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University Examinations 2012/2013

FIRST YEAR, SECOND SEMESTER EXAMINATIONS FOR THE DEGREE OF MASTER OF SCIENCE IN APPLIED MATHEMATICS

SMA 3134: FLUID MECHANICS 1

DATE: AUGUST 2012 **TIME: 3 HOURS**

INSTRUCTIONS: *Answer question **one** and any other **two** questions.*

- **The variables used have their usual meaning**

QUESTION ONE – (30 MARKS)

a) Define the “velocity of sound” as used in fluid mechanics. (2 Marks)

b) State the Carnot’s theorem. (2 Marks)

c) State the equations governing the steady two dimensional flow of an inviscid thermally non conducting fluid. (3 Marks)

d) Given that the internal energy u, the pressure P, and the volume V of a unit mass is given by u=4PV,

   i. Show that $C_V = 4V\left(\frac{\partial P}{\partial T}\right)_V$ $and\ C_P = 5P\left(\frac{\partial V}{\partial T}\right)_P$. (4 Marks)

   ii. Given that $\gamma = \frac{C_P}{C_V}$ is a constant show that $P^{4\gamma}V^5 = F(T)$ where F(T) is a function of temperature only. (7 Marks)

e) Define the Mach number (M) hence classify the various types of fluid flow in terms of the mach number. (6 Marks)

f) What is an isothermal, adiabatic and isentropic process? (4 Marks)

g) State the second law of thermodynamics. (2 Marks)

QUESTION TWO (20 MARKS)

a) Distinguish between compressible and incompressible fluids. (2 Marks)

b) The pressure, volume, temperature, internal energy and entropy of a given mass in equilibrium are P,V,T,U and S. Prove that

$$\frac{\partial U}{\partial T} = T\frac{\partial S}{\partial T}\ and$$
$$\frac{\partial U}{\partial V} = T\frac{\partial S}{\partial V} - P = T\frac{\partial P}{\partial T} - P$$ (8 Marks)

c) Show that the velocity distribution of a fluid passing through a converging – diverging nozzle of cross section A is given by $u^2 = 2a^2 1n\left[\frac{Au}{A_0 u_0}\right] + u_0^2$ where u_0 and A_0 are the neck velocity and cross sections respectively. (10 Marks)

QUESTION THREE (20 MARKS)

a) Show that the energy equation for a one dimensional compressible fluid flow is given by $\frac{\gamma}{\gamma-1}\frac{P}{\rho} + \frac{1}{2}u^2 = \frac{\gamma}{\gamma-1}\frac{P_0}{\rho_0} + \frac{1}{2}u_0^2$ for some reference values of $P_0, \rho_0\ and\ u_O$. (8 Marks)

b) Prove that the pressure corresponding to the critical velocity of sound is

$$P^* = P_0\left(\frac{\gamma-1}{2}\right)^{\frac{\gamma}{\gamma-1}}$$ (12 Marks)

QUESTION FOUR (20 MARKS)

A perfect gas is initially in a state A at pressure P_1 and temperature T_1. It is expanded adiabatically to a state B. It is then cooled at constant volume to a state C at a pressure P_2 and temperature T_2. It is then compressed adiabatically to a state D at pressure P_1. Finally it is heated at constant pressure back to state A.

a) Show that the heat per unit mass dissipated to the cold sink along BC is

$$Q = \frac{R}{\gamma-1}\left\{T_2 - T_1\left[\frac{P_2 T_1}{P_1 T_2}\right]^{\gamma-1}\right\}$$ (9 Marks)

b) Show that the efficiency of the cycle is $\eta = 1 - \frac{\gamma\left\{T_1 - T_2\left[\frac{P_1}{P_2}\right]^{\frac{\gamma-1}{\gamma}}\right\}}{T_2 - T_1\left[\frac{P_2 T_1}{P_1 T_2}\right]^{\gamma-1}}$ (11 Marks)