UNIVERSITI SAINS MALAYSIA

First Semester Examination
2012/2013 Academic Session

January 2013

ESA461/2 – Flight Stability and Control II

[Kawalan dan Kestabilan Pesawat II]

Duration : 2 hours
Masa : 2 jam

Please check that this paper contains **EIGHT (8)** printed pages, **TWO (2)** pages appendix and **FOUR (4)** questions before you begin the examination.

Sila pastikan bahawa kertas soalan ini mengandungi ***LAPAN (8)*** *mukasurat bercetak,* ***DUA (2)*** *mukasurat lampiran dan* ***EMPAT (4)*** *soalan sebelum anda memulakan peperiksaan.*

Instructions : Answer **FOUR (4)** questions.
Arahan : *Jawab* ***EMPAT (4)*** *soalan.*

1. **Appendix A**/*Lampiran A* **[1 page**/*mukasurat*]

2. **Appendix B**/*Lampiran B* **[1 page**/*mukasurat*]

Answer all questions in **English** OR **Bahasa Malaysia.**
Menjawab semua soalan dalam ***Bahasa Inggeris ATAU Bahasa Malaysia.***

Answer to each question must begin from a new page.
Jawapan untuk 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] Briefly explain about directional stability and state the conditions required for an aircraft to remain stable in this motion.

Terangkan dengan ringkas tentang kestabilan berarah dan nyatakan keadaan yang diperlukan untuk sebuah kapal terbang kekal stabil dalam pergerakan ini.

(6 marks/*markah*)

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

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

(6 marks/*markah*)

[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

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

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

where

di mana

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

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.

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 fiuslaj dengan 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.

(15 marks/*markah*)

2. [a] Explain why deflecting the ailerons produce a yawing moment.

Terangkang mengapa dengan memesongkan aileron menghasilkan momen rewang.

(6 marks/*markah*)

[b] For the twin engine airplane shown in Figure 1, determine the rudder size to control the airplane if one engine needs to be shut down. Use the following flight information

Untuk kapal terbang dengan enjin berkembar seperti dalam Gambarajah 2, tentukan saiz kemudi untuk mengawal kapal terbang jika salah satu daripada enjin tersebut perlu dimatikan. Gunakan informasi penerbangan berikut

Wing:
Sayap: $S = 980\ ft^2$ $b = 93\ ft$

Vertical tail:
Ekor tegak: $S_v = 330\ ft^2$ $AR_v = 4.3$ $l_v = 37\ ft$ $\eta_v = 1.0$
$C_{L_{\alpha_v}} = 4.02\ rad^{-1}$

Rudder:
Kemudi: $\delta_r = \pm 15°$

Propulsion:
Pendorongan: $T = 14\ 000\ lb$ each $y_T = 16\ ft$

Flight condition:
Keadaan penerbangan: $V = 250\ ft/s$ $\rho = 0.002378\ slug/ft^3$

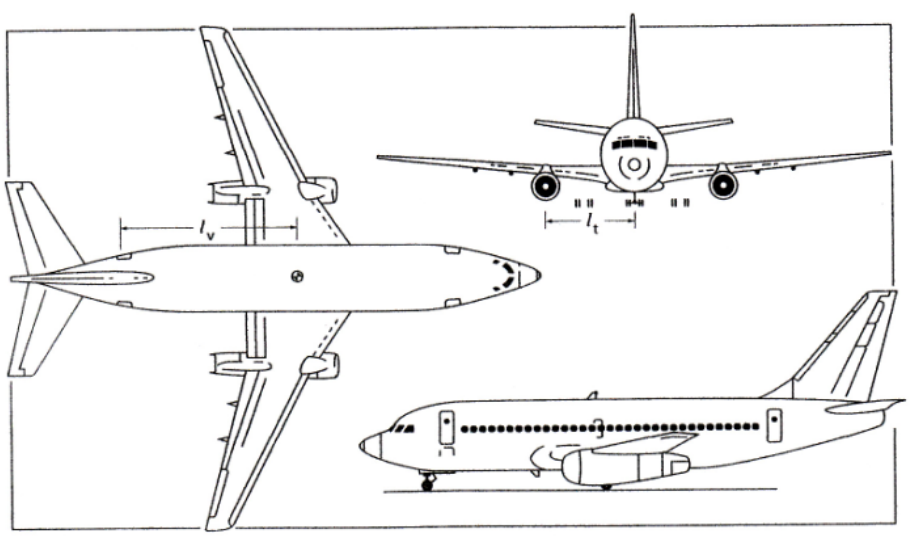

Figure 1 /*Rajah 1*

(13 marks/*markah*)

[c] Briefly explain how the force equations and moment equations of the aircraft are developed.

Terang secara ringkas bagaimana persamaan-persamaan daya dan persamaan-persamaan momen untuk pesawat diterbitkan.

(4 marks/*markah*)

3. Figure 2 illustrates a wind tunnel model that can only perform yawing motions. Using the data for general aviation airplane in Appendix A, determine the following;

Rajah 2 menunjukkan model terowong angin yang hanya boleh melaksanakan pergerakan rewang. Dengan mengunakan data bagi pesawat penerbangan umum di lampiran A, tentukan berikut;

[a] The yawing moment equation rewritten in state-space form.

Persamaan momen rewang ditulis dalam bentuk ruang keadaan.

(7 marks/*markah*)

[b] The characteristics equation and eigenvalues for the system.

Persamaan ciri-ciri dan nilai-nilai eigen bagi sistem.

(8 marks/*markah*)

[c] The damping ratio, ζ, and undamped natural frequency, ωn.

Nisbah redaman ζ, *dan frekuensi tabii tak terendam*, ωn.

(7 marks/*markah*)

[d] The response of the airplane to a 5˚ rudder input. Assume the initial conditions are $\Delta\beta(0)=0, \Delta r(0)=0$;

Sambutan pesawat tersebut kepada masukan 5˚ kemudi. Andaikan keadaan awal adalah $\Delta\beta(0)=0$, $\Delta r(0)=0$;

(8 marks/*markah*)

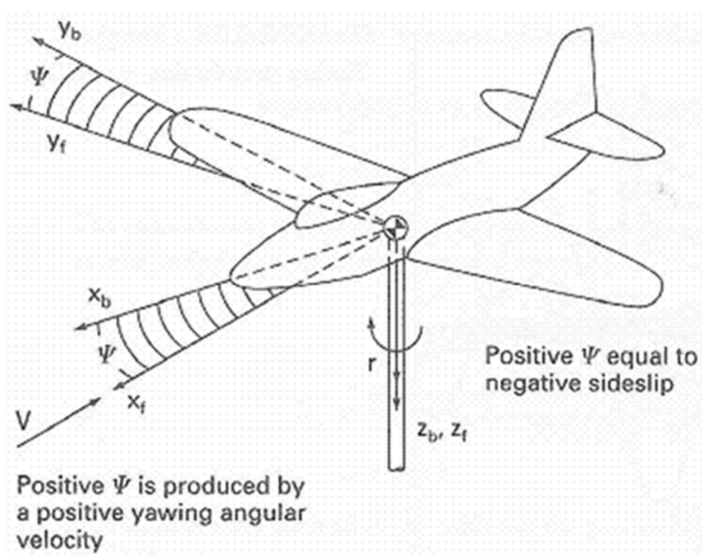

Figure 2/*Rajah 2*

4. The vertical motion of an airplane subjected to a sharp-edged gust is described by the equation **Δw(t)= Ag(1-e-t/t),** where **Δw** is in the vertical velocity, **Ag** is a magnitude of the gust, and **t** is the time constant of the airplane. Using the information in Figure 3, determine the maximum vertical acceleration and the time constant of the airplane.

Gerakan tegak kapal terbang tertakluk kepada tiupan tajam seperti digambarkan oleh persamaan ***Δw(t)= Ag(1-e-t/t),*** *di mana* **Δw** *dalam halaju menegak dan* **Ag** *adalah magnitud tiupan dan* ***t*** *adalah pemalar bagi masa pesawat tersebut. Dengan berpandukan Rajah 3,tentukan pecutan maksimum menegak dan pemalar masa bagi pesawat tersebut.*

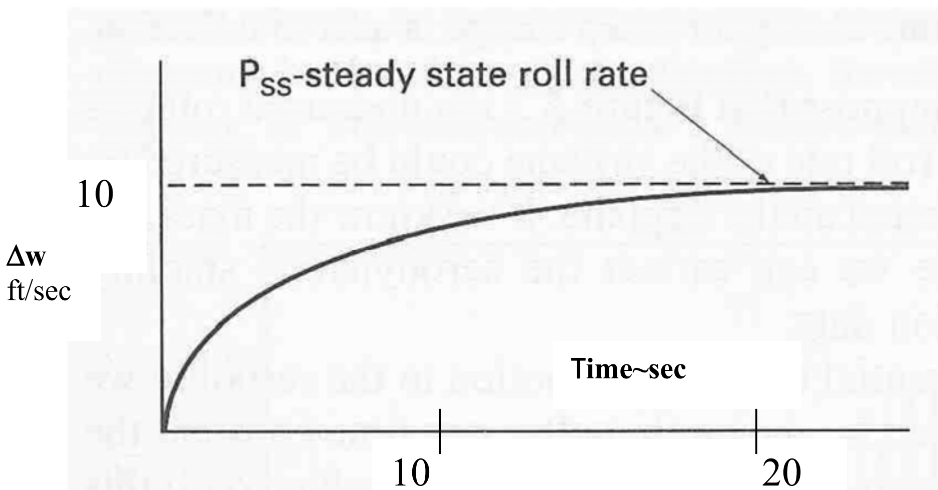

Figure 3/*Rajah 3*

(20 marks/*markah***)**

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APPENDIX A/ *LAMPIRAN A*

TABLE B.1

General aviation airplane: NAVION

Longitudinal M = 0.158	C_L	C_D	C_{L_α}	C_{D_α}	C_{m_α}	$C_{L_{\dot\alpha}}$	$C_{m_{\dot\alpha}}$	C_{L_q}	C_{m_q}	C_{L_M}	C_{D_M}	C_{m_M}	$C_{L_{\delta_e}}$	$C_{m_{\delta_e}}$
Sea level	0.41	0.05	4.44	0.33	−0.683	0.0	−4.36	3.8	−9.96	0.0	0.0	0.0	0.355	−0.923

Lateral M = 0.158	C_{y_β}	C_{l_β}	C_{n_β}	C_{l_p}	C_{n_p}	C_{l_r}	C_{n_r}	$C_{l_{\delta_a}}$	$C_{n_{\delta_a}}$	$C_{y_{\delta_r}}$	$C_{l_{\delta_r}}$	$C_{n_{\delta_r}}$
Sea level	−0.564	−0.074	−0.071	−0.410	−0.0575	0.107	−0.125	−0.134	−0.0035	0.157	0.107	−0.072

Note: All derivatives are per radian.

TABLE 5.1

Summary of lateral directional derivatives

$$Y_\beta = \frac{QSC_{y\beta}}{m} \ (\text{ft/s}^2 \text{ or m/s}^2) \quad N_\beta = \frac{QSbC_{n\beta}}{I_z} \ (\text{s}^{-2}) \quad L_\beta = \frac{QSbC_{l\beta}}{I_x} \ (\text{s}^{-2})$$

$$Y_p = \frac{QSbC_{y_p}}{2mu_0} \ (\text{ft/s}) \text{ or } (\text{m/s}) \qquad N_p = \frac{QSb^2C_{n_p}}{2I_zu_0} \ (\text{s}^{-1})$$

$$L_p = \frac{QSb^2C_{l_p}}{2I_xu_0} \ (\text{s}^{-1})$$

$$Y_r = \frac{QSbC_{y_r}}{2mu_0} \ (\text{ft/s}) \text{ or } (\text{m/s}) \qquad N_r = \frac{QSb^2C_{n_r}}{2I_zu_0} \ (\text{s}^{-1})$$

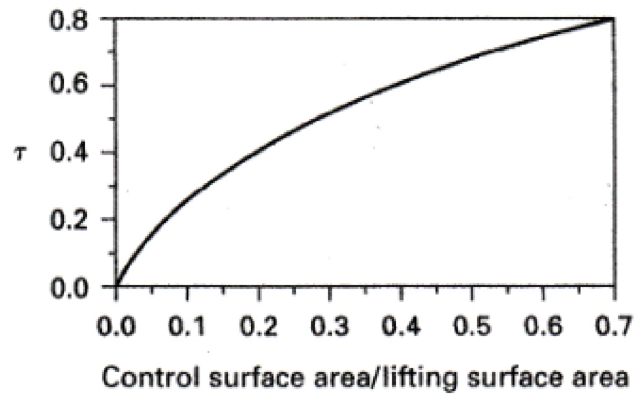
$$L_r = \frac{QSb^2C_{l_r}}{2I_xu_0} \ (\text{s}^{-1})$$

$$Y_{\delta a} = \frac{QSC_{y\delta_a}}{m} \ (\text{ft/s}^2) \text{ or } (\text{m/s}^2) \qquad Y_{\delta_r} = \frac{QSC_{y\delta_r}}{m} \ (\text{ft/s}^2) \text{ or } (\text{m/s}^2)$$

$$N_{\delta a} = \frac{QSbC_{n\delta_a}}{I_z} \ (\text{s}^{-2}) \qquad N_{\delta r} = \frac{QSbC_{n\delta_r}}{I_z} \ (\text{s}^{-2})$$

$$L_{\delta a} = \frac{QSbC_{l\delta_a}}{I_x} \ (\text{s}^{-2}) \qquad L_{\delta r} = \frac{QSbC_{l\delta_r}}{I_x} \ (\text{s}^{-2})$$

APPENDIX B/ *LAMPIRAN B*



Flap effectiveness parameter