

# NATIONAL EXAMINATIONS

## PROFESSIONAL ENGINEERS

Dec. 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. **One aid sheet written on both sides 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  $\rho$  to be  $1,000 \text{ kg/m}^3$  and the acceleration due to gravity  $g$  is  $9.81 \text{ m/s}^2$ . Atmospheric pressure  $P_a$  and temperature  $T_a$  of air are  $100 \text{ kPa}$  and  $20^\circ\text{C}$  respectively, the characteristic gas constant  $R$  for air is  $0.287 \text{ kJ/kg K}$ . and the density of air  $\rho$  is  $1.2 \text{ kg/m}^3$ .
10. One  $8 \frac{1}{2}$  " by 11" aid sheet (both sides) is permitted.

1. (a) A crane is used to lower a concrete block into the sea (specific gravity of sea water is 1.025) for an under water construction project, see fig 1a. Determine the tension in the rope of the crane lowering a rectangular 0.4 m by 0.5 m by 3 m concrete block (specific gravity 2.3) when it is (i) suspended in the air and (ii) completely immersed in the sea water.

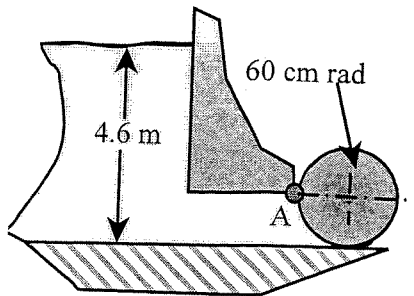
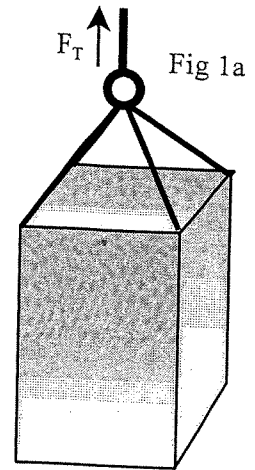
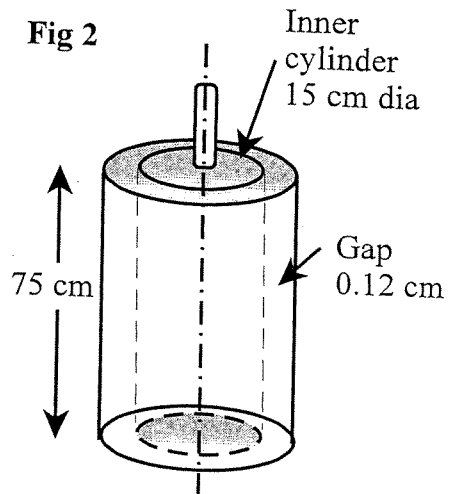


Fig 1b

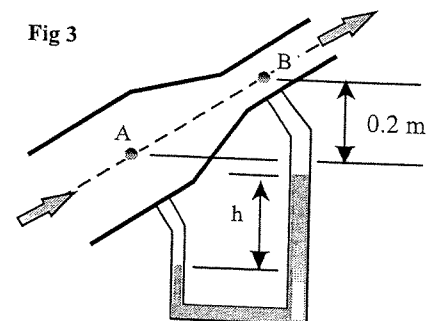
- (b) A long solid cylinder of radius 60 cm hinged at point A is used as an automatic gate, as shown in fig 1b. When the water level reaches 4.6 m, the cylindrical gate opens by turning about the hinge at point A. Determine (i) the total hydrostatic force per unit length of the cylinder acting on the cylinder and its line of action when the gate starts to open and (ii) the weight of the cylinder per metre length of the cylinder.

2. (a) Sketch a graphs of shear stress and viscosity versus shear rate for typical fluids such as Bingham plastic, dilatant, pseudoplastic and Newtonian.

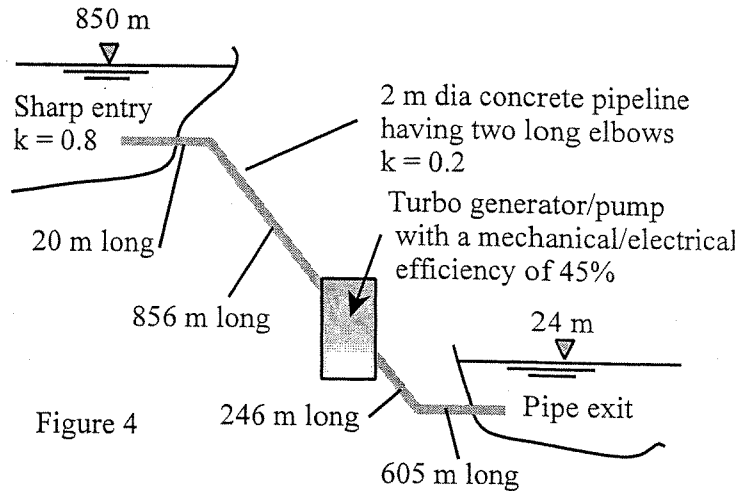
- (b) The viscosity of a fluid is to be measured using a viscometer constructed of two 75 cm long concentric cylinders as shown in figure 2. The outer diameter of the inner cylinder is 15 cm and the radial gap between the two cylinders is 0.12 cm. The inner cylinder is rotating at 200 rpm and the torque required to hold the outer cylinder stationary is measured to be 0.8 N m. (i) Determine the viscosity of the fluid in the gap between the cylinders, and (ii) if the speed is increased to 220 rpm whilst the conditions remain the same as before and the measured holding torque is measured to be 0.815 N m, determine the viscosity of the fluid and what type of fluid is being measured, i.e. Newtonian, dilatant or shear pseudoplastic etc.



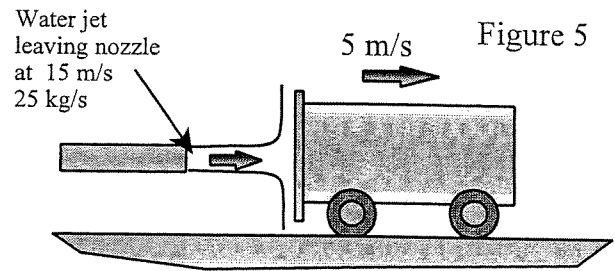
3. Air at 110 kPa and 50°C flows upwards through a 6 cm dia inclined duct at a rate of 30 L/s. The duct diameter is then reduced to 4 cm dia through a reducer section as shown in figure 3. The pressure changes across the reducer is measured using a water-in-glass manometer. The elevation difference between the two pressure measurement points A and B where the two arms of the manometer are attached is 0.2 m. Determine (i) the differential height 'h' of the water in the manometer and (ii) the mass flow rate of the air in the duct.



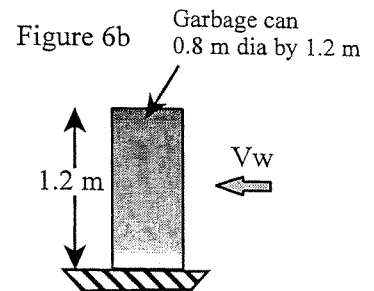
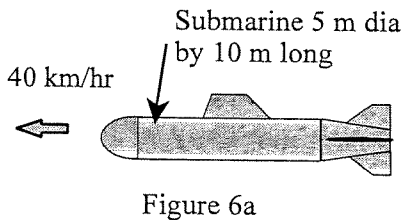
4. A reservoir is used to store energy at night. Water is pumped from a lower reservoir to an upper storage reservoir for energy storage as shown in fig 4. The upper reservoir has a mean surface area of  $0.55 \text{ km}^2$  and it has been found that over a 8 hour period at night the level in the upper reservoir rises by 40 cm. If the friction factor for the pipeline is  $f = 0.029$ , determine: (i) the required input power to the pump if the combined electrical/mechanical pump efficiency is 45%



5. Water accelerated by a nozzle to  $15 \text{ m/s}$  strikes the vertical back surface of a cart, which is mounted on wheels as shown in figure 5. The cart is moving horizontally at a constant velocity of  $5 \text{ m/s}$  in the flow direction. The mass flow rate of the water is  $25 \text{ kg/s}$ . After striking the cart the water discharges radially from the back of the cart. Determine: (a) the initial force being exerted on the cart at startup when the cart is stationary, (b) the force that is required to be applied by the cart brakes to prevent the cart from accelerating after it has reached a velocity of  $5 \text{ m/s}$ , (c) the maximum power that would be generated if the braking force is used to generate power.



6. (a) A submarine for convenience can be treated as a cylinder with a hemispherical front cap figure 6a. The submarine has a body diameter and length of 5 m and 10 m respectively. Determine the power required for this submarine to cruise horizontally and steadily at  $40 \text{ km/h}$  in seawater whose SG is 1.025. Assume the flow is turbulent and the drag coefficient is 0.11.



- (b) The  $0.8 \text{ m}$  diameter by  $1.2 \text{ m}$  deep garbage can be seen in figure 6b, is found to be tipped over due high winds. Assuming the average density of the garbage inside the can to be  $150 \text{ kg/m}^3$  and taking the air to be at  $100 \text{ kPa}$  and  $15^\circ \text{C}$ , estimate the wind velocity when the can was tipped over. Take the drag coefficient for the can to be 0.7.

The end.