UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2013/2014 Academic Session

June 2014

ESA 369/3 – Flight Stability & Control
[Kestabilan & Kawalan Penerbangan]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this paper contains **NINE (9)** printed pages and **FIVE (5)** questions before you begin examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **SEMBILAN (9)** mukasurat bercetak dan **LIMA (5)** soalan sebelum anda memulakan peperiksaan]*.

Instructions : Answer **FIVE (5)** questions.

[Arahan : *Jawab **LIMA (5)** soalan]*.

Student may answer the questions either in English or Bahasa Malaysia.

[Pelajar boleh menjawab soalan dalam Bahasa Inggeris atau Bahasa Malaysia].

Each questions must begin from a new page.

[Setiap soalan mestilah dimulakan pada mukasurat yang baru].

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai].

1. [a] The contribution of wing fuselage combination to the moment about the c.g. of an airplane is given as follow :

C_L	0.28	0.488	0.696	0.9
$\left(C_{m_{cg}}\right)_{w,f}$	-0.0216	-0.006	0.0064	0.0156

(i) If the wing loading is 850 N/m^2, find the flight velocity at sea level when the airplane is in trim with zero lift on the tail.

(40 marks)

(ii) Investigate the stability of the airplane with the following additional data,

$$C_{L_{\alpha_w}} = 0.08\ deg^{-1},\ C_{L_{\alpha_t}} = 0.072\ deg^{-1},\ \frac{d\varepsilon}{d\alpha} = 0.45,\ l_t = 2.9\bar{c},$$
$$S_t = \frac{S}{7},\ \eta = 1.0$$

Assume the contributions of power to $C_{m_{cg}}$ and C_{m_α} to be negligible.

(35 marks)

[b] An airplane has the following pitching moment characteristics at the center of gravity position

$$\frac{x_{cg}}{\bar{c}} = 0.3$$

$$C_{m_{cg}} = C_{m_0} + \frac{dC_{m_{cg}}}{dC_L} C_L + C_{m_{\delta_e}} \delta_e$$

where

$$C_{m_0} = 0.05$$

$$\frac{dC_{m_{cg}}}{dC_L} = -0.1$$

$$C_{m_{\delta_e}} = -0.01\ deg^{-1}$$

$$\frac{dC_{m_{cg}}}{dC_L} = \frac{x_{cg}}{\bar{c}} - \frac{x_{NP}}{\bar{c}}$$

If the airplane is loaded so that the center of gravity position moves to $x_{cg}/\bar{c} = 0.10$, can the airplane be trimmed during landing, $C_L = 1.0$? Assume that C_{m_0} and $C_{m_{\delta_e}}$ are unaffected by the center of gravity travel and that $\delta_e = \pm 20°$.

(25 marks)

2. [a] Differentiate between sideslip angle and yaw angle.

(20 marks)

[b] Explain about adverse yaw.

(30 marks)

[c] Vertical tail is one of the most influential components in directional stability. Its contribution to the aircraft's directional stability can be calculated from the following equation

$$C_{n_{\beta_v}} = V_v \eta_v C_{L_{\alpha_v}} \left(1 + \frac{d\sigma}{d\beta}\right)$$

where

$$\eta_v \left(1 + \frac{d\sigma}{d\beta}\right) = 0.724 + 3.06 \frac{S_v/S}{1 + \cos \Lambda_{c/4w}} + 0.4 \frac{z_w}{d} + 0.009 AR_w$$

Let say a model of an airplane is tested in a wind tunnel with vertical tail off. Contributions of various components give $C_{n_\beta} = -0.001\, deg^{-1}$. If the vertical tail is to be positioned at a point on the aft end of the fuselage giving a tail length of $4.8\, m$, estimate the required vertical tail area to give an overall $C_{n_\beta} = 0.001\, deg^{-1}$? Given $C_{L_{\alpha_v}} = 0.0454$, $\Lambda_{c/4w} = 0$, $S = 18\, m^2$, $b = 10.6\, m$ and the wing is set at the middle of the fuselage.

(50 marks)

3. [a] Briefly explain about directional-lateral stability and state the conditions required for an aircraft to remain stable in this motion.

(20 marks)

[b] Explain how wing dihedral and sweep contribute to the dihedral effect.

(30 marks)

[c] The lift curve of a light airplane wing of rectangular planform is almost straight between angle of zero lift $(-3°)$ and the incidence of $10°$ at which $C_L = 1.066$. The wing chord is $2.14\ m$, the aspect ratio is 8.3 and the dihedral angle is $5°$. Assuming that the level flight speed is $41.15\ m/s$, calculate the rolling moment set up by a sudden yaw of $5°$.

(50 marks)

4. [a] With the aid of a diagram, describe the axes systems used in aircraft stability and control analysis. State the conditions when the use of each axis system might be preferred.

(30 marks)

[b] Define the body angular velocities of the airplane in terms of Euler angles and Euler rates.

(70 marks)

5. [a] Define the characteristic equation of longitudinal motion for the general aviation airplane with details given below

Flight condition:
Steady level flight at sea level at $u_0 = 53.64\ m/s\ \ (M = 0.158)$

$W = 12232.6\ N$
$m = 1247.4\ kg$
$g = 9.80665\ m/s^2$
$I_{yy} = 40675.8\ kgm^2$

Geometric details:

$S = 17.09\ m^2$
$\bar{c} = 1.737\ m$
$b = 10.18\ m$

Other details:

$\rho = 1.255\ kgm^{-3}$	$C_L = 0.41$	$C_D = 0.05$
$C_{L_\alpha} = 4.44\ rad^{-1}$	$C_{D_\alpha} = 0.33\ rad^{-1}$	$C_{m_\alpha} = -0.683\ rad^{-1}$
$C_{L_u} = 0$	$C_{D_u} = 0$	$C_{m_u} = 0$
$C_{m_{\dot{\alpha}}} = -4.36$	$C_{L_q} = 3.8$	$C_{m_q} = -9.96$

(50 marks)

[b] Define the roots of the characteristic equation defined in question (a).

(20 marks)

[c] Based on the roots defined in (b), define the period, time and number of cycles of each roots.

(30 marks)

1. [a] *Sumbangan daripada gabungan fiuslaj dan sayap untuk momen pada titik tengah sebuah kapal terbang diberikan seperti berikut*

C_L	0.28	0.488	0.696	0.9
$\left(C_{m_{cg}}\right)_{w,f}$	-0.0216	-0.006	0.0064	0.0156

(i) Jika beban sayap adalah $850\ N/m^2$*, cari kelajuan penerbangan pada paras laut apabila pesawat tersebut dalam keadaan trim dengan lif sifar pada ekor.*

(40 markah)

(ii) Siasat kestabilan pesawat tersebut dengan data tambahan berikut,

$$C_{L_{\alpha_w}} = 0.08\ deg^{-1},\ C_{L_{\alpha_t}} = 0.072\ deg^{-1},\ \frac{d\varepsilon}{d\alpha} = 0.45,\ l_t = 2.9\bar{c},$$
$$S_t = \frac{S}{7},\ \eta = 1.0$$

Anggap sumbangan kuasa kepada $C_{m_{cg}}$ *dan* C_{m_α} *diabaikan.*

(35 markah)

[b] Sebuah pesawat mempunyai sifat momen anggul pada posisi titik tengah graviti

$$\frac{x_{cg}}{\bar{c}} = 0.3$$

$$C_{m_{cg}} = C_{m_0} + \frac{dC_{m_{cg}}}{dC_L} C_L + C_{m_{\delta_e}} \delta_e$$

di mana

$$C_{m_0} = 0.05$$

$$\frac{dC_{m_{cg}}}{dC_L} = -0.1$$

$$C_{m_{\delta_e}} = -0.01\ deg^{-1}$$

$$\frac{dC_{m_{cg}}}{dC_L} = \frac{x_{cg}}{\bar{c}} - \frac{x_{NP}}{\bar{c}}$$

Jika pesawat diisi dan menyebabkan posisi pusat gravitinya bergerak ke $x_{cg}/\bar{c} = 0.10$*, bolehkan pesawat tersebut ditrim ketika mendarat,* $C_L = 1.0$*? Anggap* C_{m_0} *dan* $C_{m_{\delta_e}}$ *tidak dijejaskan oleh pergerakan titik tengah graviti dan* $\delta_e = \pm 20°$.

(25 markah)

2. [a] *Bezakan antara sudut gelincir sisi dan sudut rewang.*

(20 markah)

[b] *Terangkan tentang rewang buruk.*

(30 markah)

[c] *Ekor menegak merupakan salah satu komponen yang berpengaruh dalam kestabilan berarah. Sumbangannya kepada kestabilan berarah pesawat boleh dikira dengan menggunakan formula berikut*

$$C_{n_{\beta_v}} = V_v \eta_v C_{L_{\alpha_v}} \left(1 + \frac{d\sigma}{d\beta}\right)$$

di mana

$$\eta_v \left(1 + \frac{d\sigma}{d\beta}\right) = 0.724 + 3.06 \frac{S_v/S}{1 + \cos \Lambda_{c/4w}} + 0.4 \frac{z_w}{d} + 0.009 A R_w$$

Katakan sebuah model pesawat tanpa ekor menegak diuji dalam sebuah terowong angin. Sumbangan pelbagai komponen pesawat tersebut memberikan $C_{n_\beta} = -0.001\, deg^{-1}$. *Jika ekor menegak diletakkan pada bahagian belakang pesawat iaitu di hujung fiuslajdengan panjang ekor adalah* $4.8\, m$, *anggarkan luas permukaan ekor menegak yang diperlukan untuk memberi kestabilan keseluruhan* $C_{n_\beta} = 0.001\, deg^{-1}$. *Diberi* $C_{L_{\alpha_v}} = 0.0454$, $\Lambda_{c/4w} = 0$, $S = 18\, m^2$, $b = 10.6\, m$ *dan pesawat diletakkan pada pertengahan fiuslaj.*

(50 markah)

3. [a] *Terangkan dengan ringkas tentang kestabilan berarah-sisian dan nyatakan keadaan yang diperlukan untuk sebuah kapal terbang kekal stabil dalam pergerakan ini.*

(20 markah)

[b] *Menjelaskan bagaimana sayap dihedral dan sapu menyumbang kepada kesan dihedral.*

(30 markah)

[c] *Lengkung daya angkat sebuah pesawat ringan dengan bentuk pelan sayap hampir lurus antara sudut daya angkat sifar* $(-3\ °)$ *dan sudut* $10°$ *yang mana* $C_L = 1.066$. *Perentas sayap adalah* $2.14\ m$, *nisbah aspek adalah* 8.3 *dan sudut dihedral adalah* $5°$. *Dengan menganggap bahawa kelajuan penerbangan separas adalah* $41.15\ m/s$, *kira masa momen guling yang dijanakan oleh anggul* $5°$ *secara tiba-tiba.*

(50 markah)

4. [a] *Dengan bantuan gambar rajah lakarkan sistem-sistem koordinat yang digunakan dalam kajian kestabilan dan kawalan kapal terbang. Nyatakan keadaan bila setiap sistem koordinat itu digunakan.*

(30 markah)

[b] *Tentukan halaju membulat jasad pesawat dalam sebutan sudut Euler dan kadar sudut Euler.*

(70 markah)

5. [a] *Tentukan persamaan ciri pergerakan membujur bagi pesawat penerbangan awam dengan butir-butir yang diberikan di bawah*

Keadaan penerbangan:
Penerbangan stabil pada paras laut pada $u_0 = 53.64\ m/s\ \ (M = 0.158)$

$W = 12232.6\ N$
$m = 1247.4\ kg$
$g = 9.80665\ m/s^2$
$I_{yy} = 40675.8\ kgm^2$

Butiran geometri:

$S = 17.09\ m^2$
$\bar{c} = 1.737\ m$
$b = 10.18\ m$

Butiran lain:

$\rho = 1.255\ kgm^{-3}$	$C_L = 0.41$	$C_D = 0.05$
$C_{L_\alpha} = 4.44\ rad^{-1}$	$C_{D_\alpha} = 0.33\ rad^{-1}$	$C_{m_\alpha} = -0.683\ rad^{-1}$
$C_{L_u} = 0$	$C_{D_u} = 0$	$C_{m_u} = 0$
$C_{m_{\dot{\alpha}}} = -4.36$	$C_{L_q} = 3.8$	$C_{m_q} = -9.96$

(50 markah)

[b] *Tenentukan akar bagi persamaan ciri yang ditentukan dalam soalan [a].*

(20 markah)

[c] *Berasaskan pada nilai akar yang dittentukan pada (b), tentukan tempoh, masa dan bilangan kitaran bagi setiap akar.*

(30 markah)

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