SG2221/SG3122

Wave motions and hydrodynamic stability, 7.5 credits

Target group

The course is optional from all engineering programmes and is addressed to graduate (SG3122) and undergraduate (SG2221) students with fundamental knowledge and interest in fluid dynamics. The course is recommended to students following the Master of Science in Engineering Mechanics programme. The extra work required for graduate students is found under Examination.

Course goals

The student will acquire knowledge in fundamental concepts and phenomena in wave motions in fluids and hydrodynamic instabilities. It will help you to understand the theory underlying some commonly observed flow phenomena, such as

- why the surface waves behind a boat have a limited spreading angle
- why the wake of a cylinder beats at a fixed frequency independently of the external disturbances
- why Tsunamis[1] arise and how they behave when approaching the shore
- why the so spectacular Billow clouds in the atmosphere are formed

After completing this course the student should manage to:

- describe the behaviour of surface gravity waves
- explain the concept of group velocity of a wave
- describe the main features of internal waves in continuously stratified fluids, such as in oceans and in the atmosphere
- identify the mechanisms behind instabilities in flows governed by thermal convection and heat exchange
- discuss effects of centrifugal and Coriolis forces in unstable rotating systems
- describe the instability nature and mechanisms in shear flows, i.e. wake, jet, boundary layer and channel flows
- discuss the influence of viscosity on stability
- explain why classic asymptotic stability analysis provides only a partial description of disturbance amplification in shear flows

Prerequisites

To follow the course students are required to have taken a course in fluid dynamics.

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[1] Tsunami: long-wavelength, high speed traveling sea wave (Japanese: *tsu*, "harbour", and *nami*, "sea").

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Teaching

The teaching is delivered by means of a mixture between traditional classroom teaching and seminar-based lectures where open discussions will be promoted by student-active-elements such as gobbets[2]. Furthermore, table experiments will be shown during classes in order to demonstrate and clarify parts of the surveyed theory. In order to activate the students to develop practical skills one experimental and one numerical assignment are given in this course. Each lecture will begin with a few minutes review and discussion of last lecture's content. The total amount of lecture hours is 42h, which are delivered over 21 gatherings (i.e. 2h per lecture).

Course literature

- Acheson D. J., Elementary Fluid Dynamics, Oxford University Press, USA, 1990 (ISBN 0198596790).
- Kundu P. K. & Cohen I. M., Fluid Mechanics, Elsevier Academic Press, USA, 2004 (ISBN 0121782530).
- Your own lecture notes and other distributed course material

Examination

The following three items have to be approved in order to obtain a pass of the course (7.5c):

- One laboration with adherent preparation tasks and lab report (for graduate students the lab report has to be an extended version)

  Experimental analysis of Tollmien-Schilichting waves over a flat plate (1.5c)
- One home assignment with report (for graduate students some Matlab programming is required and the presentation at the oral exam has to be an extended version)

  Numerical computation of flow instability for different configurations (1.5c)
- Oral/written examination (4.5c)

All items are graded. For graduate students the highest grade is required to obtain a pass.

Labs and reports

After the lab a lab-report (2-3 pages without figures, tables and other appendices) is to be handed in. The lab is carried out in-group of four, whereas group of two are for the numerical assignment. With the corresponding reports a maximum of two persons can collaborate. The report should contain:

- Introduction
- Experimental set up and measurement technique/Numerical implementation
- Results
- Conclusions
- Appendix with a statement of the preparatory lab task

[2] Pictures of real flow events are shown on the OH-projector for discussion.

- Appendix with a statement of your own impression of the lab. What was good/bad and what did you miss?

Oral/written examination

The examination is composed of an alternating oral and written test. The test is usually performed in groups of two students and will last for about 45 minutes, including the presentation of the numerical assignment. A list of about 50 questions will be available from the course homepage from where questions will be taken and asked at the individual test.

Teachers

Course responsible + lecturer:

Jens Fransson (JF)
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Course responsible + lecturer:

Luca Brandt (LB)
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Lab assistant:

Shahab Shahinfar
E-mail: shahabs@mech.kth.se
Telephone: 08-790 7594

General information

The department of Mechanics is located at Osquars Backe 18 and its lab halls at Teknikringen 8. The handing in of lab reports and literature assignment take place directly to the lecturer at class or can be put in the lecturer's post-box at:

- Teknikringen 8, hall 48, Strömningsfysiklaboratoriet — Jens Fransson
- Osquars Backe 18, 7th floor, Mekanik — Luca Brandt

All updated course information will be available on the course homepage:
http://www.mech.kth.se/~jensf/SG2221

Course schedule, 2011

Day	Time	Room	Teacher	Description
Mon 24/10	13.15-15.00	D 32	JF	Course overview. Introduction. Wave parameters.
Wed 26/10	10.15-12.00	E 53	JF	Equation for surface gravity waves.
Fri 28/10	15.15-17.00	E 53	JF	Solution for gravity waves. Particle path, pressure, energy.
Tue 1/11	10.15-12.00	E 36	JF	Dispersion relation. Group velocity.
Wed 2/11	10.15-12.00	D 34	JF	Surface tension effects. Deep and shallow water approximations.
Thu 3/11	15.15-17.00	E 35	JF	Shallow water equation with examples. Ship waves.
Fri 4/11	15.15-17.00	D 35	JF	Equation of motion for a continuously stratified fluid
Mon 7/11	15.15-17.00	D 32	JF	Instability introduction. Method of normal modes. Thermal instability.
Wed 9/11	13.15-15.00	D 32	JF	Rayleigh-Benard problem. Finite amplitude disturbances.
Fri 11/11	13.15-15.00	E 33	JF	Centrifugal instabilities. Taylor problem.
Mon 14/11	13.15-15.00	E 52	LB	Instability of parallel shear flows. Governing equations.
Wed 16/11	13.15-15.00	E 35	LB	Inviscid theory, inflection point criterion. Kelvin-Helmhotz instability.
Thu 17/11	13.15-15.00	D 41	LB	Viscous theory. Neutral stability curves.
Fri 18/11	13.15-15.00	D 35	LB	Failure of asymptotic approach. Non-normal operators.
Fri 25/11	13.15-15.00	D 34	LB	Initial value problem. Eigen-decomposition. Transient growth.
Tue 29/11	10.15-12.00	E 35	LB	Forced problem. Resolvant, eigenvalue sensitivity.
Wed 30/11	13.15-15.00	D 35	LB	Short time behavior. Numerical range. Energy analysis.
Thu 1/12	15.15-17.00	D 35	LB/JF	Lab/project introduction.
Fri 2/12	13.15-15.00	E 53	LB	Spatial approach. Absolute/convective instability
Mon 5/12	10.15-12.00	D 42	LB	Nonlinear stability. Secondary instability.
Wed 7/12	10.15-12.00	D 34	LB	Transition to turbulence

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