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University Examinations 2012/2013

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

SMA 3134: FLUID MECHANICS I

DATE: AUGUST 2013 **TIME: 3 HOURS**

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

QUESTION ONE – (30 MARKS)

(a) Define a fluid hence state when a fluid is referred to as inviscid. (3 Marks)

(b) Distinguish between the following:

(i) Newtonian and non Newtonian fluid (2 Marks)

(ii) Lift and drag. (2 Marks)

(iii) Rotational and irrotational flows. (2 Marks)

(c) Give the significance of the stream function and the velocity potential with respect to two dimensional fluid flows. (2 Marks)

(d) (i) State the necessary and sufficient condition for a thermodynamic function $\emptyset$ to be called a function of state. (2 Marks)

(ii) Show that the entropy $S = S(P, V)$ of a perfect gas is function of state. (5 Marks)

(e) State the first law of thermodynamics. (1 Mark)

(f) Formulate the fluid flow through a converging diverging nozzle and show that if the flow velocity is not equal to the velocity of sound then the velocity of the fluid is maximum at the neck where the cross section is minimum. (7 Marks)

(g) The pressure distribution of a flow is given by $p = p_0 + \frac{\rho u^2}{2}(1 - 4\sin^2\theta)$. Calculate the lift force. (4 Marks)

QUESTION TWO – (20 MARKS)

(a) Define a "reversible process" and state two factors that can render a process "irreversible". (3 Marks)

(b) Show that if free energy per unit mass $F = U - TS$ is a function of state then

$$\left(\frac{\partial u}{\partial v}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$$ (5 Marks)

(c) For a gas obeying the gas law $\left\{p + \frac{a}{v^2}\right\}(v - b) = RT$ we have $c_p - c_v \cong R + \frac{2a}{TV}$

(12 Marks)

QUESTION THREE – (20 MARKS)

(a) Describe the Carrot's cycle in relation to heat engines. (6 Marks)

(b) (i) Show that the energy equation for one dimensional compressible fluid flows is

$$\frac{\gamma}{\gamma-1}\ \frac{p}{\rho} + \frac{1}{2}u^2 = constant$$ (6 Marks)

(ii) Further, if the fluid is ideal and the change is adiabatic show that the pressure distribution is $p = p_0\left[1 - \frac{\gamma-1}{2}\ \frac{u^2}{a_0^2}\right]^{\frac{\gamma}{\gamma-1}}$ where p_0 and a_0 are quantities for fluid at rest.

(8 Marks)

QUESTION FOUR – (20 MARKS)

Show that a two dimensional irrotational fluid flow on the xy-plane for a compressible fluid can be expressed in terms of the stream function ψ and for such a flow we have the vorticity along the z-axis given as

$$w = \frac{1}{\rho}\left(\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2}\right) - \frac{1}{\rho a^2}\left\{u^2\frac{\partial^2\psi}{\partial x^2} + 2uv\frac{\partial^2\psi}{\partial x\partial y} + v^2\frac{\partial^2\psi}{\partial yx^2}\right\} + \frac{1}{\rho c_p}\ \frac{ds}{d\psi}\left\{\left(\frac{\partial\psi}{\partial x}\right)^2 + \left(\frac{\partial\psi}{\partial yx}\right)^2\right\}$$

(20 Marks)