MEMORANDUM OF UNDERSTANDING

BETWEEN

RIGA TECHNICAL UNIVERSITY,

UNIVERSITY OF LATVIA,

UNIVERSITY OF TARTU,

KAUNAS UNIVERSITY OF TECHNOLOGY
AND

VILNIUS UNIVERSITY

Riga Technical University (hereinafter referred to as RTU), registration no. 90000068977, legal address: Ķīpsalas str. 6A, Riga, LV-1048, represented by the Vice-rector for Academic Affairs, Professor Elīna Gaile-Sarkane;

University of Latvia (hereinafter referred to as UL), registration no. 90000076669, legal address: Raiņa bvld. 19, Riga, LV-1586, represented by the Vice-rector for Studies, Professor Kristīne Strada-Rozenberga;

University of Tartu (hereinafter referred to as UT), registration no. 74001073, legal address: Ülikooli 18, EE-50090 Tartu, represented by the Vice-rector for Academic Affairs, Dr Aune Valk;

Kaunas University of Technology (hereinafter referred to as KTU), registration no. 111950581, legal address: K. Donelaičio str. 73, LT-44249, Kaunas, Lithuania, represented by the Rector, Professor Eugenijus Valatka and

Vilnius University (hereinafter referred to as VU), registration no. 211950810, legal address: Universiteto str. 3, LT-01513 Vilnius, Lithuania, represented by the Rector, Professor Rimvydas Petrauskas;

all together hereinafter referred to as Parties, agree on the importance, benefits and positive regional impact of the development of a joint master's level study programme in the scientific fields of high-energy particle physics and high-energy particle physics instrumentation.

The Parties agree that this Memorandum of Understanding (hereinafter referred to as MoU) expresses the willingness of the Parties to jointly develop and implement, in good faith, a joint master's study programme by the Parties on the basis outlined in this MoU and its annexes.

Article 1 : Parties of this MoU

The Parties of this MoU shall be the five Universities signing this MoU: RTU, UL, UT, KTU, VU. Of the Parties listed, RTU shall be the coordinating party of all the activities undertaken in the attainment of the purpose of this MoU (Article 2). Outside the coordinating role of RTU, all Parties shall undertake the actions in pursuance of the purpose of this MoU in equal stature and in equal standing.

Article 2 : Purpose of this MoU

This MoU defines the cooperation between the Parties in pursuit of the development and implementation of a new joint master's level study programme titled "European Master in particle Physics and Accelerator Technologies for Research and Industry" (EMPATRI), focused on the scientific fields of high-energy particle physics and high-energy particle physics instrumentation. The steps required for the attainment of the general purpose, are outlined in the following clauses of this MoU, as well as its annexes. Any additional steps, activities, responsibilities, and deliverables will be articulated in a separate written contract, or an amendment to this MoU. Any such documentation will be signed by an authorised representative of each party.

Article 3 : Development of the EMPATRI study programme

The Parties agree to jointly undertake the following actions required for the development of the EMPATRI study programme:

a. To agree, in principle, on the joint mechanisms, such as the student admission, evaluation, enrolment and diploma award mechanisms of the proposed study programme, outlined in Annex 1 of this MoU, as the deliverable of the on-going *Erasmus Mundus Design Measures* (EMDM) project no. 101082399 – *EURO-HEAPAT-design*, with RTU as the coordinating party responsible for the timely submission of said documentation.
b. To continue the joint development of the curriculum, outline of which is provided in Annex 2 of this MoU, as well as other aspects of the proposed study programme beyond the expiry of the abovementioned EMDM project.
c. To jointly develop the project proposal for the next Erasmus Mundus Joint Master's (EMJM) project call period, expected to be opened in February 2025, with RTU as the coordinating party responsible for the collation and timely submission of all the documentation required.
d. To jointly pursue with best efforts the development, by the appropriate regulatory bodies in the respective countries of each party, of a legal framework allowing for an award of a single joint diploma for the graduates of the EMPATRI study programme.

Article 4 : Implementation of the EMPATRI study programme

The Parties agree, in principle, to pursue the implementation of the EMPATRI study programme as outlined in Annexes 1 and 2 of the MoU, subject to:

a. A successful bid for the EMJM funding, or the attainment of the required financial resources from any other appropriate source.
b. The development of an appropriate legal framework allowing for an award of a single joint diploma for the graduate of the EMPATRI study programme.

The Parties agree, in principle, to develop an enforceable and binding Consortium Agreement for the implementation of the EMPATRI study programme, to be signed and enacted if the above conditions (a) and (b) of Article 4 are met.

Article 5 : Financial obligations

This MoU explicitly does not bind any of the Parties to any financial obligations with respect to each other in relation to the purpose of the MoU. Any financial aspects arising shall be subject to other existing agreements or future negotiations, which shall be implemented under a specifically prepared, legally binding document or set of documents.

Article 6 : Validity of this MoU

This MoU shall be valid for 5 (five) years from the date of its signature by all Parties. This MoU can be extended at any time by mutual consent and a renewal of the signature by all Parties, upon when the validity of 5 (five) years shall be reset, unless indicated otherwise. The validity of this MoU will shall be terminated in case of the signature and coming to power of the Consortium Agreement stipulated in Article 4.

The termination of this MoU can also be initiated by the request of any of the Parties, subject to the agreement of the remaining Parties, whereupon the validity of this MoU shall be terminated no earlier than 1 (one) calendar month after such agreement is made.

Article 7 : Dispute resolution

The Parties shall make their best efforts to resolve any issues or disputes arising via mutual discussions and direct negotiations. Should irreconcilable differences arise, the MoU termination process shall be initiated as discussed in Article 6.

Article 8 : Final provisions

The Parties agree that this MoU is not legally binding and does not, in principle or practice, imply any financial obligations towards each other from any of the Parties. The parties recognize, however, that the success of the attainment of the purpose of this MoU depends on the good will of the Parties and the adherence to the provisions stated in this document.

This MoU has been drawn up in English and may be translated into any other language by any of the parties. The original version written in English retains the authority over any other version.

List of Annexes

Annex 1: Joint mechanisms for the implementation of the joint study programme *"European Master's in particle Physics and Accelerator Technologies for Research and Industry"*.

Annex 2: The overview of the contents and the curriculum of the joint study programme *"European Master's in particle Physics and Accelerator Technologies for Research and Industry"*.

Annex 3: Main contact persons for the development and implementation of the joint study programme *"European Master's in particle Physics and Accelerator Technologies for Research and Industry"*.

Signatures

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Rector	**Rector**
Professor Rimvydas Petrauskas	**Professor Eugenijus Valatka**

ANNEX 1

Joint management structure and joint mechanisms of the master's study programme "European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI)

"European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI) study programme is designed and will be implemented and managed by a Consortium of higher education institutions (HEIs), from the three Baltic states, Latvia, Estonia, and Lithuania. At the present time, this Consortium comprises five HEIs: Riga Technical University (RTU), University of Latvia (UL), University of Tartu (UT), Kaunas University of Technology (KTU), and Vilnius University (VU). This document outlines the proposed joint mechanisms for this study programme.

Joint management structure

EMPATRI will be managed jointly by all partners of the Consortium via the **study programme council (SPC)**, which will act as the main overseeing body of the programme. SPC will comprise of ten[1] council members, two from each HEI of the Consortium. SPC members will be delegated by the appropriate Representative of each member of the Consortium, as determined by the state and internal regulations applicable to the respective HEI. At present time these Representatives are as follows: **Vice-Rector for Academic Affairs, Professor Elīna Gaile-Sarkane at RTU**; **Vice-Rector for Studies, Professor Kristīne Strada-Rozenberga at UL**; **Vice-Rector of Academic Affairs, Dr Aune Valk at UT**; **Vice-Rector for Education, Professor Kristina Ukvalbergienė at KTU;** and **Pro-Rector for Studies, Professor Valdas Jaskūnas at VU**. The initial term of the members of the SPC will be four years, with the option to be renewed for an indefinite number of terms. The Representatives of the HEIs will, however, retain the right to make changes to their SPC delegates at any time. The SPC will internally nominate and vote on the Chair and the Vice-Chair positions of the council for the term of two years, with an option for renewal for a second term. The HEI of the Consortium holding the Chair position is also responsible for providing the secretariat services for the SPC, including but not limited to, the provision of the minuting of the SPC meetings. All decisions shall be taken by the SPC via a vote with the threshold of six votes required to pass any resolution. Additionally, at least one representative of each member of the Consortium must endorse the voting question for the resolution to be passed.

The SPC is responsible for the strategic planning and the approval of the processes and outcomes of the study programme. Such processes and outcomes include, but are not limited to, the approval of the committees of the study programme, the study course plan, assignment of the academic staff, student admissions, matriculation and exmatriculation of

[1] Each member of the Consortium will delegate two persons to the SPC. In case of contraction or expansion of the Consortium, the number of council members will decrease or increase, respectively, with the SPC always having twice the number of members as the number of members of the Consortium.

students, and the exam and final grades. The SPC meets regularly, with a minimum of no less than three meetings per year:

- following the January exam period to evaluate the students' results.
- following the June exam period to evaluate the students' results, prepare the final documentation required for graduation and to approve the annual committees for the following academic year.
- following the close of the yearly application period, likely scheduled for May/June of each year.

The programme council may convene for an *ad hoc* meeting at any time, as requested by any member of the study programme council or if requested by the Dean of a faculty implementing the study programme at either of the partner institutions, or if requested by a Vice-Rector or Rector of any of the universities of the Consortium.

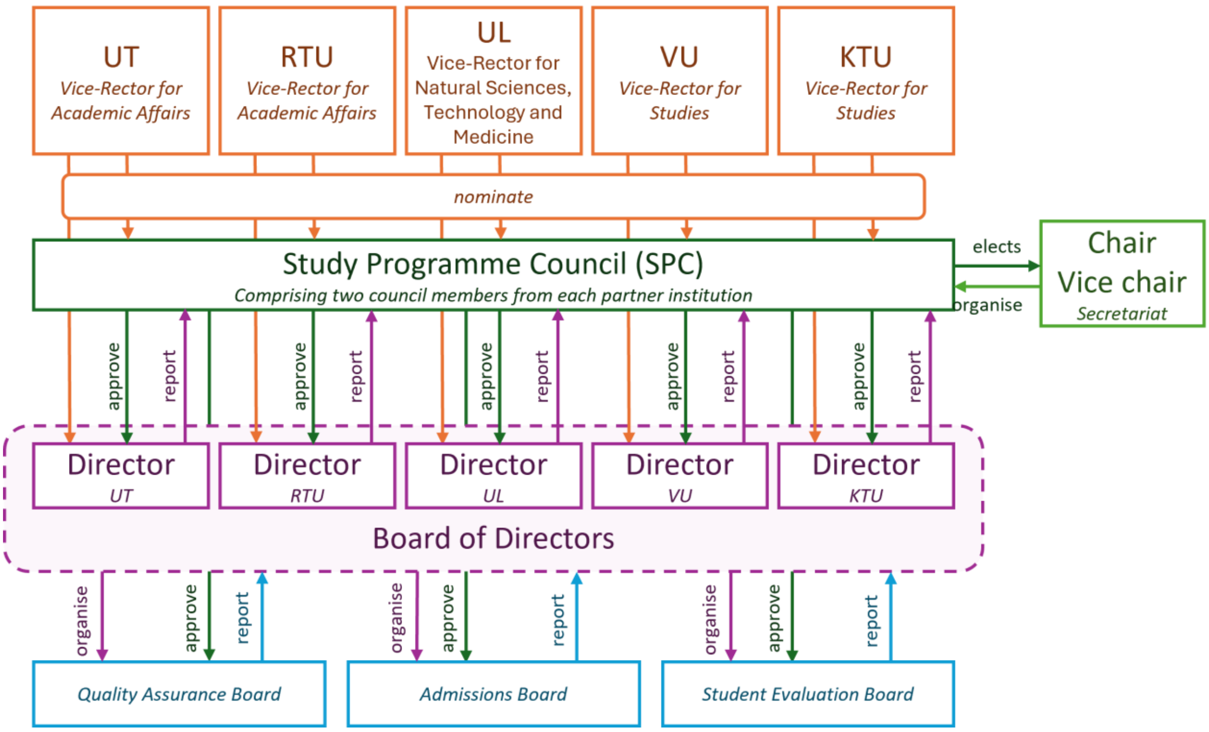

Figure 1. Organisational diagram depicting the joint management structure of the EMPATRI study programme.

The Representatives of each member of the Consortium shall nominate one of their SPC delegates to serve as a **study programme director (SPD)**. SPDs form the Board of Directors, an executive group withing the SPC.

The Board of Directors is the main executive actor regarding the day-to-day activities of the study programme. It is responsible for ensuring the implementation of the study plan and the availability of the material and technical base necessary for the study process. It is also responsible for organising the annual committees and overseeing their work, as well as the creation and implementation of the annual communication, advertising, and dissemination plan. In addition, the Board of Directors acts as the steering board of the programme, supporting the strategic planning activities of the SPC. The Board of Directors and each individual SPD report to the SPC and are bound by its decisions.

Several committees are formed annually for the study programme. The main bodies are the Quality Assurance Board, the Admissions Board, and the Student Evaluation Board. Each committee must consist of no less than one and no more than three representatives from each HEI of the Consortium. Members of the SPC are permitted to participate in the annual committees. Any individual is likewise permitted to participate in more than one annual committee.

The overall joint management structure is shown in Figure 1.

Joint admission mechanisms.

The evaluation and the ranking of students' applications prior to the admission shall be carried out by the Admissions Board, validated by the Board of Directors and approved by the SPC. Prior to the evaluation of the received applications, SPC decides on the number of admissible students for the given intake and informs the Admissions Board. Students of EMPATRI will be enrolled simultaneously in all participating partner-universities.

Admission requirements.

General requirements.

The applicant must have been awarded or is about to be awarded a **bachelor's degree** in the field of **natural sciences** or **engineering**, with **at least 60%** of the acquired undergraduate **credits** having been awarded for courses in **physics** and/or **engineering**, or other closely related field of science.

The applicant must be eligible to reside and study in the European Union or be eligible for an appropriate student visa.

English language requirements.

The applicant must be able to prove an English language comprehension level of at least B2 on the Common European Framework of Reference (CEFR) scale. The following documentation will be considered a valid proof of English language comprehension:

- International English Language Testing System (IELTS) score no lower than 5.5 in all categories;
- Internet-based Test of English as a Foreign Language (TOEFL iBT) score of no less than 75;
- A diploma of previous education where the predominant language of instruction was English;
- A proof of identity demonstrating that the applicant is a Native speaker of English from one of the following countries:
    - Australia;

- The Bahamas;
- Canada;
- Ireland;
- New Zealand;
- St Vincent and the Grenadines;
- United Kingdom;
- United States of America.

Joint admission evaluation criteria.

Student applications will be evaluated based on four main criteria:

- Interview (30% of the overall assessment).
- Letter of motivation (30% of the overall assessment).
- Academic results of their bachelor's studies (30% of the overall assessment).
- Curriculum Vitae and additional achievements (10% of the overall assessment).

Applicants must have achieved at least 60% of the overall maximum available marks for their bachelor's diploma and have passed no less than 90% (in terms of study credits) of individual courses/modules.

The letter of motivation must be no more than 3000 characters (including white-space characters). The letter should include a brief description of the applicant's previous study and work experience, scientific and research interests, and the reasons for choosing to apply for the EMPATRI programme. Additionally, the letter should include a brief discussion of the applicant's background and interests in general. The letter will be evaluated on the fit between the candidate and the study programme, as well as both the argumentation skills and the fluency of written English.

NB! Machine learning checking tools will be employed to evaluate the motivation letters and in case of the use of text-generation tools being detected, the letter will score 0%.

Joint admission evaluation methodology.

EMPATRI will have a regular yearly intake of students. Applications will be initially filtered with respect to the general admission criteria (see above) by two members of the Admissions Board nominated by the Board of Directors. The candidates whose applications are deemed invalid will be notified within seven calendar days from the closing date of the application period and given seven calendar days from the receipt of said notification to dispute and, if applicable, rectify the ineligibility factors of their application. The set of valid applications will be passed onto the full Admissions Board for further evaluation at the earliest opportunity.

The Admissions Board will evaluate the applications according to the joint admission evaluation criteria (see above). The applications will firstly be ranked with respect to the previous academic results of the applicants, from the highest to the lowest. At this stage the criteria of the total applicable credits and the total passed/failed credits described in the joint admission evaluation criteria section will be applied and applications failing these requirements will be excluded from further consideration. A predetermined number of highest-ranked candidates will be selected for an interview. The predetermined number will correspond to no less than 150% and no more than 200% of the available study places for the given year. In case of the total number of eligible applications being less than 150% of the available study places, all eligible applicants will be selected for an interview. Candidates selected for the interview will be notified at the earliest opportunity. Candidates not selected for interview will be notified concurrently.

The interview process will be conducted at the earliest possible opportunity for all selected candidates. During the interview, candidates will be asked to discuss their previous academic achievements, their academic and research interests, and the reasons for applying for the EMPATRI programme. Each individual interview will not exceed 30 minutes. The interviews will be carried out using a teleconferencing platform, such as Zoom or MS Teams. In case of unavailability of such tools to the candidate, best efforts will be made for the interview to be performed via other methods.

Following the interview process, the Admissions Board will provide the Board of Directors with the final ranking of the candidates for validation and to the SPC for approval at the earliest opportunity. For the final ranking, all four criteria listed in the joint admission evaluation criteria section will be assigned a mark from 0 to 10 (half-points will be permitted), weighted, and combined to provide an overall mark. In cases of equal overall mark, the position in the ranking will be assigned using the tie-breaking method by evaluating each of the separate marks in the following order of priority:

1) Interview.
2) Academic results of their bachelor's studies.
3) Letter of motivation.
4) Curriculum Vitae and additional achievements.

The individual marks for the letter of motivation, the interview and the Curriculum Vitae and additional achievements criteria will be constructed as described below.

Letter of motivation [0-10 marks]:

1) Motivation and research interests [0-5 marks]:
    a. Motivation and research interests are ideally suited for the study programme, the letter conveys great enthusiasm for the programme [5 marks].
    b. Motivation and research interests are well in-line with the study programme [4 marks].
    c. Motivation and research interest are broadly compatible with the study programme [3 marks].
    d. Motivation and research interest are tentatively connected and have only partial links with the study programme [2 marks].

   e. Motivation and research interests are compatible with the relevant scientific field, but not directly compatible with the study programme [1 mark].
   f. Motivation and research interests are wholly incompatible with the programme
      [0 marks].
2) Written argumentation skills [0-3 marks]:
   a. The reasons for applying for EMPATRI are exceptionally clear and well justified [3 marks].
   b. The reason for applying for EMPATRI is clear and reasonably justified [2 marks];
   c. The reasoning for the application is not particularly clear, with some justification outlined [1 mark].
   d. The reasons for applying for EMPATRI are not clear and no reasonable justification is given for the application [0 marks].
3) Written English skills [0-2 marks]:
   a. The letter is very well laid out, easy to read and to follow; the candidate demonstrates an excellent command of written English [2 marks].
   b. The letter is well written, the candidate demonstrates reasonable command of written English [1 mark].
   c. The letter is poorly written and does not demonstrate a reasonable command of written English [0 marks].

Interview [0-10 marks]:

1) Self-presentation skills and compatibility with the study programme [0-4 marks].
   a. The candidate can present themselves excellently and they are able to reaffirm their motivation and describe their research interests clearly and with ease [4 marks].
   b. The candidate presents themselves well and they can reaffirm their motivation and to describe their research interests accurately [3 marks].
   c. The candidate presents themselves well, but they have some difficulty to fully reaffirm their motivation and to describe their research interests [2 marks].
   d. The candidate has difficulty presenting themselves and/or they are not able to reaffirm their motivation and research interests [1 mark].
   e. The candidate presents themselves poorly and/or they are unable to demonstrate sufficient motivation or sufficiently describe their research interests [0 marks].
2) Quality of answers to questions posed by the members of the Admissions Board [0-3 marks]:
   a. The candidate provides thorough and knowledgeable answers questions posed by the members of the Admissions Board [3 marks].
   b. The candidate provides satisfactory answers to the questions posed by the members of the Admissions Board [2 marks].
   c. The candidate is able to provide satisfactory questions to some, but not to all of the questions posed by the members of the Admissions Board [1 mark].

    d. The candidate is unable to provide satisfactory answers to questions posed by the the members of the Admissions Board [0 marks].

3) Spoken English skills [0-3 marks]:
    a. The candidate demonstrates an excellent command of the spoken English language [3 marks].
    b. The candidate demonstrates good command of the spoken English language [2 marks].
    c. The candidate demonstrates the minimum sufficient command of the spoken English language to allow them to be able to partake in the EMPATRI programme [1 mark].
    d. The candidate is unable to demonstrate sufficient command of the spoken English language [0 marks].

Curriculum Vitae and additional achievements [0-10 marks]:

1) Research experience and publications [0-5 marks] (marks are cumulative):
    a. The candidate has previous research experience, and they are an author/co-author of Q1 or Q2 level publications [1 mark per a Q1 and 0.5 marks per a Q2 publication, up to 3 marks].
    b. The candidate has previous research experience and they have authored/co-authored a textbook on a relevant-to-EMPATRI scientific topic [2 marks]

       or

       the candidate has previous research experience and they have authored/co-authored study materials on a relevant-to-EMPATRI scientific topic [1 mark].

2) Extra-curricular activities [0-3 marks] (marks are cumulative):
    a. The candidate has a track-record of active participation in various extra-curricular activities, such as sports, arts or other notable fields/topics [1 mark].
    b. The candidate has a track record of participating in the education of school pupils or earlier-year undergraduate students [1 mark].
    c. The candidate has other significant extracurricular achievements or awards [1 mark].
3) Additional complementary skills [0-2 marks] (marks are cumulative):
    a. The candidate can communicate (at least CEFR A2) in a language other than English and their native language [1 mark].
    b. The candidate has other demonstrable skill/-s which would be complementary to their studies in the EMPATRI programme [1mark].

The final ranking will be approved by the SPC, and the successful candidates extended an Unconditional Offer for a study place in the EMPATRI programme via an official electronic mail letter, signed by the Chair of the SPC, at the earliest opportunity.

Conditional offers and clearing.

It is foreseen that a number of candidates still studying in their final year of bachelor's studies will apply for the master's studies in the EMPATRI programme. Such applications are permitted, provided that the candidate can demonstrate that they will be in possession of their full and official final results by no later than the 1st of August of the given year. Such candidates must submit the projected results of their final year of study, approved and signed by a member of personnel at their university, such as their personal tutor or the study programme director, which will be evaluated identically to the other eligible applications. In case of successful application, such candidates will be extended a Conditional Offer for a study place in the EMPATRI programme via an official electronic mail letter, signed by the Chair of the SPC, with the condition being the attainment of an overall bachelor's degree result as set by the Admissions Board of EMPATRI for the given candidate. Importantly, in the case of the candidate not attaining the results outlined in the Conditional offer, the Admissions Board will retain the right to reject the candidate without further discussions.

It is foreseen that a number of candidates will either reject the offer of a study place in EMPATRI or, in case of the conditional offers, not meet the conditions set by the Admissions Board. In such cases the next highest-ranked eligible candidate will be offered a study place via the process of clearing. This process will continue until the deadline date for admitting new students for the given academic year at any of the universities of the Consortium has passed, all study places in EMPATRI for the given academic year have been allocated, or if there are no more eligible candidates, whichever status is reached first.

Joint enrolment & study process mechanisms.

Successful applicants will be enrolled as students simultaneously in all participating partner-universities, with the matriculation taking place at RTU, and will remain enrolled for studies continuously at all HEIs of the Consortium for the entire duration of their studies. EU, EEA and Swiss nationals, as well as permanent residency permit holders in any EU country will be automatically eligible for enrolment into EMPATRI. Admission for other applicants into EMPATRI will be subject to either having a valid visa or being eligible for obtaining a valid visa for studies in the EU. Visa eligibility checks, as well as acquisition of a valid visa to undertake studies in the Republic of Latvia will be assisted by the RTU International Academic Cooperation and Studies department[2]. Equivalent assistance will be provided by the University of Tartu and Vilnius University for Estonia and Lithuania, respectively. Students requiring visa will be issued a *sponsorship letter* for the obtainment of the visa, signed by the Chair of the SPC, as soon as they will have passed the selection by the Admissions Board and accepted the study place offered to them. The issue of such *sponsorship letters* will be coordinated by RTU and the secretariat of the SPC.

[2] https://www.rtu.lv/en/university/structure-and-administration/departments/foreign-students-department

The students will be presented with the selection of available master's projects no later than the first week of study of the 3rd semester and will make their final selection of the master's project no later than week 8 of the 3rd semester of study. Following from the above, students will be eligible to undertake their 4th semester of study (master's project) in any of the universities of the Consortium.

Joint student evaluation and diploma award mechanisms.

Student performance evaluation, including but not limited to, the organisation of the marking of the exams and calculation of weighted grades, will be carried out by the Student Evaluation Board. This board will likewise be responsible for the recommendation of any student for graduation or exmatriculation. The evaluation of student performance carried out by the Student Evaluation Board will be validated by the board of directors and approved by the SPC.

Joint award of degree and diploma.

Students, who successfully complete the EMPATRI study programme will be awarded a **single joint master's diploma in science** by the Consortium of all participating universities. The diploma will hold an equivalent legal status as the currently available separate master's diplomas in physics in each of the participating countries. The official title of the degree shall be *'Master of Physical Sciences'* abbreviated as *'MSc'*. Where further specialisation title will be requested, the specialisation in *'high-energy particle physics instrumentation*' will be quoted. A standard joint diploma will be awarded for all successful graduates of EMPATRI, with no additional levels of distinction for high achievement. The Consortium reserves, however, the right to supplement the diploma with an internal, unofficial and separate award of distinction for the exceptionally performing students.

NB! At the time of writing the necessary legal framework at the governmental level for the award of the joint diploma discussed above has not yet been established. The Consortium has initiated a discussion with the policy makers in the Baltic States about the development of one single joint diploma for the graduates of EMPATRI. This discussion has been initiated via the pan-Baltic policy advisory body – the Baltic Assembly. There has been significant progress towards establishing the necessary legal framework to allow the Consortium to award one single joint diploma for the graduates of EMPATRI. As the award of a joint diploma is of critical importance, members of the Consortium will continue to lobby for the establishment of the required legal framework.

Joint study evaluation mechanisms.

For the three taught semesters, comprising of a total of 90 ECTS, students will be evaluated on an overall 10-grade scale for each individual study course. The initial marking of each individual course will be done in accordance with the existing grading methodology at the university implementing a given course[3]. These grades will then be translated directly to the 10-grade scale shown below:

- Overall final grade 10 (pass);
- Overall final grade 9 (pass);
- Overall final grade 8 (pass);
- Overall final grade 7 (pass);
- Overall final grade 6 (pass);
- Overall final grade 5 (pass);
- Overall final grade 4 (fail);
- Overall final grade 3 (fail);
- Overall final grade 2 (fail);
- Overall final grade 1 (fail).

For all taught courses, the overall percentage result will be the weighted average of all assessed parts of each study course. The choice of the weights of the final exam, coursework, or any other valid form of assessment, will remain at the remit of the HEI implementing the respective study course. Award of grades for attendance is not permitted, however, attendance of the courses will be strictly monitored.

The evaluation of each individual study course will be the responsibility of the implementing HEI and will be provided to the SPC no later than 20 calendar days after the conclusion of the exam period when the final exam for the corresponding course takes place.

The exam period will take place twice a year, at the end of each study semester, usually during January (autumn semester) and June (spring semester).

The Student Evaluation Board will collate the final results, which will be validated by the Board of Directors and approved by the SPC. The grades will be distributed to the students no later than 10 calendar days after receiving all of the exam results from the corresponding exam period and no later than 30 calendar days after the conclusion of the corresponding exam period.

Any dispute of the results must be addressed in writing to the Chair of the SPC by the student no later than 10 calendar days after the receipt of the results. Any such dispute will be dealt with on an individual basis by the Board of Directors and the SPC, with a resolution (to accept or deny the item of dispute) being provided no later than 20 calendar days after the receipt of the respective complaint and no later than 60 days after the conclusion of the

[3] RTU: https://www.rtu.lv/writable/public_files/RTU_regulation_on_the_assessment_of_learning_outcomes.pdf.
UL: https://www.lu.lv/en/admission/for-international-students/degree/academic-information/.
UT: https://ut.ee/en/courses-taught-english-and-grading.
VU: https://www.vu.lt/en/studies/exchange-students/credits-and-grading-system.
KTU: https://en.ktu.edu/studies/#student-achievement-assessment.

corresponding exam period. The methodology for resolving disputes for the EMPATRI study programme are described a later section.

Resits and exmatriculation.

Students scoring less than 40% overall or less than 35% in modules/courses comprising a total of 15 ECTS (inclusive) or more in any single semester prior to any resits will be invited to a closed session of the Student Evaluation Board, where the viability of the continuation of their studies within the programme will be discussed. If given sufficient reassurance, the Student Evaluation Board may recommend continuation of the studies on a case-by-case basis.

Students failing to achieve a passing grade in any course will be given a chance to resit the exam and, if viable, redo the coursework for the given course. The first chance for the exam resit will be given within 10 calendar days of the original exam date, or within 5 calendar days after the last exam of the given exam period, whichever comes latest. The second chance to resit the exam for courses sat in semester 1 and semester 2 will be given during the inter-year summer. The second chance to resit the exam for courses sat in semester 3 will be given on a case-by-case basis, but no later than by the Easter holiday period of the given year. A chance to redo coursework from semester 1 and 2, if viable, will be given during the inter-year summer. Redoing of coursework from semester 3 will not be permitted.

Students who still receive an overall failing grade for any individual course following the second resit will be invited to an individual meeting with the Student Evaluation Board. Following the discussion a third chance for a resit may be awarded, where possible, with the maximum attainable grade capped at 40%. If an agreement is reached that the continuation of studies in EMPATRI programme is not viable, best efforts will be made to seek an alternative study programme for the student to join in one of the HEIs of the Consortium.

Students who do not complete or receive a failing grade for their master's project will not be eligible to graduate with the joint diploma awarded for the completion of the EMPATRI study programme. Additionally, redoing a full semester or a full year due to failing grades will not be permitted within the EMPATRI study programme. In cases, where this is deemed applicable and practicable, such students might be given an opportunity to transfer their credits to one of the HEIs of the Consortium to renew their pursuit of an alternative master's diploma.

Joint quality assurance and dispute resolution mechanisms.

Study programme's quality assurance (QA), as well as conflict and dispute resolution will be handled by the Quality Assurance Board. This board will be tasked with a regular review of the QA methodology and processes, with any proposed change to the methodology vetted by the Board of Directors and approved by the SPC. Additionally, conflict and dispute resolution will fall under the remit of the Quality Assurance Board.

Dispute resolution.

The Quality Assurance Board will act as students' first point of contact in case of them encountering any issues related to the study process. Any minor disagreements, adjustments, and requests, as well as any other type of minor dispute or complaint of a student, which does not significantly impact their studies, will be dealt with directly by the Quality Assurance Board. If deemed necessary, these will be elevated to the level of the Board of Directors and, if required, the SPC. Students will be fully informed about the methodology to be used for the resolution of such disputes or complaints.

Significant disputes will be dealt with according to well established rules of dispute and conflict resolution procedures at each institution of the Consortium. The choice of the applicable procedures shall be governed by the affiliation of the source of the respective grievance.

ANNEX 2

Curriculum outline for the master's programme "European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI)

"European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI) study programme is designed and will be implemented and managed by a Consortium of higher education institutions (HEIs), from the three Baltic states, Latvia, Estonia, and Lithuania. At the present time, this Consortium comprises five HEIs: Riga Technical University (RTU), University of Latvia (UL), University of Tartu (UT), Kaunas University of Technology (KTU), and Vilnius University (VU). This document outlines the aims and the proposed outline of the curriculum for this study programme.

Study aims, study structure and the outline of the curriculum.

The EMPATRI study programme aims to train specialists in high-energy particle physics and particle physics instrumentation, including but not limited to, particle detectors, particle accelerators and computing. The graduates of EMPATRI will have the required knowledge basis to continue their academic careers pursuing a PhD in multiple fields of research, including but not limited to, particle physics, accelerator physics, and medical and diagnostic physics. Equally, graduates will have the necessary skills and experience to pursue a career in industry, with the key skills obtained from their master's programme including computer programming, data analysis, visualisation and presentation, and radiation safety.

EMPATRI is a two-year, 120 ECTS (European Credit Transfer and Accumulation System) master's programme. The two study years are split into four semesters, two autumn semesters (September-January) and two spring semesters (February-June). Each semester covers a minimum[4] of 30 ECTS. Of the 120 ECTS, 90 credits shall be awarded to the students for the completion of taught courses covering the first three semesters, with 30 credits awarded for the successful completion of a research project resulting in a master's thesis in semester four.

The four-semester structure is implemented as follows:

- Semester 1: autumn semester of year one spent in Latvia, with taught courses implemented by RTU and UL,
- Semester 2: spring semester of year one spent in Estonia, with taught courses implemented by UT,
- Semester 3: autumn semester of year two spent in Lithuania, with taught courses implemented by KTU and VU,
- Semester 4: spring semester of year two, spent working on the master's thesis research project in one of the three Baltic states.

Taught courses are split into two groups, obligatory courses (Group A) and restricted choice courses (Group B). All credits awarded towards the attainment of the joint diploma of the EMPATRI study programme must be credits covered by these two groups. Additionally, in semester one and three,

[4] The mandatory amount of attainable credits is set to 30 ECTS for each semester, however, students are allowed to take extra credit classes, both from within the courses offered by EMPATRI and from other courses available at the universities implementing the given semester.

students are required to select at least one Group B course from each of the two HEIs implementing the given semester.

Extra credits may be awarded either from further courses selected from Group B or any other courses offered by the members of the Consortium. Addition of new courses, amendment to the existing courses, closure of existing courses, the reassignment of a given course between the Groups A and B, and any other substantive changes to the curriculum of the programme shall be evaluated annually by the study programme council (SPC) of EMPATRI.

At present time, the split between Group A and Group B courses for each taught semester at the present stage are as follows:

- Semester 1 (Latvia): Group A – 18 ECTS; Group B – 12 ECTS.
- Semester 2 (Estonia): Group A – 15 ECTS; Group B – 15 ECTS.
- Semester 3 (Lithuania): Group A – 14 ECTS; Group B – 16 ECTS.

In total, the presently outlined curriculum shall award 52% (47 ECTS) of taught credits from Group A courses and 48% (43 ECTS) of taught credits from Group B courses.

As a percentage of total ECTS to be awarded, the breakdown at the present stage is as follows:

- Obligatory taught courses (Group A): 39% (47 ECTS).
- Restricted choice taught courses (Group B): 36% (43 ECTS).
- Research project (master's thesis): 25% (30 ECTS).

The list of courses at the present stage is as follows:

Semester 1 (Latvia):

- Introduction to particle physics and detectors, RTU, Group A, 6.0 ECTS.
- Introduction to accelerator physics and technologies, RTU, Group A, 6.0 ECTS.
- Statistical methods in data analysis, UL, Group A, 3.0 ECTS.
- Programming for research, UL, Group A, 3.0 ECTS.
- High-performance computing in physics, UL, Group B, 3.0 ECTS.
- Quantum mechanics, UL, Group B, 6.0 ECTS.
- Advanced electrodynamics, UL, Group B, 6.0 ECTS.
- Introduction to physics object reconstruction, RTU, Group B, 6.0 ECTS.

Semester 2 (Estonia):

- Mathematical structure of the Standard Model, UT, Group A, 6.0 ECTS.
- Computational physics, UT, Group A, 3.0 ECTS.
- Technical graphics, UT, Group A, 3.0 ECTS.
- Radiation safety, UT, Group A, 3.0 ECTS.
- Quantum Field Theory I, UT, Group B, 6.0 ECTS.
- Differential geometry for physicists, UT, Group B, 6.0 ECTS.
- General theory of relativity, UT, Group B, 6.0 ECTS.
- Dosimetric and scintillation materials, UT, Group B, 3.0 ECTS.
- Applied physics project, UT, Group B, 3.0 ECTS.
- Vacuum and cryo-engineering, UT, Group B, 3.0 ECTS.

- Plasma physics and its applications, UT, Group B, 3.0 ECTS.
- Technology of Robotics, UT, Group B, 2.0 ECTS.

Semester 3 (Lithuania):

- Particle physics data analysis, VU, Group A, 5.0 ECTS.
- Physics object reconstruction VU, Group A, 5.0 ECTS.
- Advanced materials for particle detectors, KTU, Group A, 9.0 ECTS.
- Cosmology, VU, Group B, 5.0 ECTS.
- Quantum Field Theory II, VU, Group B, 5.0 ECTS.
- Artificial intelligence, VU, Group B, 5.0 ECTS.
- Methods of parallel computation in physics, VU, Group B, 5.0 ECTS.
- Dynamics of nonlinear systems, KTU, Group B, 6.0 ECTS.
- Radiation therapy physics, KTU, Group B, 6.0 ECTS.
- Development of innovations in physical science and technology. KTU, Group B, 6.0 ECTS.
- Research project 3, KTU, Group B, 12.0 ECTS.

The following pages of this document contain the draft course descriptions for the current curriculum proposal for the EMPATRI study programme.

EMPATRI Course Overview

1. Basic Information

Title	Introduction to particle physics and detectors
ECTS	6.0 ECTS
Semester	1
University	Riga Technical University
Lecturer (name, surname)	Assoc. Prof. Kārlis Dreimanis
Lecturer ORCHID	0000-0003-0972-5641
Total number of planned contact hours	70
Number of planned contact hour per week	5

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50	25		25	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
Experimental high-energy particle physics is a scientific discipline tasked with studying the most fundamental building blocks of our Universe – elementary particles. Paradoxically, to study these particles we must build grandiose and complex particle detectors, such as the four major experiments situated on the Large Hadron Collider (LHC) at the European Organisation for Nuclear Research (CERN). To fully grasp the concepts of experimental particle physics, one must familiarise oneself with the theoretical framework behind particle physics, understand the interaction between radiation and high-energy particles with bulk material, as well as understand the methods and technologies used for collecting usable data from such interactions. This course will provide the students with an overview of the quantum field theory framework describing modern particle physics, the Standard Model, introduce the students to the various detector types and materials used in particle physics experiments, as well as providing an insight into the methods used in maximising the reconstructible information from particle-matter interactions. This study course will consist of three avenues of learning, lectures, group tutorials and homework problems.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Students must have a basic understanding of quantum physics, electromagnetism, semiconductor physics and special relativity.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
After completing this course, the students will be familiar with the particle content of the Standard Model, be able to perform kinematic calculations for basic particle interactions and be able to describe the physical processes involved in particle detection. The students will be able to describe, explain and justify the experimental setup of existing particle physics experiments, as well as to outline proposals of potential new experiments. Students will be familiar with concepts of tracking, vertexing, calorimetry, the material requirements for the respective detectors performing these actions and the physical processes governing the particle-matter interactions involved.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Required literature: Particle Physics, 3rd Edition, Brian R. Martin, Graham Shaw, ISBN: 978-0-470-72153-7 Particle Detectors: Fundamentals and Applications, Hermann Kolanoski, Norbert Wermes, ISBN: 9780198858362. Additional learning: Modern Particle Physics, Mark Thomson, ISBN: 9781139525367 Access to a computer, word processer and the world-wide web.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Introduction to accelerator physics and technologies
ECTS	6.0 ECTS
Semester	1
University	Riga Technical University
Lecturer (name, surname)	Dr Alberto Degiovanni
Lecturer ORCHID	0000-0002-3169-4629
Total number of planned contact hours	60
Number of planned contact hour per week	5

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50	25		25	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
There are two methods of experimentally probing high-energy particle physics. One way is to study the stream of particles generated by the interaction of cosmic rays with the Earth's atmosphere. The other is to use powerful man-made machines, which accelerate and collide particles, creating enormous energy densities – particle accelerators. Of the two, the second is the only one that offers fully controllable and repeatable experimental setting and thus is currently the forefront approach used in particle physics. This course will broadly introduce the history and the physics behind particle accelerators as well as the technologies used to achieve the necessary energies and precision, including the discussion on radio-frequency cavities, beam-dynamics, vacuum and cryogenic structures, and focusing and bending magnets. Additionally, this course will cover the novel approaches in the manufacture of the state-of-the-art accelerator components, such as the use of additive manufacturing. Finally, this course will briefly introduce the most recent developments and ideas in the field of particle accelerators, such as the plasma wake-field accelerators.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Students must have a basic understanding of electromagnetism and special relativity.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained

Students will gain a broad understanding on the use of particle accelerators in high-energy particle physics. Students will be familiar with the major components making up a modern particle accelerator and the challenges in both their manufacture and use. Students will likewise gain knowledge in the most state-of-the-art manufacture techniques used in the field of particle accelerators.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
An introduction to particle accelerators, Wilson, Edmund J N, ISBN 9780198520542 Accelerator physics, 4th edition, Lee, S Y, ISBN 9789813274686. Access to a computer, word processer and the world-wide web.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Statistical Methods in Data Analysis
ECTS	3
Semester	1^{st}
University	University of Latvia
Lecturer (name, surname)	Kalvis Kravalis
Lecturer ORCHID	https://orcid.org/0000-0002-0711-4786
Total number of planned contact hours	32
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	30			10	60

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
1) test No1 (30%) 2) test No2 (30%)

3. Course description

Course description / synopsis
The purpose of the course is to teach students quantitative mathematically justified techniques for analysis and processing of experimental data. Tasks of the course: Students receive an introduction in the main principles of the probability theory, based on which the mathematical justification of the data processing and testing of statistical hypotheses techniques are built. During the course, students learn the main practically used data processing techniques. This knowledge is reinforced by incorporating in lectures the solution of practical examples. The skills of practical implementation of data processing techniques are developed during practical exercises in the computer class and during independent studies. They complete processing of realistic experimental data and learn to extract from these data unknown parameters and to determine their errors.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Learning Outcomes Knowledge: 1. tells about random variables and their distribution; 2. tells about the concept of regression; Skills: 3. evaluate the parameters of random variable distributions and their accuracy; 4. evaluate the level of reliability of a certain amount of experimental data; 5. perform statistical analysis of hypotheses; 6. determine the minimum of functions; 7. use Monte-Carlo methods; Competencies: 8. understands and applies regression methods appropriate to the data.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1) Brandt, Siegmund, Data Analysis. Statistical and Computational Methods for Scientists and Engineers (4th edition), Springer 2014, 523 pages (ISBN: 978-3-319-03761-5 2) Cowan G., Statistical Data Analysis (Clarendon Press, Oxford, 1998). 3) Siva D. S., Data Analysis: A Bayesian Tutorial (Clarendon Press, Oxford, 2004).

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Programming for Research
ECTS	3
Semester	1st
University	University of Latvia
Lecturer (name, surname)	Tija Sīle
Lecturer ORCHID	https://orcid.org/0000-0001-9782-4417
Total number of planned contact hours	30
Number of planned contact hour per week	2 (15 weeks)

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	10		60		30

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
1) Electronical tests (10%) 2) Course project, its oral defence (20%),

3. Course description

Course description / synopsis
The aim of the study course is to deepen and develop students' independent scientific programming skills. The study course builds on the Computers and Programming course and prepares students for further courses that require programming and modeling skills. The course will be useful for both theoretical and applied deviations in physics for students. The course will provide the necessary background for working with Linux operating systems, preparing students for working with high-performance computing. The task of the course is to introduce students to various physics tasks and related problems, which require programming knowledge to be solved.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained

Learning Outcomes Knowledge: 1. Names and explains key terms associated with numerical methods, such as time step and accuracy 2. Names and explains how numerical modeling can be used in solving physical problems Skills: 3. Uses the Python programming language for the implementation of numerical methods for obtaining and analyzing results 4. Uses the Python programming language to automate a series of calculations, to collect results and to analyze them Competencies: 5. When analyzing the results of numerical solutions, compares the result with known analytical results, checks the fulfillment of the basic laws of physics in solutions (e.g. conservation of energy), identifies the potential causes of numerical errors and develops a plan to reduce numerical errors. 6. Students formulate and, using computational tools, solve a physical problem using numerical modeling principles, in a situation where the properties of the solution are strongly influenced by various numerical parameters, or in situations where it is necessary to perform a large number of automated calculations at different values of numerical and physical parameters, and automatically compile the results.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1) Linux Fundamentals, Paul Cobbaut, http://linux-training.be/linuxfun.pdf 2) Scientific Visualization: Python + Matplotlib. Nicolas P. Rougier. 2021, https://github.com/rougier/scientific-visualization-book

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	High-Performance Computing in Physics
ECTS	3
Semester	1st
University	University of Latvia
Lecturer (name, surname)	Andris Guļāns
Lecturer ORCHID	https://orcid.org/0000-0001-7304-1952
Total number of planned contact hours	32
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	25		75		

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The aim of the course is to create an insight into high-performance computing in Physics. The tasks of the course are: 1. To overview applications of parallel algorithms in Physics problems, 2. To overview methods of parallel computing, 3. To learn how to use high-performance libraries, 4. To analyze efficiency of parallel algorithms, 5. To gain experience in using supercomputing centers.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Learning Outcomes Knowledge: 1. Describes performance of scientific software and its limiting factors;

2. Explains parallel computing and the related main approaches: vectorisation, multi-threaded programming and MPI; Skills: 3. Analyzes the parallel efficiency using the concepts of speed-up and scalability; 4. Runs calculations in a supercomputing center; Competences: 5. Analyzes and evaluates standard tasks (linear systems, eigenvalue problem, Fourier transformation) in a given problem and to related high-performance libraries; 6. Applies parallel methods for studying physical phenomena.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1. Trobec, R., Slivnik, B., Bulić, P., Robič, B. Introduction to Parallel Computing Computer class with coresponding open source software installed

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Quantum Mechanics
ECTS	6
Semester	1st
University	University of Latvia
Lecturer (name, surname)	Vjačeslavs Kaščejevs
Lecturer ORCHID	https://orcid.org/0000-0002-4869-8837
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	40				40+20

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
1) 2 tests during the semester – 40% 2) Seminar presentation – 20%

3. Course description

Course description / synopsis
The aim of the study course is to provide students with understanding of fundamental principles of quantum mechanics and develop skills in applying the relevant mathematical formalism to practical problems. Tasks of the course are: 1. to introduce basic concepts of mathematical description of quantum phenomena: state vector, operators, Born's Law, Schrödinger's time evolution, quantum entanglement; 2. to develop intuition about behavior of elementary quantum systems by using numerical simulations and quantum computers; 3. to acquire ability to formulate mathematical equations for specific quantum mechanical problems and choose appropriate analytical and numerical methods to solve them; 4. to learn the connections between the mathematical framework of quantum mechanics and concepts, models and approximations of other branches of physics; 5. to get acquainted with usages of theoretical relationships of Quantum Mechanics in explaining structure of matter, microscopic phenomena and development of quantum technologies.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies

Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Learning Outcomes Knowledge: 1. Demonstrates deep understanding of fundamental principles and concepts of Quantum mechanics; 2. Explains phenomena in atomic, solid state and particle physics using concepts of quantum mechanics; Skills: 3. Formulates appropriate mathematical model for quantitative description of model quantum systems; 4. Uses appropriate analytic and numerical mathematical methods for quantum mechanical problems; 5. Recognizes elements and mathematical structures of quantum theories in current scientific publications; Competence: 6. Understands fundamental principles and current development of quantum technologies; 7. Evaluates the needs for quantum mechanical modelling in current research problems.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1. McIntyre, D. Quantum Mechanics (Pearson, 2012) 2. Nielsen, M. A., Chuang, I. L. Quantum Computation and Quantum Information(Cambridge University Press, 2010) 3. Sakurai, J. J., Napolitano, J. Modern Quantum Mechanics (Cambridge University Press, 2017)

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Advanced Electrodynamics
ECTS	6
Semester	1st
University	University of Latvia
Lecturer (name, surname)	Sandris Lācis
Lecturer ORCHID	https://orcid.org/0000-0003-1486-3619
Total number of planned contact hours	64
Number of planned contact hour per week	4 (16 weeks)

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	40			40	20 (2 written tests)

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
Two intermediate written tests

3. Course description

Course description / synopsis
The aim of this study course is to present the theory of an electromagnetic field based on Maxwell's equations to students of physics master program, as well as to introduce students with special theory of relativity, and to broaden understanding of the relationship between electric and magnetic fields. Tasks of the course are: 1. to derive Maxwell equations and acquire skills in using differential operators to describe physical fields; 2. to demonstrate the application of Maxwell's equations in the description of electrostatics, a stationary magnetic field, electromagnetic waves and radiation; 3. to acquire basic concepts of spacetime in the context of a special theory of relativity; 4. to acquire skills in solving problems of classical electrodynamics. Languages of instruction are Latvian and English.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Learning Outcomes Knowledge: 1. Explain the theoretical foundations of electromagnetism by deriving them from basic principles; 2. Explain the foundations of special theory of relativity (STR) by deriving it from basic principles; 3. Become familiar with the description of scalar and vector fields, and the application of the Hamiltonian operator nabla; Skills: 4. Calculate typical electromagnetism and STR problems; 5. Analyze the ways in which electromagnetic interactions manifest themselves in different fields of physics; 6. Apply 4D space-time transformations to explain events in different frames of reference and in terms of STR; Competence: 7. Formulate equations and boundary conditions describing the specific manifestation of electromagnetism; 8. Select methods for solving problems in electromagnetism; 9. Explain the electromagnetic field manifestations of moving objects by applying SRT insights.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1. Jackson, J. D. Classical Electrodynamics Third Edition, Wiley, 1998, LUB 12 eks. 2. Nolting, W. Theoretical Physics 3: Electrodynamics, Springer, 2016 3. Nolting, W. Theoretical Physics 4: Special Theory of Relativity, Springer, 2017

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Introduction to physics object reconstruction
ECTS	6.0 ECTS
Semester	1
University	Riga Technical University
Lecturer (name, surname)	Dr Markus Seidel
Lecturer ORCHID	0000-0003-0972-5641
Total number of planned contact hours	55
Number of planned contact hour per week	5

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50			50	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
Experimental and theoretical particle physics are two fields attempting to fully describe the nature of our Universe. The aim of experimental particle physics is to validate or invalidate the ideas put forward by particle physics theorists and to look for new and unexpected-by-theorists phenomena. To achieve this, not only the experimentalists are required to have a full and precise understanding of their experimental setup, but also the grasp of the tools used to create predictions of the observables expected to be detected at the experimental facilities respective to the given theoretical prediction being investigated. This interface between theory and experiment, tasked with providing experiment with theoretical predictions is called phenomenology. The most common phenomenological tool used in high-energy physics is the so-called Monte-Carlo simulation. This course will introduce the students to the various observables used in high-energy physics, introduce the use Monte-Carlo simulations, and discuss the challenges and solutions for various physics object reconstruction in high-energy physics experiments.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Students must have a basic understanding of quantum physics, electromagnetism, semiconductor physics and special relativity. Students must have basic abilities to use python3 programming language.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students will gain a broad understanding of various physics object observables in high-energy physics experiment and phenomenology of the Standard Model and Beyond the Standard Model physics. Students will acquire the skills needed to use and interpret Monte-Carlo simulation in high-energy physics.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Standard Model Phenomenology, 1st edition, Shaaban Khalil, Stefano Moretti, ISBN 9781138336438. Monte Carlo statistical methods, 2nd edition, Robert, Christian P;Casella, George, ISBN 978-0387212395 Access to a computer, python3 programming platform, word processer and the world-wide web.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Mathematical Structure of the Standard Model
ECTS	6
Semester	2nd semester
University	Tartu
Lecturer (name, surname)	Laur Järv
Lecturer ORCID	0000-0001-8879-3890
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50%			50%	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The course offers an introduction to modern field theory and explains the contents of the Standard Model of elementary particles in detail. Building group theory from scratch, we see why relativity and quantum theory imply that the fundamental physical objects must be fields, and how Wigner's theorem classifies all possible fields according to mass and spin. We construct the Lagrangians of free Klein-Gordon, Dirac, Maxwell, and Yang-Mills fields and study the respective equations, solutions, and conserved quantities. The requirement of local gauge invariance is then used to introduce the interactions between the fields. The idea of spontaneous symmetry breaking by Higgs mechanism gives masses to the gauge fields, and Yukawa interactions to the matter fields. We conclude by discussing quark and neutrino mixing, and finally assemble the complete Lagrangian of the Standard Model.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Basic familiarity with special relativity (4-formalism, tensors), electrodynamics (Maxwell's equations), mathematical physics (matrices, complex numbers, vector calculus), analytic mechanics (Lagrangian, Hamiltonian), quantum mechanics (operators and eigenfunctions). Required previous course: Introduction to Particle Physics (1st semester).

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained

After completing the course a student + knows the essentials of Lie group theory (axioms, representations, generators, algebra, Casimir operators) and the reperesentations of orthogonal, unitary, Lorentz, and Poincare groups; + understands the principles of constructing actions for relativistic fields, can derive from an action the equations of motion and conserved quantities, can determine the dimensions of fields and constants in the action, and is able to sketch the interactions encoded in the action; + knows all the fields, parameters and interactions described by the Standard Model, including the Higgs mechanism.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Required material: Lecture notes of the course Complementary literature: Ryder, Lewis. Quantum field theory (CUP 2009) Maggiore, Michele. A modern introduction to quantum field theory (OUP 2005) Sundermeyer, Kurt. Symmetries in Fundamental Physics (Springer 2014) Rubakov, Valeri. Classical theory of gauge fields (Princeton 2002) Cottingham, W. N. An introduction to the standard model of particle physics (CUP 2007) Robinson, Matthew. Symmetry and the standard model: mathematics and particle physics (Springer 2011) Costa, G; Fogli G. Symmetries and group theory in particle physics: an introduction to space-time and internal symmetries (Springer 2012) Haywood Stephen. Symmetries and conservation laws in particle physics: an introduction to group theory for particle physicists (Imperial College Press 2011) Barnes Ken. Group theory for the standard model of particle physics and beyond (CRC Press 2010) Neuenschwander, Swight E. Emmy Noether's wonderful theorem (Johns Hopkins University Press 2011) Felsager, Bjørn. Geometry, particles, and fields (Springer 1998) Burgess, Mark. Classical Covariant Fields (CUP 2002) Peskin, Michael. An introduction to quantum field theory (Westview 1995) Srednicki, Mark. Quantum field theory (CUP 2007)

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Computational Physics
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Veronika Zadin
Lecturer ORCID	0000-0003-0590-2583
Total number of planned contact hours	32
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50		25	25	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The goal of the course is to give a knowledge and skills on the Finite Element Method as a widely used method for modelling of physical systems.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
No pre-requisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
The course gives an overview about the principles on the Finite Element Method. The implementation of FEM on solving different problems in physics, chemistry and materials science are discussed. The students get aquainted themselves with differnet programs what implement FEM and performe computer experiments to solve realistic problems. After completing the course the student: * knows the principles of the finite element method; * knows how to realize the problem by using different software packages; * has solved example problems both with pre-designed modules as well as the general shape partial differential equations; * has solved the problem with the low-level programming languages;

* has solved various genuine problems in physics, chemistry, materials science and so on as examples; * has defined independently one of the real problems, the ways to solve it using finite element method, solved the problem, visualized and analysed it.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1. William B. Bickford, ``A first course in the finite element method´´, Richard D. Irwin, Inc., 1990, ISBN 0-256-07973-0. 2. Larry J. Segelind, ``Applied finite element analysis´´, John Wiley and Sons, Inc., 1984, ISBN 0-471-62789-5. 3. Niels Saabye Ottosen, Hans Peterson, ``Introduction to the finite element method´´, Prentice Hall International (UK) Ltd., 1992, ISBN 0-13-473877-2. 4. Robert D. Cook, David S. Malkus, Michael E. Plesha, Robert J. Witt, ``Concepts and applications of finite element analysis´´, John Wiley and Sons, Inc., 2002, ISBN 0-471-35605-0. 5. Jüri Kirs, Gennadi Arjassov, ``Sissejuhatus lõplike elementide meetodisse. I osa. Algõpetus´´, TTÜ kirjastus, Tallinn 1999, ISBN 9985-59-121-6. 6. Kyran D. Mish, Leonard R. Herrmann, LaDawn Haws, ``Finite element procedures in applied mechanics´´, U.C. Davis, Department of Civil and Environmental Engineering, http://cee.engr.ucdavis.edu/faculty/mish/212A/default.htm 7. Carlos A. Felippa, ``Introduction to finite element method´´, University of Colorado, Boulder, 2005, http://www.colorado.edu/engineering/CAS/courses.d/IFEM.d/Home.html.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Technical Graphics
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	**Renno Raudmäe, Rünno Lõhmus**
Lecturer ORCID	0009-0008-5967-1382 (Renno Raudmäe)
Total number of planned contact hours	32
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50		25	25	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The objective of this course is to give students knowledge of the design of assemblies, and provide students with individual work and teamwork experience of designing assemblies and drawings with the SolidWorks software.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
No pre-requisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students are asked to compile SolidWorks part and drawing files of real details with different complexity in the form of independent work and teamwork. For solving design tasks, students will be introduced to the standards of compiling assembly drawings consisting of threads and fits. Two problem-based creative assignments for three-member teams are taken from real life. Here students must find a creative solution, execute the overall design and present their design in class. After passing the course, the student 1. Is able to compose assembly models and drawings consisting of fits and tolerances; 2. Knows the basic manufacturing processes of metal; 3. Is able to use mathematical modelling and MS Excel for design tasks; 4. Is able to solve modelling assignments on the level of the SolidWorks CSWA certification;

5. Has practical and creative problem-based learning experience in team for solving engineering tasks.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Study materials presented in the LMS Moodle

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

4. Basic Information

Title	Radiation Protection and Safety
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Siiri Salupere
Lecturer ORCID	0009-0007-1888-1204
Total number of planned contact hours	32
Number of planned contact hour per week	2

5. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50	25		25	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

6. Course description

Course description / synopsis
The objective of the course is to build competence in the field of radiation protection and safety. As a basic course, it covers the scientific and technical topics necessary for the understanding of dosimetry and dose formation from ionizing ratiation. Dose and dose rate calculation excercises are performed using modelling software. In addition to physical and technical issues, an overview of the principles, methods and structure of modern radiation protection is provided. The importants of safety culture in working with ionizing radiation is discussed through analysing historical radiation accidents.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies – No.
No pre-requisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
The course deals with the terminology and measurement units used in radiation protection and safety; interactions of ionizing radiation with matter, including biological tissue; biological effects of ionizing radiation; natural and artificial ionizing radiation sources, radiation dose formation; dose and dose rate calculation methods; the physical basis of radiation protection; principles, methods and organization of modern radiation protection; the concept of safety culture. The student who has completed the course: - can use basic concepts, quantities and units of radiation protection;

- understands interaction processes between ionizing radiation and matter, including biological effects and dose formation;
- knows the basic safety standards, and dose limits of radiation protection;
- is able to apply the basic principles of radiation safety;
- is capable of performing dose and dose rate calculations.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature

Equipment

- Radiation dose modelling software, e.g. RayXpert or similar.

Literature

- J.C. Bryan "Introduction to Nuclear Science" 2nd ed., CRC Press, 2013.
- S.A. Dewji ja N.E. Hertel "*Advanced Radiation Protection Dosimetry"*, Taylor & Francis Group, LLC, 2019.

The Moodle platform will be used to share the course material. – Yes.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Quantum Field Theory I
ECTS	6
Semester	2. semester (starts 5 weeks later)
University	Tartu
Lecturer (name, surname)	Stefan Groote
Lecturer ORCID	0000-0003-4462-4408
Total number of planned contact hours	54
Number of planned contact hour per week	6

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50.00%	0.00%	0.00%	50.00%	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The aim of this course is to introduce quantum fields and their perturbation theory via second quantization.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Quantum Mechanics, Mathematical Structure of the Standard Model

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
In this lecture series we give a systematic introduction to quantum field theory. On the basis of the variation and symmetry principles we introduce classical fields describing so-called canonical quantities whose operator valued description allow to quantise free fields (scalar, spinor and vector fields). The interacting fields are quantised in the interaction picture. We also deal with perturbative calculations, normal and time ordered products, Wick's theorem, the scattering matrix, the scattering of the photon with the electron etc. After the course, the student: 1. knows the special features of second quantisation. 2. is able to calculate with secondary quantised fields. 3. knows Feynman rules and is able to calculate with them. 4. is able to apply perturbation theory for the calculation of simple processes.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1. M. Böhm, A. Denner, H. Joos. Gauge Theories of the Strong and Weak Interactions- S.G. Teubner 2001 2. M. E. Peskin, D. V. Schroeder. An Introduction to Quantum Field Theory. Addison-Wesley 1995. 3. S.S.Schweber. An Introduction to Relativistic Quantum Field Theory. NY 1961. 4. J.D.Bjorken, S.D.Drell. Relativistic Quantum Fields. 1965. 5. M.Kaku. Quantum Field Theory. NY 1993. 6. L.H.Ryder. Quantum Field Theory. Cambridge 1996. 7. W.Greiner. Relativistic Quantum Mechanics. Springer-Verlag 1990. 8. Paul A.M.Dirac. The Principles of Quantum Mechanics. Oxford 1935. 9. Paul A.M.Dirac. Lectures on Quantum Field Theory. New York 1966. 10. S.Weinberg. The Quantum Theory of Fields. I, II. Cambridge Univ. 1996. 11. W.Greiner, J.Reinhardt. Field Quantization. Springer, 1996. 12. F.J.Yndurain. Relativistic Quantum Mechanics and Introduction to Field Theory. Springer, 1996.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Differential Geometry for Physicists
ECTS	6
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Manuel Hohmann
Lecturer ORCID	
Total number of planned contact hours	64
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50			50	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The objective of the lecture course is to provide an introduction to differential geometry with examples and applications in theoretical physics.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
No pre-requisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
The lecture course is an introduction into the basic calculational methods of differential geometry and their application to typical problems of theoretical physics. After the course the student knows the basic objects of differential geometry, in particular, manifolds, fiber bundles, sections, tensor fields, Lie groups and connections, and their application in classical mechanics, field theory and gravity. He / she can perform calculations using these objects and apply them to problems from theoretical physics.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Lecture notes and the literature cited in the lecture notes

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	General Theory of Relativity
ECTS	6
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Margus Saal
Lecturer ORCID	0009-0003-0251-1656
Total number of planned contact hours	32 - 64
Number of planned contact hour per week	3

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	40 %			40 %	20%

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other: tests about theory (it has not yet been decided, whether auditorium or home); Homework - exercise tasks.

3. Course description

Course description / synopsis
The aim of the course is to acquire the basic knowledges about Riemannian geometry, foundations of general theory of relativity and main applications of the theory: black holes, cosmology and gravitational waves.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Mathematical Physics, Special Relativity

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
The aim of the course is to get acquainted with the basics of Riemannian geometry, the basic principles of general relativity and with the main applications of this theory: black holes, cosmology and gravitational waves. Basic concepts of Riemannian geometry (connection, metric, curvature of space-time) are presented. The idea of geometrizing the gravitational field (equivalence of inertia and gravity) and the need to use the Einstein equations of the gravitational field to dynamically describe the geometry of space-time are justified. Some solutions of Einstein's gravitational field equations (linear approximation, gravitational waves, black holes, expanding universe) and experiments confirming Einstein's theory are also discussed.

A student who passed the course with a positive grade:

* understands the need to deal with different frame of reference, understands the content of the principle of equivalence and the principle of general reality;
* knows the basics of Riemannian geometry;
* knows the concepts presented in the syllabus to the level that he can explain their content;
* knows the basic equation of the theory; understands the phenomena for which these equations are necessary to describe and can use them to solve simple problems;
* has a vision of how/where the material presented in the course is located in the wider natural science world view.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Main: 1. B. F. Schutz, "A First Course in General Relativity", Cambridge University Press, 1990. 2. J. Foster, J. D. Nightingale, "A short course in general relativity ", Springer, 2006. 3. S. Carroll, "Spacetime and geometry", Addison-Wesley, 2004. Additional: 4. S. Weinberg, "Gravitation and Cosmology", John Wiley and Sons, 1972. 5. W. Rindler, "Relativity", Oxford University Press, 2006. 6. T. Padmanabhan, "Gravitation", Cambridge University Press, 2010. 6. L. Landau, E. M. Lifshits, "The classical theory of fields", Butterwort-Heinemann. 7. C. Misner, K. Thorne, J.-A. Wheeler, "Gravitation", Freeman, 1973. 8. A. P. Lightman, W.H. Press, R.H. Price, S.A. Teukolsky, "Problem Book in Relativity and Gravitation" Princeton University Press, 1975 9. H. Stephani, H. "General Relativity", Cambridge University Press, 1990. 10. H.C. Ohanian, R. Ruffini, "Gravitation and Spacetime", Norton&Co, 1994. 11. S. W. Hawking, G.F.R. Ellis, "The Large Scale Structure of Space-time", Cambridge University Press 1973. 12. W .L. Burke, "Spacetime, Geometry, Cosmology", University Science Books, 1980. 13. S. Chandrasekhar, "The Mathematical Theory of Black Holes I and II", Clarendon Press, 1983.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Dosimetric and Scintillation Materials
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Aleksandr Luštšik
Lecturer ORCID	0000-0003-2035-3420
Total number of planned contact hours	28
Number of planned contact hour per week	4

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	25	50	0	25	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The present lecture course concerns an important and rapidly developing division of modern material science. For a long time, a search for and the elaboration of novel scintillation and dosimetric materials, needed for the applications in energetics, medicine, ecology, geology etc., have been performed in Estonia (Institute of Physics, University of Tartu) in close collaboration with scientists from Germany, Czech Republic, Latvia, Ukraine and Russia.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
No pre-requisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
The evolution of energetic and radiation technologies, the increased requests for radiation safety as well as the handling of fundamental physical problems demand the improvement of the existing and the elaboration of new dosimetric and scintillation materials. General concepts of the detection and dosimetry of various types of radiation with the implementation of solid-state materials are considered. Optical and electrical processes in wide-gap materials and the interaction mechanisms of materials with photons and heavy or light particles are considered on the basis of quantum-mechanical models of solids. Using the best concrete dosimetric and scintillation materials as an example, the function mechanisms and the main applications of these materials in various fields of technology, medicine and ecology are analyzed. Several unsolved problems and promising elaborations of novel materials are discussed.

The student who has passed the course: - knows the optical phenomena of solids (with the stress on different types of luminescence), energy structure of wide-gap dielectrics, structural lattice defects (mainly, nanosized/point defects); - knows optical characteristics of luminescence centres in solids and reasons of their difference from the case of a free atom, processes of energy transfer to luminescence centres by excitons and electron-hole pairs; - knows the processes of electron, proton/neutron or heavy ion interaction with solids, general evolution scheme of electronic excitations at the detection of high-energy particles/quanta; - knows the function principles of classic (NaI:Tl) and novel fast scintillators, their main characteristics and applications for high-energy physics, medicine etc.; - knows the principles of highly sensitive TSL and PSL dosimetry and dosimetry of heavy ion tracks, the applications of these dosimeters for the detection of alpha-, beta- and gamma-rays, thermal and fast neutrons; - the obtained knowledge allows to participate at the investigation, elaboration and improvement of novel scintillators (fast and ultra-fast) and dosimeters (incl. for selective detection of fast (~MeV) neutrons).

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Literature offered by the lecturer during the lecture series

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Applied Physics Project
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Olin Pinto, Madis Kiisk
Lecturer ORCID	0000-0002-5954-8586 (Madis Kiisk)
Total number of planned contact hours	32
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	25		50	25	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The aim of this course is to train experts and engineers capable of collaboration with private sector industries. During the project, students will develop ability to write research and development projects and become acquainted with the technologies necessary for the detection of cosmic radiation.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
No pre-requisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Umbrella for various project-based practics Student who has passed the subject: * knows the main technologies for muon detection * is able to formulate the project goal and scientific research questions * is able to choose suitable components, subtasks and prepare a work plan for the implementation of a project * is able to formalize and present a project

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Literature suggested by the lecturer during the lectures

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Vacuum and Cryoengineering
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Laurits Puust, Harry Alles
Lecturer ORCID	0000-0002-5963-787X (Harry Alles)
Total number of planned contact hours	24
Number of planned contact hour per week	1.5

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	100	0	0	0	0

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The main principles of vacuum techniques and cryogenics are introduced as well as methods and apparatus are described which are necessary for practical work with vacuum systems and/or in cryogenics.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
No pre-requisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
The course deals with vacuum techniques and cryogenics necessary for the students who will choose the direction of applied science to proceed. First, properties of gases will be explored and the examples of the use of vacuum in science and technology will be given. The working principles of vacuum pumps, manometers and different kind of vacuum systems will be explained. Next, the methods of liquifying the gases and measuring the temperature will be described. The overview will be given of the use of liquid helium in everyday life. Also, the principal methods to achieve ultra-low temperatures will be explained and the construction of different cryostats described. The properties of matter at ultra-low temperatures will be described as well as the phenomena of superconductivity and superfluidity. After the course a student

* Knows what is vacuum, low vacuum, high vacuum and ultra-high vacuum and also knows the absolute temperature scale * Knows where and why vacuum and low temperature are used in research and technology * Is able (using kinetic theory) to calculate the average mean free path and velocity of molecules in rarefied gases * Can calculate thermal conductivity in rarefied gases * Can calculate the resistance and conductance of holes and vacuum tubes * Is able to carry out calculations on the gas flow and pumping speeds * Knows the structure and working principle of different types of vacuum pumps and vacuum meters; can also list different type of cryostats and explain their working principles * Knows how to connect different pumps into a pumping system * Has the knowledge of leak detection and is able to describe the working principle of a leak detector * Can use the vacuum systems * Knows what is meant by negative absolute temperature and is can name physical systems where it has been achieved * Can name different low temperature thermometers and to explain their working principles * Is able to compare the mechanical cryocoolers with a pulse tube refrigerator and to explain their working principles * Can list uses of gaseous helium in everyday life * Knows what is supersolid and is able to name systems where it has been achieved * Can explain the phenomena of superconductivity and superfluidity

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Provided via Moodle

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Plasma physics and its applications
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Indrek Jõgi
Lecturer ORCID	0000-0003-0007-8732
Total number of planned contact hours	32
Number of planned contact hours per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	60			20	20

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
Each student has to prepare and give a presentation about a topic chosen together with the teacher

3. Course description

Course description / synopsis
The course provides the basic knowledge of plasma as the fourth state of matter and introduces the main parameters describing the plasma. The course covers both the equilibrium and non-equilibrium plasmas and several applications including high-temperature plasma as a triggering source of thermonuclear reaction. The course introduces various plasma phenomena such as coulomb collisions and transport processes, motion of charged particles in electric and magnetic fields, MHD models, simple equilibrium and stability analysis.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Electricity and Magnetism, Optics The student should be familiar with the basic concepts of electricity and magnetism, optics and thermodynamics.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
After passing the course, students: can define, using fundamental plasma parameters, under what conditions an ionized gas consisting of charged particles (electrons and ions) can be treated as a plasma as a 4th state of matter.

know how to describe the main mechanisms of electron production and loss and compose rate equations of plasma-chemical reactions. can distinguish main types of equilibrium and non-equilibrium plasma and describe their formation and main applications (fusion reactors, thin film deposition, ozonizers, laser medium, air and surface purification etc). know various methods of plasma diagnostics.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
1. Y.P. Raizer. Gas Discharge Physics. Editors: J.E. Allen. 1991, Heidelberg, Springer Berlin. 2. A. Fridman, L.A. Kennedy. Plasma Physics and Engineering. 2004, Boca Raton, CRC Press

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Technology of Robotics
ECTS	3
Semester	2. semester
University	Tartu
Lecturer (name, surname)	Karl Kruusamäe
Lecturer ORCID	0000-0002-1720-1509
Total number of planned contact hours	32
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50			50	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The main objectives of the course are to: 1) review the latest developments in robotics and related (e.g., sensors and software) technology, 2) introduce the fundamental concepts of robotics technology, 3) give participants practical experience of using Robot Operating System (ROS).

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Programming

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
The course will review the state of the art in robotics technology and discuss some future advancements. Special focus will be on using Robot Operating System (ROS) for solving practical problems in robotics. On successful completion, the student: 1) can list example fields of robotics technology and explain the state-of-the-art in those fields; 2) can program ROS nodes using either C++ or Python; 3) is able to integrate existing ROS packages to a larger ROS-based project; 4) is familiar with and can describe the standard tools/packages of ROS, such as RViz, MoveIt, Navigation, tf;

5) can implement ROS-based solutions for most common robotics problems, e.g., coordinate transformation, path-planning, inverse kinematics, and collision-free motion planning.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Jason M. O'Kane "A Gentle Introduction to ROS", https://cse.sc.edu/~jokane/agitr/ "ROS.org Wiki", http://wiki.ros.org/ "Springer Handbook of Robotics", http://dx.doi.org/10.1007/978-3-540-30301-5

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Particle physics data analysis
ECTS	5
Semester	3
University	Vilnius University
Lecturer (name, surname)	Dr. Andrius Juodagalvis
Lecturer ORCID	0000-0002-1501-3328
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam (+Mid-term)	Tutorials	Lab. Work (project work)	Homework	Other
Weight (%)	50		20	30	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
Particle physics experiments generate large amounts of data that has to be processed using specialised computational tools. Besides understanding of the physical process that is being studied, the analyst has to know the data-handling workflow and potential pitfalls. Batch-processing computer systems are frequently used. Computer code writing has two sides. On one hand, the analyst should be able to compose short specialised codes to process reduced datasets. On the other hand, experimental data code handling relies on a large and intricate code framework, understanding of which is needed for a meaningful contribution to the extensive collaborative efforts. These topics are presented at an advanced level. The materials of HEP Software foundation are extensively used.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
C/C++ and python programming skills. Basic use of Linux OS. Knowledge of introductory level particle physics.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students will understand the compressed experimental data formats (e.g. the ROOT framework that is used by the LHC experiments). Students will be able to write a computer code to analyse and visualise experimental data on files. Students will be able to make use of batch data processing on the CERN LXPLUS cluster. Students will be able to write an event filter for the CMSSW analysis workflow.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Access to a computer able to establish the ssh connection. 1. Lessons on HEP Software Foundation software training center website https://hepsoftwarefoundation.org/training/center.html 2. ROOT: analyzing petabytes of data, scientifically https://root.cern/

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Physics object reconstruction
ECTS	5
Semester	3
University	Vilnius University
Lecturer (name, surname)	Dr. Andrius Juodagalvis
Lecturer ORCHID	0000-0002-1501-3328
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50		20	30	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
Modern detectors (like those operating at the Large Hadron Collider experiments) are made of several layers of active materials the state of which is monitored using electric circuits. The change of the state is analyzed to gauge its correspondence to the trace of a traversing particle. Timing and signal position information is used to restore track candidates. The properties of the tracks are used to deduce particle candidates that could cause the detected signal. The collections of tracks allow identification of the vertices, i.e. places where particle collided. The collection of particle candidates associated to the same vertex is used to deduce a possible physics process that took place during particle collision. The course discusses typical signal occurrences in currently used detector materials, and the particle-flow algorithm that can be used to analyze aggregated signal information from multitude of the linked detector systems.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Ability to use basic special relativity concepts for problem solving (4-momentum). Basic understanding of particle interaction with matter. C/C++ and python programming skills.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students will be able to explain typical signals left by particles in detector materials and understand the particle-flow algorithm. Students will be able to work in a collaborative environment and present their work to others.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Access to the computer able to establish an ssh connection. **The required literature:** 1. G. Viehhauser and T. Weidberg, Detectors in Particle Physics. CRC Press, 2024. 348 p. https://doi.org/10.1201/9781003287674 . 2. CMS Collaboration, "Particle-flow reconstruction and global event description with the CMS detector", JINST 12 (2017) P10003, doi: 10.1088/1748-0221/12/10/P10003 . **Recommended practical lessons:** 3. CMS Collaboration, "Advanced physics objects", https://cms-opendata-workshop.github.io/workshop2023-lesson-advobjects/index.html

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

4. Basic Information

Title	Advanced Materials for Particle Detectors
ECTS	9
Semester	Fall
University	Kaunas University of Technology
Lecturer (name, surname)	Brigita Abakevičienė
Lecturer ORCHID	0000-0002-4359-7287
Total number of planned contact hours	112
Number of planned contact hour per week	7

5. Assessment

Type	Exam	Tutorials	Lab. work	Middle exam	Other
Weight (%)	30	20	30	20	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

6. Course description

Course description / synopsis
The course will be designed to provide students with an in-depth understanding of the principles, techniques, and applications of the advanced materials for particle detectors. This course explores the fundamental concepts and emerging trends in the field, focusing on the production and characterization of materials at the micro and nano scales and covers a wide range of advanced materials and manufacturing processes, including composite metal-clad polymer materials, resistive electrodes for Micro Pattern Gaseous Detectors (MPGD), Physical Vapour Deposition (PVD) techniques, chemical etching and lithography processes, laser drilling technique, etc. The course also explores different characterization techniques, including microscopy, probe spectroscopy, and surface analysis methods, to assess the structure and properties of materials. Throughout the course, students will engage in both theoretical and practical aspects of advanced materials and technology for particle physics, skills of teamwork and creative and critical thinking. Laboratory sessions and hands-on experiments, organised at Institute of Materials Science, will provide students with opportunities to synthesise and manipulate advanced materials for particle detectors, as well as analyse their properties using different analytical techniques. Students will also be encouraged to critically analyse research papers and contribute to discussions on current advancements and challenges in the field.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Basic Courses of Physics, Mathematics and Information Technology

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competences to be gained
Students: • Are able to define the structure and properties of advanced functional materials; • Know and understand the basic principles of operation of several analytical techniques such as scanning probe microscopy, X-ray difraction technique, laser technology; • Are able to define methods of micro- and nanotechnology; • Are able to define fabrication principles of micro- and nanoelectromechanical systems; • Are able to perform processes of thin film deposition and dry etching in vacuum as ;well as to evaluate the parameters of thin films by laser ellipsometer; • are able to use clean room technologies to create and control very small objects • Are able to present the results of scientific literature analysis; • Have understating on influence of physical technologies to the particle detectors, follow the working principles of the detectors and have abilities to control difficult situations within research context.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Equipment: Physical vapour deposition technique for formation of coatings, Analytical technique (XRD, FT-IR, Raman, UV-Vis, XPS, SEM/EDS etc.), Lithography processing technique, Laser technologies. Literature: 1. Fabio Sauli. Gaseous Radiation Detectors: Fundamentals and Applications (Cambridge Monographs on Particle Physics, Nuclear Physics and Cosmology, Series Number 36), 1st Edition; Online ISBN: 9781107337701; Cambridge University Press 2014. 2. Fabio Sauli. Micro-Pattern Gaseous Detectors: Principles of Operation and Applications (CERN, Switzerland). Pages: 364, ISBN: 978-981-122-223-8 (ebook), December 2020. 3. Fabio Sauli and Eraldo Oliveri. Gaseous Detectors Handbook GHB 1.0 FS 2.05.2022, CERN 4. W. Blum, W. Riegler, L Rolandi. Particle Detection with Drift Chambers, 2nd Edition 2008 Springer – 85 EUR bookshop, SCEM code: 90.10.03.002.8; DOI: 10.1007/978-3-540-76684-1.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Cosmology
ECTS	5
Semester	3 (fall)
University	Vilnius University
Lecturer (name, surname)	Assoc. prof. Thomas Gajdosik
Lecturer ORCID	0000-0002-4355-8878
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50			20	30

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
15% is given for a seminar presentation, and 15% for active participation in discussions during lectures and seminars.

3. Course description

Course description / synopsis
Students will learn the basic mathematical formulations that are necessary for Special and General relativity, i.e. vector calculus and differential geometry. Based on that ground work, the student will study the mathematical formulation of the evolution of the universe from the era following cosmic inflation. Contents: Special relativity. Mathematical background for differential geometry. Differential geometry. Riemann geometry. Symmetric non-vacuum solutions of the Einstein equations. Hot Big Bang. Cosmological inflation. Cosmic microwave background. Spinors and particles. The Standard model. Supersymmetry. Dark matter. Gravitational waves.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Knowledge of special relativity at an introductory level. Ability to perform symbolic manipulation of mathematical expressions.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students will be able to use the basic mathematical formulations that are necessary for Special and General Relativity, i.e. vector calculus and differential geometry. Students will be able to explain the mathematical formulation of the evolution of the universe from the era following cosmic inflation.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Compulsory reading: 1. Davig Hogg. Special Relativity. 1997. http://cosmo.nyu.edu/hogg/sr/sr.pdf . Strongly suggested reading 2. Sean M. Carroll. Lecture Notes on General Relativity. 1997. arXiv: gr-qc/9712019 . 3. Sean M. Carroll. Spacetime and geometry: An introduction to general relativity. San Francisco, USA: Addison-Wesley (2004) 513 p. **Optional reading:** 4. B. F. Schutz. A First Course In General Relativity. Cambridge, Uk: Univ. Pr. (1985) 376 p. 5. C. W. Misner, K. S. Thorne, and J. A. Wheeler. Gravitation. San Francisco (1973), 1279 p. 6. T. P. Cheng. Relativity, Gravitation, And Cosmology: A Basic Introduction. Oxford, UK: Univ. Pr. (2010) 435 p.

7. Daniel Baumann. Cosmology. Cambridge University Press (2022), ISBN 978-1-108-93709-2, 978-1-108-83807-8, doi:10.1017/9781108937092.

Optional reading about particle physics:

8. David Griffiths. Introduction to Elementary Particles. John Wiley & Sons, Inc.; ISBN 0-471-60386-4 (1987).

9. Particle Data Group. The particle adventure: http://www.particleadventure.org/ .

10. W. Siegel. Fields. 2005. http://arxiv.org/abs/hep-th/9912205 or (2021) http://insti.physics.sunysb.edu/~siegel/Fields4.pdf

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Quantum field theory II
ECTS	5
Semester	3 (fall)
University	Vilnius University
Lecturer (name, surname)	Dr. Vytautas Dūdėnas
Lecturer ORCID	0000-0001-9405-9959
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	67			33	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The aim of the course is to give the student a solid background in quantum field theory, that is needed to understand the current research in particle physics. After taking this course, the student is expected to be able to calculate first order corrections to QFT amplitudes. He is also expected to understand the construction of abelian and non-abelian gauge theories, spontaneous symmetry breaking and the renormalization group. Synopsis: Reminders of the topics of quantum field theory I. Path integral. Scalar QED. Radiative corrections. Renormalization. Fermionic fields. QED and renormalization. Non-Abelian gauge theory. QCD. BRST operator. Wilson renormalization group and critical exponents. Spontaneous symmetry breaking. The Standard model.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Ability to solve basic problems in Quantum Mechanics, Special Relativity, Quantum field theory

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students will be able to calculate first order corrections to QFT amplitudes. Students will be able to explain the construction of abelian and non-abelian gauge theories, the spontaneous symmetry breaking, and the renormalization group.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Required reading: 1. Lucian Harland-Lang. Advanced Quantum Field Theory (lecture notes). https://www2.physics.ox.ac.uk/sites/default/files/profiles/harlandlang/aqft-48484.pdf 2. M. D. Schwartz. Quantum Field Theory and the Standard Model. Cambridge University Press; ISBN 9781107034730. 2014. Pages 151-269. 3. M. E. Peskin and D. V. Schroeder. An Introduction to Quantum Field Theory. Reading, USA: Addison-Wesley; ISBN 0-201-50397-2. 1995. Pages 265-275; 393-451. **Optional reading:** 4. M. D. Schwartz. Quantum Field Theory and the Standard Model. 2014. Cambridge University Press; ISBN 9781107034730. 5. M. E. Peskin and D. V. Schroeder. An Introduction to Quantum Field Theory. Reading, USA: Addison-Wesley; ISBN 0-201-50397-2. 1995. 6. P. B. Pal. Dirac, Majorana and Weyl fermions. 2010. arXiv:1006.1718 [hep-ph]. https://arxiv.org/abs/1006.1718 7. I. J. R. Aitchison and A. J. G. Hey. Gauge theories in particle physics: A practical introduction. Vol. 1: From relativistic quantum mechanics to QED. 2013. Bristol, UK: IOP (2003) 406 p. https://inspirehep.net/files/738c9f225c3ded7585894fcd9468bca7

8. I. J. R. Aitchison and A. J. G. Hey. Gauge theories in particle physics: A practical introduction. Vol. 2: Non-Abelian gauge theories: QCD and the electroweak theory. 2013. Bristol, UK: IOP (2004) 454 p. https://inspirehep.net/files/460785b7e1e5ef87b7f8d4f9307bd027

9. A. Zee. Quantum Field Theory in a Nutshell. 2003. Princeton University Press; ISBN 0-691-01019-6 (2003).

10. F. Olness and R. Scalise. Regularization, Renormalization, and Dimensional Analysis: Dimensional Regularization meets Freshman E & M. Am. J. Phys. 79 (2011) 306, arXiv:0812.3578 [hep-ph]. https://arxiv.org/abs/0812.3578

12. W. Siegel. Fields. http://arxiv.org/abs/hep-th/9912205 or http://insti.physics.sunysb.edu/

~siegel/Fields4.pdf (2017).

13. S. Pokorsky. Gauge Field Theories. Cambridge University Press;

ISBN 0-521-47816-2. 2000.

14. F. Jegerlehner. Renormalizing The Standard Model. PSI-PR-91-08, Apr 1991.

15. S. Weinberg. The Quantum Theory of Fields, vols. I and II. Cambridge University Press;

ISBN 0-521-58555-4. 1995.

16. J. C. Romao and J. P. Silva. A resource for signs and Feynman diagrams of the Standard Model. 2012. arXiv:1209.6213 [hep-ph].

https://arxiv.org/abs/1209.6213

17. J. C. Collins. Renormalization. Cambridge University Press. 1984.

18. M. Bohm, A. Denner, and H.Joos. Gauge theories of strong and electroweak interactions. B.G.Teubner Stuttgart Leipzig/Wiesbaden ISBN-13: 978-3-322-80162-3. 2001.

19. M. Robinson. Symmetry and the Standard model. Springer-Verlag New York, ISBN 978-1-4419-8267-4. 2011.

20. D. Tong. Quantum Field Theory, University of Cambridge Part III Mathematical Tripos. 2007. http://www.damtp.cam.ac.uk/user/tong/qft/qft.pdf

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Artificial intelligence
ECTS	5
Semester	3 (fall)
University	Vilnius University
Lecturer (name, surname)	Dr. Stepas Toliautas
Lecturer ORCID	
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam (written)	Tutorials	Lab. work	Homework	Other
Weight (%)	30	-	15	40	15

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
"Lab.work" is a research project (programming, write-up and presentation). "Other" is an oral report on a given subject and code presentation.

3. Course description

Course description / synopsis
This course is aimed at students of physics and other physical sciences interested in advanced systems of information technologies, looking to find out mathematical principles and implementation algorithms behind them. The course material will discuss social, scientific and technological concepts of artificial intelligence (AI), present the most popular AI-related techniques (such as big data analysis, machine learning, logical reasoning and natural systems' modelling) and their applications in problem solving/ planning, robotics, computer vision and natural language processing. The course is developed with emphasis on practical programming exercises of both model and realistic applications.

Content: AI context. Problem solving by search. Bayesian networks. Machine learning. Logic and planning. Utility. Decisions with multiple agents. Computer vision. Robotics. Natural language processing. Information in natural systems.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Practical programming skills, ability to solve basic problems in calculus and probability theory (bachelor level).

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students will be able to explain the main principles and algorithms used in advanced information-processing and problem-solving systems (rational agents). Students will be able to create programs that control or perform tasks given to problem-solving systems. Students will be able to formulate and solve naturally arising interdisciplinary problems in physical sciences and technology.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature

Access to a computer is needed.

Compulsory reading:

1. S. J. Russell, and P. Norvig. Artificial Intelligence: A Modern Approach. 3rd edition, Prentice Hall, Upper Saddle River, NJ. 2010.
2. T. Munakata. Fundamentals of the New Artificial Intelligence. 2nd edition, Springer-Verlag, London. 2008.

Optional reading:

1. M. Lungarella, F. Iida, J. Bongard, and R. Pfeifer (Eds.). 50 Years of Artificial Intelligence: Essays. Springer-Verlag, Berlin/ Heidelberg, 2007.
2. J. van Benthem, J. van Eijck, H. van Ditmarsch, and J. Jaspars. Logic in Action (open access course) www.logicinaction.org. 2016.
3. S. Sumathi, T. Hamsapriya, and P. Surekha. Evolutionary Intelligence. Springer-Verlag, Berlin/ Heidelberg. 2008.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Methods of parallel computations in physics
ECTS	5
Semester	3 (fall)
University	Vilnius University
Lecturer (name, surname)	Prof. Dr. Juozas Šulskus
Lecturer ORCID	
Total number of planned contact hours	64
Number of planned contact hour per week	4

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50			50	

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
The course introduces parallel programming features using C/C++ programming languages. The examples of parallel algorithms are taken from applications in physics. Synopsis: Parallel computing models, analysis and performance of parallel algorithms. Shared- and distributed memory computers and algorithms. C/C++ constructs for parallel programming. Introduction of OpenMP. MPI library and use. GPU in scientific computations. Linear algebra algorithms, SCALAPACK library. Monte Carlo method. Applications in physics: heat propagation equation; molecular dynamics algorithms. Parallel codes in quantum chemistry.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Basic C/C++ programming skills.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Students will be able to use the main programming packages for parallel computing. Students will be able to describe, create and use parallel algorithms and programs for solving physics problems.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Required reading: 1. M. J. Quinn. Parallel programming in C with MPI and OpenMP. 2003. Printed in Singapore, International edition. 2. W. Gropp, E. Lusk, A. Skjellum. Using MPI. 1999. The MIT Press. 3. W. Gropp, E. Lusk, A. Skjellum. Using MPI-2. 1999. The MIT Press. 4. G. E. Karniadakis, R. M. Kirby II. Parallel Scientific Computing in C++ and MPI. 2003. Cambridge University Press. 5. L. Sanders, and E. Kandrot. CUDA by example: An Introduction to General-Purpose GPU Programming. 2011. Addison-Wesley **Recommended reading:** 1. C. L. Janssen, and I. M.B. Nielsen. Parallel Computing in Quantum Chemistry. 2008. CRC Press. 2. D. C. Rapaport. The Art of Molecular Dynamics Simulation. 2004. Cambridge University Press. 3. P. Grassberger, J. Grotendorst, and M. Lewerenz. Molecular Dynamics On Parallel Computers. 1999. Research Centre Jülich. 4. P. Pacheco. Parallel Programming with MPI. 1997. Morgan Kaufmann.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Dynamics of Nonlinear Systems
ECTS	6
Semester	Spring/Fall
University	Kaunas University of Technology
Lecturer (name, surname)	Arvaidas Galdikas
Lecturer ORCHID	0000-0002-7116-2467
Total number of planned contact hours	48
Number of planned contact hour per week	3

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50	15	15	20	0

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other

3. Course description

Course description / synopsis
Aim of the module To know how to classify dynamical systems, define systems of deterministic chaos and describe conditions of chaos in nonlinear systems. To know methods of deterministic chaos analysis and laws. Students learn classification of dynamic systems, definition of deterministic chaos and description of conditions and reasons of chaos in nonlinear dynamic systems. Learn methods of chaos analysis in dynamic systems, concepts and laws of characteristic quantities. Learn numerical solution methods of nonlinear differential and finite increments equations, analysis of solutions and finding of areas of chaos in phase space. Obtain understanding of chaos appearance in conservative and dissipative systems. Obtain knowledge on fractal dynamics and geometry, application of fractal concepts in physical systems

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
General physics, classical mechanics, mathematics, computer programming

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained

-Know classification of dynamic systems, is able to determine systems of deterministic chaos and define conditions and reasons of chaos appearance in nonlinear systems. -Is able to use methods of chaos analysis in dynamic systems, concepts of characteristic quantities and laws. -Is able to solve numerically the nonlinear differential finite increments equations, to analyse solutions and to find regions of chaos in phase space. -Is able to distinguish reasons of chaos appearance in conservative and dissipative systems. -Know characteristics of fractal dynamics and geometry, know capabilities of fractal concept applications in physical systems.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Computers with MatLab software Literature: 1. Recent trends in chaotic, nonlinear and complex dynamicsNew Jersey : World Scientific, [2022].. Recent trends in chaotic, nonlinear and complex dynamics /edited by Jan Awrejcewicz, Rajasekar Shanmuganathan, Minvydas Ragulskis.. New Jersey : World Scientific, [2022]. 550 p. 2. Rajeev, S. G.: Advanced mechanics :from Euler's determinism to Arnold's chaos New York [N.Y.] : Oxford University Press, 2013..163 p.. 3. A.Galdikas, Netiesinių nanosistemų dinamika, 2008

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

7. Basic Information

Title	Radiation Therapy Physics
ECTS	6
Semester	Fall
University	Kaunas University of Technology
Lecturer (name, surname)	Jurgita Laurikaitienė, Diana Adlienė
Lecturer ORCHID	0000-0002-4485-381X, 0000-0002-8683-8757
Total number of planned contact hours	80
Number of planned contact hour per week	5

8. Assessment

Type	Exam	Tutorials	Lab. work	Middle exam	Other
Weight (%)	30	-	25	25	20

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
Problem based solutions

9. Course description

Course description / synopsis
Theoretical knowledge on the application of ionizing radiation for the treatment of patients, on radiotherapy treatment equipment, instrumentation and methods is provided together with the practical training to operate linear accelerators and teletherapy units and to perform dosimetric quality control and verification of radiation treatment procedures. Special attention is paid to the work with dose planning systems, production of patient's dose plans and patient dosimetry issues. Clinical and ethical aspects of patient treatment is also covered.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Radiation protection and radiation safety. Radiobiology. Radiation detectors.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competences to be gained
Students: • Understand physical principles of radiotherapy treatment of cancer patients; • Know radiotherapy equipment: linear accelerators, teletherapy units with Co-60 source, high dose rate brachytherapy units; • Know quantitative and qualitative characteristics of ionizing radiation and are able to measure, calculate and evaluate them. Are able to perform phantom measurements;

- Know radiation doses, are able to measure, calculate and evaluate them. Are able to prepare simple dose plans for cancer patient treatment, to verify and optimize these plans. Are able to give advice regarding patient's dose planning;
- Are able to apply recent radiotherapy technologies and methods for the treatment of patients according to clinical indications. Are able to give advice regarding radiotherapy methods;
- Know quality assurance programme in radiotherapy and are able to perform necessary quality control measurements, to analyse the results of measurements and to actively contribute to the solution of problems regarding radiation protection optimization, quality assurance and dosimetry;
- Know clinical aspects of radiotherapy and medical ethics related to patient treatment.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature

Equipment:
Linear accelerator, brachytherapy unit, gamma knife, simulator, treatment planning systems, CT unit, MRI, various phantoms, dosimeters and quality control equipment.

Literature

1. The Physics of Radiation therapy. ed. 5th ed., ed. Khan F., Faiz M.; Gibbons, John P. Lippincott Williams & Wilkins, 2014.
2. Radiation Oncology Physics. A Handbook for Teachers and Students. ed. by E.Podgorsak, IAEA, 2005

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

1. Basic Information

Title	Development of Innovations in Physical Science and Technology
ECTS	6
Semester	Spring/Fall
University	Kaunas University of Technology
Lecturer (name, surname)	Kristina Bočkutė
Lecturer ORCHID	0000-0002-0693-9911
Total number of planned contact hours	32
Number of planned contact hour per week	2

2. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)					x

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
Peer assessment – 15% Oral presentation – 40% Reflection on action – 15% Project report – 30%

3. Course description

Course description / synopsis
Students are introduced to the process of the development of innovations in physical science and technology through the concept, goals, and principles of the challenge-based learning method. Students are trained to identify and solve complex challenges of physical technology in a real-world environment in a creative and non-traditional way fostering the skills of creative and critical thinking, fundamentals of project management, teamwork, and other skills required to adapt to a changing environment. Students develop the ability to formulate an innovative idea for a challenge solution, implement it, test it and present it to a wide audience.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
No prerequisites

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
Research Skills Project Management Skills Teamwork and Collaboration

Problem Solving Communication Skills Critical Thinking Ethical and Societal Awareness

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Nichols, M., Cator, K., & Torres, M. (2016). Challenge Based Learner User Guide. Redwood City, CA: Digital Promise.

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

EMPATRI Course Overview

10. Basic Information

Title	Research Project 3
ECTS	12
Semester	Spring/Fall
University	Kaunas University of Technology
Lecturer (name, surname)	Giedrius Laukaitis
Lecturer ORCHID	0000-0002-7355-9716
Total number of planned contact hours	Total -320 h , 20 h contact and 300 h Independent work
Number of planned contact hour per week	1,25

11. Assessment

Type	Exam	Tutorials	Lab. work	Homework	Other
Weight (%)	50	15	15	20	0

Enter the planned assessment types and the weight of each type of assessment towards the final grade. Total weight must add up to 100%. If you have selected 'Other', please specify below.

Other
Mid-term examination – 10 % Project report – 50 % Oral presentation – 40 %

12. Course description

Course description / synopsis
Aim of the module: To broaden, systematize and apply the acquired theoretical knowledge and practical skills for solving specific tasks of materials science and applied physics, to acquire skills of carrying out scientific research, evaluation and interpretation of the obtained results.

Please, provide a brief course overview/description/synopsis.

Pre-requisite competencies
Bachelor degree. Finished courses: Research Project 1 and Research Project 2.

Describe the necessary competencies, knowledge and skills required in order to be able to successfully take part in this course.

Competencies to be gained
-Is able to solve relevant material science problems by making rational decisions on various materials technology issues. -Is able to systematize and critically analyze the necessary technical and scientific information needed to perform specific tasks in materials physics and make innovative decisions. -Is able to implement individual research program, applying modern instrumental analysis methods, carry out applied research and implement their results in material processing processes. -Is able to organize and coordinate material technology research project in accordance with the principles of project activities, to communicate generalized professional knowledge in a clear,

reasoned and ambitious way to specialists and non-specialists by critically evaluating it, to communicate freely and to communicate complex professional information orally and in writing. -Is able to plan time, organize work, work efficiently individually and in a team, understand and adhere to good laboratory practice, professional integrity, responsibility and ethics, perceive a culture of continuous learning, have the independent study skills necessary for continuous professional self-development, as creativity, innovation, enthusiasm, discipline, responsibility, motivation, self-direction and self-development.

Describe the competencies, knowledge and skills the student will gain by successfully completing this course.

Required equipment & literature
Access to the laboratory/research equipment where the Research project will be made. Literature: 1. General methodology instructions for the master's degree. (Access in moodle.ktu.edu using personal university credentials.) 2. Methodological guidelines for the preparation of written works [electronic resource]: methodological tool / Aušra Berkmanienė ... [et al.]; Kaunas University of Technology. 1st edition. Kaunas: Technology, 2019. Accessible on https://www.ebooks.ktu.lt/einfo/1486/methodological-guidelines-for-the-preparation-of-written-works/

Describe the equipment, if any, that must be made available to complete this course. Additionally, list the required and/or recommended reading materials & literature sources.

ANNEX 3

Main contact persons for the development and implementation of the joint study programme "European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI)

"European Master of Particle physics and Accelerator Technologies for Research and Industry" (EMPATRI) study programme is designed and will be implemented and managed by a Consortium of higher education institutions (HEIs), from the three Baltic states, Latvia, Estonia, and Lithuania. At the present time, this Consortium comprises five HEIs: Riga Technical University (RTU), University of Latvia (UL), University of Tartu (UT), Kaunas University of Technology (KTU), and Vilnius University (VU). This document provides the contact details for the representatives of the Consortium HEIs working on the development of EMPATRI at the date of the signature of the Memorandum of Understanding.

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Ms Silva Vītola, silva.vitola@rtu.lv

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