TU Delft TEACHING AND EXAMINATION REGULATIONS (TER)

IN ACCORDANCE WITH ARTICLE 7.13 OF THE DUTCH HIGHER EDUCATION AND RESEARCH ACT [WHW]

MASTER DEGREE PROGRAMME
Applied Geophysics

2023
2024

THESE TEACHING AND EXAMINATION REGULATIONS APPLY TO ALL STUDENTS OF THE COHORT 2023-2024

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Paragraph 1 - General

Article 1 - Applicability of the regulations

1. These regulations, including the Annex to this TER, apply to the TU Delft part of the teaching and the examinations of the master's degree programme in Applied Geophysics (Joint Master Programme) (AGP), hereinafter referred to as 'the programme'. Common regulations are agreed between the three partner universities and are given in the General Programme Regulations of the programme, as published on the website idealeague.org/geophysics. The following articles apply to the first semester of the programme and, in case not given in the programme's General Programme Regulations, to the common parts of the programme (mainly paragraphs 3, 6 and 7 given below).

2. The programme is provided under the shared responsibility of the three faculties/departments of the three partner universities, i.e., the faculty of Civil Engineering and Geosciences at Delft University of Technology hereinafter referred to as the 'faculty', the department of Earth Sciences at the Swiss Federal Institute of Technology Zurich, and the Faculty of Georesources and Material Engineering at RWTH Aachen University. The corresponding regulations of ETH Zurich (second semester) and RWTH Aachen University (third semester) can be found on their websites.

Article 2 - Concepts

1. The following concepts apply in this Regulation:

a. Act:	the Dutch Higher Education and Scientific Research Act (abbreviated to WHW), Bulletin of Acts and Decrees 593 and any amendments since its introduction.
b. Assessment:	the process of testing, and making a judgment of the student's knowledge, insight, and skills with regard to a course;
c. bridging programme:	a deficiency programme aimed at moving up to a master's degree programme, as stipulated in Article 7.30e or Article 7.57i of the Act;
d. course/module:	a unit of study within the programme, as stipulated in Article 7.3, Sections 2 and 3 of the Act, with which an examination is associated;
e. credit:	credit in accordance with the European Credit Transfer System (ECTS); one credit equals a study load of 28 hours;
f. degree audit:	An assessment by the Joint Board of Examiners (see Article 1.4 in the Annex) whereby it is determined, in accordance with Section 7.10 of the Act, whether all examinations in the subjects of the degree programme have been successfully completed;
g. examiner:	the individual who, in line with Article 7.12, Subsection 3 of the Act, has been appointed by the Board of Examiners to set the examinations;
h. examination:	investigation of the student's knowledge, insight, and skills with regard to a course, along with the assessment of that investigation. An examination can also consist of interim examinations;
i. first academic year:	the first period in the programme with a study load of 60 credits, as specified in Article 7.8b Section 8 of the Act;
j. Osiris:	the education information system of TU Delft;
k. practical exercise:	course or component of a course aimed at the acquisition of particular skills. The following can be understood as practical exercises: • writing a thesis, • conducting a project or experimental design, • carrying out a project or a design/research assignment, • participating in field work or an excursion, • conducting tests and experiments, or • participating in other educational activities that are considered essential and that are aimed at acquiring particular skills;
l. programme:	the master's degree programme, as stipulated in Article 7.3a, Section 1 in the Act;
m. student:	a person enrolled at Delft University of Technology in order to receive education and take the examinations and the degree audit in the degree programme;
n. study guide:	the digital guide for the degree programme containing specific information on the courses included in the degree programme (www.studiegids.tudelft.nl);
o. working day:	Monday through Friday, with the exception of recognised holidays and the collective closure days;

2. The other concepts in these regulations are used in the sense in which they appear in the Act.

3. In these regulations, the term 'examination' also refers to 'partial examination', with the exception of Article 19, Section 1, first two complete sentences and Article 22 paragraph 1.

4. A written or oral examination may also be taken digitally and/or online. In these regulations, the term examination is also taken to mean a digital and/or online examination, unless stated otherwise in these regulations.

Paragraph 2 - Admission and prior education

Article 3 - Admission to the master's degree programme

1. Individuals holding one of the following degrees have access to the education of the master's degree programme in Applied Geophysics on the condition that all of the stated requirements have been met.

   Applicants with a bachelor's degree issued by one of the three partner universities in appropriate subject areas, such as, earth sciences, environmental sciences, physics, engineering.

   Applicants with a bachelor's degree of at least 180 EC or an equivalent university qualification in appropriate subject areas, such as earth sciences, environmental sciences, physics, engineering, which gives evidence of the required qualification for the programme from other top universities worldwide. For these applicants, the TU Delft admission criteria apply.

2. Students who do not possess a degree mentioned in Section 1 are required to obtain proof of admission to the programme from the Dean, who will seek the advice of the admission committee on this matter.

   a. Other university Bachelor degree (not including those listed in Section 1)

   Bridging programme to be followed:
   Individuals who have received foreign education prior to the earned bachelor's degree at a Dutch institution, must meet the requirements of satisfactory linguistic mastery of Dutch, as stated in the appendix, before one can participate in a Dutch-language bridging programme.
   The foregoing requirement does not apply to pre-switchers who were registered in the academic year 2021-2022, with uninterrupted enrolment for the academic years 2022-2023, 2023-2024 and 2024-2025

   b. Higher professional education degree

   Applicants who have a bachelor's degree from a Dutch higher vocational institute (HBO) are required to follow a so-called bridging programme. This programme is available only in Dutch. Applicants who would like to follow this programme should contact the master coordinator of the programme.

   The following applies to this category: Successful completion of the stated bridging programme for admission to the Master's degree programme and, if applicable, the language requirement.

   Bridging programme to be followed:
   Individuals who have received foreign education prior to the earned higher professional education degree, must meet the requirements of satisfactory linguistic mastery of Dutch, as stated in the appendix, before one can participate in a Dutch-language bridging programme.
   The foregoing requirement does not apply to pre-switchers who were registered in the academic year 2021-2022, with uninterrupted enrolment for the academic years 2022-2023, 2023-2024 and 2024-2025.

   c. Foreign degree

   This category is subject to the general selection requirements of Delft University of Technology with regard to prior foreign education, based on a Cumulative Grade Point Average of at least 75% of the maximum number of points that could be earned, included in the table of countries (see website) and meeting the requirements for satisfactory linguistic mastery of English, as stated in the appendix to article 3.

3. The following qualitative admission requirements also apply:
   Access to the education of the master's degree programme in Applied Geophysics is open to individuals who have demonstrated to the admissions committee that they possess knowledge, insight and skills at the level of the bachelor's degree mentioned Subsections 1a, or of a university bachelor's degree, in addition to the further requirements mentioned in Subsections 2a and 2b.

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Article 3b - Completion of bridging programme prior to the degree programme

1. A student who is enrolled in a bridging programme with the aim of being admitted to the master's degree programme at TU Delft must complete this bridging programme within two academic years.

2. After the programme duration of the bridging programme, the enrolment of the student will be cancelled. Under exceptional circumstances the student can submit a well-founded request for an extension of the course duration for a period of at most twelve months. The Joint Board of Examiners can decide to grant extension of the programme duration when a student is experiencing or has experienced a study delay due to circumstances that are beyond the student's control.

3. After the enrolment of the student for a bridging programme has been cancelled in accordance with section 2 or a student has unenrolled from the bridging programme before completion, a student cannot (re)enroll in a bridging programme for admission to the same master's degree programme for a period of two years after such cancellation or unenrolment. In exceptional cases, the Director of Studies of the master's degree programme is allowed to deviate from this Regulation.

Article 4 - University entrance examination

Not applicable.

Paragraph 3 - Content and composition of the programme

Article 5 - Goal of the programme

1. The programme is intended to educate students to earn a Master of Science degree in Applied Geophysics (AGP), providing them with such a level of knowledge, insight, and skills in the field of applied geophysics, that graduates can fulfil positions on the labour market at the master's level.

2. The Intended Learning Outcomes of the programme are outlined in the Annex to this TER.

Article 6 - Composition of the programme and degree audits

1. The degree programme consists of at least 120 credits. The degree audit is a final assessment by the Joint Board of Examiners Board whereby it is determined, in accordance with Section 7.10 of the Act, whether all examinations in the subjects of the degree programme have been successfully completed.

2. Following approval from the two Boards of Examiners concerned a student may take an individual double degree programme in which two master's programmes are combined simultaneously to create a programme of at least 180 credits. Upon completion the student is awarded two master's diplomas. The student must earn at least 60 unique credits for each master's degree programme.

3. A course that was part of the bachelor's degree programme that qualified a student for admission to the master's degree programme may not be included in the master's degree programme. If a compulsory component has already been completed in the bachelor's degree programme, the Board of Examiners will designate an alternative course. If an elective course of the degree programme has already been completed in the bachelor's degree programme, the student will select an alternative elective course.

4. The degree programme and its courses are described in the Annex to this TER, including the study load, and form of examination of each course, as well as the programming of the examination.

5. The actual design of the educational programme is elaborated in greater detail in the study guide of the three partner universities.

6. The Master's degree audit is concluded with a final test or assignment. This test or assignment demonstrates that the student possesses and is able to apply the knowledge, insight and skills acquired in the degree programme.

Article 7 - Form of the programme

The programme is offered exclusively as full-time.

Article 8 - Language

The education is in English, and the examinations are administered in English (See also programme's General Programme Regulations).

Article 9 - (Compulsory) participation in the programme

1. All students are expected to participate actively in the programme.

2. If necessary, there will be an obligation to participate in practical exercises, with a view to admission to the related examination. The Joint Board of Examiners may grant an exemption from this obligation, with or without imposing a substitute requirement.

3. Any supplementary obligations are described by component in the course description in the study guides of the three partner universities.

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Article 10 - Programme evaluation

1. The Director of Studies is responsible for the evaluation of the education.

2. The manner in which the education in the TU Delft's part of the programme, i.e., the first semester is evaluated is documented in the faculty's Quality Assurance Manual, which is submitted to the Faculty Student Council and the Board of Studies.

3. The Director of Studies informs the Board of Studies concerning the outcomes of the evaluation, the intended adjustments based on these outcomes and the effects of the actual adjustments.

Paragraph 4 - Registration for courses and examinations at TU Delft

Article 11 - Compulsory registration for courses

Not applicable at TU Delft, but applicable at ETH Zurich and RWTH Aachen University.

Article 12 - Withdrawal from a course

Not applicable at TU Delft, but applicable at ETH Zurich and RWTH Aachen University

Article 13 - Registration for written examinations

1. Registration to participate in a written examination, including a written examination that is taken online, remotely from the university, is compulsory and is done by entering the requested data into the education information system Osiris no later than 14 calendar days before the examination. Students receive examination tickets by email as confirmation of their registration. Contrary to this, a registration period of six calendar days applies to resits in the summer resit period. The student will receive an exam ticket by email as confirmation.

2. Students may submit a request to register for an examination after the deadline mentioned in subsection 1 has passed but no later than 6 calendar days before the examination in question, in the education information system Osiris by being placed on a waiting list. The request will be honoured provided that places are available in the room or rooms where the examination is scheduled to take place. The student will receive an exam ticket by email as confirmation.

3. In the event of circumstances beyond a student's control resulting in the student being unable to register for an examination, the Board of Examiners may nevertheless permit the student to participate in the examination.

4. Students who have not registered for the examination and are therefore not included on the list of examinees can report on the day of the examination to the invigilator beginning 15 minutes before the start of the examination until the actual start. They will be admitted to the examination room, in the order that they reported to the invigilator, 30 minutes after the start of the examination, if sufficient places are available. The loss of 30 minutes of examination time cannot be compensated. Students who have been granted late access to the examination will be added to the list of examinees. The student participates in the examination subject to the validation of entitlement to participate in the examination.

5. In the situation described in the previous section, if it is found that a student was not entitled to participate in the examination, the examination work will be deemed invalid, it will not be marked and it will not count towards a result. The student may subsequently submit an appeal to the Board of Examiners, accompanied by reasons, requesting that the examination work that has been deemed invalid be declared valid and to have it assessed. The Board of Examiners will approve the request only in case of extenuating circumstances.

6. Sections 2 and 4 of this article do not apply to a written examination that is taken online, remotely from the university.

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7. If unforeseen circumstances or measures make it necessary to change the form or manner of taking the examination, the Board of Examiners may determine a different registration period in favour of the student.

Article 14 - Registration for other examinations

1. Registration for participation in an examination other than a written examination, for which registration is open, is compulsory. This is possible up to 14 calendar days before the examination take place in the manner that is stated in the study guide for the relevant examination.
   If unforeseen circumstances or measures make it necessary to change the form or manner of taking the examination, the provisions stated in the study guide apply in full unless the Dean decides to deviate from the manner or term of registration prescribed in the study guide.
2. In special cases, the Board of Examiners may deviate from the registration term stated in Section 1, but only in favour of the student.
3. Students who have not registered on time will not be allowed to participate in the examination. The Board of Examiners can nevertheless admit a student to the examination, but only in case of special circumstances.
4. In the event of unauthorised participation in an examination, the Board of Examiners may declare the result invalid.

Article 15 - Withdrawal from examinations

1. Students can withdraw from an examination through the education information system Osiris up to three calendar days before the examination.
2. Any student who has withdrawn from an examination should re-register on a subsequent occasion, in accordance with the provisions of Articles 13 and 14.

Paragraph 5 – Examinations at TU Delft

Article 16 - Form of the examinations and the manner of testing in general

1. Examinations (oral, written or otherwise) are taken in the manner described in the appendix. In the event of unforeseen circumstances or measures, the Board of Examiners may determine that the manner prescribed may be deviated from. If an examination is taken using online proctoring, this takes place in accordance with the TU Delft Online Proctored Examination Regulation.
2. The study guide contains a description of the moments at which and the numbers of times that examinations can be taken, along with their frequency, without prejudice to the provisions of these regulations concerning written and oral examinations, as described in Article 17.
3. A student may participate in an examination for a course no more than twice in one academic year, with the understanding that registration for an examination without timely withdrawal counts as participation.
4. In special cases, the Board of Examiners may deviate from the provisions of the above sections 1 to 3 in favour of the student.
5. Well before a written examination, the examiner will give the students the opportunity to familiarise themselves with representative sample questions and the criteria by which they will be assessed. The teacher or examiner will provide accompanying guidelines for the way in which the sample questions are answered.

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Article 17 - Times and number of examinations

1. Two opportunities to take written examinations will be offered each academic year. The previous provision applies equally to assessments other than written examinations unless this cannot be reasonably demanded of the programme. In those cases, a different option will be provided, if possible. Participation in this may be subject to additional requirements. The times in which the examinations can be taken are:
   - at the end of the teaching period in which the course is taught, and
   - in the fifth week or at the end of the next teaching period or during the summer resit period according to the TU Delft academic calendar.

2. An annual timetable is issued detailing when examinations may be taken, and it is published before the start of the relevant teaching period.

3. Contrary to the provisions in Section 1, the opportunity to take the examination for a course that is not taught in a certain academic year must be given at least once in that year.

4. Contrary to the provisions of Section 1, two opportunities to sit an examination will be offered for discontinued courses in the academic year following the year in which the course was last taught. Both opportunities are in the academic year following the one in which the course was last taught.

5. In exceptional cases, the Joint Board of Examiners may permit more than two opportunities in a year for certain examinations.

Article 18 - Oral examinations

1. For oral examinations, no more than one student shall be tested at a time, unless determined otherwise by the Board of Examiners.

2. Oral examinations shall not be public, unless the Board of Examiners has decided otherwise. In deviation from this first clause, a final presentation is given publicly except in special cases in which the Board of Examiners has decided otherwise, whether or not at the request of the student.

3. The oral examination is administered by at least two examiners. In the event of unforeseen circumstances or measures, the Board of Examiners may determine that the oral examination be administered by a single examiner, in which case - provided the student consents - an audio and/or video recording of the oral examination will be made.

Article 19 - Determination and announcement of results

1. The examiner determines the result of a written examination as quickly as possible but by no later than 15 working days after the examination. The results of written interim examinations shall be announced no later than five working days before the next written interim examination.

2. The examiner determines the result of an oral examination as quickly as possible but no later than 15 working days after it is administered. The student will be notified with a written statement (e.g., e-mail) of this result.

3. The examiner records the results of the assessment of a practical exercise as quickly as possible, but no later than 15 working days after the completion of the practical exercise at the designated time. In the education information system Osiris, the result will be dated on the date of completion of the practical exercise. With regard to a series of practical exercises in which the knowledge acquired in a previous practical exercise is important to the subsequent practical exercise, the result of the previous practical exercise shall be announced before the subsequent practical exercise. If this is not possible, the examiner shall schedule a timely discussion of the previous practical exercise.

4. The examiner is responsible for the registration and publication of the results in the education information system Osiris, with observance of the student's privacy. When the result of an examination is announced, the student is informed about the right of perusal as stipulated in Article 20 as well as about the possibility of appealing to the Examinations Appeals Board.

5. Contrary to the previous provisions, results for examinations administered in the last regular examination period, as well as for resits from the first year of the BSc taken during the resit period, shall be determined, registered, and published by no later than the Friday following the final week of this examination period.

6. If special circumstances prevent the examiner from registering the results on time, the examiner will report this to the Board of Examiners, accompanied by reasons, and notify the students and student administration as quickly as possible.

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Article 20 - Right to inspect results

1. Upon request, students will have the right to inspect their assessed work during a period of at least 20 working days after the announcement of the results of a written examination or the assessment of a practical exercise. During the inspection of the assessed work, it is not permitted to copy the underlying examination questions in any way. Students intending to appeal against the assessment of their work will be issued with a copy of the assessed work.

2. During the period mentioned in Section 1, all students who have participated in the examination can become acquainted with the questions and assignments of the relevant examination, as well as with the standards that form the basis of the assessment.

3. The examiner can determine that the inspection or cognizance intended in Sections 1 and 2 will take place at a pre-established place and at a pre-established time.

4. Students proving that they were unable to appear at such an established place and time because of circumstances outside of their control will be offered another possibility, if possible within the period mentioned in Section 1. The place and times mentioned in the first sentence will be made known in good time.

Article 21 - Discussion of the results of examinations

1. Students who have taken a written examination or who have received the assessment of a practical exercise can ask the relevant examiner for a discussion of the results during a period of 20 working days after the announcement of the results. The discussion will take place within a reasonable period, at a place and time to be determined by the examiner.

2. At the request of the student or at the initiative of the examiner, a discussion justifying the assessment will take place between the examiner and the student as soon as possible after the announcement of the result of an oral examination. During the discussion of the assessed work, it is not permitted to copy the underlying examination questions in any way.

3. If a collective discussion is organised by the examiner, students may submit requests as referred to in section 1 only if they have been present at the collective discussion and have motivated their requests, or if they were unable to be present at the collective discussion because of circumstances outside their control.

4. The Board of Examiners may allow deviation from the provisions in Sections 2 and 3.

Article 22 - Period of validity for examinations

1. The period of validity of the results of an examination is indefinite. The Dean can restrict the period of validity of a successfully completed examination only if the knowledge or insight that was examined has become outdated or if the skills that were examined have become outdated.

2. In cases involving a limited period of validity based on the first section, the period of validity shall be extended at least by the duration of the acknowledged delay in studies, based on the TU Delft Profiling Fund Scheme.

3. In individual cases involving special circumstances, the Joint Board of Examiners can extend periods of validity that have been limited based on the first section or further extend periods of validity that have been extended based on the second section.

4. If a course consists of interim examinations, the period of validity of the interim examination for which no credits are assigned shall be restricted to a time period stated in the study guide.

Article 23 - Exemption from an examination or obligation to participate in a practical exercise

1. After having obtained recommendations from the relevant examiner, the Board of Examiners may grant exemptions to students:
   a. who have successfully completed an examination or degree audit in a system of higher education within or outside the Netherlands that corresponds to the examination for which the exemption has been requested in terms of content and level, or
   b. who demonstrate that they possess sufficient knowledge and skills that have been acquired outside the system of higher education.

2. After having obtained recommendations from the relevant examiner, the Board of Examiners may grant exemption from the requirement to participate in a practical exercise with a view to admission to the related examination, possibly subject to alternative requirements.

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Article 24 - Periods and frequency of degree audits

In principle, the master's degree audit will be carried out once each month by the Joint Board of Examiners. The dates for the meetings of the Board of Examiners shall be published before the beginning of the academic year.

Article 24a - Invalidation of examination

The Board of Examiners is authorised to declare invalid an examination or part thereof if a proper assessment of the knowledge, insight and skills of the student has not proved reasonably possible based on the examination or the part thereof. The Board of Examiners may draw up further rules for this.

Paragraph 6 - Studying with a support need

Article 25 - Adjustments to the benefit of students with a support need

1. Students with a support need means students who are held back due to a functional limitation, disability, chronic illness, psychological problems, pregnancy, young parenthood, gender transition, or special family circumstances, for example in relation to informal care. Upon a written and substantiated request to that effect, students with a support need may be eligible for adjustments in teaching and examinations. These adjustments are coordinated to the situations of the students as much as possible, but they may not alter the quality or level of difficulty of a course or the study programme. Facilities to be provided may include modifications to the form or duration of examinations and/or practical exercises to suit individual situations or the provision of practical aids.

2. Requests as mentioned in Section 1 must be accompanied by a recent statement from a physician or psychologist or, in cases involving dyslexia, from a testing office registered with BIG, NIP or NVO. If possible, this statement should include an estimate of the extent to which the condition is impeding the student's academic progress.

3. Decisions concerning requests for adjustments relating to educational facilities are taken by the Dean or by the Director of Studies on the Dean's behalf. Decisions concerning adjustments relating to examinations are taken by the Joint Board of Examiners or by the academic counsellor on behalf of the Joint Board of Examiners.

4. Adjustments to examinations can involve the following or other matters:
   - form (e.g., replacing a written test with an oral test or vice versa, testing the required material in the form of interim examinations or granting exemptions to the attendance requirement);
   - timing (e.g., additional time for an examination, wider spreading of examinations across the examination period, granting exemptions to admission requirements or extending the period within which a component must be completed);
   - aids permitted during testing (e.g., English-Dutch dictionaries for students with dyslexia);
   - location (taking the examination in a separate, low-stimulus space).

5. Adjustments in educational facilities could include:
   - providing modified furniture in teaching and examination spaces;
   - providing special equipment (e.g. magnification or Braille equipment for students with visual impairments and blindness or loop systems and individual equipment for students with hearing impairments and deafness);
   - providing more accessible course material;
   - providing special computer facilities (e.g. speech-recognition or speech-synthesising software);
   - providing a rest area.

Paragraph 7 - Study support

Article 26 - Study support and Monitoring of student progress

1. The Dean is responsible for providing individual study supervision to students registered for the degree programme, partly for their orientation towards potential study options within and outside the degree programme. The Dean will also ensure that effective support and supervision is provided to students in making choices related to their studies.

2. The examination and study programme applying to each student is documented in the education information system Osiris.

3. The Student Administration is responsible for ensuring that all students are able to review and check their results in the education information system Osiris student-information system.

Paragraph 8 - Final provisions

Article 28 - Conflicts with the regulations

In the case of conflict between provisions in the study guide or other document concerning the relevant teaching and examination education and study programme and these regulations, the provisions of these regulations shall take precedence.

Article 29 - Amendments to the regulations

1. Amendments to these regulations are adopted separately by the Dean.

2. Amendments that are applicable to the current academic year will be made only if they would not reasonably damage the interests of students and may not lead to disadvantageous changes to any decisions that have been made with regard to individual students.

3. In the event of unforeseen circumstances or measures, the Dean may decide to deviate from these regulations, including the actual form of the education and any compulsory attendance requirements. This also means that the provisions in the study guide may be deviated from.

Article 30 - Transitional measures

1. If the composition of the degree programme undergoes substantive changes, transitional measures will be established and published through the Dean. Transitional measures can be found in the Annex to this TER.

2. These transitional measures shall include at least the following:
   a. an arrangement regarding exemptions that may be obtained based on examinations that have already been passed;
   b. the period during which the transitional arrangement shall be valid.

3. Students shall follow the degree programme as it applied or applies during the first academic year of their enrolment, unless components of the programme are no longer offered. In such cases, students must transfer according to the applicable transitional measures. Deviations require the approval of the Joint Board of Examiners. Before submitting a request to this end, the student must have first obtained recommendations from an academic counsellor.

4. If a course within a degree programme is cancelled, four additional opportunities for taking the examination in this course shall be offered after it has been taught for the last time: the examination at the end of the teaching of the course, a resit in the same academic year and two resits in the following academic year.

Article 31 - Announcement

1. The Dean is responsible for ensuring a suitable announcement of these regulations and any amendments to them.

2. In any case, the Teaching and Examination Regulations are to be posted on the programme’s website.

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Article 32 - Entry into force

These regulations shall enter into force on 1 September 2023.

Adopted by the Dean of the faculty on August 15th 2023.

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Appendix TER MSc Applied Geophysics

Appendix to Article 2 of the TER for the master's degree programme applied geophysics

relevant websites

General programme information page

https://idealeague.org/geophysics/

programme rules and regulations documents and academic schedule

https://idealeague.org/logistics-and-organisation/

Student portal with links to relevant regulations, e.g.,

- Student Charter,
- Privacy statement online proctoring,
- Code of Ethics,
- Online Proctored Examination Regulation etc.
- Admission of (international) students

» https://www.tudelft.nl/en/student

Rules & Regulations of the Board of Examiners

» https://www.tudelft.nl/studenten/faculteiten/citg-studentenportal/onderwijs/onderwijsinformatie/educationalrules-and-regulations/

Board of Examiners general website

» https://www.tudelft.nl/studenten/faculteiten/citg-studentenportal/organisatie/board-of-examiners-ceg/

Wet op het hoger onderwijs en wetenschappelijk onderzoek (WHW)

» https://wetten.overheid.nl/BWBR0005682/2019-02-01

Examination Appeals Board

» https://www.tudelft.nl/en/student/legal-position/central-complaints-desk-for-students/objections-and-appeals

Studying with a disability

» https://www.tudelft.nl/en/student/counselling/studying-with-a-disability

Appendix to Article 3 of the Model TER (for Master's degree programmes)

Language level Dutch-language bridging programmes for individuals holding another Bachelor's degree university education (b) or a higher professional education degree (c)

The Dutch language:
By successfully passing a Dutch examination at the following level:
- GCE A Level
- Algemeen Secundair Onderwijs (ASO)
- European Baccalaureate (EB)
- Suriname VWO
- International baccalaureate (IB)
- Baccalaureate Series S

By successfully completing:
- The complete Dutch course from the TU Delft Centre for Languages and Academic Skills; or
- The NT2-II certificate and the professional language course of the TU Delft Centre for Languages and Academic Skills.

Language level for individuals holding a higher professional education degree (c)

The following candidates are exempted from the English language test requirement:
- Students with a Bachelor's degree from a Dutch university
- Students with a VWO diploma or VWO English certificate
- Students with an HBO (University of Applied Sciences) degree from a degree programme taught entirely in English
- Students who hold the nationality of one of the following countries: USA, UK, Ireland, Australia, New Zealand or Canada

Sufficient competence in the English language can be demonstrated by passing one of the following tests:
- TOEFL iBT (Test of English as a Foreign Language internet-Based Test) with an overall band score of at least 90
- IELTS (academic version) with an overall band score of at least 6.5
- Cambridge Assessment English:
  - C1 Advanced (Certificate of Advanced English) with an overall score of at least 176.
  - C2 Proficiency (Certificate of Proficiency in English) with an overall score of at least 180.

If a bridging programme needs to be completed before a candidate can be admitted to a Master's programme, the certificate should be obtained before the start of the bridging programme.

Language level for holders of a non-Dutch diploma (d)

Competence in the English language as demonstrated by passing one of the following tests:
- TOEFL iBT (Test of English as a Foreign Language internet-Based Test) with an overall band score of at least 90 and a minimum score of 21 for each section
- IELTS (academic version) with an overall band score of at least 6.5 and a minimum score of 6,0 for each section
- Cambridge Assessment English:
  - C1 Advanced (Certificate of Advanced English) with an overall score of 176 and a minimum score of 169 for each section.
  - C2 Proficiency (Certificate of Proficiency in English) with an overall score of 180 and a minimum score of 169 for each section

Certificates more than two years old will not be accepted.

The following candidates are exempted from the English language test requirement:
- Students who hold the nationality of one of the following countries: USA, UK, Ireland, Australia, New Zealand or Canada;
- Students who hold a Bachelor's degree from one of the above countries;

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Appendix to Article 5 of the TER for the master's degree programme applied geophysics

Intended learning Outcomes of the programme.

The objectives of the programme have been translated into a coherent set of intended learning outcomes (ILOs). The graduates can:

1. Explain, discuss, and use fundamental scientific knowledge about wavefield, diffusive-field and potential-field methods of applied geophysics.
2. Design and conduct scientifically sound geophysical experiments, process the collected data, and analyse and interpret the processed results.
3. Develop and use mathematical models to simulate, process, and invert geophysical data and solve related subsurface characterisation and monitoring problems.
4. Perform a literature study, identify a knowledge gap in a topic in applied geophysics, formulate a research question, and build on existing knowledge in relevant fields that are required to solve the stakeholders' problems.
5. Improve methodologies for applied geophysics that drive technological innovations to improve the responsible and sustainable use of the Earth's subsurface.
6. Observe, characterise, and explain Earth system processes related to application areas of applied geophysics.
7. Challenge existing knowledge, show a constructive critical attitude, propose novel and creative solutions, and exercise independent judgement.
8. Use written and oral communication skills to effectively exchange information and ideas with scientists and engineers, the public, and other stakeholders in the field of applied geophysics.
9. Initiate, design, plan, and monitor a project to meet the requirements set by the stakeholder.
10. Work effectively in teams of diverse expertise, talents, skills, characters, and cultures.
11. Acquire new knowledge and skills to continue operating effectively.
12. Uphold and evaluate ethical standards for scientific integrity and evaluate societal and economic trade- offs and relevant ethical issues when developing technological innovations.

The ILOs are in line with the second-cycle education level as set out in the Framework for Qualifications of the European Higher Education Area1 and with the national Frameworks for master's degrees in The Netherlands, Germany, and Switzerland. The ILOs are formulated to reflect the expected level of Master of Science graduates to receive the degree certificate of the programme.

Appendix to Article 6 of the TER for the master’s degree programme applied geophysics

The degree programme and its courses.
The curriculum of the study programme is structured by semester, and all students study together as a group at one of the partner universities during each of the first three semesters. The general setup is shown in Figure 1. The programme consists of programme modules and an individual research project which leads to the master thesis report. It has been designed to ensure that students achieve the ILOs upon completing the programme. An overview of the coverage of the ILOs in the modules is given in Appendix 4.

Table 1 shows the recommended programme and for each module the ILOs that are assessed. Mandatory modules are given in boldface. The entire list of modules with number of credits and the ILOs that are assessed, and which are available to students in the programme, is given below this table.

Semester	Module	EC	ILOs
1 TUD	**Field Geophysics with Data Analysis and Exercises**	6	1,2,3,8,10
	Advanced Reflection Seismology and Seismic Imaging	6	1,2,3
	Electromagnetic Exploration Methods	6	1,2,10
	Seismic Acquisition to Data-Information Content	6	1,2,3,8,10
	Geophysics Special Subjects	6	1,4,7,8
	See Appendix 5.1 for other electives		
2 ETH	**Reflection Seismology Processing**	5	1,3
	Numerical Modelling for Applied Geophysics	4	1,3
	Inverse Theory for Applied Geophysics I: Basics	3	3
	Geophysical Fieldwork and Processing	9	1,2,3,4,6,8,9,10,11,12
	Case Studies in Exploration and Environmental Geophysics	3	1,4,8
	Geothermal Energy	3	3,6
	Geofluids	6	1,3,6
	Inverse Theory for Applied Geophysics II: Applications	3	1,3
	Computational Methods in Seismic Data Analysis and Imaging	6	3
	See Appendix 5.2 for other electives		
3 RWTH Choose at least three from six	**Geophysical Logging and Log Interpretation**	6	1,2,3,4,5,7,10
	Application of Geophysical Prospecting Methods in Earth and Environmental Science	6	1,2,3,4,7,10
	Petrophysics for Applied Geophysics	6	2,**3**,8,10,11
	Numerical Reservoir Engineering	6	1,3,4,5,**6**,11
	Hydrogeophysics and Engineering Geophysics	6	**1**,**2**,4,7,8,9,10,11
	Research Module	6	4,7,8,9,10,11,**12**
	Machine Learning	6	4,5,7,8
	Economics of Technological Diffusion	6	8,9,11,12
	Petroleum Systems	6	3,6,7,8,10,11
	Planning and Management of Georesources	6	4,6,8,9,10
	Specialization in Methods and Applications of Applied Geosciences	6/9	4,5,6,7,10
	Plate Tectonics	6	6,7,8,11,12
	Underground Excavation	6	5,6,8,9
	Finite Elements in Fluids	6	1,3,5,6
	See Appendix 5.3 for other electives		
4	**Master Thesis Project**	30	**4,5,7,8,9,10,11**

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Module Descriptions Applied Geophysics TU Delft

Module	Electromagnetic Exploration Methods (JMAG100)
Credits	6 EC
Module manager(s)	Prof.dr.ir. E.C. Slob
Education Period	2
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,10**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students can: LO1. derive equations for electromagnetic wave, diffusive and potential fields from Maxwell's equations. (ILO: 1) LO2. explain and describe the physics underlying characteristics of electromagnetic fields. (ILO: 1) LO3. relate the physics of a method to acquisition design. (ILO: 1,2) LO4. describe data processing techniques on computed or acquired data. (ILO: 2) LO5. interpret expressions of wave and diffusive fields. (ILO: 1) LO6. explain why and under what circumstances a buried anomalous layer can be detected from diffusive field measurements. (ILO: 2) LO7. derive, explain, and use volume imaging technology as a GPR data filtering technique. (ILO: 2) LO8. describe geo-electric arrays and their design based on the desired subsurface current distribution. (ILO: 2) LO9. work in varying groups of 2 and solve problems together. (ILO: 10)
Professional and personal skills	self-study, studying with other students, deriving new equations, carrying out systematic analysis, understanding the underlying physics of mathematical expressions.
Module Content	The theory of electromagnetic fields and waves is described for electromagnetic geophysical methods for subsurface exploration and monitoring of subsurface processes. A distinction is made between potential, diffusive and wave fields. Point source-receiver response functions are derived in wavenumber-frequency, space-frequency and space-time domains. In the direct current (DC) method two electrodes are used to generate a current in the ground and between two other electrodes the electric potential difference is measured. Depending on the electrode configuration the apparent resistivity is computed as the basis of inversion. The current distribution is optimised in a desired depth range by choice of electrode distance. In the marine use of the controlled source electromagnetic (CSEM) method a horizontal electric dipole source is used, and the horizontal electric field components are measured together with the magnetic field vector. This configuration is also used on land. On land, other sources can be magnetic dipoles that are on the surface or in the air. The basic model is the same as for the DC method, but here to study the ability to detect a buried anomalous layer. Both time-domain and frequency domain methods are discussed. Ground-penetrating radar (GPR) uses electric antennas as source and receiver. Most applications acquire single-offset data. The model underlying data interpretation and imaging is scattering by a subsurface object. The expressions for the understanding of GPR data and creating a subsurface

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Module	Electromagnetic Exploration Methods (JMAG100)
	image is discussed in detail. Theoretical and practical aspects of acquisition and processing for DC, CSEM and GPR methods are discussed and evaluated.
Form of instruction	Lectures, exercises, homework
Literature and study materials	Course notes, lectures, and other materials are available on Brightspace, including old exams and a literature list is given in the lecture notes
Formative assessment (feedback)	Weekly homework assignments to be done in groups of two with feedback in class.
Summative assessment on module level	Assignment (done at home) followed by oral exam. Evaluation of answers to assignment (25%) and performance during oral exam (75%).

Module	Geophysics Special Subjects (JMAG121)
Credits	6 EC
Module manager	Dr.ir. D. Draganov
Education Period	2
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,4,7,8**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students can: LO1. Derive a unified equation for acoustic, electromagnetic, and other wave and diffusion phenomena. (ILO: 1) LO2. Use operator theory to derive symmetry properties of the unified two-way wave equation. (ILO: 1) LO3. Use these symmetry properties to derive unified two-way wavefield reciprocity theorems. (ILO: 1) LO4. Use these unified reciprocity theorems to derive unified two-way wavefield representations. (ILO: 1,2) LO5. Use pseudo-differential theory to derive a symmetric unified one-way wave equation. (ILO: 1) LO6. Use symmetric one-way wave equation to derive unified one-way wavefield reciprocity theorems. (ILO: 1) LO7. Use these unified reciprocity theorems to derive unified one-way wavefield representations. (ILO: 1,2) LO8. Use the acquired knowledge to analyse and evaluate a recent advanced geophysical method. (ILO: 4,7,8)
Professional and personal skills	Very good mathematical and physical insight
Module Content	The module aims at bringing the students' understanding of wave theory to a higher level and teaches them to analyse and evaluate geophysical methodologies in terms of the underlying theory. The course treats in a systematic way the unification of different types of wave equations, decomposition, reciprocity, and representation theorems. Moreover, it is explained how these concepts underlie a number of current advanced geophysical methods, such as seismic interferometry, time-lapse seismic, internal multiple elimination etc. (these subjects may change from year to year, hence the name Geophysics Special Subjects). The students are required to select a paper from the current geophysical literature, analyse and evaluate it, and discuss it via an oral presentation with the lecturer and their fellow students.
Form of instruction	Lectures

Module	Geophysics Special Subjects (JMAG121)
Literature and study materials	Lecture notes, provided by the lecturer
Formative assessment (feedback)	
Summative assessment on module level	Written examination (50%), plus presentation of a paper on a current topic in geophysics (50%)

Module	Advanced Reflection Seismology and Seismic Imaging (JMAG111)
Credits	6 EC
Module manager(s)	Dr. C. Weemstra
Education Period	1
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,3**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students can: LO1. Derive the linearized acoustic wave equation from conservation laws and constitutive equations. (ILO: 1) LO2. Derive 3D spherical- and plane-wave solutions and explain the space-time behaviour of these waves. (ILO: 1) LO3. Explain the difference between homogeneous and inhomogeneous plane waves. (ILO: 1) LO4. Explain the space-time Fourier transform as a decomposition of waves into plane waves. (ILO: 1) LO5. Derive the matrix form of the two-way wave equation in wavenumber-frequency domain. (ILO: 1) LO6. Derive decomposition operators to decompose the two-way wavefield into down- and upgoing waves. (ILO: 1) LO7. Decompose the two-way wave equation into a coupled system of one-way wave equations. (ILO: 1) LO8. Derive forward extrapolation operators for down- and upgoing waves in wavenumber-frequency domain. (ILO: 1,3) LO9. Derive inverse extrapolation operators for down- and upgoing waves in wavenumber-frequency domain. (ILO: 1,3) LO10. Derive reflection and transmission operators in wavenumber-frequency domain. (ILO: 1,3) LO11. Derive and explain Rayleigh's reciprocity theorem in space-frequency domain. (ILO: 1) LO12. Use Rayleigh's reciprocity theorem to derive convolution- and correlation-type wavefield representations. (ILO: 1) LO13. Use convolution-type wavefield representations to derive forward extrapolation in space-frequency domain. (ILO: 1,2) LO14. Use correlation-type wavefield representations to derive inverse extrapolation in space-frequency domain. (ILO: 1,2) LO15. Combine extrapolation, reflection and decomposition operators into forward model of seismic data. (ILO: 1,2,3) LO16. Derive decomposition, multiple elimination and imaging schemes from forward model of seismic data. (ILO: 1,2,3)
Professional and personal skills	Good mathematical and physical insight
Module Content	The module starts with the fundamentals of seismic wave theory, which covers the propagation of waves through homogeneous and inhomogeneous media, decomposition of waves into downgoing and upgoing wave fields, and reflection of waves at interfaces between layers with

Module	Advanced Reflection Seismology and Seismic Imaging (JMAG111)
	different geological properties. Next, it discusses more advanced concepts like Rayleigh's reciprocity theorem, Green's functions and wave field representations, from which forward and inverse wave field extrapolation algorithms are derived. Finally, these concepts are used together to derive a systematic forward model of seismic reflection data and it is shown how seismic imaging and multiple elimination can be derived by applying the inverse of this model to the seismic data.
Form of instruction	14 two-hour lectures. The other hours are used for self-study and preparation for the exam.
Literature and study materials	"Elastic wave field extrapolation" by C.P.A. Wapenaar and A.J. Berkhout (1989, Elsevier). Available at the lecturer.
Formative assessment (feedback)	
Summative assessment on module level	Written exam counting for 100% of the grade

Module	**Seismic Acquisition to Data Information Content (JMAG120)**
Credits	6 EC
Module manager(s)	Dr. R. Ghose
Education Period	2
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,3,8,10**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students can: LO1. link the important steps, starting from understanding the underlying physics through seismic data acquisition in field to data processing and interpretation, to the extraction of subsurface structural and property information. (ILO: 1,2) LO2. plan and design a seismic survey that enables optimal imaging and characterization of the subsurface. (ILO: 2) LO3. do essential processing of seismic reflection data for subsurface imaging. (ILO: 2) LO4. use in a judicious manner seismic body waves for subsurface property estimation. (ILO: 3,8,10) LO5. use normal- and oblique-incidence seismic reflection amplitude for property estimation and monitoring. (ILO: 2,3) LO6. analyse the vertical and lateral resolvability, given a seismic reflection signal of a certain bandwidth. (ILO: 2,3) LO7. enhance and optimize seismic resolution through proper selection of acquisition parameters, filtering, to advanced data processing. (ILO: 2,3)
Professional and personal skills	Self-studying skill, knowledge and skills in mathematics and physics, basic MATLAB.
Module Content	The aim of this module is to provide the students the essential knowledge-base and practical insights on the reasons behind and on how to extract information of subsurface structure/heterogeneities and material properties, with desired details/resolution, from exploration seismic data acquired in the field. The module starts with introducing the basic principles and concepts underlying exploration-seismic data acquisition and data processing, focusing on obtaining the structural information of the subsurface. Next, the physics behind the sensitivity of seismic body waves to subsurface material properties and the use of normal-incidence and angle-dependent reflection coefficients are discussed. In the second part of this course, the key issues related to seismic resolution, which include thin-bed resolution, tuning effect and interference, and the spectral properties of the earth affecting resolution, are considered. Challenges in extending the seismic bandwidth, means to address these challenges, and some prevalent approaches to optimize seismic resolution and achieve information with sub-seismic resolution are discussed using synthetic- and field-data examples.

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Module	Seismic Acquisition to Data Information Content (JMAG120)
Form of instruction	15 two-hour lectures and problem-solving, and 5 two-hour MATLAB sessions. The other hours are used for self-study, MATLAB exercises, and preparation for the exams
Literature and study materials	Illustrative slides used in the lecture, limited lecture notes, published articles, and Matlab codes
Formative assessment (feedback)	
Summative assessment on module level	Two exams (in the middle (30%) and at the end (50%)) and presentation of published articles (20%)

Module	**Field Geophysics and Signal Analysis with Exercises (JMAG110)**
Credits	6 EC
Module manager(s)	Dr. Ir. D.S. Draganov
Education Period	1
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,3,4,8**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students can: LO1. describe what an LTI system is and what consequences that has on signal analysis. (ILO: 1) LO2. demonstrate how the notion of distributions helps in applying the principle of superposition. (ILO: 1) LO3. describe the Laplace and the temporal Fourier transformations and their properties and derive impulse-response transform pairs. (ILO: 1) LO4. describe the discrete Fourier transformation and the effect of sampling. (ILO: 1) LO5. perform simple field measurements using DC resistivity, diffusive field EM, GPR, seismic refraction techniques. (ILO: 2) LO6. make basic interpretation of the data from the four methods. (ILO: 2,4) LO7. explain a measurement in terms of the convolutional model. (ILO: 1) LO8. derive the norm of a signal and the energy in a signal and explain the difference between convolution and correlation. (ILO: 2) LO9. give physically meaningful interpretations of impulse responses in various transformed domains. (ILO: 4) LO10. explain how signals should be sampled and give the conditions for perfect reconstruction. (ILO: 2) LO11. conceptualize and translate scientific problems into (clear/well-structured) programmable workflow. (ILO: 8) LO12. translate a programmable workflow into a MATLAB code. (ILO: 3) LO13. find code or algorithmic errors in a MATLAB code and correct them. (ILO: 3) LO14. make and use your own functions in MATLAB. (ILO: 3) LO15. use 2D and 3D graphical visualization in MATLAB in insightful and clear ways. (ILO: 3)
Professional and personal skills	Self-study, working in groups, presentation
Module Content	The course provides first-year MSc students of Applied Geophysics with hands-on experience with some basic exploration methods, working knowledge of signal theory for signals in linear time-invariant systems, and working knowledge of the programming language MATLAB. The course is also meant to serve as a refresher of basic computer-programming skills.
Form of instruction	Week 1 – unsupervised methods study and data processing; one hour supervised data processing; one day of fieldwork; week 2 to 7 – three hours lectures, three hours supervised signal-analysis exercises, two hours supervised Matlab lecture/exercises, two hours unsupervised Matlab exercises; week 8 – two hours supervised Matlab lecture/exercises. Blended education. Computer exercises.

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Module	Field Geophysics and Signal Analysis with Exercises (JMAG110)
	Lectures and exercises can be online or on-campus. In case of online education, Zoom will be used.
Literature and study materials	Field geophysics – course reader available on Internet; Signal Analysis and Matlab: course readers and all other learning materials are available on Brightspace.
Formative assessment (feedback)	
Summative assessment on module level	Presentation of results for Field Geophysics (online or in-campus); final assignment for Matlab (done at home, submitted digitally); assignment (done at home) followed by oral examination for Signal Analysis (online or in-campus). Final grade calculation: - "Passed" required for Field Geophysics; - 5/9 written exam Signal Analysis; - 4/9 final assignment Matlab.

Module Descriptions Applied Geophysics ETH Zurich

Module	**Reflection Seismology Processing** (651-4079-00L)
Credits	5 EC
Module manager(s)	D.-J. van Manen
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,3,10**
Learning objectives module, including the link to the ILO(s) in brackets	Application of theoretical knowledge acquired in previous courses to the processing of a seismic data set and an extensive introduction to commercial processing software. After completion of this module the students are able to: LO1. Apply theoretical knowledge acquired in previous courses on seismic wave propagation and signal processing (ILO 1) LO2. Process a seismic data set in a team (ILO 1,3,10) LO1. Use a commercial seismic processing software (ILO 3)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Collaboration with peers; Application of theory to new situations; Data analysis
Module Content	Keywords: data conversion, amplitude reconstruction, filtering (in time and space), geometry assignment, static corrections, velocity analyses, normal-moveout (NMO) corrections, deconvolution, stacking, migration, interpretation.
Form of instruction	Lectures and exercises
Literature and study materials	Access to commercial processing software manuals and Yilmaz's (2001) textbook "Seismic Data Analysis"
Formative assessment (feedback)	
Summative assessment on module level	Written exam (100%)

Module	**Case Studies in Exploration and Environmental Geophysics** (651-4087-00L)
Credits	3 EC
Module manager(s)	H. Maurer, M. Hertrich, J. Robertsson, M. O. Saar, T. Spillmann
Education Period	Q3-Q4 (spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,4,8**
Learning objectives module, including the link to the ILO(s) in brackets	This course is set up for both, geophysicists and non-geophysicists. The former will become familiar with applications of geophysical methods, for which they have learned the underlying theory in other courses. Non-geophysicists (i.e., potential users of geophysical technics, such as geologists and geotechnical engineers) will learn, which geophysical method or which combination of geophysical methods can be used to solve a particular in their realm. The main learning goal for both groups is to understand the benefits and limitations of geophysical techniques for important applications, such as exploration problems, waste disposal, or natural hazards. After completion of this module the students are able to: LO1. Explain and discuss the strengths and weaknesses of different geophysical methods for important applications (ILO: 1) LO2. Perform a literature study and present to peers (ILO: 4,8)
Professional and personal skills	Analytical thinking; Problem-based learning; Collaboration with peers; Ethical reflection/consideration.
Module Content	This course focuses on benefits and limitations of geophysical methods applied to problems of high societal relevance. It is demonstrated, how seismics, ground-penetrating-radar and other electromagnetic methods can be employed in geothermics, the cryosphere, hydrocarbon exploration, natural hazard assessments and radioactive waste disposal problems. During the first part of the course, various themes will be introduced, in which geophysical methods play a key role. Module 1 (25.2./4.3): Geothermal Energy (M. Saar) Module 2 (11.3.): Natural Hazards (H.R. Maurer) Module 3 (18.3.): Cryosphere Applications (H.R. Maurer) Module 4 (25.3./1.4.): Radioactive Waste Disposal (T. Spillmann) Module 5 (15.4.): Marine Seismics (J. Robertsson) Module 6 (22.4.): Hydrocarbon Exploration (Fons ten Kroode) During the second part of the course, we will focus on Deep Underground Laboratories. They offer exciting opportunities for research associated with many themes covered in Modules 1 to 6. This block starts with an introductory lecture (29.4.), followed by visits of the three main Deep Underground Laboratories in Switzerland: 6.5: Bedretto Laboratory 20.5.: Mont Terri Laboratory

Module	**Case Studies in Exploration and Environmental Geophysics** (651-4087-00L)
Form of instruction	Lectures, excursions
Literature and study materials	Course material will be provided in the teaching repository associated with this course.
Formative assessment (feedback)	
Summative assessment on module level	Active participation of the students will be required. Prior to the laboratory visits, the students must familiarize themselves with one experiment (in total, not per laboratory), and they will introduce this experiment during the visit to their fellow students. Finally, a short report on the experiment assigned will have to be written. Presentation and report will contribute 50% to the final grade. The remaining 50% of the final grade will be earned during a project work on June 3. The students will receive a small project out of the themes of Modules 1 to 6. During a few hours, they will work independently on the project, and they have to summarize their results in a short report.

Module	**Numerical Modelling for Applied Geophysics** (651-4094-00L)
Credits	4 EC
Module manager(s)	J. Robertsson, H. Maurer
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,3**
Learning objectives module, including the link to the ILO(s) in brackets	After this course students should have a good overview of numerical modelling techniques commonly used in environmental and exploration geophysics. Students should be familiar with the basic principles of the methods and how they are used to solve real problems. They should know advantages and disadvantages as well as the limitations of the individual approaches. The course includes exercises in Matlab where the students both should learn, understand and use existing scripts as well as carrying out some coding in Matlab themselves. After completion of this module the students are able to: LO1. Explain and use the most common numerical methods in applied geophysics (ILO: 1) LO2. Describe the main advantages, disadvantages and limitations of common numerical methods (ILO: 3) LO3. Design applications of numerical tools to common problems (ILO: 3)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Application of theory to new situations using relevant equations; Data analysis
Module Content	The following topics are covered: - Applications of modelling - Physics of acoustic, elastic, viscoelastic wave equations as well as Maxwell's equations for electromagnetic wave propagation and diffusive problems - Recap of basic techniques in signal processing and applied mathematics - Solving PDE's, boundary conditions and initial conditions - Acoustic/elastic wave propagation I, explicit time-domain finite-difference methods - Acoustic/elastic wave propagation II, Viscoelastic, pseudospectral - Acoustic/elastic wave propagation III, spectral accuracy in time, frequency domain FD, Eikonal - Implicit finite-difference methods (geoelectric) - Finite element methods, 1D/2D (heat equation) - Finite element methods, 3D (geoelectric) - Acoustic/elastic wave propagation IV, Finite element and spectral element methods Most of the lecture modules are accompanied by exercises. Small projects will be assigned to the students. They either include a programming exercise or applications of existing modelling codes.

Module	**Numerical Modelling for Applied Geophysics** (651-4094-00L)
Form of instruction	Lectures and exercises
Literature and study materials	Presentation slides and some background material will be provided. Igel, H., 2017. Computational seismology: a practical introduction. Oxford University Press.
Formative assessment (feedback)	
Summative assessment on module level	Written exam (100%)

Module	**Inverse Theory I: Basics** (651-4096-00L)
Credits	3 EC
Module manager(s)	A. Fichtner
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 3**
Learning objectives module, including the link to the ILO(s) in brackets	The goal of this course is to enable students to develop a mathematical formulation of specific inference (inverse) problems that may arise anywhere in the physical sciences, and to implement suitable solution methods. Furthermore, students should become aware that nearly all relevant inverse problems are ill-posed, and that their meaningful solution requires the addition of prior knowledge in the form of expertise and physical intuition. This is what makes inverse theory an art. After completion of this module the students are able to: LO1. Develop the mathematical formulation of a specific inverse problem (ILO: 3) LO2. Set-up the solution of inverse problems (ILO: 3) LO3. Solve standard inverse problems in geophysics (ILO: 3)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Application of theory to new situations using relevant equations; Data analysis.
Module Content	This first of two courses covers the basics needed to address (and hopefully solve) any kind of inverse problem. Starting from the description of information in terms of probabilities, we will derive Bayes' Theorem, which forms the mathematical foundation of modern scientific inference. This will allow us to formalise the process of gaining information about a physical system using new observations. Following the conceptual part of the course, we will focus on practical solutions of inverse problems, which will lead us to study Monte Carlo methods and the special case of least-squares inversion. In more detail, we aim to cover the following main topics: 1. The nature of observations and physical model parameters 2. Representing information by probabilities 3. Bayes' theorem and mathematical scientific inference 4. Random walks and Monte Carlo Methods 5. The Metropolis-Hastings algorithm 6. Simulated Annealing 7. Linear inverse problems and the least-squares method 8. Resolution and the nullspace 9. Basic concepts of iterative nonlinear inversion methods While the concepts introduced in this course are universal, they will be illustrated with numerous simple and intuitive examples. These will be complemented with a collection of computer and programming exercises.
Form of instruction	Lectures and exercises
Literature and study materials	Presentation slides and detailed lecture notes will be provided.

Module	**Inverse Theory I: Basics** (651-4096-00L)
Formative assessment (feedback)	
Summative assessment on module level	Written Exam and exercises (100%)

Module	**Inverse Theory II: Applications** (651-4096-02L)
Credits	3 EC
Module manager(s)	A. Fichtner, C. Böhm
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,3**
Learning objectives module, including the link to the ILO(s) in brackets	This course provides numerical tools and recipes to solve (non)-linear inverse problems arising in nearly all fields of science and engineering. After successful completion of the class, the students will have a thorough understanding of suitable solution algorithms, common challenges and possible mitigations to infer parameters that govern large-scale physical systems from sparse data measurements. After completion of this module the students are able to: LO1. Understand the strengths and weaknesses of common solution algorithms (ILO: 3) LO2. Find solution strategies for large-scale physical systems and sparse-data measurements (ILO: 1,3) LO3. Use various software solutions to solve common inverse problems (ILO: 3)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Application of theory to new situations using relevant equations; Data analysis.
Module Content	This second part of the course on Inverse Theory provides an introduction to the numerical solution of large-scale inverse problems. Specific examples are drawn from different areas of geophysics and image processing. Students solve various model problems using python and jupyter notebooks, and familiarize themselves with relevant open-source libraries and commercial software. The class discusses several important concepts to solve (non)-linear inverse problems and demonstrates how to apply them to real-world data applications. All sessions are split into a lecture part in the first half, followed by tutorials using python and jupyter notebooks in the second. The range of covered topics include: 1. Regularization filters and image deblurring 2. Travel-time tomography 3. Line-search methods 4. Time reversal and Born's approximation 5. Adjoint methods 6. Full-waveform inversion
Form of instruction	Lectures and exercises
Literature and study materials	Presentation slides and some background material will be provided.
Formative assessment (feedback)	
Summative assessment on module level	Reports on 5 out of 6 projects (100%)

Module	**Geophysical Fieldwork and Processing: Methods** (651-4104-00L)
Credits	2 EC
Module manager(s)	C. Schmelzbach, H. Maurer
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,3**
Learning objectives module, including the link to the ILO(s) in brackets	Students should (1) acquire a basis knowledge on theory and working principles of the most common techniques in Applied Geophysics and (2) acquire the necessary knowledge to plan, conduct, process and document a near-surface geophysics survey. After completion of this module the students are able to: LO1. Explain and use the fundamental knowledge about the most common geophysical methods (ILO: 1) LO2. Analyse and interpret processed geophysical data (ILO: 1,3)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Collaboration with peers; Application of theory to new situations using relevant equations; Data analysis.
Module Content	The 'Methods' part of 'Geophysical Fieldwork and Processing' provides an overview of the most common methods used in Applied Geophysics. Theoretical and conceptual aspects as well as data acquisition and processing of the methods used in the other two parts of the course are introduced. The course is divided into four parts: 1. Introduction to the course held in the lecture hall (first lecture) 2. Online lectures and quizzes covering short reviews of the theory, techniques, acquisition and processing of: - Ground Penetrating Radar (GPR) - Electrical Resistivity Tomography (ERT) - Magnetic Surveying - Electromagnetic Induction Surveying - Seismic Refraction Tomography There will be a questions-and-answers session before the exam. 3. Practical exercise and field equipment demonstration (outdoor; location and date will be communicated during the introduction lecture). Participation in the practical exercise is a requirement. 4. Written examination during the last lecture. A pass in this exam is a REQUIREMENT to continue with the second part of the course 651-4106-03L Geophysical Field Work and Processing: Preparation and Field Work.
Form of instruction	Lecture, computer and field exercises
Literature and study materials	Lecture notes: Available over the ETH online lecture Moodle page. Link will be given during the first lecture. Recommended literature:

Module	**Geophysical Fieldwork and Processing: Methods** (651-4104-00L)
	• An introduction to geophysical exploration. Third Edition. Kearey, Brooks, and Hill, 2002, WILEY-BLACKWELL. ISBN: 978-0-632-04929-5 • Environmental Geology, Handbook of Field Methods and Case Studies. Knödel, Klaus, Lange, Gerhard, Voigt, Hans-Jürgen, Bundesanstalt für Geowissenschaften (Ed.), 2007, XXVI, 1358 p. 501 illus., 243 in color. Hardcover. ISBN: 978-3-540-74669-0 • Fundamentals of Geophysics. William Lowrie, 2nd Edition, Cambridge University Press. ISBN: 9780521675963 Good overview literature: • An Introduction to Applied and Environmental Geophysics. John M, Reynolds WILEY-BLACKWELL. ISBN: 978-0-471-48535-3 More detailed and specific: • Near-Surface Geophysics. Edited by Dwain K. Butler. Society of Exploration Geophysicists (SEG). ISBN: 9781560801306 (13); 1560801301 (10)
Formative assessment (feedback)	
Summative assessment on module level	The final grade is based on a written exam at the end of the course (100%). Exercises (learning tasks/'Lernelemente', voluntary) during the course provide the opportunity to improve the final grade. Completion of all voluntary learning tasks ('Lernelemente') allows to improve the final grade by a maximum of 0.25. The highest grade can also be achieved without completion of the learning tasks ('Lernelemente').

Module	**Geophysical Field Work and Processing: Preparation and Field Work** (651-4106-03L)
Credits	7 EC
Module manager(s)	C. Schmelzbach, P. Nagy, A. Wieser
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 2,3,4,6,8,9,10,11,12**
Learning objectives module, including the link to the ILO(s) in brackets	Students should acquire the knowledge to (1) design and plan a geophysical survey appropriate for the target of investigation, (2) acquire geophysical data, (3) process the data using state-of-the-art techniques and software, (3) analyze and interpret the results, (4) write a report according to commercial and scientific standards. After completion of this module the students are able to: LO1. Design and plan a geophysical survey appropriate for the target of investigation (ILO: 2,4,9,10,11,12) LO2. Conduct a geophysical field campaign and acquire geophysical data (ILO: 2,9,10,11, 12) LO3. Process the data using state-of-the-art techniques and software (ILO: 2,3) LO4. Analyse and interpret geophysical models (ILO: 3,6) LO5. Document geophysical experiments according to commercial and scientific standards. (ILO 4,6,8,10,12)
Professional and personal skills	Critical thinking; Analytical thinking; Problem-based learning; Solving; Collaboration with peers; Data analysis; Advice stakeholders; Ethical reflection/consideration.
Module Content	The 'Preparation' and 'Field Work' parts of 'Geophysical Field Work and Processing' involve the planning and conducting of a near-surface geophysical field campaign using common geophysical techniques to study, for example, archeological remains, internal structures of landslides or aquifers. Students work in small groups, and plan, acquire, process and document a field campaign together. The course is split into two parts: 1. **'Preparation'**: Introductory lectures and exercises (lab and field) covering Geographical Information Systems (GIS), surveying, and introductions to the field sites. Participation in the 'Preparation' part is a requirement to participate in the 'Field Work' part. 2. '**Field Work**': Four-weeks field course. The students work in groups on the following topics: - Planning and design of a comprehensive geophysical survey - Data acquisition - Data processing and inversion - Interpretation of the results - Report writing and presentation of results

Module	**Geophysical Field Work and Processing: Preparation and Field Work** (651-4106-03L)
Form of instruction	Lectures, field work, lab work
Literature and study materials	Relevant reading material, manuals and instructions for all methods of the field course will be handed out to each group at the beginning of the 'Field Work' part. Recommended literature: • An introduction to geophysical exploration. Third Edition. Kearey, Brooks, and Hill, 2002, WILEY-BLACKWELL. ISBN: 978-0-632-04929-5 • Environmental Geology, Handbook of Field Methods and Case Studies. Knödel, Klaus, Lange, Gerhard, Voigt, Hans-Jürgen, Bundesanstalt für Geowissenschaften (Ed.), 2007, XXVI, 1358 p. 501 illus., 243 in color. Hardcover. ISBN: 978-3-540-74669-0 • Fundamentals of Geophysics. William Lowrie, 2nd Edition, Cambridge University Press. ISBN: 9780521675963 Good overview literature: • An Introduction to Applied and Environmental Geophysics. John M, Reynolds WILEY-BLACKWELL. ISBN: 978-0-471-48535-3 More detailed and specific: • Near-Surface Geophysics. Edited by Dwain K. Butler. Society of Exploration Geophysicists (SEG). ISBN: 9781560801306 (13); 1560801301 (10)
Formative assessment (feedback)	
Summative assessment on module level	Written report (100%)

Module	**Geothermal Energy** (651-4109-00L)
Credits	4 EC
Module manager(s)	M. O. Saar, P. Bayer, M. Brehme, F. Samrock
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 3,6**
Learning objectives module, including the link to the ILO(s) in brackets	To provide students with a broad understanding of the systems used to exploit geothermal energy in diverse settings. After completion of this module the students are able to: LO1. Distinguish between the different geothermal systems (ILO: 6) LO2. Describe different exploration and exploitation strategies for geothermal reservoirs (ILO: 3,6)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Application of theory to new situations using relevant equations; Data analysis.
Module Content	The course will begin with an overview of heat generation and the thermal structure of the Earth. The basic theory describing the flow of heat in the shallow crust will be covered, as will be the methods used to measure it. Petrophysical parameters of relevance to Geothermics, such as thermal conductivity, heat capacity and radiogenic heat productivity, are described together with the laboratory and borehole measurement techniques used to estimate their values. The focus will then shift towards the exploitation of geothermal heat at various depths and temperatures, ranging from electricity and heat production in various types of deep geothermal systems (including high and medium temperature hydrothermal systems, and Engineered Geothermal Systems at depths of 5 km or more), to ground-source heat pumps installed in boreholes at depths of a few tens to hundreds of meters for heating domestic houses. The subjects covered are as follows: Week 1: Introduction. Earth's thermal structure. Conductive heat flow Week 2: Heat flow measurement. Advective heat flow. Petrophysical parameters and their measurement. Week 3: Temperature measurement. Hydrothermal reservoirs & well productivity Week 4: Hydrological characterisation of reservoirs. Drilling. Optimized systems Week 5: Petrothermal or Engineered Geothermal Systems Week 6: Low-enthalpy systems 1 Week 7: Low-enthalpy systems 2.
Form of instruction	Lectures and exercises
Literature and study materials	Lecture notes: The script for each class will be available for download from the Ilias website no later than 1 day before the class.
Formative assessment (feedback)	
Summative assessment on module level	Written exam (100%)

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Module	**Geofluids** (651-4240-00L)
Credits	6 EC
Module manager(s)	X.-Z. Kong, T. Driesner, S. Kyas, A. Moreira Mulin Leal
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,3,6**
Learning objectives module, including the link to the ILO(s) in brackets	This course presents the tools for understanding and modeling basic physical and chemical processes in the subsurface. In particular, it will focus on fluid flow, reactive transport, heat transfer, and fluid-rock interactions in a porous and/or fractured medium. The students will learn the underlying governing equations, followed by a demonstration of corresponding analytical or/and numerical solutions. After completion of this module the students are able to: LO1. Understand, formulate, and derive the governing equations of fluid flow, heat transfer, and solute transport (ILO: 1,6) LO2. Understand and apply the underlying physical and chemical processes to simplify and model practical subsurface problems (ILO: 3,6) LO3. Solve simple flow problems affected by fluid density (induced by the solute concentration or temperature) (ILO: 3,6) LO4. Understand and be able to assess the uncertainties pertaining to the reactive transport processes (ILO: 3) LO5. Assess simple coupled reactive transport problems (ILO: 1,3,6)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Collaboration with peers; Application of theory to new situations using relevant equations; Data analysis.
Module Content	This course presents advanced topics of single/multiphase fluid flow, heat transfer, reactive transport, and geochemical reactions in the subsurface. Emphasis is on the understanding of the underlying governing equations of each physical and chemical process, and their relevance to applications, e.g., groundwater management, geothermal energy, CO2 storage, waste disposal, and oil/gas production. 1) Introduction to the fundamental concepts of fluid flow in the subsurface 2) Immiscible fluid flow in porous/fractured media 3) Solute transport and heat transfer in subsurface 4) Density-driven flow 5) Uncertainty estimation 6) Reactive transport 7) Fluid injection and production 8) Fluid-rock interactions (non-mechanical) (8a) mineral and gas solubility in brines (8b) mineral dissolution/precipitation affecting rock porosity and permeability
Form of instruction	Lectures and exercises
Literature and study materials	• R. Allan Freeze and John A. Cherry. Groundwater. 1979. • Steven E. Ingebritsen, Ward E. Sanford, and Christopher E. Neuzil. Groundwater in geologic processes. 2008. • Vedat Batu. Applied flow and solute transport modelling in aquifers. 2006.

Module	**Geofluids** (651-4240-00L)
	• Luigi Marini. Geological sequestration of carbon dioxide: thermodynamics, kinetics, and reaction path modeling. 2006. • Jacob Bear. Dynamics of fluids in porous media. 1988.
Formative assessment (feedback)	
Summative assessment on module level	A final written exam at the end of the semester (100%)

Module	**Computational Methods in Seismic Data Analysis and Imaging** (651-4110-00V+U)
Credits	3 EC
Module manager(s)	P. F. Andersson
Education Period	Q3-Q4 (Spring semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 3**
Learning objectives module, including the link to the ILO(s) in brackets	The students are expected to learn to deal with Fourier analysis on unequally spaced data, frequency estimation methods, Radon transforms, rank constraints and splitting methods of complex problems into smaller sub-problems. The students are expected to be able to implement algorithms within the area on their own during the course. Another objective is to be able to adapt and apply these methods to seismic data. After completion of this module the students are able to: LO1. Understand and apply methods of applied mathematics in geophysics (ILO: 3) LO2. Implement and use computational methods in seismic data analysis and imaging (ILO: 3)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Collaboration with peers; Application of theory to new situations using relevant equations; Data analysis.
Module Content	6 (2 hour) lectures followed by 2h lab, Computer laboratory exercises every week. Recap of linear algebra concepts. Duality, norms, eigenvalues and singular value decomposition The Radon transform The FFT and the unequally spaced FFT. Frequency estimation methods Data sparsity Low-rank methods The alternating direction method of multipliers Kirchhoff migration Reverse time migration The adjoint state method GPU programming model. CUDA kernels in C. Computer laboratory exercises covering * The Radon transform and the unequally spaced FFT. Using GPU in MATLAB or Python. * Frequency estimation, data sparsity and the alternating method of multipliers. * Seismic migration.
Form of instruction	Lectures and exercises
Literature and study materials	
Formative assessment (feedback)	

Summative assessment on module level	Written exam (100%)

Module Descriptions Applied Geophysics RWTH Aachen

Module	**Inversion concepts for multi-method geophysics**
Credits	6 EC
Module manager(s)	N.N. Geophysik (Dr. rer. nat. Norbert Klitzsch)
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,3,4,7,10**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Students can explain the measurement principles of different EM methods (ILO: 1) LO2. Students understand the principle and application to combine different geophysical methods for improved subsurface imaging (ILO: 3,4) LO3. Students can assess the quality of subsurface images via sensitivity and resolution analyses (ILO: 3,4) LO4. Students understand the advantages and disadvantages of different geophysical methods in the context of environmental geophysics (ILO: 1,2) LO5. Students can design multi-disciplinary geophysical surveys (ILO: 2,7) LO6. Students can program inversion and experimental design approaches (ILO: 3,4) LO7. Students can conduct numerical work in groups (ILO: 10)
Professional and personal skills	Programming, analytical and critical thinking, self-study, teamwork
Module Content	This course focuses on the theory and the application of electromagnetic (EM) prospection methods. It comprises active and passive methods, EM theory and EM wave propagation as well as data acquisition, processing and interpretation. Moreover, forward and inverse modelling of EM data will be addressed. The latter will focus on the combination of different geophysical methods (e.g., joint inversion), which is a common practice in Earth and environmental science. The inverse modelling part is therefore complementary to previous courses on inverse modelling at TU Delft and ETH Zurich.
Form of instruction	Lectures, exercises, homework
Literature and study materials	• Nabighian, M.N., 1988. Electromagnetic Methods Vol.1: Theory, Society Of Exploration Geophysicists. • Nabighian, M.N., 1988. Electromagnetic Methods Vol.2: Application, Society Of Exploration Geophysicists • Everett, M. E. (2013). Near-Surface Applied Geophysics. Cambridge University Press. https://doi.org/10.1017/cbo9781139088435 • Integrated Imaging of the Earth. (2016). In M. Moorkamp, P. G. Lelièvre, N. Linde, & A. Khan (Eds.), Geophysical Monograph Series. John Wiley & Sons, Inc. https://doi.org/10.1002/9781118929063
Formative assessment (feedback)	Weekly homework assignments in group requiring programming with subsequent feedback in class

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Module	Inversion concepts for multi-method geophysics
Summative assessment on module level	Written exam (100%)

Module	Hydrogeophysics and Engineering Geophysics
Credits	6 EC
Module manager(s)	Prof. Dr. Ir. Jan van der Kruk
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,4,7,8,9,10,11**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: a) Hydrogeophysics LO1. Link hydrogeological properties with geophysical techniques, including the parameters and quantities used in these disciplines (ILO: 2,4,7) LO2. Select an appropriate measurement setup and corresponding processing steps to solve hydrogeophysical problems (ILO: 1,2,4,7,9) LO3. Understand advanced approaches in hydrogeophysics including full-waveform, full-wavefield inversion and waveguide inversion (ILO: 1,2,4,7,11) LO4. Present the measurement objectives and corresponding survey layout for a hydrogeophysical case study (2,8,11) b) Engineering Geophysics LO5. Understand the issues to be solved in geotechnical and civil engineering projects, including the parameters and quantities used in these disciplines (ILO: 2,4,9,11) LO6. Select appropriate measurements/processing methods and measurement/processing parameters to solve specific problems in engineering geophysics (ILO: 2,4,7,9) LO7. Develop a geophysical solution to an engineering problem in teams and present and explain it to a non-geophysical audience. (ILO: 8,9,10) LO8. Understand non-standard measurement methods used in engineering (ILO: 1,4,7,11)
Professional and personal skills	Self-study, analytical thinking, critical thinking, hydrogeophysical insight, work interdisciplinary, problem solving, presentation skills, advice (non-geophysical) stakeholders, collaboration with peers
Module Content	**a) Hydrogeophysics** This module discusses the geophysical principles specifically important for hydrogeophysics, including resistivity, induced polarization, electromagnetic induction, ground penetrating radar & seismics. Advantages and disadvantages of each technique are highlighted. The coupling between the geophysical and hydrological parameters, the pertaining petrophysical relationships are discussed and several hydrogeophysical case studies are analysed in detail. **b) Engineering Geophysics** Solving engineering problems requires special knowledge on near surface geophysical methods including the capability to apply them solely or in combination in an efficient and effective manner. This module provides guidance driven by examples from geotechnics (subsoil investigation, landslides, levees), civil engineering (investigation of buildings and

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Module	Hydrogeophysics and Engineering Geophysics
	foundations) and environmental problems (localization and assessment of contaminated material). How to set up a measurement concept and how to explain it to clients will be also discussed. Some instruments used in civil engineering will be shown for hands-on experience.
Form of instruction	Lectures, exercises, homework
Literature and study materials	a) • Hydrogeophysics - Lecture notes • Rubin, Y., and Hubbard, S., (2005), Hydrogeophysics, Springer. • Vereecken, H. et al., (2006), Applied Hydrogeophysics, Springer. • -Kirsch, R., (Hrsg.) 2006, Groundwater Geophysics, Springer. b) • Engineering Geophysics - lecture notes • Reynolds, J. M. ,(2011), An Introduction to Applied and Environmental Geophysics, 2nd Edition, Wiley
Formative assessment (feedback)	Hydrogeophysics: Exercises are homework and discussed during the course. Presentations are discussed by the students and the instructor and feedback is given directly. Engineering Geophysics: Short exercises are performed and evaluated during the course under supervision, feedback is given immediately. Programming skills (beginner/intermediate level) are of benefit. The presentations are discussed by the students and the instructor and feedback is given directly.
Summative assessment on module level	Weighting of exam “Hydrogeophysics”: 75% written examination & 25% presentation. Engineering Geophysics: presentation (100 %) Both Hydrogeophysics and Engineering Geophysics contribute with 50 % to the module grade.

Module	Numerical Reservoir Engineering
Credits	6 EC
Module manager(s)	Prof. Florian Wellmann (PhD)
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,3,4,5,6,11**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Have a solid understanding of the interesting challenges and the multiple facets of subsurface usage, both from a theoretical as well as a practical perspective (ILO: 3,6) LO2. Determine relevant physical processes in different reservoir scenarios and understand the underlying approaches to address practical problems such as geothermal energy extraction or CO2 sequestration. (ILO: 1,3) LO3. Solve simple reservoir engineering problems numerically, and this is a valuable and important basis for a possible future use of highly complex reservoir simulation tools that are commonly applied in industry. (ILO: 3,6,11) LO4. Be familiar with advanced mathematical modelling concepts, such as homogenisation, asymptotic expansions and other spatial reduction strategies, as well as techniques to model freesurfaces and open-domain problems. (ILO: 3) LO5. Recognize common modelling features of otherwise distinct simulation tools through cutting across different geo-applications. (ILO: 3,4) LO6. Develop and apply computer models, and contributes to a better understanding of assessing model integrity and predictive power. (ILO: 3,4,11)
Professional and personal skills	Self-study, problem-based learning and solving, solid fundamental knowledge of numerical and mathematical principles, computer skills, working with other students
Module Content	**a) Numerical Reservoir Engineering: Geophysical Process Simulation** Numerical reservoir engineering combines geological and geophysical data and knowledge with geophysical process simulations to address challenges related to an effective and sustainable use of the subsurface. Typical examples include geothermal reservoirs and groundwater studies, conventional and unconventional hydrocarbon reservoirs, but also reservoirs for gas storage and CO2 sequestration. In this course, the fundamental concepts to study these reservoir types will be examined from the perspective of numerical analysis and simulations. **b) Scientific Machine Learning and Advanced Numerical Methods** Huge efforts are made to develop powerful, multi-physics simulation tools capable of predicting complex systems on a large range of spatio-temporal scales. Essential to any simulation tool is an appropriately formulated mathematical model tailored to optimally capture the process of interest. This course is located at the interface between the geosciences and applied mathematics and concerns model development on a general level. It focusses on advanced techniques to derive mathematical systems of reduced complexity. These techniques will be introduced and applied to derive and analyse well-known models, e.g. Darcy's law. The course is designed to complement the contents 'Numerical Reservoir Engineering' and 'Introduction to Numerical Methods for Geophysical Flows'. In a first section, we will recall on the balance laws for mass, momentum and energy, as well as common closure relations for the stress tensor. We will discuss dimensional scaling and physical similitude and use these to classify regimes and their relevance to geo-applications. Next, we introduce homogenisation and asymptotic expansion, and apply these to derive e.g. Darcy's law*).

Module	Numerical Reservoir Engineering
	The third section is devoted to mathematical models for shallow free-surface problems. Shallowness in cross-flow direction justifies depth-integration and results into St. Venant type models. These can be adopted to model river flow, mass movements, atmospheric flows, or glacier dynamics. We will formulate implicit boundary functions, as well as kinematic and dynamic conditions, and conduct depth-averaging for various settings **). Next, linear stability analysis is introduced. As one example St. Venant type models are analysed. The final section of this course is devoted to the modelling of phase-change processes and in particular melting and refreezing processes. Different modelling techniques to describe the evolving interface will be introduced. In its simplest setting this results into the so-called Stefan problem, initially phrased to describe the growth of sea ice. Extended to allow for natural convection, these models are also used to study geodynamic processes in the interior Earth. The lectures will be supplemented with a selection of exercises that apply the introduced concepts to relevant geo-applications.
Form of instruction	Lecture, exercises, homework
Literature and study materials	**a) Numerical Reservoir Engineering: Geophysical Process Simulation** • Course handouts • Additional literature will be given during the course. **b) Advanced Mathematical Modeling in Applied Geoscience** • Course handouts • Additional literature will be given during the course.
Formative assessment (feedback)	Regular homework assignments to be done in groups with feedback in class
Summative assessment on module level	Written examination in Numerical reservoir Engineering (50 % of the module grade) and written examination in Advanced Mathematical Modeling (50 % of the module grade).

Module	Research Module in Applied Geophysics
Credits	6 EC
Module manager(s)	Prof. Florian Wellmann (PhD)
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 4,7,8,9,10,11,12**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Have a solid understanding of the requirements of performing a scientific research project. (ILO: 4,7,9,10) LO2. Identify, be aware and know how to address potential pitfalls of scientific misconduct. (ILO: 4,7,11,12) LO3. Be aware of the increasingly important issues of research data management and generate research data management plans. (ILO: 9,10) LO4. Develop scientific codes and data analyses, as well as to maintain such codes in form of version-controlled repositories. (ILO: 8,9,11) LO5. Be familiar with methods for publication and the general form of scientific documents, allowing them to generate such documents. (ILO: 4,7,8,9,10,11,12)
Professional and personal skills	Self-study, problem-based learning and solving, solid fundamental knowledge of numerical and mathematical principles, computer skills, working with other students
Module Content	In this module, students will be introduced to the fundamental requirements and structures of scientific research projects. Content discussed in the seminar will include aspects of research project structures, literature research, research data management, scientific code management and good practices, scientific misconduct and scientific writing. In the second half of the module, students will work with their subsequent thesis supervisors on a defined research project. The final report will contain aspects of the scientific research project practice discussed before (data management, literature research), as well as the result of the research project, in the form of typical scientific documents.
Form of instruction	Lecture, exercises, homework
Literature and study materials	David Lindsay: Scientific Writing = Thinking in Words Course handouts. Additional literature will be given during the course.
Formative assessment (feedback)	Regular homework assignments to be done in groups with feedback in class
Summative assessment on module level	Project work (100 %)

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Module	Petrophysics for Applied Geophysics
Credits	6 EC
Module manager(s)	Littke, Ralf; Univ.-Prof. Dr. rer. nat.
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 2,3,8,10,11**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. [understand the fundamental physical background of transport and storage properties of sedimentary rocks and various laboratory methods to determine these properties.] (ILO: 3,11) LO2. [apply laboratory-based methods related to the characterisation of transport properties and pore space (e.g., pycnometry, low-pressure nitrogen adsorption, high-pressure gas sorption, NMR, TCS, MICP, steady and non-steady state permeability tests with liquids and gases, ...).] (ILO: 2,3,11) LO3. [evaluate, visualise, interpret and present raw data from different laboratory methods.] (ILO: 3,8,10,11)
Professional and personal skills	Analytical & critical thinking; Problem-based learning & solving; Planning and conducting laboratory experiments; Report writing; Time management, Organization, Data processing & analysis; Collaboration with peers; Solid fundamental knowledge of relevant physical parameters
Module Content	**a) Petrophysics** **b) Laboratory Practicals: Applied Reservoir Petrophysics** The course deals with both the direct determination of rock properties (such as porosity, specific surface area, permeability) and the derivation of rock properties from physical parameters (e. g. resistivity, seismic velocity, density, and natural gamma radiation). The course comprises two parts: The first part focuses on theories for describing physical rock properties. In the second part laboratory exercises or problem sets test students' perception of key concepts and methods; the results are to be presented by the students.
Form of instruction	Lecture, Laboratory Practicals
Literature and study materials	• Schön (2015): Physical Properties of Rocks: A Workbook, Elsevier. • Tiab & Donaldson (2016): Petrophysics: Theory and Practice of Measuring Reservoir Rock and Fluid Transport Properties, Elsevier Science & Technology. • Mavko, Mukerji & Dvorkin (1998): The rock physics handbook, Cambridge University Press.
Formative assessment (feedback)	Exercises – to actively understand and apply lecture material - are made under supervision of the instructors or given as homework assignments (this may include usage of a simple, interactive computer-program to visualize the result; no specific computer skills are required). All answers to exercises are provided after completion.
Summative assessment on module level	Exams in petrophysics (50 % of the module grade) and reports for Laboratory Practicals (50 % of the module grade).

Module	**Geophysical Logging and Log Interpretation**
Credits	6 EC
Module manager(s)	Dr. rer. nat. Renate Pechnig
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,2,3,4,5,7,10**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Explain the measurement principles of all important borehole geophysical methods in use (ILO: 1) LO2. Understand the principle and application to combine different borehole geophysical methods for improved log interpretation and formation evaluation in terms of reservoir characterization (oil and gas, geothermal, drinking water resources) (ILO: 3, 4) LO3. Assess the quality of borehole geophysical data via log quality control routines, comparison with other petrophysical data and plausibility checks to drilled geology and lithology (ILO: 3,4) LO4. Understand the advantages and disadvantages of different borehole geophysical methods for aspects of log interpretation studies targeted to solve geological and petrophysical questions (ILO: 1,2) LO5. Design borehole geophysical surveys and are able to perform upcoming steps of data handling and processing, QC routines and data analysis (ILO: 2,7) LO7. Conduct log interpretation work in teams and are able to transfer methods established for oil and gas exploration for a sustainable use of the Earth's subsurface (geothermal energy, subsurface storages). (ILO:10,5)
Professional and personal skills	Cross-disciplinary thinking, analytical thinking, teamwork
Module Content	The module consists of two parts: Part A focuses on the physical principles of the different borehole measurements and the petrophysical uses and geological interpretation of the logs. Part B comprises practical examination in well log data acquisition followed by data processing and interpretation. The training of basic log interpretation techniques is supported by examples and the use of standard log interpretation software. Contents of part A: • Basics of data acquisition, data processing and quality control. • Wireline and LWD techniques. • Principles of conventional measurements (gamma, neutron, density, sonic, resistivity). • Principles of special measurements (Image logs, NMR) • Log interpretation techniques: e.g., rock identification, sequence analysis, fluid and hydrocarbon identification, cross-plot and overlay techniques. • Basics of core-log integration; link to laboratory petrophysics and geochemistry. • Basics of petrophysical applications: e.g., porosity, saturation, permeability. Contents of part B: • Practice in slim hole logging • On-site training: unit mobilization, tool calibration and data acquisition.

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Module	Geophysical Logging and Log Interpretation
	• Data editing and quality control: borehole corrections, depth matching, splicing. • Integration of logs with information from core or cuttings from the measured well. • Interpretation of the recorded data and preparing a report.
Form of instruction	Lectures, exercises, homework, fieldwork
Literature and study materials	Lecture notes • Access to commercial processing software • Ellis, D.V. & Singer, J.M. (2007). Well Logging for Earth Scientists (2nd Edition). Springer, Dordrecht, 692 p. • Hearst, J.R. et al. (2000). Well logging for physical properties - a handbook for geophysicists, geologists, and engineers. Wiley, Chichester, 483 p. • Labo, J. (1986). A practical introduction to borehole geophysics - an overview of wireline well logging principles for geophysicists. Society of Exploration Geophysicists, Tulsa, 330 p. • Serra, O. & Serra, L. (2004). Well logging data acquisition and applications. Serralog, Méry Corbon, 674 p.
Formative assessment (feedback)	Practical part with exercises and field work part for data interpretation with subsequent feedback in class
Summative assessment on module level	Written Examination + Field data interpretation, documentation and presentation in groups

Module	Planning and Management of Georesources
Credits	6 EC
Module manager(s)	Prof. Florian Wellmann (PhD)
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 4,6,8,9,10**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Be familiar with modern project ranking and decision-making tools in the energy and minerals industries including the meaning of Expected Value/Net Present Value and its use in E&P investment decisions (ILO: 4,8,9,10) LO2. Understand the importance of integrated decision-making from geological/geophysical prospect evaluation to exploration and production (ILO: 4,6,8,9,10) LO3. Have an overview of renewable and non-renewable geogenic energy resources and -reservoirs. (ILO: 4,6,8) LO4. Be familiar with the basic project planning and risk analysis, using standard project management software. (ILO: 4,8,9,10)
Professional and personal skills	Self-study, problem-based learning and solving, working with other students, cross-disciplinary thinking, analytical thinking
Module Content	a) Portfolio Management and Prospect Evaluation Definition of portfolio management, its application to the resource industry, particularly in the realm of exploration and appraisal campaigns. Introduction to common volume and economic value parameters used when carrying geoscience interpretation to portfolio management-based decision making. Company risk profiles, related portfolio types and expected value creation (NPV). Technical and basic statistical input requirements for portfolio management. Principles of economic and technical prospect evaluation. b) Energy Resources Management Overview of renewable and non-renewable geogenic energy resources; subsurface reservoirs: pores, fractures, caverns; subsurface storage of renewable and non-renewable energy; challenges in exploration, production and usage of subsurface reservoirs; tools of project- and quality management in the field of energy resources; software based work-out of a project
Form of instruction	Lecture, exercises, homework
Literature and study materials	• Sheahan, P.A. & Cherry, M. E. (edit): Ore deposit Model I and II: Geoscience Canada, Reprint Series; • Kirkham, R.V., Sinclair, W.D., Thorpe, - R.I. & Duke, J.M. (edits): Mineral Deposit • Modeling. Geological Association of Canada, Spec. Paper 40. • Stone, J.G. & Dunn, P.G.: Ore Reserve Calculations in the Real World. SEG, Special Publication Number 3. • Mantel, S.J., Meredith, J.R., Shafer, S.M., Suton, M.M. 2005. Core concepts of project management. Wiley, 302 pp • Lerche, I., Noeth, S. 2004. Economics of petroleum production. 332 pp
Formative assessment (feedback)	Regular feedback in class

Module	Planning and Management of Georesources
Summative assessment on module level	Portfolio Management and Prospect Evaluation: Written exam Energy Resources Management: Report Both Portfolio Management and Energy Resources Management contribute with 50 % to the module grade.

Module	Finite Elements in Fluids
Credits	6 EC
Module manager(s)	Universitätsprofessor Marek Behr Ph. D.
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 1,3,5,6**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Know the mathematical principles and elementary concepts necessary to apply the finite element method in fluid mechanics: Convection-Diffusion equation, time discretization method, Stokes equation, Navier- Stokes equation. (ILO: 1) LO2. Be aware of the practical aspects of finite element discretization in problems with multiple fields. (ILO: 1) LO3. Be aware of the problems encountered in finite element discretization-by high Péclet numbers and poorly chosen interpolation functions. (ILO: 1,3) LO4. Understand the concept of finite element stabilization using residual-based methods, "Finite Increment Calculus" and "Variational Multiscale" approaches. Non-technical (e.g., teamwork, presentation, project management, etc.) (ILO: 3,5) LO5. Get experience with a flow simulation program from research, as well as visualization of data, through exercises. (ILO: 3,5,6)
Professional and personal skills	Self-study, studying with other students, modifying sample code in Matlab, presenting results in a scientific report, accepting or disputing feedback
Module Content	1 - Introduction: - Outline, - History of the finite element method. 2 - Conservation laws (1): - Kinematic description, "Arbitrary-Lagrangian-Eulerian" description - Reynolds transport theorem. 3 - Conservation laws (2): - Conservation of mass, momentum, and energy, - Euler and Navier-Stokes equations. 4 - Fundamentals of the finite element method (1): - Function spaces, norms, - Poisson equation, weak and strong formulation. 5 - Fundamentals of the Finite Element Method (2): - Lax-Milgram lemma, discrete formulation, - Cea's lemma, computational aspects. 6 - Convection-Diffusion equation (1): - weak and Galerkin formulation, and the matrix representation, - Péclet number, discretization errors 7 - Convection- Diffusion equation (2): - historical overview of stabilization methods, - Petrov-Galerkin formulation. 8 - Convection-diffusion equation (3): - Error estimation, - Finite Increment Calculus, Variational Multiscale Method 9 - Time Discretization (1): - Theta, Lax-Wendroff, "leap-frog" methods, - Discretization of the time-dependent convection-diffusion equation 10 - Time Discretization (2): - Stability, accuracy, - Fourier analysis. 11 - Time discretization (3): - "modified-equation" method, - Taylor-Galerkin methods. 12 - Time discretization (4): - Time-space methods, - linear multistep methods. 13 - Stokes equation (1): - constitutive approach, boundary conditions, - "saddle-point" aspects. 14 - Stokes equation (2): - weak, Galerkin, and discrete formulation, - LBB condition, interpolation approaches, stabilization. 15 - Time-dependent Navier-Stokes equations: - weak, Galerkin and stabilized formulation, - summary.
Form of instruction	Lectures, exercises, homework
Literature and study materials	Textbook: Donea, Huerta, "Finite Element Methods for Flow Problems", Wiley & Sons

Module	Finite Elements in Fluids
Formative assessment (feedback)	Weekly homework assignments to be done singly or in groups with feedback in class. Three individual projects with feedback, also discussed in oral exam.
Summative assessment on module level	Oral exam (100 %)

Module	Economics of Technological Diffusion
Credits	6 EC
Module manager(s)	Universitätsprofessor Dr. rer. soc. oec. Reinhard Madlener
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 8,9,11,12**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Understand why diffusion may take a long time and often shows an S-shaped diffusion curve. (ILO: 9,11) LO2. Know what is meant by the term “diffusion of (technological) innovation” and to understand the difference between the terms “adoption” and “diffusion”. (ILO: 9,11) LO3. Be able to classify / understand diffusion research from different angles pursued in different research disciplines. (ILO: 9,11) LO4. Learn about economic modeling of technological diffusion. (ILO: 9,11) LO5. Understand how competing technologies influence each other’s diffusion processes. (ILO: 9,11) LO6. Understand energy/climate policy-making based on considerations of optimal speed of technological diffusion. (ILO: 9,11) LO7. Learn about empirical research topics and approaches (through selected examples from the literature). (ILO: 8,9,11,12)
Professional and personal skills	Self-study, studying with other students, insights into economics
Module Content	For various reasons (such as emerging new technologies, problems related to resource supply and use, climate change, etc.) it is expected that in the coming decades significant technical change will happen. Thus, the challenges faced by engineers, economists, and natural scientists involved in management, plant operation or administration will rise to understand, adequately describe and – subject to certain assumptions regarding the framework conditions – to better understand and predict the diffusion dynamics and potentials of new technologies and products. To this end, a significant basic knowledge in the fields of technology assessment, market analysis, cost reduction potentials, and the theories of innovation diffusion is needed. In the underlying course (comprising lecture and exercise unit) a basic knowledge in economic theory and methods related to the study of the diffusion of new technologies will be acquired and applied to innovative (energy and other) technologies. In this way the student receives a useful overview on the subject, which in many occupational areas (e.g., product development, market observation, marketing, technology assessment, and policy-making) is of increasing relevance in everyday business.
Form of instruction	Lecture, exercises, homework
Literature and study materials	Stoneman P. (2001), The Economics of Technological Diffusion, ISBN-13: 978-0-631-21976-7

Module	**Economics of Technological Diffusion**
Formative assessment (feedback)	Regular homework assignments to be done in groups with feedback in class
Summative assessment on module level	Successful examination (100%, graded, 60 min.) or, if no. of participants is < 12, alternatively an oral examination in groups of 3-4; (100%, graded, 60min.)

Module	**Specialization in Methods and Applications of Applied Geosciences**
Credits	Choose 6 EC or 9 EC
Module manager(s)	Prof. Florian Wellmann (PhD)
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 4,5,6,7,10**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: a) Mineral Exploration LO1. Understand how geochemistry of suitable surficial material can be employed in the search for mineral deposits by using the chemistry of the environment surrounding a deposit in order to locate it. (ILO: 5,6,7) LO2. Define geochemical anomalies which distinguish a mineral deposit from enhancements in background and nonsignificant ore enrichments. (ILO: 5,6,7) b) Neotectonics and Earthquake Geology LO3. Understand and analyse geoscientific processes, earthquakes and impacts. (ILO: 5,6,7) c) Remote Sensing of Sedimentary Basins LO4. Obtain a thorough understanding of remote sensing methods to analyze geological features in sedimentary basins. (ILO: 5,6,7) d) Data Analysis in Geoscience LO5. Understand data analysis methods for typical applications in geosciences, as well as practical experience in using suitable scientific software and programming approaches to solve related problems. (ILO: 4,7,10) e) Seismic Interpretation in Geology LO6. Understand seismic stratigraphy as an interpretation method (ILO: 5,6,7,10) LO7. Perform basic subsurface interpretations, seismic stratigraphic analyses and sequence stratigraphic interpretations in different basin settings and different depositional settings (ILO: 5,6,7,10) LO8. Judge the controls on sequence development in common depositional settings; consider these controls while interpreting seismic-reflection data of basin successions- understand sequence stratigraphy as a concept and method (ILO: 5,6,7,10) LO9. Understand different sequence stratigraphic interpretation approaches (ILO: 5,6,7,10) LO10. Apply sequence stratigraphy and seismic stratigraphy as tools for subsurface lithofacies prediction (ILO: 5,6,7,10)
Professional and personal skills	Analytical thinking; Problem-based learning; Solving; Application of theory to new situations using relevant equations; Data analysis, Self-study, studying with other students, carrying out systematic analysis

Module	Specialization in Methods and Applications of Applied Geosciences
Module Content	**a) Mineral Exploration** Introduction into mineral economics and mineral exploration, reconnaissance techniques, geochemical exploration and sampling techniques. Integration of exploration data in order to identify and select exploration targets. Planning of exploration campaigns taking into account both geological and economical considerations. **b) Neotectonics and Earthquake Geology** Neotectonics, recent crustal stresses and causes, earthquake geology, secondary effects of earthquakes, investigation methods of active disturbances **c) Remote Sensing of Sedimentary Basins** Lectures and exercise comprise remote sensing data of basins and basin-related structures (satellite and aerial photos). The course focus on several basin-types, which are in detail explained according their geodynamic position. Another major focus is put on tectonics of active and passive basins, and the effects on basin formation and inversion. **d) Data Analysis in Geoscience** Descriptive statistics Introduction in geostatistical methods (variogram analysis, ordinary and simple kriging, cokriging, geostatistical simulation) Introduction in time series analysis (Box-Jenkins methods, Markov Chain Monte Carlo method, Spectral methods) Application on problems in geosciences: subsurface contamination, groundwater hydrology, surface hydrology. Exercises with help of the software packages GSLIB und SPSS (about 40% of the module) **e) Seismic Interpretation in Geology** Seismic interpretation and sequence stratigraphy are both well-established analytical tools for investigating sedimentary successions, with the aim of predicting subsurface geology. This course provides an introduction to seismic interpretation and sequence stratigraphy, teaching concepts of defining tectonic structures and depositional sequences on subsurface data (seismic data &; well data). The course furthermore provides a foundation in the techniques of analytical seismic stratigraphy and sequence stratigraphy, and their application to various basins and depositional settings. An emphasis will be on pragmatically selecting interpretation methods that are appropriate for particular data and purposes to ensure that a sequence stratigraphic and seismic stratigraphic interpretation is meaningful and applicable.
Form of instruction	Lecture, exercises, homework
Literature and study materials	**a) Mineral Exploration** • Kessler S.E., Simon A.C. (2015) Mineral Resources, Economics and the Environment. Cambridge University Press, 434 pp. • Whateley M.K.G., Harvey P.K. (1994) Mineral Resource Evaluation II. Methods and Case Histories. Geological Society London Special Publications, v. 79, 249 p. • Kirkham R.V., Sinclair W.D., Thorpe R.I., Duke J.M. (1993) Mineral Deposit Modeling. Geological Association of Canada, Special Papers, v. 40, 770 p. **b) Neotectonics and Earthquake Geology** • Keller, E., &;; N. Pinter, N. (2002). Active tectonics: earthquakes, uplift, and landscape, 2nd edition, Prentice Hall, 122-150. • McCalpin, J. P. (2009). Paleoseismology, 2nd edition. Academic Press, Elsevier, Amsterdam, 613 pp. • Walker, M.J.C. (2005). Quaternary Dating Methods. John Wiley &;; Sons Ltd. • Wells, D.L. &;; Coppersmith, K.J. (1994). New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement, Bulletin of the Seismological Society America 84: 974-1002. • Yeats, R. (2012). Active faults of the world.

Module	Specialization in Methods and Applications of Applied Geosciences
	c) Remote Sensing of Sedimentary Basins • Adams, J.B., Gillespie, A.R., 2006. Remote Sensing of Landscapes with Spectral Images. A Physical Modeling Approach. Cambridge University Press, 378 pp. • Campbell, B.C., 2002. Radar Remote Sensing of Planetary Surfaces. Cambridge University Press, 342 pp. • Martin, S., 2004. An Introduction to Ocean Remote Sensing. Cambridge University Press, 454 pp. • Rees, G., 2001. Physical Principles of Remote Sensing. 2nd Edition, Cambridge University Press, 372 pp. • Rees, G., 2005. The Remote Sensing Data Book. Cambridge University Press, 276 pp. **d) Data Analysis in Geoscience** • An introduction to applied geostatistics- E.H. Isaaks &; R.M. Srivastava (1989), Oxford University Press. • Statistical methods in the atmospheri sciences- Daniel Wilks (2006), Elsevier Academic Press **e) Seismic Interpretation in Geology** • Course handouts
Formative assessment (feedback)	Exercises – to actively understand and apply lecture material - are made under supervision of the instructors (this may include usage of a simple, interactive computer-program to visualize the result; no specific computer skills are required). All answers to exercises are provided after completion and discussed in the lecture.
Summative assessment on module level	For 9 EC, 3 out of 5 courses with their particular exams have to be passed to finish this module. For 6 EC, 2 out of 5 courses with their particular exams have to be passed to finish this module. The mark of the module is calculated from the exams in the module which are weighted by their particular Credit Points (CP).

Module	**Principles of Plate Tectonics**
Credits	3 EC
Module manager(s)	Univ.-Prof. Dr. Susanne Buiter
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 6,7,11,12**
Learning objectives module, including the link to the ILO(s) in brackets	Students will learn first-order dynamic principles of plate tectonics and the expected tectonic deformation of Earth's surface. After completion of this module the students are able to: LO1. Positively critically examine scientific theories (ILO: 7) LO2. Apply analytical equations for evaluating first-order processes within the plate tectonic system (ILO: 6,7,11) LO3. Ask relevant and constructively critical questions on data acquisition and new exploration frontiers (ILO: 7,12)
Professional and personal skills	• Learn to critically examine and discuss scientific theories. • Find the key messages in scientific articles. • Learn to evaluate the first-order forces at play in the plate tectonic system. • Practise analytical thinking. Know which type of analytical equations are relevant for a new plate tectonic problem. • Know how to use the plate reconstruction software GPlates.
Module Content	This course provides insight into the large-scale deformation processes that shape Earth's topography. The stages of the plate tectonics cycle are systematically described and their underlying physics explained. The course includes lectures, short exercises, open discussions, and plate tectonic reconstructions using open-source software.
Form of instruction	Lectures. Short exercises during the lectures. Hands-on tutorials and independent use of plate tectonic reconstruction software, including visualization of deformation fields.
Literature and study materials	Selected scientific papers and further materials announced in the course and made available over the teaching platform Moodle prior to each lecture.
Formative assessment (feedback)	Short exercises are made during the lectures to actively understand and apply lecture materials. The solutions are discussed in the lectures. Open questions and discussions encourage reflection on the lecture content. Feedback on the written exam is offered during an exam review.
Summative assessment on module level	Written exam

Module	Machine Learning
Credits	6 EC
Module manager(s)	Universitätsprofessor Dr. sc. techn. Bastian Leibe
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 4,5,7,8**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Derive and explain methods and techniques that enable a machine to learn from data. (ILO: 4,5,7,8) LO2. Be aware of current research trends and developments. As a result, they will be able to select the basic machine learning techniques needed for these skills. (ILO: 4,5,7,8) LO3. Independently apply the methods covered to real-world problems, (ILO: 4,5,7,8) LO4. Implement the presented algorithms themselves and to implement them in a programming language of their choice. (ILO: 4,5,7,8)
Professional and personal skills	Analytical thinking; data-driven method; machine learning; data analysis, self-study, studying with other students
Module Content	Basic concepts: Introduction to Probability Theory, Bayes decision Theory | Probability Density Estimation | Discriminative Methods for Classification: Linear discriminants, Support Vector Machines, AdaBoost | Deep Learning: Multi-Layer Perceptrons, Convolutional Neural Networks, Recurrent Neural Networks
Form of instruction	Lecture, exercises, homework
Literature and study materials	C.M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, 2016.
Formative assessment (feedback)	Regular feedback in class
Summative assessment on module level	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.

Module	Underground Excavation
Credits	6 EC
Module manager(s)	Amann, Florian; Univ.-Prof. Dr. rer. nat.
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	**ILO: 5,6,8,9**
Learning objectives module, including the link to the ILO(s) in brackets	After completion of this module the students are able to: LO1. Understand the most important tasks an engineering geologist has to carry out in the context of planning and building an underground excavation (ILO: 5,6,8,9) LO2. Know how to integrate the knowledge gained during the fundamental and methods courses for an underground construction. (ILO: 5,8,9) LO3. Understand the role of an engineering geologist in the planning and execution of underground excavations. (ILO: 5,6,8,9) LO4. Learn to carry out the typical tasks of an engineering geologist, i.e. build geological models of the target area, design preliminary investigations; interpret results from lab and field tests; classify and describe the geological and hydrogeological conditions, rock mass properties and behaviour; assess environmental impacts; design and implement exploration and monitoring investigations during construction of an underground excavation. (ILO: 5,6,8,9)
Professional and personal skills	Analytical thinking; self-study; studying with other students; communication in interdisciplinary environment
Module Content	**a) Lecture** The course covers engineering geological aspects for the planning, execution and documentation of underground excavations in rocks (from shallow to deep) and soils (i.e. urban tunnels). The content spans from engineering geological site investigations to the fundamental assessment of underground excavation stability to mitigation measures. **b) Exercises** The exercises cover the development of engineering geological tunnel cross section and plan views, simple tunnel related calculations such as wedge failure or squeezing
Form of instruction	Lecturers and exercises
Literature and study materials	Lecture hand-outs and online resources
Formative assessment (feedback)	Regular feedback in class
Summative assessment on module level	Written Exam (100 %)

Module	GIS - Intensive Course
Credits	3 EC
Module manager(s)	Univ.-Prof. Dr. Klaus Reicherter
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	ILO: 1, 2, 8, 11
Learning objectives module, including the link to the ILO(s) in brackets	Students will enhance GIS operational methods, with a focus on raster data analysis. They will deepen their knowledge of GIS working techniques and will acquire the skills to utilize complex digital spatial analysis tools. After completion of this module, the students are able to: LO1. Explain, discuss, and use fundamental spatial analysis tools in GIS. (ILO 1) LO2. Process collected data, analyse and interpret the processed results. (ILO 2) LO3. Use written and figure communication skills to effectively exchange information and ideas. (ILO 8) ILO4: Apply enhanced spatial analysis methods in GIS. (ILO 11)
Professional and personal skills	Learn how to apply enhanced spatial analysis methods in GIS. Gain knowledge of collecting and processing data and spatial analysis in GIS. Learn to interpret and present processed results.
Module Content	This module provides insight into enhanced GIS analysis methods. It includes a deeper understanding of GIS software and shows how to interpret and present results regarding research questions.
Form of instruction	Lectures. Short exercises during the lectures. Hands-on tutorials and independent use of GIS software.
Literature and study materials	Selected scientific papers and further materials announced in the course and made available over the teaching platform Moodle prior to each lecture.
Formative assessment (feedback)	Short exercises are made during the lectures to actively understand and apply lecture materials. Open questions and discussions can be asked during the lecture time. Feedback on the final homework is offered.
Summative assessment on module level	The mark of the module is calculated from the short exercises and final homework in the module, which are weighted by their particular Credit Points (CP). a) Short exercises (45%) b) Finale Homework (55%)

Module	Basics of Final Disposal
Credits	6 EC
Module manager(s)	Klaus Fischer-Appelt Frank Charlier
Education Period	Q5-Q6 (winter semester)
Link to intended learning outcomes (ILOs) programme	ILO: 2, 3, 6, 7, 8
Learning objectives module, including the link to the ILO(s) in brackets	The students will learn the fundamentals regarding deep geological disposal of radioactive waste and the required knowledge about geological and engineering tasks to carry out planning, constructing, operating, closing and assessing the long-term safety of a repository for radioactive waste. In this course, students will obtain the necessary understanding of the main geological and engineering methods, processes and applications that are crucial in the interdisciplinary field of final disposal and for attending further modules in the specialization course Repository Safety. After completion of this module, the students will be able to: • Comprehend the relevance and implication of geological and mining engineering challenges related to repository selection, design and safety. (ILO 2) • Understand the influence of climatic and geologic exogenic and endogenic processes and their relevance in the context of site selection, repository design and safety. (ILO 6) • Identify the advantages, disadvantages and characteristics of the three host rocks (rock salt, claystone and crystalline rock) which are relevant for the final disposal of high-level waste. (ILO 2) • Comprehend the governing principles of flow and radionuclide transport process in the saturated and unsaturated zone. (ILO 6) • Understand the most important methods (field, laboratory, and computer-based methods) used in geology and hydrogeology and identify which data and tools are needed for the application of these methods. (ILO 3) • Understand engineering fundamentals of subsurface mine operation. (ILO 2,6) • Perform calculations related to mining processes, rock mechanics and mine ventilation. (ILO 3) • Identify and select suitable mining methods (e.g., rock breaking and shaft sinking method) and mining equipment in the context of repository safety. (ILO 6) • Develop problems-solving and critical-thinking skills through the adoption of logical scientific approach. (ILO 7,8)
Module Content	The module consists of two courses: Final disposal and projects and Geological and engineering basics of final disposal. The Final disposal and projects lecture aims at providing those students who have not received basic knowledge of radioactive waste disposal in their Bachelor's degree, e.g., because they come from external universities. However, the relevant subject aspects are only roughly touched upon, since these are dealt with in greater depth in the other lectures. Due to the fact that the specialisation "repository safety" is aimed at both bachelor students of mining engineering and geosciences, the lecture Geological and engineering basics of final disposal has to transfer the missing subject content to the respective cohort from other subjects. This means that students of geosciences are taught the basics of mining engineering required for final disposal. Conversely, students with a background in mining engineering will be taught the basics of geology related to disposal.

Module	Basics of Final Disposal
	The following subjects are taught in **Final disposal and projects**: • Waste management fundamentals: International use of nuclear power production, waste management, discarded disposal options, ionizing radiation, waste types and their origin • International waste management standards and national regulations • Barrier concepts: Technical, geotechnical and geological barriers, technical design, safety functions and safety conceptual effective duration • Disposal concepts: Drift disposal, borehole disposal, disposal in deep boreholes, retrieval and recovery, host rock specific differences • National repository projects: Asse, Konrad, Morsleben, site selection procedure for a repository for high active waste • International repository projects: France, Switzerland, Canada, Sweden, Finland, etc. The following subjects are taught in **Geological and engineering basics of final disposal**: • Formation, properties and regional distribution of host rocks pursued in final disposal (rock salt, claystone and crystalline) • Host rock-specific advantages and disadvantages regarded to the final disposal of radioactive waste • Fundamentals of groundwater flow and radionuclide transport of radionuclides in the geological subsurface • Rock and soil mechanics • Geomechanics fundamentals in deep disposal: backfill compaction, host rock convergence, excavation damaged zone, ice shield load, tectonic stress, earthquakes etc. • Significance of the geoscientific criteria in the Site Selection Act for site selection for a repository for high-level radioactive waste • Possible geological and climatological scenarios in the future, likelihood and impact • Overall geoscientific assessment of a repository system within a safety analysis Mine Engineering fundamentals: • Introduction to mining terms and general mining methods • Types and engineering design of underground equipment for rock breaking, conveying and transport of mine debris • Excavation methods (partial cut, full cut, etc.) • Support of mine workings • Shaft sinking methods and shaft hoisting technology • Backfilling of mining cavities • Mine infrastructure (operating materials, maintenance, energy supply, etc.) • Mine ventilation technology, also from a radiological point of view • Mine water management • Mine surveying
Form of instruction	Lecture / Exercise.
Literature and study materials	Lecture hand-outs and online in CMS (RWTHmoodle).
Formative assessment (feedback)	Short Q&A sessions are made during the lectures to actively understand and apply lecture materials.
Summative assessment on module level	The mark of the module is calculated from the short exercises and final homework in the module, which are weighted by their particular Credit Points (CP).

Module Description Final Thesis Applied Geophysics

Module	**Final Thesis Applied Geophysics (JMAG230)**
Credits	30 EC
Module manager(s)	TUD: Prof.dr.ir. E. C. Slob ETH: Prof.dr. H. Maurer RWTH: Prof.dr. F. Wellmann
Education Period	Q7-Q8
Link to intended learning outcomes (ILOs) programme	**ILO: 2,3,4,5,7,8,9,10,11**
Learning objectives module, including the link to the ILO(s) in brackets	The graduate student learns to apply the skills and knowledge gained in the course programme in a research project that is to be carried out independently. After completion of the master thesis project, the student: LO1. Shows a scientific approach consisting of: theoretical profundity; ability to relate thesis topic to current literature; design, plan, and execute the research; use scientific arguments, exercise critical attitude and judgement. (ILO: 2,3,4,7,9,11) LO2. Focuses on quality, consisting of: contribute significantly to original ideas for the research project; demonstrated experimental/modelling skills; critically evaluate used methods, data, and own results, taking limitations into account. (ILO: 5,7,8,11) LO3. Demonstrates behavioural competences, consisting of: project management, effective communication, independence, giving and receiving feedback. (ILO: 7,8,9,10) LO4. Demonstrates written presentation skills, consisting of: writing a scientific abstract that captures the essence of the work; using a logical, explicit and consistent structure, text flow, and presentation; using a concise, clear, and professional style in proper English; using clear, conscious, and conscientious referencing to pertinent literature. (ILO: 4,8) LO5. Gives an oral presentation and defends the work, consisting of: presenting in an enthusiastic and persuasive way that is easy to follow; using a clear structure for subject, materials and methods, main results, and conclusions; using intelligible material that is attractive and supports the story; defending own method, results and conclusions in an oral exam and answering questions in depth yet concisely. (ILO: 8)
Professional and personal skills	Self-study, project management, activity management, scientific approach, scientific reflection and judgement, responsibility and initiative, literature search, literature research, report writing in proper English, oral presentation, and thesis defence.
Module Content	The final project is a graduation thesis: A research project of about 20 weeks, the results of which are reported in a thesis. The results are presented in public to the graduation committee. The subject of the graduation project is to be decided jointly with the graduation coordinator and the student. In October of the second MSc year, a group of staff members of ETH, RWTH, and TUD will come together to inform the group of students on the possible graduation subjects. These subjects are usually related to one of the PhD research projects, in which case the PhD student will be the daily supervisor of the graduation project. The research can also take place in an external company or institute. In any case, there will always be an academic member of staff responsible for the quality requirements and supervision. The colloquium consists of a public presentation of the graduation thesis by means of a 20-minute

Module	**Final Thesis Applied Geophysics (JMAG230)**
	lecture, after which the audience can pose questions. A closed oral exam of the candidate by the graduation committee follows the presentation.
Form of instruction	Individual research project under daily supervision by a scientific staff member
Literature and study materials	Partly given by supervisor depending on project and partly acquired through literature search.
Formative assessment (feedback)	Regular progress/feedback meetings with supervisor/supervisory team, frequency reduces over time.
Summative assessment on module level	Assessment of final report, public presentation, and oral examination

ANNEX

MASTER DEGREE PROGRAMME

Applied Geophysics

2023
2024

THESE TEACHING AND EXAMINATION REGULATIONS APPLY TO ALL STUDENTS OF THE COHORT 2023-2024

Paragraph 1 – General Programme Regulations

Article 1.1 – Subject and scope of the General Programme Regulations

The General Programme Regulations set out the requirements according to which students of the Joint Master Programme in Applied Geophysics (Programme) may acquire their Master degrees in Applied Geophysics.

Article 1.2 – Programme partners

The Programme is the shared responsibility of the following three universities:

1. The Faculty of Civil Engineering and Geosciences at Delft University of Technology **(TUD)**,
2. The Department of Earth Sciences at the Swiss Federal Institute of Technology Zurich **(ETH)**, and
3. The Faculty of Geo-resources and Material Engineering at RWTH Aachen University **(RWTH)**, thereafter referred to as the partner universities.

Article 1.3 – Organization of the Programme

The students of the Programme study together at each university and move between universities as a group.

a. The students start their 120 credit points Programme at TUD in the fall.
b. After their first semester they move to ETH where they spend the spring semester, and
c. Finally, they move on to RWTH for their third semester.

The number of credits per university is specified in Paragraph 3.

Depending on their Master thesis project they will spend their last semester at one of the three partner universities or outside organisations such as industry, government agencies or other university laboratories. The Programme ends with a joint diploma ceremony at TUD where the students receive a degree certificate of each university, making it in fact a triple degree programme. All degree certificates make reference to the Programme.

Article 1.4 – Joint Board of Examiners

1. The Joint Board of Examiners (JBE) is independent of the Boars of the Examiners at each of the partner universities, and is responsible for all decisions concerning credit examinations, which are not part of local rules and regulations.
2. It is formed by one senior academic from each of the partner universities.
3. The members of the JBE, who are nominated by their home universities, each have one vote.
4. As a rule, the position of JBE Chairperson rotates on a two-yearly basis between the partner universities.
5. The duties of the JBE are specified either explicitly or implicitly in these General Programme Regulations as well as the Agreement.
6. Local boards at each partner university are responsible for local credit examinations. Details are specified in the local rules and regulations of each partner university.

Article 1.5 – Credit examinations

1. Credit examinations are in the responsibility of each partner university and thus handled according to local rules and regulations. The course schedule of each partner university specifies the type and modalities of credit examination.
2. The results of the credit examinations are to be declared to the students, the respective administration units and in particular the coordinating office at TUD within the timeframe stipulated by each partner university.

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3. The Director of Studies may require students who have interrupted or delayed their studies to retake any credit examination they passed during their previous enrolment in the Programme if the content of the course in question has considerably changed since then. Such re-entries will be evaluated on a case-by-case basis.

Article 1.6 – Obtaining credit points

A student will receive the allocated number of credit points for each course provided he/she has obtained a minimum grade of E (see 4.4 – Grading system) in the respective examination or has been granted an exemption.

Paragraph 2 – Compiling the Study Programme

Article 2.1 – Study load

Each student must obtain a minimum of **120 credit points** within 4 years to be awarded their Master degrees. It is recommended that students acquire their 120 credit points from the list of recommended courses.

Article 2.2 – Intended learning outcomes (final attainments)

The student is able to…

1. Explain, discuss, and use fundamental scientific knowledge about wavefield, diffusive-field and potential-field methods of applied geophysics.
2. Design and conduct scientifically sound geophysical experiments, process the collected data, and analyse and interpret the processed results.
3. Develop and use mathematical models to simulate, process, and invert geophysical data and solve related subsurface characterisation and monitoring problems.
4. Perform a literature study, identify a knowledge gap in a topic in applied geophysics, formulate a research question, and build on existing knowledge in relevant fields that are required to solve the stakeholders' problems.
5. Improve methodologies for applied geophysics that drive technological innovations to improve the responsible and sustainable use of the Earth's subsurface.
6. Observe, characterise, and explain Earth system processes related to application areas of applied geophysics.
7. Challenge existing knowledge, show a constructive critical attitude, propose novel and creative solutions, and exercise independent judgement.
8. Use written and oral communication skills to effectively exchange information and ideas with scientists and engineers, the public, and other stakeholders in the field of applied geophysics.
9. Initiate, design, plan, and monitor a project to meet the requirements set by the stakeholder
10. Work effectively in teams of diverse expertise, talents, skills, characters, and cultures.
11. Acquire new knowledge and skills to continue operating effectively.
12. Uphold and evaluate ethical standards for scientific integrity and evaluate societal and economic trade- offs and relevant ethical issues when developing technological innovations

Article 2.3 – Admission requirements

1. Admission to the Programme may be granted to:
   a. Applicants with a Bachelor degree in appropriate subject areas (e. g. earth sciences, environmental sciences, physics, engineering) issued by one of the partner universities;
   b. applicants with a Bachelor degree of at least 180 ECTS CPs or an equivalent university qualification in appropriate subject areas (e.g., earth sciences, environmental sciences, physics, engineering) which gives evidence of the required qualification for the Programme from other top universities worldwide.

2. In order to be sufficiently qualified for the Programme applicants must have a solid background in the fundamentals of mathematics and physics as well as basic knowledge of geology and geophysics.

Article 2.4 – Admission and selection procedure

1. Candidates for the Programme apply through the TUD admission system.
2. A pre-selection of applications is made by designated personnel of the TUD Admissions Office.
3. Applications passing the pre-selection procedure are then evaluated by the Admission Committee.
4. Admission is granted by the Dean of the Faculty of Civil Engineering and Geosciences of TUD to students who have been selected for the Programme by the Admission Committee.
5. Admission to the Programme may be conditional, such that some applicants may have to fulfil specific conditions (e.g., pass certain examinations at their home universities) before final admission.
6. Students who accept their admission offer will automatically be admitted to and enrolled at all partner universities for the entire duration of the Programme.

Article 2.5 – Language requirements

1. The language of tuition is English. All teaching, exercise and practical material will be provided in English.
2. All students are required to provide a proof of English language proficiency. The detailed requirements are published by TUD at the beginning of each admission period.
3. Only students with a Bachelor from either TUD, ETH or RWTH, nationals from the U.S., U.K., Ireland, Australia, New Zealand and Canada as well as students with a Bachelor degree from one of these countries are exempt from the proof of English language proficiency requirement.
4. TUD specifies the requirements in consultation with the Executive and the Administrative Committees.

Article 2.6 – Composing and registering the Individual Study Plan (ISP)

1. At the beginning of each academic year, the courses of the Programme, including details of compulsory credits, and type and weight of exam, will be provided by each partner university. Students register for their courses through the respective system of each partner university.
2. Students must submit an Individual Study Plan (ISP) in My Study Planning. The ISP provides an overview of the full MSc programme the student intends to follow, including all courses or modules and electives.
3. The ISP and any subsequent changes to it have to be approved by programme coordinator.
4. Approved ISPs are registered in Osiris and are used to monitor the students’ progress, as well as to check whether the student has fulfilled all components necessary to graduate.

Paragraph 3 – Programme Composition

Article 3.1 – Programme overview

1. Each student must obtain a minimum of **24 EC** from each partner university;
2. Each student must pass the obligatory course and 2 out of 2 core modules at TUD, pass the obligatory course and 1 out of 2 core modules at ETH and 3 out of 6 core modules at RWTH;
3. Each student must obtain 30 credit points for the Master thesis project including an obligatory colloquium at the end of the project.

The programme consists of the following components:

	Semester 1 (Sep.-Jan.)	EC		Semester 2 (Feb.-Jul)	EC
TU Delft	Nominal study load	**30**	**ETH Zürich**	Nominal study load	**30**
	Minimum study load	**24**		Minimum study load	**24**
	Mandatory modules	**18**		Mandatory modules	**21**
	Semester 3 (Oct.-Feb.)	**EC**		**Semester 4 (Mar.-Aug.)**	**EC**
RWTH Aachen	Nominal study load	**30**	**All partners**	Nominal study load	**30**
	Minimum study load	**24**			
	Mandatory modules	**18**		Master thesis	**30**

Article 3.2 – Programme Requirements

1. Each student must obtain a minimum of **120 credit** points[1] within 4 years to be awarded their Master degrees. It is recommended that students acquire their 120 credit points from the list of recommended courses. However, each student must:
   a. obtain a minimum of **24 credit** points from each partner universities courses;
   b. pass the obligatory course and 2 out of 2 core modules at **TUD**, pass the obligatory course and 1 out of 2 core modules at **ETH** and 3 out of 6 core modules at **RWTH**;
   c. obtain **30 credit** points for the Master thesis project including an obligatory colloquium at the end of the project.

   A students can compensate the difference between the nominal amount of **30 credit** points and the minimum of **24 credit** points in one partner university with the corresponding number of extra credits at another partner university.

2. Students need to have obtained at least **40 credit** points from TUD and ETH after one academic year before 1 October of the calendar year in which they study at ETH. Students who do not obtain the necessary **40 credits**, will be expelled from the programme.

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[1] The Programme follows a credit system which is aligned with the European Credit Transfer System (ECTS). Credit points describe the average time expenditure required to achieve a learning goal. The curriculum is designed such that students may obtain an average of 30 credit points per semester.

Article 3.3 – Programme composition

1. **First year TU Delft:** A minimum of **24 credits** should be passed from TU Delft subjects, including the following three compulsory courses:
2.

	Course code	Course title	EC
Semester 1	**JMAG110**	Field Geophysics and Signal Analysis with exercises	6
	JMAG111	Advanced Reflection Seismology and Seismic Imaging	6
	JMAG100	Electromagnetic Exploration Methods	6

Additional courses at TU Delft:

Course code	Course title	EC
JMAG121	Geophysics Special Subjects	6
JMAG120	Seismic Acquisition to Data Information Content	6

3. **First year Zürich:** A minimum of **24 credits** should be passed from ETH Zürich subjects, where Block 2 is obligatory and one out of the Blocks 1 and 3 must be passed:

	Course code	Block	Course title	EC
Semester 2	651-4079-00L	Block 1	Reflection Seismology Processing	**5**
	651-4104-00L	Block 2	Geophysical Field Work & Processing: Methods	**2**
	651-4106-03L	Block 2	Geophysical Field Work & Processing: Preparation and Field Work	**7**
	651-4094-00L	Block 3	Numerical Modelling for Applied Geophysics	**4**
	651-4096-00L	Block 3	Inverse Theory I: Basics	**3**

Additional courses at Zürich:

Course code	Course title	EC
651-4087-01L	Case Studies in Exploration and Environmental Geophysics	**3**
651-4096-02L	Inverse Theory II: Applications	**3**
651-4109-00L	Geothermal Energy	**4**
651-4110-00L	Computational Methods in Seismic Data Analysis and Imaging	**3**
651-4240-00L	Geofluids	**6**
701-0106-00L	Mathematics V: Applied Deepening of Mathematics I-III	**3**

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4. **Second year Aachen:** a minimum of **24 credits** should be passed from RWTH Aachen subjects, whereby three of the following six blocks must be passed.

	Course code	Block	Course title	EC
Semester 3	5.314.584	Block 1	Petrophysics	**3**
	5.326.003	Block 1	Laboratory Practicals: Applied Reservoir Petrophysics	**3**
	5.314.570	Block 2	Geophysical Logging and Log Interpretation	**3**
	5.350.132	Block 2	Fieldwork: Geophysical Logging and Log Interpretation	**3**
	5.412.003	Block 3	Inversion concepts for multi-method geophysics	**6**
	5.318.482	Block 4	Hydrogeophysics	**3**
	5.329.469	Block 4	Engineering geophysics	**3**
	5.342.487	Block 5	Numerical Reservoir Engineering: Geophysical process simulation	**3**
	5.350.028	Block 5	Scientific Machine Learning and Advanced Numerical Methods	**3**
	5.412.000	Block 6	Research Module in Applied Geophysics	**6**

Additional courses at Aachen:

Course code	Block	Course title	EC
5.314.584	Block 1	Petrophysics	3
5.326.003	Block 1	Laboratory Practicals: Applied Reservoir Petrophysics	3
5.314.570	Block 2	Geophysical Logging and Log Interpretation	3
5.350.132	Block 2	Fieldwork: Geophysical Logging and Log Interpretation	3
5.412.003	Block 3	Inversion concepts for multi-method geophysics	6
5.318.482	Block 4	Hydrogeophysics	3
5.329.469	Block 4	Engineering geophysics	3
5.342.487	Block 5	Numerical Reservoir Engineering: Geophysical process simulation	3
5.350.028	Block 5	Scientific Machine Learning and Advanced Numerical Methods	3
5.412.000	Block 6	Research Module in Applied Geophysics	6
1.147.549		Numerical Methods for Geophysical Flows	3
1.253.420		Machine Learning	6
4.100.220		Finite Elements in Fluids	6
5.312.002		Principles of Plate Tectonics	3
5.323.301		Sedimentary Basin Dynamics	3
5.330.255		Seismic Interpretation and Well Integration	3
5.331.439		Data analysis in Geoscience	3
5.332.383		Underground Excavation	6
5.333.690		Remote Sensing of Sedimentary Basins	3
5.345.471		Portfolio Management and Prospect Evaluation	3
5.349.932		Neotectonics and Earthquake Geology	3
5.424.346		Energy Resource Management	3
5.434.827		Mineral Exploration	3
8.118.471		Economics of Technological Diffusion	6
5.321.003		GIS-intensive course for Engineering	3
5.213.002		Geohazards Remote Sensing of Geohazards	3
5.100.010		Final Disposal and Projects	3
5.100.017		Geological & Engineering Basics of Final Disposal	3

5. **Second year Delft/Zürich/Aachen:** Master thesis **30 credits**

	Course code	Course title	EC
Semester 4	**JMAG230**	Master Thesis Project	30

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Article 3.4 – Thesis preparation

1. A student may only begin his/her Master thesis project once the research project has been approved by JBE and he/she can reach **83 ECTS** by the end of the first exam period at RWTH.
2. Should there be cogent grounds for a student not obtaining the required **83 ECTS**, a student may submit an individual request for an exception to the JBE and the JBE may allow the Master thesis project to begin.
3. As thesis preparation, students are strongly advised to complete the following research module.

Module code	Module title	EC
5.412.000	Research Module in Applied geophysics	**6**

Article 3.5 – Master Thesis Project

Since the Master thesis is common to the three partner universities, the rules laid down here are common to the three universities.

1. **Choice of master thesis theme:** The JBE publishes a list and description of research themes for Master thesis projects. Representatives from each of the three partner universities and, if applicable, from industry give short presentations on the potential research projects at a thesis presentation day and are available to discuss these with the students. Some research projects may involve extensive periods of closely supervised research in industry, government or other university laboratories.
   After the presentations, each student submits to the JBE a ranked list of three research themes, each one supervised by a different partner university, that he/she may be interested in pursuing in his/her thesis project. Subject to availability, every reasonable effort is made to provide the student with a research theme that matches his/her preferences and suites his/her knowledge, skills and experience.

2. **Master thesis projects outside of the partner universities:** A Master thesis project may be conducted outside of the partner universities but requires the explicit approval of the JBE. Proposals for such projects must be submitted to the JBE at least ten days before the presentation of research themes. The JBE will take the decision of approval before the thesis presentation day. Acceptable outside organisations include companies, government agencies and other university groups, all of which work in various fields of Applied Geophysics.

3. **Beginning the Master thesis project:** A student may only begin his/her Master thesis project once the research project has been approved by the Joint Examination Board and he/she can reach 83 ECTS by the end of the first exam period at RWTH.
   Should there be cogent grounds for a student not obtaining the required 83 ECTS, the Joint Examination Board may allow the Master thesis project to begin.

4. **Duration of the Master thesis projects:** The duration of the Master thesis project up to the submission of the report is 22 weeks. The student will present and defend her/his thesis work within 2 weeks after the submission of the report. The Joint Examination Board may extend the duration of the Master thesis project, if cogent grounds are provided by the thesis supervisor.

5. **Supervision and form of the Master thesis projects:** The student must report to his/her supervisor(s) at least once every two weeks during the course of the Master thesis project.
   At the 6- and 12-week marks, the student presents verbal reports on the status of the research. At the 15-week mark, the students and supervisors decide on the content and form of the written Master thesis. If there are sufficient original results, then an article may be prepared for publication in a scientific journal. Such an article, appropriately bound in the form of a thesis, is acceptable as the Master thesis. The maximum page number of the thesis is 70 excluding (digital) appendices.
   The resulting Master thesis should be subjected to one round of corrections by the principal supervisor or his/her delegate before being formally submitted and examined.

6. **Completion of the Master thesis report, public presentation and defence:** The completed Master thesis report must be made available to an ad hoc thesis committee (see below, under 7) directly after the submission, whose date is specified in the academic calendar, which is at least 1 week before the defence. After the completion of the Master thesis report the students have to present their results in a 20-minute public presentation with 5 minutes for questions from the public. After the presentation the ad hoc thesis committee will examine the candidate on the thesis work in a closed sitting (defence) of at least 15 minutes.

7. **Composition of the Master-thesis assessment committee:** Each Master thesis is assessed by an ad hoc thesis committee which consists at least of:
   - Two members, one of whom is the principal supervisor and one from a partner university.
   - Each of these members must be a full professor, associate professor, assistant professor or senior lecturer at one of the partner universities.
   - Each of these members must be qualified to assess courses/theses at her/his own university.
     The principal supervisor is responsible for forming the ad hoc thesis committee. The ad hoc thesis committee might be extended to additional members (e.g., the external supervisors from external master thesis projects) without voting right.

8. **Grading the Master thesis:** The ad hoc committee assesses the thesis, the public presentation and the defence, and the final decision on the grade is made by the committee members with voting rights. These committee members have to be involved in assessing the thesis, the public presentation and the thesis defence.
The JBE establishes a list of evaluation criteria, with which all these are assessed.
The ad hoc thesis committee makes recommendations concerning the grades (in the local grading system) to be given to the thesis including colloquium. The final decision concerning the grades is the responsibility of the two committee members with voting right.
The principal supervisor shall declare the results to the student after the colloquium presentation and the thesis defence. He/she will also inform the respective administration units and in particular the coordinating office at TUD.

9. **Repetition of a failed Master Thesis:** A failed Master thesis may be repeated once. A repetition of a failed Master thesis must be on a different topic and may be conducted with the same or a new supervisor. To repeat a failed Master thesis, the student has to submit a proposal to the JBE which then assigns a principal supervisor for the Master thesis project. The student must start the repeated

   Master thesis within three semesters after the failed first attempt. For the duration, supervision, form, completion, presentation and grading of the Master thesis the same rules apply as for the failed Master thesis (Art. 10.4 – 10.7). If the repetition of the Master thesis fails or if the time limit to start the repeated Master thesis is exceeded, the student is expelled from the Programme. However, the student has the possibility to choose another track within the Applied Earth Sciences Master programme at TUD.

Article 3.6 – Award of degree

A student is eligible for the award of his/her Master degree once his/her grade list is complete and all the final grades are passes (A through E; see 4.4 – Grading system).

Article 3.7 – Documents and title

As proof that candidates have successfully gained their Master degree, the students receive a joint- degree diploma certificate from the three partner universities and a corresponding diploma supplement which also includes the grades. This gives the student the right to use the title of **Master of Science Applied Geophysics**.

Article 3.8 – With honours

A student will be awarded a degree “with honours” provided the following conditions have been satisfied (see 4.4 – Grading system):

1. The grade given for the Master thesis is an A;
2. The weighted average grade gained in the course list as being statutory for the Master’s degree is at least a B;
3. The grades list contains no grades lower than a D;
4. The study duration for the Programme is 2 years. Exceptions can be requested from the examination board of the JMAG program when study delay is due to extenuating circumstances unrelated to the student’s study behaviour;
5. Not more than 1 re-sit has been taken on all courses of the program.

If the candidate has been awarded a Master degree "with honours", then the term "with honours" will be printed on the degree certificate.

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Article 3.9 – Electives

1. A list of recommended courses will be provided to the students at the beginning of each semester at TUD, ETH and RWTH.

2. At TUD, the list of recommended courses can be extended with any course of their Applied Earth Science programme.

3. At ETH, the list of recommended courses can be extended with any course of their Earth Science programme.

4. At RWTH, the provided list of courses includes possible elective and voluntary courses that can be followed.

5. For courses outside these lists, a permission from the JBE is required.

6. Students may not choose as free electives[2]:
   - Language courses
   - Courses offered by the Graduate School;
   - Skill courses and MOOCs.

   Company internships, language courses, skills subjects and MOOCs are not allowed within the examination Programme, they can only be part of the extracurricular section of the diploma supplement.

Paragraph 4 – Practical information

At the TU Delft:
The following articles apply only in the TU Delft.

At ETH Zürich:
The rules and regulations at ETH Zürich apply. See the regulations of ETH Zürich.

At RWTH Aachen:
The rules and regulations at RWTH Aachen apply. See the regulations of RWTH Aachen.

Article 4.1 – Registering for courses

1. At the beginning of each academic year, the courses of the Programme, including details of compulsory credits, and type and weight of exam, will be provided by each partner university.

2. Students register for their courses through the respective system of each partner university.

Article 4.2 – Credit examinations

1. Credit examinations are in the responsibility of each partner university and thus handled according to local rules and regulations. The course schedule of each partner university specifies the type and modalities of credit examination.

2. The results of the credit examinations are to be declared to the students, the respective administration units and in particular the coordinating office at TUD within a reasonable timeframe.

3. The JBE may require students who have interrupted or delayed their studies to retake any credit examination they passed during their previous enrolment in the Programme if the content of the course in question has considerably changed since then. Such re-entries will be evaluated on a case-by-case basis.

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[2] This means that the courses are not allowed within the examination programme but only as extracurricular.

Article 4.3– Practicals and/or Exercises

1. The course or module teaching takes the form of lectures, practicals and/or exercises.

2. Practicals and/or exercises must be completed before students participate in the examination, unless indicated otherwise in the study guide.

3. Unless specified otherwise by the corresponding course or module description in the study guide, the following rules apply with respect to improving an unsatisfactory result for a project or practical for which a student receives a (partial) grade:
   a. If the result of a practical exercise is less than satisfactory, i.e., if the practical exercise is assessed with a grade **5.5** or lower, the grade for the practical exercise may be improved during the next teaching period, through one of the following options depending on the grade obtained:
      - Grade 5.0 or higher: The student may submit an addendum to the original submission
      - Grade lower than **5.0:** The student must redo the practical exercise completely, i.e., based on a new case or a new set of input parameters.
   b. The maximum grade that can be obtained by improving an unsatisfactory result for a project or a practical is a grade **6.0**.

Article 4.4 – Grading system

1. National grading scales and conversion to absolute **A-F grades.** Each partner university uses its local grading scale. On the degree certificate the grades of all courses are converted to absolute A-F scale according to the following table:

·F grading scale	Description	TU Delft	RWTH Aachen	ETH Zürich
A	Excellent	9.2 to 10	1.0 to < 1.5	> 5.5 to 6.0
B	Very good	8.4 to < 9.2	1.5 to < 2.1	> 5.0 to 5.5
C	Good	7.6 to < 8.4	2.1 to < 2.8	> 4.5 to 5.0
D	Satisfactory	6.8 to < 7.6	2.8 to < 3.5	> 4.0 to 4.5
E	Sufficient	6.0 to < 6.8	3.5 to 4.0	4.0
F OR FX	Fail	< 6.0	> 4.0	< 4.0
X	Exemption			
> larger than, < less than				

ECTS and local grades will be listed on the diploma supplement.

2. Obtaining credit points. A student will receive the allocated number of credit points for each course provided he/she has obtained a minimum grade of E in the respective examination or has been granted an exemption.

3. Final average grade. TUD is responsible for providing the final average grade. For calculating this average, the marks of the courses from each university are converted to the TUD grading scale that has the finest scale and uses the scale 1 to 10, rounded off to one decimal. For these conversions, the following table is used:

ETH mark	TUD-equivalent		RWTH-mark	TUD-equivalent
6.00	10.0		1.00	10.0
5.75	9.5		1.30	9.6
5.50	9.0		1.70	9.1
5.25	8.5		2.00	8.7
5.00	8.0		2.30	8.3
4.75	7.5		2.70	7.7
4.50	7.0		3.00	7.3
4.25	6.5		3.30	6.9
4.00	6.0		3.70	6.4
			4.00	6.0

4. The Weighted average. Then the weighted average, with the ECTS credits of the courses as weights, is determined. Finally, the TUD-scale average is converted to the average in the absolute A-F grading scale using the table under 9.1.

Article 4.5 – Graduation ceremony

A joint graduation ceremony will be held annually at TU Delft.

Article 4.6 – Leaving without completion of the programme

Students who have successfully passed one or more credit examinations, but who leave the Programme without eligibility for a degree certificate, may receive a declaration of such from the JBE provided that they submit such a request.

Article 4.7 – Appeals

Appeals with regard to the admission fall under the appeal regulations of TUD. All other appeals, including appeals regarding the master thesis project, fall under the appeal regulations of the institution where the incident occurred.

Paragraph 5 – Bridging Programme

Article 5.1– Bridging Programme Dutch Higher Vocational Institute Bachelor Degree

1. This bridging programme is designed especially for the Dutch students from Dutch Higher Vocational Institutes.
2. The courses in this bridging programme will be taught only in Dutch.
3. Students who want to be admitted to the Master's degree course on the basis of a relevant Dutch Higher Vocational Institute Bachelor degree have to complete the following bridging programme first.

Course code	Course title	EC
	Compulsory courses	
IFEEMCS012100	Calculus for Engineering, deel 1	**3**
IFEEMCS012200	Calculus for Engineering, deel 2	**3**
IFEEMCS010400	Lineaire algebra	**5**
IFEEMCS010500	Probability and Statistics	**3**
WI1909TH	Differential Equations	**3**
CTB2400	Numerical Maths	**3**
CT2023	Programming in Python	**3**
AGPB1320-17	Mechanics	**5**
AGPB2320	Physical Transport Phenomena	**5**
	AGP Optional: Choose one out of three	
AGPB1130-21	Geology 1: Basics	**5**
AGPB1440-21	Methodology of Geophysics and Remote Sensing	**5**
AGPB1230	Geology 2: North West Europe	**5**

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Paragraph 6 – Deviations from the study programme

Article 6.1 – Deviations from the programme

The Joint Board of Examiners may allow students to deviate from the rules of the programme, including the transitional rules, if the achievement of the intended learning outcomes of the programme are safeguarded.

Article 6.2 – When the rules do not provide

Insofar as this annex does not provide for specific circumstances, the Joint Board of Examiners will make a decision that is in line with this annex to every extent possible.

Article 6.3 – Final provision

The General Programme Regulations come into effect at the beginning of the autumn semester 2023. They apply to students who enter the degree programme.

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