NATIONAL EXAMINATIONS

PROFESSIONAL ENGINEERS
May 2003

98-BS-7, Mechanics of Fluids

3 hours duration

Notes:

1. This examination paper is comprised of three 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/m^3 and the acceleration due to gravity g is 9.81 m/s^2. Atmospheric pressure Pa and temperature Ta 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. (a) A vertical dam wall ABCD shown in figure 1a which is 1.5 m wide is used to control flood water conditions. The dam holds back water on its left hand side. A centrally located support rod BE inclined at 45° to the vertical and freely hinged at B and E is used to permit the dam to tip over automatically when the water under flood conditions rises to A.

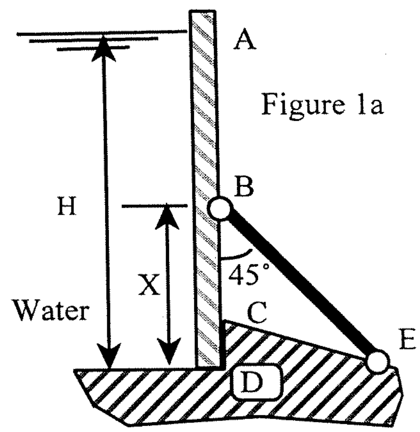
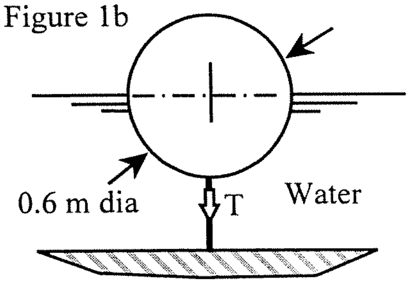


Figure 1a

(i) Obtain an expression for the distance X, the location of B above D as a function of the water depth H. (ii) If the depth of the water H is 2.75 m, calculate the distance X at which the hinge B should be located for the gate to tip automatically; (iii) Calculate the force in the rod BE just before the gate tilts (i.e. when the water reaches A) when H is 2.75 m.

(b) A hollow cylindrical drum is tethered in water using a cable as shown in figure 1b. The drum is 0.6 m diameter with a length of 1.5 m. The apparent specific gravity of the drum is 0.4. Calculate the force in the cable if the drum is half submerged, as shown.

Figure 1b


2. (a) On a graph of shear stress versus shear rate, sketch typical curves for Newtonian, shear thinning and shear thickening fluids.

(b) (i) In order to determine the viscosity μ of a fluid, a spherical ball of diameter 'd' having a specific gravity Sb is permitted to fall through the fluid having a specific gravity Sf and permitted reaches a steady terminal velocity V. If the drag on a small sphere is $3 \pi \mu V d$, obtain the following expression for the velocity V, where ρ is the density of water:

$$V = d^2 g (Sb - Sf) \rho/(18 \mu)$$

(b) (ii) In a particular experiment, an aluminum ball having a specific gravity of 2.7 and a diameter of 0.1 cm is permitted to fall in a small reservoir of the oil. It was found that the terminal velocity of the ball was 12.1 cm/s. If the specific gravity of the oil is 0.93, calculate the viscosity μ and the kinematic viscosity ν of the oil.

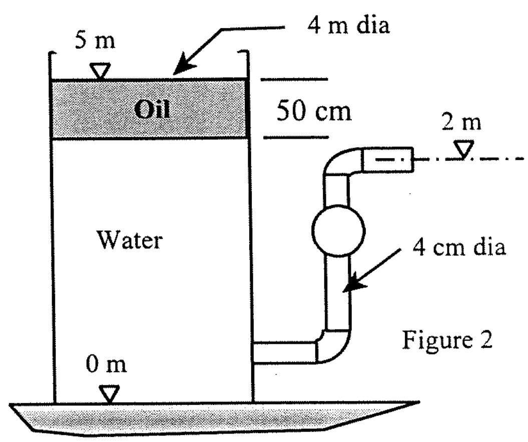


Figure 2

3. A 4 m diameter tank filled with water has a 50 cm thick layer of oil having a specific gravity of 0.86 floating on its surface. The axis of the tank is vertical. A 4 cm diameter discharge pipe is connected to it, as shown in figure 2. If the estimated total losses in the discharge pipe can be assumed to be $3Ve^2/2g$, where Ve is the liquid velocity in the pipe, calculate (i) the mass flow rate of the water issuing from the pipe when the overall liquid level has dropped by 1 m from the initial value of 5 m and (ii) the time for the overall liquid to fall by 1 m from the initial value of 5 m.

4. Water flows through a 60 cm I.D. concrete pipeline from an upper reservoir to a lower reservoir. The pipeline has four 45° elbows, a turbo-generator and a fully opened gate valve as shown in figure 3. The loss coefficients k for a long elbow, a fully open gate valve, and the sudden entry are 0.2, 0.15 and 0.22 respectively and the friction factor for the pipe f is 0.0235.

If the volumetric flow rate of the water through the pipeline is 45 m^3/min, calculate (i) the output power being generated by the turbo-generator if all the losses are neglected (kW), (ii) the pressure drop across the water turbine (kPa) considering all the losses, (iii) the output power being generated by the turbo generator taking into account all the losses (kW) and (iv) the pressure at point A just before the gate valve (kPa).

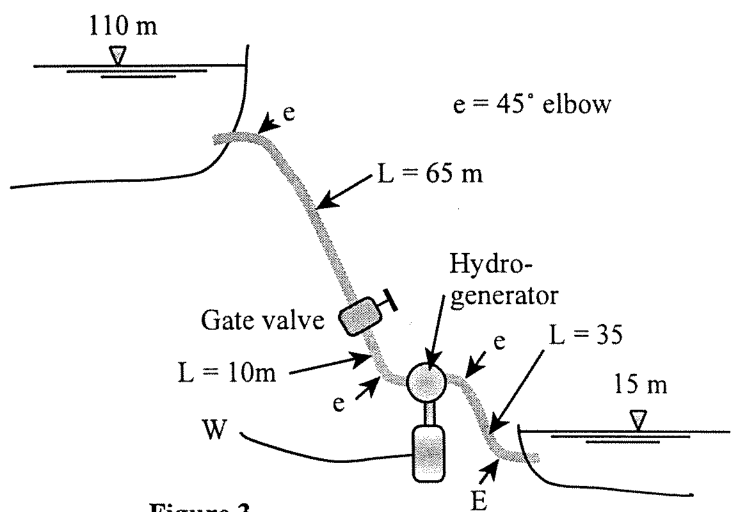


Figure 3

5. A cylindrical torpedo which has a diameter of 0.6 m travels in sea water having a specific gravity of 1.026 at a velocity of 13.5 m/s. The torpedo is propelled by a propeller located at its rear end having an efficiency of 44%. If the drag coefficient for the torpedo is 0.595 calculate:

(i) the drag force on the torpedo, (kN)
(ii) the power required to move the torpedo under these conditions, (kW)
(iii) the approximate running time if its energy is supplied from a battery having a storage capacity of 2.5 kWh, (seconds).

6. (a) A circular cylinder of given length/diameter ratio is kept in steady rotation at 'n' revs per sec in a uniform stream of fluid of velocity 'V'. Assuming that the power 'P' required to maintain the motion depends only on the density 'ρ' and the kinematic viscosity 'ν' of the fluid, the cylinder diameter 'D' and speed of rotation 'n' and the fluid velocity 'V', using the Buckingham Π theorem obtain the following expression for the power P.

$$P = (\rho \nu^3)/D \;\; \phi\{(VD/\nu), (n D^2/\nu)\},$$ where $\phi\{\ \}$ is a non-dimensional function.

(b) Compare the power required to maintain uniform rotation a cylinder of 10 cm dia in water with a cylinder of 20 cm dia rotating in air under dynamically similar conditions, assuming that the kinematic viscosity of air is 13 times that of water.

The end.