) = x^2 - y^2 + x$$
$$v(x,y) = -(2xy + y)$$

   a) Show that the fluid is incompressible.
   b) What is the acceleration in the x-direction felt by a fluid particle located at $(x,y)=(1,2)$?


pipe friction chart
applicable to circular pipes running full
relative roughness k/d
transitional
fully turbulent
critical
laminar: f = 64/Re
f = h / (L/d · u²/2g)
Re = u d / ν
f
Re
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.035
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