Course Specifications

Program(s) on which this course is given:	Masters program.
Department offering the program:	**Aerospace department**
Department offering the course:	**Aerospace department**
Academic Level:	Post graduate
Date	2014-2015
Semester (based on final exam timing)	☐ Fall ☐ Spring

A- Basic Information

1. Title:	Optimal control of vehicles			**Code:**	AER651		
2. Units/Credit hours per week:	Lectures	2	Tutorial		Practical		Total 2

B- Professional Information

1. Coursedescription:	In this course, methods are presented for analysis and synthesis of the steady state and perturbed state stability and control of fixed wing aircraft. The course is aimed at first level graduate students of aeronautical engineering. Aeronautical engineers working in the aircraft industry will also find this course useful. Throughout this course the practical (design) applications of the theory are stressed with many examples. Aircraft stability and control characteristics are all heavily regulated by civil as well as by military airworthiness authorities for reasons of safety. The role of these safety regulations in the application of the theory is therefore stressed throughout. Many of the examples used to illustrate the application of the theory were generated with the help of a computer programs. An introduction to the construction and interpretation of Bode plots with open and closed loop airplane applications is presented. An important inverse application is also given. The use of the root locus method and the Bode method are illustrated with examples. Classical control theory can be used to predict whether or not an airplane can be controlled by a human pilot. This is done with the aid of human pilot transfer functions. The student is introduced to various aspects of automatic control of airplanes. It is shown why certain airplanes require stability augmentation. Pitch dampers, yaw dampers and roll dampers are discussed. The student is familiarized with the basic synthesis concepts of automatic flight control modes such as: control-stick steering, various auto-pilot hold modes, speed control, navigation modes and automatic landing modes. A brief introduction to digital control systems using classical control theory is provided. Applications of the Z-transformation method are also included.
2. Intended Learning	**a) Knowledge and Understanding**

Outcomes of Course (ILOs):	Root locus method for control system analysis and design.
	Frequency response method for control system analysis and design.
	Design and compensation techniques.
	Digital control system analysis and design.
	b) Intellectual Skills
	Analyze autopilot control system and evaluate transient and steady state performance.
	Select appropriate compensation technique for autopilot.
	Design autopilot to meet defined performance specifications and evaluate design.
	c) Professional and Practical Skills
	Identify basic components of autopilot control system.
	Use computer software packages to design, simulate, and evaluate autopilot control systems.
	d) General and Transferable Skills
	Prepare effective and informative technical reports and present results on autopilot control systems.
	Communicate effectively with colleagues to interchange knowledge and information in ad control systems.

3. Contents

Topic	Total hours	Lectures hours	Tutorial/ Practical hours
1. Theory and Applications of Bode Plots 1.1 Introduction to the frequency response of linear systems 1.2 Determination of the frequency response of linear systems directly from the system open loop transfer function 1.3 Asymptotic approximations to real frequency response of transfer functions: Differentiators	3	3	

and Integrators, First order lead and lag transfer functions, Second order lead and lag transfer functions.			
1.4 Applications of Bode plots to airplanes: Bode plots for speed, angle of attack and pitch attitude angle response to elevator inputs, Bode plots for sideslip angle, bank angle and heading angle response to aileron and rudder inputs 1.5 Inverse application of Bode plots.	3	3	
2. Classical Control Theory with Applications to Airplanes 2.1 Example of the potential of feedback control 2.2 Basic relationships and definitions used in feedback Control systems. 2.3 The root locus method, Root locus fundamentals, Root locus asymptotes, Breakaway angle from a complex pole, Step-by-step construction of a root locus diagram.	3	3	

2.4 Application of the Bode plot method to control System analysis 2.5 Connection between frequency and time domains. 2.6 system performance specifications: Frequency domain specifications, Time domain specifications, Error and error constant specifications, Error characteristics of unity negative feedback systems, Error characteristics of general systems, System sensitivity. 2.7 Some feedback control system design applications: A multiple feedback loop system: pole assignment, Setting system gain to achieve a specified damping ratio, Setting gain to achieve a specified gain margin and position error constant, Finding lag compensation to alter the breakaway angle from complex poles, Finding a lead-lag compensator to increase system gain margin, Using cancellation compensation to achieve better closed loop characteristics, Root	3	3	

contours for variable poles, Root contours for variable zeros.			
3. Analysis of Airplane Plus Pilot as a Closed Loop Control System 3.1 The human pilot transfer function. 3.2 Pilot control of bank angle. 3.3 Pilot control of pitch attitude angle.	3	3	
4. Stability Augmentation and Automatic Flight Control Systems 4.1 Yaw dampers. 4.2 Pitch dampers. 4.3 static stability augmentation systems: Angle-of-attack feedback to the longitudinal controls, Load factor feedback to the longitudinal controls, Sideslip feedback to the directional controls.	3	3	
4.4 Basic autopilot systems. 4.5 Basic longitudinal autopilot modes: Pitch attitude hold mode, Altitude hold mode, Airspeed or mach number hold mode, Airspeed hold mode using auto	3	3	

throttles, Airspeed hold mode using speed brakes, Mach hold using the elevator, Mach tuck control (mach trim), Control wheel steering mode. 4.6 Basic lateral-directional autopilot modes: Bank angle hold mode, Heading angle hold mode, Turn rate mode at constant speed and altitude, Turn coordination (zero lateral acceleration). 4.7 longitudinal navigation modes: Approach categories and guidance, Glide slope mode, Automatic flare mode.			
4.8 Lateral-directional navigation modes: Localizer hold mode, V.O.R. hold mode 4.9 Multiple loop, multiple variable control systems 4.10 Separate surface control systems: Introduction and definitions, Closed loop analysis of separate surface control systems.	3	3	
5. Fundamentals of Digital Control System Analysis	3	3	

5.1 Introduction to signal sampling. 5.2 Laplace transforms and sampled data systems: The uniqueness problem, The Laplace transform of the sampled unit step, The Laplace transform of the sampled function.			
5.3 Reconstruction of analog data from sampled data: Introductory observations, The zero order hold, The first order hold. 5.4 Fundamentals of z-transform theory: Definition and derivation of z-transforms, Mapping of the s-plane into the z-plane, Mapping of constant damping loci, Mapping of constant frequency loci, Mapping of constant damping ratio loci, Mapping of constant un-damped natural frequency loci, Inverse z-transforms, Important z-transform properties.	3	3	
5.5 An application of z-transforms: The pulse transfer function of sampled data systems, Closed loop sampled data systems, A simple	3	3	

bank angle control system. 5.6 Effect of sampling frequency on the stability of digital systems: Jury's test, Routh-Hurwitz criterion, The root-locus method. 5.7 Relations between the s-, z- and time domains.			
6. Hardware Aspects of Autopilot Systems 6.1 Autopilot and sensor fundamentals: Pitch attitude angle, 8 and bank angle, Heading angle, Angular rates.	3	3	
6.2 Autopilot modes.	3	3	
4. Teaching and Learning Methods	Lectures (*)	Practical Training/ Laboratory ()	Seminar/Workshop ()
	Class Activity ()	Case Study ()	Projects ()
	E-learning ()	Assignments /Homework ()	Other:

5. Student Assessment Methods	
• **.Assessment Schedule**	**Week**
-Assessment 1;Class test	10
-Assessment 2; Project Assignment	
-Assessment 3; Presentations	
-Assessment 3; Midterm Exam	8
-Assessment 4; Final Exam	14
• **Weighting of Assessments**	
-Mid-Term Examination	10
-Final-term Examination	80
-Project	
-Class Test	10
-Presentation	

-Total	100

6. List of References

Jan Roskam, "Airplane Flight Dynamics and Automatic Flight Controls", Part II, DARcorporation, 1998.
Donald Mclean, "Automatic Flight Control Systems", Prentice Hall, 1990.
Journal of Guidance and Control, AIAA Journal.

7. Facilities Required for Teaching and Learning

Normal class, white board, projector, computer.

Course Coordinator:	**Prof. Gamal El-Bayoumi**
Head of Department:	**Prof. Ayman Hamdy Kassem**