ÉCOLE NATIONALE D'AÉROTECHNIQUE
UN CAMPUS DU CÉGEP ÉDOUARD-MONTPETIT

280-3B4-EM
FALL 2015
Pre-Flight

# COURSE OUTLINE

**COURSE:** **Aerodynamics**

**PROGRAM:** 280.C0 Aircraft Maintenance Technology

**DISCIPLINE:** 280 Aeronautics

**WEIGHTING:** Theory: 2 Practical Work: 2 Personal Study: 2

| **Instructor(s)** | **Office** | **☎ extension** | **✉ e-mail or website** |
|---|---|---|---|
| Éric Jetté | C-182 | 4615 | eric.jette@cegepmontpetit.ca |

**OFFICE HOURS**

| | MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY |
|---|---|---|---|---|---|
| Morning | | | | | |
| Afternoon | | | | | |

| **Coordinator(s)** | **Office** | **☎ extension** | **✉ e-mail or website** |
|---|---|---|---|
| Dany Charette | B-125 | 4661 | dany.charette@cegepmontpetit.ca |
| Louis Guimont | B-125 | 4703 | louis.guimont@cegepmontpetit.ca |

## CONTEXT OF THIS COURSE IN THE PROGRAM

This course is offered during the third session of the program and is designed for all students in the Aircraft Maintenance Technology program. By the end of this course, students will have developed:

- The ability to recognize factors that influence drag and lift on aircraft.
- The ability to recognize factors that influence the propulsive force of propellers.
- The ability to make calculations in order to compare and observe aircraft performance.
- The ability to recognize factors that influence aircraft performance.

**Students must keep this course outline for the duration of their studies as it will be useful for the comprehensive assessment at the end of the program.**

**Transport Canada**

This course outline meets the requirements of Training Organisation Certification Manual (MCF) of Transport Canada.

The Department applies Transport Canada standard which allows a maximum absence of 5% for the course (theory and laboratory). The department compiles absences of all students enrolled in Aircraft Maintenance (280.C0) and Avionics (280.D0) according to Transport Canada requirements. The application of Transport Canada policies regarding absences is available on the college website and in the student agenda under the heading « Privilèges accordés par Transports Canada ».

## MINISTERIAL OBJECTIVE(S) AND COMPETENCIES

**0260** To apply the principles of aerodynamics.

## TEACHING AND LEARNING STRATEGIES

**Theory:**

- The theory part of the course is divided into four modules that deal with advanced concepts of the principles of aerodynamics, aircraft performance and flight.
- Formal lectures will be supported with examples, exercises, illustrations, transparencies, multimedia projection, video, photographs and aircraft parts as teaching aids.
- Before summative evaluations, students will be informed of the important points and elements of the study table which could be targeted on the exam to allow them the best opportunity to succeed in the course.
- Students will complete their learning with their class notes, reviewing exercises and homework.

**Laboratory :**

- The laboratory part of the course is divided into five modules that deal with advanced concepts of aerodynamics. Students will apply and validate the theoretical elements through wind tunnel tests.
- Students will complete their learning with class notes, reviewing exercises and homework.
- Transparencies, multimedia projection, videos, photographs and aircraft parts will be used as teaching aids.

**Warning**: exercises or preparatory activities in class (theory) and in the laboratory (practical work) assigned by the instructor(s) must be completed before arriving in class or the laboratory. The instructor(s) reserve the right to refuse access to class or the lab if the exercises have not been completed beforehand and the absence will be recorded in the student's file. It is the student's responsibility to finish exercises in time.

In case of an absence, it is the student's responsibility to find out from classmates what was done in class and the work that was assigned in order to be up to date (refer to the learning objectives in the *Synthesis of Summative Evaluation Methods* Table).

**COURSE PLAN– THEORY**

**Activity Periods: 8 hours (approximately)**

**MODULE 1 – Study of Aerodynamic Drag**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Use demonstrations to recognize the major inherent laws, constants and variables of aerodynamics. | Aircraft descriptive forms, mass, standard atmosphere, length weight, surface, volume, density, general gas equation, speed, speed of sound, Mach numbers, specific gravity, pressure, force, dynamic viscosity, Reynolds number, work, power, energy | Review course notes 280-265<br><br>Course Notes<br><br>Readings and exercises as assigned by the instructor |
| 2. Determine the reactions produced on aerodynamic variables due to external changes. | Density, viscosity, speed, pressure, surface, volume, mass, humidity, altitude, laminar and turbulent flow | |
| 3. Use demonstrations and calculations to recognize different facets of air resistance and different types of drag. | Boundary layer, reference surface, Reynolds number, fluid flow, viscosity, aspect ratio, relative thickness, relative camber, surface finish<br><br>Total drag<br>Induced drag<br>Parasitic drag: T form<br>T friction<br>T profile<br>T interference<br>T compensation<br>T cooling<br>T parasite<br>Shockwave drag | |
| 4. Analyse the factors that influence the drag coefficient and drag. | Characteristic curves of airfoils, surface condition, adjustments, positions, settings, relative thickness, relative camber, plan form, speed, Oswald coefficient, altitude, weight, $W_{TO}$/S ratio, $W_{TO}$/HP ratio. | |

**Activity Period:** **8 hours (approximately)**

**MODULE 2 – STUDY OF DRAG**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Compare aircraft characteristics | Aircraft descriptive forms, single engines, twin-engines, business, wide-bodied aircraft, military, supersonic, subsonic | Review course notes 280-265<br><br>Course Notes |
| 2. Use calculations to recognize the factors that influence aircraft performance. | Surface, elongation, weight $W_{TO}/S$ report, $W_{TO}/HP$ ratio, $W_E/W_{TO}$ ratio, $W_{FUEL}/W_{TO}$ ratio, range, autonomy, endurance, takeoff distance, vertical speed, horizontal speed, altitude, turn | Readings and exercises as assigned by the instructor(s) |
| 3. Analyze the factors that influence the lift coefficient ($C_Z$) and lift. | Boundary level, cross-section, Reynolds number, flow type, viscosity, plan form, aspect ratio, relative thickness, relative camber, surface finish, maintenance | |
| 4. Analyze the information in a graph representing the curves characteristic of a wing and an airplane. | Relationship between the AR and the characteristic curves of a wing, relationship between the Reynolds number and the characteristic curve of a wing. | |
| 5. Recognize the angles of attack of a flight at subsonic, transsonic, and supersonic speeds. | Compressibility, speed of shockwave creation, speed of sound, Mach angle, Mach number, pressure wave, expansion wave, maximum speed | |
| 6. Calculate the lift of an airplane | Weight, wing loading, $W_{TO}/S$ ratio, $W_{TO}/HP$ ratio, $W_{TO}/T$ ratio, $W_E/W_{TO}$ ratio, $W_{FUEL}/W_{TO}$ ratio, $W_U/W_{TO}$ ratio, | |
| 7. Calculate the moment of an airplane. | Center of pressure, aerodynamic center, moment coefficient and moment, influence of the relative thickness and relative camber on the center of pressure, aerodynamic center and moment coefficient. | |

**Activity Periods :** **6 hours (approximately)**

**MODULE 3 – PERFORMANCE STUDY**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Compare aircraft characteristics. | Aircraft descriptive forms, single engines, twin-engines, business, wide-bodied aircraft, military, supersonic, subsonic. | Review Course Notes 280-265.<br><br>Course Notes.<br><br>Readings and exercises assigned by the instructor(s). |
| 2. Use calculations to recognize the factors that influence the performance of an aircraft. | Surfaces, surface ratios, aspect ratio, weight, $W_{TO}/S$, rapport ratio $W_{TO}/HP$, $W_E/ W_{TO}$ ratio, $W_{FUEL}/$ WTO ratio, range, autonomy, endurance, take-off distance, vertical speed, horizontal speed, altitude, turning, G force. | |
| 3. Make calculations to validate aircraft performance. | Aircraft descriptive forms, standard atmosphere, mass flow, volume flow, specific fuel consumption, flight time, filling time, flight distance, speed. | |

**Activity Period :** **6 hours (approximately)**

**MODULE 4 – STUDY OF THE PROPELLER**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Explain the theory of propulsion for a propeller. | Gear ratio, advance ratio, thrust coefficient, power coefficient, speed power coefficient, efficiency. | Review Course Notes 280-265.<br><br>Course Notes.<br><br>Readings and exercises assigned by the instructor(s). |
| 2. Explain the propeller geometrically. | - Plane of rotation, hub, blades of the propeller shaft, blade shaft, geometric pitch, experimental pitch. | |
| 3. Explain the kinematics of the propeller. | - Ideal propeller, simplified theory of the blade element, effective pitch, slip | |
| 4. Use vectors to explain the different modes of a propeller. | - Thrust, wind milling, transparency, feather, brake and reverse pitch. | |
| 5. Distinguish the factors that influence traction, torque, power and performance of a propeller. | - Angle of attack, helix angle, pitch angle geometry, speed, RPM of the propeller, torque of the propeller, propeller diameter, blade plan form, blade profile, number of blades, solidity coefficient, critical engine, thrust asymmetry | |
| 6. Make calculations related to propellers. | Propulsive forces, torque, power, geometric pitch angle, experimental pitch angle, helix angle, tangential speed, speed. | |

**COURSE PLAN – PRACTICAL PART**

**Activity Period : 2 hours (approximately**

**MODULE 1 – PERFORM WIND TUNNEL CALIBRATIONS**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Design an assembly using a pitot-static tube. | 18X18 Plint&Partners Wind Tunnel<br>Aerolab 12 Wind Tunnel<br>Hampden 8X8 Wind Tunnel,<br>Pitot-static tube, total pressure, static pressure, dynamic pressure, anemometer (airspeed indicator), observed speed, actual speed, theoretical speed, dynamic pressure constant of the wind tunnel. | Review Course Notes 280-265<br><br>Course Notes<br><br>Readings and exercises assigned by the instructor(s) |
| 2. Determine the dynamic pressure in the test chamber. | Formula : $P_D = ½\rho V^2$<br>density, voltage, speed, anemometer (airspeed indicator), barometer | |
| 3. Determine the actual speed in the test chamber. | Formula : $P_D = ½\rho V^2$<br>density, voltage, speed, anemometer (airspeed indicator), barometer | |

**Activity Period :** **6 hours (approximately)**

**MODULE 2 – STUDY OF DRAG AND PROFILE SHAPE**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Measure pressure distribution | 18X18 Plint&Partners Wind Tunnel, Disc, pressure gauge, shapes, | Review Course Notes 280-265 |
| 2. Determine the normal aerodynamic resultant | Hampden 8X8 Wind Tunnel, cylinder, pressure gauge, shapes, profiles, balance | Course Notes<br><br>Readings and exercises assigned by the instructor(s) |
| 3. Determine the coefficient of pressure (CP) | - Formula: $FN = \Delta P * S$<br>- Formula: $FN = \frac{1}{2}\rho V^2 S C_N$ | |
| 4. Determine the normal coefficient | - Formula: $T = \frac{1}{2}\rho V^2 S C_X$ | |
| 5. Determine the form drag coefficient | | |
| 6. Determine the profile drag coefficient | | |
| 7. Evaluate the thickness of the boundary layer | Hampden 8X8 Wind Tunnel,,<br>Surface and comb<br>Reynolds Number | |
| 8. Describe the shock waves produced in front of various shapes. | Supersonic Wind Tunnel,<br>Shapes | |
| 9. Describe the influence of speed on the shock waves. | Supersonic Wind Tunnel,<br>Shapes | |
| 10. Determine the maximum speed of a supersonic airplane. | Model and photos<br>Formula: $Mach_{MAX} = 1/Sin(\theta)$ | |

**Activity Period:** **8 hours (approximately)**

**MODULE 3 – STUDY OF LIFT AND DRAG ON WINGS**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Take pressure distribution measurements<br>2. Determine the normal aerodynamic resultant<br>3. Determine the coefficient of pressure (CP)<br>4. Determine the coefficient of lift ($C_Z$)<br>5. Determine the position of the center of pressure (c.p.) | Aerolab Wind Tunnel, NACA 0012 wing, manometers<br>Hampden 8X8 Wind Tunnel, NACA 0020 wing, manometers | Review Course Notes 280-265<br><br>Course Notes<br><br>Readings and exercises as assigned by the instructor(s) |
| 6. Distinguish reactions to the characteristic curves of a wing due to changes in aspect ratio. | - Aerolab Wind Tunnel, NACA 0012 wing,<br>- Hampden 8X8 Wind Tunnel, NACA 0000 and 0020 wings<br>- Lift and drag<br>- Lift and drag coefficient<br>- Formula: $T = \frac{1}{2}\rho V^2 S C_X$<br>- Formula: $P = \frac{1}{2}\rho V^2 S C_Z$<br>- Stall angle<br>- Dynamic pressure<br>- Reynolds number | Review Course Notes 280-265<br><br>Course Notes<br><br>Readings and exercises as assigned by the instructor(s) |
| 7. Distinguish reactions to the characteristic curves of a wing due to changes in the plan form of the relative thickness and relative camber. | - 18X18 Plint&Partners WindTunnel NACA 0012, 2412 wings<br>- Hampden 8X8 wind tunnel NACA 0000 wings, rectangular, trapezoidal, rectangular sweep, trapezoidal sweep, delta, elliptical<br>- Same content as # 6 | Review Course Notes 280-265<br><br>Course Notes<br><br>Readings and exercises as assigned by the instructor(s) |
| 8. Calculate lift and drag. | - Lift and drag<br>- Dynamic pressure<br>- Formula : $P=\frac{1}{2}\rho V^2 S C_Z$<br>- Formula: $T =\frac{1}{2}\rho V^2 S C_X$<br>- Lift and drag coefficients<br>- $C_Z / C_X$ ratio<br>- Reynolds Number | Review Course Notes 280-265<br><br>Course Notes<br><br>Readings and exercises as assigned by the instructor(s) |

**Activity Period:** **4 hours (approximately)**

**MODULE 4 – STUDY OF MOMENTS**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Analyse the stresses generated by the control surfaces.<br><br>2. Compare a stabilator with a standard empennage (tail). | - 18X18 Plint&Partners wind tunnel wing with control surface, model airplane, center of pressure, coefficient of moment, moment, speed.<br><br>Formula: $M_n = ½\rho V^2 S C C_{Mn}$<br><br>Hampden 8X8 wind tunnel, wing with control surface, lift, drag, speed. | Review Course Notes 280-265.<br><br>Course Notes.<br><br>Readings and exercises as assigned by the instructor(s). |

**Activity Period:** **4 hours (approximately)**

**MODULE 5 – STUDY OF PROPELLERS**

| Learning Objective | Content | Personal Study Activities |
|---|---|---|
| 1. Distinguish the factors that influence thrust, power consumption and efficiency of a propeller.<br><br>2. Make calculations related to propellers.<br><br>3. Plot characteristic curves of propellers.<br><br>4. Observe the different types of propellers. | 18X18 Plint&Partners Wind Tunnel Types of propellers, number of blades, geometric pitch, diameter, forward speed, tangential speed, mode, efficiency, power, propulsive force, speed (RPM), angle of advance, geometric pitch, real pitch, angle of attack, solidity coefficient.<br><br>Propulsive force, power, efficiency, speed-power ratio, advance ratio, speed.<br><br>Thrust mode, transparency, brake, wind milling. | Review Course Notes 280-265.<br><br>Course Notes.<br><br>Readings and exercises as assigned by the instructor(s). |

## SYNTHESIS OF SUMMATIVE EVALUATION METHODS

**Theory**

| Description of Evaluation Activity | Context | Learning Objective(s) | Due Date (approximate date assignment due or exam given) | Weighting (%) |
|---|---|---|---|---|
| Written exam with short answers and multiple choice. | In class, individually, no notes permitted. | Module 1 | Week 5 | 15% |
| Written exam with short answers and multiple choice. | In class, individually, no notes permitted. | Module 2<br>and<br>Module 1 (review) | Week 10 | 20% |
| Written exam with short answers and multiple choice.<br>Synthesis of the learning objectives of the course. | In class, individually, no notes permitted. | Module 3 and 4<br>and<br>main objectives | Week 15 | 25% |

**SUB-TOTAL: 60%**

**Practical Work**

| Description of Evaluation Activity | Context | Learning Objective(s) | Due Date (approximate date assignment due or exam given) | Weighting (%) |
|---|---|---|---|---|
| Written exam with short answers and multiple choice. | In class, individually, no notes permitted.<br>The exam includes a written part, calculations and manipulations. | Module 1 and 2 | Week 5 | 10 |
| Written exam with short answers and multiple choice. | In class, individually, no notes permitted.<br>The exam includes a written part, calculations and manipulations. | Module 3<br>and<br>Module 1 and 2 (review) | Week 10 | 15 |
| Written exam with short answers and multiple choice.<br>Synthesis of the learning objectives of the course. | In class, individually, no notes permitted.<br>The exam includes a written part, calculations and manipulations. | Module 4 and 5<br>and<br>Module 1 to 3 (review) | Week 15 | 15 |

**SUB-TOTAL: 40%**

**TOTAL: 100%**

## REQUIREMENTS TO PASS THE COURSE

### (1) Passing Mark

The passing mark for this course is 60% by adding the marks for the theory and practical work for the course.

### (2) Tardiness

Students who arrive late after the beginning of the first period of a course are considered absent for this period.

### (3) Attendance for Summative Evaluations

Students must be present for summative evaluations and must comply with the instructions given by the instructor to carry out the evaluation activity and written in the course outline.

Unexcused tardiness for a summative evaluation could result in being excluded from the activity.

Any absence from a summative evaluation that is not due to serious reasons (illness, death in the family, etc.) could result in a mark of zero (0) for the activity.

Students are responsible for meeting with the instructor before an evaluation activity is held or immediately upon returning to ENA to explain the reason for an absence. Proper documentation, such as a medical certificate, a death certificate, legal papers, etc., must be shown if the reason for absence is serious and recognized as such by the instructor(s), arrangements will be made between the instructor(s) and the student to make up the activity.

### (4) Submitting Assignments

All assignments must be submitted by the date, hour and location designated by the instructor(s). Late assignments will be penalized 10% per day that they are late and will receive a mark of zero (0) after one week.

### (5) Presentation of Written Work

The instructor(s) will provide students with information and guidelines regarding the presentation of written work. When the presentation of an assignment is inacceptable, the work will be penalized as a late assignment until an acceptable version is submitted. In this case, the penalties for late work will be applied.

Students must follow the standards adopted by the Cégep for written work (« *Normes de présentation matérielle des travaux écrits* »). These can be found in the documentation center on the Cégep web site http://ena.cegepmontpetit.ca/liens-eclair under the heading ***Liens éclair*, Bibliothèques, « Aide ».**

## METHODS OF COURSE PARTICIPATION

The following rules must be respected in the classroom and laboratories:

**In the classroom:**

- Food, drinks cell phones, pagers, MP3 players, IPODs, cameras and any similar devices are prohibited.
- Students must keep the classroom clean and tidy.

**In the laboratory:**

- Food, drinks cell phones, pagers, MP3 players, IPODs, cameras and any similar devices are prohibited.
- Students must keep the classroom clean and tidy.
- Flames (from a lighter, matches) are prohibited.
- ENA overalls (jumpsuit) and safety shoes or boots are **mandatory**. Students who are not properly dressed will not be admitted to the workshop or hanger and the absence will be recorded in their file.
- Safety glasses are **mandatory** for working with wind tunnels and must be at hand in the hangars.

- Students may not use aircraft or equipment without authorization from an instructor and proper operating instructions must be respected.
- It is prohibited to get up on a stool, a table, a workbench or a wind tunnel.
- There must never be more than 3 students per team unless otherwise indicated by the instructor and there must never be more than one team per workbench or aircraft.
- Students must clean the workbench and put equipment away after being used; the premises must be left clean and organized.

## REQUIRED MATERIAL

- Canada Exercise Book : 200 sheets
- SHARP EL 531 Calculator

## MEDIAGRAPHY

1) CHUAN-TAU Edward et ROSKAM, Jan Dr., **Airplane Aérodynamics**, Roskam Aviation and Engineering Corporation, Lawrence, Kansas, University of Kansas, 1990, 550 p.
2) HURT, H. H., **Aerodynamics for naval aviators**, USA, University of Southern California, 1965, 416 p.
3) KERMORE, A.C., **Mécanique du vol**, Translation by Didier Feminier, Outremont, Modulo, C 2000, 447 p.
4) CAUVIN, D., **Aérodynamique mécanique du vol**, Paris, Institut aéronautique Jean Mermoz, 1979, 281 p.
5) GILES, R.V., **Low-Speed Wind Tunnel Testing**, USA, John Wiley & Sons, Mcgraw-Hill, 1984, 535 p.
6) GILES, R.V., **Mécanique des fluides et hydrauliques**, cours et problèmes, Série Schaum, Toronto, Mcgraw-Hill, 1975, 272 p.
7) Rice, **Handbook of airfoil sections for light aircraft**,

## INSTITUTIONAL POLICIES AND REGULATIONS

All students enrolled at Cégep Édouard-Montpetit must become familiar with and comply with the institutional policies and regulations. In particular, these policies address learning evaluations, maintaining admission status, French language policies, maintaining a violence-free and harassment-free environment, and procedures regarding student complaints. The French titles for the policies are: *Politique institutionnelle d'évaluation des apprentissages, les conditions particulières concernant le maintien de l'admission d'un étudiant, la Politique de valorisation de la langue française, la Politique pour un milieu d'études et de travail exempt de harcèlement et de violence, les procédures et règles concernant le traitement des plaintes étudiantes.*

The full text of these policies and regulations is accessible on the Cégep web site at the following address: http://ena.cegepmontpetit.ca/l-ecole/reglements-et-politiques. If there is a disparity between shortened versions of the text and the full text, the full text will be applied and will be considered the official version for legal purposes.

### (1) Course Attendance

Students are required to attend all courses and participate actively. Students who have missed 10% of the practical part (laboratory) of the course will immediately receive a warning informing them of their attendance record; when students have missed more that 20% of the practical part of the course, they will be excluded from the course.

Students who believe a mark is not justified may appeal to the administrator responsible for the department.

**(2) Absence of the Instructor(s)**

Students must wait 10 minutes before considering that an instructor is absent for the first period of a course and they must be present for the second hour unless an absence has been posted.

**(3) Safety and Use of Department Services and Workshops or Classrooms**

See the regulations for the Pre-Flight Department on the College website under the heading *Règles et politiques de l'ÉNA.*

**(4) Mark Revisions**

See Article 6.6.2 of the institutional policies for learning evaluation *(Politique institutionnelle d'évaluation des apprentissages).*

## OTHER DEPARTMENTAL REGULATIONS

Students are invited to consult the website for the specific rules for this course:
http://guideena-en.cegepmontpetit.ca/department-rules/