

ENERGY AND FUSION RESEARCH

Course PM Spring 2021

NOTE! The course is **digitalized this year** due to the pandemic.
Please pay particular attention to green-marked text below.

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Visiting address: Division of Fusion Plasma Physics, Teknikringen 31, KTH
Course home page: <https://canvas.kth.se/courses/21410>
(<https://www.kth.se/kursutveckling/ED2200?l=en> for course development)

COURSE SUBJECT

In earlier days, the question "For how long will the fossil fuels last?" was often raised, but the development during the last decades rather imply the question "When can we free ourselves from the dependence on fossil fuels?".

In this course, a background is given to the problems concerning future energy production that we are realizing today and that will become critical towards the mid-century unless new energy sources are developed. We will also discuss the alternative energy sources that are known today. Within fusion research, the goal is to produce a sustainable energy source for large scale generation of electricity. By using the surplus energy that is released in fusion reactions, as light atomic nuclei merge, the final benefit comes from an enduring, affordable and environmentally friendly "Sun on earth".

The Alfvén Laboratory at KTH collaborates internationally in this field. This introductory course will provide the physical and technological basics and give a picture of the state of present day fusion research. Development in fusion has now reached a state where we may say, with some confidence, that fusion power will indeed be realized. In the course, different solutions to this "the greatest technological challenge ever pursued by man" will be presented.

COURSE LITERATURE

- *Fusion Physics – introduction to the physics behind fusion energy*, J. Scheffel and P. Brunsell
- *Exercises with solutions*, J. Scheffel and P. Brunsell

Course book and exercises are freely available as pdf:s. Physical course book cost is 200 kr.

ABOUT TEACHING AND LEARNING IN THIS COURSE

Lectures (Le) provide an overview of the energy provision problem and the development of fusion research, as well as an understanding for important problems in fusion research. Some course book material will be taught as home assignments.

THIS YEAR:

- The digitalized course design as presented here may possibly be modified later on. Any change will, however, be posted as a message on the course home page.
- Instead of a physical lecture (Le1) on Monday 22 March at 10:15, there will be a brief digital introductory lecture where the course design for this year will be presented.
The Zoom link is: <https://kth-se.zoom.us/j/67312612060>
- The course book is available as a pdf for free on the course home page. If you are interested in purchasing a physical copy (200 kr), please send an e-mail to either of the course teachers.

- Instead of physical lectures Le1 and Le2, normally given the first course week, please watch the video lectures on fusion, primarily lectures 1-4, at <https://www.kth.se/fpp/education/video-lectures-on-fusion-1.648407>
- Remaining lectures Le3 - Le12 are posted as video recordings on the course home page in Canvas

Home assignments provide credits for the course examination.

Class exercises (Ex) develop skills to solve formal problems within fusion research and an opportunity to discuss questions encountered during the studies. Normally a few problems are solved on the blackboard during the first hour, whereafter the students solve a given problem as a group exercise the second hour. Protocols from each group are handed in at the end of the session, as part of the examination.

THIS YEAR no class exercises will be given in the physical class room:

- *Solved problems*, relating to the first part of the class exercise, will be posted on the course home page early each week
- *Group work exercise problems*, and answer sheets for these, will be posted on the course home page at the scheduled day for exercises (see Course Program). For solving these, and examination of these, please see below

EXAMINATION

Continual examination, based on a credit point system, is used.

The grades “pass” (P) or “fail” (F) are determined by the total number of credit points accumulated during the course. Maximum 42 credit points are available. A minimum of 30 credit points is required for grade “pass”. Students achieving 26-29.5 credit points may be awarded “pass” grade after completing an additional exam within 6 weeks after the course.

Course activities required for examination:

HOME ASSIGNMENTS are six in total and provide a total maximum of 30 credit points.

They are handed out each week, and should be handed in at the first lecture the week after.

The first five assignments cover the subjects presented in the lectures the same week. Each assignment gives maximally 4 credit points.

The second and sixth assignments contain surveys on the Canvas course platform as first questions. These *must* be answered for receiving credit points from assignments two and six.

The first part of the sixth assignment covers last week’s lectures and can give 4 credit points while the *second part* of the sixth assignment covers the whole course and can give maximally 6 credit points.

THIS YEAR:

- Home assignments are made available at the course home page on Canvas
- Solutions should be uploaded to Canvas on the same web page as where the Home assignment was posted.
- If you scan: you must use an app that delivers pdf files (recommended: SwiftScan; <https://www.kth.se/en/student/kurs/tentamen/tentamen-pa-distans/lamna-in-handskriven-text-i-canvas-1.972798>)
- Note that Home assignments uploaded after the time specified above will not be considered!

NOTE: In this course your individual understanding is in focus; you are free to cooperate with other students during the solution of the problems, but *your answers must be formulated from your personal understanding. Measures will be taken in cases of plagiarism!*

GROUP WORK SESSIONS (see above) may provide 12 credit points in total. Handed in protocols for each session are graded “pass” or “fail”. Constructive participation is a minimum requirement for the “pass” grade. Protocols graded “pass” in 4-6 sessions give 12 credit points while protocols graded “pass” in 2-3 sessions give 6 credit points.

THIS YEAR:

- The group exercises may, as before, be solved in groups of 2-3 students. In this case, a “secretary” for the group should be appointed, that should fill in the answer sheet
- You also have the possibility to solve the problems individually
- Upload the answer sheets no later than by the end of the day for the exercise (see Course Program below) to Canvas on the same web page as where the exercise was posted.
- If you scan: you must use an app that delivers pdf files (recommended: SwiftScan; <https://www.kth.se/en/student/kurs/tentamen/tentamen-pa-distans/lamna-in-handskriven-text-i-canvas-1.972798>)
- Please note that plagiarism checks will be carried out

COURSE PROGRAM

Week	Day	Date	Time	Place	Le/Ex	Topic
12	Mon	22 Mar	10-12	Digital	Le 1	Fusion in nature, future energy needs, energy alternatives (Ch 1.1).
	Wed	24 Mar	15-17	Digital	Le 2	Energy alternatives, cont'd., fusion reactions, brief fusion history (Ch 1.2).
	Thu	25 Mar	10-12		Ex 1	Le 1, 2
13	Mon	29 Mar	10-12	Digital	Le 3	Lawson criterion, quality parameters of the fusion plasma (Ch 1.2, 2).
	Wed	31 Mar	15-18	Digital	Le 4	Plasma models; particle, kinetic and fluid models (Ch 2).
	Thu	1 Apr	10-12		Ex 2	Le 3, 4
15	Mon	12 Apr	10-12	Digital	Le 5	Equilibrium, plasma waves (Ch 3, 4).
	Wed	14 Apr	15-18	Digital	Le 6	Stability (Ch 4).
	Thu	15 Apr	10-12		Ex 3	Le 5, 6
16	Mon	19 Apr	10-12	Digital	Le 7	Transport (Ch 5).
	Wed	21 Apr	15-17	Digital	Le 8	Transport cont'd (Ch 5).
	Thu	22 Apr	10-12		Ex 4	Le 7, 8
17	Mon	26 Apr	10-12	Digital	Le 9	Radiation, boundary, heating (Ch 6).
	Wed	28 Apr	15-17	Digital	Le 10	Diagnostics (Ch 7). Visit to the Alfvén laboratory.
	Thu	29 Apr	10-12		Ex 5	Le 9, 10
19	Mon	10 May	10-12	Digital	Le 11	Alternative concepts, inertial confinement fusion (Ch 8).
	Wed	12 May	15-17	Digital	Le 12	Reactor, safety, environment (Ch 9).
20	Mon	17 May	10-12		Ex 6	Le 11, 12

Disability

If you have a disability, you may receive support from Funka, KTH’s coordinator for students with disabilities, see <https://www.kth.se/en/student/studentliv/funktionsnedsattning> . Please inform the course coordinator if you have special needs not related to the written exam, and show your certificate from Funka.

- Support measures under code R (i.e. adjustments related to space, time, and physical circumstances) are generally granted by the examiner.
- Support measures under code P (pedagogical measures) may be granted or rejected by the examiner, after you have applied for this in accordance with KTH rules. Normally, support measures under code P will be granted.