THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF MECHANICAL ENGINEERING

EXAMINATION FOR THE DEGREE OF B.E.

June 1999

FLUID MECHANICS 2 (5526)

TIME: 3 HOURS

In addition, candidates are allowed ten minutes before the examination begins to read the paper.

Candidates may attempt any **FOUR** problems.

The use of notes, books and suitable calculating devices is permitted in the examination room.

All problems are of equal value. Descriptive and short questions (2(a), 3(a), 4(a) and 5(a)) are worth 20 % of the marks for each main problem.

The Given/Find/Schematic/Assumptions protocol is not required for the descriptive and short questions (2(a), 3(a), 4(a) and 5(a)).

State all assumptions.

Use $g = 9.81$ m/s^2.

Problem 1

A small aircraft cruises at 216 km/h at an altitude of 2000 metres where the air has a density of 1.007 kg/m^3 and a kinematic viscosity of 1.715 x 10^{-5} m^2/s. The aeroplane's wing has an aspect ratio of 7.5 and a planform area of 19.2 m^2. The planform is essentially rectangular. The weight of the aircraft is 1064 kg.

a) Assuming that the skin friction drag of the wing can be approximated by that of a smooth rectangular flat plate of the same span and planform area, and that the boundary layer is turbulent from the leading edge, estimate the power required to overcome the skin friction drag.

b) What power savings would be possible if the boundary layer could be maintained in a laminar state over the entire wing?

c) If the total power required to overcome drag at this flight condition is 48 kW, what is the ratio of lift to drag (Lift/Drag) of the aircraft?

d) Is the boundary layer on the wing likely to be mainly laminar or mainly turbulent?

e) Estimate the thickness of the boundary layer if it is turbulent from the leading edge.

f) Estimate the thickness of the boundary layer if it is entirely laminar.

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Problem 2

(a) What is the effect of surface roughness on the friction factor for flow in a pipe if the flow is:
(i) laminar?
(ii) turbulent?

(b) The three water-filled tanks shown in Figure 1 below are connected by pipes as indicated.

If minor losses are neglected, determine the flow rate in each pipe.

Hint: assume initially that the water flows from tank B to tank C, and from tank A to tank C.
The properties of water are: $\rho = 1000$ kg/m^3 and $\mu = 1.31 \times 10^{-3}$ N.s/m^2.

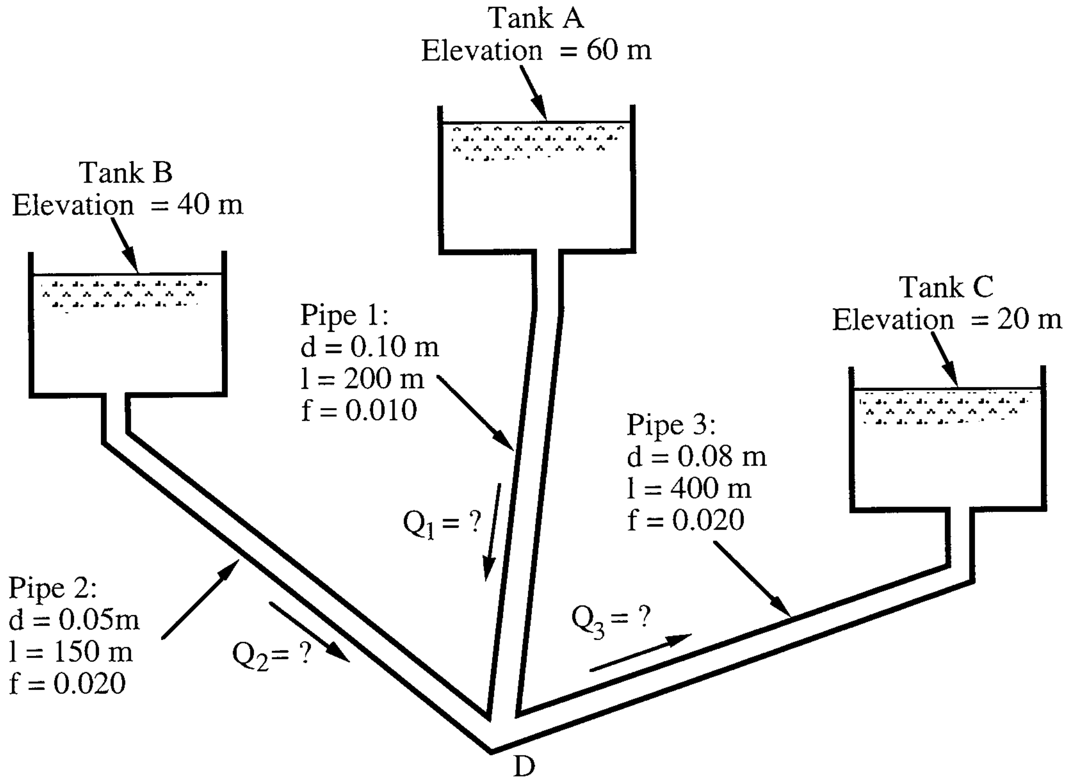

Figure 1.

Problem 3

(a) The total drag force acting on a body fully submerged in a fluid flow consists of a number of individual components. What are these components and what flow phenomena give rise to them.

(b) Describe how you would modify the shape of a short circular cylinder (length/diameter = 2, $C_D = 0.83$), mounted with its axis parallel to the flow direction, in order to minimise its drag. Explain how each proposed modification affects the flow. Assume that the flow around the cylinder is fully turbulent (i.e. $Re > 10^5$).

(c) A lead ball 25 mm in diameter is suspended by a thin piece of thread in the test section of a wind tunnel, as shown in Figure 2 below. The uniform air flow past the ball has a velocity of U = 240 km/h. The air density and kinematic viscosity are 1.23 kg/m^3 and 1.47 x 10^{-5} m^2/s respectively. The specific gravity of lead is 11.3.

Determine the angle (θ) that the thread makes relative to the vertical direction.

Some data are provided in Figure 3 below.

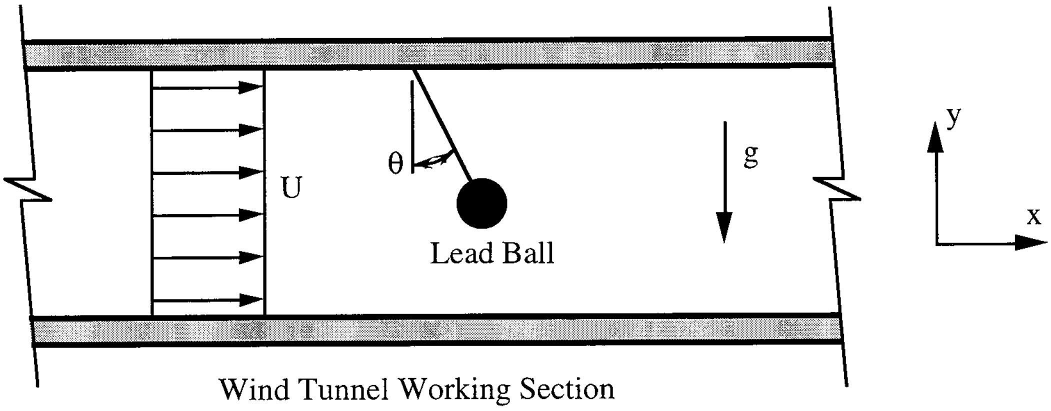

Figure 2.

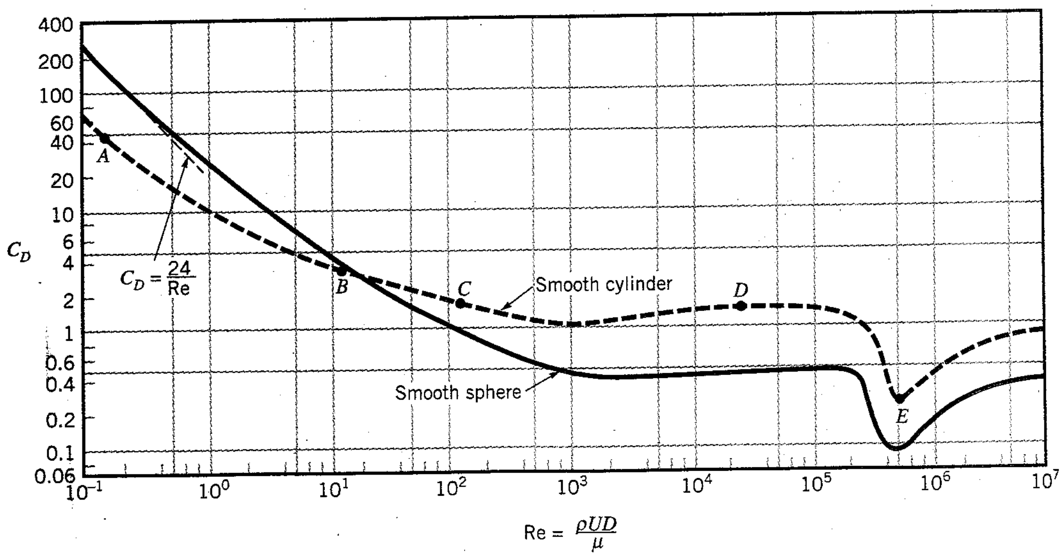

Figure 3. C_D versus Re for smooth spheres and cylinders.

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Problem 4

(a) A two-dimensional flow field is defined by:

$u = 3y^2 + 7$ m/s,
$v = 8x + 2$ m/s.

(i) Is this flow field possible in an incompressible fluid?
(ii) Can a potential function exist in this flow?

(b) A long porous pipe runs parallel to the horizontal floor of a factory building as shown in Figure 4 below. (The longitudinal axis of the pipe is perpendicular to the plane of the paper.) The pipe is located 3 metres above the factory floor. Air flows radially from the pipe at a rate of π m^3/s per metre of pipe length.

Making appropriate assumptions, do the following:

(i) Write down the stream function that describes this flow.

(ii) Locate the stagnation point on the factory floor and determine the equations for the two streamlines passing through the stagnation point. Show all working.

(iii) Sketch the flow pattern.

(iv) Determine the velocity at point A in Figure 4.

(v) Determine the difference in pressure between point A and point B.

Hint: the flow may be approximated by using one or more two-dimensional sources in a potential flow analysis.

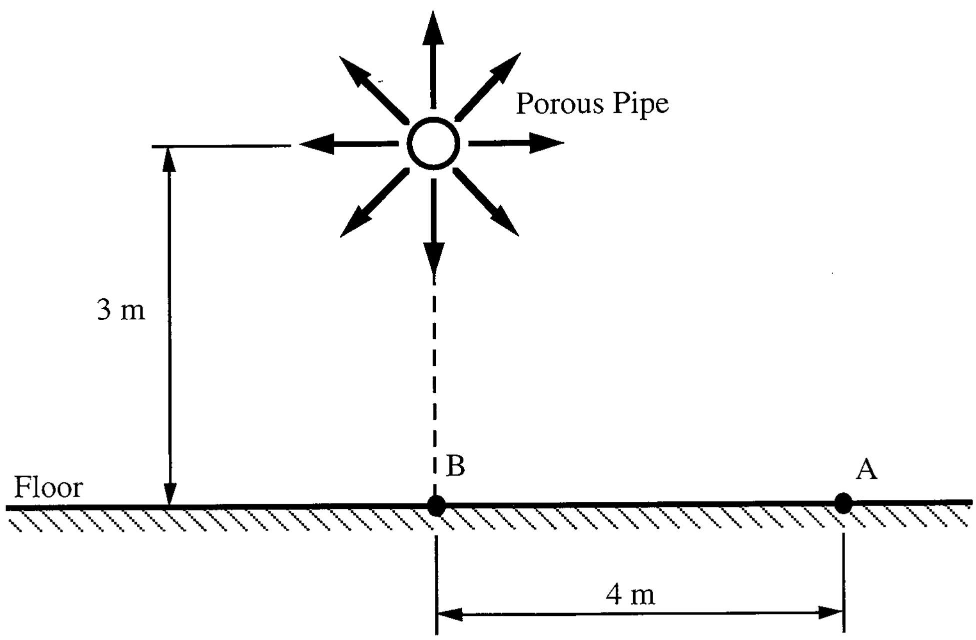


Figure 4.

Problem 5

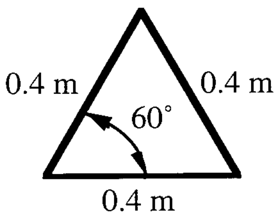
(a) Define the term "exit loss" and explain why it occurs.

(b) Water at 10 °C flows along a horizontal conduit with a triangular cross-section as shown in Figure 5(a). At this temperature $\rho = 1000$ kg/m^3 and $\mu = 1.31 \times 10^{-3}$ N.s/m^2. The roughness height on the conduit walls is $\varepsilon = 0.05$ mm. The head loss along the conduit is 2 metres per 100 metres of length. Find the flow rate in the conduit.

(c) A pump is used to raise water from one reservoir to another 50 metres above along a length of the triangular conduit shown in Figure 5(a) (now aligned vertically) and at the same flow rate as calculated in part (b) above. The arrangement is shown in Figure 5(b). Assume that there are no bends in the conduit and the connection between the pump and conduit is loss-free. There are entrance and exit losses with coefficients as shown. The overall efficiency of the pump is 0.9 and the efficiency of the electric motor driving the pump is 0.95.

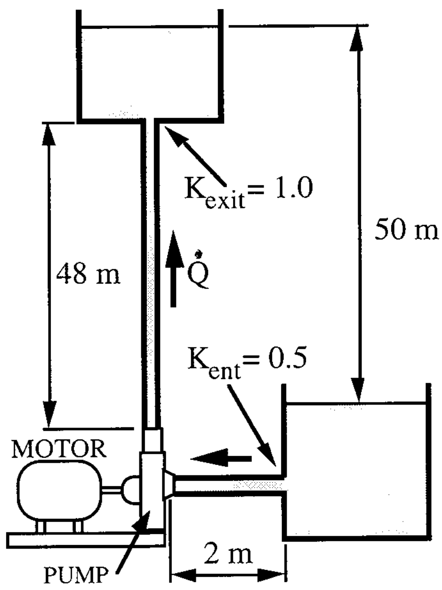
(i) How much power is delivered to the fluid by the pump?

(ii) How much electrical power is required to pump the water to the upper reservoir?



Cross-sectional shape of the duct.

(a)



(b)

Figure 5.

END OF EXAMINATION