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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	FLIGHT STABILITY AND CONTROL
COURSE CODE	:	BDL 30102
PROGRAMME CODE	:	BDC
EXAMINATION DATE	:	DECEMBER 2018/JANUARY 2019
DURATION	:	2 HOURS AND 30 MINUTES
INSTRUCTION	:	ANSWERS **FOUR** (4) QUESTIONS **ONLY**

THIS QUESTION PAPER CONSISTS OF **FOUR (4)** PAGES

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Q1 (a) In the study of airplane motion, we normally begin with the study of longitudinal motion (stick fixed). Explain briefly the longitudinal motion (stick fixed)

(5 marks)

(b) A flat lifting surface is mounted on a hollow slender as shown in **Figure Q1(b)**. The slender rod is supported in the wind tunnel by a transverse rod. A low friction bearing is used so that the slender rod-flat plate system can rotate freely in pitch. To have the centre of gravity located at the pivot point, ballast is placed inside the slender tube forward of the pivot. The mass of the slender rod and the contribution of pitching moment due to slender rod are neglected. The mechanical friction of the bearings is also neglected. The equation of motion is given as $\ddot{\theta} - M_q\dot{\theta} - M_\alpha\theta = 0$ and moment of inertia, $I_y = 1.4 \times 10^{-2}$ *slug.ft*^{2}. Use $C_{l\alpha} = \frac{2\pi}{rad}$ for an infinite flat plate and $u_o = 25$ *ft/s*. Estimate the following for the system;

(i) damping ratio.

(8 marks)

(ii) undamped natural frequency.

(8 marks)

(ii) damped natural frequency

(4 marks)

Q2 (a) In airplane lateral motion, one of the most common dynamic phenomena experienced when flying at high angle of attack is known as wing rock. State the primary motion in wing rock.

(5 marks)

(b) A Navion General Aviation airplane is constrained to pure yawing moment. The yawing moment equation written in state-space form for Navion is given as;

$$\begin{bmatrix}\Delta\dot{\varphi}\\ \Delta\dot{r}\end{bmatrix} = \begin{bmatrix}0 & 1\\ -4.55 & -0.76\end{bmatrix}\begin{bmatrix}\Delta\varphi\\ \Delta r\end{bmatrix} + \begin{bmatrix}0\\ -4.6\end{bmatrix}\Delta\delta_r$$

By using the airplane data given in **Figure Q2(b)** and the yawing moment equation, determine the following;

(i) characteristic equation and eigenvalues for the system and predict the type of response of the airplane.

(10 marks)

(ii) damping ratio

(5 marks)

(iii) undamped natural frequency

(5 marks)

Q3 (a) Describe how Routh-Hurwitz can be used to determine the stability of an airplane system that can be model mathematically?

(5 marks)

(b) A transport airplane has the closed loop control system that has the characteristic equation of $s^3 + 5s^2 + 7s + 3 = 0$. By using Routh-Hurwitz criterion, determine the absolute stability of the system.

(20 marks)

Q4 (a) Define the flying qualities.

(5 marks)

(b) A light airplane trainer has the following aerodynamic, mass and geometric properties.

$W = 17{,}580$ lb	$I_y = 25{,}900$ slug.ft^2	$C_{m\dot{\alpha}} = -0.4\ \text{rad}^{-1}$
$S = 260\ \text{ft}^2$	$c = 10.8$ ft	$C_{m\alpha} = -1.7\ \text{rad}^{-1}$
$C_{L\alpha} = 4.0\ \text{rad}^{-1}$	$C_{mq} = -4.3\ \text{rad}^{-1}$	

Determine the following;

(i) Short-period flying qualities in terms of damping ratio and natural frequency at sea level for a true airspeed of 800 ft/s.

(15 marks)

(ii) Examine the effect of damping ratio and natural frequency and suggest how can the design engineer improve the flying qualities for this airplane?

(5 marks)

Q5 (a) Describe briefly what is the root locus technic and how this technical is useful in designing the control system?

(5 marks)

(b) A fighter airplane is equipped with an automatic control for its steering system has the open loop transfer function of $G(s) = \dfrac{K(s+2)(s+3)}{s(s+4)(s^2+2s+2)}$.

(i) Sketch the root locus for this control system.

(10 marks)

(ii) From the sketched root locus, determine the pole when the system has the damping ratio of 0.5, damped and undamped natural frequencies and gain at this damping ratio.

(10 marks)

-END OF QUESTIONS –

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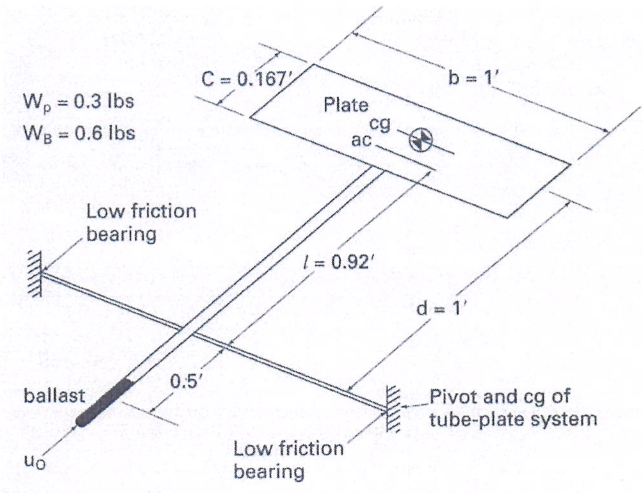

Figure Q1(b)

General aviation airplane: NAVION

Longitudinal M = 0.158 Sea level	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}	$C_{L_{\delta_e}}$	$C_{m_{\delta_e}}$
	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 Sea level	C_{y_β}	C_{l_β}	C_{n_β}	C_{l_p}	C_{n_p}	C_{l_r}	C_{n_r}	$C_{l_{\delta_a}}$	$C_{n_{\delta_a}}$	$C_{y_{\delta_r}}$	$C_{l_{\delta_r}}$	$C_{n_{\delta_r}}$
	−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.

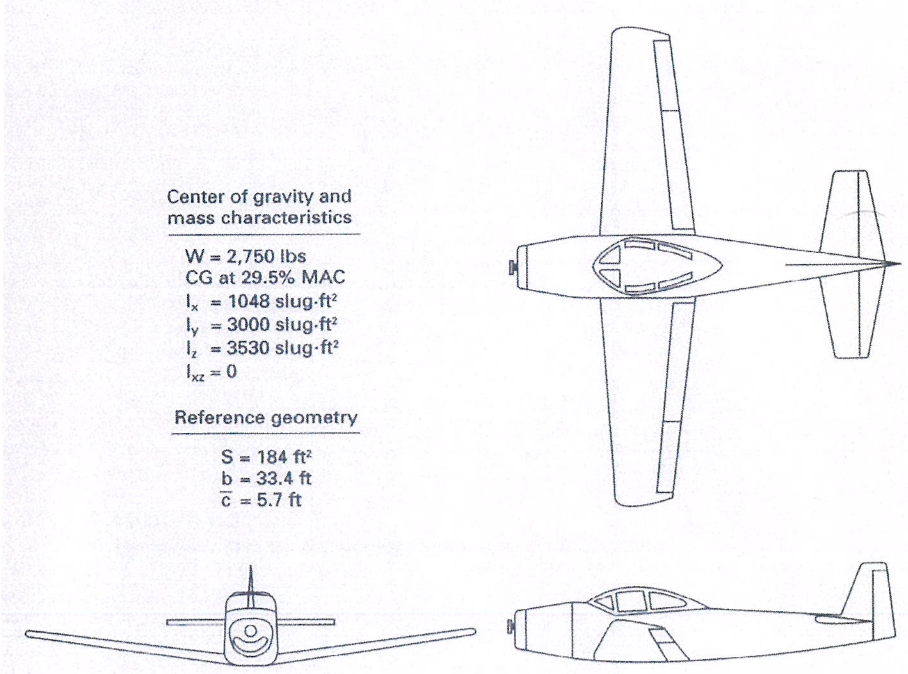

Figure Q2(b)