THE UNIVERSITY OF ADELAIDE
DEPARTMENT OF MECHANICAL ENGINEERING

EXAMINATION FOR THE DEGREE OF B.E.

June 2000

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. Short questions (1(a), 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 (1(a), 2(a), 3(a), 4(a) and 5(a)).

State all assumptions. Unless otherwise stated, use $g = 9.81 \text{ m/s}^2$.

Problem 1

(a) Figure 1 below shows the variation of the lift coefficient with angle of attack for an aircraft wing.
  (i) From this graph, estimate the camber of the wing if its chord is 2.0 m.
  (ii) Calculate the lift-curve-slope of the wing. Compare it with the value for an ideal wing.

(b) A small powered aircraft cruises at 252 km/h at an altitude of 50 metres where the air has a density of 1.225 kg/m^3 and a kinematic viscosity of $1.460 \times 10^{-5} \text{ m}^2/\text{s}$. The aeroplane's rectangular wing has a span of 12 m and a plan area of 24 m^2. The mass of the aircraft is 2000 kg. The total drag of the aircraft (including the drag on the wing and fuselage, and the induced drag) is 90% higher than the drag of the wing alone.
  (i) Estimate the proportion (eg. percentage) of the wing subjected to a laminar boundary layer.
  (ii) Estimate the drag on the wing.
  (iii) Estimate the induced drag on the wing.
  (iv) Estimate the L/D ratio for the whole aircraft.
  (v) The characteristics of the wing are given below in Figure 1. Using this graph, estimate the angle of attack required to keep the aircraft in stable flight.
  (vi) If the aircraft speeds up to 288 km/h, how does it maintain steady, level flight? Estimate the change in the appropriate parameter or parameters.

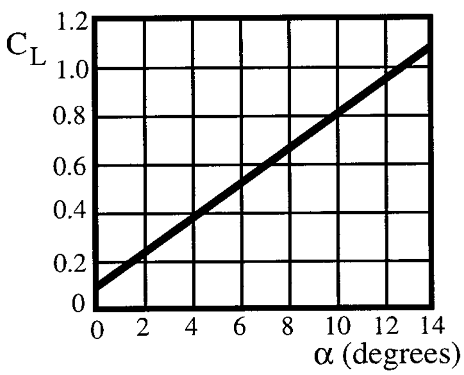

Figure 1.

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Problem 2

(a) (i) What is meant by the term "hydraulically smooth"?
(ii) What is the effect of surface roughness on the friction factor for flow in a pipe if the flow is:
- laminar?
- turbulent?

(b) Air flows through a multi-tube heat exchanger as shown in Figure 2. The flow enters a manifold and then flows through 100 smooth parallel tubes, each with diameter 10 mm and length 150 mm, into a second manifold. The average air temperature in the heat exchanger is 20 °C. The pressure drop between the two manifolds is 0.20 Pa (i.e. $p_1 - p_2 = 0.20$ Pa). Neglect entrance and exit losses of the tubes.

Find the total mass flow rate of air through the heat exchanger.

Fluid properties for air at 15 °C: $\rho = 1.225$ kg/m^3 and $\mu = 1.789 \times 10^{-5}$ N.sm^{-2}.

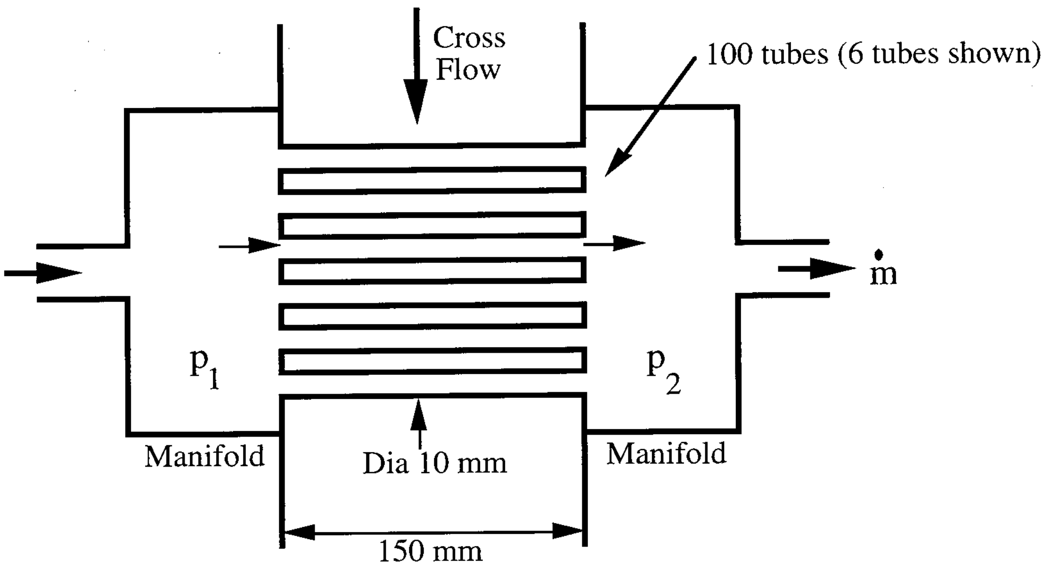

Figure 2.

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) A bracing strut is fitted to a small aircraft to strengthen the wing assembly. The strut is circular in cross-section with a diameter of 120 mm and an overall length of 2.0 m. During flight the smooth strut is found to vibrate at 50 Hz, due to the wake vortex shedding phenomenon. Making appropriate assumptions and using the data given in Figure 3, estimate:

(i) the speed of the aircraft,
(ii) the drag on the strut.

Use: ρ = 1.225 kg/m^3 and μ = 1.789 x 10^{-5} N.s/m^2.

(c) Find the terminal velocity of a parachutist, assuming that the parachute can be modelled as a semicircular cup of diameter 6 m. The total mass of the person and parachute is 90 kg. The altitude of the parachute is 3000 m. Use g = 9.797 m/s^2, ρ = 0.9093 kg/m^3 and μ = 1.694 x 10^{-5} N.s/m^2.

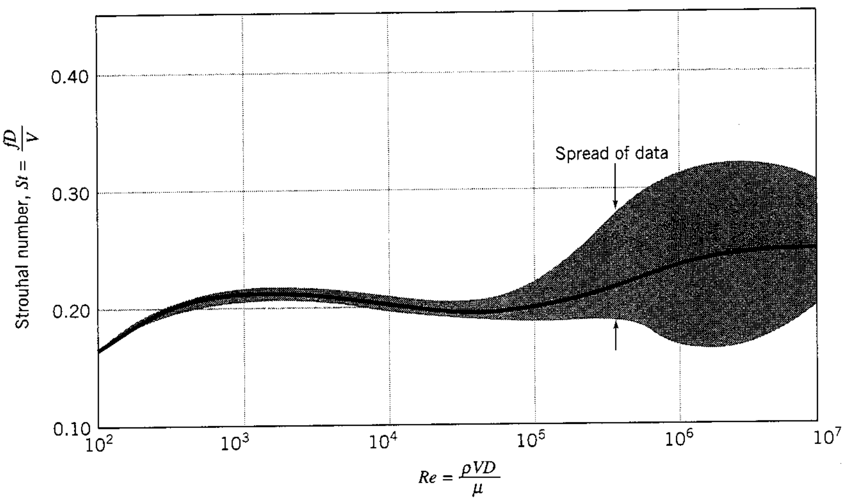

Figure 3a. Strouhal number versus Reynolds Number for smooth cylinders.

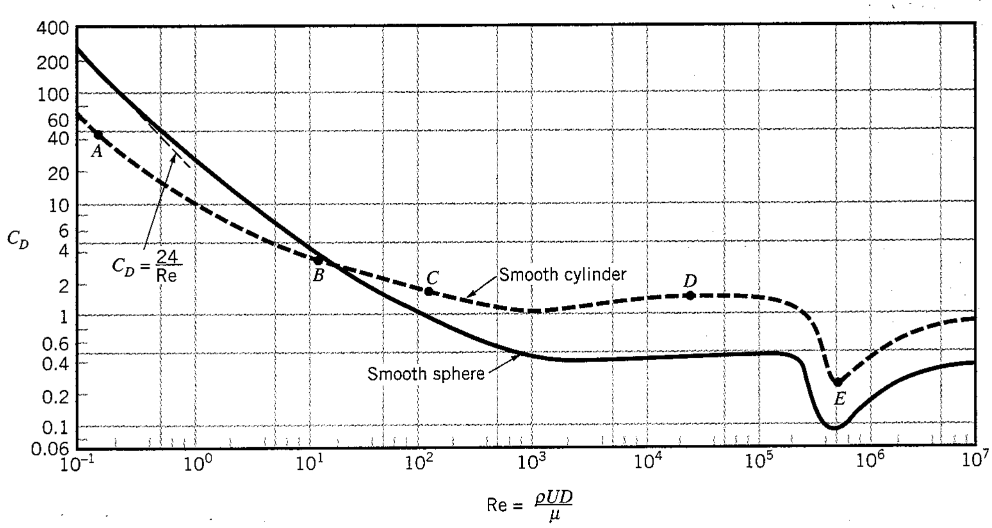

Figure 3b. Drag Coefficient versus Reynolds Number for smooth spheres and cylinders.

Problem 4

(a) What is Prandtl's boundary Layer Hypothesis? How is it relevant to the developing flow within a two-dimensional duct?

(b) Air enters a long two-dimensional horizontal duct of constant height h, as shown in Figure 4 below. Identical boundary layers develop on the top and bottom surfaces. In the core region, outside the boundary layers, the flow is inviscid and irrotational (ie. loss-free). The flow is incompressible and steady.

(i) Show that:

$$\frac{U_2}{U_1} = \frac{h}{h - 2\delta^*}$$

where δ^* is the displacement thickness at station 2.

(ii) Given the information in part (i), find the pressure drop between stations 1 and 2 along the central streamline.

(iii) Find L (the distance between stations 1 and 2) in terms of the fluid properties and the parameters shown in Figure 4. Assume that the boundary layers are laminar.

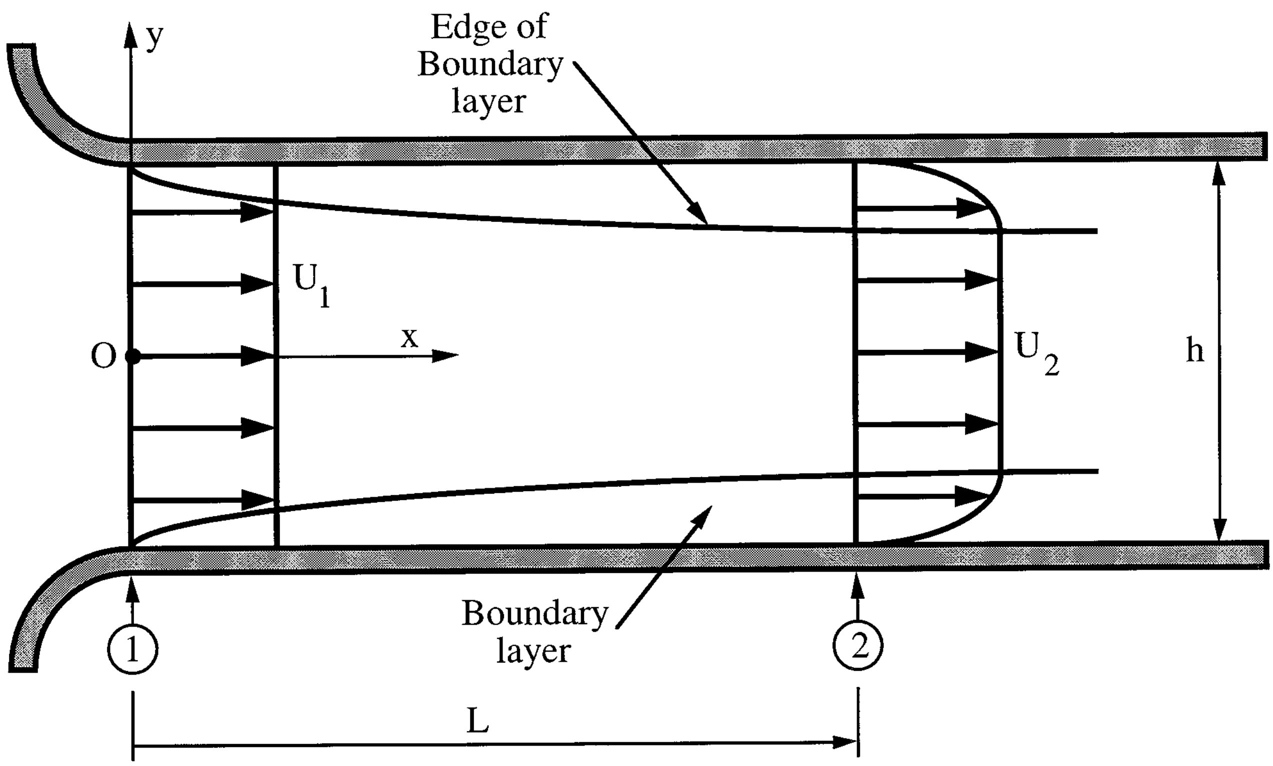

Figure 4.

Problem 5

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

(b) Water is circulated from a large tank, through a filter and a valve and back to the tank, as shown in Figure 5. The power transferred to the water by the pump is 300 W. The circuit contains a total of 60 metres of 30 mm inside diameter pipe with a roughness height of 0.3 mm. The circuit contains five 90° elbows.

Determine the volume flow rate through the pipe system in m^3/s.

The properties of water are: $\rho = 1000$ kg/m³ and $\mu = 1.31 \times 10^{-3}$ N.s/m². The Moody Chart is provided in Figure 7 on Page 6.

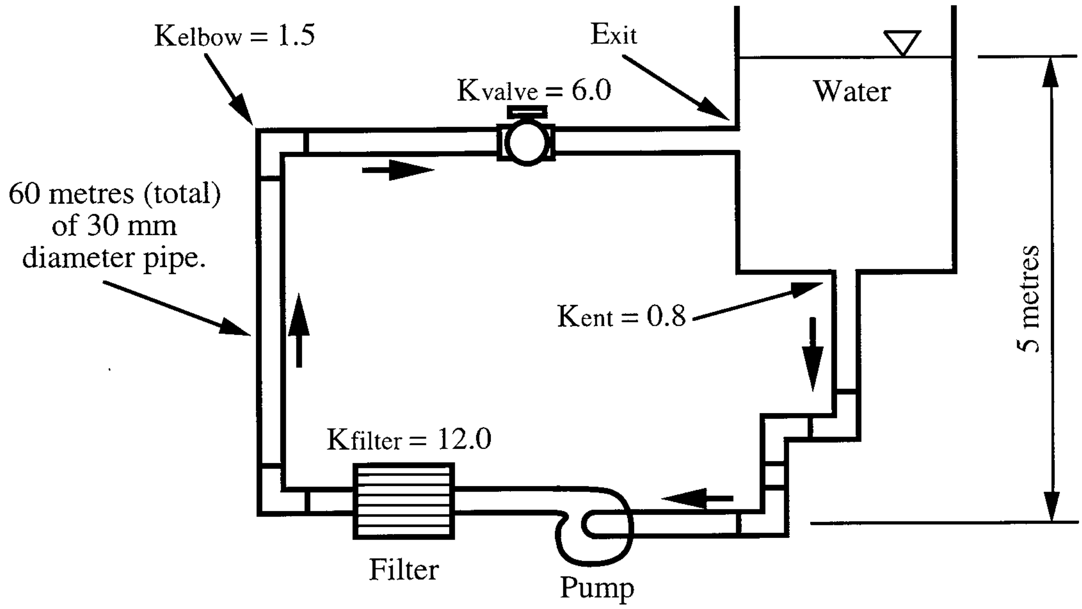

Figure 5.

(c) A water pump is required to provide a head of 20 m at a flow rate of $0.002\ m^3/s$. If the pump operates at a rotational speed of 1440 rpm, indicate whether a radial, mixed flow or axial pump is required. Show all calculations. Figure 6 below may aid in your choice.

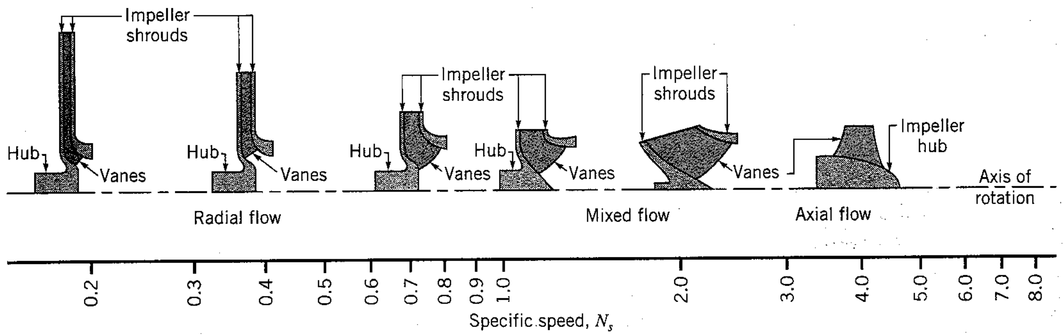

Figure 6. Pump type versus Specific Speed N_s

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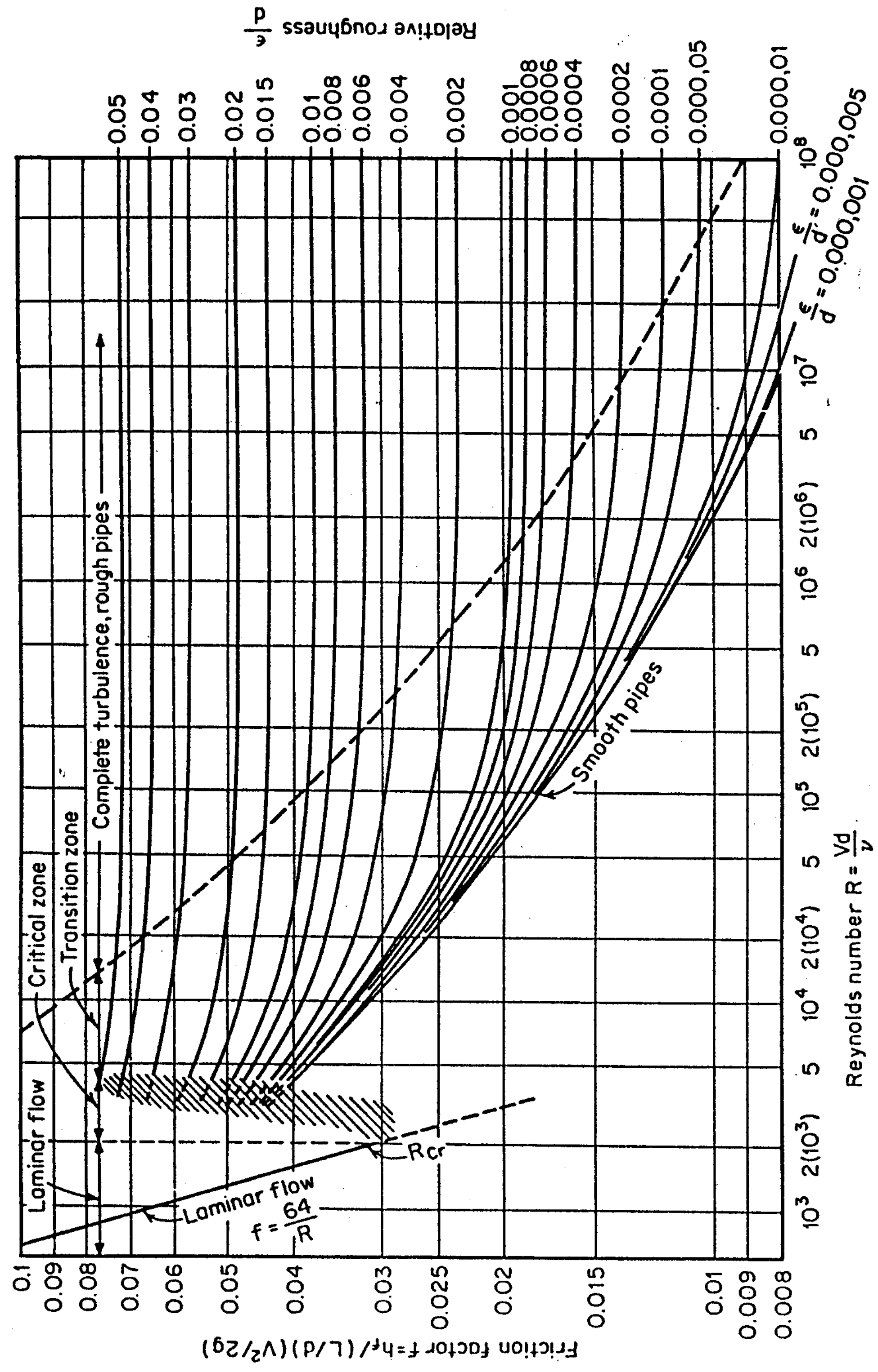

Figure 7. The Moody Chart.

END OF EXAMINATION