No. of pages........................ 7
No. of questions 4
Total marks........................ 75

THE UNIVERSITY OF ADELAIDE

Examination for the Degree of B.E.

3008 Fluid Mechanics 2

Department of Mechanical Engineering

Semester 1, June 2002

Duration: 2 hours + 10 minutes.

Allocate the first 10 minutes to reading the paper.

Answer THREE of the four questions.
All questions are of equal value.

Calculators, notes and textbooks are permitted.
Acceleration due to gravity: $g = 9.81$ m/s^2.

Problem 1

(a) (5 marks) Show that for unpowered flight (i.e. an aircraft gliding at steady state) the glide path angle θ (relative to horizontal) is given by:

$$\tan\theta = C_D/C_L$$

where C_L and C_D are the aircraft's lift and drag coefficients respectively.

(b) (20 marks) Two steel balls of 35 mm diameter are dropped into the ocean. One ball is smooth and the other is very rough. Find the terminal velocities of both balls. Are the results sensible? Figure 1 below may be of assistance. This figure is repeated on the last page. A graphical solution is acceptable.

Use $\rho_{steel} = 7830$ kg/m^3, and $\rho_{water} = 1008$ kg/m^3 and $\mu_{water} = 1.07 \times 10^{-3}$ N.sm^{-2}.

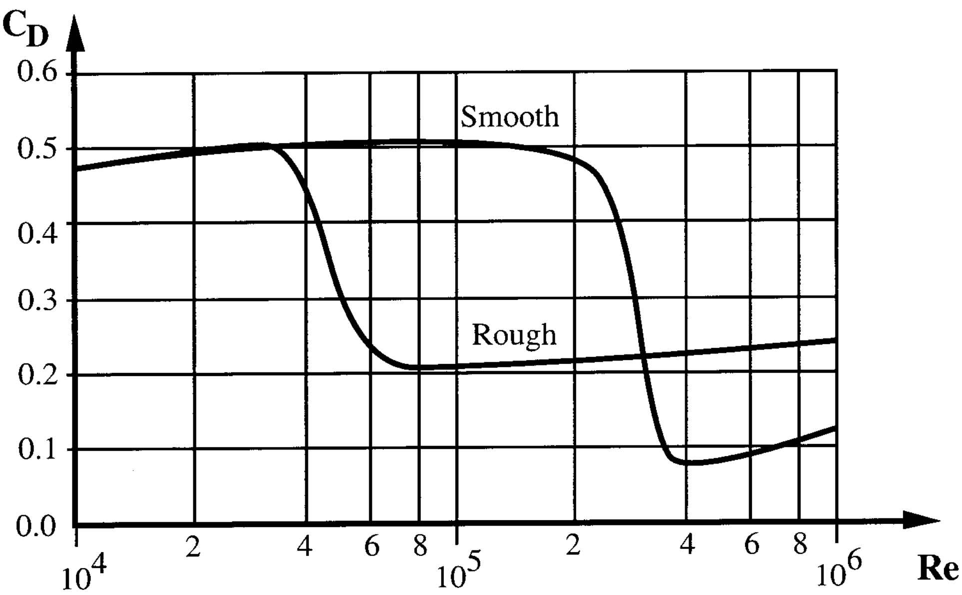


Figure 1. C_D versus Re for rough and smooth spheres.

Problem 2

(a) (5 marks) Consider water flow along a pipe of diameter D with a fixed head loss per unit length and a relative roughness height of ε/D. If the diameter of the pipe is doubled, what is the effect on the flow rate when the flow is **laminar**.

(b) (20 marks) To conserve water and energy, a “flow reducer” (orifice plate) is installed in the shower head, as shown in Figure 2. The pressure at the inlet (Point 1) remains constant, independent of the flow rate. The external pressure (Point 2) is atmospheric. The “flow reducer” reduces the flow rate by a factor of 2.

Determine the value of the head loss coefficient K for the “flow reducer”, based on the velocity in the pipe (i.e. velocity at Point 1).

Neglect all losses except for that of the “flow reducer”.

Hint: consider the flow **with** and **without** the “flow reducer”.

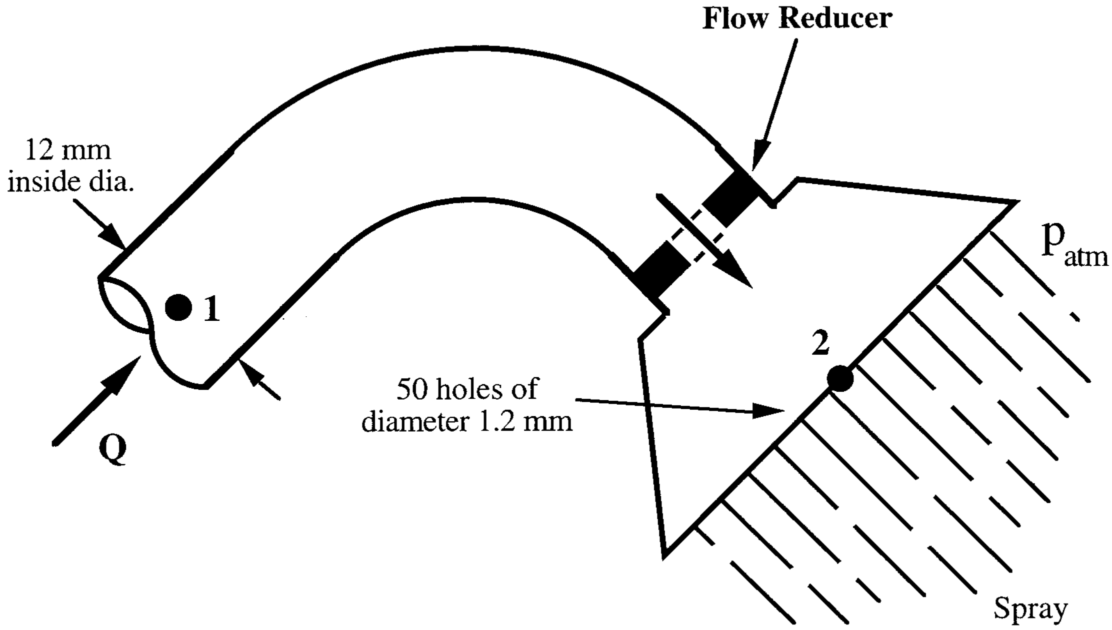


Figure 2. Shower head with “flow reducer”.

Problem 3

The front wing on a race car is shown in Figure 3(a). End plates (not shown) are fitted to the wing to ensure two-dimensional flow and the surface of the wing is smooth. An engineer wishes to find the maximum angle at which the lower surface of the wing can be set without causing boundary layer separation on that surface. To find this angle, the flow is modeled using the geometry shown in Figure 3(b). The model assumes that the wing surface and road behave like a two-dimensional divergent channel with a divergence angle β. It also assumes that the flow is laminar, and that the boundary layer is negligibly thin at the beginning of the divergence.

The relevant parameters (h, L and U_o) are given in Figure 3(b) where h = 0.125 m, L = 0.3 m and U_o = 10 m/s. The properties of air are: $\rho = 1.20$ kg/m^3 and $\mu = 1.80 \times 10^{-5}$ N.s/m^2.

(a) (20 marks) Use the Thwaites method to estimate the angle β at which separation of the laminar boundary layer occurs at the trailing edge of the wing.

(b) (2 marks) If the boundary layer on the wing became turbulent, would you expect an increase or decrease in the angle (β) at which separation occurs? Explain your answer.

(c) (3 marks) If the chord length (C) of the actual wing is 0.5 m, at what speed would you expect the boundary layer on the wing to begin to develop turbulent regions? Assume (for this calculation) that the streamwise pressure gradient is small.

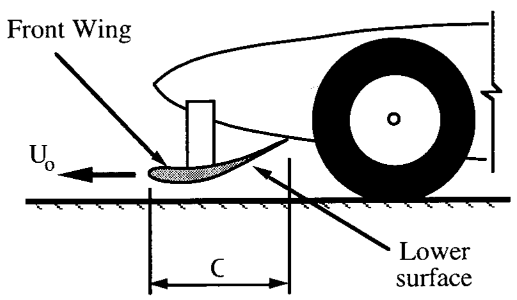


Figure 3(a). Wing arrangement.

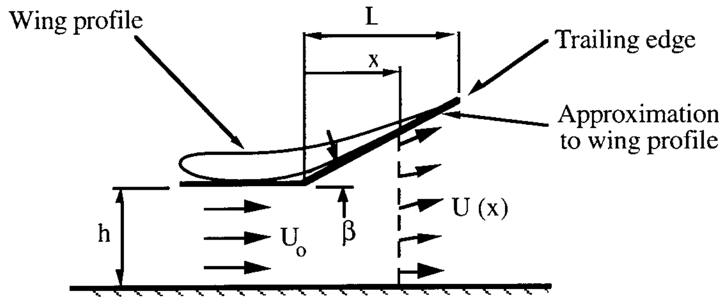


Figure 3(b). Model geometry.

Note:

$$\int \frac{1}{(1+kx)^5}.dx = \frac{-1}{4k}\frac{1}{(1+kx)^4}$$

Problem 4

Water is to be pumped from a low reservoir to a higher reservoir as shown in Figure 4(a). The difference in water levels is 50 metres. The pipe joining the two reservoirs has an internal diameter of 50 mm, a roughness height of 2.5 mm and a total length of 60 metres. The pipe contains two 90° elbows (K_{90} = 0.95 each), and the square-edge pipe entrance has K_{ent} = 0.45. The properties of water are ρ = 1000 kg/m^3 and μ = 1.31 x 10^{-3} N.s/m^2. The Moody Chart is provided in Figure 5.

Two identical pumps are available for the task of pumping the water to the higher reservoir. These pumps can be connected in series or in parallel. The h-Q characteristic of each pump is given in Figure 4(b) for the case where the pump is driven by a constant-speed electric motor. The equation of the characteristic curve is $h_{pump} = 40 - 2Q$ where Q is the pump flow rate in litres/second.

(a) (5 marks) Should the pumps be connected in series or in parallel? Explain your answer.
(b) (10 marks) Determine the system resistance equation. Hint: the flow can initially be considered to be fully (or wholly) turbulent, but this should be confirmed by you after solving Part (c).
(c) (10 marks) Determine the flow rate that the 2-pump unit will produce. Graphical or algebraic solutions are acceptable. Figure 4(b) is repeated on the last page to aid graphical solution.

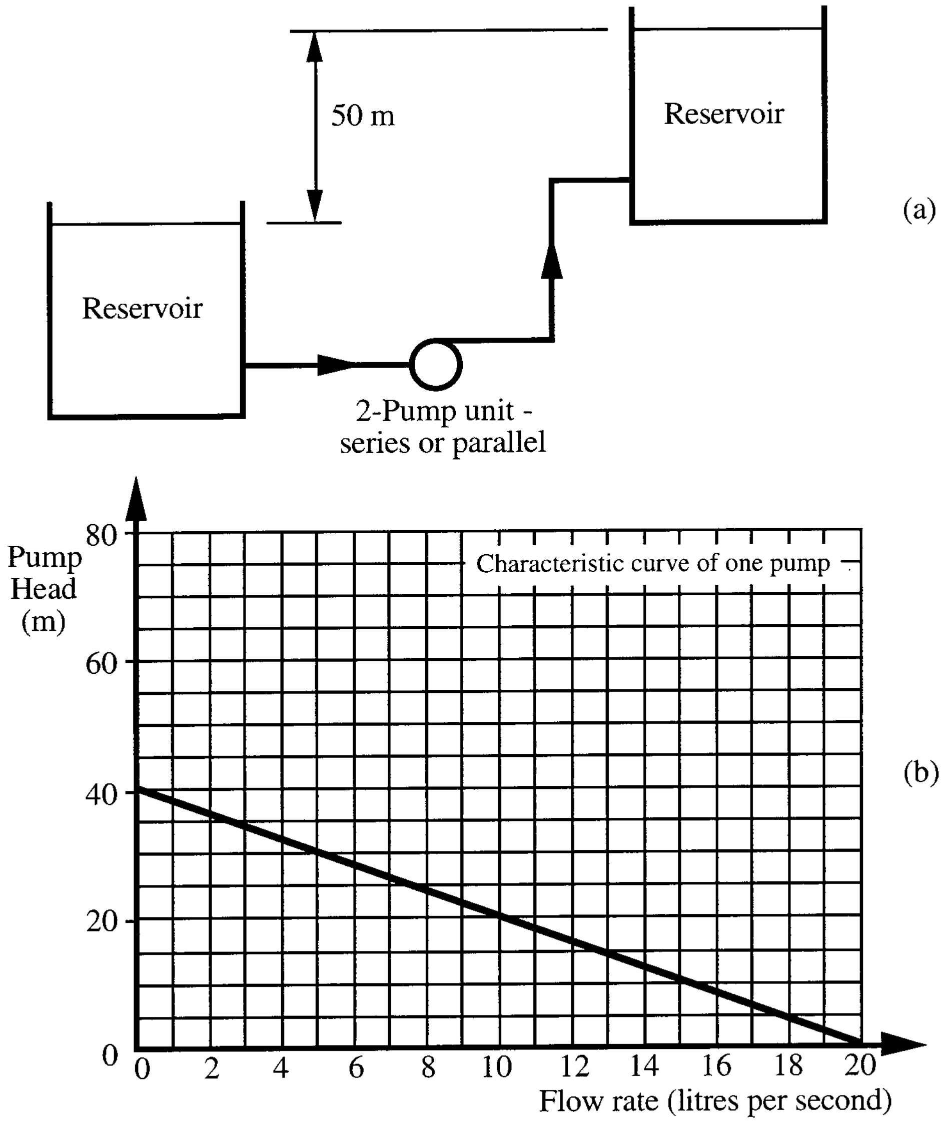
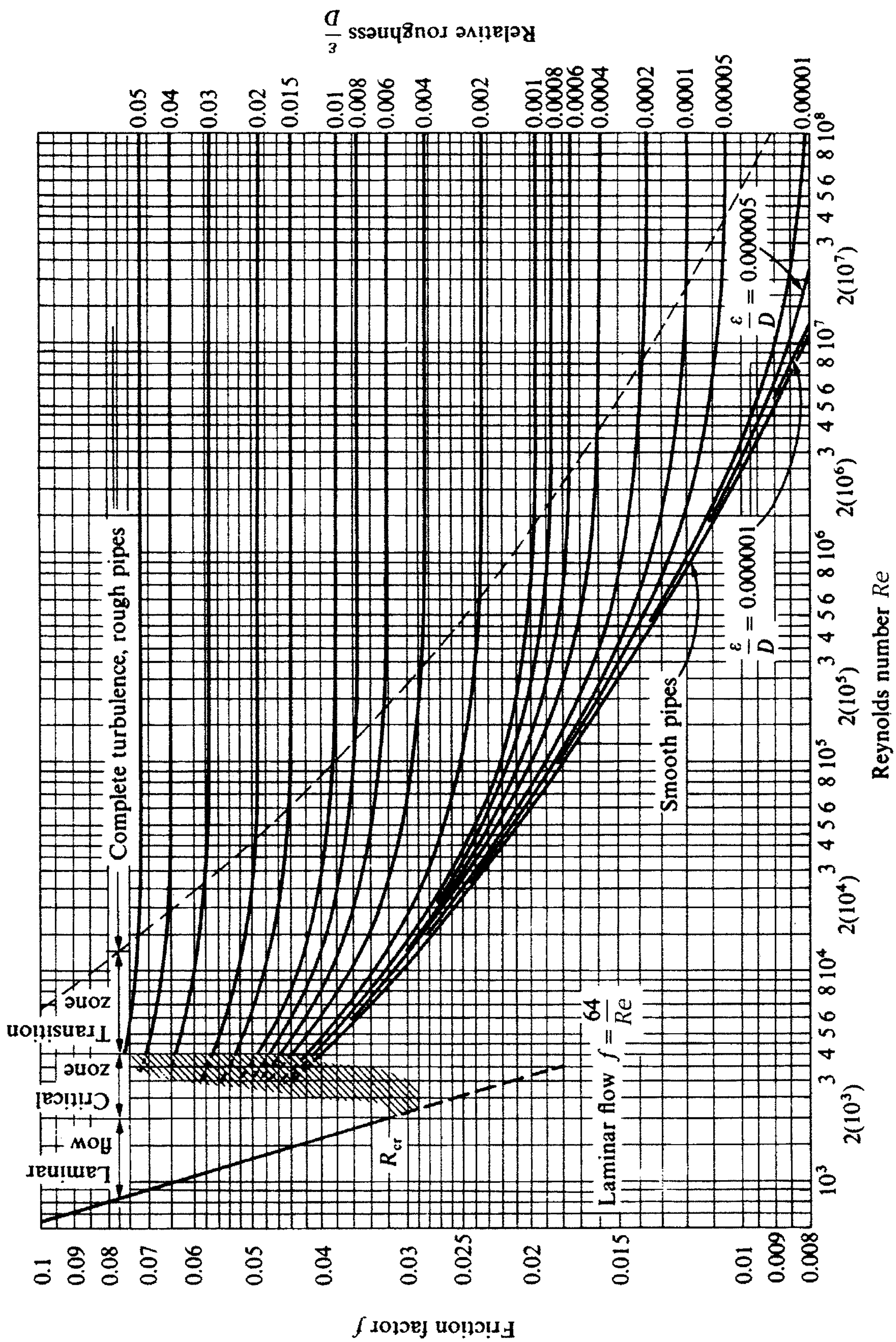


Figure 4. (a.) Pipe system, and (b.) Pump h-Q curve.



From Lewis F. Moody, "Friction Factors for Pipe Flows," *ASME Trans.*, vol. 66, pp. 671–684, 1944.

Figure 5. The Moody Chart.

Repeated Figures

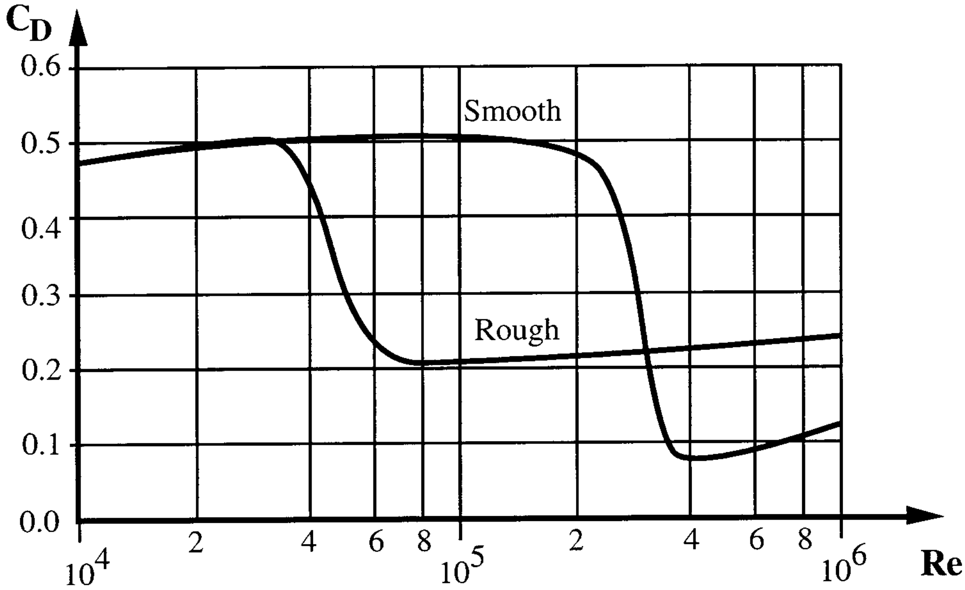


Figure 1. – Repeat for use in graphical solution.

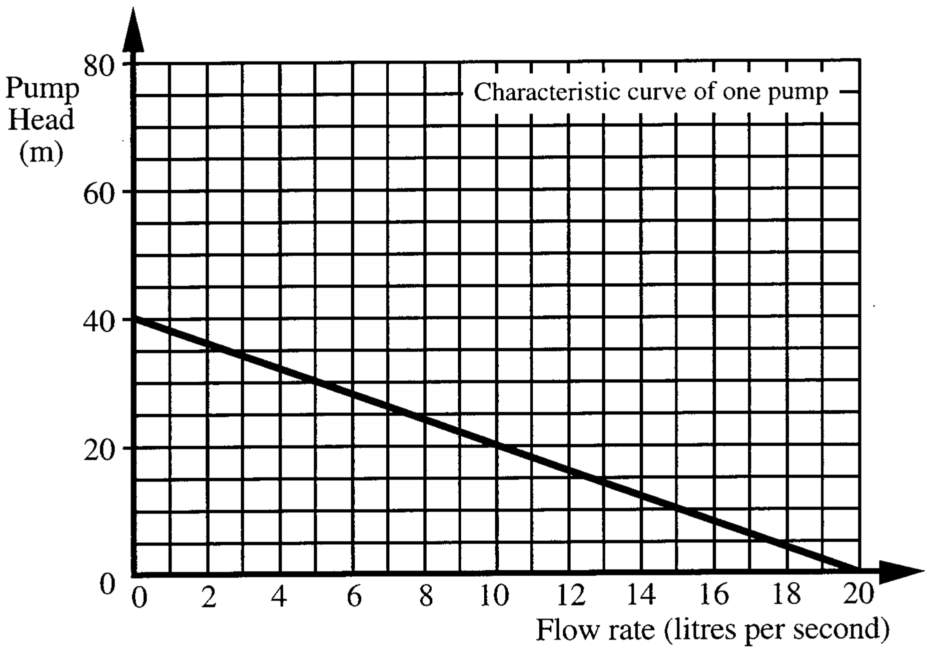


Figure 4(b). – Repeat for use in graphical solution.

END OF EXAMINATION