CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

TERBUKA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	AERODYNAMICS
COURSE CODE	:	BDE 40803
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2016 / JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTIONS	:	ANSWER **FOUR (5)** FROM **SIX (6)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

CONFIDENTIAL

Q1 (a) **Figure Q1(a)** shows plots of streamlines for flow of air entering a mouth of a duct. AB and CD are vertical straight lines joining two streamlines ψ_1 and ψ_2. The line CD in the figure is closer to the mouth of the duct. Based on the conservation of mass principle, explain why the length CD is greater than AB for the case shown in the figure.

(5 marks)

(b) A two dimensional steady incompressible inviscid flow is described in polar coordinates by the stream function:

$$\psi = 3r^2 \sin 2\theta$$

From the stream function above:

(i) determine the velocity components in r and θ directions (v_r and v_θ respectively);

(ii) prove that the flow satisfies the conservation of mass principle; and

(iii) plot **three** streamlines for $r = 1$, $r = 2$ and $r = 3$ with a minimum of **three** points for each line.

(15 marks)

Q2 (a) Based on the Potential Flow theory, a half body can be represented by a combination (superposition) of a *uniform flow* and a *source flow* ($\psi_{\text{half body}} = \psi_{\text{uniform}} + \psi_{\text{source}}$). For a half body:

(i) sketch the streamlines and include appropriate labels;

(ii) employ the superposition of plane potential flow and state the expression of stream function and the velocity potential; and

(iii) show that the distance between the source and the stagnation point in the flow is represented by:

$$r = \frac{b(\pi - \theta)}{\sin \theta}$$

(10 marks)

(b) **Figure Q2(b)** shows the roof of a plaza which may be considered to be a closed semi-cylinder, whose radius is 5 m. The roof is mounted on pillars as indicated in the figure. The flow over the plaza is assumed to be inviscid and is identical to the flow over a cylinder for $0 \leq \theta \leq \pi$. The air under the roof is assumed to be at rest with pressure equal to the stagnation pressure. The table in **Figure Q2(b)** gives the stream and potential functions for elementary flows. If the wind speed is $U_\infty = 50$ m/s and the air density is taken as $\rho = 1.225$ kg/m^3:

(i) show the expression for the velocity component in θ-direction, v_θ

(ii) show the expression for pressure acting on the upper and lower surfaces of the roof (p_u and p_l respectively) ;

(iii) determine the lift coefficient of the roof; and

(iv) evaluate the net lift force per unit depth acting on the roof.

(10 marks)

Q3 **Figure Q3** shows a test section of a wind tunnel which has a square cross-section with 300 mm in height, 300 mm in width and 500 mm in length. In the design of this wind tunnel, the flow through the test section is to be optimized for an air speed of $U_\infty = 4.0$ m/s. Taking the kinematic viscosity of air to be $\nu = 1.507 \times 10^{-5}$ m^2/s and using boundary layer expressions for smooth flat plates, evaluate:

(i) the Reynolds number (Re) of the flow at the exit of the test section and show that the flow is laminar;

(ii) the displacement thickness of the boundary layer (δ^*);

(iii) the increase or decrease in velocity at the exit of the test section as a result of the boundary layer effect;

(iv) the difference in velocity at the exit of the test section if the flow is fully turbulent from at the beginning of the test section; and

(v) a method to ensure a more uniform test section flow.

(20 marks)

Q4 A **NACA 2412** airfoil is to be used as a wing of a small aircraft. The chord length and span of this wing is 0.8 m and 5 m respectively. For this airfoil:

(i) explain the meaning of each digits in the NACA airfoil nomenclature and sketch the wing with appropriate labels; and

(ii) sketch the graph for section lift coefficient (C_L) and section moment coefficient (C_M) against angle of attack. (You may plot both of them on a single graph)

(20 marks)

Q5 A **NACA 2412** airfoil is to be used as a wing of a small aircraft. The chord length and span of this wing is 0.8 m and 5 m respectively. For this airfoil:

(i) evaluate the section lift coefficient

(ii) the angle of attack for zero lift

(20 marks)

Q6 (a) Describe the physical meaning of the "choking" phenomenon in a converging-diverging nozzle gas flow and explain whether it is possible for this phenomenon to occur in frictionless flows.

(5 marks)

(b) A nozzle with 600 mm^2 throat area and 1800 mm^2 exit area is used to expand air at stagnation temperature 100 °C into a tank. The maximum mass flow rate through the nozzle is 0.5 kg/s. With the aid of the property diagram given in **Figure Q5(b)** and the normal shock table given below, determine:

(i) the stagnation pressure;
(ii) the exit pressure if the flow is subsonic for an isentropic expansion;
(iii) the exit pressure if the flow is supersonic for an isentropic expansion;
(iv) the range of exit pressure for a fully supersonic flow in the tank if the flow is non-isentropic; and
(v) the range of exit pressure for a fully subsonic flow in the tank if the flow is non-isentropic.

Normal-Shock Table

The ratio of specific heats, k = 1.4

M_1	M_2	$p_{02}/p_{01} = \rho_{02}/\rho_{01}$	T_2/T_1	p_2/p_1	V_1/V_2 ρ_2/ρ_1
1.00	1.00000	1.00000	1.00000	1.00000	1.00000
1.10	0.91177	0.99893	1.06494	1.24500	1.16908
1.20	0.84217	0.99280	1.12799	1.51333	1.34161
1.30	0.78596	0.97937	1.19087	1.80500	1.51570
1.40	0.73971	0.95819	1.25469	2.12000	1.68966
1.50	0.70109	0.92979	1.32022	2.45833	1.86207
1.60	0.66844	0.89520	1.38797	2.82000	2.03175
1.70	0.64054	0.85572	1.45833	3.20500	2.19772
1.80	0.61650	0.81268	1.53158	3.61333	2.35922
1.90	0.59562	0.76736	1.60792	4.04500	2.51568
2.00	0.57735	0.72087	1.68750	4.50000	2.66667
2.10	0.56128	0.67420	1.77045	4.97833	2.81190
2.20	0.54706	0.62814	1.85686	5.48000	2.95122
2.30	0.53441	0.58329	1.94680	6.00500	3.08455
2.40	0.52312	0.54014	2.04033	6.55333	3.21190
2.50	0.51299	0.49901	2.13750	7.12500	3.33333
2.60	0.50387	0.46012	2.23834	7.72000	3.44898
2.70	0.49563	0.42359	2.34289	8.33833	3.55899
2.80	0.48817	0.38946	2.45117	8.98000	3.66355
2.90	0.48138	0.35773	2.56321	9.64500	3.76286
3.00	0.47519	0.32834	2.67901	10.33333	3.85714

(15 marks)

- END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER/SESSION:	SEM I / 2016-2017	PROGRAMME:	BDD
COURSE NAME:	AERODYNAMICS	COURSE CODE:	BDE 40803

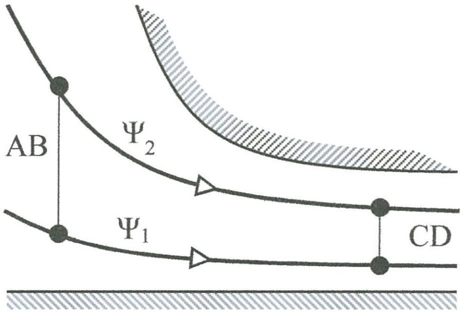

Figure Q1(a)

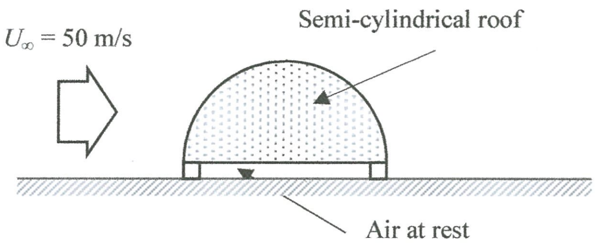

Table: Stream Functions and Potential Functions for Elementary Flows

Flow	ψ	ϕ
Uniform	$U_\infty r \sin\theta$	$U_\infty r \cos\theta$
Source	$\frac{K\theta}{2\pi}$	$\frac{K}{2\pi}\ln r$
Doublet	$-\frac{B}{r}\sin\theta$	$\frac{B}{r}\cos\theta$
Vortex (with clockwise circulation)	$\frac{\Gamma}{2\pi}\ln r$	$-\frac{\Gamma\theta}{2\pi}$
90 ° corner flow	Axy	$\frac{1}{2}A(x^2-y^2)$
Solid-body rotation	$\frac{1}{2}\varpi r^2$	-

Figure Q2(b)

FINAL EXAMINATION

SEMESTER/SESSION: SEM I / 2016-2017 PROGRAMME: BDD
COURSE NAME: AERODYNAMICS COURSE CODE: BDE 40803

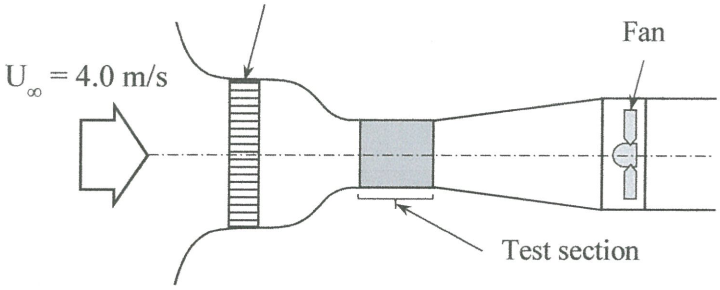

Figure Q3

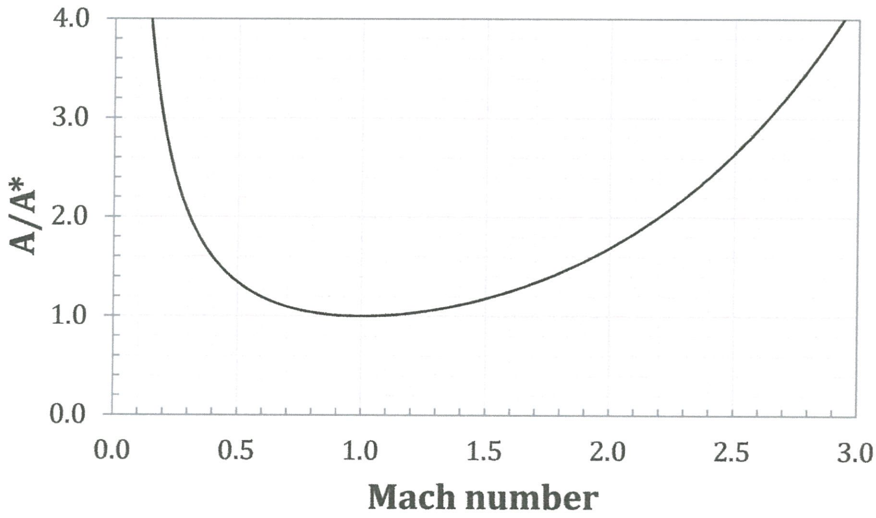

Figure Q5(b)