UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2004/2005
Second Semester Examination
2004/2005 Academic Session

Mac 2005
March 2005

ESA 372/3 – Aerodinamik Pesawat
Aircraft Aerodynamics

Masa : [3 jam]
Hour : [3 hours]

ARAHAN KEPADA CALON :
INSTRUCTION TO CANDIDATES:

Sila pastikan bahawa kertas soalan ini mengandungi **ENAM BELAS (16)** mukasurat dan **SEBELAS (11)** soalan sebelum anda memulakan peperiksaan.
Please ensure that this paper contains ***SIXTEEN (16)*** *printed pages and* ***ELEVEN (11)*** *questions before you begin examination.*

Bahagian A: Jawab **LIMA (5)** soalan.
Bahagian B: Jawab **TIGA (3)** soalan.
Part A: Answer ***FIVE (5)*** *questions.*
Part B: Answer ***THREE (3)*** *questions.*

Calon perlu menjawab dalam Bahasa Inggeris soalan no. 1, 2, 3, 4, 5, 6, 7 dan dalam Bahasa Malaysia soalan no. 8, 9, 10, 11.
Student should answer in English questions no. 1, 2, 3, 4, 5, 6, 7 and in Bahasa Malaysia questions no. 8, 9, 10, 11.

Setiap soalan mestilah dimulakan pada mukasurat yang baru.
Each questions must begin from a new page.

BAHAGIAN A/*PART A*

1. Berikan definisi dan perbezaan di antara 'Piuh Geometri' dan 'Piuh Aerodinamik' bagi sebuah pesawat sivil. Terangkan secara ringkas bagaimana piuhan sayap memberi kesan kepada pekali seretan sebuah sayap.

   Give the definitions and differences between 'Geometric Twist' and 'Aerodynamic Twist' of a civil aircraft wing. Briefly describe how the wing twist will effect the drag coefficient of the wing.

   (100 markah/*marks*)

2. Secara ringkas terangkan konsep 'Teorem Sears-Haack' untuk mengurangkan seretan gelombang bagi sebuah pesawat pejuang pada laju supersonik. Apakah yang dimaksudkan dengan 'keperluan minimum' bagi panjang, diameter dan isipadu bahan dan kelengkapan sebuah pesawat yang terletak di dalam badan pesawat?

   Briefly explain the concept of 'Sears-Haack Theorem' to reduce the wave drag of fighter aircraft at supersonic speeds. What is the meaning of 'minimum requirements' for length, diameter and volume of aircraft parts and equipments allocated inside the aircraft body?

   (100 markah/*marks*)

3. Apakah konsep 'Seretan-kecapahan Nombor Mach; M_{DD}' dan kesannya kepada seretan akibat kebolehmampatan (atau seretan gelombang) bagi sebuah pesawat subsonik? Terangkan bagaimana perubahan parameter penerbangan dan ciri sayap termasuk nisbah bidang (AR), nombor Mach pada jajap (M_C), sudut sapu belakang sayap pada suku perentas ($\Lambda_{c/4}$), nisbah tebal sayap kepada perentas (t/c), dan pekali angkat (C_L) memberi kesan kepada M_{DD} sebuah pesawat? ('Hint': Bertambah atau berkurang?!)

   What is the concept of 'Drag-divergence Mach Number; M_{DD}' and its effect on drag due to compressibility (or wave drag) of a high-subsonic aircraft? Explain how the changes of the flight parameters and the wing characteristics including wing aspect ratio (AR), Mach number at cruise (M_C), wing sweepback angle at quarter chord ($\Lambda_{c/4}$), wing thickness-to-chord ratio (t/c), and lift coefficient (C_L) affect the M_{DD} of the wing? (Hint: Increasing or decreasing?!)

   (100 markah/*marks*)

4. Secara ringkas terangkan maksud dan perbezaan 'kawasan basah' dan 'kawasan dedah'. Terangkan bagaimana kawasan basah bagi sebuah pesawat dikira dan bagaimana kawasan basah memberi kesan kepada jumlah pekali seret-angkat sifar (C_{Do}) bagi pesawat.

Briefly explain the meanings and differences of 'wetted area' and 'exposed area'. Describe how the total wetted area of the aircraft is calculated and how the wetted area affects the amount of total zero-lift drag coefficient (C_{Do}) of the aircraft.

(100 markah/*marks*)

5. Secara ringkas terangkan perbezaan di antara kaedah Roskam dan Torenbeek dalam pengiraan pekali seret-angkat sifar (C_{Do}) sebuah pesawat. (Tidak perlu menulis persamaan yang diperlukan secara berasingan untuk setiap komponen pesawat! Hanya bincang dalam bentuk ayat!)

Briefly explain the differences between Roskam's method and Torenbeek's method for calculating the total zero-lift drag coefficient (C_{Do}) of an aircraft. (No need to write down the equations required for each component of the aircraft separately! Just discuss in words!)

(100 markah/*marks*)

6. Apakah perbezaan utama di antara pekali seretan-teraruh (C_{Di}) sebuah pesawat pada kelajuan subsonik ($M<0.6$) dan pada kelajuan supersonik ($M>1.2$)? ('Hint': Bincang mengenai kesan nombor Mach ke atas parameter yang menyumbang kepada C_{Di}).

What are the main differences between the induced-drag coefficients (C_{Di}) of an aircraft at subsonic speeds ($M<0.6$) and supersonic speeds ($M>1.2$)? (Hint: Discuss on the Mach number effects on the parameters which are contributing in the C_{Di}).

(100 markah/*marks*)

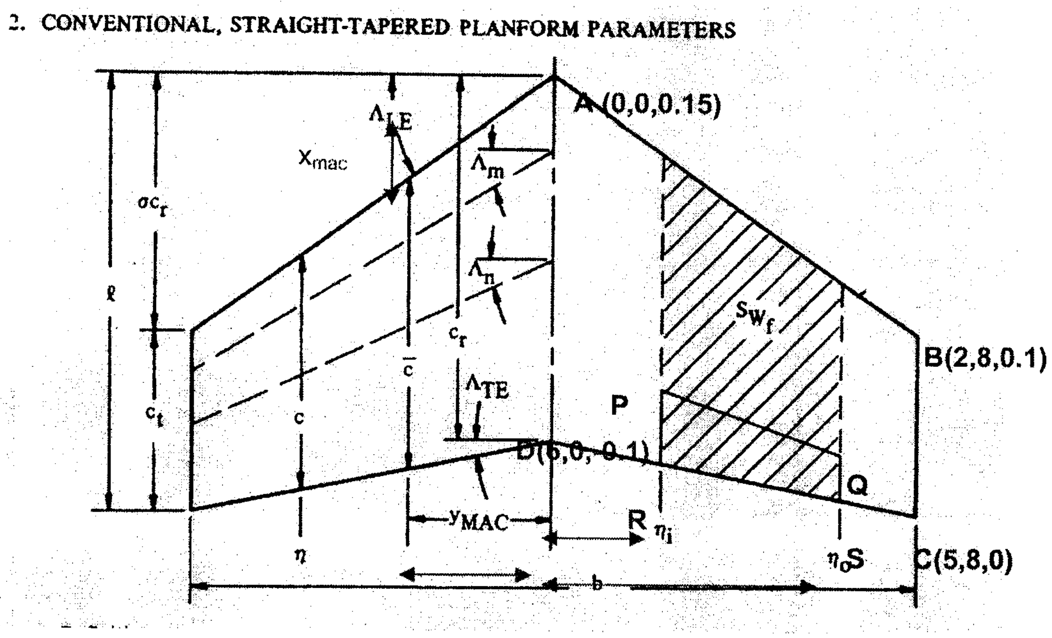
7. Apakah yang dimaksudkan dengan 'Seretan Trim', 'Seretan akibat Gangguan', 'Kepak berlubang-alur kembar Fowler' dan 'Seretan Ekor' dalam aerodinamik pesawat?

What are the meanings of 'Trim Drag', 'Drag due to Interference', 'Double-slotted Fowler Flaps' and 'Empennage Drag' in the aircraft aerodynamics?

(100 markah/*markah*)

BAHAGIAN B/*PART B*

8.



PR and QS : 0.25 Local chord

Rajah 1.1 Data geometri sayap
Figure 1.1 Wing geometry data

Rajah 1.1 memperlihatkan suatu sayap dengan data koordinat seperti yang terdapat dalam rajah tersebut posisi flap terletak pada :

Figure 1.1 shows a wing with coordinate data as in figure. Flap position is located at:

$$\eta_i = \frac{y_i}{(b/2)} = 0.35$$

$$\eta_o = \frac{y_o}{(b/2)} = 0.70$$

Tentukan parameter sayap tersebut di atas :

Determine the wing parameter above:

(i) rentang sayap b

wing span b

(2 markah/*marks*)

(ii) nisbah taper λ

taper ratio λ

(2 markah/*marks*)

(iii) persamaan garis leading edge $x_{LE}(y)$

the equation of leading edge line $x_{LE}(y)$

(2 markah/*marks*)

(iv) persamaan garis trailing edge $x_{TE}(y)$

the equation of trailing edge line $x_{TE}(y)$

(2 markah/*marks*)

(v) distribusi perentas sebagai fungsi y : c(y)

the chord distributions as function of y : c(y)

(2 markah/*marks*)

(vi) sudut swept pada leading edge Λ_{LE}

the swept angle leading edge Λ_{LE}

(2 markah/*marks*)

(vii) sudut swept pada garis c/4 line edge $\Lambda_{c/4}$

the swept angle $c_{/4}$ line edge $\Lambda_{c/4}$

(2 markah/*marks*)

(viii) Sudut swept pada garis tengah perentas $\Lambda c/2$

The swept angle mid chord line $\Lambda c/2$

(2 markah/*marks*)

(ix) Sudut swept pada trailing edge Λ_{TE}

The swept angle trailing edge Λ_{TE}

(2 markah/*marks*)

(x) Sudut twist angle ε

The twist angle ε

(2 markah/*marks*)

(xi) Luas sayap acuhan kawasan S_{Ref}

The wing Area S_{Ref}

(2 markah/*marks*)

(xii) Min aerodinamik perentas C_{mac}

The mean aerodynamic chord C_{mac}

(3 markah/*marks*)

9. (a) Sayap di atas mempunyai penampang melintang airfoil NACA serie 2412 dengan data koordinat seperti pada Jadual berikut :

The wing as mentioned above has a cross section Airfoil NACA serie 2412 with the coordinate data as shown in the following table.

NACA 4412

(Stations and ordinates given in percent of airfoil chord)

Upper Surfaces		**Lower Surface**	
Station	Ordinate	Station	Ordinate
0	0	0	0
1.25	2.44	1.26	-1.48
2.5	3.39	2.6	-1.95
5.0	4.78	5.0	-2.49
7.5	5.76	7.5	-2.74
10	6.59	10	-2.86
15	7.89	15	-2.88
20	8.80	20	-2.74
25	9.11	25	-2.50
30	9.76	30	-2.20
40	9.80	40	-1.80
50	9.19	50	-1.40
60	8.14	60	-1.00
70	6.89	70	-.65
80	4.89	80	-.89
90	2.71	90	-.22
95	1.47	95	-.16
100	0.18	100	(-.18)
100	----------	100	0
L.E radius : 1.58			
Slope radius through L.E : 0.20			

Data data aerodinamik lainnya untuk airfoil ini ialah :

Other aerodynamics data for this airfoil are given by:

- pekali daya angkat reka bentuk $c_{\ell i} = 0.3$
- sudut serang reka bentuk $\alpha_i = 2.0^0$
- sudut trailing angle $\Phi_{TE} = \text{arctg}\left(\frac{Y_{90} - Y_{99}}{9}\right)$

- *the design lift coefficient* $c_{\ell i} = 0.3$
- *the design angle of attack* $\alpha_i = 2.0^0$
- *trailing edge angle* $\Phi_{TE} = \text{arctg}\left(\frac{Y_{90} - Y_{99}}{9}\right)$

Y_{99} : ordinat airfoil pada posisi $x = 99\ \%$
Y_{90} : ordinate airfoil pada posisi $x = 90\ \%$

Y_{99} : *the ordinate of airfoil at position* $x = 99\ \%$
Y_{90} : *the ordinate of airfoil at position* $x = 90\ \%$

Tentukan:

Determine:

Y_{90} : ordinate airfoil pada posisi $x = 90\ \%$

Y_{90} : *the ordinate of airfoil at position* $x = 90\ \%$

(i) Kemiringan kurva pekali daya angkat airfoil $\frac{dc_\ell}{d\alpha}$

The slope of lift coefficient curve $\frac{dc_\ell}{d\alpha}$

(2 markah/*marks*)

(ii) Sudut serang pada pekali daya angkat sifar $\alpha_{L=0}$

The angle of attack at zero lift $\alpha_{L=0}$

(2 markah/*marks*)

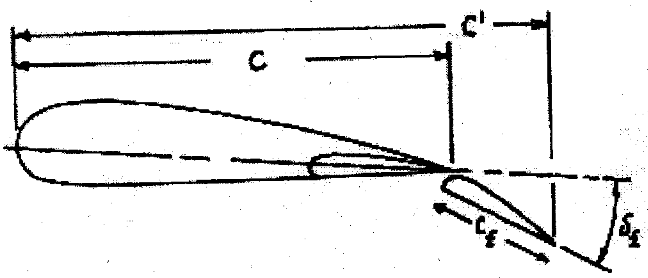
(iii) Pekali daya angkat maksimum $c_{\ell\,max}$

The maximum lift coefficient $c_{\ell\,max}$

(4 markah/*marks*)

(b) Airfoil di atas dilengkapi dengan flap tipe flower flap yang didefleksikan pada sudut defleksi $\delta_f = 15^0$ dengan konfigurasi seperti rajah 2.1 dengan $c' = 1.235$ c

Above airfoil was equipped with fowler type of flap with the defection flap angle $\delta_f = 15^0$ *as it was shown in the Figure 2.1 with* $c' = 1.235$ *c*



Rajah 2.1 Geometri fowler flap
Figure 2.1 Geometry fowler flap

Tentukan :

Determine:

(i) Kenaikan pekali daya angkat Δc_ℓ pada sudut serang $\alpha = 0$

The increment of lift coefficient increment Δc_ℓ *at zero angle of attack* $\alpha = 0$

(2 markah/*marks*)

(ii) Kemiringan kurva pekali daya angkat airfoil akibat flap defleksi $\left(\frac{dc_\ell}{d\alpha}\right)_{airfoil+flap}$

The slope of lift coefficient curve $\left(\frac{dc_\ell}{d\alpha}\right)_{airfoil+flap}$ *due to flap deflection*

(2 markah/*marks*)

(iii) Kenaikan pekali daya angkat maximum $\left(\Delta c_{\ell\,\max}\right)_{airfoil+flap}$

The increment of maximum lift coefficient $\left(\Delta c_{\ell\,\max}\right)_{airfoil+flap}$

(4 markah/*marks*)

(c) Menggunakan data geometri sayap seperti yang diberikan pada soalan no 1 dan data airfoil soalan no 2a dan soalan no 2b. tentukan:

Using the geometry data of wing as given in the problem No 1and also airfoil data as given in problem No 2a and 2b. determine:

(i) Kemiringan kurva pekali daya angkat sayap $\left(\dfrac{dC_\ell}{d\alpha}\right)_{Wing}$

The slope of lift coefficient curve $\left(\dfrac{dC_\ell}{d\alpha}\right)_{Wing}$

(3 markah/*marks*)

(ii) Kemiringan kurva pekali daya angkat sayap akibat flap defleksi $\left(\dfrac{dC_\ell}{d\alpha}\right)_{Wing+flap}$

The slope of lift coefficient curve $\left(\dfrac{dC_\ell}{d\alpha}\right)_{Wing+flap}$ *due to flap deflection*

(4 markah/*marks*)

(iii) Terangkan mengapa sudut serang sayap pada pekali daya angkat sifar sama dengan airfoilnya $\left(C_{\ell\ \alpha=0}\right)_{wing} = \left(c_{\ell\ \alpha=0}\right)_{airfoil}$

Explain why the angle of attack for zero lift coefficient for the wing is equal to its airfoil. $\left(C_{\ell\ \alpha=0}\right)_{wing} = \left(c_{\ell\ \alpha=0}\right)_{airfoil}$

(2 markah/*marks*)

10. Suatu Pesawat terbang dengan data sayap, airfoil dan flap seperti yang diberikan pada soalan no 1 dan no 2 tersebut di atas. Di samping itu pesawat mempunyai data tambahan sebagai berikut:

An aircraft with the data for the wing, airfoil and flap as described in the problems no 1 and no 2, In addition to this the additional data are given as follow:

Luas ekor mendatar $S_h = 0.20 \ S_w$

Sudut ekor terpasang $i_h = 4^0$

Tekanan dinamik ekor mendatar $n_h = 0.85$

Kemiring kurva pekali angkat ekor $\left(\frac{dC_\ell}{d\alpha}\right)_{th} = 5.84$ /rad

Horizontal tail area $S_h = 0.20 \ S_w$

Tail incidence angle $i_h = 4^0$

Horisontal tail dynamics pressure $n_h = 0.85$

The slope of tail lift coefficients $\left(\frac{dC_\ell}{d\alpha}\right)_{th} = 5.84$ /rad

Jarak mendatar antara min aerodinamik titik kontrol sayap dan ekor mendatar $\ell_h = 3.5 \ c_{mac}$

Jarak vertical sayap dan ekor mendatar $h_h = 0.85 \ c_{mac}$

Diameter badan pesawat $d_f = 2.5 \ c_{mac}$

Sudut sayap terpasang $i_w = 3^0$

Horizontal distance among the mean aerodynamic control points of wing and horizontal tail $\ell_h = 3.5 \ c_{mac}$

Vertical distance wing and horizontal tail $h_h = 0.85 \ c_{mac}$

Fuselage diameter $d_f = 2.5 \ c_{mac}$

The wing incidence $i_w = 3^0$

Kirakan :

Calculate:

(i) Kemiringan kurva pekali daya angkat sayap –badan pesawat $(C_{L\alpha})_{WF}$

The wing body lift curve slope $(C_{L\alpha})_{WF}$

(5 markah/*marks*)

(ii) Kemiringan kurva pekali daya angkat pesawat $(C_{L\alpha})_A$

The airplane lift curve slope coefficients $(C_{L\alpha})_A$

(5 markah/*marks*)

(iii) Pekali daya angkat pesawat pada sudut serang sifar

The airplane zero angle of attack lift coefficient $(C_{L\ \alpha=0})_A$

(5 markah/*marks*)

(iv) Sudut serang pada pekali daya angkat sifar $(\alpha_{L=0})_A$

The airplane zero lift angle of attack $(\alpha_{L=0})_A$

(5 markah/*marks*)

(v) Pekali daya angkat maximum pesawat $(C_{Lmax})_A$

The airplane maximum lift coefficients $(C_{Lmax})_A$

(5 markah/*marks*)

11. Dengan data geometri sayap dan airfoil seperti yang diberikan pada soalan no 1 dan 2 dan data tambahan lainnya sebagai berikut:

With the wing geometry and airfoil data as given in the problem No 1 and No 2 and also other additional data as follows:

- Pekali momen agih airfoil NACA 2412 pada sudut serang sifar c_{m_o} = -0.32
- Pusat aerodinamik sayap η_{ref} = 0.28 c_{mac}
- Momen reference sayap η_{ac} = 0.4 c_{mac}

- *Moment pitching coefficient airfoil NACA 2412 at zero lift* c_{m_o} = - 0.32
- *Wing aerodynamics center* η_{ref} = 0.28 c_{mac}
- *Wing moment reference point* η_{ac} = 0.4 c_{mac}

Tentukan :

Determine:

(i) Pekali momen agih sayap pada daya angkat sifar $(C_{mo})_W$

Wing zero lift piching moment coefficients $(C_{mo})_W$

(5 markah/*marks*)

(ii) Kemiringan kurva pekali moment agih sayap $\left(\frac{dC_m}{dC_L}\right)_W$

Slope of the wing pitcing moment curve $\left(\frac{dC_m}{dC_L}\right)_W$

(5 markah/*marks*)

(iii) Jika sayap ini di reka bentuk untuk terbang pada nombor Mach M = 0.5 , hitung Wing zero lift piching moment coefficients $(C_{mo})_W$ pada nombor Mach tersebut.

If the wing was designed to fly at the Mach Number M = 0.5 , calculate the Wing zero lift pitching moment coefficients $(C_{mo})_W$ *at that Mach Number*

(5 markah/*marks*)

(iv) Jika x_{ref} = 0.21 c_{mac} tentukan kenaikan moment pitching pada sayap akibat flap dideflesikan 15^0

IF x_{ref} *= 0.21* c_{mac} *determine the moment pitching increment on the wing due to flap deflection* 15^0

(10 markah/*marks*)

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