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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	AIRCRAFT AERODYNAMICS
COURSE CODE	:	BDU 10703
PROGRAMME CODE	:	BDC / BDM
EXAMINATION DATE	:	DECEMBER 2018 / JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	PART A : ANSWER ALL **THREE (3)** QUESTIONS PART B : ANSWER **ONE (1)** QUESTION **ONLY**

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

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Q1 The governing equation of fluid motion for inviscid , two dimensional steady incompressible flow in Cartesian coordinate can be written as below.

Continuity Equation : $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$

Momentum Equation in x-direction : $u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x}$

Momentum Equation in y-direction : $u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y}$

By introducing introducing irrational flow condition shows that:

(a) The momentum equation can be converted to become Bernoulli equation.
(12 marks)

(b) The continuity equation can be solved through Laplace equation.
(8 marks)

(c) Describe the advantages and disadvantages this approach.
(5 marks)

Q2 (a) The potential flow field consist three elementary flow models : uniform flow, vortex and source flow mode as depicted in the **Figure Q2(a)**. The uniform flow model makes an angle of attack $\alpha = 5^0$ with respect to the x – axis and the flow speed is 40 m/sec. The vortex of strength $\gamma = 10\ \frac{m^2}{sec}$ located at the point A(2,1) has a clock wise direction. The source with strength $\sigma = 20\ \frac{m^2}{sec}$ is located at the point B(0,-2.0). Determine:

(i) The potential function Φ and the stream function Ψ of the flow model.
(5 marks)

(ii) Write down the flow model in term of its complex velocity potential function F(z).
(5 marks)

(iii) Determine the flow velocity at point (4,4).
(5 marks)

(b) A trapezoidal wing plan form with the data is given as:

- Wing root chord $c_r = 1.0$ m
- Wing tip chord $c_t = 1.6$ m
- Wing span $b = 9.0$ m
- Leading edge swept angle $A_{LE} = \mathbf{30^0}$

(i) Calculate the wing taper ratio λ, wing area reference S, wing aspect ratio A_R and the wing mean aerodynamics chord C_{mac}.
(5 marks)

(ii) Evaluate the advantage of leading edge swept angle.
(5 marks)

Q3. A NACA 2412 airfoil has a camber line in the form as given by the following equations:

$$y_c\left(\frac{x}{c}\right) = \begin{cases} 0.1\left(\frac{x}{c}\right) - 0.125\left(\frac{x}{c}\right) & \text{for } 0 \le \left(\frac{x}{c}\right) \le 0.4 \\ \frac{1}{90} + \frac{2}{45}\left(\frac{x}{c}\right) - \frac{2}{36}\left(\frac{x}{c}\right) & \text{for } 0.4 < \left(\frac{x}{c}\right) \le 1.0 \end{cases}$$

The airfoil angle of attack is $\alpha = 3^0$, by using a Thin Airfoil Theory determine:

(a) The camber line derivative in transformation coordinate θ.

(5 marks)

(b) The thin airfoil theory coefficient A_0, A_1 and A_2.

(15 marks)

(c) The lift coefficient C_L and the pitching moment coefficient at c/4 point $C_{Mc/4}$.

(5 marks)

PART B : SELECT ONE QUESTION.

Q4 The parameter boundary layers are defined as :

- The momentum thickness : $\theta = \int_0^\delta \left(\frac{u}{U_\infty}\right)\left(1 - \left(\frac{u}{U_\infty}\right)\right) dy$
- The displacement thickness: $\delta^* = \int_0^\delta \left(1 - \left(\frac{u}{U_\infty}\right)\right) dy$
- The shape factor $H = \frac{\delta^*}{\theta}$
- The skin friction $\tau_w = \mu \frac{du}{dy}$
- δ is the boundary layer thickness

The relationship between boundary layer parameters for case of flow past through a sharp edged flat plate, is given by:

$$\rho U_\infty^2 \left(\frac{d\theta}{dx}\right) = \tau_w$$

Above equation is known as the boundary layer Integral Momentum Von Karman. If the velocity profile inside the boundary layer $\left(\frac{u}{U_\infty}\right)$ as function of $\left(\frac{y}{\delta}\right)$ is known, the Integral momentum Von Karman can be solved and all the boundary layer parameters can be determined.

Suppose the velocity profile inside the boundary layer is given as:

$$\left(\frac{u}{U_\infty}\right) = \eta \quad \text{Where} \quad \eta = \left(\frac{y}{\delta}\right).$$

Using above velocity profile, determine:

(a) Boundary layer thickness δ.

(b) Displacement thickness δ^*.

(c) Momentum thickness θ.

(d) Skin friction τ_w.

(25 marks)

Q5 The Boundary Layer Integral Momentum Von Karman for the case flow along the plate is given as :

$$\rho U_\infty^2 \left(\frac{d\theta}{dx}\right) = \tau_w$$

where :

The momentum thickness : $\theta = \int_0^\delta \left(\frac{u}{U_\infty}\right)\left(1 - \left(\frac{u}{U_\infty}\right)\right) dy$

The skin friction $\tau_w = \mu \frac{du}{dy}$

δ : Boundary layer thickness

ρ : Air density

μ : Air viscosity

U_∞ : Free stream velocity

u : Local velocity inside the boundary layer

If the velocity profile inside the boundary layer $\left(\frac{u}{U_\infty}\right)$ as function of $\left(\frac{y}{\delta}\right)$ is known, the Integral momentum Von Karman can be solved by converting this integral equation as the equation which gives a relationship between boundary layer thickness δ with distance x. Determine the boundary layer thickness if the velocity profile is:

(a) $\left(\frac{u}{U_\infty}\right) = \eta$

(b) $\left(\frac{u}{U_\infty}\right) = \frac{3}{2}\eta - \frac{1}{2}\eta^2$

(c) $\left(\frac{u}{U_\infty}\right) = \sin\left(\frac{\pi}{2}\eta\right)$

(d) $\left(\frac{u}{U_\infty}\right) = \eta^{1/7}$ and $\tau_w = \frac{\rho U_\infty^2}{44}\left(\frac{\mu}{U_\infty \delta}\right)^{1/4}$

(25 marks)

-END OF QUESTIONS –

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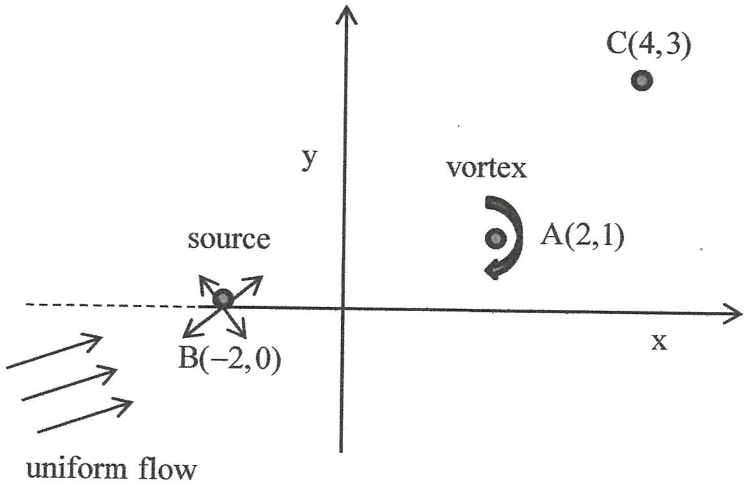

Figure Q2(a)