THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY
BACHELOR OF TECHNOLOGY – LEVEL 05
FINAL EXAMINATION 2005
MEU3301 – THERMODYNAMICS AND FLUID MECHANICS
DATE : 15th MARCH 2006
TIME : 0930-1230
DURATION : THREE HOURS

031

ANSWER FIVE QUESTIONS ONLY.
ALL QUESTIONS CARRY EQUAL MARKS. YOU MAY OBTAIN TABLES OF THERMODYNAMIC AND TRANSPORT PROPERTIES OF FLUIDS ON REQUEST.

1. The mass flow rate $\dot{m}$, through a cross-sectional area A_2 of a convergent-divergent nozzle is given by

$$\frac{\dot{m}}{A_2}=\left[\left(\frac{2n}{1-n}\right)\frac{p_1}{v}\left\{\left(\frac{p_2}{p_1}\right)^{\frac{n+1}{n}}-\left(\frac{p_2}{p_1}\right)^{\frac{2}{n}}\right\}\right]^{\frac{1}{2}}$$

where n is the ratio of specific heat, v is the specific volume at entry conditions, p_1 is the inlet pressure and p_2 is the pressure at cross section A_2.

Show that $\frac{\dot{m}}{A_2}$ will be a maximum when $\frac{p_2}{p_1}=\left[\frac{2}{(n+1)}\right]^{\frac{n}{n-1}}$

Air expands in a propulsion nozzle from 3.5bar and 400° C, down to a back pressure of 1.03 bar at the rate of 16kg/s. Determine
(a) the throat area required if the coefficient of discharge is 0.99 and the nozzle efficiency is 0.94
(b) the exit area and the exit velocity.
Assume the inlet velocity to be zero.

2. Show that for a hollow cylinder, the rate of heat transferred through the outer surface is given by

$$Q=-\frac{2\pi k(t_1-t_2)}{\ln r_2/r_1}$$

where r_1 and r_2 are the inner and outer radii.

Water at 90°C flows through a 50mm bore steel pipe of 5mm thickness and the atmospheric temperature is 25°C. Calculate the heat loss per meter length of pipe. The thermal conductivity of steel is 48W/mK and the inside and outside heat transfer coefficients are $2800 W/m^2K$ and $17 W/m^2K$ respectively. Neglect radiation.

3. Steam with absolute velocity 360m/s enters the stage of an impulse turbine provided with a single row wheel. The nozzles are inclined at 20° to the plane of the wheel. The blade rotor with diameter 955mm rotates with a speed of 3000 rev/min. Find,
   (a) suitable inlet and outlet angles for the moving blade so that there is no axial thrust on the blade. It may be assumed that friction in blade passages is 19% of the kinetic energy corresponding to relative velocity at inlet blades,
   (b) power developed in blading for a steam flow of 1kg/s, and
   (c) kinetic energy of steam finally leaving the stage.

4. State Buckingham's π theorem.
   Using this theorem, show that the discharge Q consumed by an oil ring is given by

$$Q = Nd^3\phi\left[\frac{\mu}{\rho N d^2}, \frac{\sigma}{\rho N^2 d^3}, \frac{w}{\rho N^2 d}\right]$$

   where **d** is the internal diameter of the ring, **N** is the rotational speed, **ρ** is density, **μ** is viscosity, **σ** is surface tension and **w** is specific weight of oil.

5. A 50m long horizontal pipe line which is connected to a water tank at one end discharges freely into the atmosphere at the other end as shown in Figure Q5. For the first 30m of its length from the tank, the pipe diameter is 150mm and then its diameter is suddenly enlarged to 300mm. The height of water level in the tank is 8m above the center of the pipe. Considering all losses of head which occur along the length of the pipe, determine the rate of flow of water. Take f = 0.01 for both sections of the pipe.

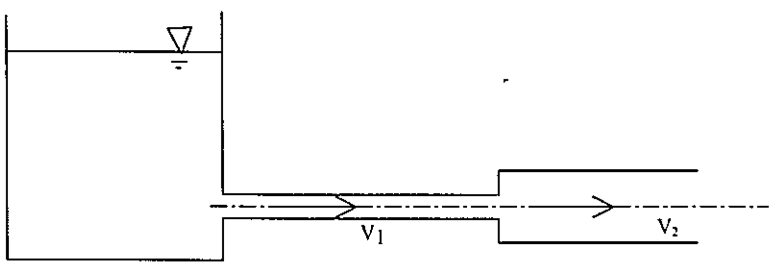

Figure Q5

6. Figure Q6 shows the geometry of the single tilting pad of a thrust bearing. Simplify the Reynolds equation for this application on the basis that the bearing is very wide in a direction perpendicular to the plane of the paper. Integrate and show that the pressure variation in the fluid film is given by

$$P = \frac{6\mu u}{\tau}\frac{(h-h_1)(h-h_2)}{(h_2-h_1)h^2}$$

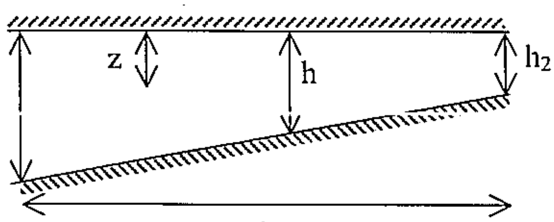

Figure Q6

7. State the momentum integral equation of a two dimensional boundary layer. Explain the significance of each term in the equation.
A thin rectangular flat plate of length 2m and width 1m is held in an uniform stream of water of velocity 2m/s. The long side of the plate is held parallel to the direction of flow. A laminar boundary layer forms on the plate and its velocity profile may be approximated as,

$$\frac{u}{U} = 1.5\left(\frac{y}{\delta}\right) - 0.5\left(\frac{y}{\delta}\right)^3$$

where δ is the boundary layer thickness, U the free stream velocity and y is the distance from the plate.
Calculate the total drag on the plate.
(viscosity of water = 1×10^{-6} m^2/s, density of water = $1000 kg/m^3$)

8. Prove that discharge through fully submerged orifice is,

$$Q = C_d b(H_2 - H_1)x\sqrt{2gH}$$

and for partially submerged orifice is,

$$Q = C_d b(H_2 - H_1)\sqrt{2gH} + \frac{2}{3}C_d b\sqrt{2g}\left(H_2^{3/2} - H_1^{3/2}\right)$$

Where, b = width of the orifice
H = difference of water level
H_1 = height of the water from top of the orifice
H_2 = height of the water from bottom of the orifice

A rectangular orifice of 2m width and 1.2m deep is fitted in one side of a large tank. The water level on one side of the orifice is 3m above the top edge of the orifice, while on the other side of the orifice the water level is 0.5m below its top edge. Calculate the discharge through the orifice if coefficient of discharge is 0.64.