# SD2805 Flight Mechanics, 9 credits

Course Manual

Revised version 2.0, February 13, 2021

## 1 About this course

This is a basic course on flight mechanics with emphasis on phenomena and design methods for aircraft flying in subsonic conditions. The course is based on significant project work that involves development of a complete flight dynamics simulation model for an electrically powered aircraft. The model is used to illustrate the theoretical and numerical analysis methods covered in the course.

Each stage of the course is initiated by a general lecture on the topic to be covered. This is followed by a team session where initial estimates are made and the testing and analysis is planned. Then follows a wind tunnel test which is combined with a workshop where results are discussed and the test data is analyzed and processed using your own portable computing equipment.

The aim with the course is that you should develop an understanding of fundamental aspects of aerodynamics for aircraft design, flight dynamics modeling and analysis. Both numerical methods and experimental testing is used in the course. You will also learn how to plan and conduct wind tunnel tests and use experimental techniques for improving the design of aircraft. You will develop increased understanding of basic physical phenomena and their influence on the performance of aircraft. Comparisons between experimental and computational results are used to gain experience concerning what type of investigations are most suitable for a given case.

## 2 Learning objectives

The overall learning objectives of the course are that you should be able to

- explain basic concepts of aerodynamics, such as flow separation, stall, boundary layers, vortex generation and how they affect aircraft performance,
- perform a preliminary aerodynamic analysis of a subsonic aircraft,
- explain under what circumstances an aerodynamic analysis can be expected to produce useful results,
- derive, assemble and implement a simulation model for rigid body flight dynamics,
- perform stability and control analysis using a simulation model, and
- explain how aircraft configuration influences the stability, performance, and control of aircraft.

Aside from the aims related to your knowledge and skills in aerodynamics, the course also aims at improving your ability to

- work effectively in a culturally mixed group,
- learn with and from other students,
- approach and solve a complex engineering task,
- present your results and conclusions effectively, and
- review and give constructive feedback on work.

## 3 Prerequisites

You should preferably have knowledge in calculus, linear algebra, numerical methods, fluid mechanics. You will also need some basic understanding of Aeronautics as provided by the course Fundamentals of Flight (SD2601). Experience of programming in Octave/Matlab is also an needed.

## 4 Coordinator, teacher and examiner

Ulf Ringertz (UR) - 4th floor - rzu@kth.se
Flight Dynamics, KTH
Teknikringen 8

## 5 Literature

The course essentially follows the book

Etkin och Reid, *Dynamics of Flight, Stability and Control*, Wiley, ISBN 9780471034186, 1996,

There is also an older and possibly less costly edition of the text book,

Etkin, *Dynamics of Atmospheric Flight*, published by Dover Publications, with ISBN 9780486445229, 2005.

that can be purchased from various book stores on the Internet. The older book essentially contains the needed material but is structured differently. There is a file on canvas in the admin folder that may be of help when using the older book.

For details on aerodynamics modeling, the course refers to

Mark Drela, *Flight Vehicle Aerodynamics*, MIT Press, 2014.

which can be obtained in digital form at no cost from the KTH library.

## 6 Forum

The learning management system canvas will be used in the course. Once registered to the course, you can access the aerodynamics event at

`https://kth.instructure.com`

using your kth-login. If necessary, it will be demonstrated in class how to use the forum.

## 7 Computer resources, Matlab, and Octave

No dedicated computer resources are provided in the course. Instead, each team is expected to work out a feasible solution using available computers on campus or your own laptops. You will need to install xfoil and Matlab or Octave on your computer. Xfoil is an interactive software for analysis and design of airfoils. Xfoil documentation and download is available at

`http://web.mit.edu/drela/Public/web/xfoil/`

You can also use Xfoil through the system Xflr5 available at

`http://www.xflr5.com/xflr5.htm`

There will also be a set of Matlab/Octave scripts for so-called lifting line analysis available on canvas for your use in the course.

If you have never used Matlab (an interactive system for numerical computations), it is recommended that you get familiar with it as soon as possible. It will be very useful in the project assignments in this course as well as in many other courses at KTH, and likely in your future career. Matlab will not be taught in class, but some material to get going on your own is provided [1, 2]. Based on this material, you may also complete the course SD1105 Matlab (3 credits) by performing an individual assignment in Matlab. As an alternative to Matlab you can also use Octave which is largely compatible with Matlab but is free software. See `www.octave.org` for further details.

# 8 Teaching and learning

In this course, your learning will be facilitated by a peer learning approach similar to the one described in Ref. [3]. The objective is to enable a natural and creative learning environment that hopefully leads to a deeper learning experience and at the same time develops some of your personal and interpersonal skills. You will therefore be part of a team, formed by four to six students. Each team will meet on a weekly basis to engage with the course material and collaborate on different project tasks. The team activities are, as a central part of the course, described in more detail in the following.

Every two weeks in the course approximately constitutes a learning cycle, which is based on suitable parts of the course book. The main task for you and your team is to engage with the content of each cycle in four successive steps:

1. The first step is a two-hour overview lecture by one of the teachers. The purpose of this lecture is not to teach all the technical details in the book, but to emphasize principles and concepts and to provide an overview of the current learning cycle.

2. In the second step, you prepare yourself for a team discussion by carefully reading the course literature and carrying out some homework. When you arrive to the teamwork session, you should be able to summarize your reading and explain the main insight you gained and the main difficulty you encountered (in terms of understanding a central aspect of the course).

3. The third step is a two-hour team discussion. The ambition here is to have a fruitful discussion in your team about the insights and difficulties that are brought to the meeting. The meeting should start and end with a round that allows each team member to speak in turn. Finally, the team should agree on a main insight and a main difficulty, that are documented and uploaded to canvas along with the minutes of the meeting. More on team organization, responsibilities and reporting later on.

4. The last step is a project workshop. The workshop begins with a short seminar where selected teams will present either some results for the analysis and/or testing performed or a main insight/difficulty. After the seminar, your team will get the opportunity to collaborate on the given computer tasks and the final project with some assistance from the teachers. The main objective of this work is that you should train your ability to perform a basic aerodynamics and flight mechanics analysis in practice.

On top of this weekly process, you will perform several lab experiments with your team, where the usefulness of the developed analysis is investigated by comparing theoretical and experimental results.

The structure of the described peer learning approach is illustrated in Figure 1. A significant difference with this approach is that you will have some influence on what is emphasized in the course. With this follows a responsibility for your own learning. Your team has to consider that all the material in the notes cannot be treated in class, and you have to agree on what is the most essential to bring up. The teachers will provide structure, support and expertise to the process to support your learning.

# 9 Course program

## Milestones and deliverables

As previously mentioned, you will be responsible for your own learning in the course. However, since the course activities are designed to support your learning, it will not be difficult to monitor your own progress. For example, if you make sure to meet the milestones and deliverables in Table 1, you will always be in good shape. The deliverables as well as the milestones should be met individually, but you are allowed and encouraged to collaborate with your team in order to reach the milestones as efficiently

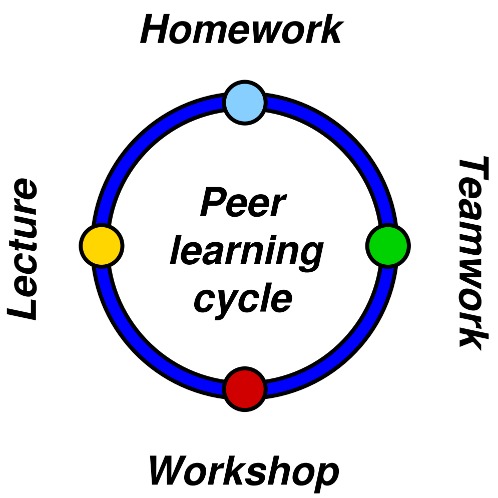


Figure 1: Illustration of the peer learning cycle.

as possible.

| Week | Milestones | Deliverables |
|---|---|---|
| 1 | Preliminary analysis and software install | Running codes |
| 2 | Finite wing analysis and test | Team notes with team rules |
| 3 | Steady state modeling and analysis | Team notes |
| 4 | Unsteady aerodynamics analysis completed | Team notes and upload of draft I |
| 5 | Equations of motion implemented | Team notes |
| 6 | Dynamic stability analysis | Team notes and plan for review |
| 7 | Open and closed loop control | Upload and peer review of draft II |
| 8 | Course completed. All learning objectives reached. | Upload of final paper and oral presentation. |

Table 1: Milestones and deliverables.

### Schedule

The overview lectures (OL), team sessions (TS) and workshops (TW/WS) will take place according to the schedule in Table 3. Due to the pandemic this year, the experimental testing will be performed as zoom sessions during the workshops. The course will start on zoom and depending on how the pandemic develops, it will continue on zoom with possible meetings in Hugin and Munin it the situation permits.

## 10 Requirements

To be approved in the course (grade E) you must

| | | |
|---|---|---|
| Events: | OL | Overview Lecture |
| | TBD | To Be Determined |
| | TS | Team Session |
| | WS | Workshop |
| | TW | Team workshop |
| | PR | Peer review |
| | ET | Experimental Testing |
| | DL | Deadline |

Table 2: Abbreviations in course program.

| Date | Time | Place | Event | Teacher | Topic |
|---|---|---|---|---|---|
| Mon, Jan 18 | 13-15 | zoom | OL | UR | Introduction |
| Wed, Jan 20 | 15-17 | zoom | TS | - | Introduction |
| Fri, Jan 22 | 15-17 | zoom | WS | UR | Software and preliminary analysis |
| Mon, Jan 25 | 13-15 | zoom | OL | UR | Aerodynamics analysis |
| Wed, Jan 27 | 15-18 | zoom | TS | - | Prepare test and analysis |
| Fri, Jan 29 | 15-17 | zoom | WS/ET | UR | Finite wing test and analysis |
| Mon, Feb 1 | 13-15 | zoom | OL | UR | Steady state conditions |
| Wed, Feb 3 | 15-18 | zoom | TS | - | Prepare fuselage test |
| Fri, Feb 5 | 15-17 | zoom | WS/ET | UR | Fuselage test and modeling |
| Mon, Feb 8 | 13-15 | zoom | OL | UR | Unsteady aerodynamics |
| Wed, Feb 10 | 12:00 | Canvas | DL | - | **Paper draft I** |
| Wed, Feb 10 | 15-18 | zoom | TS | - | Prepare unsteady test |
| Fri, Feb 12 | 08-12 | zoom | TW | UR | Aerodynamics modeling |
| Fri, Feb 12 | 15-17 | zoom | WS/ET | UR | Unsteady test and modeling |
| Mon, Feb 15 | 13-15 | zoom | OL | UR | Equations of motion |
| Wed, Feb 17 | 15-18 | zoom | TS | - | Implementation of (EoM) |
| Fri, Feb 19 | 15-17 | zoom | WS | UR | Solving the trim problem |
| Mon, Feb 22 | 13-15 | zoom | OL | UR | Stability and control |
| Wed, Feb 24 | 15-18 | zoom | TS | - | Linearize EoM for analysis |
| Fri, Feb 26 | 08-12 | zoom | TW | UR | Dynamic stability |
| Fri, Feb 26 | 15-17 | zoom | WS | UR | Open and closed loop control |
| Tue, Mar 2 | 15-18 | zoom | OL | UR | Nonlinear simulation |
| Wed, Mar 3 | 13:00 | Canvas | DL | - | **Paper draft II** |
| Wed, Mar 3 | 15-17 | zoom | PR | - | Peer review |
| Fri, Mar 5 | 08-12 | zoom | TW | UR | Simulation |
| Fri, Mar 5 | 15-17 | zoom | WS | UR | Finishing up |
| Thu, Mar 11 | 12:00 | Canvas | DL | - | **Final paper** |
| Fri, Mar 12 | 08-18 | Hugin | - | UR | **Oral presentations** |
| Wed, Mar 17 | 08-18 | Hugin | - | - | **Oral presentations** |

Table 3: Preliminary course program. (Abbreviations in Table 2)

1. participate in the teamwork activities by carrying out homework, participating in the discussions, and sharing your team's responsibilities;
2. perform the project with reasonable results, that are presented in an individually written paper.

Your project results will be used to assess how well you have reached the learning objectives, and your course grade will be set according to the criteria detailed in Appendix A.

The message is simple: focus on the course activities and to learn from them. Once you reach the learning objectives, you will be approved in the course and get a fair grade (that is final). Just like that. If you get the grade Fx you will be given opportunity to improve your project work in order to obtain the final grade E.

If you have a high ambition in the course the following advice is very useful: **the best possible way to prepare for the oral presentation is to participate in the team discussions.** Or, as stated in a saying: to teach is to learn twice. If you help your team to understand different matters, you will at the same time improve yourself and obtain even better results in the course.

In summary: you should only take this course if you want to learn something. Get involved in the team activities, have fun and learn a lot. And by the way, you will get some credits for your effort (and a grade too!).

# 11 About your teamwork

In this course you will be part of a cross-cultural team of (nominally) six students. As described in the section about teaching and learning, you will for example meet on a weekly basis to discuss the content of the current learning cycle. The teams will be formed by the teacher. To give the teamwork some structure, two of the team members will act as chairperson and secretary. A new chairperson and secretary will be appointed in each cycle, so that all team members are given opportunity to practice in these positions.

## Chairperson

The main responsibilities for the chairperson are to

- initiate the meeting with a round (see the separate note on rounds),
- if necessary, pass the word around during the discussion,
- bring the discussion back on track if too much time are spent on a minor issue,
- make sure that the team agrees on a main insight and a main difficulty to be reported in the minutes of the meeting (see below), and
- conclude the meeting with final round.

## Secretary

The main responsibilities for the secretary are to

- take notes during the session, and
- **upload a set of meeting minutes in the team's log book shortly after the meeting**.

The meeting minutes can be very brief, but should at least cover today's date, the name of the team, meeting participants, a short summary of the discussion in the team, and your main insight and difficulty, and a note on the next meeting. The following lines can be used as a template for the meeting minutes:

```
Meeting minutes of November 8, 2017

Team:
The Smarties

Meeting participants:
Vanessa W. Vortex (chairperson)
Isaac Newton (secretary)
Amelia Earhart
William Thomson, 1st Baron Kelvin
Nabla Phi

Main discussion: The session was about basic aerodynamics
 phenomena. We agreed on definitions for basic properties.  We
 discussed how the different phenomena arise and tried to understand
 the mechanisms leading to stall. We also settled the basic rules for
 our team (see below). Overall, it was a good discussion.

Basic rules:
* The working language is English.
* Everybody should prepare themselves properly before
  the meetings.
```

```
...

Main insight:
We understood how to derive the basic flow equations for
an airfoil, in particular the coupling of the boundary layer and the
invisicid far-field flow.

Main difficulty:
Getting xfoil to run and how to use it.

Next meeting:
Chairperson: Isaac Newton
Secretary: Amelia Earhart
Topics:
- Prepare the wind tunnel test.
- How to get lift and drag from the pressure measurements.
- Download and check the provided Matlab package.
```

### The first cycle

In the first learning cycle, you will mainly get acquainted with your home team and how the course works. In the following, some guidelines for the first learning cycle are provided.

#### The first meeting (TS)

It is suggested that you start the meeting by introducing yourself to one another, and perhaps share some thoughts about the course. Note, however, that the main objective of the meeting is to have your first technical discussion. Be sure to acknowledge the chairperson and secretary of the first week, and that you are all familiar with their responsibilities. Later on, do not forget to allow time for a final round and to agree on your team's main insight and main difficulty in the learning cycle. Note that the main insight/difficulty should preferably be related to the principles and concepts that are discussed in course (in order to keep focus). Also note that you may be given the task to present your main insight/difficulty to the class at the subsequent workshop (more on this below). You have an additional task to complete at this meeting: to agree on a set of basic rules for your teamwork. Your basic rules should be uploaded in your team's log book!

#### The first workshop (WS)

The purpose of the weekly workshop is to have a concluding discussion about the work that has been carried out during the week, and to perform project work. To make the workshop more inclusive and interactive, a few teams may be given opportunity to share their progress with the class. Typically, one team will be expected to present their results. Other teams may be given opportunity to present a relevant insight or difficulty to the class. In turn, the class is expected to support the team that presents in a respectful and meaningful way.

When preparing a contribution to the workshop, please consider the following. First of all, it is up to your team to decide how your contribution should be delivered. If one member really wants to present and everybody is happy with it, that's fine. If you decide to split the presentation among several members, that's fine too. The most important is that you are comfortable with your decision. **However, the whole team should participate during the presentation.** When presenting, try your best to speak loud and clear and to write properly on the whiteboard. And try to keep it as short as possible.

## 12 About your paper

The results of the project should be presented in an individually written paper. The paper should be written in English and include a title, your name and a KTH address (see the sample paper), an abstract, an introduction, suitable sections for the technical part, and separate conclusions and references. The length of the paper must not exceed 10 pages in single column layout.

To support you in this effort, two references are provided (available in canvas). The first is a very good text by Ashby [4] about how to write a paper, and the second is a sample paper written in this format [5]. **Try to use a style that matches the sample paper as closely as possible.** However, the double-column format is not required. Note that a paper does not have a front page, and no table of content. When writing the paper, it is also useful to consider the criteria in Table 4, that will be used in the different reviews of your paper.

## Individually written paper?

Your paper should be an individual accomplishment. This means that you are not allowed to share formulations with other course participants, you must use your own words and reasoning. This requirement will not be compromised. If you break it, it will be considered as cheating.

In order to distribute your work throughout the course, the paper is written in three successive steps. Before completing the final paper, you are therefore required to write two draft versions that are described in the following.

## First draft

The first draft should include a preliminary title, your name, a KTH address, and an introduction. The introduction should briefly describe the aircraft and the analysis and modeling to follow. Then you should describe the aerodynamics modeling and analysis used and the steady state aerodynamics data and flight mechanics characteristics treated this far in the course. Of course, you will be able to update your first draft to the final version, based on feedback from your team (more on this below). **Upload a PDF of your first draft to canvas no later than the given deadline. Label your draft as "yourlastname_first.pdf".**

## Second draft

In the second draft, the analysis should be close to complete also covering the unsteady aerodynamics, dynamic stability analysis open and closed loop control. **Your second draft should be uploaded in PDF format on canvas no later than the given deadline. Label your draft as "yourlastname_second.pdf".**

## Peer review

The teams will be utilized to perform a peer review of the **second draft**. The main purpose of this is to further consolidate your learning by reading the work of other authors. Another purpose is that you should improve your ability to review the work of someone else, and to provide constructive feedback. To give constructive feedback is not necessarily an easy task [6], but the basic principle is: instead of just pointing out all negative aspects of the work, first highlight the good aspects of it and then deliver the bad news as suggestions for improvement (in a gentle manner).

The first step of this process is an individual review of at least two papers written by other members in your team. First review the papers on your own using the criteria in Table 4. Then write a short feedback with reference to the given criteria, telling what strengths and possible areas of improvement the paper has from an engineering as well as writing point of view. For this, you can, but do not have to, use the provided peer review form. You should also prepare an oral summary of approximately 6-8 minutes (per paper) of your feedback.

In the second step of the process, you should bring your feedback to a peer review session with your team. At this session, it is suggested that you focus on one draft at a time, and give each other oral as well as written feedback (prepared in the first step). Note that the feedback is a personal opinion, that should be respected. It is up to each author to judge the relevance and usefulness of the feedback (and not argue about it).

**Management:** During the team session **before** the peer review, figure out who is going to review which papers (two each), and put that plan into your meeting minutes. Before the deadline for the 2nd draft, upload your paper to canvas and email a copy of the same to the reviewer. Your homework for this day is writing feedback of the two drafts which you were assigned. Soon after that (usually on the next day) is the peer review session, in which you are to present your feedback orally.

### Final version

The final version of your paper should also include sections that account for the final aspects of the project in the course. Overall, you should describe the approach that has been used to develop the numerical model, how results from the theory section are applied to perform analysis, the main results that you have obtained, and what conclusions you can draw from these. In total, you should have written a neat and digestive paper that covers the background, approach, results and conclusions for a flight dynamics analysis of the aircraft. **A PDF version of your paper should be uploaded to canvas no later than the given deadline. Label your paper as "yourlastname_final.pdf".**

In addition to the paper, please upload the final version of the Matlab code that you used for the project. Make sure that all input data and function files that are needed to run your main scripts are included and upload a compressed archive (zip, 7z or tgz).

## 13 About the oral presentation

The course is concluded with a short oral presentation with emphasis on the overall learning objectives. It is not a secret what the oral presentation will be about. On the contrary, we will talk about the fundamentals of flight dynamics that you have already discussed with your team or dealt with in the project. Consequently, if you have performed the preparatory homework, participated actively in the team activities and performed the project, it should be straightforward.

The oral presentation is meant to be an *opportunity* for you to show what you have learned in the course. Therefore, the oral presentation does not have the traditional format of a teacher asking questions and a student answering them. Instead, you will perform the oral presentation together with another student (and the teacher). At the oral presentation, each candidate should give a 10-15 minutes presentation about the flight dynamics of the aircraft and how the various parts of the course have contributed to the development process. Each presentation will be followed by a discussion, where the presenter should be able to answer questions from the partner and the teacher. By asking relevant and insightful questions and participating in the discussion that follows, each participant will thus be able to show that a particular topic is well understood. Of course, both candidates should be able to answer questions about any of the main topics in the course. In order to document each participant's contributions, the teacher will take notes during the session. Finally, the teacher will summarize his impression and inform the participants about their performance. In total, the session will take 1/2 to 1 hour.

**No other aids than a whiteboard and a pen are allowed. Please respect the slot that you have been assigned (see schedule in canvas) and show up in time!**

## 14 Homework

### First cycle

- Read relevant Chapters 1-2 in Etkin as well as the relevant airfoil sections of Drela such as 3.4-3.5
- Install software on your computer
- Perform initial analysis of the aircraft configuration
- Use Xfoil to analyze the airfoil to be used in the wind tunnel test.
- Compare inviscid analysis to a viscous model at different Reynolds number.
- Prepare for the team discussion by writing down the main insight you have gained and the main difficulty you have encountered in your homework.

### Second cycle

- Read relevant Chapters such as 5.6, 5.6, 10 and Appendix E in Drela's book on the lifting line modeling and wind tunnel testing.
- Explain the approximations made using a lifting line model.
- Explain how airfoil properties from viscous xfoil analysis can be used to improve lifting line modeling.
- Prepare analysis of the finite wing
- Prepare for the team discussion.

### Third cycle

- Read Etkin chapters 5.1-5.2 and 5.6 and Drela 2.12 and 6.6.
- Try to estimate the fuselage influence using for example a slender body approximation.
- Explain how airfoil properties can influence aircraft handling and performance.
- Consider which flap settings are useful for different flight conditions such as high speed cruise, low speed loitering, take off and landing.
- Prepare for the team discussion.

### Fourth cycle

- Finish your first draft of the paper.
- Read Etkin Ch 5 and Drela Ch 7.
- Modify the simple lifting line model to estimate Clp.
- Compare with the nonlinear lifting line model.
- Prepare the processing of experimental data.
- Prepare for the team discussion.

### Fifth cycle

- Read Etkin Ch 4 and Drela Ch 9.
- Begin implementing the equations of motion for time integration.
- Prepare for the team discussion.

### Sixth cycle

- Read Etkin Ch 6 and 7.
- Prepare for the team discussion.

### Seventh cycle

- Read Etkin Ch 8.
- Prepare for the team discussion.

### Eighth cycle

- Finish your second draft of the paper.
- Prepare reviews and upload them.
- Prepare for the team discussion.

### Final cycle

- Use the received reviews to improve and finalize your paper.
- Finish your paper.
- Prepare for the oral presentation.

## References


[1] Griffiths, D. F., *An Introduction to Matlab*. With additional material by Ulf Carlsson, KTH Aeronautical and Vehicle Engineering. The University of Dundee, 2005.

[2] Carlsson, U., *Miscellaneous Exercises in Matlab*. KTH Aeronautical and Vehicle Engineering, 2009.

[3] Borglund, D., "A Case Study of Peer Learning in Higher Aeronautical Education," *European Journal of Engineering Education*, Vol. 32, No. 1, 2007, pp. 35–42.

[4] Ashby, M., "How to Write a Paper," Engineering Department, University of Cambridge, Cambridge, $6^{\text{th}}$ Edition, April 2005.

[5] Borglund, D., "Robust Eigenvalue Analysis Using the Structured Singular Value: The $\mu$-$p$ Flutter Method," *AIAA Journal*, Vol. 46, No. 11, 2008, pp. 2806–2813.

[6] Gibbs, G., *Learning in Teams: A Student Guide*. The Oxford Centre for Staff Development, Oxford Brookes University, 1998.

# A Grading criteria

**A** You can readily derive and explain the fundamentals of aerodynamics that are referred to in the learning objectives and the homework assignments, respectively. You are also, to some extent, able to develop the theoretical models on your own. You have participated in the teamwork activities in an active and meaningful way. Your project work is characterized by a discernible, creative and thorough approach that is based on correct principles. Your results and conclusions are focused and relevant in relation to the project description. Your approach, results and conclusions are presented in a complete, concise, coherent and well structured paper.

**B** You can readily derive and explain the fundamentals of aerodynamics that are referred to in the learning objectives and the homework assignments, respectively. You are also, to some extent, able to develop the theoretical models on your own. You have participated in the teamwork activities in an active and meaningful way. Your project work is characterized by a discernible and thorough approach that is based on correct principles. Most of your results and conclusions are relevant in relation to the project description. Your approach, results and conclusions are presented in a complete and well structured paper.

**C** You can derive and explain most of the fundamentals of aerodynamics that are referred to in the learning objectives and the homework assignments, respectively. You have participated in the teamwork activities in an active way. Your project work is characterized by a discernible approach that is based on correct principles. Most of your results and conclusions are relevant in relation to the project description. Your approach, results and conclusions are presented in a complete and well structured paper.

**D** You can derive and explain most of the fundamentals of aerodynamics that are referred to in the learning objectives and the homework assignments, respectively. You have participated in the teamwork activities in an active way. Your project work is characterized by a valid but not so well explained approach. Most of your results and conclusions are relevant in relation to the project description. Your approach, results and conclusions are presented in a partially complete and fairly well structured paper.

**E** You can explain most and derive some of the fundamentals of aerodynamics that are referred to in the learning objectives and the homework assignments, respectively. You have participated in the teamwork activities in an active way. Your project work is characterized by a valid but not so well explained approach. Most of your results and conclusions are relevant in relation to the project description. Your approach, results and conclusions are presented in a partially complete and fairly well structured paper.

**Fx** You can explain most and derive some of the fundamentals of aerodynamics that are referred to in the learning objectives and the homework assignments, respectively. You have participated in the teamwork activities, but perhaps only to some extent. Your project work is characterized by an approach that is poorly explained or not valid. Only some of your results and conclusions are relevant in relation to the project description. Your approach, results and conclusions are presented in a partially complete paper.

**F** You can only explain some and hardly derive any of the fundamentals of aerodynamics that are referred to in the learning objectives and the homework assignments, respectively. You have participated in the teamwork activities, but perhaps only to some extent. Your project work is characterized by an approach that is poorly explained or not valid. Only some of your results and conclusions are relevant in relation to the project description. Your approach, results and conclusions are presented in a partially complete paper.

## B Paper review criteria

| Technical work |
| --- |
| Are all major aspects of the project description treated? Is there a valid reasoning used, and does it show an apparent understanding and grasp of the subject? Does the work even show some originality and imagination? Are conditions, approximations and assumptions clearly stated? Are governing equations included, and are they valid for this problem? Are appropriate methods used for solving the equations, and are they suitably explained? Does the technical work appear to be correct, or at least reasonable? If some results are obviously not realistic, have the author commented on this? Are the validity and accuracy of the results motivated? Are an appropriate number of figures used when presenting numerical or experimental results? Are the conclusions reasonable and relevant in relation to the project description? |
| Content |
| Is the title meaningful and brief? Does the abstract cover the motive, method, key results and main conclusions of the work? Does the introduction communicate why the topic is interesting or important, who have contributed what in the past, and the purpose of the present paper (alternatively, a historical background and/or important applications of the technology)? Does the paper have an apparent and natural structure that helps the reader to keep track? Are theory/methods and results presented in separate sections? Are the section headings meaningful and brief? Is the content relevant and concise, or can some parts even be omitted without loosing quality? Does the level of detail stand in reasonable proportion to the results and conclusions that are reported? Are the most important results drawn together in a separate section with conclusions? Finally, are sources of previous work, theories, methods or data cited in a concluding list of references? |
| Style |
| Is the paper written in commendable English and does it present the material in a clear and apparent form? Does the introduction have a good first sentence? Is the spelling correct? Are figures and tables clear, easy to read and properly integrated in the text? Are figure and table captions meaningful and brief? In graphs: are axes properly labeled, units well defined and a decent fontsize used? Are equations suitably formatted and properly presented in the text? Are all properties in the equations defined in the text? Are pages, figures, tables and equations numbered? Is the list of references complete and properly used in the text? |
| Overall impression |
| What is your overall impression of the paper? What was the main point that the author tried to convey? What did you like the most about the paper? What did you like the least? If the author have additional time to work on the paper, what would you mainly recommend him/her to improve? |

Table 4: Criteria for the review of your paper.