THE INSTITUTION OF ENGINEERS SRI LANKA

PART II Examination-2011

212 – Applied Thermodynamics and Fluid Mechanics

DATE: **FROM: 0900 HRS to 1200HRS**

DURATION: THREE HOURS

READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THE QUESTION PAPER

1. Answer only five (05) questions selecting at least Two questions from each section. All questions carry equal marks.
2. Wherever appropriate, use tables and charts available in the in the examination hall. At the end of the examination return all such material to the examiner/supervisor.
3. Any missing data can be sensibly and reasonably assumed, but state such assumptions clearly with justifications.
4. Any result from calculations should have units, unless they are dimensionless.
5. All answers to the given questions should be underlined for the purpose of easy identification.
6. Write the question Number to which you answer on the cover page appropriately.
7. Assume density of water is 1000kg/m^3 and acceleration due to gravity is 10m/s^2 wherever relevant.

Section A

1 a Explain the difference between single stage compressor and multistage compressor.

b Show that for a reciprocating compressor that compress air polytropically , the work required **(W)** per unit mass is given by

$$W = \frac{n}{n-1} RT_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

Where ***n*** is the polytropic index.

c A single acting single stage compressor is belt driven from an electric motor at 400rpm. The cylinder diameter is 150mm and the stroke 175mm. The air is compressed from 1bar to 7 bar and the law of compression $PV^{1.3} = C$. Find the power of the motor, if transmission efficiency is 97% and the mechanical efficiency of the compressor is 90%. Neglect the clearance effects.

2 a Explain the physical significance of critical pressure ratio with respect to a steam nozzle.

b Dry saturated steam at a pressure of 8 bar enters a convergent divergent nozzle and leaves it at a pressure of 1.5 bar. If the flow is isentropic and if the corresponding expansion index is 1.133, find the ratio of cross sectional area at exit and throat for maximum discharge.

3 a Explain the difference between impulse turbine and reaction turbine.

b The mean diameter of the blades of an impulse turbine with a single raw wheel is 1050mm and the speed is 3000rpm. The nozzle angle is 18°, the ratio of blade speed to steam speed is 0.42 and the ratio of the relative velocity at outlet from the blades to that at inlet is 0.84. The outlet angle of the blades is to be made 3° less than the inlet angle. The steam flow is 8kg /s. Draw the velocity diagram for the blade inlet & exit and determine:

a Resultant thrust on the blades

b Tangential thrust on the blades

c Axial thrust on the blades

d Power developed

e Blading efficiecy

4 a Explain the two terms "higher calorific value" and "lower calorific value".

b The percentage composition of a sample of anthracite coal is C: 90%, H_2:3.5%, O_2:3%, N_2:1%, S: 0.5% and the remainder being ash. Estimate the minimum mass of air required for the combustion of 1kg of this fuel, and the composition of the dry products of combustion by volume, if 50% excess air is supplied.

Section B

5 a State the Buckingham's-Pi theorem.

b The efficiency η of a fan depends on the density ρ, the dynamic viscosity μ of the fluid, angular velocity ω, diameter D of the rotor and the discharge Q. By using the Buckingham's Pi theorem show that

$$\eta = \oint \left[\frac{\mu}{D^2\omega\rho}, \frac{Q}{D^3\omega}\right]$$

6 a Show that in a two dimensional incompressible steady flow field the equation of continuity is satisfied with the velocity components in rectangular coordinates given by

$$u(x,y) = \frac{k(x^2 - y^2)}{(x^2 + y^2)^2}$$
$$v(x,y) = \frac{2kxy}{(x^2 + y^2)^2}$$

where k is an arbitrary constant.

6 A plane surface is fixed and another plane surface rotates with angular velocity ω about an axis perpendicular to its plane and there is a film of oil fluid between them as shown in Figure Q 6. Prove that the pressure ***p*** in the oil film satisfies the equation

$$h^3\left(\frac{\partial^2 p}{\partial r^2}+\frac{1}{r}\frac{\partial p}{\partial r}+\frac{1}{r^2}\frac{\partial^2 p}{\partial \theta^2}\right)+\frac{\partial h^3}{\partial r}\frac{\partial p}{\partial r}+\frac{1}{r^3}\frac{\partial h^3}{\partial \theta}\frac{\partial p}{\partial \theta}=6\mu\omega\frac{\partial h}{\partial \theta}$$

where (r,θ) are polar coordinates in the plane of the film, the origin being in the axis of the film of rotation, and ***h*** is the thickness of the film.

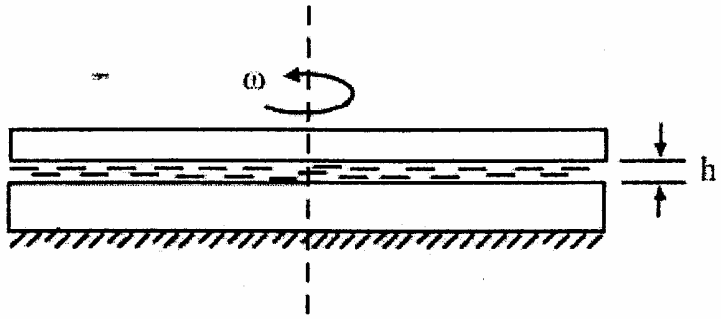

Figure Q 6

Equation of continuity for flow in the direction of ***y*** with velocity ***V*** along with the flow in the direction of ***x*** with velocity ***U*** is given by

$$\frac{\partial}{\partial x}\left(h^3\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(h^3\frac{\partial p}{\partial y}\right)=6\mu\left(\frac{\partial}{\partial x}(hU)+\frac{\partial}{\partial y}(hV)\right)$$

and

$x = r\cos\theta\ , y = r\sin\theta,$

$$\frac{\partial}{\partial x}=\cos\theta\frac{\partial}{\partial r}-\frac{\sin\theta}{r}\frac{\partial}{\partial \theta}$$

$$\frac{\partial}{\partial y}=\sin\theta\frac{\partial}{\partial r}-\frac{\cos\theta}{r}\frac{\partial}{\partial \theta}$$

$$\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}=\frac{\partial^2}{\partial r^2}+\frac{1}{r}\frac{\partial}{\partial r}+\frac{1}{r^2}\frac{\partial^2}{\partial \theta^2}$$

7 a Show that in a two dimensional incompressible steady flow field the equation of continuity is satisfied with the velocity components in rectangular coordinates given by

$$u(x,y) = \frac{k(x^2 - y^2)}{(x^2 + y^2)^2}$$
$$v(x,y) = \frac{2kxy}{(x^2 + y^2)^2}$$

where k is an arbitrary constant.

b Two sources each of strength m are placed at the points (-a,0),(a,0) . Show that the stream function is given by

$$x^2 - y^2 - a^2 = 2\lambda xy$$

where λ is a variable.

You may use the following relationships.
$z = (x + iy)$ and $\ln(\alpha + i\beta) = \frac{1}{2}\ln(\alpha^2 + \beta^2) + i\tan^{-1}\left(\frac{\beta}{\alpha}\right)$

8 a Define the term "specific speed" for a centrifugal pump.

b A centrifugal pump, with a discharge $\boldsymbol{Q}$, develops head $\boldsymbol{H}$ when running at a rotational speed $\boldsymbol{N}$. Write expressions for the following.

i. Head coefficient

ii. Flow coefficient

iii. Power coefficient

c To predict the performance of a large centrifugal pump to be fitted in an industrial application, a scale model of one sixth size was made with the following specifications.

Power	35kW
Head	10m
Speed	1000rpm

If the prototype pump has to work against a head of 30m, calculate the following.

i. Speed of the prototype.

ii. Power required to drive the pump.

iii. Ratio of flow rates handled by the two pumps.