UNIVERSITI SAINS MALAYSIA

First Semester Examination
2013/2014 Academic Session

December 2013/January 2014

ESA461/2 – Flight Stability and Control II
[Kawalan dan Kestabilan Pesawat II]

Duration : 2 hours
Masa : 2 jam

Please check that this paper contains **THIRTEEN (13)** printed pages, **THREE (3)** pages appendix and **FIVE(5)** questions before you begin the examination.

[Sila pastikan bahawa kertas soalan ini mengandungi ***TIGA BELAS (13)*** *mukasurat bercetak,* ***TIGA (3)*** *mukasurat lampiran dan* ***LIMA (5)*** *soalan sebelum anda memulakan peperiksaan].*

Instructions : Part A : Choose **ONE (1)** question **ONLY**. **Part B:** Answer **ALL** questions.

Arahan : BAHAGIAN A : Pilih **SATU (1)** soalan **SAHAJA.**
BAHAGIAN B **:** Jawab **SEMUA** soalan

1.	**Appendix A/***Lampiran A[FORMULA]:*	**[1 page**/*mukasurat*]
2.	**Appendix B/***Lampiran B*	**[2 pages**/*mukasurat*]

Answer all questions in **English** OR **Bahasa Malaysia.**

*[Menjawabsemuasoalandalam****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].

PART A: Choose **ONE (1)** question **ONLY**
BAHAGIAN A : Pilih **SATU (1)** soalan **SAHAJA**

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

(6 marks)

[b] 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.

(14 marks)

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

(5 marks)

[a] *Terangkan dengan ringkas tentang kestabilan berarah dan nyatakan keadaan yang diperlukan untuk sebuah kapalterbang kekal stabil dalam pergerakan ini.*

(6 markah)

[b] *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

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

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 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.*

(14 markah)

[c] *Terangkan mengapa dengan memesongkan aileron menghasilkan momen rewang.*

(5 markah)

2. [a] Briefly explain about asymmetric power and state the conditions required for an aircraft to remain stable in this motion.

(4 marks)

[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 and **Figure 2** to solve this problem.

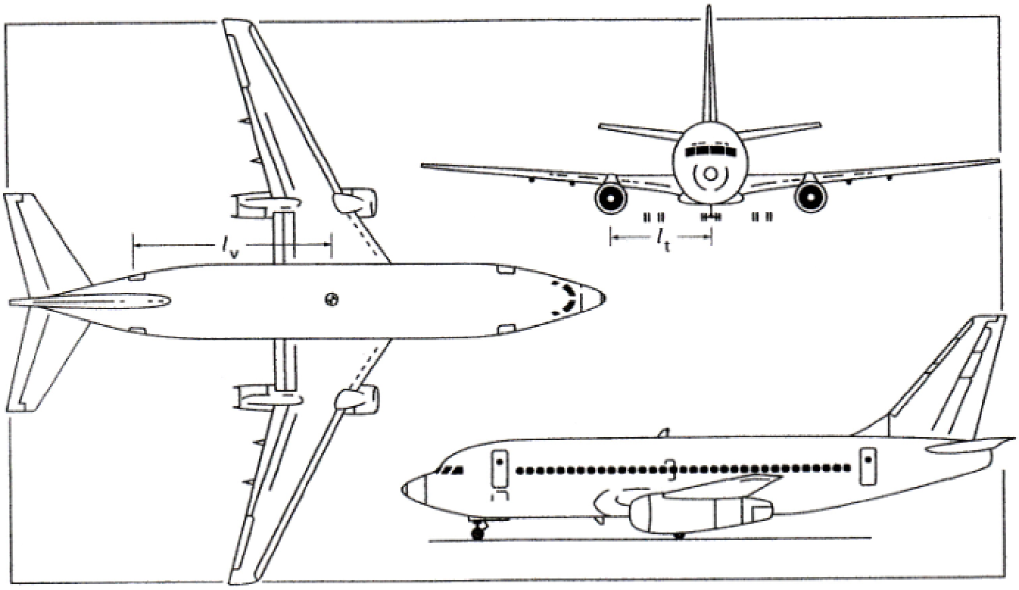


Figure 1

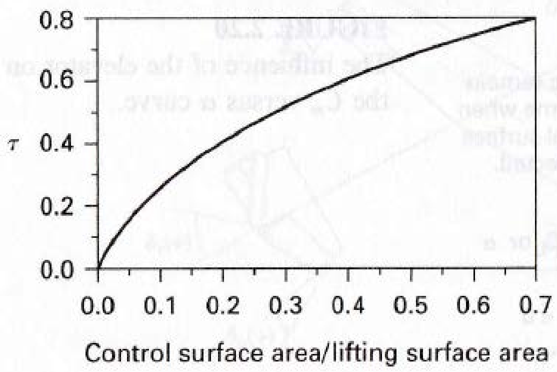


Figure 2

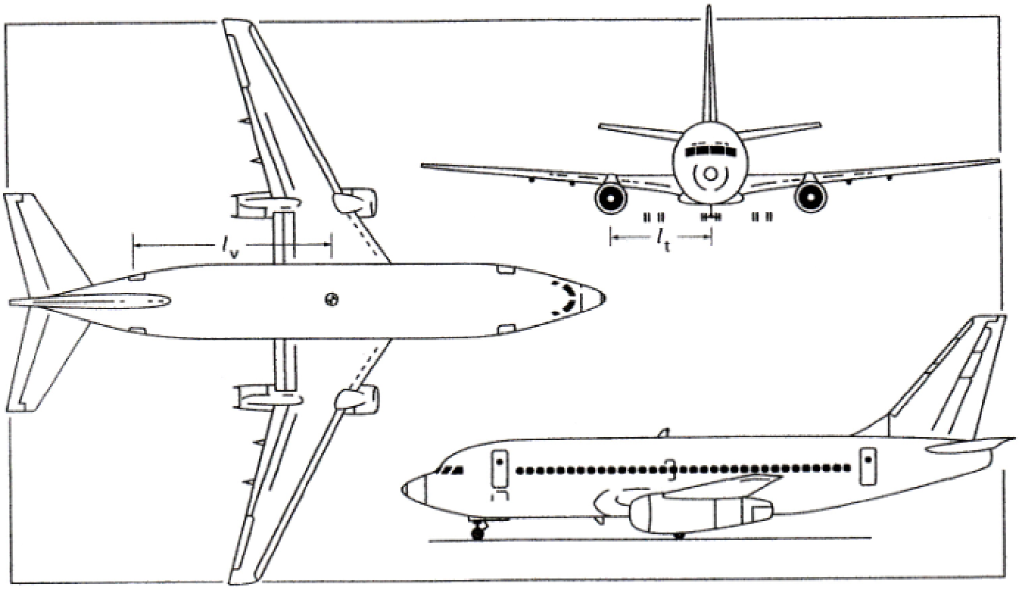
Wing: $S = 980\ ft^2$, $b = 93\ ft$
Vertical tail: $S_v = 330\ ft^2$, $AR_v = 4.3$, $l_v = 37\ ft$, $\eta_v = 1.0$, $C_{l_{\alpha v}} = 0.1/deg$
Rudder: $\delta_r = \pm 15°$
Propulsion: $T = 14\ 000\ lb$ each $y_T = 16\ ft$
Flight condition: $V = 250\ ft/s$, $\rho = 0.002378\ slug/ft^3$

(21 marks)

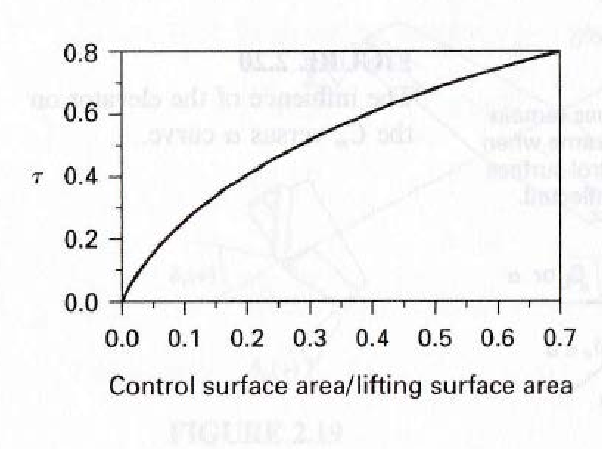
[a] *Terangkan dengan ringkas tentang kuasa asimetri dan nyatakan keadaan yang diperlukan untuk sebuahkapalterbang kekal stabil dalam pergerakan ini.*

(4 markah)

[b] *Untuk kapalterbang dengan enjin berkembar seperti dalam R**ajah 1,** tentukan saiz kemudi untuk mengawal kapalterbang jika salah satu daripada enjin tersebut perlu dimatikan. Gunakan informasi penerbangan berikut dengan **Rajah 2** untuk menyelesaikan masalah ini.*



Rajah 1



Rajah 2

Sayap: $S = 980\ ft^2$, $b = 93\ ft$
Ekor Tegak: $S_v = 330\ ft^2$, $AR_v = 4.3$, $l_v = 37\ ft$, $\eta_v = 1.0$, $C_{l_{\alpha v}} = 0.1/deg$
Kemudi: $\delta_r = \pm 15°$
Pendorongan: $T = 14\ 000\ lb$ each $y_T = 16\ ft$
Keadaan penerbangan: :$V = 250\ ft/s$, $\rho = 0.002378\ slug/ft^3$

(21 markah)

PART B: Answer **ALL** questions.
***BAHAGIAN B* :** Jawab **SEMUA** soalan.

3. [a] The stability coefficient C_{l_r} is the change in roll moment due to the yawing rate. What cause this effect and how does the vertical tail contribute to the C_{l_r}? A simple discussion with appropriate sketches is required for this problem.

(4 marks)

[b] The stability coefficient $C_{l_{\delta_r}}$ is the change in roll moment coefficient due to rudder deflection. Again, explain how this effect occurs.

(1 marks*)*

[c] Using the geometric data given below and in **Figure 3**, estimate C_{l_p} and C_{n_r}. The roll moment coefficient due to rolling rate, C_{l_p} and yaw moment coefficient due to yawing rate, C_{n_r} can be formulated from the following equations respectively.

$$C_{l_p} = -\frac{C_{L_\alpha}}{12}\frac{1+3\lambda}{1+\lambda}$$

$$C_{n_r} = -2\eta_v V_v\left(\frac{l_v}{b}\right)C_{L_{\alpha v}}$$

(20 marks)

Wing: $S = 232\ ft^2$, $b = 36\ ft$, $C_{l_{\alpha w}} = 0.1/deg$
Vertical tail: $S_v = 37.4\ ft^2$, $l_v = 18.5\ ft$, $C_{l_{\alpha v}} = 0.1/deg$, $\eta_v = 1$

Wing: $C_{L_{\alpha_w}} = 0.1/\text{deg}$ $C_{m_{ac_w}} = -0.02/\text{deg}$

$\alpha_{Lo} = -1.0°$

Tail: $C_{L_{\alpha_w}} = 0.1/\text{deg}$ $C_{m_{ac_w}} = 0.00$

$\alpha_{Lo} = 0°$

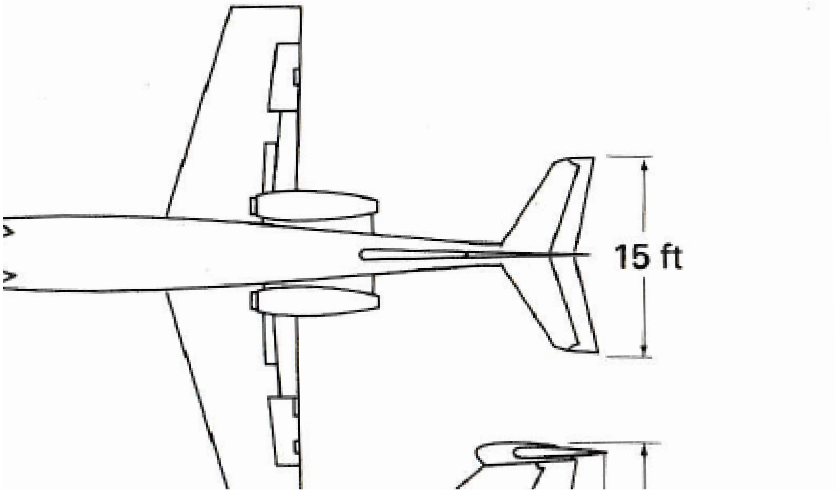


Figure 3

[a] *Kestabilan pekali* C_{l_r} *adalah perubahan dalam masa roll disebabkan oleh kadar rewang. Apa yang menyebabkan kesan ini dan bagaimana ekor menegak menyumbang kepada pekali* C_{l_r}*? Satu perbincangan ringkas dengan lakaran yang sesuai diperlukan untuk masalah ini.*

(4 markah)

[b] *Pekali kestabilan* $C_{l_{\delta_r}}$ *adalah perubahan pekali momen roll yang disebabkan oleh kemudi pesongan. Sekali lagi, menjelaskan bagaimana kesan ini berlaku.*

(1 markah)

[c] *Menggunakan data geometri yang diberikan di bawah dan di dalam* ***Rajah 3,*** *anggaran* C_{l_p} *and* C_{n_r} *.Pekali momen roll yang disebabkan oleh kadar roll,* C_{l_p} *dan pekali momen rewang yang disebabkan oleh kadar rewang,* C_{n_r} *boleh dirumuskan daripada persamaan berikut.*

$$C_{l_p} = -\frac{C_{L_\alpha}}{12}\frac{1+3\lambda}{1+\lambda}$$

$$C_{n_r} = -2\eta_v V_v\left(\frac{l_v}{b}\right)C_{L_{\alpha v}}$$

(20 markah)

Sayap: $S = 232\ ft^2$, $b = 36\ ft$, $C_{l_{\alpha w}} = 0.1/deg$

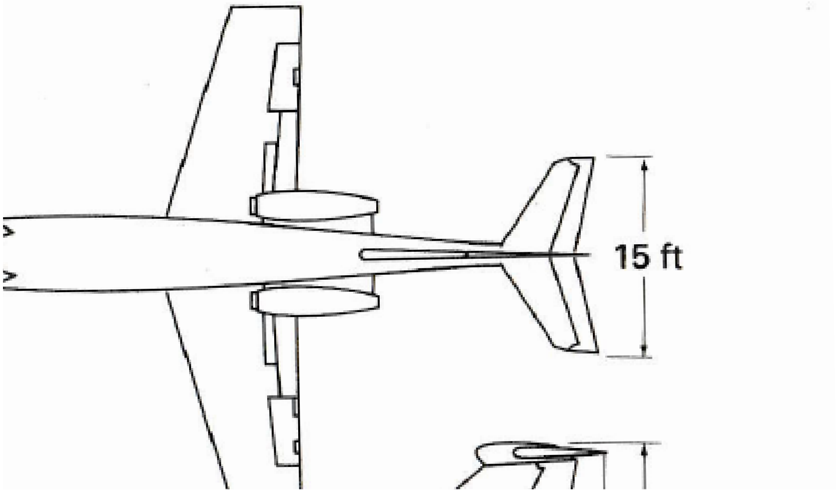
Ekor Tegak : $S_v = 37.4\ ft^2$, $l_v = 18.5\ ft$, $C_{l_{\alpha v}} = 0.1/deg$, $\eta_v = 1$

Wing: $C_{L_{\alpha_w}} = 0.1/\text{deg}$ $C_{m_{ac_w}} = -0.02/\text{deg}$

$\alpha_{Lo} = -1.0°$

Tail: $C_{L_{\alpha_w}} = 0.1/\text{deg}$ $C_{m_{ac_w}} = 0.00$

$\alpha_{Lo} = 0°$



Rajah 3

4. Assuming the cruciform finned model in Figure 4 is mounted in a wind tunnel so that it is constrained to a pure yawing motion.The model is displaced from its trim position by 10^0 and then released. Neglect the fuselage and $\dot{\beta}$ contribution and assume $S = \pi D^2/4$.

[a] Find the time for the motion to damp to half its initial amplitude.

(15 marks)

[b] What is the period of the motion.

(10 marks)

$D = Characteristic\ length = 5.0$

Tail surfaces are flat plates: $I_z = 5.0\ X\ 10^{-2} kgm^2$, $S = \pi D^2/4$

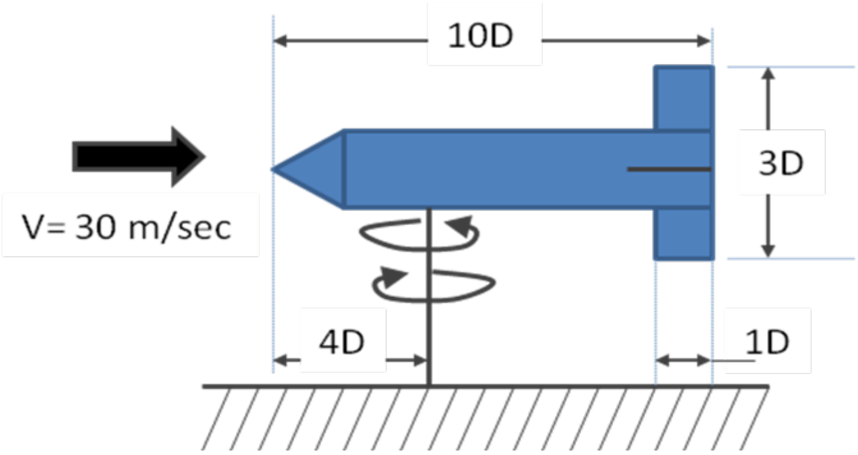


Figure 4

Dengan andaian model bersirip bentuk 'Cruci' seperti di **Rajah 4** *yang dipasang di dalam terowong angin supaya ianya berlaku pengerakan rewang asli. Model yang disasarkan dari kedudukan cantas dengan* 10^0 *dan kemudian dibebaskan. Abaikan fuslaj dan* β *sumbangan dan anggapkan* $S = \pi D^2/4$.

[a] *Tentukan masa bagi pergerakan menjadi rendam untuk setengah amplitude awal.*

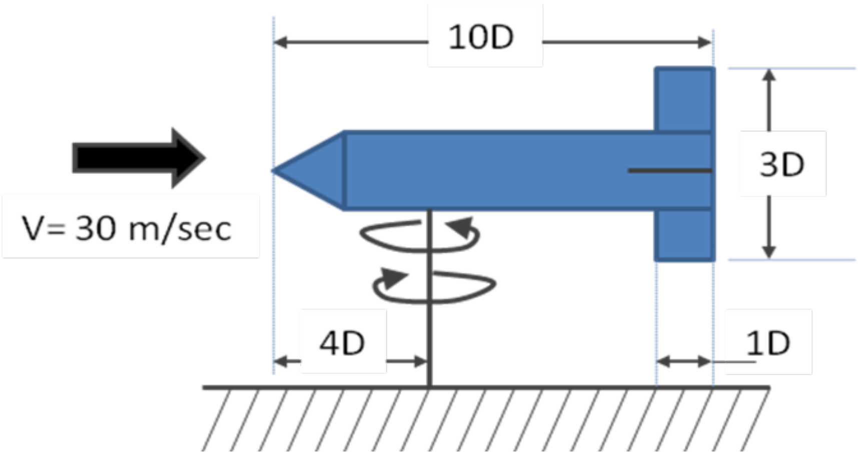
(15 markah)

[b] *Apakah tempoh pergerakan.*

(10 markah)

$D = Panjang\ Kriteria = 5.0$

Permukaaan ekor adalah permukaan rata: $I_z = 5.0\ X\ 10^{-2} kgm^2$, $S = \pi D^2/4$



Rajah 4

5. Examine the performance characteristics of a speed control autopilot similar to the one shown in **Figure 5** for the STOL transport included in **Appendix A**. The transfer functions for the throttle servo, engine lag, forward path compensation, and the feedback elements follow:

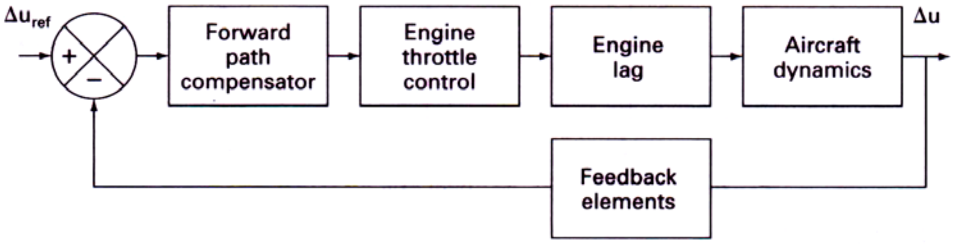


Figure 5

$$G_{Throttle}(s) = \frac{10}{s+10}, G_{enginelag}(s) = \frac{1}{s+0.1},$$

$$G_c(s) = 1 + \frac{0.1}{s} = \frac{k_a(s+0.1)}{s}, H = 10s + 1$$

[a] Find the loop transfer function G(s)H(s)

(10 marks)

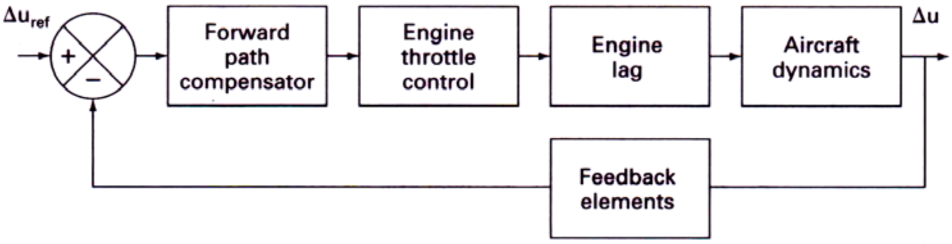
[b] Using unit step response, determine the gains by sketch the graph time vs amplitude.

(10 marks)

[c] Discuss, how to improve the performance of this system.

(5 marks)

Kaji ciri-ciri prestasi kelajuan kawalan autopilot yang sama seperti yang ditunjukkan dalam ***Rajah 5*** *pengangkutan STOL yang disertakan dalam* ***Lampiran A.*** *Berikut adalah rangkap pindah bagi servo pendikit, lag enjin, kompensator laluan hadapan dan elemen suapbalik.*



Rajah 5

$$G_{Throttle}(s) = \frac{10}{s+10}, G_{enginelag}(s) = \frac{1}{s+0.1},$$
$$G_c(s) = 1 + \frac{0.1}{s} = \frac{k_a(s+0.1)}{s}, H = 10s + 1$$

[a] *Tentukan gelung rangkap pindah G(s)H(s)*

(10 markah)

[b] *Tentukan gandar dengan memplot graf masa berlawanan dengan amplitud.*

(10 markah)

[c] *Bincangkan bagaimana untuk meningkatkan prestasi dalam sistem ini.*

(5 markah)

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APPENDIX A/ *LAMPIRAN A*

Geometric,Mass, and Aerodynamic Characteristic of Selected Airplanes

b Wing span

$\bar{c}$ Mean chord

$$C_L = \frac{L}{QS}$$

$$C_{L_M} = \frac{\partial C_L}{\partial M}$$

$$C_{L_{\delta_e}} = \frac{\partial C_L}{\partial \delta_e} \text{ (rad}^{-1}\text{)}$$

$$C_D = \frac{D}{QS}$$

$$C_{D_\alpha} = \frac{\partial C_D}{\partial \alpha} \text{ (rad}^{-1}\text{)}$$

$$C_{L_\alpha} = \frac{\partial C_L}{\partial \alpha} \text{ (rad}^{-1}\text{)}$$

$$C_{L_{\dot\alpha}} = \frac{\partial C_L}{\partial\left(\dfrac{\dot\alpha \bar{c}}{2u_0}\right)} \text{ (rad}^{-1}\text{)}$$

$$C_{l_{\delta_a}} = \frac{\partial C_l}{\partial \delta_r} \text{ (rad}^{-1}\text{)}$$

$$C_{l_{\delta_r}} = \frac{\partial C_l}{\partial \delta_r} \text{ (rad}^{-1}\text{)}$$

$$C_n = \frac{N}{QSb}$$

$$C_{n_\beta} = \frac{\partial C_n}{\partial \beta} \text{ (rad}^{-1}\text{)}$$

$$C_{D_M} = \frac{\partial C_D}{\partial M}$$

$$C_{D_{\delta_e}} = \frac{\partial C_D}{\partial \delta_e} \text{ (rad}^{-1}\text{)}$$

$$C_m = \frac{M}{QS\bar{c}}$$

$$C_{m_\alpha} = \frac{\partial C_m}{\partial \alpha} \text{ (rad}^{-1}\text{)}$$

$$C_y = \frac{Y}{QS}$$

$$C_{y_\beta} = \frac{\partial C_y}{\partial \beta} \text{ (rad}^{-1}\text{)}$$

$$C_{y_{\delta_r}} = \frac{\partial C_y}{\partial \delta_r} \text{ (rad}^{-1}\text{)}$$

$$C_l = \frac{L}{QSb}$$

$$C_{l_\beta} = \frac{\partial C_l}{\partial \beta} \text{ (rad}^{-1}\text{)}$$

$$C_{l_p} = \frac{\partial C_l}{\partial (pb/2u_0)} \text{ (rad}^{-1}\text{)}$$

$$C_{l_r} = \frac{\partial C_l}{\partial (rb/2u_0)} \text{ (rad}^{-1}\text{)}$$

$$C_{n_p} = \frac{\partial C_n}{\partial (pb/2u_0)} \text{ (rad}^{-1}\text{)}$$

$$C_{n_r} = \frac{\partial C_n}{\partial (rb/2u_0)} \text{ (rad}^{-1}\text{)}$$

$$C_{m_{\dot\alpha}} = \frac{\partial C_m}{\partial (\dot\alpha \bar{c}/2u_0)} \text{ (rad}^{-1}\text{)}$$

$$C_{m_M} = \frac{\partial C_m}{\partial M}$$

$$C_{m_q} = \frac{\partial C_m}{\partial (q\bar{c}/2u_0)} \text{ (rad}^{-1}\text{)}$$

$$C_{n_{\delta_a}} = \frac{\partial C_n}{\partial \delta_a} \text{ (rad}^{-1}\text{)}$$

$$C_{n_{\delta_r}} = \frac{\partial C_n}{\partial \delta_r} \text{ (rad}^{-1}\text{)}$$

I_x	Rolling moment of inertia
I_y	Pitching moment of intertia
I_z	Yawing moment of inertia
I_{xz}	Product of inertia about xz axis
M	Mach number
Q	Dynamic pressure
S	Wing planform area
u_0	Reference flight speed

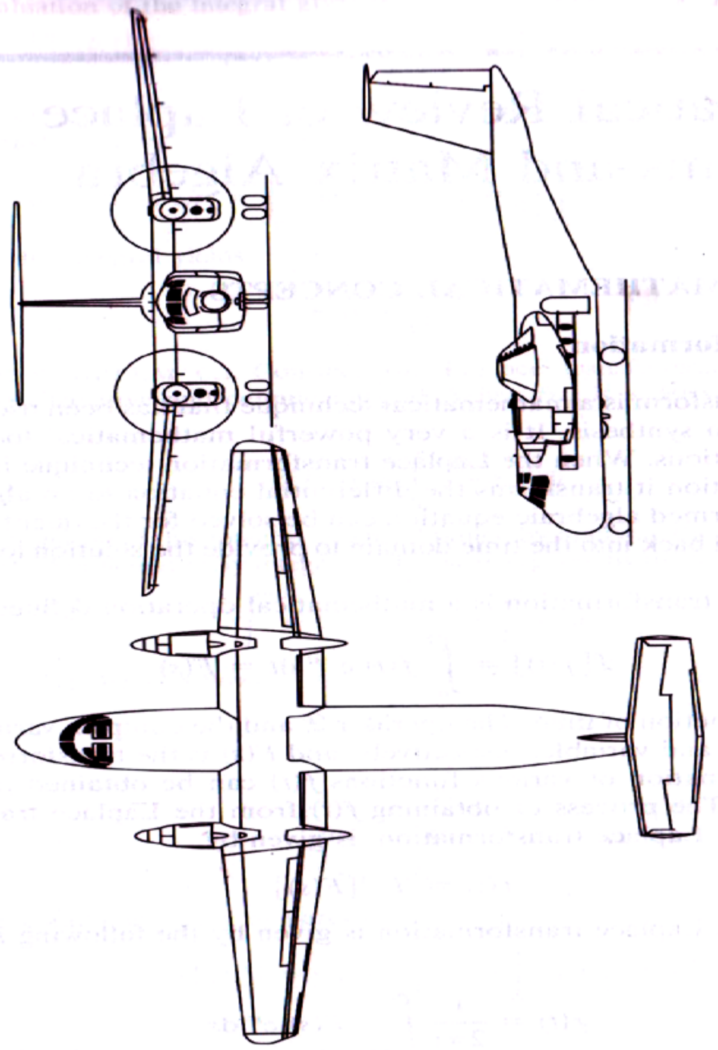
APPENDIX B */LAMPIRANB*

STOL Transport Reference data

TABLE B.28
STOL Transport

Longitudinal	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}	$C_{L_{\delta_e}}$	$C_{m_{\delta_e}}$
M = 0.14 Sea level	1.5	0.127	5.24	0.67	−0.78	1.33	−6.05	7.83	−35.6	0	0	0	0.465	−2.12
M = 0.37 10,000 ft	0.3	0.036	5.24	0.67	−0.78	1.33	−6.05	7.83	−35.6	0	0	0	0.465	−2.12
Lateral	C_{y_β}	C_{l_β}	C_{n_β}	C_{l_p}	C_{n_p}	C_{l_r}	C_{n_r}	$C_{l_{\delta_a}}$	$C_{n_{\delta_a}}$	$C_{y_{\delta_r}}$	$C_{l_{\delta_r}}$	$C_{n_{\delta_r}}$		
M = 0.14 Sea level	−0.362	−0.125	0.101	−0.53	−0.283	0.410	−0.188	0.20	0	−0.233	−0.024	0.107		
M = 0.37 10,000 ft	−0.362	−0.125	0.101	−0.53	−0.037	0.113	−0.171	0.20	0	−0.233	−0.024	0.107		

Note: All derivatives are per radian.



Center of gravity and mass characteristics

W = 40,000 lbs.
CG at 25% MAC
I_x = 273,000 Slug·ft²
I_y = 215,000 Slug·ft²
I_z = 447,000 Slug·ft²
I_{xz} = 0

Reference geometry

S = 945 ft²
b = 96 ft
$\bar{c}$ = 10.1 ft