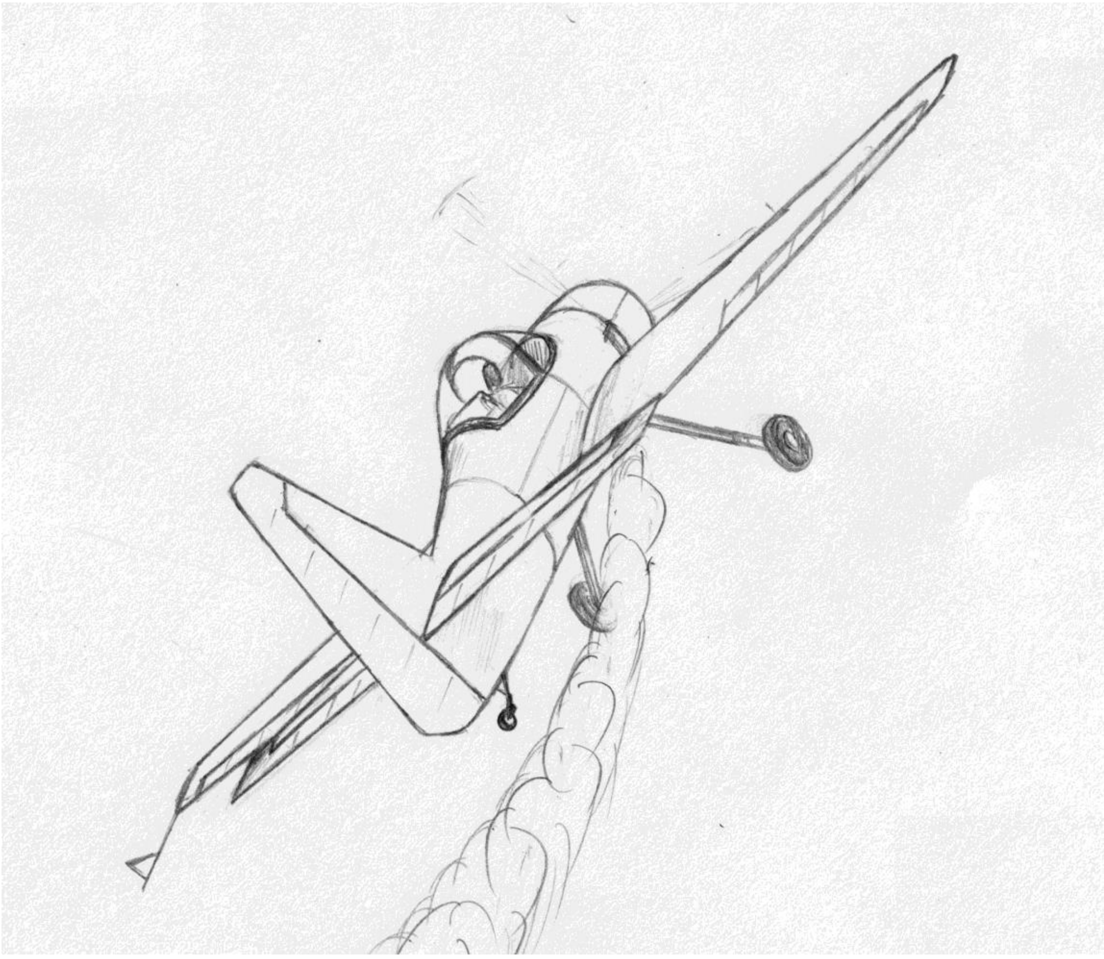
PROJETO DE AERONAVES
AIRCRAFT DESIGN – 10403

2022/2023



Curricular Unit Description

and

Design Project Description

PART I
THE CURRICULAR UNIT

1. OBJECTIVES

Students should acquire skills in the development of an aircraft subject to specific requirements and constraints, know how to apply aircraft design standards, develop integration, decision and compromise capabilities in a multidisciplinary team project and know how to communicate their results effectively.

With this UC students should be able to:
- describe the traditional aircraft design process and adapt it to specific cases;
- develop simple programs for the analysis and conceptual/preliminary design of an aircraft;
- integrate knowledge from various areas of science and engineering in the development of a multidisciplinary design project;
- carry out the conceptual and preliminary design of an aircraft to meet specific requirements;
- analyse design results and identify the most relevant parameters for the optimization of a given aircraft;
- effectively communicate project results;
- work in a team.

2. SYLLABUS

I. Introduction
1. Introduction to the curricular unit. 2. The aircraft design process. 3. Airworthiness standards for aircraft design.

II. Conceptual Design
4. Sizing from a conceptual drawing. 5. Selection of the airfoil and geometry of the wings and tail. 6. Initial sizing. 7. Configuration and drawing. 8. Configuration considerations. 9. Cabin, passengers and payload. 10. Integration of the propulsive system and the power system. 11. Landing gear and other systems. 12. Case studies.

III. Sizing, Analysis and Optimization
13. Aerodynamics. 14. Propulsion. 15. Structures and loads. 16. Weight and balance. 17. Stability and control. 18. Performance. 19. Cost analysis. 20. Optimization.

IV. Design of a New Aircraft
21. Concept of operations. 22. Aircraft design. 23. Development of analysis and optimization tool. 24. Sizing and analysis. 25. Oral presentations. 26. Written report.

3. SYLLABUS/OBJECTIVES

The contents of this curricular unit are structured in four blocks, the first three consisting of oral exposition and discussion of topics and the fourth consisting in practical and application of the knowledge. Those were designed with the main objective to develop teamwork skills in a complex multidisciplinary project in which theoretical and practical, technical and scientific knowledge of various areas is necessary, in which the critical thought and compromise is essential and, at the same time, to foster the spirit of innovation through research of new scientific and technological information (outside the syllabus of the course) so that the requirements of a given project can be met.

In essence, the syllabus is designed so that students can deepen, develop and integrate knowledge from different areas (aerodynamics, propulsion, structures, materials, flight performance, flight stability and dynamics, systems, etc.) to produce a viable and optimized aircraft design.

4. TEACHING METHODOLOGIES

This curricular unit is structured in two parts: one essentially theoretical and the other essentially practical. In the first part, the material is transmitted orally with multimedia slideshow support and additional information written on the blackboard. In the second part, methods for building a spreadsheet tool for analysis and optimization are taught and a new aircraft design is partially developed based on specific design requirements.

5. TEACHING METHODOLOGIES/OBJECTIVES

The methodologies adopted for this curricular unit follow the trends of similar curricular units in other universities and the experience acquired by the University of Beira Interior in the development of several unmanned aircraft and in various research and development work. This curricular unit has four weekly hours of theoretical-practical lectures and is structured in two parts: one part (2 hours) essentially theoretical and the other (2 hours) essentially practical.

In the first part, the materials (blocks I, II and III) are orally transmitted using multimedia slides and supplementary information written on the board. The slides are made available online to students in pdf format for their individual study and for reference, as they are built in the form of notes. In this part, examples of application are also presented. The discussion of the topics presented is fostered during the contact hours for better understanding by the students and for the development of their critical thought.

In the second part (block IV), methodologies are taught for the construction of an analysis and optimization spreadsheet tool. With this basis and with the knowledge of the theoretical part, students develop in teams (typically 5 students) the conceptual design and preliminary design of a new aircraft to meet the requirements provided by the teacher. During these classes, the exchange of ideas among teams is also encouraged and short oral presentations concerning the design progress are made throughout the semester. A large volume of this work must be performed outside the class period due to the considerable amount of required work. This project allows the student to develop analytical and synthesis skills, also using knowledge acquired in other curricular units, and to acquire critical decision and teamwork skills in the development of a complex system. At the end of the curricular unit the design is orally presented, and a written design report is submitted.

Although the professor monitors the developed students' work during the contact hours, both in the theoretical and practical lectures, a considerable amount of individual work outside the class is necessary by the students, regarding the study of the syllabus of the curricular unit, the study of other related subjects contained in the bibliographic references and the realization of the design work. This individual work promotes the autonomy and critical capacity of the student.

To support the teaching of this curricular unit, different but essential teaching/learning resources are used, namely:

- Video projector
- Books, articles, and other bibliography
- Notes
- Computer
- Internet
- Spreadsheets
- Analysis software for: airfoils, wings, propellers, flight stability, etc.
- CAD/CAE software
- Aircraft models developed previously at UBI and others

PART II
THE DESIGN PROJECT

Electric Light Aircraft

ELA-22

6. INTRODUCTION

In the past few years electric propulsion for aircraft has seen tremendous developments and a widespread use. Its application ranges from the model aircraft, UAVs, sailplanes, ultralight, general aviation aircraft and even passenger aircraft. Because batteries have a limited energy density, resulting in flights of short duration, the use of fuel cells for battery charging is an interesting option that has already been exploited. Conventional propulsion with a piston engine allows flights with longer duration and with the help of an alternator coupled to the engine batteries, that provide on-board power for systems, can recharge these in flight. To avoid consumption of petrol-based fuels to produce electricity, the incorporation of photovoltaic cells on the aircraft can provide part, or all, of the electrical energy required on board. In some situations, a hybrid propulsion system may be preferred.

Also, the developments in electrical propulsion, with increasing safety levels has enabled the study and implementation of several designs for urban air mobility to transport people and cargo and small passenger aircraft.

The main objective of this subject is to show students what the conceptual design of an aircraft is and what steps are necessary to follow given mission and performance requirements, design constraints, design methods and the need for optimization. To achieve this, the knowledge gained will be applied to the design of a new aircraft subjected to specific requirements. The optimization of the project is of extreme importance in the development of a new aircraft.

This project description presents the requirements that the aircraft must respond to in terms of mission, configuration, performance, systems, materials, and design standards. It also describes the necessary tasks to be performed during the semester and the work plan to follow. This project requires dedication and continuous work to ensure that deadlines are met, and results lead to a good design.

7. REQUIREMENTS

The current requirements present a need for an aerobatic capable electric light aircraft (ELA). The requirements for this aircraft are listed below and during the development of the project they must be respected. Possible changes in the requirements will be discussed and agreed upon by the professor and all teams involved in the project.

It is required to perform the conceptual and preliminary design of the ELA considering some specific design requirements. The aircraft must have good flying qualities to allow easy and precise flying. The vehicle’s structure and aerodynamics must be carefully designed to achieve low power consumption levels. Simplicity, robustness, reliability, and ease of repair are essential to maintain high levels of operational readiness of the ELA. All in all, the design must be practical, rugged, and maintainable.

These requirements are based on the International Light Aircraft Design Competition rules found in https://www.aerosociety.com/get-involved/specialist-groups/business-general-aviation/general-aviation/light-aircraft-design-competition/ and https://www.aerosociety.com/media/18671/raes-international-light-aircraft-design-competition-2022-23_rules-v41-final.pdf.

7.1. Mission

The aim is to design a piloted electric aircraft that is fully aerobatic and can be used for aerobatic training. It will have two seats for training purposes but for solo practice of competition aerobatics the space occupied by the second pilot can be replaced by 86 kg of batteries, giving longer endurance.

The design must conform to the requirements of CS-23 Amendment 5 and shall operate under daytime Visual Flight Rules.

7.1.1. Aerobatic mission profile

This mission profile consists of around 30 minutes of aerobatic manoeuvres with high load factors.

Segment	Duration [min]	Distance [m]	Power setting [%]	Propeller pitch*	Initial altitude [m]	Final altitude [m]
Taxi	5	-	idle-50	fine	0	0
Takeoff	-	300	100	fine	0	15
Climb	-	-	100	fine	15	600
Aerobatics/manoeuvres	30	-	75	course/fine	600	600
Circuit	5	-	75	course	600	600
Approach	-	-	idle	fine	600	15
Landing	-	500	idle	fine	15	0
Taxi	5	-	Idle-50	fine	0	0

* If applicable.

7.2. Performance

The vehicle must show the following performance figures (ISA – *International Standard Atmosphere* conditions):

Take-off	300 m on a runway
Maximum stall speed in landing configuration	111 km/h (60 kts)
Maximum speed at 2500 m	333 km/h (180 kts)
Maximum rate of climb at sea level	15 m/s (2950 ft/min)
Climb time to 2500 m	5 minutes
Maximum rolling rate at sea level	350 deg/s
Maximum turning rate at sea level	50 deg/s
Landing	500 m on a runway

7.3. Propulsion

The aircraft shall utilise an electric powertrain using only batteries for energy storage. Up to four motors and up to four propellers may be used. In selecting the motor(s), careful attention must be given to its durability and reliability. Proper cooling of the motor(s) must be provided. Propellers may be fixed pitch or variable pitch/constant speed. The propellers must be selected according to the motor performance and ELA performance required. The aircraft can either have tractor or pusher propellers. No thrust vectoring is permitted. The design shall be fault tolerant: able to continue to fly safely and land having suffered a failure of a single motor, battery, or propeller

The batteries must be sized to provide both the required maximum power and endurance. Batteries may only be used between 100% and 20% energy levels, to allow a reserve. It may be assumed that a 100% discharge rate is available throughout this range. Proper cooling of the batteries must be provided. Teams must clearly state and justify their choice of battery parameters (e.g. specific power, discharge rate) based on battery cells currently available – not cells that are simply at the research stage.

Electric motors (including controllers) shall have a power density of no greater than 7 kW/kg continuous (for cruise and descent) and 10 kW/kg peak (for a maximum of 5 minutes). Batteries shall have a specific energy of not more than 350 Wh/kg at the cell level and a value of not more than 250 Wh/kg for the cells integrated into packs, including monitoring, control, and cooling. Credit will be given for analysis of thermal loads resulting from the electric powertrain, and how these thermal loads will be managed in flight.

7.4. Wings

The aircraft shall have a fixed wing configuration, with a maximum wing span of 10 m. The wings must be well designed, both aerodynamically and structurally, so that the overall efficiency of the vehicle is high and to allow the required mission to be accomplished with low energy requirements. According to the mission, the wings can be designed for high lift-to-drag ratio. The structure should use high specific strength and high specific stiffness materials to allow for an empty weight as low as possible.

7.5. Fuselage

The fuselage should be slender and light yet possess the necessary internal space for systems, pilots, and batteries. It should have high tolerance on payload weight (see 7.8).

Equipment substitution should be quick and simple to perform.

7.6. Tail

The tail, when present, must be small and effective. It should use in their structure the same materials selected for the wings.

7.7. Landing Gear

A fixed and rugged but simple landing gear must be used. The aircraft shall have a minimum wheel size (all wheels) of 6.00×6” and use at least 6.00×6’’ 8-ply tyres. The aircraft shall have either hydraulic disc brakes or electromechanical braking on each of the mainwheels.

7.8. Payload

The design must cater for the mass of any pilot and co-pilot in the range of 50 kg to 100 kg. The battery substitute for the co-pilot, and the pilot mass when flying single-pilot, will both be assumed to be 86 kg.

7.9. Weight and Balance

A Maximum Total Mass Authorised (MTMA) of 1000 kg is allowed. The CG travel must be such that no negative impact on the stability or on the normal operation of the aircraft is imposed for any payload weight transported on board (see 7.10). It is important that the maximum take-off mass of the aircraft is kept as low as possible. The vehicle should be capable of flying with partial load payloads (see 7.8).

7.10. Controls and Systems

All moving aerodynamic surfaces must be mechanically actuated. The aircraft must be aerodynamically stable in yaw but may be neutrally stable in roll and pitch at the design speed used for aerobatics. It must not be aerodynamically unstable in any axis anywhere in the flight envelope. Artificial stability systems may not be used to enhance an otherwise aerodynamically unstable aircraft.

All electronic and electric components and mission equipment must be placed within the fuselage or wing according to their function and in such a way as to allow its quick preparation or replacement. The electric system should be powered by batteries.

7.11. Design Airworthiness Requirements

The aircraft must be designed broadly to CS-23 Amendment 5. Stall and performance limitations, and acceptable means of compliance, may be taken from CS-23 Amendment 4. The aircraft’s design manoeuvre limit load factors will be +6/-3. All work performed in the design should aim at achieving high levels of safety, reliability, and performance.

8. TASKS

There are several tasks in the design project that must be carried out according to the time plan below. All tasks depend on each other so that there must be a close interaction and updating between them. The design process is also iterative in nature, but perfection is not possible nor is necessary, but an effort must be put forward to achieve a good optimization level in the outcome.

The necessary calculations may be performed with the help of spread sheets and other analysis computer programs. All drawings should be developed in CATIA V5 or similar.

8.1. Concept of Operations

The exact mission profile and the way it is going to be operationally implemented must be defined and explained. The design of the vehicle will follow from the concept of operations (CONOPS) proposed to respond to the mission requirements.

8.2. Layout

The layout and functionalities of the vehicle must be selected so that the requirements are fully met. This task is very important because it integrates all needs of the other parts of the project into a viable configuration. A preliminary three-dimensional (3D) study of all major components must be performed, and these must be incorporated in the aircraft structure. 3D drawings must be produced in a CAD system for the complete UAV.

8.3. Aerodynamics and Stability

The aerodynamic study must cover the selection of the aerofoils, geometry and size of the lifting surfaces, nacelles, and the computation of the aerodynamic characteristics of the whole vehicle (C_L, C_D e C_M). It must be assured that all choices made in the overall design do not impair the aerodynamic performance. A study of the stability and control of the UAV must also be performed.

The aerodynamic work must concentrate on the wings design and tail sizing. These must be optimized having in mind the necessary compromises for different flight conditions.

8.4. Propulsion and Performance

The propulsive system (motor, propeller, power source) must be selected and sized according to the requirements. An estimate of the vehicle’s performance (speeds, times, battery, and solar energy usage, etc.) must be carried out.

8.5. Systems

A study of the landing gear system (if it exists), of the control system and of the electric system must be performed. These studies should include not only the selection of the main components and definition of its functionalities but also the positioning of components and cables routing inside the aircraft. Commercially available components are preferred to speed up both design and building processes. A database containing such data as suppliers, working characteristics, mass, power consumption and price of all components selected must be produced.

8.6. Structure and Materials

The type of structure and materials for the different components of the vehicle must be selected and defined adequately keeping in mind their configuration and function. Preliminary sizing of the wing must be performed. A database containing such data as suppliers, physical characteristics, mechanical characteristics, and price of all materials selected must be produced. A study on the manufacturing processes to be used must be carried out together with estimates of weight and balance and total cost of the UAV.

8.7. Time plan

The table below presents the time plan with the tasks required to complete de project.

Month	S	S	O	O	O	O	N	N	N	N	N	D	D	D	D	J	J	J	J	F	F
Task \ Week	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21
Lectures	20	27	04	11	18	25	01	08	15	22	29	06	13			03	10				
Concept of operations																					
Layout																					
Aerodynamics/Stability																					
Propulsion/Performance																					
Systems																					
Structure/Materials																					
Test													14								
Presentations			06					10													
Report																					
Exams																					

Legend:
- Lectures
- Design work
- Weeks without lectures
- Assessment

8.8. Design Teams

The design is carried out by groups of 5 students. All students should work hard for the project objectives to be fulfilled in time.

	Student's Name	Nº	Team	E-mail	Task
01	Ana Teresa	41462	A		layout
02	Ana Domingues	42436	A		aerodynamics/stability
03	Rita Pereira	41137	A		propulsion/performance
04	Raquel Coutinho	41821	A	raquel.coutinho@ubi.pt	systems
05	Carlos Gomes	40718	A		structures/materials
06	Hugo Sousa	41736	B		layout
07	Guilherme Pangas	41176	B		aerodynamics/stability
08	Adriana Pinto	41794	B	adriana.raquel.pinto@ubi.pt	propulsion/performance
09	Sérgio Brito	41731	B		systems
10	Pedro Gouveia	41241	B		structures/materials
11	Miguel Ascensão	41886	C	jose.miguel.ascensao@ubi.pt	layout
12	Bruno Silva	41256	C	bruno.ferreira.silva@ubi.pt	aerodynamics/stability
13	Samuel Martins	41754	C	samuel.s.martins@ubi.pt	propulsion/performance
14	Marco Nóbrega	41906	C	marco.nobrega@ubi.pt	systems

15	Felippe Silva	40689	C	felippe.silva@ubi.pt	structures/materials
16	Afonso Fonseca	41875	D		layout
17	António Abreu	41166	D		aerodynamics/stability
18	Miguel Martins	41238	D	miguel.martins@ubi.pt	propulsion/performance
19	Marco Silva	41375	D		systems
20	Paulo Luís	42138	D		structures/materials
21	Rodrigo Filipe	41106	E	rodrigo.filipe@ubi.pt	layout
22	Guilherme Quaresma	41201	E		aerodynamics/stability
23	Diogo Domingos	41843	E		propulsion/performance
24	Gonçalo Silva	41198	E		systems
25	Beatriz Santos	41863	E	beatriz.varela.santos@ubi.pt	structures/materials
26	Beatriz Fernandes	41591	F	beatriz.teixeira.fernandes@ubi.pt	layout
27	João Silva	41136	F	cristovao.silva@ubi.pt	aerodynamics/stability
28	Clara Dias	41430	F	clara.simoes.dias@ubi.pt	propulsion/performance
29	Ana Nogueira	41457	F	ana.claudia.silva.nogueira@ubi.pt	systems
30	Diogo Santos	41458	F	diogo.goncalves.santos@ubi.pt	structures/materials
31	Bruno Rocha	40726	G		layout
32	Lucas Borges	42140	G		aerodynamics/stability
33	André Almeida	32776	G	andre.almeida@ubi.pt	propulsion/performance
34	Tiago Vidinha	42758	G		systems
35	Filip Podwyszyński		G		structures/materials
36	Bruno Eusébio	44315	H		layout
37	António Duarte	41977	H		aerodynamics/stability
38	Nuno Santos	39835	H		propulsion/performance
39	Gonçalo Almeida	44317	H		systems
40	João Moura	37630	H		structures/materials
41	Afonso Botelho	41669	I	afonso.botelho@ubi.pt	layout
42	Diogo Carrito	26801	I	diogo_carrito@hotmail.com	aerodynamics/stability
43	Luís Costa	38985	I	luis.edgar.dinis.costa@ubi.pt	propulsion/performance
44	André Viana	38593	I	andre.viana@ubi.pt	systems
45	João Azevedo	41419	I	joao.bruno.azevedo@ubi.pt	structures/materials
46	João Pereira	41476	J	joao.fonseca.pereira@ubi.pt	layout
47	Miguel Ferro	41989	J	miguel.ferro@ubi.pt	aerodynamics/stability
48	João Miranda	41937	J	joao.miranda@ubi.pt	propulsion/performance
49	Tiago Rodrigues	41278	J	tiago.bessa.rodrigues@ubi.pt	systems
50	Joel Castro	39719	J	guedes.castro@ubi.pt	structures/materials
51	Ricardo Marques	41123	K		layout
52	Luís Diogo	42437	K		aerodynamics/stability
53	Marco Bessa	41100	K		propulsion/performance
54	José Macedo	42335	K	jose.diogo.macedo@ubi.pt	systems
55			K		structures/materials

9. ASSESSMENT

The grade of this subject is given based on one written test (T), three oral presentations (P) and one report (R).

9.1. Test

The test covers all the topics discussed during classes up to the date of the test (14 December 2022, 18:00 – week 13). The test is divided into two parts: the first is closed book and the second is open book.

9.2. Presentations

There will be 3 oral presentations: one for the concept of operations (6 October 2022 – week 3); one for the conceptual design (10 November 2022 – week 8); and one for the complete design (10 & 12 January 2023 – week 17). In the presentations, each design team (all elements of the team must participate in the presentations) must describe to the other teams its concepts, design philosophy, analyses, and results. The first and second presentations should take only 5 minutes each while the last presentation should take 20-30 minutes, depending on the number of teams. The presentation files should be handed in at the end of each presentation session.

All presentations will be assessed based on:

• Oral expression and quality of the information on the slides;

• Relevance and scope of the presented information;

• Objectivity and coherence of the discussed topics;

• Adequate understanding of the discussed matters and knowledge of the developed design;

• Usage of the available time;

• Technical content.

9.3. Report

Each team must write up a design report that should contain all relevant steps taken in the aircraft design process, including:

• A description of the concept of operations;

• A description of the main features and innovations in your design, and justification of your design decisions (sketches may be used to illustrate these concepts);

• A three-view general arrangement drawing of your design with all major dimensions and aircraft characteristics;

• Estimates of the aerodynamic properties, flight envelope, loadings, strength, weight, stability, control and performance of your vehicle design;

• A mass breakdown of the aircraft, including reasonable estimates or calculations for each major component of the aircraft;

• Detailed calculations and system block diagrams for the power system, demonstrating that the system architecture, power requirements, energy storage and energy losses are appropriate for the design and the mission.

The number of pages is limited to around 30, using letter size 12 and single line spacing. The report should be handed in *pdf* format at the last day of lectures (13 January 2023 – week 17).

9.4. Exam

There will be no written exam. If students fail the “Frequência” assessment or wish to improve their final grade, they must hand in an improved report of their design project at the dates of the exam, in weeks 19 and/or 21.

9.5. Grade

The mark of this subject is given by $F = 0.3T + 0.2P + 0.5R$ and approval is obtained if $F \geq 10$. The same is true for the exam final mark.

1.	Frequência ($F = 0.3T + 0.2P + 0.5R$)	100

T	Test	14-12-2022 (18h00)	30
P	Presentations	06-10-2022 ; 10-11-2022 ; 10 & 12-01-2023	20
R	Report	13-01-2023 (24h00)	50
2.	Exam (E = 0.3T + 0.2P +0.5 R1)		100
R1	Report (*época normal*)	??-01-2023 (??h30)	50
R1	Report (*época recurso*)	??-02-2023 (??h30)	50
3.	Exam (E = 0.3T + 0.2P +0.5 R2)		100
R2	Report (*época especial*)	??-07-2023 (??h30)	50

10. BIBLIOGRAPHY

The books listed below can be used for the design. The design reports of previous years may also be useful as general guideline and source of ideas. However, one must bear in mind that the information contained in them may be incorrect. A lot of information can also be found in the internet using appropriate search criteria.

10.1. Notes

00. Gamboa. P.V., Apontamentos de Projeto de Aeronaves, ~600 acetatos, UBI, 2020

10.2. Text Book

01. Raymer, D. P., *Aircraft Design: A Conceptual Approach* – 5th edition, AIAA Education Series, 2012

10.3. Aircraft Design Books

02. Gudmundsson, S., *General Aviation Aircraft Design: Applied Methods and Procedures*, Elsevier, 2014.
03. Torenbeek, E., *Advanced Aircraft Design: Conceptual Design, Analysis and Optimization of Subsonic Civil Airplanes*, Hoboken, New Jersey: John Wiley & Sons, 2013.
04. Gundlach, J., *Designing Unmanned Aircraft Systems: A Comprehensive Approach*, AIAA Education Series, 2012
05. Jenkinson, Lloyd R., Marchman III, James F., *Aircraft Design Projects for Engineering Students*, Butterworth-Heinemann, 2003
06. Corke, T. C., *Design of Aircraft*, Pearson Education, Inc., 2003
07. Howe, D., *Aircraft Conceptual Design Synthesis*, Professional Engineering Publishing, 2000
08. Jenkinson, L. R., Simpkin, P., Rhodes, D., *Civil Jet Aircraft Design*, Arnold, 1999
09. Brandt, S. A., Stiles, R. J., Bertin, J. J., Whitford, R., *Introduction to Aeronautics: A Design Perspective*, AIAA Education Series, 1997
10. Roskam, J., *Airplane Design* – Volumes I to VIII, The University of Kansas, 1990
11. Stinton, D., *The Design of the Aeroplane*, Blackwell Science, 1983
12. Torenbeek E., *Synthesis of Subsonic Airplane Design*, Delft University Press, 1982
13. Barros, C., *Introdução ao Projecto de Aeronaves* – Volumes 1 & 2, CEA/UFMG, 1979
14. Pazmany, L., *Light Airplane Design*, Pazmany Aircraft Corporation, 1963

10.4. Other Books

15. Abbot & Doenhoff, *Theory of Wing Sections*, Dover Publications Inc, 1959
16. Barnaby Wainfan, *Airfoil Selection – Understanding and Choosing Airfoils for Light Aircraft*, 1988
17. Barnes W. McCormick, *Aerodynamics, Aeronautics and Flight Mechanics* – 2nd edition, John Wiley & Sons Inc, 1995
18. Bernard Etkin, Lloyd Duff Reid, *Dynamics of Flight, Stability and Control* – 3rd edition, John Wiley & Sons Inc., 1996
19. Bill Clarke, *The Cessna 172* – 2nd edition, Tab Books, 1993
20. Darrol Stinton, *Flying Qualities and Flight Testing of the Airplane*, AIAA Education Series, 1996
21. David A. Lombardo, *Aircraft Systems –Understanding Your Airplane*, Tab Books, 1988
22. Euroavia, *Future Trainer Concept*, 1999
23. Geoff Jones, *Building and Flying Your Own Plane*, Patrick Stephens Limited, 1992
24. Ian Moir & Allan Seabridge, *Aircraft Systems*, Longman Scientific & Technical, 1992
25. *Jane's All the World Aircraft*, 1995
26. Certification Specifications for Light Sport Aeroplanes (CS-LSA), Initial Airworthiness, EASA, 2011, and Amendment 1 (2013)
27. Certification Specifications for Very Light Aeroplanes (CS-VLA), Initial Airworthiness, EASA, 2003, and Amendments 1 to 5 (2009 to 2017)
28. Certification Specifications for Normal, Utility, Aerobatic and Commuter Aeroplanes (CS-23), Initial Airworthiness, EASA, 2003, and Amendments 1 to 5 (2009 to 2020)
29. Ladislao Pazmany, *Landing Gear Design for Light Aircraft* – Volumes I & II, Pazmany Aircraft Corporation, 1986
30. John Cutler, *Understanding Aircraft Structures*, Blackwell Science, 1999
31. Martín Cuesta Alvarez, *Vuelo con Motor Alternativo*, Paraninfo, 1981
32. Robert C. Nelson, *Flight Stability and Automatic Control*, McGraw-Hill, 1989
33. S. Hoerner, *Fluid-Dynamic Drag, Hoerner Fluid Dynamics*, 1965
34. S. Hoerner, *Fluid-Dynamic Lift, Hoerner Fluid Dynamics*, 2nd Edition, 1985
35. Stelio Frati, *L'Aliante*, Editore Ulrico Hoepli, Milano, 1946
36. Ted L. Lomax, *Structural Loads Analysis for Commercial Transport Aircraft – Theory and Practice*, AIAA Education Series, 1996
37. *The Metals Black Book – Volume 1 – Ferrous Metals*, Casti Publishing Inc, 1995
38. *The Metals Red Book – Volume 2 – Nonferrous Metals*, Casti Publishing Inc, 1995
39. T. H. G. Megson, *Aircraft Structures for Engineering Students* – 2nd edition, Edward Arnold, 1990
40. Tony Bingelis, *Firewall Forward – Engine Installation Methods*, EAA Aviation Foundation, 1992
41. Tony Bingelis, *Sportplane Construction Techniques – A Builder's Handbook*, EAA Aviation Foundation, 1992
42. Tony Bingelis, *The Sportplane Builder – Aircraft Construction Methods*, EAA Aviation Foundation, 1992