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University Examinations 2012/2013

FIRST YEAR, FIRST SEMESTER EXAMINATION FOR MASTER OF SCIENCE IN APPLIED MATHEMATICS

SMA 3134: FLUID MECHANICS I

DATE: DECEMBER 2012 **TIME: 3HOURS**

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

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

QUESTION ONE - (30 MARKS)

a) Distinguish between a streamline and a pathline as used in fluid mechanics. (2 Marks)

b) Define a compressible flow and show that for such flows $\vec{\nabla}.\vec{q} = 0$ (4 Marks)

c) Define a cycle as used in relation to heat engines. (2 Marks)

d) A fluid (gas) is defined such that for a unit mass $P = \frac{u}{4V}$. Verify that $c_v = 4V\left(\frac{\partial P}{\partial T}\right)_v$ and $C_p = 5p\left(\frac{\partial v}{\partial T}\right)_p$ (5 Marks)

e) Show that the mass conservation equation of a two dimensional irrotational fluid flow of a compressible fluid can be written as.
$\frac{\partial^2 \emptyset}{\partial t^2} + \vec{q}.\frac{\overrightarrow{\partial q}}{\partial t} + \frac{a^2}{\rho}\frac{\partial \rho}{\partial t} = 0$ where $\emptyset, \overrightarrow{q}$ and a are scalar functions, fluid velocity and speed of sound respectively. (7 Marks)

f) Briefly discuss the flow of a compressible fluid through a converging diverging nozzle. (6 Marks)

g) Define a mach cone and how it generated in the flow of a fluid. (4 Marks)

QUESTION TWO – (20 MARKS)

a) State the Zeroth law of thermodynamics. (2 Marks)

b) Test if the quantity of heat $Q = Q(P, V)$ added to a unit mass of a perfect gas is a function of state. (8 Marks)

c) State and prove the Carnot's theorem. (10 Marks)

QUESITON THREE - (20 MARKS)

A perfect bas is initially at a state A at pressure P_1 and temperature T_1. It is then cooled at constant pressure to a state B. The gas is expanded adiabatically to a state C at a pressure P_2 and volume V_2. It is then heated at constant volume to a state D before finally being compressed adiabatically back to state A.

a) Draw an indicator diagram for the cycle. (2 Marks)

b) Show that the heat per unit mass absorbed from the hot source along CD is

$$Q = \frac{\gamma R}{\gamma - 1}\left\{T_2\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} - T_1\right\}$$ (8 Marks)

c) Compute the efficiency of the cycle. (10 Marks)

QUESTION FIVE – (20 MARKS)

a) An ideal gas moving at a free stream supersonic speed U_1 experiences a normal shock and moves at a speed U_2. Show that for this gas

$$\frac{\rho_2}{\rho_1} = \frac{U_1}{U_2} = \frac{(\gamma+1)M^2}{2+(\gamma-1)M^2}$$ (7 Marks)

b) The flow past a stationary cylinder of radius R can be modeled as a superpositionof a uniform flow of velocity U and a doublet of strength μ. Show the following

i. The maximum velocity of the flow is at the surface $r = R$ where $\theta = \pm {}^{\pi}/_{2}$ (6 Marks)

ii. The pressure $P = P^* + \frac{\rho u^2}{2}(1 - 4\,sin^2\theta)$ where P^* is the free stream pressure. (3 Marks)

iii. The lift $L = 0$ (4 Marks)