The Papua New Guinea University of Technology

Department of Mechanical Engineering

ME 223: Fluid Mechanics

Second Semester Examination – 2021

Second Year Mechanical Engineering

Thursday, October 27, 2022 – 12:50 pm

Time Allowed: Two (2) Hours

Instructions

(1) You have 10 minutes to read the paper. Do not write anything during this time.

(2) Write your name clearly on the front page using block letters.

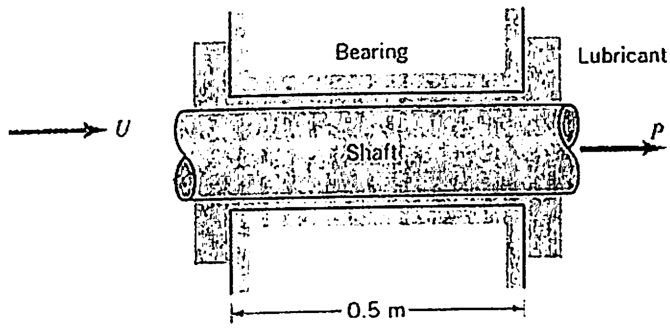
(3) There are four (4) questions. Answer each question.

(4) All questions must be answered only in the booklet provided.

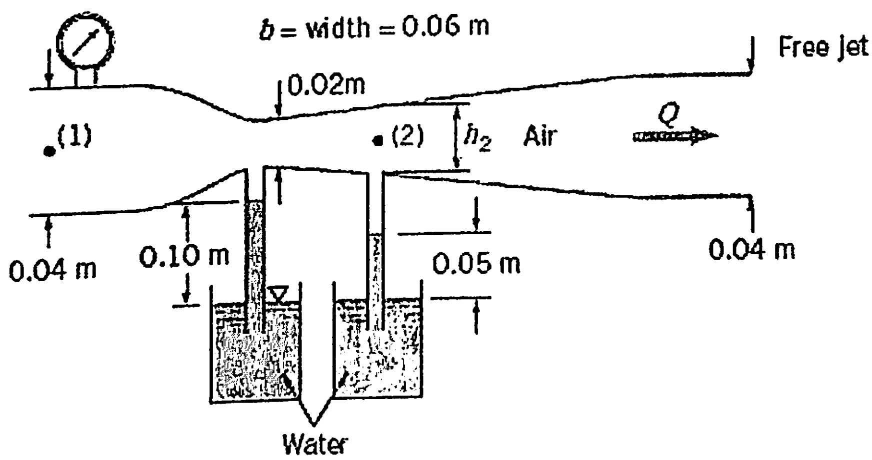
(5) Calculators are permitted in the examination room.

(6) Any student found in cheating will be disqualified.

Q1. A 25-mm-diameter shaft is pulled through a cylindrical bearing as shown in Figure. The lubricant that fills the 0.3-mm gap between the shaft and bearing is an oil having a kinematic viscosity of 8.0×10^{-4} m^2/s and a specific gravity of 0.91. Determine the force P required to pull the shaft at a uniform velocity of 3 m/s. Assume the velocity distribution in the gap is linear. ***(25 Marks)***



Q2. Air flows through a venture of rectangular cross-section as shown in the figure given below. The constant width, b, of the channel is 0.06 m and the height at the inlet and exit is 0.04m. The datum line is taken at the centre line of the venture channel. The atmospheric pressure is taken to be 101.325 KN/m^2 and the density of air is 1.22 kg/ m^3. The pressure across the free jet at the exit is atmospheric. The unsteady, compressibility and viscous effects are negligible. Neglect also the elevation effect of the air. Determine the flow rate when water is drawn up 0.1 m in a small tube attached to the static pressure tap at the throat (minimum cross-section) where the channel height is 0.02m. ***(25 Marks)***

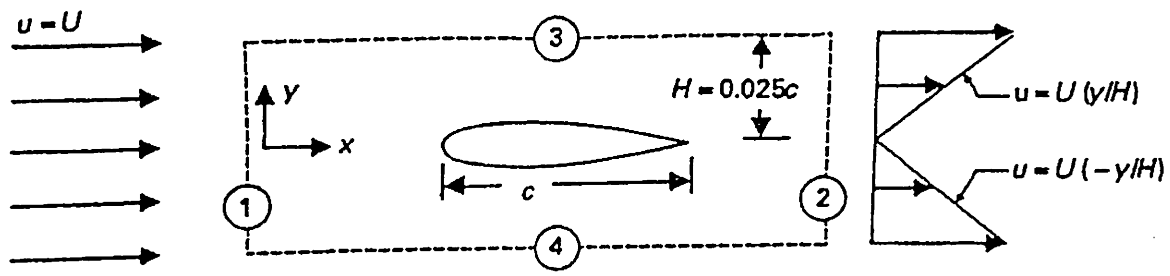


(25 Marks)

Q3.
Consider a two dimensional, steady, and incompressible flow past a symmetric aerofoil. Consider a rectangular control volume around the aerofoil whose chord length (c) is aligned with the horizontal centre line of the control volume. The x-velocity at the upstream side (control surface 1) of the control volume is $u = U$ and the x-velocity at the downstream side (control surface 2) of the control volume is given by

$$u = \begin{cases} \frac{y}{H} U & -H \le y \le H, \\ U & y > H \text{ or } y < -H. \end{cases}$$

Assume pressure is uniform over the entire surface of the control volume and the weight of the aerofoil acts along negative y axis. Determine the drag coefficient $C_D = \frac{D}{\frac{1}{2}\rho U^2 wc}$ for the aerofoil due to horizontal drag force D if the vertical dimension (H) from the chord length to the horizontal edge of the control volume is 0.025c and w is the width (span) of the aerofoil.



Q4. ***(25 Marks)***

(a) Consider the laminar flow of an incompressible fluid past a flat plate at $y = 0$. The boundary layer velocity profile is approximated as $\frac{u}{U} = \frac{y}{\delta}$ for $0 \le \frac{y}{\delta} \le 1$ and $\frac{u}{U} = 1$ for $\frac{y}{\delta} > 1$. Using the momentum integral equation ($\tau_w = \rho U^2 \frac{d\theta}{dx}$), determine the following:

(i) The rate of growth of δ as a function of x.

(ii) The displacement thickness (δ^*) as a function of x.

(b) The velocity profile in a laminar fully-developed flow in a horizontal pipe of diameter ($D = 2R$) and length (L) is given by

$$\frac{u}{U} = 1 - \left(\frac{r}{R}\right)^2$$

where $U = -\frac{R^2}{4\mu}\left(\frac{\partial p}{\partial x}\right)$ is the maximum velocity at the centre of the pipe. Show the volume flow rate, Q,

$$Q = \frac{\pi D^4 \Delta p}{128 \mu L}$$

Show that the friction factor, f, is

$$f = \frac{64}{Re}$$

where Re is the pipe Reynolds number based on density (ρ), absolute viscosity (μ), average velocity ($\bar{V}$) and the diameter (D). The formula for friction factor is the following:

$$h_l = f \frac{L}{D} \frac{\bar{V}^2}{2}$$