TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering and Technology

DEPARTMENT OF MECHANICAL & AUTOMOTIVE ENGINEERING

UNIVERSITY EXAMINATION 2013/2014

SECOND YEAR FIRST SEMESTER UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMG 2407 : WIND TUNNEL EXPERIMENTAL TECHNIQUES

TIME: 2 HOURS **SERIES:** DECEMBER, 2013

INSTRUCTIONS TO CANDIDATES

1. You are required to have the following for these examinations:
   - Drawing Instruments
   - Scientific Calculator
2. This paper has **FIVE** Questions.
3. Answer Question **ONE** and any other **TWO** Questions.
4. All relevant tables and formulae have been provided on the question paper.
5. All symbols have their usual meaning.
6. This paper consists of **FOUR** ***Printed pages.***

QUESTION 1 (Compulsory)

(a) (i) Using a sketch, show how flow is normally distributed over a sphere at low subsonic speeds, and at supersonic speeds. **(3 marks)**

(ii) For the object in (i) above, describe methods of reducing drag on such objects. Use sketches to support your answer. **(4 marks)**

(iii) Show how the sphere from (i) above can be mounted in a tunnel in order to keep interference at a minimum. **(2 marks)**

(b) Sketch a simplified closed-circuit wind tunnel, and identify its key components. **(6 marks)**

(c) Wind tunnels operating in the transonic flow regime are normally fitted with an adjustable top or bottom section. Explain why this is so, and why other wind tunnels do not need such a provision. **(2 marks)**

(d) Using the conservation of mass, momentum and energy equations, show how the following relationship is determine:

$$\frac{dA}{A} = \frac{1-m^2}{rm^2}\frac{dp}{p}$$

(6 marks)

(e) In order to test the performance of a prototype sports car, an experimental model, which is $\frac{1}{5}th$ the size of the prototype is build. The prototype is expected to achieve 250km/hr in an environment where the temperature is 27°C. The model is to be tested in a water tunnel with an inlet temperature of 5°C.

(i) Sketch the set-up needed to produce accurate experimental results. **(3 marks)**

(ii) Determine the velocity of the flow in the tunnel for dynamic similarity to be achieved. **(4 marks)**

Refer to the tables provided for missing values:

$\mu_{water} = 1.002\times10^{-3}$, $\mu_{air} = 1.849\times10^{-5}$, $\rho_{water} = 998kg/m^3$

QUESTION 2

(a) We wish to design a supersonic wind tunnel which produces M = 2.8 in the test section at standard sea level conditions. The mass flow is equal to 14.5kg/s.
Determine the following parameters, necessary to achieve these conditions:

(i) Reservoir pressure **(2 marks)**
(ii) Reservoir temperature **(2 marks)**
(iii) Nozzle throat area **(2 marks)**
(iv) Exit area **(2 marks)**

(v) If a normal shock is allowed to form at the end of the test section, what will be the exit area necessary to create this shock? **(4 marks)**

(b) A pitot tube inserted at the exit of a supersonic nozzle measures 8.92×10^4Pa. If the reservoir pressure is 2.02×10^5Pa:

(i) Calculate the area ratio of the nozzle. **(4 marks)**

(ii) If the throat area is $25.4cm^2$, calculate the mass flow through the nozzle. Take $T_o = 290k$. **(4 marks)**

QUESTION 3

(a) (i) List the assumptions made on the type of gases and thermodynamic processes in a wind tunnel. **(3 marks)**

(ii) Static pressure is not directly measurable in a wind tunnel. Starting from the basic gas relationships, derive an equation that can be used to determine this temperature. **(7 marks)**

(b) A convergent tunnel section has an inlet and outlet as $1.5m^2$. The length of the entrance to the throat is 1m, and that from the throat to the exit is 2m. The throat area is $1m^2$. Assume that the sections are tapered with no bends, and that the length of the test section is negligible. Flow is chocked at the throat. Draw a graph showing the variation of T/T_t against the length x for:

(i) A subsonic flow throughout the nozzle. **(5 marks)**

(ii) A supersonic flow after the throat **(5 marks)**

QUESTION 4

(a) Briefly explain the principle utilized by the hot wire yaw meter. **(5 marks)**

(b) In a low-speed wind tunnel, a hot wire CTA operates at a temperature of 250°C while the air is at a temperature of 30°C. The velocity of the air may vary between 0 – 20m/s. The hot wire element is a platinum wire of 4.2μm diameter, and 1.4mm length. The resistance of the wire is given by the relationship.

$$R_w = 0.0082 T_{ar} \, \Omega/k$$

Given that the measured voltage is 0.3V, and that $C_1 = 0.26$, $C_2 = 0.3g$, $n = 0.5$, determine the measured velocity.

You may use the average temperature to determine the missing values from the table.

(8 marks)

(c) A pitot-static tube is pointed into an airstream which has a pressure of 151kPa. The differential pressure is 32kPa, and the ambient temperature is 15°C. Determine the mach number of the flow, and subsequently the flow velocity.

(7 marks)

QUESTION 5

(a) In a test measurement set-up, a pitot-tube is attached via an aquatic tubing to a differential manometer. Static pressure measurement is also attached to the same device. For this instrument, 4mA is equal two niches of water, while 20mA = 3inches of water. (1 inch of water column is equal to 249W/m^2). The relationship between these two points may be estimated to be linear. Ten readings are taken during the test, and are as tabulated below.

Point	**Reading (A)**
1	0.00475
2	0.00485
3	0.00495
4	0.005
5	0.0052
6	0.00635
7	0.00543
8	0.0055
9	0.0056
10	0.00569

Given that the room temperature is 20°C:

(i) Determine Δp for each point. **(4 marks)**

(ii) Determine the velocity for each point. **(4 marks)**

(iii) What is the trend exhibited by the measurement? **(4 marks)**

(b) With the aid of relevant relationships, show how the velocity it relates to the area of an inviscid incompressible flow. **(8 marks)**