

NATIONAL EXAMINATIONS

PROFESSIONAL ENGINEERS

May 2002

98-BS-7, Mechanics of Fluids

3 hours duration

Notes:

This examination paper is comprised of six pages and has six questions. Each candidate is responsible for ensuring that he/she has the complete paper. **Answer any five questions only.**

2. If any doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a statement of any assumptions made.
3. "Closed-Book" - no aids other than a CASIO FX 991 or a SHARP EL 540 electronic calculator is permitted.
4. Any data required are given with the questions.
5. All questions have equal value.
6. **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.
7. Neat sketches, wherever possible, should accompany your solutions. All calculations must be clearly shown.
8. All pressures given are absolute, except when noted otherwise.
9. Unless otherwise stated, assume that the density of water ρ is 1,000 kg/m³ and the acceleration due to gravity g is 9.81 m/s². Atmospheric pressure P_a and temperature T_a of air are 100 kPa and 20°C respectively, and the characteristic gas constant R for air is 0.287 kJ/kg K.
10. One 8 ½ " by 11" aid sheet (both sides) is permitted.

1. (i) Neatly sketch typical graphs of shear stress versus shear rate and viscosity versus shear rate for various fluids, indicating clearly typical curves for Newtonian, shear thickening, shear thinning and Bingham plastic liquids.

(ii) A reciprocating drive shaft is shown in figure 1. The shaft diameter is 10 cm and the inside diameter of the surrounding sleeve is 10.1 cm. Oil with a kinematic viscosity of $9.05 \times 10^{-6} \text{ m}^2/\text{s}$ and a specific gravity of 0.84 is used as the lubricant in the annular gap between the shaft and the sleeve. If the length of the shaft is 0.94 m, estimate the frictional drag (N) caused by the lubricant when the shaft is travelling at a linear velocity of 1.2 m/s.
2. An automatic water control gate is shown in figure 2. It is comprised of a long cylinder of radius 0.8 m which is hinged at point A. When the fresh water level in the reservoir reaches a depth of 5 m, the gate opens by rotating about the hinge at point A. Determine: (a) the horizontal hydrostatic force acting on the cylinder (kN); (b) the vertical hydrostatic force acting on the cylinder (kN); (c) the total hydrostatic force acting on the cylinder and its line of action when the gate starts to open (kN, ° from horizontal); (d) the weight of the cylinder per m length N/m; and (e) the depth of the water H (m) on the left hand side when the gate is just about to rise, when the water on the right hand side rises to the depth of the radius of the cylindrical gate as shown in the figure.
3. Air flows in an inclined reducer is shown in figure 3. An oil-in-glass manometer is used to measure the pressure across the reducer. The diameter at section 1 is 6 cm, the reduced diameter at section 2 is 4 cm and the elevation difference between locations 1 and 2 where the two arms of the manometer are attached is 0.2 m. Neglecting losses calculate: (a) the pressure difference H registered on the manometer (cm of water); (b) the absolute pressure at P_2 (kPa).
4. Water at 10°C flows from a large reservoir to a smaller reservoir through a 5 cm diameter cast iron pipeline as shown in figure 4. If the loss coefficients k for a sharp edged entrance is 0.5, for an elbow is 0.3, a gate valve fully open is 0.3 and the friction factor f is 0.0315 determine (a) the elevation difference between the two reservoir surface levels (m) when the water flow rate is 6 litre/s and (b) the gauge pressure (kPa) registered at point A just prior to the valve.
5. Water issues from a pipe at 10 kg/s with a velocity of 20 m/s and strikes against a smooth plate i.e. neglecting any losses, as shown in figure 5 (a and b). (a) Determine the force required to hold the plate stationary in the direction of the water jet (N); (b) Determine the force on the plate when it moves at 3 m/s away from the water jet (N); and (c) (i) What is the division of flow, i.e. the mass flow rates M_1 and M_2 , (kg/s) and (ii) the force F_x exerted on the plate (N) if the plate is inclined at 60° to the horizontal as shown in figure 5(c) .

6. (i) As part of the continuing efforts to reduce the drag coefficient and thus to improve the fuel efficiency of automobiles, the design of side rear-view mirrors has changed drastically from a simple circular plate to a streamlined shape. Determine the drag reduction per car (N) when replacing a 13 cm dia flat mirror by one with a hemispherical back see figure 6(a) for a car traveling at 95 km/h, if the drag coefficient C_d for a flat circular plate is 1.1 whilst for a hemispherical backed circular plate C_d is 0.4. The air conditions are 101 kPa and 18°C.
- (ii) A wind turbine see figure 6(b), has a blade diameter of 40 m and is located on a 80 m tower. Calculate the axial force (kN) and moment (kNm) of the force at the base of the tower when the wind conditions are 98 kPa and 21°C with a velocity of 60 km/h, given that the maximum axial thrust on the turbine is given by $\pi/32 \rho D^2 V_i^2$ where ρ is air density, D is the turbine blade diameter and V_i is the wind velocity and the drag coefficient C_d for a cylindrical body in turbulent flow is 0.3.







