Swansea University
Faculty of Science and Engineering
January Assessment period 21-22

Module Code: EG-M81

Module Title: FLIGHT DYNAMICS AND CONTROL

Assessment Type: Online Exam

Instructions:

Assessment Start Date: TBD

Assessment End Date: TBD

Assessment Duration: 4 Hours

Submission method: Canvas file submission and online test

For this assessment: there are **two parts** (Part 1 and Part 2).

PART 1	55 points
PART 2	25 points
TOTAL	80 points

You need to complete both parts within the assessment duration which is **4 hours**.

PART 1:

In this part there are **FIVE questions**, and you need to submit your answers for **ALL FIVE questions** through Canvas. Note that questions have varying marks assigned as follows:

Q1	Q2	Q3	Q4	Q5
8	10	5	18	14

- The maximum score of this part is **55 points**.

Submitting Handwritten Solutions

For photographed hand-written solutions, use of a scanning app such as Microsoft Office Lens (Links to an external site.) or Adobe Scanner App (Links to an external site.) is highly recommended. Please, if possible, package your solution pages into a single PDF file. Finally, before submitting the PDF, review the document for readability:

• Are all the images clear and in focus?

• Is there any distortion in the images that will make them hard to read?

• Are the images oriented in the correct way?

• Are there artefacts that your app or camera has added, such as watermarks, that have obscured part of what you have written?

• Will I be able to read and mark your work easily?

The few extra minutes this will take can avoid serious issues later.

Please make sure that your student number is visible on each of your answer sheet(s). Any submission should not include your name. An effective way to title your submissions, if applicable, is with your student number, module code, and a brief title (i.e. EG-M81_0123456_EssayX).

PART 2:

In this part you need to complete a Canvas online test. Answer **ALL FIVE questions**. Note that questions have varying marks assigned as follows:

Q1	Q2	Q3	Q4	Q5
3	5	6	6	5

- The maximum score of this part is **25 points**.
- You have **TWO** attempts, and the **highest grade** will be considered as your final marks.
- There **will NOT** be a **countdown timer**; it is, therefore, your responsibility to submit the test by the **deadline** (allowing an appropriate safety margin would be a good idea).
- Your total score at the end of your attempt **will NOT** be displayed.

Important notes for both parts of assessment:

• This is open book assessment, which means you can access appropriate academic sources to help you complete your assessments as necessary.

• This is an individual assessment; working in groups, helping or receiving help from other students or third parties is not permitted. The work you submit must be your own work. The usual University regulations regarding academic misconduct apply. For further information regarding Academic Misconduct please follow the links:

Academic Misconduct Procedure - Swansea University

UNIVERSITY OF WALES (swansea.ac.uk)

• If you have circumstances that impact your ability to complete or submit your assessment by the deadline, the University's Extenuating Circumstances processes are there to support you. Find out more here:

Student Information Team - Swansea University

Please note that there is a zero tolerance policy for late submissions and I will not be able to accept and mark your late work unless you apply and are approved for Extenuating Circumstances.

• If you experience IT issues, during your assessment, you can contact the University's Customer Service Team either by emailing customerservice@swansea.ac.uk or calling +44 (0) 1792 295500. For issues relating to Quizzes, you can email the Faculty Assessment & Awards Team – assessments-scienceengineering@swansea.ac.uk

• To check you have successfully submitted your assignment, please go into the 'Assignments' area and click on the assignment title. In the top right-hand corner, you should see the text 'Submitted' and confirmation of the submission time.

• Canvas will allow multiple uploads; only the most recent submission before the deadline will be marked.

Please make sure you retain any evidence of submission, should there be any query at a later date.

END OF INSTRUCTIONS

PART 1: In this part, there are five questions, and you need to answer all of them.

1. The nonlinear equations of motion of a system are obtained as

$$(M+m)\ddot{x} + ml\ \cos\theta\ \ddot{\theta} = -c\dot{x} + ml\ \sin\theta\ \dot{\theta}^2 + u$$
$$(J+ml^2)\ddot{\theta} + ml\ \cos\theta\,\ddot{x}\ = -ml\ \sin\theta$$

where m, l, M, J and c are constant coefficients.

Considering the linear equations of motion of the system, obtain the state space form as

$$\dot{X} = AX + Bu$$

Hint. Consider the state variables as: $x, \theta, \dot{x}$ and $\dot{\theta}$.

[Total 8 Marks]

2. Using a 2-DOF model, determine the crosswind limit of an aircraft assuming a final approach equivalent airspeed of 100 kn and following characteristics:

$$C_{l_0} = 0 \qquad C_{l_\beta} = -0.11/\text{deg} \qquad C_{l_{\delta_a}} = 0.178/\text{deg} \qquad C_{l_{\delta_r}} = 0.172/\text{deg}$$
$$C_{n_0} = 0 \qquad C_{n_\beta} = 0.127/\text{deg} \qquad C_{n_{\delta_a}} = -0.0172/\text{deg} \qquad C_{n_{\delta_r}} = -0.0747/\text{deg}$$

$$\delta_{r_{max}} = \pm 20\ deg \qquad \delta_{a_{max}} = \pm 15\ deg$$

[Total 10 Marks]

3. For a flying wing configuration, the coefficient of moment about the aerodynamic centre of the wing $C_{m_{ac_w}} = -0.1$; the zero-angle lift coefficient $C_{L_{0_w}} = 0.3$; the location of the aerodynamic centre is $\bar{x}_{ac_w} = 0.2$; the location of centre of gravity is $\bar{x}_{cg} = 0.3$; and the rate of change of lift coefficient with respect to angle of attack $C_{L_\alpha} = 4.1$ per radian. Given this information,

Determine if the aircraft is balanceable and longitudinally stable. Plot $C_{m_{cg_w}}$ versus α, and if balanceable, find the trim angle of attack.

[Total 5 Marks]

4. The longitudinal dynamics of an aircraft to an elevator input is considered at 30,000 ft and 0.46 Mach. The transfer function of the response w/δ_e is given.

$$\frac{w}{\delta_e} = \frac{-32.7266(s + 254.139)(s^2 + 0.0068s + 0.0021)}{s^4 + k\, s^3 + 14.74\, s^2 + 0.1005s + 0.02945}$$

a) For the given value of $k = 1.678$, approximately factorise the characteristic polynomial as product of two quadratic polynomials.

[4 marks]

b) For the given value of $k = 1.678$, calculate the frequency and damping factor corresponding to the phugoid mode and short-period mode.

[5 marks]

c) Use the Routh-Hurwitz criterion to find the range of parameter k for which the system transfer function is stable.

[9 marks]

[Total 18 Marks]

5. The pitch response in the Laplace domain to unit step elevator input at certain flight conditions for a Lockheed F-104 Starfighter aircraft is given by

$$\theta(s) = 4.664\left[\frac{-0.333}{s} + \frac{0.19s + 0.246}{s^2 + 0.893s + 4.884} + \frac{0.143s - 0.071}{(s^2 + 0.033s + 0.022)}\right]$$

a) Calculate the frequency and damping factor corresponding to the phugoid mode and short-period mode. Comment on the flying characteristics of the aircraft based on your results

[6 marks]

b) Obtain the pitch response in the time domain and explain the role of the frequency and damping factor corresponding to the two modes. Use the inverse Laplace transform formulae

$$L^{-1}\left(\frac{1}{s}\right) = 1, \qquad L^{-1}\left(\frac{b}{(s+a)^2+b^2}\right) = e^{-at}\sin bt,$$

$$L^{-1}\left(\frac{(s+a)}{(s+a)^2+b^2}\right) = e^{-at}\cos bt$$

[6 marks]

c) Calculate the long-term (steady-state) pitch due to the unit step elevator input.

[2 marks]

[Total 14 Marks]

END OF PART 1

PART 2: In this part, students need to answer the following questions through Canvas online test.

Consider the feedback control system of an aircraft shown in Figure I. $G_p(s)$ and $G_c(s)$ are respectively the plant and controller transfer functions. Answer questions 1 – 5.

$$G_p(s) = \frac{1}{(s+a)(s+b)(s+c)}, \qquad G_c(s) = \frac{K(s+d)}{(s+3d)}$$

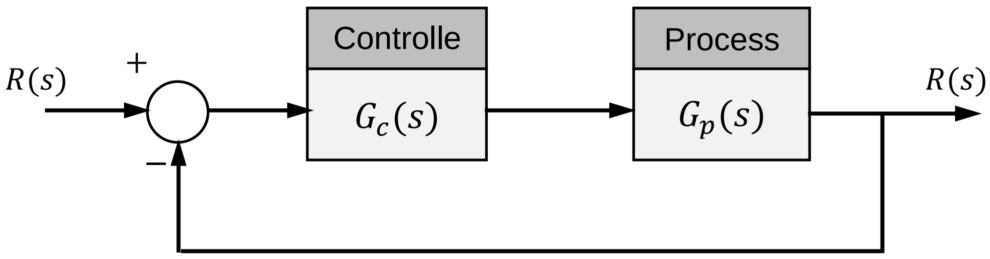

Figure I: Block diagram of a feedback control system.

(NOTE: the values of the parameters "*a*", "*b*", "*c*", "*d*" are likely to change between questions).

1. **(Multiple choice question)**

What is the angle between the asymptotes of the root locus plot of the system?

(a) $72°$

(b) $120°$

(c) $90°$

(d) $180°$

(e) $60°$

(f) None of the above

[3 *marks*]

2. **(Formula type question)**

Calculate the asymptotic centroid of the system, for $a =$ \`$a$\`, $b =$ \`$b$\`, $c =$ \`$c$\`, and $d =$ \`$d$\`.

[5 *marks*]

3. (**Formula type question**)

Determine the critical gain K for the system, for $a = `a`$, $b = `b`$, $c = `c`$, and $d = `d`$.

[6 *marks*]

4. (**Formula type question**)

Consider the characteristic equation of the system as

$$Ch_{Eq} = s^4 + As^3 + Bs^2 + Cs + D$$

$$A = (a + b + c + 3d), \qquad B = [ab + 3d(a + b + c) + c(a + b)],$$

$$C = [K + 3d(ab + c(a + b)) + abc], \qquad D = Kd + 3abcd,$$

Use the Routh-Hurwitz criterion to find the maximum value of K for the system to be stable, for $a = `a`$, $b = `b`$, $c = `c`$, and $d = `d`$.

[*6 marks*]

5. (**Formula type question**)

Determine the value of gain K for the system $a = `a`$, $b = `b`$, $c = `c`$, and $d = `d`$ so that the point $s = `s`$ is a closed-loop pole.

[5 *marks*]

[Total 25 Marks]

END OF PART 2